Appendix A

Scarborough Offshore Benthic Marine Habitat Assessment

Scarborough

Offshore Benthic Marine Habitat Assessment

1 February 2019

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West Perth WA 6005
Australia

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Advisian

WorleyParsons Group

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Executive Summary

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

This report is a summary of relevant information on benthic habitats from the offshore slope and deeper development area and is based on survey work previously completed in the permit area (>950 m water depth), on the escarpment of the continental shelf (300-950m water depth) and on the shelf (<300 m water depth). The data used in the assessment is based on video recordings and still images collected from ROV footage obtained during industry operations at a range of locations from the offshore project area as well as project specific surveys for the Scarborough Development.

Regional and site specific studies reviewed indicate that seabed material along the proposed trunkline alignment (and around the gas field) is predominantly flat and featureless and comprises thick, unconsolidated fine grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans).

Sedimentary infauna associated with soft unconsolidated sediments of the general area is widespread and well represented throughout the North West Shelf (NWS) region. In the context of the broader extent of habitats across the region, benthic habitat along the proposed trunkline corridor and within the Scarborough field consists primarily of soft unconsolidated sediments and is considered to be of relatively low environmental sensitivity.

Benthic communities of filter feeders generally live in areas that have strong currents and hard substratum and are closely associated with substrate type, with areas of hard substrate typically supporting more diverse epibenthic communities. The only natural habitat within the offshore permit area and trunkline corridor that is not classified as soft sediment is the pinnacle field that lies in about 300m water depth, on the continental slope. The pinnacle field covers an area that is less than 3 km^2 in size and at its closest point is more than 350m away from the proposed trunkline. Furthermore, the pinnacles are isolated forms and do not constitute continuous reef. It remains unclear what the rock pinnacles are constructed from, however the structures provide habitat for a diverse range of epifaunal and demersal species that commonly occur elsewhere in the NWS.

Interestingly, the habitats containing the greatest biodiversity in these offshore environments are the habitats formed by colonising invertebrates on oil and gas subsea infrastructure including the well heads and pipelines. These habitats and the species present on these structures in the NWS of Western Australia have been recently subject to detailed quantitative and qualitative assessment

(McLean et al. (2018), McLean et al. (2017), Bond et al (2018)). These habitats not only have structural complexity but also create habitat for a large diversity of fish species that commonly occur elsewhere in the NWS but do not occur over soft unconsolidated sediments.

1 Introduction

1.1 Background

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field.

WEL engaged Advisian to undertake an offshore marine habitat assessment to further the understanding of the environmental conditions of permit area WA-1-R. Findings from the marine studies will support the Scarborough Project environmental approvals.

The report is a summary of relevant information on benthic habitats from the offshore slope and deeper development area and is based on survey work previously completed in the permit area (>950 m water depth), on the escarpment of the continental shelf (300-950m water depth) and on the shelf (<300 m water depth).

1.2 Scope of Work

The objectives of the offshore marine habitat assessment were:

- To provide sufficiently detailed background information to enable the existing benthic habitat to be adequately described, particularly for benthic species and habitats of conservation significance, and
- To assess and interpret the available benthic habitat data which will be used to inform environmental approvals documentation for the Scarborough Development.

2 Method of Assessment

2.1 Review of Existing Literature

The offshore marine habitat assessment was undertaken by reviewing relevant literature from the areas of interest. This includes use of site specific environmental survey data that were commissioned to investigate the environmental conditions at both the Scarborough and Pluto field developments. Additional information was sourced from geophysical investigations, ROV surveys and sub-sea infrastructure inspections in the areas of interest.

An environmental characterisation report based on seasonal marine surveys was undertaken within Permit Area WA-1-R by ERM (2013). The surveys were completed in November 2012 (wet season) and July/August 2013 (dry season) and included sampling of water, sediment, plankton and infauna communities. Characterisation of seabed habitat was undertaken using multibeam.

The offshore marine environmental survey for the Pluto LNG development (SKM 2006) was also reviewed as the trunkline alignment from Scarborough will follow a similar route as that taken by the Pluto gas trunkline. The Pluto survey included infauna and epifauna sampling, sediment sampling for particle size analysis and sediment chemistry, ROV / video investigations of benthic habitats and anecdotal recordings of seabirds, cetaceans and other marine mammals, sea turtles and other reptiles. Detailed AUV and ROV survey data for Pluto were also reviewed as part of a comprehensive geophysical and geotechnical survey of the Pluto field (Geoconsult 2005).

The historical marine survey work was supplemented by a series of more recent marine surveys, including geophysical and ROV surveys that filmed the proposed trunkline route through the Scarborough field. These include the ROV survey of the export pipeline route (Ocean Affinity, July 2018) along a section of the continental slope between Scarborough and Pluto.

2.2 Report Layout

For the purpose of this report, the offshore marine habitat assessment has been divided into three sections according to water depth. These include describing habitats in the:

- Deeper Water (>950m depth), which includes the seabed where the Scarborough gas field is located;
- Continental Slope (300-950m water depth), which includes the section of seabed between the Scarborough gas field and the Pluto tieback;
- Continental Shelf (<300m water depth), which covers the seabed around the Pluto platform

For the purpose of this report, survey scopes that involved water quality, plankton and other surveys of the open water environment are not included in this report.

3 Deepwater Habitat

Much of the following section has been adapted from the Scarborough marine studies completed by ERM in 2013.

3.1 Background

The Scarborough Development is located on the Exmouth Plateau, within the North-west Marine Bioregion (Figure 3-1), as defined by DoE's framework for coordinating conservation and sustainable management (DoE 2013). The region comprises Commonwealth waters from the Western Australian/ Northern Territory border to Kalbarri, south of Shark Bay and covers 1.07 million square kilometres (km^2) of tropical and sub-tropical waters (DEWHA 2008). The Exmouth Plateau is located within the region's Northwest Province, which covers an area of 178,651 km^2 and is situated entirely on the continental slope (DEWHA 2008). The water depths of the North-west Province predominantly range between 1,000 m and 3,000 m reaching a maximum depth of 5,170 m.

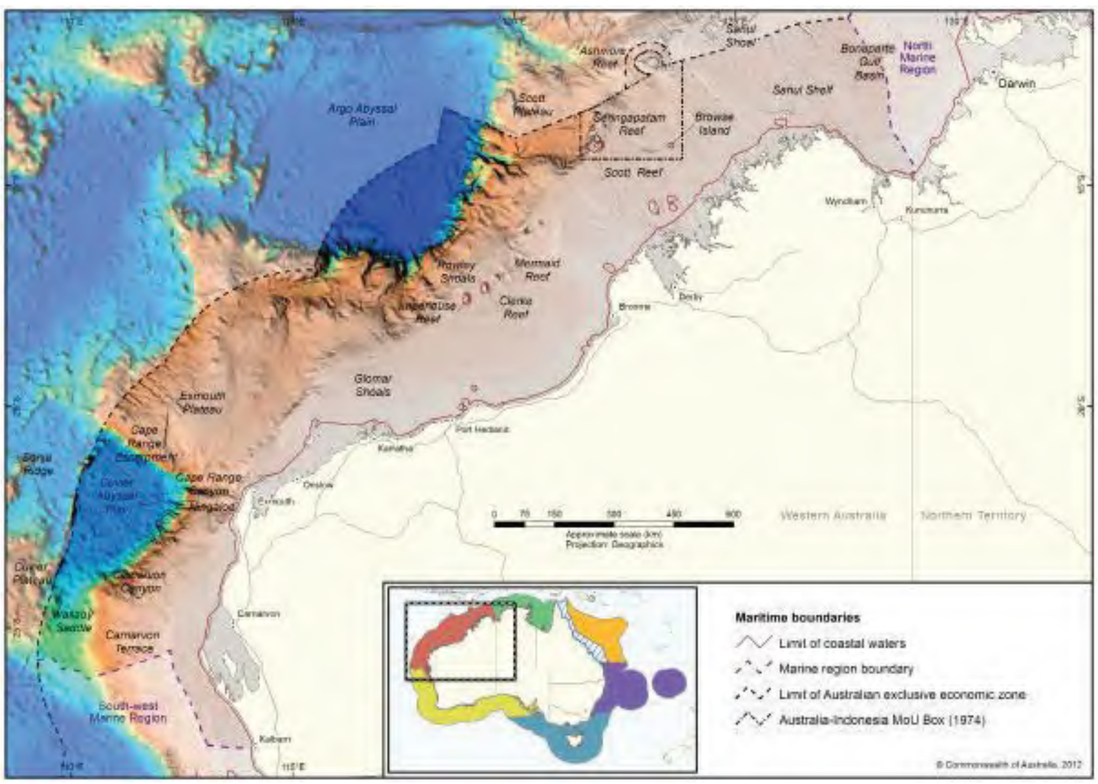

Figure 3-1 The North West Marine Bioregion, showing location of the Exmouth Plateau

The Exmouth Plateau, a deepwater plateau adjacent to the continental slope, is a dominant geomorphic feature of the region Figure 3-2. The Montebello Trough along the south-east edge of the plateau drains into the Cape Range Canyon, while the northern portion of the plateau comprises the Dampier Ridge and Swan Canyon. The Exmouth Plateau peaks at approximately 1,000 m deep with a narrow, steep southern slope and a wider, less steep northern slope. WA-1-R is located in the north-central section of the Exmouth Plateau in water depths of approximately 900 m to 970 m.

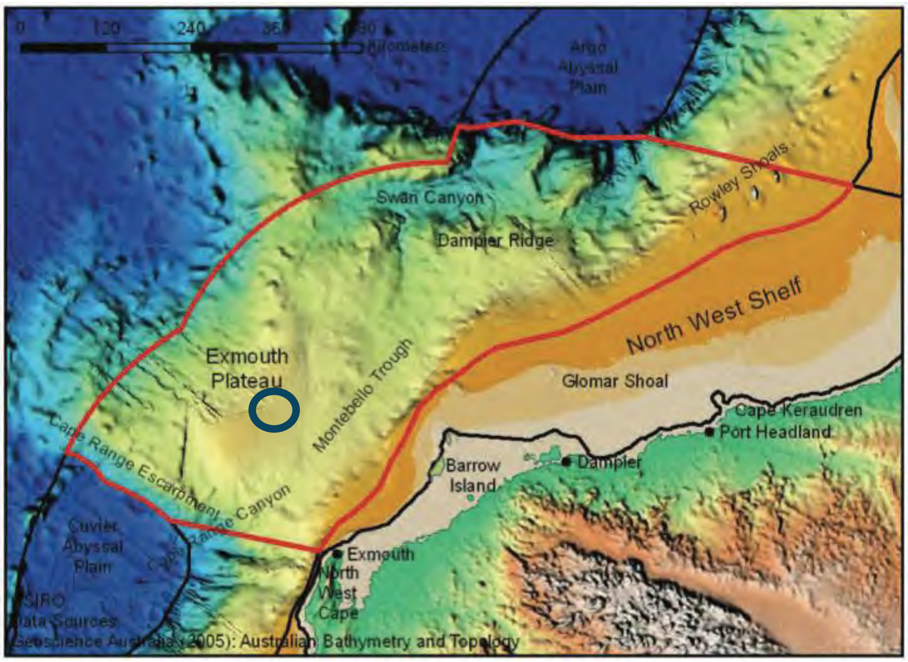

Figure 3-2 The Exmouth Plateau (showing location of Scarborough Development)

3.1.1 Seabed Characteristics

The region comprises bio-clastic, calcareous and organogenic sediments deposited from relatively slow and uniform sedimentation rates (Carrigy and Fairbridge 1954 in Baker *et al.* 2008 and Jones 1971 in Baker *et al.* 2008).

Sediments vary from sands and gravels on the shelf, to muds on the slope and abyssal plain/deep ocean floor (Baker *et al.* 2008). Calcium carbonate deposits are located on the inner shelf, middle shelf and outer shelf/ slope. The Exmouth Plateau is characterised by a thick Triassic sequence overlain by a Jurassic, Cretaceous and Cainozoic sediment sequence; and fine-grained carbonate ooze (Fugro 2010).

Sediment transport at WA-1-R on the outer shelf/ slope of the Exmouth Plateau is influenced by a combination of slope processes and large ocean currents.

The seafloor is generally flat and uniform with water depths ranging from 900 m to 970 m, with a gradual increase from the north/north-west to the south/ south-east of the area (*Figure 2.4*; Fugro 2010). To the south-west of WA-1-R, craters (up to 400 m across and depth of up to 10 m) and smaller pockmarks (metres to tens of metres across) have been identified through geophysical surveys (Fugro 2010). The seafloor exhibits gradients less than 1 degree (°) but extends to approximately 15 ° on the edge of craters (Fugro 2010). These crater and pockmark formations in WA-1-R may be associated with hydrocarbon seeps as well associated authigenic carbonate formations (Fugro 2010), and were a particular focus of the studies completed by ERM.

3.1.2 Benthic Communities

Studies completed within the region indicate that benthic composition in deepwater habitats is generally lower in abundance than shallow water habitats (DEWHA 2008, Brewer *et al.* 2007). Gage (1996) reported that the density of benthic fauna tends to be lower in deepwater sediments (>200 m) than in shallower coastal sediments, but the diversity of communities may be similar.

Information exists on the benthic communities of the Exmouth Plateau, although macrofaunal species diversity has been shown to be positively correlated to sediment diversity (Etter & Grassle, 1992). The mostly fine sediment environment of the Exmouth Plateau is expected to support scavengers, benthic filter feeders and epifauna, particularly at the intersection with the continental margin (Brewer *et al.* 2007). This soft bottom habitat is also likely to support patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea-pens (DEWHA 2008).

3.1.3 Hydrocarbon Seep-Associated Benthic Communities

Hydrocarbon seeps are the seeping of gaseous or liquid hydrocarbons (including oil and methane) to the surface of the seabed from fractures and fissures in the underlying rock, resulting in possible hydrocarbons and other chemicals in the water column (DEWHA 2008). It is possible that these formations may host thiotrophic (sulphur based metabolism) or methanotrophic (methane based metabolism) benthic communities and chemosymbiotic benthic fauna reliant on methane-oxidising bacteria, which usually aggregate in the form of mats over the seafloor (Barry *et al.* 1996).

These naturally occurring seeps are known to be present in the region, with an estimated 3,300 tonnes seepage of hydrocarbons annually (Fandry *et al.* 2006). Active hydrocarbon seeps have not been identified in WA-1-R. However, geophysical surveys conducted in 2010 identified crater and pockmark formations in WA-1-R, which may be associated with current or historic hydrocarbon seeps as well associated authigenic carbonate formations (Fugro 2010).

3.2 Survey Methods

The ERM marine investigation included sampling at 15 sampling sites as shown Figure 3-3 to:

- provide a broad characterisation of the habitats within WA-1-R;
- achieve spatial coverage across WA-1-R; and
- provide a representative selection of the various topographic features and corresponding benthic habitats (i.e. crater/pockmark versus non-crater areas).

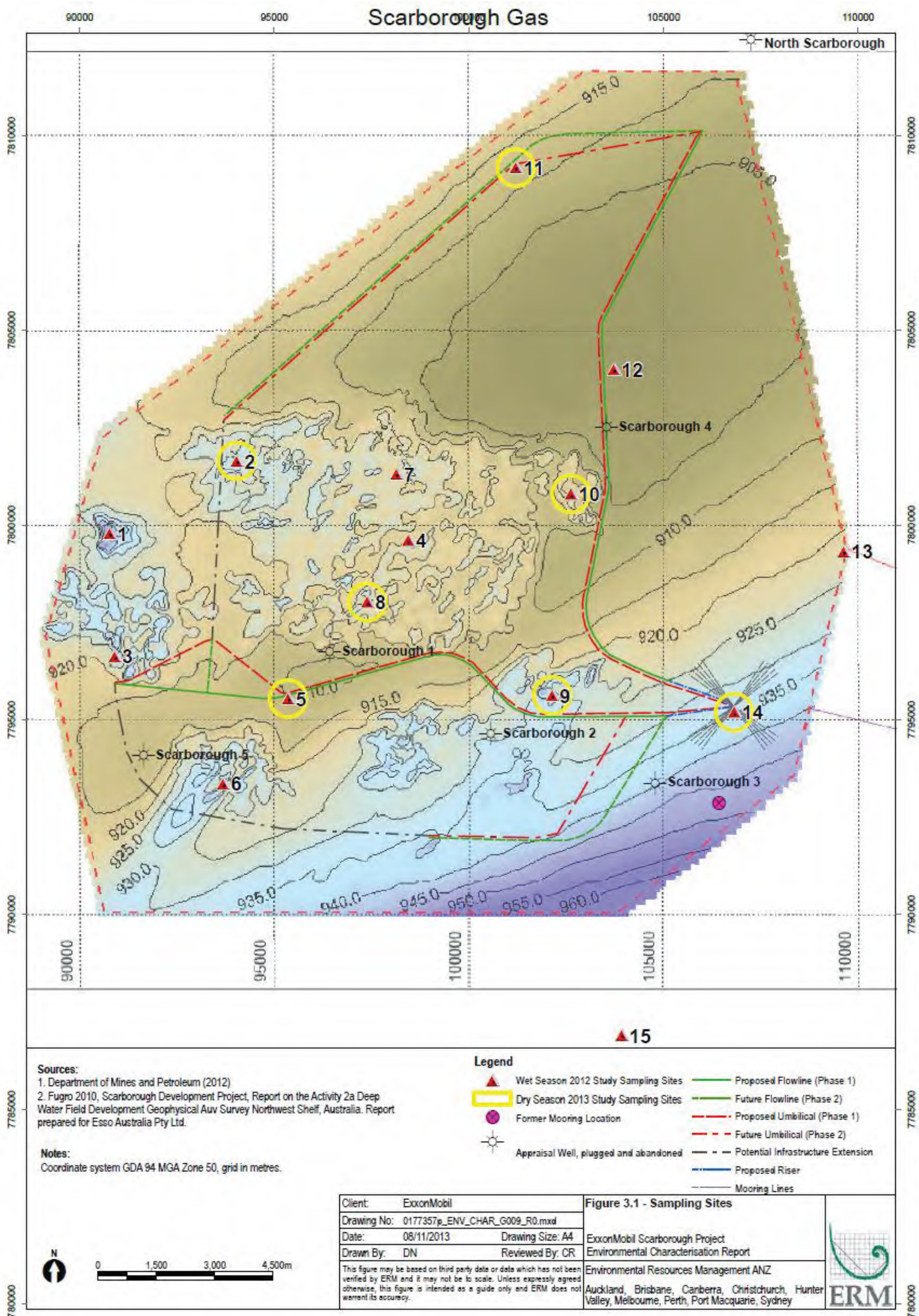

Figure 3-3 Sampling Sites used in the ERM Environmental Characterisation Report (ERM 2013)

3.2.1 Camera Study (Benthic Communities)

At each site, the camera was lowered to the seafloor of each sampling station. The vessel then drifted as slowly as possible across the station target area, capturing video footage. Video footage was collected for approximately 15 minutes at each of the three stations (45 minutes of footage per sampling site), with footage reviewed in real time. Video footage was acquired at all sites with the exception of Site 15 Stations 2 and 3 (due to bad weather).

Additionally, approximately 25 still images were captured opportunistically at each station sampled (75 images per sampling site). A total of 1,120 images were collected.

3.2.2 Infauna Study

Seafloor sediment was collected for physico-chemical analyses and identification of infauna. Sampling was undertaken using a box corer of the following dimensions: 0.49 x 0.52 x 0.55 m (length x width x height). The box corer was lowered to the seafloor for collection and recovered to the deck for inspection. The sample was split into quarters whereby one quarter was used for physicochemical subsamples and the other full quarters were sieved through a 0.5 mm mesh sieve.

3.3 Results

3.3.1 Benthic Communities

A total of 865 still images were quantitatively assessed by the South Australian Research and Development Institute (SARDI). A review of the benthic camera study recordings indicated a soft sediment seafloor across the area surveyed.

The quantitative assessment identified a total of 79 benthic taxa, consisting of the following phyla: echinoderms (28%), arthropods (24%), chordates (20%), cnidarians (19%), molluscs (4%) and poriferans (3%). In addition, there were 2% of taxa that appeared to be large protists (kingdom Chromista). Organisms were identified to the lowest recognisable taxonomic unit including species (5), genus (12), family (13), order (18), class (26), phylum (3) and kingdom (2).

The five species identified comprised a crab (*Eplumula* cf. *australiensis;),* sea urchin (*Phormosoma* cf. *placenta),* skate (*Insentiraja subtilispinosa)* and two fish species (*Bathypterois* cf *guentheri* and *Bathysaurus ferox*). Overall, a total of 605 individuals (including 54 unidentifiable organisms) were counted, dominated by arthropods (54.70%), followed by echinoderms (16.36**%**), cnidarians (10.41%), unidentified organisms (8.94%), chordates (7.44%), molluscs (0.99%), poriferans (0.83%) and the kingdom Chromista (0.33%).

The most abundant species were two shrimp species, of the genus *Nematocarcinus*. The next most abundant species were the gorgonian coral *Metallogorgia* sp. 1 (35 individuals) and the basket star *Gorgonocephalid* sp. 1 (29 individuals). Motile taxa such as shrimp, sea cucumbers and fish dominated the benthic fauna, comprising 75% of the species richness and 87% of the species.

Sessile taxa such as sea pens, corals, sponges, anemones and stalked crinoids made up the remainder of the contribution to overall species richness and abundance (25% and 13%, respectively).

The ERM (2013) study also noted bioturbation of the seabed in many of the images although most traces could not be confidently assigned to contributing taxa. Those that could be identified were considered potentially representative of echinoderms as well as biotic groups not identified in the still imagery such as foraminiferans, echiurans and annelids.

Bivalve shell debris was also recorded at several sites and was believed to be comprised of at least two species of the Vesicomyidae family. Aggregations of lithodid crabs were present in one occurrence of shell debris within one station. Small-scale bacterial mats that appear similar typical of *Beggiatoa* sp. were observed in a few of these bivalve shell debris occurrences. Shell debris and bacterial mats had mean percentage covers of 3.8% and 0.4%, respectively, across all the sites. For sites located in areas of coalescing seafloor craters, shell debris and bacterial mats had mean percentage covers of 6.3% and 0.7%, respectively.

3.3.2 Infauna

A total of 281 individuals and 43 different species were identified from the seven sediment samples collected from Sites 5, 8, and 14.

Of the 43-species identified, 33 were identified to family level, with the remainder identified to higher taxonomic levels. Crustaceans and polychaete worms were the dominant taxonomic groups, accounting for 89% and 86% of the individuals and species richness, respectively. The majority of crustaceans identified belonged to the Leptocheliidae and Apseudoidae families. The majority of polychaetes identified belonged to the Pilargidae family. Holothureans, molluscs, sponges, sipunculids and octocorals were recorded in relatively low abundances. The average density of infauna was estimated to be 214.1/m^2 (±43.3).

3.4 Discussion

No organisms identified to species level for the studies were listed as Threatened or Migratory under the EPBC Act according to the Species Profile and Threats (SPRAT) database (ERM 2013).

Benthic camera and sediment results indicated that the seafloor around the Scarborough Development is characterised by sparse marine life dominated by motile organisms. Such motile organisms included shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans (Figure 3-4, Figure 3-5 and Figure 3-6). Although these images were obtained from the original Pluto survey (Geoconsult 2005) and are closer to the Pluto slope, they are representative images of the deepwater habitat present at ~1,000m depth. The observed dominance by motile taxa is typical of deepwater soft substrates (DEWHA 2008), with sessile taxa more common on harder substrates (Ramirez-Llodra *et al.* 2010). Overall, observations made are representative of tropical deepwater soft sediment habitats reported in the region (BHP Billiton 2004; Woodside 2005; Woodside 2006; Brewer *et al.* 2007; RPS 2011; Apache 2013; Woodside 2013).

Figure 3-4 Deepwater soft bottom habitat (depths 1047-1068m), Tape 07 (January 2006)

Figure 3-5 Deepwater soft bottom habitat (depths 944-1025m), Tape 06 (January 2006)

Figure 3-6 Deepwater soft bottom habitat (depths 1029-1067m), Tape 07 (January 2006)

The majority of the 15 taxa that were identified to species or genus level in the benthic camera study are distributed worldwide. It is thought that offshore deepwater habitats of the NWS tend to support widespread Indo-pacific species, retaining extensive genetic connections over large distances (Heyward *et al.* 2006).

Four taxa were classified as Indo-pacific species, namely the carrier crab *Eplumula* cf. *australiensis* (typically in waters off southern Australia, New Zealand and New Caledonia (Poore 2004)), the velvet skate *Insentiraja subtilispinosa* (only in waters off north-west Australia and the Western Central Pacific (Last and Stevens 2009, Froese and Pauly 2011)), the halosaur fish *Aldrovandia* sp. 1 (previously recorded in the North West Province (Sorokin and Brock 2013)) and the tribute spiderfish *Bathypterois* cf. *guentheri* (Indo- West Pacific to the north east Indian Ocean and southern Japan (Froese and Pauly 2011)).

The demersal fish observed potentially reflects the community near the Exmouth Plateau. The upper and middle parts of the continental slope in the North-west Province have a high number of demersal fish species with high endemism (DEWHA 2008). This is especially so in the area between the North West Cape and the Montebello Trough (along the south-east edge of the plateau, *Figure 2.1*), which supports over 508 fish species of which 76 are endemic. It is noted that the demersal fish species identified for the benthic camera study did not correlate with the ichthyoplankton species identified in the zooplankton samples. This is attributed to the large depths at WA-1-R and general lack of vertical mixing between the surface and deeper layers (Sundby 1996).

The dominant types of epifauna were arthropods and echinoderms (especially shrimp and sea cucumbers, respectively), while the dominant infauna groups were crustaceans and polychaetes.

Benthic community composition was generally similar across sampling sites. There was not a strong correlation between bathymetric features and sessile or motile organisms. However, bathymetric features may have played a role in the abundance of certain organisms. The majority of sites where soft coral was identified were found outside of the coalescing seafloor crater areas. More than double the number of sea fans was identified in noncrater areas as opposed to coalescing seafloor craters.

The ERM (2013) study also noted that potential indicators of historic or localised ephemeral hydrocarbon seep activity were the most noticeable exception to a uniform benthic composition across WA-1-R. These indicators were in the form of bivalve shell debris and bacterial mats and they were only identified across the sites in the seafloor crater areas, where hydrocarbon seeps were considered to be potentially present (Fugro 2010). The shell debris and bacterial mats had low mean percentage covers of 6.3 % and 0.7 %, respectively, across the seafloor crater sites. The shell debris is considered to comprise at least two species of the Vesicomyidae family, which are common components of communities of sulphide-rich reducing environments such as hydrocarbon seeps (Krylova and Sahling 2010).

3.5 Summary

The low energy, soft bottom seafloor around the Scarborough Offshore Project Area supports sparse marine fauna as reported for the Exmouth Plateau. Sediments are calcareous, fine-grained and low in nutrients. Benthic communities are dominated by motile organisms, including shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. No threatened species/ecological communities or migratory species were identified in the studies (as defined under the EPBC Act).

4 Continental Slope

Much of the following section has been adapted from the offshore marine environmental survey for the Pluto LNG development (SKM 2006) and supporting investigations such as the Pluto AUV/ROV survey conducted by Geoconsult (2005) and most recently by the ROV survey completed by the Ocean Affinity (2018).

4.1 Background

The Pluto field is located on the continental slope of the NWS, where the slope is at its narrowest.

Assessment of geophysical and ROV data confirmed that the Pluto field is traversed by several canyon systems as shown in Figure 4-1. The work area was located more than 200 km NW of Dampier off the NW coast of Australia and covered approximately 311 km^2 in water depths ranging from approximately 160m to 1220m.

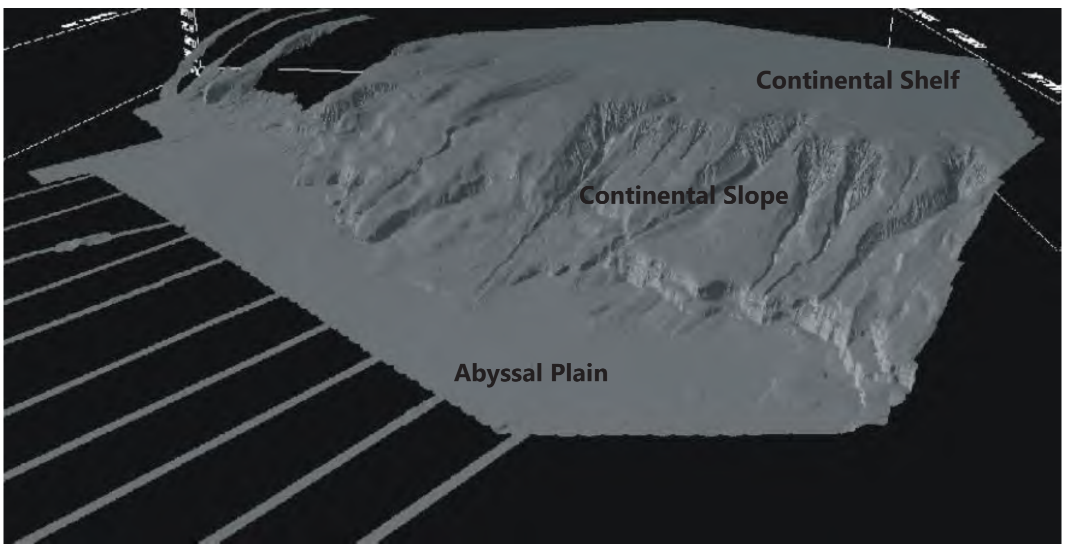

Figure 4-1 Continental slope adjacent to the existing Pluto field development

The Geoconsult (2005) report divides the Continental Slope into three sub-divisions, namely:

- Dendritic channel areas
- Channel areas
- Continental slope areas (between channels)

A total of six major and nine minor dendritic channel areas were recorded that are up to 200m deep and with gradients of 1:1. Major channels were well spaced through the site: in 300m to 750m water depth: between 500m to 1500m wide and up to 5km in length. The minor channels are prevalent in the southern half of the site: in 320m to 550m water depths: 500m to 900m wide and up to 2.4km in length. They are formed by the gradual erosion of the Continental Slope as numerous small, localised slumps, which trigger turbidity currents. It is suspected that dendritic channel areas act as a focus for seafloor currents. Sediments expected to comprise very soft sandy clay/silt.

Six major and nine minor complete channels were identified. Ten channels discharge sediment into the deeper water with the remaining minor channels discharging varying amounts of sediment on to the Continental Slope. Generally, they are between 15m and 300m wide, 5m to 150m deep with sidewall gradients of 1:1. The channels and their dendritic roots gradually erode the upper slope and transfer sediment to deeper water. Sediment is transported as local slumps and sediment flows and also as more extensive turbidity currents, which erode channel sidewalls and floors. Layered sediments in the base of channels document deposition following sediment flows. Plunge pools up to 230m wide and 20m deep have been observed. Channel sidewalls are susceptible to slumping and erosion.

The presence of sand in the channels has been confirmed by drop cores. Within the channel base current driven bedforms or erosive "back stepping" of bedding planes was observed. ROV stills show current driven bedforms and rounded cobble sized clasts and sediment clumps in the channel base. Channels are not only developed by seafloor currents but have in the past been conduits for large scale turbidity currents. Present day sedimentary processes are observed to be significant, with active seafloor currents.

The Continental Slope Area (between channels) undulates and deepens from the SE to the NW over a series of linear and steep scarps from water depths of ~250m to 1100m.

4.2 Survey Methods

4.2.1 SKM (2006) survey

The sampling programme was designed to collect representative biota across the outer shelf and slope habitats, to characterise species and habitat composition along a depth gradient down the slope (150 m, 200 m, 400 m, 600 m, 800 m and 1000 m). Sampling was conducted along two depth gradient transects, one transect orientate directly down a canyon system (referred to as canyon transect) and the second transect orientated down the continental slope outside of the canyon systems (referred to as slope transect).

The bathymetry of the canyon systems transecting the Pluto field include some very steep gradients, which suggests that the canyon systems could potentially contain some exposed hard substrate or cliff like structures. Surveys for the Vincent and Enfield fields, located near North West Cape, discovered rich and diverse epifaunal communities located on several rock outcroppings in 350–600 m water depth (Heyward and Rees 2001a and b; Heyward et al. 2001a and 2001b). In the absence of targeted geotechnical and geophysical data, the sampling strategy was focused on the seabed with the steepest gradients in the canyon systems. A total of twenty-eight sled tows were successfully completed by SKM (2006) across depths between 150 m and 800 m.

Over 40 hours of video of the seabed were collected by the ROV from depths ranging between 250 and 1050 m. While the majority of the seabed was composed of soft sediments, extensive video recording was collected of the steep cliffs located just below 1000 m and isolated pinnacles in the 300 m depth range.

4.2.2 Ocean Affinity (2018) survey

The purpose of this operation was to use a KD31 ROV to visually inspect points of interest (POI) along the base case route slope region that were identified during the geophysical survey and to revisit POI1 that was previously surveyed during the SKM (2006) ROV survey. The POI locations were identified following review of side scan sonar (SSS) and multi bean echo sounder (MBE) data collected during autonomous underwater vehicle (AUV) surveys as shown in Table 4-1.

Table 4-1 Positioning Details for Points of Interest Survey, (Ocean Affinity 2018)

POI	Easting	Northing	Depth (m)
1	310308	7798411	303
2	308721	7799862	454
3	309089	7800880	490
4	309498	7800578	422
5	309736	7800316	390
6	310145	7802325	450
7	311170.0	7796744	259

4.3 Results

4.3.1 Infauna

The infauna of the continental slope, (as based on data collected from the Pluto field) was very sparse with a maximum density of 167 individuals/m^2 from a sample collected in 400 m. Infauna was generally more abundant in sites located in shallow water, although this trend with depth was somewhat obscured because three samples contained no infauna, both samples from 800 m and one sample from 1000 m. A total of 47 individuals, representing 32 nominal species, were collected from the 12 samples. The fauna was dominated by polychaetes, which comprised 79% of the fauna by abundance and 75% of the fauna by species richness. Some crustaceans, sipunculids and nemerteans were also recorded but no molluscs or echinoderms were collected in any of the box core samples.

4.3.2 Epifauna

The sled catches varied between depths but were consistent across the two transects across the continental slope, inside and outside the canyon system.

Approximately 1200 specimens were collected from 25 sled shots. Cnidarians, mostly free-living deep water solitarily corals, were the most abundant phyla, followed by malacostracan crustaceans, mostly decapods, bony fish, and sponges. Together, these groups accounted for 70% of the fauna by abundance.

The fauna was most abundant along the 200 m contour but this was largely a result of the distribution of the free-living deep water, solitarily corals. Seventy percent of the corals collected occurred in samples collected from the 200 m sites. Crustaceans were most abundant at 400 m.

Commercial fishing for crustaceans (scampi, prawns) is concentrated between 200–400 m. Fish were most abundant in shallower water, particularly near the shelf break at 200 m depth. Sponges were most abundant in the deeper stations (600 m and 800 m). Ascidians were common in 150 m where one unidentified species was particularly abundant.

The Western Australian Museum (WAM) has identified the sponges, fish, molluscs, echinoderms, cnidarians and most of the crustaceans and made comparisons with existing deepwater collections. Five species of sponges, 45 species of fishes, 54 species of molluscs, 25 species of cnidarians, 34 species of echinoderms, and 50 species of crustaceans have been identified.

The WAM findings can be summarised as follows:

- Of the five species of sponges collected in the study, three belonged to the Class Demospongiae, which are shallow water sponges found at depths of 150 m or 200 m and two species belong to the Class Hexactinellida (glass sponges), which are deepwater species found at 600 m and 800 m. The glass sponges have a glass stalk holding the cup shaped sponge. The stalk is often covered in a cnidarian. No live sponges were collected from tows at 400 m.
- The fish species collected are typical of the area and depths with most of the taxa being deepwater representatives with tropical distribution.
- The echinoderm species belonged mainly to three classes, namely Asteroidea (seastars), Ophiuroidea (brittlestars) and Echinoidea (urchins), with only one species representing the class Holothuroidea (sea cucumbers). A number of animals could be identified to species level, with some of the identified species not previously recorded and many were not previously recorded in the area. Curiously, when compared to other recent sampling off the north west peninsula, several Asteriod genera found in similar water depths were absent in the Pluto samples. The Asteroid *Sidonaster waney* have not previously been recorded within Australian waters. Of the eleven Asteroid genera found, only 4 species could be identified to species level.
- The cnidarian species belonged mainly to the Family Nephtheidae and to a lesser extent the Family Alcyoniidae and Nephtheidae. Of the 41 cnidarian specimens, three specimens were black coral.
- The majority of the 50 crustacean species identified belonged to the Order Decapoda (48 decapods and two barnacles, Order Pedunculata). Most of the genera collected have been recorded previously from the deeper waters of Western Australia and all species were collected at depths typical for the species or genus. The material is mainly tropical with strong Indo-West Pacific affinities, particularly with the fauna of the Indo-Malayan sub-province, the area defined by the Indo-Malayan Archipelago, Australia and New Guinea to Japan. At the generic

level, the collection is comparable with material from similar depths in eastern Australian waters. The collection contains the first Australian records of *Raninoides hendersoni* Chopra, 1933 (Raninidae), *Mursia armata* de Haan, 1834 (Calappidae), *Polycheles coccifer* Galil, 2000 (Polychelidae), and *Eumunida (Eumunida) pacifica* Gordon, 1930 (Chyrostylidae). These species have known distributions in the Indo-Malayan sub-province of the Indo-west Pacific province. One species previously recorded in Australia from the east coast is recorded for the first time, *Conchoecetes artificiosus* (Dromiidae). A further two species, *Agonida* ? *eminens* and *A.* ? *incerta* (Galatheidae), are possible new records for WA but confirmation of their identifications is required. The specimens of the portunid crab *Charybdis (Charybdis) rufodactylus* represent the first record of the species outside of Queensland, Australia. The galitheid genus *Munidopsis* is also reported for first time from WA.

- Most of the 45 mollusc species had been previously recorded from western and northern Australian waters (WAM, January 2006), although some of the specimens in the collection belong to species that have been rarely collected for example, *Amoria diamantina*. Most molluscs occurred in depths of between 150 and 600 m. They represent 27 families, of which four are cephalopods, three are bivalves and the remaining 47 species are gastropods. The gastropods represented in this collection are mainly carnivores as would be expected from depths low in and below the photic zone. The broken shell of the sundial shell, *Discotectonica acutissima*, appears to be the first record for this species in Western Australian waters (WAM, January 2006). Of the cephalopods, those specimens identified as probably belonging to the genus *Mastigoteuthis* are the most noteworthy, being new to the collections of the Western Australian Museum. The actual depth at which the squids of the genera *Histioteuthis* and *Mastigoteuthis* were collected is doubtful as they swim in the water column, not on the substrate, and so must have been taken as the dredge was descending or ascending (Slack-Smith 2006).

4.3.3 ROV (SKM 2006)

The ROV recording was collected during December 2005 from five areas between 250 m and 1050 m depth (Figure 4-2). The soft sediments supported a very sparse coverage of epifauna overall but small areas supporting a higher density of epifaunal were also observed. The diversity of epifauna was far more limited overall than the diversity of fauna collected by the sled. Many tracks and marks were observed on the seabed through all depths but the fauna responsible for these tracks or living just below the sediment surface could not be identified. Only demersal species could be identified. The seafloor below about 800 m supported a similar fauna to that observed in shallow depths with mostly shrimps, batfish and holothurians observed. Glass sponges were noted to occur at high densities, particularly along the 750 m depth contour with an estimated density of 0.2 individuals/m^2.

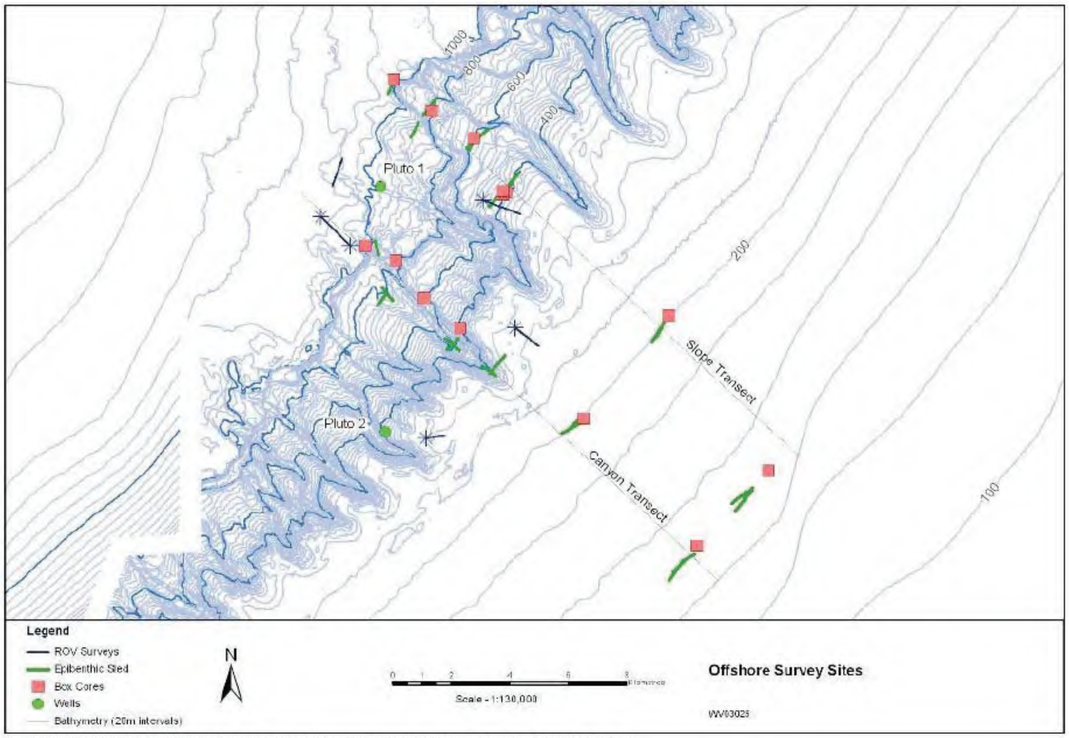

Figure 4-2 Location of Pluto field, showing ROV survey transects (from SKM (2006)

The majority of the substrate consisted of soft sediments, which were green, grey in colour below about 400 m and a light brown in shallower depths. Box core samples found the sediments to be silt below about 400 m and fine sand above this depth. Seabed gradients varied from flat to gradients in excess of 80°. Preliminary results from the geotechnical and geophysical survey of the Pluto field indicate that the seabed of the Pluto field is devoid of hard substrate except for two areas of seabed (M. Bowler [Woodside] 2006 *pers. comm.*, January) which are particularly noteworthy.

Sea Cliffs

Preliminary results of the geotechnical and geophysical studies (completed during the Geoconsult 2006 survey), which commenced at the same time as the offshore environmental survey, indicate that the continental slope at the Pluto field is largely devoid of hard substrate exposed above the sedimentary seafloor. The main area of exposed hard substrate occurs in about 1000 m depth where the continental slope meets the abyssal plain (Figure 4-3).

Figure 4-3 Sea cliffs at the base of the continental slope where it meets the abyssal plain, (depth 1039-1045m)

The bottom of the rocky cliffs is situated in about 1050 m water depths with an almost vertical wall extending 20 m up to about 1030 m at the surveyed location. The rock appears to be sedimentary with clear bands or layers occurring in the rock profile. No epifauna was observed on the exposed rock. Where the seabed gradients are less steep, sediments accumulate and large anemones and batfish were observed. However, both the abundance and diversity of epifauna was limited in these rock areas, compared to the sedimentary seabed located above and below this area of rock cliffs. The size of the areas were not stated but were limited in size.

From about 1030 m to 880 m, rock and mud stone outcrops occur, interspersed with large areas of soft sediment which in places supported large numbers of glass sponges. Observations of the ROV's manipulator arm indicated that the mudstone was very soft, disintegrating very easily. The mudstone was quite flat in areas with limited vertical relief and the sediment build up on the exposed rock and mudstone minimal, which suggests that sediment movement down the slope is very limited and/or strong currents sweep away exposed sediments.

Rock Pinnacles

The only other exposed hard substrate known to occur in the Pluto field is a series of rock pinnacles located about 300 m water depth (Figure 4-4). Results from the geotechnical studies indicate that there are a number of these pinnacles present in a confined area along the 300 m depth contour. They are also described as "coral heads" as they up to 2.5 m in height and 6 m in diameter which often occur in over 10m deep scour depressions (Geoconsult 2005).

The pinnacles contain a very low percentage cover of live soft coral with only a few live specimens of soft coral observed growing on top of the pinnacles.

Figure 4-4 Rock Pinnacles, depth =297-299 m (Source: Geoconsult, 2006)

4.3.4 ROV (Ocean Affinity 2018)

A total of seven POIs were surveyed using ROV in July 2018 by Ocean Affinity. POIs 3, 4 and 5 were mostly flat, sandy seabed, whereas PO1 encountered some of the pinnacles previously described.

The original SKM (2006) survey incorrectly identified the the rock pinnacle structures as biogenic in origin having been created by the deep-water coral *Lophelia* (SKM 2005). The subsequent ROV survey, completed by Ocean Affinity (July 2018), collected much higher resolution imagery of the rock pinnacle field which were sent to Professor Murray Roberts (University of Edinburgh) for expert assessment. It was confirmed that the yellow corals which were originally identified as *Lophelia* were "at first glance *Dendrophyllia cornigera* (well known in the Mediterranean Sea), but perhaps more likely a Leptosammia species (same family: Dendrophylliidae)". It was also confirmed that there was no evidence of *Lophelia* sp. in the imagery that was reviewed (M. Roberts, pers. comm).

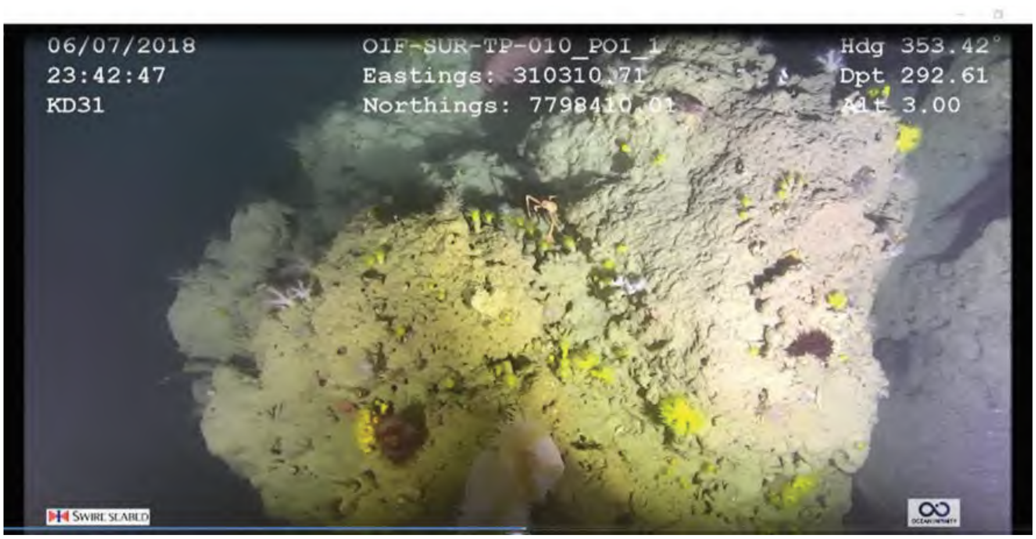

Figure 4-5 Rock Pinnacles at POI1, depth=292m, (Source: Ocean Affinity, 2018)

Figure 4-6 Dendrophyllids on rock pinnacles (POI1), depth = 295m, (Source: Ocean Affinity, 2018)

The pinnacles also provide structure for a diversity of fauna including fish and invertebrates. Many tens of fish were observed gathered around these pinnacles, most probably belonging to either the Glaucosomidae or Pricanthidae families. Crinoids, hydroids and ophiuroids were also common. Other species visible on the mounds include anemones, soft corals, small crustacean like shrimp and some larger brachyurans, possibly *Cyrtomaia suhmii* (Figure 4-7).

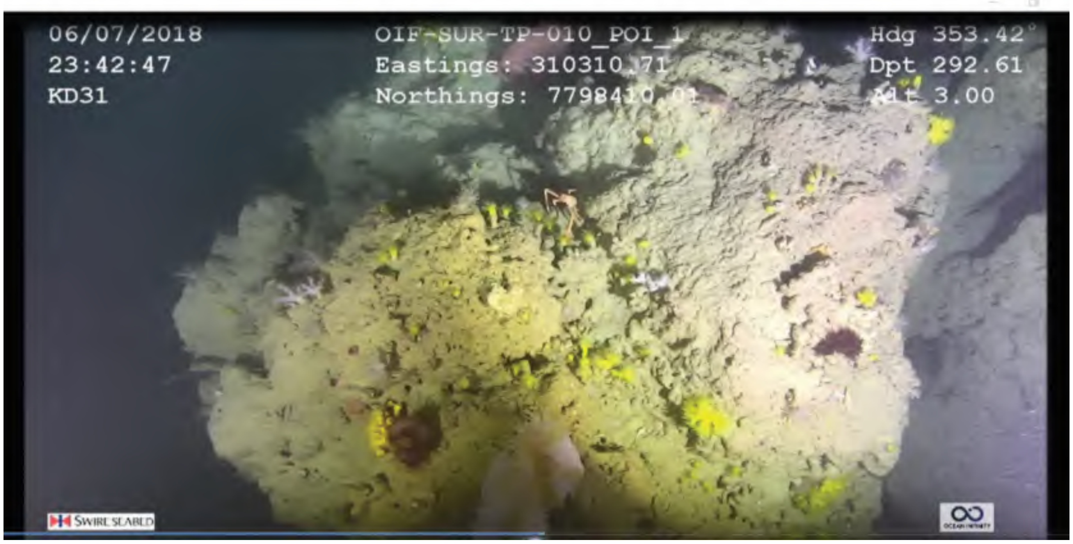

Figure 4-7 Rock Pinnacle (POI1), depth =292m, (Source: Ocean Affinity, 2018)

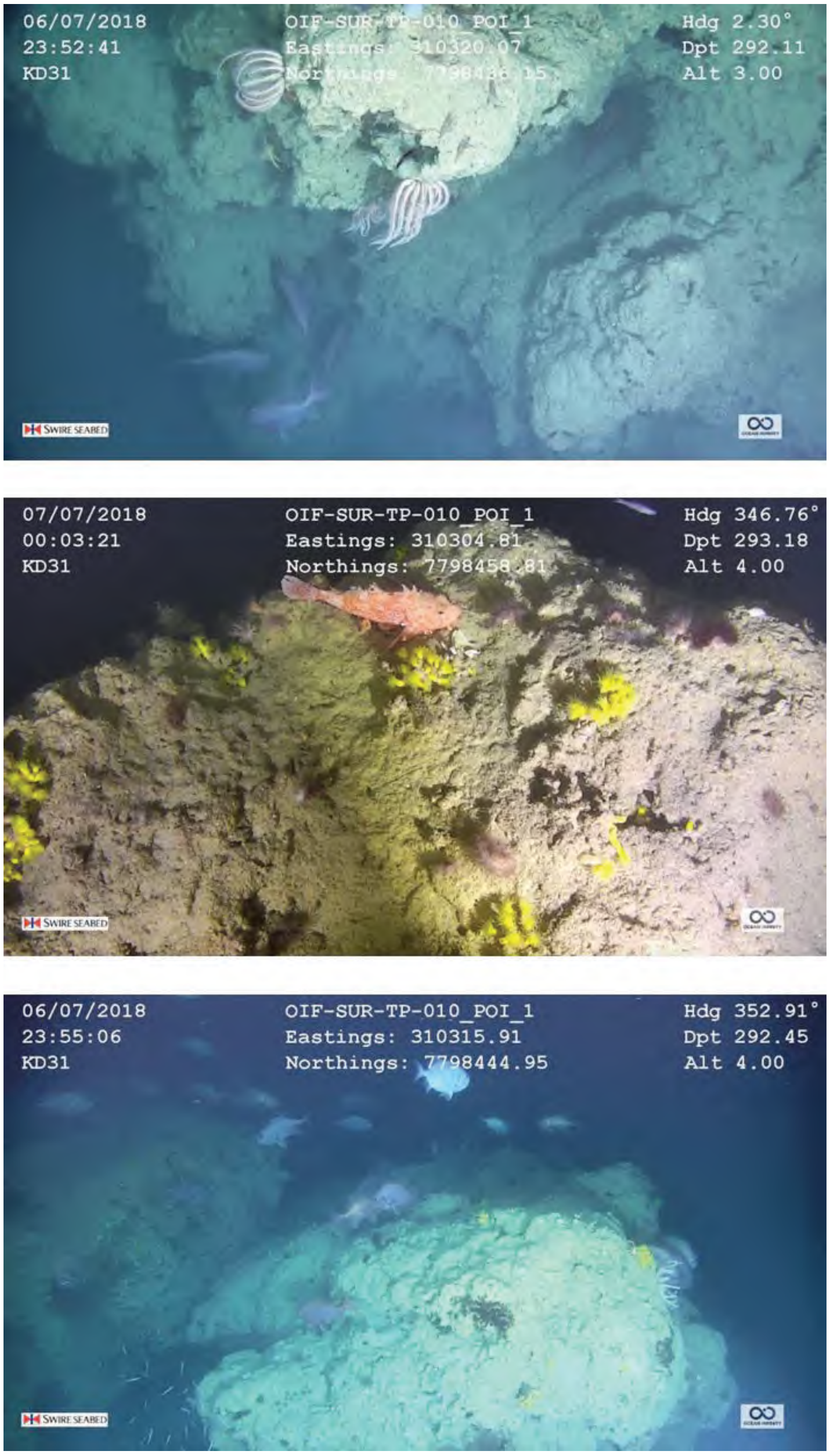

Figure 4-8 Rock Pinnacles from POI 1, showing fish depth =292m, (Source: Ocean Affinity, 2018)

Examples of the soft seabed from POI 3, 4 and 5 are shown in Figure 4-9.

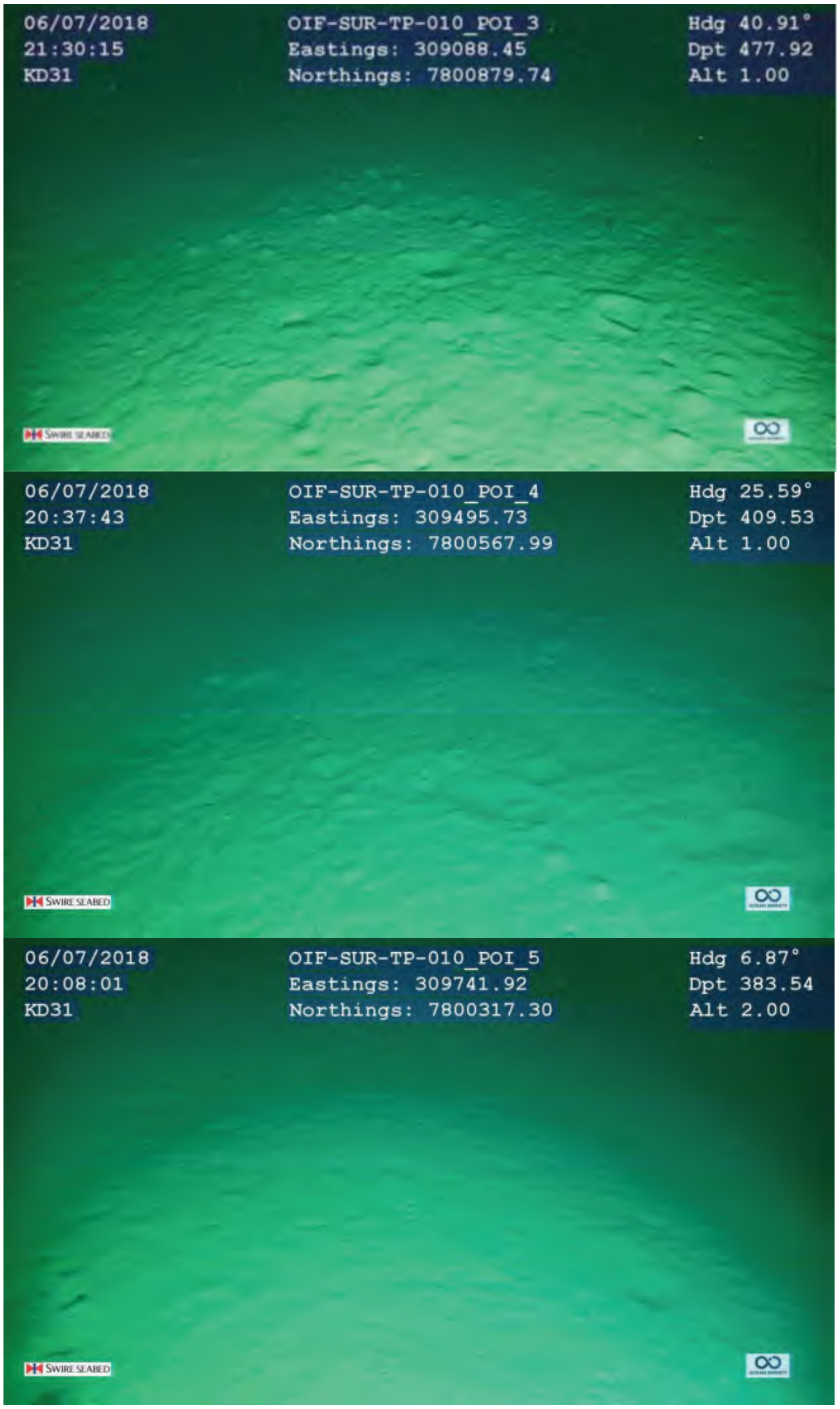

Figure 4-9 Soft sediment substrate at POI 3,4 and 5, depth 383-477m

The POI 2 was mostly soft sandy seabed, with one of the images capturing a solitary dory (Family Zeidae) close to the seabed (Figure 4-10). POI 6 was similar, with very little epifauna visible on the seabed. Species such as that shown in Figure 4-11 were uncommon.

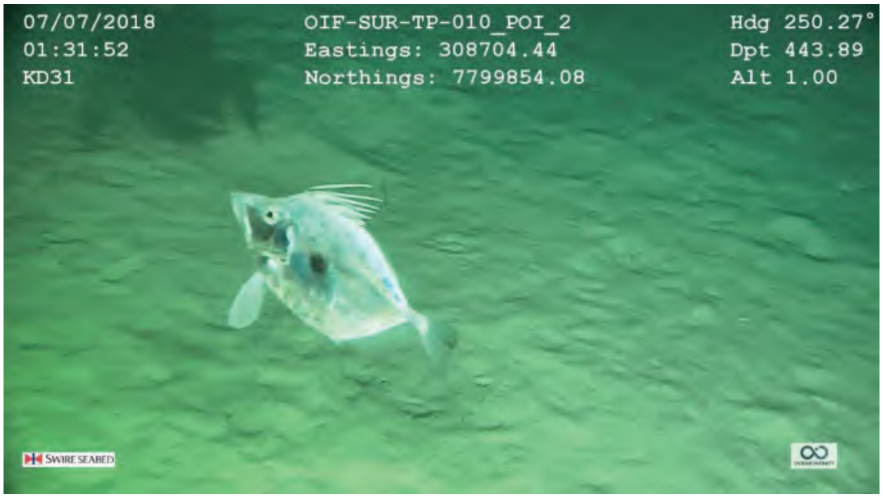

Figure 4-10 Dory, (Family Zeidae), depth 443m, POI2

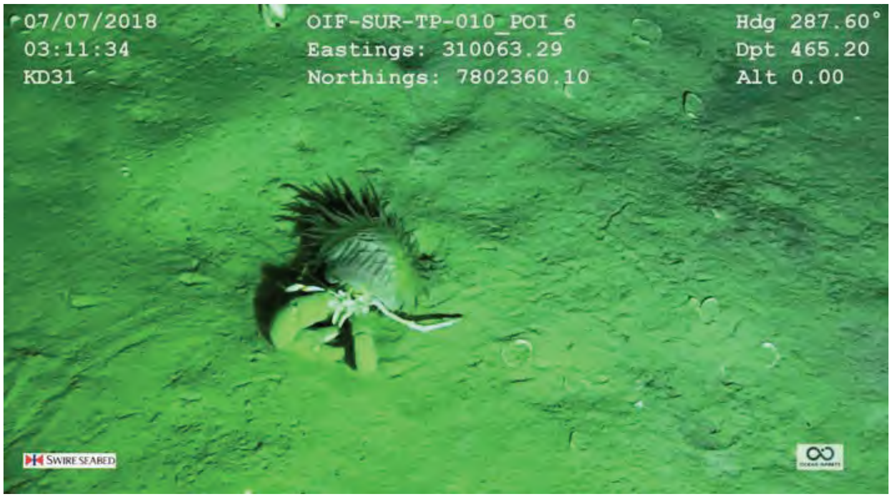

Figure 4-11 ?Opisthobranchia, depth=465m, POI6

All points of interest including the pinnacle field located at POI1 are shown in Figure 4-12. The ROV footage confirms that that the seabed along the trunkline alignment is entirely soft sediment benthos and that the pinnacles at their closest point are more than 350m away from the proposed trunkline alignment.

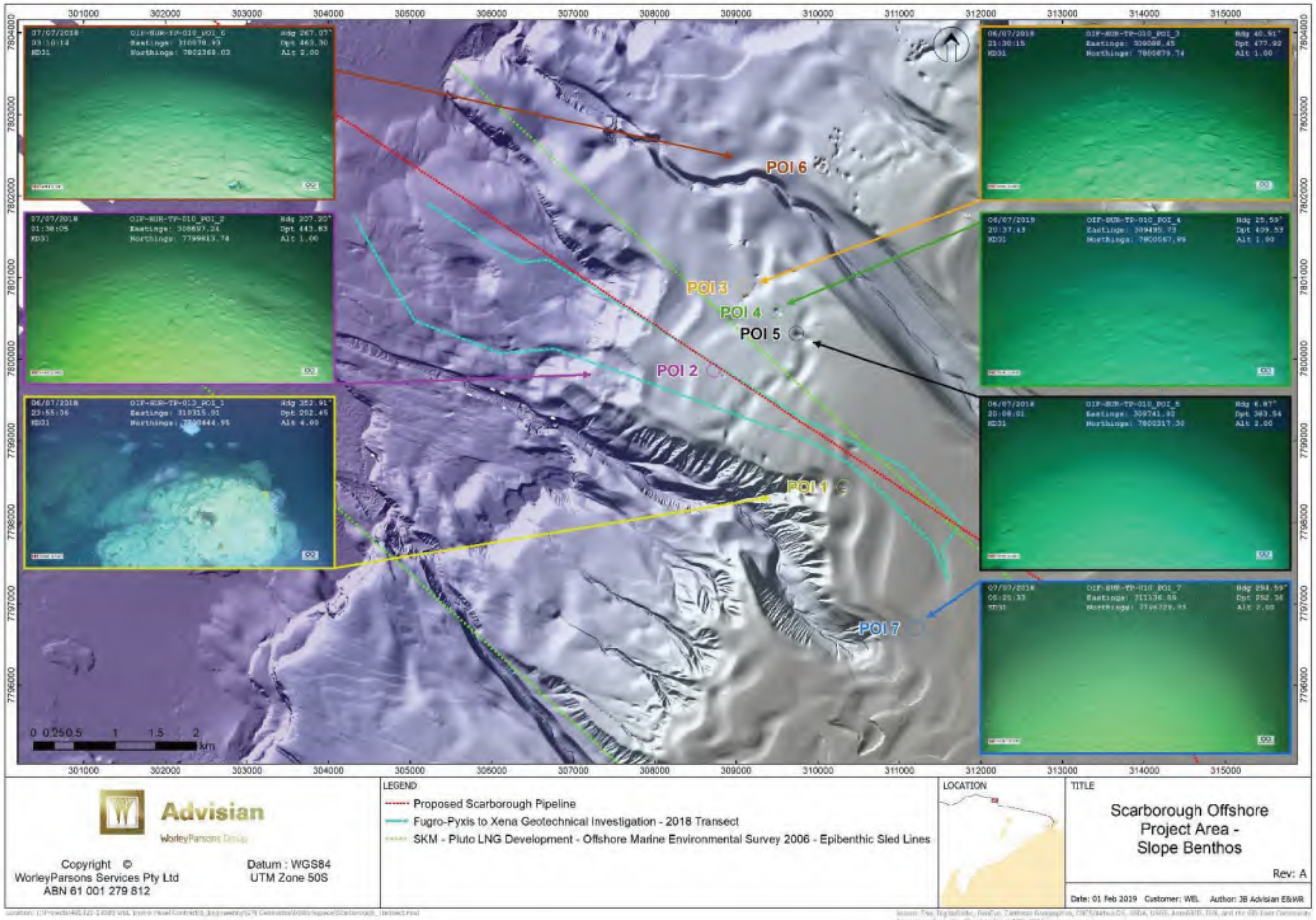

Figure 4-12 Points of Interest surveyed relative to proposed Scarborough trunkline, Continental Slope

4.4 Discussion

The greatest proportion of images analysed from around the Pluto field survey consist of soft sediments supporting a typically sparse deep-water fauna. The fauna was typical of the fauna expected on the North-West Shelf (NWS) and slope. A total of 231 epifaunal species and 32 infaunal species were identified during the SKM (2006) survey.

The infauna of the Pluto field was sparse but highly diverse (given the limited number of individuals collected). While a number of epifaunal species had not been recorded previously in Australia, Western Australia or the NWS region, this is attributed to the limited number of previous studies of the continental slope rather than the rarity of the fauna (SKM 2006).

Despite the limited distance between the Pluto and the Vincent and Enfield fields, the proportion of epibenthic species common to both fields was low. The distribution of fauna across the Pluto field differs to the patterns observed by AIMS during their recent studies around the Vincent and Enfield fields, where the fauna was patchily distributed and more strongly related to substrate type (rock outcrops *versus* soft sediments) than depth. The diversity of epifauna at Pluto was also lower than was observed in the AIMS studies off the North West Cape but this is largely attributable to the lack of rock outcrops in shallow water in the Pluto field.

While the majority of the Pluto field seabed was comprised of soft sediments, geotechnical data indicated the presence of a pinnacle field located in about 300 m depth. The pinnacle field covers an area that is less than 3km^2 and consist of solitary outcrops rather than continuous reef. It remains unclear what the rock pinnacles are constructed from, however the structures provide habitat for a diverse suite of epifaunal and demersal species, including fish that are not usually found on the soft sediments.

4.5 Summary

The fauna observed was consistent with what would be expected to be found at the surveyed depths on the North West Shelf. The distribution of fauna across the Pluto field differs to the patterns observed by AIMS (Heyward and Rees 2001a and 2001b; Heyward et al. 2001 and 2001b) during historical studies around the Vincent and Enfield fields, off North West Cape. AIMS observed that the fauna was patchily distributed and more strongly related to substrate type (rock outcrops versus soft sediments) than depth. At Vincent and Enfield, the highest diversity of fauna was found on exposed rock outcrops. Preliminary geotechnical and geophysical data suggests that hard substrate is limited in the Pluto field. ROV recordings also indicate that the hard substrate located around 1000 m does not support a rich epifaunal community. The depth of water and sediment movement over the near vertical walls of the hard substrate may be the factors limiting the development of a rich epifaunal community (SKM 2006).

Despite the lack of similarities between the fauna in the collections made at Vincent-Enfield and the historical survey at the Pluto field, which are separated by less than 300 km, the Western Australian Museum researchers indicated that the species recorded from the Pluto field are representative of the area and collection depths with most species having been collected previously.

5 Continental Shelf

5.1 Background

The assessment of the offshore habitats that occur on the continental shelf (<300m water depth), have been based on ROV footage collected as part of subsea facility inspections around the Pluto field within Permit Area WA-34-L and WA-48-L. Whilst the Pluto platform itself is located within WA-48-L, in 83m water depth, much of the subsea infrastructure including pipelines and wellheads are in WA-34-L in ~190m water depth. The seabed composition through these areas has been previously described as being predominantly flat and featureless and comprises thick, unconsolidated fine grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans).

5.2 Survey Method

A total of 56 ROV video records from several subsea inspections were used as a basis for assessment. These included a review of footage from the following locations:

- Xeres-1A Well Head, (depth ~190m)
- Pluto Frond Mats (2015-2017), (depth ~170m)

5.3 Results

5.3.1 Xeres Well Head

The footage from the wellhead confirms that the seabed is comprised of soft unconsolidated sediments, possibly fine sand silts (Figure 5-1). The well head structure provides hard substrate for the colonisation by a range of invertebrates such as barnacles, hydroids and anemones. The structure in turn provides habitat for a range of fish species, as shown in Figure 5-1.

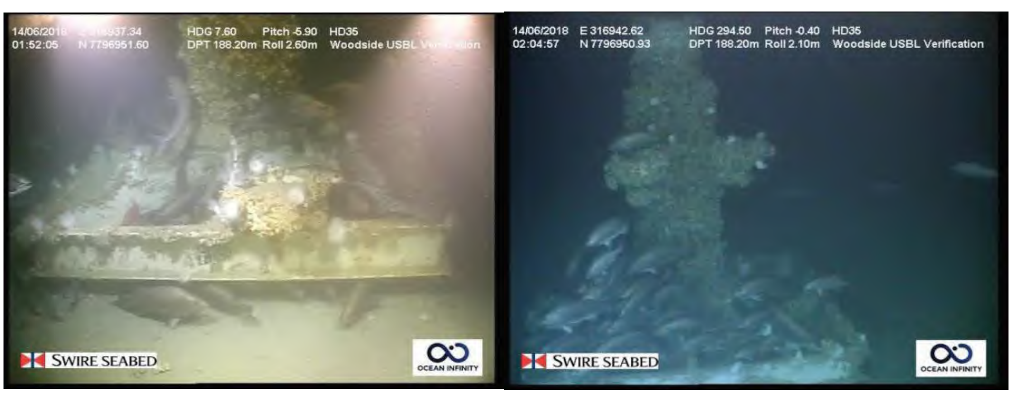

Figure 5-1 Schools of fish, Xeres Well Head, Depth 188m

5.3.2 Pluto Frond Mats

The footage from the annual surveys of the Pluto frond mats also confirms that the seabed surrounding the pipeline is comprised of soft unconsolidated sediments that is mainly fine sand (Figure 5-4, Figure 5-5, Figure 5-5).

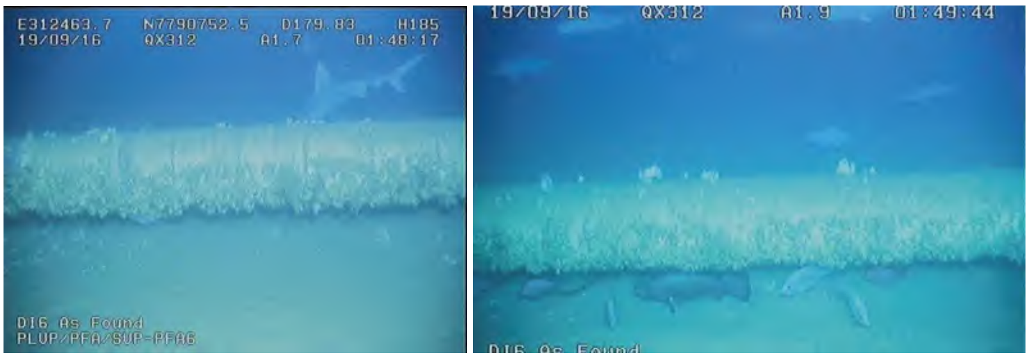

Figure 5-2 Pipeline showing sandy substrate in the foreground, Pluto, depth =179m

5.1 Discussion

Epifauna was observed to be most abundant on the continental shelf (150–200 m) and the abundance of the fauna appeared to be inversely associated with depth, with distinct differences in the fauna on the Shelf and slope (SKM 2006). However additional analysis of the proposed trunkline route shows the pipelines and wellheads offer significant areas of hard bottom habitat in a region that is characterised by soft unconsolidated sediments. Figure 5-3 provides a snapshot of images from the ROV locations surveyed relative to the trunkline alignment. Due to the uniform nature of the seabed across much of this area of shelf (as also confirmed by regional geomorphological mapping, refer to IMCRA 4.0), the ROV locations are considered representative of the larger project area and have been used to confirm that the trunkline route over the entire section of seabed is likely to be dominated by sand and other sediment types.

It is the pipeline itself that provides hard substrate for the establishment of a habitat that supports a diversity of species that includes invertebrates and fish. The images within Figure 5-4 and Figure 5-5 show how cover by species can also vary. The most common forms present include barnacles, sea whips (Octocorals), anemones, hydroids and to a lesser extent sponges and crinoids. The type and number of fish present is also highly variable and also depends on the relative position of the pipeline above the seabed. Partially buried pipelines do not appear to provide the same habitat complexity and opportunity that suspended or resting pipelines provide (McLean *et al*. 2017).

Fish assemblages and colonising invertebrate habitats on these artificial hard substrates also vary with depth and age. Generally speaking, the structures that are located in shallower water (<135m) had a greater diversity of fish compared to habitats at 350m depth where the number of fish species and abundance declined markedly (McLean *et al*. 2018). The study by Bond (*et al*. 2018) also confirmed that compared to adjacent natural seabed habitats, pipeline fish fauna were characterised by higher relative abundance and biomass of commercially important species.

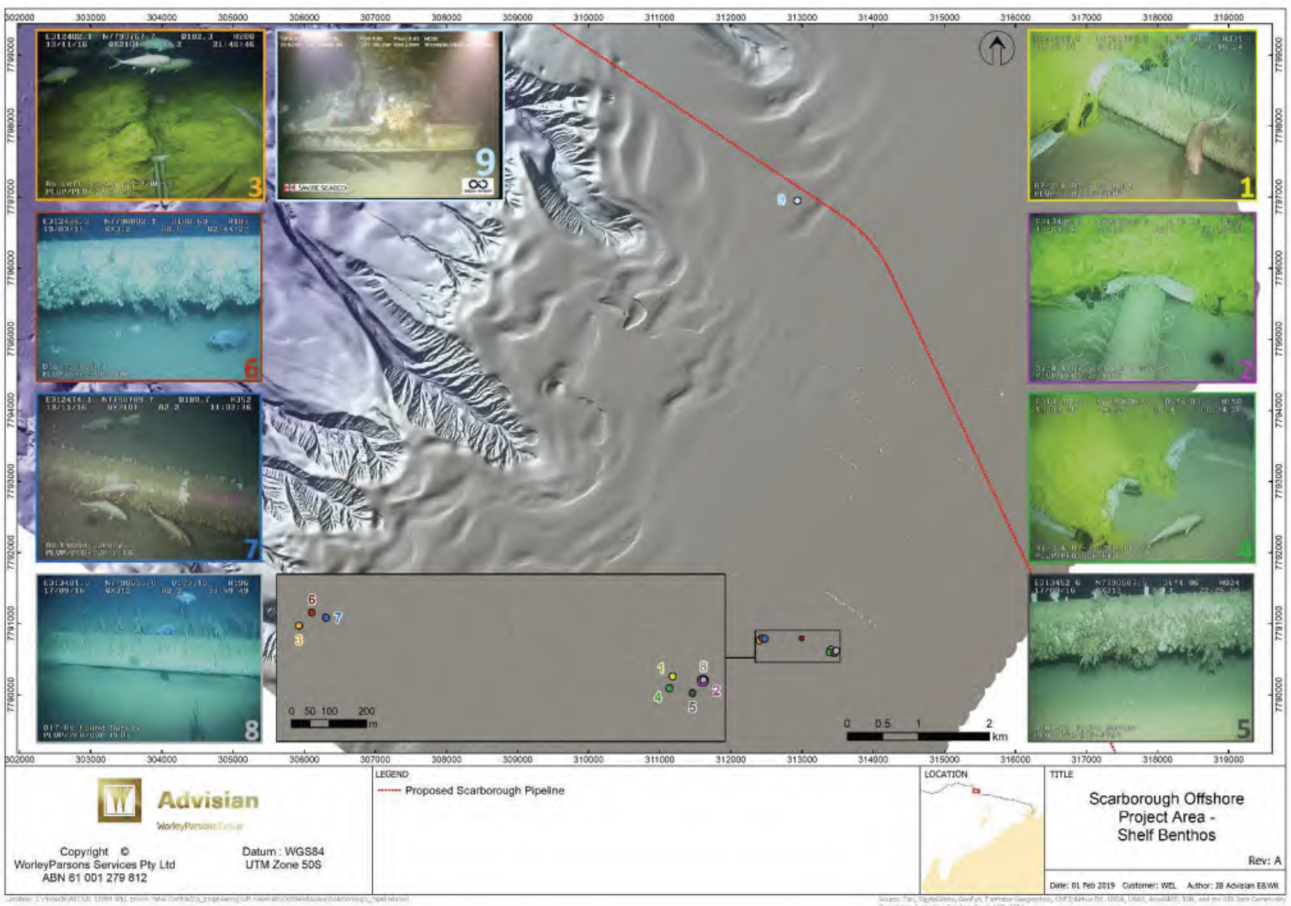

Figure 5-3 ROV survey locations, Continental Shelf

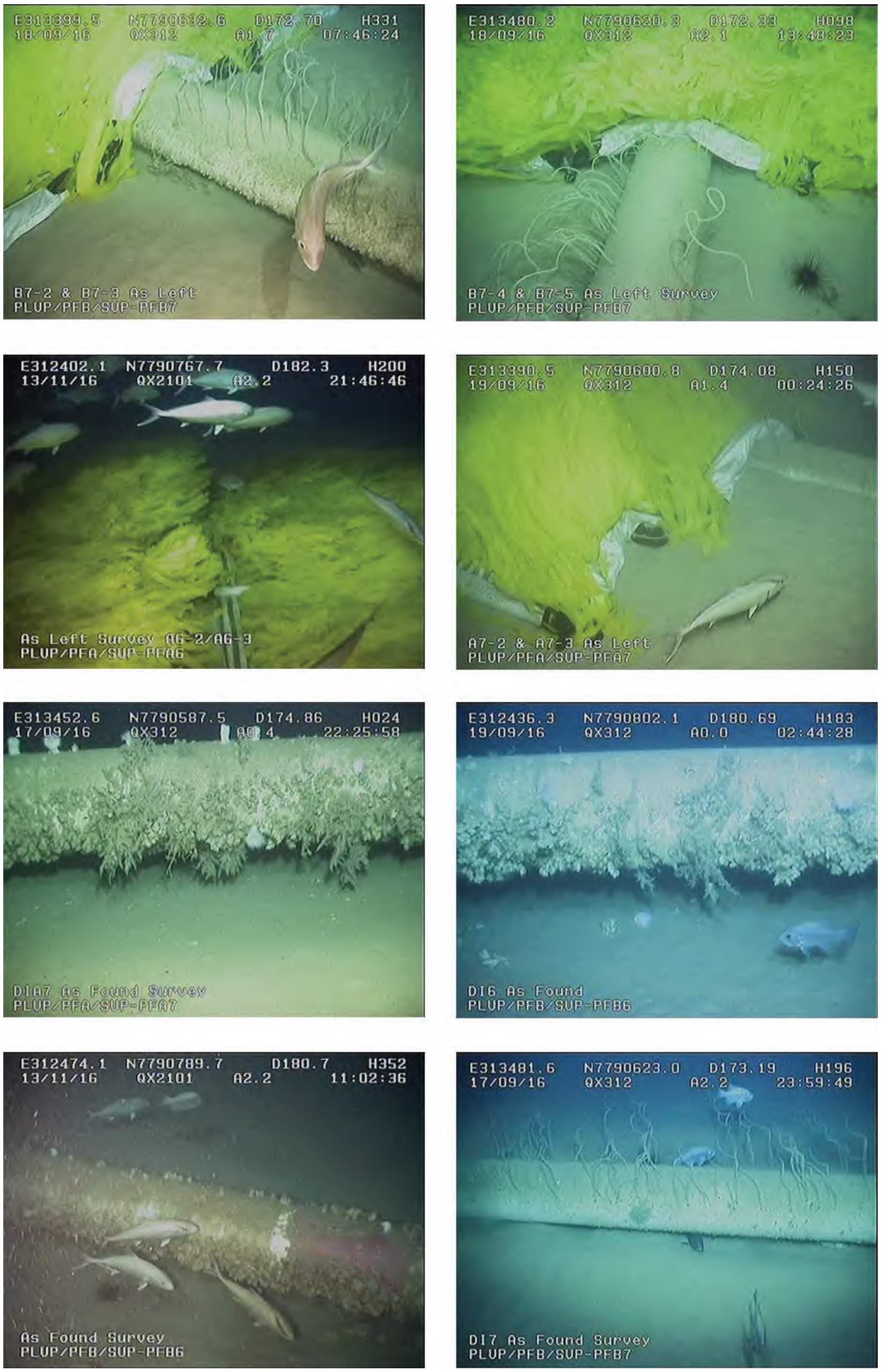

Figure 5-4 Pluto Frond Mats, 2016 Survey, Depth ~170m

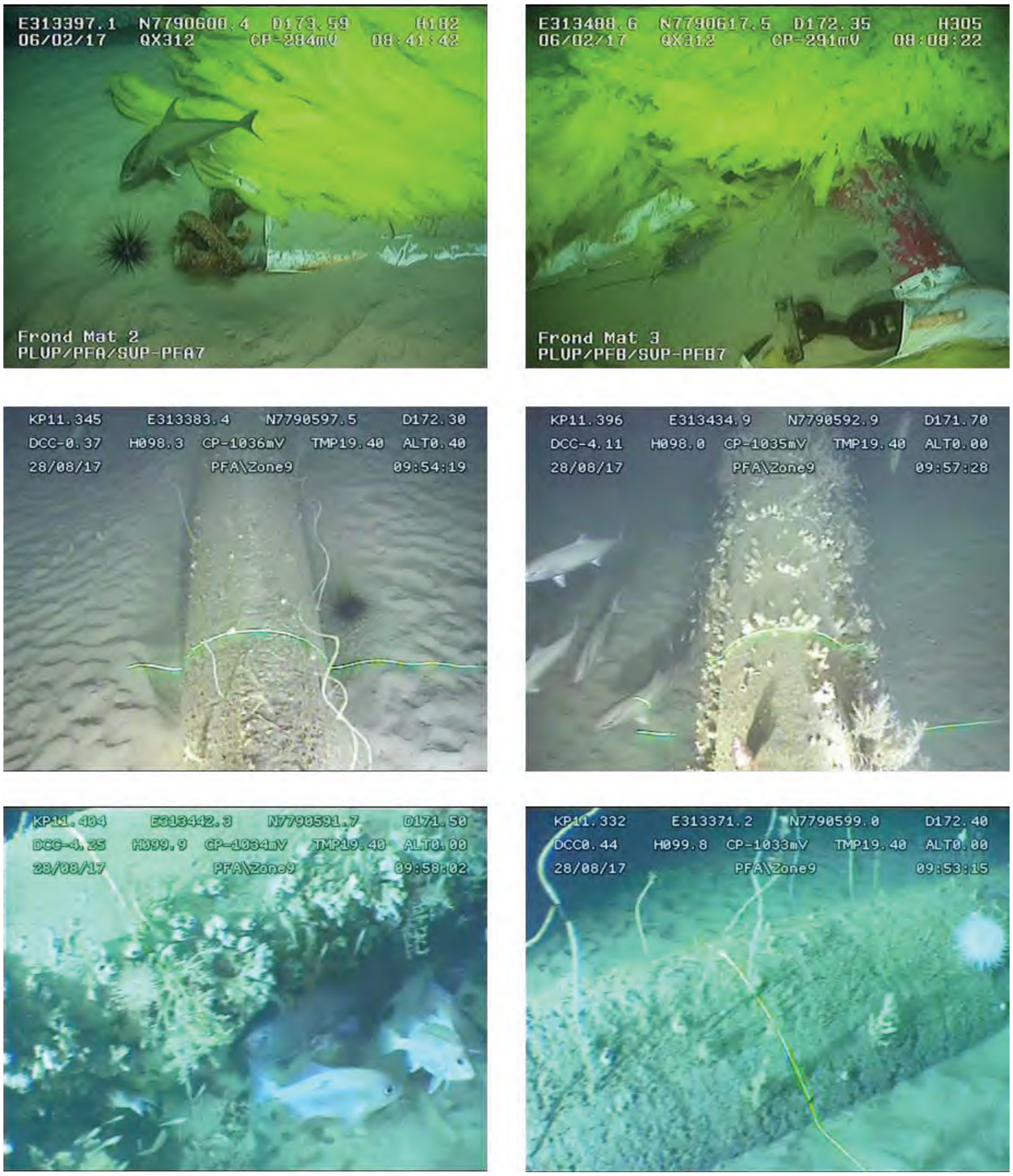

Figure 5-5 Pluto Frond Mats, 2017 Survey, Depth ~170m

6 Conclusions

Regional studies and the site specific studies reviewed indicate that seabed material along the proposed pipeline alignment (and around the gas field) is predominantly flat and featureless and comprises thick, unconsolidated fine grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans).

Sedimentary infauna associated with soft unconsolidated sediments of the general area is widespread and well represented along the continental shelf and upper slopes in the NWS region (Woodside 2004; SKM, 2007; Brewer *et al.,* 2007; RPS, 2011). Consequently, in the context of the contiguous extent of habitats across the region, benthic habitat along the proposed pipeline alignment consists primarily of soft unconsolidated sediments and is considered to be of relatively low environmental sensitivity.

Benthic communities of filter feeders generally live in areas that have strong currents and hard substratum (CALM, 2005) and are closely associated with substrate type, with areas of hard substrate typically supporting more diverse epibenthic communities (Heyward et al., 2001). The only natural habitat that is not classified as soft sediment is the pinnacle field that lies in about 300m water depth, on the continental slope. The pinnacle field covers an area less than 3km^2 but the pinnacles are isolated forms and do not constitute continuous reef. It remains unclear what the pinnacles are constructed from, however the structures provide habitat for a diverse suite of epifaunal and demersal species that commonly occur elsewhere in the NWS.

Recent research has also confirmed that habitats containing the greatest biodiversity in these offshore environments are the habitats formed by colonising invertebrates on oil and gas subsea infrastructure including the well heads and pipelines. These habitats and the species present on these structures in the NWS of Western Australia have been subject to detailed assessment by McLean *et al.* (2018), Bond *et al*. (2018) and McLean *et al*. (2017). These habitats not only have structural complexity but also create habitat for a large diversity of fish species that commonly occur elsewhere in the NWS but do not occur over soft unconsolidated sediments.

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Appendix B

Dampier Archipelago Commonwealth waters Marine Benthic Habitat Survey

Dampier Archipelago

Commonwealth Waters Marine Benthic Habitat Survey

18 January 2019

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West Perth WA 6005
Australia

401012-02612-EN-REP-0001

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Project No: SPA-ENG-00-EN-REP-0001 – Dampier Archipelago: Commonwealth Waters Marine Benthic Habitat Survey

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Executive Summary

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

As part of the trunkline installation, Woodside is assessing the feasibility of using backfill material from a potential borrow ground that has been identified in Commonwealth Waters. The potential borrow ground is located adjacent to the north-western extent of the habitat protection zone of the Dampier Marine Park. A benthic habitat survey of the potential borrow ground and surrounding areas within the Dampier Marine Park was commissioned (this study) to support the environmental impact assessment of the intended activities.

Surveys of marine benthic habitat of the potential borrow ground and nearby areas within the Dampier Marine Park were undertaken between 18th and 20th December 2018. This report presents the methodology and results from the survey.

Bare sandy substrate dominated most of the locations where towed/drop camera transects were conducted. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10% and typically less than 5% cover. Of the 24 survey locations within the potential borrow ground, sparse invertebrate cover was observed at only two locations. Of the 51 survey locations within the habitat protection zone of the Dampier Marine Park, sparse invertebrate cover was observed at 12 locations.

1 Introduction

1.1 Project Background

Woodside is assessing the feasibility of using backfill material from a potential borrow ground in Commonwealth Waters. The potential borrow ground is adjacent to the north western extent of the Dampier Marine Park (DMP). The area of the DMP that is adjacent to the potential borrow ground is an International Union for Conservation of Nature (IUCN) Protected Area. It has been attributed Category IV status, which has the primary objective to maintain, conserve and restore species and habitats. An understanding of benthic communities at and surrounding the potential borrow ground is required to help inform the impact assessment for the intended activities associated with using the potential borrow ground.

This report presents the methodology and reports the findings of the benthic habitat survey that was undertaken in December 2018 at the potential borrow ground and adjacent areas within the DMP.

1.2 Scope of Work

The primary aim of the Commonwealth Waters survey was to gather information to support an environmental impact assessment of using the proposed borrow ground. The survey was completed to acquire qualitative data on species present, and to report on the presence of sensitive benthic biota or habitat near the proposed borrow ground and the adjacent DMP.

1.3 Survey Location

The potential borrow ground is located directly north of the western extent of the DMP, about 9 km north of the north-western extent of Legendre Island, outside the Dampier Archipelago (Figure 1-1).

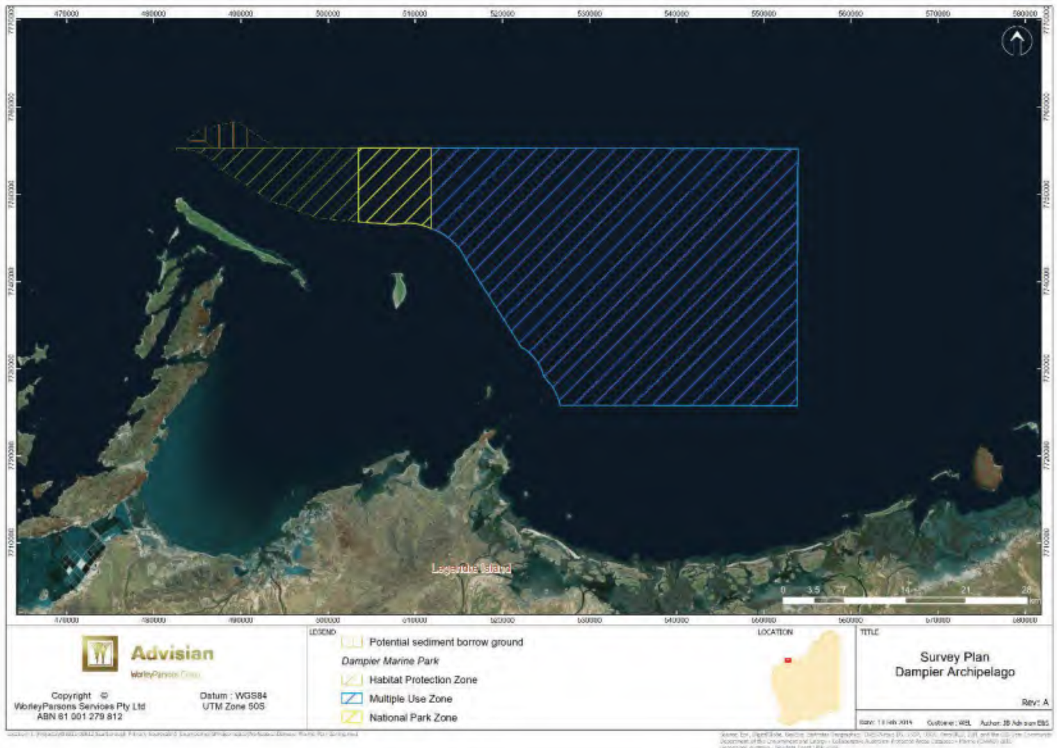

Figure 1-1: Survey location showing potential borrow ground and adjacent section of Dampier Marine Park

1.4 Previous Knowledge

The Marine Park was proclaimed in December 2013, though has been known as Dampier Marine Park since October 2017. DMP is significant because, as a whole, it provides protection for offshore shelf habitats adjacent to the Dampier Archipelago, the area between Dampier and Port Hedland and a seafloor rich with sponges (DNP, 2018). The habitat protection zone adjacent to the potential borrow ground is allocated Category IV Protection as it provides important habitat for benthic communities in the region. Previous knowledge of the benthic habitats and communities of the survey location includes a study by the CSIRO (Pitcher *et al* 2016), which covered an extensive area of the west Pilbara describing benthic habitats and categorizing the assemblages' present. The survey location appears to be on the outer fringes of the CSIRO study. Bathymetric information was limited to nautical charts of the region.

2 Methods

2.1 Survey Design

To optimise the field campaign, survey locations for video and still images were positioned to target the potential borrow ground and surrounding area (Figure 2-1). A 5km buffer was applied to the potential borrow ground to define the survey area in the Dampier Marine Park.

Existing historical data was not available to assist with directing survey effort. To maximise spatial coverage over this area in the available timeframe, a 1 km grid survey pattern was applied. Locations within the potential borrow ground and locations in the DMP closest to the potential borrow ground, were prioritised.

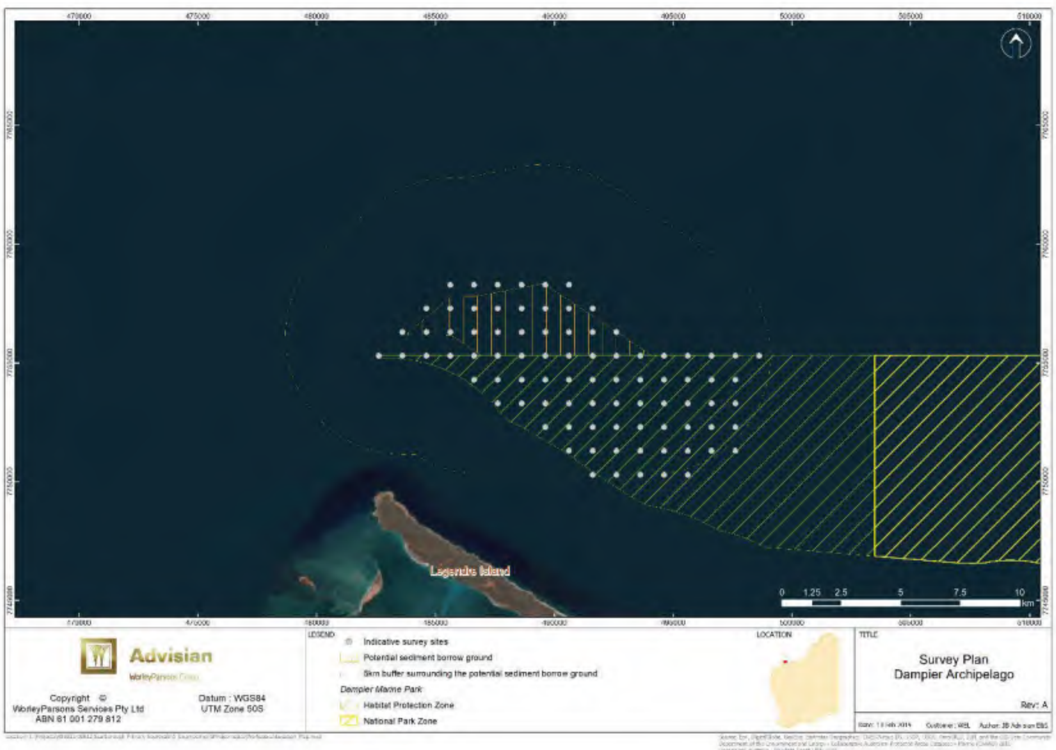

Figure 2-1: Survey sites planned in Commonwealth Waters at the potential borrow ground and Dampier Marine Park

2.2 Field Survey

The field survey was undertaken onboard the vessel *Kaelani*, operated by Bhagwan Marine, between 16th and 20th December 2018. A total of 24 transects were completed within the potential borrow ground and a further 51 transects were completed within the DMP during the survey. Transects varied in length from 30 m to about 230 m, though were typically around 100 m (Figure 2-2). The planned survey locations at the southern extent of the DMP were unable to be surveyed due to time constraints. Habitat data was obtained using a towed/drop camera array including digital recordings of high resolution still photographs and high definition video footage. When possible, real-time standard definition footage was observed by an attending marine scientist on the vessel. Preliminary qualitative habitat information was recorded into log sheets for subsequent review. Information recorded to the log sheet for each transect included:

- transect number (identifier)
- time of transect data collection (start/end) and observed changes of habitat
- dominant benthic habitat (substrate type and biota density)
- approximate depth (as measured by the vessel echo sounder)
- general comments relating to each transect.

Spatial positioning data was acquired using a Garmin GPSMap 62 and a Holux RCV-3000 located onboard the vessel. Two units were used for redundancy. The global positioning system (GPS) units recorded a tracklog for each day of operation and were time-synchronised with the laptops and cameras used to record habitat data.

At each survey location the camera array started recording on the deck of the vessel, where information about the transect and location was recorded before the array was deployed. Once the camera array reached the seabed, the vessel was allowed to drift for two to three minutes, depending on the rate of drift. When real-time viewing was available and more complex habitat was observed, or bathymetry was more variable, the transect/drift was allowed to proceed for a longer period but capped at around five minutes for operational efficacy. The typical drift speed was between 0.5 and 1.7 knots according to the vessel chart plotter.

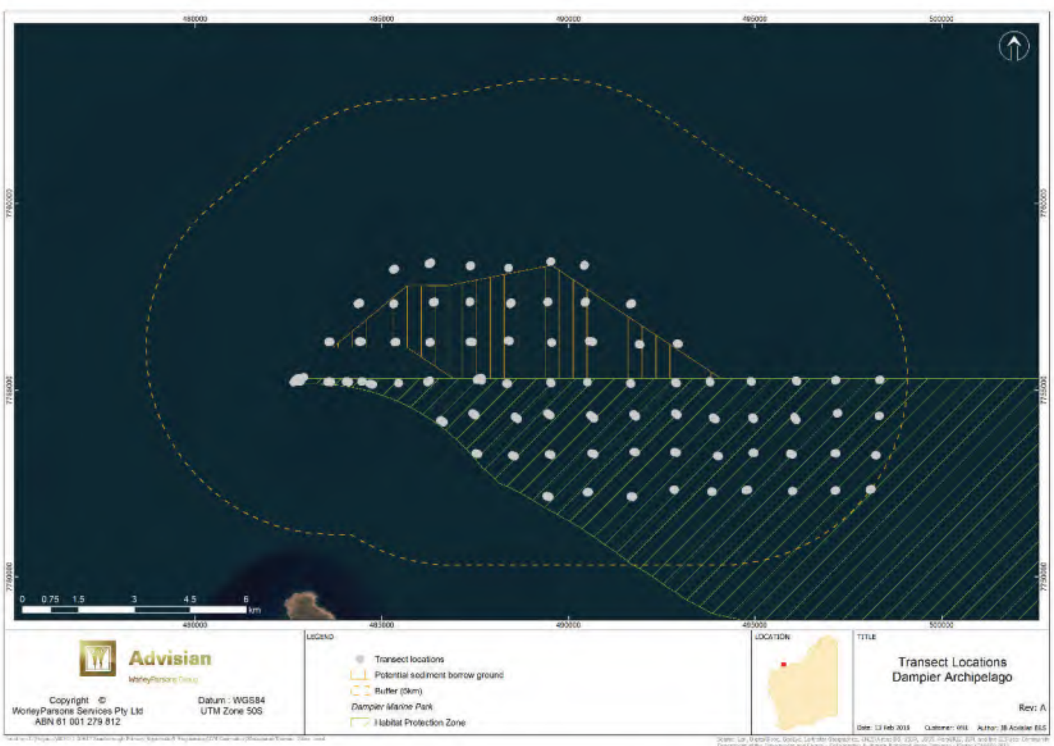

Figure 2-2: Benthic habitat transects conducted in Commonwealth Waters at the potential borrow ground and Dampier Marine Park, December 2018

2.3 Benthic Habitat Characterisation

High level habitat classes were derived from a benthic habitat map of the Dampier Archipelago by MScience (2018). These classes were refined based on habitats and biota observed during the survey (Table 2-1). The video footage and still imagery was reviewed after the field survey was complete, to confirm habitat classifications and to refine spatial data where necessary by improving time logs of habitat boundaries and transect start/end points. Where habitat boundaries or changes in epibenthic density were different to the initial logs, the elapsed time in the video was applied to determine the time and relative spatial position for the particular attribute and a new revision of the log was created.

Habitat information was georeferenced by relating the times recorded on the log sheets with the position logged by the GPS onboard the vessel. Position information was logged by the Holux GPS each second. For each spatial position received, the relative habitat information was attributed to create habitat point data of the areas surveyed.

Habitat point data was imported into ArcMap geographical information systems platform to create Esri shape files and to be displayed with other relevant spatial data for presentation in this report.

Table 2-1: Habitat classification scheme utilised for the survey

Habitat Class	Definition
Coral	Hard coral communities dominate and were present in ≥10% cover. Some minor biota may be present (i.e. ascidians, bryozoans and sponges); however, they are secondary in density and ecological function. No coral was observed along any of the survey transects.
Algae	Macroalgae were the dominant biota (≥10% cover) over a consolidated hard substrate that may contain sparse (≤10%) secondary biota (i.e. solitary corals or seagrasses). No macroalgae or seagrass was observed along any of the survey transects.
Invertebrates	Sessile and mobile benthic invertebrate biota (including crinoids, ascidians, hydroids and sponges) were present (≥3%) on sandy substrate with little or no other biota. Both sessile and mobile invertebrates were observed along survey transects. Example images are supplied in Figure 2-3.
Bare Sediment	Substrate is predominantly bare sand. Biota is very sparse (≤10% cover of macroalgae or coral and ≤3% invertebrates) or entirely absent. Bare sediment was the dominant habitat class in the survey transects. Example images are supplied in Figure 2-4.

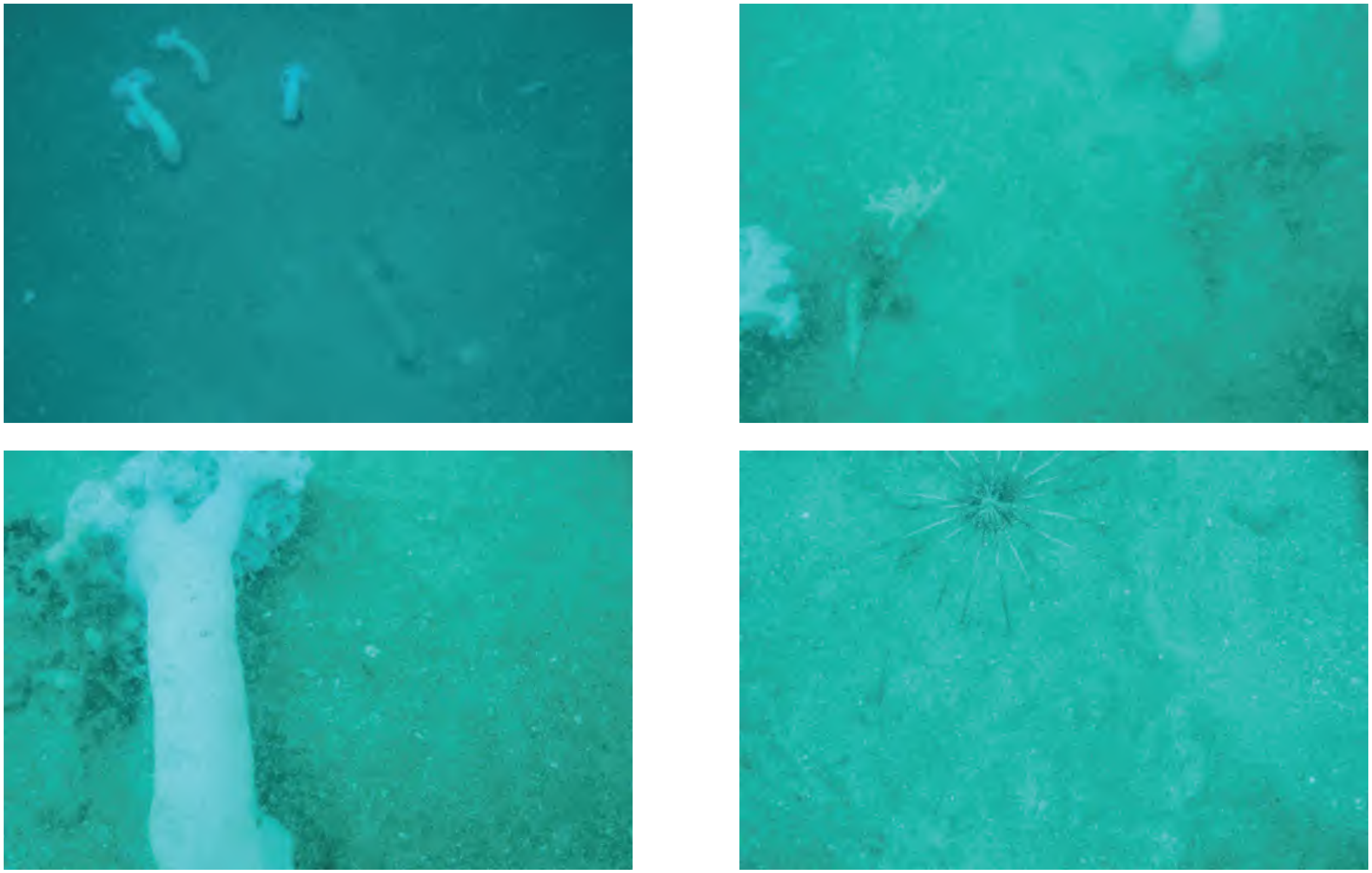

Figure 2-3: Examples of typical habitat classified as Invertebrates

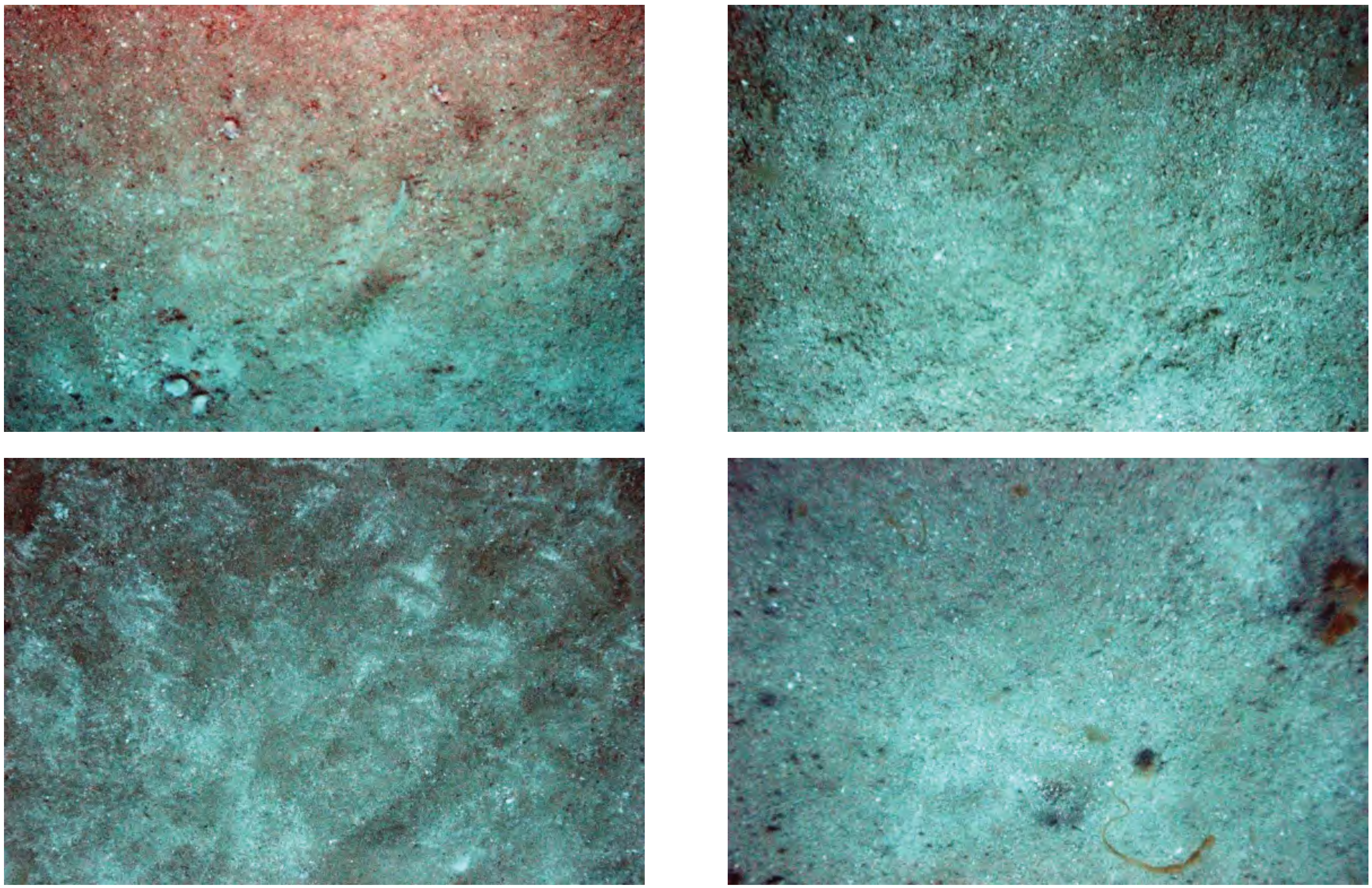

Figure 2-4: Examples of typical habitat classified as Bare Sediment

3 Results

3.1 Benthic Habitat

At the proposed borrow ground bare sandy substrate dominated areas where towed/drop camera transects were conducted. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10%. Of the 24 survey locations, invertebrates were observed at only two (Figure 3-2 and Figure 3-3). Most transects were conducted in depths between 40 m and 42 m. Four transects were conducted in water depths between 37 and 40 m.

Like the potential borrow ground, bare sandy substrate dominated areas where towed/drop camera transects were conducted in the Dampier Marine Park. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10%. Of the 51 survey locations, sparse invertebrate cover (3–10%) was observed at 12 of them (Figure 3-4, Figure 3-5 and Figure 3-6). Bathymetry was more variable within the marine park survey area, ranging from 31 m to 43 m. No particular association between habitat and depth is evident based on this data.

Figure 3-1 displays the general location of each the subsequent figures.

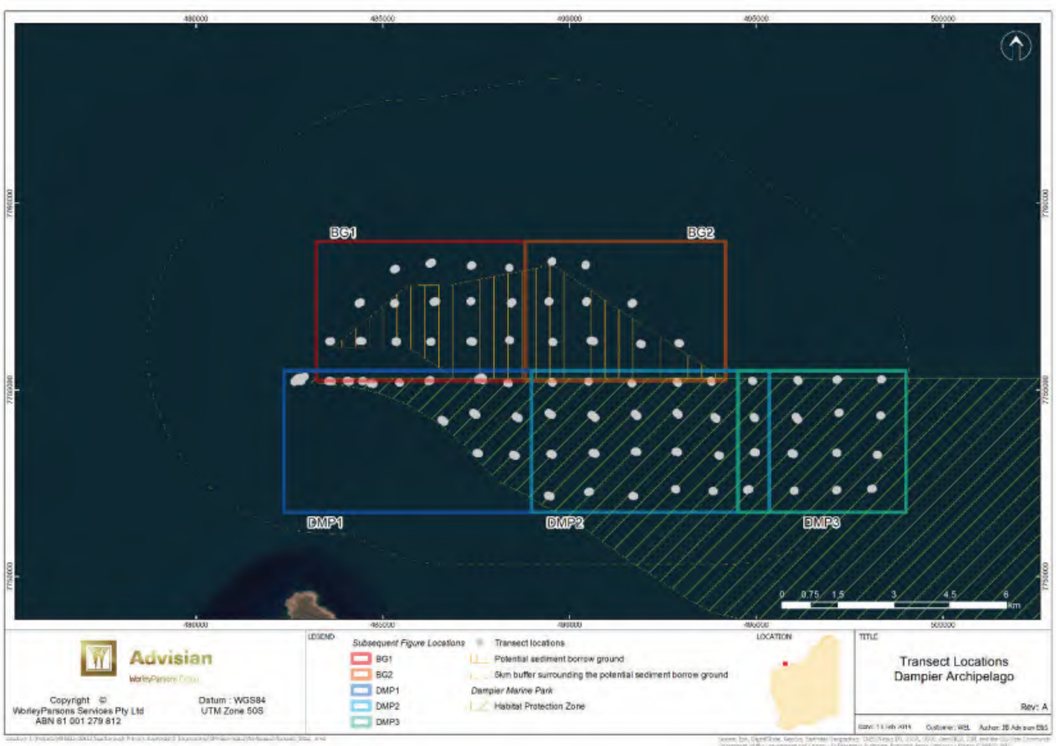

Figure 3-1: Transects with superimposed boxes indicating where subsequent figures presented are located

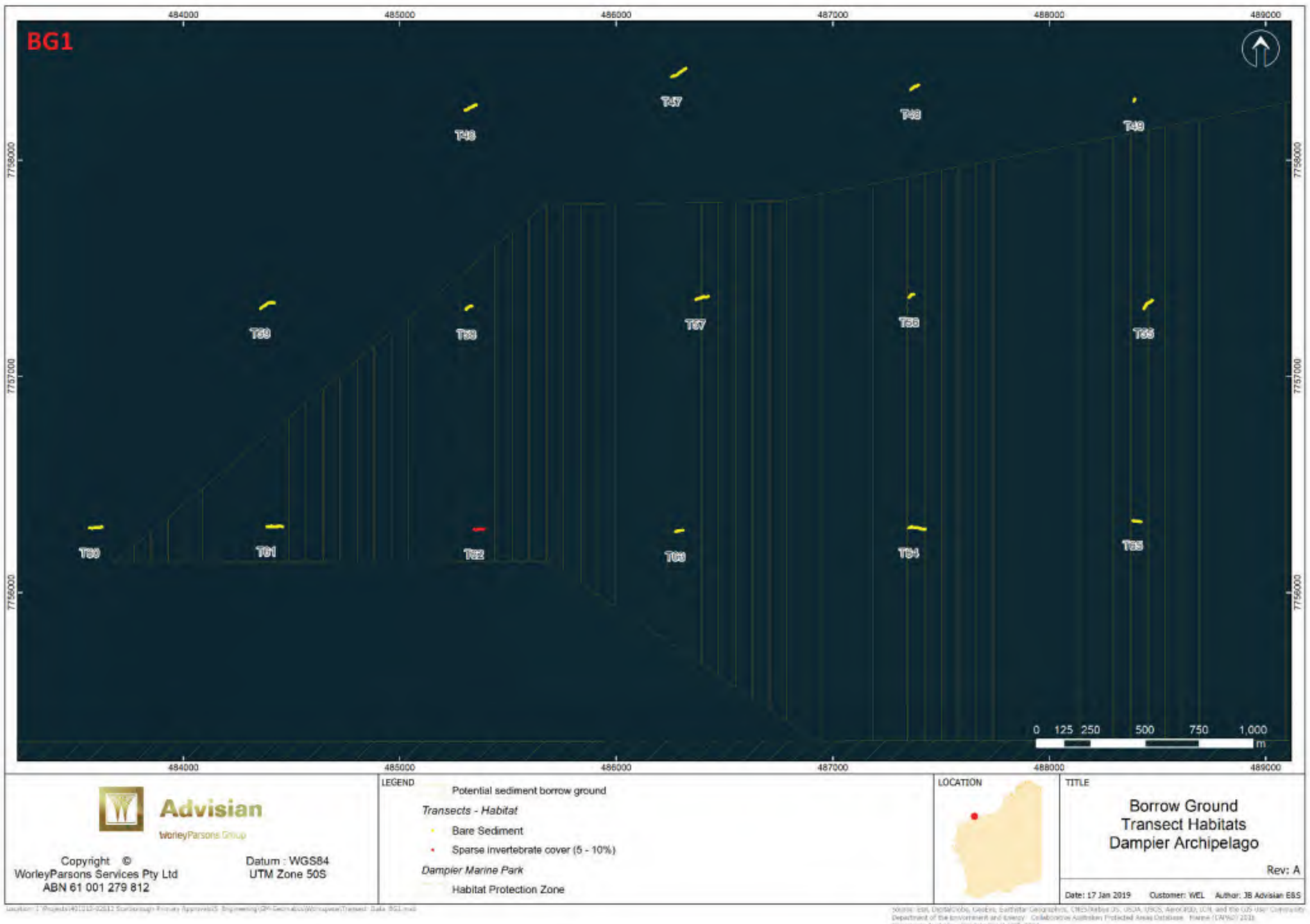

Figure 3-2: Benthic habitat in the western portion of the potential borrow ground

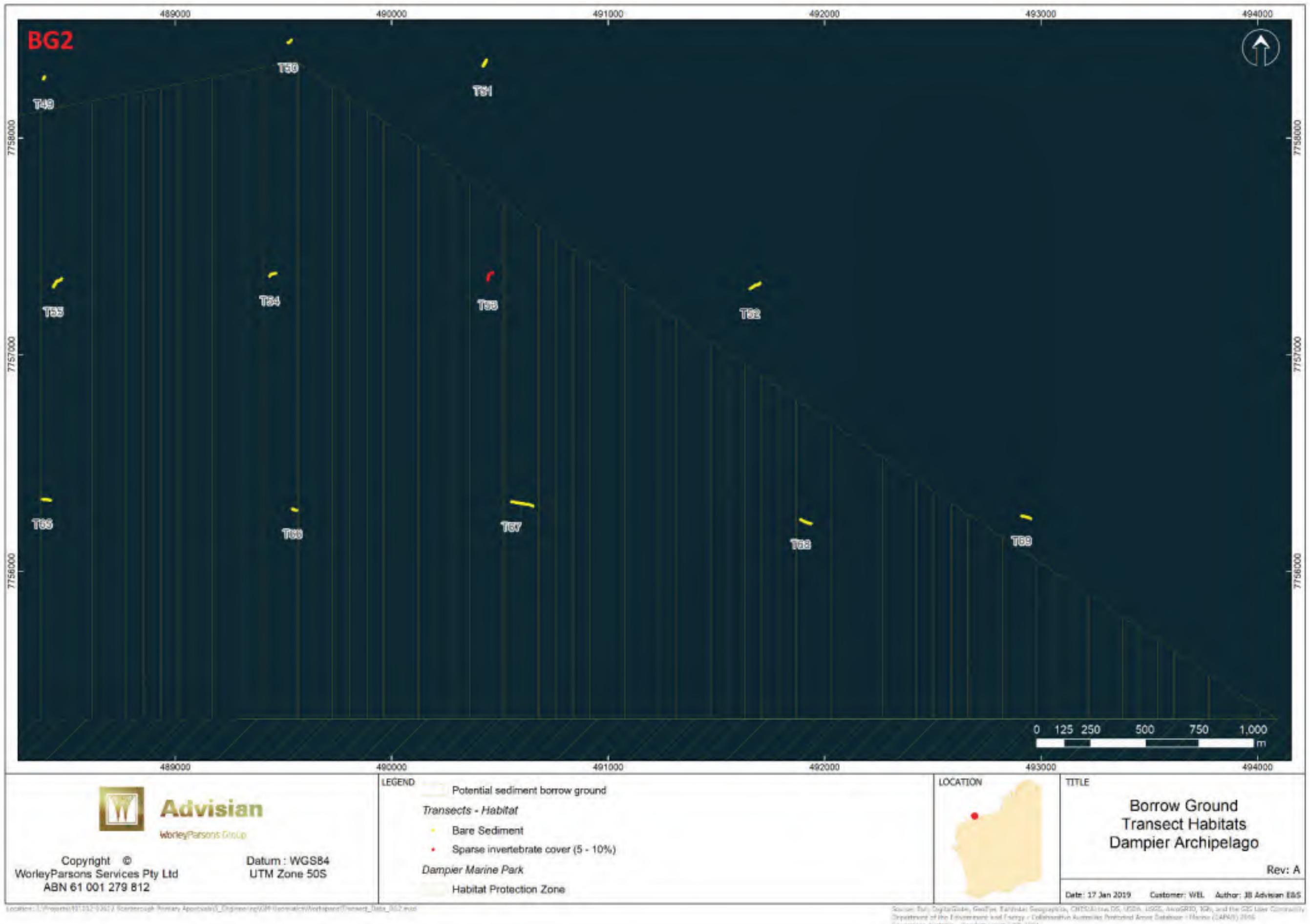

Figure 3-3: Benthic habitat in the eastern portion of the potential borrow ground

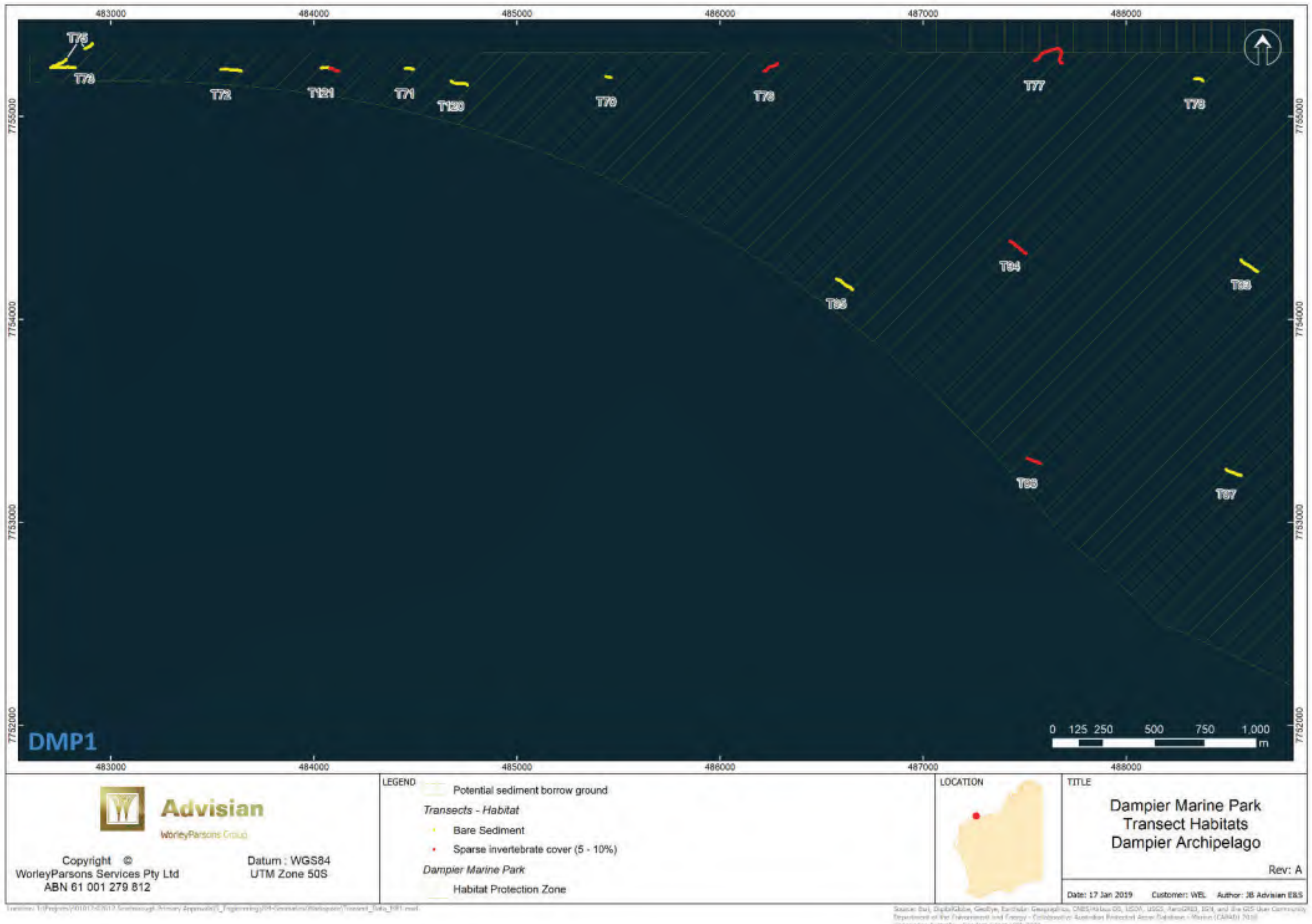

Figure 3-4: Benthic habitat in the western portion of the Dampier Marine Park

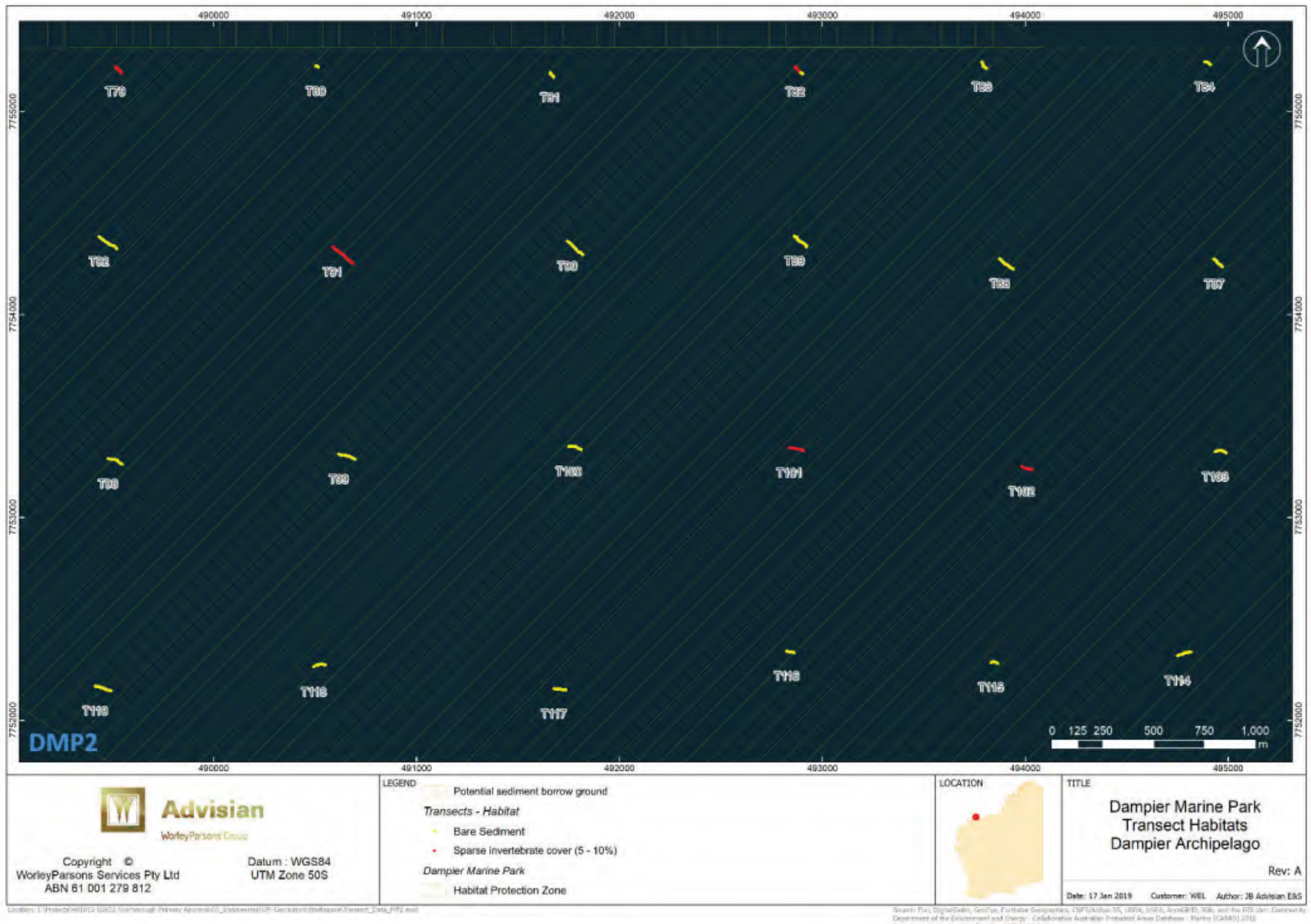

Figure 3-5: Benthic habitat in the middle of the Dampier Marine Park

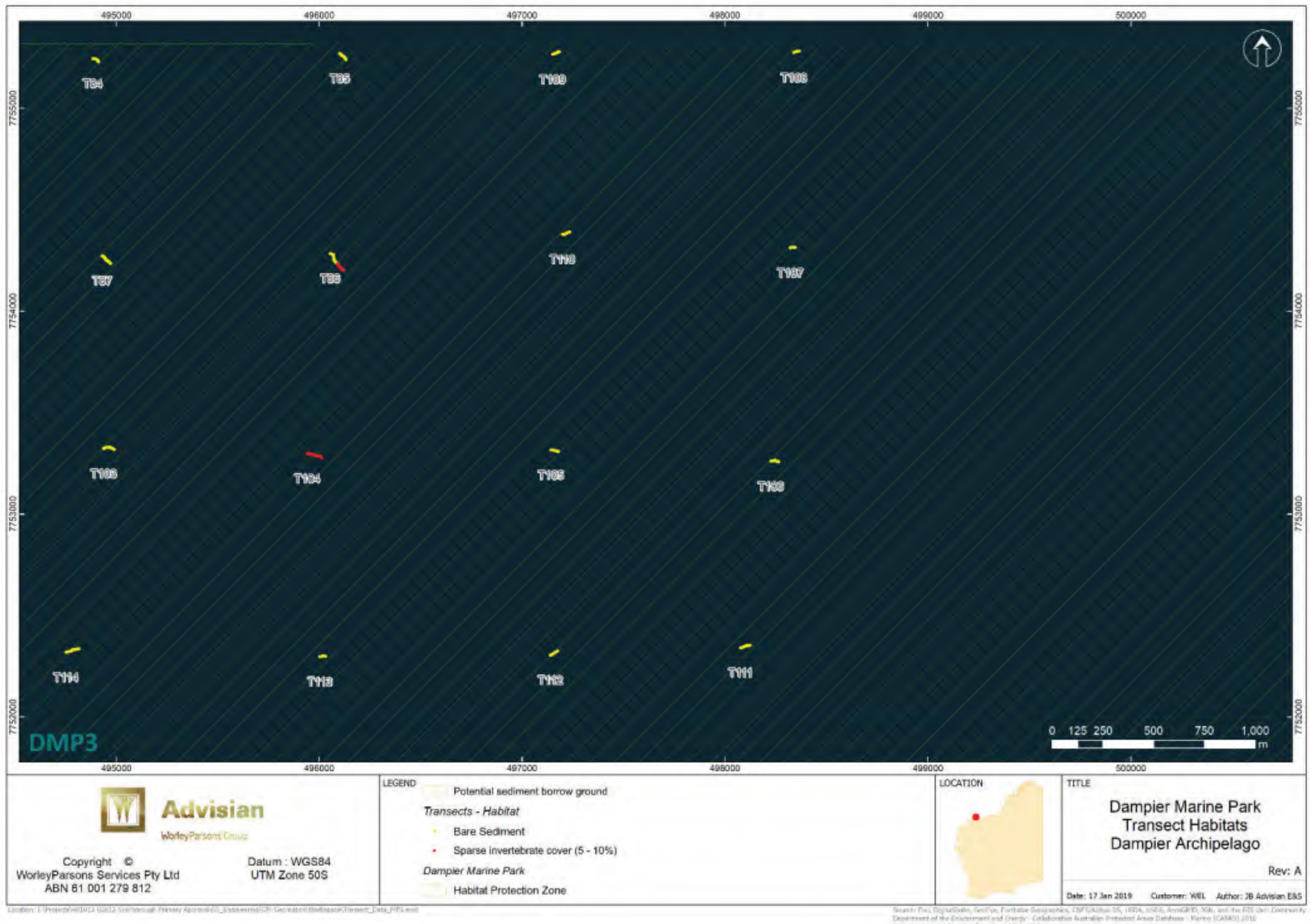

Figure 3-6: Benthic habitat in the eastern portion of the Dampier Marine Park

4 Discussions and Conclusions

Towed video and drop camera survey of both the potential borrow ground and the DMP directly adjacent to the borrow ground confirm that the seabed and its benthic composition are relatively uniform in structure and composition. Both locations are dominated by bare substrate with large areas of seabed that are apparently largely devoid of any epibenthic species. Where epibenthos is present, the percentage cover of species is comparatively low (in the order of 5%), with no transects recording greater than 10% coverage in the species present.

Common species present were alcyonaceans (mainly solitary soft corals), pennatulaceans (sea pens), crinoids (feather stars), asteroids (sea stars), anemones and hydroids. No benthic primary producer habitat in the form of hard corals, macroalgae or seagrass was recorded or observed along any of the survey transects.

The benthic habitat observed during this survey appears to be consistent with a broad scale characterisation of the Pilbara seabed undertaken by UWA and CSIRO (Pitcher *et al* 2016), which categorises this area as “Assemblage 2” and describes it as “typically bare seabed interspersed with moderately high cover of whips (0– 95.6%), median gorgonians (0–12.4%) and median sponges (0–73.4%), some cover of algae (0 25%), and low cover of alcyonarians (0–2.2%), corals (0–6.8%), coral reef (0–5.4%), bioturbation (0– 13.4%) and halimeda (0–0.8%), and ~no cover of seagrass”.

The similarity between benthic habitats observed within the potential borrow ground and habitat protection zone of the DMP during this survey, and those described above as Assemblage 2, indicates that the area surveyed is well represented in the regional context as opposed to more spatially discrete habitat features such as submerged coral reefs (Delambre Reef) and shoals (Tessa Shoals).

5 References

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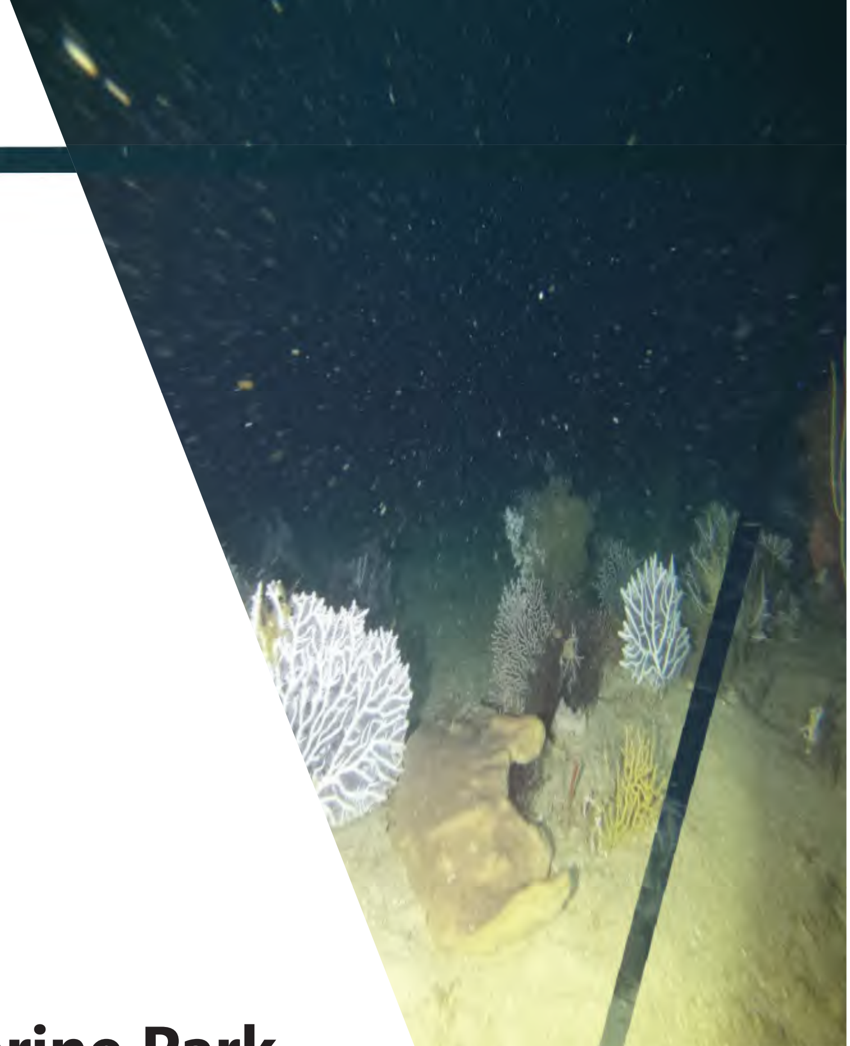
Appendix C

Montebello Marine Park Benthic Habitat Survey



Montebello Marine Park Benthic Habitat Survey

ROV Analysis of the Scarborough Pipeline Route

18 April 2019

Level 4, 600 Murray St
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Project No: 401012-02698- – Montebello Marine Park Benthic Habitat Survey: ROV Analysis of the Scarborough Pipeline Route

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Rev0	Final submitted to client	K Newton / R Tate	P Nichols	P Nichols	18 April 2019

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Appendix F: Additional Images Area 5

Executive Summary

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

This report provides the results of ROV surveys which were undertaken for the Scarborough project to characterise benthic habitat along the proposed trunkline route within the Montebello Australian Marine Park (AMP).

The objectives of this study were to:

- Confirm the environmental characteristics (physical and biological attributes) of the seabed along the pipeline route, including identification and qualitative descriptions of seabed habitat types and their general distribution;
- Provide spatial and habitat representation of the area of the Montebello AMP that the trunkline traverses; and
- Provide benthic habitat data at Key Ecological Features (KEFs) including the ancient coastline at the 125m depth contour KEF and potential turtle foraging habitat on hard substrate in the AMP where the trunkline overlaps.

Five areas within the Montebello AMP were surveyed, with three Remote Operated Vehicle (ROV) video transects undertaken within each area, except for Area 5 where only one transect was completed. The benthic habitat and epibenthic organisms within each area of the Montebello AMP were characterised through the assessment of the high definition (HD) video collected. Benthic habitat was described and classified in accordance with the CATAMI Classification Scheme for Scoring Marine Biota and Substrata in Underwater Imagery. Area 1, which was by far the deepest location, and which had one transect within the KEF, was most different with a much lower cover of benthic organisms than Areas 2 to 5. Areas 2 to 5 were quite similar in depth and in nature, with some small differences in the density and occurrence of benthic organisms and also in substrate type (e.g. variants of soft sediment bedforms and cover of biologenic gavel). A summary of findings for each area is provided below along with a discussion of the ROV results in relation to the published values for the Montebello AMP and 125m Depth Contour KEF.

Area 1 Summary

Area 1 was selected to assess the benthic habitat in the vicinity of the ancient coastline 125 m depth contour KEF and to provide spatial coverage of the AMP. One transect in Area 1 was located within the KEF (Transect 1A) and was 0.8 km from the eastern edge and 1.36 km from the north-western edge of the KEF. The most northern tip of this transect was located 0.45 km from the northern edge of the Montebello AMP and the south-western tip was 1.238 km from the western edge of the Montebello AMP. The depth at the midpoint of the transects surveyed in this area ranged from 103.2 m to 126.4 m. Benthic habitat was typically bare sand with various bedforms. Some areas of seafloor were covered in a light bacterial mat and others were seen to have a cover of biologenic gravel. No moderate or high relief features or areas of consolidated hard substrate were present. Benthic organisms (sponges and soft corals) typically occurred as single or in very low density aggregations. Mobile organisms including fish and echinoderms were also present on occasion.

The environmental values of the KEF refer to potential areas of hard substrate or rocky escarpments which may provide enhanced biodiversity or biologically important habitat in areas otherwise dominated by soft sediments. However, no potential features of the KEF described above were observed in any of the transects surveyed in Area 1.

Area 2 to 5

Areas 2 to 5 were selected to provide spatial coverage of the AMP, investigate areas of potentially high rugosity, areas that may include ancient coastline and areas of potential turtle foraging habitat. The depths in areas 2 to 5 were very similar with the midpoints depth of transects ranging from approximately 70 m to 78 m. The benthic habitats present along all transects in Areas 2 to 5 were very similar to each other. The seafloor in each area was relatively flat and sandy with a light to high cover of unconsolidated biologenic gravel and/or organic material. Small undulations of the seafloor were seen at times, as was scouring which typically occurred around large benthic organisms or aggregations of organisms. No significant high relief habitat features, or obvious areas of consolidated hard substrate, were observed in Areas 2 to 5. Benthic epifauna was present over the length of each transect, occurring in patches which varied from low (~5%) to high (~80%) density. Area 5 tended to have lower cover of organisms than areas 2 to 4. Benthic fauna in all of these areas comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent. Mobile fauna including echinoderms (sea stars, feather stars) and Holothurians (sea cucumbers) and fish were common along most of the transects. Fish were especially abundant amongst the patches of sponges and corals. Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters.

For many transects a higher cover of benthic organisms was often seen in areas with higher amounts of biologenic gravel, however, benthic organisms were in no way limited to these areas, also being common in areas with fine sediment with little or no biologenic gravel. While at times the occurrence of benthic organisms could be loosely related to areas of high rugosity seen on detailed bathymetric mapping, this was not always apparent.

The high biodiversity of sessile and mobile organisms seen at depths of around 70 m – 78 m in Areas 2 to 5 of the Montebello AMO was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. These areas are all likely to provide foraging habitat for mobile (and potentially threatened) fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

The benthic habitat descriptions in the current study are generally in alignment with the findings of previous (recent and historical) benthic habitat surveys undertaken in the Montebello AMP. These studies have also reported the typical benthic habitat in the AMP as low relief sandy seafloor (with various bedforms such as ripples and ridges) with occasional areas of rubble (often increasing at more inshore sites). Dominant benthic organisms recorded for the AMP (noted to vary in diversity and density between sites) typically include a wide variety of sponges, soft corals and crinoids.

1 Introduction

1.1 Project Background

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

Activities undertaken as a part of the Scarborough Project will include seabed preparation and trunkline installation activities, which will result in localised seabed disturbance and ongoing physical presence of the trunkline for the life of the project. The proposed pipeline is approximately 32 inch in diameter and the disturbance corridor is estimated at less than 30 m. The Scarborough trunkline is proposed to traverse through the northern section of the Montebello Australian Marine Park (AMP) as shown in Figure 1-1. This report provides the results of ROV surveys which were undertaken for the Scarborough Project to characterise benthic habitat along the proposed trunkline route within the Montebello AMP.

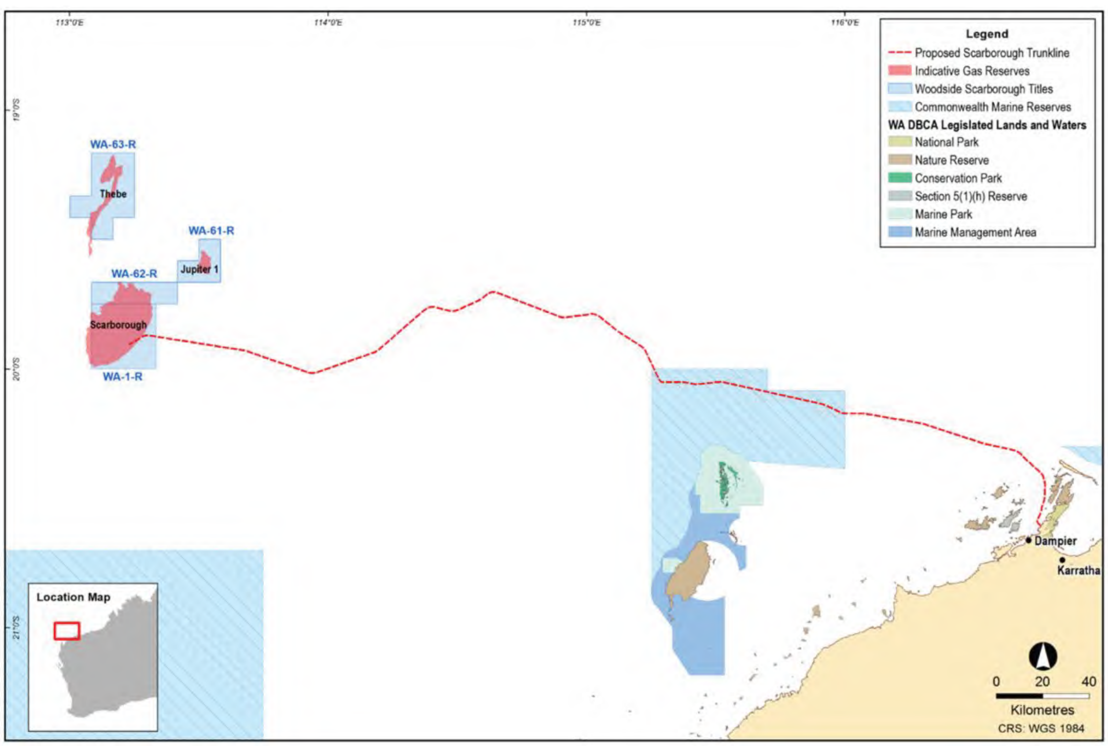

Figure 1-1 Location of the Scarborough Project and proposed trunkline (Image Source: Woodside 2019).

1.2 Environmental Setting of the Proposed Trunkline Route

The Scarborough Project occurs in Commonwealth waters off the northwest coast of Western Australia (WA) within the North-west Marine Region (NWMR) (Integrated Marine and Coastal Regionalisation of Australia (IMCRA) 4.0). The target fields occur within the Northern Carnarvon Basin on the Exmouth Plateau, and are about 380 km offshore from Dampier, in water depths of approximately 900 - 970 m, with the proposed trunkline ultimately crossing into State waters along the same alignment as the Pluto Gas Export Pipeline (Figure 1-2).

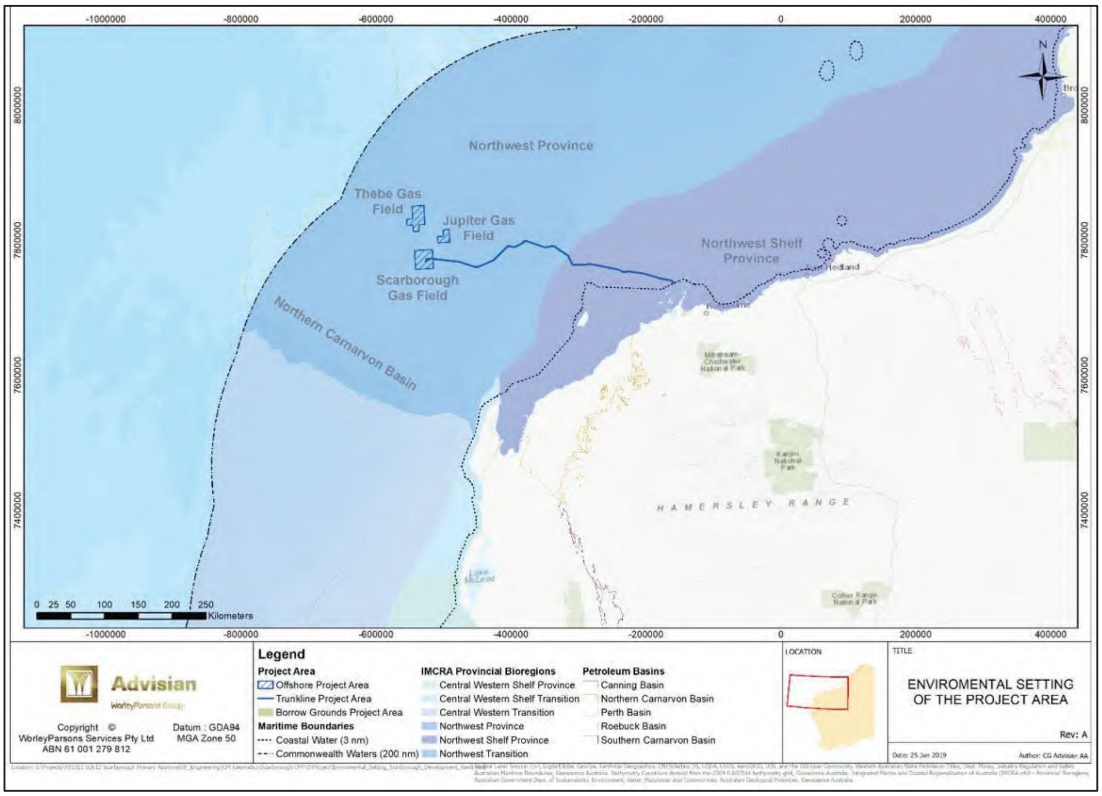

Figure 1-2 Environmental setting of the project area.

A number of studies and reviews of the Exmouth Plateau and North West Shelf have been compiled and/or undertaken to provide an understanding of the physical, biological and socio-economic environmental conditions within the Project Area. The majority of these have been made available in the public domain. The environmental values of the Montebello AMP and the ancient coastline KEF have been described in Sections 1.2.1 and 1.2.2 of this report.

The Trunkline Project Area extends from the State-Commonwealth boundary on the inner continental shelf, onto the continental slope where it traverses the continental slope westwards to the Offshore Project Area on the Exmouth Plateau. The eastern half of the Trunkline Project Area is adjacent to the existing Pluto trunkline. The inner continental shelf is the area from the coast to about 30 m water depth, and the middle continental shelf is the area between 30 m and 120 m water depth. At about 120 m depth, a terrace (start of the outer shelf) of gradients of between 5° and 20° represents a paleo-shoreline and marks an important divide between the continental shelf and continental slope (SKM, 2006). Sediments along the Trunkline Project Area are expected to be dominated by sand as is typical of the continental slope in the Northwest Transition bioregion (DEWHA, 2008a).

1.2.1 Natural Values of the Montebello AMP

Location

The Montebello Marine Park is located offshore of Barrow Island and 80 km west of Dampier extending from the Western Australian state water boundary and is adjacent to the Western Australian Barrow Island and Montebello Islands Marine Parks. The Marine Park covers an area of 3413 km^2 and water depths from less than 15 m to 150 m. The Marine Park was proclaimed under the EPBC Act on 14 December 2013 and renamed Montebello Marine Park on 9 October 2017 (Director of National Parks, 2018).

Statement of Significance

The Montebello AMP is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. It includes one KEF: the ancient coastline at the 125-m depth contour (valued as a unique seafloor feature with ecological properties of regional significance) (environmental values of the KEF are provided in Section 1.2.2). The Marine Park provides connectivity between deeper waters of the shelf and slope, and the adjacent Barrow Island and Montebello Islands Marine Parks. A prominent seafloor feature in the Marine Park is Trial Rocks consisting of two close coral reefs. The reefs are emergent at low tide (Director of National Parks, 2018).

Natural Values

The values of the Montebello AMP are outlined in the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018). The Marine Park includes examples of ecosystems representative of the Northwest Shelf Province, which is a dynamic environment influenced by strong tides, cyclonic storms, long-period swells and internal tides. The bioregion includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for humpback whales. A KEF of the Marine Park is the ancient coastline at the 125-m depth contour where rocky escarpments are thought to provide biologically important habitat in areas otherwise dominated by soft sediments (Director of National Parks, 2018).

The Marine Park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act 1999. Biologically important areas within the Marine Park include breeding habitat for seabirds, internesting, foraging, mating, and nesting habitat for marine turtles, a migratory pathway for humpback whales and foraging habitat for whale sharks (Director of National Parks, 2018).

1.2.2 Environmental Values of the Ancient Coastline at 125 m Depth Contour (KEF)

The shelf of the North-west Marine Region contains several terraces and steps which reflect changes in sea level that occurred over the last 100 000 years. The most prominent of these features occurs as an escarpment along the North West Shelf and Sahul Shelf at a depth of 125 m. The ancient coastline at 125 m depth contour is defined as a KEF as it is a unique seafloor feature with ecological properties of regional significance. The spatial boundary of this KEF, as defined in the Conservation Values Atlas, is defined by depth range 115-135 m in the Northwest Shelf Province and Northwest Shelf Transition provincial bioregions as defined in the Integrated Marine and Coastal Regionalisation of Australia (IMCRA v 4.0) (DSEWPaC, 2012). The boundary of the KEF in the study area is shown in Figure 2-1.

Environmental Values

The 'environmental values' of the 'ancient coastline at 125 m depth contour' KEF are described in the Marine Bioregional Plan for the North-west Marine Region (DSEWPaC, 2012). The ancient submerged coastline provides areas of hard substrate and therefore may provide sites for higher diversity and enhanced species richness relative to surrounding areas of predominantly soft sediment. Little is known about the fauna associated with the hard substrate of the escarpment, likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of hard substrate fauna in the North West Shelf bioregion (DSEWPaC, 2012).

The escarpment may also facilitate increased availability of nutrients off the Pilbara by interacting with internal waves and enhancing vertical mixing of water layers. Enhanced productivity associated with the sessile communities and increased nutrient availability may attract larger marine life such as whale sharks and large pelagic fish (DEWHA, 2008).

1.3 Objectives

The objectives of the current study were to:

- Characterise benthic habitat along the proposed trunkline route in the Montebello AMP;
- Confirm the environmental characteristics (physical and biological attributes) of the seabed along the pipeline route, including identification and qualitative descriptions of seabed habitat types and their general distribution;
- Provide spatial and habitat representation of the area of the Montebello AMP that the trunkline traverses; and
- Provide benthic habitat data at environmental sensitive locations including the ancient coastline at the 125m depth contour Key Ecological Feature (KEF) and potential turtle foraging habitat on hard substrate in the AMP where the trunkline overlaps.

2 Methods

Habitat characterisation was undertaken using a remotely operated underwater vehicle (ROV) to capture seabed imagery (video/stills) along pre-defined survey locations. Imagery was then used to describe the physical habitats and the presence/absence of benthic communities within the vicinity of the trunkline route in the section that traverses the Montebello AMP.

The survey was focused along the proposed trunkline route where it deviates from the existing Pluto pipeline route (located in the eastern area of the multi-use zone of the park). Survey sites reflected the potential variation in habitat, as determined by the geophysical data (e.g. bathymetry and interpreted seabed substrates) and general representativeness of the main seabed characteristics of the multi-use zone of the park, that the proposed trunkline route will traverse.

2.1 Survey Areas

Seafloor imagery was collected by Neptune, within five survey areas, which were sized approximately 4 km x 250 m, inside the Montebello AMP. The survey areas selected provide spatial coverage and representative habitat of the Montebello AMP. The locations of survey areas and transects, along with transect depths are provided in Table 2-1 and Figure 2-1. Figure 2-1 also provides the location of the ancient coastline 125 m depth contour KEF.

The five survey areas were selected for the following reasons:

- **Survey areas 1**: Was selected to assess benthic habitat in the vicinity of the ancient coastline 125 m depth contour KEF and to provide spatial coverage of the AMP (Figure 2-1 and Figure 2-2).

- **Survey areas 2 to 5**: Were selected to provide spatial coverage of the AMP, identify any outcropping / subcropping in rugose areas of seafloor (as seen on bathymetry) and assess the benthic habitat in areas which could provide potential turtle foraging habitat (Figure 2-1, Figure 2-3, Figure 2-4, Figure 2-5 and Figure 2-6).

The approximate distance between all adjacent transects from each other is shown in Table 2-2.

Within each survey area, there were three proposed sampling locations (Figure 2-1). At each location an ~500 m transect of trunkline was attempted to be surveyed. Transects were to provide a snake like path deviating from the proposed pipeline route by approximately 100 m each side of the pipeline and were to follow the pipeline route in a parallel direction (rather than running perpendicular). A kilometre buffer was allowed around each survey location, for flexibility given weather conditions etc. A minimum distance of 200 m between transects was to be maintained. Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route in Area 5 and the transect locations 5B and 5C were unable to be surveyed. Table 2-1 provides details for all transects.

Table 2-1 Location of the five survey areas and transect details.

Survey Area	Sampling Location	Position GDA94 Zone 50 (Midpoint)		Potential Seafloor Features	Actual Midpoint Depth (m)
		Latitude	Longitude		
Survey Area 1	1A	318462.69	7787004.58	125m contour KEF	-126.4
	1B	319281.801	7785309.82	125m contour KEF	-110.2
	1C	320006.8476	7783542.972	125m contour KEF	-103.2
Survey Area 2	2A	328859.16	7781967.15	Outcrop/subcrop	-70.6
	2B	330692.8515	7781974.137	Outcrop/sand	-74.4
	2C	332650.32	7781636.45	Outcrop/sand	-74
Survey Area 3	3A	336633.23	7781316.65	Outcrop/subcrop	-73.8
	3B	338590.04	7781516.29	Sand	-72.5
	3C	341540.88	7781917.17	Outcrop/subcrop	-71.6
Survey Area 4	4A	342526.27	7782010.53	Sand	-75.3
	4B	344543.13	7782286.02	Sand/subcrop	-74.5
	4C	346553.46	7782136.72	Subcrop/outcrop	-78.2
Survey Area 5	5A	361146.91	7778773.61	Sand	-74.6
	5B	Not surveyed		Sand	NA
	5C	Not surveyed		Sand	NA

Table 2-2 Distances between adjacent transects (based on the approx. centre of each transect).

Transects	Distance
1A TO 1B	1.85 km
1B TO 1C	1.88 km
1C TO 2A	1.88 km
2A TO 2B	1.88 km
2B TO 2C	1.88 km
2C TO 3A	3.98 km
3A TO 3B	1.88 km
3B TO 3C	2.89 km
3C TO 4A	0.98 km
4A TO 4B	2.06 km
4B TO 4C	1.96 km
4C TO 5A	15 km

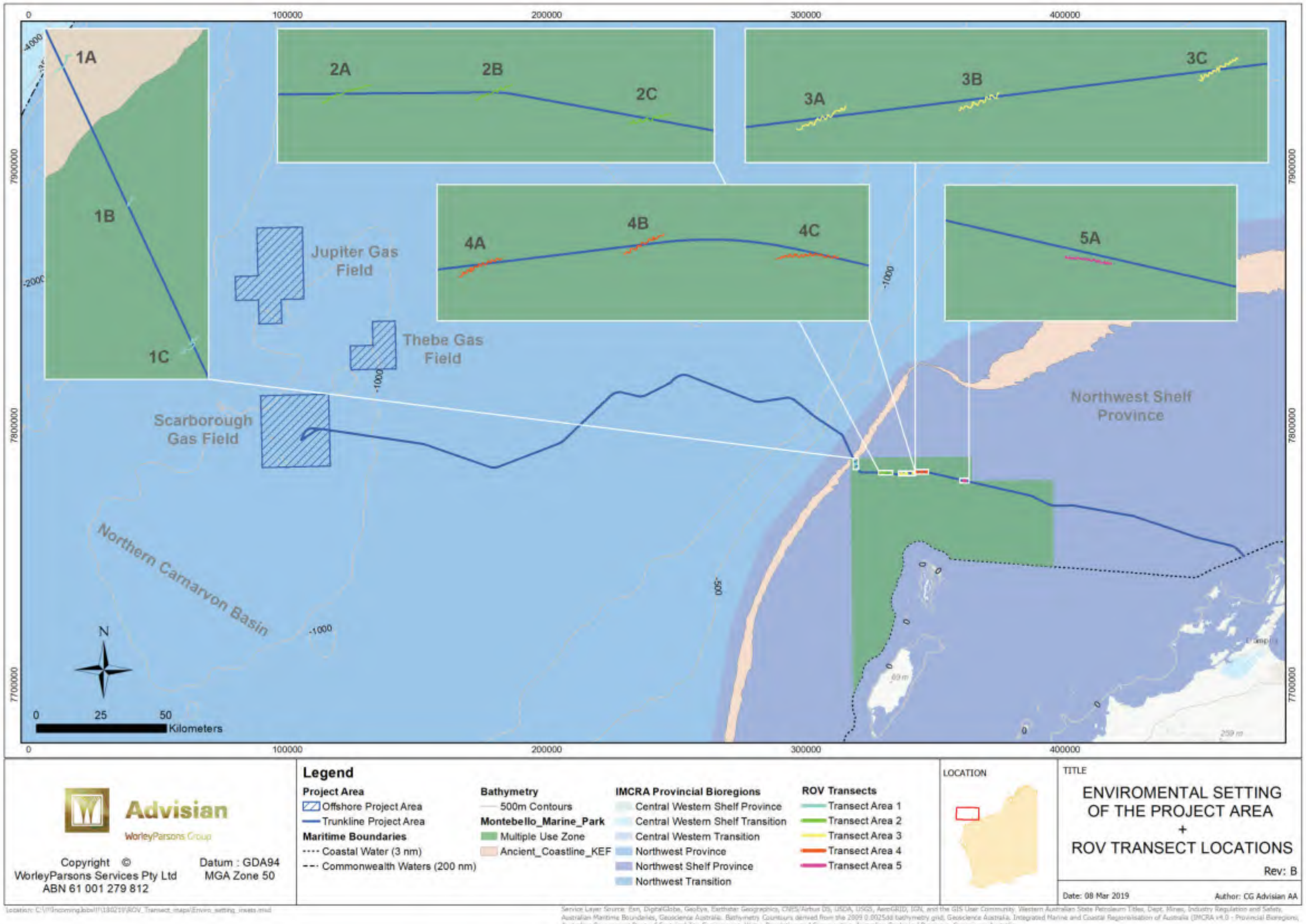

Figure 2-1 Location of the five survey areas and ROV transects.

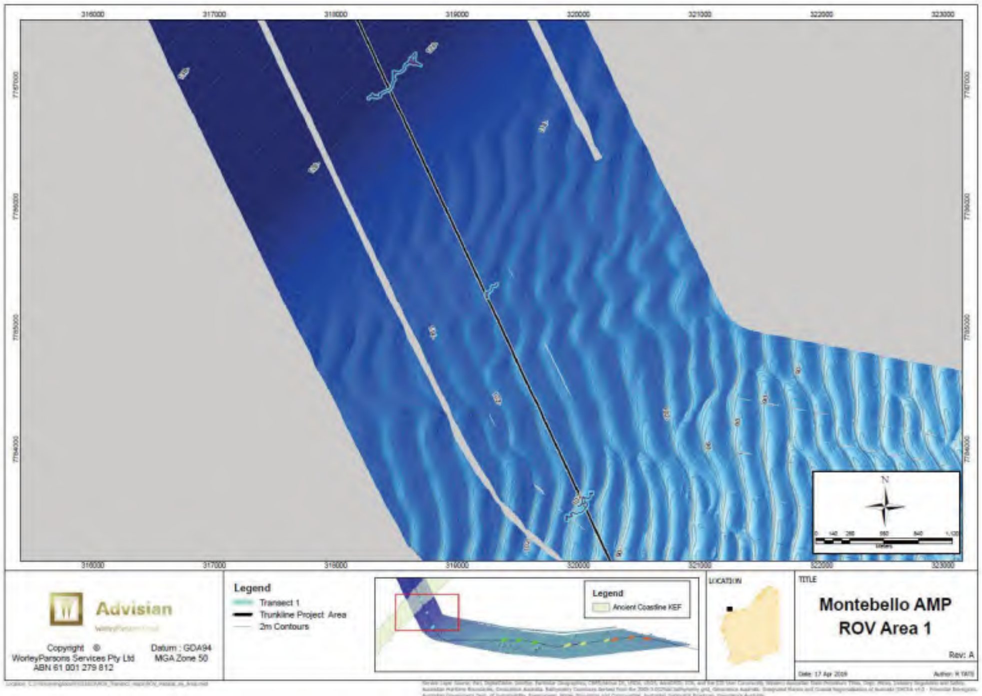

Figure 2-2 Transects 1A, 1B and 1C.

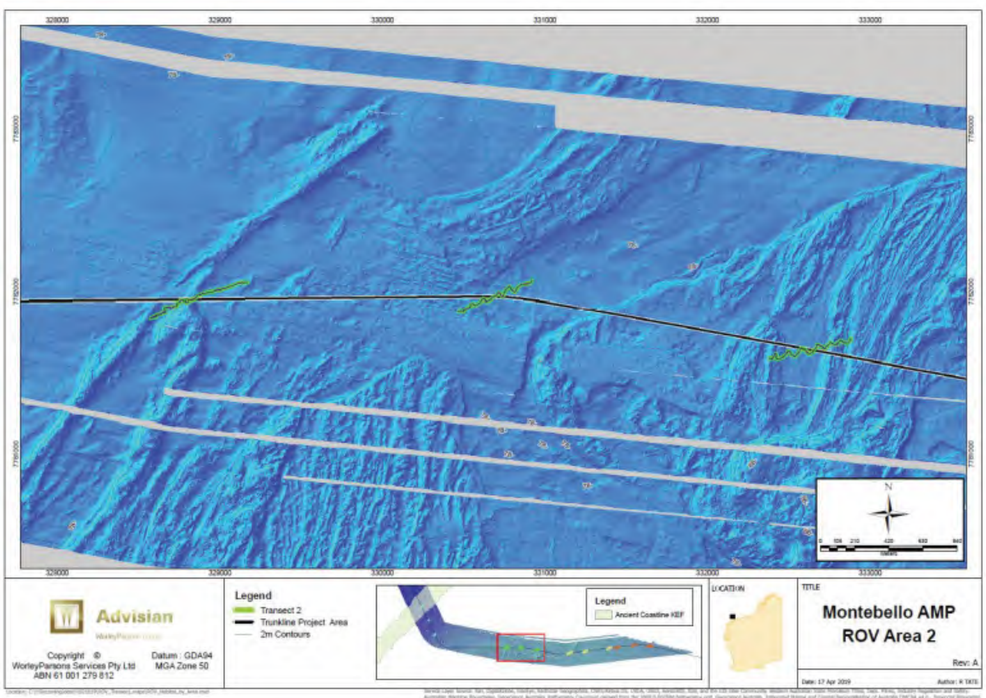

Figure 2-3 Transects 2A, 2B and 2C.

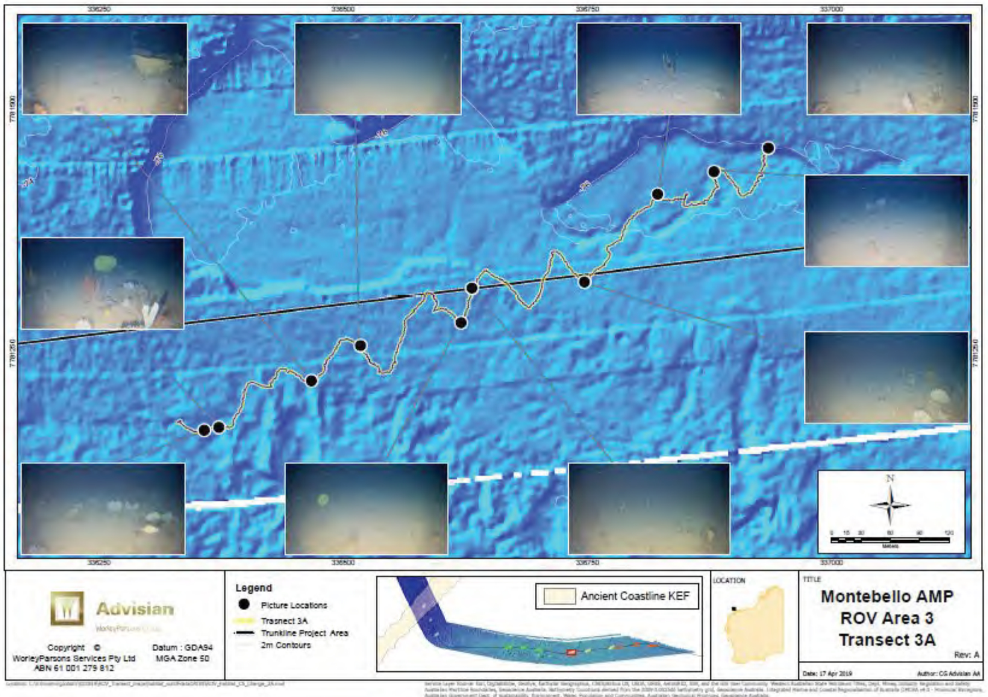

Figure 2-4 Transects 3A, 3B and 3C.

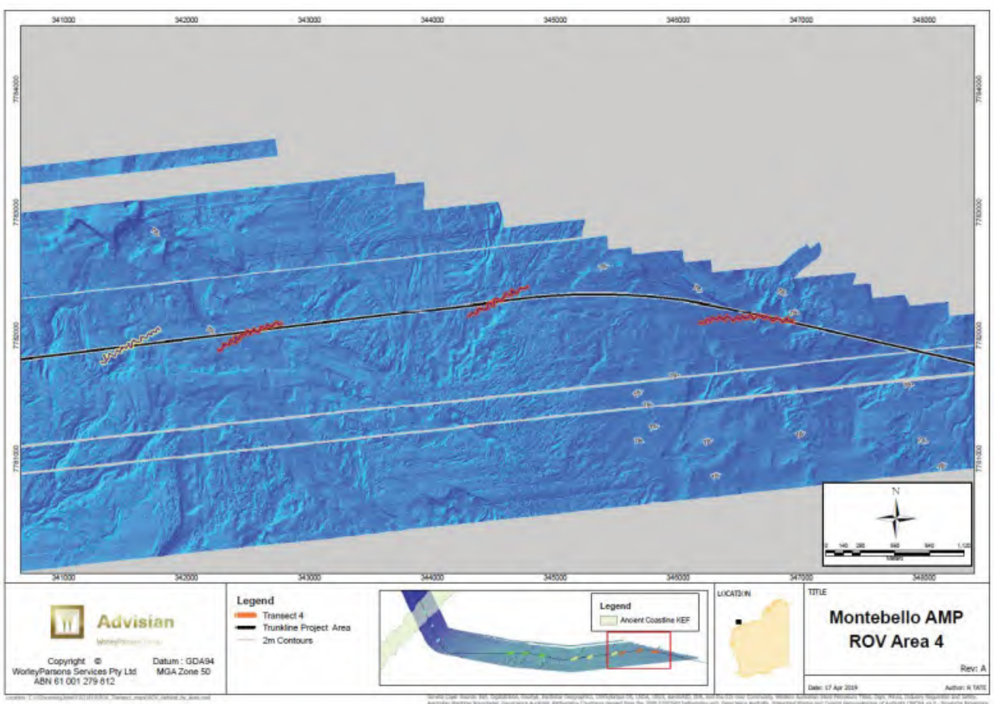

Figure 2-5 Transects 4A, 4B and 4C.

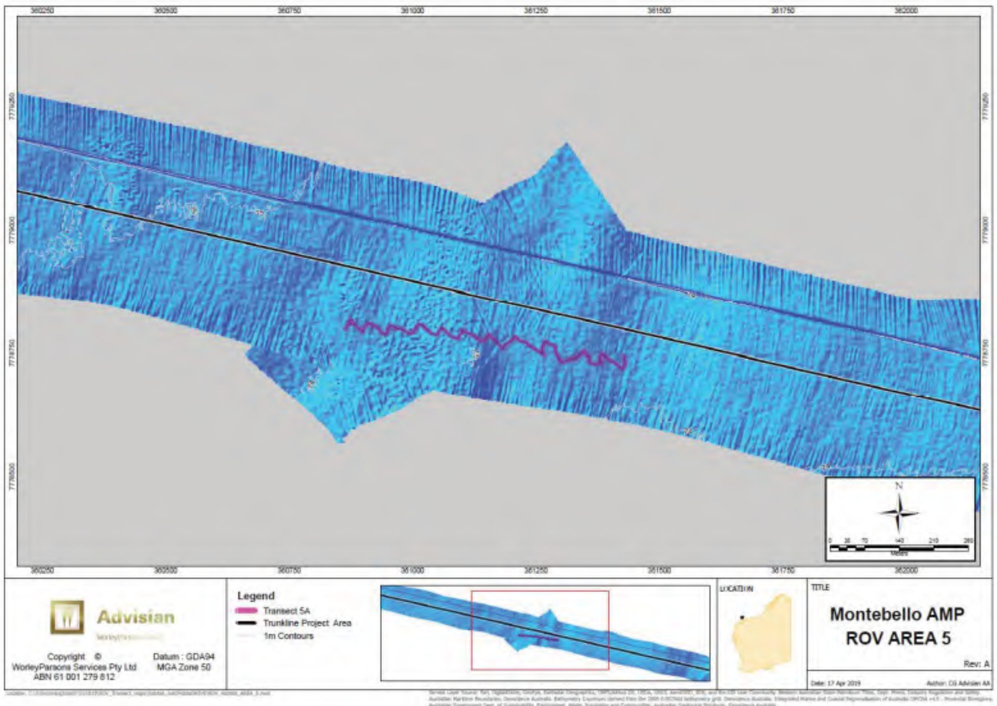

Figure 2-6 Transect 5A.

2.2 Remotely Operated Vehicle (ROV) Surveys

ROV surveys were undertaken by Neptune at each of the survey locations provided in Table 2-1 and shown in Figure 2-1. HD video was collected from a standardised height of approximately 1 m to 2 m. The camera was angled where possible to capture both the seabed and forward facing perspective of the general seascape. Depth and geospatial data of the ROV location was recorded at all sites. The depth and location of the midpoint of each transect is provided in Table 2-1.

2.3 Video Analysis

2.3.1 Technical Memos (Neptune)

Following the collection of the ROV video data, Neptune prepared a short technical memo for each transect which included the survey date, time, area of operations, location, brief seabed description, conclusions and recommendations and any issues encountered. All technical memos were reviewed and are provided in **Appendix A**.

2.3.2 Benthic Habitat Analysis

Prior to assessment of the benthic habitat, potential differences in seafloor bathymetry / rugosity were identified along each of the transect routes and five points of interest were selected for each. On video analysis, still images from each of these locations were captured.

High definition (HD) video data was viewed using VLC Media Player and the benthic habitat and sessile organisms present were classified in accordance with the CATAMI Classification Scheme for Scoring Marine Biota and Substrata in Underwater Imagery (http://CATAMI.github.io/) (Althaus et al. 2014). Data specifically collected and reported for each transect included:

- Substrate Type
- Bedform
- Relief
- Bioturbation
- Bacterial mats
- Flora
- Fauna

HD video assessment showed that the seafloor along all transects was low profile and no moderate or high profile features were present within any transect. For all transects surveyed, the seafloor habitat was found to be very similar along the entire transect length, or consisted of a mosaic of benthic habitat types / variations in habitat type which changed continually at small scales (typically a couple of m's) but represented the transect as a whole (e.g. area of bare sandy substrate, to area of sponges/corals on sandy substrate, back to bare substrate, or continually changing percentage cover of sponges and corals). For these reasons, and the qualitative nature of the assessment, an overall habitat classification was applied to each transect.

Still images of the various states of benthic habitat and the sessile benthic organisms seen along each transect were also taken from the HD video. Some of these were georeferenced and are overlaid on the transect maps. The report Appendices also include a greater number of images from each transect which are provided to demonstrate the small scale variability within a single general habitat type.

2.4 Transect and Habitat Mapping

Transects were created as line shapefiles from ROV derived X, Y point data. High resolution (2 m) bathymetry data was then used to generate the underlying raster surface as well as 2 m contour line data. All data was projected in GDA MGA Zone 50 coordinate system and processed in ArcMAP 10.4.

As the benthic habitat along each individual transect was generally the same and consisted of often very small scale (every few meters) and continual changes in substrate (e.g. sand ripple type) or the cover of benthic organisms (i.e. changes in density of benthic organisms), georeferenced 'habitat types' were not defined along the length of each transect. Each transect was mapped with detailed seafloor bathymetry and these transect maps were overlaid with georeferenced images of the benthic habitat along the transect.

3 Results

3.1 Area 1

Three transects (of varying length) were surveyed in Area 1 and are described in more detail below. The depth at the midpoint of these transects ranged from 103.2 m to 126.4 m. One transect in Area 1 (Transect 1a) was located within the KEF; located 0.8 km from the eastern edge and 1.36 km from the north-western edge of the KEF. The most northern tip of this transect was located 0.45 km from the northern edge of the Montebello AMP and the south-western tip was 1.238 km from the western edge of the Montebello AMP. While some representative images of each transect are provided in the Sections below, **Appendix B** provides additional images of the benthic habitat and organisms seen along each transect in Area 1.

3.1.1 Area 1a

Notes provided by Neptune for Area 1a included:

- The ROV transect crossed the pipeline route at E318445, N7786967 (time stamp 13:49:11).
- The ROV was on bottom at 13:49 and off bottom at 14:03.
- The seabed comprised a flat fine sandy seabed, with small isolated sand waves. There was a sparse benthic sand-dwelling habitat. Ripples had an organic/algae covering, particularly in the troughs. Isolated corals also occurred on the sand.
- No significant high relief habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 1a are provided:

- The entire seafloor along the transect in Area 1a consisted of a low relief, flat and fine sandy seabed with bedforms alternating between small 2D and 3D ripples (< 10 cm) and some areas which had no ripples.
- No significant, or other, moderate or high relief features, or areas of hard substrate, were present. The transect ran almost entirely along the 126 m depth contour (Figure 3-2).
- Transect 1a was entirely located within the boundary of the ancient coastline KEF (refer to Figure 2-1 and Figure 3-2). However, no potential features of the KEF (i.e. areas of hard substrate with high biodiversity) were noted here, and the transect was comprised fully of soft sediment habitat.

- The seabed was generally bare sand (with very occasional benthic epifauna) and much of the transect area was noted to have a light covering of organic matter. This is very likely to be a bacterial mat considering the water depth and lack of light penetration in this location (refer to Figure 3-2 and **Appendix B** for images).
- No benthic flora (i.e. macroalgae or seagrass) was present in Area 1a.
- Benthic epifauna were present, although were quite uncommon. They generally occurred as single individuals (i.e. not in aggregations / clusters). Benthic epifauna included echinoderms (e.g. brittle stars and feather stars), sponges (erect simple, erect laminar, erect branching and cup like forms) and cnidarians (whip corals and quill corals (seapens) (refer to Table 3-1 for additional detail and CATAMI classification codes).
- The percentage cover of benthic organisms (within the entire video frame) in Area 1a ranged from 0% to ~5% (excluding any cover of biologenic gravel) over the entire transect length. No obvious bathymetric features could be seen on the transect maps or corresponded with the occurrence of different substrate types (e.g. sand ripples / flat sand / steps) or scattered benthic organisms. The benthic organisms recorded occurred on all different substrate types/bedforms.
- Occasional bioturbation of the seabed in the form of light trails, small mounds and craters was seen over the entire transect indicating the presence of various mobile fauna living on top of and within the seabed.
- Mobile fauna were seen on occasion but were also uncommon. They included small bony fishes (often quickly moving out of the field of view of the ROV) and jellies. Both types of fauna were unidentified.
- Due to currents affecting the stability of the ROV, along with a high level of suspended material in the water at times, visibility of the seabed was compromised in places. However, these less visible areas are very likely to be similar to the seafloor which could be seen based on the overall transect assessment.

A summary of the general benthic habitat characteristics, flora and fauna seen along the transect in Area 1a is provided in Table 3-1. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that were identified.

The benthic habitat in the location where the transect crossed the pipeline route (as per the time stamp provided by Neptune) is shown in Figure 3-1 and consists of rippled bare sand.

A map showing the location of the transect in Area 1a in relation to seafloor bathymetry and the KEF, along with some georeferenced representative images of benthic habitat in this area, is provided in Figure 3-2. No correlation between the seafloor bathymetry / rugosity as evident on the transect map and the occurrence of benthic organisms was apparent for Transect 1a.

Additional seafloor images and images of some of the isolated benthic fauna recorded in Area 1a are provided in **Appendix B**.

Figure 3-1 Benthic habitat in the location of the pipeline crossing in Area 1a.

Table 3-1 Summary of habitat features in Area 1a.

Habitat Features	Description	CATAMI Species Code(s)	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm)	82001005	Entire Transect
Bedform	2D ripples (<10 cm height) 3D ripples (<10 cm height)	82002003 82002007	Alternating 2D and 3D ripples over transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional sightings over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Ophiuroids: Brittle / snake stars Echinoderms: Feather stars Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Corals: Black & Octocorals: Whip Corals: Black & Octocorals: Quill (seapen) Jellies Fishes: Bony fishes	25160901 25000000 10000916 10000913 10000915 10000909 11168917 11168918 80600903 37990083	Occasional sightings over the entire transect length – most organisms occurred in isolation

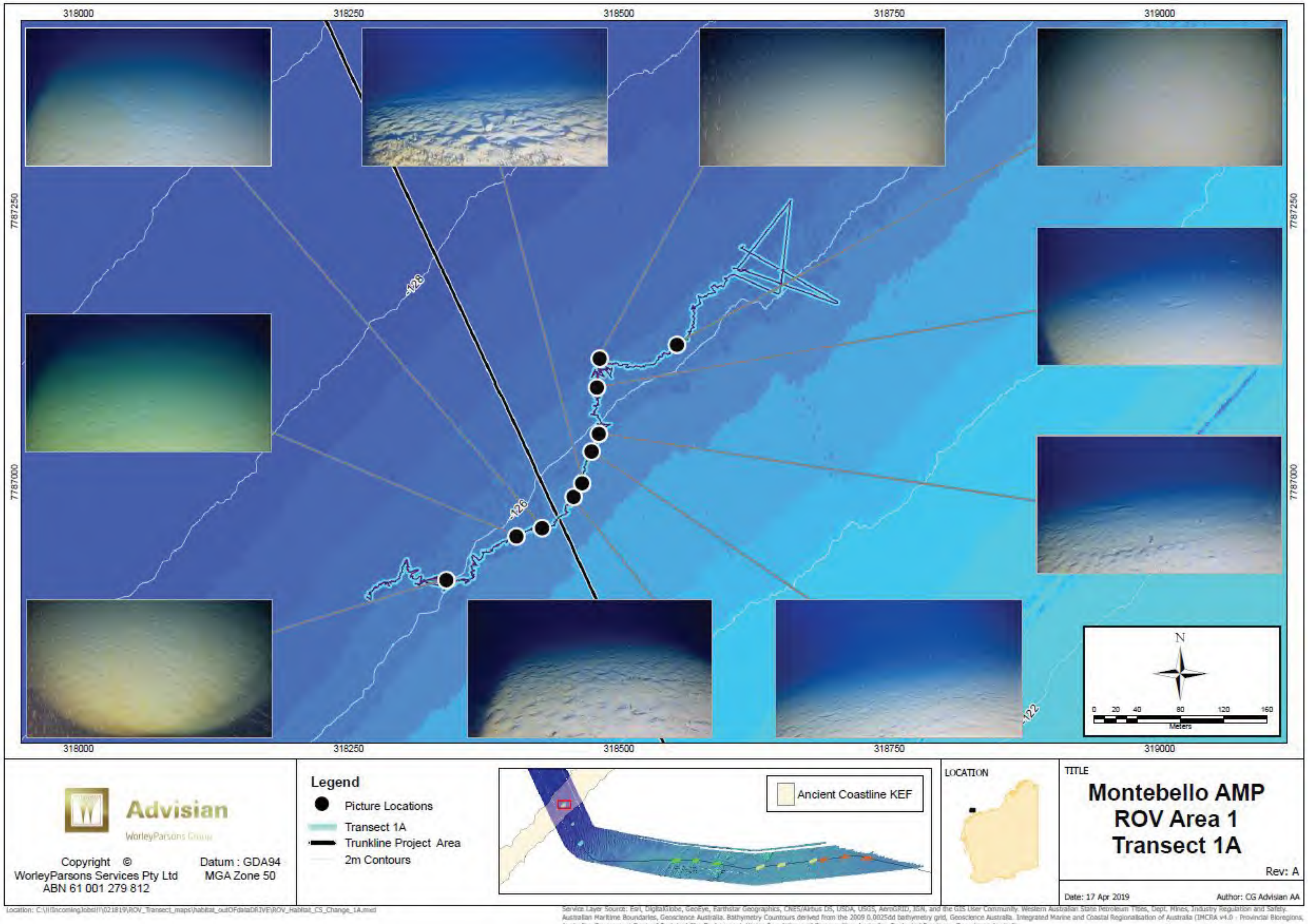

Figure 3-2 Typical benthic habitat and bathymetry in Area 1a.

3.1.2 Area 1b

Notes provided by Neptune for Area 1b included:

- The ROV crossed the proposed pipeline route at E 319248, N 7785254 at approximately 17:44:15.
- The ROV was on bottom at 17:43 and off bottom at 17:48.
- The seabed comprised a typically flat fine sandy seabed with ripples and larger sand waves. There was sparse benthic sand-dwelling habitat. Sand ripples had an organic/algae covering particularly in the troughs. The small sand wave crests (probably less than 0.5 m high) were cleaner and could be seen to prograde over the sediments burying isolated benthic fauna which typically occurred as soft corals and sponges.
- No significant high relief habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 1b are provided:

- The seafloor along the transect in Area 1b was similar to that observed in Area 1a and was also similar along the entire transect length.
- Where the transect crossed the proposed pipeline route (as per the time stamp provided by Neptune), a flat sandy seafloor with 3D ripples was present (see image in Figure 3-3).
- Benthic habitat typically consisted of a low relief sandy seabed, with bedforms alternating between small 2D and 3D ripples and areas of flat sand. A series of small 'steps' / rises in the sand occurred over the entire length of the transect and these were generally <50 cm high. These 'steps' were identified as 'sand wave crests' by Neptune. Towards the end of the transect the small 2D and 3D sand ripples became slightly less common and the seafloor had a slightly flatter form. This area of flatter sand is not considered to be a separate habitat type, nor can it been identified on the transect map showing detailed bathymetry. Images of the variable types of sandy seafloor along Transect 1b are provided in Figure 3-4 and **Appendix B**.
- No significant, or other, moderate or high relief features, or areas of consolidated hard substrate, were present in Area 1b. However, some small areas of scattered biologenic rubble (perhaps shell, coral or small gravel) were noted along the transects length (see Figure 3-4 and **Appendix B)**. These areas cannot be seen on the transect maps with detailed bathymetry.
- Area 1b was located near to, but not within, the area mapped as the KEF (ancient coastline 125 m depth contour). The transect traversed an area of seabed which had a depth of

around 108 m to 113 m (refer to Figure 3-4). No potential features of the KEF (i.e. hard substrate with high biodiversity) were seen here.

- Some areas of sand were bare while others were covered in a light bacterial mat. This covering occurred over the entire transect however was more prevalent in the troughs of ripples and the base of each of the sand 'steps'. It was also common towards the end of the transect where sand ripples were less common.

- No benthic flora (i.e. macroalgae or seagrass) was present in Area 1b.

- Benthic epifauna were present, although were relatively uncommon and most often occurred as single organisms. Fauna included echinoderms (e.g. feather stars and sea cucumbers), cnidaria (e.g. seapens), soft corals and sponges (various erect forms). Some organisms were partially buried under the sand and could not be identified (refer to Table 3-2 for additional detail and CATAMI classification codes).

- The percentage cover of benthic organisms (within the entire video frame) in Area 1b ranged from 0% to ~10% (excluding cover of biologenic gravel) over the entire transect length. As for Transect 1a, no obvious bathymetric features were seen on the transect maps or corresponded with the occurrence of different substrate types (e.g. sand ripples / flat sand / steps) or these scattered benthic organisms. These organisms occurred on all different substrate 'types'.

- Small bony fishes were seen on occasion, usually quickly moving out of the field of view of the ROV but were not identified for this assessment.

- Bioturbation of the seafloor in the form of small mounds, craters and thin trails was seen along the entire length of the transect indicating the presence of mobile organisms living on and within the seabed.

A summary of the habitat characteristics, flora and fauna recorded in Area 1b is provided in Table 3-2. This table also provides the CATAMI Species Codes for each seafloor feature and taxa identified.

The benthic habitat in the location where the transect crossed the pipeline route (as per the time stamp provided by Neptune) is shown in Figure 3-3 and consists of 3D rippled sand with a small amount of biologenic gravel.

A map showing the location of the transect in Area 1b in relation to bathymetry and the KEF, along with some georeferenced representative images of benthic habitat, is provided in Figure 3-4. No correlation between the seafloor bathymetry / rugosity and occurrence of benthic organisms could be seen for Transect 1b. Less sand ripples were apparent in the north-eastern deeper portion of the transect but this could not be seen on the mapping.

Additional images of benthic habitat and organisms present are provided in **Appendix B**.

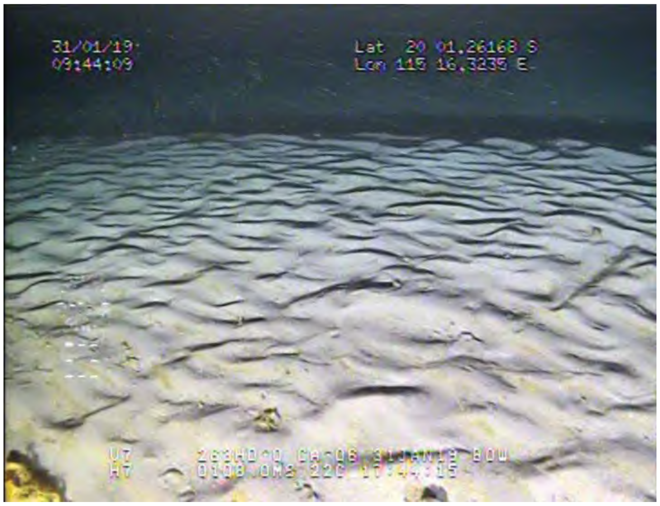

Figure 3-3 Benthic habitat in the location of the pipeline crossing in Area 1b.

Table 3-2 Summary of habitat features in Area 1b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm)	82001005	Entire Transect
Bedform	2D ripples (<10 cm height) 3D ripples (<10 cm height)	82002003 82002007	Alternating 2D and 3D ripples over transect
Relief	Flat (with some small sand steps <50 cm)	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Fishes: Bony fishes	25000000 25400901 10000916 10000913 10000915 10000909 11168918 11168000 37990083	Occasional sightings over the entire transect length – most organisms occurred in isolation

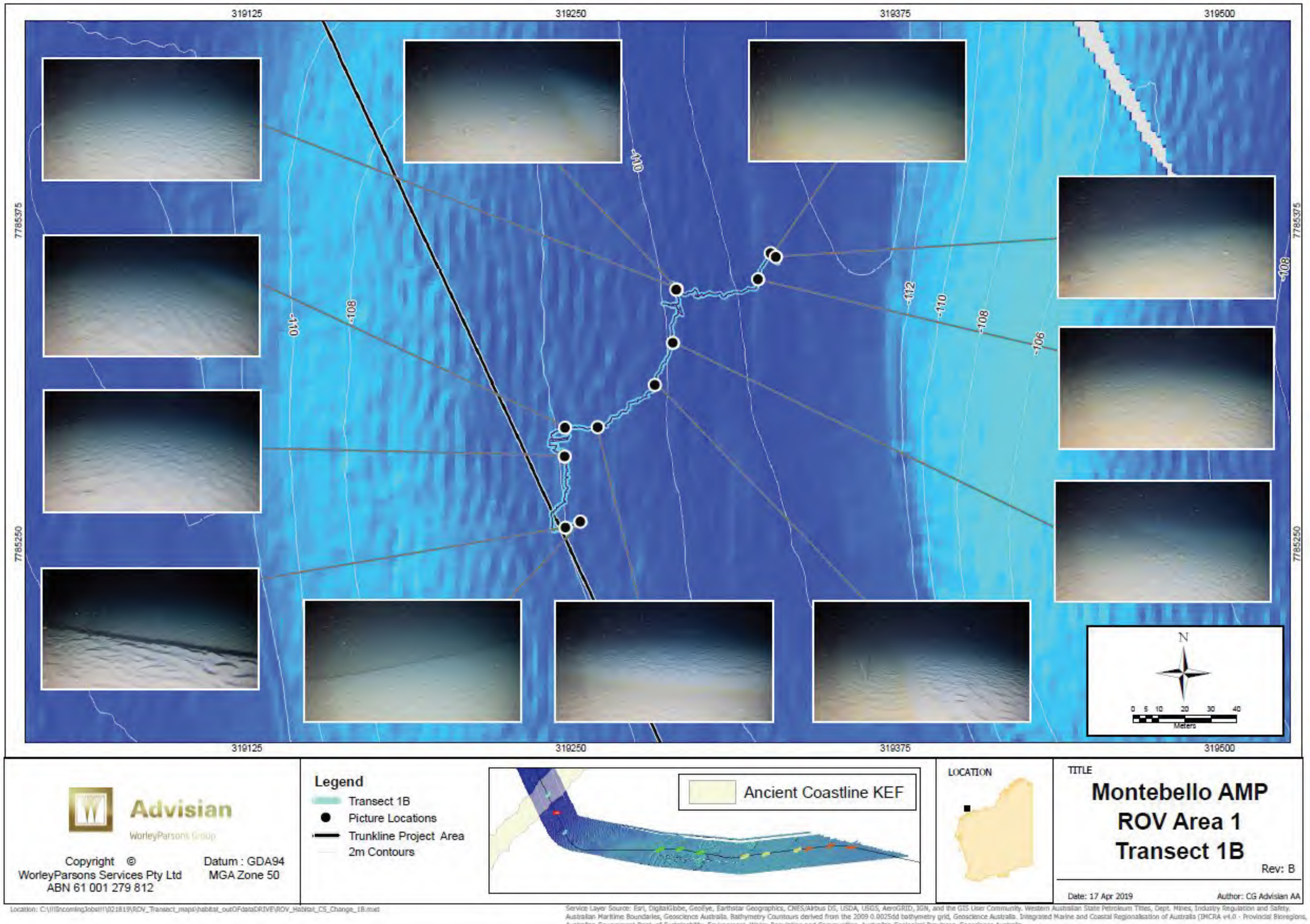

Figure 3-4 Typical benthic habitat and bathymetry in Area 1b.

3.1.3 Area 1c

Notes provided by Neptune for Area 1c included:

- The ROV crossed the proposed pipeline route at E320057, N7783523 at approximately 18:41:46.
- The ROV was on bottom at 18:34 and off bottom at 18:49.
- The south western margin of the track showed the seabed was flat comprising sand and larger gravel to small boulder sized carbonate debris which may be a localised hardpan formed from biological activity or sub-outcropping calcarenite.
- In the vicinity of the pipeline route the seabed was typically flat and had ripples associated with it. These typically had an organic/algae covering particularly in the troughs. Isolated soft corals also occurred.
- The seabed comprised a flat sandy seabed which had a sparse benthic habitat.
- No significant habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The entire seafloor along the transect in Area 1c was flat and the bedforms alternated continually between flat bare sand to flat sand with small ripples (of both 2D and 3D forms) as for Area 1a and 1b. Some areas of seafloor had a higher cover of biologenic rubble (of unidentified origin) while others were bare (see Figure 3-6 and **Appendix 2**).
- In the vicinity of the pipeline route (as identified by the timestamp provided by Neptune), the seafloor was sandy with small ripples and occasional epifauna (see Figure 3-5).
- No moderate or high relief features or areas of consolidated hard substrate were present along the transect in Area 1c. However, some areas of biologenic rubble (perhaps shell, coral or small gravel but unidentifiable) were noted on the seafloor. However, the location of these areas could not be determined on the transect map with detailed bathymetry.
- Area 1c was located near to, but not within, the area mapped as the KEF (ancient coastline 125 m depth contour). The transect traversed an area of seabed which had a depth of around 95 to 100 m depth (see Figure 3-6). No potential features of the KEF (i.e. hard substrate with high biodiversity) were seen in Area 1c.

- Some areas of sand were bare while others were covered in a light bacterial mat. The bacterial mat was more prevalent in the troughs of ripples. This occurred over the length of the transect.

- Benthic epifauna were present on occasion and included echinoderms (e.g. feather stars and sea stars), cnidaria (e.g. seapens), soft corals (various forms) and sponges (various forms). Some organisms were buried under the sand and could not be identified (further detail and CATAMI classifications are provided in Table 3-3).

- The percentage cover of benthic organisms (within the entire video frame) in Area 1c ranged from 0% to ~ 15% and was typically greater in areas that had a higher cover of biologenic gravel. However, no obvious bathymetric features seen on the transect map corresponded with the occurrence of different substrate types (e.g. sand ripples / flat sand), areas with higher cover biologenic gravel or these scattered benthic organisms.

- Bioturbation of the seafloor in the form of small mounds, craters and thin trails was seen over the transect length, evidence of mobile organisms living within and on the seafloor.

- Sightings of mobile fauna were uncommon but included echinoderms (sea stars and sea cucumbers) and various small bony fishes (unidentified and usually quickly moving out of the field of view of the ROV).

A summary of the habitat characteristics, flora and fauna seen in Area 1c is provided in Table 3-3. This table also provides the CATAMI Species Codes for each seafloor feature and taxa identified.

The benthic habitat in the location of the pipeline crossing in Area 1c (as per the time stamp provided by Neptune) is shown in Figure 3-5 and includes a rippled sandy seabed with a low (<5%) cover of benthic organisms and some biologenic gravel.

A map showing the location of the transect in Area 1c in relation to bathymetry and the KEF, along with georeferenced representative images of benthic habitat is provided in Figure 3-6. No obvious correlation between the seafloor bathymetry / rugosity and occurrence of different habitat types or cover of benthic organisms could be seen for Transect 1c when looking at the transect map. However, video analysis noted that benthic cover was typically greater in areas which had a higher cover of biologenic gravel.

Additional images of the seafloor and benthic organisms in Area 1c are provided in **Appendix B**.

Figure 3-5 Benthic habitat in the location of the pipeline crossing in Area 1c.

Table 3-3 Summary of habitat features in Area 1c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm)	82001005	Entire Transect
Bedform	2D ripples (<10 cm height) 3D ripples (<10 cm height)	82002003 82002007	Alternating between flat, 2D and 3D ripples over transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Feather stars - Unstalked crinoids Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like	25000000 25001902 25102000 25400901 10000916 10000913 10000915 10000909	Occasional sightings over the entire transect length – most organisms occurred in isolation

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Crusts: Creeping / ramose	10000917	
	Sponges: Massive forms – simple	10000904	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Fishes: Bony fishes	37990083	

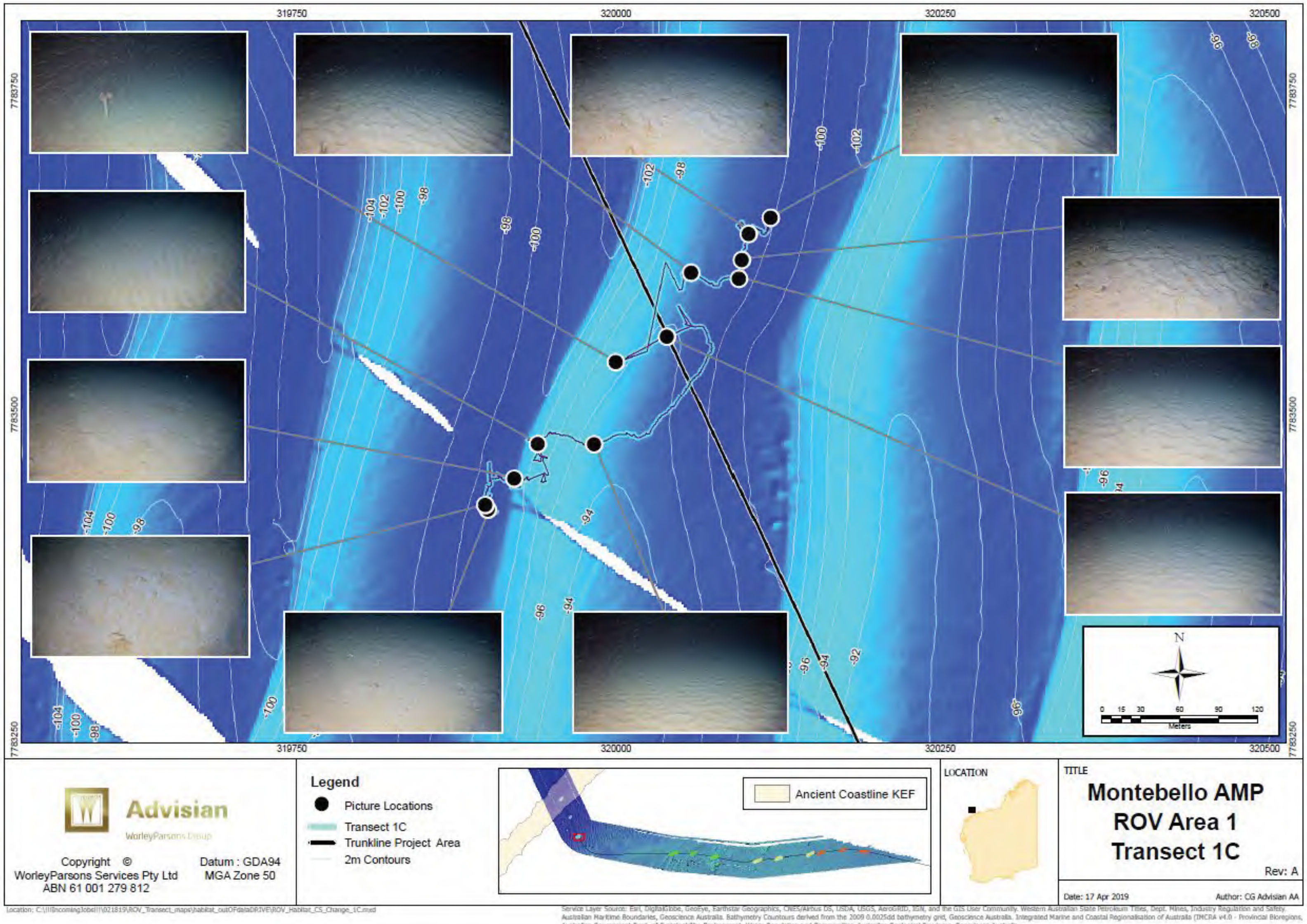

Figure 3-6 Typical benthic habitat and bathymetry in Area 1c.

3.2 Area 2

Three transects (of varying length) were surveyed in Area 2 and are described in more detail below. The depth at the midpoint of each of these transects ranged from 70.6 m to 74.4 m. While some representative images of each transect are provided in the Sections below, **Appendix C** provides additional images of benthic habitat and organisms seen along each transect in Area 2.

3.2.1 Area 2a

Notes provided by Neptune for Area 2a included:

- The ROV crossed the proposed pipeline route at E328839, N7781947 at approximately 06:48:04.
- The ROV was on bottom at 06:34 and off bottom at 06:59.
- The seabed was flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included prolific soft corals, including large gorgonians and sponges.
- The seabed comprised a flat and predominantly sandy seabed which had considerable benthic habitat in the form of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 2a was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length. Some areas were relatively bare while others had a low (~5%) to high (~75%) density of benthic organisms. This benthic cover changed continually (within meters) over the transects length. Small undulations of the seabed were seen at times but no other bedforms such as sand ripples or sand waves were apparent (images are provided in Figure 3-8 and in **Appendix C**).
- The seafloor in the vicinity of the pipeline crossing (as per the timestamp provided by Neptune) was flat and sandy with a cover of ~30% of sponges and corals. This habitat types was similar to the rest of the transect (Figure 3-7).
- Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was apparent, evidence of mobile organisms living within and on the seabed.
- No significant high relief habitat features, or areas of consolidated hard substrate, were observed. The entire transect occurred in water depths ranging from around 72 m to 74 m (refer to Figure 3-8).

- Benthic epifauna were present along almost the entire transect, occurring in patches which varied from low (~5%) to high (~75%) density, and which changed continuously. High density aggregations were often found in areas which had a high cover of biologenic gravel, but were not limited to these areas, also being found where the sediment appeared to be quite fine and where no biologenic gravel was obvious. This benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours (refer to Figure 3-8 and **Appendix C**). Hydroids were also apparent on occasion along the transect length. Further details of taxa present and CATAMI codes are provided in Table 3-4.

- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and over bare sandy seafloor. Identification of fish fauna was not undertaken as part of this assessment.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 2a is provided in Table 3-4. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing in Area 2a (as per timestamp provided by Neptune) is shown in Figure 3-7. This area was flat and sandy with many sponges and corals present (~30% cover).

A map showing the location of the transect in Area 2a in relation to depth contours and detailed bathymetry, along with georeferenced representative images of benthic habitat is provided in Figure 3-8. There were no obvious differences in the cover of benthic organisms related to seafloor bathymetry / rugosity on the map which could be clearly differentiated by looking at the transect map, with a higher cover of organisms occurring in areas which appeared to be highly rugose and also in areas not as rugose. Similarly, areas with low cover of organisms occurred in more rugose and less rugose areas. Video analysis showed that sponges and corals occurred in low to high density along most of the transect length and occurred in varying density in areas of bare soft sediment and also those areas with higher levels of biologenic gravel.

Benthic habitat in the location of the pipeline crossing in Area 2a (as per the time stamp provided by Neptune) is shown in Figure 3-7. Additional images of the benthic habitat and fauna in Area 2a are provided in **Appendix C**.

Figure 3-7 Benthic habitat in the location of the pipeline crossing in Area 2a.

Table 3-4 Summary of habitat features in Area 2a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 2a. Patches of benthic epifauna changed

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Cup-likes: Tubes and chimneys	10000911	continuously from low to high density.
	Sponges: Crusts: Creeping / ramose	10000917	
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

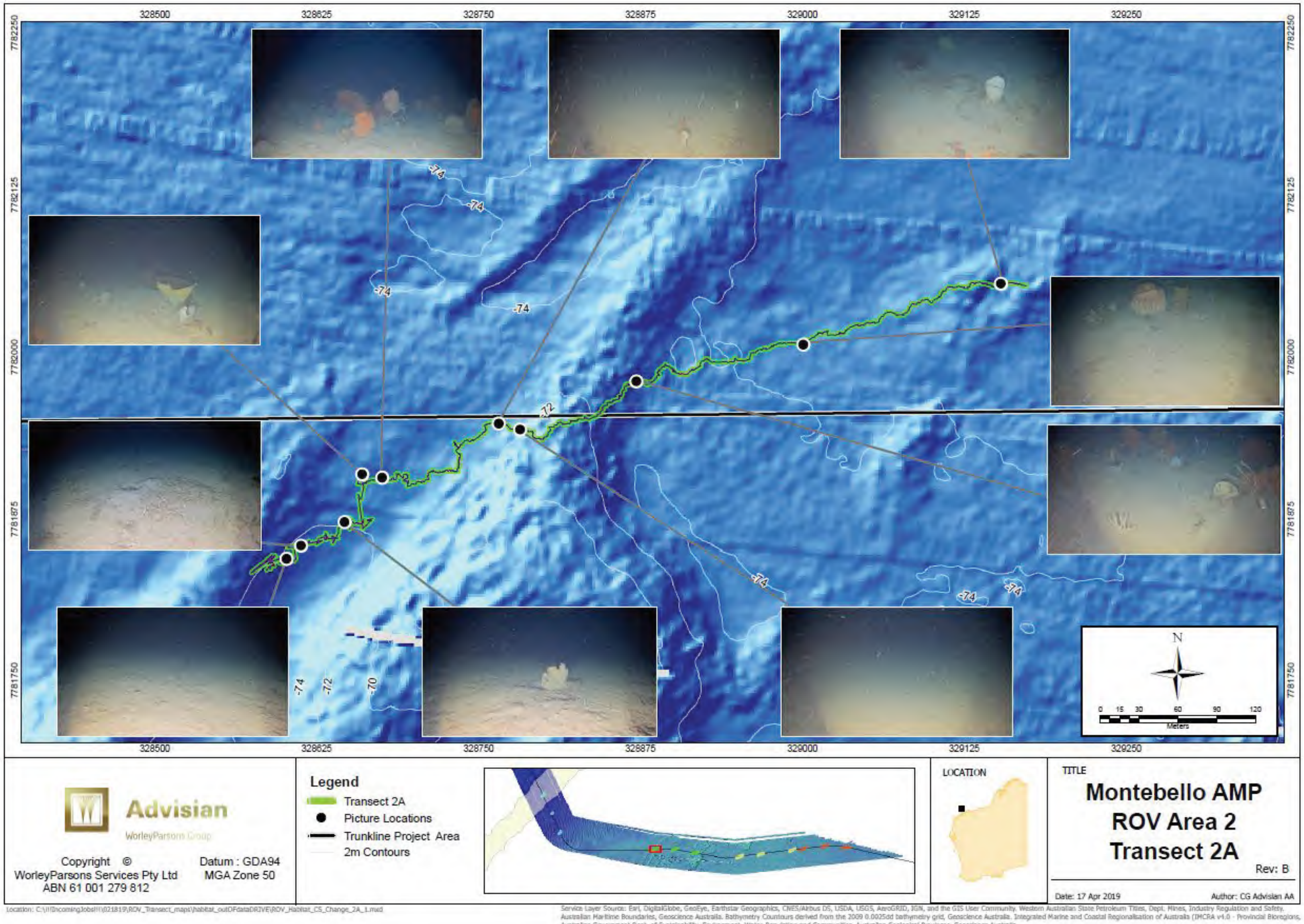

Figure 3-8 Typical benthic habitat and bathymetry in Area 2a.

3.2.2 Area 2b

Notes provided by Neptune for Area 2b included:

- The ROV crossed the proposed pipeline route in the vicinity of E330686, N7781970 at approximately 07:38:39.
- The ROV was on bottom at 07:29 and off bottom at 07:47.
- The seabed was flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included soft corals, including large gorgonians and sponges.
- The seabed comprised a flat predominantly sandy seabed with considerable benthic habitat in the form of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 2b was very similar to 2a. The seafloor was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length. Some areas were relatively bare while others had a low (~5%) to high (~75%) density cover of benthic organisms. The cover of benthic organisms changed continually over the transect length. Small undulations of the seabed and some more pronounced scouring around larger sponges / soft corals was seen at times but no other formal bedforms such as sand ripples or sand waves were apparent. Images are provided in Figure 3-10 and **Appendix C**.
- The seafloor in the vicinity of the pipeline crossing was flat and sandy with many sponges and soft corals present (~50% cover). This habitat was similar to the rest of the transect (see Figure 3-9).
- Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was apparent providing evidence of mobile organisms within and on the seafloor.
- No significant moderate or high relief habitat features, or areas of consolidated hard substrate, were observed. Biologenic gravel was present and quite common. The transect occurred in water depths ranging from around 74 m to 76 m (refer to Figure 3-10)
- Benthic epifauna were present along almost the entire transect, occurring in aggregations which varied continually from low (~5%) to high (~75%) density. As for Transect 2a, high density aggregations were often found in areas which had a high cover of biologenic gravel, but were in no way limited to these areas, with dense aggregations also found in areas with less or no biologenic gravel and soft sediment.

- This benthic epifauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. More detail on taxa and CATAMI codes are provided in

- Table 3-5.

- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and over bare sandy seafloor. Although, IDs of fish fauna were not undertaken for this assessment.

- A summary of the habitat characteristics, flora and fauna seen along the transect in Area 2b is provided in

- Table 3-5. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing in Area 2b (as per timestamp provided by Neptune) is shown in Figure 3-9. This area was flat and sandy with many sponges and corals present (around 50% cover).

A map showing the location of the transect in Area 2b in relation to depth contours, detailed bathymetry and with georeferenced representative images of benthic habitat is provided in Figure 3-10. Rugosity along the length of transect was quite similar and while some georeferenced images suggest that areas with slightly higher rugosity had a higher cover of organisms, other images show that some areas of higher rugosity also had a lower cover of benthic organisms. Similarly, high cover of organisms was also seen in relatively less rugose areas. However, the 'generally' rugose nature of the seabed as indicated by the transect image may provide some explanation for the generally common occurrence of benthic organisms in this location. Additional images of habitat and fauna are provided in **Appendix C**.

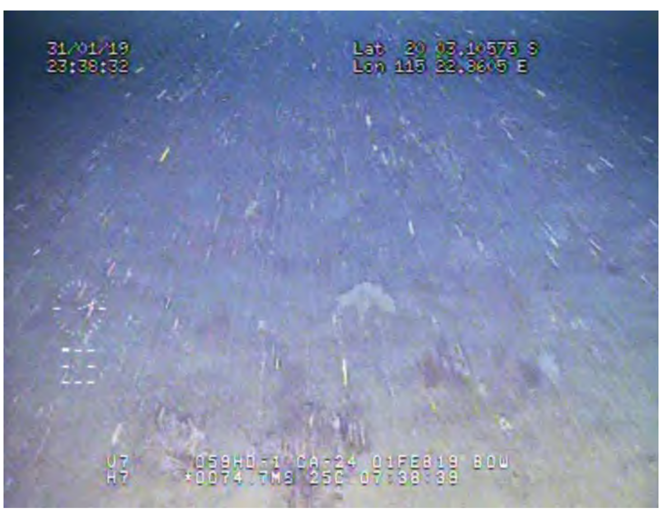

Figure 3-9 Benthic habitat in the location of the pipeline crossing in Area 2b.

Table 3-5 Summary of habitat features in Area 2b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 2b. Patches of benthic epifauna changed continuously from low to high density.

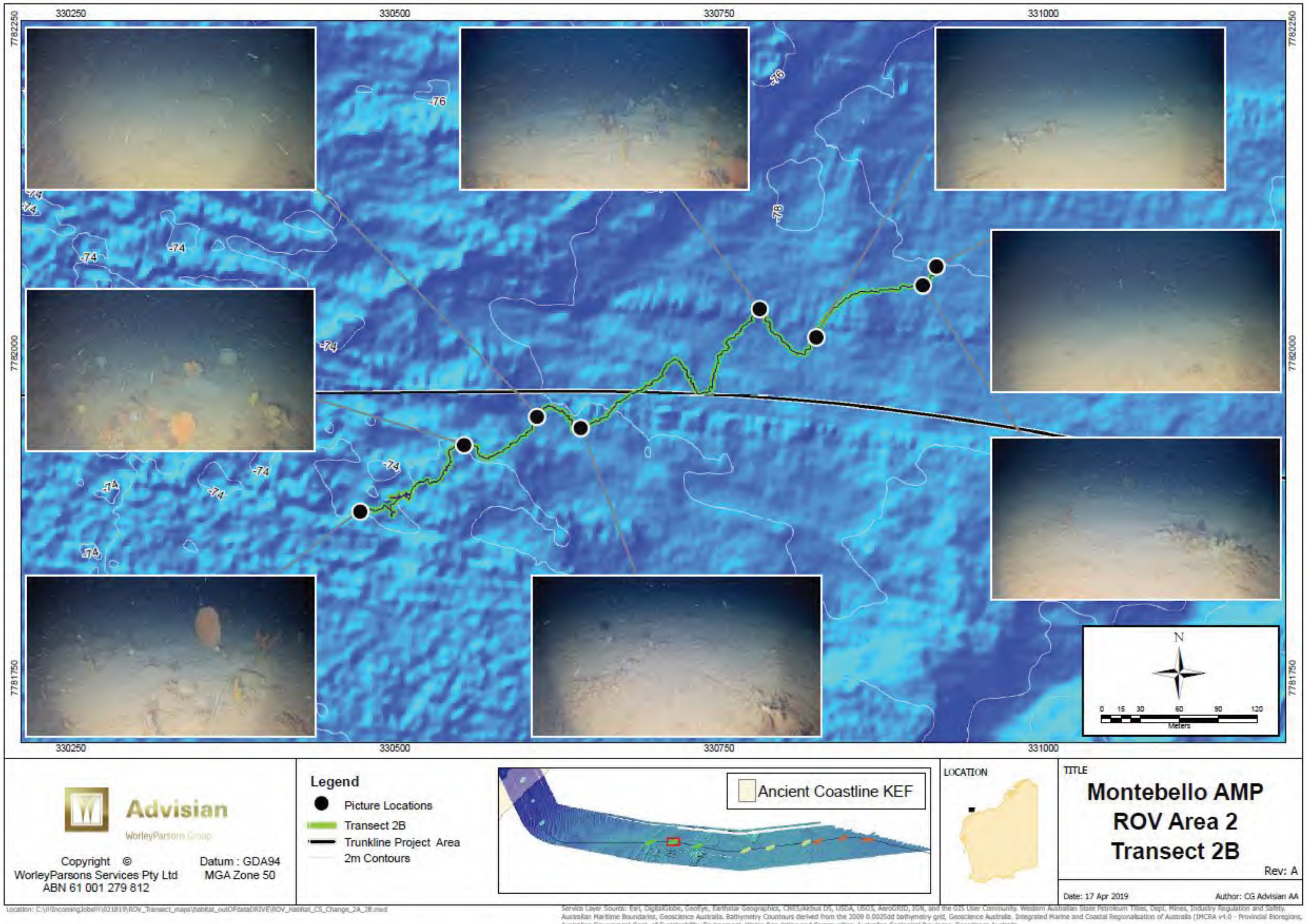

Figure 3-10 Typical benthic habitat and bathymetry in Area 2b.

3.2.3 Area 2c

Notes provided by Neptune for Area 2c included:

- The ROV crossed the proposed pipeline route in the vicinity of E332653, N7781637 at approximately 08:26:10.
- The ROV was on bottom at 08:16 and off bottom at 08:34.
- The seabed was flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included areas of soft corals, including large gorgonians and sponges.
- The seabed comprised a flat predominantly sandy seabed with benthic habitat in the form of areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 2c was again very similar to that in Area 2a and 2b. The seafloor was relatively flat and sandy (fine sand) with a light to high cover of biologenic gravel and/or organic material over most of its length. Some areas were relatively bare while others had a low (~5%) to high (~80%) density of benthic organisms. The benthic cover changed continually (and within meters) over the transects length. Small undulations of the seabed and some scouring around larger sponges / soft corals was seen, but no other formal bedforms such as sand ripples or sand waves were apparent. Images are provided in Figure 3-12 and **Appendix C**.
- The seafloor in the vicinity of the pipeline crossing (as per timestamp provided by Neptune) was flat and sandy with sponges and soft corals present (~20%) and the habitat was similar to the rest of the transect (see Figure 3-11).
- Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was apparent providing evidence of mobile organisms living on and within the seabed.
- No significant moderate or high relief habitat features, or areas of consolidated hard substrate, were observed on the video. Some areas of unconsolidated biologenic rubble of unknown origin were seen. The depth of the seafloor in Area 2c ranged from around 72 m to 74 m (refer to Figure 3-12). Figure 3-12 shows that the seafloor was slightly more rugose at the start and end of the transect with a flatter expanse in the middle.
- Benthic epifauna were present along almost the entire transect, occurring in patches which varied continually from low (~5%) to high (~80%) density. This benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional details and CATAMI

classifications are provided in Table 3-6. Video analysis (and georeferenced images to some degree) showed that benthic organisms were more common (and their cover was denser) at the start and end of the transect. This may be related to the reduced rugosity of the seafloor in the middle expanse seen in Figure 3-12. However, benthic organisms were in no way excluded from this less rugose area, they just tended to occur in lower densities when they did occur.

- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and over bare sandy seafloor. Although, IDs of fish fauna were not undertaken.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 2c is provided in Table 3-6. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing (as per timestamp provided by Neptune) is shown in Figure 3-11. This area was flat and sandy sponges and soft corals present, representing about 20% cover.

A map showing the location of the transect in Area 2c in relation to depth contours, along with representative images of benthic habitat, is provided in Figure 3-12. Area 2c showed some increased rugosity at either end of the transect with an expansive flatter area in the middle. The occurrence (and density) of benthic organisms was also generally greater at both ends of the transect and these bottom features may be related in this case. Notwithstanding this, benthic organisms were not excluded from the flatter mid section of Transect 2c.

Additional images of benthic habitat and fauna are provided in **Appendix C**.

Figure 3-11 Benthic habitat in the location of the pipeline crossing in Area 2c.

Table 3-6 Summary of habitat features in Area 2c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 2c. Patches of benthic epifauna changed continuously from low to high density.

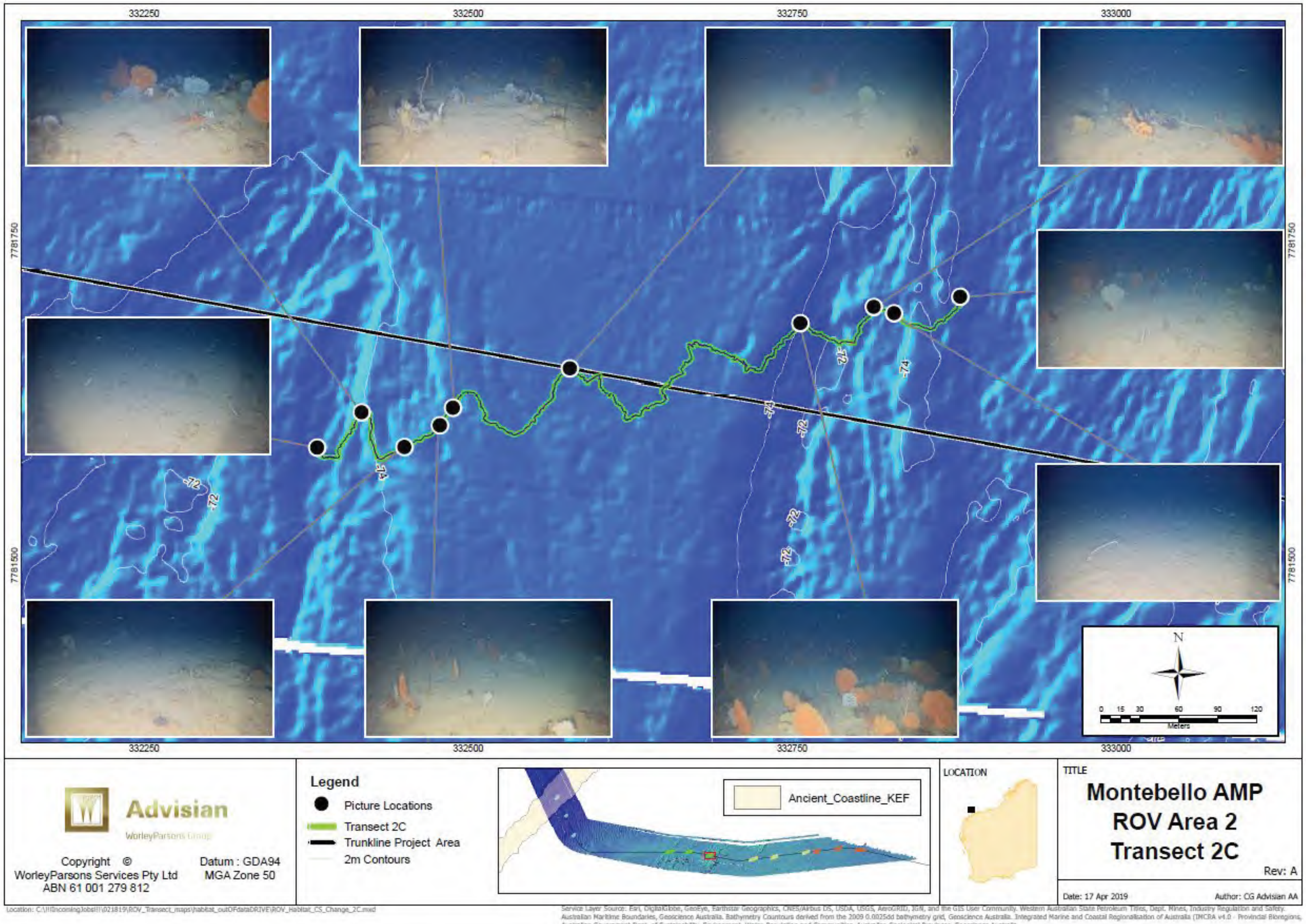

Figure 3-12 Typical benthic habitat and bathymetry in Area 2c.

3.3 Area 3

Three transects were completed in Area 3 and are described in more detail in the Sections below. The depth at the midpoint of these transects ranged from 71.6 m to 73.8 m. While some representative images of each transect are provided in the Sections below, **Appendix D** provides additional images of the benthic habitat and organisms seen along each transect in Area 3.

3.3.1 Area 3a

Notes provided by Neptune for Area 3a included:

- The ROV crossed the proposed pipeline route in the vicinity of E336608, N7781312 at approximately 09:35.
- The ROV was on bottom at 09:25 and off bottom at 09:51.
- The seabed was typically flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals.
- The seabed comprised a flat predominantly sandy seabed with benthic habitat in the form of areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 3a was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). The seabed was a mosaic of bare substrate and low (~5%) to high (~75%) density cover of benthic organisms (e.g. sponges / soft corals), changing every few meters. This was very similar to Area 2. Small undulations of the seabed and some small sand waves were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. Images are provided in Figure 3-14 and **Appendix D**.
- The seafloor in the vicinity of the pipeline crossing (as identified by the time stamp provided by Neptune) was flat and sandy with a low-medium density cover (~20%) of sponges and soft corals and this habitat was typical of the rest of the transect (see Figure 3-13).
- Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. This occurred over the entire transect length and indicates the presence of mobile organisms living within and on top of the seabed.

- No significant moderate or high relief habitat features or areas which could clearly be defined as consolidated hard substrate were observed. Some potential very low profile outcropping was seen, although this was hard to clearly define with the often high cover of biologenic gravel and benthic organisms. The depth of the seafloor was between 75 m to 76 m along the entire transect (refer to Figure 3-14).
- Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to high (~75%) density. This benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional details and CATAMI classifications are provided in Table 3-7. High density benthic cover was seen in areas where biologenic gravel was high but also in areas of fine sediment. In addition, there were areas with a high cover of biologenic gravel which lacked any benthic organisms. The detailed bathymetry shown in Figure 3-14 did not differ significantly over the transect length. While there is some evidence of higher benthic cover in more rugose areas and less benthic cover in less rugose areas, this was not always the case as seen on the video.
- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and also over bare sandy seafloor. Identifications of fish were not undertaken as part of this assessment. Seastars and feather stars were both present.

A summary of the habitat characteristics, flora and fauna seen in Area 3a is provided in Table 3-7. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing (as per the timestamp provided by Neptune) is shown in Figure 3-13. The seafloor in this area was flat and sandy with a low-medium density cover (~20%) of sponges and soft corals. This habitat type was typical of the transect.

A map showing the location of the transect in Area 3a in relation to detailed bathymetry, along with georeferenced representative images of benthic habitat, is provided in Figure 3-14. While this mapping shows some evidence for higher benthic cover in areas of slightly higher rugosity, this was not always the case. In addition, the video analysis found that high benthic cover was not limited to particular substrate types (e.g. bare sand/soft sediment or areas with higher biologenic gravel).

Additional images of the seafloor habitat and epifauna in Area 3a are provided in **Appendix D**.

Figure 3-13 Benthic habitat in the location of the pipeline crossing in Area 3a.

Table 3-7 Summary of habitat features in Area 3a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919	Sponges and corals of high diversity were common and scattered over

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Cup-likes: Tubes and chimneys	10000911	most of the seafloor in transect Area 3a. Patches of benthic epifauna changed continuously from low to high density.
	Sponges: Crusts: Creeping / ramose	10000917	
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

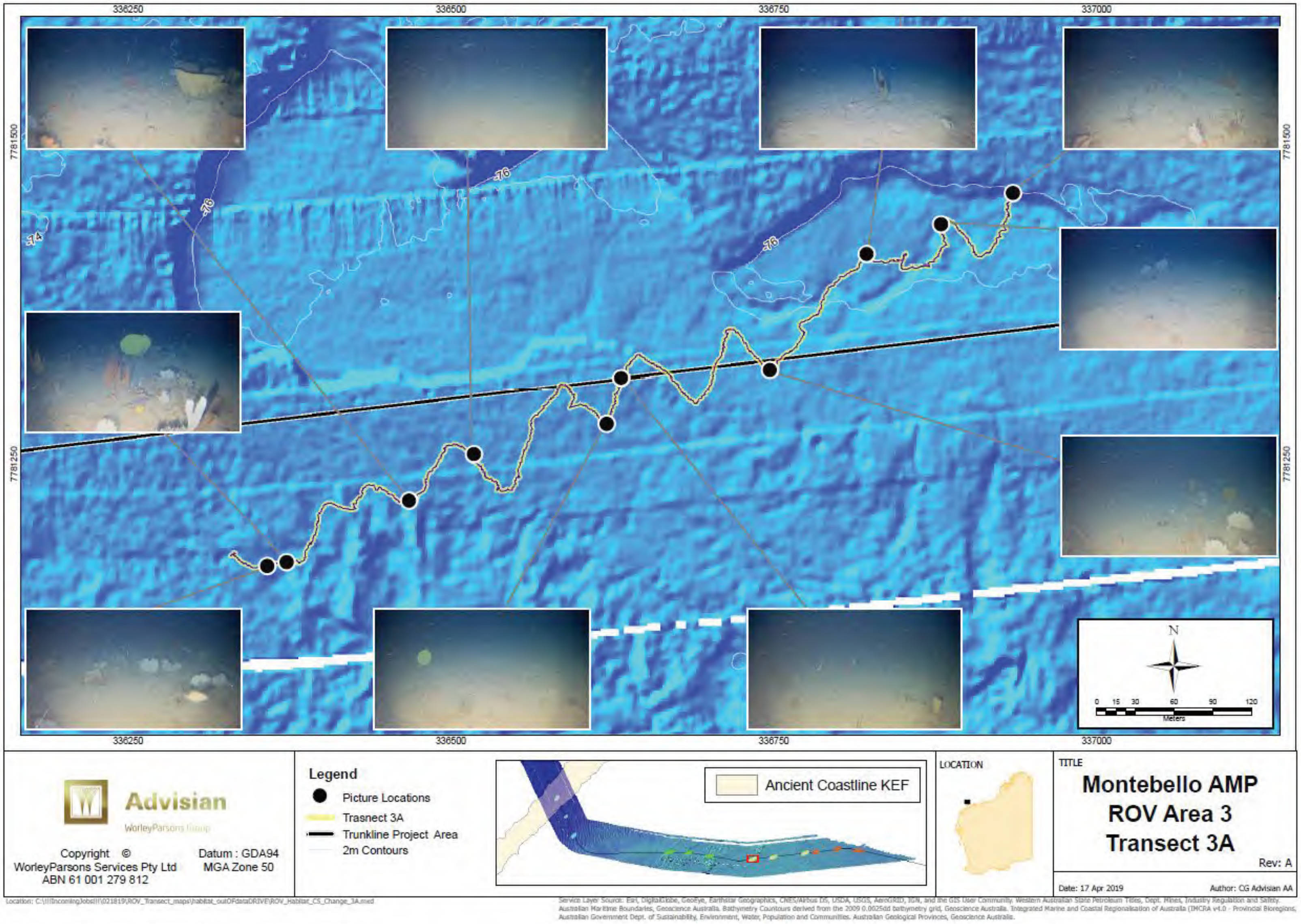

Figure 3-14 Typical benthic habitat and bathymetry in Area 3a.

3.3.2 Area 3b

Notes provided by Neptune for Area 3b included:

- The ROV crossed the proposed pipeline route in the vicinity of E338667, N7781567 at approximately 10:41.
- The ROV was on bottom at 10:25 and off bottom at 10:49.
- The seabed was typically flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included areas of soft corals, including large gorgonians and sponges.
- The seabed comprised a flat and predominantly sandy seabed with benthic habitat in the form of areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 3b was very similar to 3a. The seafloor was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). Small undulations of the seabed and some small sand waves and scour pits (typically around larger organisms or aggregations of organisms) were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. The seabed was a mosaic of bare substrate and low (~5%) to medium (~50%) density cover of benthic organisms (e.g. sponges / soft corals), changing every few meters. Images are provided in Figure 3-16 and **Appendix D**.
- The seafloor in the vicinity of the pipeline crossing (as identified by the time stamp provided by Neptune) was flat and sandy with a low-medium density cover (~30%) of sponges and soft corals (see Figure 3-15).
- Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. This occurred over the entire transect length and provides evidence for mobile organisms living within and on the seafloor.
- No significant moderate or high relief habitat features, or significant areas of consolidated hard substrate, were present. Some potential small areas of outcropping were seen although this was hard to clearly define with the high cover of biologenic gravel and benthic organisms. The entire transect occurred in water depths of about 73 m to 74 m (refer to Figure 3-16). Rugosity was quite consistent over the transect length.
- Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to medium (~50%) density. Benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional

classification details and CATAMI codes are provided in Table 3-8. The transect map for Area 3b (Figure 3-16), overlaid with georeferenced images, shows that benthic organisms occurred along the entire transect length and were often of a medium density (~30-40% cover). Bare substrate was less common in Area 3b.

- Fish fauna diversity was quite high, as seen for transect 3a, and varying sizes of fish were seen amongst the aggregations of soft corals and sponges and over bare sandy seafloor. Identifications of fish were not undertaken as part of this assessment. Seastars and feather stars were both present.

A summary of the habitat characteristics, flora and fauna seen in Area 3b is provided in Table 3-8. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing in Area 3b is shown in Figure 3-15. This area was flat and sandy with a low-medium density cover (~30%) of sponges and soft corals.

A map showing the location of the transect in Area 3b in relation to bathymetry, along with representative images of benthic habitat, is provided in Figure 3-16. Benthic organisms were common along the entire length of the transect, which was quite similar in its rugosity.

Additional images of the seafloor habitat and epifauna in Area 3b are provided in **Appendix D**.

Figure 3-15 Benthic habitat in the location of the pipeline crossing in Area 3b.

Table 3-8 Summary of habitat features in Area 3b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 3b. Patches of benthic epifauna changed continuously from low to high density.

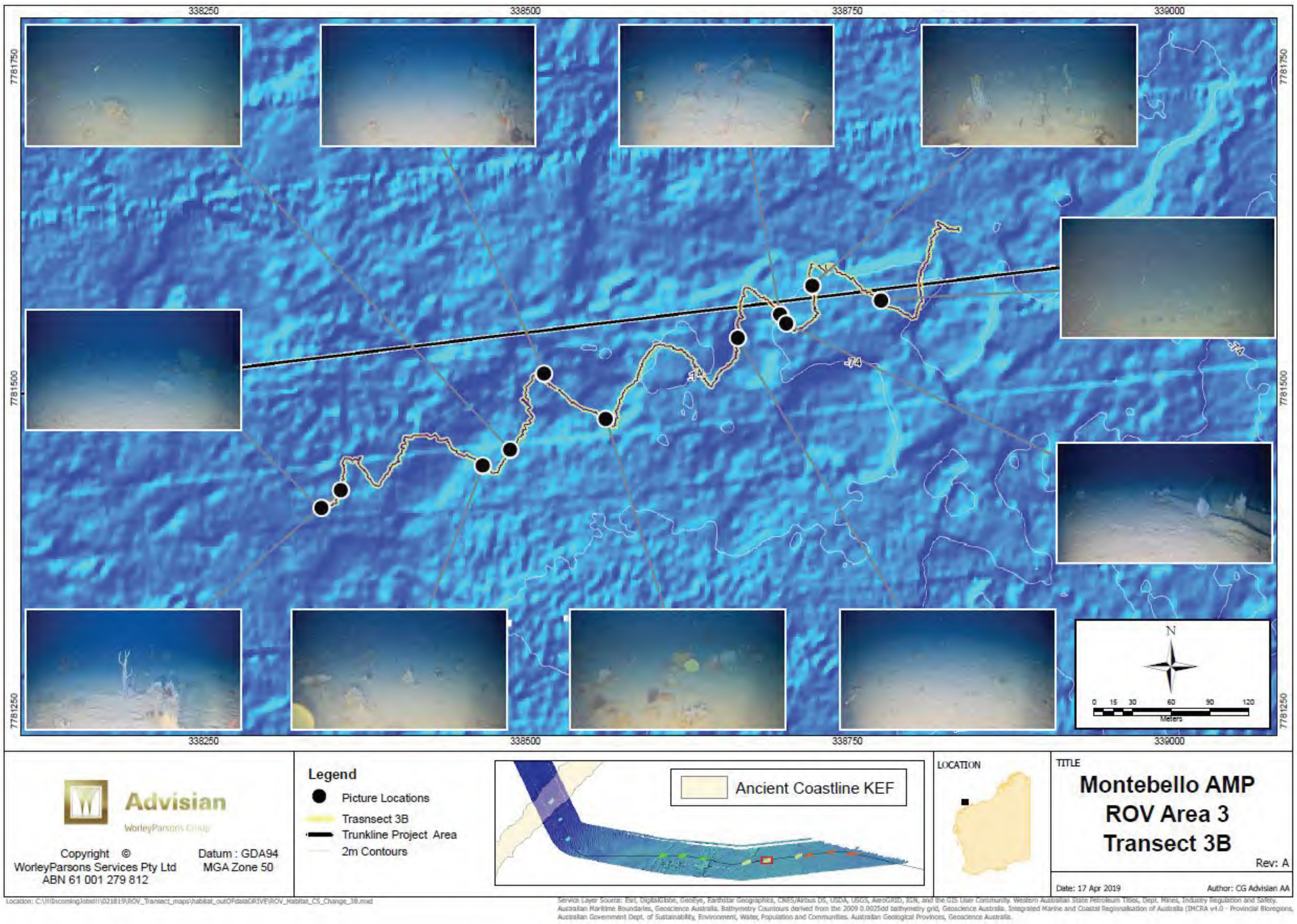

Figure 3-16 Typical benthic habitat and bathymetry in Area 3b.

3.3.3 Area 3c

Notes provided by Neptune for Area 3c included:

- The ROV crossed the proposed pipeline route in the vicinity of E341572, N7781919 at approximately 11:40.
- The ROV was on bottom at 11:28 and off bottom at 11:54.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. Benthic fauna included sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats were noted around some of the sponges.
- The seabed comprised a flat predominantly sandy seabed with benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 3c was very similar to 3a and 3b. The seafloor was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). Small undulations of the seabed and some small sand waves and scour pits were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. The seabed was a mosaic of bare substrate and low to high density cover of benthic organisms (e.g. sponges / soft corals), changing every few meters. Images are provided in Figure 3-18 and **Appendix D**.
- The seafloor in the vicinity of the pipeline crossing (as identified by the time stamp provided by Neptune) was flat and sandy with a low-medium density cover (~30%) of sponges and soft corals (see Figure 3-17).
- Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. This occurred over the entire transect length and provides evidence for mobile organisms living within and on the soft sediment.
- No significant moderate or high relief habitat features, or significant areas of consolidated hard substrate, were present. Some potential small areas of outcropping were seen on the video although this was hard to clearly define with the high cover of biologenic gravel and benthic organisms. The entire transect occurred in water depths between around 75 m and 76 m (refer to Figure 3-18). Rugosity was generally consistent over the transect length but was slightly higher in the south-western end of the transect.
- Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to medium (~50%) density, very similar to the other

transects in Area 3. Benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional classification details and CATAMI codes are provided in Table 3-9. While video analysis showed that benthic cover was often higher in areas which had a higher cover of biologenic gravel, and also occurred in higher densities in more rugose areas as shown in Figure 3-18, this was not always the case, with moderate benthic cover also seen in areas with little or no biologenic gravel and areas of the transect map which appear to be less rugose.

- Fish fauna diversity was again quite high with fish were seen amongst the aggregations of corals and sponges and also over areas of sandy seafloor. Identifications of fish were not undertaken as part of this assessment. Seastars and feather stars were both present.

A summary of the habitat characteristics, flora and fauna seen in Area 3c is provided in Table 3-9. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The seafloor in the area of the pipeline crossing is shown in Figure 3-17. This area was flat and sandy with a low-medium density cover of sponges and soft corals.

A map showing the location of the transect in Area 3c in relation to bathymetry, along with representative images of benthic habitat, is provided in Figure 3-18. While higher benthic cover could be related to a higher cover of biologenic gravel and/or rugosity on some occasions, this was not always the case. the detailed bathymetry / rugosity shown on the transect map cannot be used as an accurate predictor of the occurrence, or lack of, benthic organisms.

Additional images of the seafloor habitat and epifauna in Area 3c are provided in **Appendix D**.

Figure 3-17 Benthic habitat in the location of the pipeline crossing in Area 3c.

Table 3-9 Summary of habitat features in Area 3c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 3c. Patches of benthic epifauna changed continuously from low to high density.

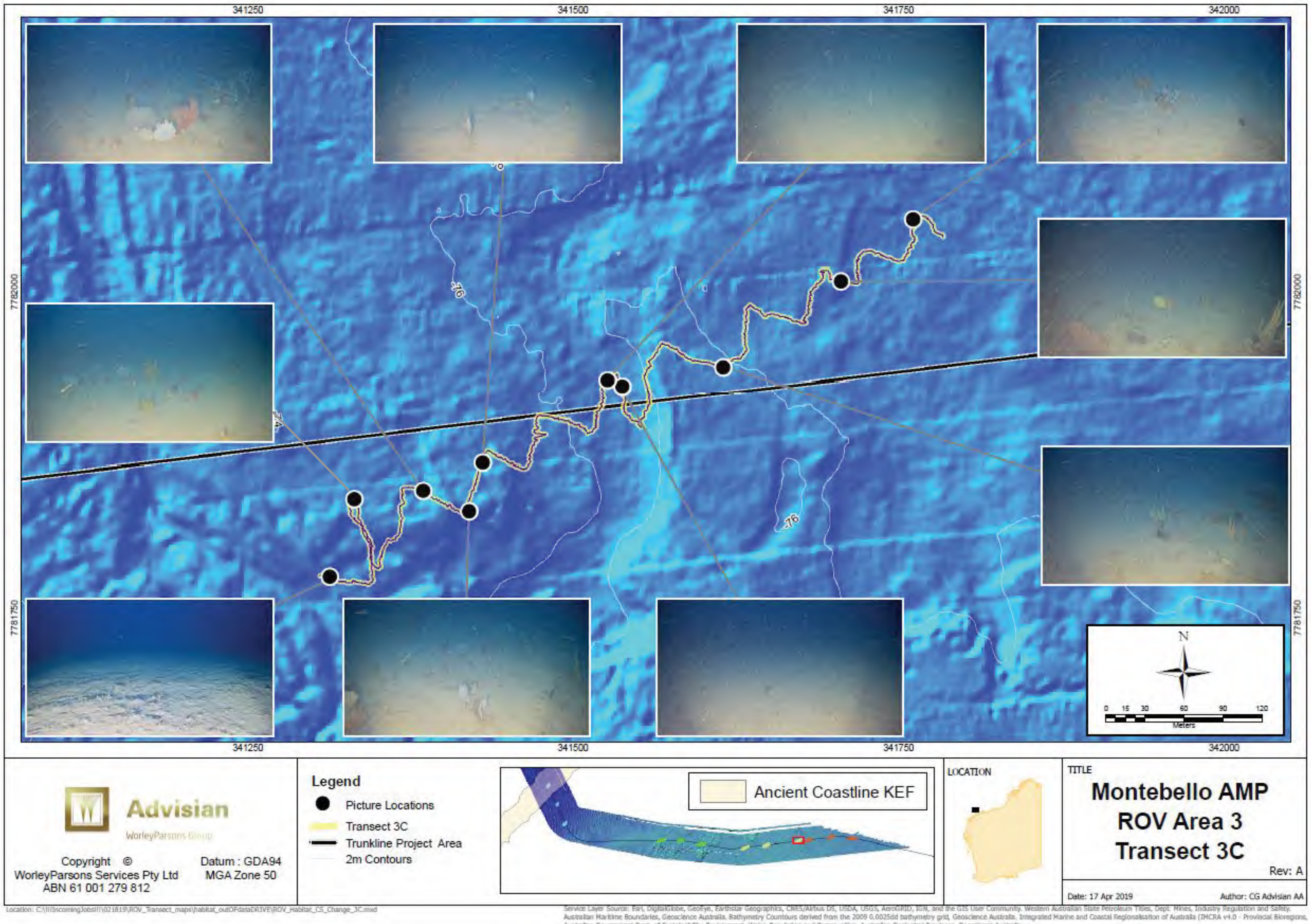

Figure 3-18 Typical benthic habitat and bathymetry in Area 3c.

3.4 Area 4

Three transects were completed in Area 4 and are described in more detail in the Sections below. The depth at the midpoint of these transects ranged from 74.5 m to 78.2 m (slightly deeper but similar to the depth in Area 2 and 3). **Appendix E** provides additional images of the benthic habitat and organisms seen along each transect in Area 4.

3.4.1 Area 4a

Notes provided by Neptune for Area 4a included:

- The ROV crossed the proposed pipeline route around E342566, N7782035 at approximately 13:15.
- The ROV was on bottom at 13:01 and off bottom at 13:29.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. 'Starved' ripples occurred and typically had coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats are noted around some of the sponges.
- The seabed comprised a flat predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 4a are provided:

- The seafloor within Area 4a was typically flat sand with a high level of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and mainly occurred around aggregations of benthic epifauna (i.e. sponges and soft corals). Images are provided in Figure 3-20 and **Appendix E**.
- In the vicinity of the pipeline route (as identified by the time stamp provided by Neptune), the seafloor was typical of the area being flat and sandy with biologenic rubble and a medium density cover (~30%) of scattered sponges and soft corals (Figure 3-19).
- The vast majority of the seafloor along the transect in Area 4a was scattered with sponges and soft corals of varying forms and sizes. Some occurred as individuals and more dense clusters (up to ~50% cover) of these organisms were also common. Large areas of bare substrate were quite uncommon in Area 4a.
- No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present along the transect in Area 4a (i.e. they were not seen on the video nor can be seen on the transect map). However, like in Area 2 and Area 3, much of the

seafloor was covered in a biologic gravel of unknown origin and this was quite dense at times. The depth along the Area 4a transect was around 76 m to 78 m (refer to Figure 3-20). This transect was in close proximity to the transect in Area 3c (which occurred in waters from 75 – 76 m).

- Benthic epifauna were common throughout the entire Area 4a, scattered in low to medium density clusters (5% - 30%) for the most part but also commonly occurring in larger more dense clusters (up to ~50% density). Soft corals (including gorgonians and seapens) and sponges were abundant and diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars which were often attached to sponges/corals). Additional details and CATAMI classifications are provided in Table 3-10. Like in other areas, the occurrence of benthic organisms could not be clearly predicted from any rugosity or other features shown on the detailed bathymetric map (Figure 3-20) nor were they always associated with a certain substrate type (e.g. high biologenic gravel).
- Mobile fauna (mainly small bony fishes) were most common around the larger clusters of sponges and soft corals. Fish were not identified as part of this assessment.
- Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length and provides evidence for the occurrence of mobile fauna (typically invertebrates) living within and on the soft sediment seafloor.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 4a is provided in Table 3-10. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The seafloor in the vicinity of the pipeline crossing in Area 4a (as identified by the timestamp provided by Neptune) is shown in Figure 3-19. This area was flat and sandy with biologenic rubble and a medium density cover (~30%) of sponges and soft corals.

A map showing the location of the transect in Area 4a in relation to bathymetry, along with representative images of benthic habitat, is provided in Figure 3-20. There were no clear or consistent relationships that could be seen between bathymetric features or rugosity in Area 4a with the occurrence or cover of benthic organisms.

Additional images of the seafloor habitat and epifauna in Area 4a are provided in **Appendix E**.

Figure 3-19 Benthic habitat in the location of the pipeline crossing in Area 4a.

Table 3-10 Summary of habitat features in Area 4a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Occasional
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 4a. Larger 'clumps' of sponges and corals were also seen on occasion along the entire transect.

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

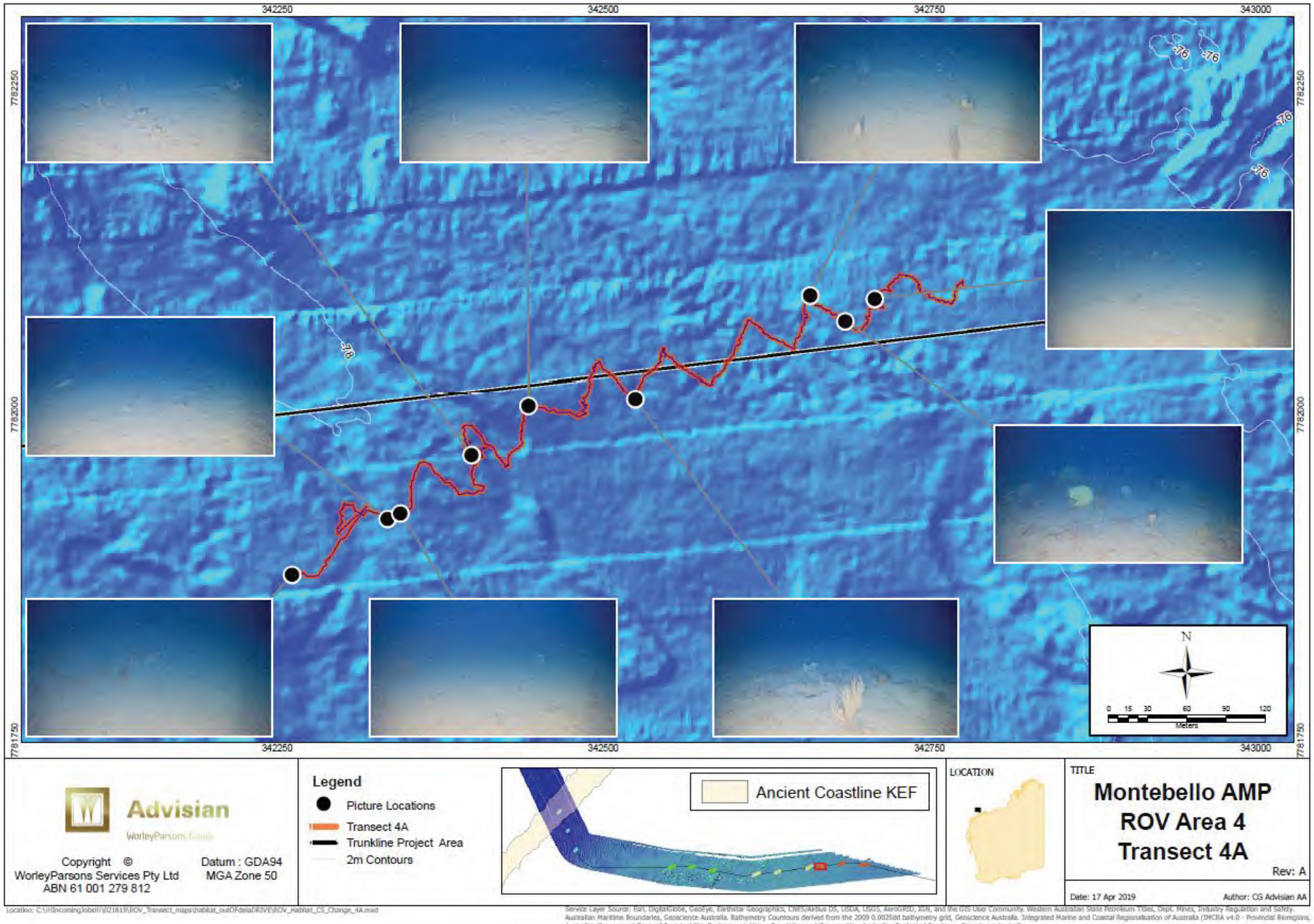

Figure 3-20 Typical benthic habitat and bathymetry in Area 4a.

3.4.2 Area 4b

Notes provided by Neptune for Area 4b included:

- The ROV crossed the proposed pipeline route around E344502, N7782269 at approximately 14:23.
- The ROV was on bottom at 14:15 and off bottom at 14:38.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. 'Starved' ripples occurred and typically had coarser gravel in their troughs. Benthic fauna included sporadic areas of soft corals, including gorgonians and sponges as well as black 'whip' corals. Current scour moats were noted around some of the sponges.
- The seabed comprised a flat and predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 4b are provided:

- The seafloor within Area 4b was very similar to 4a, consisting of a typically flat and sandy seabed with a high level of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and these mainly occurred around aggregations of benthic epifauna (i.e. sponges and soft corals). Images are provided in Figure 3-22 and **Appendix E**.
- The vast majority of the seafloor along the transect was scattered with a low to medium density cover (~5-30%) of sponges and soft corals of varying forms and sizes, although bare patches of sand were slightly more common than was seen in Area 4a. Medium density clusters of these organisms (up to ~40-50% cover) also occurred along the transects length. Images are provided in Figure 3-22 and **Appendix E**.
- In the vicinity of the pipeline route (as identified with the time stamp provided by Neptune), the seafloor was flat and sandy with biologenic rubble and a medium density cover of scattered sponges and soft corals (~30% cover). This habitat was consistent with the rest of the habitat in Area 4b (refer to Figure 3-21).
- No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present along the transect in Area 4b (as seen on the video and on the detailed bathymetric mapping; Figure 3-22). However, much of the seafloor in this area was covered in a biologic gravel of unknown origin (with variable cover). The depth of the seafloor in Area 4b was around 74 m over the entire transect length. Rugosity along the transects length was relatively consistent and given the consistent depth, any small bathymetric features seen on the map would be of a very small scale (Figure 3-22).

- Benthic epifauna were common throughout the entire Area 4b, scattered for the most part in low density (ranging from ~5-20% cover), but also occurring in larger and more dense clusters of up to ~40-50% cover. Soft corals (including gorgonians and seapens) and sponges were abundant and diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars). Images are provided in Figure 3-22 and **Appendix E**. These shown that benthic organisms were common over most of the transect length regardless of small scale bathymetry / rugosity or substrate type (e.g. bare soft sediment or biologenic gravel).

- Mobile fauna (i.e. bony fishes) were most common around the larger clusters of sponges and soft corals in Area 4c. A high diversity of fish fauna was observed on the video however; these species were not identified as part of this assessment.

- Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length providing evidence for mobile fauna (typically invertebrates) living within and on the soft sediment seafloor.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 4b is provided in Table 3-11. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified. The seafloor in the vicinity of the pipeline crossing in Area 4b (as per the timestamp provided by Neptune) is shown in Figure 3-21. This area was flat and sandy with biologenic rubble and scattered sponges and soft corals of about 30% cover.

The location of the transect in Area 4b in relation to detailed bathymetry, with georeferenced representative images of benthic habitat, is provided in Figure 3-22. There were no consistent patterns seen in the occurrence of benthic organisms or substrate type in relation to rugosity, nor were there significant changes in depth or rugosity. Additional images of seafloor habitat and epifauna in Area 4b are provided in **Appendix E**.

Figure 3-21 Benthic habitat in the location of the pipeline crossing in Area 4b.

Table 3-11 Summary of habitat features in Area 4b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Occasional
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 4b. Larger 'clumps' of sponges and corals were also seen on occasion along the entire transect.

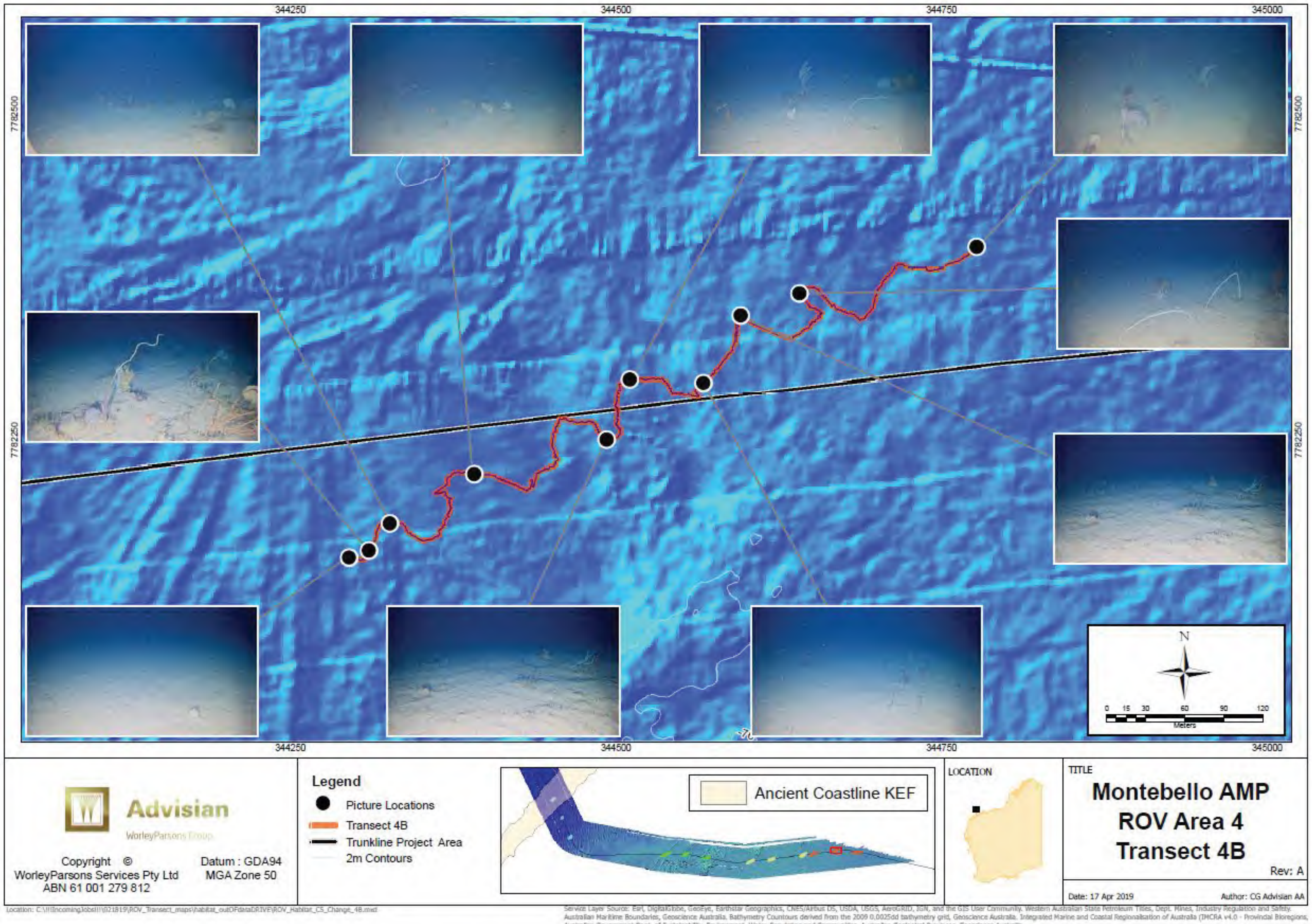

Figure 3-22 Typical benthic habitat and bathymetry in Area 4b.

3.4.3 Area 4c

Notes provided by Neptune for Area 4c included:

- The ROV crossed the proposed pipeline route at about E346650, N7782160 at approximately 15:34.
- The ROV was on bottom at 15:13 and off bottom at 15:47.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. 'Starved' ripples occurred and typically had coarser gravel in their troughs. Benthic fauna included sporadic areas of soft corals, including gorgonians and sponges. Current scour moats were noted around some of the sponges.
- The seabed comprised a flat and predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 4c are provided:

- The seafloor within Area 4c was very similar to 4a and 4b, consisting of typically flat fine sand with a generally high cover of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion, mainly around aggregations of benthic epifauna (sponges and soft corals). Images are provided in Figure 3-24 and **Appendix E**.
- The vast majority of the seafloor along the transect 4c was bare soft sediment, however, some areas were scattered with sponges and soft corals of varying forms and sizes. The majority of these were smaller in their form, however, larger forms tended to increase in occurrence towards the end of the transect. The density of benthic organisms in Area 4c was generally low (~5-15%) but some more dense clusters of these organisms also occurred towards the end of the transect (up to ~30% cover). The occurrence of sponges and corals in transect 4c was generally less than in Areas 4a and 4b. Bare sand was also more common in Area 4c than it was in 4b and 4a (while Area 4b also had more bare sand than Area 4a). Images are provided in Figure 3-24 and **Appendix E**.
- In the vicinity of the pipeline route (as identified by the time stamp provided by Neptune), the seafloor was flat and sandy with biologenic rubble and a low density of scattered sponges and soft corals (~5%). This is shown in in Figure 3-23.
- No significant moderate or high relief features or significant areas of consolidated hard substrate were present along the transect in Area 4c (as indicated on the video and the transect map with detailed bathymetry Figure 3-24). However, some of the seafloor was covered in a biologic gravel of unknown origin. The depth of the seafloor in Area 4c ranged between around 76 m to 78 m (refer to Figure 3-24). The eastern end of the

transect had a couple of smaller features relative to the rest of the transect which typically had low rugosity, however, these were only small scale (i.e. ~1 m).

- Benthic epifauna were diverse in Area 4c, as seen in Areas 4a and 4b, and were scattered throughout the entire Area 4c. Some larger clusters of epibenthic organisms occurred on occasion and these were mainly towards the eastern end of the transect. These areas of denser benthic fauna may be related to the small features which can be seen on the eastern half of the transect map. Soft corals (which included but were not limited to gorgonians and seapens) and sponges in this area were abundant and very diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars). Additional details and CATAMI classifications are shown in Table 3-12.

- Mobile fauna including bony fishes, sea stars and feather stars were most common around the larger clusters of sponges and corals. Sea cucumbers were also seen on occasion on the bare sand.

- Bioturbation of the seafloor in the form of small mounds, craters and large / small trails was evident over the entire transect length, again providing evidence for mobile fauna (typically invertebrates) living within and on the soft sediment seafloor.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 4c is provided in Table 3-12. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the vicinity of the pipeline crossing in Area 4c is shown in Figure 3-23. The seafloor was sandy and quite bare in this location which was consistent with much of the rest of this transect. There was ~5% cover of benthic organisms in this location.

A map showing the location of the transect in Area 4c in relation to bathymetry, along with georeferenced representative images of benthic habitat, is provided in Figure 3-24. The video analysis and transect map for Area 4c both provide some indication of a higher density of benthic organisms occurring in the eastern half of the transect, the location of a couple of bathymetric features on a relatively low rugosity seafloor. However, benthic organisms were not limited to this location and bare substrate was also seen in these locations.

Additional images of the seafloor habitat and epifauna in Area 4c are provided in **Appendix E**.

Figure 3-23 Benthic habitat in the location of the pipeline crossing in Area 4c.

Table 3-12 Summary of habitat features in Area 4c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Occasional
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911	Sponges and corals of high diversity were scattered over the seafloor in transect Area 4c. Larger 'clumps' of sponges and corals were also seen on occasion along the entire transect, mainly in the

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Crusts: Creeping / ramose	10000917	second half of the transect.
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

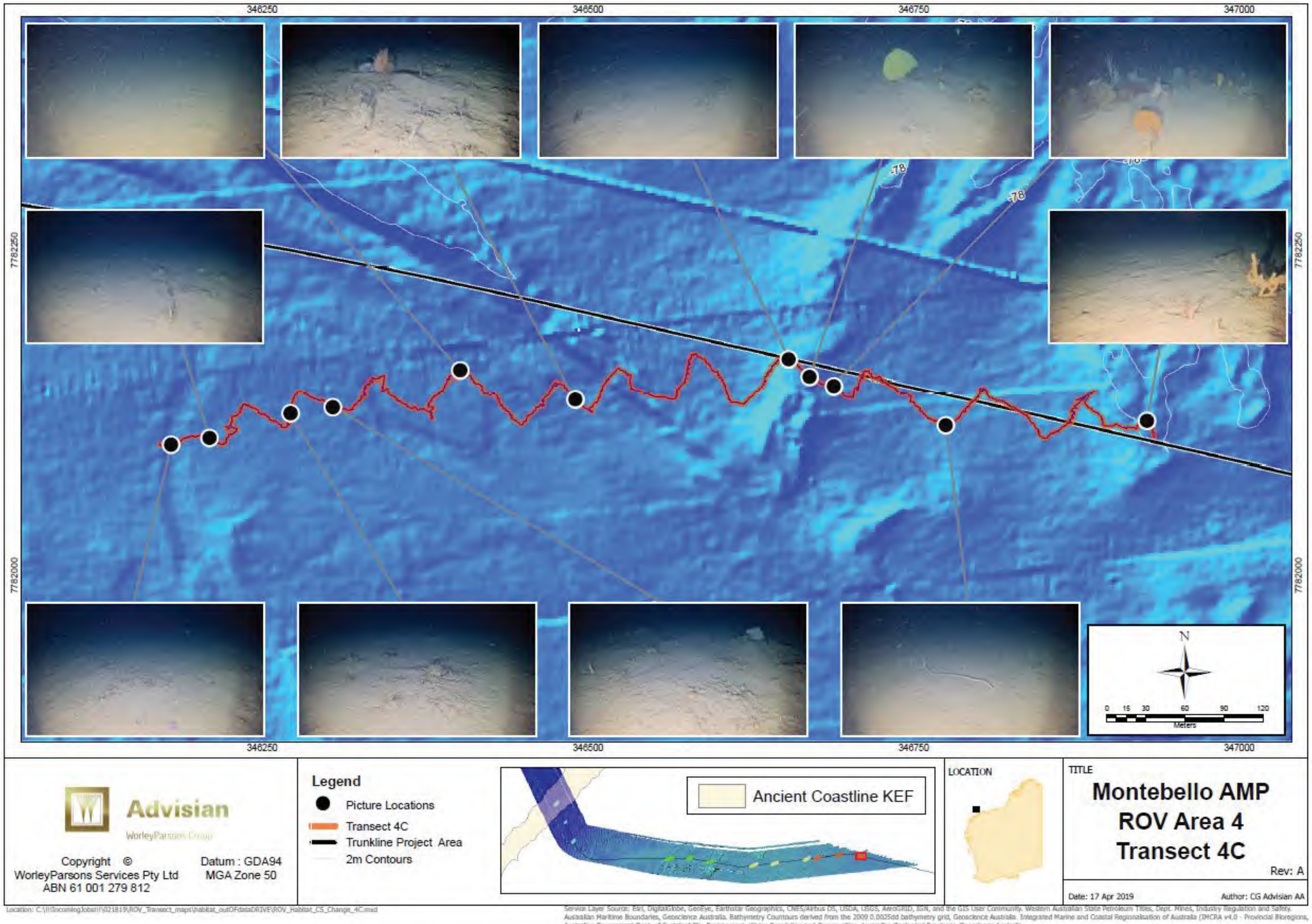

Figure 3-24 Typical benthic habitat and bathymetry in Area 4c.

3.5 Area 5

Only one transect was completed in Area 5. The depth at the midpoint of this transect was 74.6 m. This transect did not cross the pipeline route. **Appendix F** provides additional images of the benthic habitat and organisms seen in Area 5.

3.5.1 Area 5a

Notes provided by Neptune for Area 5a included:

- The ROV surveyed south of the proposed pipeline route round E361160, N7778778.
- The ROV was on bottom at 18:31 and off bottom at 19:00.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. Where flat, the seabed had an algae cover. Where undulating, the seabed was characterised by starved ripples and scour moats, typically around sponges. Benthic fauna included sporadic areas of soft corals, including gorgonians and sponges.
- The seabed comprised a flat predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route. No image of the pipeline crossing area is shown for this reason.

Further analysis of video data by Advisian resulted in the following notes regarding benthic habitat in this location:

- The seafloor in Area 5a consisted of flat sand, often with an organic cover (likely bacterial or algae) or biologenic gravel component. The seafloor showed some slight undulation in places and scour marks commonly occurred around small ‘clusters’ of benthic epifauna (i.e. sponges and soft corals). No regular bedforms such as sand ripples or sand waves were present in this location. Images are provided in Figure 3-25 and **Appendix F**.
- No significant moderate or high relief features were present along the transect in Area 5a as identified during the video analysis or on the detailed bathymetric map (Figure 3-25). No areas of consolidated hard substrate were present. However, some small and more expansive areas of unconsolidated biologenic gravel resulted in the appearance of a partially-hard substrate. This gravel component was more common in the second half of the transect however cannot be identified on the transect map. The transect was located in water depths which ranged from around 74 m to 76 m (Figure 3-25). Rugosity was generally consistent over the entire transect length.

- While much of the seafloor was bare, benthic epifauna occurred sporadically along the entire transect length and sometimes occurred as small and diverse 'clusters' of sponges and soft corals. These organisms were often quite large and were very diverse in form. Isolated organisms also occurred and were more common in the second half of the transect where the seafloor tended to have a higher biologenic gravel component. Additional classification details and CATAMI codes are provided in Table 3-13. The percentage cover of benthic organisms (within the entire video frame) ranged from around 5% to 40% (excluding any cover of biologenic gravel). The location of georeferenced images with higher benthic cover on the transect map do correspond somewhat to areas with slightly increased rugosity, however, video analysis found they were not restricted to these areas. In addition, higher densities were found in areas with higher biologenic gravel cover and also areas without gravel and fine soft sediment.

- Mobile fauna was present and more common around these clumps of sponges and soft corals. They included echinoderms (e.g. sea stars, feather stars and sea cucumbers) and small bony fishes (unidentified and usually quickly moving out of the field of view of the ROV).

- Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters. These indicate that mobile fauna (typically invertebrates) live within and on the soft sediment seafloor.

- Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route. In addition, Area 5a was the only area which was surveyed within Area 5.

A summary of the habitat characteristics, flora and fauna seen in Area 5a is provided in Table 3-13. This table also provides the CATAMI Species Codes for each seafloor feature and taxa identified.

A map showing the location of the transect in Area 5a in relation to bathymetry, along with representative images of benthic habitat is provided in Figure 3-25. While some images with benthic cover do tend to occur in locations with slightly higher rugosity this variation in seafloor bathymetry is actually very small. No strong or consistent relationship between bathymetry / rugosity and the occurrence or density of benthic organisms could be inferred from the combined video and mapping analysis, with organisms occurring along the length of the transect and in areas with higher biologenic gravel and also areas with fine soft sediment and no gravel.

Additional images of benthic habitat and sessile organism in Area 5a are provided in **Appendix F**.

Table 3-13 Summary of habitat features in Area 5a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional bioturbation over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic - Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Diverse 'clumps' of sponges and corals were seen on occasion along the entire transect in Area 5

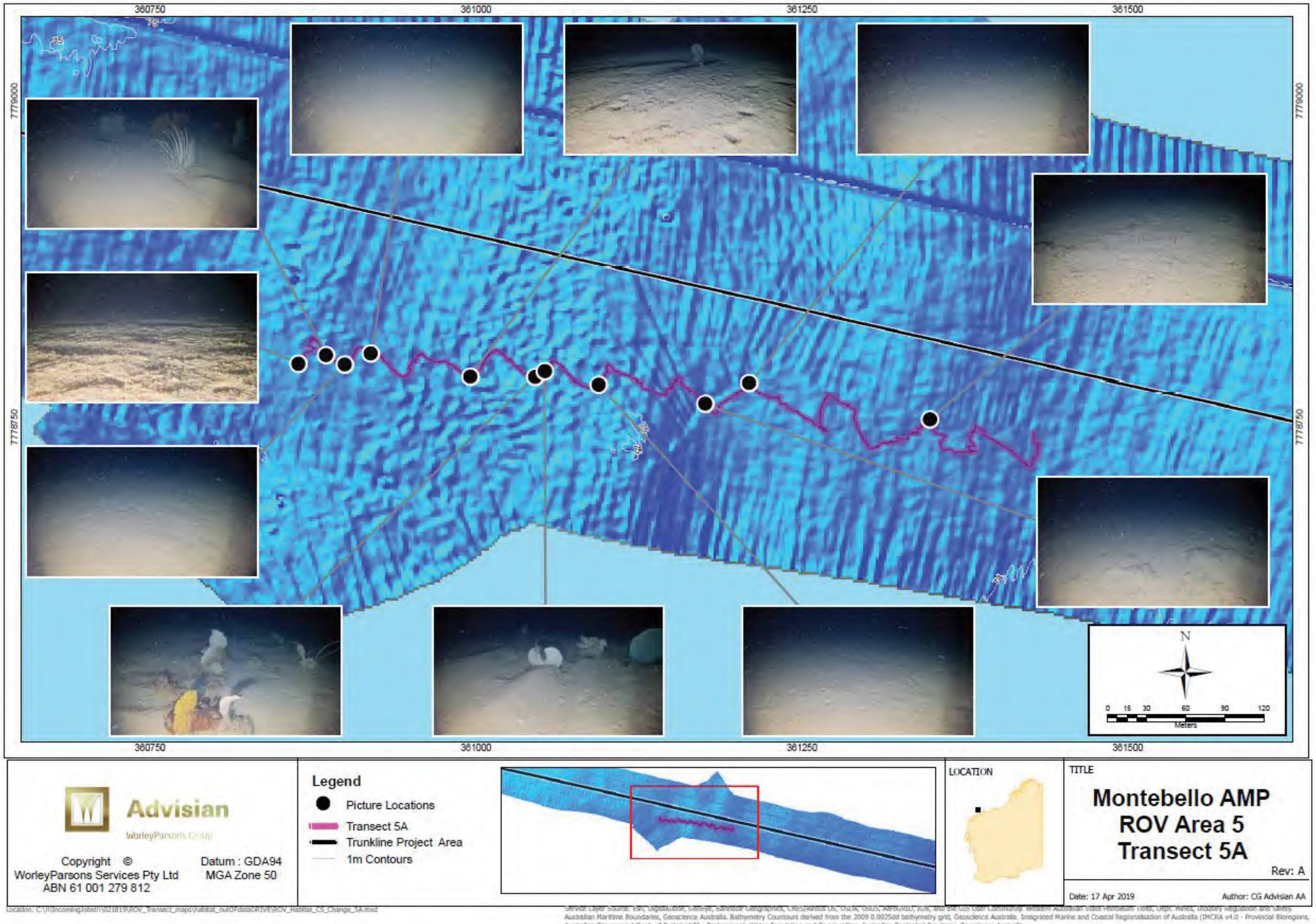

Figure 3-25 Typical benthic habitat in Area 5a.

4 Summary and Discussion

The benthic habitat within five areas of the Montebello AMP was characterised through assessment of video collected by ROV. This habitat has been described and classified in accordance with the CATAMI Classification System. Area 1 which was the deepest location and was located in the vicinity of the KEF was most different, with a much lower cover of benthic organisms than Areas 2 to 5. Areas 2 to 5 were quite similar in depth and in nature, with some small differences in the density and occurrence of benthic organisms and in substrate type (e.g. variants of soft sediment bedforms and cover of biologenic gavel). A summary of findings for each area surveyed is provided below along with a discussion of the results in relation to the published values for the Montebello AMP and 125m Depth Contour KEF.

4.1 Area 1

Area 1 was selected to assess the benthic habitat at the ancient coastline 125 m depth contour KEF and to provide spatial coverage of the AMP. Area 1a was located within the KEF, however Area 1b and 1c were not. No potential features of the KEF (i.e. areas of hard substrate with high biodiversity) were seen along any of the transects surveyed. The actual depth at the midpoint of the transects in Area 1 ranged from 103.2 m to 126.4 m. Benthic habitat along all transects surveyed in Area 1 were typically bare sand with various bedforms including flat bare sand, small ripples (of 2D and 3D forms) and small 'steps' (<50 cm). Some areas of seafloor were bare, while others were covered in a light bacterial mat and others were seen to have a cover of biologenic gravel (of unidentified origin). The cover of biologenic gravel changed continuously over the course of the transects. No moderate or high relief features or areas of consolidated hard substrate were present within any transect.

Benthic organisms (including sponges and soft corals) were present on occasion and generally occurred as single or low density aggregations of individuals. The cover of benthic organisms in Area 1 ranged from 0% to ~15% (being highest in Transect 1c). Slightly higher occurrences of benthic organisms were noted in areas with a higher cover of biologenic gravel (although were in no way limited to these areas and this feature could not be identified by looking at the transect maps). Furthermore, this relationship was not quantified. No relationship between bathymetry and different habitat 'types' or the cover of benthic organisms was seen along individual transects. The occurrence and cover of benthic organisms and the location of different substrate types could not be predicted from any obvious features on the bathymetric maps. Bioturbation of the seafloor was evident in all three transects in Area 1 indicating the presence of mobile organisms living on and within the seabed. Mobile organisms including fish, echinoderms and jellies, were also noted on the video.

The environmental values of the KEF refer to potential areas of hard substrate or rocky escarpments which may provide enhanced biodiversity or biologically important habitat in areas otherwise dominated by soft sediments. However, no hard substrate or rocky escarpments were recorded in Area 1 in the current study. Nonetheless, the soft sediment habitat did support a number of epibenthic and mobile fauna in the form of corals, sponges, echinoderms and fish.

4.2 Area 2

Area 2 was selected to provide spatial coverage of the AMP in an area which may include ancient coastline. The actual depth at the midpoint of each of the transects in Area 2 ranged from 70.6 m to 74.4 m. The benthic habitats present along all transects in Area 2 were very similar to each other. The seafloor in Area 2 was relatively flat and sandy with a light to high cover of unconsolidated biologenic gravel and/or organic material. Small undulations of the seabed were seen but no other regular bedforms such as sand ripples or sand waves were apparent. No significant high relief habitat features, or areas of consolidated hard substrate, were observed in any transect. Some areas of seafloor were relatively bare while others included a low (~5%) to high (~80%) density cover of benthic organisms. This was true for all three transects. This benthic cover changed continually and often (within m's) over each transect. Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was also apparent. Mobile organisms including fish, echinoderms and jellies, were also noted on the videos for Area 2.

Benthic epifauna was present over the length of each transect, occurring in patches which varied from low (~5%) to high (~80%) density, and which changed continuously. All three transects were quite similar. Benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids and cnidarians were also apparent on occasion along the transect length. Fish fauna were also common amongst the patches of sponges and corals. Higher cover of benthic organisms were often seen in areas which had higher amounts of visible biologenic gravel, however this was also seen in areas which seemed to comprise more fine sediment with less or no biologenic gravel. The generally common occurrence of benthic organisms in Area 2 may be related to the generally high rugosity which can be seen in all three transect maps. A decrease in benthic cover on some occasions could be related to more expansive areas of lower rugosity (e.g. in Transect 2c) however this was not always the case.

The high biodiversity of sessile and mobile organisms seen at depths of around 70 m – 76 m in Area 2 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. Area 2 may provide foraging habitat for mobile threatened fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

4.3 Area 3

Area 3 was selected because it was identified as a point of interest in the AMP and along the trunkline corridor where there are likely to be outcropping / subcropping calcarenite with shallow sediment cover and sediment ponds, along with sections of sandy bottom (KP165-170). The actual depth at the midpoint of the transects in Area 3 ranged from 71.6 m to 73.8 m. The seafloor in Area 3 was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). The seabed was a mosaic of bare substrate and low (~5%) to high (~75% - in Area 3a) density cover of benthic organisms (e.g. sponges / corals). Small undulations of the seabed and some small sand waves were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. No significant moderate or high relief habitat features were observed on the video or can be seen on the transect maps with detailed bathymetry. Any features seen are in the order of ~1 m and occur over relatively large scales. Some potential outcropping was seen, although this was hard to clearly define with the often high cover of unconsolidated biologenic gravel and cover of benthic organisms. Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. Mobile organisms including fish, echinoderms and jellies, were also noted on the videos for Area 3. Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and also over bare sandy seafloor.

Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to high (~75%) density. Area 3a contained high density (~75%) aggregations on occasion, however, Area 3b and 3c only reached a medium density (~50%). Benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids and cnidarians were also apparent on occasion along the transect length. While some indication for higher benthic cover in areas containing a higher cover of biologenic gravel and/or areas which appeared slightly more rugose on the transect maps was seen, this relationship was not consistent and there were many occasions where a higher density of organisms was seen on soft sediment with little gravel cover and also on areas of the transect maps which appeared to be quite flat in relation to the rest of the transect.

The high biodiversity of sessile and mobile organisms seen at depths of around 73 m – 76 m in Area 3 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. Although no clear outcropping / subcropping of calcarenite was seen, areas of biologenic gravel with a medium cover of benthic organisms were common. Area 3, like Area 2, may provide foraging habitat for mobile threatened fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

4.4 Area 4

Area 4 was included to provide data to assess the benthic habitat adjacent to the Pluto pipeline, in an area that could potentially provide turtle foraging on hard substrate / subcrops (KP160-164). The actual depth at the midpoint of the transects in Area 4 ranged from 74.5 m to 78.2 m. The seafloor within Area 4 was typically flat sand with a high level of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and mainly occurred around aggregations of benthic epifauna (i.e. sponges and corals). The seafloor in Area 4 was scattered with sponges and corals of varying forms and sizes. Some occurred as individuals with a low density cover (~5%) and more dense clusters (up to about 50% cover) of organisms were also seen and were more common in some transects (namely 4a and 4b). Areas of bare sand were present amongst the patches of epifauna and were more common in Area 4c than 4b and again than in Area 4a. The switch between bare sand to benthic cover changed constantly and quickly however. Corals and sponges were abundant and diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars which were often attached to sponges/corals) and cnidaria (e.g. seapens). Mobile fauna (mainly small bony fishes) were most common around the larger clusters of sponges and corals. Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length.

No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present in Area 4 as could be seen on the video or transect maps. However, much of the seafloor was covered in a biologic gravel of unknown origin and this was quite dense at times. While at times the bathymetric maps provided some indication of increased cover of benthic organisms in areas with higher rugosity, this was not always the case. In general, Area 4a and 4b were more rugose than 4c, and these two areas did appear to have a more consistent cover of benthic organisms. However, within individual transects, a medium - high density of benthic organisms could be seen in areas that were not necessarily highly rugose (as indicated on the bathymetric maps), and in some cases, density was high in areas with expansive biologenic gravel and at other times was high on areas of bare soft sediment.

The high biodiversity of sessile and mobile organisms seen at depths of around 74 m – 78 m in Area 4 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. Although no areas of consolidated hard substrate or subcrops were seen, the high epibenthic diversity, which included soft corals and sponges, could very well provide a foraging habitat for threatened marine turtles, along with other mobile fauna which are able to live at or travel to these depths.

4.5 Area 5

Area 5 was included for completeness to compare benthic habitat adjacent to the existing Pluto pipeline at the eastern end of the AMP. The actual depth at the midpoint of the only transect surveyed in Area 5 was 74.6 m. The seafloor in Area 5 consisted of flat sand, often with an organic cover (likely bacterial or algae) or a biologenic gravel component. The seafloor showed some slight undulation in places and scour marks commonly occurred around small 'clusters' of benthic epifauna (i.e. sponges and corals). No regular bedforms such as sand ripples or sand waves were present in this location. No significant moderate or high relief features were present along the transect in Area 5. No significant areas of consolidated hard substrate were seen. However, the biologenic gravel resulted in a partially-hard looking substrate.

Benthic epifauna occurred sporadically along the entire transect length and generally occurred as diverse 'clusters' of sponges and corals. These organisms were often large and were very diverse in form. The percentage cover of benthic organisms (within the entire video frame) ranged from 5% to ~40% (excluding any cover of biologenic gravel). No strong or consistent relationship between bathymetry / rugosity and the occurrence or density of benthic organisms could be inferred from the combined video and mapping analysis, with organisms occurring along the length of the transect and in areas with higher biologenic gravel and also areas with fine soft sediment and no gravel.

Mobile fauna were common around these clumps of sponges and corals. They included echinoderms (e.g. sea stars, feather stars and sea cucumbers) and small bony fishes. Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters.

The high biodiversity of sessile and mobile organisms seen at depths of around 74 m in Area 5 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. This area may provide foraging habitat for mobile threatened fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

4.6 Previous Benthic Surveys

Benthic habitat data from the North-West Shelf including the Montebello AMP has been collected in several previous surveys including the 2017 RV Investigator voyage (Keesing, 2019), the 2013 Pilbara Marine Conservation Partnership (PMCP) surveys (Pitcher et al., 2016) and the 1982–1997 CSIRO North West Shelf (NWS) Effects of Trawling project (Sainsbury, 1988; 1991). General findings of these studies are provided below.

Data used to describe benthic substrates and biota from the 2017 RV Investigator voyage were principally derived from still camera images. This study showed that substrate and topography in the Montebello AMP was predominantly fine sand or a mix of fine and coarse sand. While deeper sites were often all coarse sand, some rubbly areas were observed at the shallowest sites. The general topography was predominantly flat bottom with occasional bioturbated areas. Apart from the most inshore site, most sites surveyed in the eastern section of the Montebello AMP had low numbers of sponges, whips and gorgonians. Complex benthic filter feeder communities were largely absent. The dominant filter feeders were hydroids, seapens and crinoids. The most commonly recorded crinoid was *Comatula rotalaria* which is free living on sand rather than associated with other filter feeders like gorgonians. One site surveyed was notable for the large numbers of seapens present and most sites had large areas characterised by soft sediment dwelling crinoids or hydroids and seapens rather than the complex sponge and soft coral communities observed in the Dampier MP.

The CSIRO Effects of Trawling Project conducted between 1982 and 1997 included 21 transects in the Montebello AMP. Substrate type was very similar across the whole of the AMP and similar to the 2017 surveys, being predominantly fine sand or a mix or fine and coarse sand, with some sites having rubbly areas. Topography was mostly fine sand or fine sand with ripples. Three sites had large proportions of ridges or large ripples or very large ripples. All of these sites were located at the far western side of the MP, two of these in the very south-western section of the MP. The biota recorded in the CSIRO studies varied notably from that during the 2017 RV Investigator surveys. In particular, the large proportion of sponges and small proportion of crinoids seen on the historical voyages. However, two historical sites located in the eastern part of the MP where the 2017 samples were taken also had a large proportion of images with no biota.

The Pilbara Marine Conservation Partnership (PMCP) project (Babcock et al. 2017) included habitat and biodiversity mapping in the region between North West Cape and Barrow Island and the Montebello Islands. One of the study components assessed benthic habitats and biodiversity in this region (Pitcher et al. 2016) and included sites in what is now the Montebello AMP. Substrate type recorded by video at the 2013 survey sites was either fine or coarse sand at four sites and rippled at two sites located in the south-western section of the AMP. The towed video sites surveyed in the south-western part of the AMP had large proportions of video transects where no biota was evident. Dense sponges occurred at shallower sites on the central southern and south-western section of the MP, west of the islands and a site also in the south-western section had a large proportion of gorgonian habitat.

The results of previous benthic studies in the Montebello AMP are largely in alignment with the findings of the current study in terms of the benthic habitat recorded (typically low relief sandy seafloor (with various bedforms) with occasional rubbly areas increasing at sites more inshore) as well as the dominant benthic organisms identified (which varied in diversity and density within and between survey areas, but typically included a wide variety of sponges and soft corals including whips and gorgonians, hydroids, seapens and crinoids).

5 References

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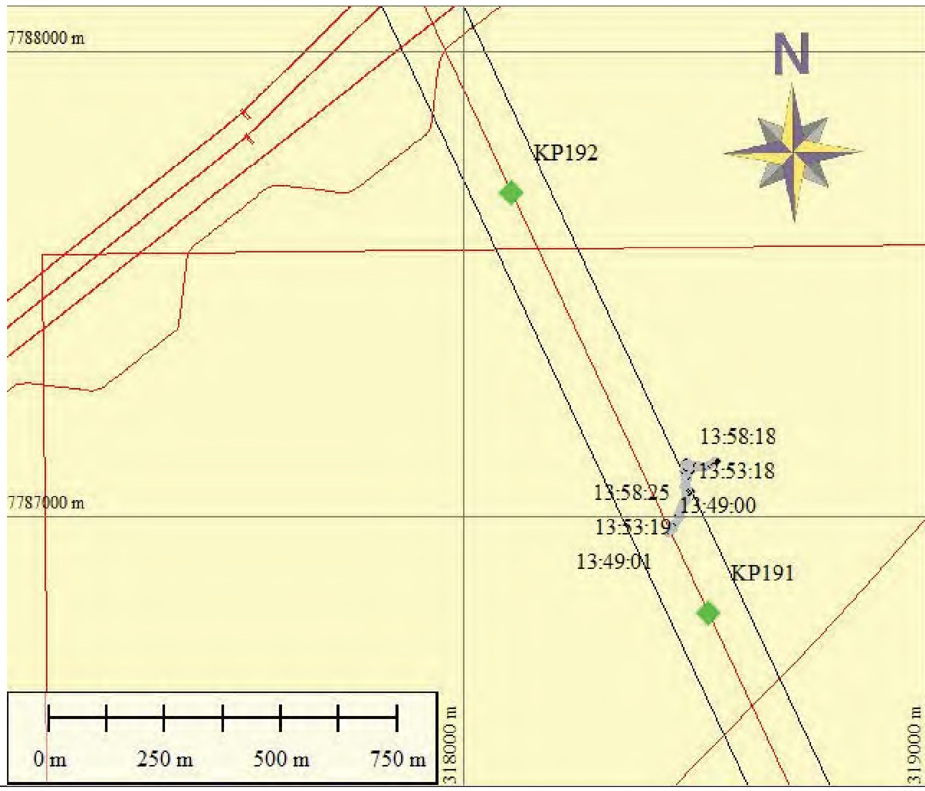
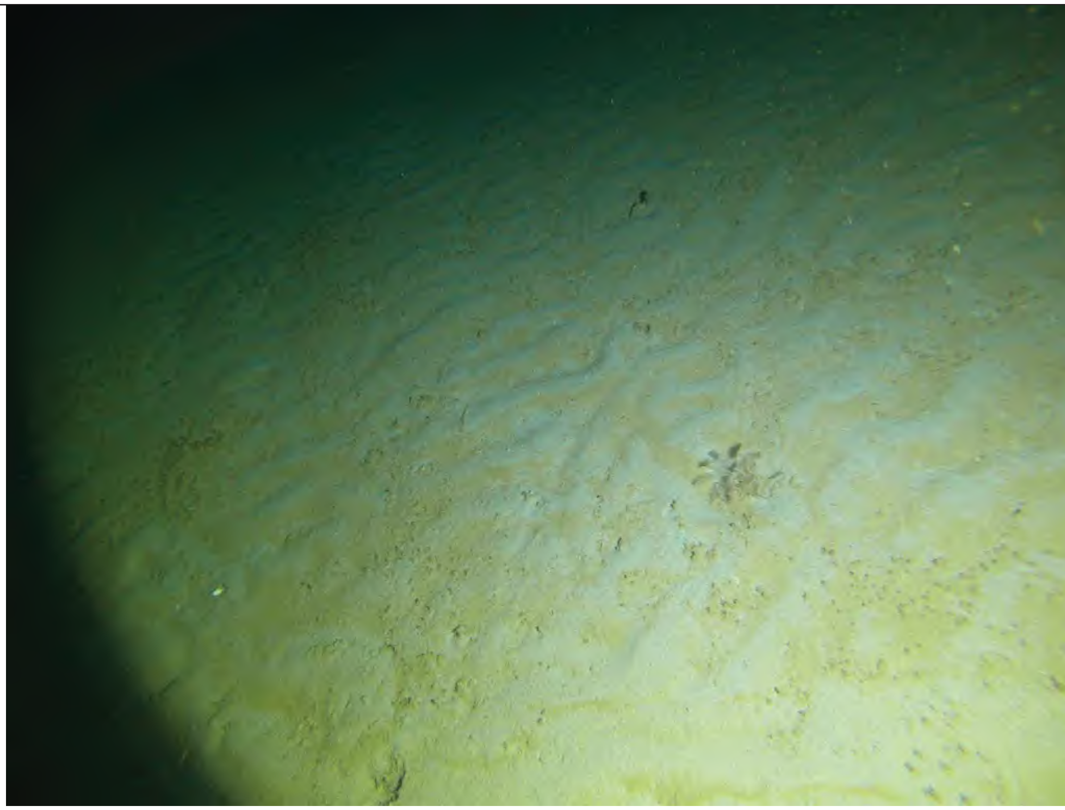
Appendix A: Transect Memos (Neptune)

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 01	Date: 31/01/2019	Phase: Environmental	Area of Ops: Area 1A (KP191.5)	Rev.1
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 1A				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: Proposed pipeline route in the vicinity of KP191.195, in the area of the AMP. The ROV transect crosses the PL route at E318445, N7786967 (time stamp 13:49:11). ROV on bottom at 13:49, off bottom at 14:03.				

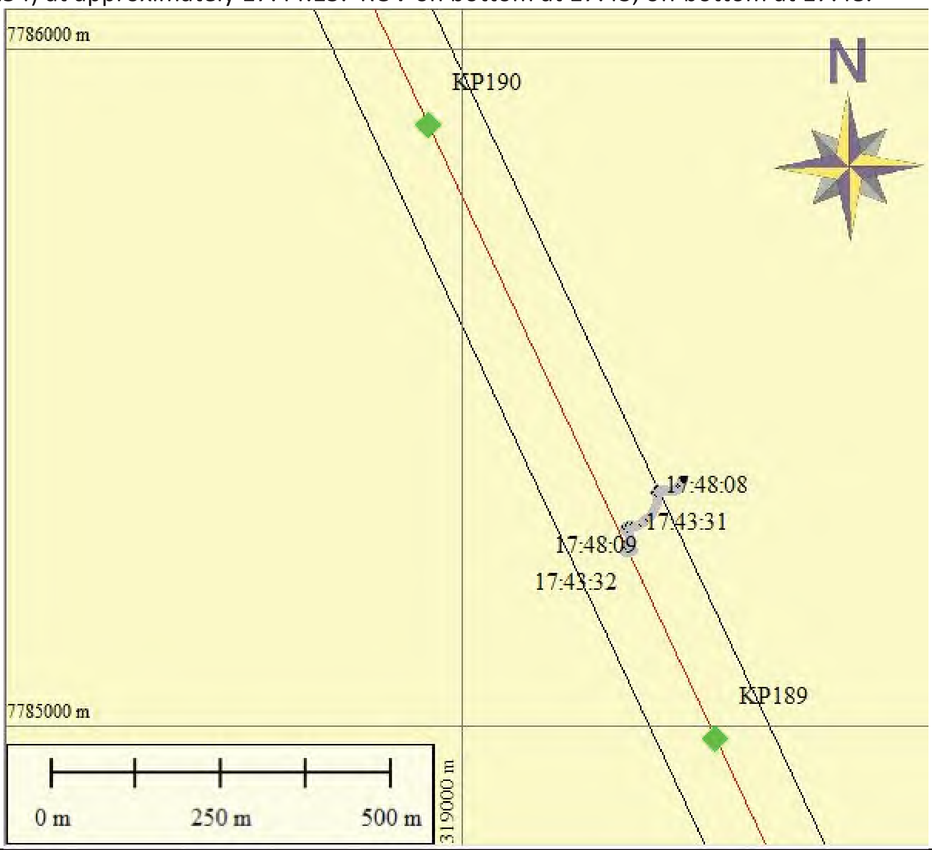


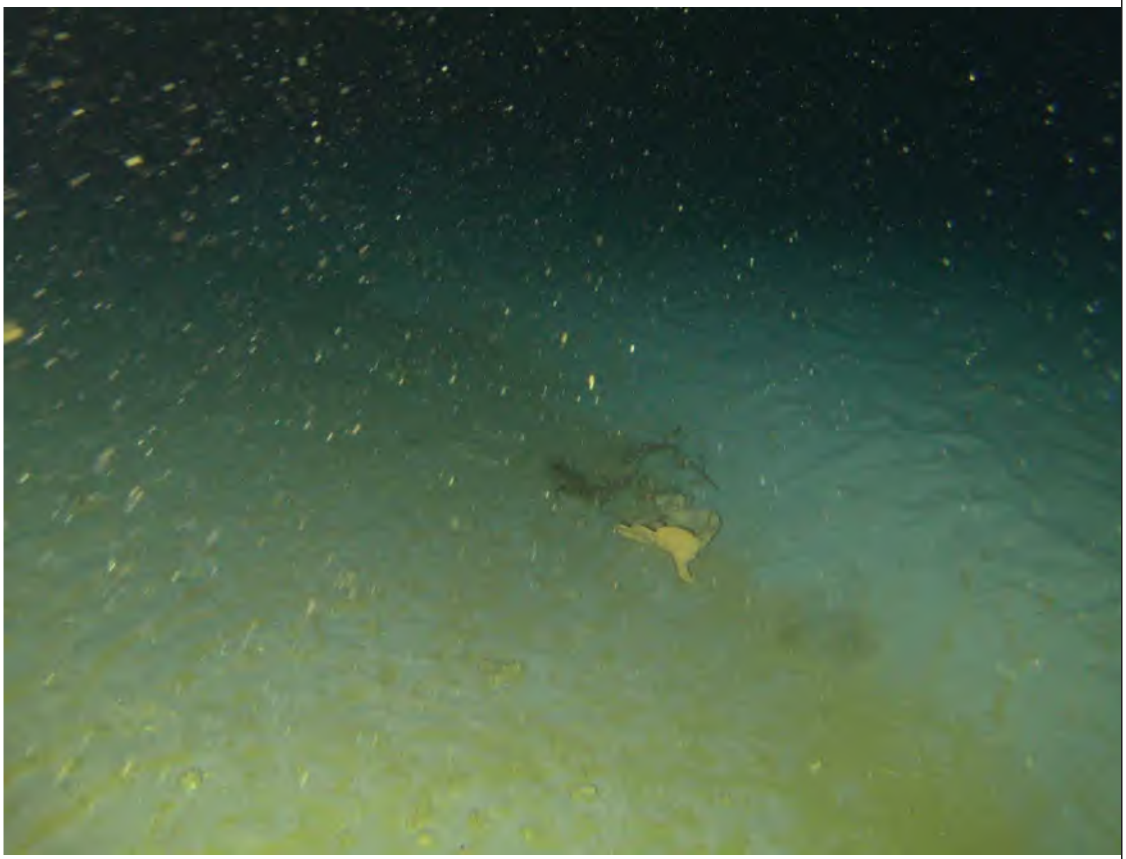
Description:
A flat rippled fine sandy seabed with small isolated sandwaves. Ripples have an organic/algae? covering particularly in the troughs. Isolated soft corals also occur on the sand.



Conclusions and recommendations: Seabed comprise a flat sandy seabed which has a sparse benthic sand-dwelling habitat. No significant high relief habitat features were observed. Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 02	Date: 31/01/2019	Phase: Environmental	Area of Ops: Area 1B (KP189.5)	Rev.1
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 1B				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP189.308 (E 319248, N7785254) at approximately 17:44:15. ROV on bottom at 17:43, off bottom at 17:48. 				
Description: A typically flat fine sandy seabed which has ripples and larger sandwaves associated with it. Ripples have an organic/algae? covering particularly in the troughs. The small sandwave crests (probably less than 0.5m high) are cleaner and can be seen to prograde over the sediments burying isolated benthic fauna which typically occurs as soft corals and sponges				



Conclusions and recommendations:
Seabed comprise a flat sandy seabed which has a sparse benthic sand-dwelling habitat. No significant high relief habitat features were observed.

Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Author: Ian Wright	Client Approval: Mike Varsanyi

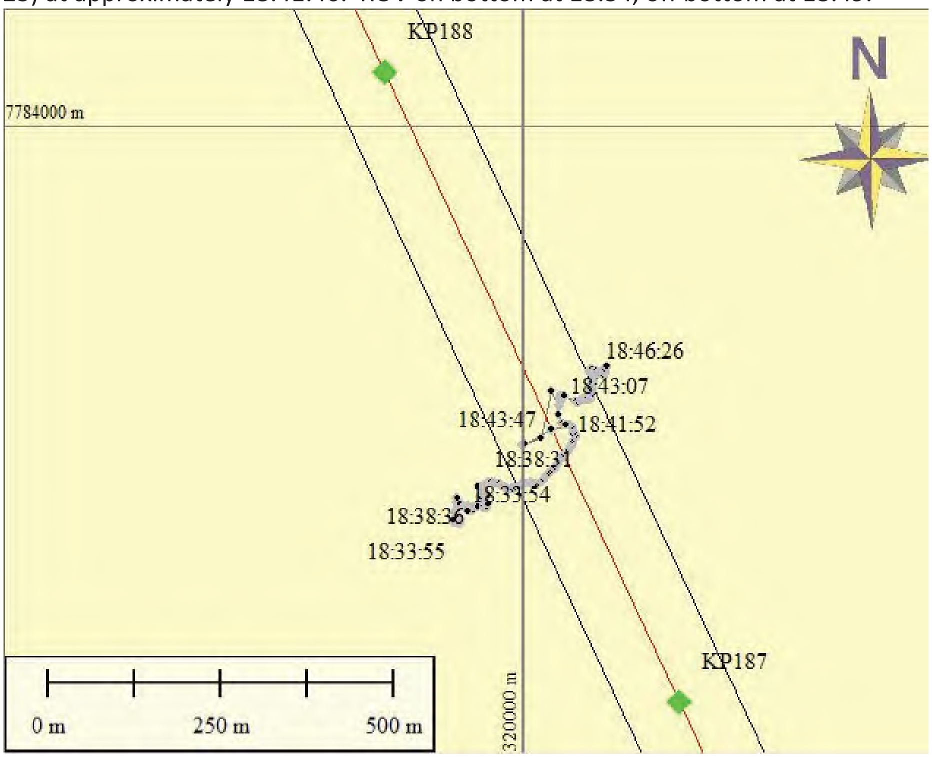
SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 03	Date: 31/01/2019	Phase: Environmental	Area of Ops: Area 1C (KP187.5)	Rev.1

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 1C

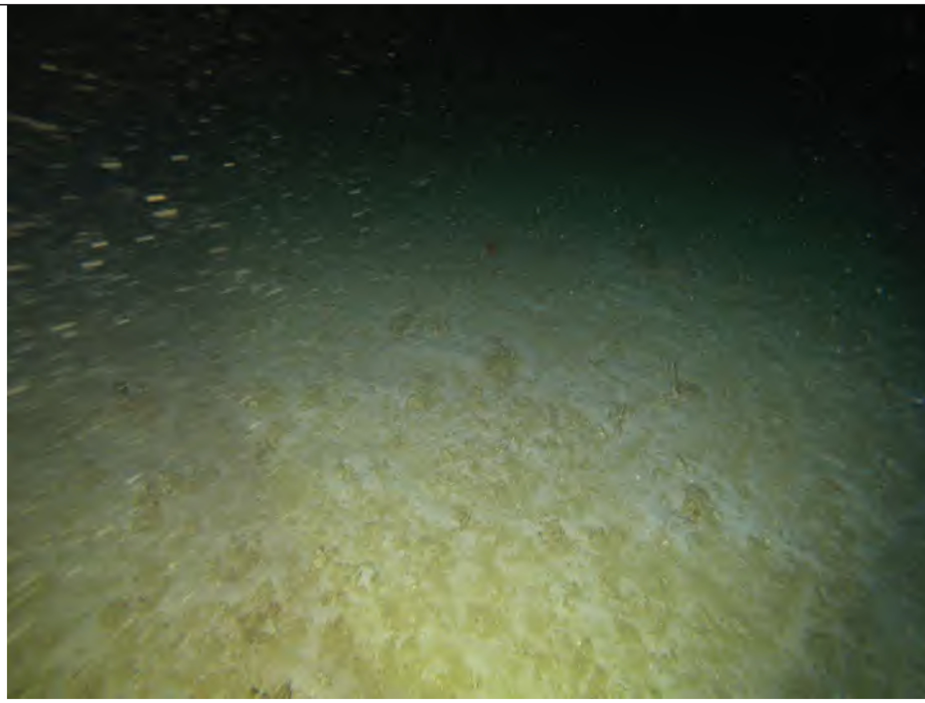
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

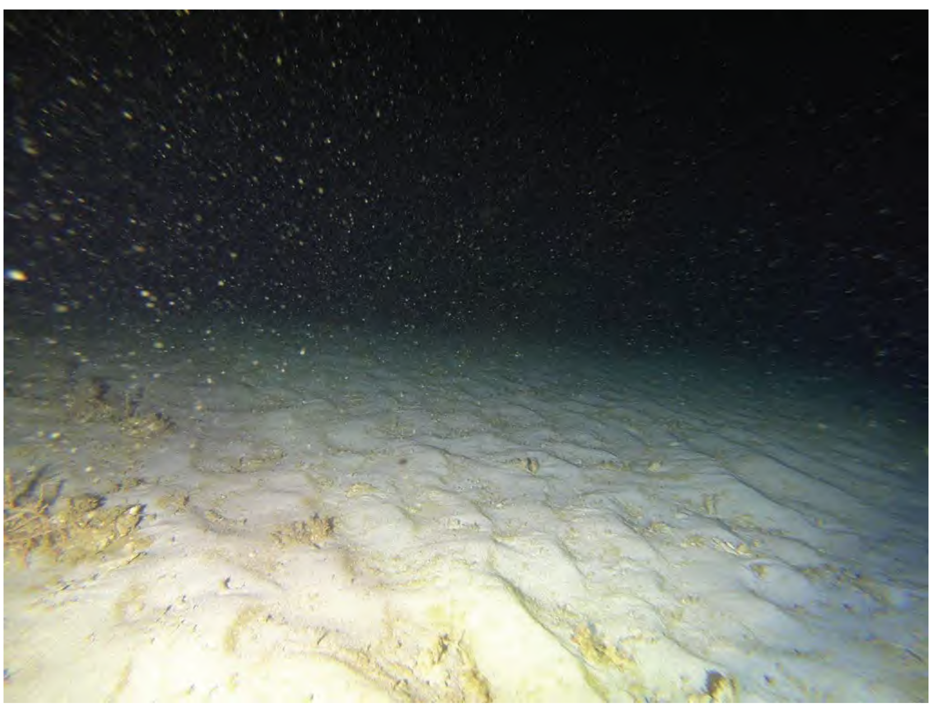
Location: ROV crosses the proposed pipeline route in the vicinity of KP187.392 (E320057, N7783523) at approximately 18:41:46. ROV on bottom at 18:34, off bottom at 18:49.



Description: The south western margin of the track shows the seabed is flat comprising sand and larger gravel to small boulder sized carbonate debris which may be a localised hardpan formed from biological activity or sub-outcropping calcarenite.

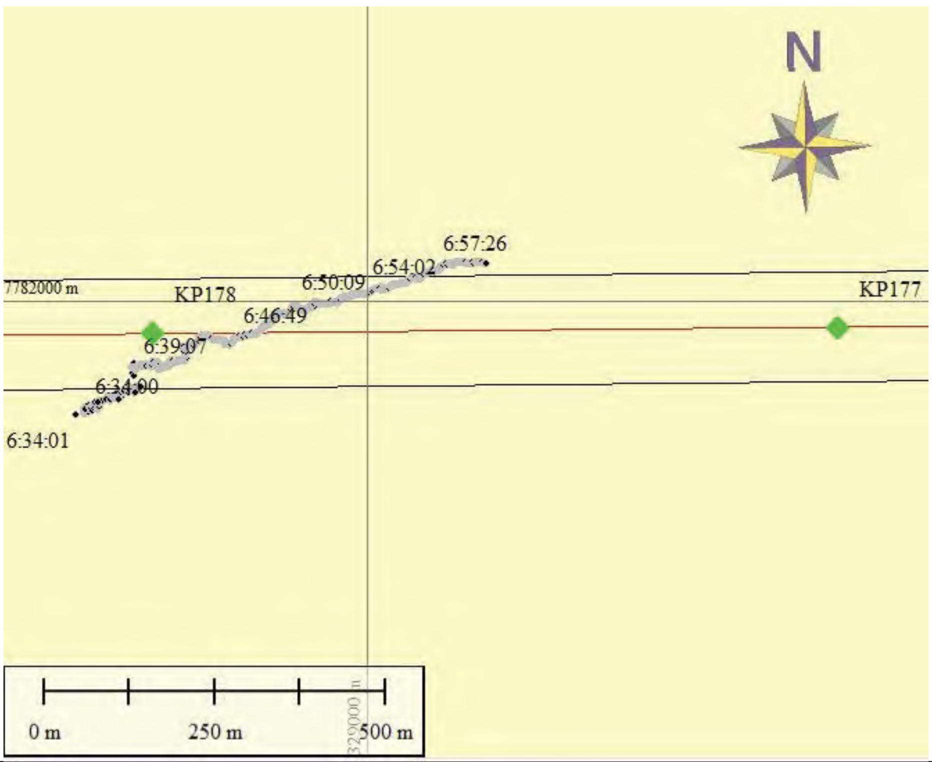


In the vicinity of the PL route (KP187.392, E320057, N7783520) the seabed is typically flat and has ripples associated with it. These typically have an organic/algae? covering particularly in the troughs. Isolated soft corals also occur.

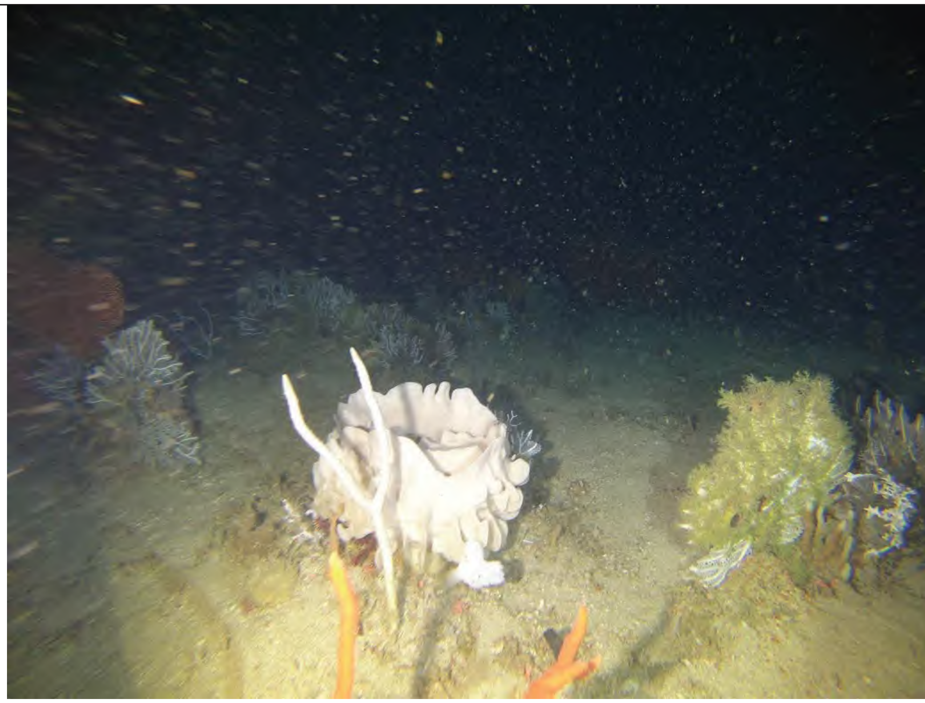


Conclusions and recommendations: Seabed comprise a flat sandy seabed which has a sparse benthic habitat. No significant habitat features were observed. Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 04	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 2A (KP178)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 2A				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP177.8 (E328839, N7781947) at approximately 06:48:04. ROV on bottom at 06:34, off bottom at 06:59.				

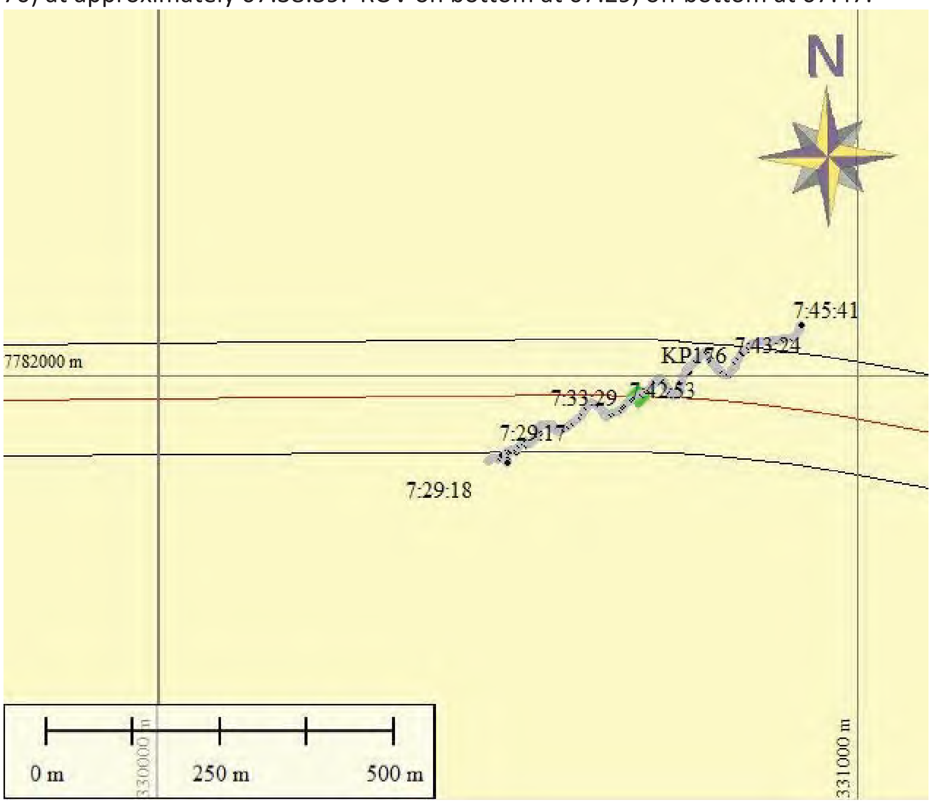


Description: The seabed is flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes prolific soft corals, including large gorgonians and sponges				



Conclusions and recommendations: Seabed comprise a flat predominantly sandy seabed which has a considerable benthic habitat in the form of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 05	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 2B (KP176)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 2B				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP175.95 (E330686, N7781970) at approximately 07:38:39. ROV on bottom at 07:29, off bottom at 07:47.				
Description: The seabed is flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes soft corals, including large gorgonians and sponges				



Conclusions and recommendations:	
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

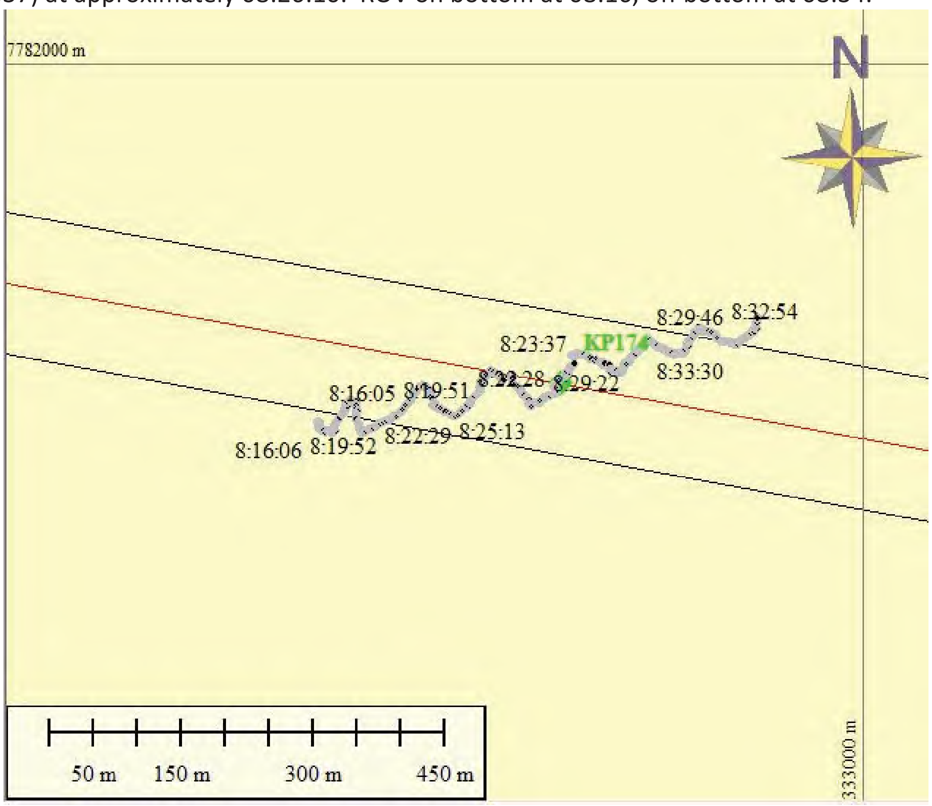
Technical Memo: No. 06	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 2C (KP174)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 2C

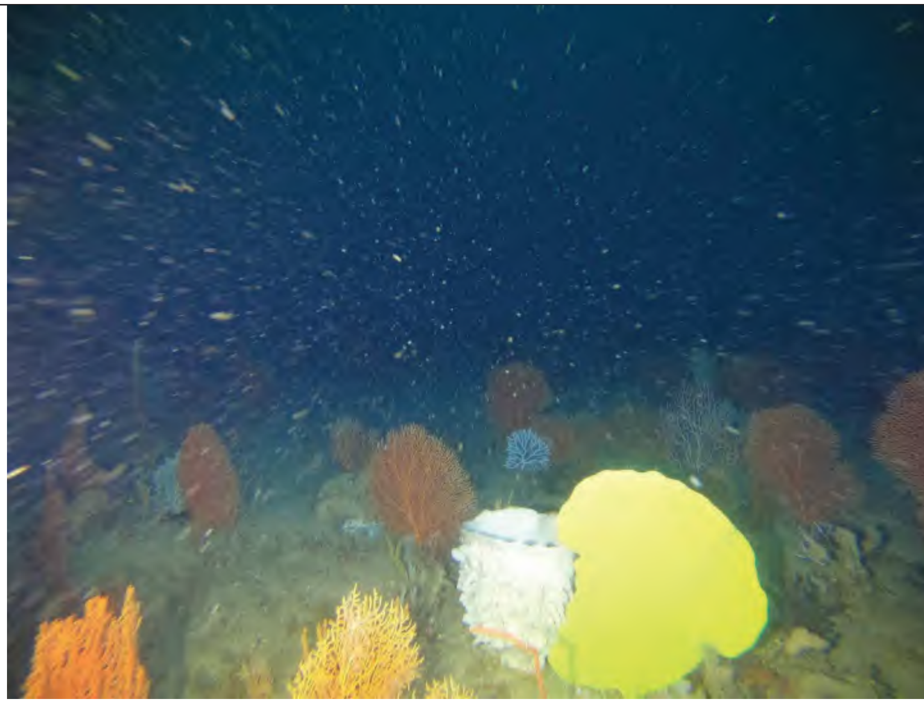
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP173.95 (E332653, N7781637) at approximately 08:26:10. ROV on bottom at 08:16, off bottom at 08:34.



Description: The seabed is flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes areas of soft corals, including large gorgonians and sponges.



Conclusions and recommendations: Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of areas of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

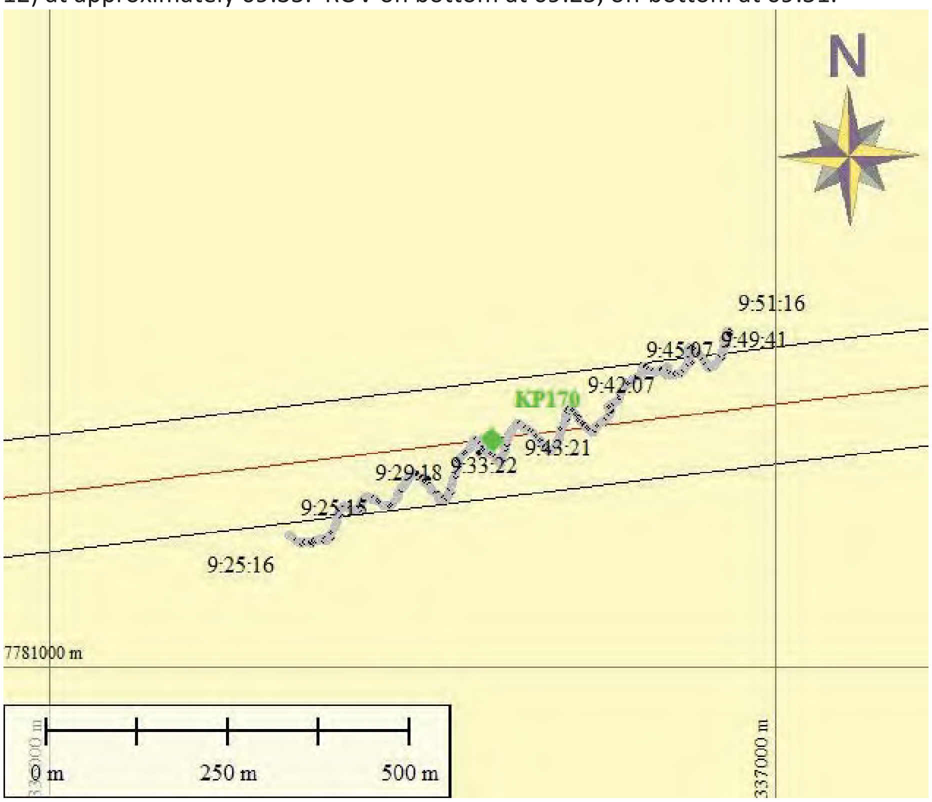
Technical Memo: No. 07	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 3A (KP170)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 3A

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP169.05 (E336608, N7781312) at approximately 09:35. ROV on bottom at 09:25, off bottom at 09:51.



Description: The seabed is typically flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

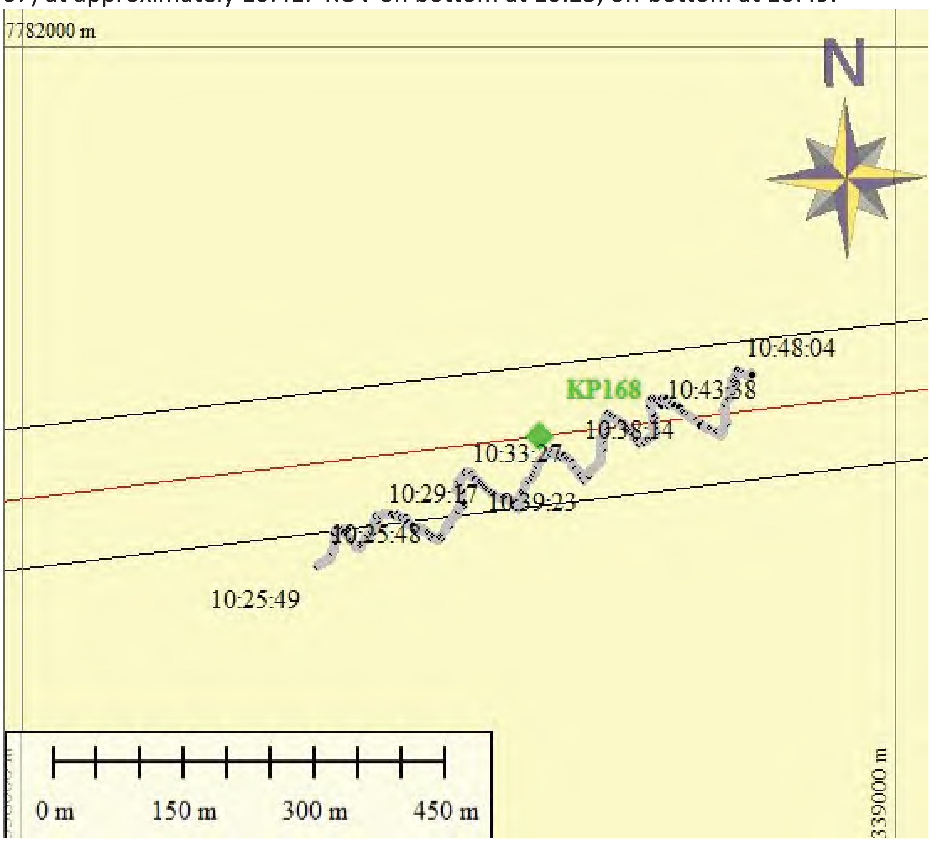
Technical Memo: No. 08	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 3B (KP168)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 3B

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP167.88 (E338667, N7781567) at approximately 10:41. ROV on bottom at 10:25, off bottom at 10:49.



Description: The seabed is typically flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes areas of soft corals, including large gorgonians and sponges.

Conclusions and recommendations: Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of areas of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

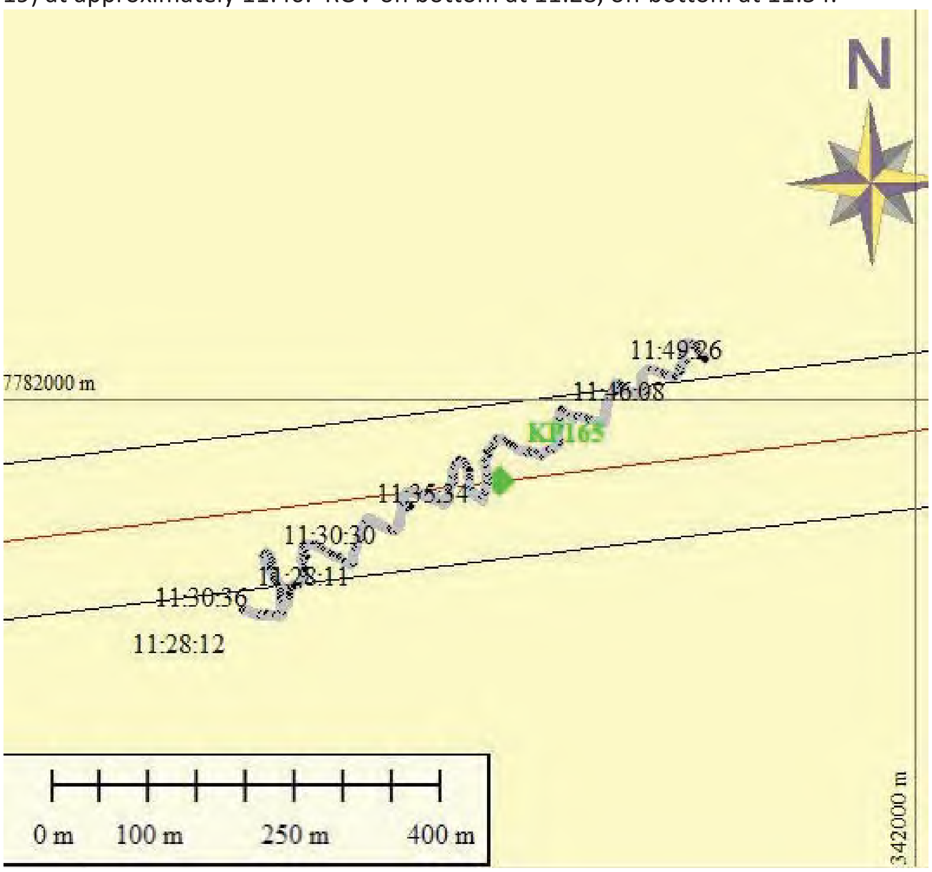
Technical Memo:	Date:	Phase:	Area of Ops: Area 3C	Rev.0
No. 09	01/02/2019	Environmental	(KP165)	

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 3C

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP164.95 (E341572, N7781919) at approximately 11:40. ROV on bottom at 11:28, off bottom at 11:54.



Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. Benthic fauna includes sporadic areas of soft corals, including large gorgonians and sponges as well as black ‘whip’ corals. Current scour moats are noted around some of the sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

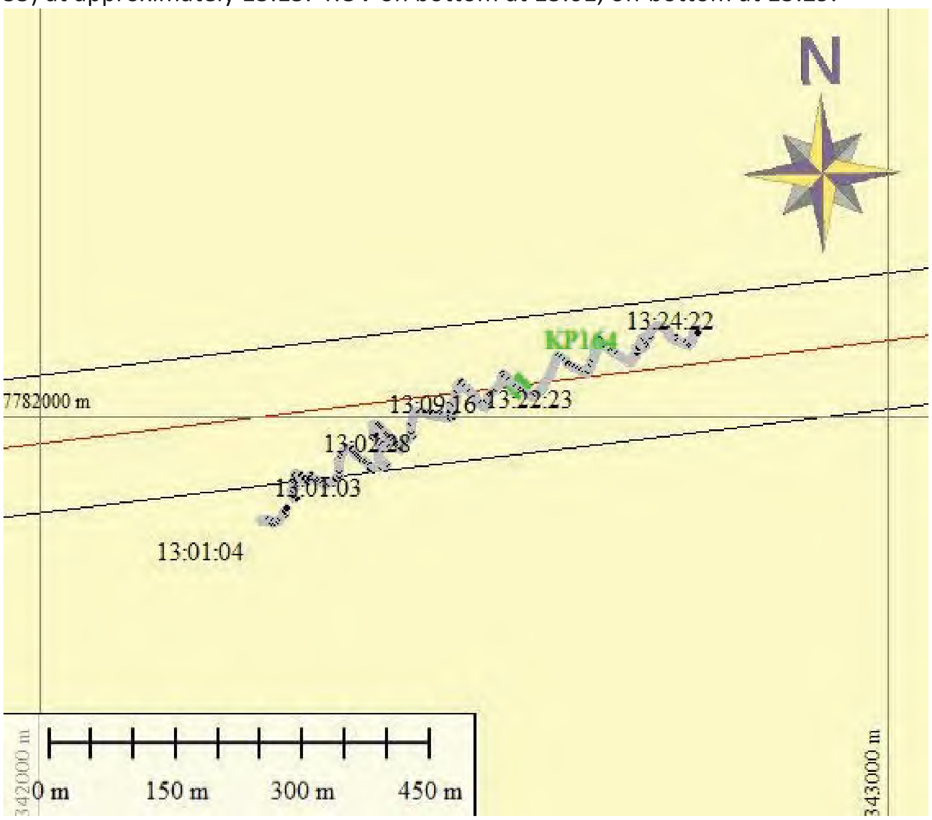
Technical Memo: No. 10	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 4A (KP164)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 4A

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP163.95 (E342566, N7782035) at approximately 13:15. ROV on bottom at 13:01, off bottom at 13:29.

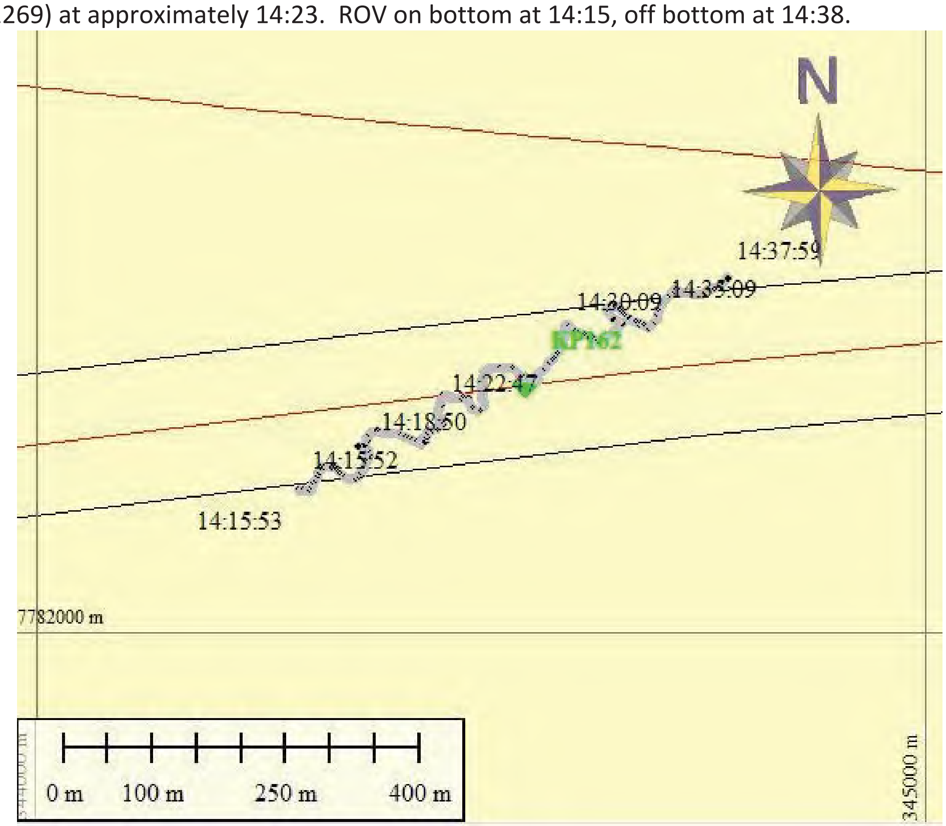


Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. 'Starved' ripples occur and typically have coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats are noted around some of the sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

<table>
<tr><td colspan="5">SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018</td></tr>
<tr><td>Technical Memo: No. 11</td><td>Date: 01/02/2019</td><td>Phase: Environmental</td><td>Area of Ops: Area 4B (KP162)</td><td>Rev.0</td></tr>
<tr><td colspan="5">Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 4B</td></tr>
<tr><td colspan="5">Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office</td></tr>
<tr><td colspan="5">Location: ROV crosses the proposed pipeline route in the vicinity of KP162.00 (E344502, N7782269) at approximately 14:23. ROV on bottom at 14:15, off bottom at 14:38.

</td></tr>
<tr><td colspan="5">Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. ‘Starved’ ripples occur and typically have coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including gorgonians and sponges as well as black ‘whip’ corals. Current scour moats are noted around some of the sponges.</td></tr>
</table>

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

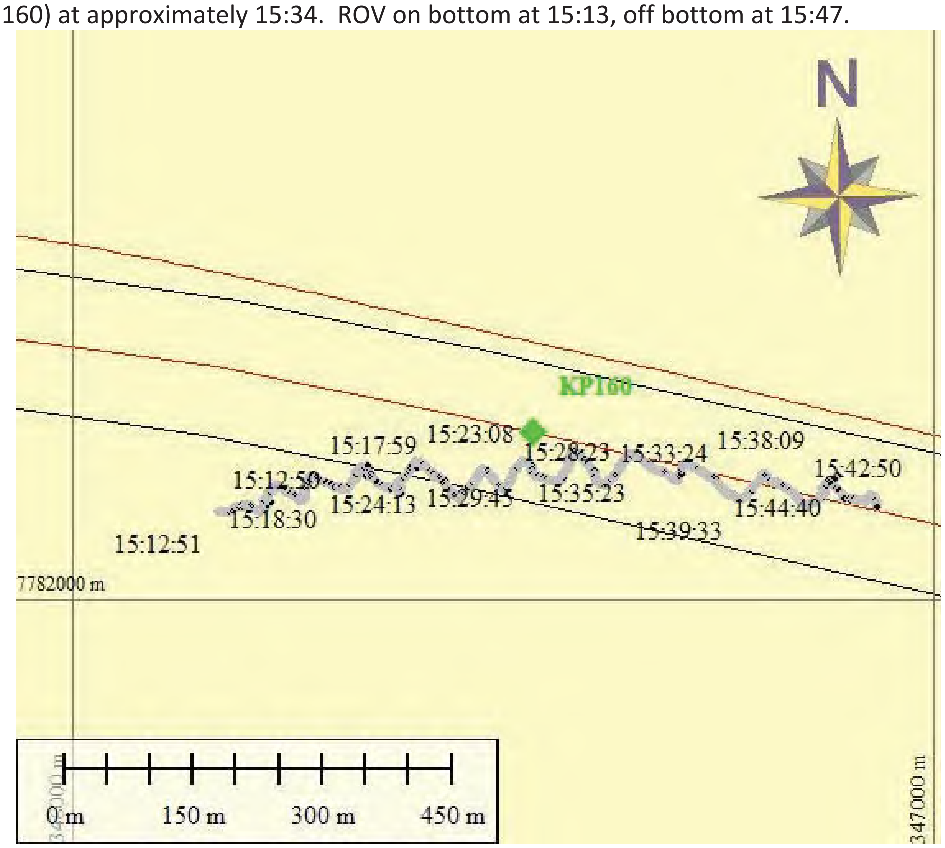
SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 12	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 4C (KP160)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 4C

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP159.83 (E346650, N7782160) at approximately 15:34. ROV on bottom at 15:13, off bottom at 15:47.



Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. ‘Starved’ ripples occur and typically have coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including gorgonians and sponges. Current scour moats are noted around some of the sponges.

Conclusions and recommendations: Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

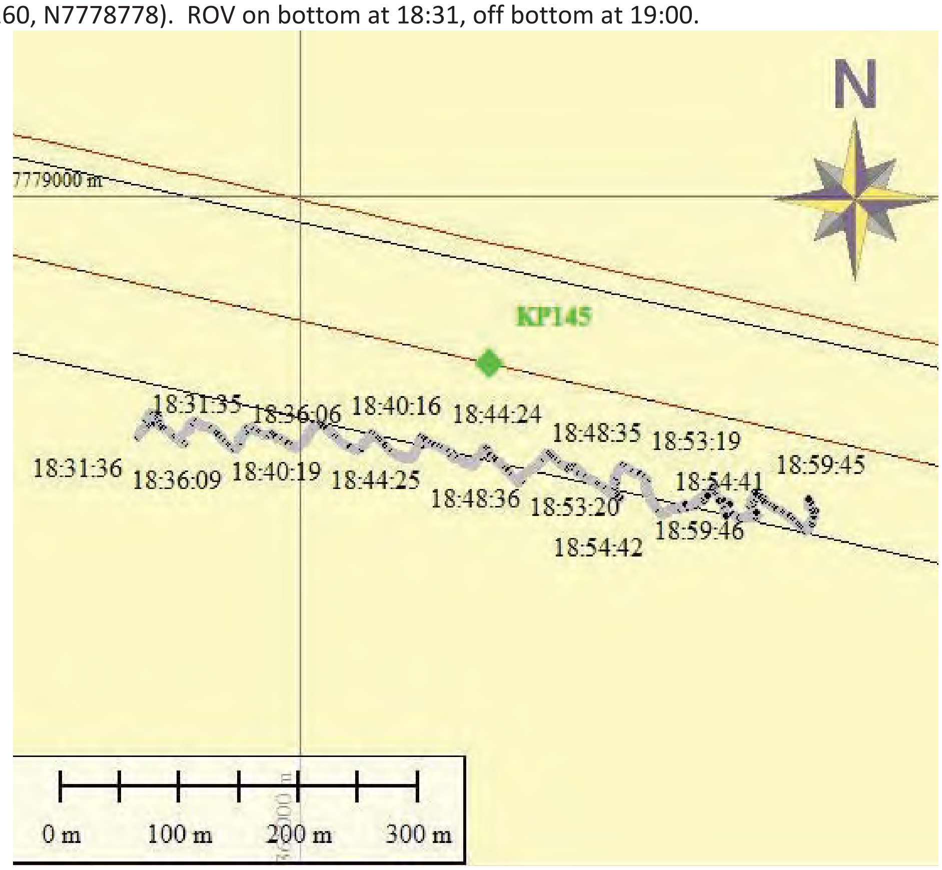
SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 13	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 5A (KP145)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 5A (NO 5B or C)

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV surveyed south of the proposed pipeline route in the vicinity of KP144.93 (E361160, N7778778). ROV on bottom at 18:31, off bottom at 19:00.



Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. Where flat, the seabed has an algae cover. Where undulating, the seabed is characterised by starved ripples and scour moats, typically around sponges. Benthic fauna includes sporadic areas of soft corals, including gorgonians and sponges.

Conclusions and recommendations:

Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route.

Author: Ian Wright	Client Approval: Mike Varsanyi

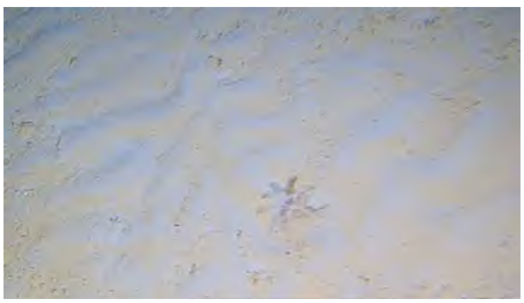
Appendix B: Additional Images Area 1

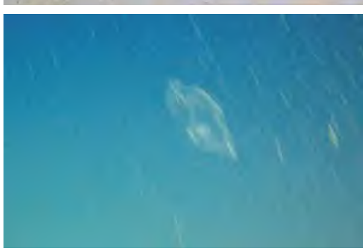
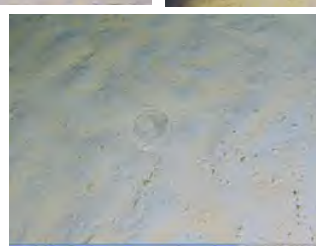
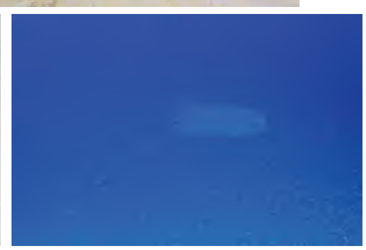
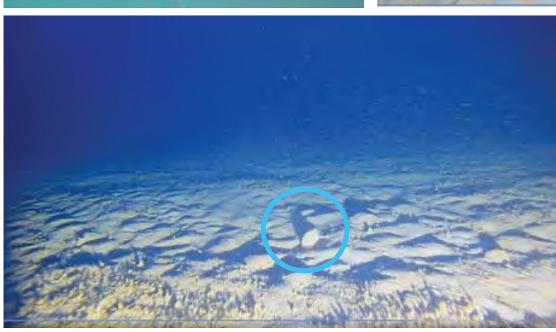
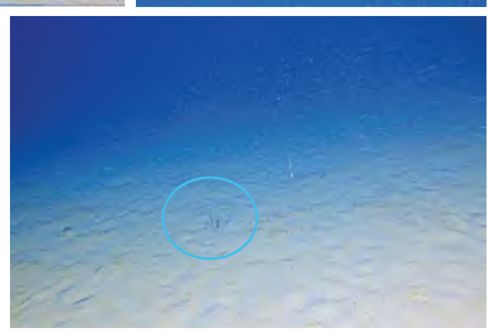
Transect Images – Area 1

Area 1 – Transect 1a

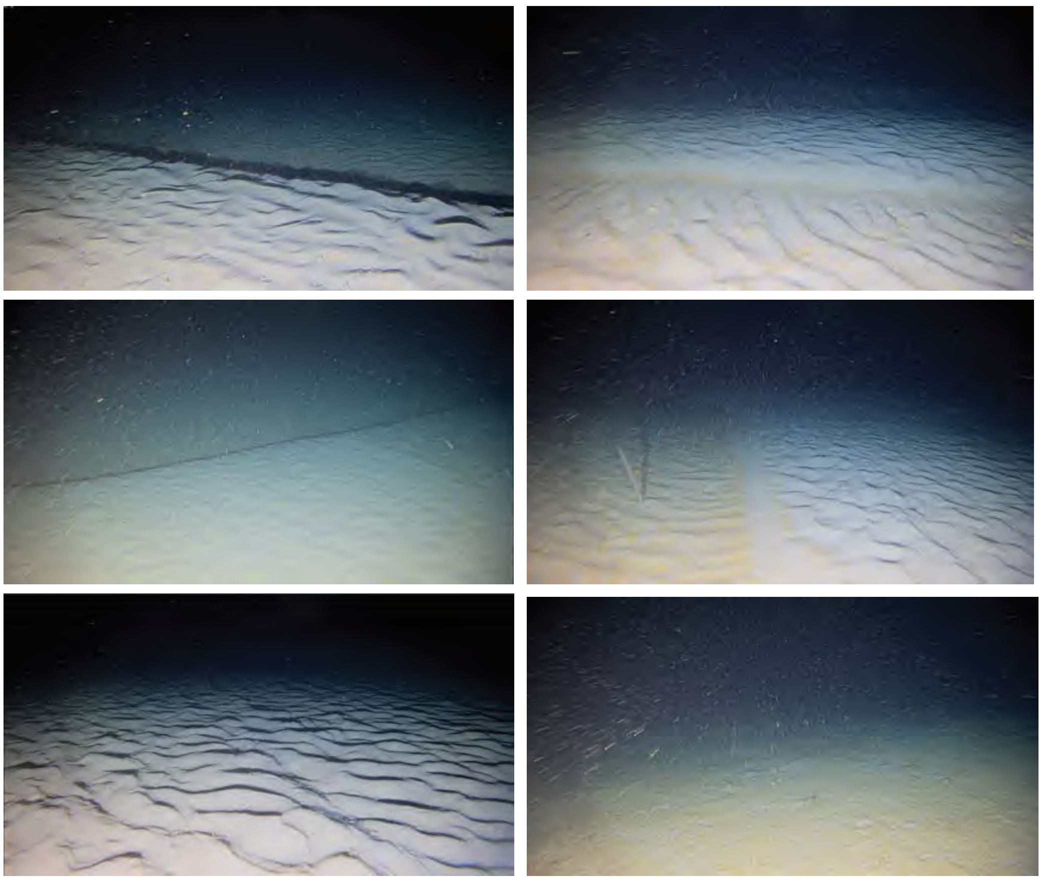



Benthic Organisms – Transect 1a

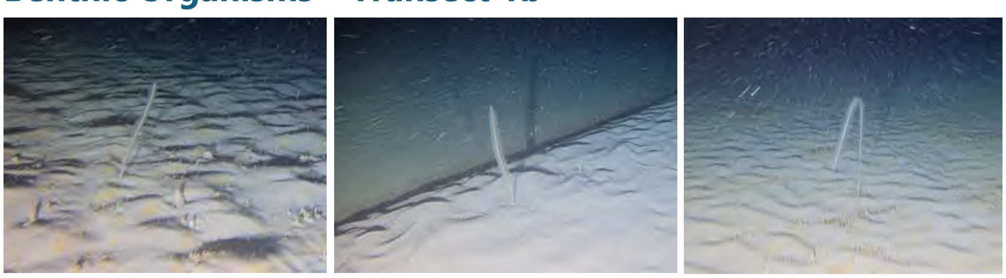


Area 1 – Transect 1b



Benthic Organisms – Transect 1b



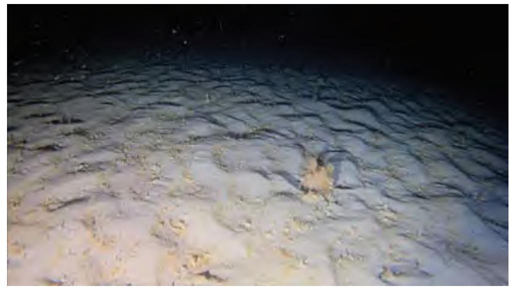
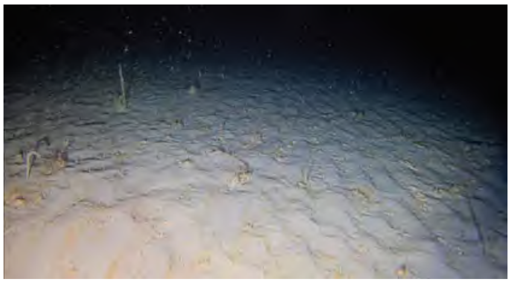
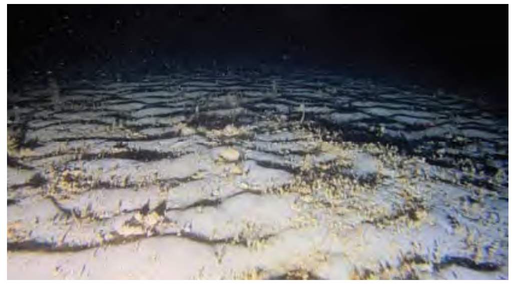
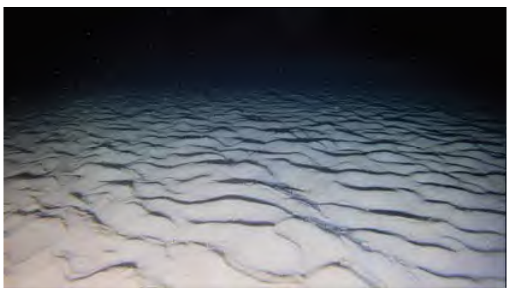




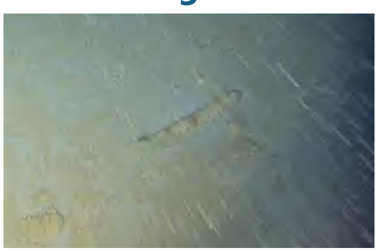

Area 1 – Transect 1c






Benthic Organisms – Transect 1c





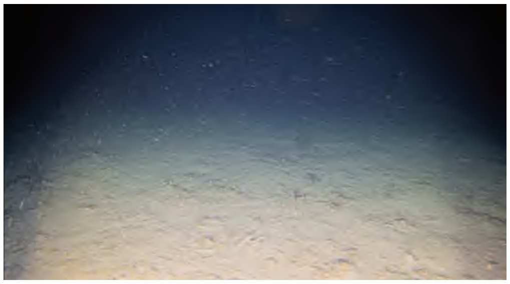
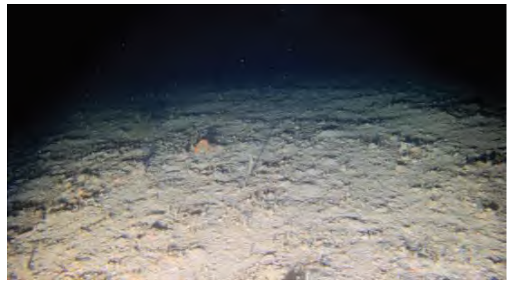
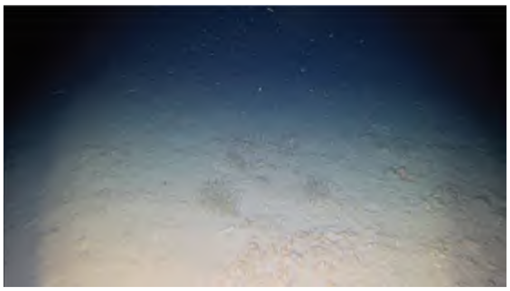
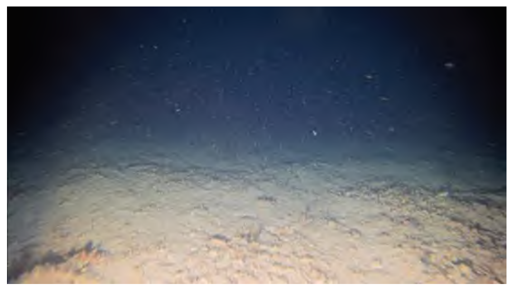


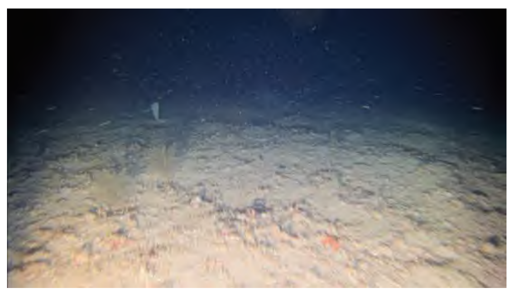
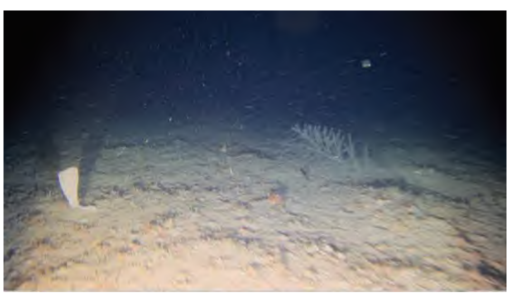


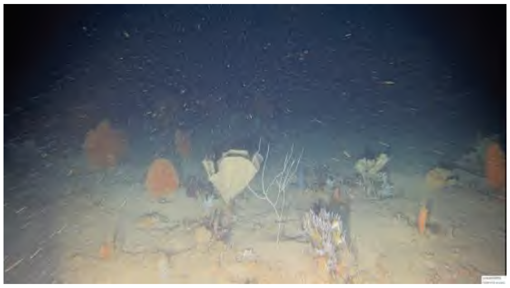
Appendix C: Additional Images Area 2

Transect Images – Area 2

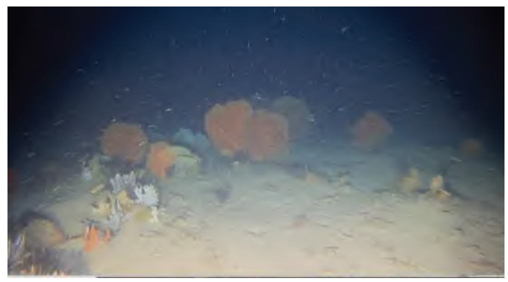
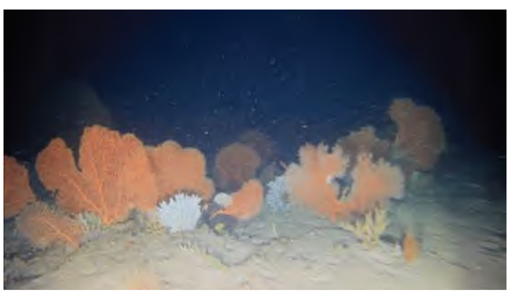
Area 2 – Transect 2a

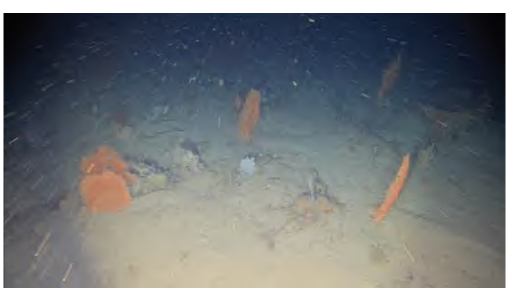
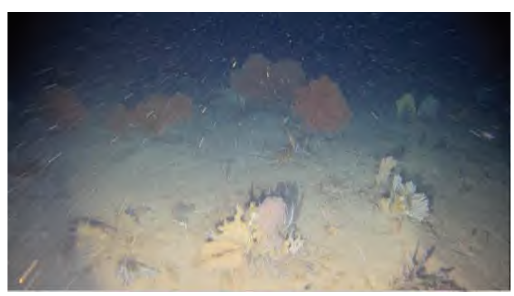





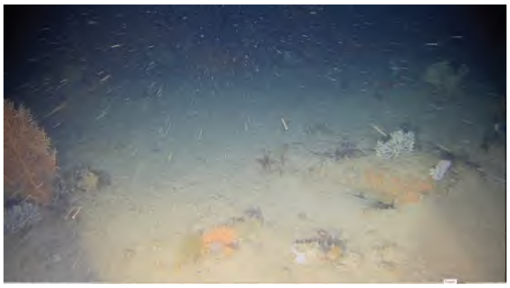
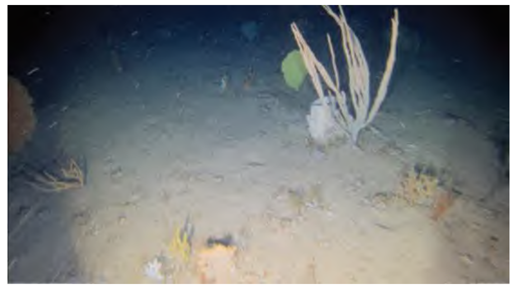







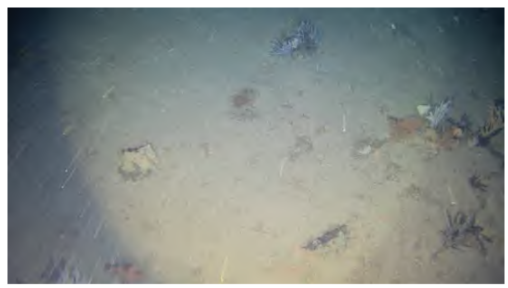
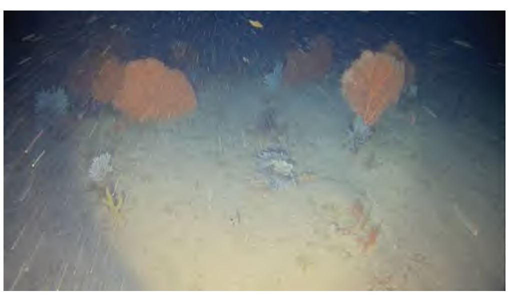
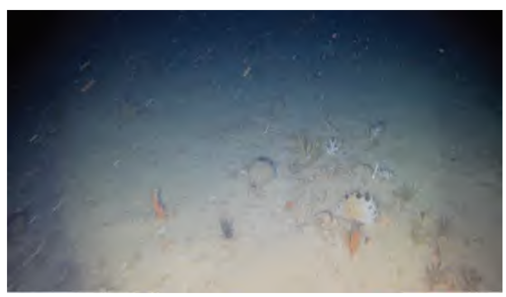
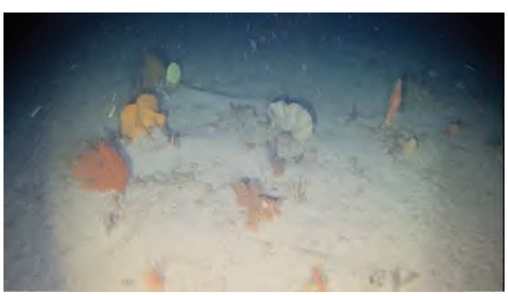





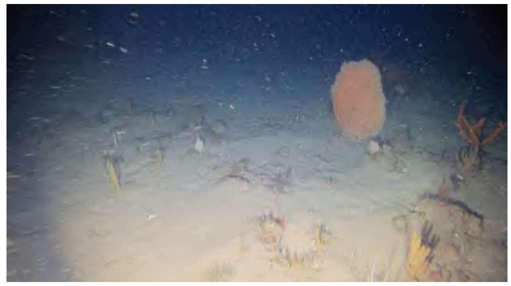
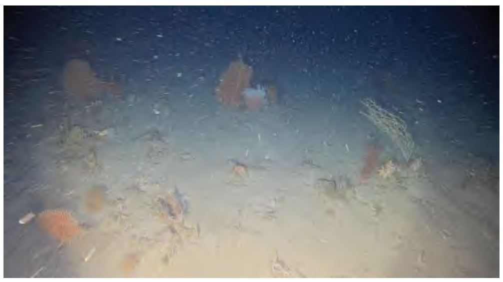







Area 2 – Transect 2b







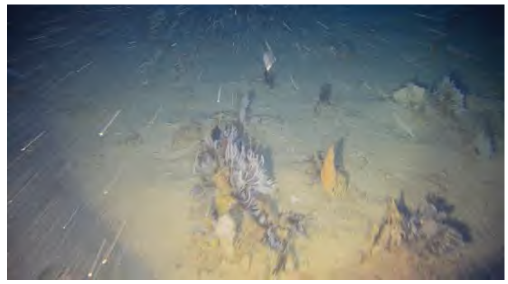


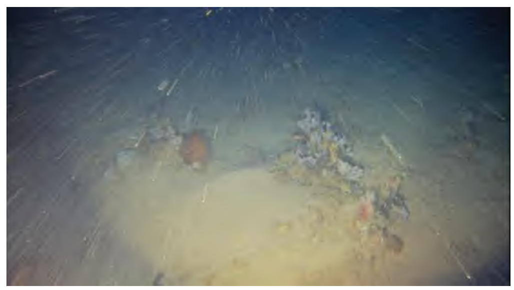
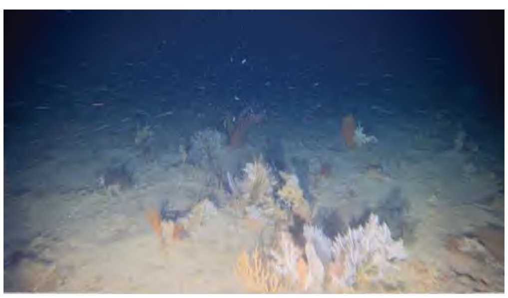
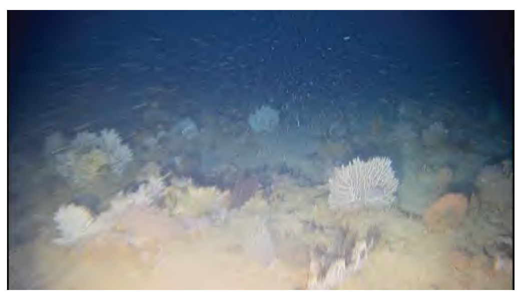
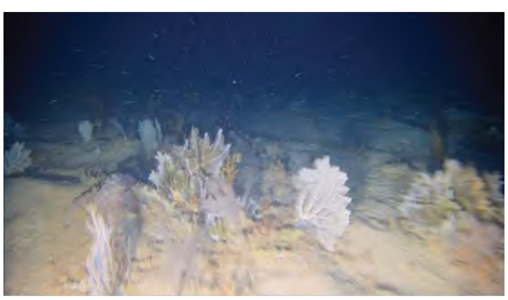
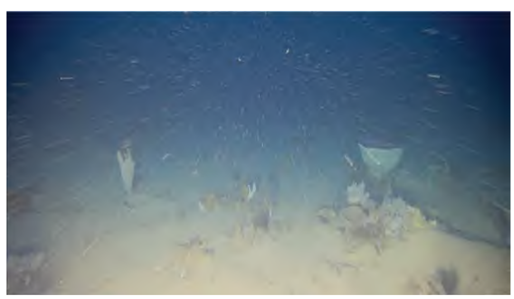


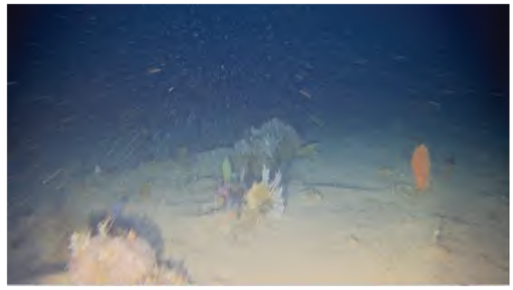
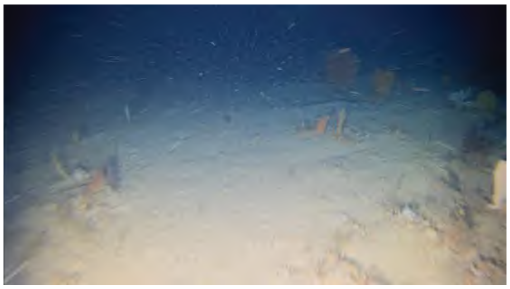






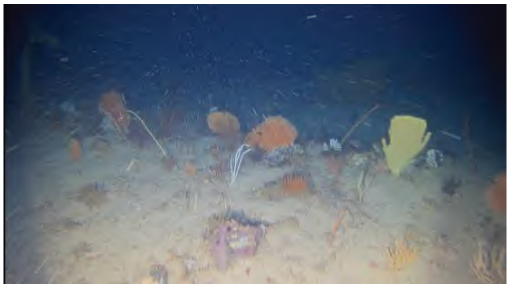



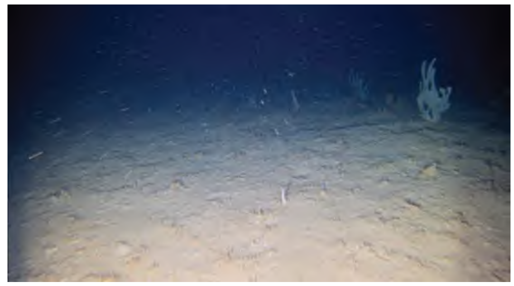
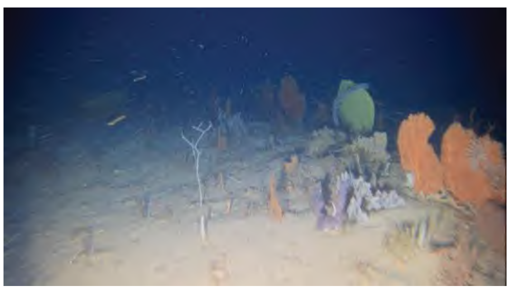
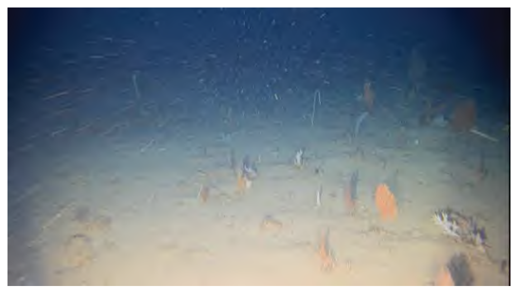
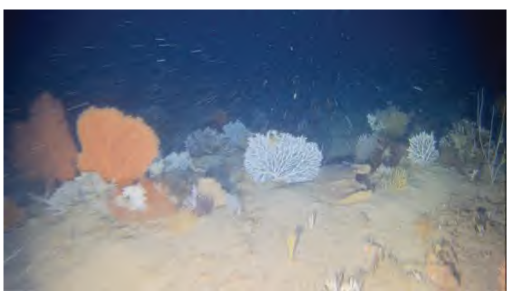
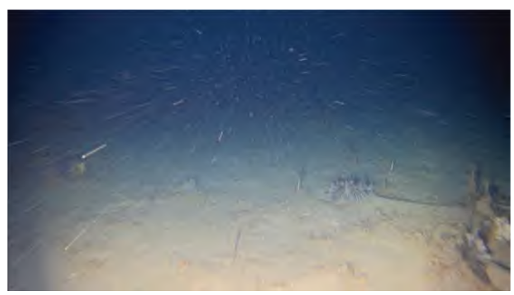
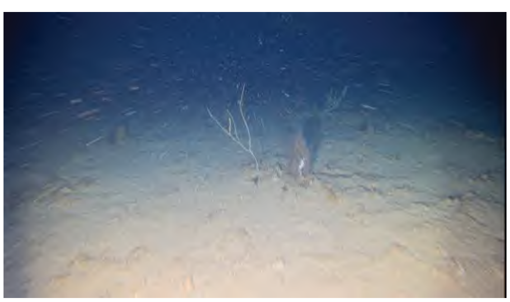






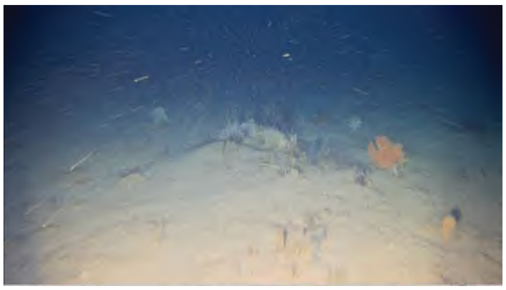

Area 2 – Transect 2c

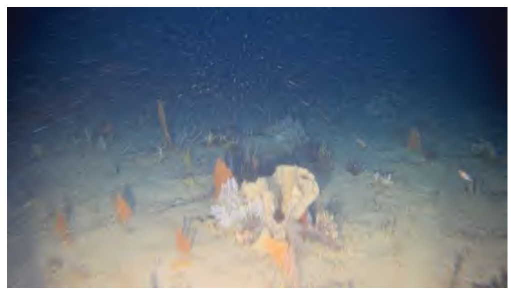
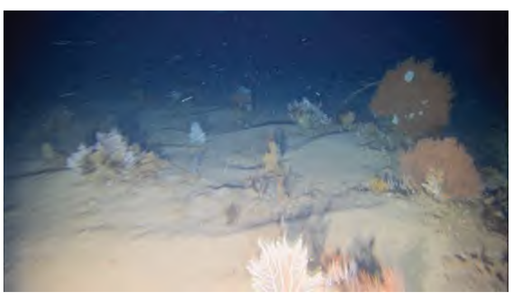


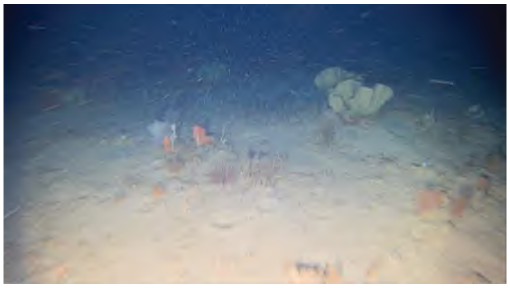
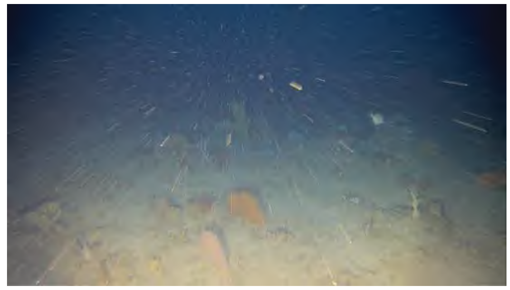



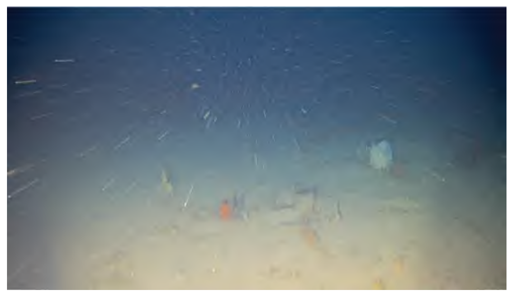


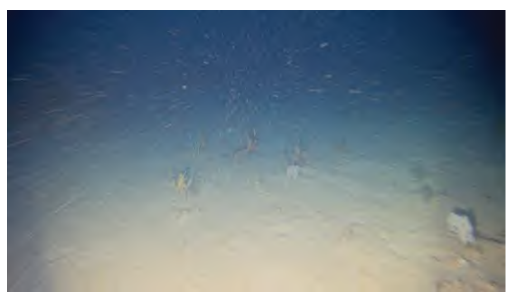



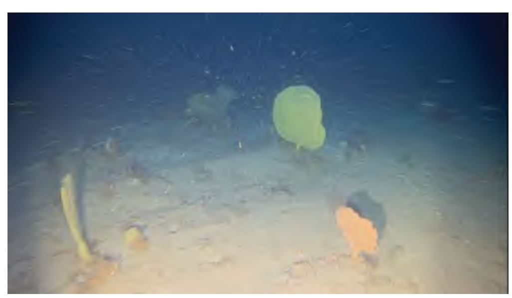






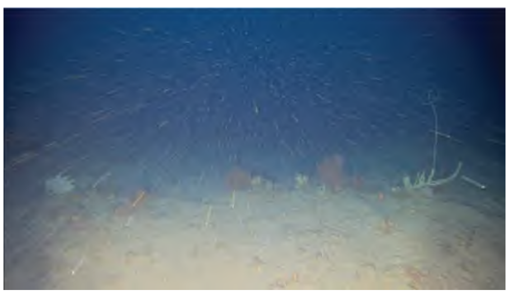
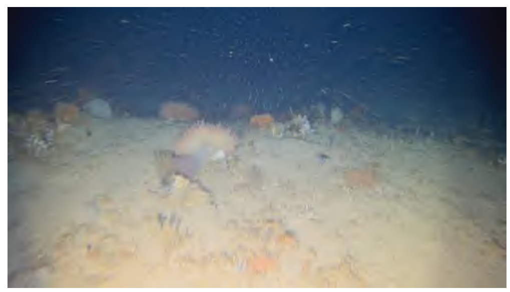


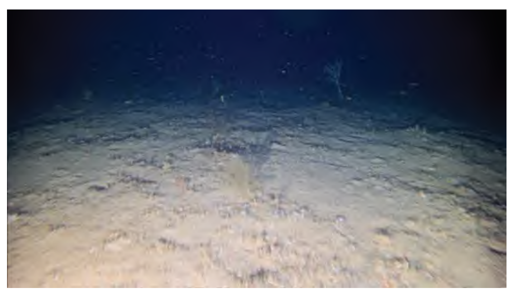
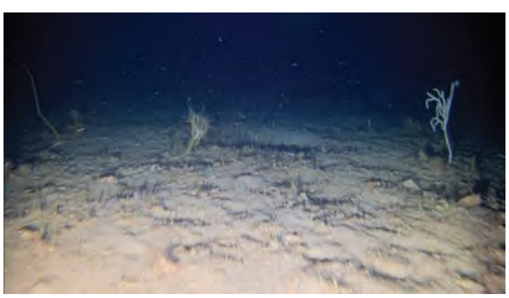
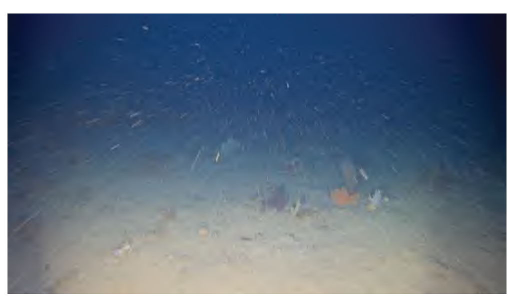








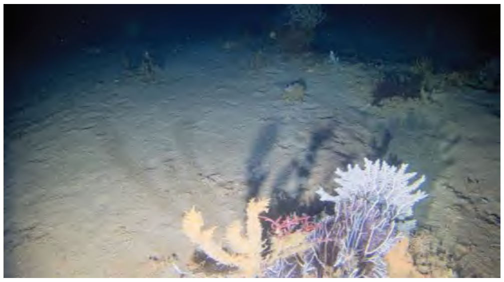




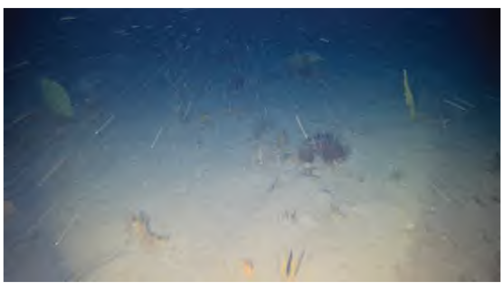

Appendix D: Additional Images Area 3

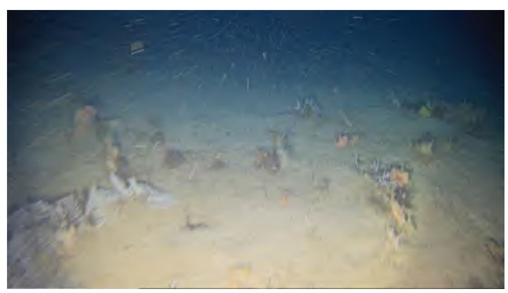
Transect Images – Area 3

Area 3 – Transect 3a

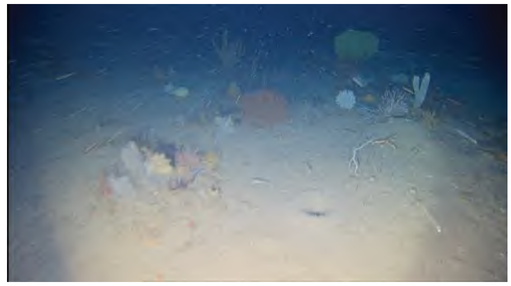


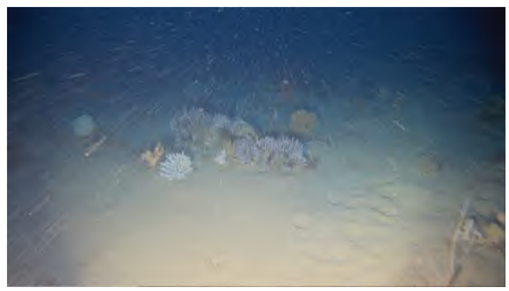
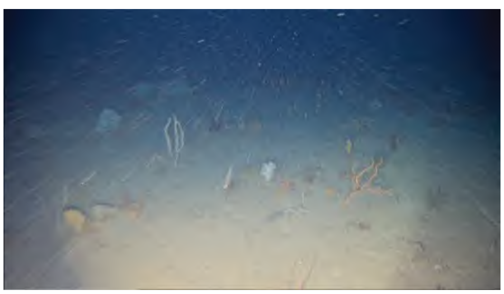




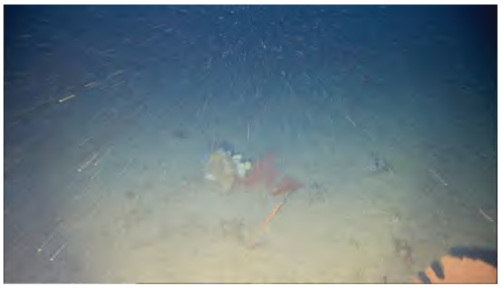


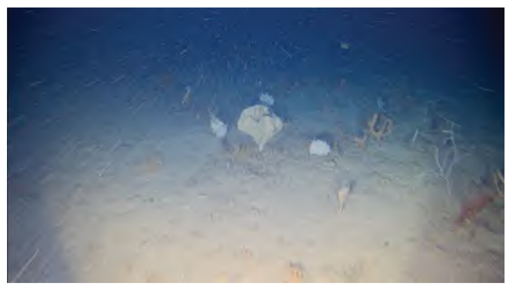



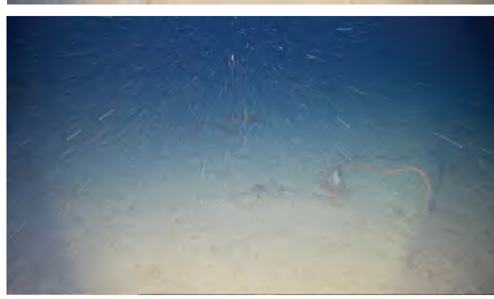




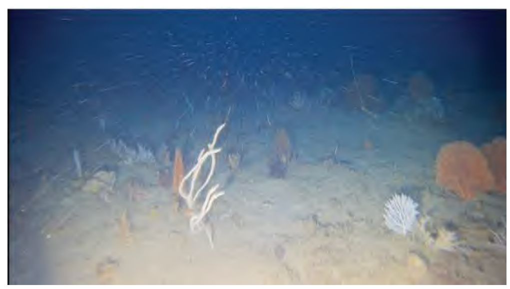
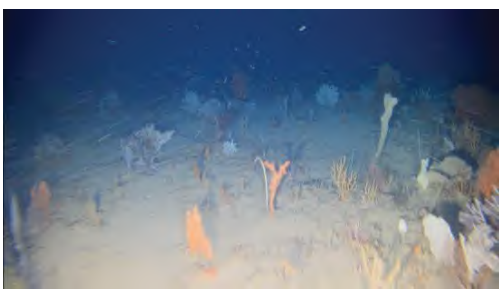



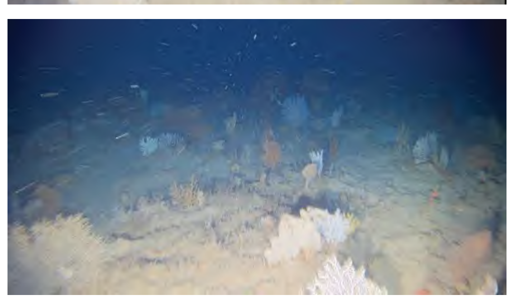


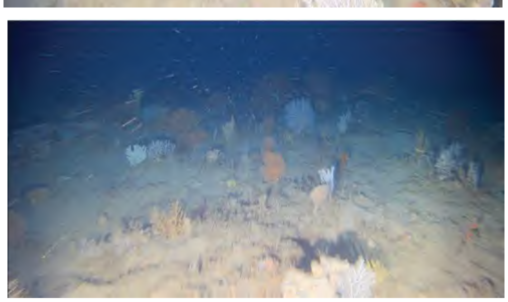


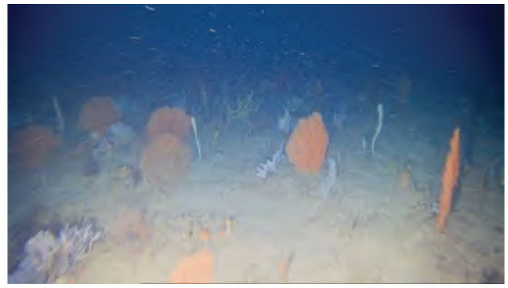
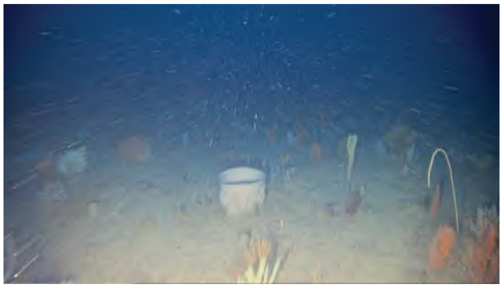


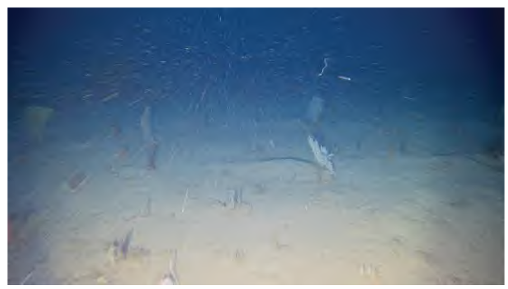
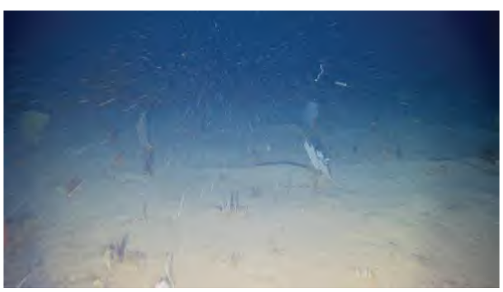


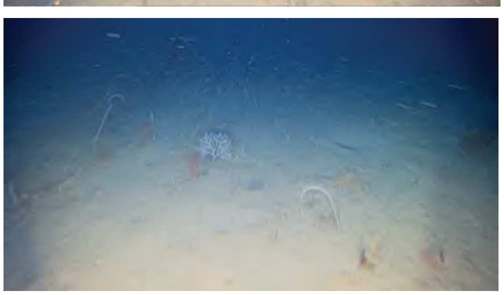





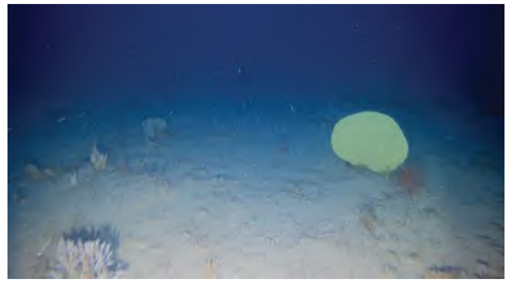
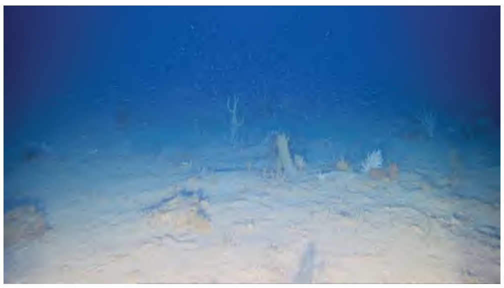




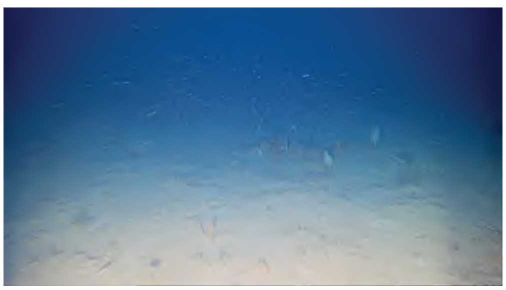




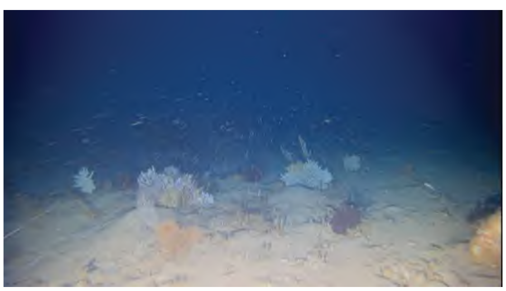


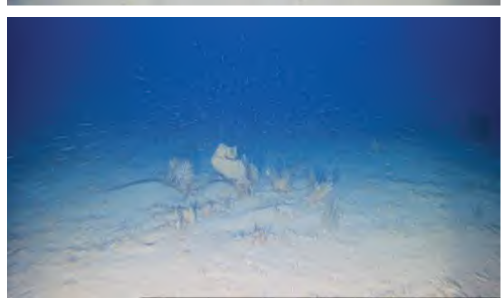



Area 3 – Transect 3b

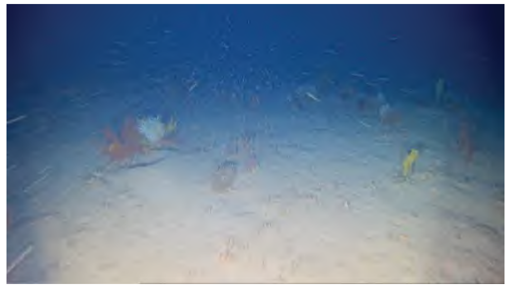
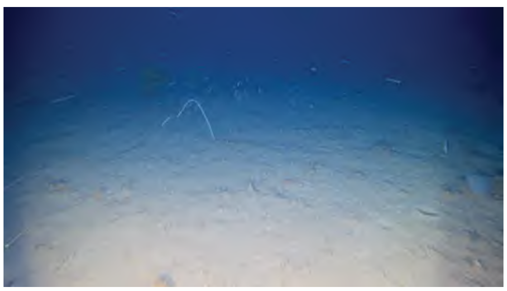




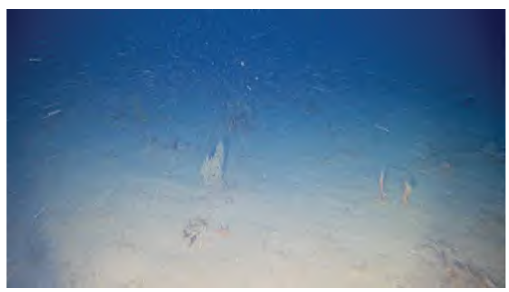
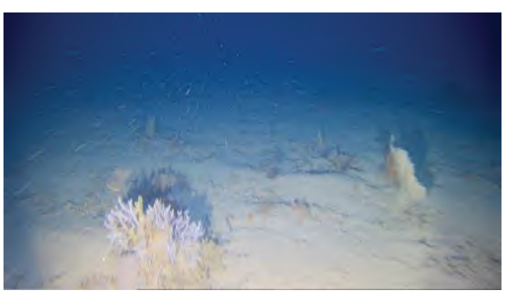


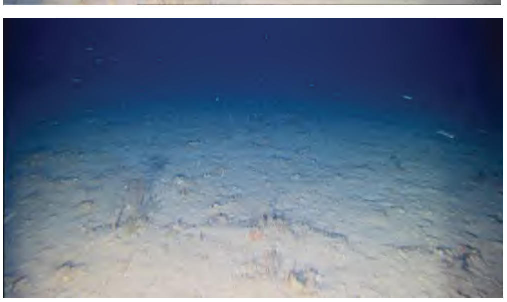




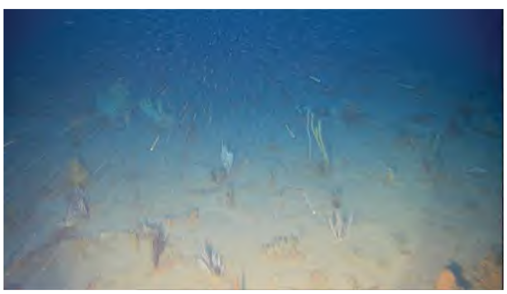




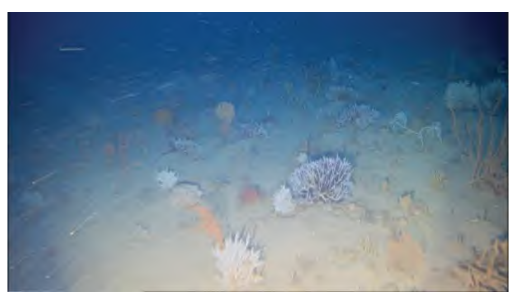


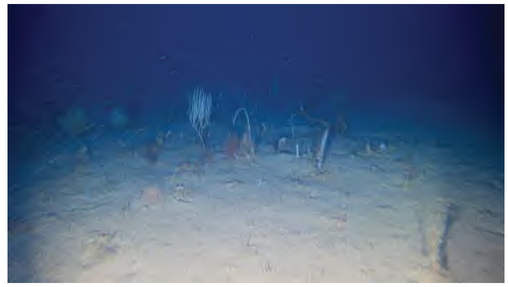
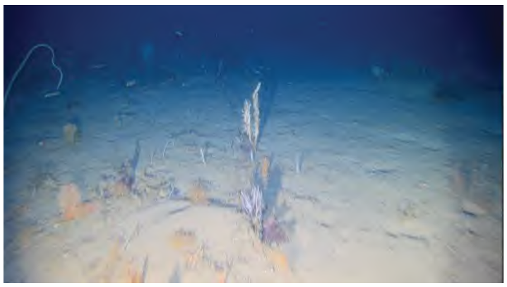






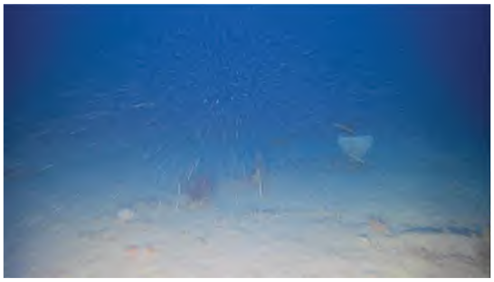




Area 3 – Transect 3c





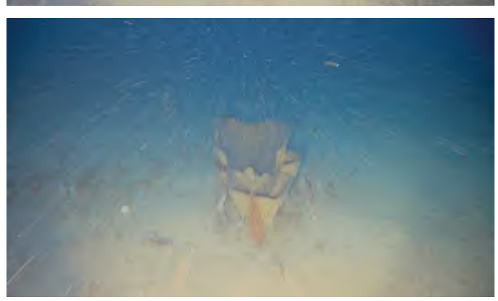







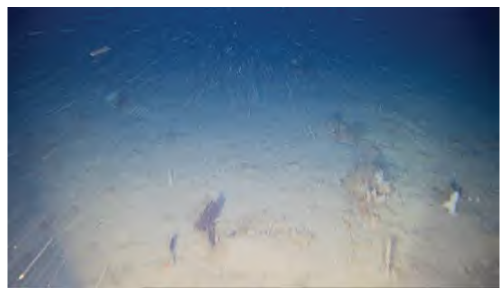








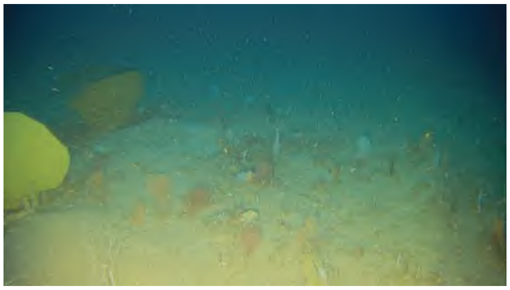




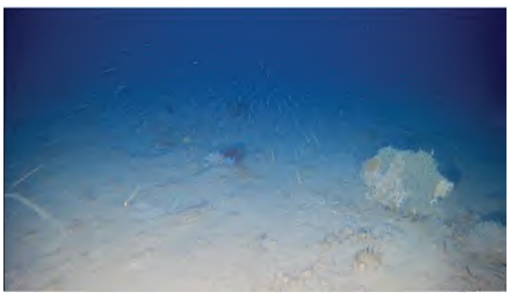
Appendix E: Additional Images Area 4

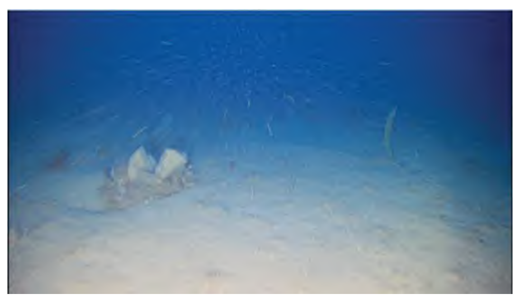
Transect Images – Area 4

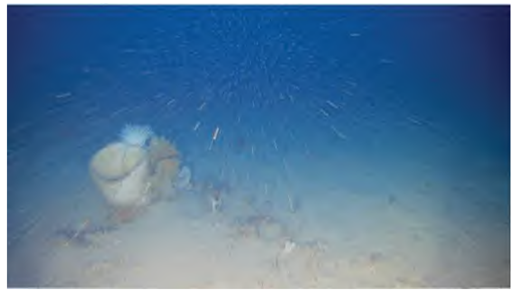
Area 4 - Transect 4a



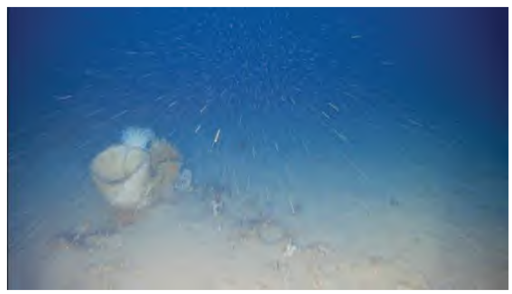


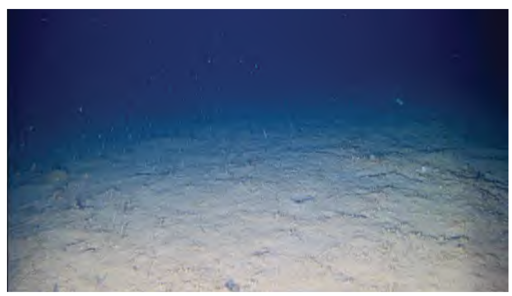






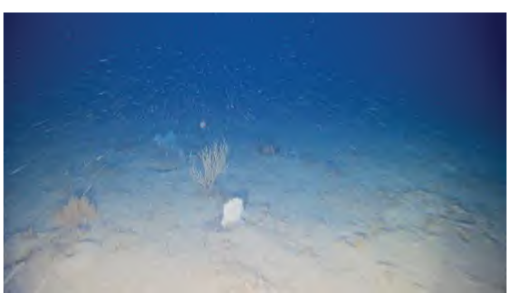
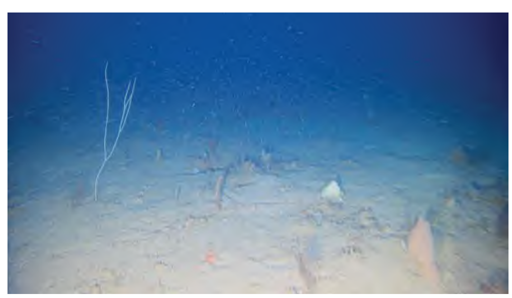


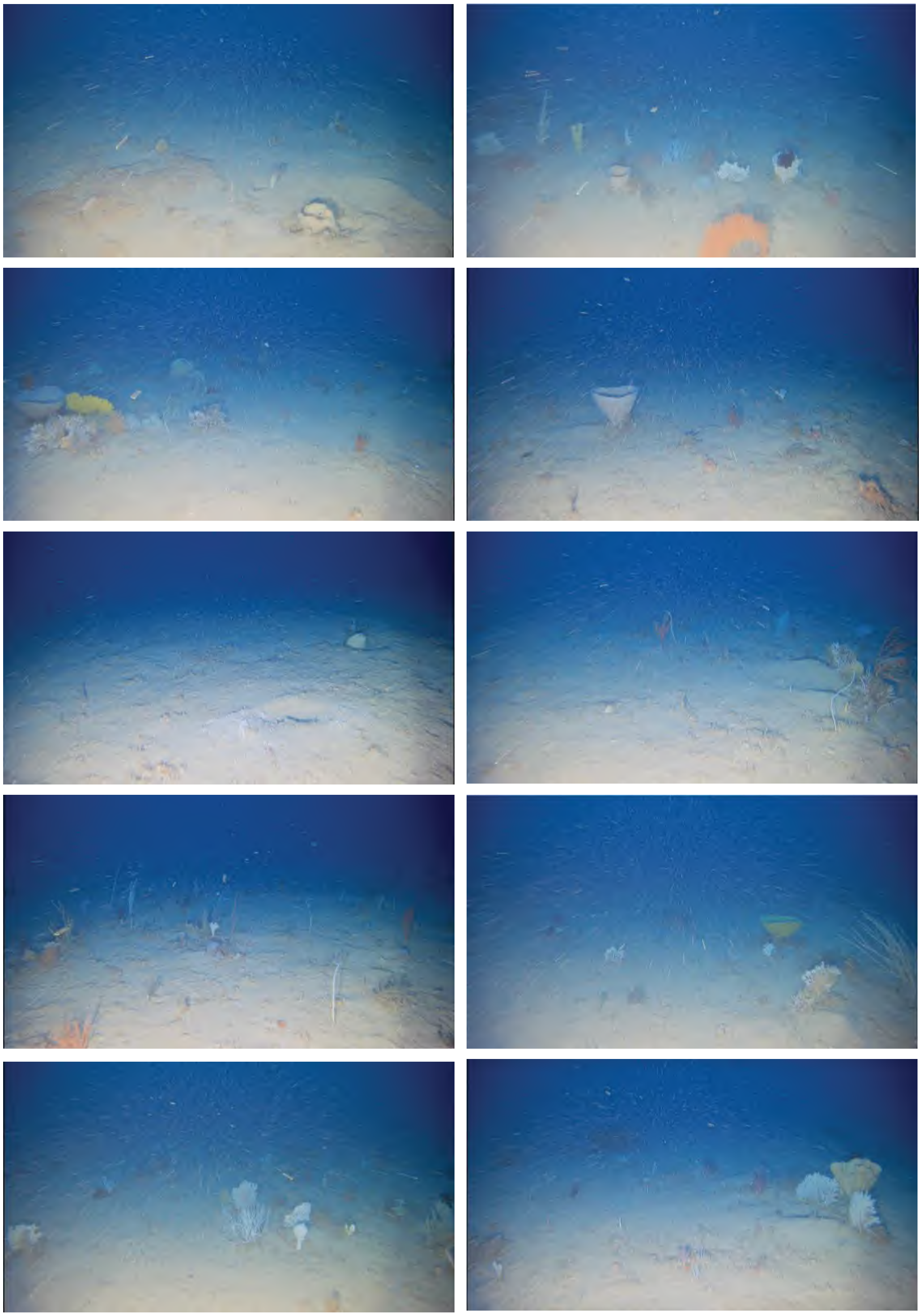




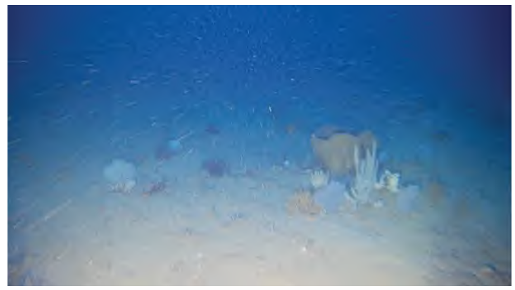


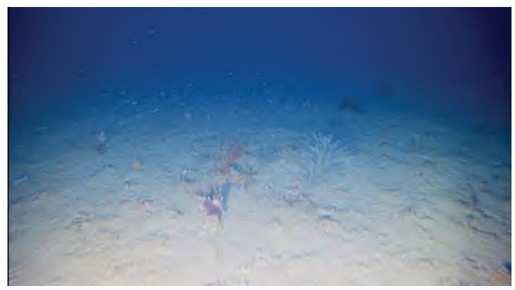


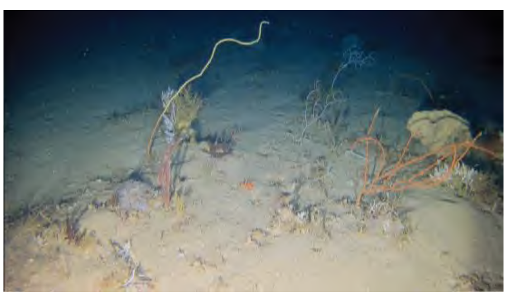


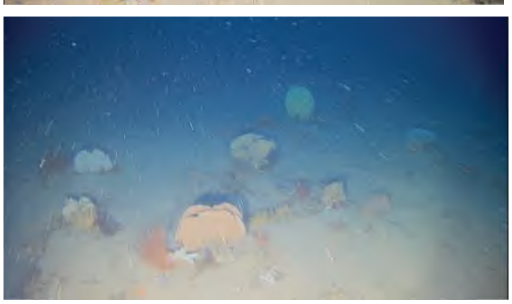


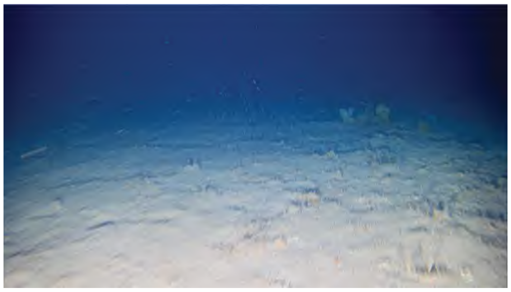



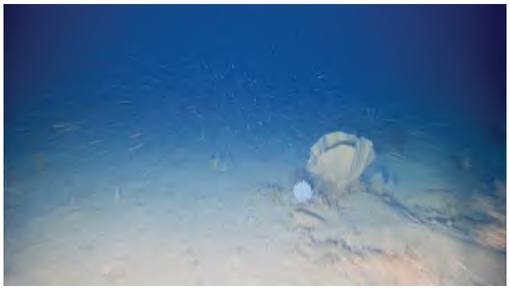
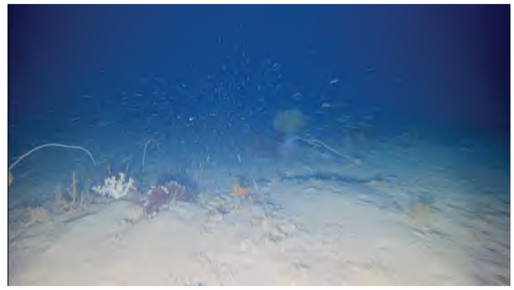


Area 4 – Transect 4b

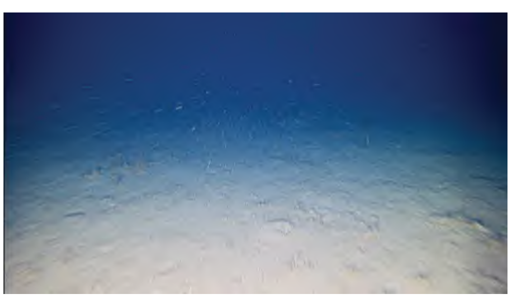
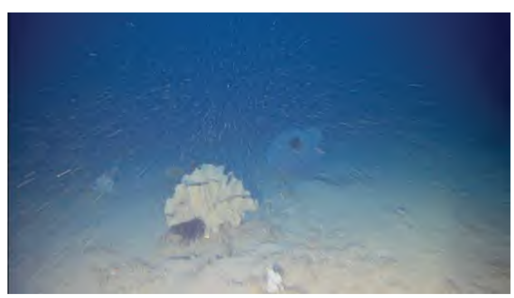




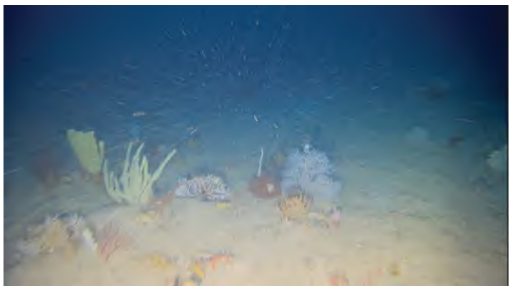
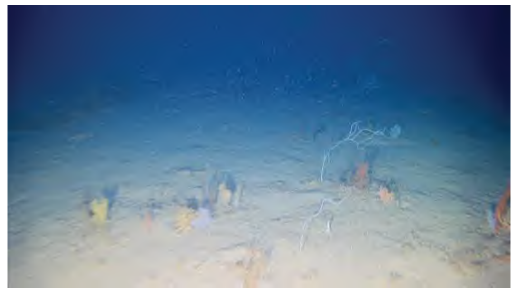



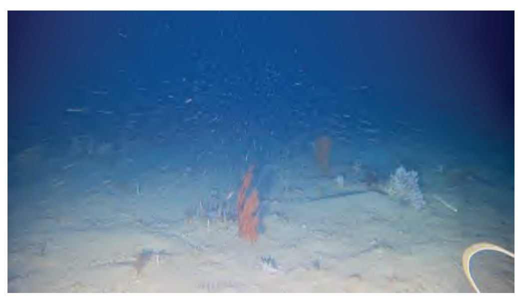






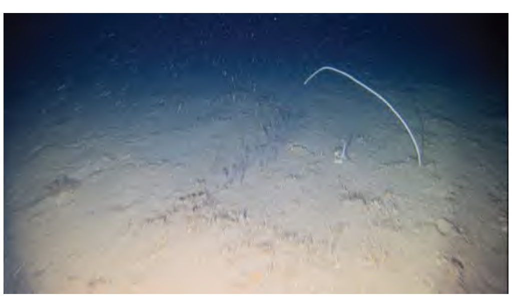


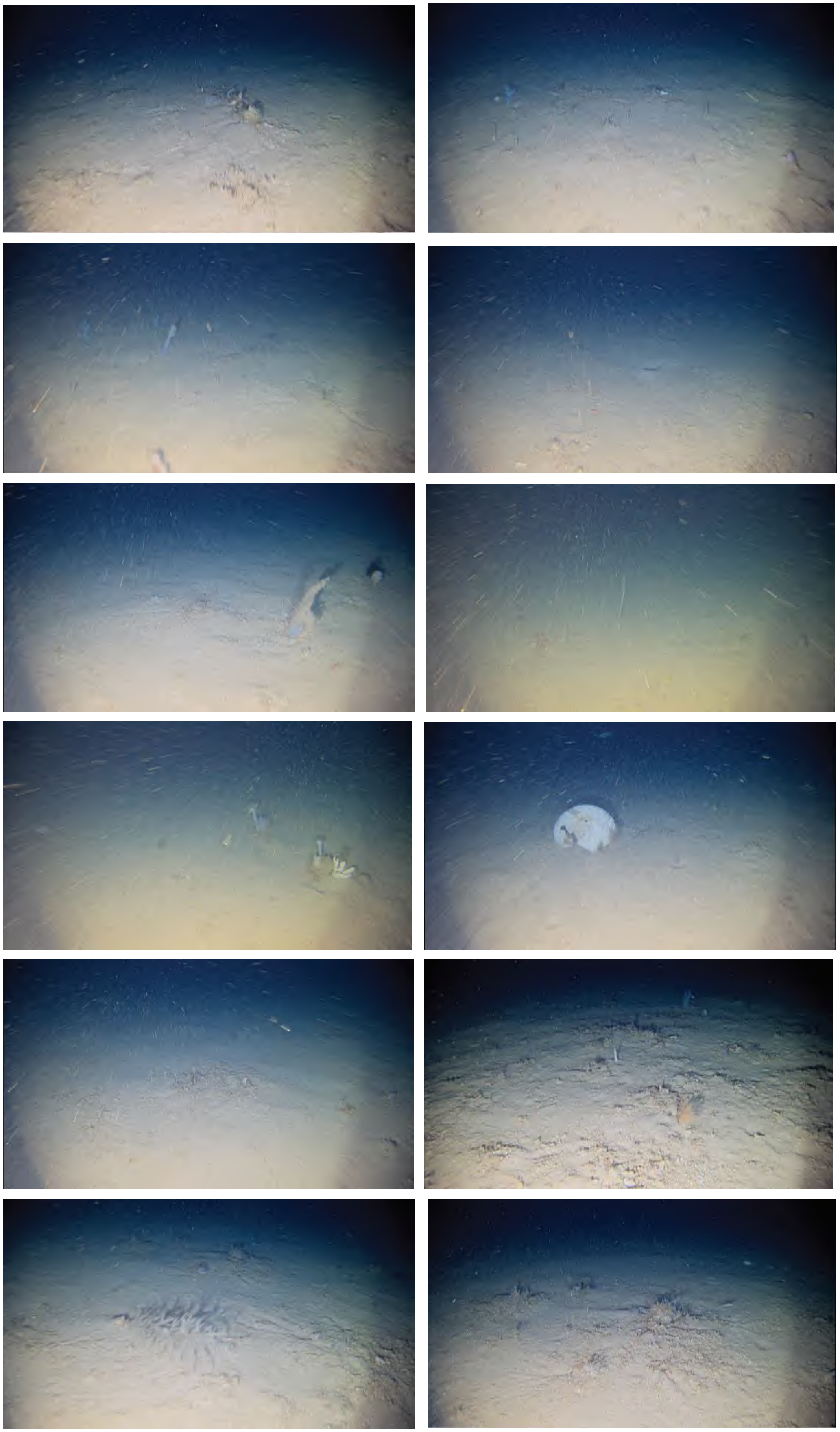




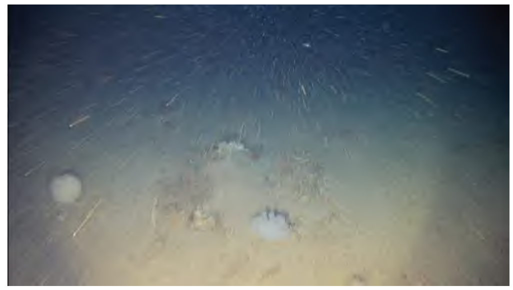



Area 4 – Transect 4c





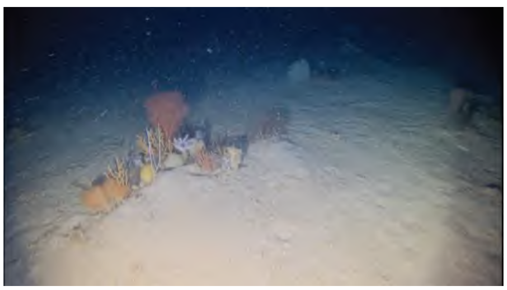



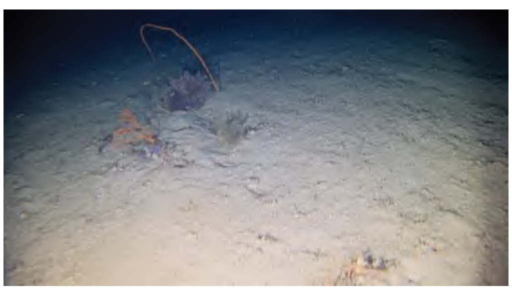




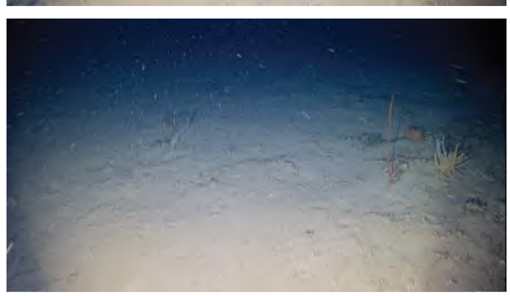








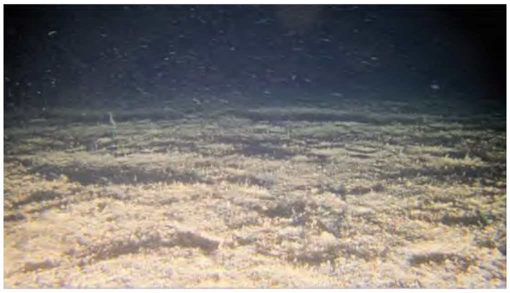
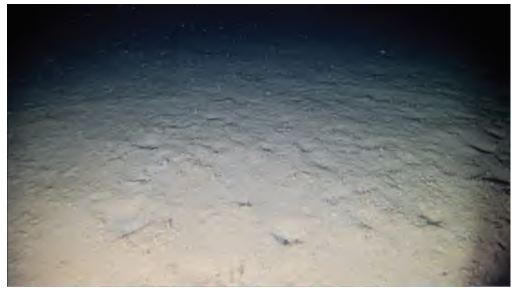


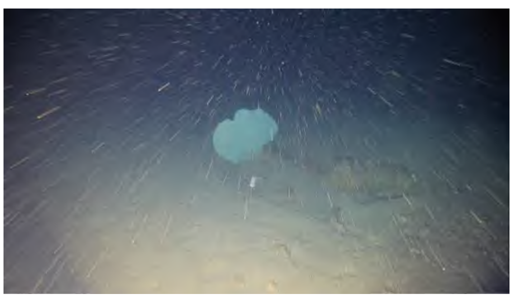



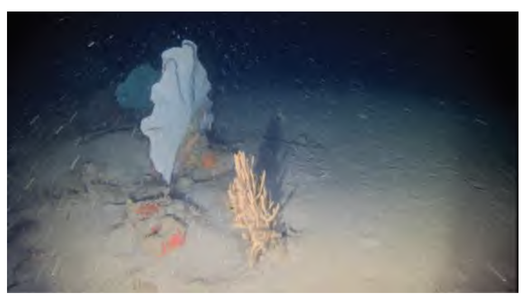
Appendix F: Additional Images Area 5

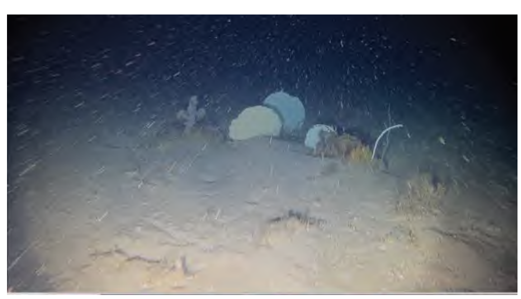
Transect Images – Area 5

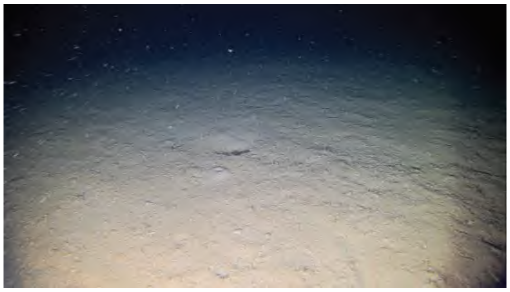
Area 5 – Transect 5a

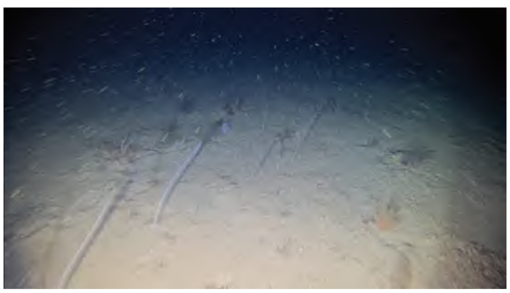
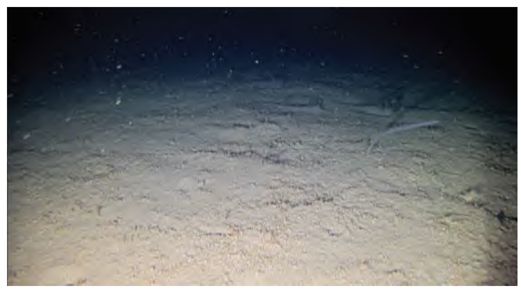



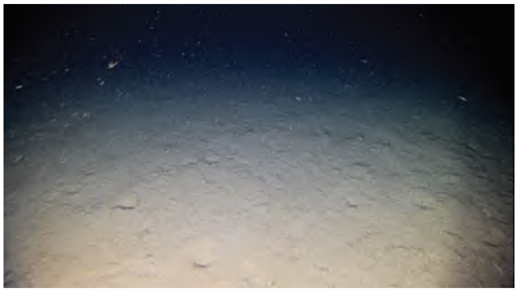




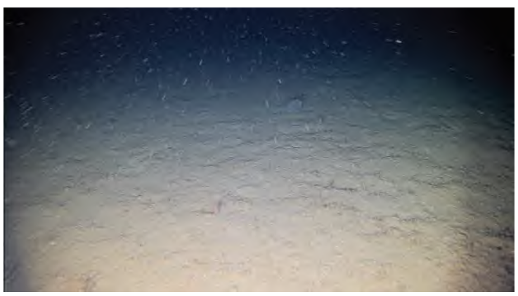
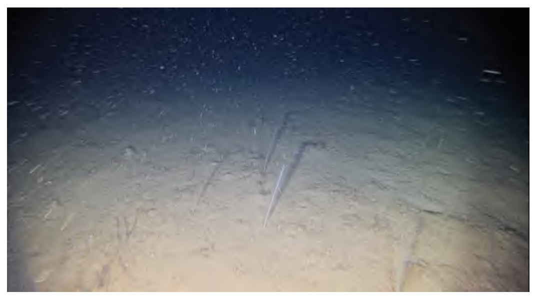


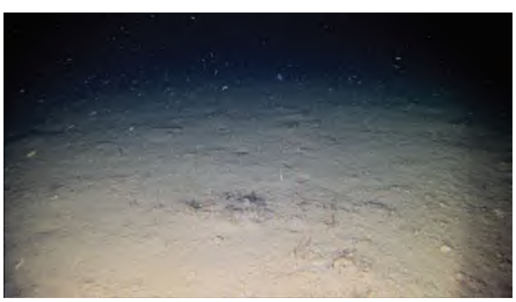



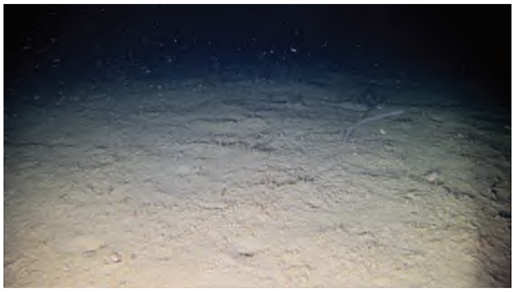
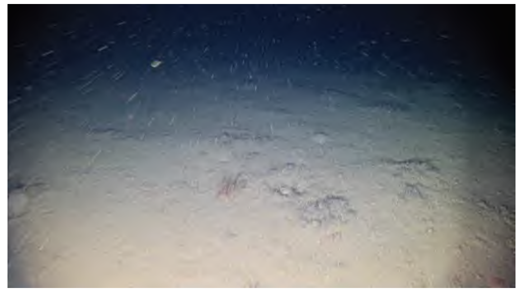






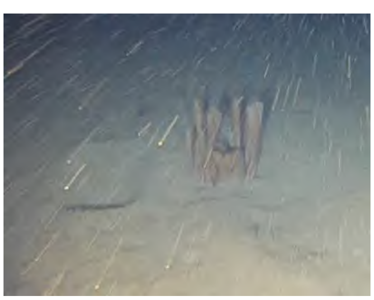



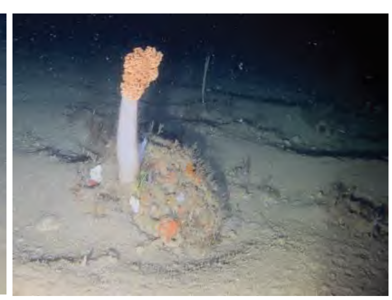






Transect 5a – Sessile Organisms



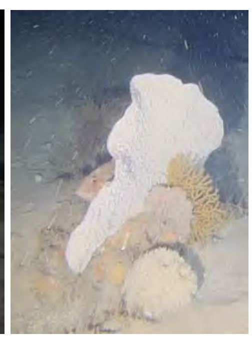
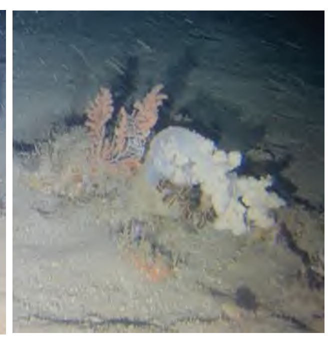


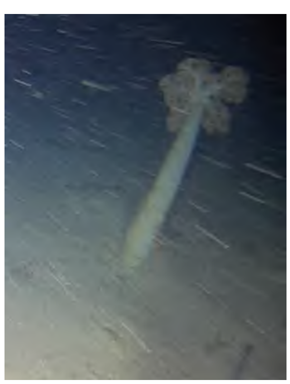






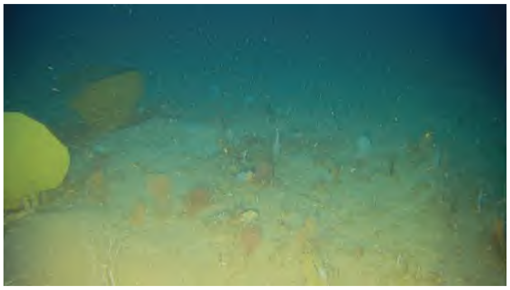


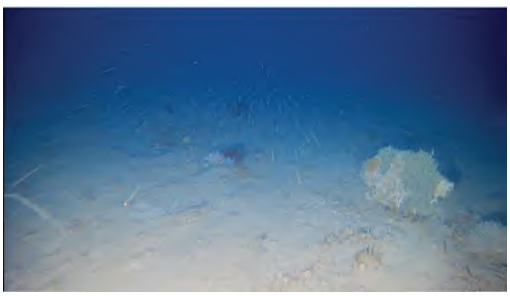


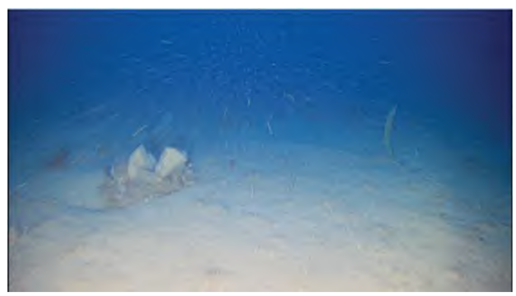

Transect Images – Area 4

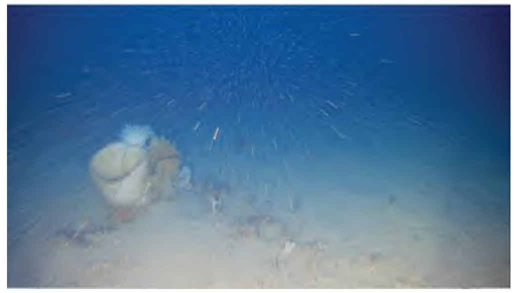
Area 4 - Transect 4a



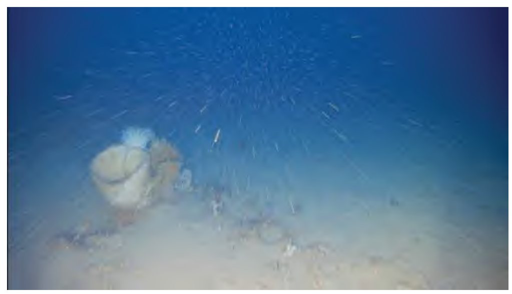


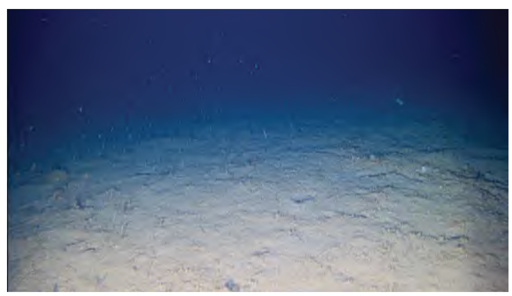


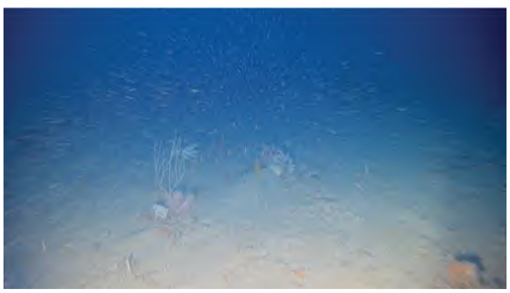




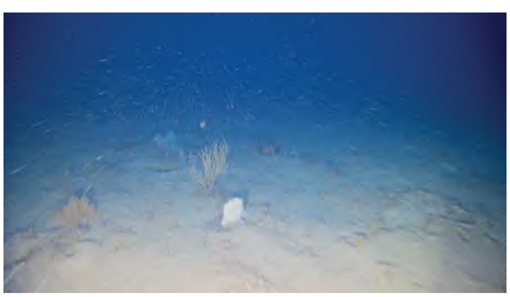
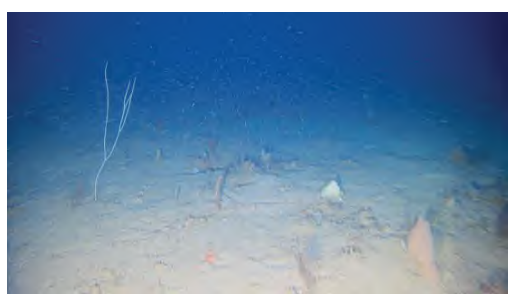


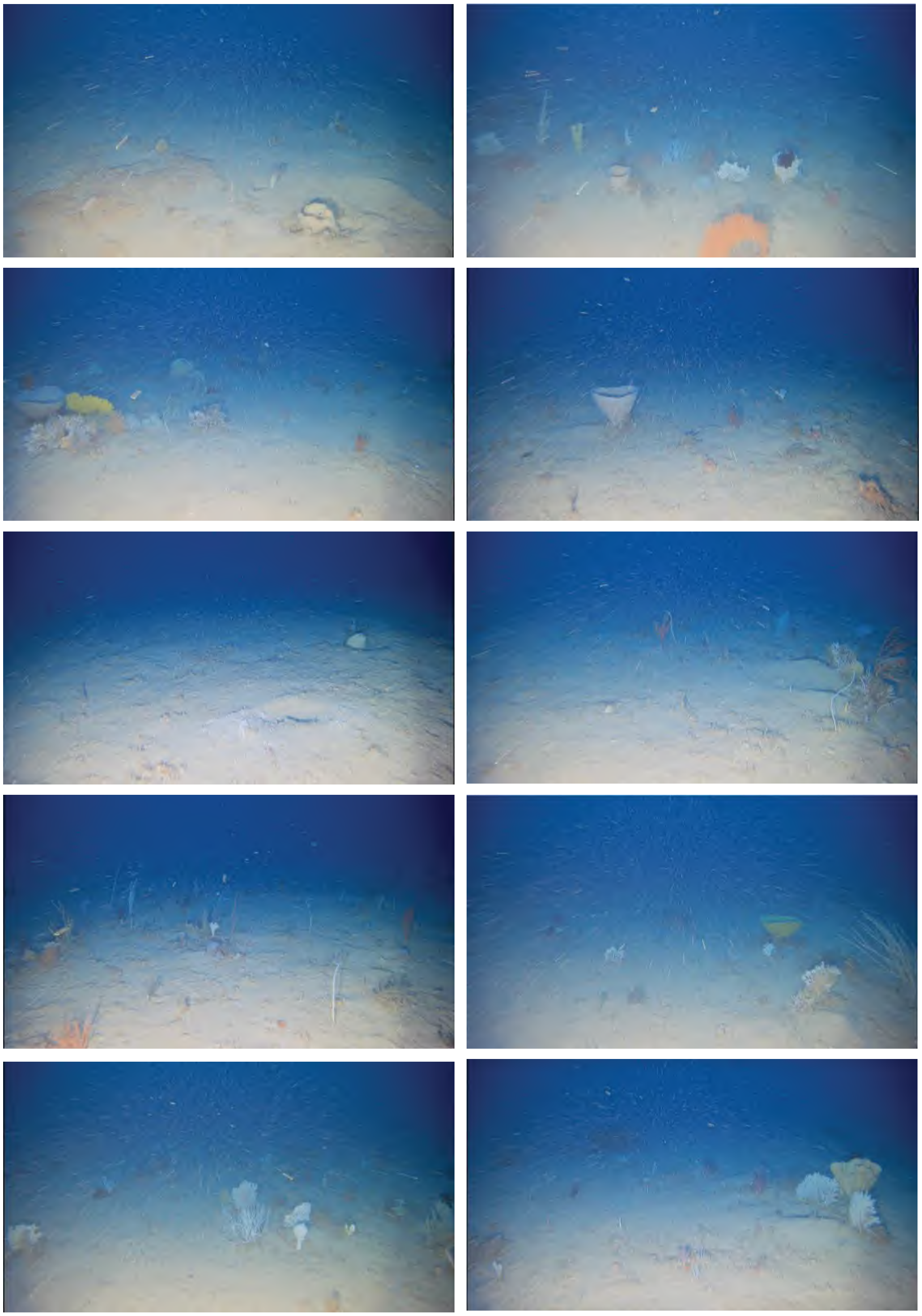




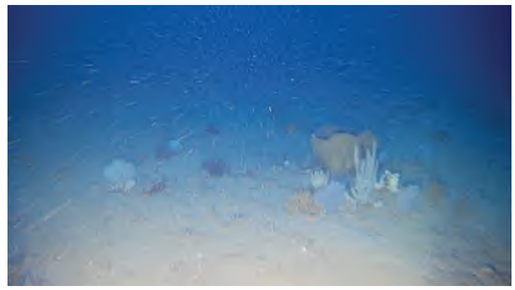


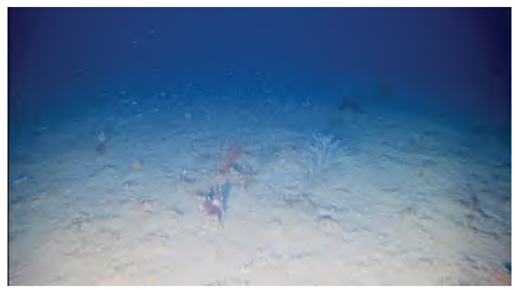


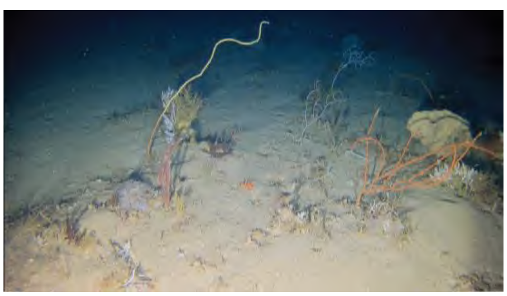
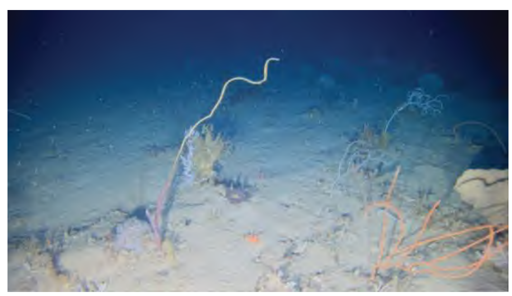
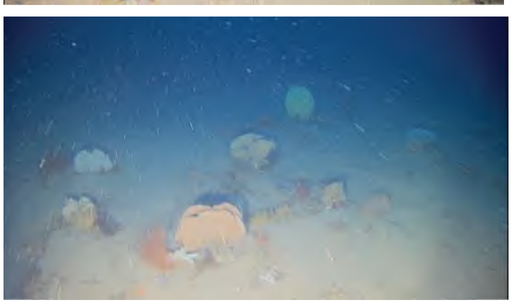


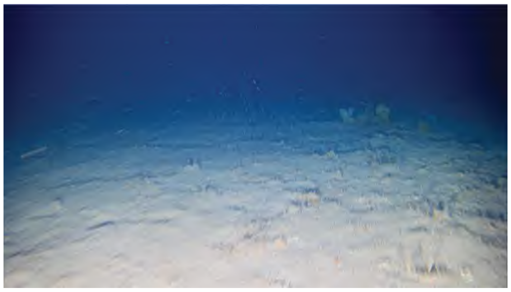


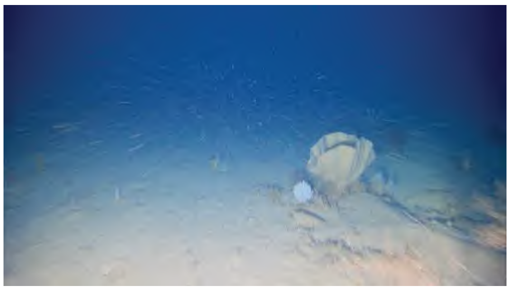
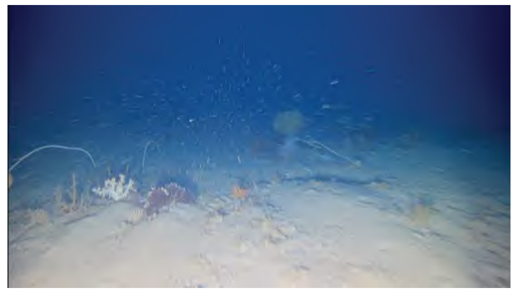





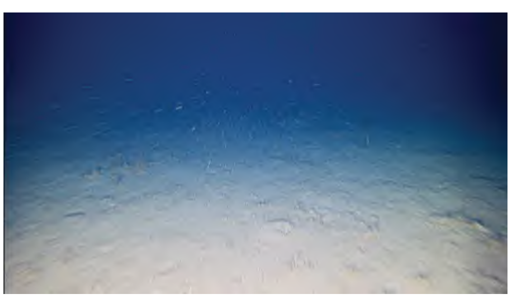
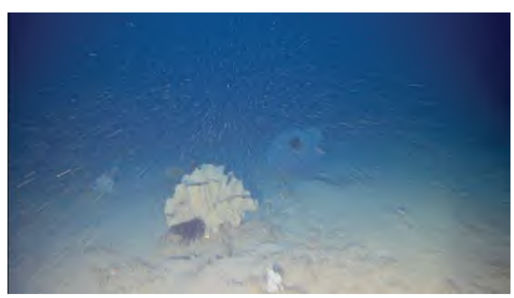
Area 4 – Transect 4b

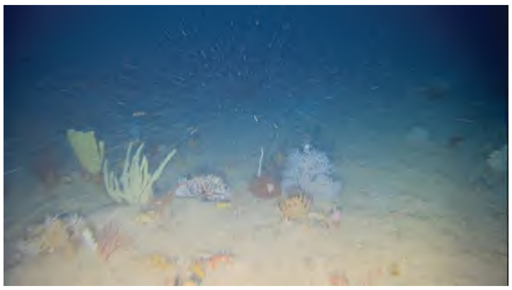
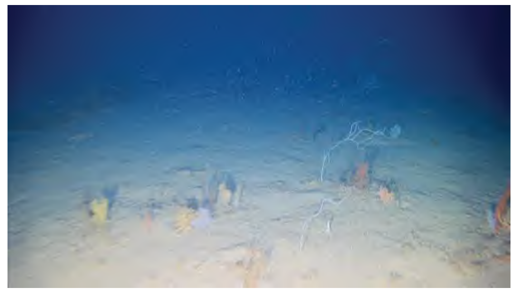



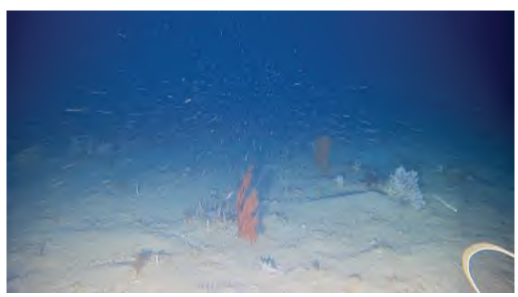






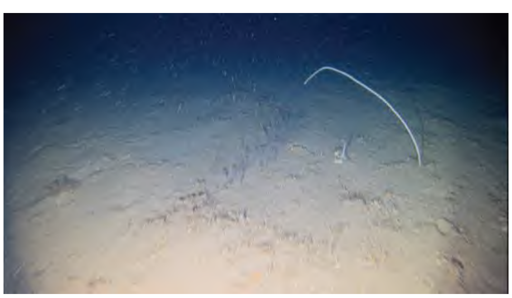


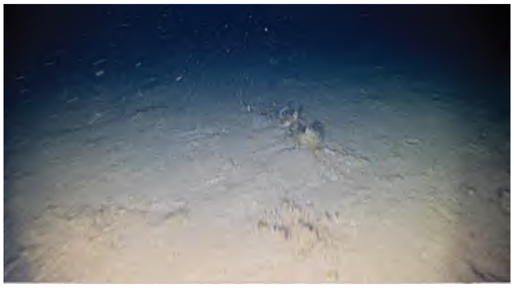




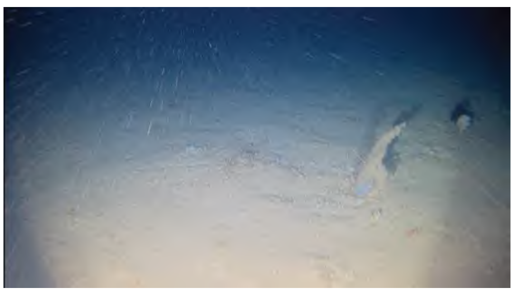



Area 4 – Transect 4c

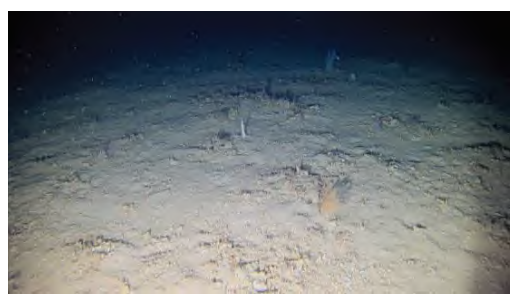
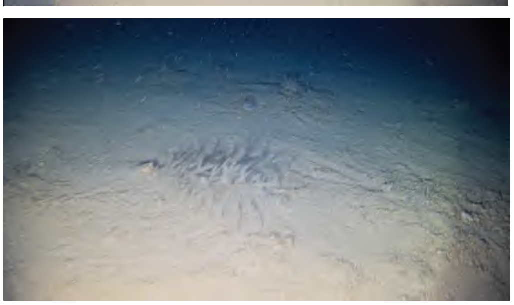




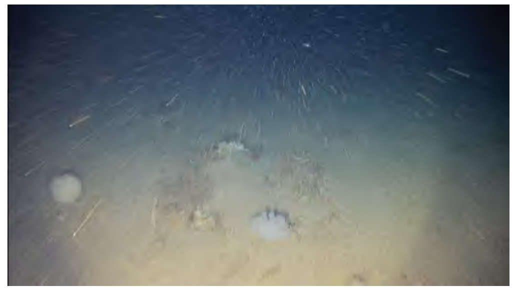










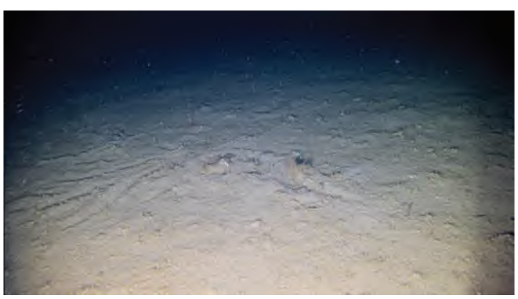
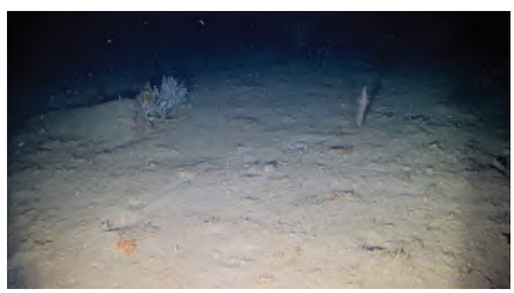










Appendix D

EPBC Act Protected Matters Reports

OFFSHORE PROJECT AREA

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

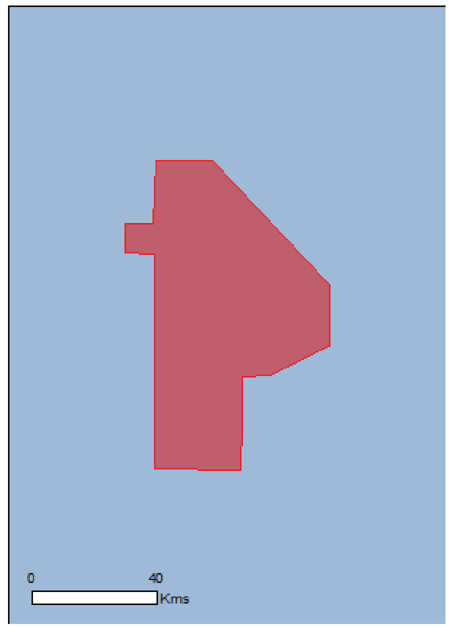
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 03/04/19 15:22:24

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements



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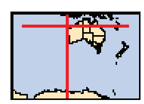

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	12
Listed Migratory Species:	24

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	15
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	1

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat may occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat may occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera bonaerensis		
Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Reptiles		
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area

Name	Status	Type of Presence
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Exmouth Plateau	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-19.165 113.087,-19.165 113.251,-19.5 113.586,-19.666 113.585,-19.746 113.419,-19.751 113.335,-20.002 113.332,-19.998 113.084,-19.418 113.084,-19.415 113.002,-19.333 113.001,-19.333 113.081,-19.165 113.087

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Australian Government
Department of the Environment and Energy

TRUNKLINE PROJECT AREA
ORIGINAL SEARCH

EPBC Act Protected Matters Report

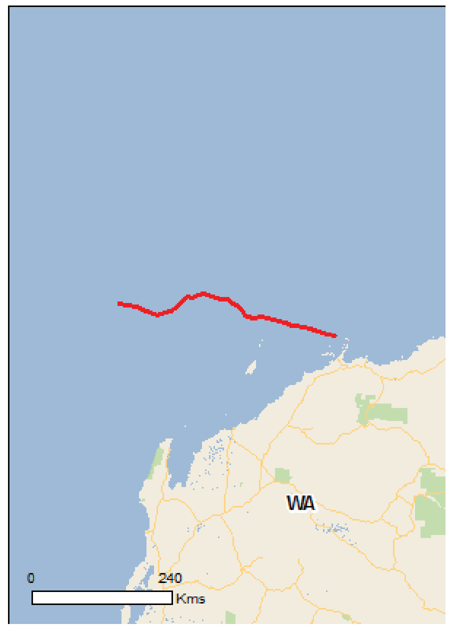
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

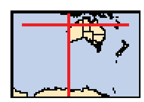
Report created: 03/04/19 15:27:24

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	20
Listed Migratory Species:	38

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	71
Whales and Other Cetaceans:	28
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	3

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species

Name	Status	Type of Presence
		habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Name	Label
Montebello	Multiple Use Zone (IUCN VI)

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-19.867 113.336,-19.911 113.628,-19.937 113.725,-20.021 113.937,-19.936 114.18,-19.755 114.403,-19.777 114.483,-19.704 114.638,-19.797 114.925,-19.789 115.025,-19.862 115.116,-19.895 115.193,-19.936 115.232,-20.038 115.284,-20.06 115.426,-20.052 115.532,-20.139 115.918,-20.172 115.997,-20.171 116.078,-20.21 116.299,-20.294 116.56,-20.318 116.672,-20.351 116.699

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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TRUNKLINE PROJECT AREA
NEW SEARCH

Australian Government

Department of the Environment and Energy

EPBC Act Protected Matters Report

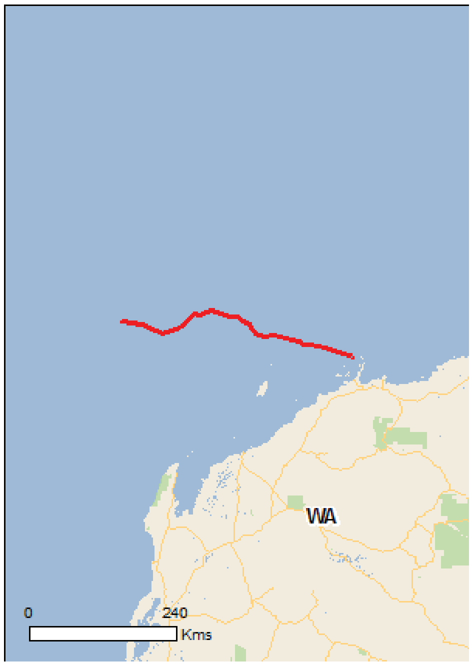
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

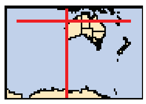
Report created: 09/12/19 17:48:20

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



Coordinates

Buffer: 1.5Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	20
Listed Migratory Species:	38

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	71
Whales and Other Cetaceans:	28
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	3

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species

Name	Status	Type of Presence
		habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Name	Label
Montebello	Multiple Use Zone (IUCN VI)

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-19.867 113.336,-19.911 113.628,-19.937 113.725,-20.021 113.937,-19.936 114.18,-19.755 114.403,-19.777 114.483,-19.704 114.638,-19.797 114.925,-19.789 115.025,-19.862 115.116,-19.895 115.193,-19.936 115.232,-20.038 115.284,-20.06 115.426,-20.052 115.532,-20.139 115.918,-20.172 115.997,-20.171 116.078,-20.21 116.299,-20.294 116.56,-20.318 116.672,-20.351 116.699

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
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-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

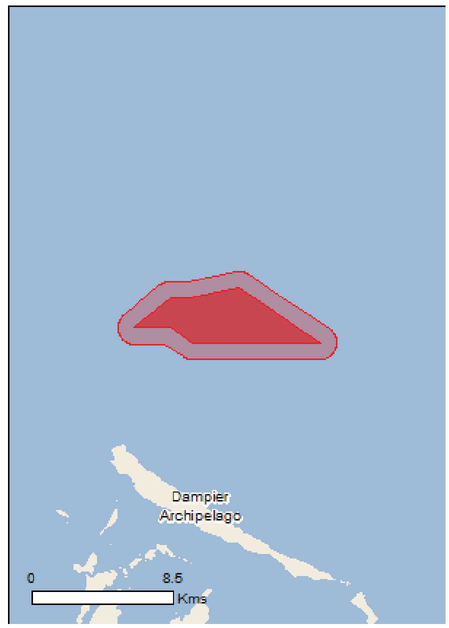
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

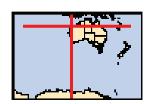
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 29/01/19 16:47:06

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



Coordinates
Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	18
Listed Migratory Species:	32

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	67
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area

Migratory Wetlands Species

Name	Threatened	Type of Presence
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus		
Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus		
Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		

Name	Threatened	Type of Presence
Dugong dugon Dugong [28]		Species or species habitat likely to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Australian Marine Parks	[Resource Information]
Name	Label
Dampier	Habitat Protection Zone (IUCN IV)

Extra Information

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

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Acknowledgements

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-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
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-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

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Please feel free to provide feedback via the Contact Us page.

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EMBA

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Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 05/04/19 18:46:08

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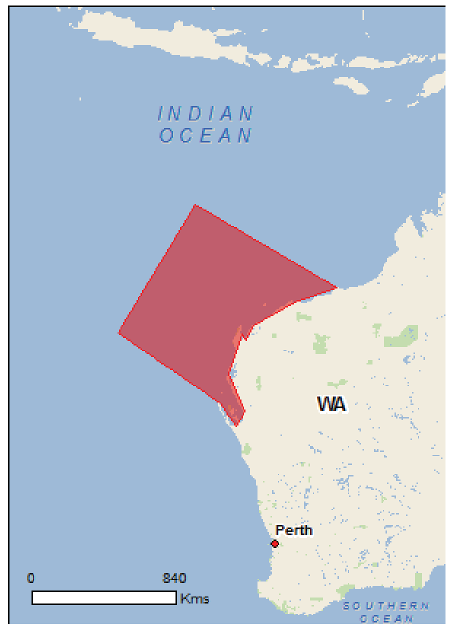
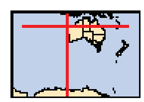
- Caveat
- Acknowledgements



Coordinates
Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	2
National Heritage Places:	4
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	73
Listed Migratory Species:	85

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	10
Commonwealth Heritage Places:	2
Listed Marine Species:	138
Whales and Other Cetaceans:	31
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	11

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	53
Regional Forest Agreements:	None
Invasive Species:	25
Nationally Important Wetlands:	8
Key Ecological Features (Marine)	6

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
Shark Bay, Western Australia	WA	Declared property
The Ningaloo Coast	WA	Declared property

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
Shark Bay, Western Australia	WA	Listed place
The Ningaloo Coast	WA	Listed place
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place
Historic		
Dirk Hartog Landing Site 1616 - Cape Inscription Area	WA	Listed place

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea
Extended Continental Shelf

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area

Name	Status	Type of Presence
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur within area
Malurus leucopterus leucopterus White-winged Fairy-wren (Dirk Hartog Island), Dirk Hartog Black-and-White Fairy-wren [26004]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Foraging, feeding or

Name	Status	Type of Presence
		related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Fish		
Milyeringa veritas Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Ophisternon candidum Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
Bettongia lesueur lesueur Burrowing Bettong (Shark Bay), Boodie [66659]	Vulnerable	Species or species habitat known to occur within area
Bettongia penicillata ogilbyi Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Lagorchestes hirsutus bernieri Rufous Hare-wallaby (Bernier Island) [66662]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus dorreae Rufous Hare-wallaby (Dorre Island) [66663]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Lagostrophus fasciatus fasciatus Banded Hare-wallaby, Merrnine, Marnine, Munning [66664]	Vulnerable	Species or species habitat known to occur within area
Leporillus conditor Wopilkara, Greater Stick-nest Rat [137]	Vulnerable	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area
Perameles bougainville bougainville Western Barred Bandicoot (Shark Bay) [66631]	Endangered	Species or species habitat known to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Pseudomys fieldi Shark Bay Mouse, Djoongari, Alice Springs Mouse [113]	Vulnerable	Species or species habitat likely to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
Other		
Idiosoma nigrum Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat likely to occur within area
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat known to occur within area
Plants		
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat may occur within area
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aprasia rostrata rostrata Monte Bello Worm-lizard, Hermite Island Worm-lizard [64481]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area

Name	Status	Type of Presence
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus angusticeps Northwestern Coastal Ctenotus, Airlie Island Ctenotus [25937]	Vulnerable	Species or species habitat known to occur within area
Ctenotus zastictus Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lerista nevinae Nevin's Slider [85296]	Endangered	Species or species habitat known to occur within area
Liasis olivaceus barroni Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species

Name	Threatened	Type of Presence
		habitat likely to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area

Name	Threatened	Type of Presence
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Defence - CARNARVON TRAINING DEPOT
Defence - EXMOUTH ADMIN & HF TRANSMITTING
Defence - EXMOUTH NAVAL HF RECEIVING STATION (H/F Receiving Station, Learmonth, WA)
Defence - EXMOUTH VLF TRANSMITTER STATION
Defence - LEARMONTH - AIR WEAPONS RANGE
Defence - LEARMONTH - RAAF BASE
Defence - LEARMONTH RADAR SITE - TWIN TANKS EXMOUTH
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH
Defence - LEARMONTH TRANSMITTING STATION

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Breeding known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Breeding known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area

Name	Threatened	Type of Presence
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat likely to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Species or species habitat known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish,		Species or species

Name	Threatened	Type of Presence
Pacific Blue-stripe Pipefish [66211]		habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area

Name	Status	Type of Presence
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Name	Label
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Dampier	Habitat Protection Zone (IUCN IV)
Dampier	Multiple Use Zone (IUCN VI)
Dampier	National Park Zone (IUCN II)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Shark Bay	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Airlie Island	WA
Barrow Island	WA
Bernier And Dorre Islands	WA
Bessieres Island	WA
Boodie, Double Middle Islands	WA
Bundegi Coastal Park	WA
Burnside And Simpson Island	WA

Name	State
Cape Range	WA
Chinamans Pool	WA
Dirk Hartog Island	WA
Faure Island	WA
Francois Peron	WA
Freycinet, Double Islands etc	WA
Giralia	WA
Gnandaroo Island	WA
Jurabi Coastal Park	WA
Koks Island	WA
Little Rocky Island	WA
Locker Island	WA
Lowendal Islands	WA
Monkey Mia Reserve	WA
Montebello Islands	WA
Muiron Islands	WA
Murujuga	WA
Nanga Station	WA
North Sandy Island	WA
North Turtle Island	WA
One Tree Point	WA
Rocky Island	WA
Round Island	WA
Serrurier Island	WA
Shell Beach	WA
Tent Island	WA
Unnamed WA36907	WA
Unnamed WA36909	WA
Unnamed WA36910	WA
Unnamed WA36913	WA
Unnamed WA36915	WA
Unnamed WA37338	WA
Unnamed WA37383	WA
Unnamed WA37500	WA
Unnamed WA40322	WA
Unnamed WA40828	WA
Unnamed WA40877	WA
Unnamed WA41080	WA
Unnamed WA44665	WA
Unnamed WA44667	WA
Unnamed WA44688	WA
Unnamed WA49144	WA
Victor Island	WA
Weld Island	WA
Y Island	WA
Yaringga	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia		
Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus		
House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus		
Eurasian Tree Sparrow [406]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Cylindropuntia spp. Prickly Pears [85131]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree,		Species or species

Name	Status	Type of Presence
Horse Bean [12301]		habitat likely to occur within area
Prosopis spp.		
Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Tamarix aphylla		
Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus		
Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus		
Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat likely to occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
Exmouth Gulf East	WA
Hamelin Pool	WA
Lake MacLeod	WA
Learmonth Air Weapons Range - Saline Coastal Flats	WA
McNeill Claypan System	WA
Shark Bay East	WA

Key Ecological Features (Marine)

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Cuvier Abyssal Plain and the	North-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-19.9557 119.0944,-15.8051 111.6964,-22.1384 107.6624,-25.4807 112.9971,-26.602 113.829,-25.914 114.282,-24.149 113.431,-22.222 114.137,-22.511 114.354,-21.801 114.744,-20.678 116.916,-19.9557 119.0944

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Appendix E

Scarborough Gas Development Underwater Noise Modelling Study

MARSHALL DAY Acoustics

SCARBOROUGH GAS US4A/B DEVELOPMENT

UNDERWATER NOISE MODELLING STUDY

Rp 001 20181331 | 15 February 2019

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Project: **SCARBOROUGH GAS US4A/B DEVELOPMENT**

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Report No.: **Rp 001 20181331**

Document Control

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1.0 INTRODUCTION

Advisian has engaged Marshall Day Acoustics (MDA) to carry out modelling of underwater acoustic emissions from selected activities associated with the proposed Scarborough gas field development (the Scarborough project), located in Western Australia's North West Shelf region. The Scarborough project is being developed by Woodside Energy Ltd.

Three key noise generating activities associated with the Scarborough project have been identified by Advisian for detailed modelling as follows:

1. Floating Production Unit (FPU) installation and operation
2. Vessel operations associated with pipelaying
3. Pile driving required for the trunkline connection near the Pluto LNG facility in Dampier.

This report has been prepared to inform an assessment of potential impacts from development activities in Commonwealth waters, to be included in an Offshore Project Proposal (OPP) for submission to the Australian National Offshore Petroleum Safety and Environmental Management Authority NOPSEMA. Since the activities in item 3 in the list above take place in State water, only items 1 and 2 have been considered in this report.

This report outlines details of the noise model inputs, the noise propagation prediction methodology, and a summary of the noise predication results, presented in metrics that are relevant to the various marine fauna species of interest. The predicted underwater noise levels are compared to criteria from widely used scientific studies and international guidelines, as nominated by the project ecologist, to assist with the evaluation of noise impacts.

A glossary of acoustic terms and symbols used herein is provided in Appendix A.

2.0 PROJECT DESCRIPTION

The Scarborough gas field is located within the offshore area designated as Permit Area WA-1-R by the National Offshore Petroleum Titles Administrator. The area is located approximately 380 km WNW of the Burrup Peninsula in the North West of Australia where water depths range between 900m and 1000m.

We understand that the Scarborough project proposes drilling of up to 22 subsea gas wells. It is proposed that wells will be tied back to a Floating Production Unit (FPU), with processing facilities on the FPU enabling transport of the gas through a 420-kilometre-long trunkline to the Woodside operated Pluto LNG Facility. The trunkline and associated installation works will occur in both State and Commonwealth waters.

2.1 Noise generating activities

A preliminary impact assessment has been carried out by Advisian (document reference US4A/B Noise Modelling Study Scope of work) which has identified activities associated with the proposed Scarborough project that generate noise emissions. Of these, three key noise generating activities in Commonwealth waters have been identified by Advisian for detailed modelling to assess the risk of noise impacts. These impacts include:

- Change in ambient noise;
- Disturbance to fauna behaviour;
- Injury/mortality to fauna; and
- Changes to the functions, interests or activities of other users.

A description of the three activities is presented in Table 1. Each activity has been assigned a scenario reference which will be used throughout this report.

Table 1: Activities requiring noise modelling

Scenario reference	Activity	Description of noise/sources
1a.	FPU installation	Impact piling associated with the FPU installation. Involves installation of 20 x 5 m diameter steel anchor piles. Piles located in approximately 950 m deep water at the FPU site.
1b.	FPU operation	Topside equipment noise associated with hydrocarbon processing and transportation to a shore-based refinery situation on the FPU Noise from the operation of dynamic positioning (DP) support vessel
2.	Pipelay vessel operations	Pipelay vessel with support vessels will operate in Commonwealth and State waters. Sources comprise: - Noise from the operation of dynamic positioning (DP) pipelay vessel - Noise from the operation of dynamic positioning (DP) support vessel For modelling purposes, the support vessel used for scenarios 1b and 2 is the same.

2.2 Project area

Each of the three activities will take place at separate locations as indicated in Figure 1 - Figure 2 below. The maps show the modelling calculation areas for each scenario as well as marine parks and relevant biologically important areas (BIAs) that partially overlap with the modelling areas. For some scenarios, BIAs fully overlap the modelled area and this is not easily shown using the maps in Figure 1 - Figure 2. For reference, the BIAs that either partially or fully overlap the modelled areas are listed in Appendix B. Map coordinate details of the source locations are provided in the relevant sections below.

Figure 1: Project area – Scenario 1a (FPU piling) and Scenario 1b (FPU operations)

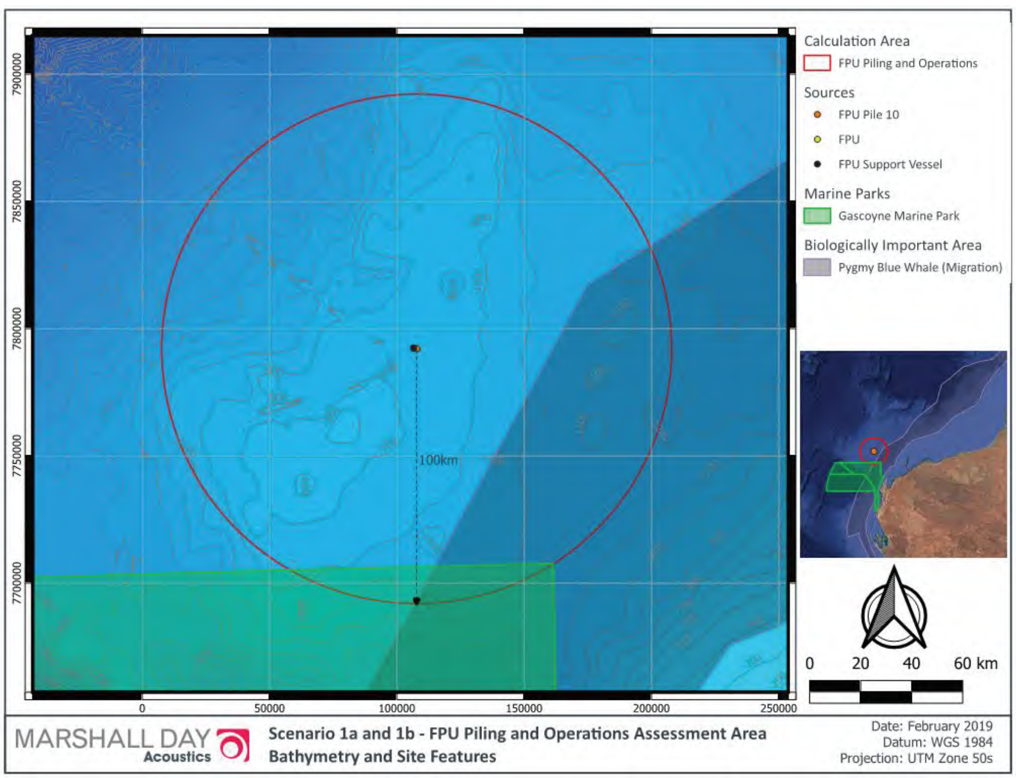
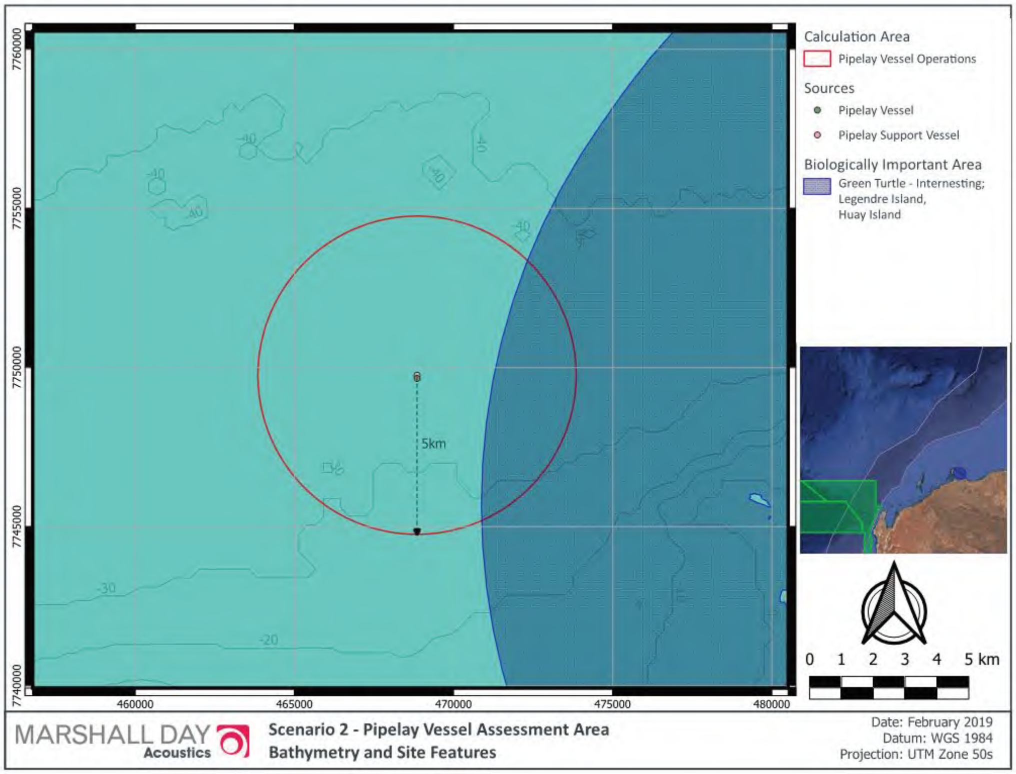


Figure 2: Project area – Scenario 2 (Vessel operations)



3.0 SPECIES OF INTEREST

The species of interest in the vicinity of the Scarborough project sites have been identified by the project environmental consultant (Advisian). Each species of interest considered in this report has been categorised based on its hearing sensitivity grouping. The guidance used to assess noise impacts set varying criteria for different hearing sensitivity groups. The corresponding hearing sensitive group for each species of interest is therefore provided in Table 2. Further details of the criteria for each species is provide in Section 4.0

Table 2: Species of interest summary

Species	Comment	Hearing Category
Pygmy blue whales	Presence of migration BIAs identified within the vicinity of the FPU and trunkline corridor.	Low-Frequency Cetaceans
Humpback whales	Presence of migration BIAs identified within the trunkline corridor	Low-Frequency Cetaceans
Flatback turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea turtles
Loggerhead turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea Turtles
Hawksbill turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea Turtles

Species	Comment	Hearing Category
Green turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea Turtles
Fish	Includes whale sharks and fish generally	Fish

The potential noise impacts on marine fauna from underwater development activity can be categorised into four discrete areas as follows, from highest to lowest in order of the degree of potential impact:

1. Physiological damage that can lead to death or injury of the organism
2. Permanent Threshold Shift (PTS), which is described as a permanent shift in hearing sensitivity and can be considered as an injury
3. Temporary Threshold Shift (TTS), which is described as a temporary effect upon hearing and is often a recoverable impact
4. Behavioural response, which may manifest as avoidance, or a change to movement pathways/migration.

For each of the species hearing categories above, relevant noise criteria have been assigned to assist with the assessment of noise impacts. Details of the noise criteria are outlined in Section 4.0.

4.0 NOISE IMPACT CRITERIA

4.1 Legislation and policy

The Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act) is the central piece of environmental legislation relevant to assessments of impacts on marine fauna. It provides the legal framework to protect and manage nationally and internationally important areas, which are defined in the EPBC Act as matters of National Environmental Significance (NES).

When a proposal has the potential to have a significant impact on a matter of national environmental significance, the proposal is assessed on the basis of a ‘referral’. A referral should contain sufficient information to provide an adequate basis for a decision on the likely impacts. For noise impacts an assessment would commonly be made with reference to relevant performance criteria.

The EPBC Act Policy Statement 2.1 outlines performance criteria and provides a framework to minimise the risk of underwater acoustic impacts, however this only applies to seismic operations, and only considers impacts on whale species - there are no EPBC policy statements which address other underwater noise sources and marine species.

In the absence of any other Australian specific underwater noise performance criteria, for this assessment, reference has been made to widely used scientific studies and international guidelines in order to evaluate the underwater noise impacts. These impact criteria sources have been nominated by the project marine ecologist.

4.2 Underwater noise criteria for marine mammals

The US Department of Commerce National Oceanic and Atmospheric Administration (NOAA) has produced guidance for assessing the effects of anthropogenic (human-made) sound on marine mammals. Details are provided in the following sections.

4.2.1 Physiological impacts

NOAA Technical Memorandum[1] provides thresholds for the onset of permanent threshold shift (PTS) and temporary threshold shifts (TTS) [2] in marine mammal hearing for all underwater sound sources. The guidance of the NOAA Technical Memorandum is commonly used in Australia to help evaluate the effects of sound exposure on marine mammal hearing.

Auditory threshold shifts can be caused by both impulsive noise sources (e.g. piling or seismic airguns) and continuous noise sources (e.g. vessel noise). When the source is impulsive, threshold shifts can be caused by peak exposure (momentary, high-level impulsive events such as pile strikes) or from cumulative exposure (lower noise levels over an extended period such as from vibro-piling or multiple pile strikes).

The NOAA Technical Memorandum provide TTS and PTS onset thresholds for marine mammals using $L_{p,pk}$ and 'SEL_{cum}' assessment descriptors. The $L_{p,pk}$ level is the highest un-weighted instantaneous pressure level recorded during the measurement period, whereas SEL_{cum} is the species-weighted cumulative sound exposure level over a 24-hour period. Table 3 presents the current NOAA thresholds. Explanation of marine mammal auditory frequency weightings is provided in Appendix C.

It should be noted that the $L_{p,pk}$ assessment of noise levels is relevant for impulsive noise sources only. SEL_{cum} assessment is applicable to both impulsive and non-impulsive (continuous) noise sources.

Table 3: NOAA 2018 threshold criteria

	Impulsive				**Non-Impulsive**	
	$L_{p,pk}$ *		**$SEL_{(cum)}$ †**		**$SEL_{(cum)}$**	
Hearing group	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**
Low-Frequency Cetaceans	213	219	168	183	179	199
Mid-Frequency Cetaceans	224	230	170	185	178	198
High-Frequency Cetaceans	196	202	140	155	153	173

* The $L_{p,pk}$ is the un-weighted peak instantaneous pressure level

† The $SEL_{(cum)}$ is the weighted cumulative sound exposure level over a 24-hour period

4.2.2 Behavioural impacts

Behavioural responses to underwater noise can vary significantly depending on species, the background noise levels, and the frequency content of the noise source. These effects can range from temporary avoidance of the noisy area to masking of biologically important sounds.

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[1] National Oceanic and Atmospheric Administration, 2018 *Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0) Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.* Available from: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance

[2] TTS in humans can be likened to the 'muffled' effect on hearing after being exposed to high noise levels such as at a concert. The effect eventually goes away, but the longer the exposure, the longer the threshold shift lasts. Eventually, the TTS becomes permanent. Long exposure TTS causing PTS in marine mammals is typically associated with continuous noise sources but is unlikely when dealing with impulsive sources due to the understanding that there is TTS recovery in between pulses.

For underwater impulsive noise such as impact piling, NOAA guidance[3] states that behavioural impacts can occur at levels of 160 dB re. 1 µPa rms, and as low as 120 dB re. 1 µPa rms for non-impulsive noise.

Table 4: NOAA criteria for behavioural impacts

	Impulsive $L_{p,rms}$ (dB re. 1 µPa)	Non-Impulsive $L_{p,rms}$ (dB re. 1 µPa)
Behavioural	160	120

4.3 Underwater noise criteria for fish

The 2014 publication '*Effects of Sound on Fish and Turtles*'[4] (herein referred to as ASA S3/SC1.4-2014) provides comprehensive sound exposure guidelines for fishes and sea turtles. ASA S3/SC1.4-2014 was prepared by an ANSI-accredited Standards Committee Working Group of experts and was sponsored by the Acoustical Society of America.

ASA S3/SC1.4-2014 outlines hearing category groups based on the way different non-mammalian marine animals detect and respond to sound and provides sound exposure metrics for a ranges of source types for noise impact assessment purposes. ASA S3/SC1.4-2014 divides fishes and sea turtles into five groups as follows:

- Fish with no swim bladder
- Fish with swim bladder not involved with hearing
- Fish with swim bladder that is involved with hearing
- Sea turtles
- Eggs and larvae

4.3.1 Physiological impacts

ASA S3/SC1.4-2014 provides guideline noise level criteria for different types of sound sources. Sound levels from a source that are above the guideline criteria are considered likely to result in the stated effect (mortality, injury etc).

A summary of the guideline noise level criteria from ASA S3/SC1.4-2014, for piling noise sources, is provided in Table 5. A summary of the guideline noise levels criteria from ASA S3/SC1.4-2014, for shipping and other continuous noise sources, is provided in Table 6.

Where quantitative criteria have not been provided in the ASA S3/SC1.4-2014, the entry has been shown blank.

[3] https://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html

[4] Popper et al, 2014, Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI Accredited Standards Committee S3/SC 1 and registered with ANSI, ASA Press (ASA S3/SC1.4 TR-2014)

Table 5: Guidelines for pile driving

		Mortality and potential mortal injury		Recoverable injury		TTS
Group	**Type of Fish**	$L_{p,pk}$	$SEL_{(cum)}$	$L_{p,pk}$	$SEL_{(cum)}$	$SEL_{(cum)}$
A	Fish: no swim bladder (particle motion detection)	213	219	213	216	186
B	Fish: swim bladder is not involved in hearing (particle motion detection)	207	210	207	203	186
C	Fish: swim bladder involved in hearing (primarily pressure detection)	207	207	207	203	186
D	Sea turtles	207	210	-	-	-
E	Eggs and larvae	207	210	-	-	-

Table 6: Guidelines for shipping and continuous sounds

Group	Type of Fish	Mortality and potential mortal injury	Recoverable injury	TTS
A	Fish: no swim bladder (particle motion detection)	-	-	-
B	Fish: swim bladder is not involved in hearing (particle motion detection)	-	-	-
C	Fish: swim bladder involved in hearing (primarily pressure detection)	-	170 dB rms for 48 hrs	158 dB rms for 12 h
D	Sea turtles	-	-	-
E	Eggs and larvae	-	-	-

4.3.2 Behavioural impacts

Studies on the behavioural impacts from noise on fish are very limited and there are no widely accepted or validate guideline criteria. This is partly due to the practicalities of conducting such studies in the field, as well as the potential for large variations in responses across all fish species.

Given the lack of available evidence or validated criteria, quantitative guidelines for the behavioural impact of fish are not provided in ASA S3/SC1.4-2014, and instead a subjective risk assessment approach is used. For this reason, only physiological impacts on fish have been considered in this report. Behavioural impacts for sea turtles are addressed in the following section.

4.4 Underwater noise criteria for turtles

4.4.1 Physiological impacts

Data on hearing by sea turtles is very limited and specific TTS noise threshold criteria are not available currently[5]. Finneran et al. 2017[6] includes per-strike $L_{p,pk}$ PTS criteria for turtles of 232 dB re 1 µPa.

Physiological impacts risks relating to injury or death also have been assessed, based on ASA S3/SC1.4-2014 guidance as outlined in Table 5 above.

4.4.2 Behavioural impacts

National Science Foundation: Final Programmatic Environmental Impact Statement Overseas Environmental Impact Statement (OEIS), June 2011 (NSF 2011) provides guideline noise criteria for sea turtle behavioural responses, as presented in Table 7. Also included in the table is criteria for increased behavioural response from McCauley et al. (2000a)[7].

Table 7: Sea turtle guideline criteria

Response	$L_{p,rms}$ (dB re 1 µPa)
Behavioural	166
Turtles (increased response)	175 dB re 1µPa

5.0 METHODOLOGY

5.1 Modelling overview

There is no defined international standard for the prediction or underwater propagation. However, a number of established analytical methods are representative of current industry practice and are routinely used for impact assessment purpose. These methods have been implemented in the proprietary dBSea software to produce noise contours which show the distribution of levels around a source of noise.

It should be noted that modelling of underwater noise can be are highly sensitive to input parameters. Also, while the methods provide high accuracy for a specific environmental condition, in practice, propagation is highly variable and sensitive to temporal and spatial variations in environmental conditions (in contrast to the to the water condition simplifications which are necessary for practical modelling purposes).

5.2 Model input parameters

To predict underwater noise levels, the following factors have been considered:

- Source noise level spectra based on in-water measurement or other suitable reference data, as provided by Advisian.
- Source locations and depths as provided by Advisian
- The noise levels are calculated using a dBSea propagation solvers. The particular solvers used for each scenario are outlined in the relevant sections below. A description of solvers can be found in Appendix D.

[5] NSF 2011 provides conservative safety radius of 180 dB re 1 µPa above which TTS or PTS is considered possible, however specific threshold criteria are not defined.

[6] Reference detail are required from Advisian

[7] Reference detail are required from Advisian

- Bathymetry of the area as provided by Advisian (9 second longitude grid spacing, ~ 250mx250m)
- The yearly average sound speed profile variations with depth as provided by Advisian. Details and discussion of the sound speed profile are provided in Appendix E.
- Seafloor/seabed sediment properties as provided by Advisian (map in Appendix F). Common to all modelling scenarios.

For this report, three different modelling scenarios have been considered, each involving different sources, geographic locations and environmental inputs. Each scenario is discussed in greater detail in the following sections.

5.3 Scenario 1a – FPU installation

For this study, FPU installation refers to piling activity associated with the construction of mooring anchors for the FPU.

5.3.1 Piling details

The mooring arrangement drawing provided by Woodside[8] shows 20 anchor piles positioned around the FPU site.

Details of the piling properties, as provided by Woodside, are presented in Table 8. Installation details (strike rate, number of blows) has been provided by Woodside, as determined by a piling drivability assessment.

Table 8: Piling details

Parameter description	Value
Pile length	60 m
Pile diameter	5 m
Wall Thickness	50 mm
Material	Steel
Water depth	~950 m
Installation depth below sea floor (total driven depth)	60 m
Installation type	Impact
Installation rate	1 pile per day
Total blows per pile	2752 (case #1)

5.3.2 Source levels

Piling noise level predications in underwater environments are commonly made on the basis of measured near-field source levels of similar piling operations (operations that have used comparable pile sizes, pile types and in similar environments). A commonly used source for reference piling noise levels is the CALTRANS *Compendium of Pile Driving Sound Data*[9] (CALTRANS). However, following a

[8] Woodside drawing reference 195369-MA-GAS-015.01 (rev 00)

[9] The document California Department of Transportation's document 'Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish' (referred to as CALTRANS) Appendix I, *Compendium of Pile Driving Sound Data*, provides a summary of measured underwater sound levels for a variety of pile driving situations.

review of CALTRANS and other available literature, no suitable measured noise level data corresponding to the specific configuration proposed could be found.

For this study, reference has been made to the South Australia Pile Driving Guidelines[10] (SA piling guidelines). While this document does not provide specific details of measured piling noise data, it does provide guidance on the typical range of levels. The SA piling guidelines state that '*Typical source levels range from SEL 170–225 dB re 1 µPa²·s for a single pulse….*' For this study, the SEL maximum value of the SA piling guidelines range has been used to represent piling associated with the FPU installation on the basis that the proposed pile size is at the upper end of the typical pile diameter size range[11]. It should be noted there can be significant variation between piling noise level measurements, even when measured at the same site (as a result of poor hammer strikes for example) so the maximum values have been referenced to account for the potential upper emissions of the proposed piling operations.

Source noise levels and other piling details used in this underwater noise modelling scenario are presented in Table 9. The RMS noise levels in Table 9 have been estimated based on analysis of the measured data provided in CALTRANS.

Modelling the sound propagation of peak noise levels requires complex numerical methods that take into account multipath, multi-component (time, frequency, phase etc) interference effects from the seafloor, sea surface and other propagation variables. Such methods require significant computation power and are generally not suited for practical use due to the significant processing times required. Alternative methods that can estimate the $L_{p,pk}$ levels based on the SEL have been developed to overcome these issues. Such methods typically overestimate the $L_{p,pk}$ and are therefore considered to be conservative. For this study, a simple linear regression method outlined in Lippert et. Al. (2015) has been used to estimate the $L_{p,pk}$ level based on the received SEL level, as calculated in the dBSea model. Since the estimated $L_{p,pk}$ level varies with range, a single figure has not been shown in the source levels in Table 9.

Figure 3 shows a plot of the 1/3 octave levels for the source (SEL values shown). The source spectrum is based on in-water measurements of impact driven steel piles[12] between 31.5Hz – 20kHz, scaled to the levels provided in Table 9.

Table 9: Broadband source levels – Impact piling

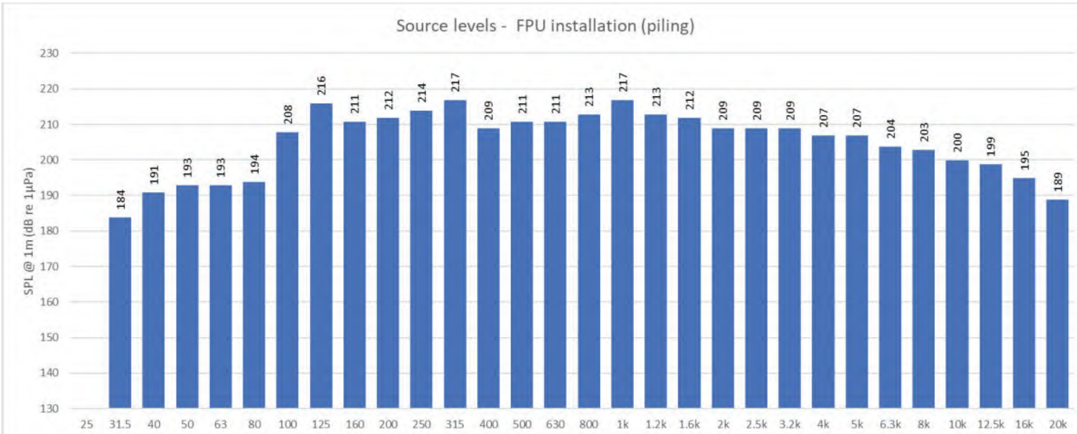
Type	Size and Method	Source Levels (@ 1m)		
		Peak	$L_{p,rms}$, (dB re 1µPa)	$SEL_{(single\ strike)}$, (dB re 1µPa²)
Anchor pile	Impact driven 5000mm steel	See discussion above	235	225

[10] South Australian Department of Planning, Transport and Infrastructure (DPTI), South Australia Pile Driving Guidelines, November 2012, Document: # 4785592

[11] Pile noise source estimates are supported by analysis of the available large pile data in CALTRANS and reference to other publicly available studies (e.g. Barossa Area Development OPP - www.nopsema.gov.au/assets/OPPs/A598152.pdf)

[12] ITAP –Institut für technische und angewandte Physik GmbH: 'Spektren der Vibrationsramme beim Umspannwerk' (2011)

Figure 3: 1/3 Octave spectral source levels – Impact piling (per strike)



5.3.3 Source locations

The location coordinates for the noise sources and the assumed source depth are provided in Table 14. The source depth is based on 0m pile penetration on the basis that this would represent a worst-case scenario in terms of noise propagation.

For impact assessment purposes, a single representative pile location only (pile #10) has been considered in the noise model. On the basis that the environmental conditions are similar at each pile location, the results (threshold distances) are considered to be representative for all pile locations i.e. derived threshold distances will be the same for each pile with the subject pile location representing the origin.

Table 10: Source locations and depths

Source description	MGA 94 coordinates (Zone 50K)		Modelling Source Depth
	Easting (X)	Northing (Y)	
Impact piling (pile #10)	107832.5	7792069.4	880 m

5.3.4 Underwater modelling parameters

The dbSea modelling software allows various input parameters to be set, based on the specific requirements and limitations of the modelling scenarios. A summary of the key parameter settings for the FPU installation scenario is presented in Table 11.

The maximum model distance was determined using a simplified cylindrical spreading model to estimate the noise levels and then calculate the maximum distance from the source to the lowest threshold level contour.

The frequency range considered is dictated by the range provided in the source data.

The cross over frequency was determined by considering guidance provided in the dBSea documentation (see Appendix D and through sensitivity analysis carried out during preliminary model runs.

Table 11: Key modelling parameters – Scenario 1a

Propagation Solver Configuration	
Maximum model distance	100 km
Frequency Range	31.5Hz – 20kHz
Azimuthal Increment	4.5^{o} (80 radials)
Crossover frequency	615Hz
Low Frequency Solver	dBSeaPE
High Frequency Solver	dBSeaRay

5.3.5 Seabed geoacoustic properties

Information provided in the benthic substrate map (see Appendix F) is limited to a single geoacoustic seabed type. This simplified data provides no information with respect to the presence of shallow layer structures or ocean floor strata. As such, the influence of any complicated sub-surface characteristics has not been evaluated in the model. Review of the benthic substrate map indicates that the sea bed in the vicinity of FPC location is described as 'mud and calcareous clay'. This has been modelled as a halfspace due to insufficient information on shallow layered structures.

This substrate description has been used in in conjunction with literature information on seafloor geoacoustics[13] to determine the properties shown in Table 16.

Table 12: Geoacoustic properties for Scenario 1

Sediment Description	**Thickness (m)**	ρ (kg/m^3)	c_p (m/s)	α_p (dB/λ)
Clay	Halfspace	1500	1500	0.2

5.4 Scenario 1b – FPU operations

5.4.1 Source levels

Noise source data has been provided by Advisian. Broadband source noise levels used in this underwater noise modelling scenario are presented in Table 13. Figure 4 shows a plot of the corresponding 1/3 octave levels for the sources. Note that source data for FPU operations is limited to a frequency range of 31.5 Hz to 2.5kHz. Modelling for the FPU operations scenario is accordingly limited to this range only.

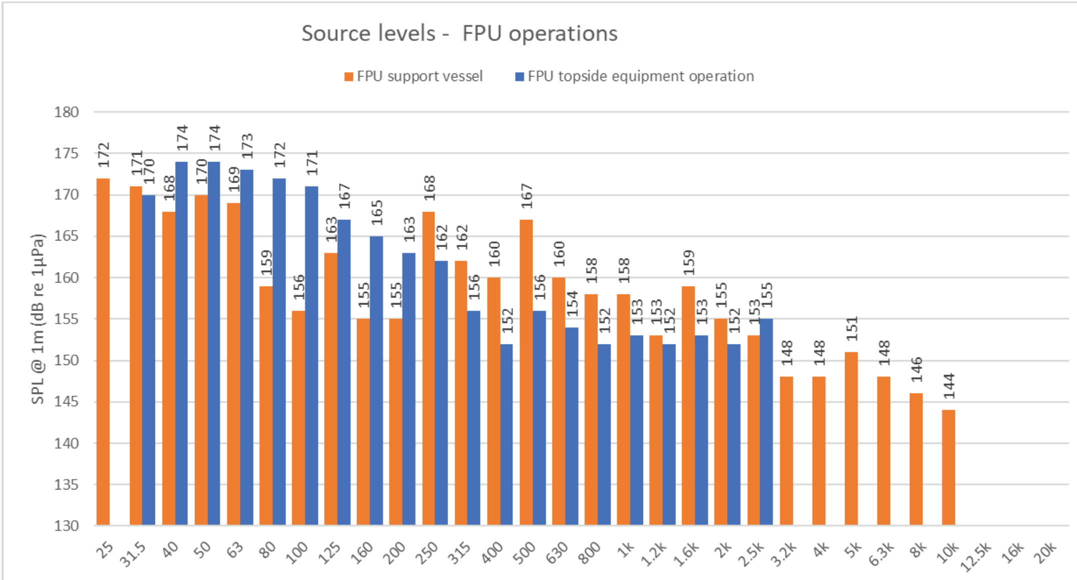
Table 13: Broadband source levels for noise prediction – Scenario 1b

Source description	**Details**	$L_{p,rms}$ **@1m (dB re 1 µPa)**
FPU	Stationary moored, typically FPU topside equipment operating. Data derived from Erbe et al [14] (50^{th} percentile data used) as directed by Advisian.	180

[13] Hamilton, E. L. (1980). Geoacoustic modelling of the sea floor. The Journal of the Acoustical Society of America, 68(5), 1313-1340.

Source description	Details	$L_{p,rms}$ @1m (dB re 1 µPa)
Support vessel	Data derived from measured levels of the *Setouchi Surveyor* (Hannay et al. 2004) as directed by Advisian	186

Figure 4: 1/3 Octave spectral source levels - FPU operations



5.4.2 Source locations

The location coordinates for the noise sources and the assumed source depth location are provided in Table 14.

Table 14: Source locations and depths

Source description	UTM coordinates (MGA94)		Modelling Source Depth
	Easting (X)	Northing (Y)	
FPU	106450	7792300	5 m
Support vessel	106450	7792500	5 m

5.4.3 Underwater modelling parameters

For the FPU operation scenario, the key parameter settings presented in Table 15 have been used for modelling in dbSea.

Maximum model distances, evaluation frequency ranges and solver cross-over frequency have been determined based on the methodologies described in Section 5.3.4.

[14] Erbe, C., McCauley, R., McPherson, C., & Gavrilov, A. (2013). Underwater noise from offshore oil production vessels. *The Journal of the Acoustical Society of America*, *133*(6), EL465-EL470.

Table 15: Key modelling parameters – Scenario 1b

Propagation Solver Configuration	
Maximum model distance	100 km
Frequency Range	31.5Hz – 2.5kHz (limited by source data)
Azimuthal Increment	3.6^{o}
Crossover frequency	615kHz
Low Frequency Solver	dBSeaPE
High Frequency Solver	dBSeaRay

5.4.4 Seabed geoacoustic properties

As the FPU installation and FPU operations activities occur in the same localised area, benthic substrate data and, consequentially, dbSea modelling parameters, are common for the two scenarios, with the same shallow surface layer limitations described in Section 5.3.5. These geoacoustic properties are repeated in Table 16 for convenience.

Table 16: Geoacoustic properties for Scenario 1

Sediment Description	**Thickness (m)**	ρ (kg/m^3)	c_p (m/s)	α_p (dB/λ)
Clay	Halfspace	1500	1500	0.2

5.5 Scenario 2 – Pipelay vessel operations

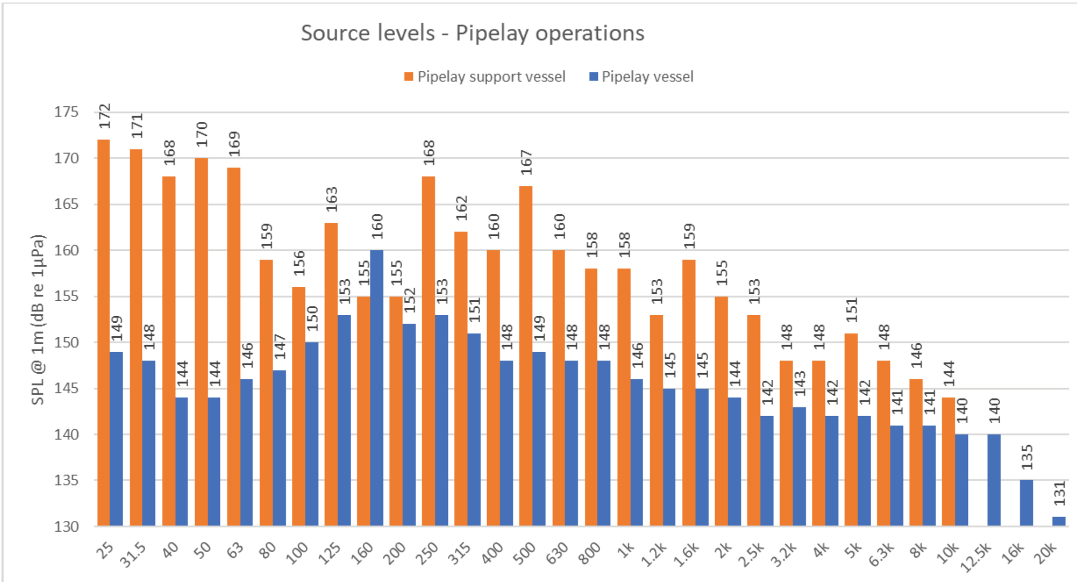
5.5.1 Source levels

Noise source data has been provided by Woodside. Broadband source noise levels used in this underwater noise modelling scenario are presented in Table 17. Figure 5 shows a plot of the 1/3 octave levels. Note that source data for support vessel operation is limited to a frequency range of 31.5 Hz to 10kHz. Modelling for the pipelay vessel operation scenario is accordingly limited to this range only.

Table 17: Broadband source levels for noise prediction – Scenario 1b

Source description	**Details**	**$L_{p,rms}$ @1m (dB re 1 µPa)**
Pipelay vessel	Data derived from measured levels of the *Deep Orient*. Length 135 m, Breadth – 27m, Draft 6.85m. Source data based on dynamic positioning in calm seas as directed by Advisian.	168
Support vessel	Data derived from measured levels of the *Setouchi Surveyor* (Hannay et al. 2004) as directed by Advisian.	186

Figure 5: 1/3 Octave spectral source levels - Pipelay operations



5.5.2 Source locations

The location coordinates for the noise sources and the assumed source depth location are provided in Table 18.

Table 18: Source locations and depths

Source description	MGA 94 coordinates (Zone 50K)		Modelling Source Depth
	Easting (X)	Northing (Y)	
Pipelay vessel	468850	7749658	5 m
Support vessel	468850	7749758	5 m

5.5.3 Underwater modelling parameters

For the pipelay vessel operation scenario, the key parameter settings presented in Table 19 have been used for modelling in dbSea.

Maximum model distances and evaluation frequency ranges have been determined based on the methodologies described in Section 5.3.4.

Evaluation of pipelay vessel operation noise has been conducted using dbSeaModes normal mode solver. Normal mode calculation techniques are a fundamental concept of underwater noise modelling and have been verified to be appropriate for use in shallow water environments with homogenous bathymetry and sediment composition[15]. Bathymetry and benthic substrate data in the 5km maximum model distance area have minor variations making dbSeaModes an appropriate solver for the subject site. Further information on dBSea solvers provided in Appendix D.

[15] Pedersen R., Keane, M. (2016), V*alidation of dBSea, Underwater Noise Prediction Software. Pile Driving Focus*

Table 19: Key modelling parameters – Scenario 2

Propagation Solver Configuration	
Maximum model distance	5 km
Frequency Range	25Hz – 10kHz
Azimuthal Increment	1.2^o
Solver	dBSeaModes

5.5.4 Seabed geoacoustic properties

Review of the benthic substrate map indicates that the sea bed in the vicinity of FPC location is described as 'gravel.' This substrate description has been used in in conjunction with literature information on seafloor geoacoustics[16] to determine the properties shown in Table 20. As per Section 5.3.5 this has been modelled as a halfspace due to insufficient information on shallow layered structures.

Table 20: Geoacoustic properties for Scenario 1

Sediment Description	**Thickness (m)**	ρ (kg/m^3)	c_p (m/s)	α_p (dB/λ)
Gravel	halfspace	1800	2000	0.6

6.0 MODELLING RESULTS

The following sections outline the results of the noise modelling for each scenario. The results are split into tables based on the species and/or threshold type. The results are presented in the form of a distance from the source to the predicted noise level contour with a value equal to the threshold of interest for each species and type of effect (referred to as the *threshold contour*).

Selected noise contour plots for each scenario are presented in Appendix G. The noise level contours represent the maximum predicted noise level across all water depths at each point (as opposed to presenting the predicted noise level for a single constant depth). This is often referred to as a 'maximum over depth' result.

The distances presented in the tables below are stated in terms of a R_{max} (the maximum radial distance in any direction from the source to the threshold contour) and the R_{95} (the radius of the circular area, equivalent to 95% of the total area encompassed by the threshold contour).

6.1 Scenario 1a – FPU installation (anchor piling)

Table 21 through Table 28 present the modelling results for the FPU installation scenario (anchor piling).

[16] Hamilton, E. L. (1980). Geoacoustic modelling of the sea floor. The Journal of the Acoustical Society of America, 68(5), 1313-1340.

Table 21: SEL_{cum} threshold distances (maximum over depth) - Impulsive noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	168 re 1µPa^2.s	99.44	90.77
Mid-Frequency Cetaceans	170 re 1µPa^2.s	7.75	7.36
High-Frequency Cetaceans	140 re 1µPa^2.s	42.91	39.24

Table 22: $SEL_{(cum)}$ threshold distances (maximum over depth) - Impulsive noise PTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	183 re 1µPa^2.s	34.34	29.13
Mid-Frequency Cetaceans	185 re 1µPa^2.s	1.14	1.02
High-Frequency Cetaceans	155 re 1µPa^2.s	17.49	14.85

Table 23: $L_{p,pk}$ threshold distances (maximum over depth) - Impulsive noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	213 re 1µPa	0.751	0.440
Mid-Frequency Cetaceans	224 re 1µPa	0.468	0.282
High-Frequency Cetaceans	196 re 1µPa	1.512	1.195

Table 24: $L_{p,pk}$ threshold distances (maximum over depth) - Impulsive noise PTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	219 re 1µPa	0.59	0.35
Mid-Frequency Cetaceans	230 re 1µPa	0.31	0.19
High-Frequency Cetaceans	202 re 1µPa	0.88	0.74
Turtle	232 re 1µPa	0.26	0.17

Table 25: $L_{p,rms}$ threshold distances (maximum over depth) – Impulsive noise behavioural response

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Marine mammals	160 dB re 1µPa	38.25	33.80
Turtles	166 dB re 1µPa	24.61	21.85
Turtles (increased response	175 dB re 1µPa	11.11	10.36

Table 26: Fish and sea turtle $SEL_{(cum)}$ threshold distances (maximum over depth) – Impulsive noise mortality and potential mortal injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: no swim bladder (particle motion detection)	219 re $1\mu Pa^2.s$	0.75	0.58
Fish: swim bladder is not involved in hearing (particle motion detection)	210 re $1\mu Pa^2.s$	2.39	2.28
Fish: swim bladder involved in hearing (primarily pressure detection)	207 re $1\mu Pa^2.s$	3.50	3.28
Sea turtles	210 re $1\mu Pa^2.s$	2.39	2.28
Eggs and larvae	210 re $1\mu Pa^2.s$	2.39	2.28

Table 27: Fish and sea turtle $SEL_{(cum)}$ threshold distances (maximum over depth) - Impulsive noise recoverable injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: no swim bladder (particle motion detection)	216 re $1\mu Pa^2.s$	0.99	0.89
Fish: swim bladder is not involved in hearing (particle motion detection)	203 re $1\mu Pa^2.s$	9.62	9.12
Fish: swim bladder involved in hearing (primarily pressure detection)	203 re $1\mu Pa^2.s$	9.62	9.12
Sea turtles	-		
Eggs and larvae	-		

Table 28 Fish $SEL_{(cum)}$ threshold distances (maximum over depth) - Impulsive noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
All fish	186 re $1\mu Pa^2.s$	34.06	27.86

6.1.1 Results summary – Marine mammals

The TTS and PTS cumulative exposure (SEL_{cum}) thresholds distances represent a boundary, outside of which, there is predicted to be no significant risk of hearing impairment regardless of the duration a marine mammal is in the project vicinity. These thresholds distances are significantly greater than the thresholds distances for the peak pressure criteria.

If a marine mammal enters a cumulative exposure threshold zone, there is potential for the onset of TTS or PTS. How close the marine mammal gets to the piling determines how fast the cumulative exposure thresholds limits are reached. For this scenario, the low-frequency cetacean TTS threshold contour extends into the pygmy blue whale migration BIA, however this is not the case for the PTS threshold contour, as shown in Appendix G, Figure 8.

6.1.2 Results summary – Turtles

The R_{max} distance to the various threshold zone boundaries considered for turtles is as follows:

- Behavioural response -24.61 km (Table 25).
- Possible mortality and potential mortal injury - 2.395 km (Table 26)

6.1.3 Results summary – Fish

The greatest R_{max} distance to the various threshold contours, when considering all fish type, is as follows:

- Possible mortality and potential mortal injury – 3.50 km (see Table 26)
- Recoverable injury - 9.62 km (see Table 27)
- Temporary threshold shift - 34.06 km (see Table 28)

6.2 Scenario 1b – FPU operations

Table 29 through Table 31 present the modelling results for the FPU operations scenario (FPU topside equipment operating, and support vessel operating).

Threshold distances for PTS and TTS have not been presented on the basis that these effects are unlikely to occur in a real-world situation. To exceed the cumulative PTS or TTS threshold levels would necessarily require marine mammals to remain in vicinity of the vessel over a 24-hour period, which is unlikely. Furthermore, the model is based on a point source representation of the vessels so the predicted levels (and distances to the thresholds) are conservative estimates at close range, given the relatively large scale of the vessels.

Table 29: SPL threshold distances (maximum over depth) – Continuous noise behavioural response

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Marine mammals	120 dB re 1µPa	4.55	4.29
Turtles	166 dB re 1µPa	0.48	0.32
Turtles (increased response)	175 dB re 1µPa	0.23	0.18

Table 30: Fish $SEL_{(cum)}$ threshold distances (maximum over depth) – Continuous noise recoverable injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	170 re 1µPa^2.s	0.36	0.26

Table 31 Fish $SEL_{(cum)}$ threshold distances (maximum over depth) -Continuous noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	156 re 1µPa^2.s	0.78	0.48

6.2.1 Results summary – Marine mammals

The R_{max} distance to the behavioural response threshold contour for marine mammals is 4.55 km (Table 29).

The TTS and PTS effects on marine mammals are not a consideration this scenario, as discussed above.

6.2.2 Results summary – Turtles

The R_{max} distance to the behavioural response threshold contour for turtles is 0.48 km (Table 29).

6.2.3 Results summary – Fish

The greatest R_{max} distance to the various threshold zone boundaries, when considering all fish type, is as follows:

- Recoverable injury - 0.36 km (Table 30)
- Temporary threshold shift (TTS) - 0.78 km (Table 31)

6.3 Scenario 2 – Vessel operations

Table 32**Error! Reference source not found.** through Table 34 present the modelling results for the pipelay operations scenario (pipelay vessel and support vessel operating)

As was the case for scenario 1b, threshold distances for PTS and TTS have not been presented on the basis that these effects are unlikely to occur in a real-world situation.

Table 32: SLP threshold distances (maximum over depth) – Continuous noise behavioural response

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Marine mammals	120 dB re 1µPa	4.903	4.581
Turtles	166 dB re 1µPa	0.046	0.022
Turtles (increased response)	175 dB re 1µPa	<0.010	<0.010

Table 33: Fish $SEL_{(cum)}$ threshold distances (maximum over depth) – Continuous noise recoverable injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	170 re 1µPa^2.s	<0.010	<0.010

Table 34 Fish $SEL_{(cum)}$ threshold distances (maximum over depth) -Continuous noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	156 re 1µPa^2.s	0.097	0.063

6.3.1 Results summary – Marine mammals

The R_{max} distance to the behavioural response threshold contour for marine mammals is 4.903 km (Table 32). .

The TTS and PTS effects on marine mammals are not a consideration this scenario, as discussed in Section 6.2 above.

6.3.2 Results summary – Turtles

The R_{max} distance to the behavioural response threshold contour for turtles is 0.046 km (Table 32).

6.3.3 Results summary – Fish

The greatest R_{max} distance to the various threshold contours, when considering all fish types, is as follows:

- Recoverable injury - less than 10 m (Table 33)
- Temporary threshold shift (TTS) - 0.097km (Table 34)

7.0 SUMMARY

A study of underwater noise levels from the proposed Scarborough gas field development has been carried out to determine the areas over which marine fauna could be impacted. The study has considered three scenarios which represent the main noise generating activities associated with the development.

Noise modelling has been carried out using dBSea software. The model has taken into account various data inputs including the noise sources and locations, bathymetry data, sound speed profile data and seafloor properties. Suitable noise propagation solvers have been configured for each scenario.

There are no prescribed underwater noise criteria that apply to the project. To assist with the assessment of underwater noise impacts, reference has been made to noise level criteria from widely used scientific studies and international guidelines. These impact criteria sources have been nominated by the project marine ecologist.

The results of the noise modelling have been presented in the form of a distance from the various noise sources to the predicted noise level contour representing the particular threshold of interest.

APPENDIX A GLOSSARY OF TERMINOLOGY

dB	Decibel The unit of sound level. Expressed as a logarithmic ratio of sound pressure P relative to a reference pressure
Frequency	The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).
Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
$L_{p,pk}$	The peak instantaneous pressure level (un-weighted).
PTS	Permanent Threshold Shift (PTS) is the permanent loss of hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear.
R_{95}	The distance defined by the radius of the circular area that is equivalent to 95% of the total area encompassed by the threshold boundary contour.
R_{max}	The maximum radial distance in any direction from the source to the threshold contour boundary.
$L_{p,rms}$	Root Mean Square (RMS) is the equivalent continuous (time-averaged) sound level commonly referred to as the average level (period matches the event duration).
SEL	Sound exposure level (SEL) is the total sound energy of an event, normalised to an average sound level over one second. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels and temporal characteristics.
SEL_{cum}	The SEL_{cum} is the 'cumulative' sound energy of all events in a 24-hour period, normalised to an average sound level over one second.
TTS	Temporary Threshold Shift (TTS) is the temporary loss of hearing caused by sound exposure. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time. TTS in humans can be likened to the 'muffled' effect on hearing after being exposed to high noise levels such as at a concert. The effect eventually goes away, but the longer the exposure, the longer the threshold shift lasts. Eventually, the TTS becomes permanent (PTS).
Underwater noise	A sound that is unwanted by, or distracting to, the receiver underwater.

APPENDIX B BIA OVERLAP WITH MODELLED AREAS

Table 35: BIA overlap summary for modelled scenarios

Species	BIA type	Scenario 1a		Scenario 1b		Scenario 2	
		Partial	Full	Partial	Full	Partial	Full
Pygmy Blue Whale	Migration	✓	×	×	×	×	×
	Distribution	×	✓	×	✓	×	×
Humpback Whale	Migration	×	×	×	×	×	✓
Green Turtle	Internesting Buffer;Legendre Island Huay Island	×	×	×	×	✓	×
	Internesting buffer; Dampier Archipelago (islands to the west of the Burrup Peninsula)	×	×	×	×	×	✓
Flatback Turtle	Internesting buffer; Dixon Island	×	×	×	×	×	✓
	Internesting buffer; Intercourse Is	×	×	×	×	×	✓
	Internesting buffer; Dampier Archipelago (islands to the west of the Burrup Peninsula)	×	×	×	×	×	✓
	Internesting buffer; Legendre Is, Huay Is	×	×	×	×	×	✓
	Internesting buffer; Delambre Is	×	×	×	×	×	✓
	Internesting buffer; West of Cape Lambert	×	×	×	×	×	✓
Hawksbill Turtle	Internesting buffer; Rosemary Is	×	×	×	×	×	✓
	Internesting buffer; Dampier Archipelago (islands to the west of the Burrup Peninsula)	×	×	×	×	×	✓
	Internesting buffer; Delambre Is (and other Dampier Archipelago Islands)	×	×	×	×	×	✓
Loggerhead Turtle	Internesting buffer; Rosemary Island	×	×	×	×	×	✓
	Internesting buffer; Cohen Island	×	×	×	×	×	✓

APPENDIX C MARINE MAMMAL AUDITORY WEIGHTING FUNCTIONS

The following extract from the NOAA Technical Memorandum provides an industry referred explanation of marine mammal auditory weighting functions.

2.2 MARINE MAMMAL AUDITORY WEIGHTING FUNCTIONS

The ability to hear sounds varies across a species' hearing range. Most mammal audiograms have a typical "U-shape," with frequencies at the bottom of the "U" being those to which the animal is more sensitive, in terms of hearing (i.e. the animal's best hearing range; for example audiogram, see Glossary, Figure F1). Auditory weighting functions best reflect an animal's ability to hear a sound (and do not necessarily reflect how an animal will perceive and behaviorally react to that sound). To reflect higher hearing sensitivity at particular frequencies, sounds are often weighted. For example, A-weighting for humans deemphasize frequencies below 1 kHz and above 6 kHz based on the inverse of the idealized (smoothed) 40-phon equal loudness hearing function across frequencies, standardized to 0 dB at 1 kHz (e.g., Harris 1998). Other types of weighting functions for humans (e.g., B, C, D) deemphasize different frequencies to different extremes (e.g., flattens equal-loudness perception across wider frequencies with increasing received level; for example, C-weighting is uniform from 50 Hz to 5 kHz; ANSI 2011).

Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS onset thresholds expressed in the weighted SEL_{cum} [17] metric, which take into account what is known about marine mammal hearing (Southall et al. 2007; Erbe et al. 2016). The Finneran Technical Report (Finneran 2016) developed marine mammal auditory weighting functions that reflect new data on:

- Marine mammal hearing (e.g., Sills et al. 2014; Sills et al. 2015; Cranford and Krysl, 2015; Kastelein et al. 2015c)
- Marine mammal equal latency contours (e.g., Reichmuth 2013; Wensveen et al. 2014; Mulsow et al. 2015
- Effects of noise on marine mammal hearing (e.g., Kastelein et al. 2012a; Kastelein et al. 2012b; Finneran and Schlundt 2013; Kastelein et al. 2013a; Kastelein et al. 2013b; Popov et al. 2013; Kastelein et al. 2014a; Kastelein et al. 2014b; Popov et al. 2014; Finneran et al. 2015; Kastelein et al., 2015a; Kastelein et al. 2015b; Popov et al. 2015).

This reflects a transition from auditory weighting functions that have previously been more similar to human dB(C) functions (i.e., M-weighting from Southall et al. 2007) to that more similar to human dB(A) functions. These marine mammal auditory weighting functions also provide a more consistent approach/methodology for all hearing groups.

Upon evaluation, NMFS determined that the proposed methodology in Finneran 2016 reflects the scientific literature and incorporated it directly into this Technical Guidance (Appendix A) following an independent peer review (see Appendix C for details on peer review and link to Peer Review Report).

2.2.2 Marine Mammal Auditory Weighting Functions

Frequency-dependent marine mammal auditory weighting functions were derived using data on hearing ability (composite audiograms), effects of noise on hearing, and data on equal latency (Finneran 2016[18]). Separate functions were derived for each marine mammal hearing group (Figures 1 and 2).

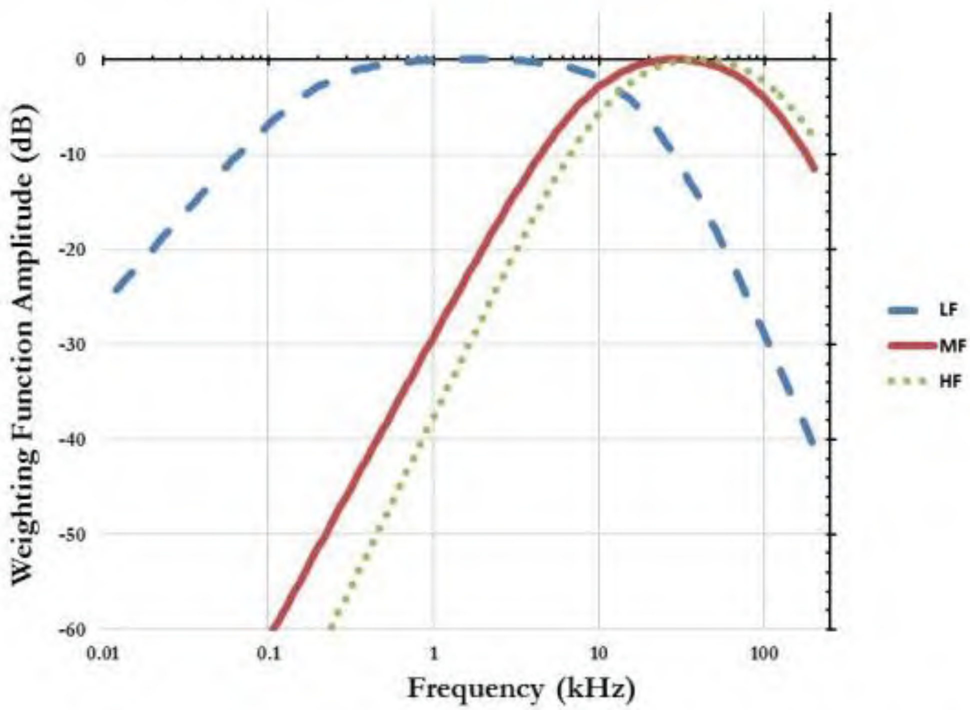


Figure 1: Auditory weighting functions for low-frequency (LF; dashed line), mid-frequency (MF; solid line), and high-frequency (HF; dotted line) cetaceans.

APPENDIX D PROPAGATION SOLVERS

Underwater acoustic propagation is commonly described mathematically by a partial differential called the "Helmholtz Wave Equation". The different solvers available in dBSea each employ various methods and approximations to yield a solution to the wave equation, i.e. the propagation loss. The propagation loss is used to make predictions of acoustic levels. As such each solver has specific scenarios of applicability.

The 3D levels predicted by dBSea are interpolated from 2D slices. All the solvers in dBSea can calculate propagation loss for range-dependent environments. A range-dependant is an environmental where parameters such as, bathymetry, sound speed and/or seabed geoacoustic properties, may vary in range away from the source. dBSea does not yet support elastic geoacoustic properties in the seabed. Approximations can be made where necessary to best derive equivalent fluid parameters to represent elastic seabed layers.

Table 36 provides a summary types of environment where dBSea's numerical solvers are applicable, in general the table follows a similar form to that presented in standard underwater acoustic textbooks[17].

Table 36: Applicability of dBSea solvers types

	Shallow water		**Deep water**	
Propagation Solver Type	**Low Frequency**	**High Frequency**	**Low Frequency**	**High Frequency**
Parabolic Equations	●	◍	◍	◍
Normal Modes	●	◍	◍	◍
Rays	○	◍	●	●

Symbol Key:

●	Applicable solver type, fit for purpose and widely used and numerically benchmarked
◍	Applicable solver type, however there may be limitation due to excessive computation time or accuracy
○	None applicable

Shallow water and deep water environments are distinguished by the extent that acoustic waves interact with the seabed. Acoustic wave interact significantly with the seabed in shallow water environments. Typical transition water depths are 50 m – 100 m. Similarly, the cross over between high and low frequencies is not a precisely defined and is also dependent on the water depth. Typical cross over frequencies would be between 100 – 500 Hz, this frequency can be estimated using the equation below,

$$f_{crossover} = 10 * \frac{c_w}{H}$$

Where c_w is the water column wave speed and H is the thickness of the duct or water column.

The dBSea solvers have been validated and benchmarked against accepted analytical solutions. Information on the benchmarking results can be found on dBSea's website[18]. A description of the three main

[17] Etter, P. C. (2013). *Underwater Acoustic Modelling and Simulation*. CRC Press.

[18] http://www.dbsea.co.uk/validation/

propagation solvers is presented below. Refer to textbooks like Jensen et al. (2011)[19] for further detailed information numerical implementations and description of each solver type.

D1 dBSeaModes

dBSeaModes is a propagation solver is finite difference implementation of a normal mode algorithm. The solver can be used in range-dependent scenarios where there is variation in bathymetry, sound speed and/or seabed geoacoustic properties in range away from the source. Range dependent calculations are based on the outward propagating adiabatic approximation. The adiabatic method is not applicable to scenarios where significant range-dependant variations in parameters occur. Care must be taken in applying dBSeaModes to range-dependent environments.

D2 dBSeaPE

dBSea's parabolic equation solver (dBSeaPE) is a finite difference implementation of the parabolic equation method. Parabolic equation methods are the preferred low frequency solvers for range-dependent scenarios and have been used extensively in research and commercial applications for underwater propagation modelling. The solver can incorporate range-dependent environmental parameters in bathymetry, sound speed and seabed geoacoustic properties into the propagation loss predictions.

The algorithm is implemented by calculating an initial starting sound field, which is source depth dependent, and is stepped out in range from the source using the PE method. dBSeaPE will use the dBSeaModes solver to generate the starting field. If the modal solver fails to converge to a results Greene's starter is used. If the modal starter fails, the software will prompt with a message 'PE solver used analytical starter', which indicates that the software is using an analytical starter (i.e. Greene's starter) for the specified frequencies and slice numbers.

D3 dBSeaRay

Ray tracing methods are family of numerical solvers that use a frequency approximation to reduce the Helmholtz equation to a form that can be solved numerically. The ray solver forms a solution by tracing rays from the source out into the sound field. A large number of rays leave the source covering a range of angles, and the sound level at each point in the receiving field is calculated by combining the components from each individual ray.

When multiple seafloor layers are present, rays are not split and traced into the seafloor. A complex reflection coefficient is calculated which is representative of the underlying layers, and this coefficient is applied to the ray at the point of seafloor reflection.

dBSeaRay is used for time domain calculations. Instead of returning a transmission loss at each point in the slice, a list of ray arrivals is returned (with separate entries for each frequency). These arrivals lists can be used to calculate the effective time series at each point in the slice, which is then used to calculate peak, peak to peak, and frequency band SEL levels.

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[19] Jensen, F. B., Kuperman, W. A., Porter, M. B., & Schmidt, H. (2011). Computational ocean acoustics. Springer Science & Business Media.

APPENDIX E WATER COLUMN SOUND SPEED PROPERTIES

Due to the sparse environmental data in deep oceans, a single representative sound speed profile (SSP) has been applied for the entire area considered in the modelling. The average SSP was calculated from temperature and salinity data for Scarborough field, as provided by Woodside. No data was provided for depths below 1000m so a constant sound profile was been assumed below this depth, as directed by Advisian. The resultant SSP is shown in Figure 6 (full depth profile) and Figure 7 (detail of upper 100m).

The yearly average SPP profile in Figure 6 shows no significant surface duct or deep sound channel for the depths considered. It is noted that these SSP characteristics may be more pronounced at particular times of year, however seasonal SPP data for the areas was not provided for this assessment.

Figure 6: Average sound speed profile

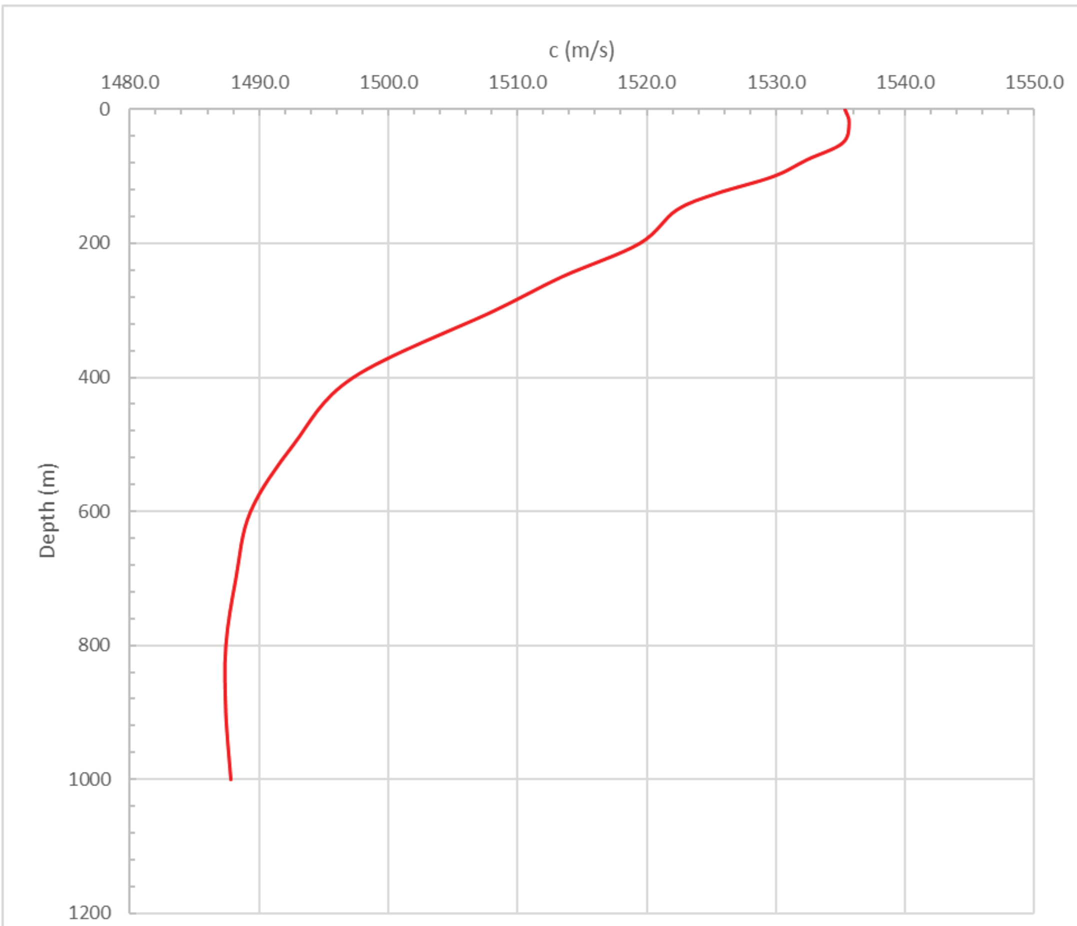
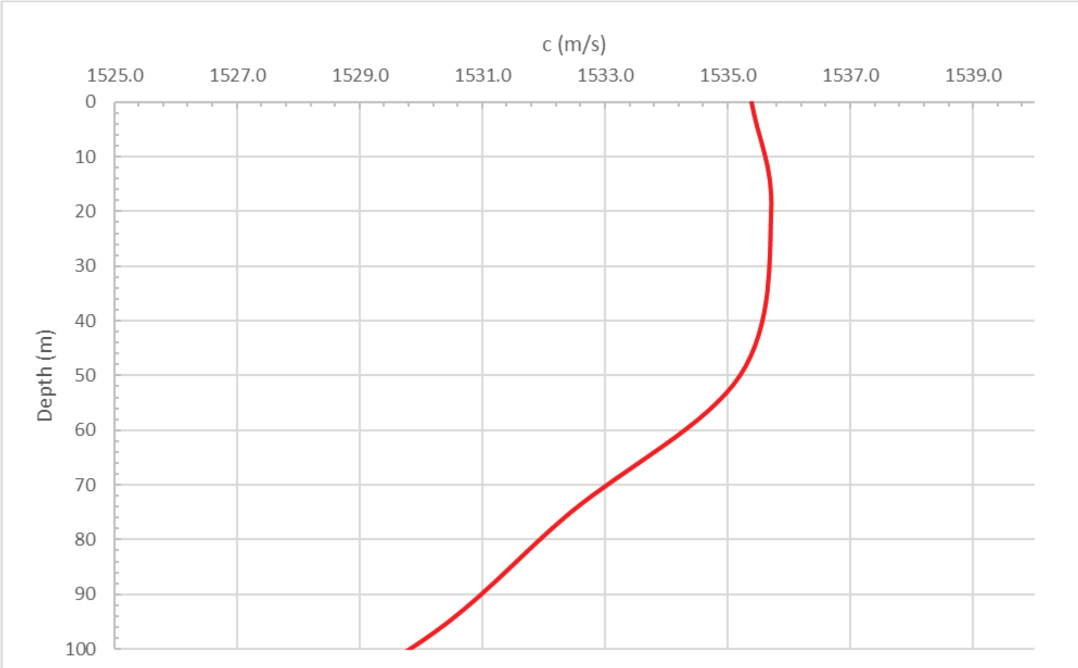
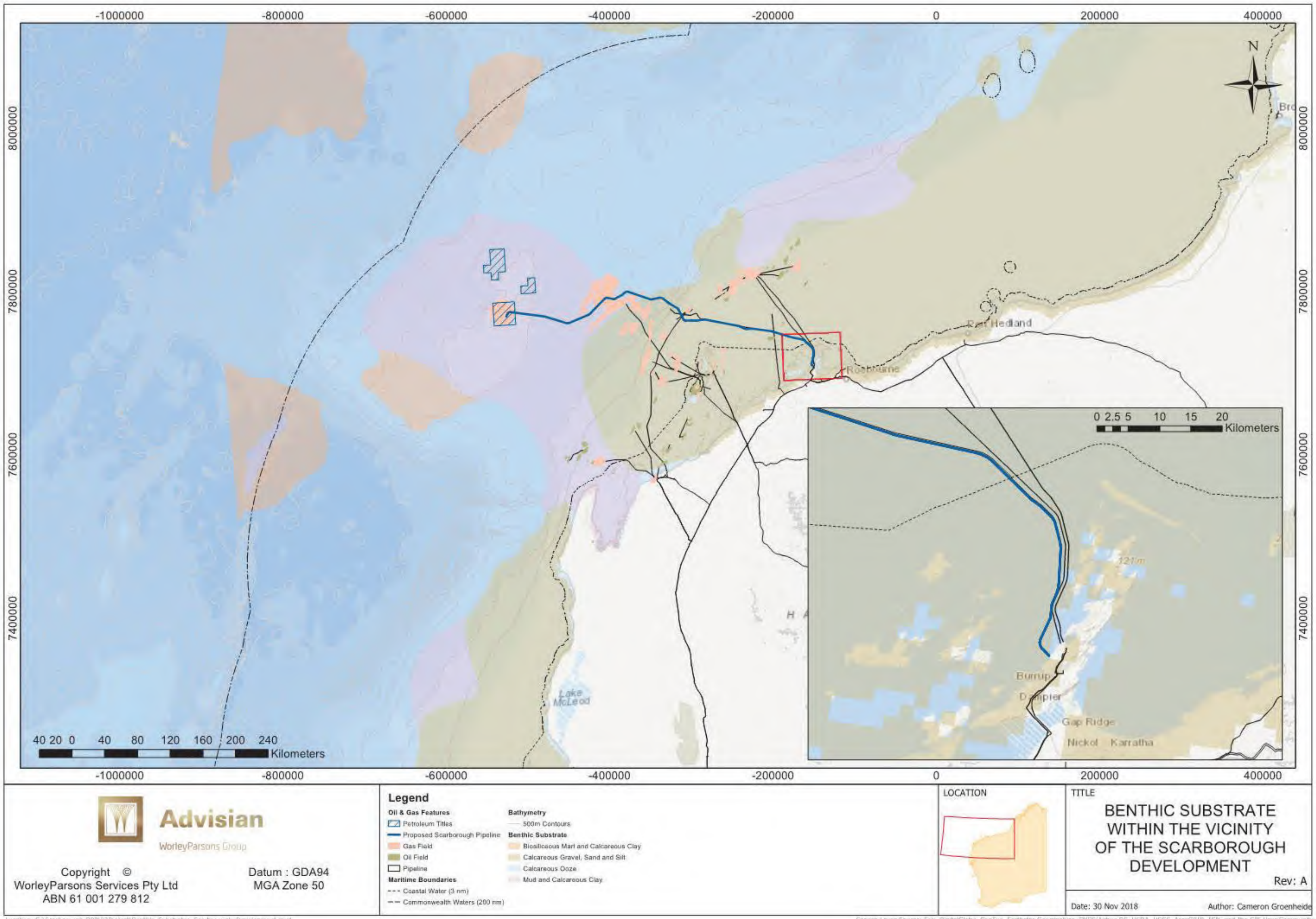


Figure 7: Average sound speed profile – upper 100m



APPENDIX F SEA BED PROPERTIES



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Lake McLeod
Burrup
Dampier
Gap Ridge
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Karratha
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40 20 0 40 80 120 160 200 240 Kilometers
Advisian
WorleyParsons Group
Copyright © WorleyParsons Services Pty Ltd ABN 61 001 279 812
Datum : GDA94 MGA Zone 50
Legend
Oil & Gas Features
Petroleum Titles
Proposed Scarborough Pipeline
Gas Field
Oil Field
Pipeline
Maritime Boundaries
Coastal Water (3 nm)
Commonwealth Waters (200 nm)
Bathymetry
500m Contours
Benthic Substrate
Biosiliceous Marl and Calcareous Clay
Calcareous Gravel, Sand and Silt
Calcareous Ooze
Mud and Calcareous Clay
LOCATION
TITLE
BENTHIC SUBSTRATE WITHIN THE VICINITY OF THE SCARBOROUGH DEVELOPMENT
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APPENDIX G PREDICTED UNDERWATER NOISE CONTOURS

G1 Scenario 1a

Figure 8: Noise contour map - Scenario 1a $SEL_{(cum)}$ unweighted (maximum over depth) – Marine mammal PTS thresholds

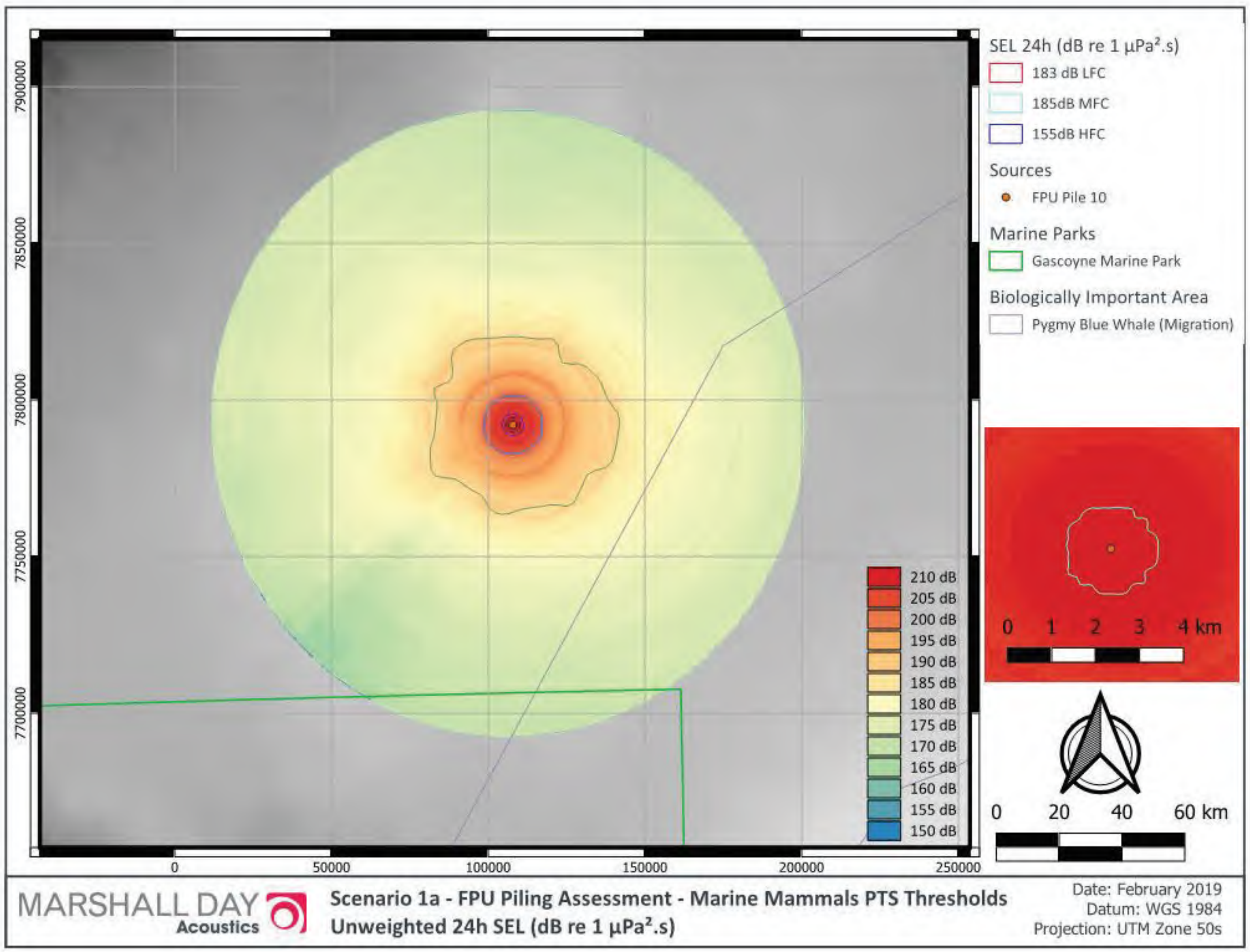


Figure 9: Noise contour map - Scenario 1a $SEL_{(cum)}$ unweighted (maximum over depth) – Fish and marine turtle thresholds

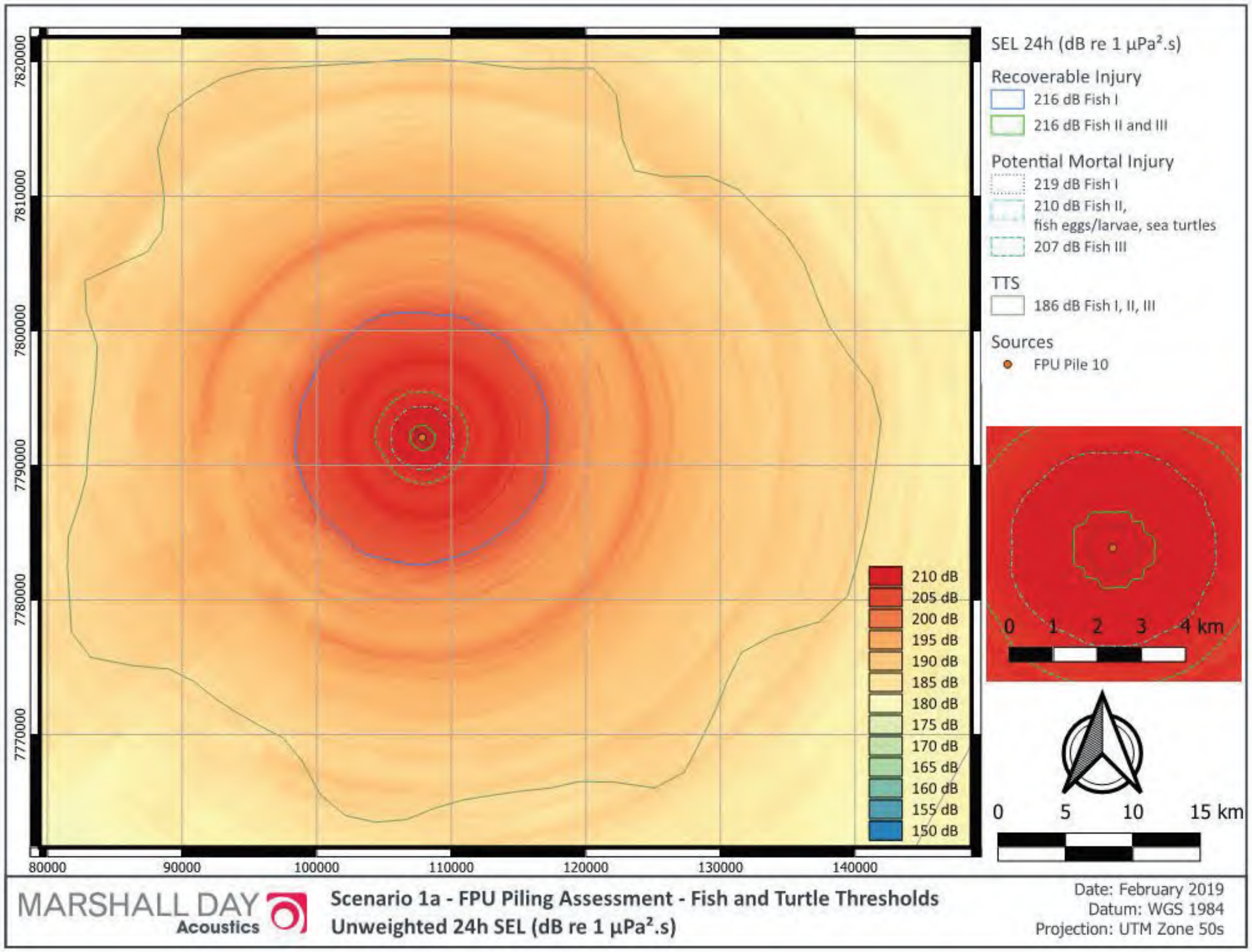
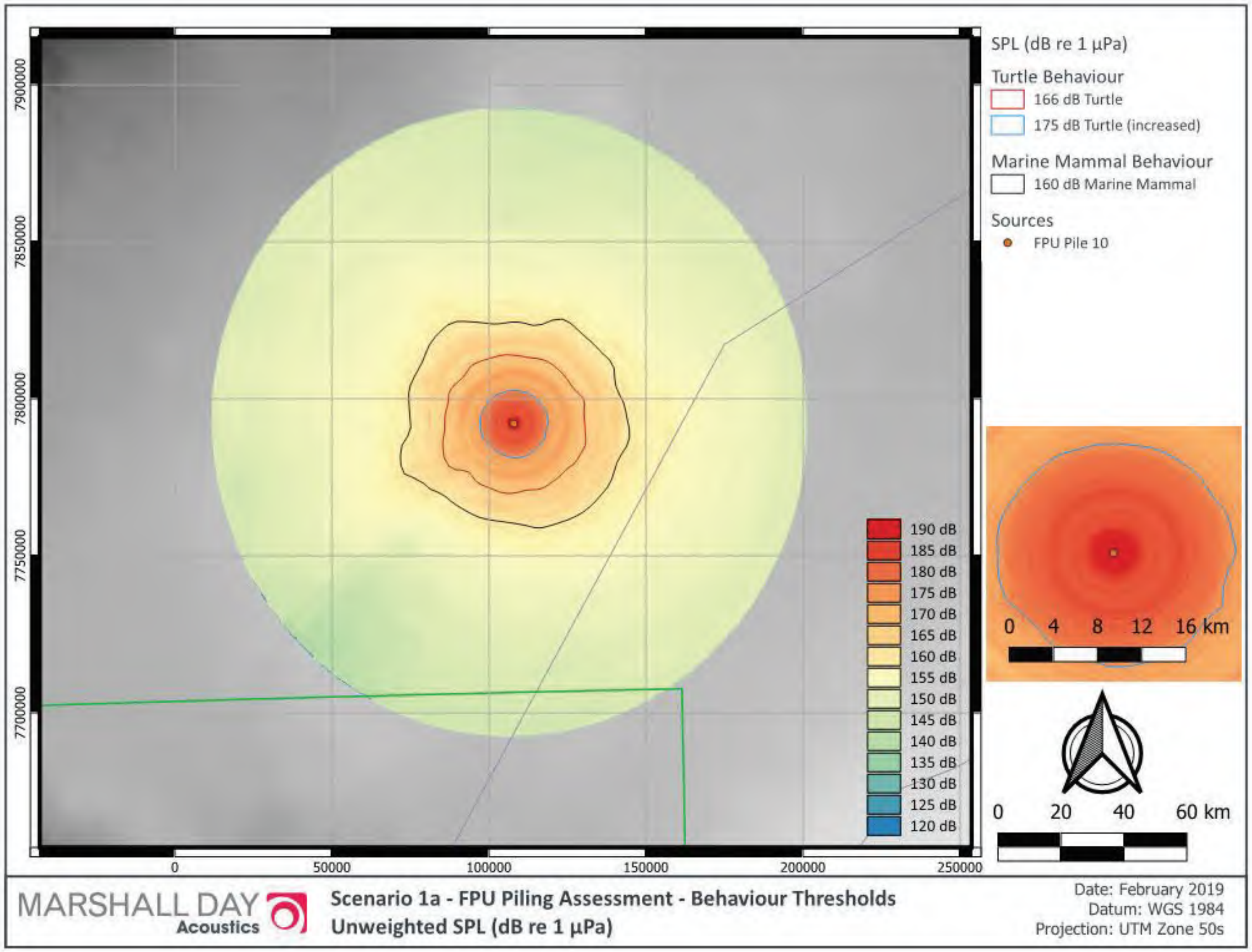


Figure 10: Noise contour map - Scenario 1a $L_{p,rms}$ (un-weighted) maximum over depth – Behavioural thresholds



G2 Scenario 1b

Figure 11: Noise contour map - Scenario 1b $SEL_{(cum)}$ (unweighted) maximum over depth

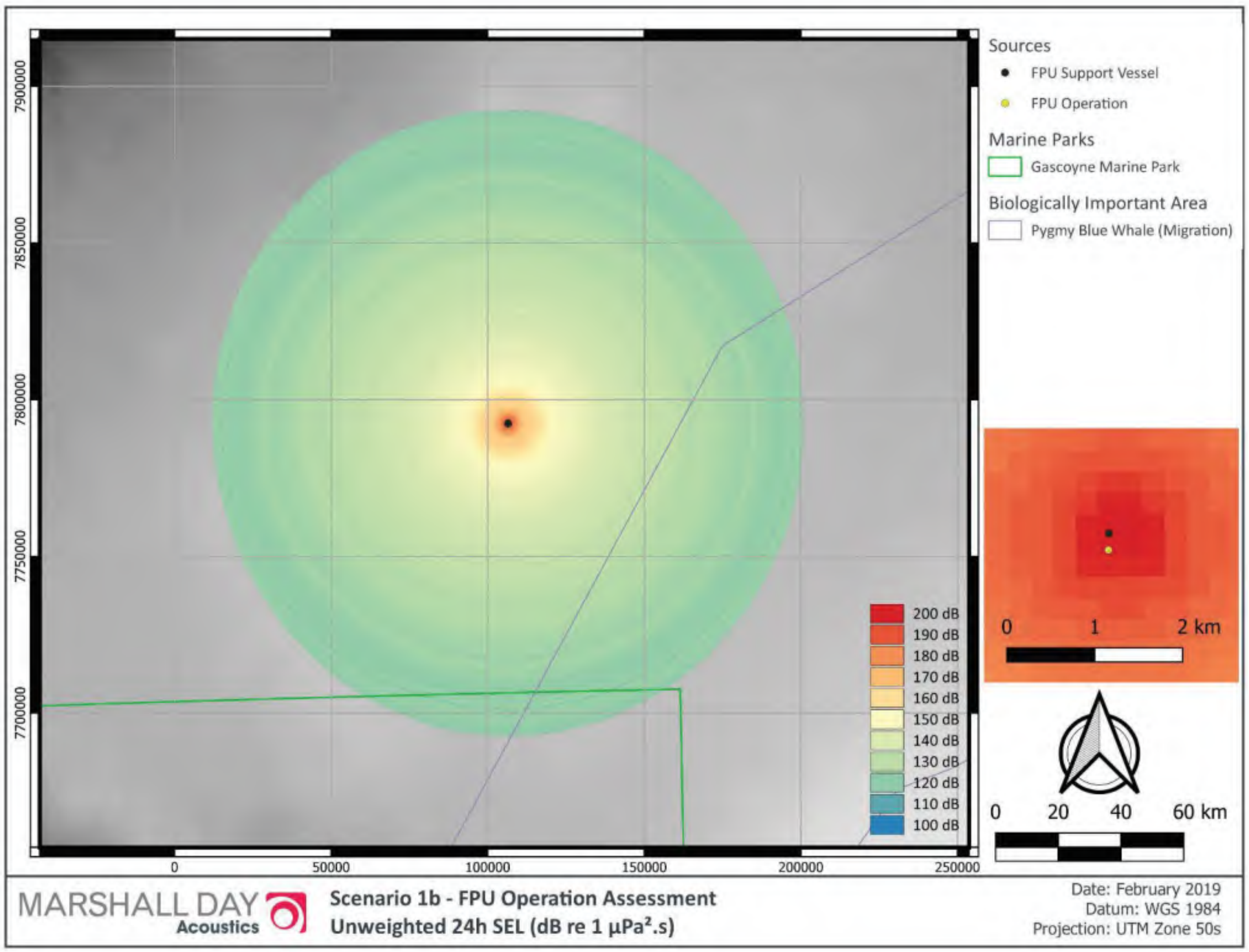
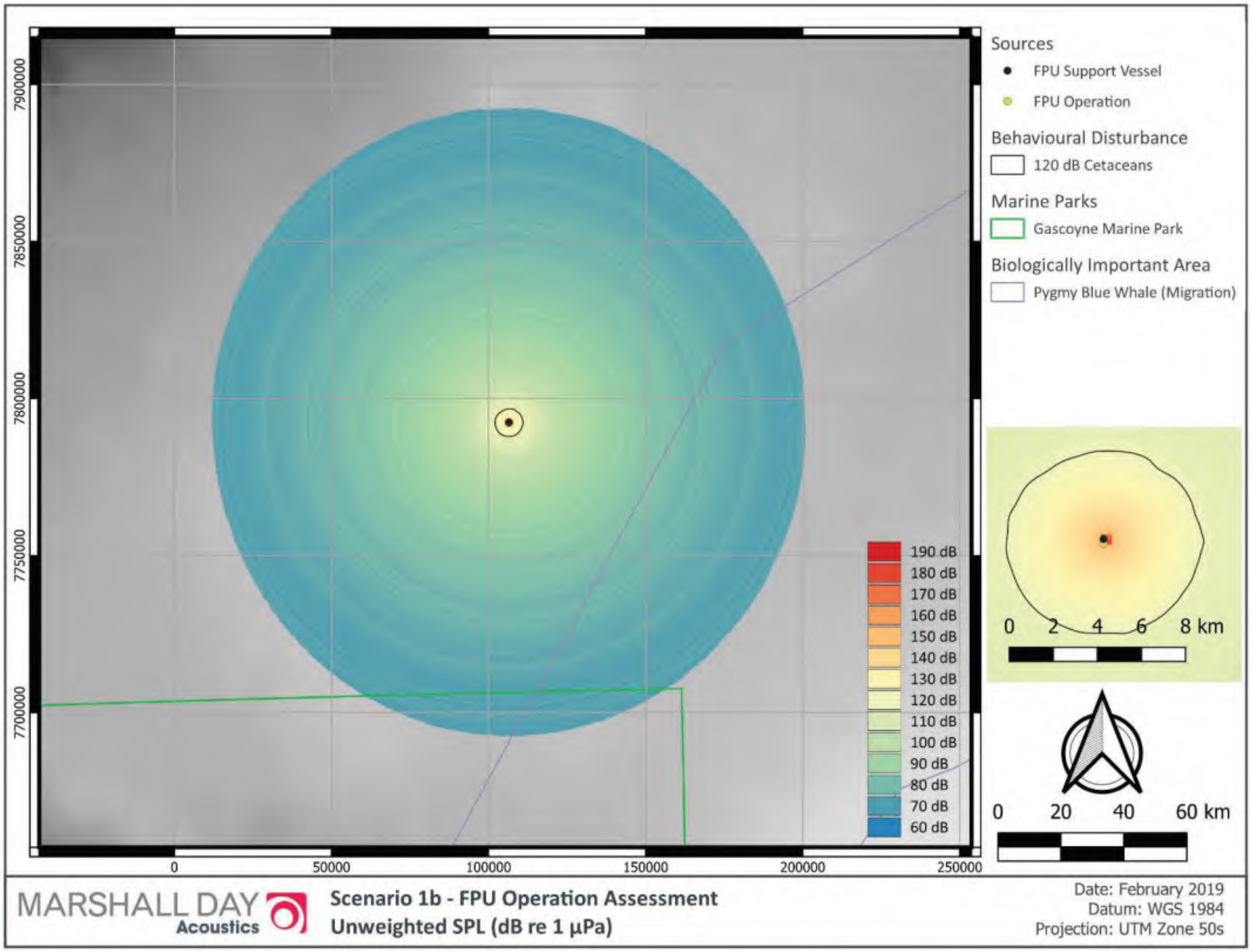


Figure 12: Noise contour map - Scenario 1b $L_{p,rms}$ (un-weighted) maximum over depth



G3 Scenario 2

Figure 13: Noise contour map - Scenario 2 $SEL_{(cum)}$ (un-weighted) maximum over depth

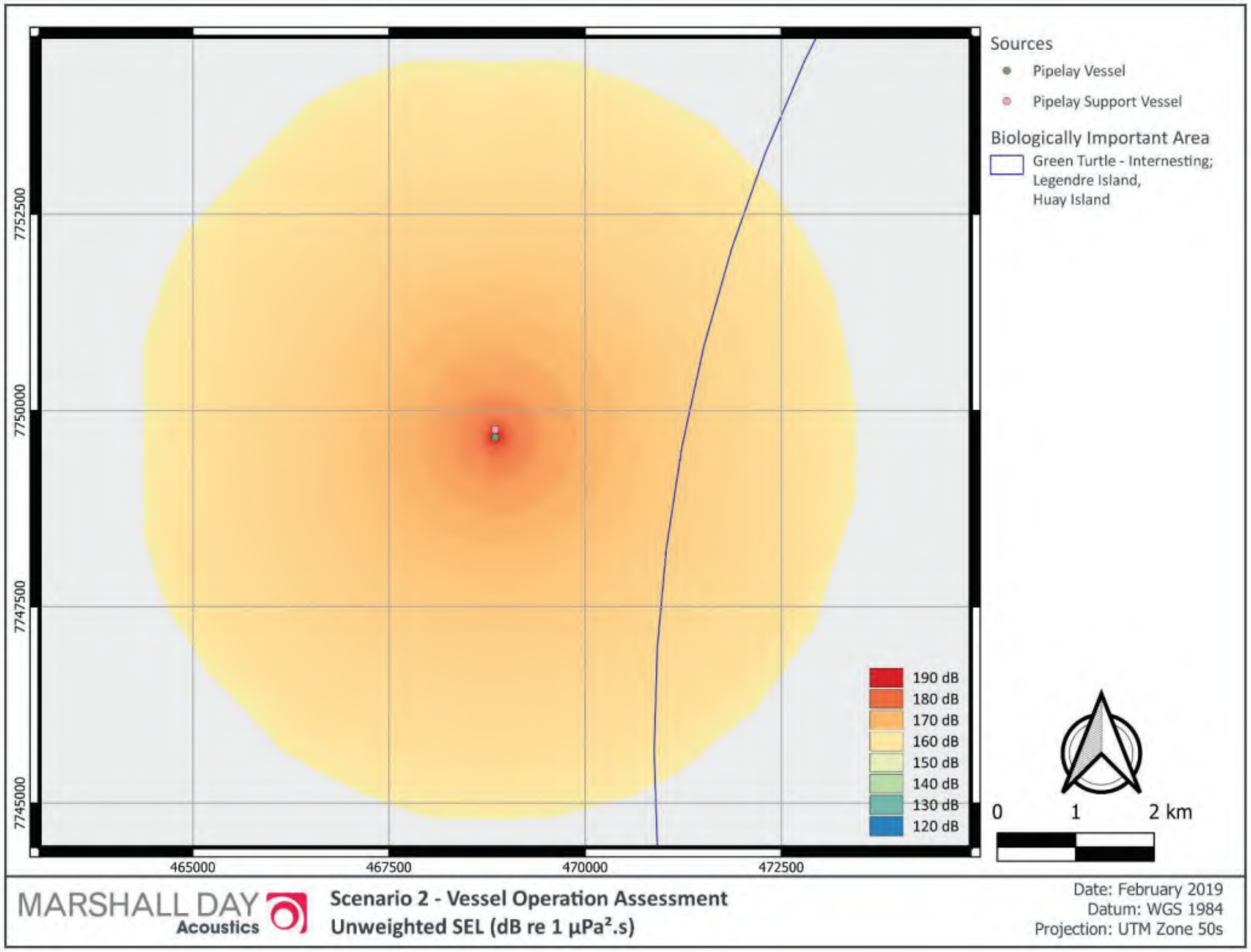
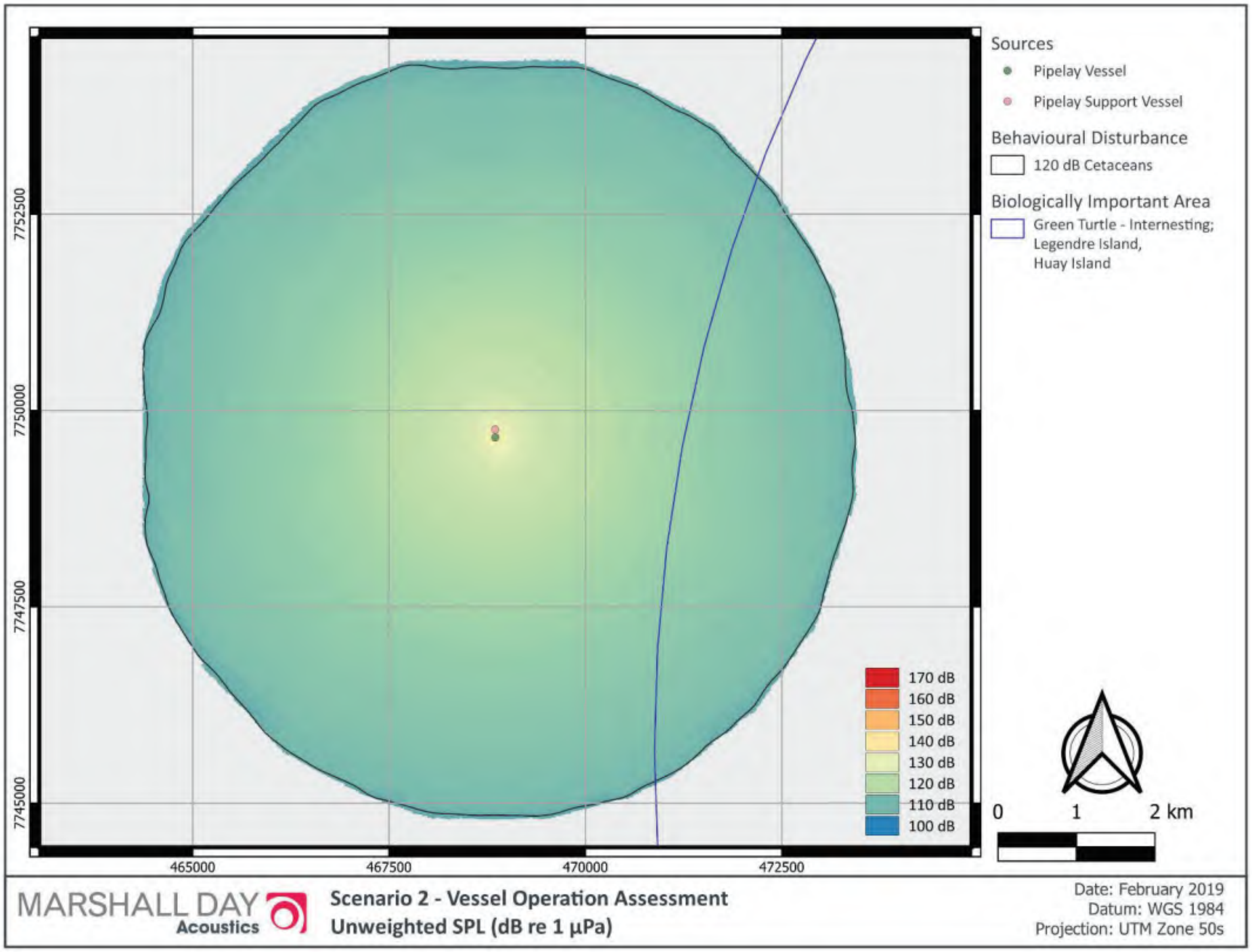


Figure 14: Noise contour map - Scenario 2 $L_{p,rms}$ (un-weighted) maximum over depth



Appendix F

Scarborough Gas Development Cooling Water Discharge Modelling Study

WOODSIDE SCARBOROUGH PROJECT – COOLING WATER DISCHARGE MODELLING

Report

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Woodside Scarborough Project – Cooling Water Discharge Modelling
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EXECUTIVE SUMMARY

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough Project will involve the processing of hydrocarbons which will result in the production of cooling water (CW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for chlorine in the cooling water (CW) discharge and temperature differential between the discharge and the ambient receiving water. This will indicate whether concentrations of this contaminant and the temperature of the plume are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the CW discharge and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the chlorine in the CW stream from the FPU, dispersion modelling was carried out for flow rates of 165,600 m^3/d (45 °C), 64,800 m^3/d (57 °C) and 82,800 m^3/d (60 °C) at discharge depths of 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the CW discharge stream was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). An annualised aggregation of outcomes was also assembled.

The main findings of the study are as follows:

Near-Field Modelling

- The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 0 m (Cases C1, C4 and C7), 10 m (Cases C2, C5 and C8) and 30 m (Cases C3, C6 and C9) below the water surface. The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively-buoyant plumes are predicted to rise in the water column.
- For Cases C1, C4 and C7 (0 m depth discharge), the plume is predicted to plunge up to 14 m below the sea surface, with the highest flow rate yielding the greatest plunge depth due to the vertical orientation of the discharges. For the discharges at depths of 10 m and 30 m, the plumes are predicted

to plunge up to 25 m and 43 m below the sea surface, respectively, with the highest flow rate yielding the greatest plunge depths.

- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For a discharge at a 165,600 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 75.0 m. The dilution level for this case is predicted as 1:52.
- For a discharge at a 64,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 69.7 m. The dilution level for this case is predicted as 1:77.
- For a discharge at an 82,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 59.8 m. The dilution level for this case is predicted as 1:59.
- For a discharge at 0 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 5.7 m. The dilution level for this case is predicted as 1:6.
- For a discharge at 10 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 11.1 m. The dilution level for this case is predicted as 1:17.
- For a discharge at 30 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 24.5 m. The dilution level for this case is predicted as 1:52.
- For each combination of discharge flow rate and depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the surface (or trapping depth, at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.
- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.
- The results for each combination of discharge flow rate and depth indicate that the chlorine constituent of the CW discharge is not expected to reach the required levels of dilution in the near field mixing zone.
- The temperature differential between the plume and the ambient water meets the required criterion in all conditions for Cases C2, C3, C6 and C9, and in the stronger-current simulations for Cases C1, C5 and C8. For Cases C4 and C7, however, compliance with the temperature differential criterion is not achieved.
- Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface.

Far-Field Modelling

- For Cases C1 and C3, dilution to reach threshold concentration is achieved for chlorine within an area of influence extending up to 1.79 km and 2.47 km, respectively, at the 99th percentile. For Cases C4 and C6, the maximum spatial extents of the relevant dilution contour are up to 0.62 km and 0.63 km, respectively, at the 99th percentile.
- For Cases C1 and C3, the areas of exposure defined by the relevant dilution contour are predicted to reach maximums of 4.59 km^2 and 6.56 km^2, respectively, at the 99th percentile. For Cases C4 and C6, the corresponding maximum areas of exposure are up to 0.40 km^2 and 0.68 km^2, respectively, at the 99th percentile.
- Maximum depths reached by. the discharges are predicted as 8 m, 38 m, 6 m and 38 m for Cases C1, C3, C4 and C6, respectively.
- Because the 3 °C plume-ambient temperature differential requirement is forecast to be met within a distance of 115 m at the 99th percentile in any case, the limiting factor for the plume's area of influence will be defined by its chlorine constituent rather than its temperature.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents may promote the highest levels of mixing and dilution.
- Because the discharge will be initially positively buoyant, it will rise in the water column and may resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions. This outcome is particularly likely for the surface discharge.
- Outcomes show that below-threshold chlorine concentrations are achieved closer to the discharge point for a flow rate of 64,800 m^3/d than for a higher flow rate of 165,600 m^3/d. This is attributable to the fact that initial peak chlorine concentrations in the water column are lower in the former case, which reduces the average concentrations likely to be recorded in each model grid cell during episodes of recirculation and pooling.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough Project will involve the processing of hydrocarbons which will result in the production of cooling water (CW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for chlorine in the cooling water (CW) discharge and temperature differential between the discharge and the ambient receiving water. This will indicate whether concentrations of this contaminant and the temperature of the plume are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the CW discharge and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the chlorine in the CW stream from the FPU (location shown in Table 1.1), dispersion modelling was carried out for flow rates of 165,600 m^3/d (45 °C), 64,800 m^3/d (57 °C) and 82,800 m^3/d (60 °C) at discharge depths of 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the CW discharge stream was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). An annualised aggregation of outcomes was also assembled.

All CW discharge characteristics used as input to the modelling are specified in the Model Input Form for this study (Advisian, 2018).

Table 1.1 Location of the proposed FPU used as the release site for the CW dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
FPU	19° 53' 54.715"	113° 14' 19.561"	930

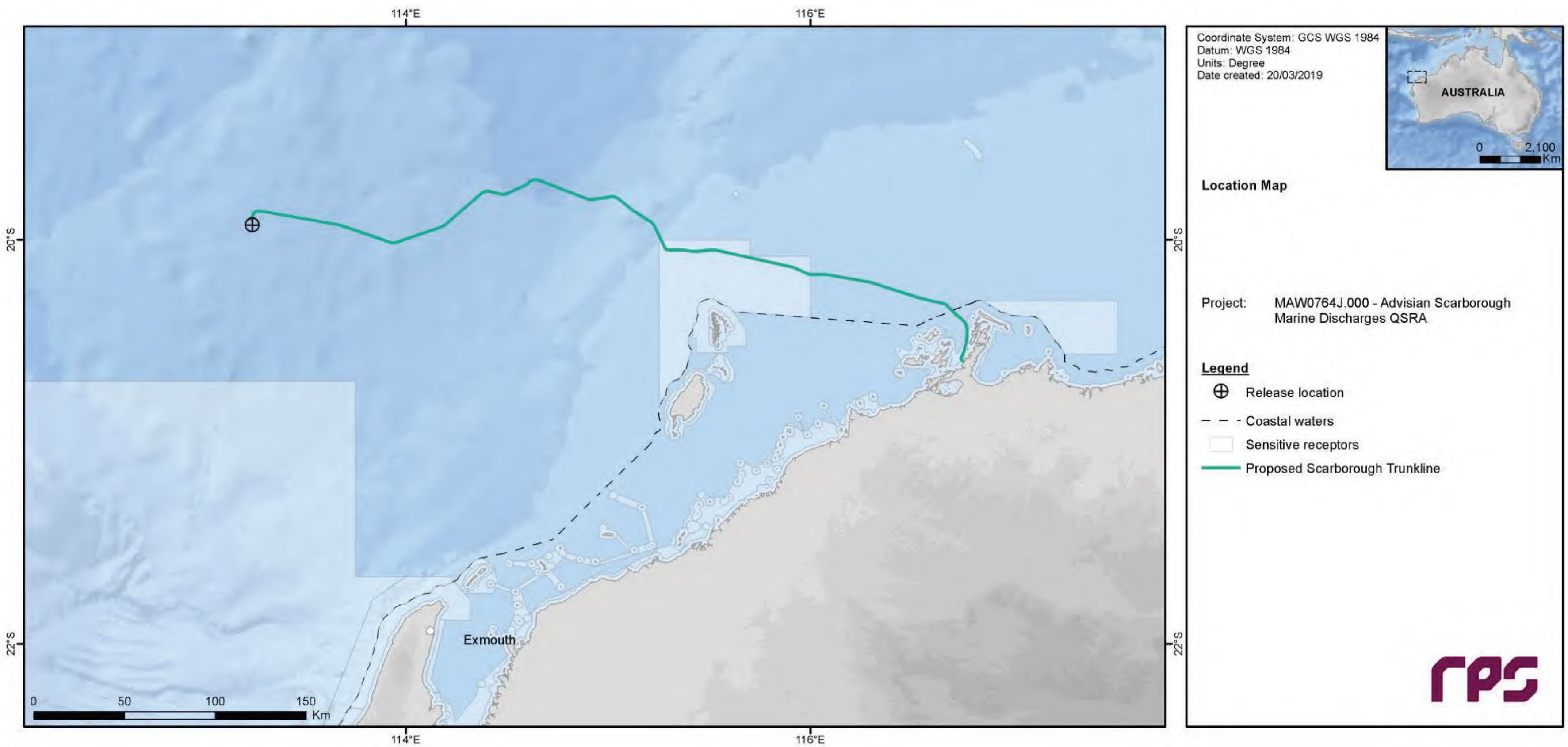

Figure 1.1 Location of the proposed Scarborough trunkline and FPU on the North West Shelf of Australia.

1.2 Modelling Scope

The physical mixing of the CW plume was first investigated for the near-field mixing zone. The limits of the near-field mixing zone are defined by the area where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from density differences between the plume and the receiving water. When the plume encounters a boundary such as the water surface, near-field mixing is complete. At this point, the plume is considered to enter the far-field mixing zone.

The scope of the modelling included the following components:

- Collation of a suitable three-dimensional, spatially-varying current data set surrounding the FPU location for a ten-year (2006-2015) hindcast period. The current data set included the combined influence of drift and tidal currents and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against metocean data collected in the Scarborough Project area.
- Derivation of statistical distributions for the current speed and directions for use in the near-field modelling. Analyses included percentile distributions and development of current roses. This analysis was important to ensure that current data samples applied in the dispersion model were statistically representative.
- Collation of seasonally-varying vertical water density profiles at the FPU location for use as input to the dispersion models.
- Near-field modelling conducted for each unique discharge to assess the initial mixing of the discharge due to turbulence and subsequent entrainment of ambient water. This modelling was conducted at high spatial and temporal resolution (scales of metres and seconds, respectively).
- Outcomes from the near-field modelling included estimates of the width, shape and orientation of the plumes, and resulting contaminant concentrations and dilutions, for each discharge at a range of incident current speeds.
- Establishment of a far-field dispersion model to repeatedly assess discharge scenarios under different sample conditions, with each sample represented by a unique time-sequence of current flow, chosen at random from the time series of current data.
- Analysis of the results of all simulations to quantify, by return frequency, the potential extent and shape of the mixing zone.

2 MODELLING METHODS

2.1 Near-Field Modelling

2.1.1 Overview

Numerical modelling was applied to quantify the area of influence of CW water discharges, in terms of the distribution of the maximum contaminant concentrations that might occur with distance from the source given defined discharge configurations, source concentrations, and the distribution of the metocean conditions affecting the discharge location.

The dispersion of the CW discharge will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. As the discharges mix with the ambient waters, the momentum and buoyancy signatures are eroded, and the background – or ambient – processes become dominant.

The shape and orientation of the discharged water plumes, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a statistically representative range of current speeds representative of the FPU location.

2.1.2 Description of Near-Field Model: Updated Merge

The near-field mixing and dispersion of the water discharge was simulated using the Updated Merge (UM3) flow model. The UM3 model is a three-dimensional Lagrangian steady-state plume trajectory model designed for simulating single and multiple-port submerged discharges in a range of configurations, available within the Visual Plumes modelling package provided by the United States Environmental Protection Agency (Frick *et al.*, 2003). The UM3 model was selected because it has been extensively tested for various discharges and found to predict observed dilutions more accurately (Roberts & Tian, 2004) than other near-field models (i.e. RSB and CORMIX).

In the UM3 model, the equations for conservation of mass, momentum, and energy are solved at each time step, giving the dilution along the plume trajectory. To determine the change of each term, UM3 follows the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment (PAE) hypothesis, which quantifies forced entrainment in the presence of a background ocean current. The flows begin as round buoyant jets and can merge to a plane buoyant jet (Carvalho *et al.*, 2002). Model output consists of plume characteristics including centreline dilution, rise-rate, width, centreline height and plume diameter. Dilution is reported as the "effective dilution", the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner *et al.* (1994).

The near-field zone ends where the discharged plume reaches a physical boundary or assumes the same density as the ambient water.

Figure 2.1 shows a conceptual diagram of the dispersion and fates of a positively buoyant discharge and the idealised representation of the discharge phases.

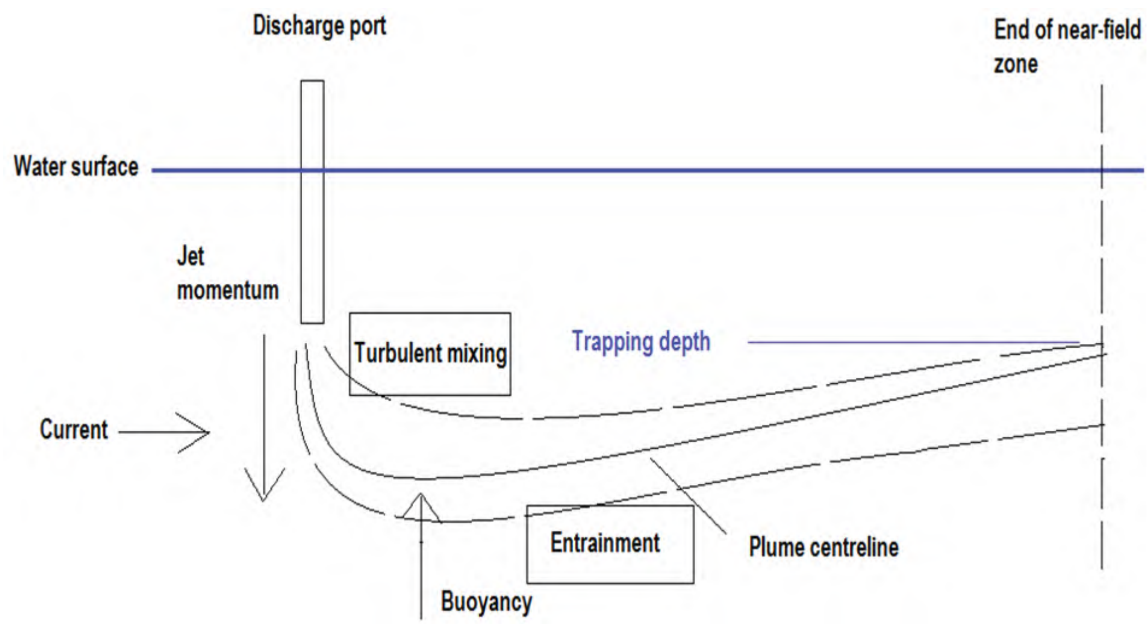

Figure 2.1 Conceptual diagram showing the general behaviour of positively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The CW discharge characteristics for Cases C1 to C9 are summarised in Table 2.1.

Cases C1 to C3 were assumed to occur at depths of 0 m below mean sea level (BMSL), 10 m BMSL and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 1.4 m diameter at a rate of 165,600 m^3/d and have a salinity and temperature of 35 parts per thousand (ppt) and 45 °C, respectively.

Cases C4 to C6 were assumed to occur at depths of 0 m, 10 m and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 1.4 m diameter at a rate of 64,800 m^3/d and have a salinity and temperature of 35 parts per thousand (ppt) and 57 °C, respectively.

Cases C7 to C9 were assumed to occur at depths of 0 m, 10 m and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 1.4 m diameter at a rate of 82,800 m^3/d and have a salinity and temperature of 35 parts per thousand (ppt) and 60 °C, respectively.

Concentrations of the constituent of interest (chlorine) within the discharges are described in Table 2.2, along with the required dilution factor to reach the defined threshold concentration (Advisian, 2018).

Table 2.1 Summary of CW discharge characteristics.

Parameter	Case C1	Case C2	Case C3	Case C4	Case C5	Case C6	Case C7	Case C8	Case C9
Flow rate (m^3/d)		165,600			64,800			82,800	
Outlet pipe internal diameter (m) [in]					1.4 [55]				
Outlet pipe orientation					Vertical (downwards)				
Depth of pipe below sea surface (m)	0	10	30	0	10	30	0	10	30
Discharge salinity (ppt)					35				
Discharge temperature (°C)		45 °C			57 °C			60 °C	

Table 2.2 Constituent of interest within the CW discharges and criteria for analysis of exposure.

Constituent/Property	Source Concentration or Temperature	Threshold Concentration or Temperature	Required Dilution Factor
Chlorine	1,000 ppb	5 ppb	200
Temperature	45-60 °C	3 °C above ambient	-

2.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the UM3 model included a vertical profile of temperature and salinity, along with constant current speeds and general direction. The temperature and salinity profiles are required to accurately account for the buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the CW plume. These inputs are described in the following sections.

2.1.3.2.1 Ambient Temperature and Salinity

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration, NOAA) and its co-located World Data Center for Oceanography (Levitus *et al.*, 2013).

Table 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 m to 50 m. This data can be considered representative of seasonal conditions at the FPU location.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth. Salinity levels are generally more consistent and exhibit a vertically well-mixed water body (34.7-34.8 practical salinity unit, PSU), irrespective of season or depth.

Table 2.3 Average temperature and salinity levels adjacent to the proposed FPU location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	27.8	34.7
	20	27.3	34.8
	50	26.2	34.8
Transitional	0	26.0	34.7
	20	25.7	34.7
	50	25.1	34.7
Winter	0	26.4	34.7
	20	26.3	34.7
	50	26.2	34.7
Annualised	0	26.6	34.7
	20	26.3	34.7
	50	25.8	34.7

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-year hindcast data set of combined large-scale ocean (BRAN) and tidal currents. The data was statistically analysed to determine the 5th, 50th and 95th percentile current speeds. These statistical current speeds can be considered representative of seasonal conditions at the FPU location.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 5th percentile current speed: weak currents, low dilution and slow advection.
- 50th percentile (median) current speed: average currents, moderate dilution and advection.
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2.4 Adopted ambient current conditions adjacent to the proposed FPU location.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	2.5	0.041	0.158	0.326
	22.7	0.049	0.154	0.312
	56.7	0.044	0.138	0.267
Transitional	2.5	0.045	0.177	0.375
	22.7	0.045	0.173	0.369
	56.7	0.043	0.157	0.322
Winter	2.5	0.044	0.172	0.395
	22.7	0.043	0.166	0.375
	56.7	0.039	0.156	0.341
Annualised	2.5	0.043	0.170	0.374
	22.7	0.045	0.164	0.361
	56.7	0.042	0.151	0.320

2.2 Far-Field Modelling

2.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh & Chang, 1973; Khondaker, 2000).

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals/constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al*., 1999; King & McAllister, 1997, 1998).

2.2.3 Stochastic Modelling

A stochastic modelling procedure was applied in the far-field modelling to sample a representative set of conditions that could affect the distribution of constituents. This approach involves multiple (25) simulations of a given discharge scenario and season, with each simulation being carried out under a randomly-selected period of currents. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents at the discharge location. Once the stochastic modelling is complete, all simulations are statistically analysed to develop the distribution of outcomes based on time and event.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

Four CW discharge scenarios were modelled as a continuous discharge using 25 simulations for each season. Once the simulations were complete, they were reported on a seasonal basis: (i) summer (December to February); (ii) transitional (March and September to November) and (iii) winter (April to August). The CW discharge characteristics for the selected cases (C1, C3, C4 and C6) are summarised in Table 2.5. These cases were chosen to cover the full range of proposed discharge flow rates and depths.

Table 2.5 Summary of far-field CW discharge modelling assumptions.

Parameter	Case C1	Case C3	Case C4	Case C6
Hindcast modelling period	2006-2015			
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August) Annual			
Flow rate (m^3/d)	165,600		64,800	
Discharge depth (m)	0	30	0	30
Discharge salinity (ppt)	35			
Discharge temperature (°C)	45 °C		57 °C	
Number of simulations	75 (25 per season)			
Simulated discharge type	Continuous			
Simulated discharge period (days)	5			

2.2.4.2 Mixing Parameters

The horizontal and vertical dispersion coefficients represent the mixing and diffusion caused by turbulence, both of which are sub-grid-scale processes. Both coefficients are expressed in units of rate of area change per second (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations faster. Increasing the vertical dispersion coefficient spreads the discharge across the vertical layers (or depths) faster.

Spatially constant, conservative dispersion coefficients of 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the CW plume in the horizontal and vertical directions, respectively. Each of the mixing parameters was selected following extensive sensitivity testing to recreate the plume characteristics predicted by the near-field modelling. It would be expected that the in-situ mixing dynamics would be greater under average and high energy conditions by a factor of 10 (King & McAllister, 1997, 1998) and thus the far-field model results are designed to produce a worst-case result for concentration extents.

2.2.4.3 Grid Configuration

MUDMAP uses a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). Due to the rapid mixing and small-scale effect of the effluent discharge, it was necessary to use a fine grid with a resolution of 40 m x 40 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 40 km (longitude or x-axis) by 40 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 2 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Background

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the island groups stretching from the Dampier Archipelago to the North West Cape. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have greater influence upon the net trajectory of slicks over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of pollutants can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is critical to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration of pollutants. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.2.5.2 Mesoscale Circulation Model

Representation of the drift currents that affect the area were available from the output of the BRAN (Bluelink ReANalysis; Oke *et al.*, 2008, 2009; Schiller *et al.*, 2008) ocean model, which is sponsored by the Australian Government through the Commonwealth Bureau of Meteorology (BoM), Royal Australian Navy, and Commonwealth Scientific and Industrial Research Organisation (CSIRO). BRAN is a data-assimilative, three-dimensional ocean model that has been run as a hindcast for many periods and is now used for ocean forecasting (Schiller *et al.*, 2008).

The BRAN predictions for drift currents are produced at a horizontal spatial resolution of approximately 0.1° over the region, at a frequency of once per day, averaged over the 24-hour period. Hence, the BRAN model data provides estimates of mesoscale circulation with horizontal resolution suitable to resolve eddies of a few tens of kilometres' diameter, as well as connecting stream currents of similar spatial scale. Drift currents that are represented over the inner shelf waters in the BRAN data are principally attributable to wind induced drift.

There are several versions of the BRAN database available. The latest BRAN simulation spans the period of January 1994 to August 2016. From this database, time series of current speed and direction were extracted for all points in the model domain for the years 2006-2015 (inclusive). The data was assumed to be a suitably representative sample of the current conditions over the study area for future years.

Figure 2.2 shows the seasonal distribution of current speeds and directions for the BRAN data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The data shows that current speeds and directions vary between seasons. In general, during transitional months (March and September to November) currents have the strongest average speed (0.22 m/s with a maximum of 0.56 m/s) and tend to flow south-east. During winter (April to August), current flow conditions are more variable, with lower average speed (0.21 m/s with a maximum of 0.53 m/s). During summer (December to February), the current flow occurs in a predominantly south/south-westerly direction with the lowest average speed (0.20 m/s with a maximum of 0.46 m/s).

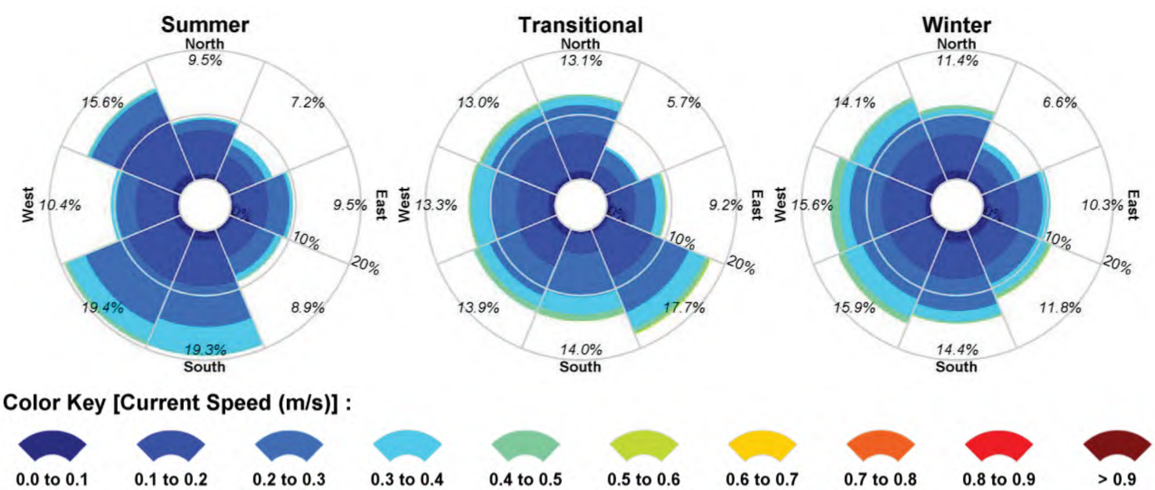

Figure 2.2 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Circulation Model

As the BRAN model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 25 years (Isaji & Spaulding, 1984, 1986; Isaji *et al.*, 2001; Zigic *et al.*, 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.3).

Four layers of sub-gridding were applied to provide variable resolution throughout the domain. The resolution at the primary level was 15 km. The finer levels were defined by subdividing these cells into 4, 16 and 64 cells, resulting in resolutions of 7.5 km, 3.75 km and 1.88 km. The finer grids were allocated in a step-wise fashion to areas where higher resolution of circulation patterns was required to resolve flows through channels, around shorelines or over more complex bathymetry. Approximately 98,600 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office. Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992-2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone *et al.*, 1998; Matsumoto *et al.*, 2000; Kostianoy *et al.*, 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

For the purpose of verification of the tidal predictions, the model output was compared against independent predictions of tides using the XTide database (Flater, 1998). The XTide database contains harmonic tidal constituents derived from measured water level data at locations around the world. Of more than 40 tidal stations within the HYDROMAP model domain, ten were used for comparison.

Water level time series for these locations are shown in Figure 2.4 for a one-month period (January 2005). All comparisons show that the model produces a very good match to the known tidal behaviour for a wide range of tidal amplitudes and clearly represents the varying diurnal and semi-diurnal nature of the tidal signal.

The model skill was further evaluated through a comparison of the predicted and observed tidal constituents, derived from an analysis of model-predicted time-series at each location. A scatter plot of the observed and modelled amplitude (top) and phase (bottom) of the five dominant tidal constituents (S_2, M_2,

N_2, K_1 and O_1) is presented in Figure 2.5. The red line on each plot shows the 1:1 line, which would indicate a perfect match between the modelled and observed data. Note that the data is generally closely aligned to the 1:1 line demonstrating the high quality of the model performance.

Figure 2.6 shows the seasonal distribution of current speeds and directions for the HYDROMAP data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The current data indicates cyclical tidal flow directions along a northeast-southwest axis, with maximum speeds of around 0.09 m/s.

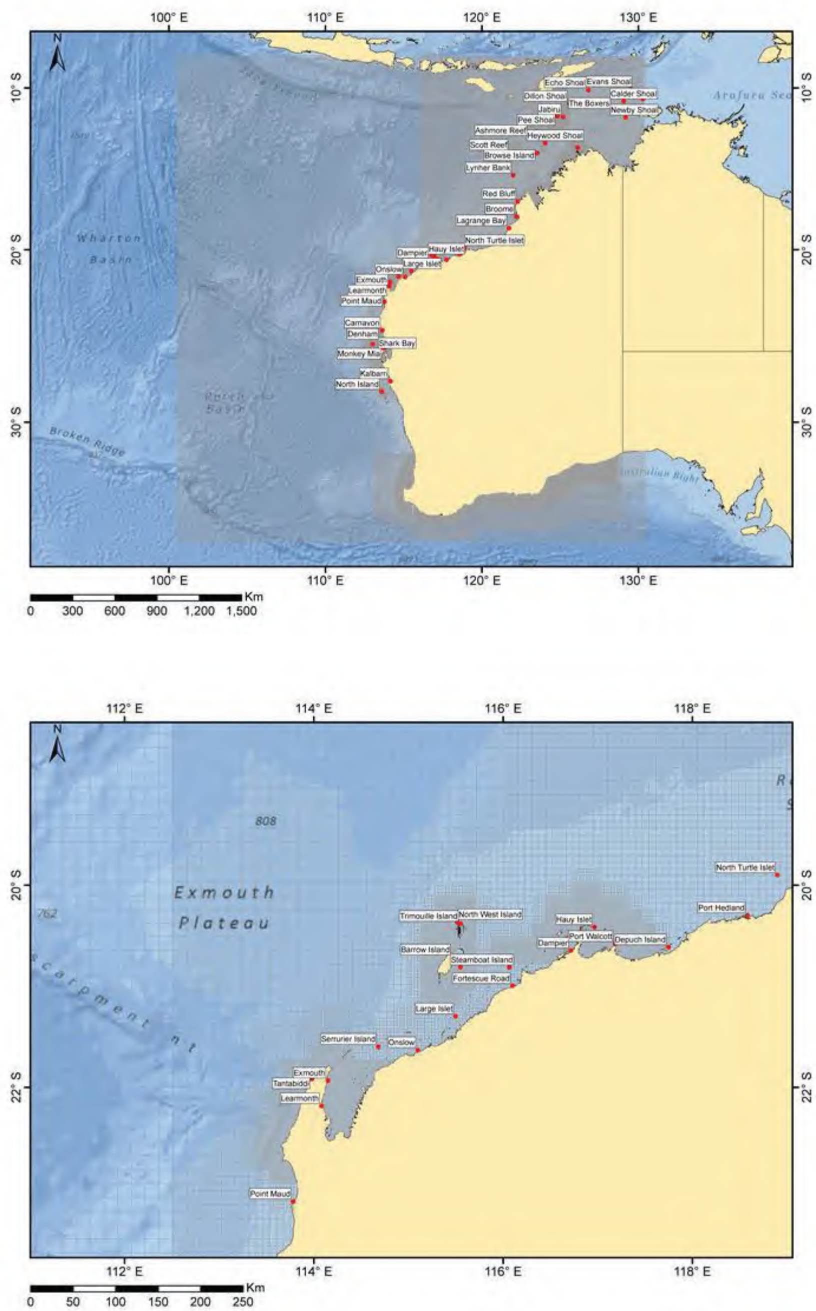

Figure 2.3 **Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing locations available for tidal comparisons (red labelled dots). The top panel shows the full domain in context with the continental land mass, while the bottom panel shows a zoomed subset near the discharge locations. Higher-resolution areas are indicated by the denser mesh zones.**

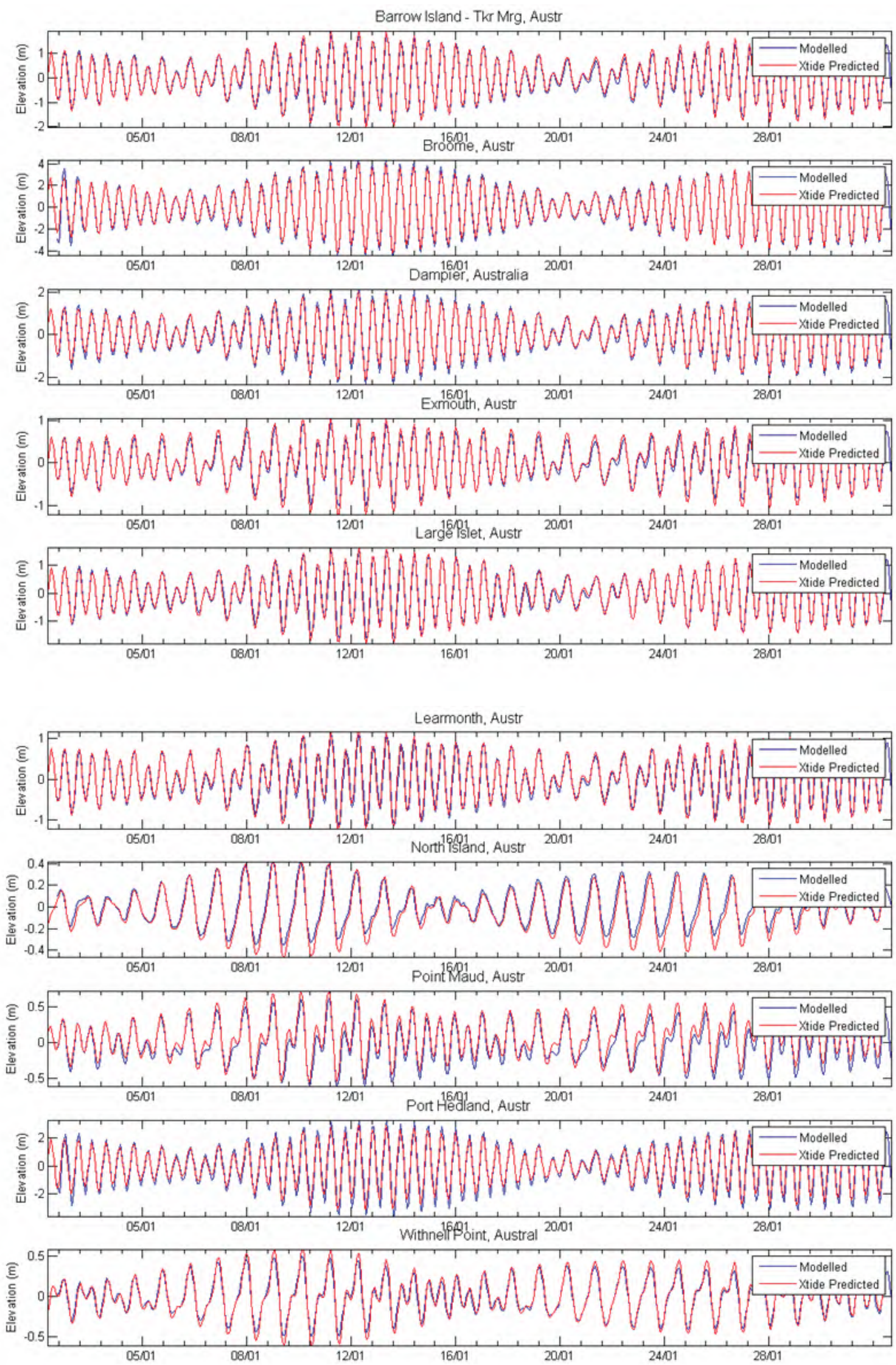

Figure 2.4 **Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at ten locations in the tidal model domain for January 2005.**

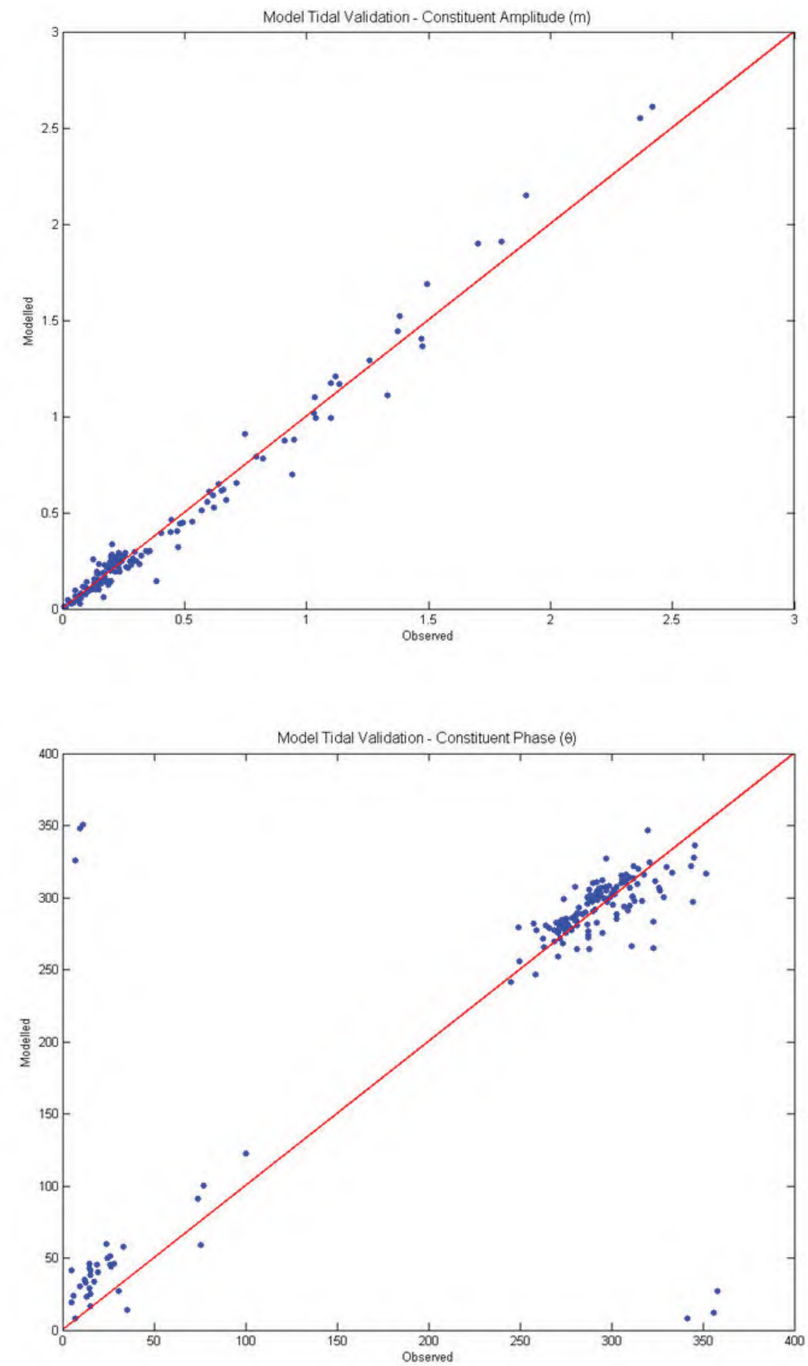

Figure 2.5 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all stations in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

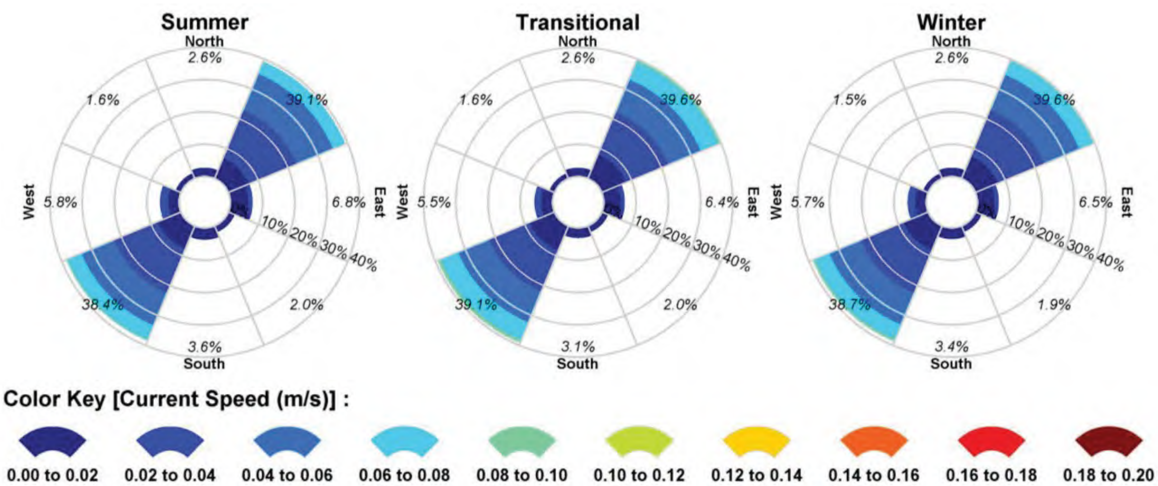

Figure 2.6 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 MODELLING RESULTS

3.1 Near-Field Modelling

3.1.1 Overview

In the following sections, information for each of the modelled discharge cases is presented first in a table summarising the predicted plume characteristics in the near-field mixing zone under varying current speeds, and then in further tables summarising the concentrations of chlorine at the end of the near-field mixing zone, the concentration threshold, and the amount of dilution for each season and for the annual period. Any dilution rates indicated in red show that suitable dilution is not achieved during the near-field stage for at least one current-speed case.

Figure 3.1 to Figure 3.72 (note the differing x-axis and y-axis aspect ratios) show the change in average dilution and temperature of the plume under varying discharge rates (165,600 m^3/day, 64,800 m^3/day and 82,800 m^3/day), depths (0 m, 10 m and 30 m), seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

In each figure, the plots have been arranged to: (i) demonstrate the variation in predicted outcomes for the same discharge at different depths under identical current conditions (Sections 3.1.3.1, 3.1.3.2 and 3.1.3.3); and (ii) demonstrate the variation in predicted outcomes for different discharges at the same depth under identical current conditions (Sections 3.1.3.4, 3.1.3.5 and 3.1.3.6).

The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 0 m (Cases C1, C4 and C7), 10 m (Cases C2, C5 and C8) and 30 m (Cases C3, C6 and C9) below the water surface. The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively-buoyant plumes are predicted to rise in the water column. For the surface discharges, the plume is predicted to plunge up to 14 m below the sea surface depending on flow rate and season. For the discharges at depths of 10 m and 30 m, the plumes are predicted to plunge up to 25 m and 43 m below the sea surface, respectively, depending on flow rate and season. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

The plume characteristics data for each of the discharge flow rates, depths, seasonal conditions and current speeds show that the plume will reach a maximum horizontal distance of between <1 m and 81 m before surfacing, in the case of the surface discharges, or reaching the trapping depth, in the case of the subsea discharges.

The diameter of the plume at the end of the near-field zone ranged from <1 m to 17 m. Increases in current speed serve to restrict the diameter of the plume.

For most combinations of season, flow rate and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution. Note that predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

The results for each of the discharge flow rates, depths, seasonal conditions and current speeds indicate that the chlorine constituent of the CW discharge is not expected to reach the required levels of dilution in the near field mixing zone. The temperature differential between the plume and the ambient water meets the required criterion in all conditions for Cases C2, C3, C6 and C9, and in the stronger-current simulations for Cases C1, C5 and C8. For Cases C4 and C7, however, compliance with the temperature differential criterion is not achieved. Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface.

3.1.2 Results – Tables

3.1.2.1 Discharge Case C1: Flow Rate of 165,600 m³/day at 0 m Depth (Surface)

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	15.2 [6.9]	34.02	6.33	1.4	2.7	0.5
	Medium (0.16)	7.6 [1.9]	30.44	2.64	2.8	6.4	5.6
	Strong (0.33)	8.4 [3.9]	29.72	1.95	2.3	8.8	10.3
Transitional	Weak (0.05)	14.4 [6.6]	33.07	3.16	1.3	2.7	0.5
	Medium (0.18)	7.5 [2.0]	28.97	2.96	2.7	6.3	5.7
	Strong (0.38)	8.0 [3.7]	28.09	2.12	2.2	9.0	10.7
Winter	Weak (0.04)	14.7 [6.7]	33.28	6.97	1.3	2.7	0.5
	Medium (0.17)	7.6 [1.9]	29.27	2.87	2.8	6.4	5.7
	Strong (0.40)	7.9 [3.8]	28.40	2.03	2.2	9.1	11.1
Annual	Weak (0.04)	14.8 [6.7]	33.39	6.88	1.3	2.7	0.5
	Medium (0.17)	7.6 [1.8]	29.43	2.83	2.8	6.4	5.7
	Strong (0.37)	8.0 [3.8]	28.61	2.04	2.2	9.0	10.8

Table 3.2 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.4 and 8.8, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.4x Dilution	8.8x Dilution		
Chlorine in Water (ppb)	1,000	370.4	156.3	113.6	5	200
Δ Temperature (°C)	45	6.33	6.24	1.95	3° above ambient	-

Table 3.3 **Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.3 and 9.0, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.**

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.3x Dilution	9.0x Dilution		
Chlorine in Water (ppb)	1,000	370.4	158.7	111.1	5	200
Δ Temperature (°C)	45	3.16	2.96	2.12	3° above ambient	-

Table 3.4 **Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.4 and 9.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.**

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.4x Dilution	9.1x Dilution		
Chlorine in Water (ppb)	1,000	370.4	156.3	109.9	5	200
Δ Temperature (°C)	45	6.97	2.87	2.03	3° above ambient	-

Table 3.5 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.4 and 9.0, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.4x Dilution	9.0x Dilution		
Chlorine in Water (ppb)	1,000	370.4	156.3	111.1	5	200
Δ Temperature (°C)	45	6.88	2.83	2.04	3° above ambient	-

3.1.2.2 Discharge Case C2: Flow Rate of 165,600 m^3/day at 10 m Depth

Table 3.6 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	7.5 [0.3]	29.73	1.93	4.3	8.2	2.2
	Medium (0.16)	12.3 [3.5]	28.72	0.95	6.7	15.8	10.6
	Strong (0.33)	15.4 [7.1]	28.13	0.44	9.0	32.4	26.7
Transitional	Weak (0.05)	7.4 [0.1]	28.16	2.16	4.3	8.3	2.3
	Medium (0.18)	12.6 [3.8]	26.98	1.01	6.8	16.8	11.4
	Strong (0.38)	15.2 [7.1]	26.35	0.45	9.6	35.6	30.5
Winter	Weak (0.04)	7.4 [0.2]	28.52	2.12	4.2	8.2	2.3
	Medium (0.17)	12.4 [3.8]	27.38	1.01	6.7	16.4	11.1
	Strong (0.40)	15.1 [7.2]	26.72	0.43	9.9	37.1	32.8
Annual	Weak (0.04)	7.3 [0.3]	28.72	2.12	4.2	8.1	2.2
	Medium (0.17)	12.5 [3.7]	27.56	0.99	6.8	16.5	11.1
	Strong (0.37)	15.2 [7.2]	26.93	0.44	9.6	35.7	30.8

Table 3.7 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.2, 15.8 and 32.4, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.2x Dilution	15.8x Dilution	32.4x Dilution		
Chlorine in Water (ppb)	1,000	122.0	60.3	30.9	5	200
Δ Temperature (°C)	45	1.93	0.95	0.44	3° above ambient	-

Table 3.8 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.3, 16.8 and 35.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.3x Dilution	16.8x Dilution	35.6x Dilution		
Chlorine in Water (ppb)	1,000	120.5	59.5	28.1	5	200
Δ Temperature (°C)	45	2.16	1.01	0.45	3° above ambient	-

Table 3.9 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.2, 16.4 and 37.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.2x Dilution	16.4x Dilution	37.1x Dilution		
Chlorine in Water (ppb)	1,000	121.9	60.9	26.9	5	200
Δ Temperature (°C)	45	2.12	1.01	0.43	3° above ambient	-

Table 3.10 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.1, 16.5 and 35.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.1x Dilution	16.5x Dilution	35.7x Dilution		
Chlorine in Water (ppb)	1,000	123.5	60.6	28.0	5	200
Δ Temperature (°C)	45	2.12	0.99	0.44	3° above ambient	-

3.1.2.3 Discharge Case C3: Flow Rate of 165,600 m³/day at 30 m Depth

Table 3.11 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	12.7 [0.3]	28.35	0.55	9.8	19.1	4.4
	Medium (0.16)	24.6 [9.2]	27.74	0.11	17.5	49.1	23.2
	Strong (0.33)	28.0 [16.9]	27.45	0.00	27.3	104.1	63.1
Transitional	Weak (0.05)	12.5 [0.6]	26.67	0.67	9.8	19.1	4.6
	Medium (0.18)	25.1 [10.1]	25.97	0.14	18.5	54.4	25.5
	Strong (0.38)	28.4 [16.6]	25.68	0.00	31.9	122.5	76.7
Winter	Weak (0.04)	12.5 [0.7]	27.05	0.65	9.8	19.0	4.5
	Medium (0.17)	25.0 [9.8]	26.36	0.13	18.3	53.1	24.9
	Strong (0.40)	27.8 [17.2]	26.06	0.00	31.9	123.2	80.7
Annual	Weak (0.04)	12.4 [0.8]	27.24	0.64	9.7	18.8	4.4
	Medium (0.17)	24.9 [9.8]	26.56	0.13	18.1	52.2	24.5
	Strong (0.37)	27.9 [17.1]	26.26	0.00	30.7	117.9	75.0

Table 3.12 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 19.1, 49.1 and 104.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		19.1x Dilution	49.1x Dilution	104.1x Dilution		
Chlorine in Water (ppb)	1,000	52.4	20.4	9.6	5	200
Δ Temperature (°C)	45	0.55	0.11	0.00	3° above ambient	-

Table 3.13 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 19.1, 54.4 and 122.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		19.1x Dilution	54.4x Dilution	122.5x Dilution		
Chlorine in Water (ppb)	1,000	52.4	18.4	8.2	5	200
Δ Temperature (°C)	45	0.67	0.14	0.00	3° above ambient	-

Table 3.14 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 19.0, 53.1 and 123.2, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		19.0x Dilution	53.1x Dilution	123.2x Dilution		
Chlorine in Water (ppb)	1,000	52.6	18.8	8.1	5	200
Δ Temperature (°C)	45	0.65	0.13	0.00	3° above ambient	-

Table 3.15 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 18.8, 52.2 and 117.9, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		18.8x Dilution	52.2x Dilution	117.9x Dilution		
Chlorine in Water (ppb)	1,000	53.2	19.2	8.5	5	200
Δ Temperature (°C)	45	0.64	0.13	0.00	3° above ambient	-

3.1.2.4 Discharge Case C4: Flow Rate of 64,800 m^3/day at 0 m Depth (Surface)

Table 3.16 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	6.5 [0.9]	51.43	23.63	1.0	1.2	<0.1
	Medium (0.16)	3.7 [0.9]	48.64	20.84	1.0	1.4	0.1
	Strong (0.33)	2.7 [0.7]	47.58	19.78	1.0	1.5	0.2
Transitional	Weak (0.05)	6.3 [0.9]	51.18	25.15	1.0	1.2	<0.1
	Medium (0.18)	3.5 [0.8]	48.08	22.08	1.0	1.4	0.1
	Strong (0.38)	2.5 [0.7]	47.42	21.42	1.0	1.4	0.1
Winter	Weak (0.04)	6.4 [0.9]	51.24	24.84	1.0	1.2	<0.1
	Medium (0.17)	3.6 [0.9]	48.21	21.81	1.0	1.4	0.1
	Strong (0.40)	2.4 [0.7]	47.62	21.22	1.0	1.4	0.1
Annual	Weak (0.04)	6.4 [0.9]	51.28	24.68	1.0	1.2	<0.1
	Medium (0.17)	3.6 [0.9]	48.27	21.67	1.0	1.4	0.1
	Strong (0.37)	2.5 [0.7]	47.55	20.95	1.0	1.4	0.1

Table 3.17 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.5x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	666.7	5	200
Δ Temperature (°C)	57	23.63	20.84	19.78	3° above ambient	-

Table 3.18 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.4, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.4x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	714.3	5	200
Δ Temperature (°C)	57	25.15	22.08	21.42	3° above ambient	-

Table 3.19 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.4, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.4x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	714.3	5	200
Δ Temperature (°C)	57	25.15	22.08	21.42	3° above ambient	-

Table 3.20 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile 1.2x Dilution	50th %ile 1.4x Dilution	95th %ile 1.5x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	714.3	5	200
Δ Temperature (°C)	57	24.68	21.67	20.95	3° above ambient	-

3.1.2.5 Discharge Case C5: Flow Rate of 64,800 m^3/day at 10 m Depth

Table 3.21 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	3.8 [0.1]	32.22	4.42	3.3	6.4	0.7
	Medium (0.16)	6.3 [1.5]	30.11	2.31	5.5	12.1	3.9
	Strong (0.33)	8.8 [4.0]	28.75	0.99	8.0	27.7	11.0
Transitional	Weak (0.05)	3.8 [<0.1]	30.66	4.66	3.4	6.5	0.7
	Medium (0.18)	6.7 [1.8]	28.19	2.19	5.8	13.6	4.3
	Strong (0.38)	9.0 [4.2]	26.86	0.90	8.9	32.3	14.9
Winter	Weak (0.04)	3.8 [0.1]	31.01	4.61	3.4	6.5	0.7
	Medium (0.17)	6.6 [1.7]	28.61	2.21	5.8	13.3	4.3
	Strong (0.40)	9.1 [4.3]	27.18	0.82	9.4	34.6	14.9
Annual	Weak (0.04)	3.8 [0.1]	31.19	4.59	3.3	6.5	0.7
	Medium (0.17)	6.5 [1.7]	28.85	2.25	5.7	13.0	4.2
	Strong (0.37)	9.0 [4.2]	27.44	0.88	8.9	32.3	13.5

Table 3.22 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.4, 12.1 and 27.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.4x Dilution	12.1x Dilution	27.7x Dilution		
Chlorine in Water (ppb)	1,000	156.3	82.6	36.1	5	200
Δ Temperature (°C)	57	4.42	2.31	0.99	3° above ambient	-

Table 3.23 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.5, 13.6 and 32.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.5x Dilution	13.6x Dilution	32.3x Dilution		
Chlorine in Water (ppb)	1,000	153.8	73.5	30.9	5	200
Δ Temperature (°C)	57	4.66	2.19	0.90	3° above ambient	-

Table 3.24 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.5, 13.3 and 34.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.5x Dilution	13.3x Dilution	34.6x Dilution		
Chlorine in Water (ppb)	1,000	153.8	75.2	28.9	5	200
Δ Temperature (°C)	57	4.61	2.21	0.82	3° above ambient	-

Table 3.25 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.6, 13.0 and 32.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.6x Dilution	13.0x Dilution	32.3x Dilution		
Chlorine in Water (ppb)	1,000	151.5	76.9	31.0	5	200
Δ Temperature (°C)	57	4.59	2.25	0.88	3° above ambient	-

3.1.2.6 Discharge Case C6: Flow Rate of 64,800 m³/day at 30 m Depth

Table 3.26 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	8.9 [0.5]	28.72	0.92	12.7	24.6	2.8
	Medium (0.16)	18.1 [6.7]	27.92	0.22	25.0	69.2	16.2
	Strong (0.33)	24.0 [11.9]	27.57	0.00	51.5	196.6	57.1
Transitional	Weak (0.05)	9.0 [0.3]	26.98	0.98	13.0	25.4	3.1
	Medium (0.18)	19.2 [7.8]	26.10	0.22	27.1	80.6	18.9
	Strong (0.38)	24.3 [12.1]	25.78	0.00	59.6	229.7	70.9
Winter	Weak (0.04)	9.0 [0.2]	27.36	0.96	13.0	25.3	3.0
	Medium (0.17)	18.9 [7.5]	26.51	0.23	26.5	77.5	18.1
	Strong (0.40)	23.6 [12.8]	26.16	0.00	59.1	228.3	73.4
Annual	Weak (0.04)	8.9 [0.6]	27.58	0.98	12.7	24.8	2.9
	Medium (0.17)	18.9 [7.3]	26.71	0.22	26.5	76.8	18.0
	Strong (0.37)	24.0 [12.3]	26.37	0.00	58.2	224.0	69.7

Table 3.27 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 24.6, 69.2 and 196.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		24.6x Dilution	69.2x Dilution	196.6x Dilution		
Chlorine in Water (ppb)	1,000	40.7	14.5	5.1	5	200
Δ Temperature (°C)	57	0.92	0.22	0.00	3° above ambient	-

Table 3.28 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 25.4, 80.6 and 229.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		25.4x Dilution	80.6x Dilution	229.7x Dilution		
Chlorine in Water (ppb)	1,000	39.4	12.4	4.4	5	200
Δ Temperature (°C)	57	0.98	0.22	0.00	3° above ambient	-

Table 3.29 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 25.3, 77.5 and 228.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		25.3x Dilution	77.5x Dilution	228.3x Dilution		
Chlorine in Water (ppb)	1,000	39.5	12.9	4.4	5	200
Δ Temperature (°C)	57	0.96	0.23	0.00	3° above ambient	-

Table 3.30 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 24.8, 76.8 and 224.0, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		24.8x Dilution	76.8x Dilution	224.0x Dilution		
Chlorine in Water (ppb)	1,000	40.3	13.0	4.5	5	200
Δ Temperature (°C)	57	0.98	0.22	0.00	3° above ambient	-

3.1.2.7 Discharge Case C7: Flow Rate of 82,800 m³/day at 0 m Depth (Surface)

Table 3.31 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	7.5 [1.3]	52.22	24.42	1.0	1.3	<0.1
	Medium (0.16)	4.4 [1.2]	49.01	21.21	1.0	1.5	0.2
	Strong (0.33)	3.2 [1.0]	46.97	19.17	1.0	1.7	0.3
Transitional	Weak (0.05)	7.2 [1.3]	51.92	25.92	1.0	1.3	<0.1
	Medium (0.18)	4.1 [1.2]	48.24	22.24	1.0	1.5	0.2
	Strong (0.38)	3.0 [0.1]	46.45	20.45	1.0	1.7	0.3
Winter	Weak (0.04)	7.3 [1.3]	51.99	25.59	1.0	1.3	<0.1
	Medium (0.17)	4.2 [1.2]	48.43	22.03	1.0	1.5	0.2
	Strong (0.40)	2.9 [0.9]	46.55	20.15	1.0	1.7	0.3
Annual	Weak (0.04)	7.4 [1.3]	52.03	25.43	1.0	1.3	<0.1
	Medium (0.17)	4.2 [1.2]	48.51	21.91	1.0	1.5	0.2
	Strong (0.37)	3.0 [1.0]	46.58	19.98	1.0	1.7	0.3

Table 3.32 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	60	24.42	21.21	19.17	3° above ambient	-

Table 3.33 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	57	25.92	22.24	20.45	3° above ambient	-

Table 3.34 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	60	25.59	22.03	20.15	3° above ambient	-

Table 3.35 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	60	25.43	21.91	19.98	3° above ambient	-

3.1.2.8 Discharge Case C8: Flow Rate of 82,800 m³/day at 10 m Depth

Table 3.36 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	4.1 [<0.1]	32.77	4.97	3.3	6.3	0.7
	Medium (0.16)	6.3 [1.3]	30.65	2.85	5.1	10.9	3.7
	Strong (0.33)	9.1 [3.9]	29.04	1.28	7.1	27.3	10.2
Transitional	Weak (0.05)	4.1 [0.1]	31.30	5.30	3.2	6.3	0.7
	Medium (0.18)	6.7 [1.6]	28.76	2.76	5.3	11.8	4.2
	Strong (0.38)	9.3 [4.2]	27.13	1.17	7.8	27.5	12.4
Winter	Weak (0.04)	4.1 [0.1]	31.65	5.25	3.2	6.2	0.7
	Medium (0.17)	6.6 [1.6]	29.20	2.80	5.2	11.6	4.1
	Strong (0.40)	9.3 [4.4]	27.45	1.09	8.0	28.9	13.4
Annual	Weak (0.04)	4.1 [0.1]	31.84	5.24	3.2	6.2	0.7
	Medium (0.17)	6.5 [1.5]	29.41	2.81	5.2	11.5	4.0
	Strong (0.37)	9.3 [4.3]	27.71	1.15	7.7	27.3	12.3

Table 3.37 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.3, 10.9 and 27.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.3x Dilution	10.9x Dilution	27.3x Dilution		
Chlorine in Water (ppb)	1,000	158.7	91.7	36.6	5	200
Δ Temperature (°C)	60	4.97	2.85	1.28	3° above ambient	-

Table 3.38 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.3, 11.8 and 27.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.3x Dilution	11.8x Dilution	27.5x Dilution		
Chlorine in Water (ppb)	1,000	158.7	84.7	36.4	5	200
Δ Temperature (°C)	60	5.30	2.76	1.17	3° above ambient	-

Table 3.39 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.2, 11.6 and 28.9, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.2x Dilution	11.6x Dilution	28.9x Dilution		
Chlorine in Water (ppb)	1,000	161.3	86.2	34.6	5	200
Δ Temperature (°C)	60	5.25	2.80	1.09	3° above ambient	-

Table 3.40 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.2, 11.5 and 27.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.2x Dilution	11.5x Dilution	27.3x Dilution		
Chlorine in Water (ppb)	1,000	161.3	86.9	36.6	5	200
Δ Temperature (°C)	60	5.24	2.81	1.15	3° above ambient	-

3.1.2.9 Discharge Case C9: Flow Rate of 82,800 m^3/day at 30 m Depth

Table 3.41 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	9.1 [0.1]	28.94	1.14	11.7	22.7	2.6
	Medium (0.16)	17.0 [5.7]	28.10	0.38	21.4	53.9	14.1
	Strong (0.33)	24.0 [11.7]	27.63	0.05	41.6	155.6	47.2
Transitional	Weak (0.05)	9.1 [0.1]	27.22	1.22	11.9	23.0	2.8
	Medium (0.18)	18.4 [6.7]	26.25	0.35	23.3	63.6	16.6
	Strong (0.38)	24.7 [11.9]	25.83	0.04	49.1	187.1	60.1
Winter	Weak (0.04)	9.0 [0.5]	27.63	1.23	11.6	22.5	2.7
	Medium (0.17)	18.0 [6.4]	26.67	0.36	22.8	60.9	16.0
	Strong (0.40)	24.6 [12.1]	26.21	0.03	51.1	195.6	65.0
Annual	Weak (0.04)	9.1 [0.1]	27.80	1.20	11.8	22.9	2.7
	Medium (0.17)	17.8 [6.4]	26.88	0.37	22.4	59.2	15.5
	Strong (0.37)	24.6 [11.2]	26.41	0.03	48.7	185.7	59.8

Table 3.42 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 22.7, 53.9 and 155.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		22.7x Dilution	53.9x Dilution	155.6x Dilution		
Chlorine in Water (ppb)	1,000	44.1	18.6	6.4	5	200
Δ Temperature (°C)	60	1.14	0.38	0.05	3° above ambient	-

Table 3.43 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 23.0, 63.6 and 187.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		23.0x Dilution	63.6x Dilution	187.1x Dilution		
Chlorine in Water (ppb)	1,000	43.5	15.7	5.3	5	200
Δ Temperature (°C)	60	1.22	0.35	0.04	3° above ambient	-

Table 3.44 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 22.5, 60.9 and 195.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		22.5x Dilution	60.9x Dilution	195.6x Dilution		
Chlorine in Water (ppb)	1,000	44.4	16.4	5.1	5	200
Δ Temperature (°C)	60	1.23	0.36	0.03	3° above ambient	-

Table 3.45 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 22.9, 59.2 and 185.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		22.9x Dilution	59.2x Dilution	185.7x Dilution		
Chlorine in Water (ppb)	1,000	43.7	16.9	5.4	5	200
Δ Temperature (°C)	60	1.20	0.37	0.03	3° above ambient	-

3.1.3 Results – Figures

3.1.3.1 Discharge Flow Rate of 165,600 m³/day at Varying Depths

3.1.3.1.1 Annualised

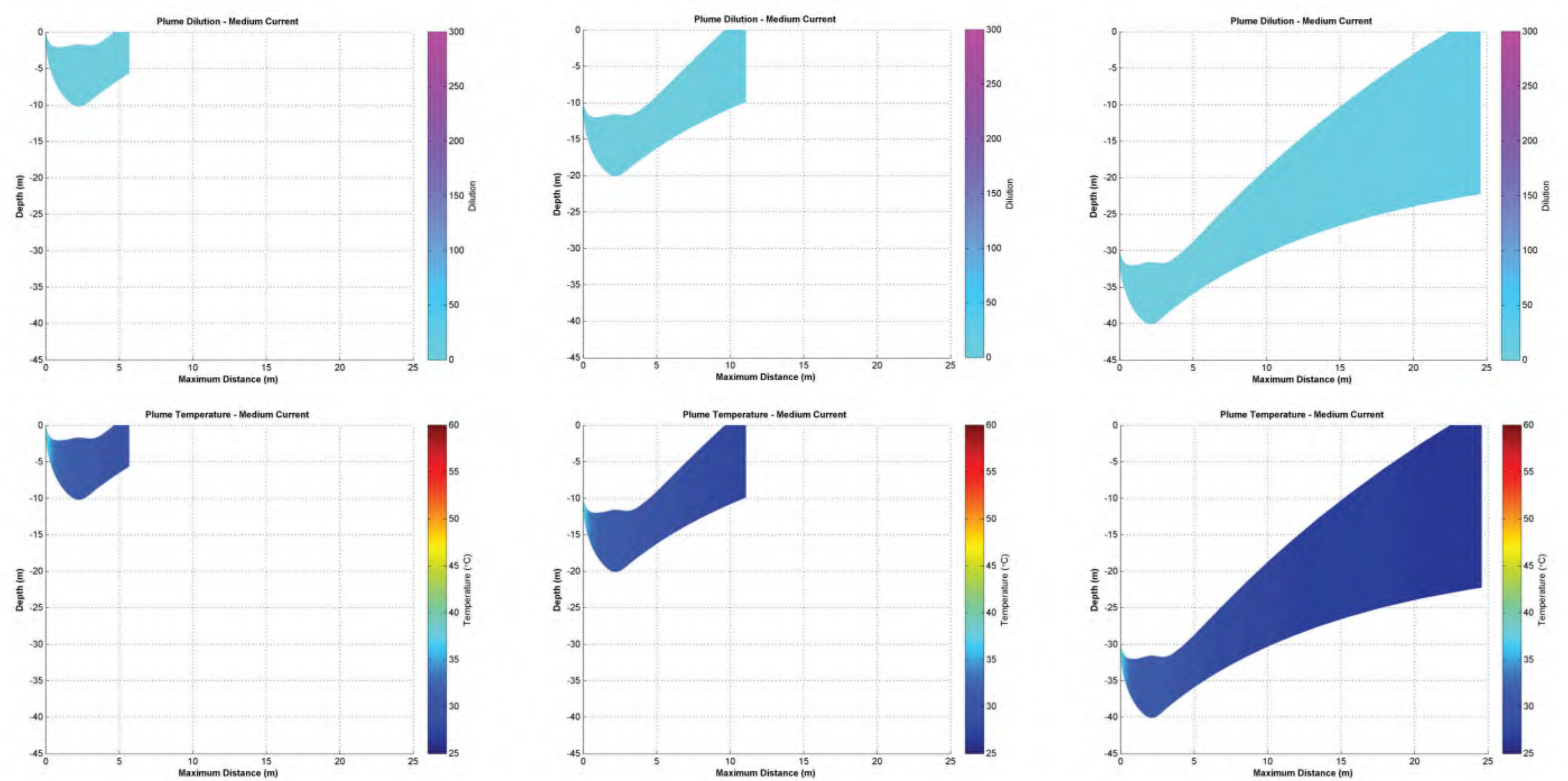

Figure 3.1 Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 165,600 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

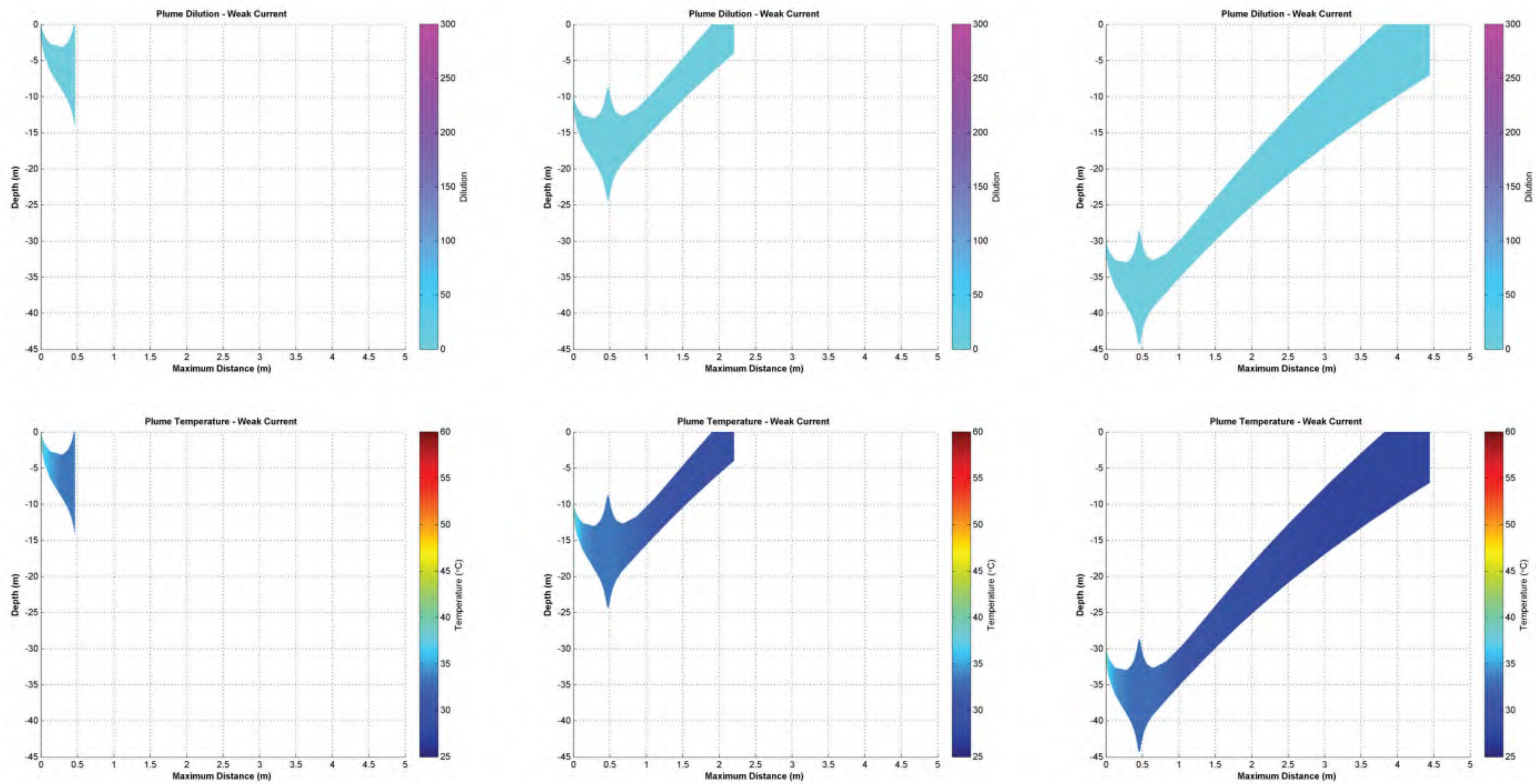

Figure 3.2 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

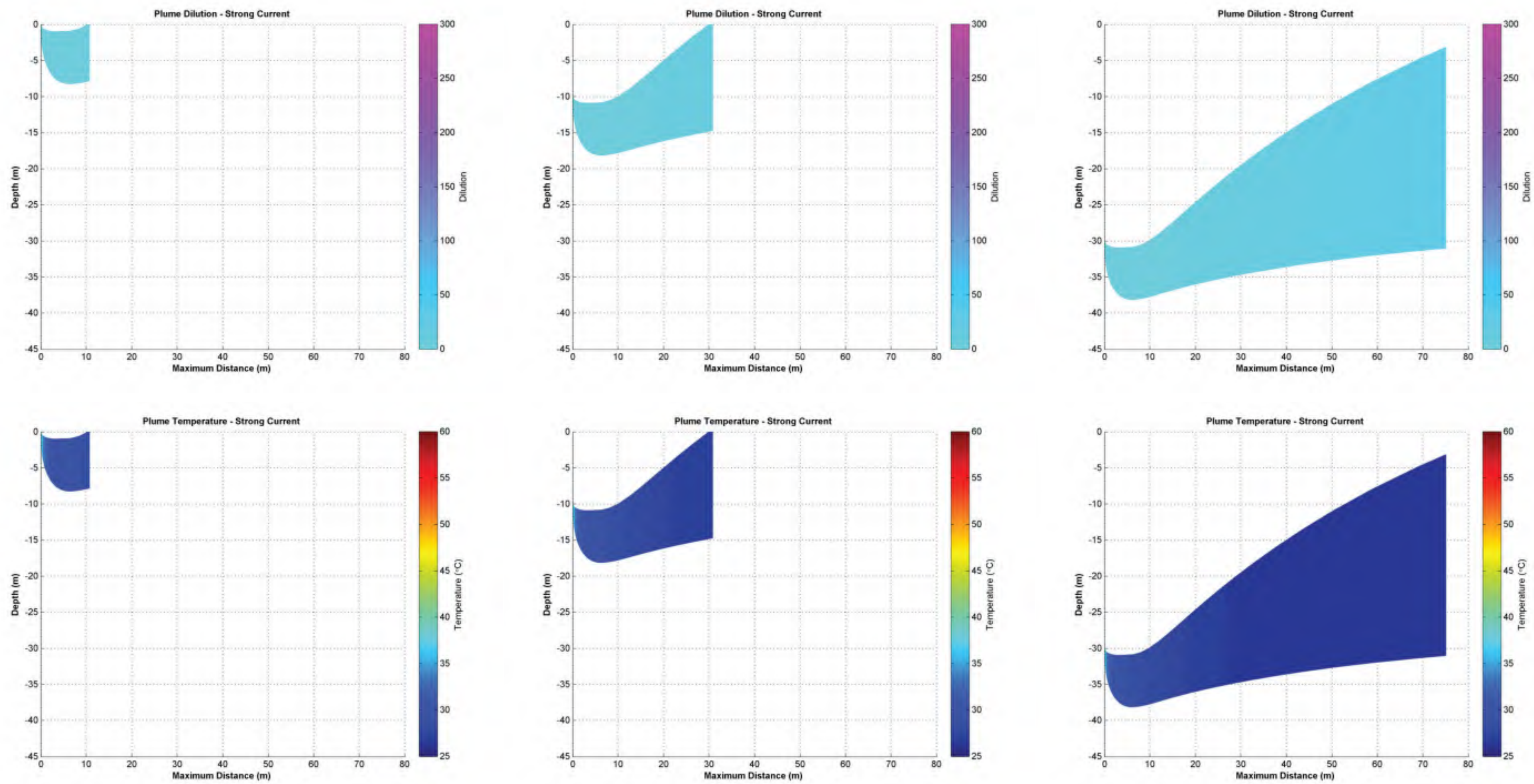

Figure 3.3 Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.1.2 Summer

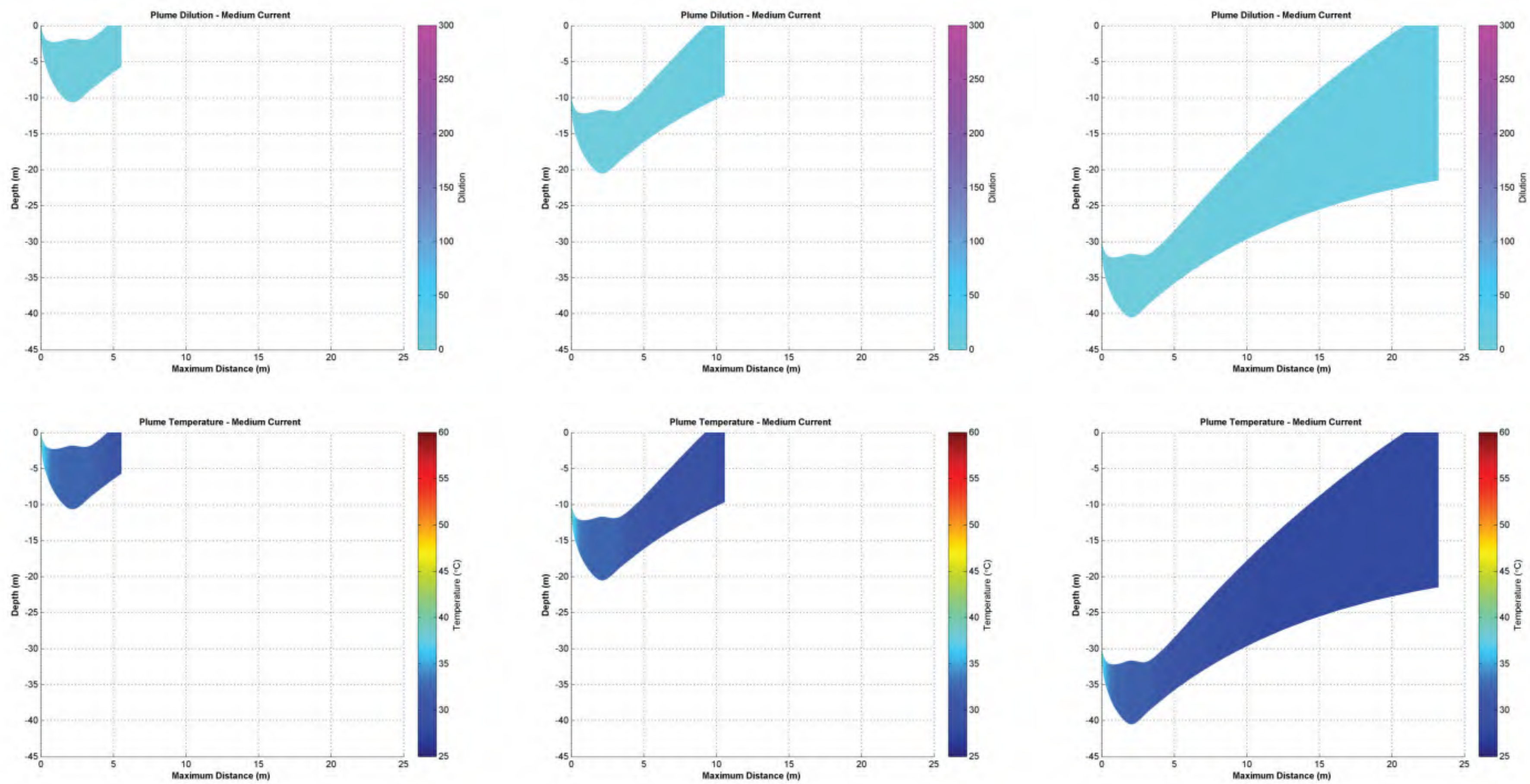

Figure 3.4 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

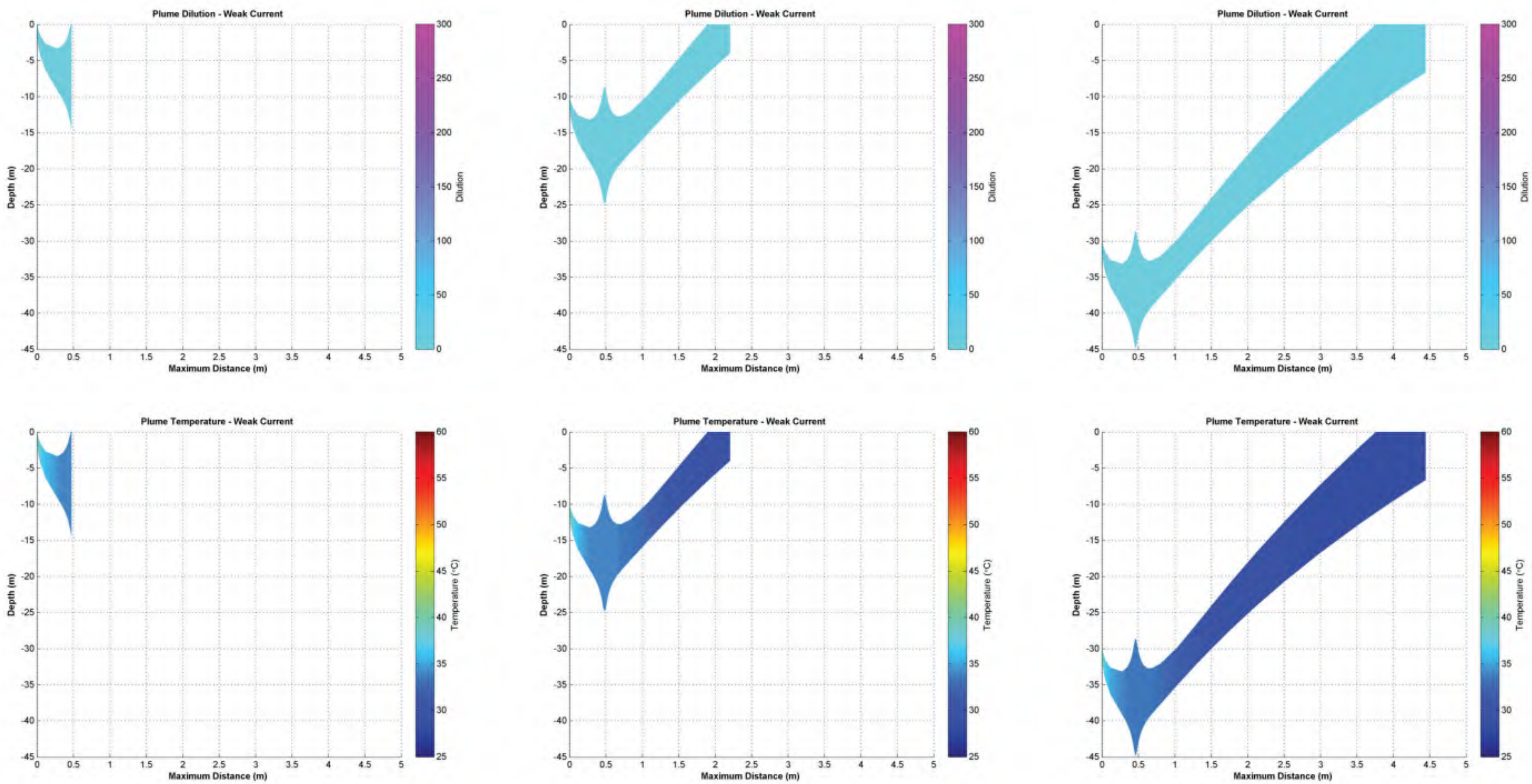

Figure 3.5 Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

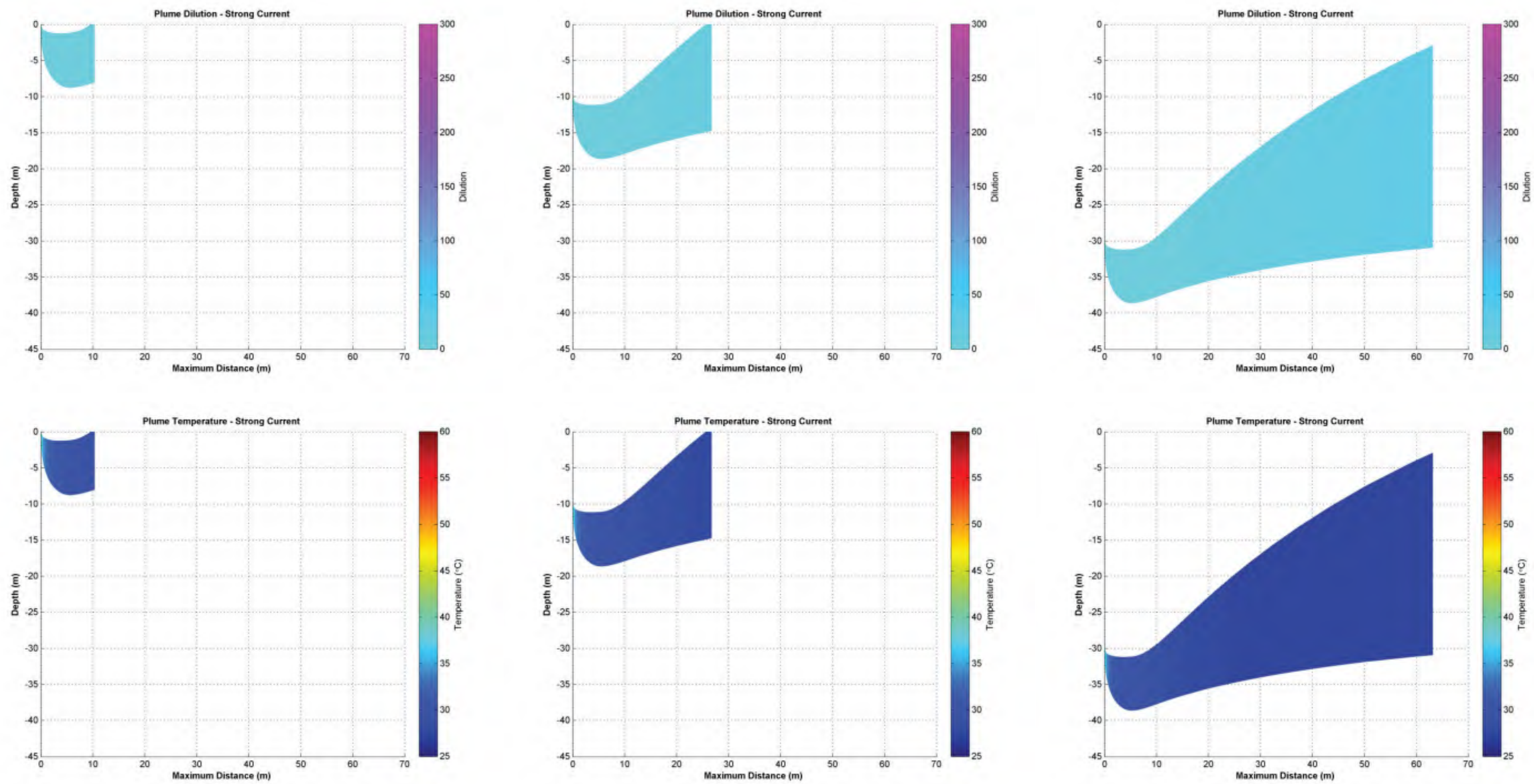

Figure 3.6 Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.1.3 Transitional

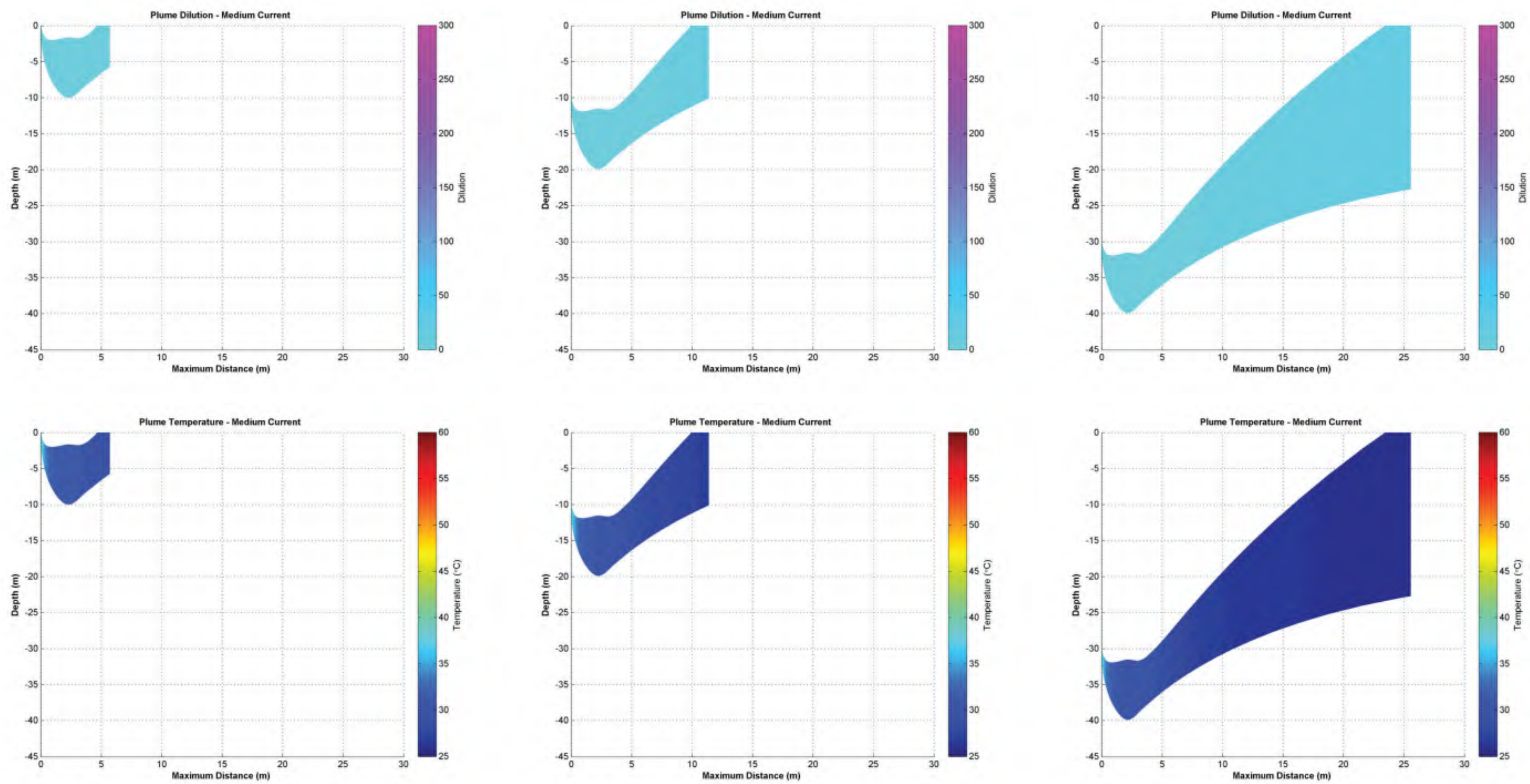

Figure 3.7 Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

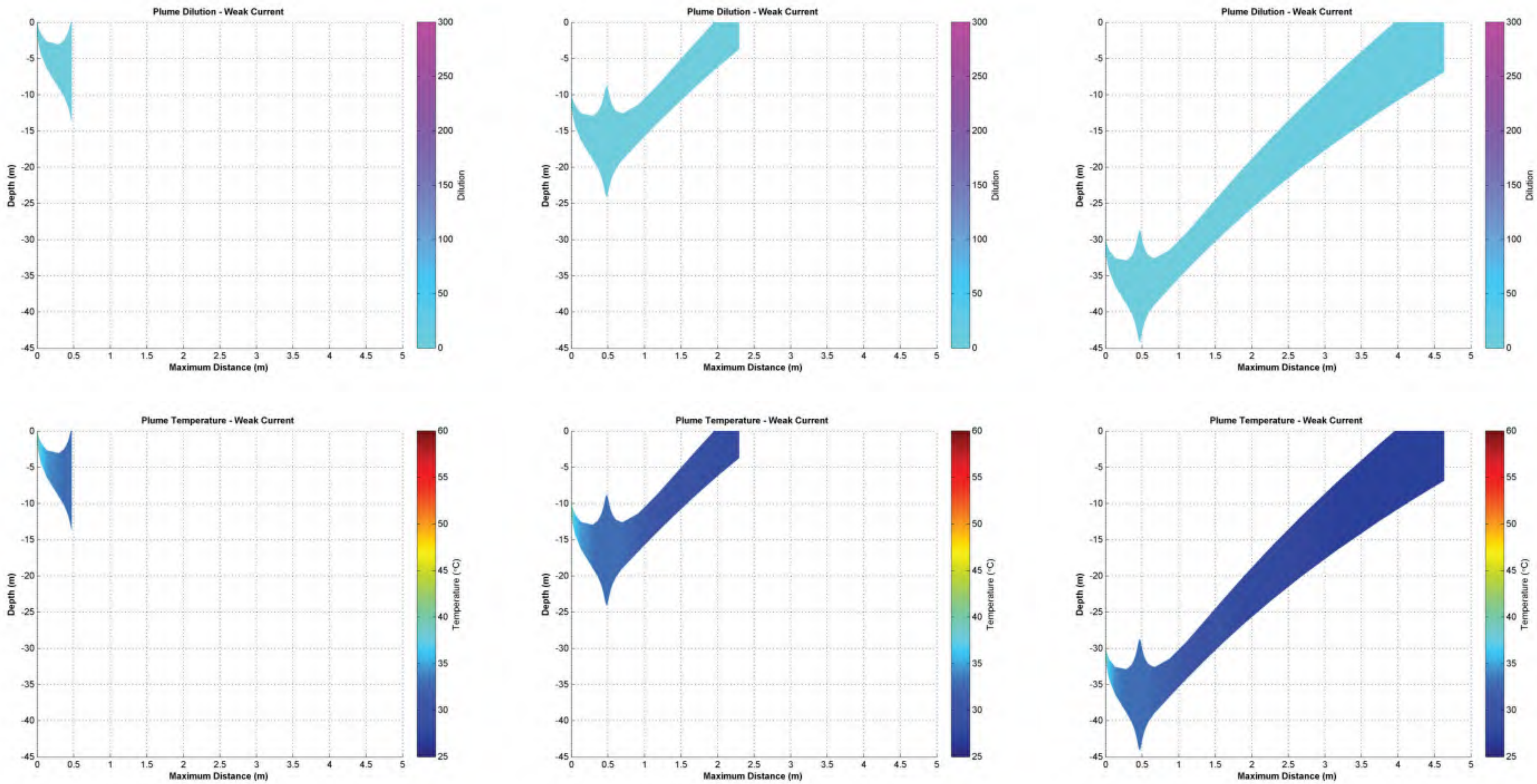

Figure 3.8 **Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

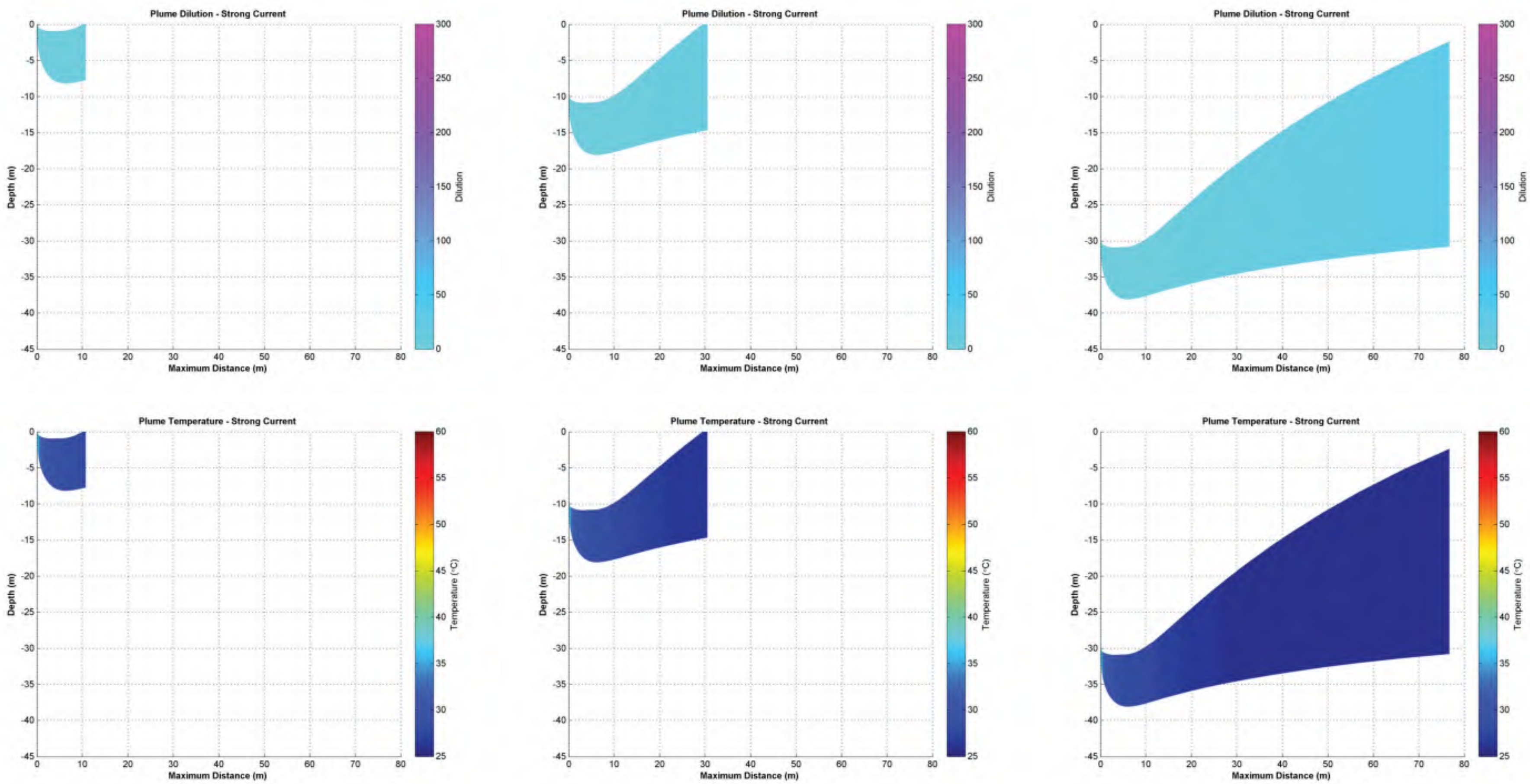

Figure 3.9 Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.1.4 Winter

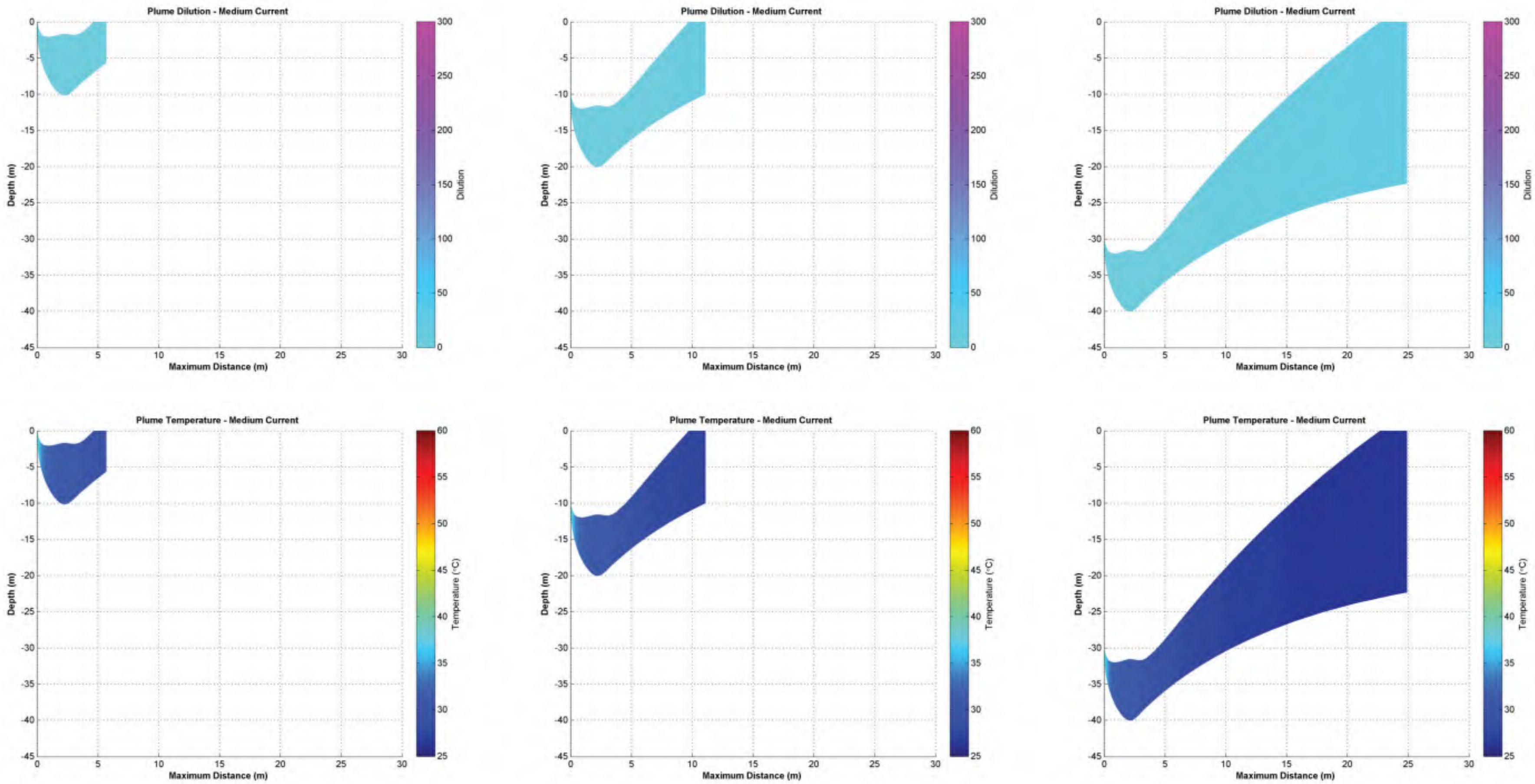

Figure 3.10 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

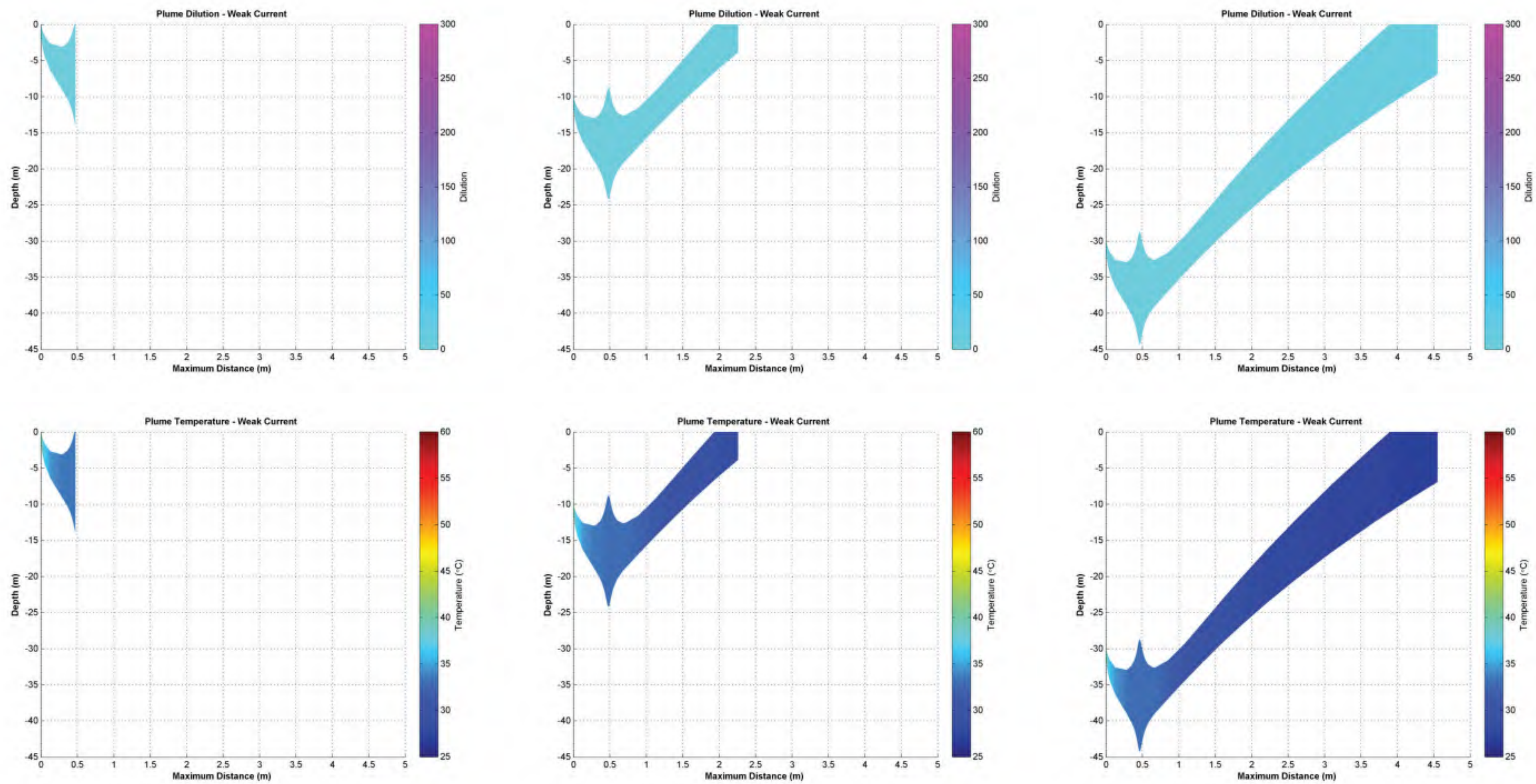

Figure 3.11 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

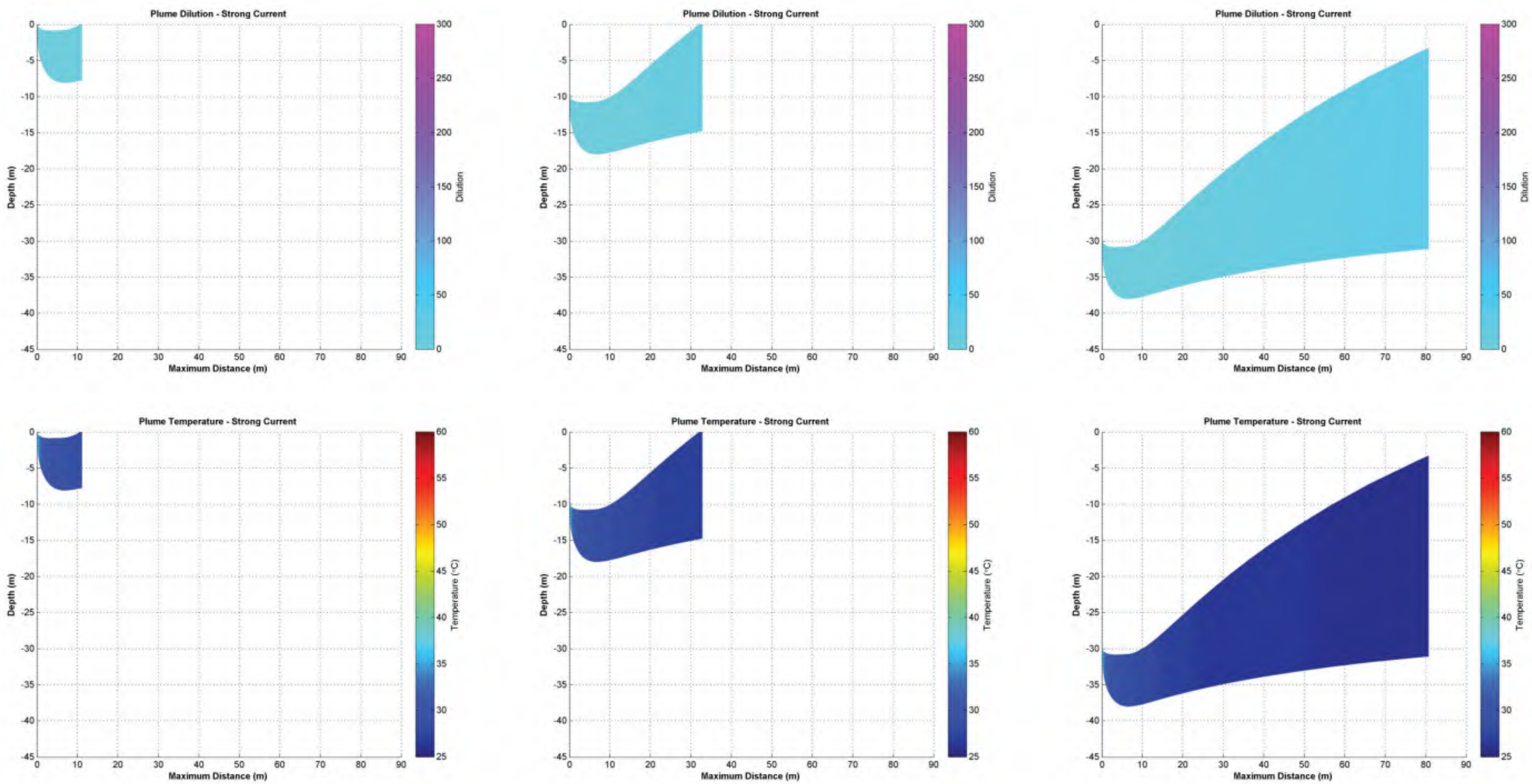

Figure 3.12 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2 Discharge Flow Rate of 64,800 m^3/day at Varying Depths

3.1.3.2.1 Annualised

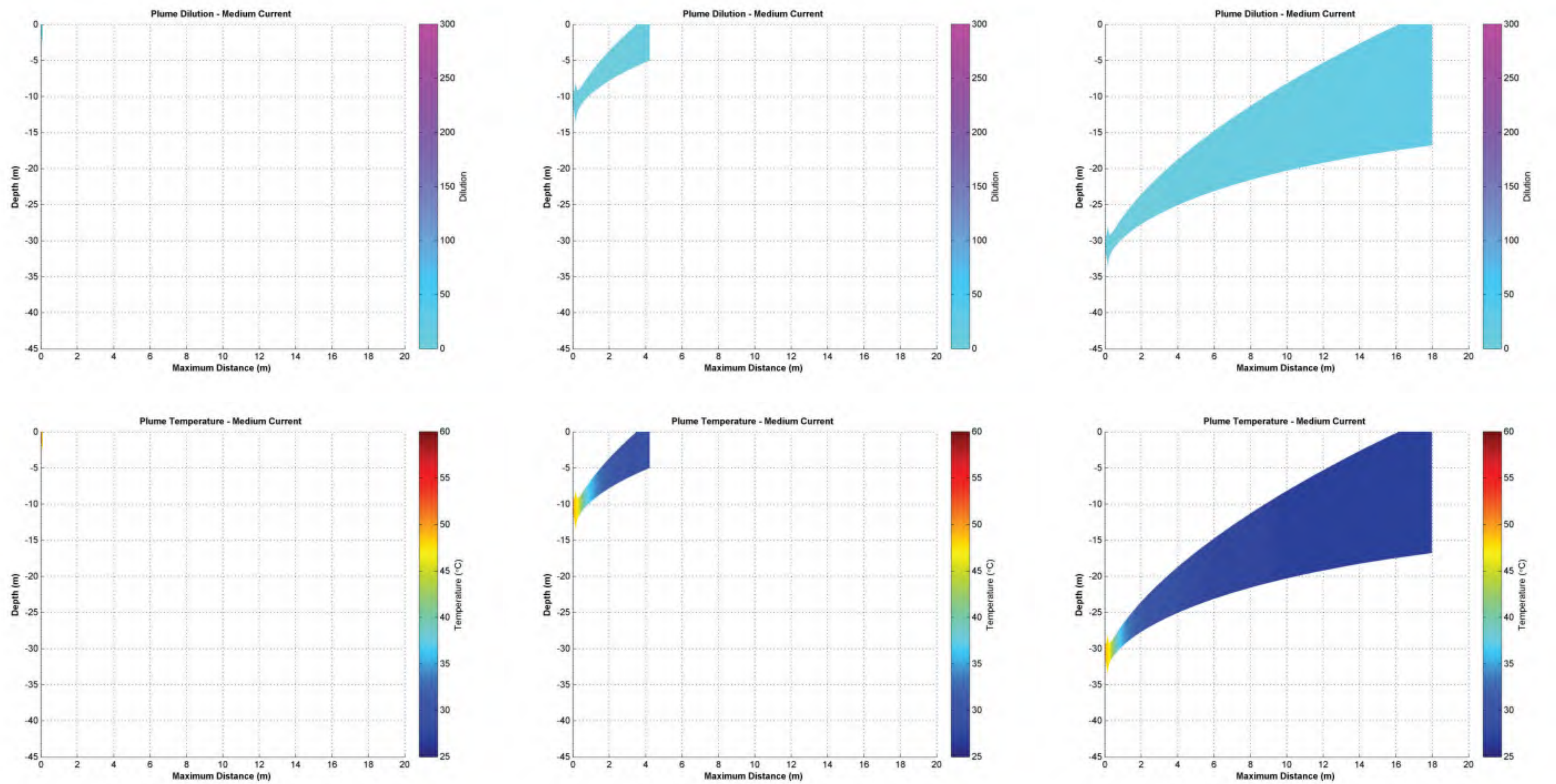

Figure 3.13 Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

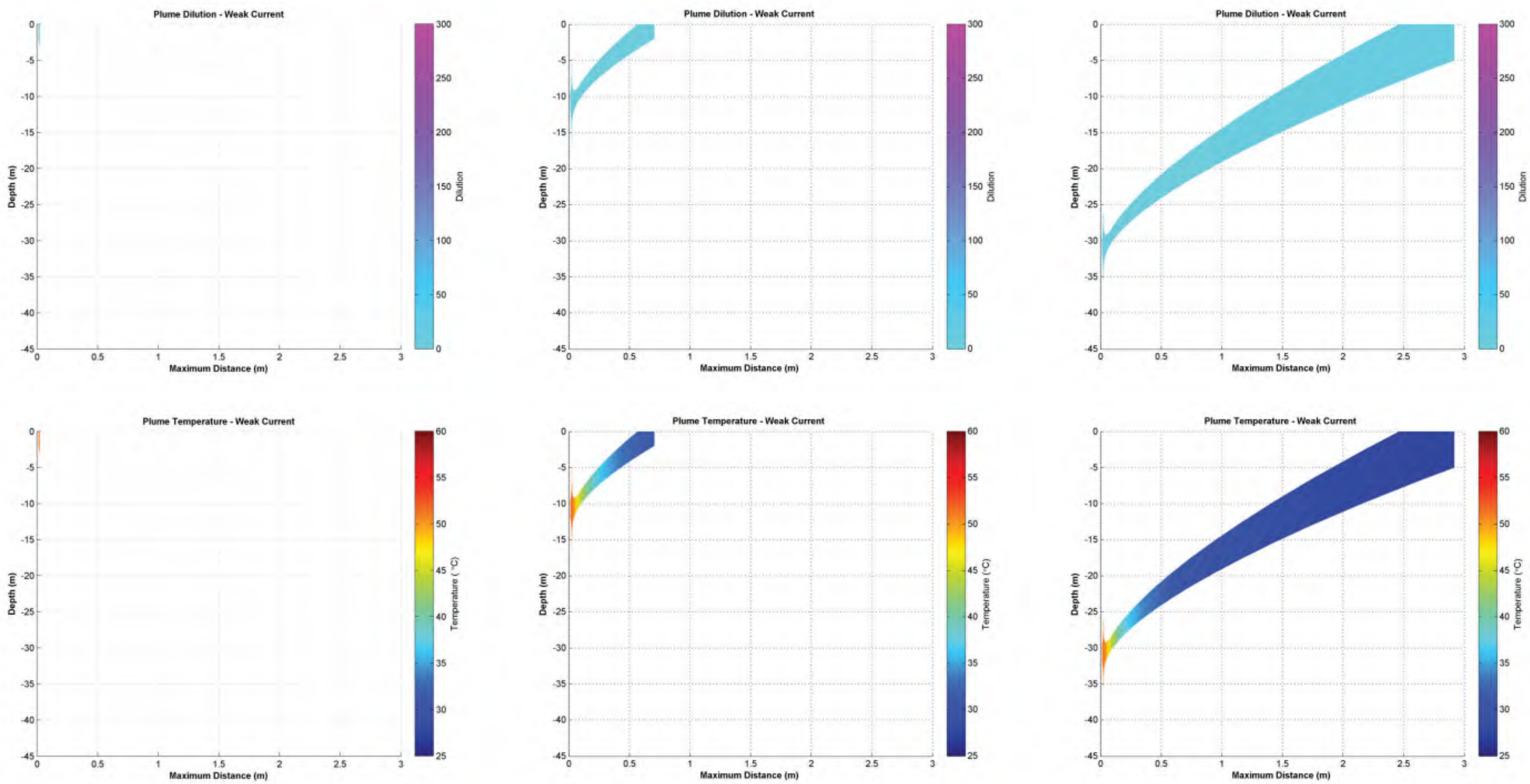

Figure 3.14 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

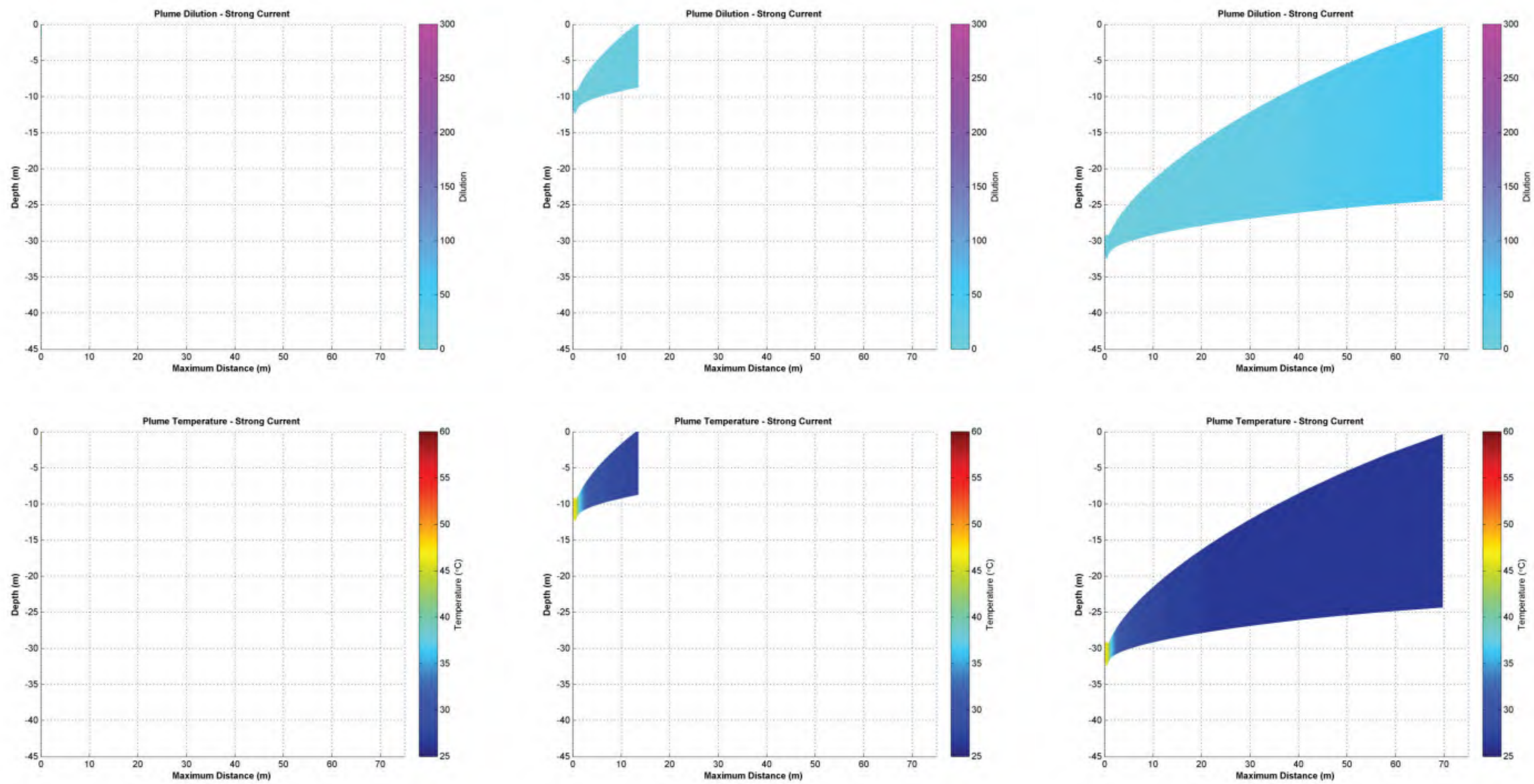

Figure 3.15 Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2.2 Summer

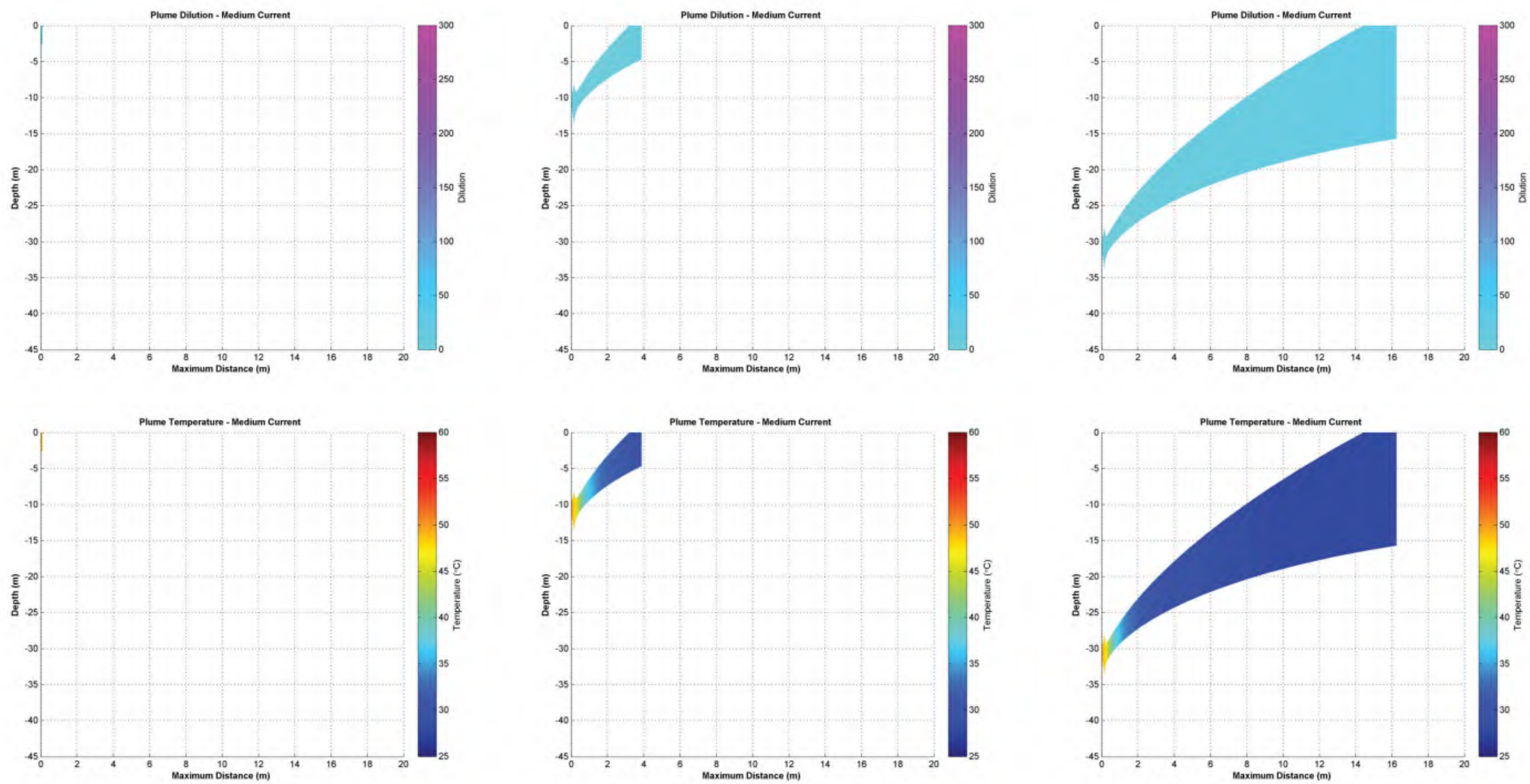

Figure 3.16 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

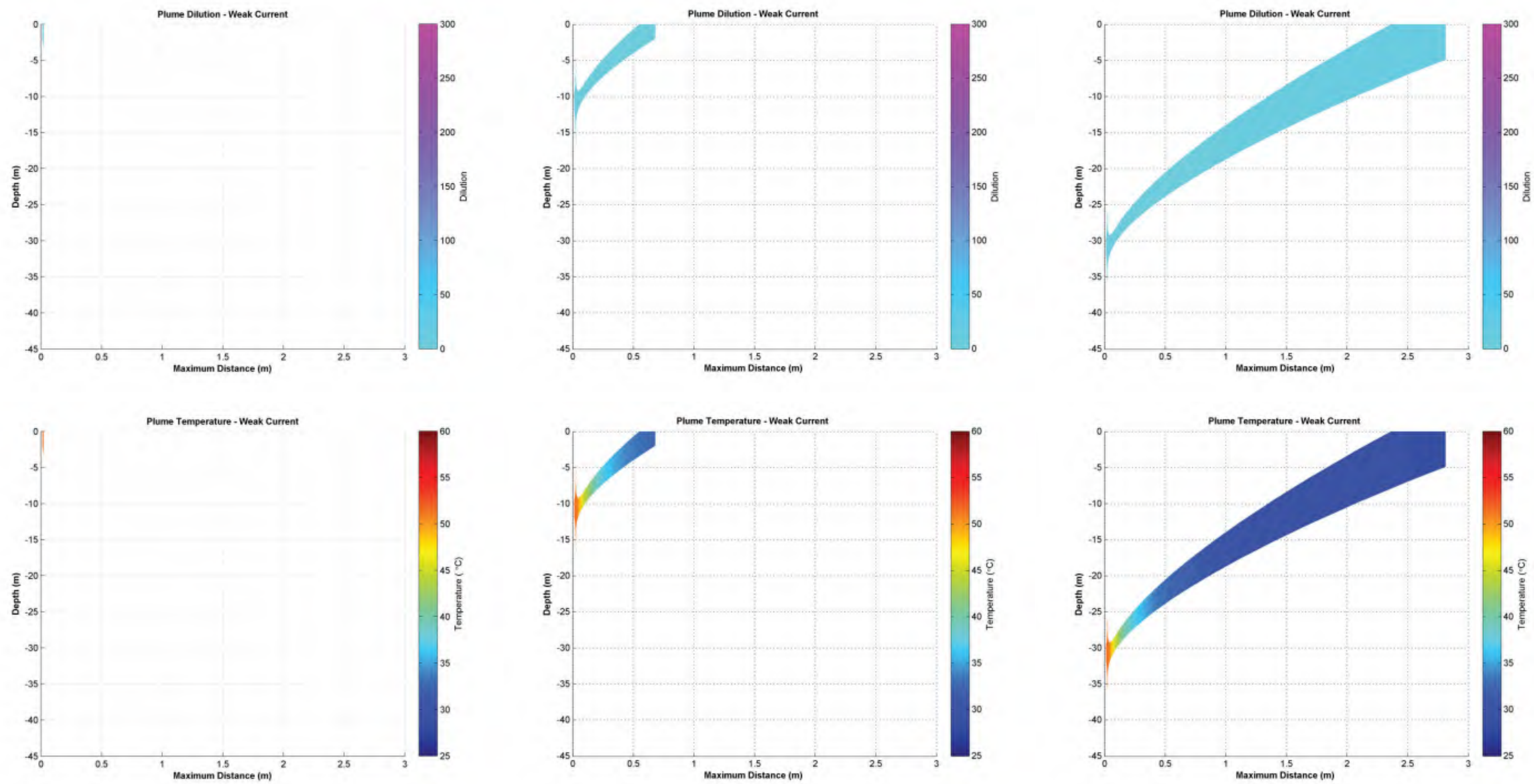

Figure 3.17 Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

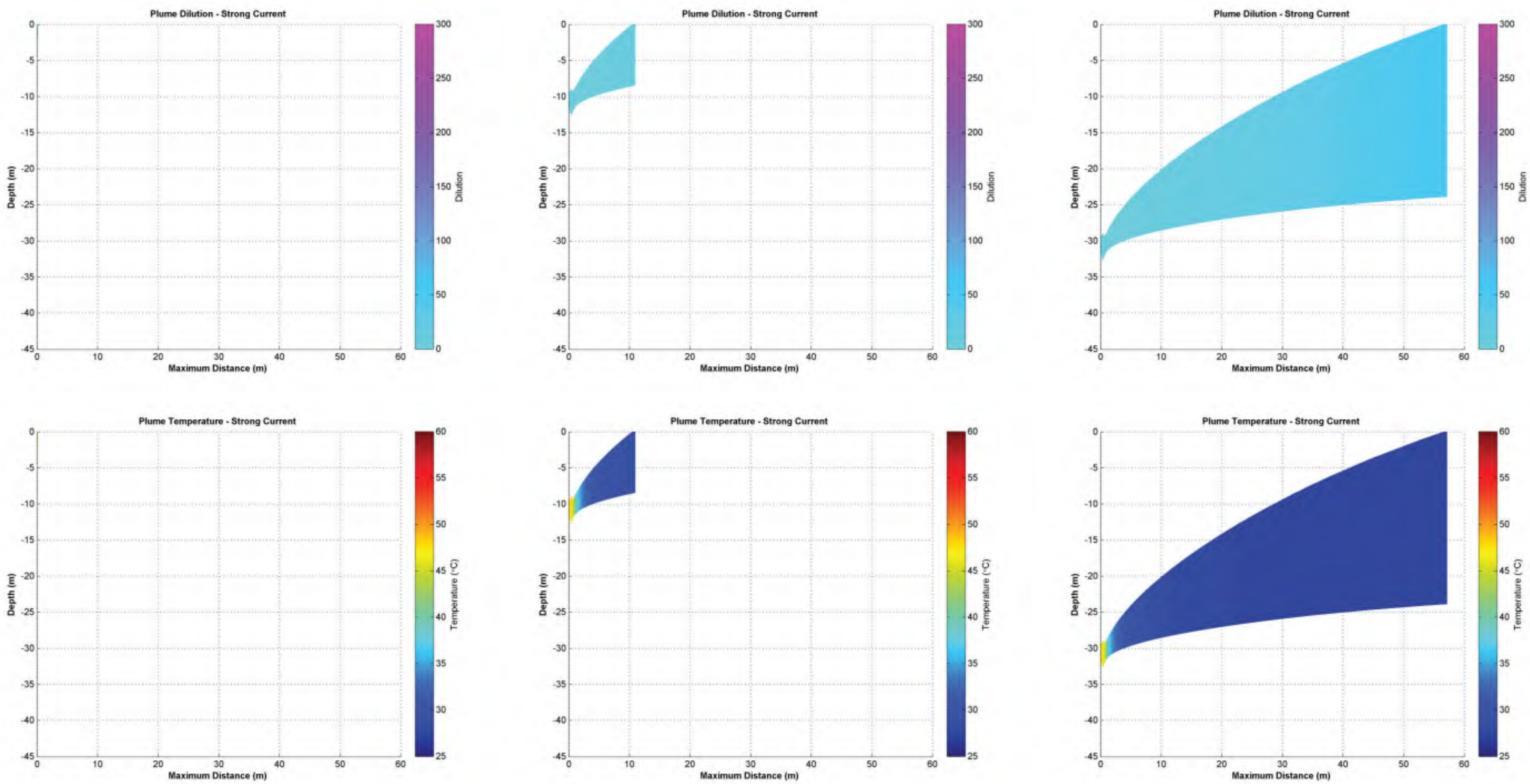

Figure 3.18 Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2.3 Transitional

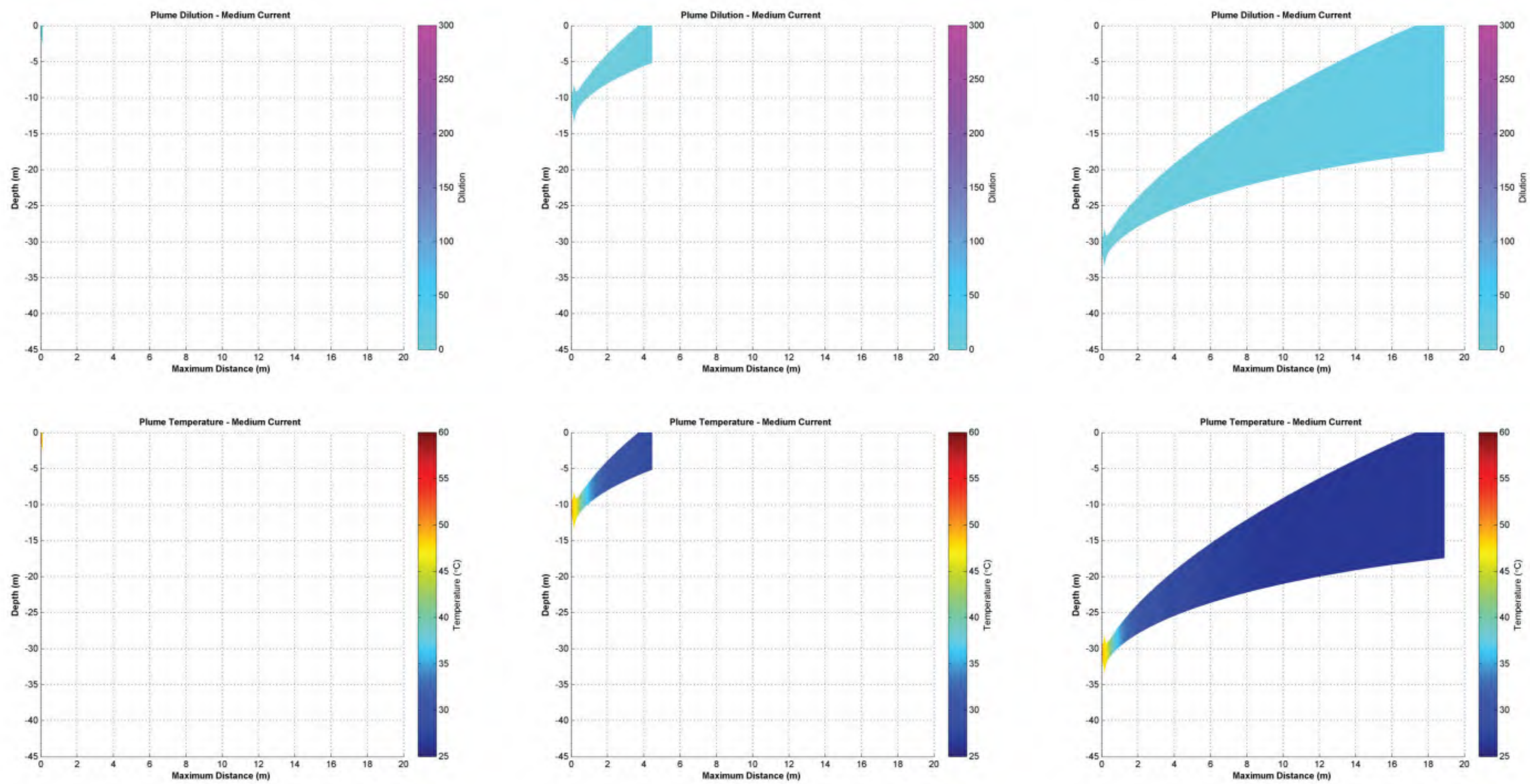

Figure 3.19 Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

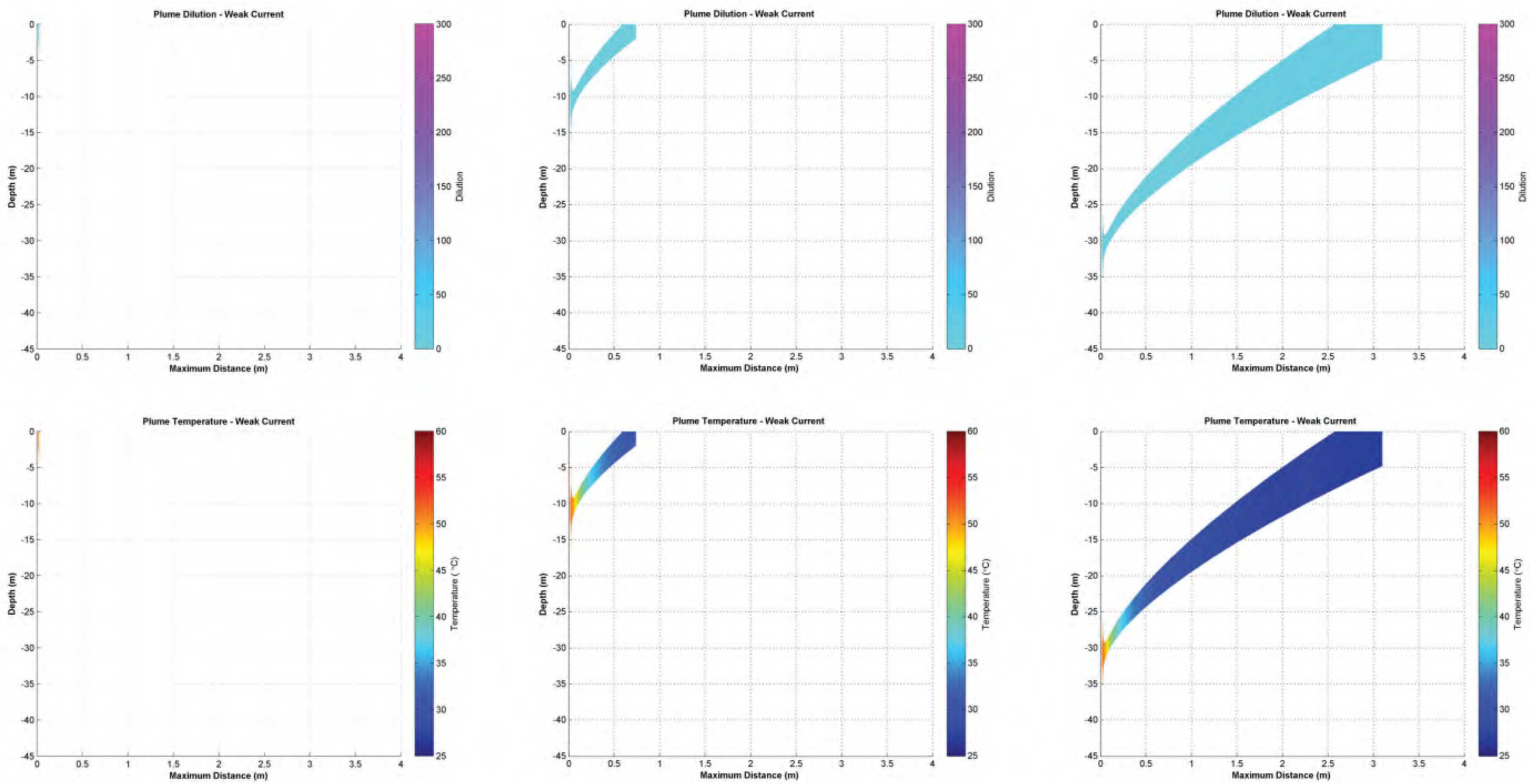

Figure 3.20 Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

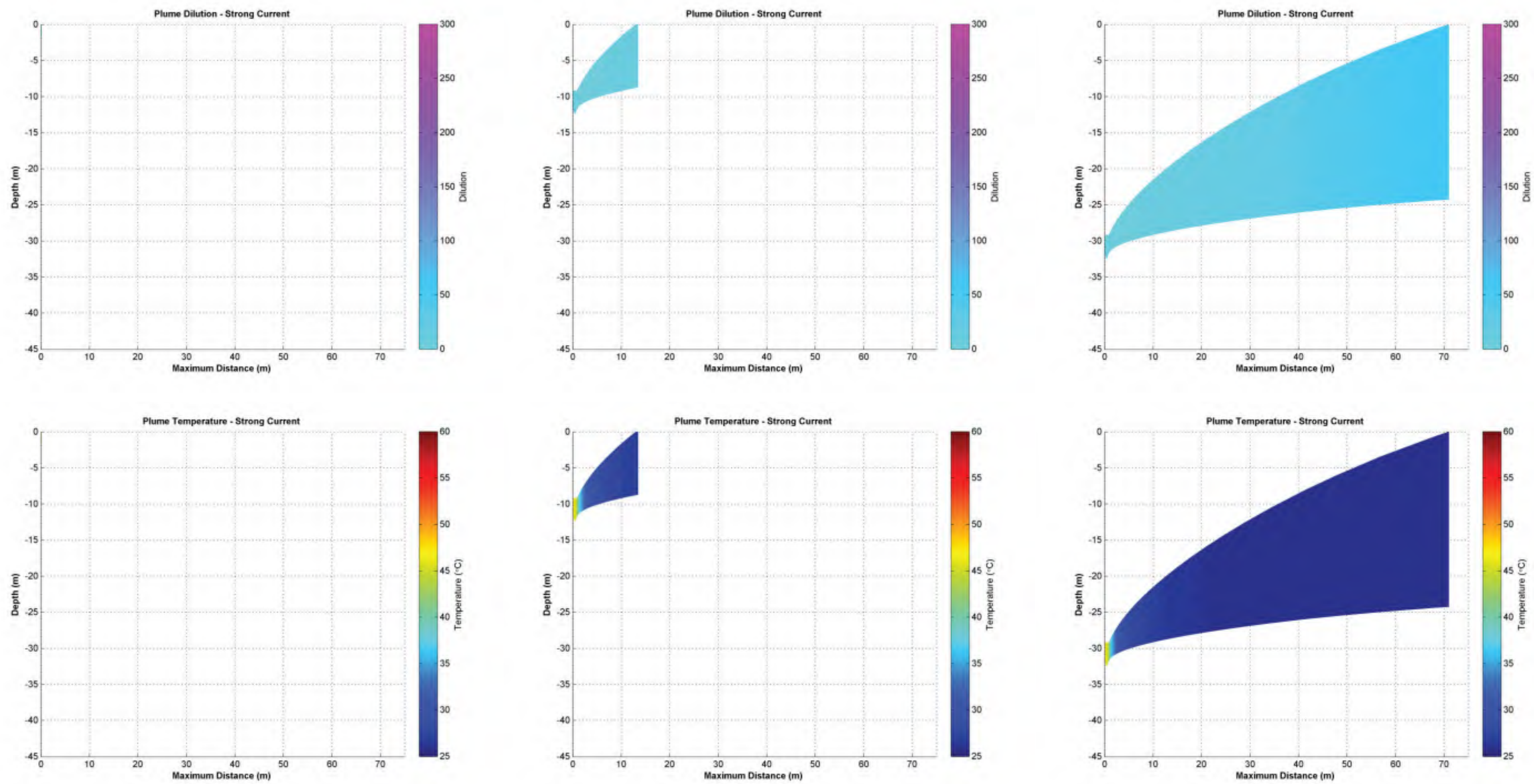

Figure 3.21 Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2.4 Winter

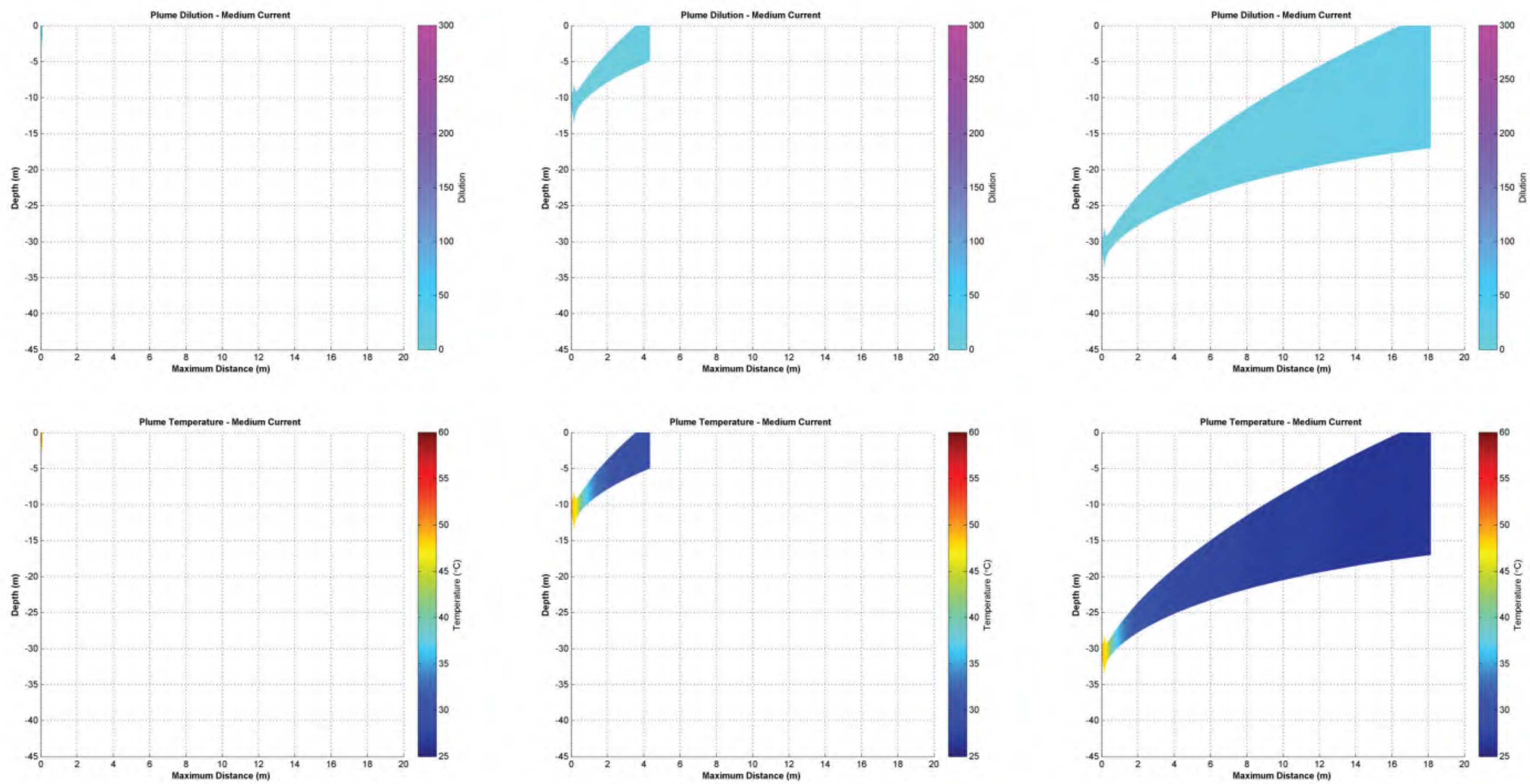

Figure 3.22 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

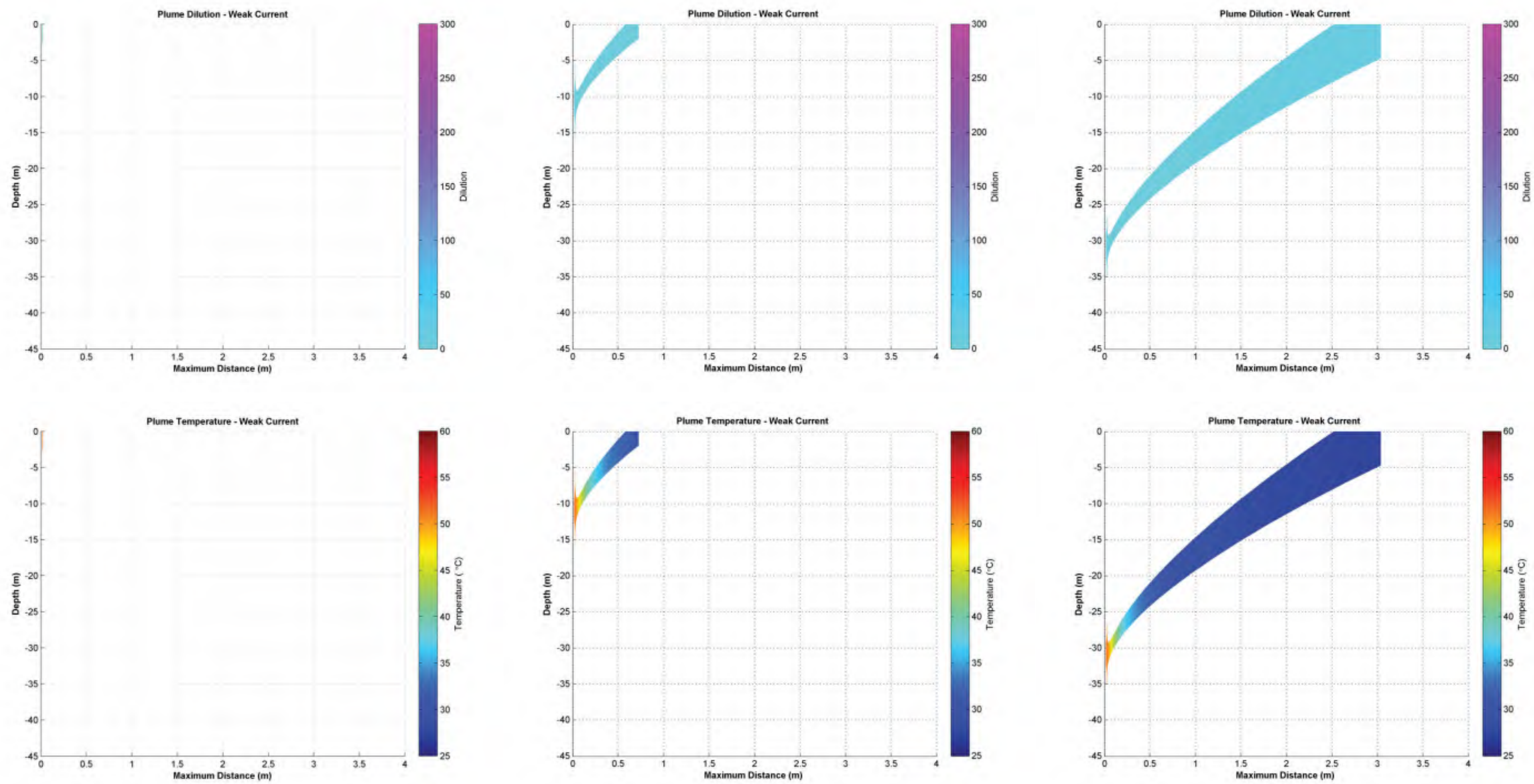

Figure 3.23 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

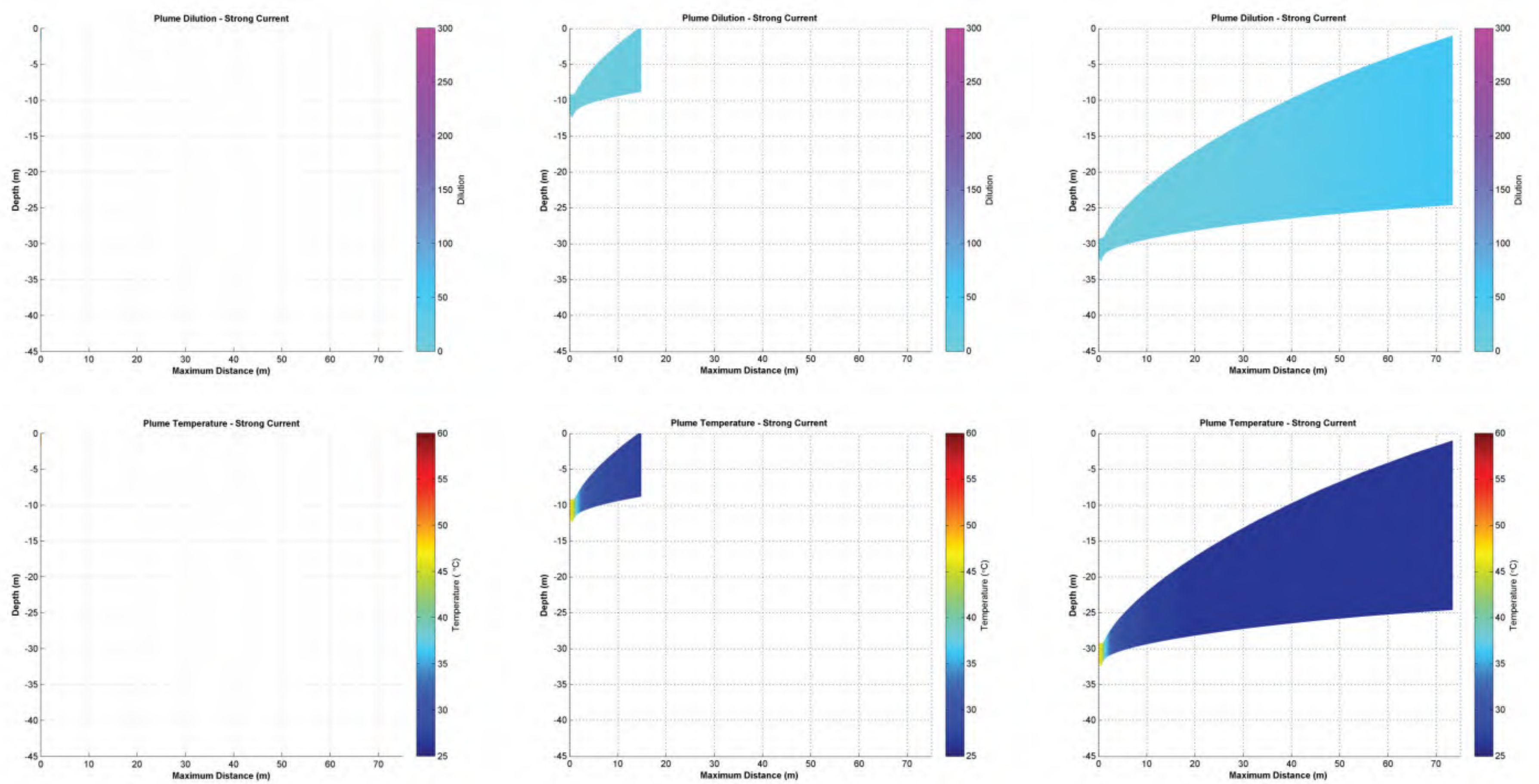

Figure 3.24 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.3 Discharge Flow Rate of 82,800 m^3/day at Varying Depths

3.1.3.3.1 Annualised

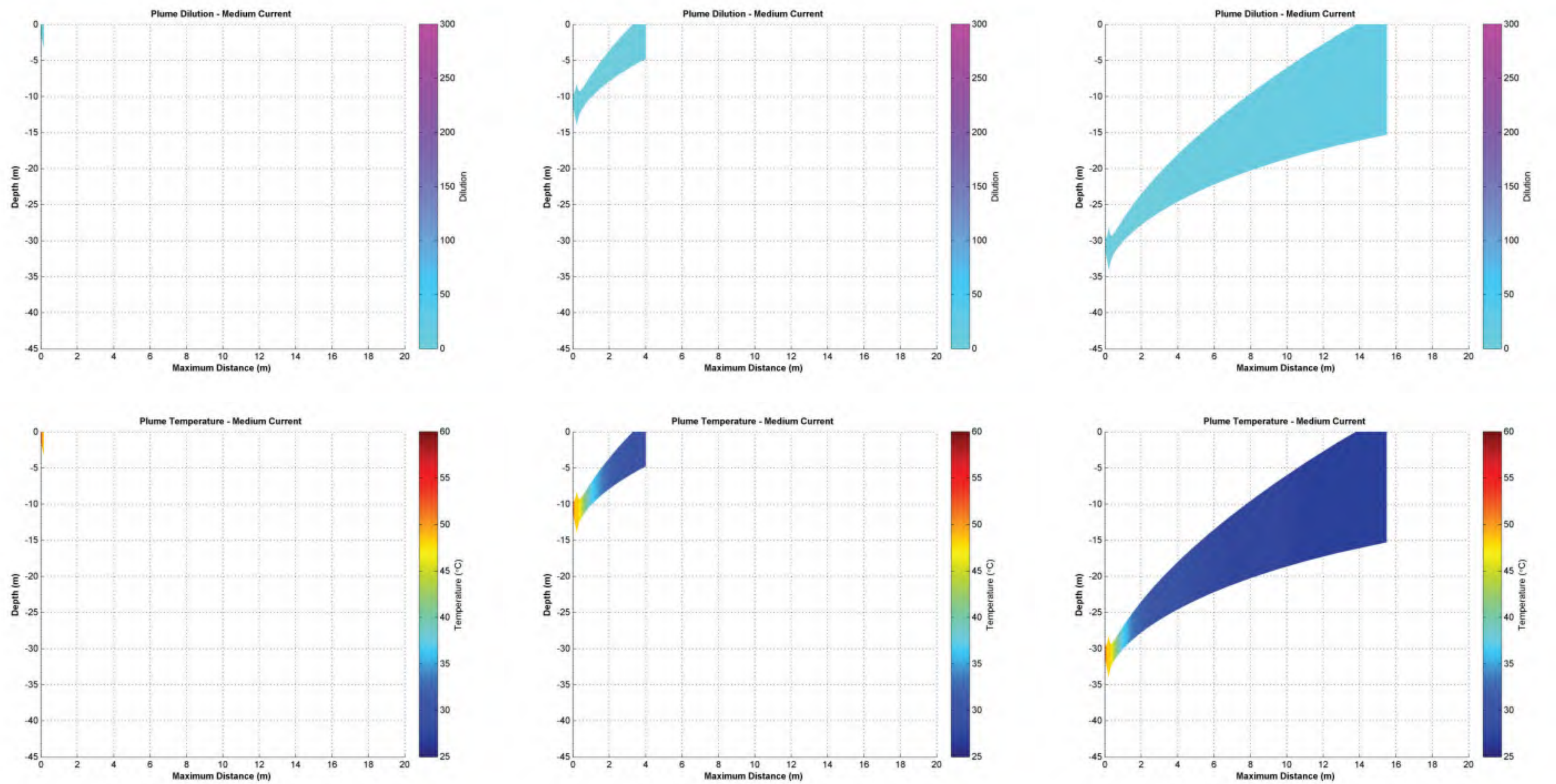

Figure 3.25 Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

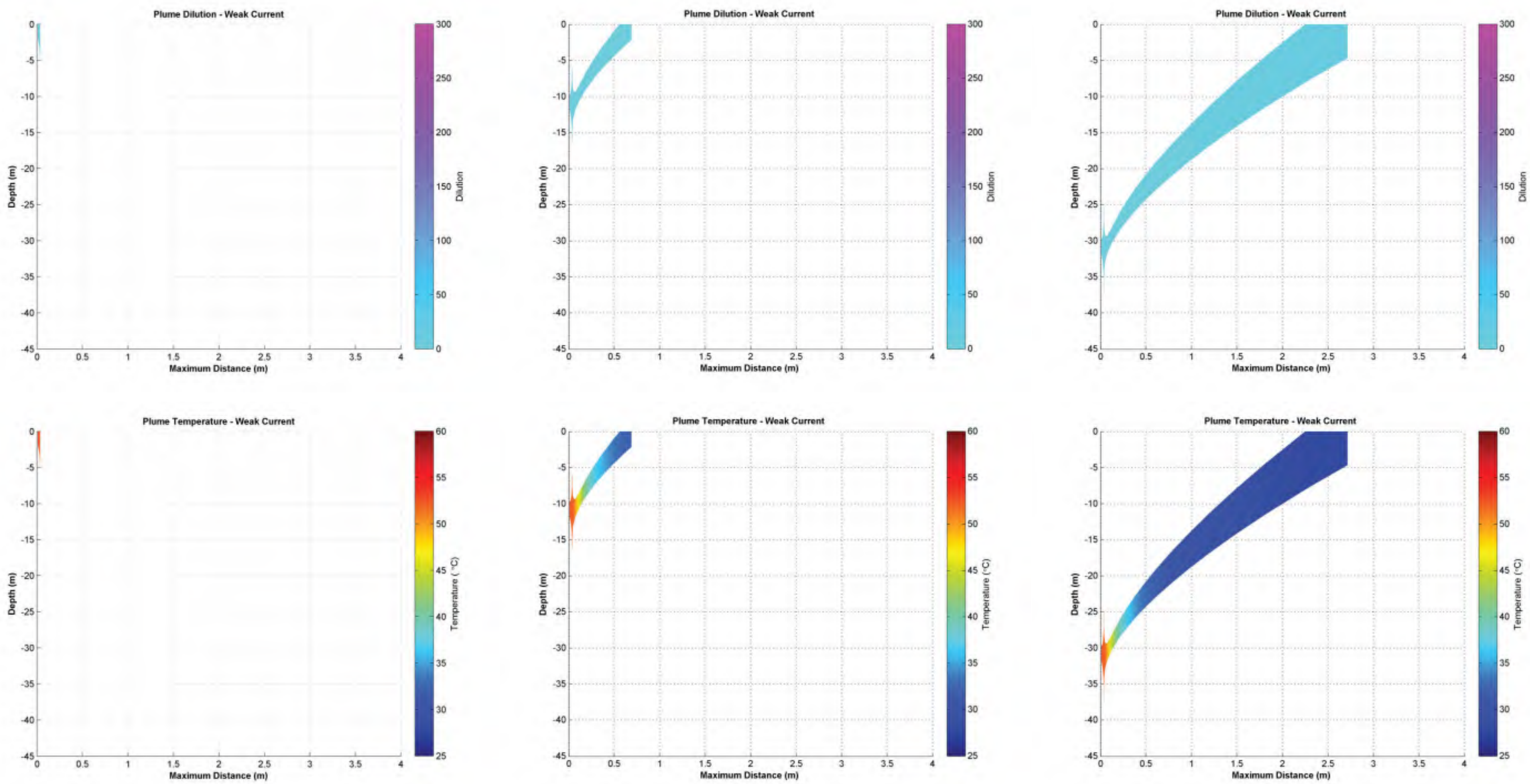

Figure 3.26 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

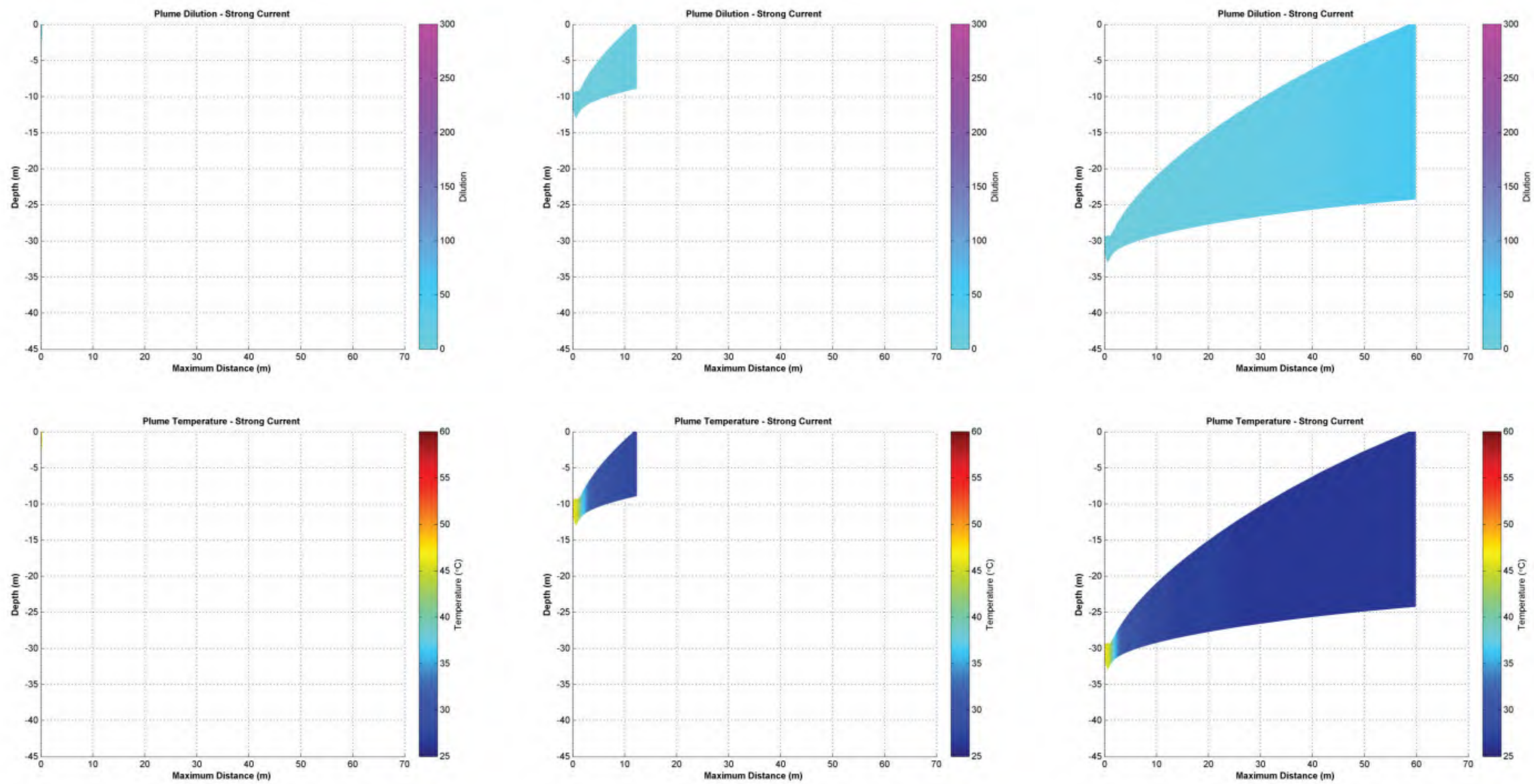

Figure 3.27 **Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

3.1.3.3.2 Summer

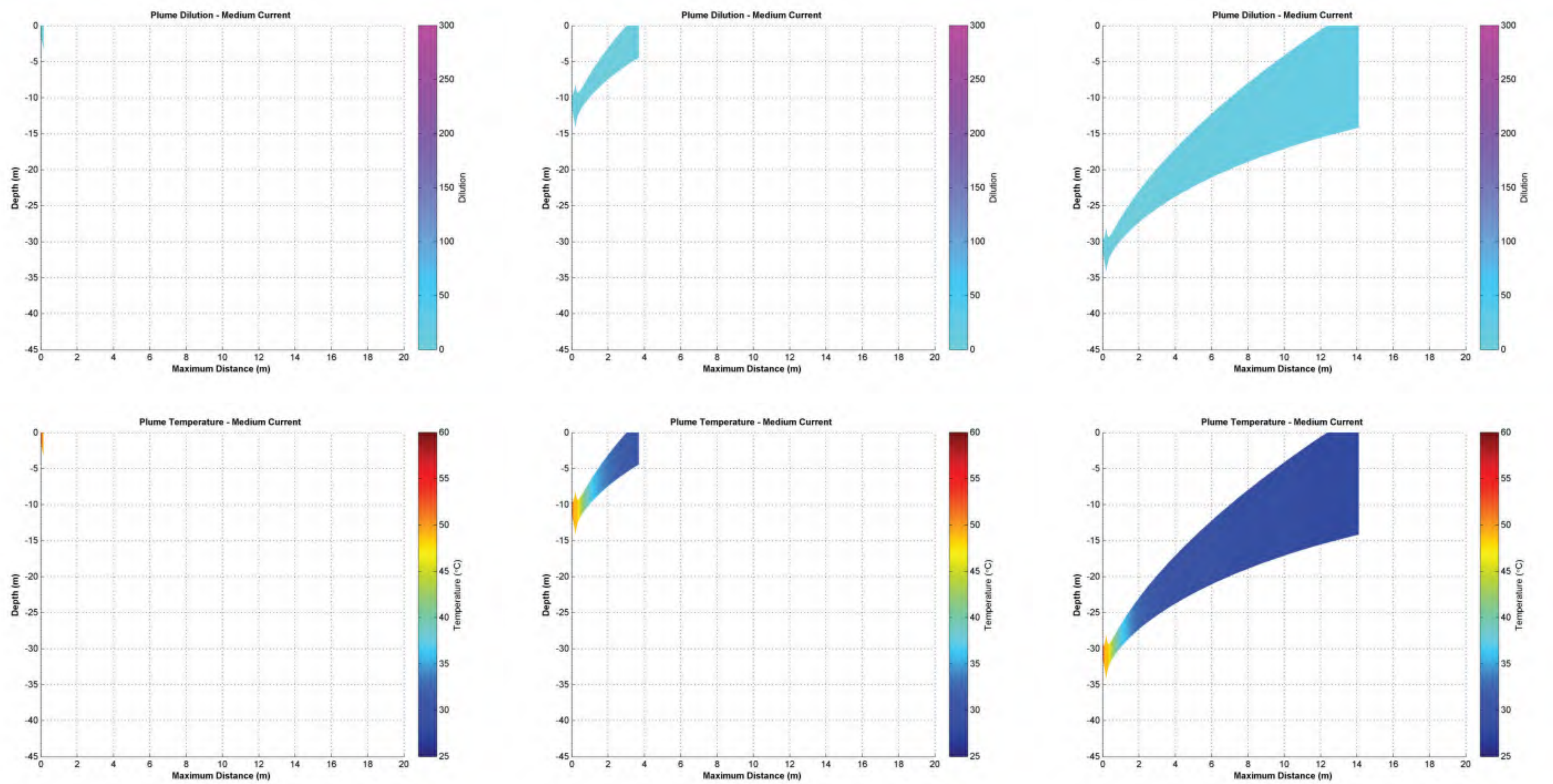

Figure 3.28 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

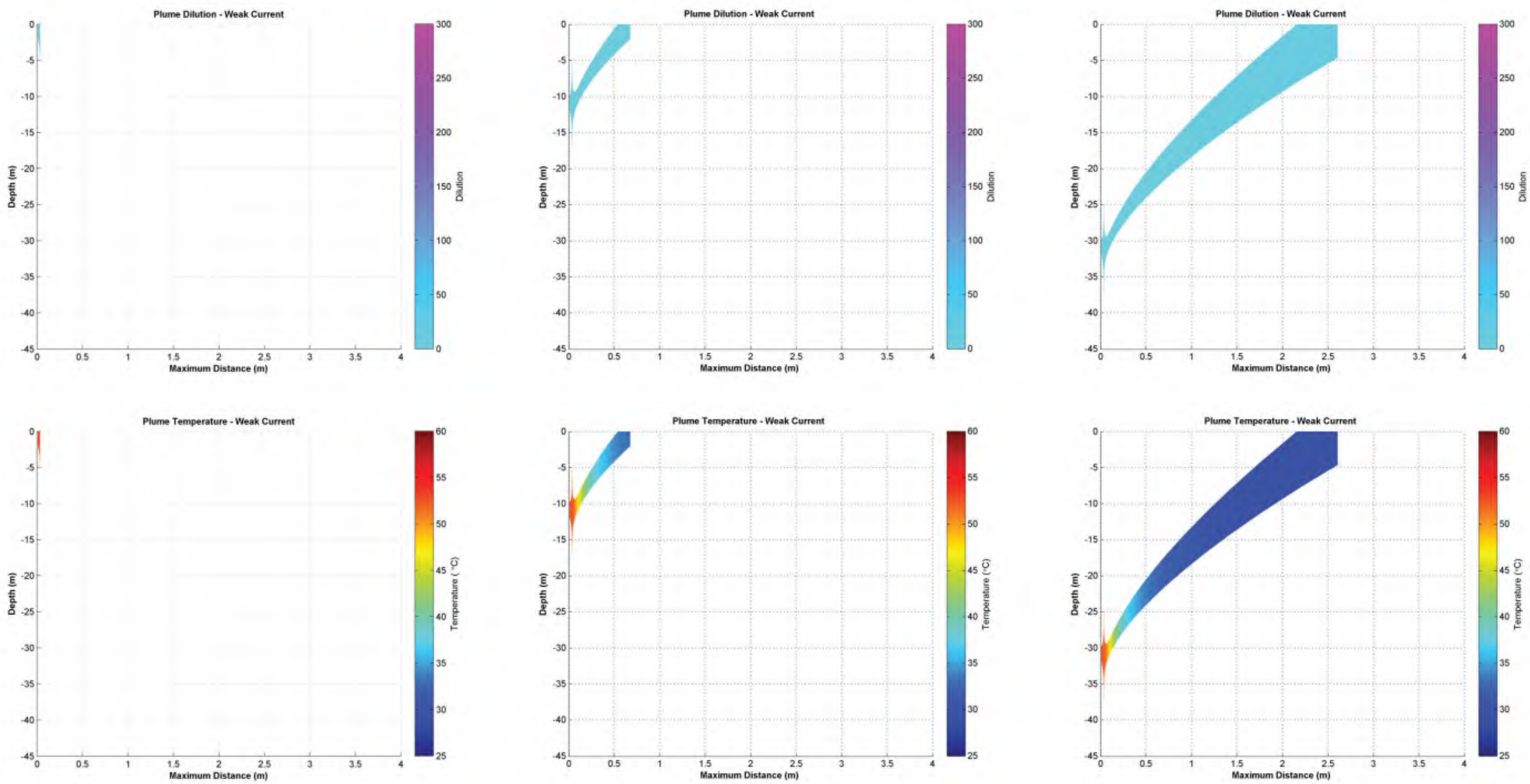

Figure 3.29 Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

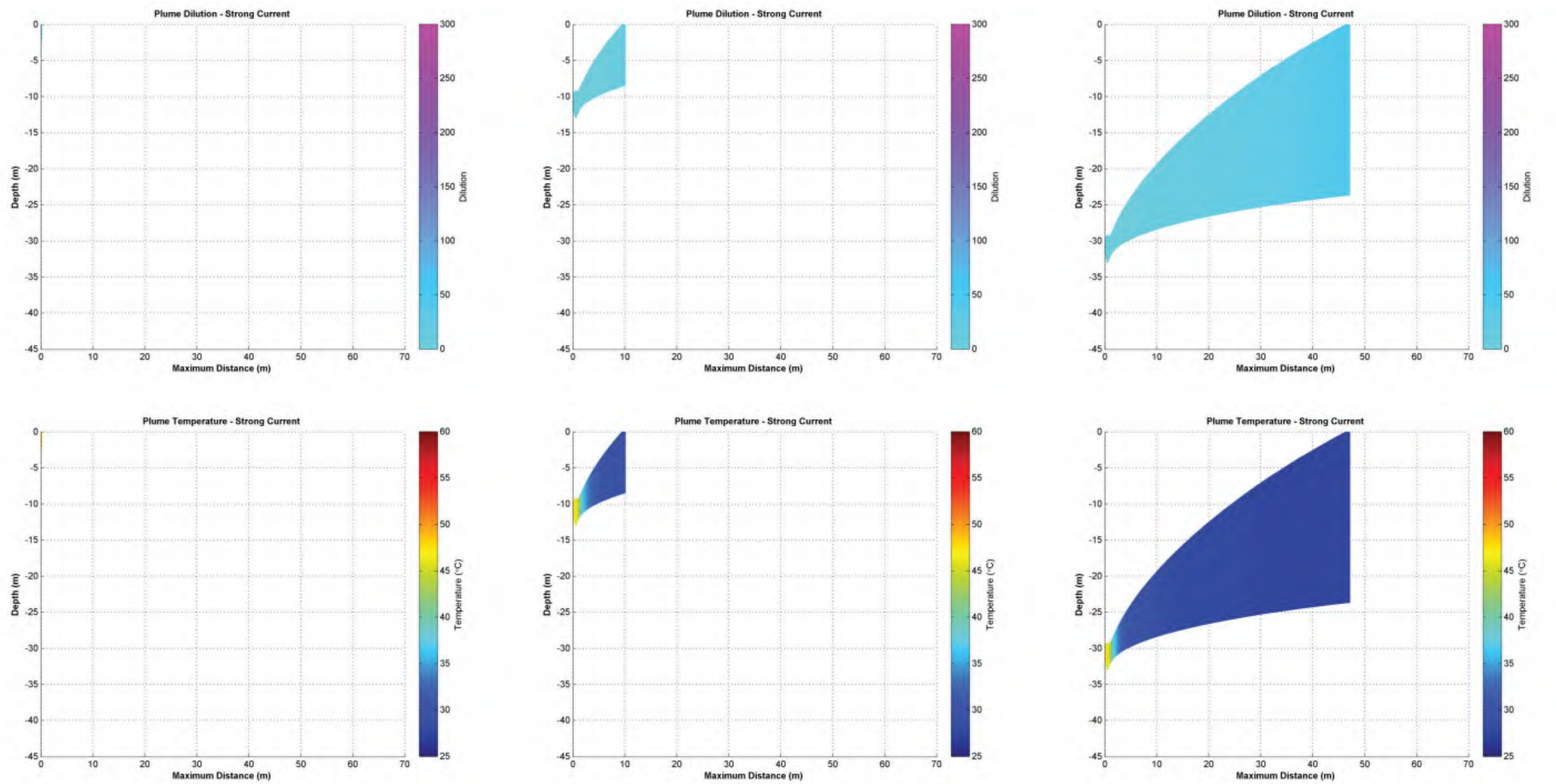

Figure 3.30 Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.3.3 Transitional

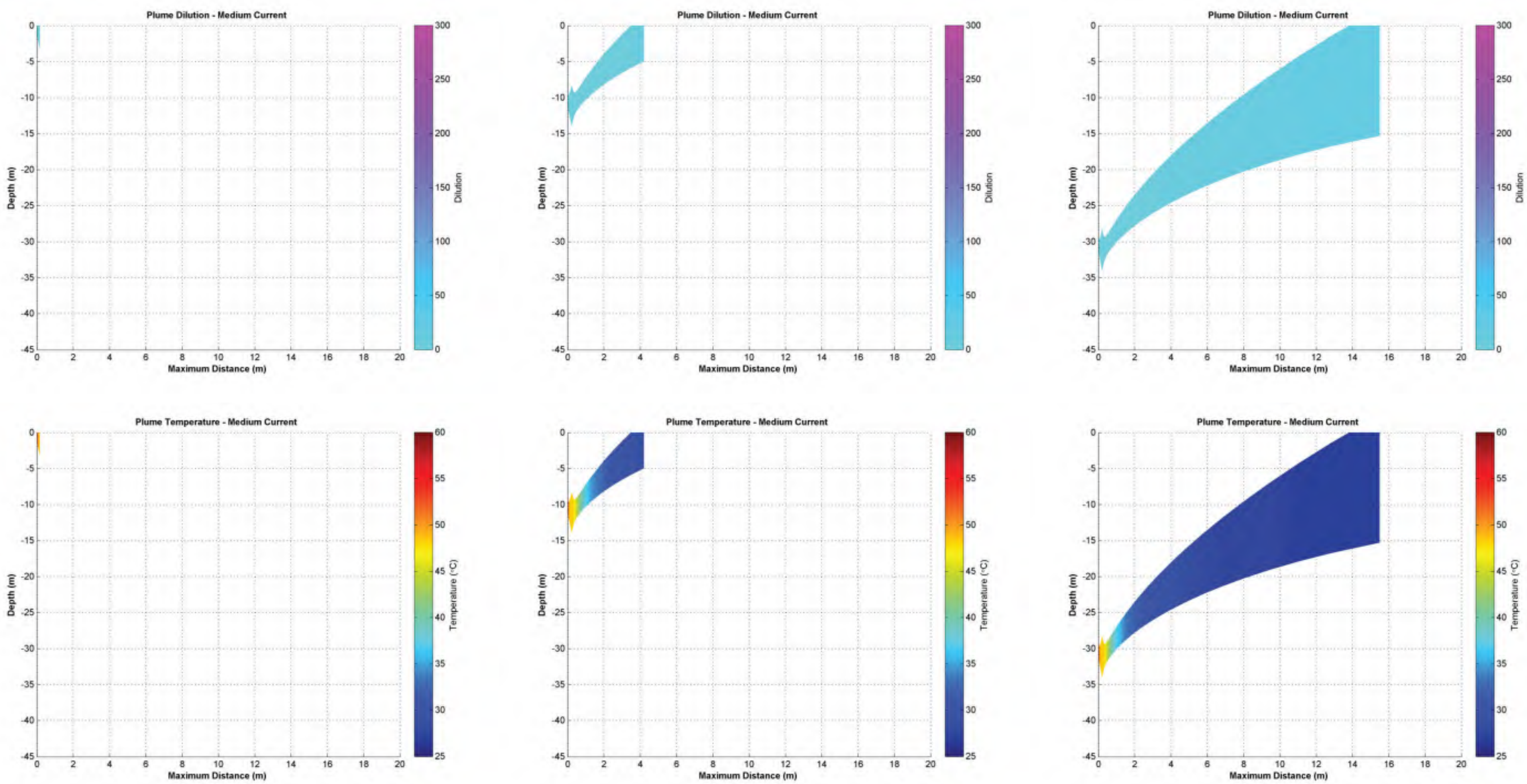

Figure 3.31 Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

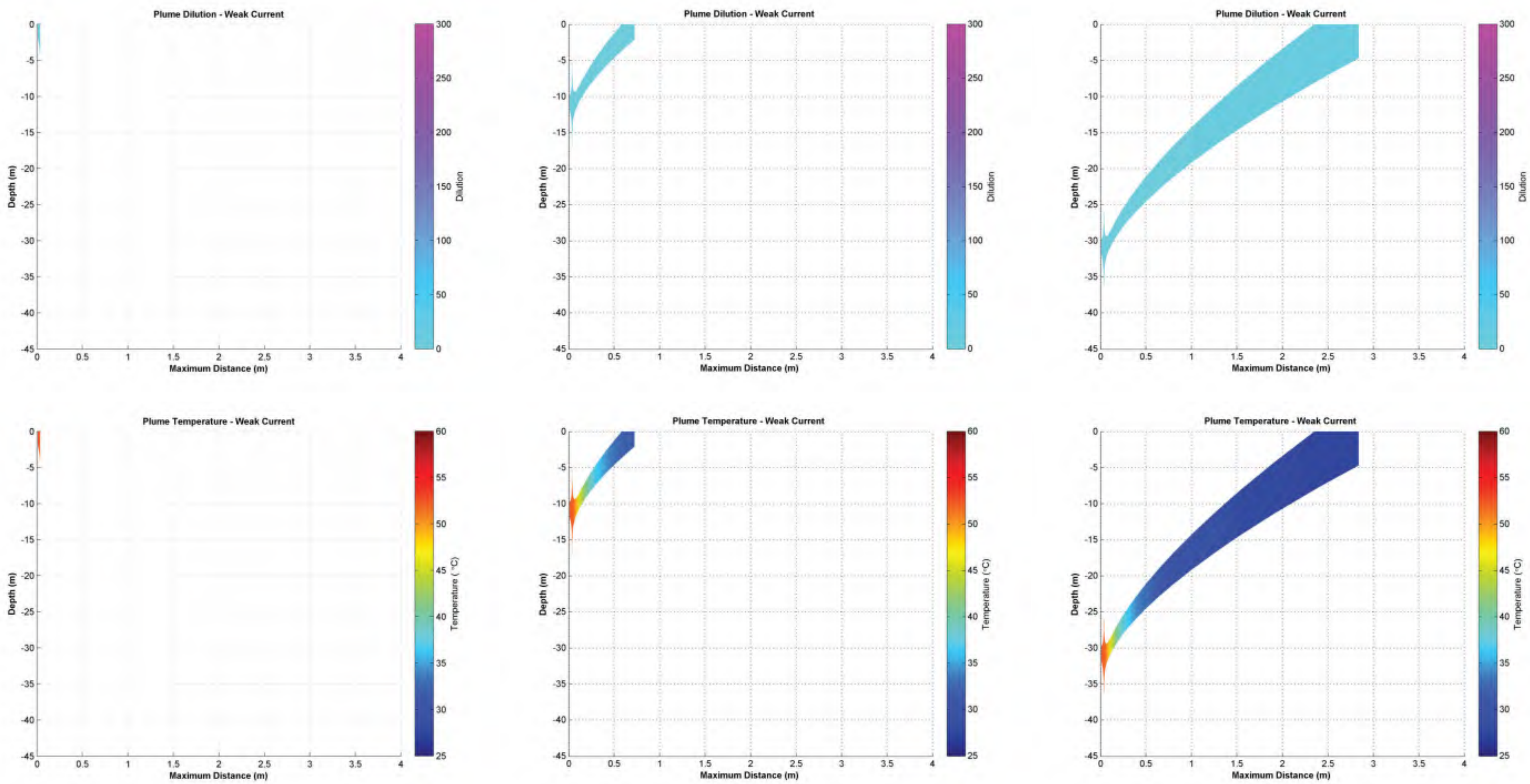

Figure 3.32 Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

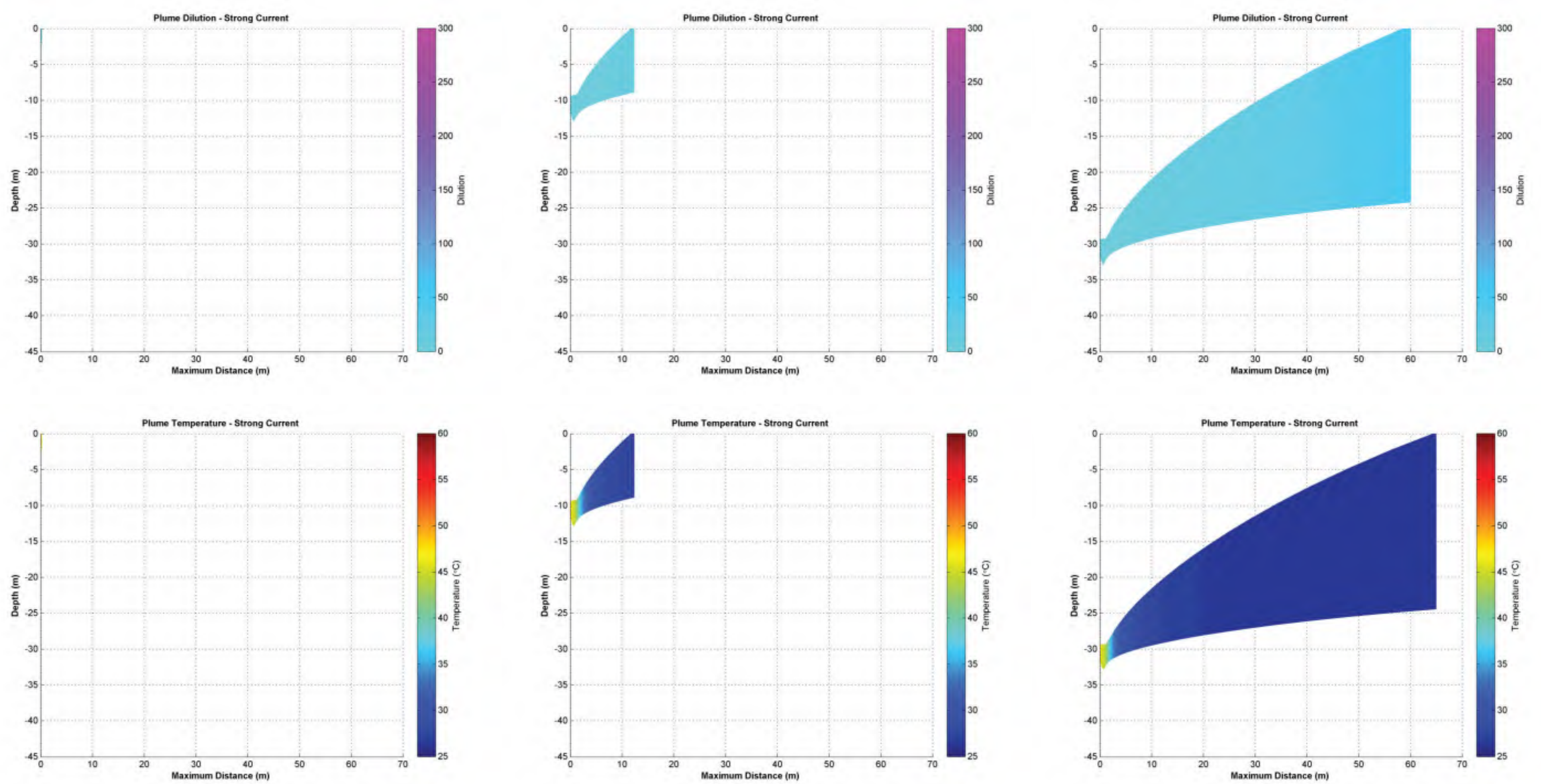

Figure 3.33 Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.3.4 Winter

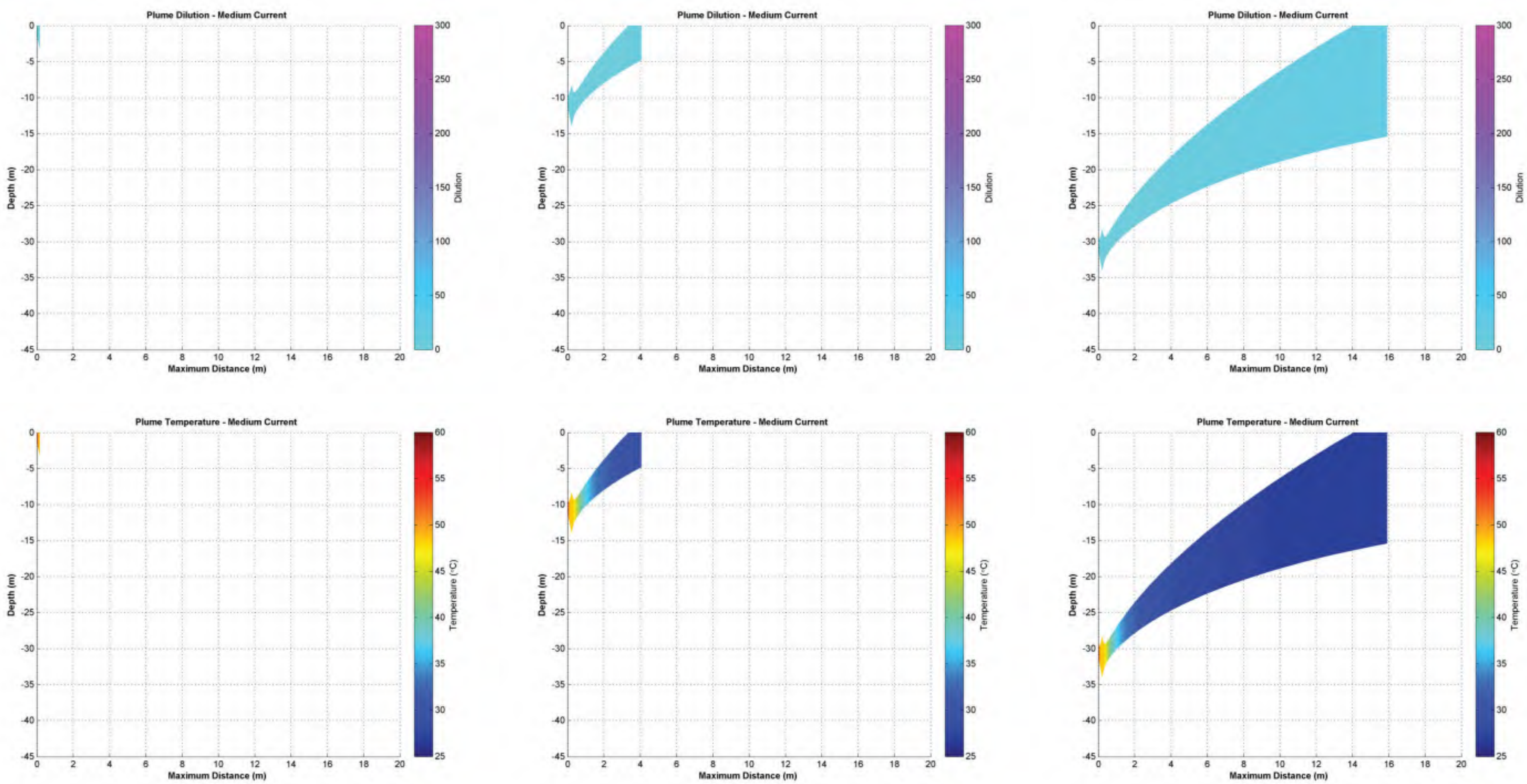

Figure 3.34 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

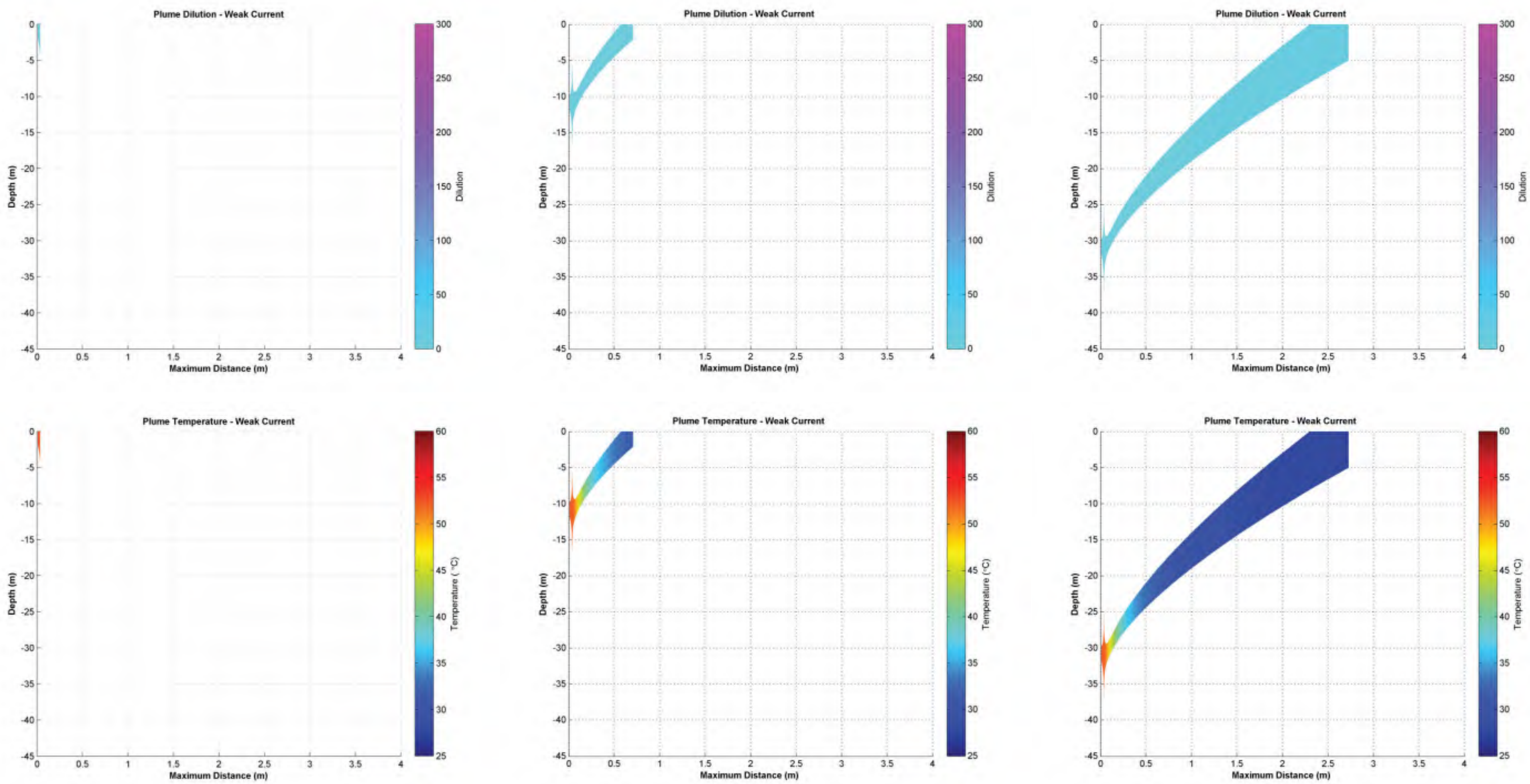

Figure 3.35 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

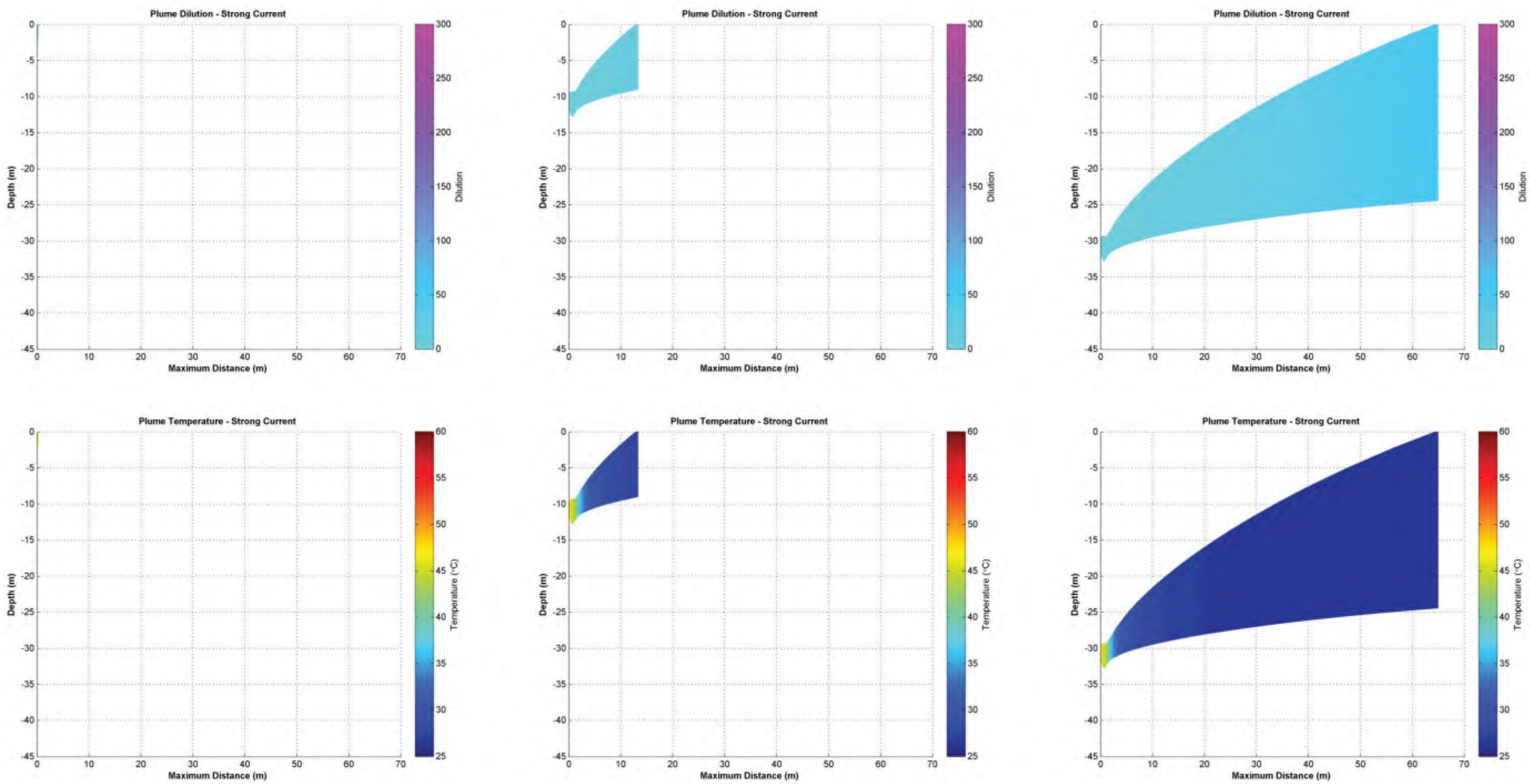

Figure 3.36 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.4 Discharge Depth of 0 m (Surface) with Varying Flow Rates

3.1.3.4.1 Annualised

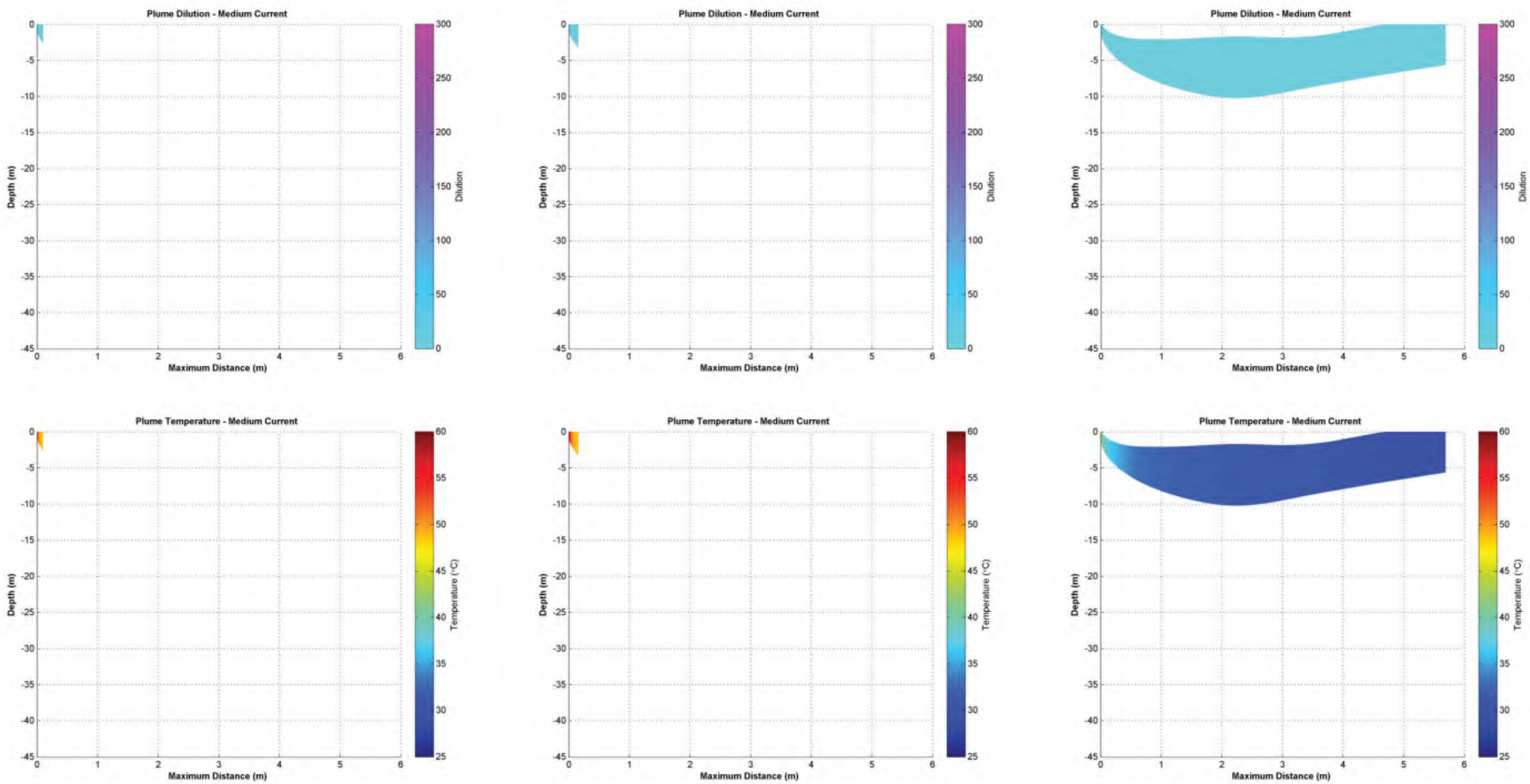

Figure 3.37 Near-field average dilution and temperature results for constant medium annualised currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

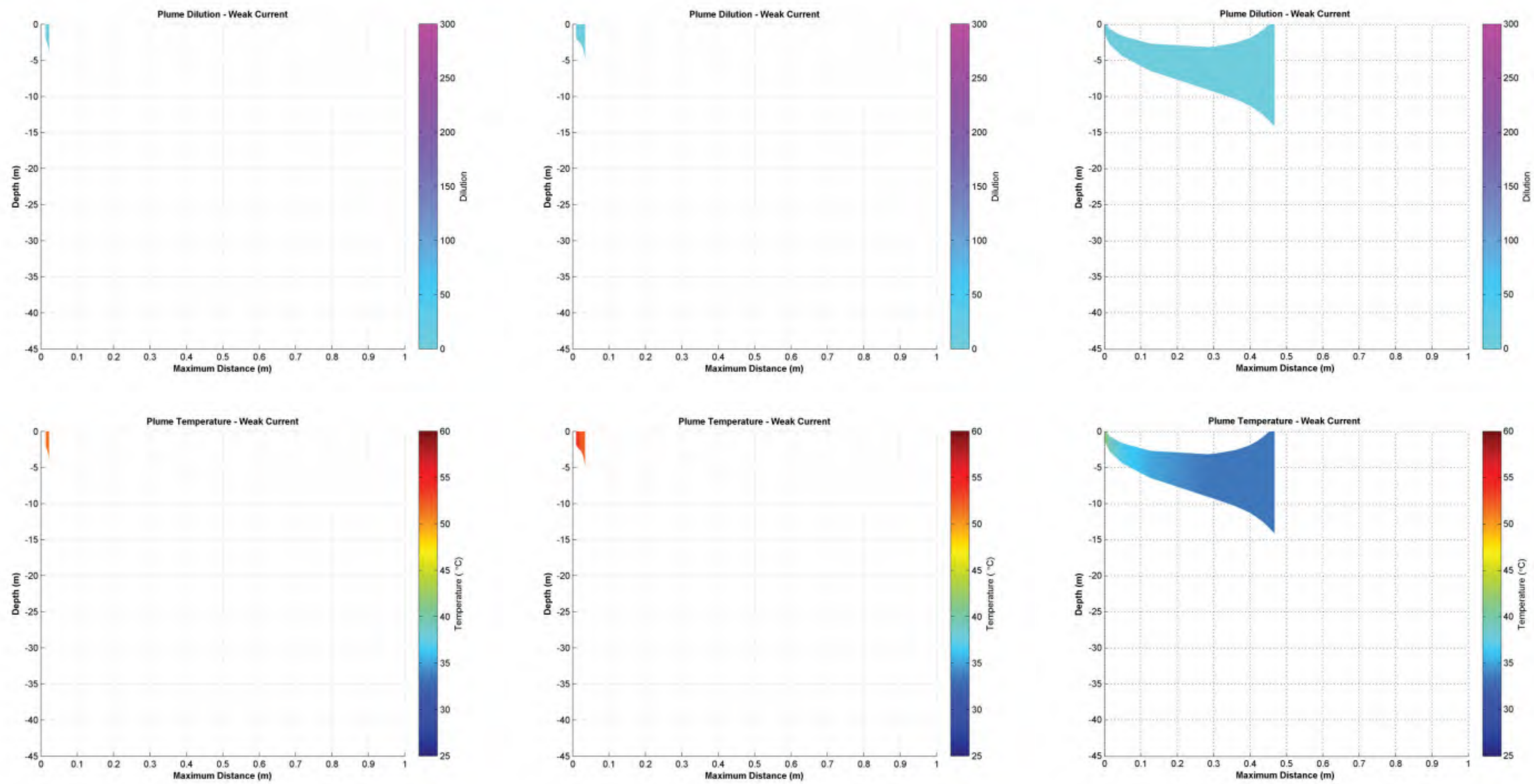

Figure 3.38 Near-field average dilution and temperature results for constant weak annualised currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

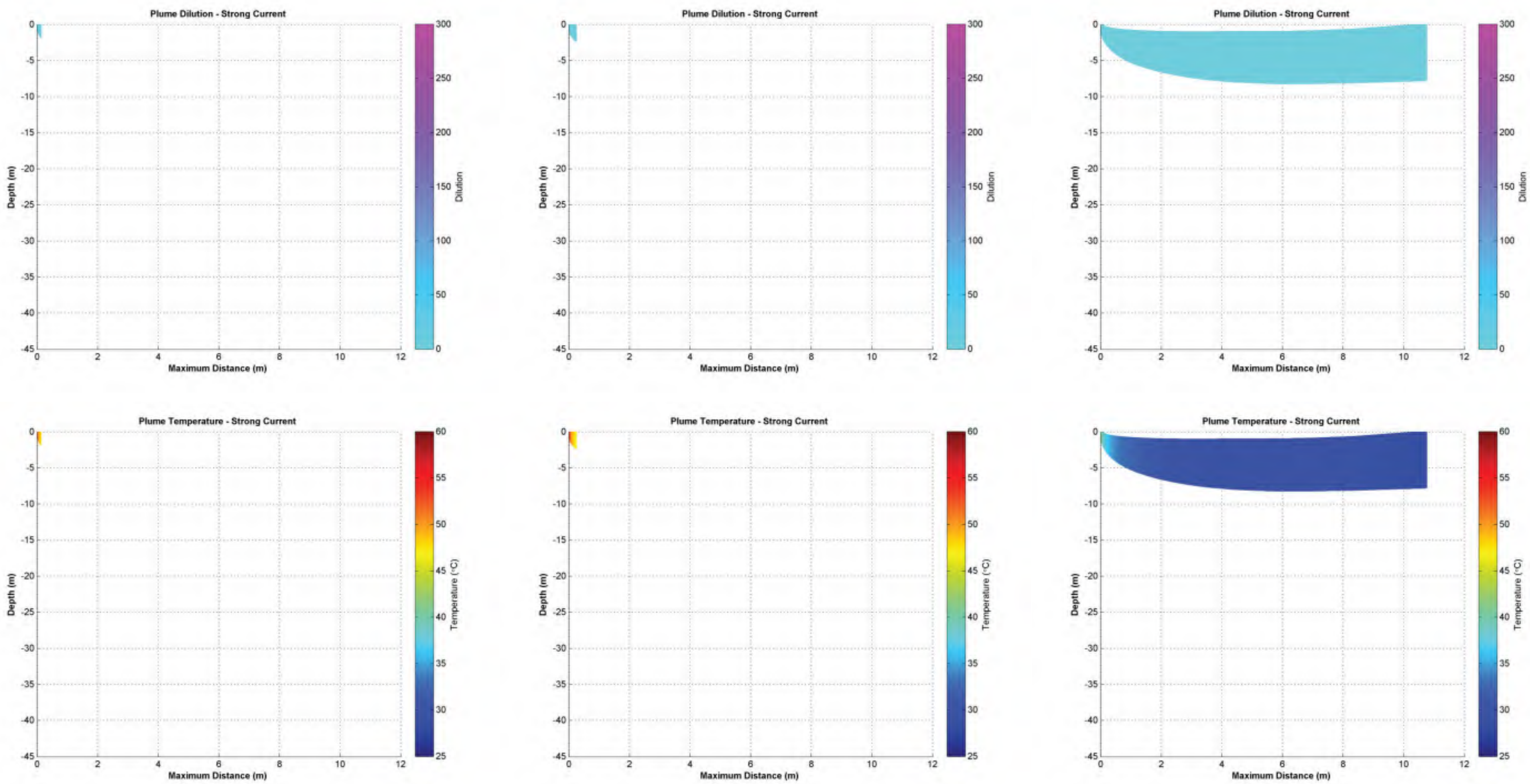

Figure 3.39 Near-field average dilution and temperature results for constant strong annualised currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.4.2 Summer

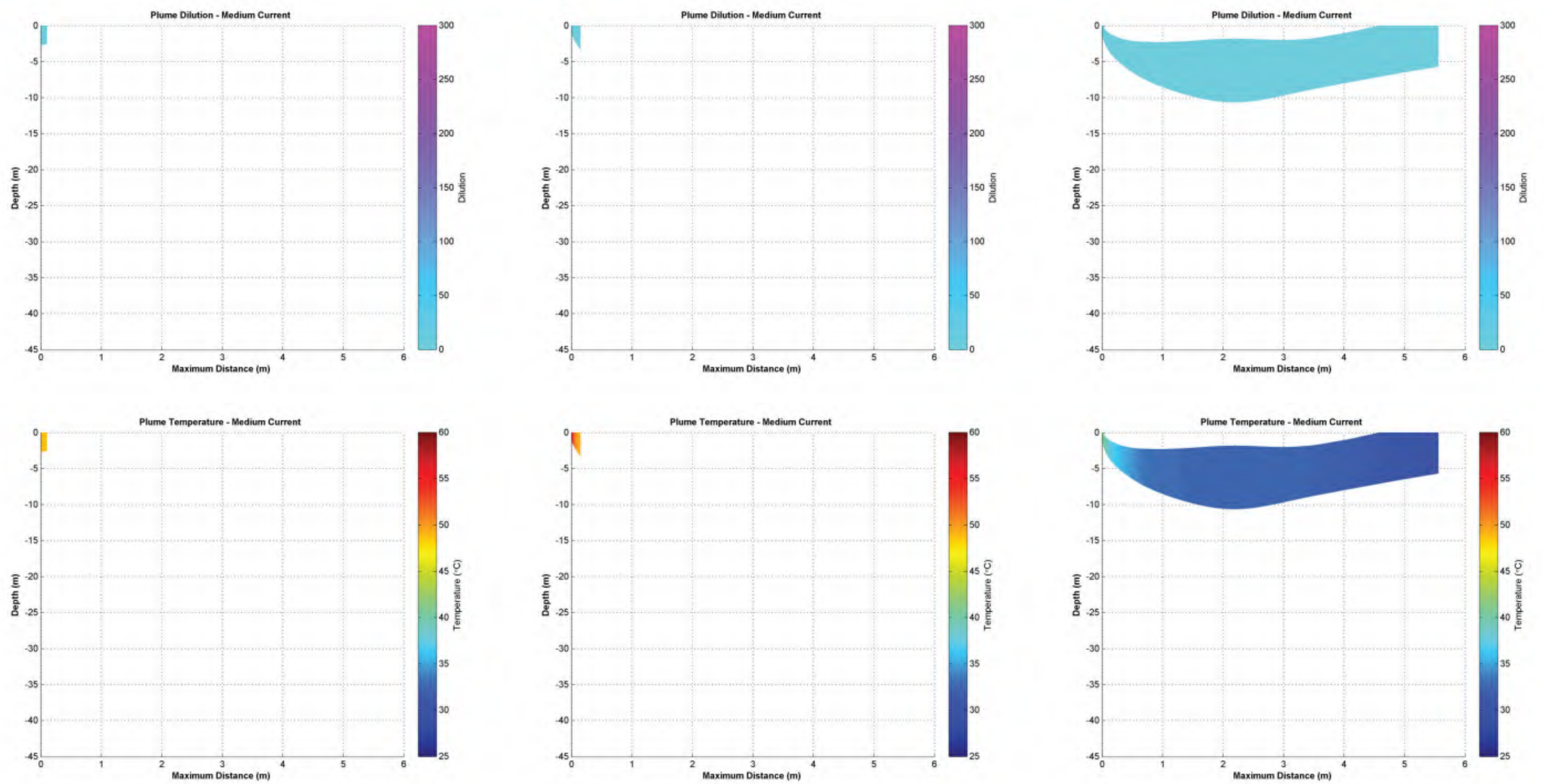

Figure 3.40 Near-field average dilution and temperature results for constant medium summer currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

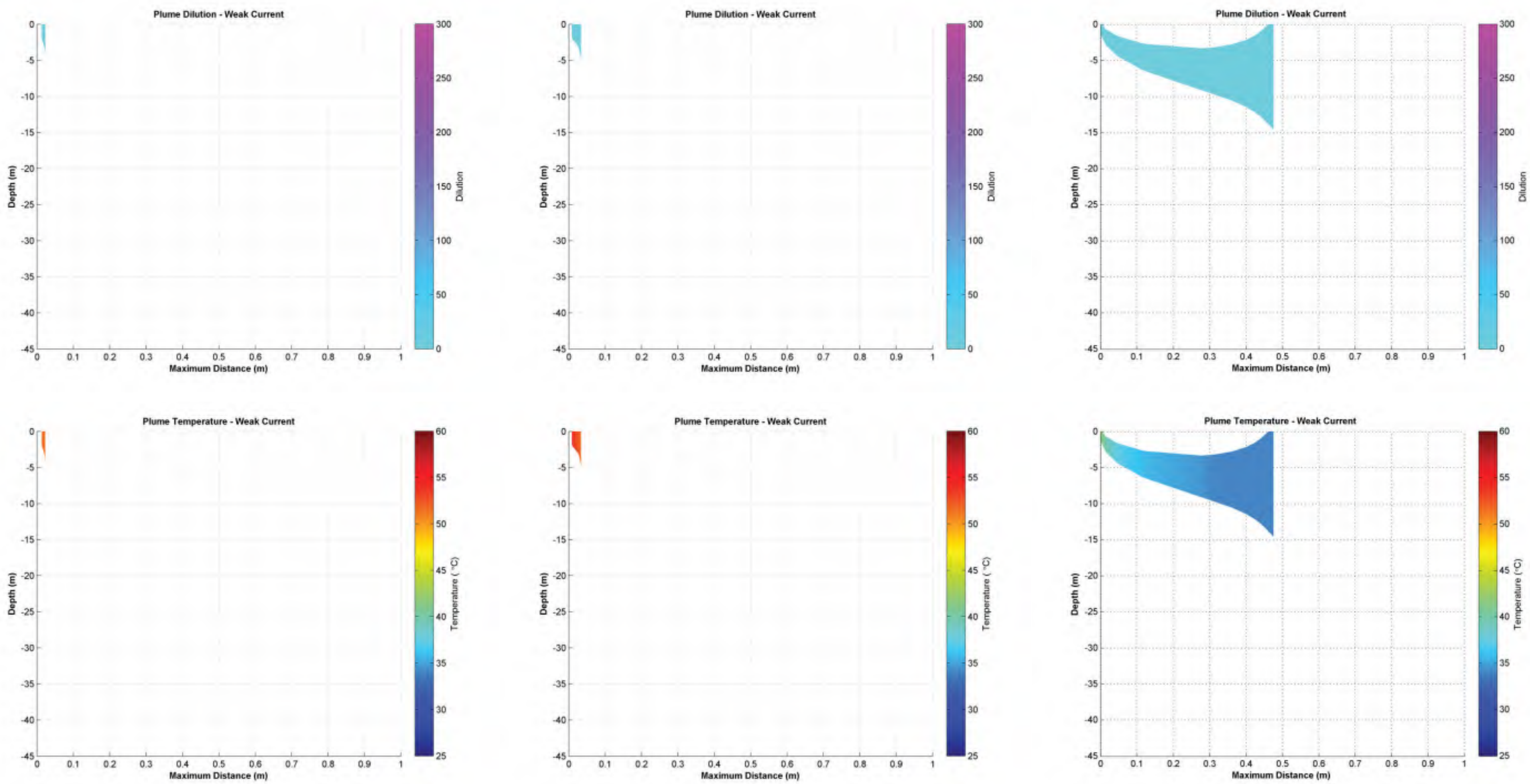

Figure 3.41 Near-field average dilution and temperature results for constant weak summer currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

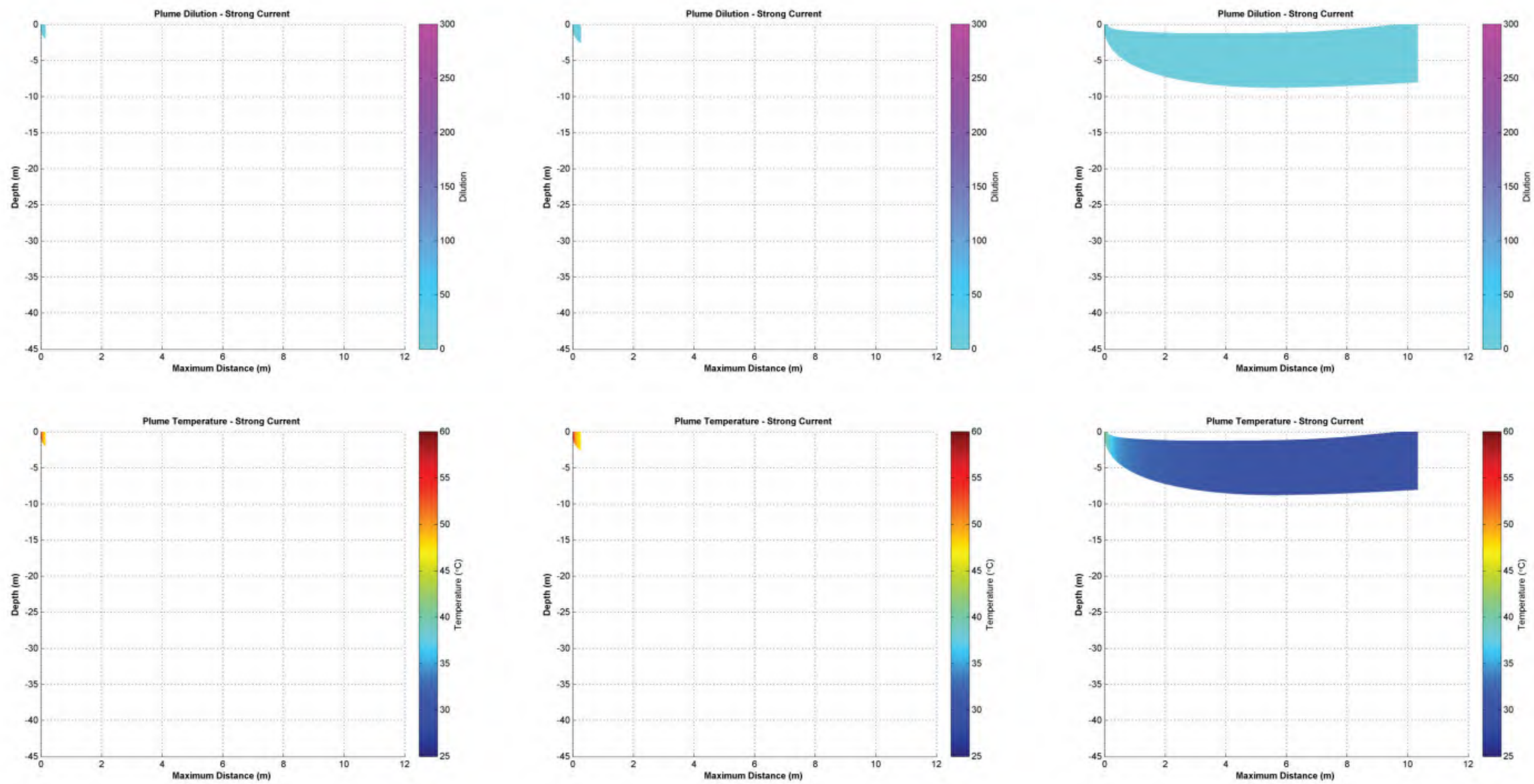

Figure 3.42 Near-field average dilution and temperature results for constant strong summer currents with discharge flow rates of 64,800 m³/d (Case C4; left column), 82,800 m³/d (Case C7; middle column) and 165,600 m³/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.4.3 Transitional

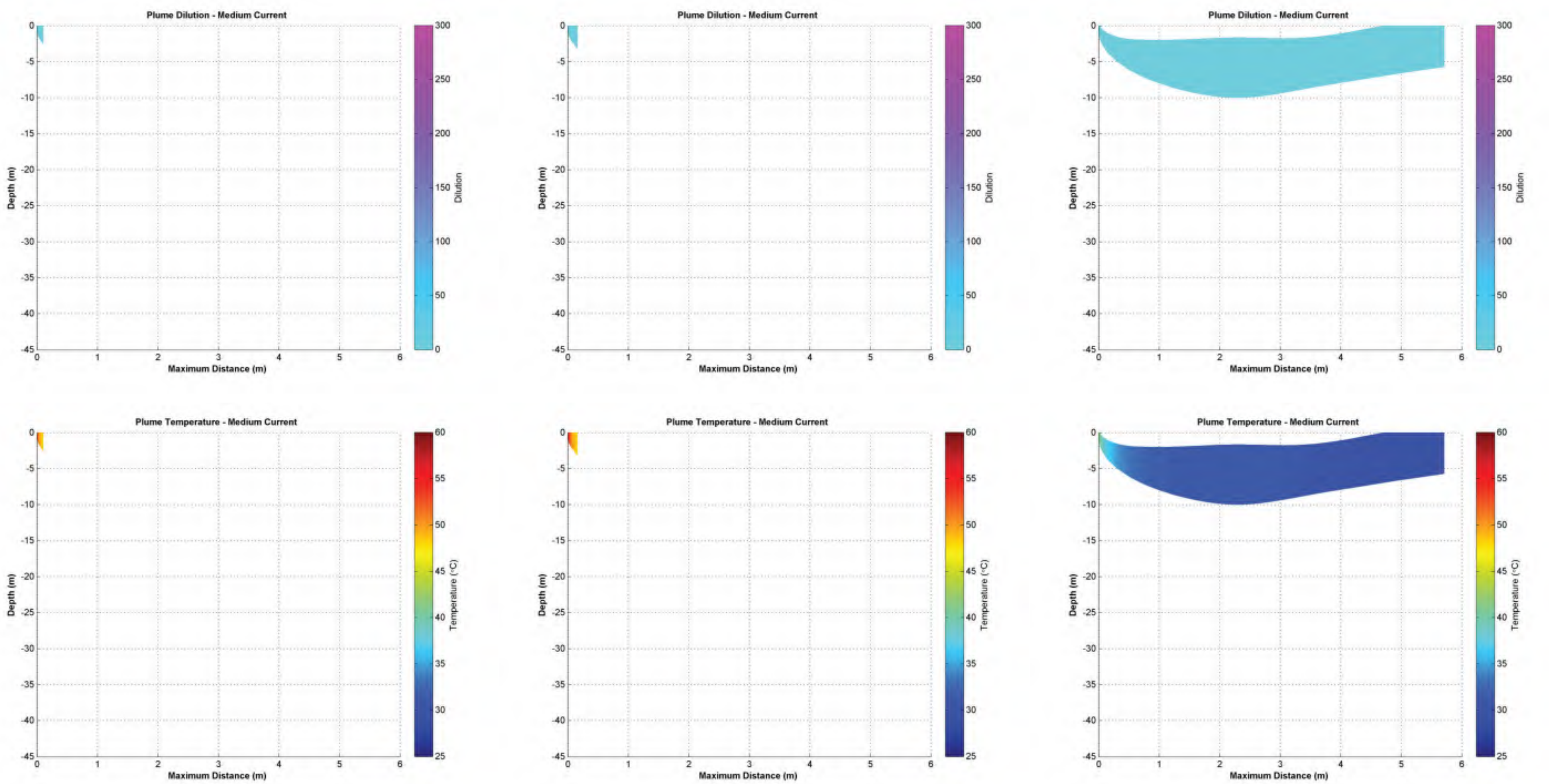

Figure 3.43 Near-field average dilution and temperature results for constant medium transitional currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

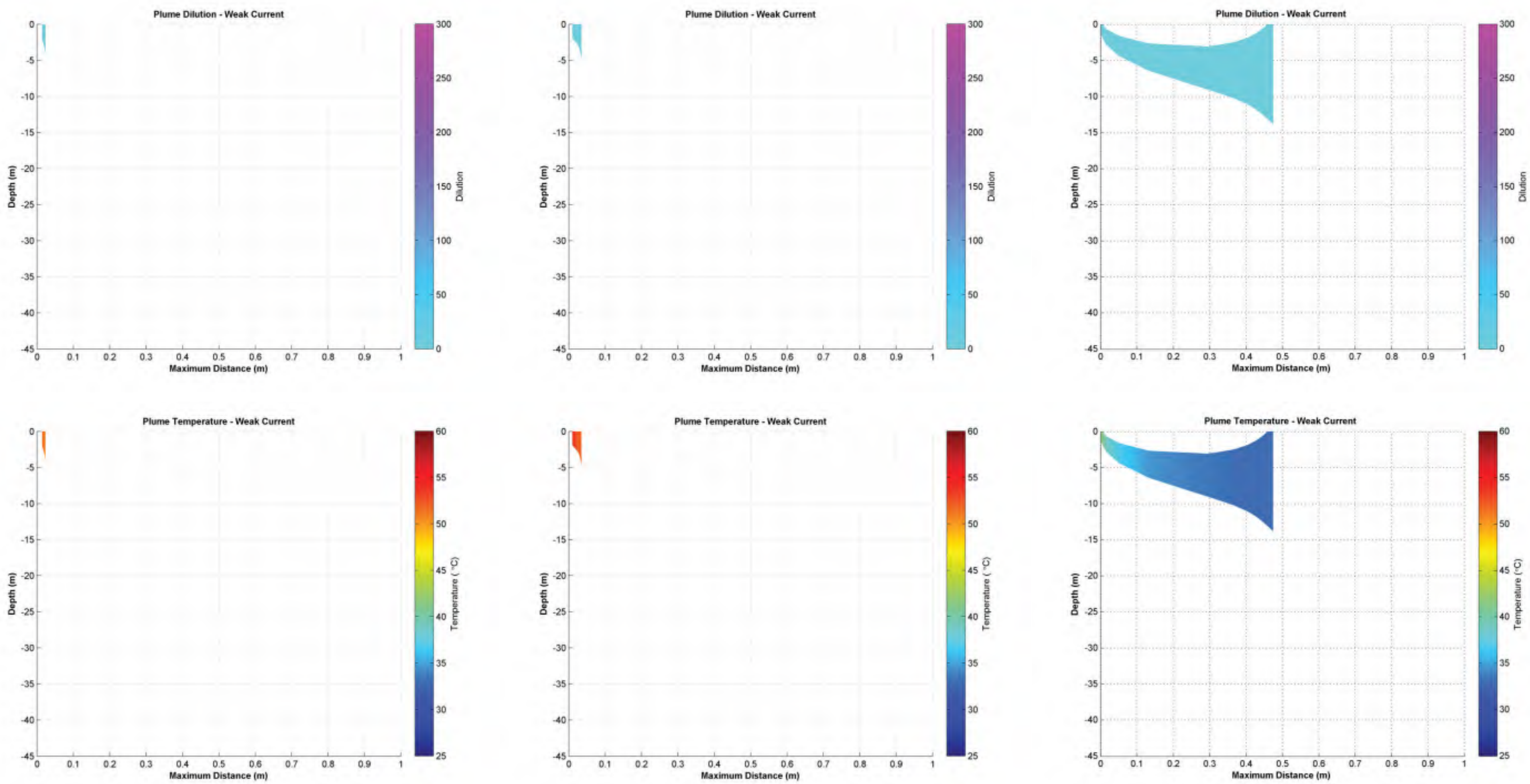

Figure 3.44 Near-field average dilution and temperature results for constant weak transitional currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

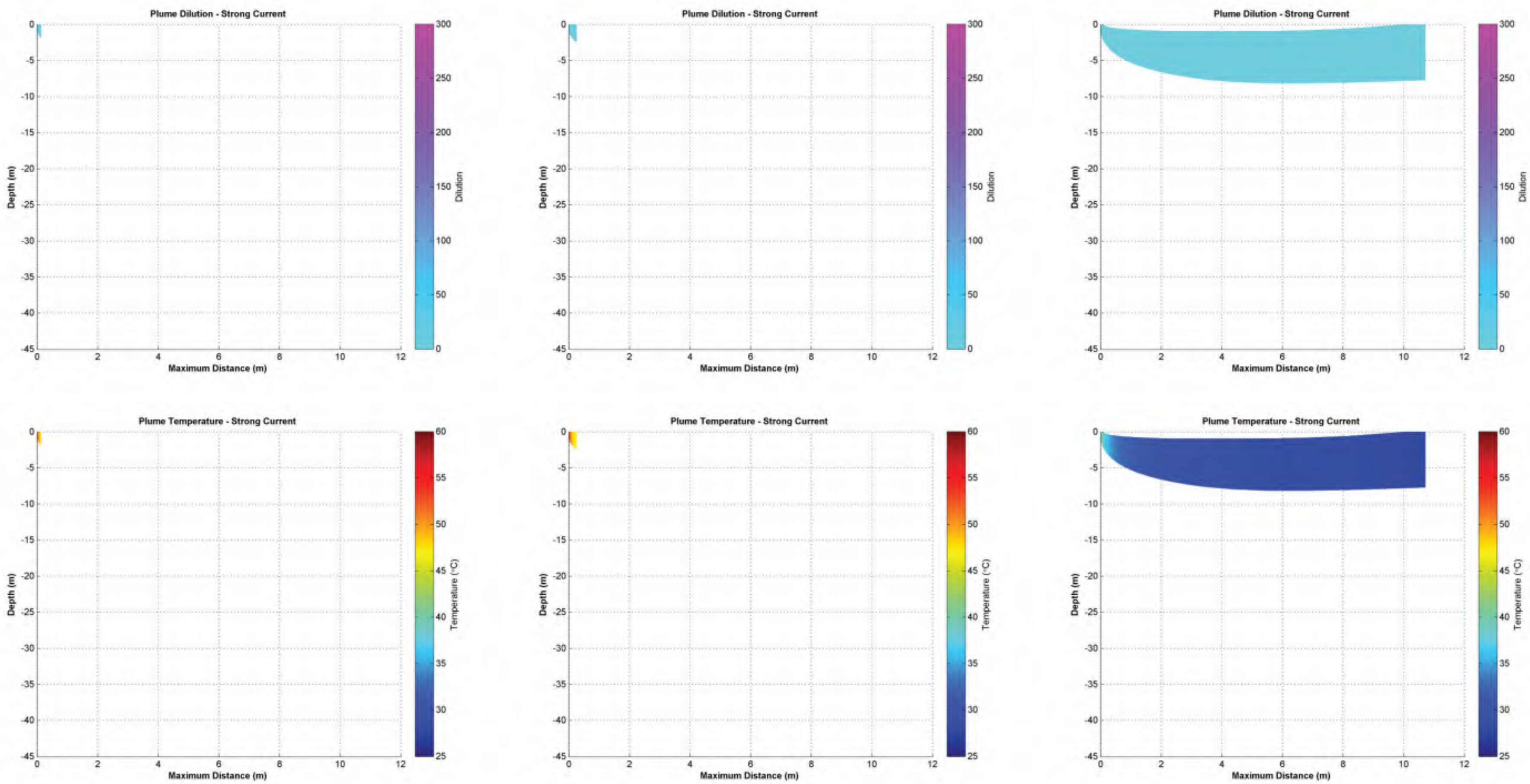

Figure 3.45 Near-field average dilution and temperature results for constant strong transitional currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.4.4 Winter

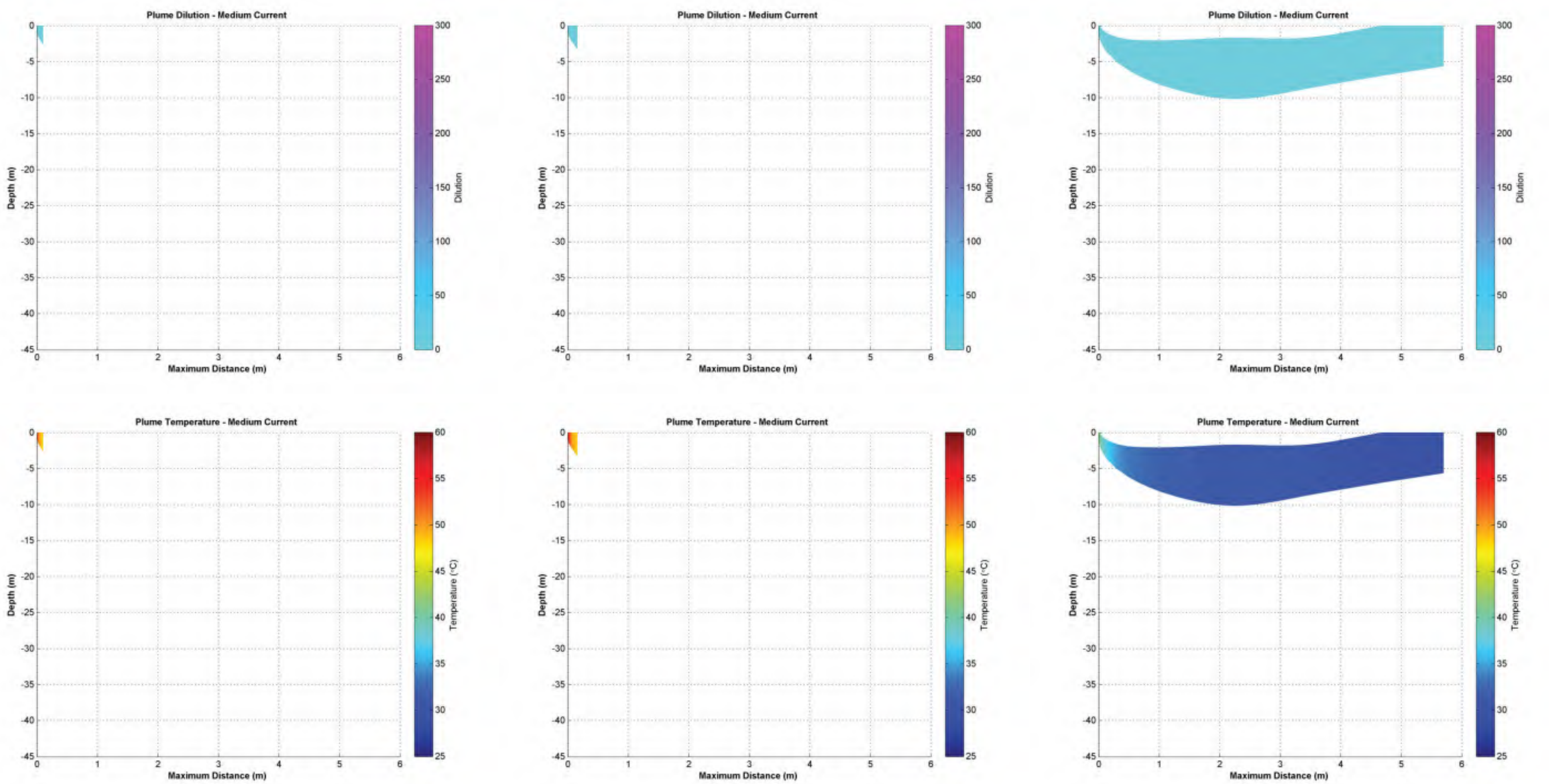

Figure 3.46 Near-field average dilution and temperature results for constant medium winter currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

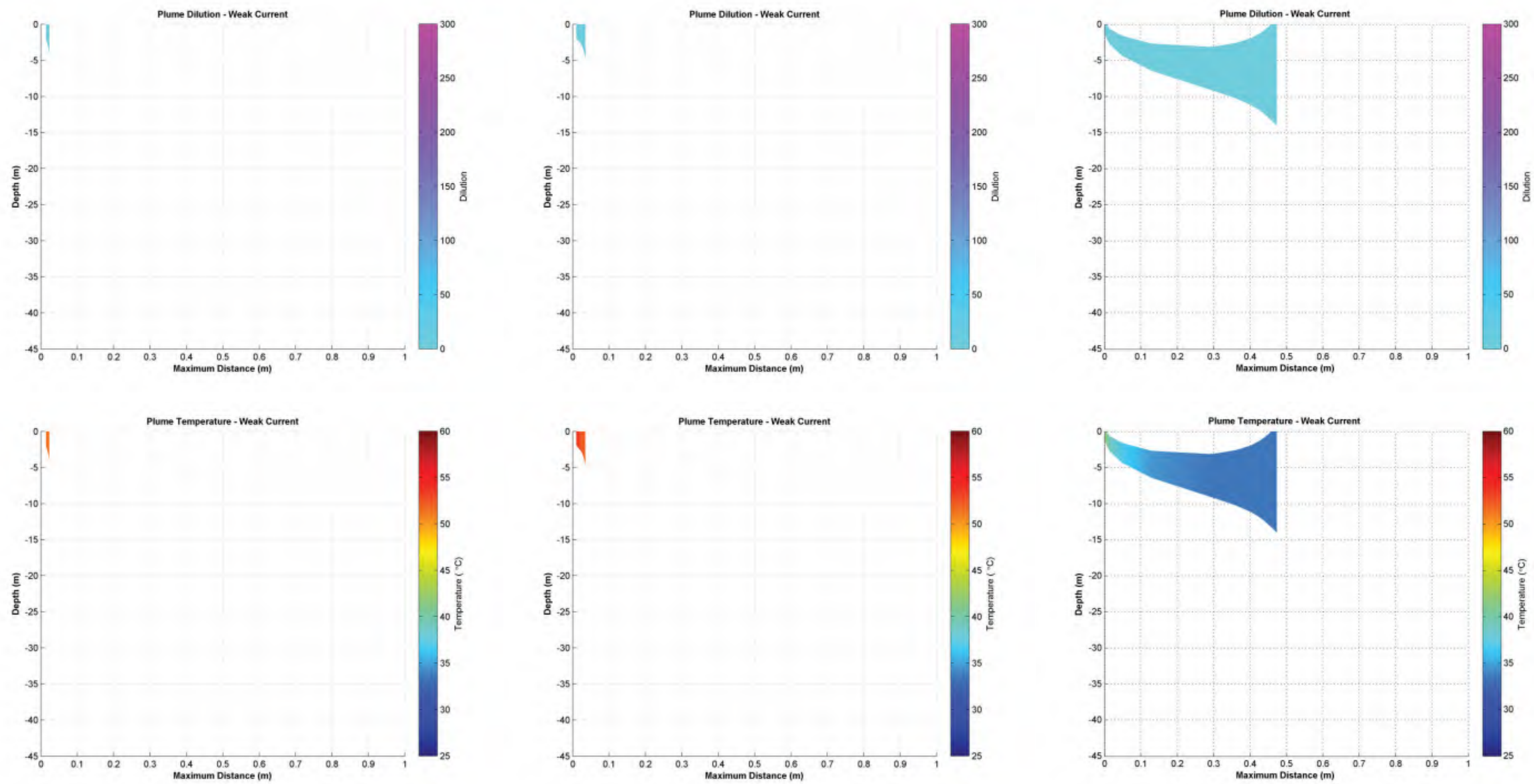

Figure 3.47 Near-field average dilution and temperature results for constant weak winter currents with discharge flow rates of 64,800 m³/d (Case C4; left column), 82,800 m³/d (Case C7; middle column) and 165,600 m³/d (Case C1; right column) at a discharge depth of 0 m.

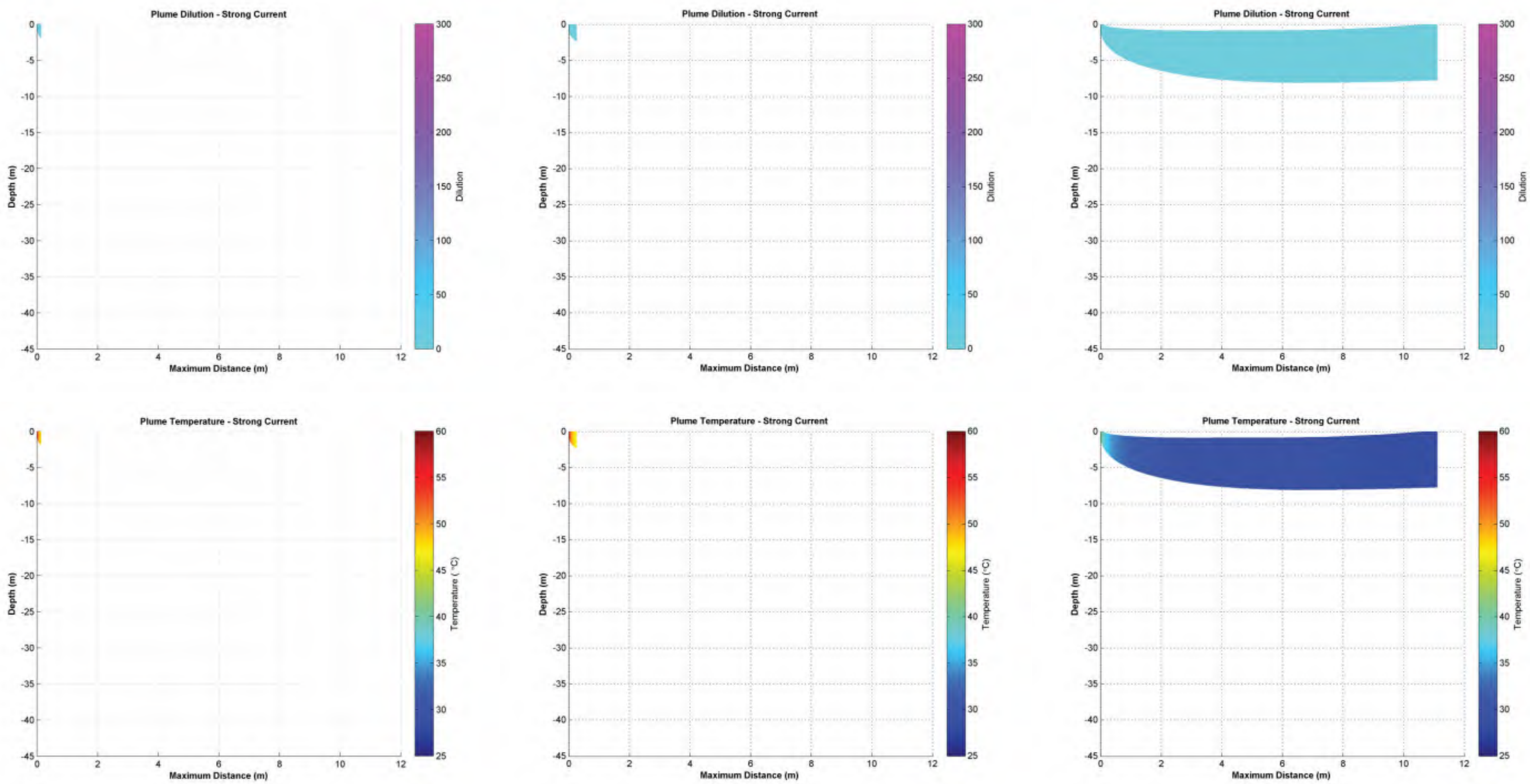

Figure 3.48 Near-field average dilution and temperature results for constant strong winter currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.5 Discharge Depth of 10 m with Varying Flow Rates

3.1.3.5.1 Annualised

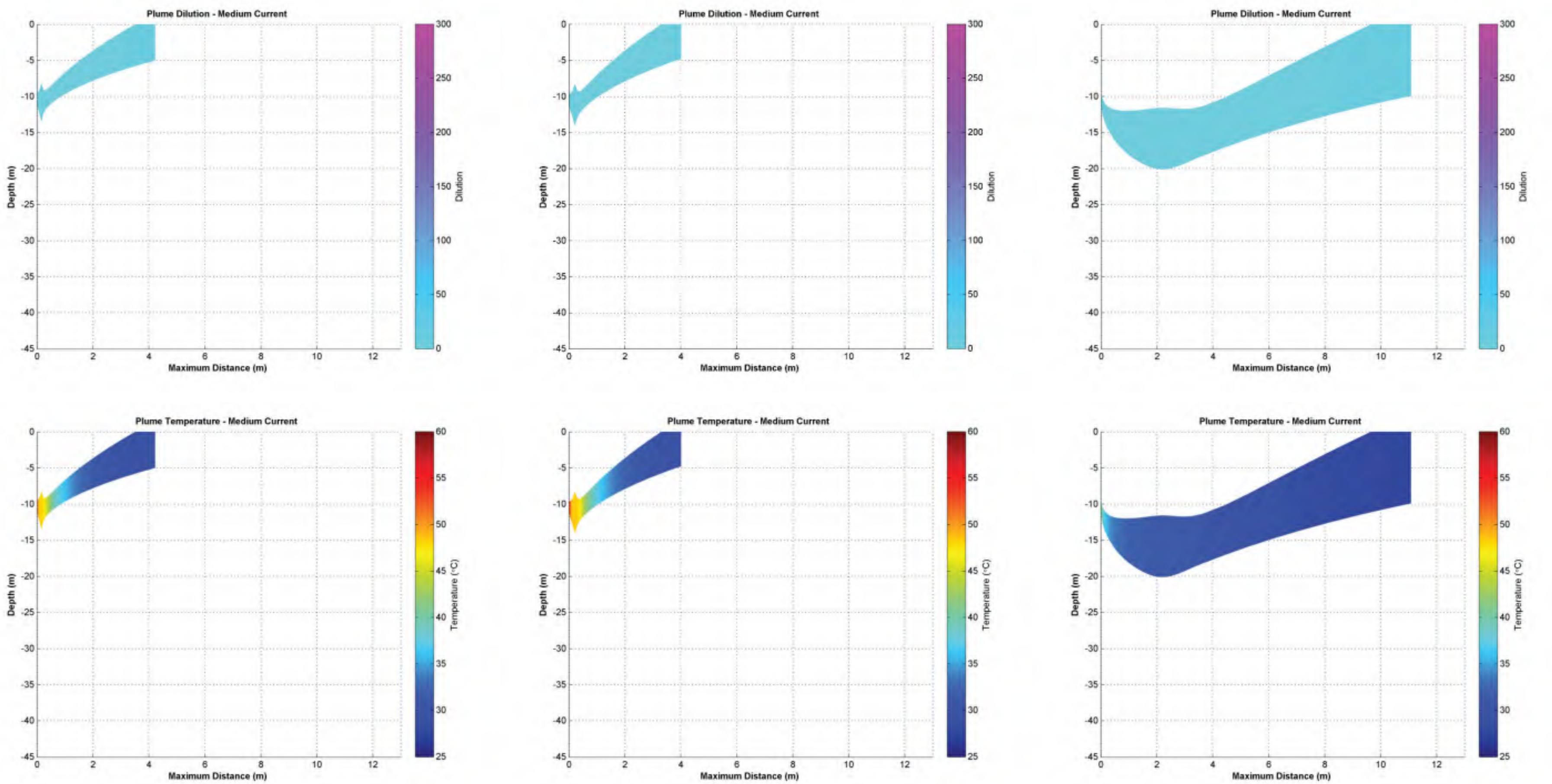

Figure 3.49 Near-field average dilution and temperature results for constant medium annualised currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.

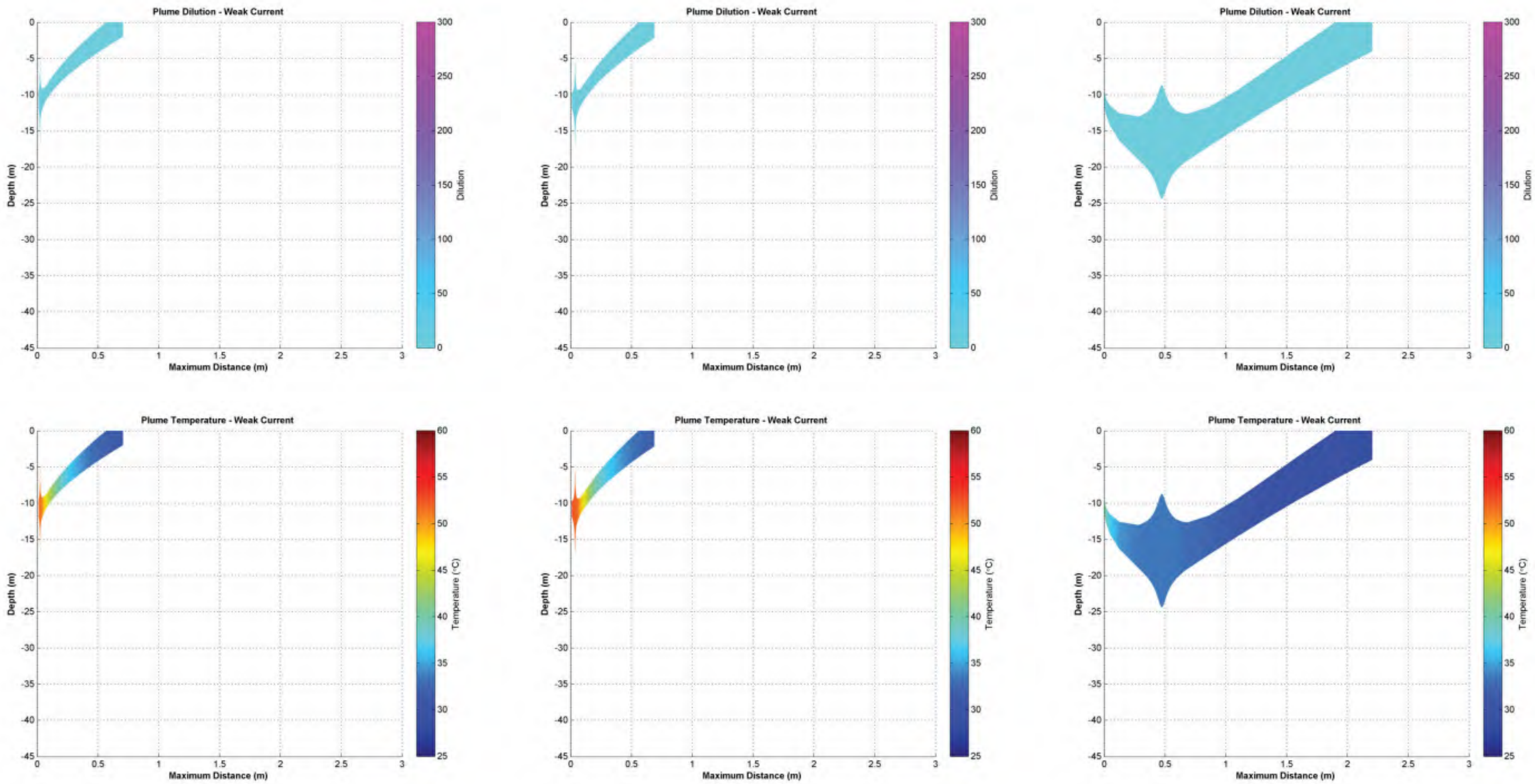

Figure 3.50 Near-field average dilution and temperature results for constant weak annualised currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

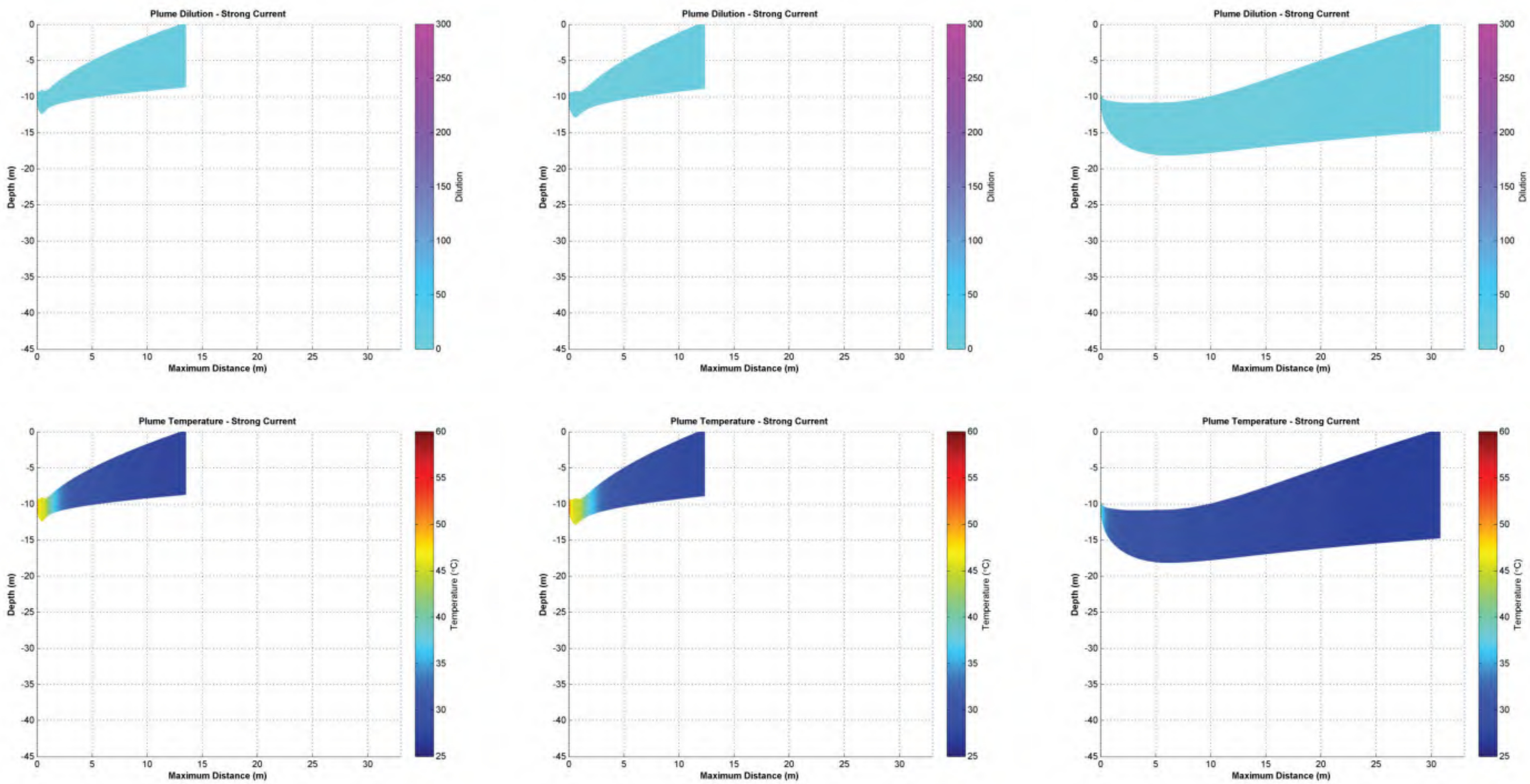

Figure 3.51 Near-field average dilution and temperature results for constant strong annualised currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

3.1.3.5.2 Summer

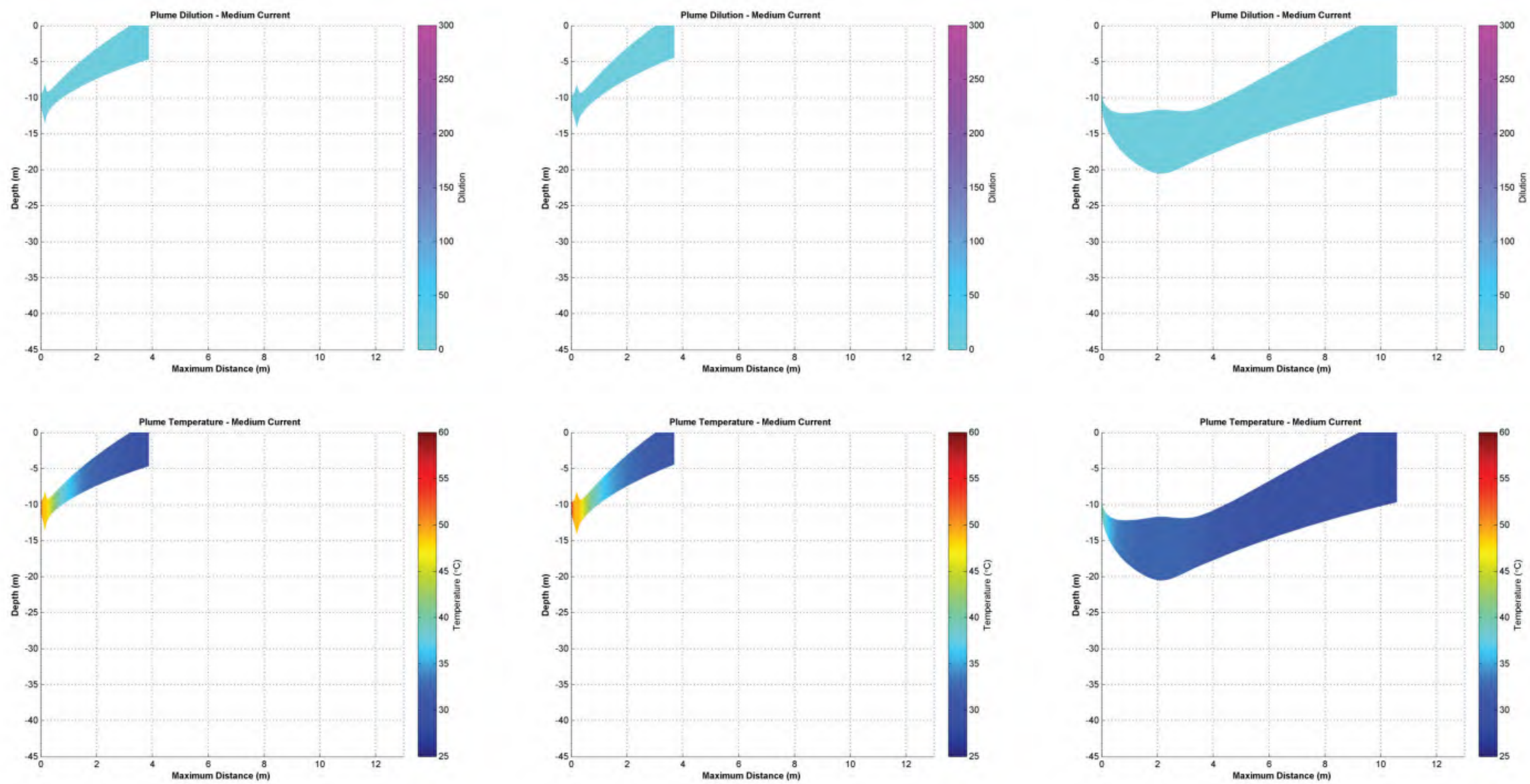

Figure 3.52 Near-field average dilution and temperature results for constant medium summer currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

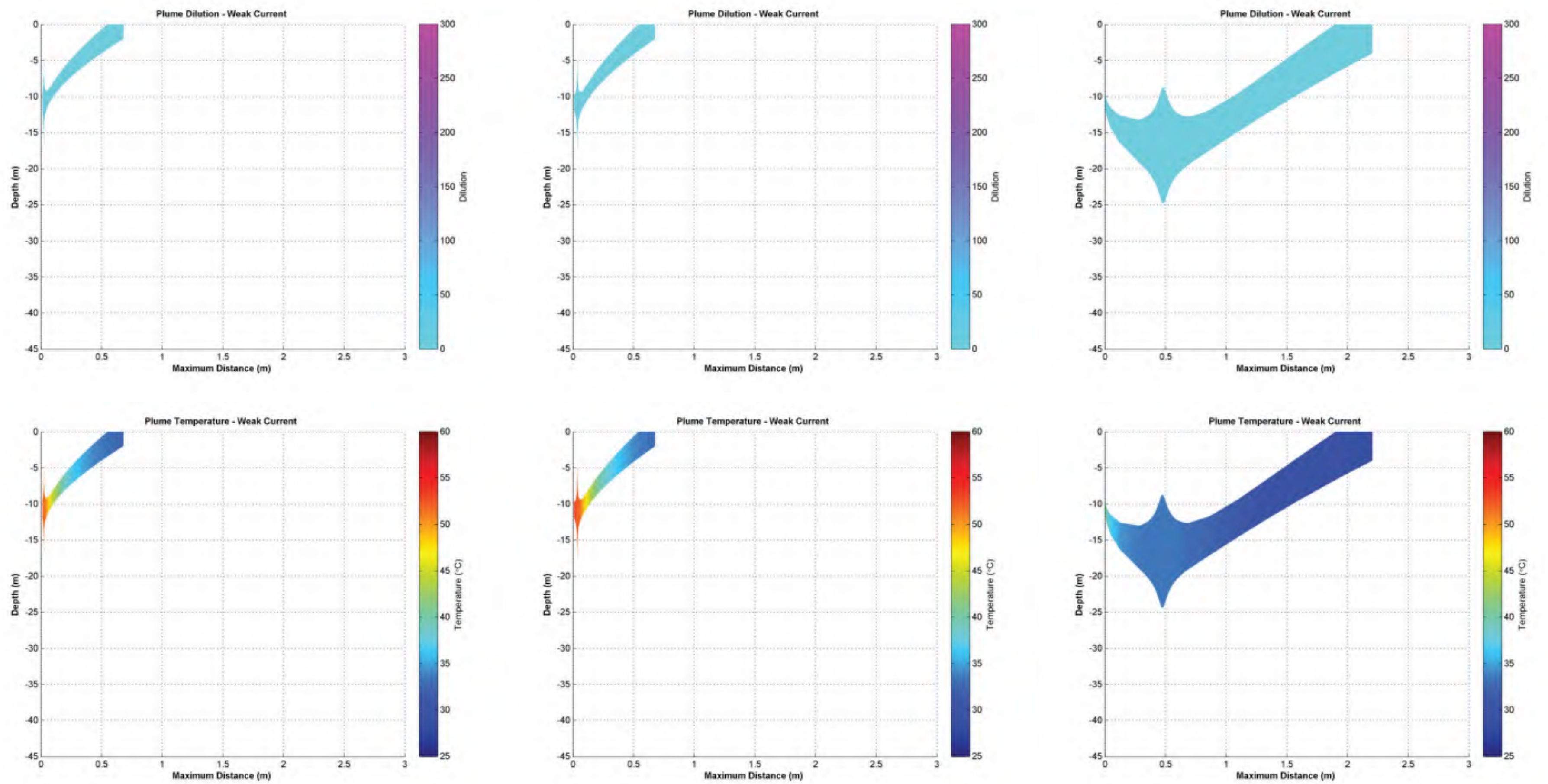

Figure 3.53 Near-field average dilution and temperature results for constant weak summer currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

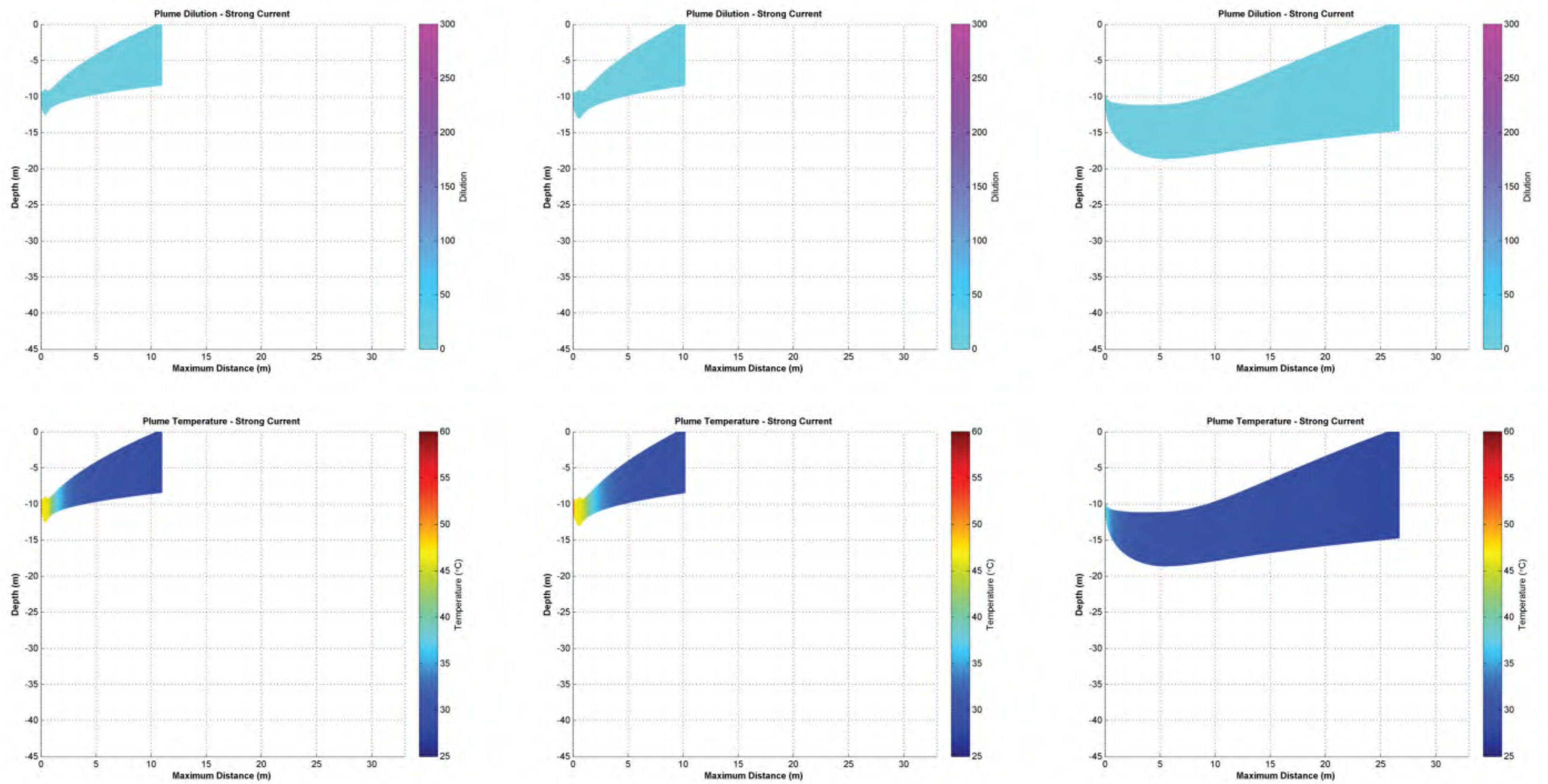

Figure 3.54 Near-field average dilution and temperature results for constant strong summer currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

3.1.3.5.3 Transitional

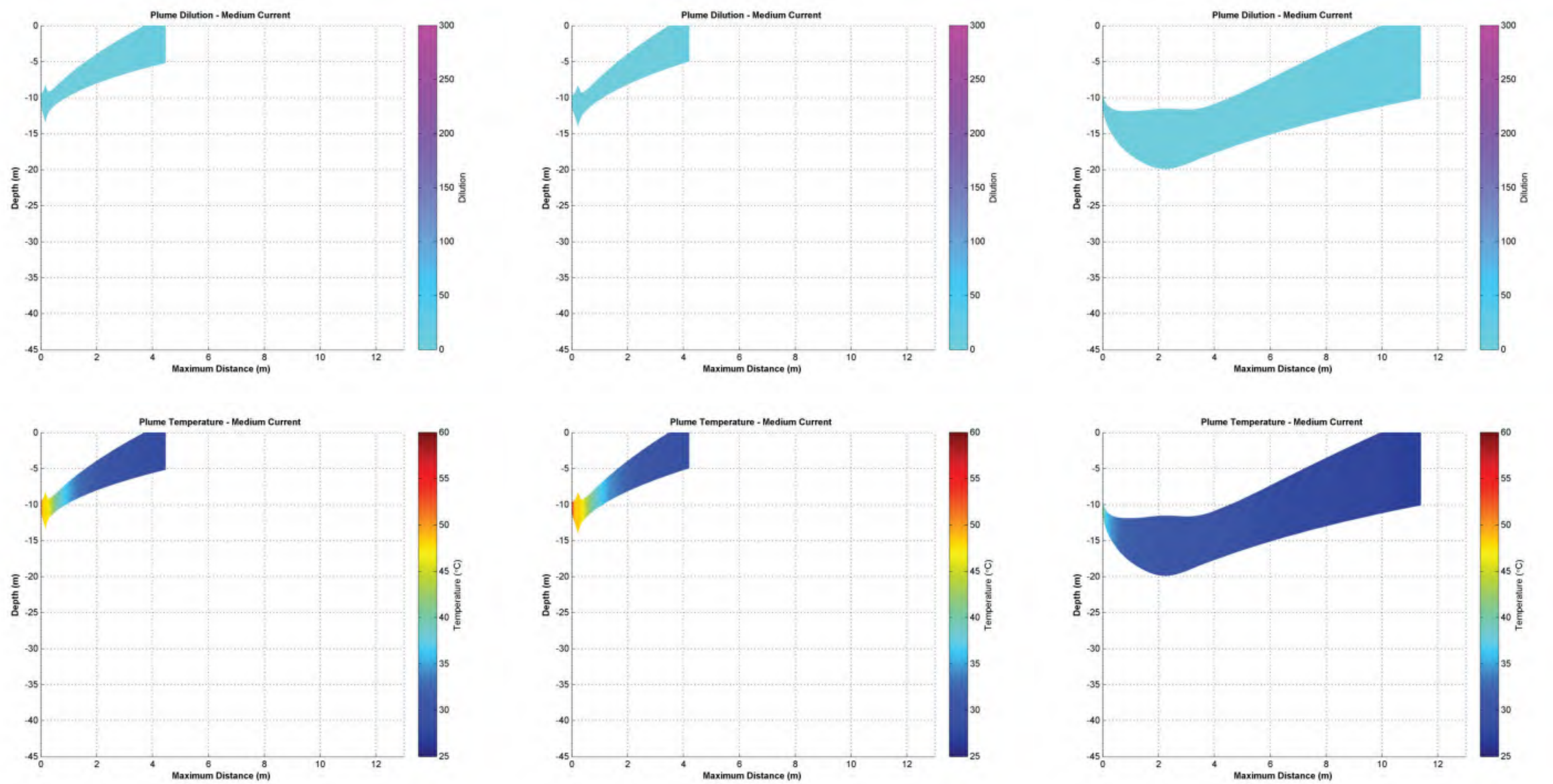

Figure 3.55 Near-field average dilution and temperature results for constant medium transitional currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

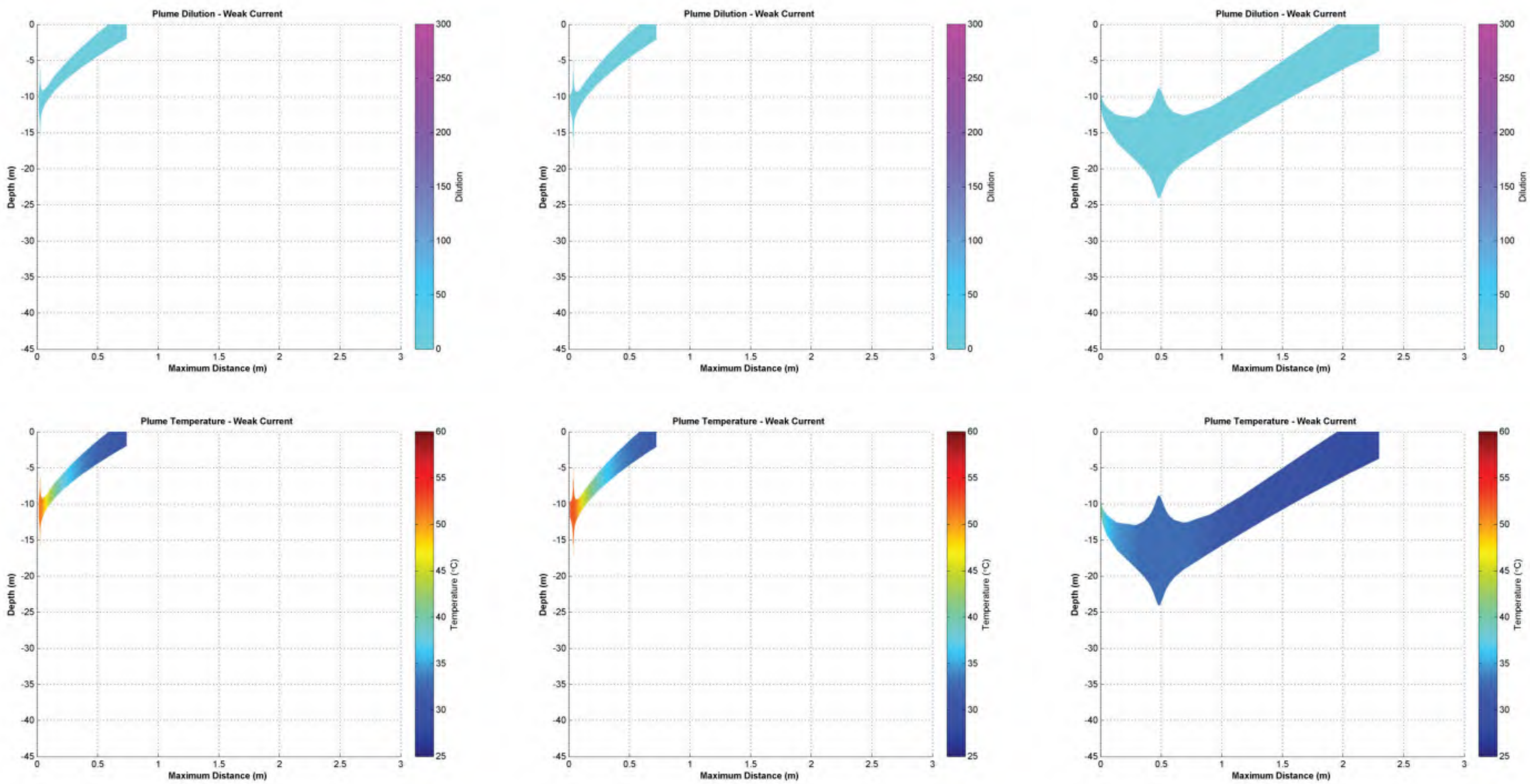

Figure 3.56 Near-field average dilution and temperature results for constant weak transitional currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

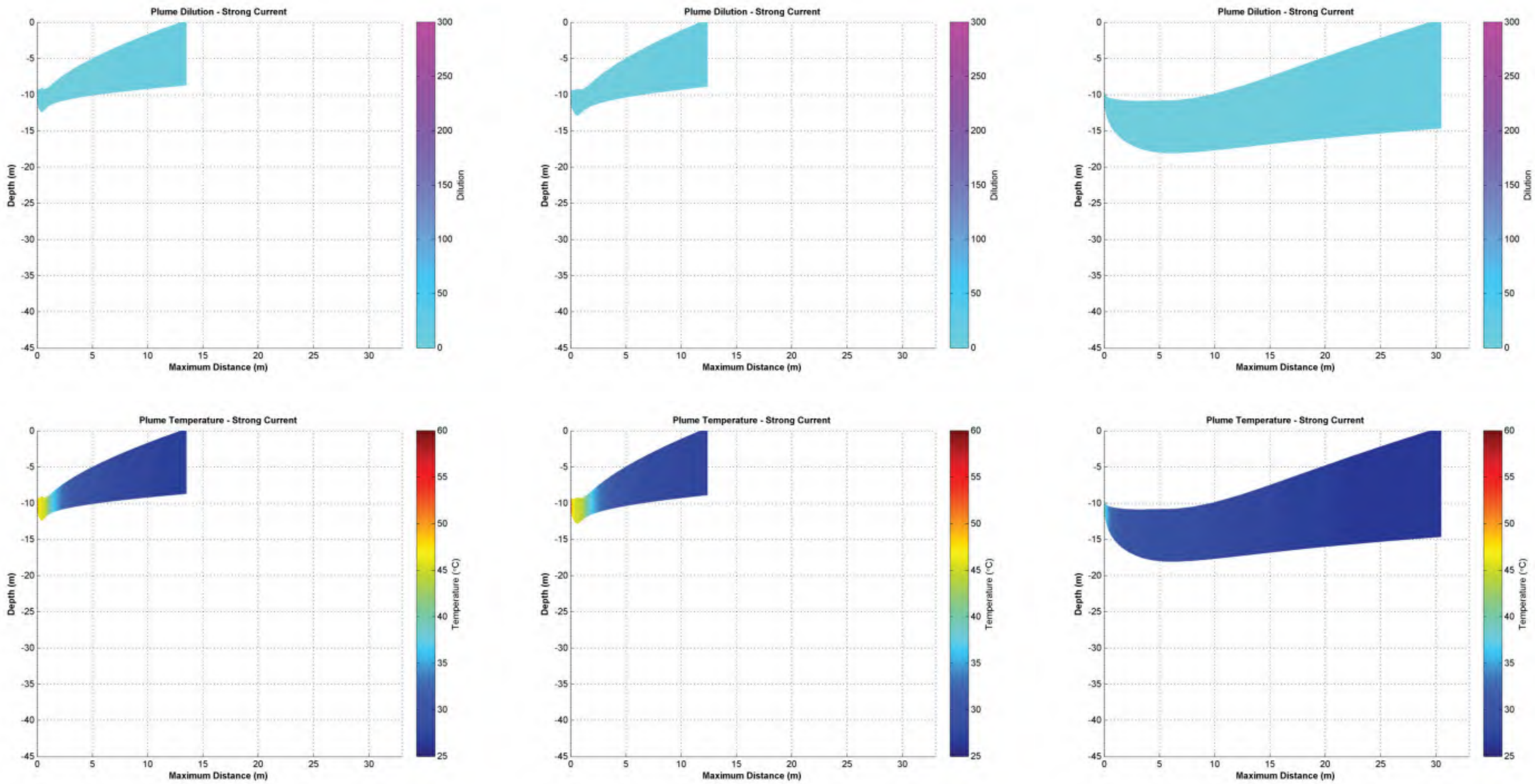

Figure 3.57 Near-field average dilution and temperature results for constant strong transitional currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

3.1.3.5.4 Winter

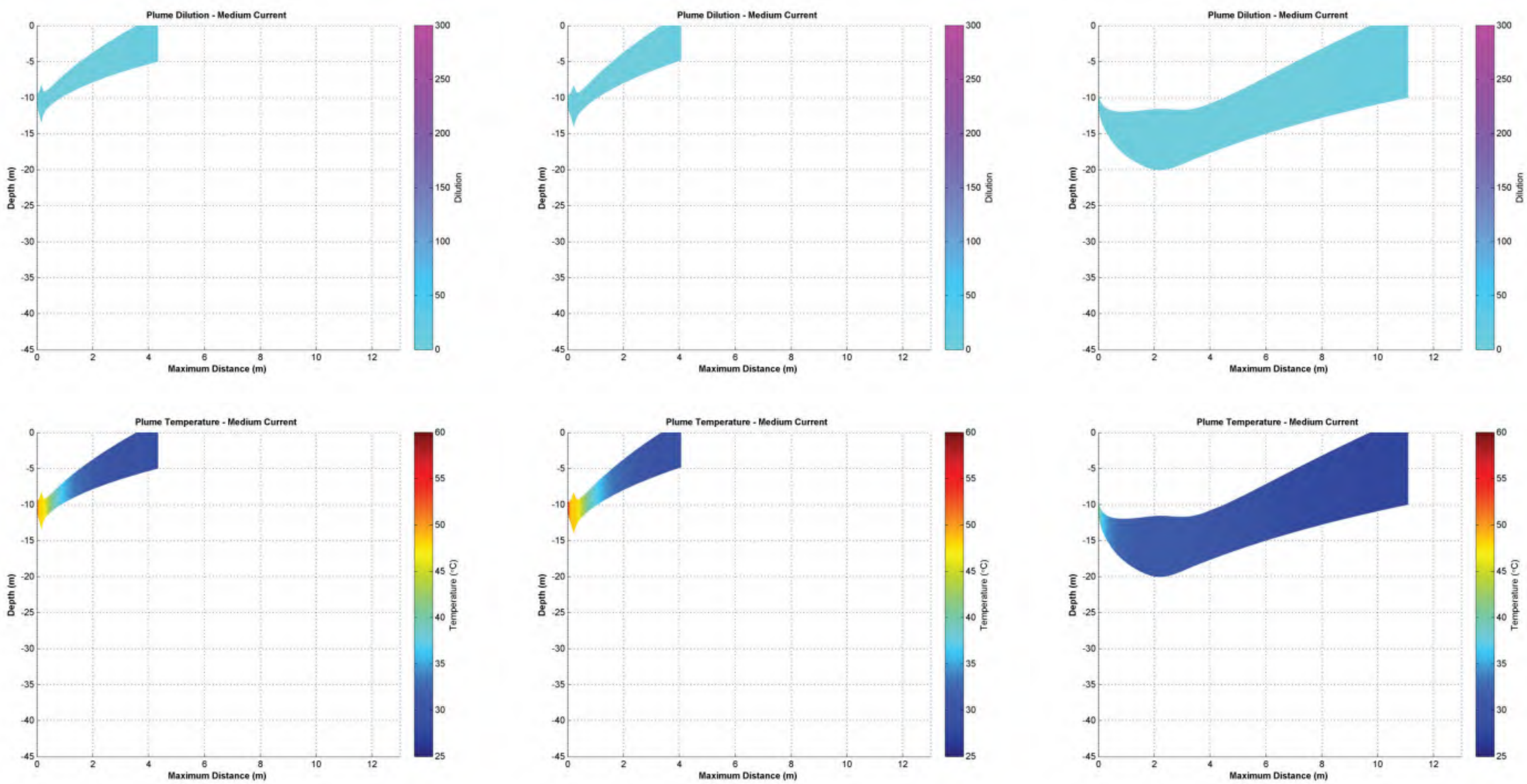

Figure 3.58 Near-field average dilution and temperature results for constant medium winter currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

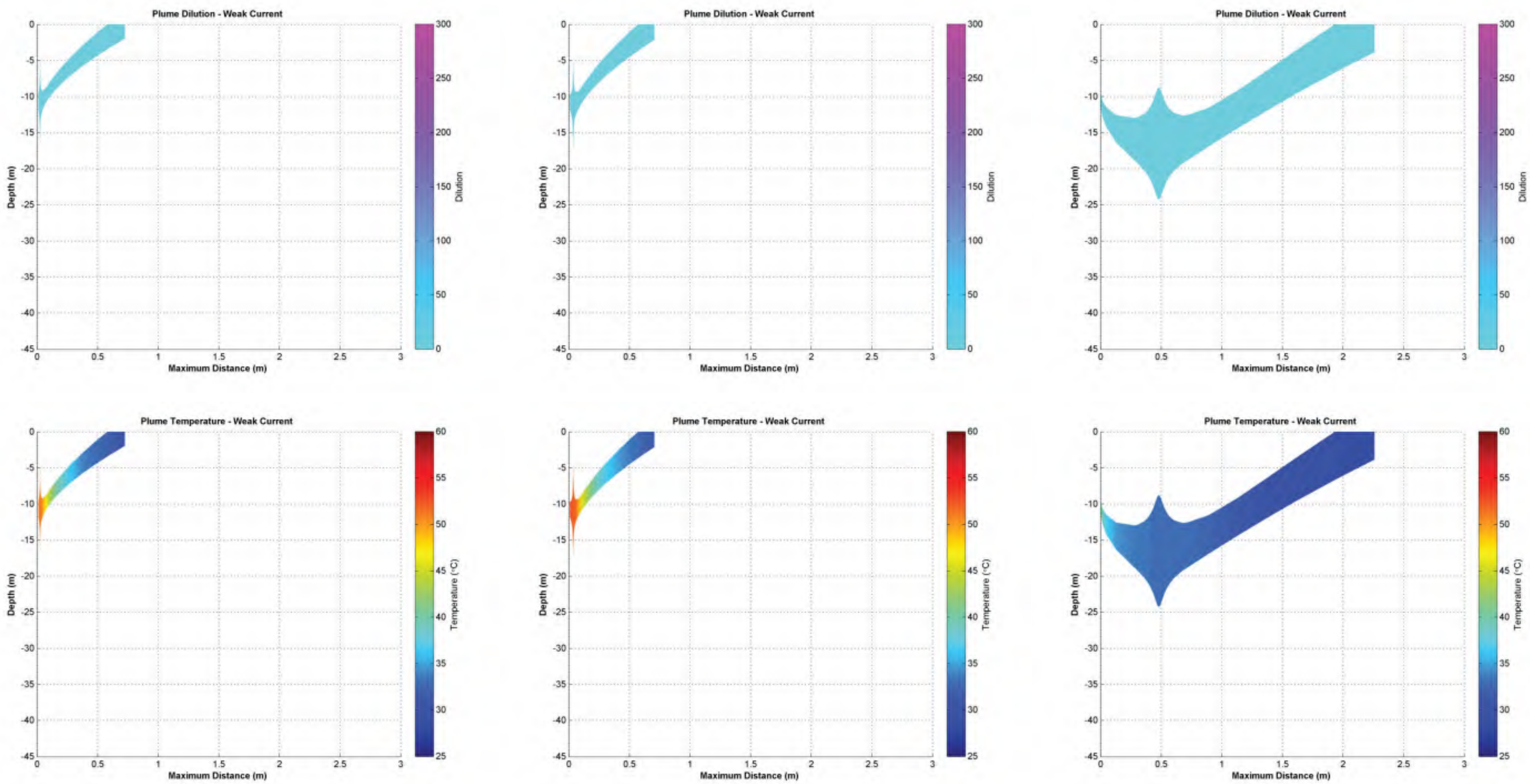

Figure 3.59 Near-field average dilution and temperature results for constant weak winter currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

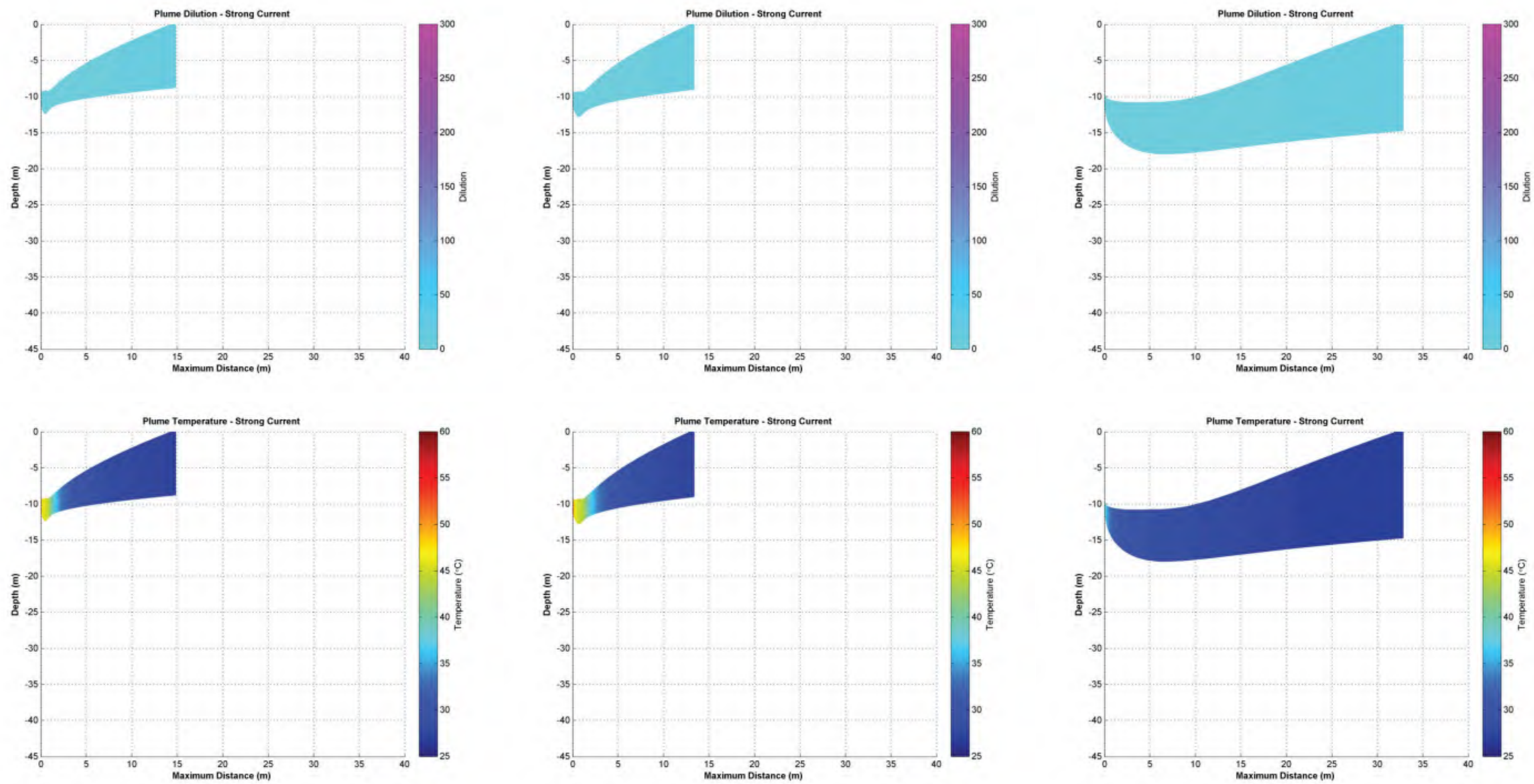

Figure 3.60 Near-field average dilution and temperature results for constant strong winter currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

3.1.3.6 Discharge Depth of 30 m with Varying Flow Rates

3.1.3.6.1 Annualised

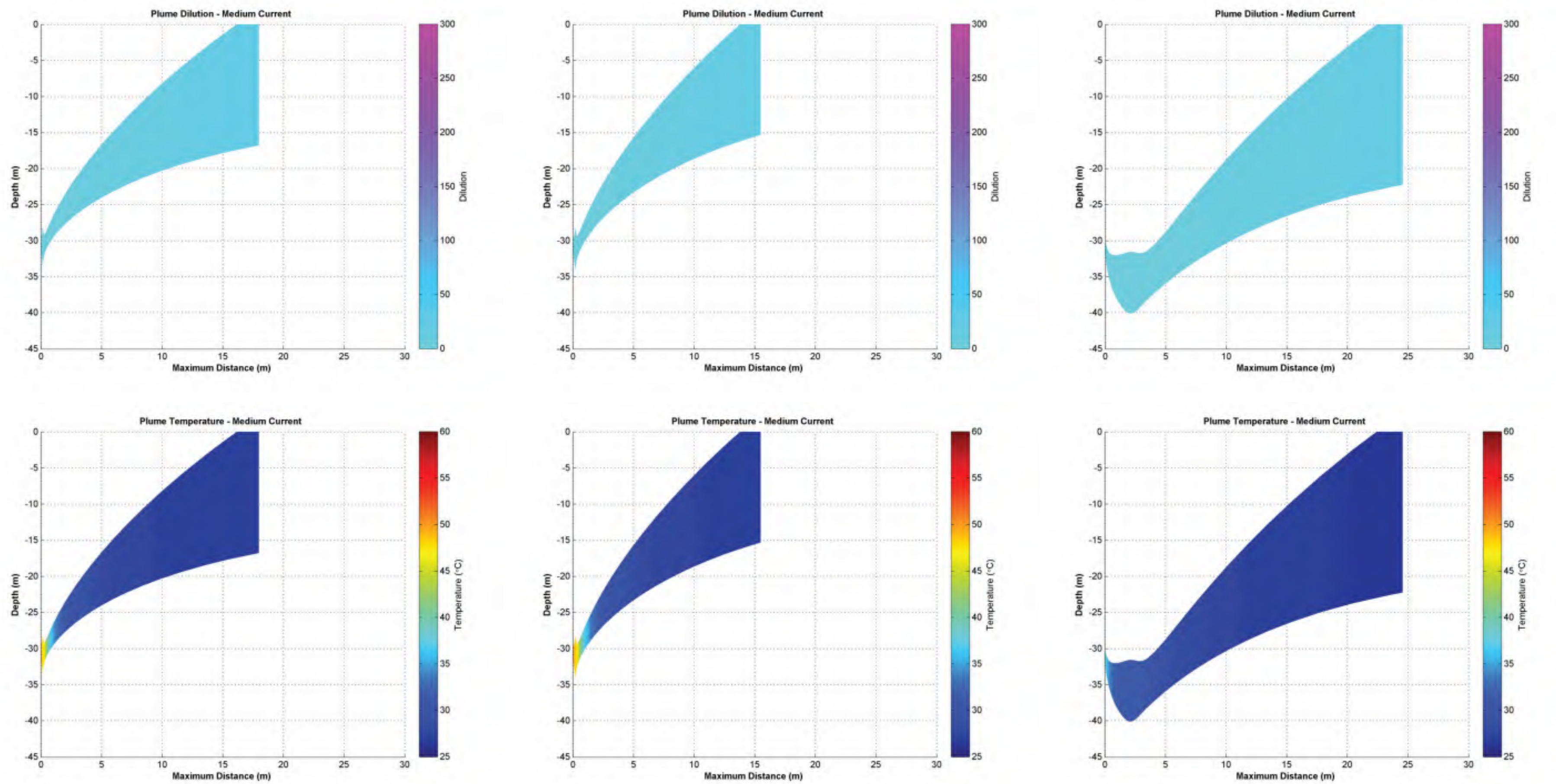

Figure 3.61 Near-field average dilution and temperature results for constant medium annualised currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

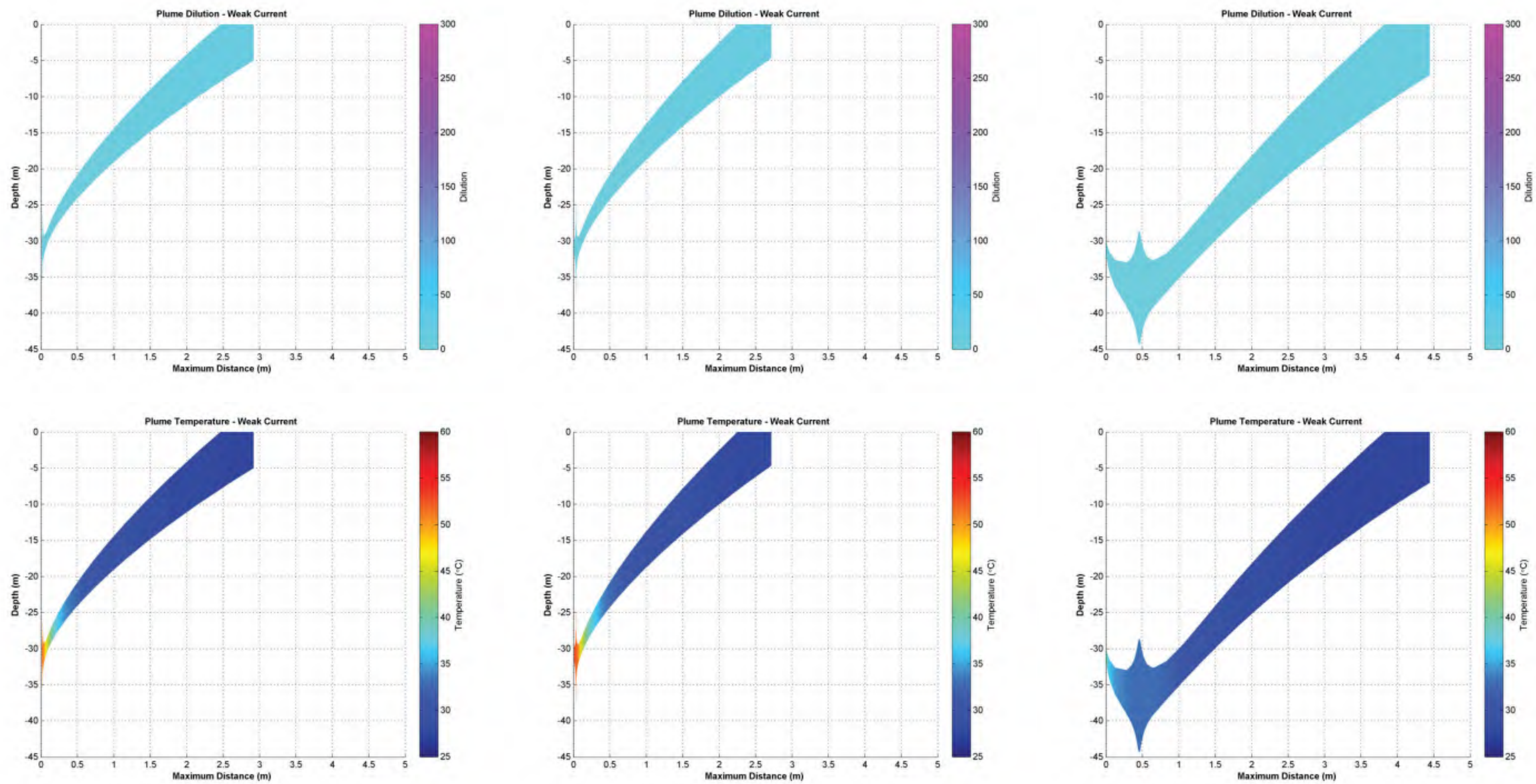

Figure 3.62 Near-field average dilution and temperature results for constant weak annualised currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

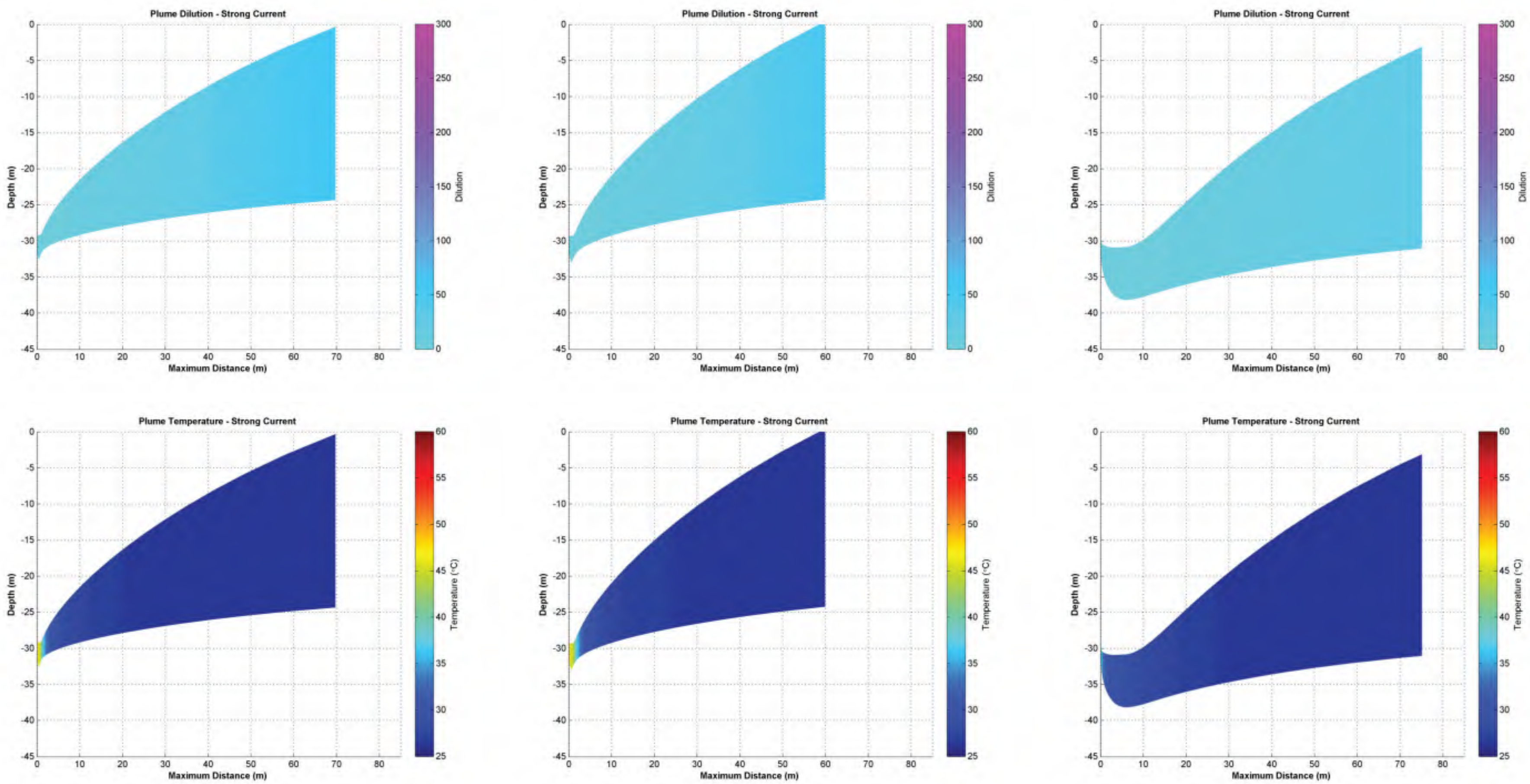

Figure 3.63 Near-field average dilution and temperature results for constant strong annualised currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.1.3.6.2 Summer

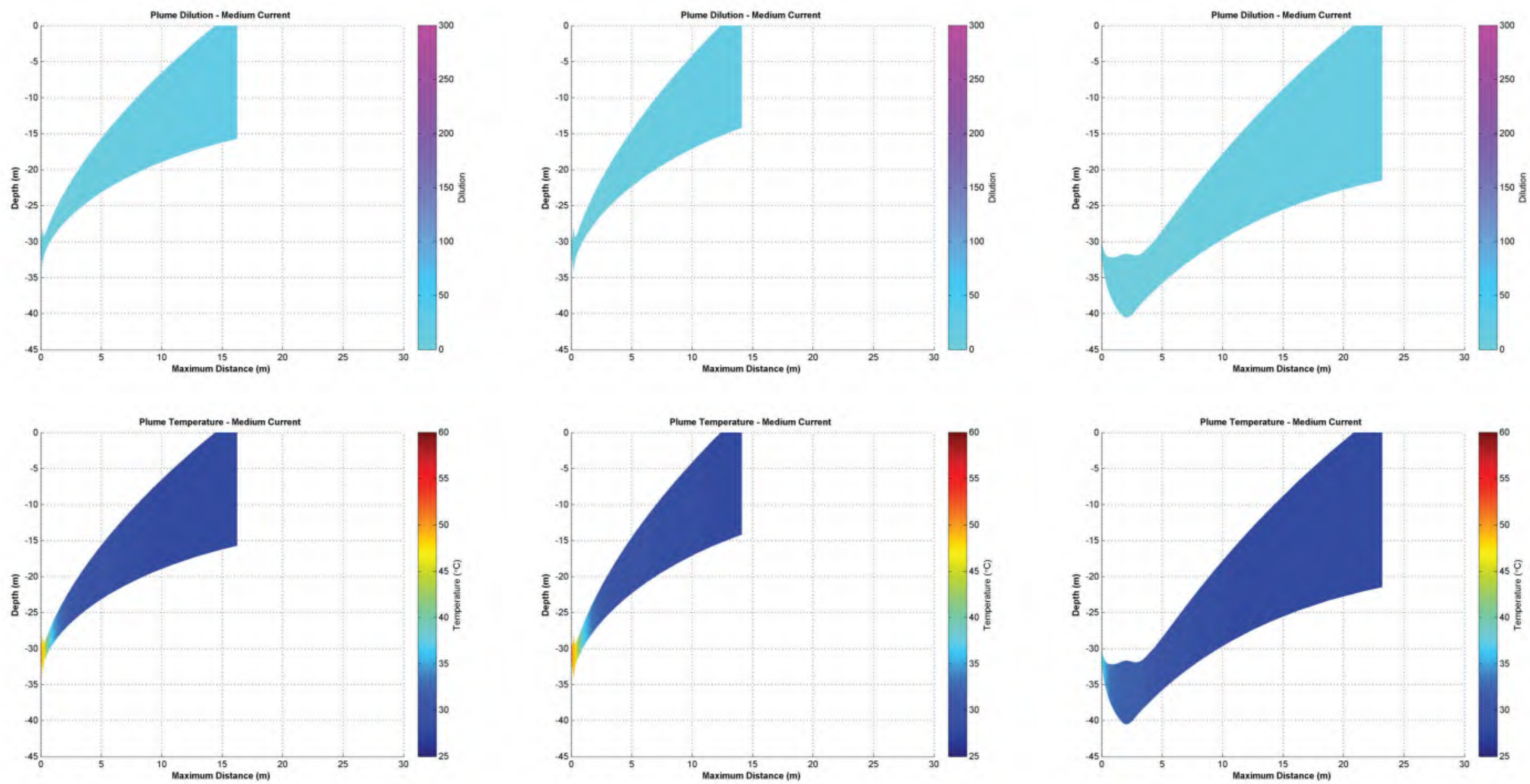

Figure 3.64 Near-field average dilution and temperature results for constant medium summer currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

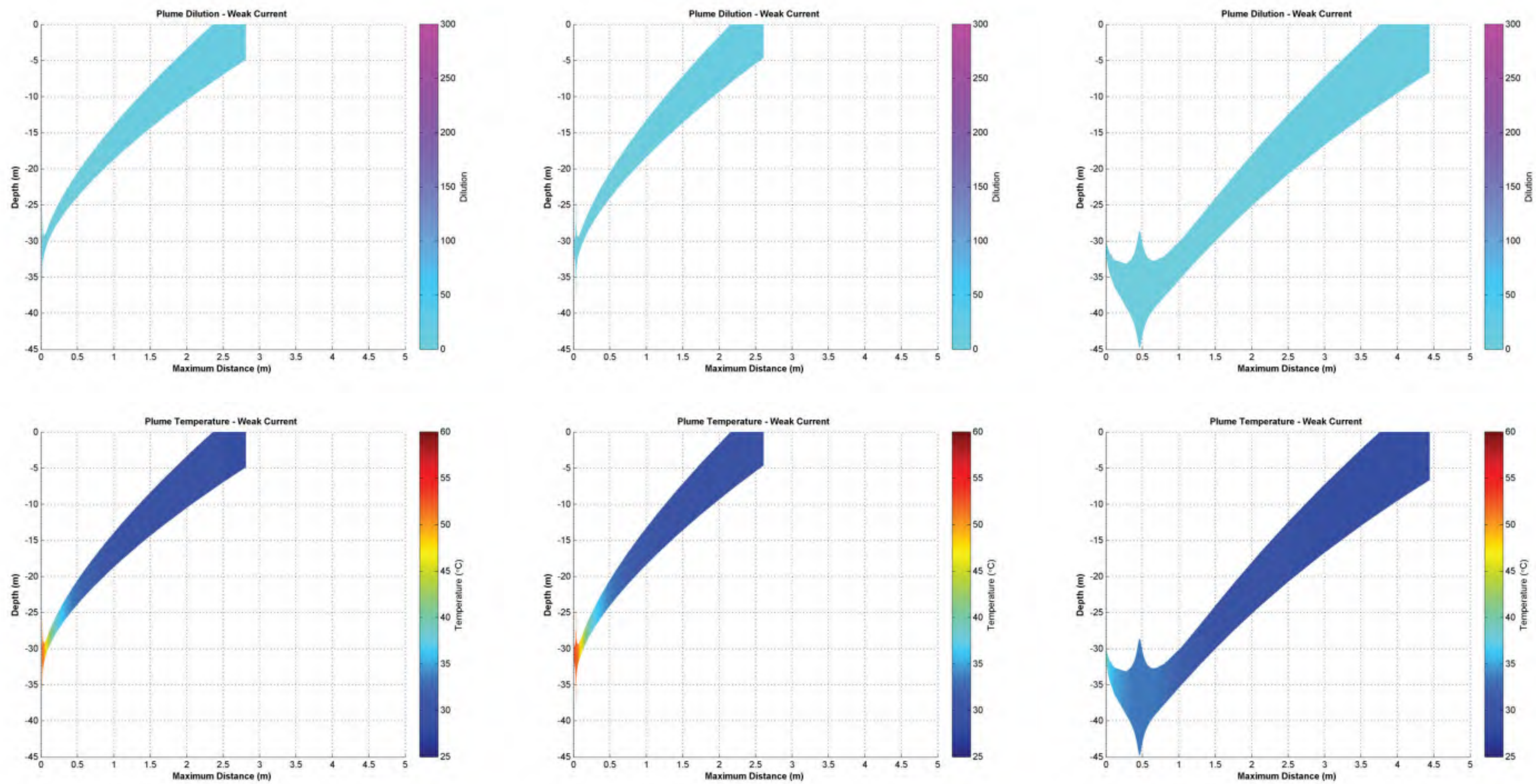

Figure 3.65 Near-field average dilution and temperature results for constant weak summer currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

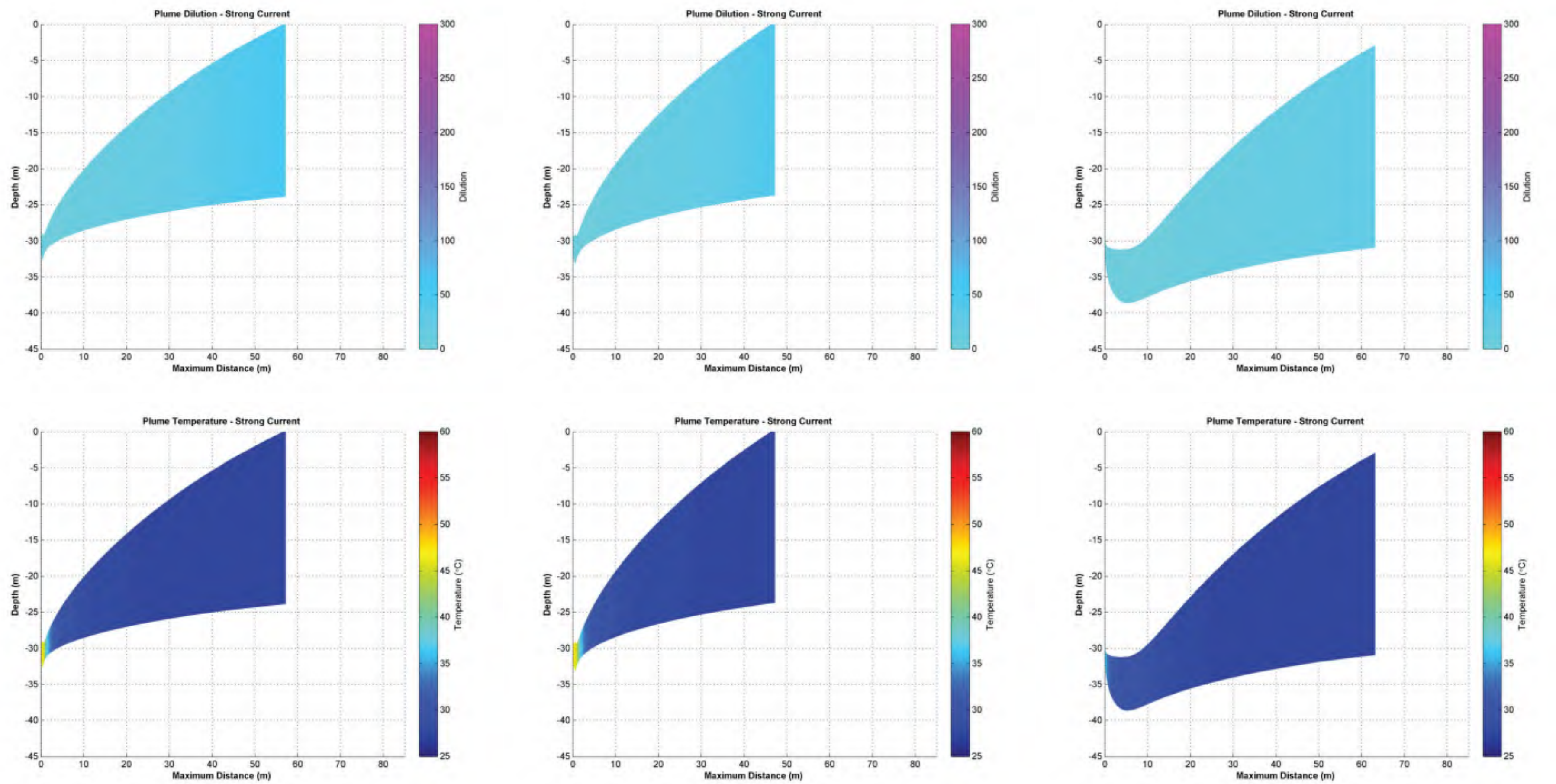

Figure 3.66 Near-field average dilution and temperature results for constant strong summer currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.1.3.6.3 Transitional

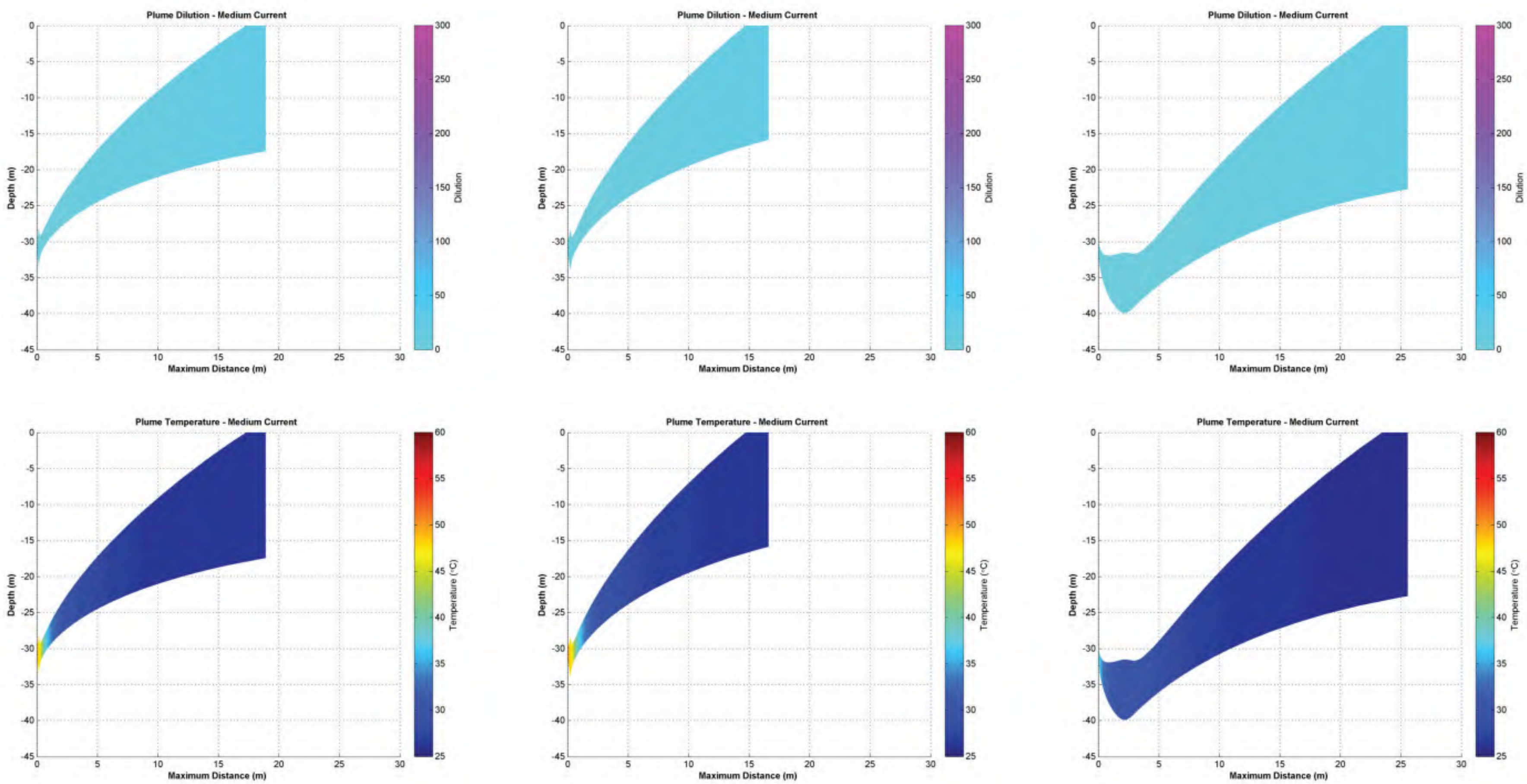

Figure 3.67 Near-field average dilution and temperature results for constant medium transitional currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

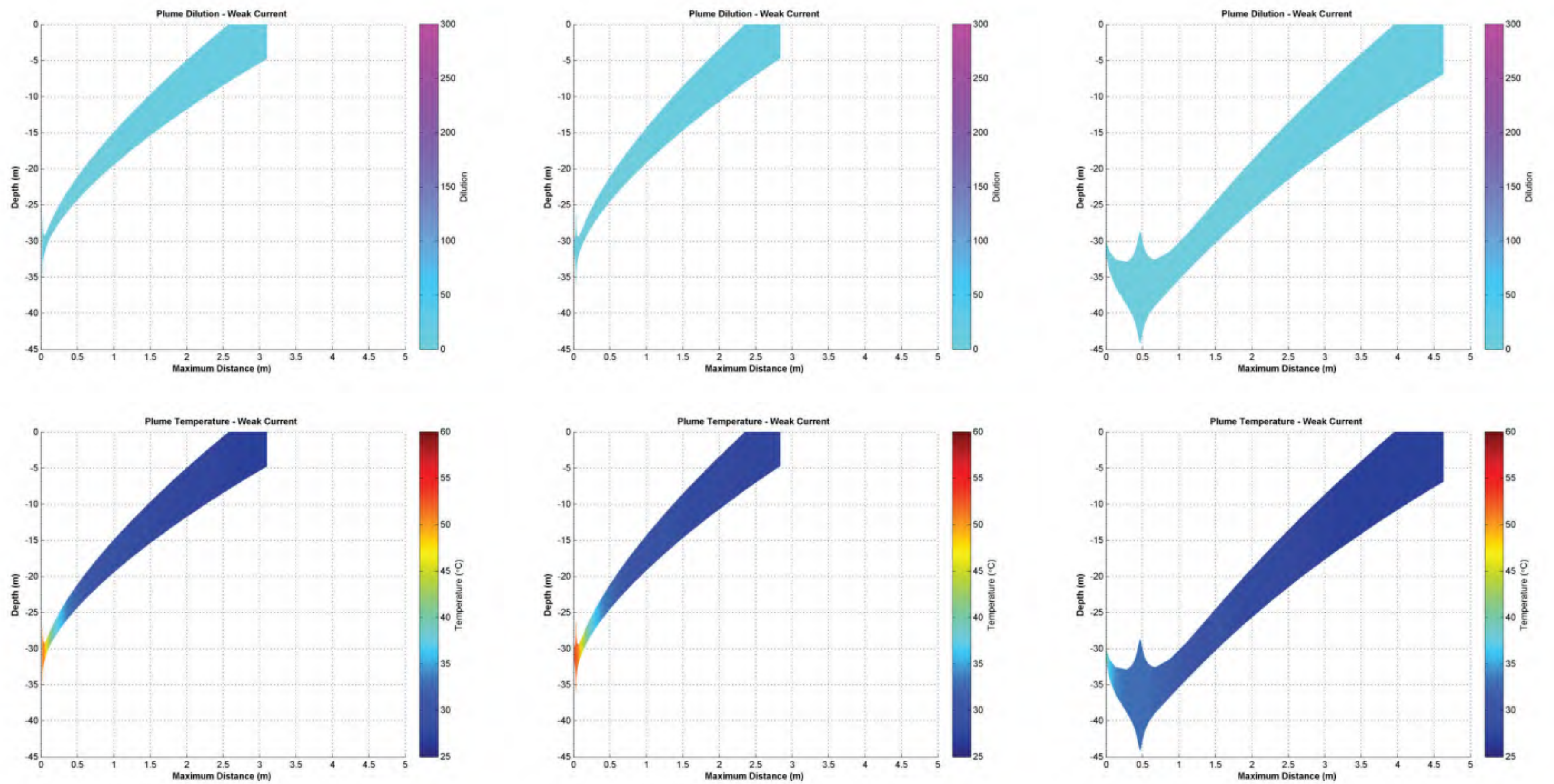

Figure 3.68 Near-field average dilution and temperature results for constant weak transitional currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

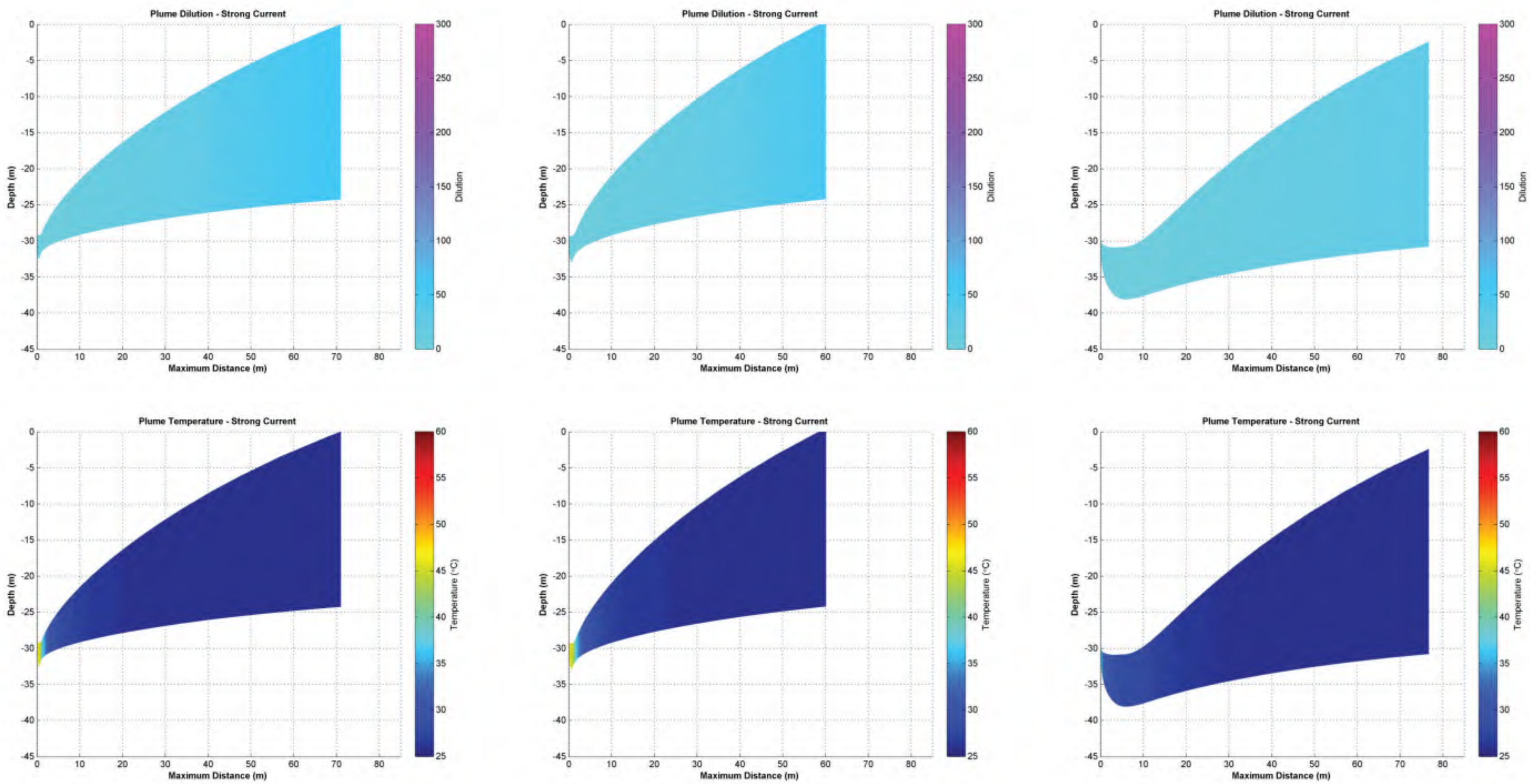

Figure 3.69 Near-field average dilution and temperature results for constant strong transitional currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.1.3.6.4 Winter

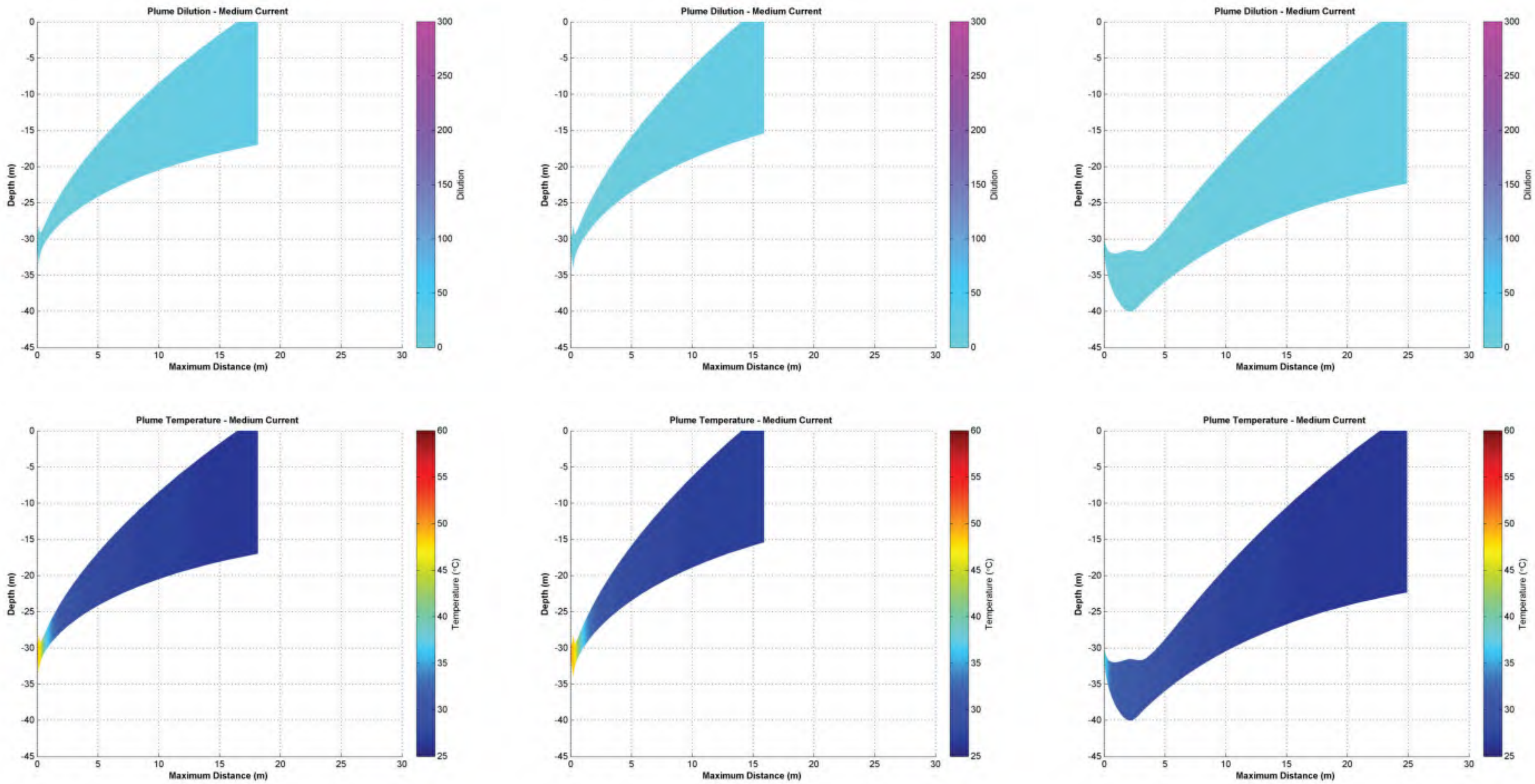

Figure 3.70 Near-field average dilution and temperature results for constant medium winter currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

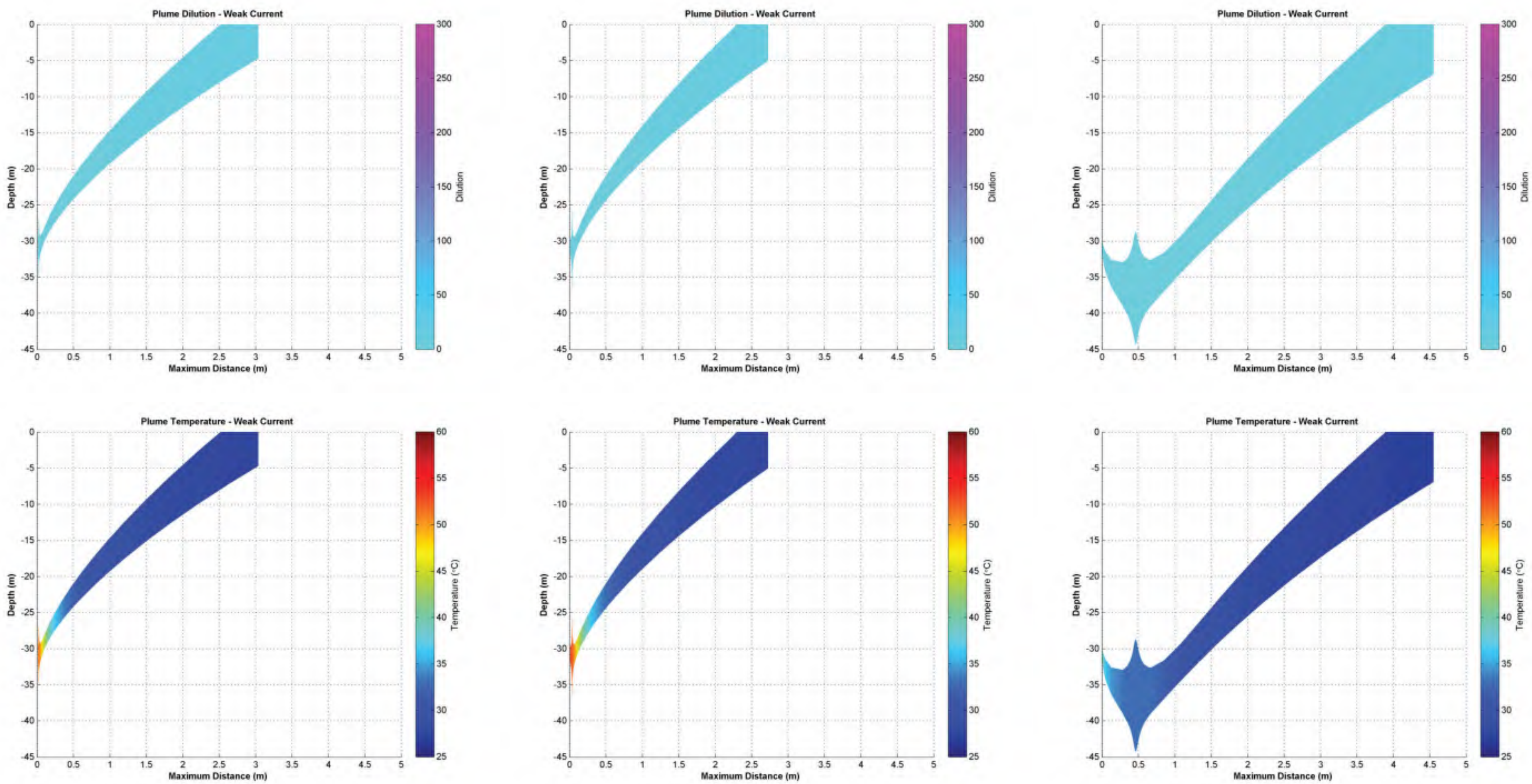

Figure 3.71 Near-field average dilution and temperature results for constant weak winter currents with discharge flow rates of 64,800 m³/d (Case C6; left column), 82,800 m³/d (Case C9; middle column) and 165,600 m³/d (Case C3; right column) at a discharge depth of 30 m.

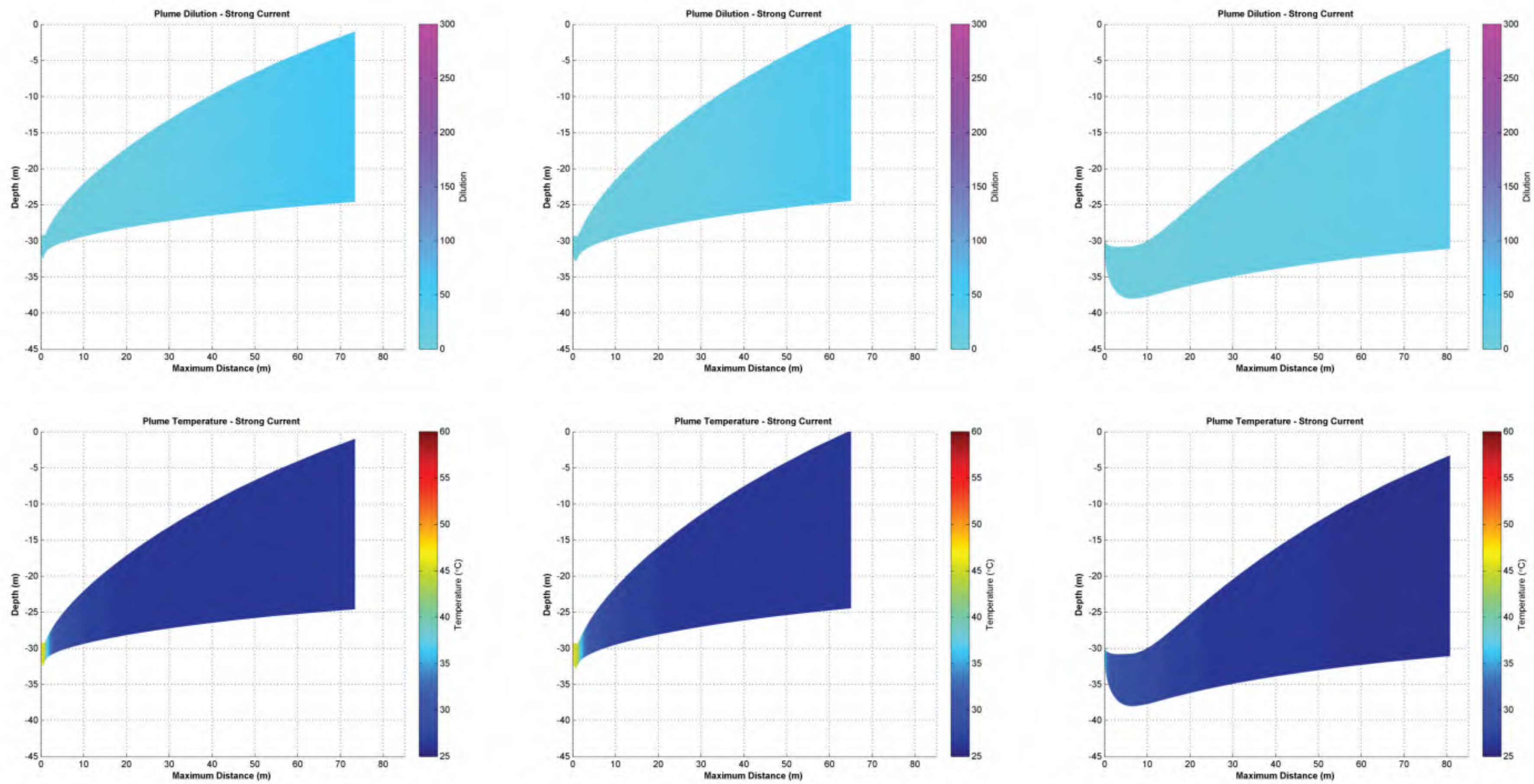

Figure 3.72 Near-field average dilution and temperature results for constant strong winter currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.2 Far-Field Modelling

3.2.1 Overview

It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario. The far-field results included episodes of pooling of the discharge plume under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location when the pooled plume was advected away. Episodes of recirculation – where the plume moved back under the discharge at some later time due to the oscillatory nature of the tide – were also observed, compounding the pooling effect and further lowering the dilution values.

3.2.2 Interpretation of Percentile Dilution Contours

For each of the modelled discharge cases, the results for all simulations were combined and a statistical analysis performed to produce percentile contours of dilution. In the following sections, outcomes based on 95th and 99th percentile dilution contours are presented.

Calculation of 95th and 99th percentile statistics is a common approach to assessing the impact of dispersing plumes and captures the variability in outcomes, for all but the most ephemeral of forcing conditions, in the data set under consideration. Impact assessment criteria for water quality are often defined using similar statistical indicators.

Note that the percentile figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that particular dilution values occur across all replicate simulations and time steps. For example, if the 95th percentile minimum dilution at a particular location in the model domain is predicted as a value of 100, this means that for 95% of the time the dilution level will be higher than 100 and for only 5% of the time the dilution level will be lower than 100. A comparison of the plume extents shown in Figure 3.73 with those shown in Sections 3.2.4 and 3.2.5 demonstrates the significant difference between an instantaneous snapshot and a cumulative estimate of coverage over several days and many individual simulations.

Dilution contours are calculated from the ratios of dispersing contaminant concentrations in the receiving waters to the initial concentration of the contaminant in the discharge. Note that this assumes the background concentration of the constituent in the receiving waters is zero and there is no significant biodegradation of the discharged constituent over the short duration of the dispersion process.

Table 3.46 summarises the initial concentrations of chlorine, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200 and 1:400). These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

Table 3.46 Initial concentrations of chlorine and equivalent concentrations at example dilution levels.

Chlorine Parameter	Chlorine Concentration (mg/L)
Initial concentration in discharge	1,000.0
Initial concentration in receiving waters	0.0
Concentration at 1:100 dilution	10.0
Concentration at 1:200 dilution	5.0
Concentration at 1:400 dilution	1.5

3.2.3 General Observations

Figure 3.73 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 18:00 on 25th October 2013 to 10:00 on 26th October 2013. This simulation – selected merely to be representative of typical conditions – considers the Case C1 flow rate of 165,600 m^3/d at 0 m BMSL. The spatially-varying orientation of the plume with the currents and the rapidly-varying nature of the concentrations around the source can be observed. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

These snapshots illustrate that the dilutions (and in turn concentrations) become more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) are predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume has a more continuous appearance, with higher-concentration patches moving as a unified group. These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.

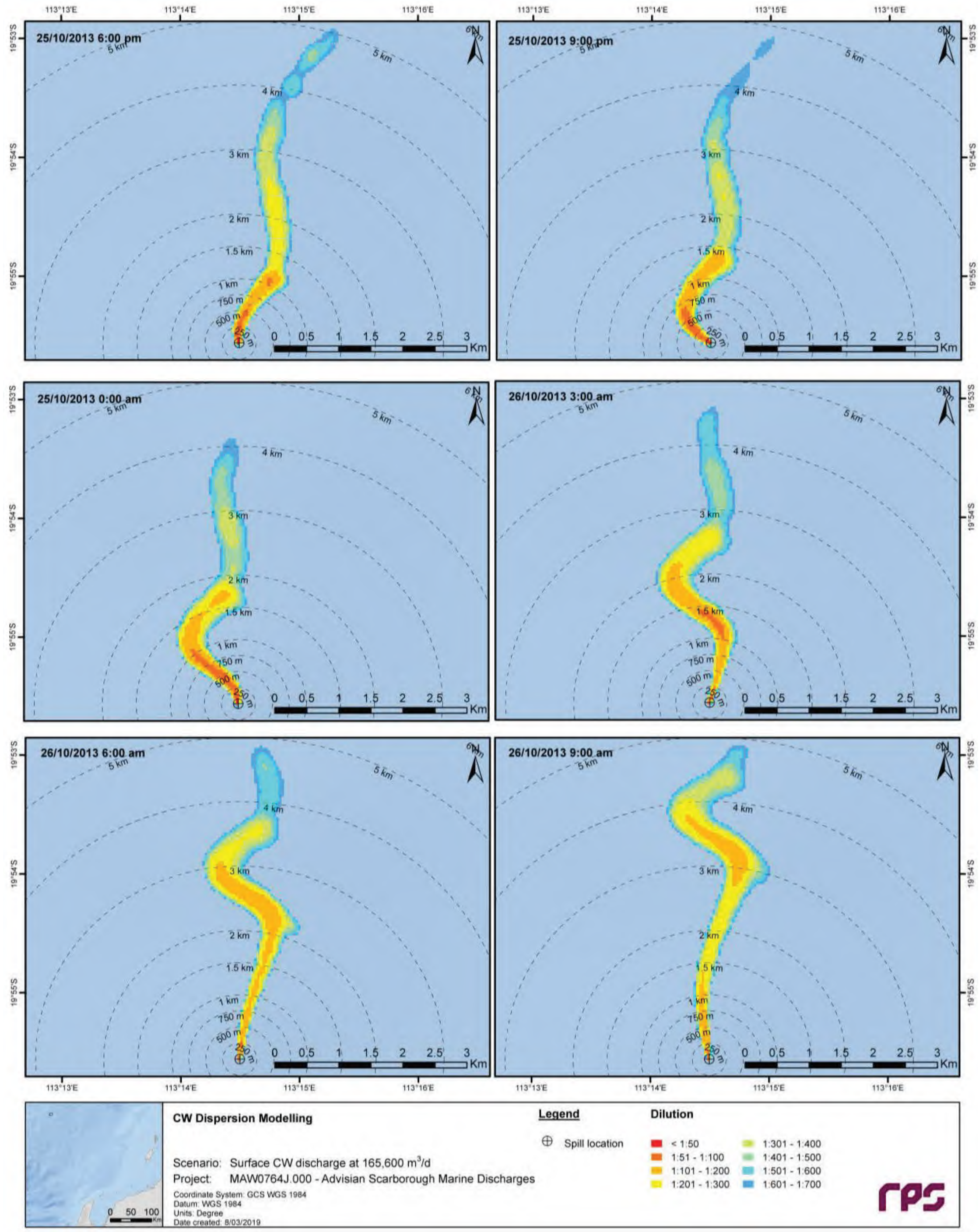

Figure 3.73 Snapshots of predicted dilution levels, at 3-hour intervals from 18:00 on 25th October 2013 to 09:00 on 26th October 2013, for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

3.2.4 Seasonal Analysis

The model outputs over the ten-year hindcast period (2006-2015) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to surrounding sensitive receptors whilst considering inter-annual variability in ocean current conditions.

Table 3.47 to Table 3.50 summarise the minimum dilution achieved at specific radial distances from the discharge location for each season and percentile.

Table 3.51 to Table 3.54 provide summaries of the maximum distances from the discharge location to achieve 1:200 dilution for each season and percentile. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion within the ambient environment. For Cases C1 and C3, dilution to reach threshold concentration is achieved for chlorine within an area of influence ranging from 588 m to 639 m and 623 m to 771 m, respectively, at the 95th percentile across all seasons (Table 3.51 and Table 3.52). For Cases C4 and C6, the maximum spatial extents of the relevant dilution contour vary from 140 m to 182 m and 169 m to 212 m, respectively, at the 95th percentile across all seasons (Table 3.53 and Table 3.54). The greatest spatial extents are observed in winter.

Table 3.55 to Table 3.58 provide summaries of the total area of coverage for the 1:200 dilution contour for each season and percentile. For Cases C1 and C3, the area of exposure defined by the relevant dilution contour is predicted to reach maximums of 0.34 km^2 to 0.53 km^2 and 0.39 km^2 to 0.70 km^2, respectively, at the 95th percentile (Table 3.55 and Table 3.56). For Cases C4 and C6, the corresponding maximum areas of exposure vary from 0.04 km^2 to 0.05 km^2 and 0.05 km^2 to 0.08 km^2, respectively, at the 95th percentile (Table 3.57 and Table 3.58).

Table 3.59 to Table 3.62 provide summaries of the maximum depths from the discharge location to achieve 1:200 dilution for each season and percentile. Maximum depths are predicted as 8 m (summer and winter), 38 m (winter), 6 m (all seasons) and 38 m (summer) for Cases C1, C3, C4 and C6, respectively.

Table 3.63 to Table 3.66 provide summaries of the maximum distances from the discharge location to achieve a 3 °C plume-ambient temperature differential for each season and percentile. For all cases, the requirement is forecast to be met within 115 m at the 99th percentile across all seasons. In many cases, the requirement is forecast to be met within the scale of the model grid resolution (40 m).

For Cases C1, C3, C4 and C6, Figure 3.74 to Figure 3.97 show the aggregated spatial extents of the minimum dilutions for each season and percentile. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

For the cases where the temperature requirement is not met within the scale of the model grid resolution, Figure 3.98 to Figure 3.104 show the aggregated spatial extents of the maximum plume-ambient temperature differential for each season and percentile.

Table 3.47 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C1 (0 m depth discharge at 165,600 m³/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:35.0	1:36.0	1:41.3	1:76.0	1:107.1	1:132.7	1:151.4	1:176.0	1:205.8	1:233.6	1:261.6	1:287.6	1:303.5	1:365.1	1:391.1	1:442.6	1:489.0	1:542.9	1:588.7	1:651.8	1:671.0	1:692.1
	Transitional	1:36.8	1:34.0	1:49.5	1:72.9	1:106.5	1:128.7	1:148.8	1:182.7	1:209.1	1:232.9	1:262.4	1:293.7	1:326.9	1:344.4	1:388.6	1:418.2	1:437.6	1:476.6	1:521.2	1:548.7	1:585.7	1:617.3
	Winter	1:28.7	1:26.4	1:35.0	1:68.8	1:102.2	1:123.1	1:151.8	1:181.2	1:209.1	1:237.3	1:260.7	1:304.9	1:329.9	1:363.9	1:397.4	1:418.3	1:460.4	1:469.2	1:512.8	1:560.0	1:580.9	1:609.5
99th	Summer	1:17.0	1:18.9	1:19.1	1:38.6	1:63.9	1:75.2	1:91.1	1:104.8	1:116.5	1:130.2	1:136.2	1:147.7	1:163.1	1:165.9	1:186.4	1:196.2	1:204.9	1:230.3	1:244.1	1:250.5	1:261.8	1:268.6
	Transitional	1:19.4	1:17.2	1:18.6	1:31.6	1:49.6	1:68.6	1:89.8	1:109.7	1:132.1	1:151.3	1:160.1	1:179.2	1:186.4	1:196.1	1:214.7	1:233.0	1:235.9	1:252.3	1:267.0	1:275.4	1:288.9	1:307.6
	Winter	1:14.3	1:11.6	1:17.0	1:32.7	1:49.5	1:61.0	1:71.1	1:74.3	1:81.7	1:94.8	1:98.4	1:106.3	1:126.6	1:136.2	1:147.0	1:149.1	1:161.2	1:165.4	1:170.8	1:176.6	1:212.8	1:237.8

Table 3.48 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C3 (30 m depth discharge at 165,600 m³/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:29.9	1:18.0	1:30.8	1:64.2	1:98.8	1:122.8	1:157.8	1:177.0	1:204.2	1:224.0	1:256.3	1:302.6	1:320.4	1:342.1	1:387.8	1:412.1	1:426.9	1:446.3	1:506.0	1:510.9	1:548.7	1:671.9
	Transitional	1:33.2	1:23.9	1:35.6	1:66.7	1:99.2	1:120.0	1:136.7	1:156.3	1:177.5	1:196.3	1:217.3	1:231.7	1:244.4	1:260.0	1:283.8	1:292.9	1:316.9	1:330.2	1:337.8	1:363.3	1:394.3	1:408.2
	Winter	1:24.5	1:18.8	1:29.7	1:58.9	1:82.6	1:125.0	1:140.7	1:166.1	1:174.6	1:202.1	1:208.5	1:235.7	1:271.3	1:363.9	1:423.2	1:458.8	1:539.1	1:669.4	1:758.1	1:875.3	1:1,055.4	1:1,144.4
99th	Summer	1:9.7	1:13.6	1:15.1	1:32.0	1:50.0	1:61.7	1:70.1	1:84.7	1:86.5	1:100.3	1:100.9	1:107.8	1:112.1	1:124.3	1:129.1	1:141.4	1:154.8	1:165.5	1:174.5	1:181.6	1:195.5	1:206.0
	Transitional	1:18.5	1:12.8	1:16.1	1:31.8	1:51.8	1:72.1	1:83.3	1:98.7	1:104.1	1:112.3	1:115.5	1:122.4	1:132.2	1:147.0	1:163.3	1:182.0	1:186.9	1:186.0	1:187.4	1:193.9	1:211.4	1:231.7
	Winter	1:13.0	1:9.6	1:16.0	1:28.8	1:41.0	1:49.8	1:56.7	1:69.3	1:79.3	1:94.1	1:93.2	1:98.8	1:118.5	1:130.8	1:140.5	1:163.3	1:171.6	1:178.2	1:191.8	1:192.7	1:214.8	1:224.2

Table 3.49 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C4 (0 m depth discharge at 64,800 m³/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:89.5	1:92.5	1:105.4	1:194.0	1:273.7	1:339.0	1:387.0	1:449.9	1:526.1	1:596.9	1:668.6	1:735.0	1:775.7	1:933.1	1:999.5	1:1,131.0	1:1,249.7	1:1,387.4	1:1,504.5	1:1,665.8	1:1,714.7	1:1,768.7
	Transitional	1:94.0	1:87.0	1:90.3	1:186.4	1:272.3	1:328.8	1:380.3	1:467.0	1:534.3	1:595.2	1:670.6	1:750.6	1:835.5	1:880.1	1:993.1	1:1,068.6	1:1,118.4	1:1,217.9	1:1,331.9	1:1,402.1	1:1,496.7	1:1,577.6
	Winter	1:67.4	1:73.3	1:89.5	1:175.7	1:261.2	1:314.6	1:387.9	1:463.2	1:534.3	1:606.3	1:666.1	1:779.1	1:843.1	1:929.9	1:1,015.6	1:1,069.1	1:1,176.5	1:1,199.0	1:1,310.6	1:1,431.2	1:1,484.6	1:1,557.7
99th	Summer	1:43.5	1:48.2	1:48.8	1:98.7	1:163.2	1:192.1	1:232.8	1:267.8	1:297.8	1:332.7	1:348.0	1:377.5	1:416.9	1:424.0	1:476.4	1:501.4	1:523.6	1:588.5	1:623.9	1:640.1	1:669.0	1:686.4
	Transitional	1:49.7	1:44.0	1:47.6	1:80.8	1:126.6	1:175.4	1:229.4	1:280.4	1:337.6	1:386.8	1:409.2	1:457.9	1:476.2	1:501.0	1:548.6	1:595.4	1:602.9	1:644.8	1:682.4	1:703.9	1:738.3	1:786.2
	Winter	1:29.6	1:36.5	1:43.2	1:83.5	1:126.6	1:156.0	1:181.7	1:189.8	1:208.7	1:242.3	1:251.6	1:271.7	1:313.4	1:348.0	1:375.7	1:381.1	1:411.8	1:422.6	1:436.4	1:451.4	1:543.8	1:607.8

Table 3.50 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C6 (30 m depth discharge at 64,800 m³/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:44.7	1:72.6	1:99.7	1:156.6	1:256.5	1:321.2	1:400.4	1:450.5	1:537.7	1:617.3	1:655.1	1:773.2	1:818.7	1:874.3	1:991.1	1:1,053.1	1:1,091.1	1:1,140.7	1:1,293.1	1:1,305.7	1:1,402.3	1:1,717.2
	Transitional	1:61.2	1:89.4	1:111.0	1:162.2	1:252.6	1:306.6	1:350.9	1:407.4	1:458.9	1:507.0	1:561.3	1:595.5	1:630.0	1:680.7	1:741.7	1:772.3	1:856.5	1:856.6	1:892.2	1:1,001.1	1:1,064.3	1:1,056.5
	Winter	1:50.7	1:62.7	1:76.5	1:151.7	1:208.6	1:281.5	1:359.8	1:424.6	1:446.2	1:516.6	1:532.9	1:602.4	1:693.4	1:930.0	1:1,081.5	1:1,172.4	1:1,377.7	1:1,710.7	1:1,835.9	1:2,197.7	1:2,411.9	1:2,611.3
99th	Summer	1:24.6	1:34.7	1:37.9	1:81.2	1:121.0	1:150.2	1:175.3	1:209.6	1:216.6	1:256.2	1:257.8	1:275.6	1:286.6	1:317.6	1:329.9	1:361.4	1:395.6	1:423.0	1:445.9	1:464.2	1:499.6	1:526.4
	Transitional	1:29.5	1:40.6	1:60.3	1:92.6	1:132.9	1:179.8	1:207.3	1:230.8	1:251.6	1:270.1	1:285.6	1:312.6	1:315.5	1:319.8	1:376.2	1:423.1	1:465.4	1:453.9	1:455.8	1:445.5	1:503.0	1:548.3
	Winter	1:24.4	1:33.2	1:40.8	1:73.6	1:104.9	1:130.7	1:141.9	1:181.2	1:195.2	1:240.5	1:238.2	1:252.7	1:302.7	1:331.3	1:395.0	1:417.4	1:438.6	1:455.4	1:504.9	1:492.5	1:548.8	1:572.9

Table 3.51 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	639
	Transitional	588
	Winter	636
99th	Summer	1,354
	Transitional	1,175
	Winter	1,789
100th	Summer	3,572
	Transitional	3,741
	Winter	4,705

Table 3.52 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	623
	Transitional	757
	Winter	771
99th	Summer	1,896
	Transitional	1,758
	Winter	2,470
100th	Summer	5,857
	Transitional	6,391
	Winter	5,549

Table 3.53 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C4 (0 m depth discharge at 64,800 m³/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	140
	Transitional	152
	Winter	182
99th	Summer	351
	Transitional	393
	Winter	621
100th	Summer	1,723
	Transitional	1,579
	Winter	2,272

Table 3.54 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C6 (30 m depth discharge at 64,800 m³/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	188
	Transitional	169
	Winter	212
99th	Summer	519
	Transitional	413
	Winter	631
100th	Summer	3,258
	Transitional	3,258
	Winter	3,566

Table 3.55 Total area of coverage for 1:200 dilution in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.353
	Transitional	0.343
	Winter	0.528
99th	Summer	2.016
	Transitional	2.086
	Winter	4.409
100th	Summer	10.966
	Transitional	9.992
	Winter	20.163

Table 3.56 Total area of coverage for 1:200 dilution in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.441
	Transitional	0.385
	Winter	0.701
99th	Summer	4.625
	Transitional	3.768
	Winter	5.482
100th	Summer	33.376
	Transitional	29.964
	Winter	30.908

Table 3.57 Total area of coverage for 1:200 dilution in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.039
	Transitional	0.035
	Winter	0.053
99th	Summer	0.189
	Transitional	0.215
	Winter	0.374
100th	Summer	1.425
	Transitional	1.164
	Winter	3.334

Table 3.58 Total area of coverage for 1:200 dilution in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.061
	Transitional	0.045
	Winter	0.075
99th	Summer	0.465
	Transitional	0.242
	Winter	0.550
100th	Summer	5.286
	Transitional	2.948
	Winter	5.635

Table 3.59 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	8
Transitional	6
Winter	8

Table 3.60 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	36
Transitional	36
Winter	38

Table 3.61 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	6
Transitional	6
Winter	6

Table 3.62 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	38
Transitional	36
Winter	36

Table 3.63 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	<40
	Transitional	<40
	Winter	90
100th	Summer	115
	Transitional	145
	Winter	285

Table 3.64 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	115
	Transitional	115
	Winter	115
100th	Summer	350
	Transitional	380
	Winter	345

Table 3.65 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	<40
	Transitional	<40
	Winter	<40
100th	Summer	90
	Transitional	90
	Winter	145

Table 3.66 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	90
	Transitional	90
	Winter	90
100th	Summer	145
	Transitional	175
	Winter	145

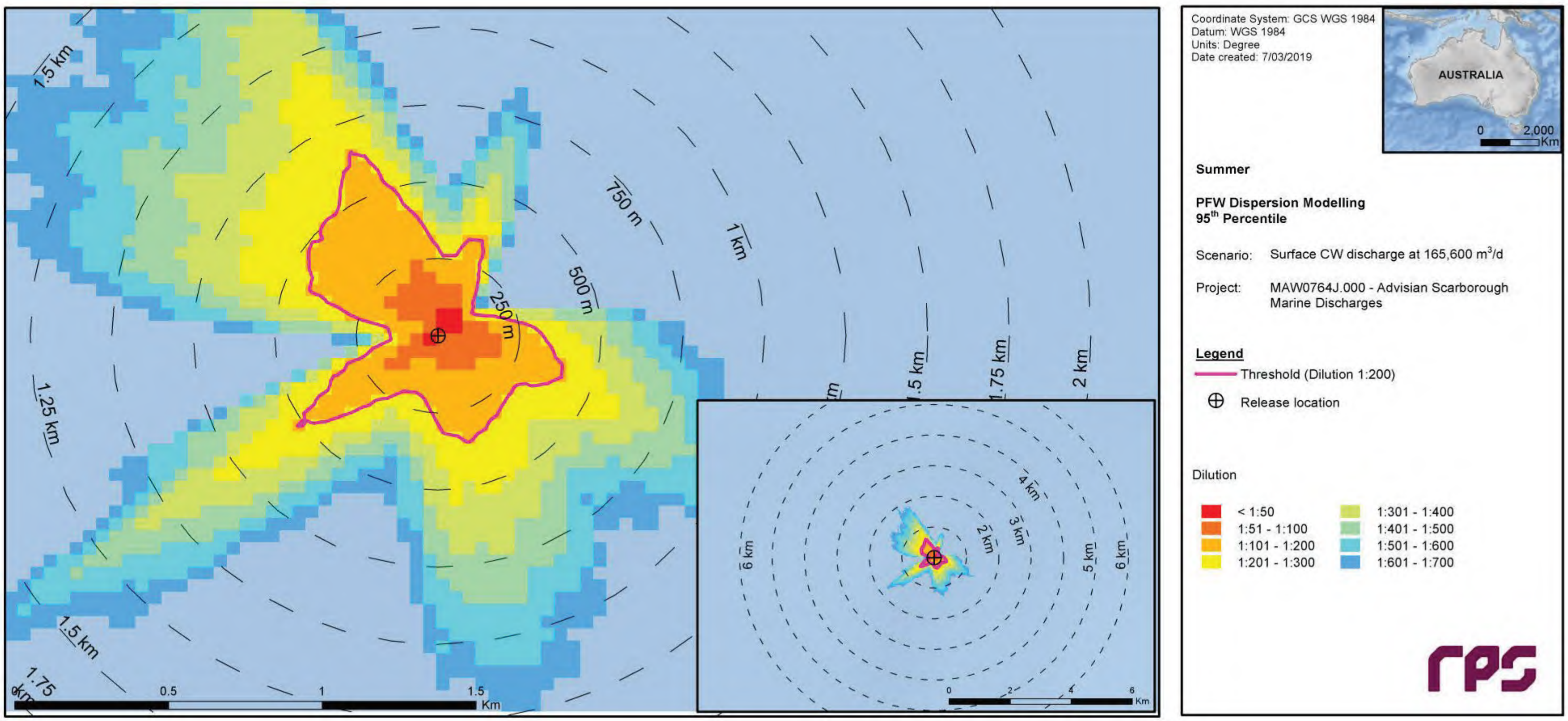

Figure 3.74 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

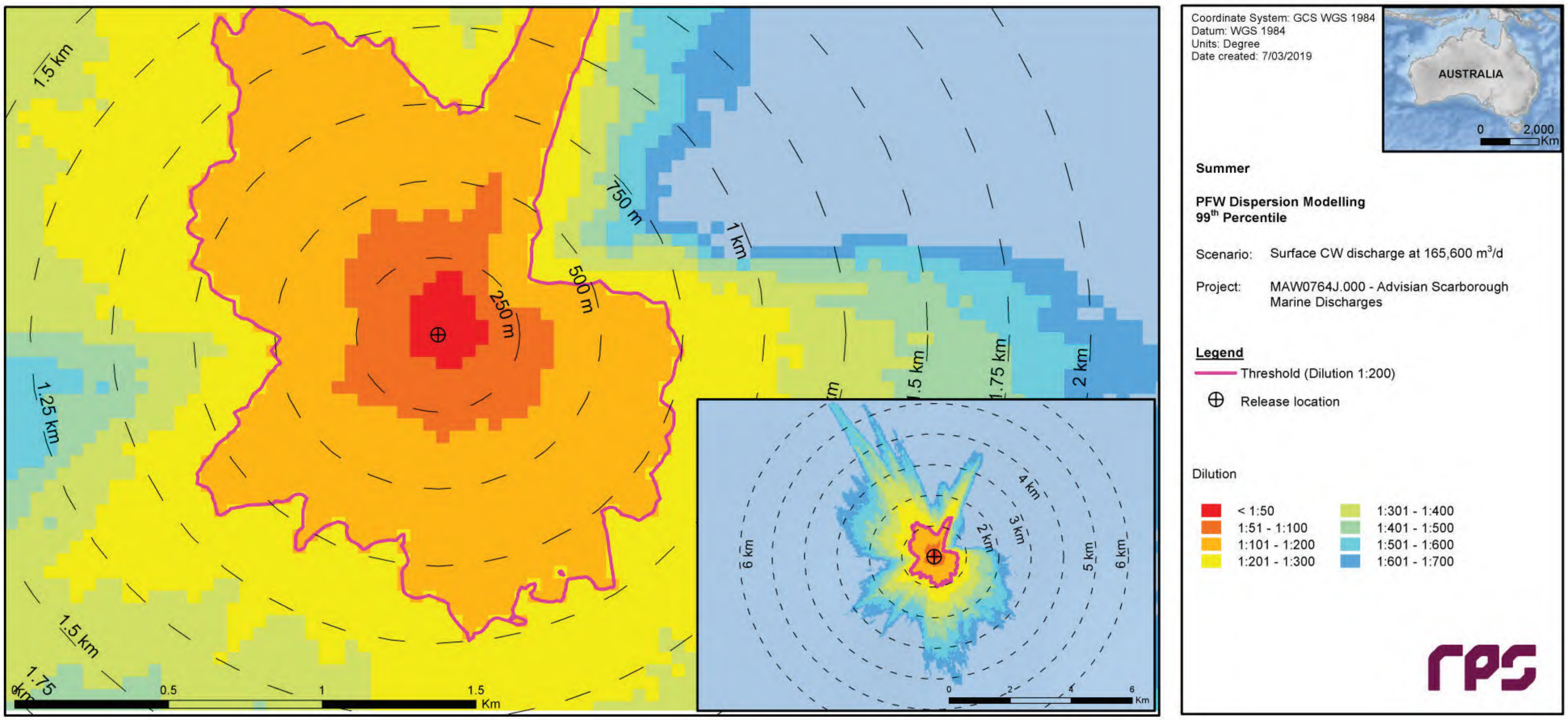

Figure 3.75 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

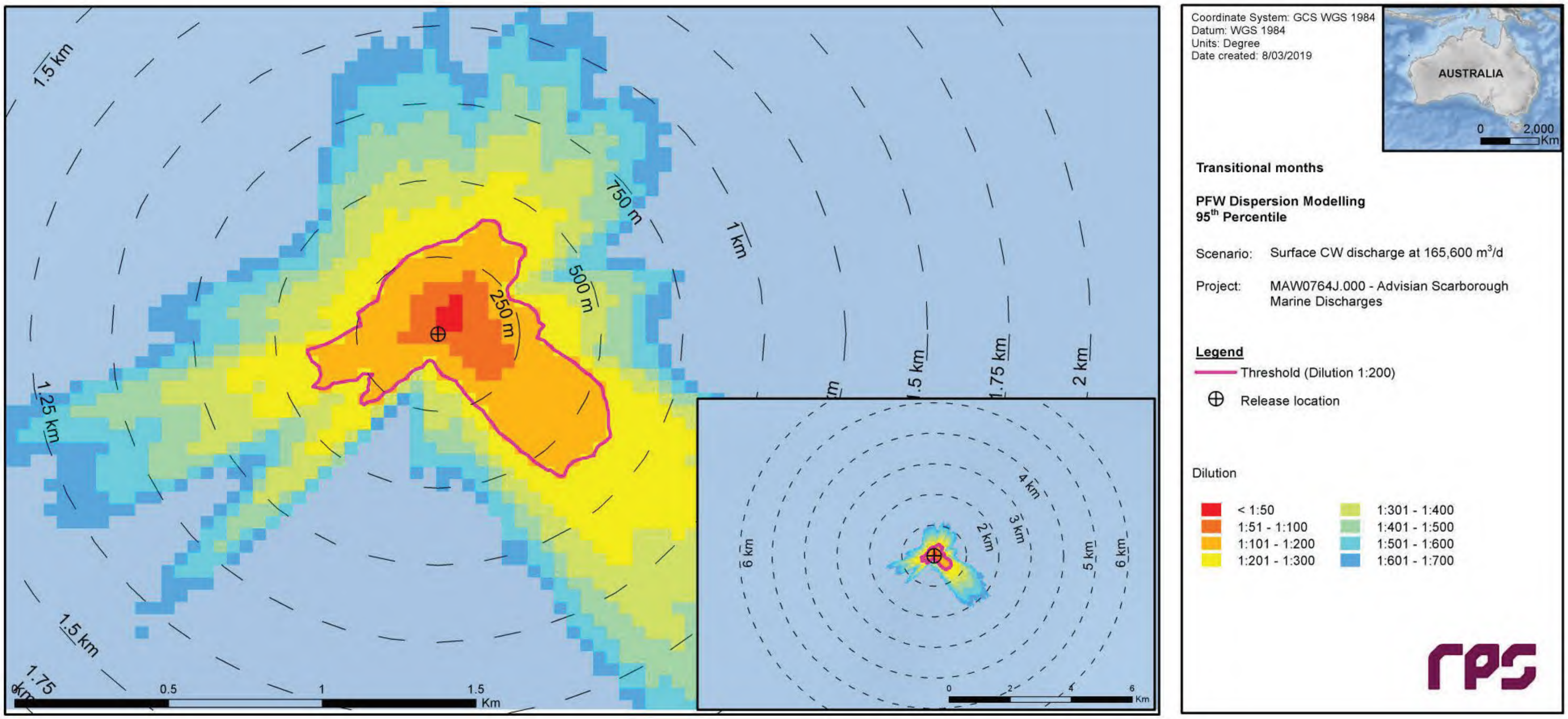

Figure 3.76 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

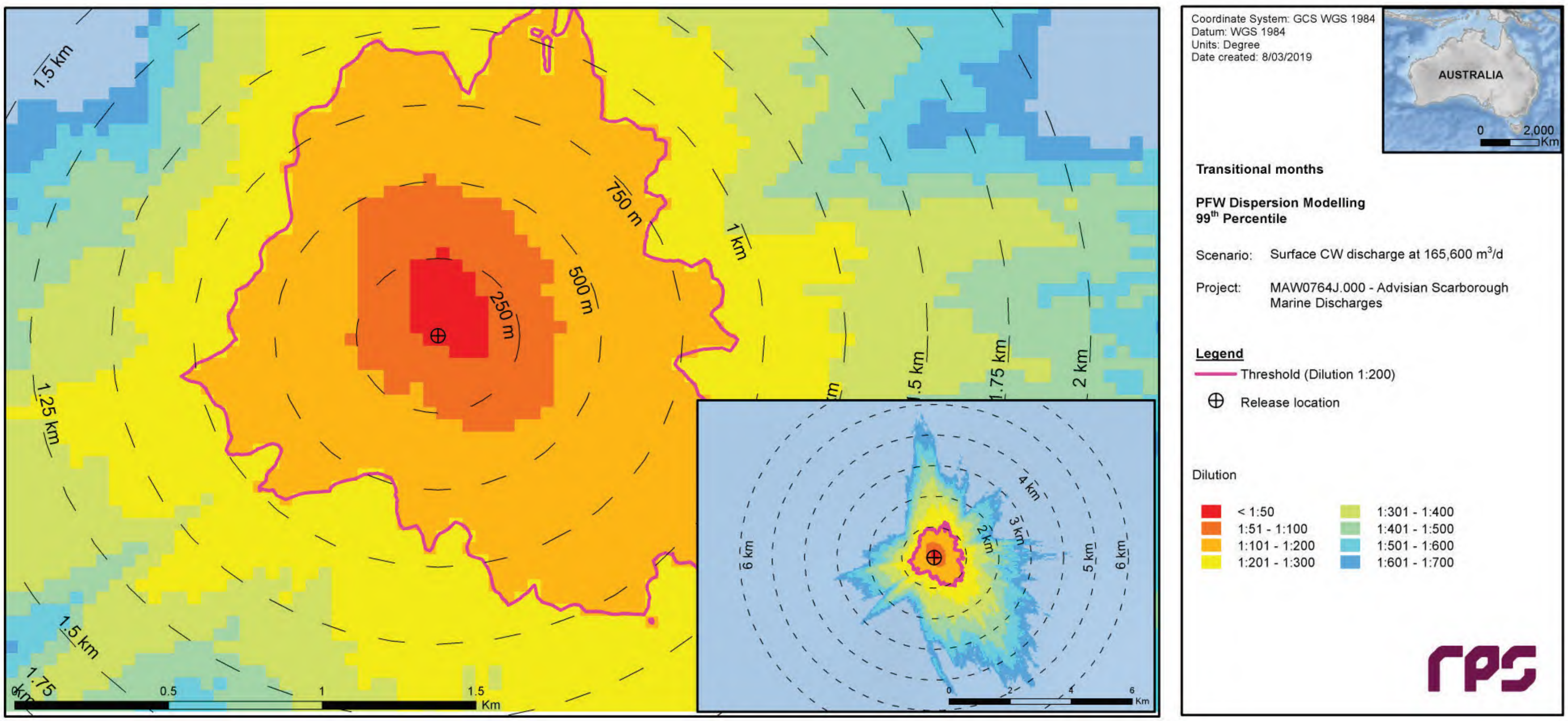

Figure 3.77 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

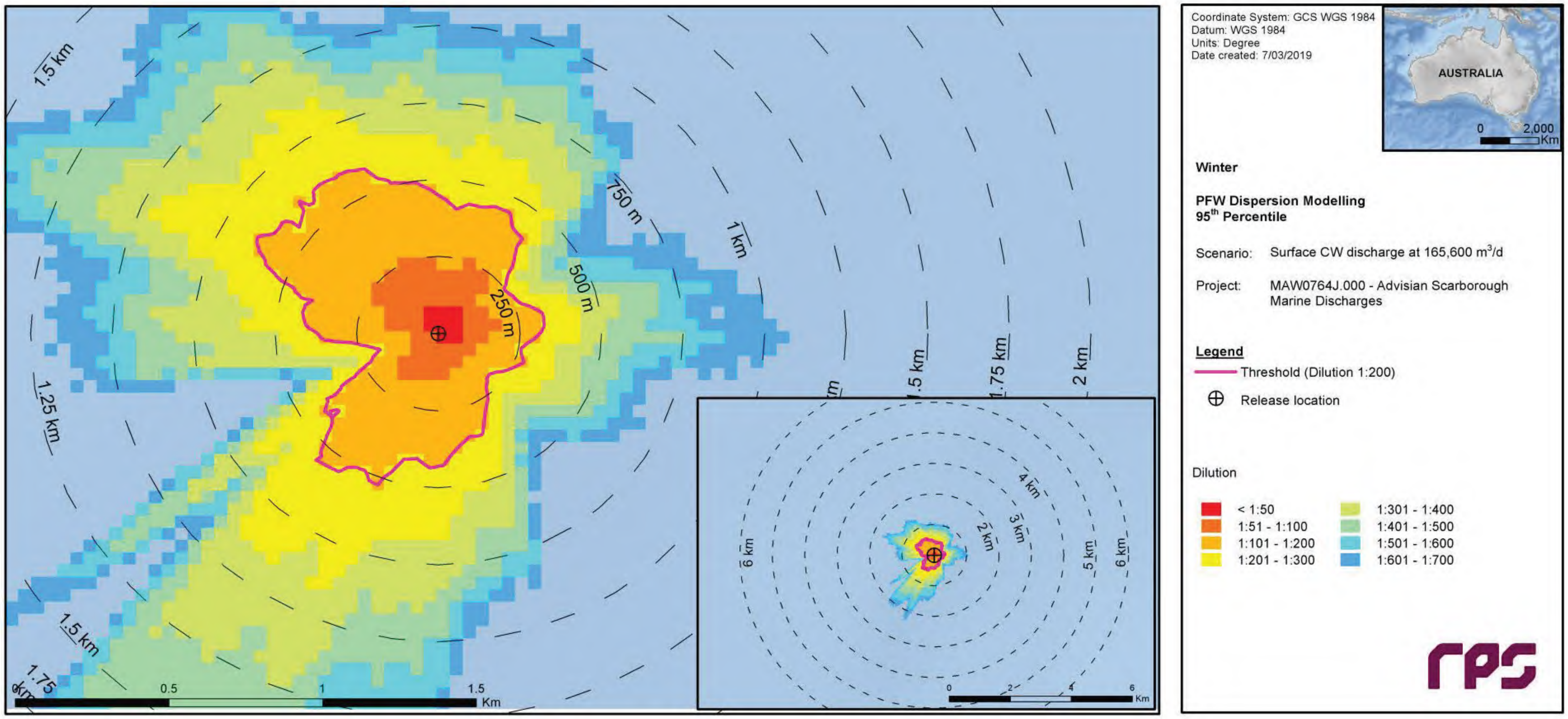

Figure 3.78 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

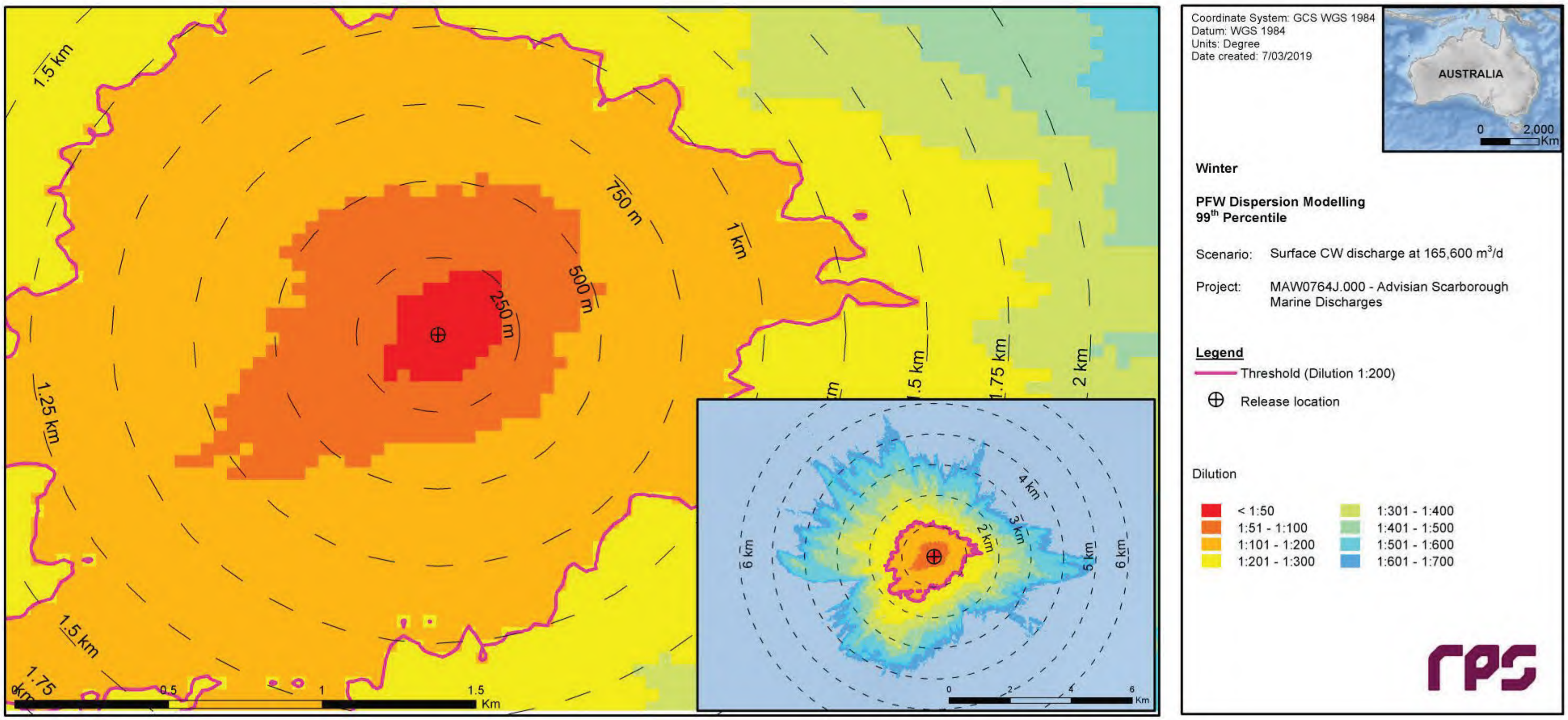

Figure 3.79 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

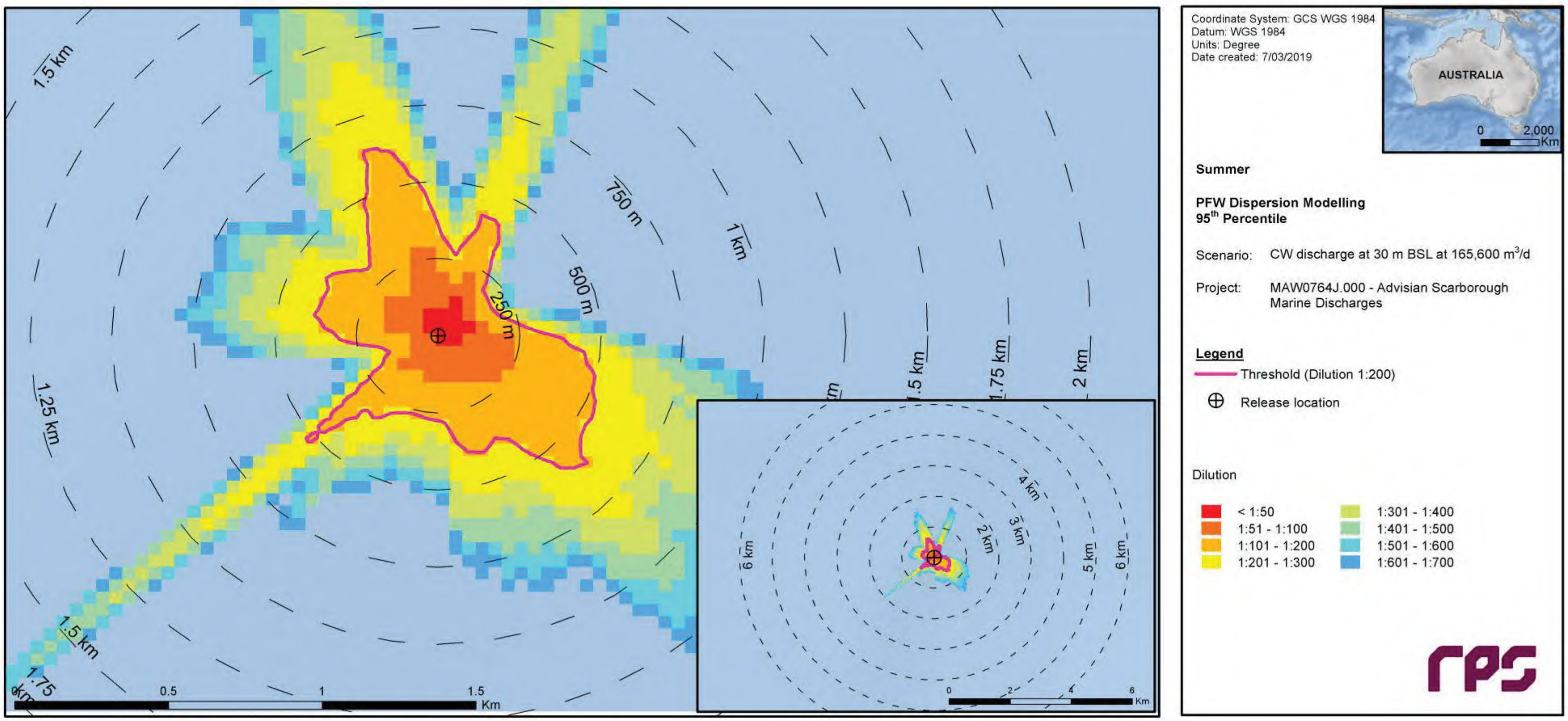

Figure 3.80 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

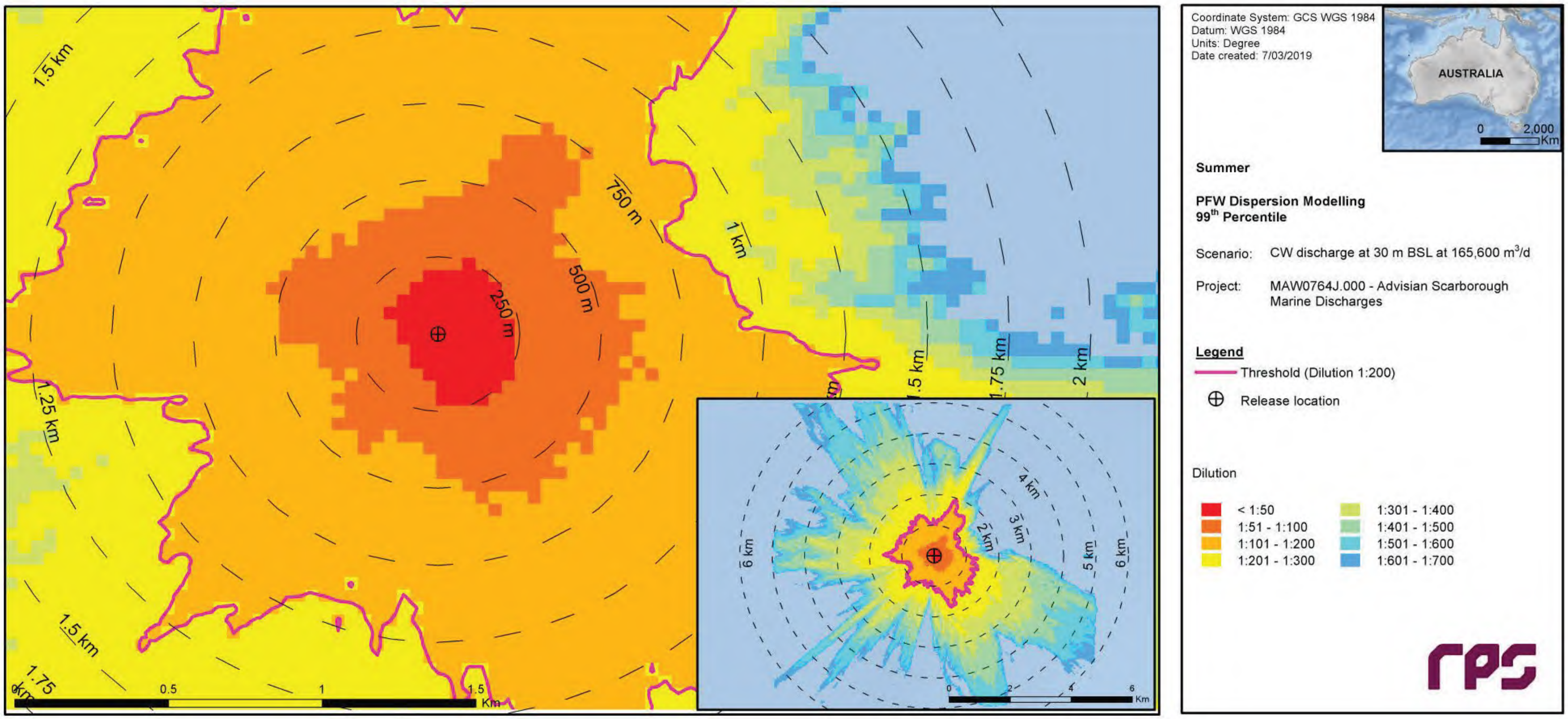

Figure 3.81 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C3 (30 m depth discharge at 165,600 m³/d flow rate).

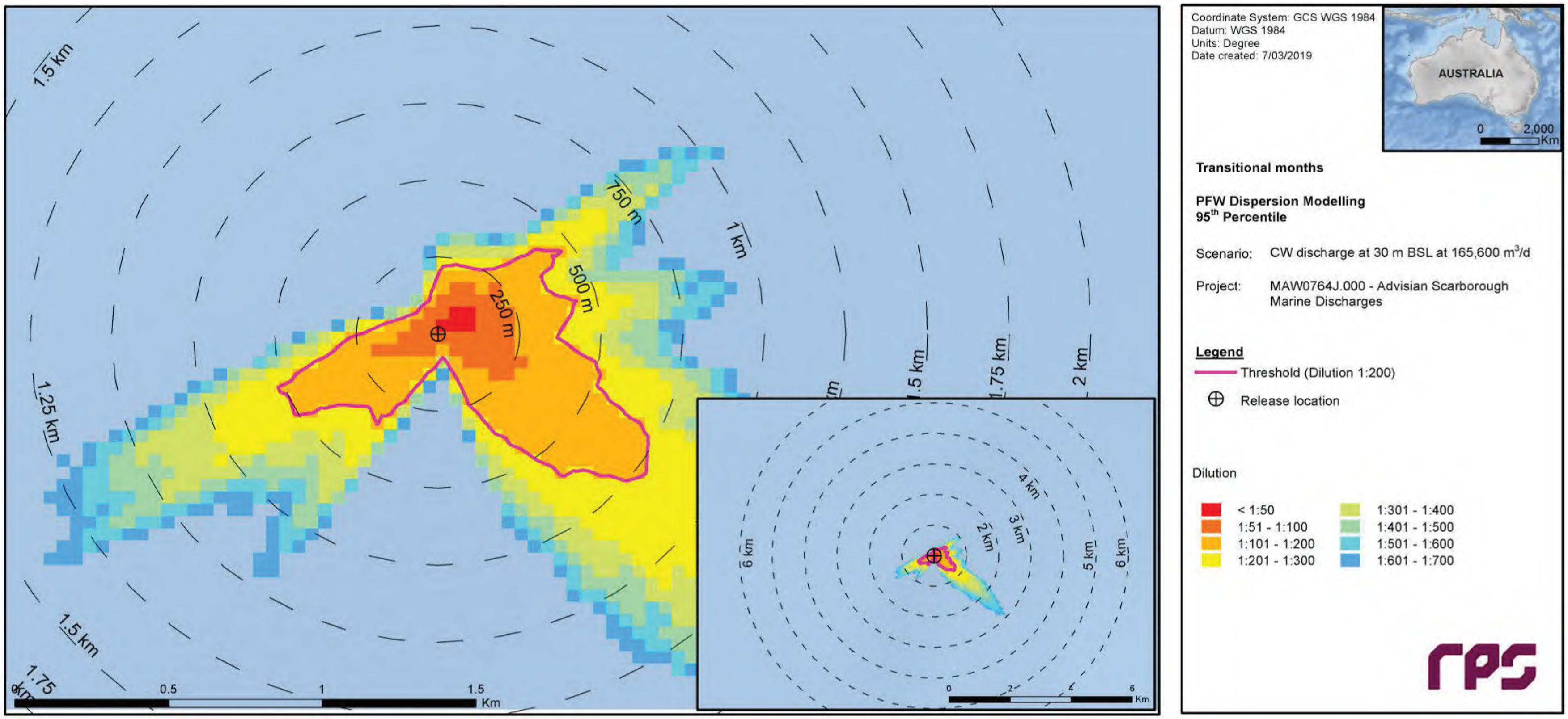

Figure 3.82 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

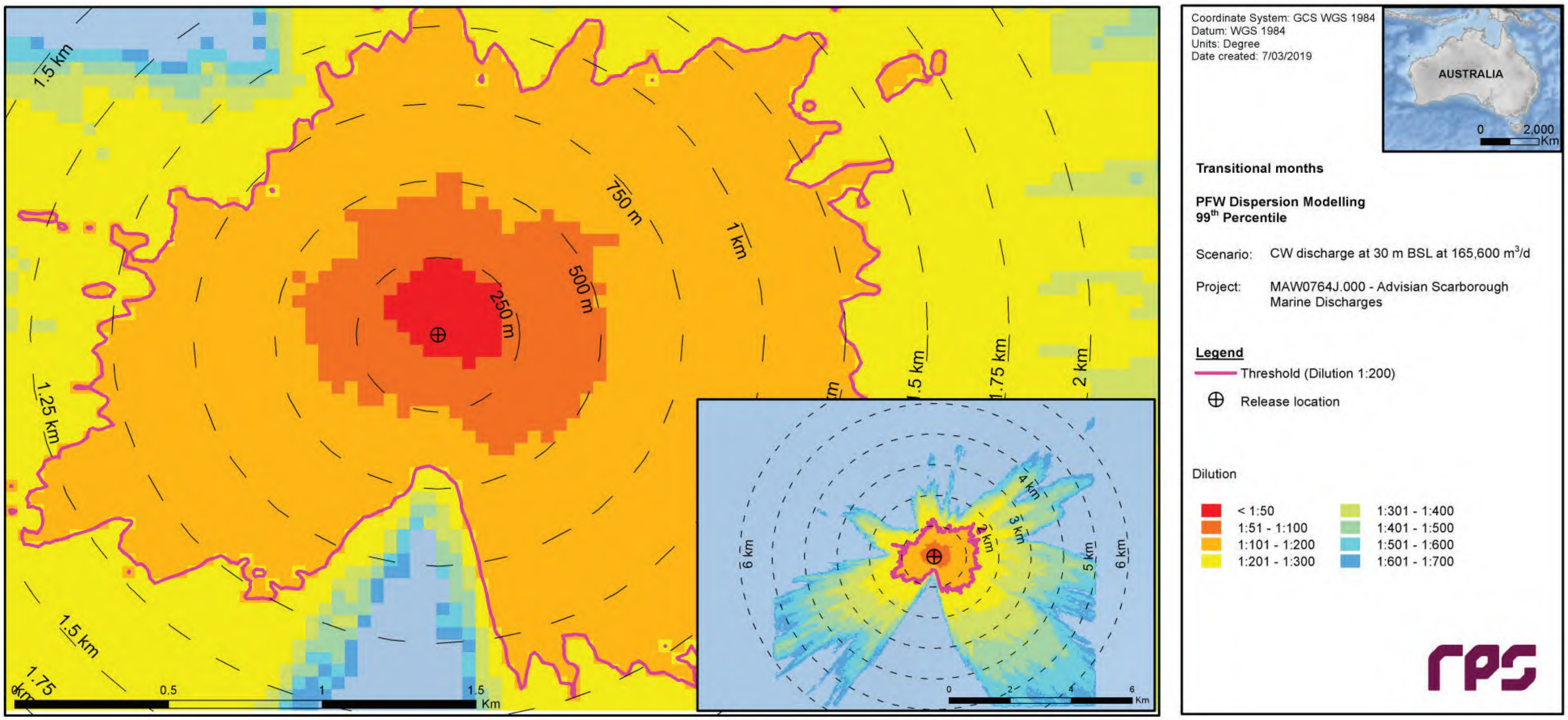

Figure 3.83 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

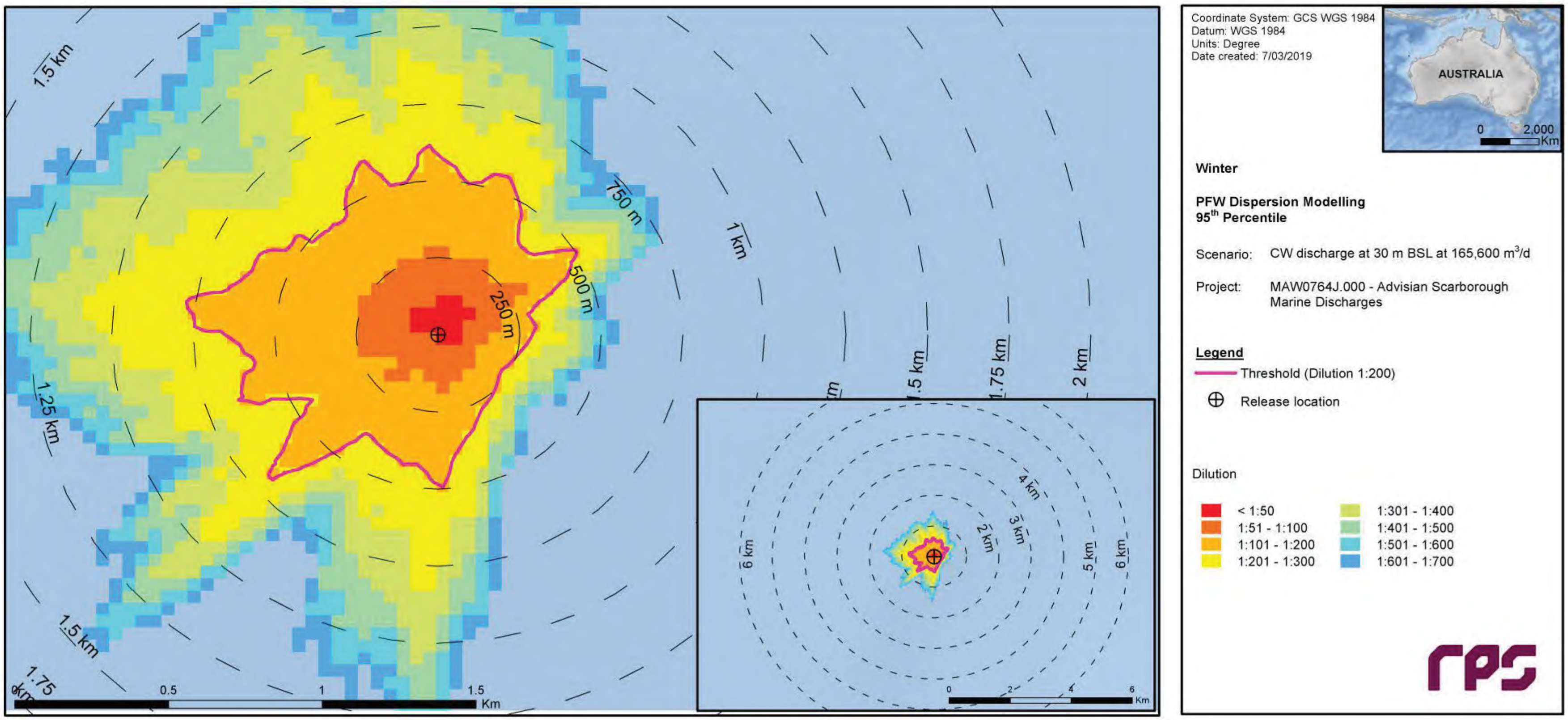

Figure 3.84 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

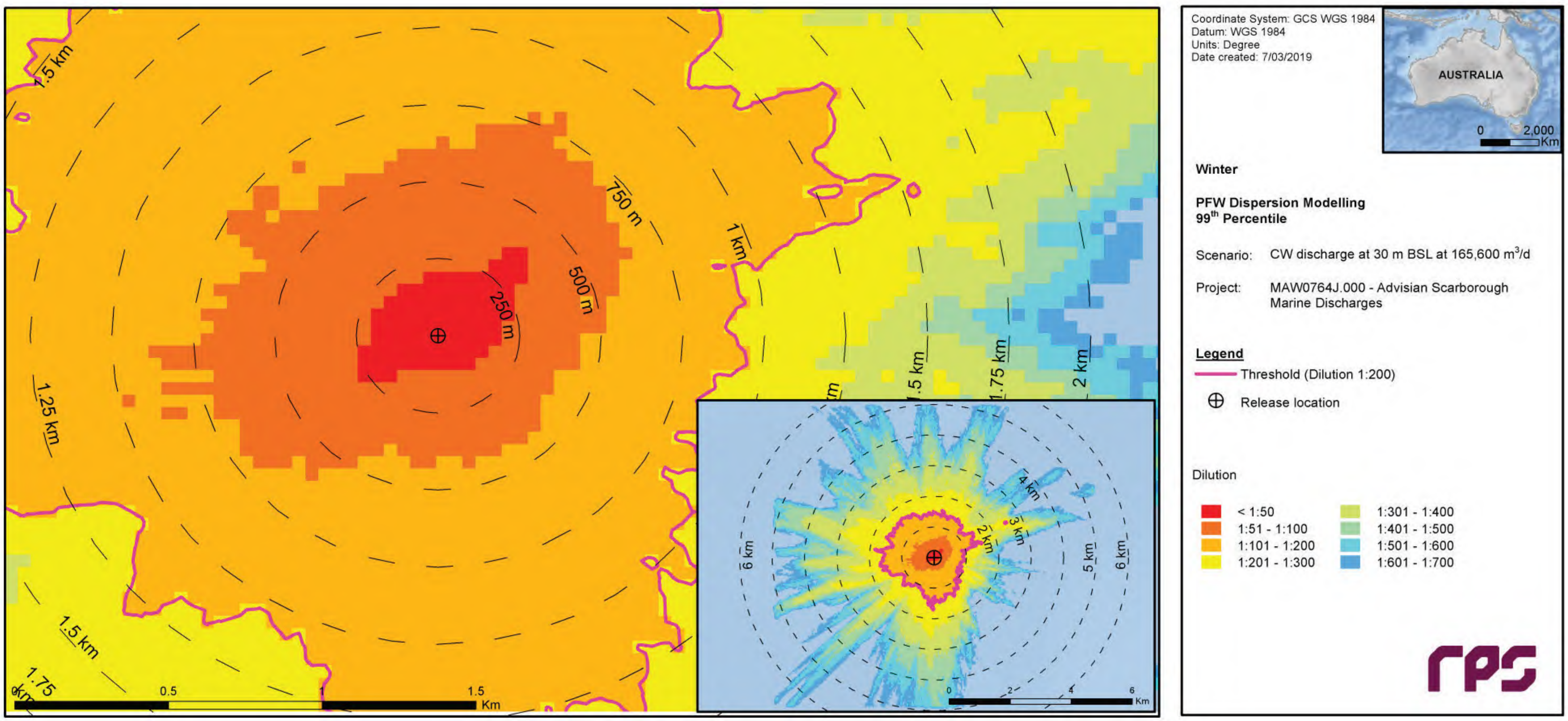

Figure 3.85 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

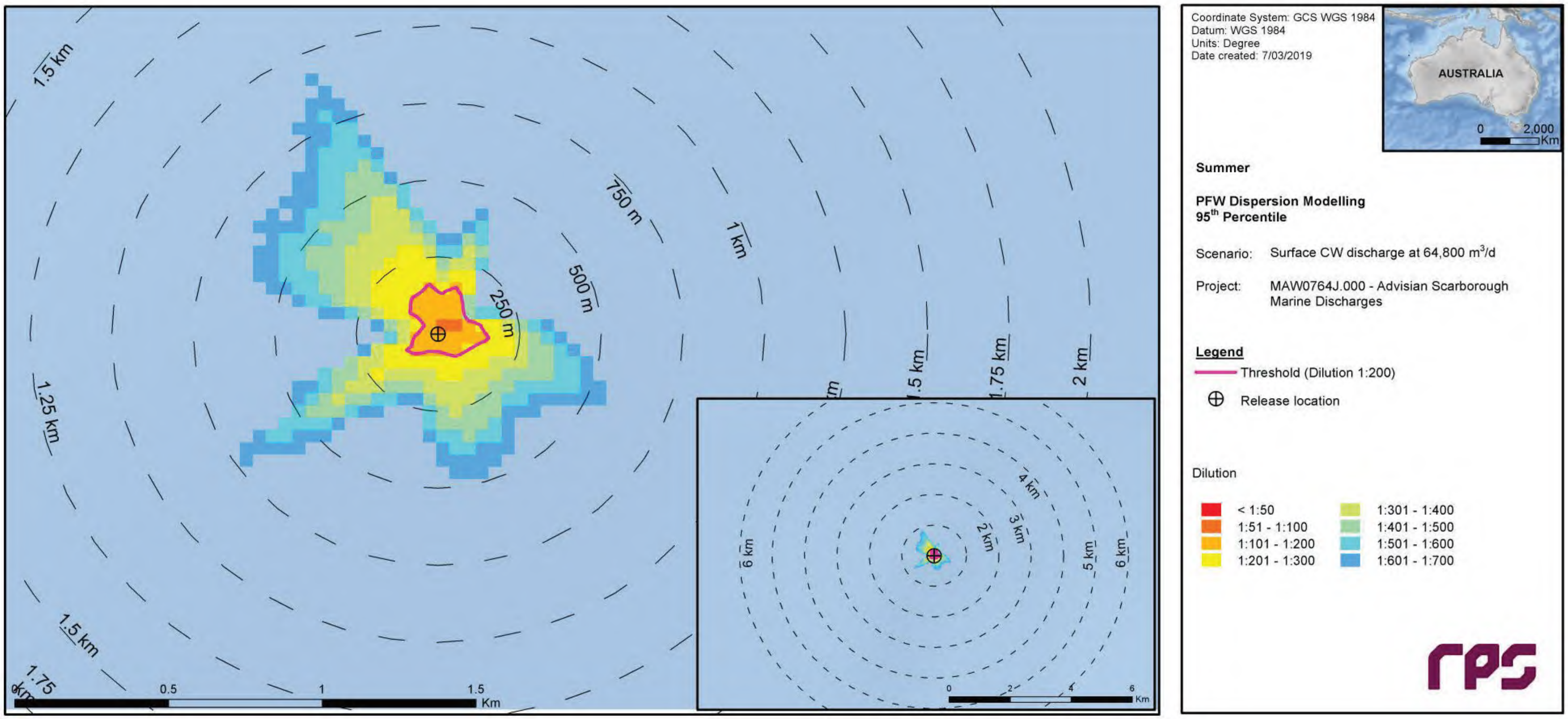

Figure 3.86 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C4 (0 m depth discharge at 64,800 m³/d flow rate).

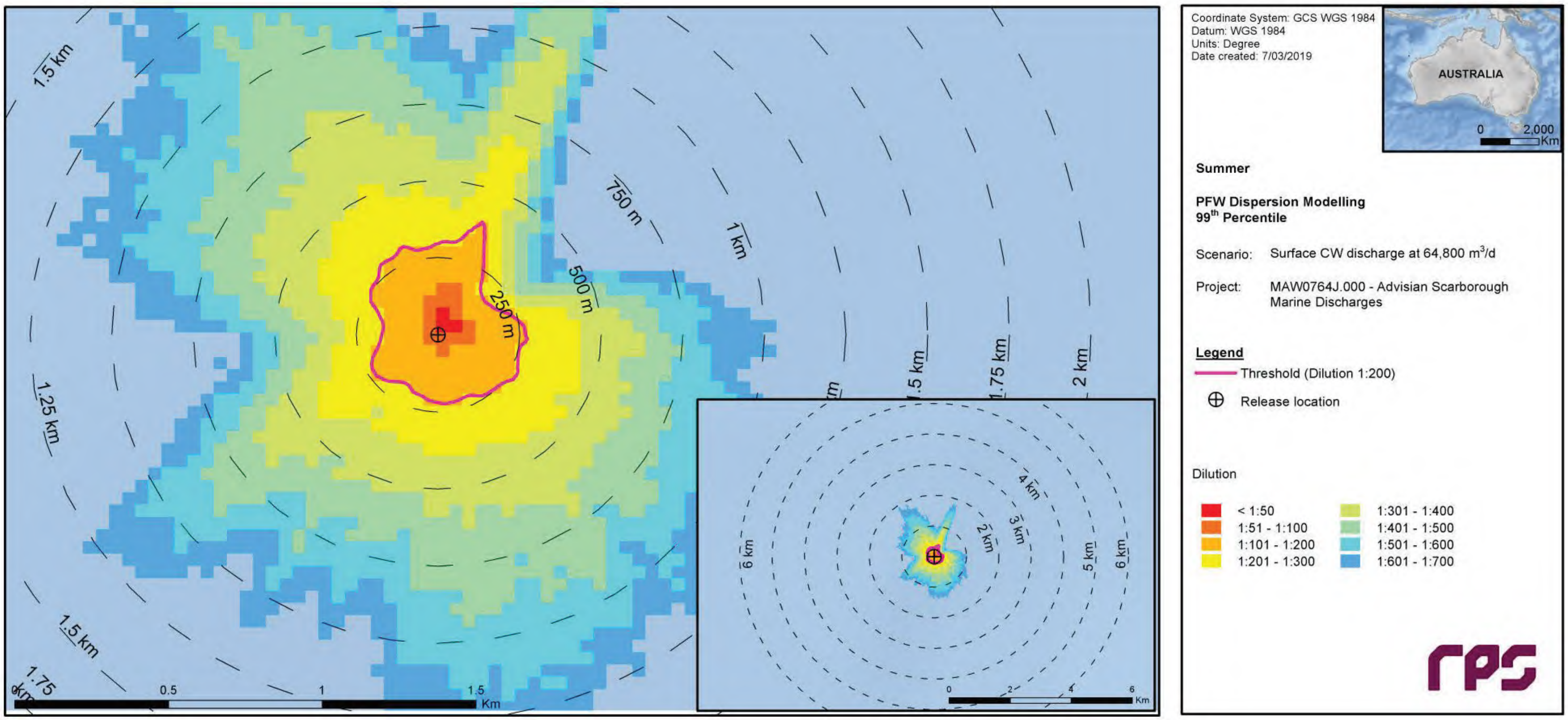

Figure 3.87 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

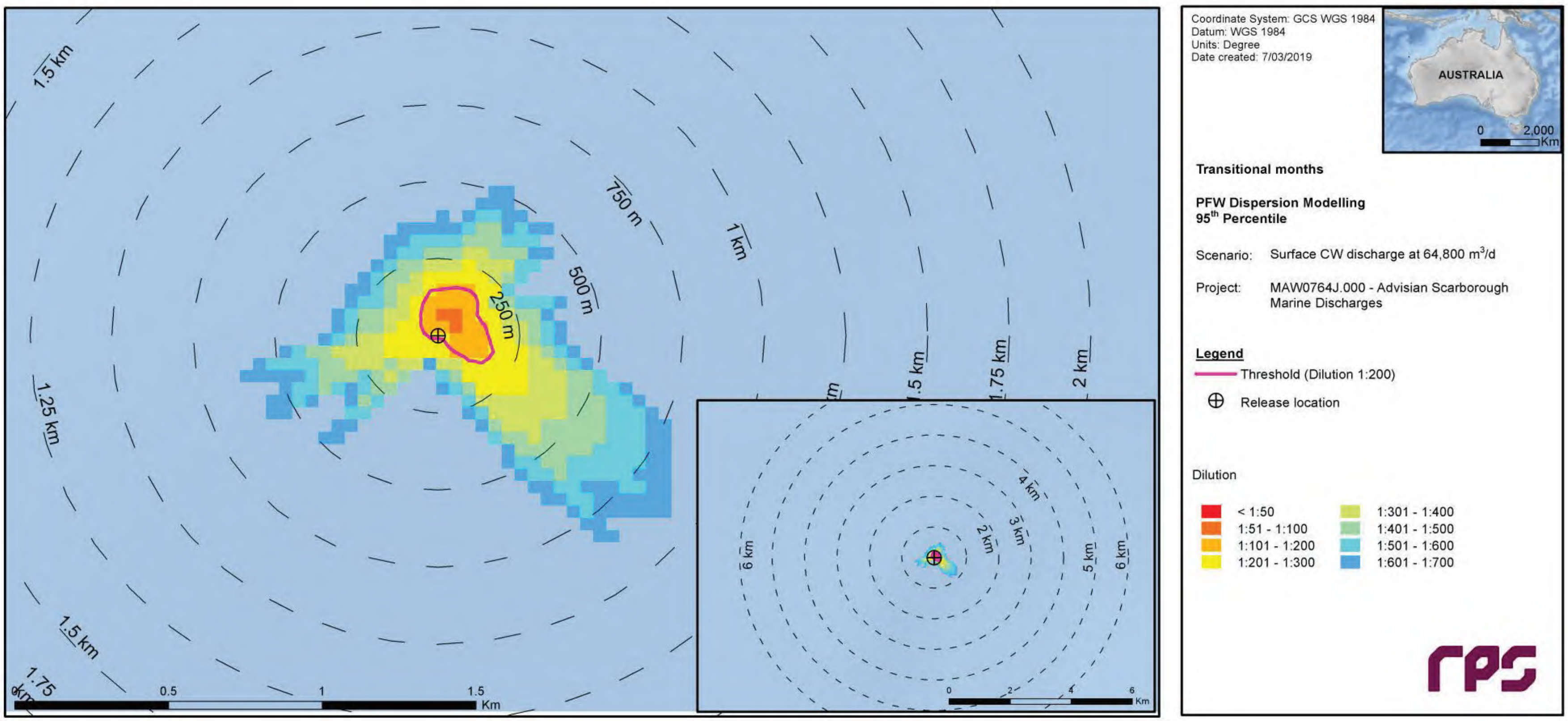

Figure 3.88 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

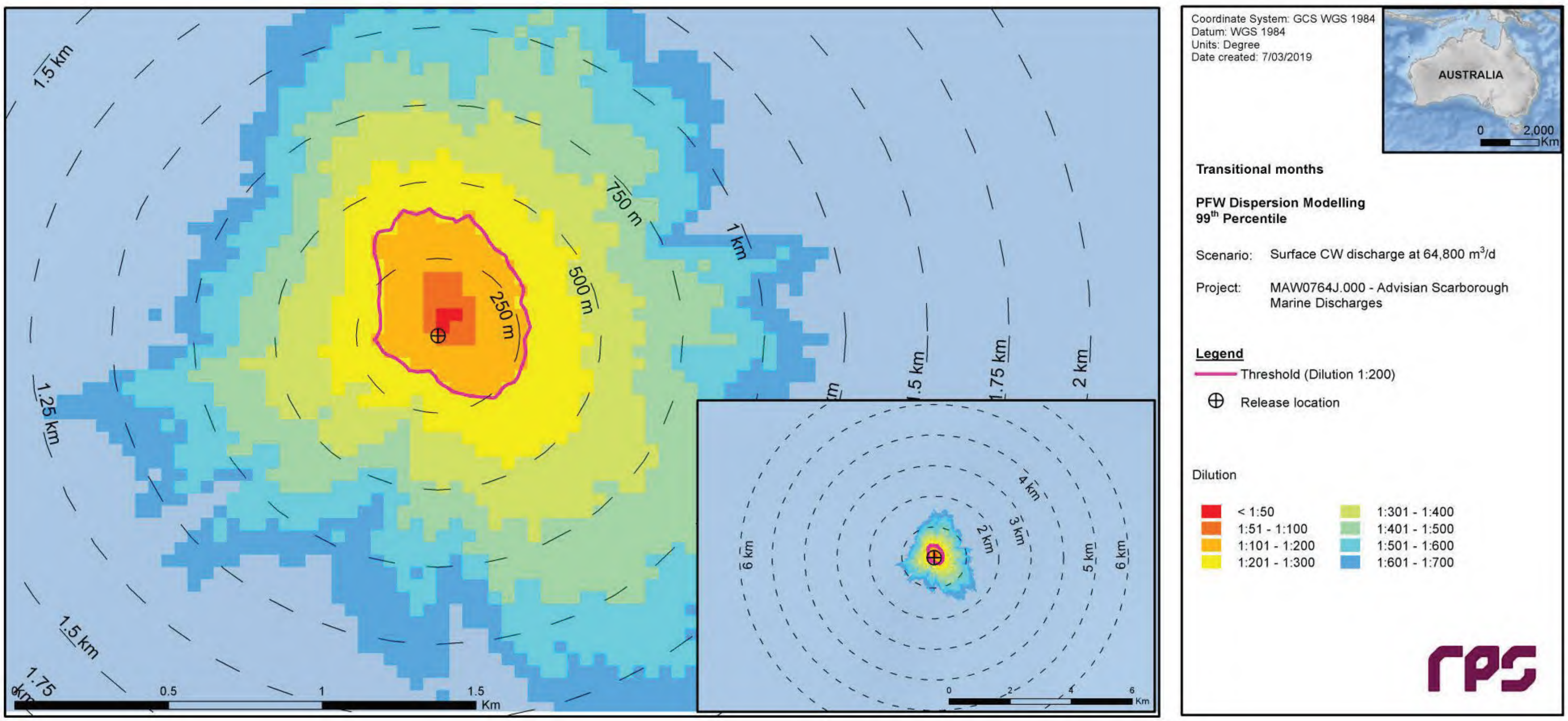

Figure 3.89 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

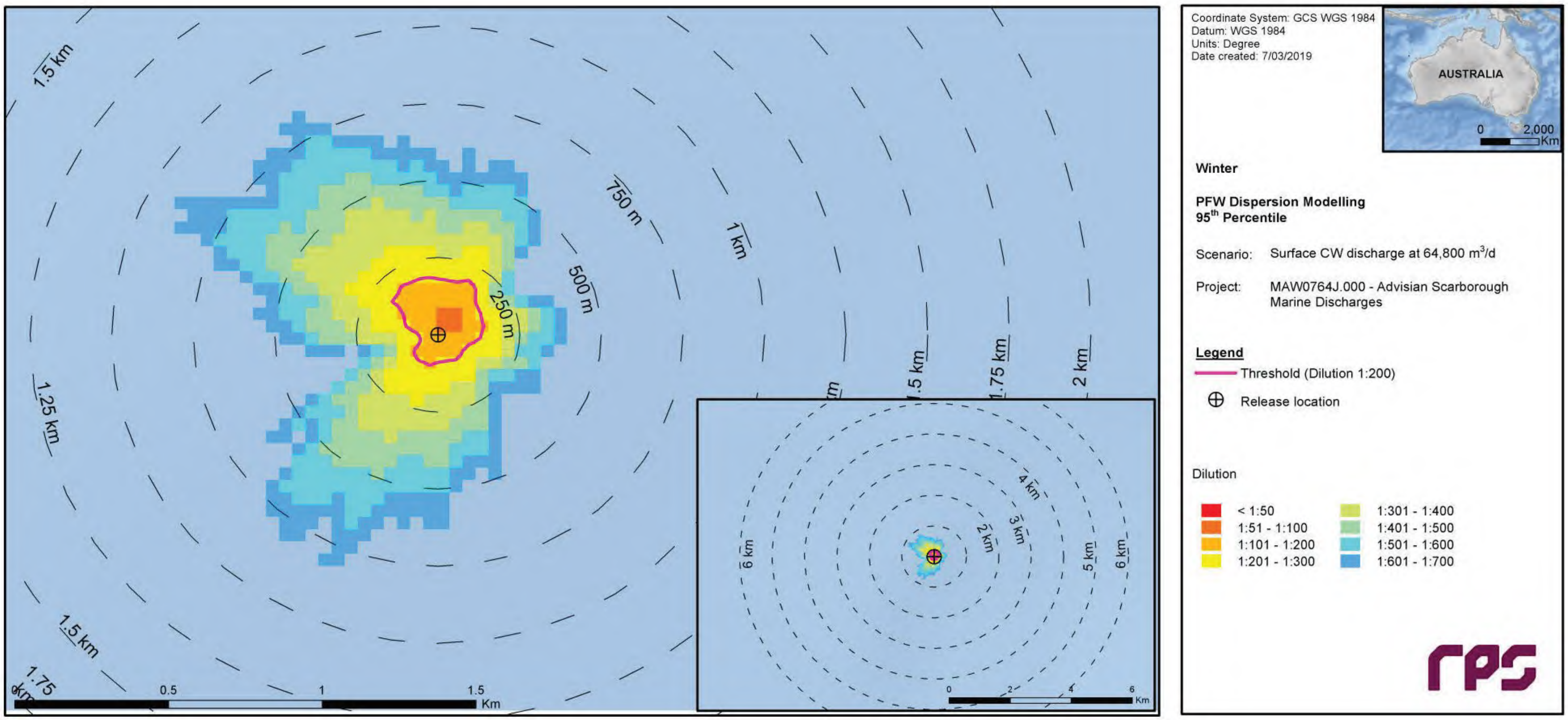

Figure 3.90 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

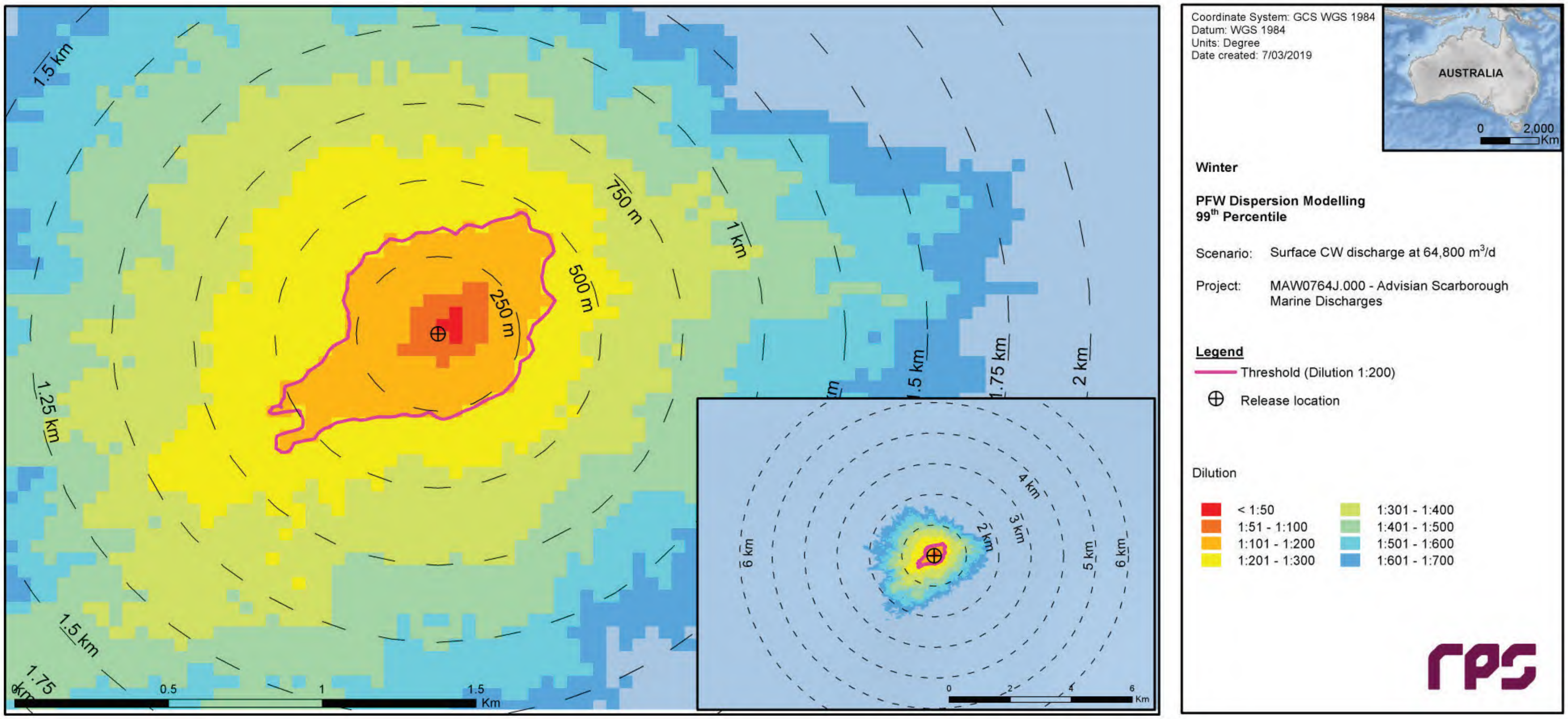

Figure 3.91 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

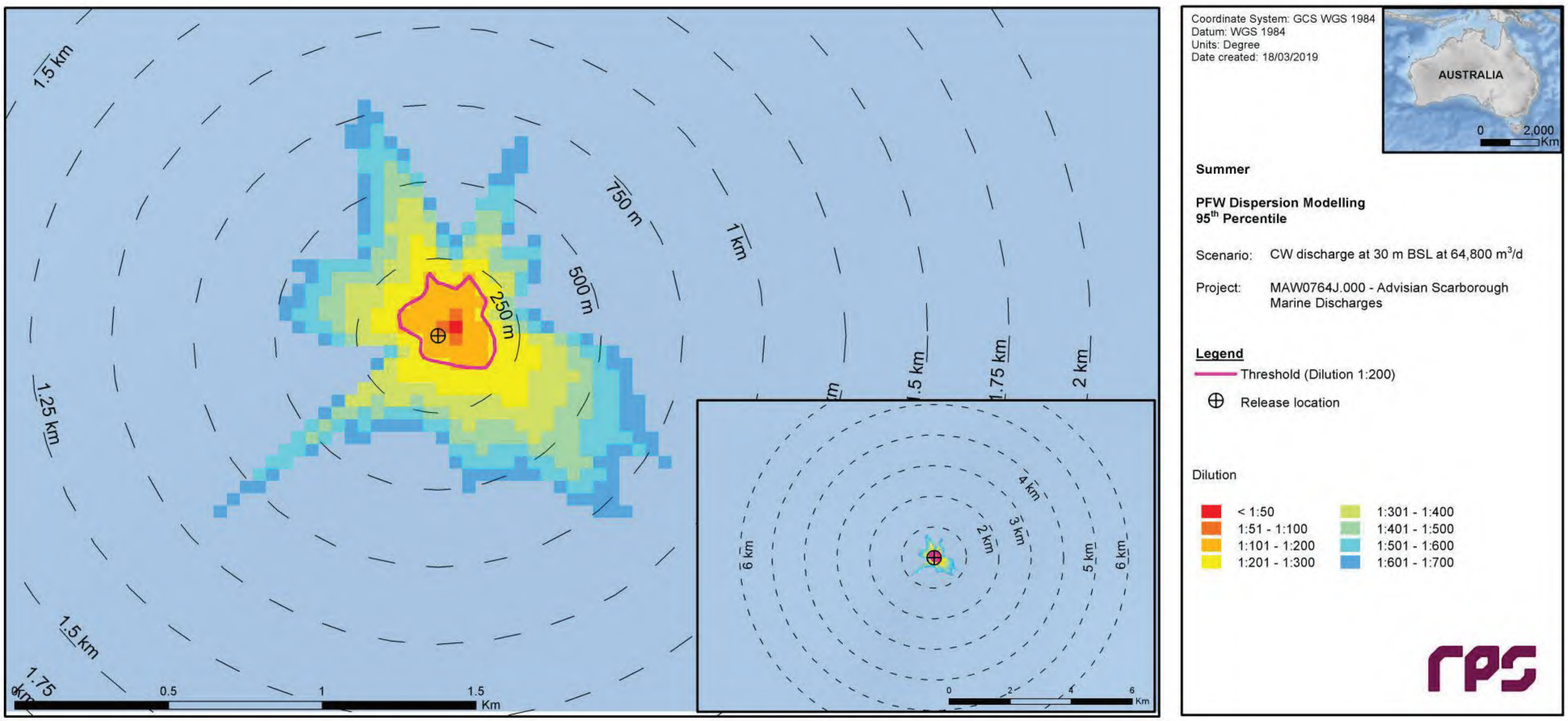

Figure 3.92 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

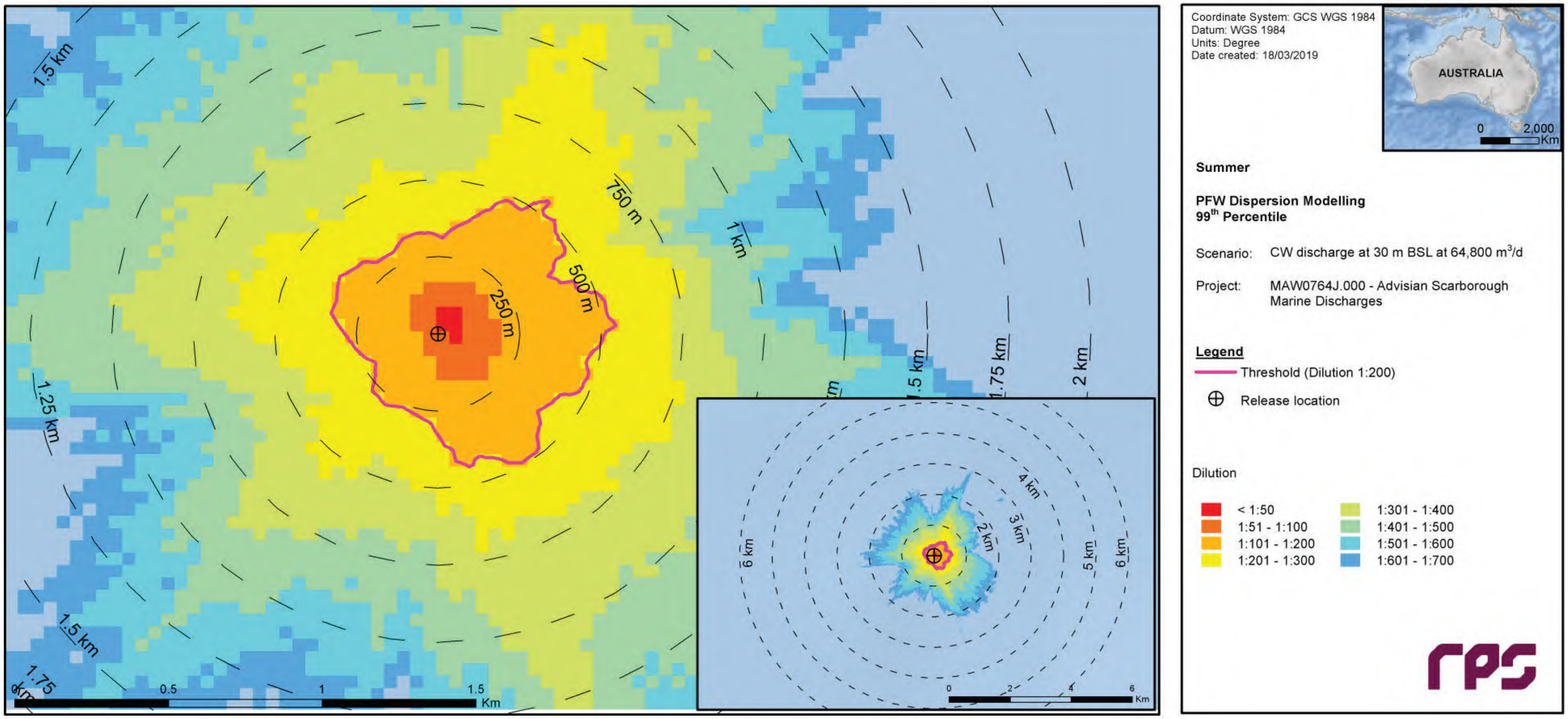

Figure 3.93 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

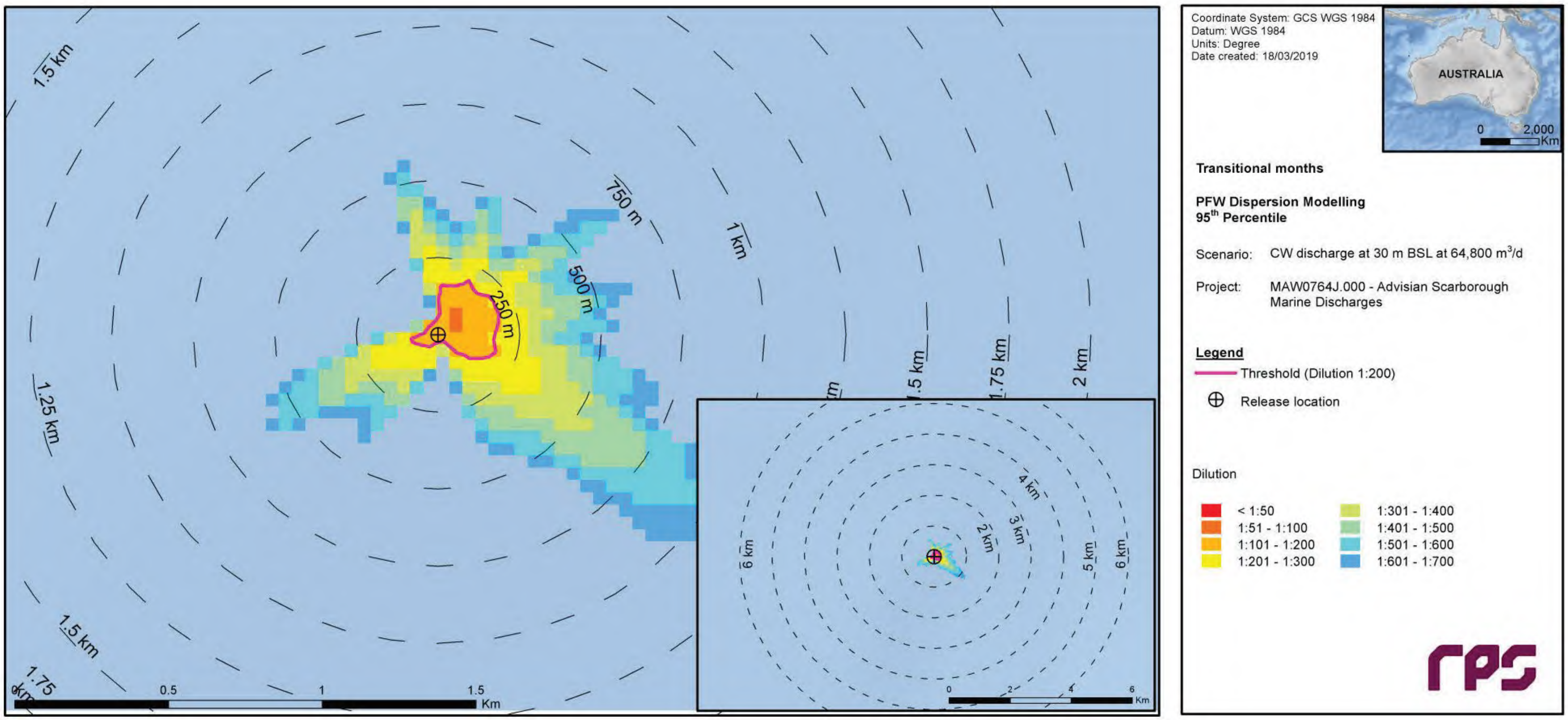

Figure 3.94 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

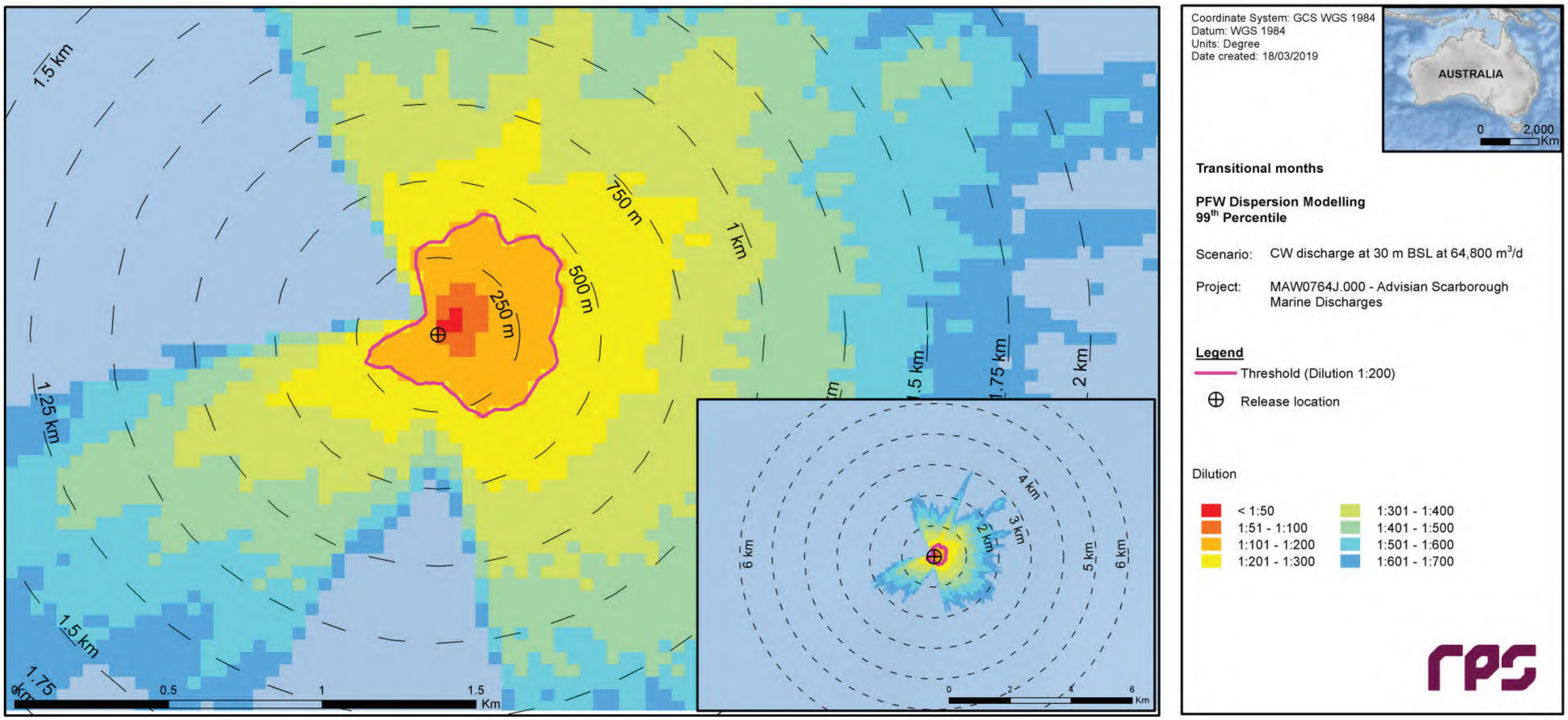

Figure 3.95 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

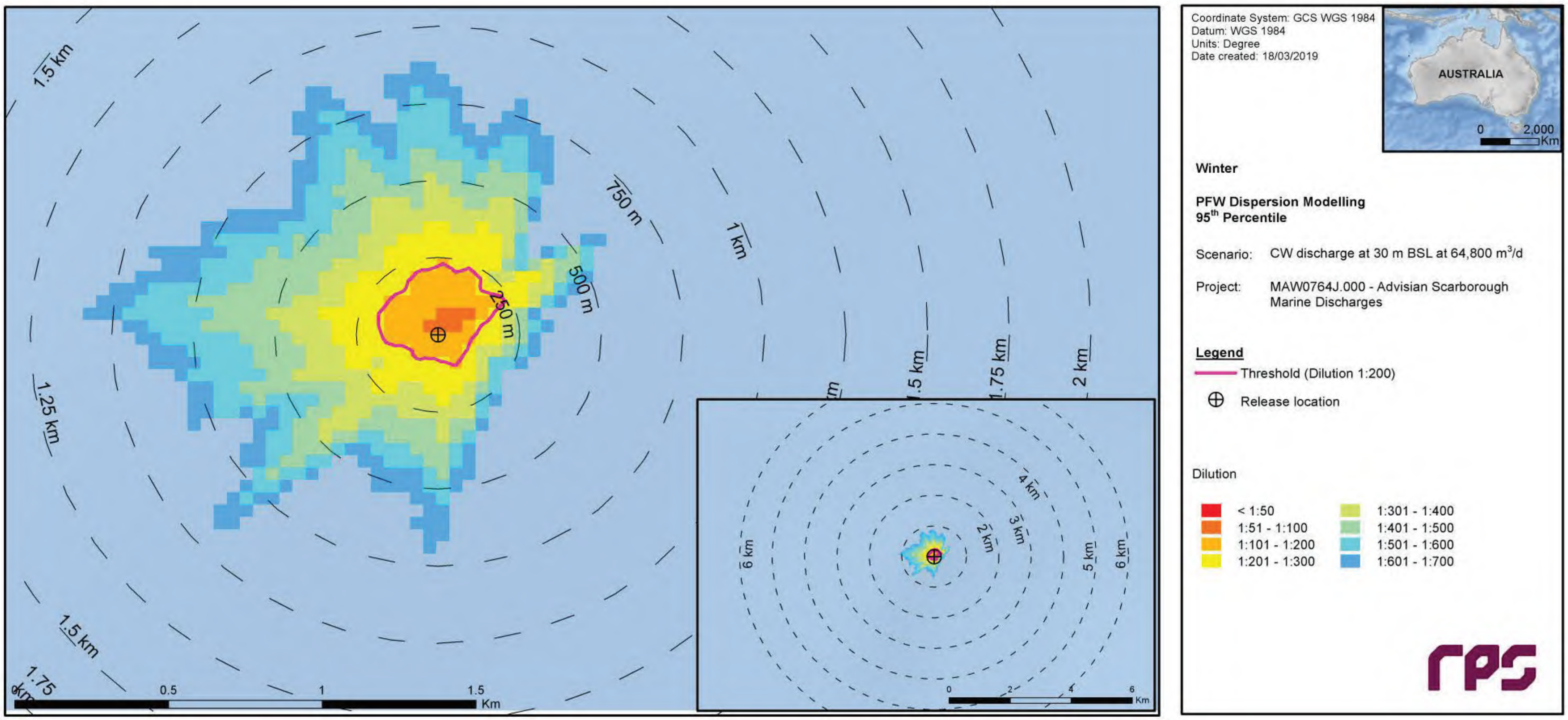

Figure 3.96 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

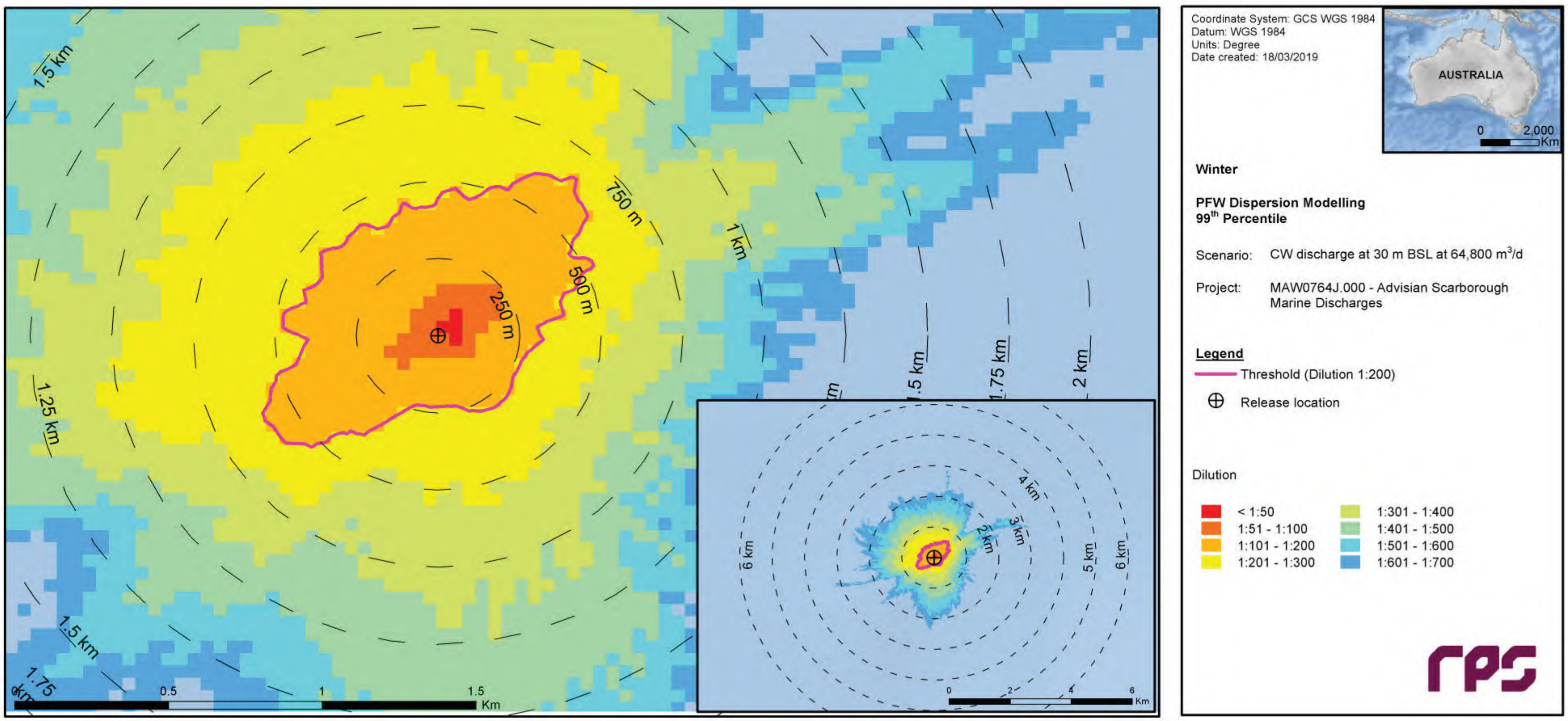

Figure 3.97 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

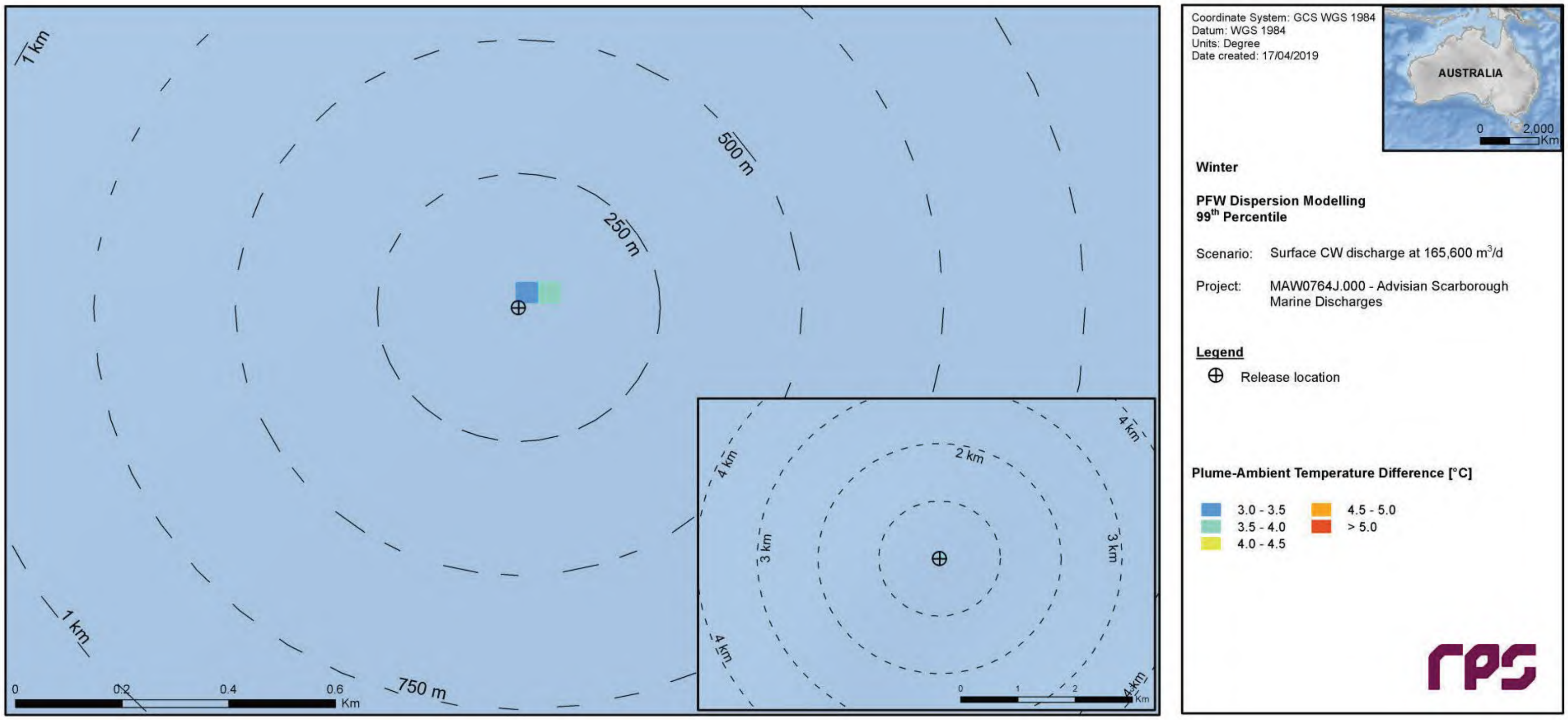

Figure 3.98 Predicted maximum plume-ambient ΔT at the 99th percentile under winter conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

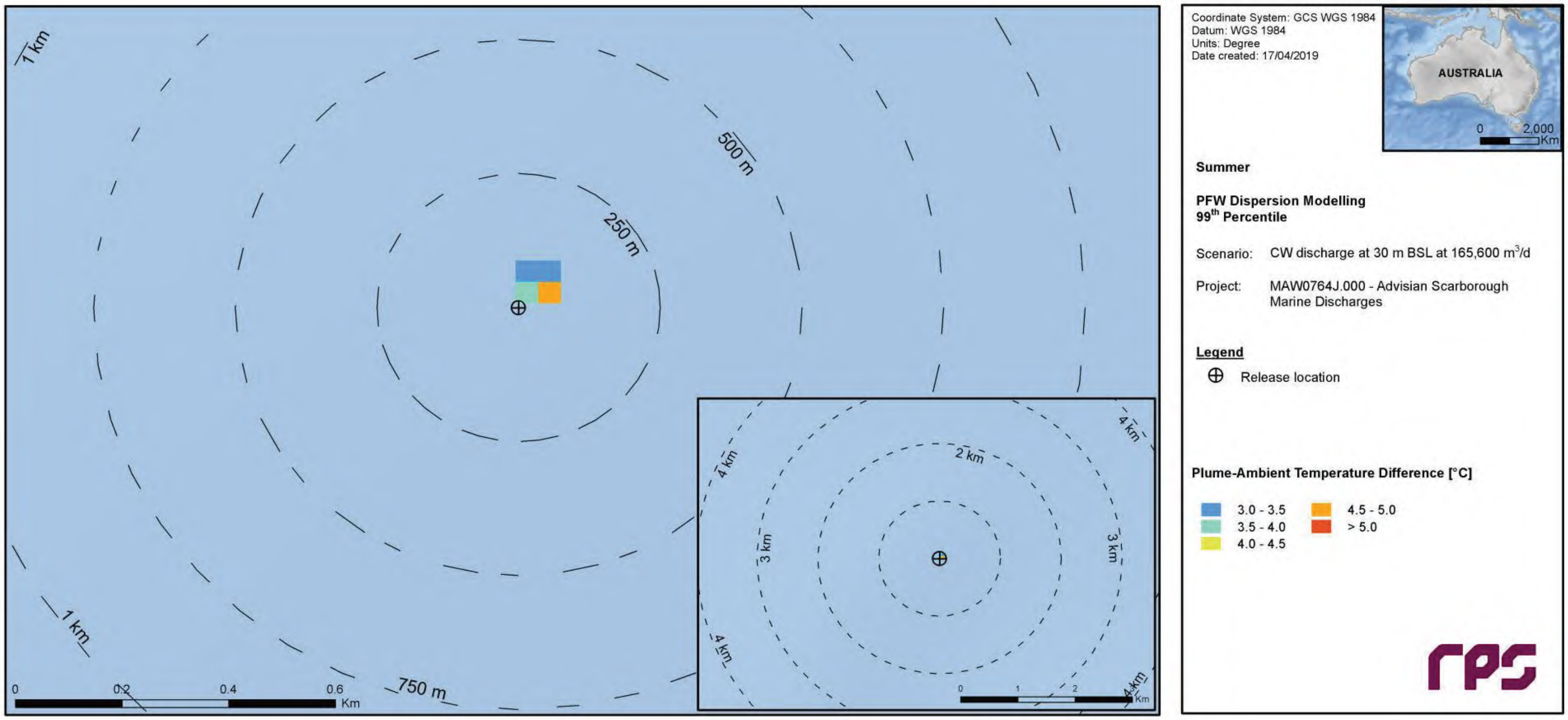

Figure 3.99 Predicted maximum plume-ambient ΔT at the 99th percentile under summer conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

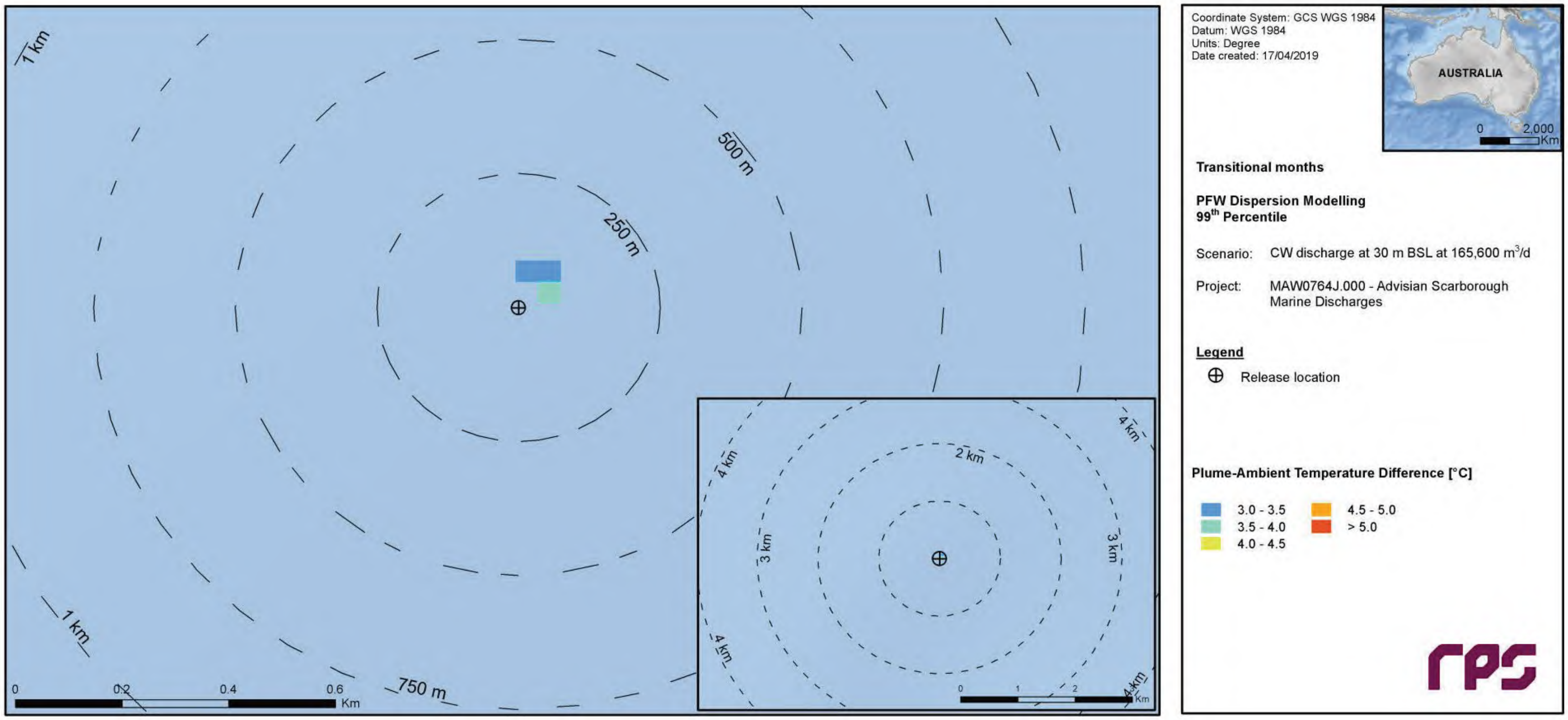

Figure 3.100 Predicted maximum plume-ambient ΔT at the 99th percentile under transitional conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

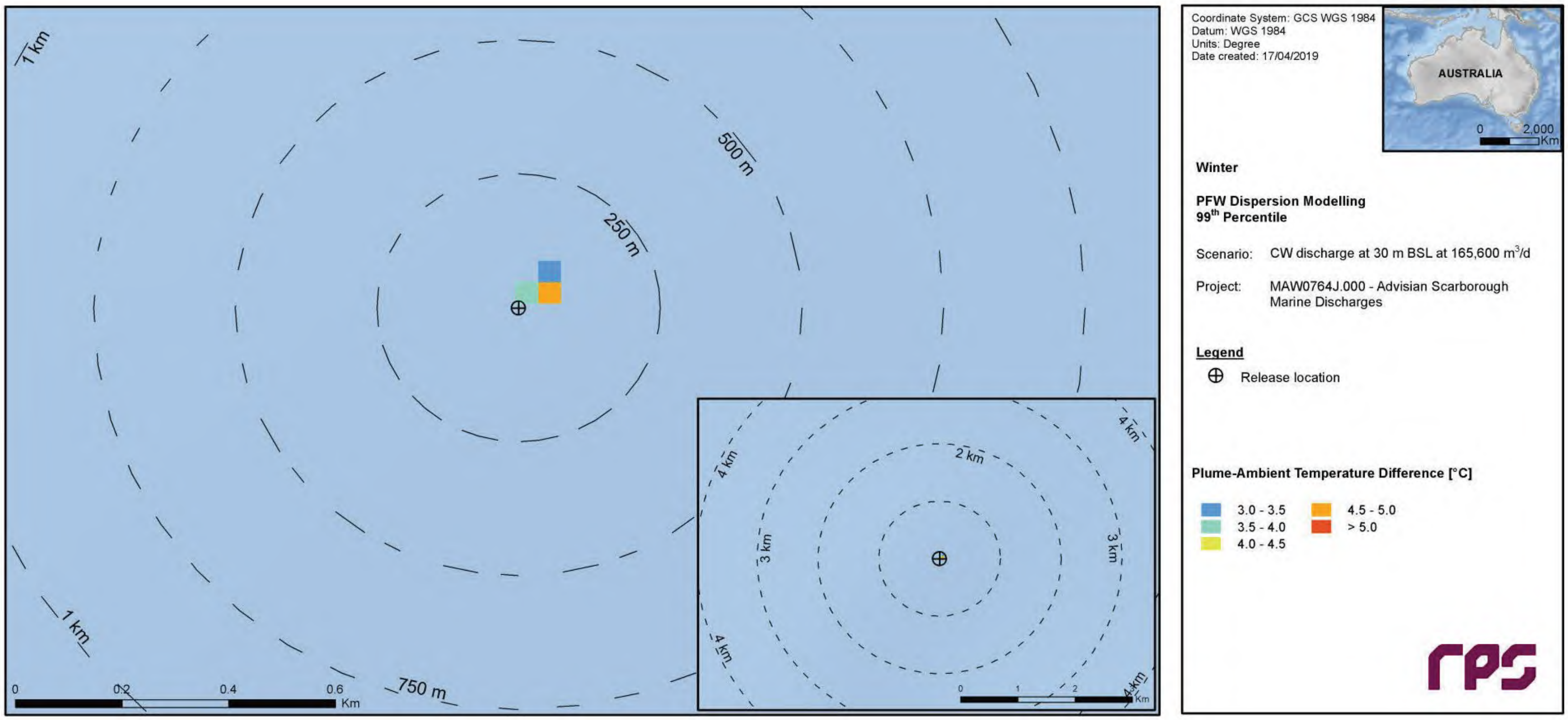

Figure 3.101 Predicted maximum plume-ambient ΔT at the 99th percentile under winter conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

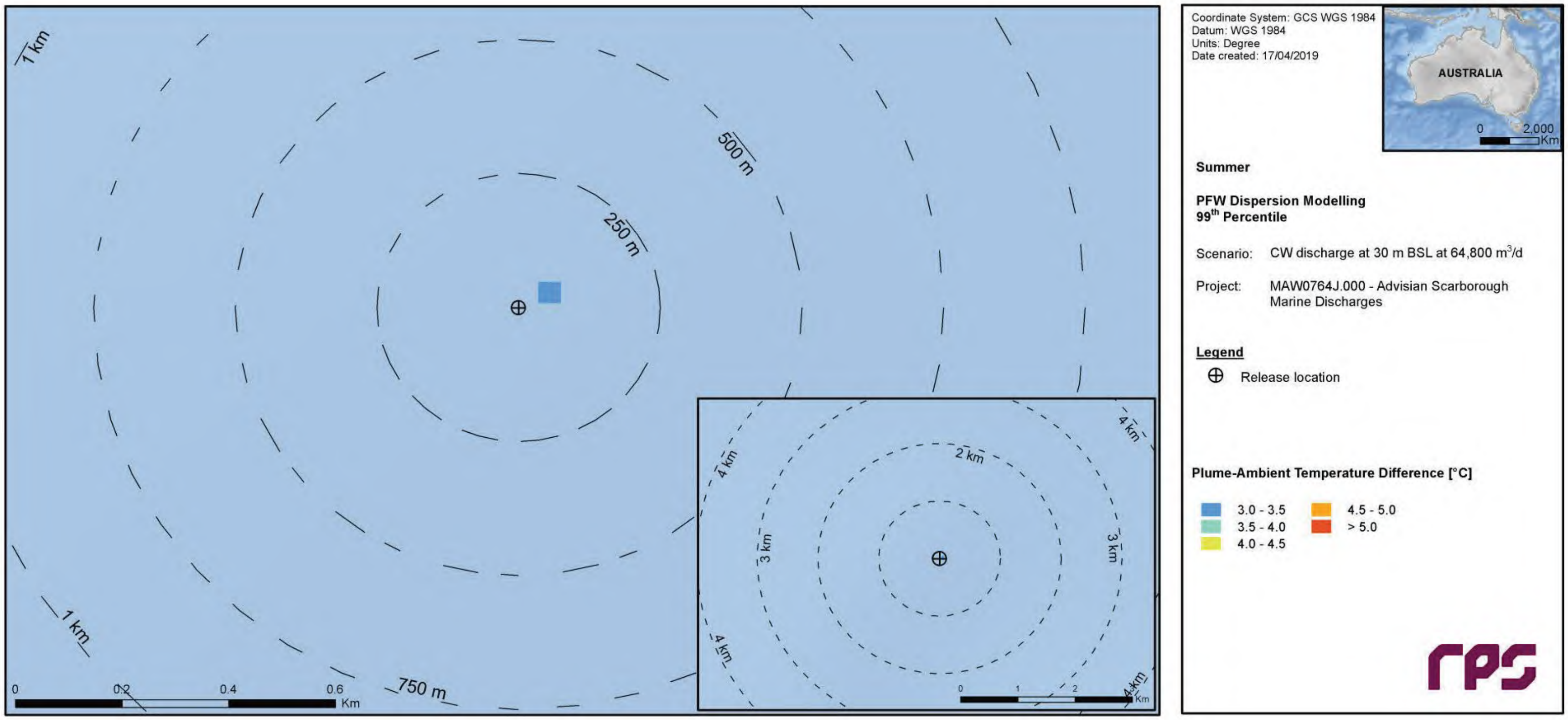

Figure 3.102 Predicted maximum plume-ambient ΔT at the 99th percentile under summer conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

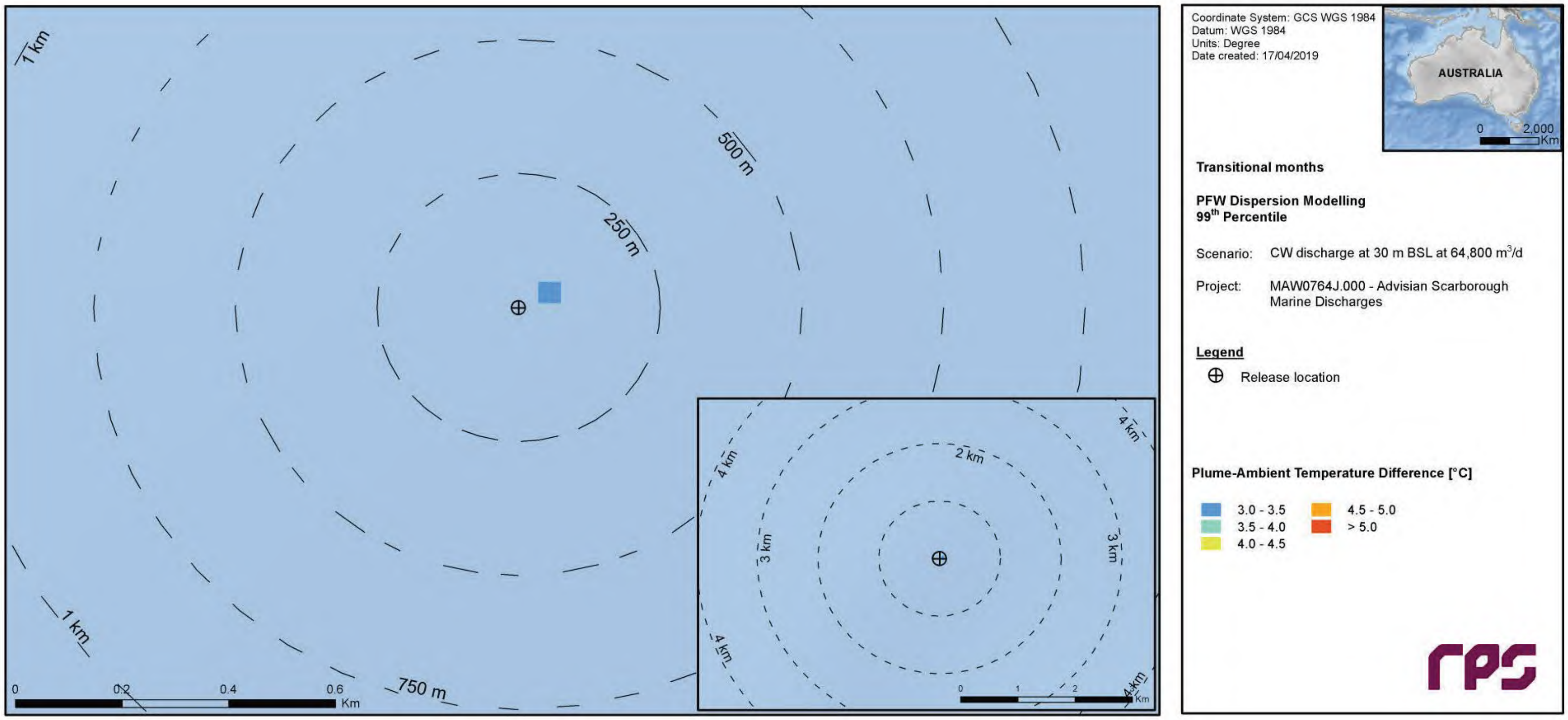

Figure 3.103 Predicted maximum plume-ambient ΔT at the 99th percentile under transitional conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

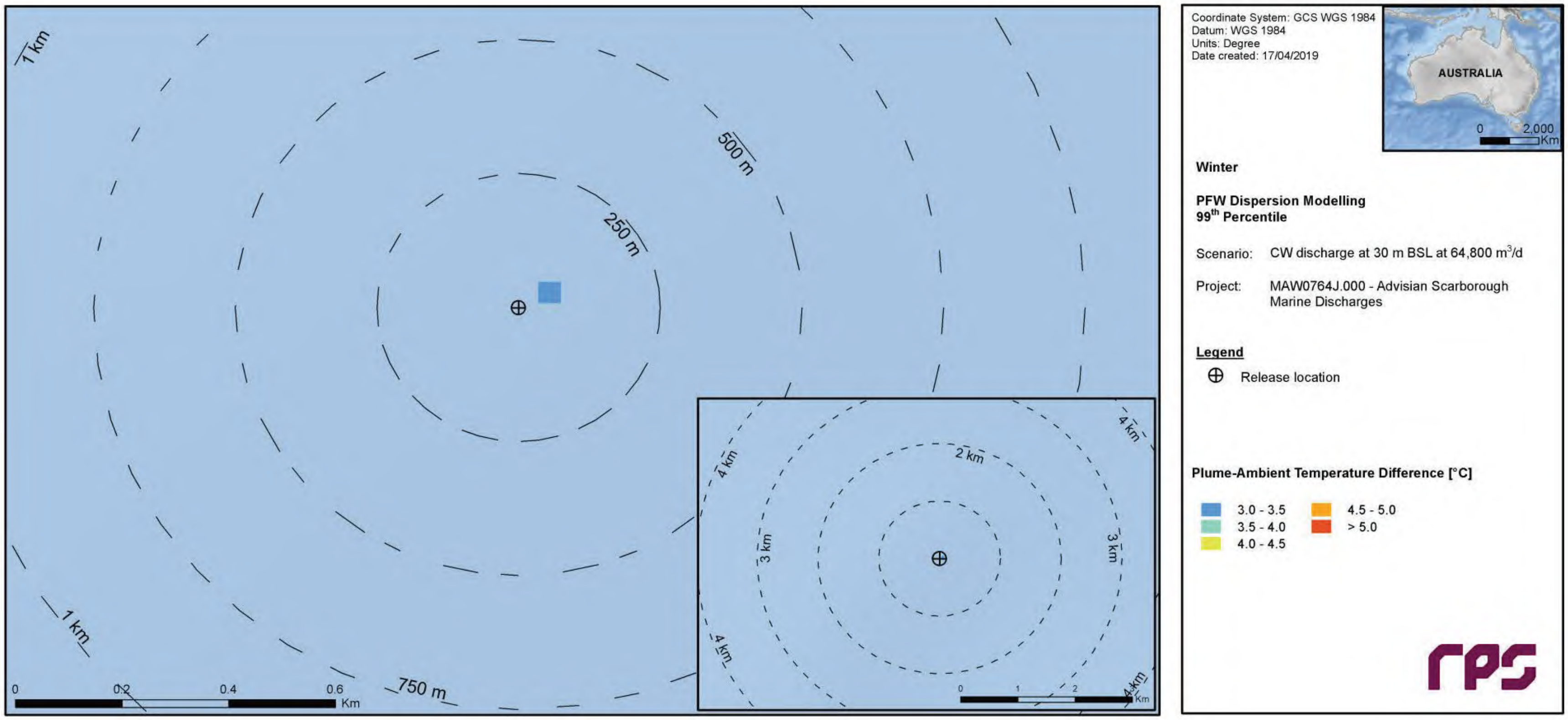

Figure 3.104 Predicted maximum plume-ambient ΔT at the 99th percentile under winter conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

3.2.5 Annualised Analysis

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2006-2015) were combined and analysed on an annualised basis.

Table 3.67 to Table 3.70 summarise the minimum dilution achieved at specific radial distances from the discharge location for each percentile over the annual period.

Table 3.71 to Table 3.74 provide summaries of the annualised maximum distances from the discharge location to achieve 1:200 dilution for each percentile. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion within the ambient environment. Dilution to reach threshold concentration is achieved for chlorine within a maximum area of influence of 1.79 km (Case C1), 2.47 km (Case C3), 0.62 km (Case C4) and 0.63 km (Case C6) at the 99th percentile, this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season.

Table 3.75 to Table 3.78 provide summaries of the total area of coverage for the 1:200 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach maximum values of 4.59 km^2 (Case C1), 6.56 km^2 (Case C3), 0.40 km^2 (Case C4) and 0.68 km^2 (Case C6) at the 99th percentile in any season.

Table 3.79 to Table 3.82 provide summaries of the annualised maximum distances from the discharge location to achieve a 3 °C plume-ambient temperature differential for each percentile. For all cases, the requirement is forecast to be met within 115 m at the 99th percentile. In many cases, the requirement is forecast to be met within the scale of the model grid resolution (40 m).

For Cases C1, C3, C4 and C6, Figure 3.105 to Figure 3.112 show the aggregated spatial extents of the minimum dilutions for each percentile. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

For the cases where the temperature requirement is not met within the scale of the model grid resolution, Figure 3.113 to Figure 3.115 show the aggregated spatial extents of the maximum plume-ambient temperature differential for each percentile.

Table 3.67 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:28.7	1:26.4	1:35.0	1:68.8	1:102.2	1:123.1	1:148.8	1:176.0	1:205.8	1:232.9	1:260.7	1:287.6	1:326.9	1:344.4	1:388.6	1:418.2	1:437.6	1:469.2	1:512.8	1:548.7	1:580.9	1:609.5
99th		1:14.3	1:11.6	1:17.0	1:31.6	1:49.5	1:61.0	1:71.1	1:74.3	1:81.7	1:94.8	1:98.4	1:106.3	1:126.6	1:136.2	1:147.0	1:149.1	1:161.2	1:165.4	1:244.1	1:176.6	1:212.8	1:237.8

Table 3.68 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:24.5	1:18.0	1:29.7	1:58.9	1:82.6	1:120.0	1:136.7	1:156.3	1:174.6	1:196.3	1:208.5	1:231.7	1:244.4	1:260.0	1:283.8	1:292.9	1:316.9	1:330.2	1:337.8	1:363.3	1:394.3	1:408.2
99th		1:9.7	1:9.6	1:15.1	1:28.8	1:41.0	1:49.8	1:56.7	1:69.3	1:69.3	1:94.1	1:93.2	1:98.8	1:112.1	1:124.3	1:124.3	1:141.4	1:154.8	1:165.5	1:174.5	1:181.6	1:195.5	1:206.0

Table 3.69 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:67.4	1:73.3	1:89.5	1:175.7	1:261.2	1:314.6	1:380.3	1:449.9	1:526.1	1:595.2	1:666.1	1:735.0	1:775.7	1:880.1	1:993.1	1:1,068.6	1:1,118.4	1:1,199.0	1:1,310.6	1:1,402.1	1:1,484.6	1:1,577.6
99th		1:29.6	1:36.5	1:43.2	1:80.8	1:126.6	1:156.0	1:181.7	1:189.8	1:208.7	1:242.3	1:251.6	1:271.7	1:313.4	1:348.0	1:375.7	1:381.1	1:411.8	1:422.6	1:436.4	1:451.4	1:543.8	1:607.8

Table 3.70 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:44.7	1:62.7	1:76.5	1:151.7	1:208.6	1:281.5	1:350.9	1:407.4	1:446.2	1:507.0	1:532.9	1:595.5	1:630.0	1:680.7	1:741.7	1:772.3	1:856.5	1:856.6	1:8,92.2	1:1,001.1	1:1,064.3	1:1,056.5
99th		1:24.4	1:33.2	1:37.9	1:73.6	1:104.9	1:130.7	1:141.9	1:181.2	1:195.2	1:240.5	1:238.2	1:252.7	1:302.7	1:317.6	1:329.9	1:361.4	1:395.6	1:423.0	1:445.9	1:445.5	1:499.6	1:526.4

Table 3.71 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	639
99th		1,789
100th		4,705

Table 3.72 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	771
99th		2,470
100th		6,391

Table 3.73 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	182
99th		621
100th		2,272

Table 3.74 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	212
99th		631
100th		3,566

Table 3.75 Annualised total area of coverage for 1:200 dilution for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.680
99th		4.591
100th		22.347

Table 3.76 Annualised total area of coverage for 1:200 dilution for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.897
99th		6.557
100th		45.284

Table 3.77 Annualised total area of coverage for 1:200 dilution for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.059
99th		0.397
100th		3.556

Table 3.78 Annualised total area of coverage for 1:200 dilution for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.090
99th		0.680
100th		7.597

Table 3.79 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		90
100th		285

Table 3.80 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		115
100th		380

Table 3.81 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		<40
100th		145

Table 3.82 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		90
100th		175

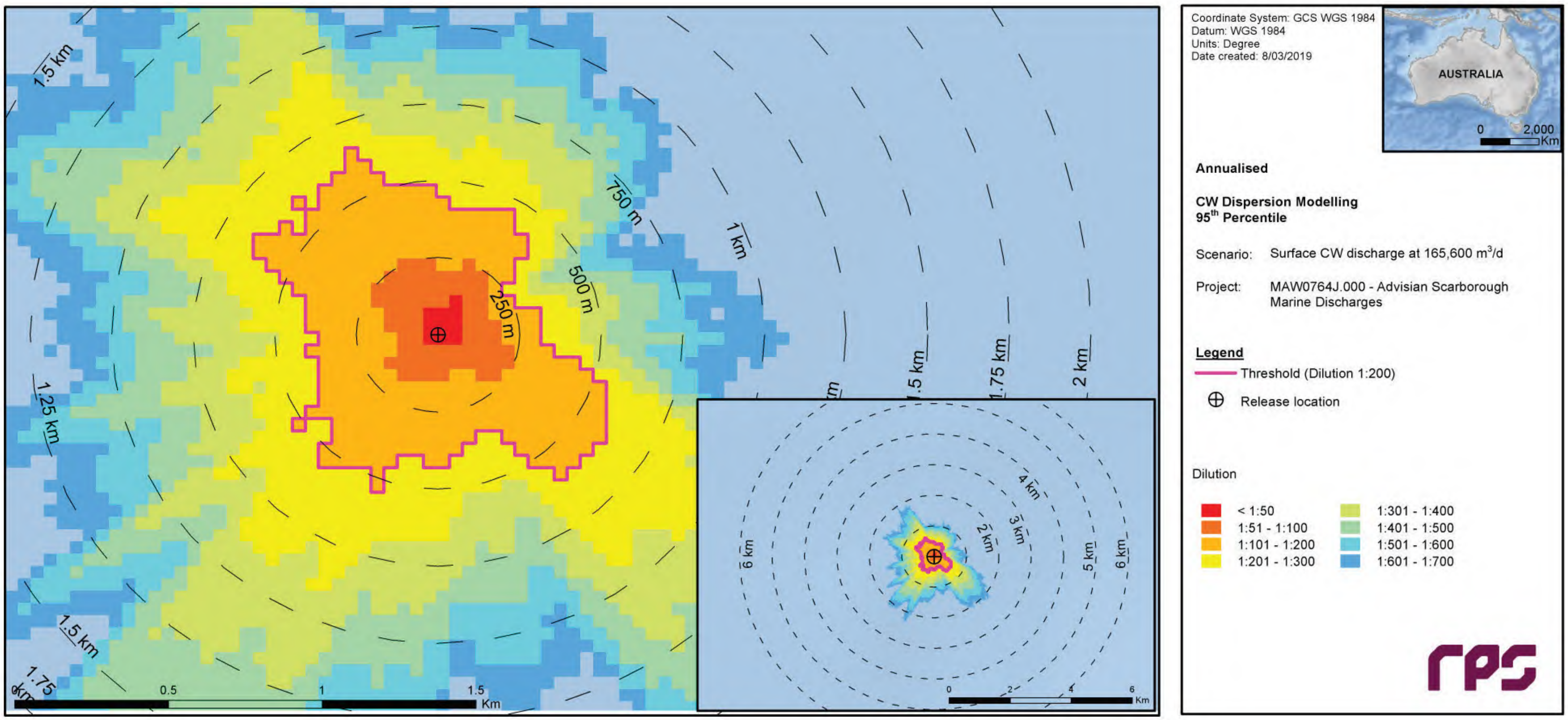

Figure 3.105 Predicted annualised minimum dilutions at the 95th percentile for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

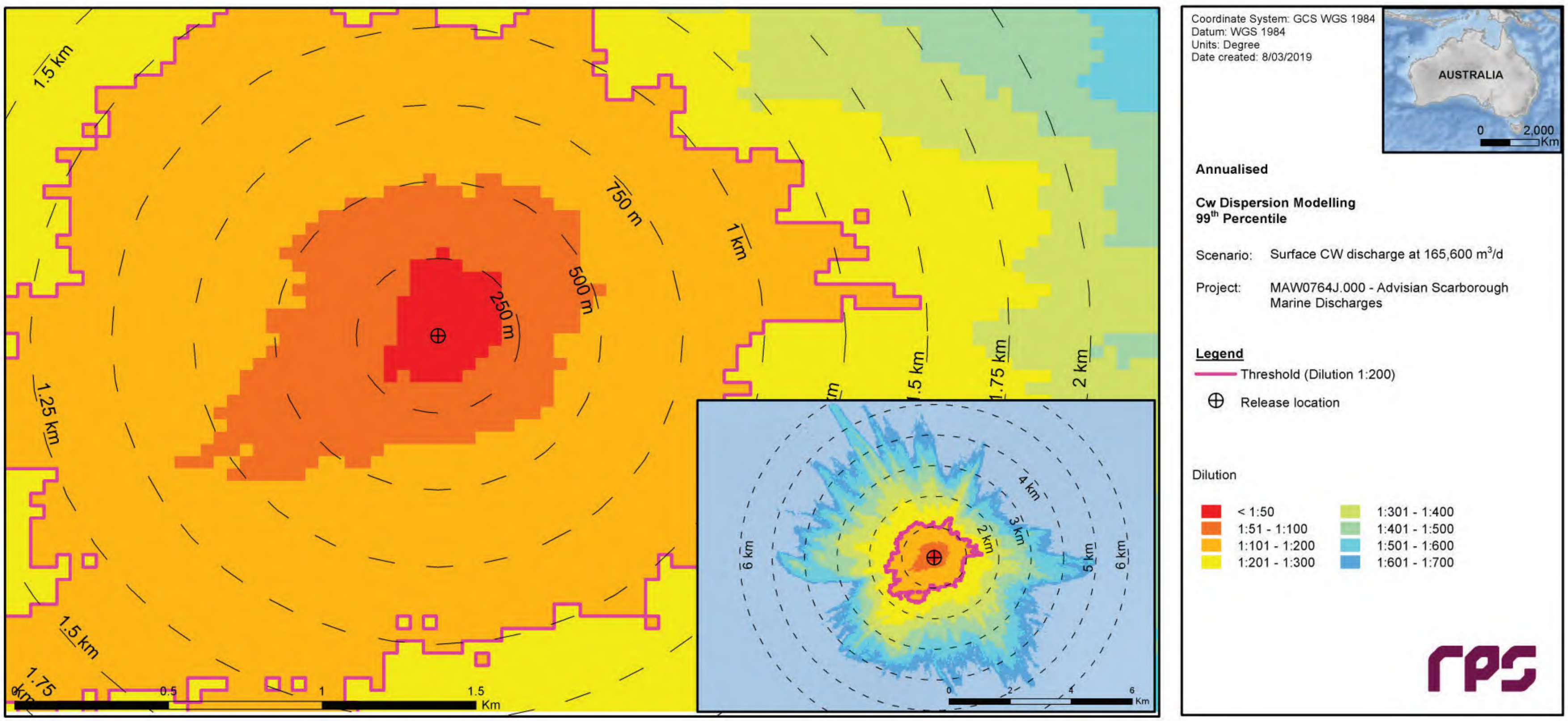

Figure 3.106 Predicted annualised minimum dilutions at the 99th percentile for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

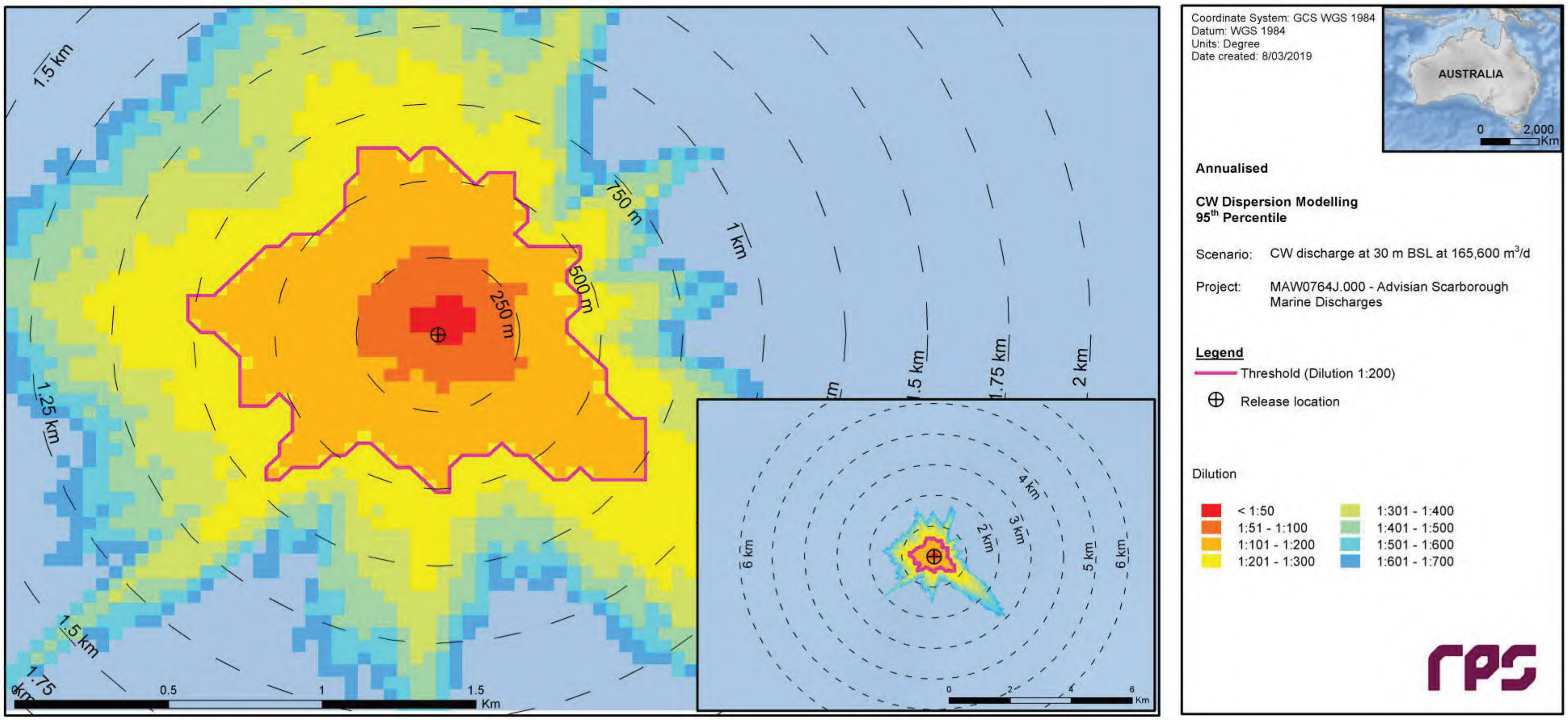

Figure 3.107 Predicted annualised minimum dilutions at the 95th percentile for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

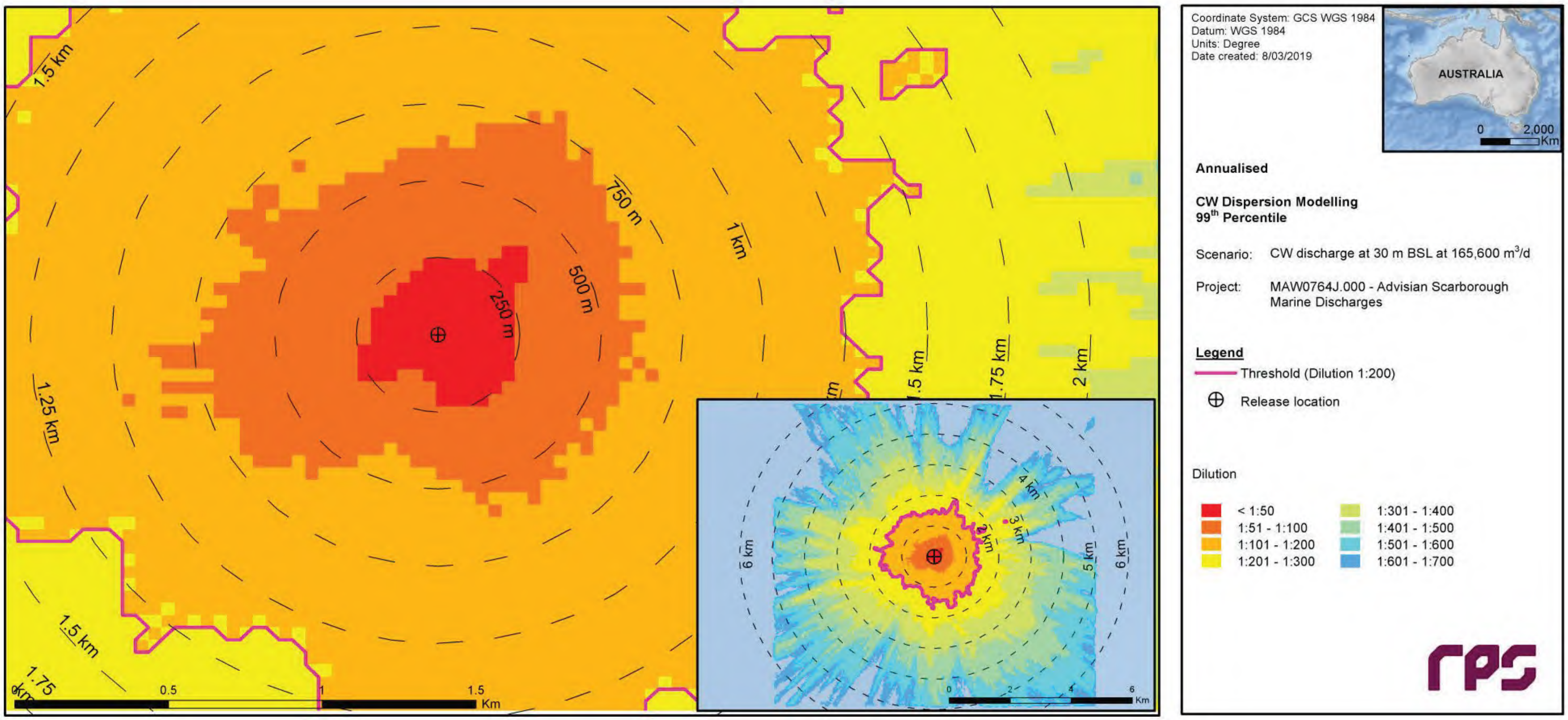

Figure 3.108 Predicted annualised minimum dilutions at the 99th percentile for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

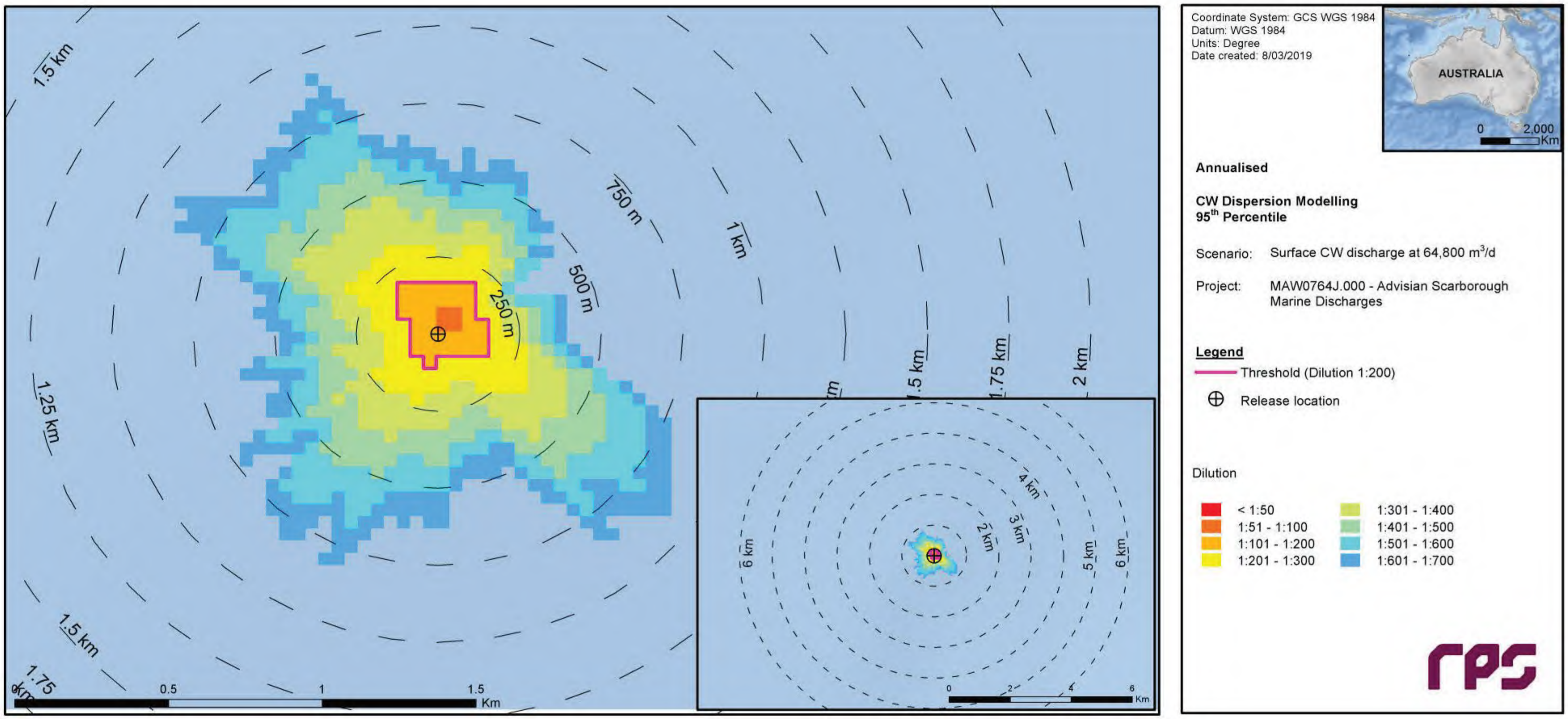

Figure 3.109 Predicted annualised minimum dilutions at the 95th percentile for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

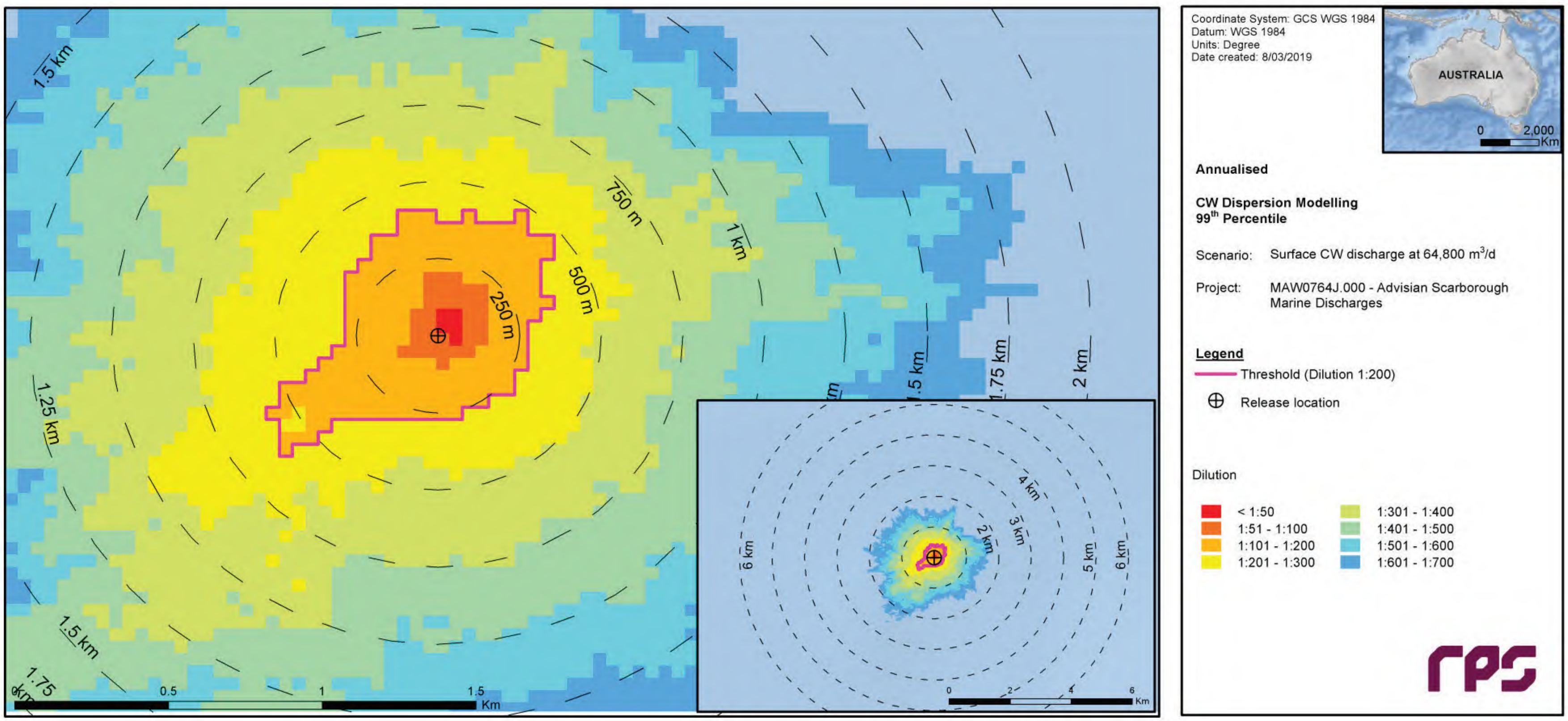

Figure 3.110 Predicted annualised minimum dilutions at the 99th percentile for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

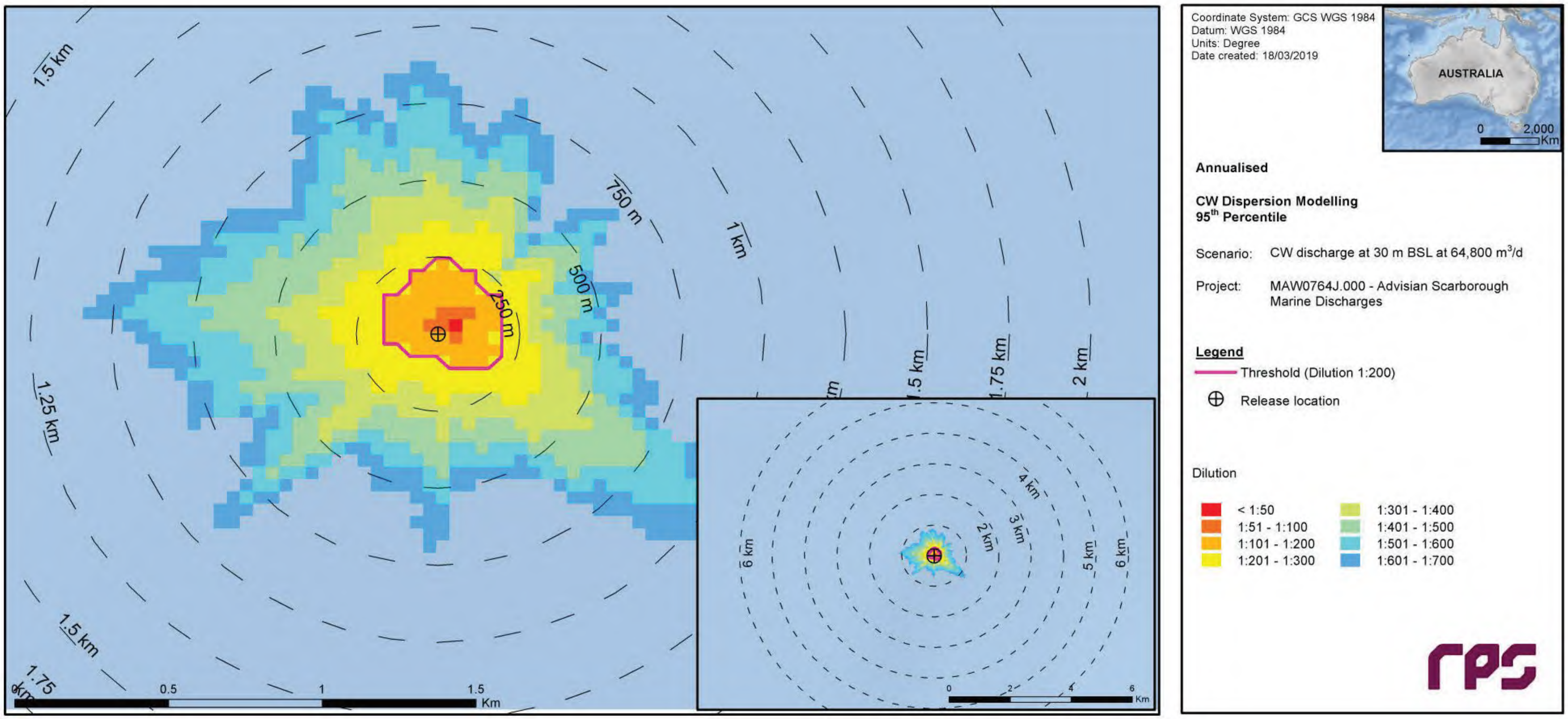

Figure 3.111 Predicted annualised minimum dilutions at the 95th percentile for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

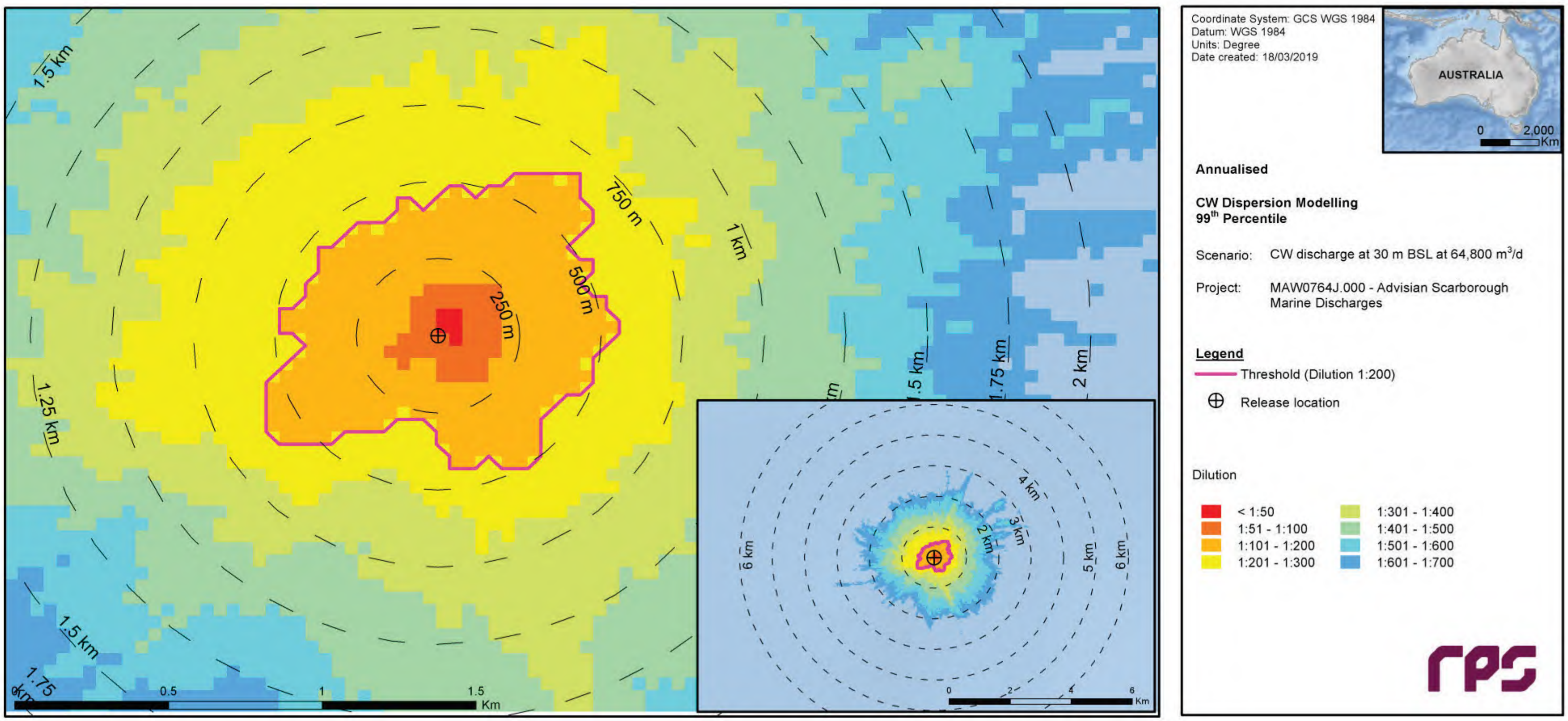

Figure 3.112 Predicted annualised minimum dilutions at the 99th percentile for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

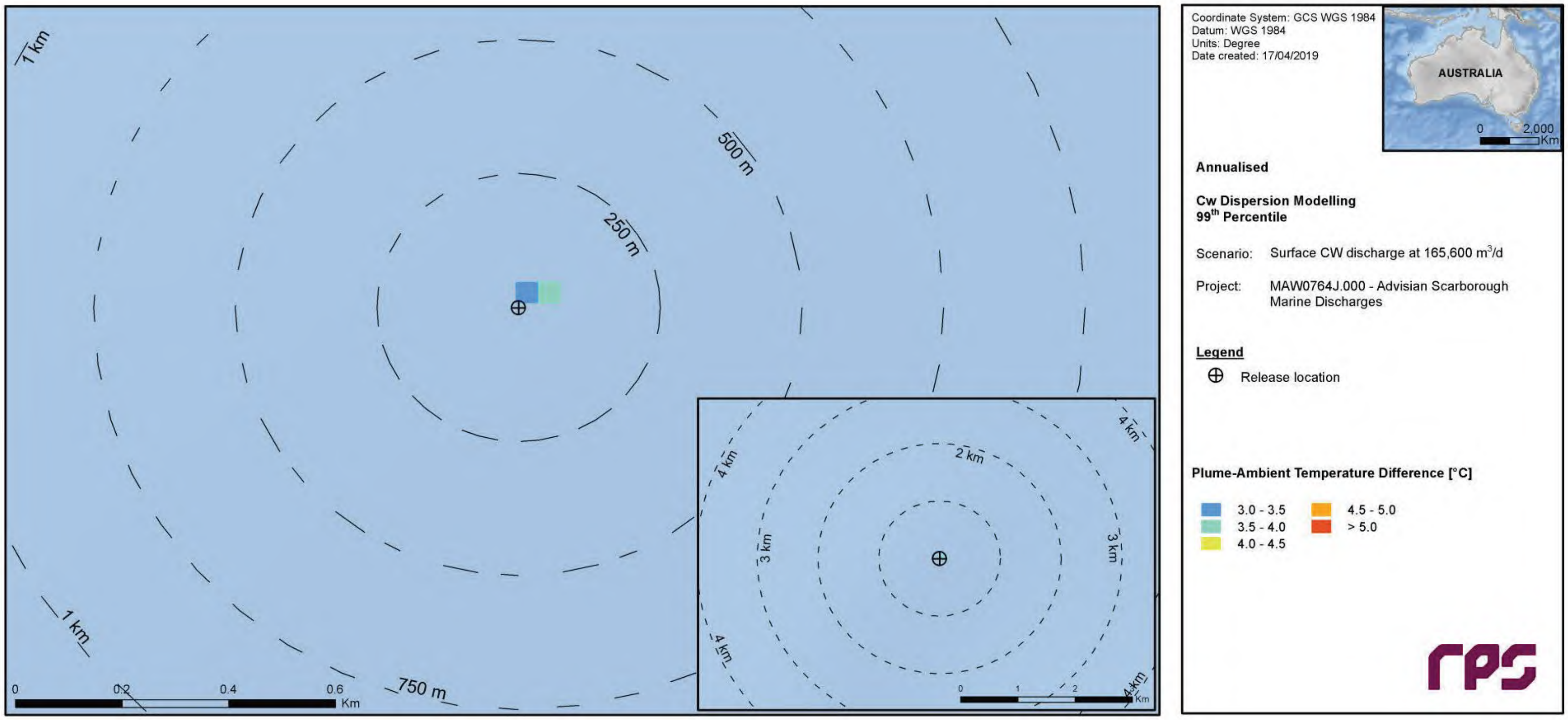

Figure 3.113 **Predicted annualised maximum plume-ambient ΔT at the 99th percentile for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).**

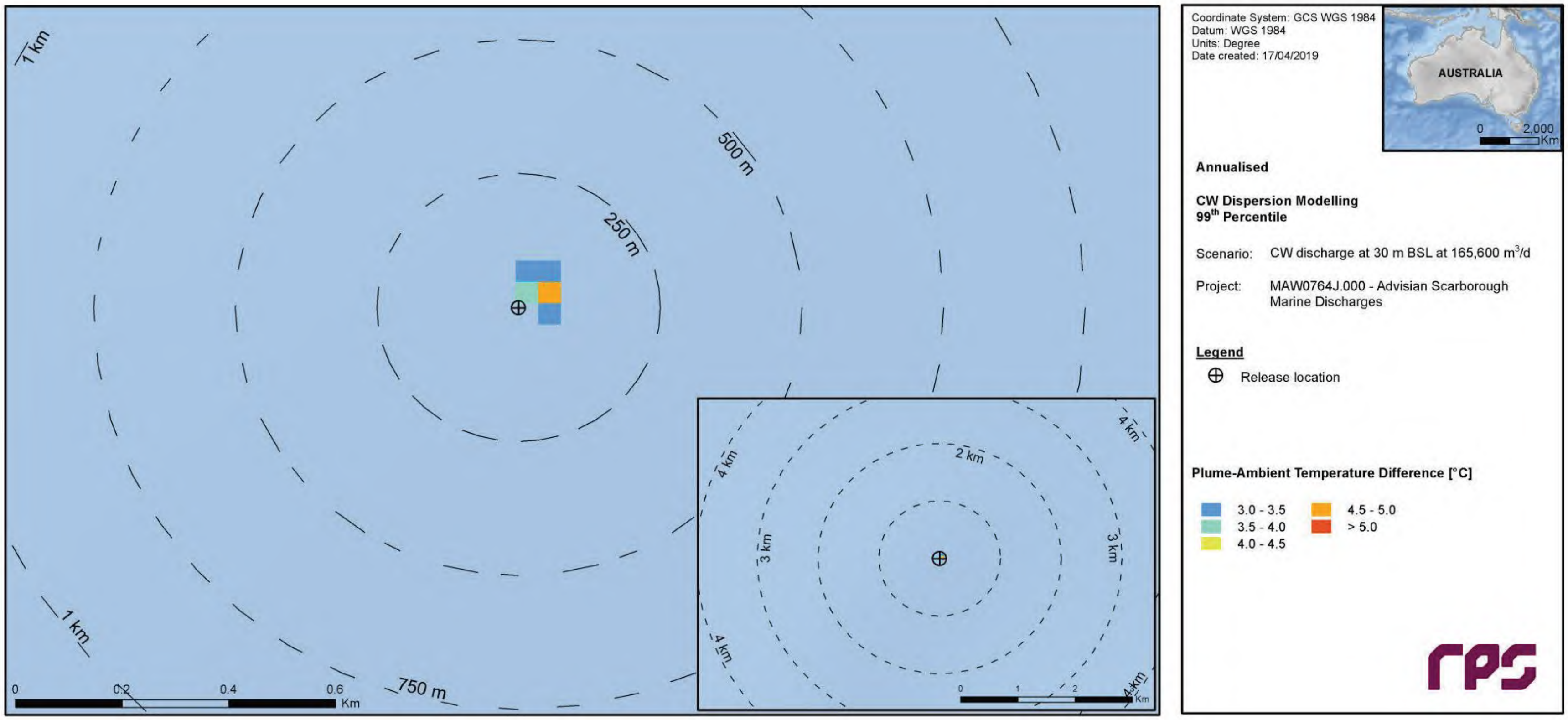

Figure 3.114 Predicted annualised maximum plume-ambient ΔT at the 99th percentile for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

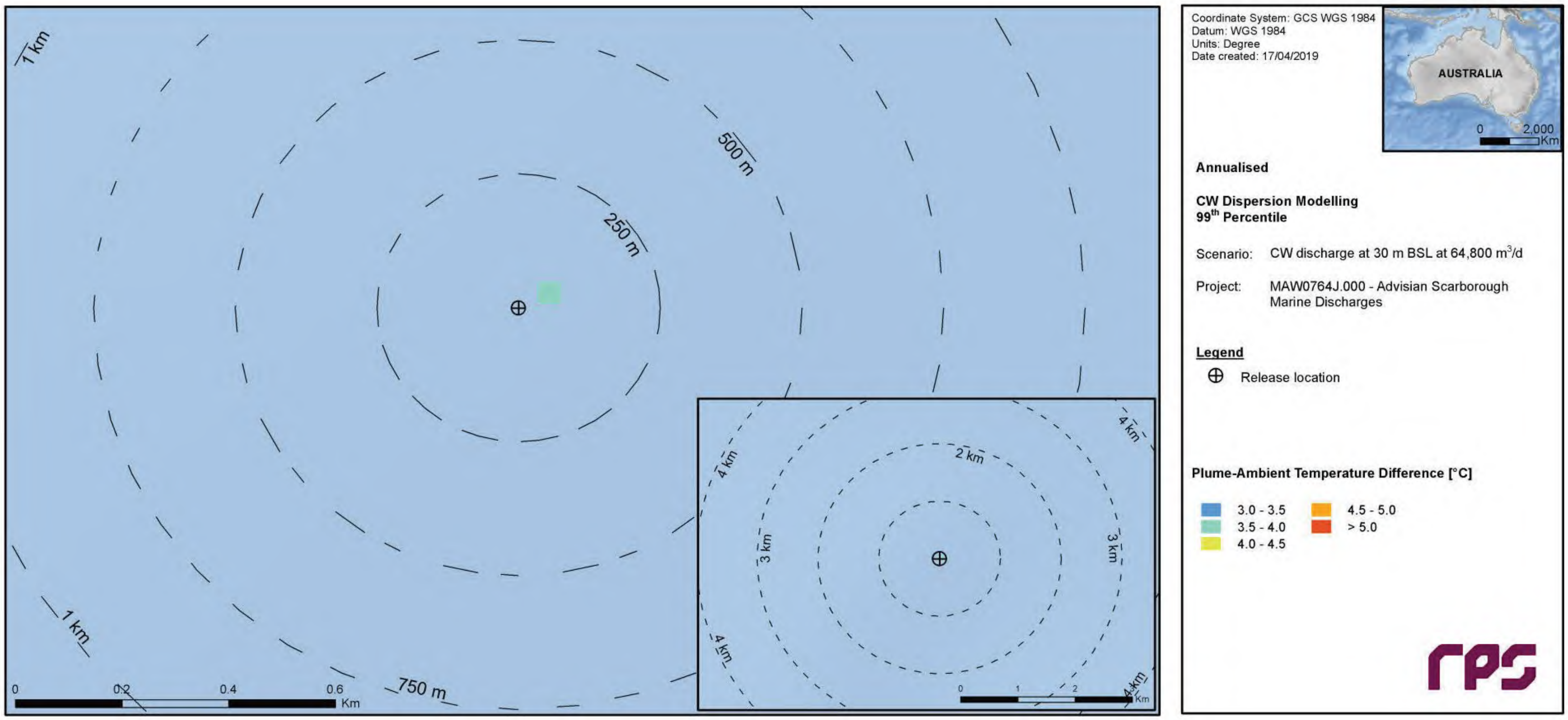

Figure 3.115 Predicted annualised maximum plume-ambient ΔT at the 99th percentile for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

4 CONCLUSIONS

The main findings of the study are as follows:

Near-Field Modelling

- The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 0 m (Cases C1, C4 and C7), 10 m (Cases C2, C5 and C8) and 30 m (Cases C3, C6 and C9) below the water surface. The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively-buoyant plumes are predicted to rise in the water column.
- For Cases C1, C4 and C7 (0 m depth discharge), the plume is predicted to plunge up to 14 m below the sea surface, with the highest flow rate yielding the greatest plunge depth due to the vertical orientation of the discharges. For the discharges at depths of 10 m and 30 m, the plumes are predicted to plunge up to 25 m and 43 m below the sea surface, respectively, with the highest flow rate yielding the greatest plunge depths.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For a discharge at a 165,600 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 75.0 m. The dilution level for this case is predicted as 1:52.
- For a discharge at a 64,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 69.7 m. The dilution level for this case is predicted as 1:77.
- For a discharge at an 82,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 59.8 m. The dilution level for this case is predicted as 1:59.
- For a discharge at 0 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 5.7 m. The dilution level for this case is predicted as 1:6.
- For a discharge at 10 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 11.1 m. The dilution level for this case is predicted as 1:17.
- For a discharge at 30 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 24.5 m. The dilution level for this case is predicted as 1:52.
- For each combination of discharge flow rate and depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the surface (or trapping depth, at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.

- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.
- The results for each combination of discharge flow rate and depth indicate that the chlorine constituent of the CW discharge is not expected to reach the required levels of dilution in the near field mixing zone.
- The temperature differential between the plume and the ambient water meets the required criterion in all conditions for Cases C2, C3, C6 and C9, and in the stronger-current simulations for Cases C1, C5 and C8. For Cases C4 and C7, however, compliance with the temperature differential criterion is not achieved.
- Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface.

Far-Field Modelling

- For Cases C1 and C3, dilution to reach threshold concentration is achieved for chlorine within an area of influence extending up to 1.79 km and 2.47 km, respectively, at the 99th percentile. For Cases C4 and C6, the maximum spatial extents of the relevant dilution contour are up to 0.62 km and 0.63 km, respectively, at the 99th percentile.
- For Cases C1 and C3, the areas of exposure defined by the relevant dilution contour are predicted to reach maximums of 4.59 km^2 and 6.56 km^2, respectively, at the 99th percentile. For Cases C4 and C6, the corresponding maximum areas of exposure are up to 0.40 km^2 and 0.68 km^2, respectively, at the 99th percentile.
- Maximum depths reached by. the discharges are predicted as 8 m, 38 m, 6 m and 38 m for Cases C1, C3, C4 and C6, respectively.
- Because the 3 °C plume-ambient temperature differential requirement is forecast to be met within a distance of 115 m at the 99th percentile in any case, the limiting factor for the plume's area of influence will be defined by its chlorine constituent rather than its temperature.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents may promote the highest levels of mixing and dilution.
- Because the discharge will be initially positively buoyant, it will rise in the water column and may resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions. This outcome is particularly likely for the surface discharge.
- Outcomes show that below-threshold chlorine concentrations are achieved closer to the discharge point for a flow rate of 64,800 m^3/d than for a higher flow rate of 165,600 m^3/d. This is attributable to the fact that initial peak chlorine concentrations in the water column are lower in the former case, which reduces the average concentrations likely to be recorded in each model grid cell during episodes of recirculation and pooling.

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Appendix G

Scarborough Gas Development Produced Water Discharge Modelling Study

MAKING COMPLEX EASY

WOODSIDE SCARBOROUGH PROJECT – PRODUCED WATER DISCHARGE MODELLING

Report

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EXECUTIVE SUMMARY

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough Project will involve the processing of hydrocarbons which will result in the production of produced water (PW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for the Total Petroleum Hydrocarbons (TPH) in the produced water (PW) discharge. This will indicate whether concentrations of this contaminant are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the PW discharge and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the TPH in the PW stream from the FPU, dispersion modelling was carried out for a flow rate of 95 m^3/d at three discharge depths: 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the PW discharge stream was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). An annualised aggregation of outcomes was also assembled.

The main findings of the study are as follows:

Near-Field Modelling

- The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 0 m, 10 m and 30 m below the water surface (Cases P1, P2 and P3, respectively). The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column.
- For Case P1, the plume is predicted to plunge up to 4.4 m below the sea surface. For Cases P2 and P3, the plumes are predicted to remain at approximately the discharge depth: up to 11 m below the surface for Case P2 and up to 31 m below the surface for Case P3.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

- For a discharge at a 95 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 0 m depth as 255 m. The dilution level for this case is predicted as 1:1,519.
- The maximum diameter of the plume at the end of the near-field zone was predicted as 3.7 m for Case P1, 1.8 m for Case P2 and 1.7 m for Case P3. Increases in current speed serve to restrict the diameter of the plume.
- For each discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.
- The average dilution levels of the plume upon reaching the trapping depth under average current speeds are predicted to be 1:1,519 for Case P1, 1:88 for Case P2 and 1:43 for Case P3. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under average current speeds are predicted to be 1:390 for Case P1, 1:22 for Case P2 and 1:11 for Case P3.
- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.
- The results for the Case P1, P2 and P3 discharges indicate that the TPH constituent of the PW discharge is not expected to reach the required levels of dilution in the near field mixing zone.

Far-Field Modelling

- For Case P1, dilution to reach threshold concentration is achieved for TPH within an area of influence extending up to 543 m at the 99th percentile. For Case P3, the maximum spatial extents of the relevant dilution contour are up to 810 m at the 99th percentile.
- For Case P1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum of 0.48 km^2 at the 99th percentile. For Case P3, the corresponding maximum area of exposure is up to 0.70 km^2 at the 99th percentile.
- Maximum depths reached by the discharges are predicted as 5 m and 33 m for Cases P1 and P3, respectively.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents will promote the highest levels of mixing and dilution.
- Because the discharge will be initially negatively buoyant, it will sink in the water column and even a surface discharge is unlikely to resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

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The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for the Total Petroleum Hydrocarbons (TPH) in the produced water (PW) discharge. This will indicate whether concentrations of this contaminant are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the PW discharge and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the TPH in the PW stream from the FPU (location shown in Table 1.1), dispersion modelling was carried out for a flow rate of 95 m^3/d at three discharge depths: 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the PW discharge stream was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). An annualised aggregation of outcomes was also assembled.

All PW discharge characteristics used as input to the modelling are specified in the Model Input Form for this study (Advisian, 2018).

Table 1.1 Location of the proposed FPU used as the release site for the PW dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
FPU	19° 53' 54.715"	113° 14' 19.561"	930

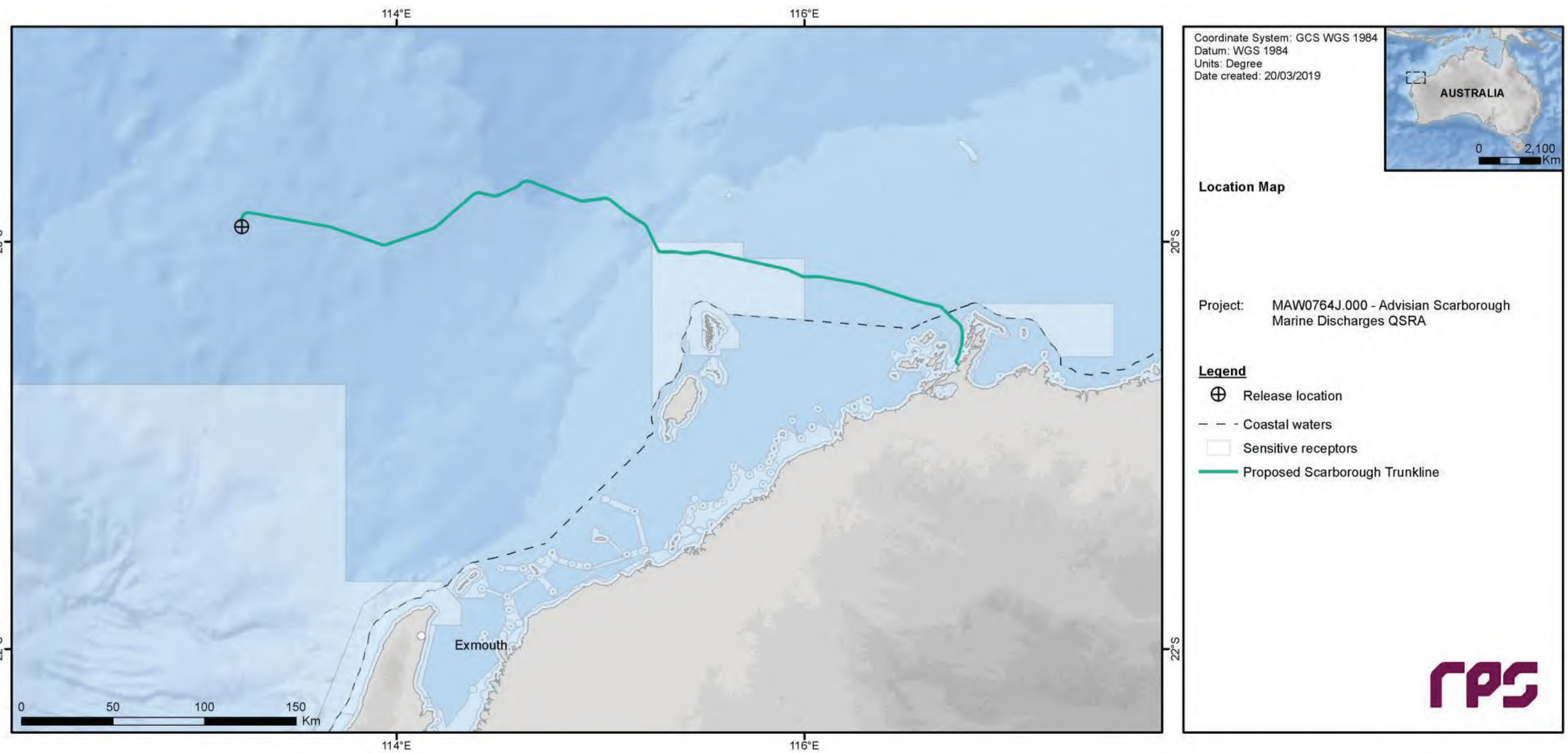

Figure 1.1 Location of the proposed Scarborough pipeline and FPU on the North West Shelf of Australia.

1.2 Modelling Scope

The physical mixing of the PW plume was first investigated for the near-field mixing zone. The limits of the near-field mixing zone are defined by the area where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from density differences between the plume and the receiving water. When the plume encounters a boundary such as the water surface, near-field mixing is complete. At this point, the plume is considered to enter the far-field mixing zone.

The scope of the modelling included the following components:

- Collation of a suitable three-dimensional, spatially-varying current data set surrounding the FPU location for a ten-year (2006-2015) hindcast period. The current data set included the combined influence of drift and tidal currents and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against metocean data collected in the Scarborough Project area.
- Derivation of statistical distributions for the current speed and directions for use in the near-field modelling. Analyses included percentile distributions and development of current roses. This analysis was important to ensure that current data samples applied in the dispersion model were statistically representative.
- Collation of seasonally-varying vertical water density profiles at the FPU location for use as input to the dispersion models.
- Near-field modelling conducted for each unique discharge to assess the initial mixing of the discharge due to turbulence and subsequent entrainment of ambient water. This modelling was conducted at high spatial and temporal resolution (scales of metres and seconds, respectively).
- Outcomes from the near-field modelling included estimates of the width, shape and orientation of the plumes, and resulting contaminant concentrations and dilutions, for each discharge at a range of incident current speeds.
- Establishment of a far-field dispersion model to repeatedly assess discharge scenarios under different sample conditions, with each sample represented by a unique time-sequence of current flow, chosen at random from the time series of current data.
- Analysis of the results of all simulations to quantify, by return frequency, the potential extent and shape of the mixing zone.

2 MODELLING METHODS

2.1 Near-Field Modelling

2.1.1 Overview

Numerical modelling was applied to quantify the area of influence of PW water discharges, in terms of the distribution of the maximum contaminant concentrations that might occur with distance from the source given defined discharge configurations, source concentrations, and the distribution of the metocean conditions affecting the discharge location.

The dispersion of the PW discharge will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. As the discharges mix with the ambient waters, the momentum and buoyancy signatures are eroded, and the background – or ambient – processes become dominant.

The shape and orientation of the discharged water plumes, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a statistically representative range of current speeds representative of the FPU location.

2.1.2 Description of Near-Field Model: Updated Merge

The near-field mixing and dispersion of the water discharge was simulated using the Updated Merge (UM3) flow model. The UM3 model is a three-dimensional Lagrangian steady-state plume trajectory model designed for simulating single and multiple-port submerged discharges in a range of configurations, available within the Visual Plumes modelling package provided by the United States Environmental Protection Agency (Frick *et al.*, 2003). The UM3 model was selected because it has been extensively tested for various discharges and found to predict observed dilutions more accurately (Roberts & Tian, 2004) than other near-field models (i.e. RSB and CORMIX).

In the UM3 model, the equations for conservation of mass, momentum, and energy are solved at each time step, giving the dilution along the plume trajectory. To determine the change of each term, UM3 follows the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment (PAE) hypothesis, which quantifies forced entrainment in the presence of a background ocean current. The flows begin as round buoyant jets and can merge to a plane buoyant jet (Carvalho *et al.*, 2002). Model output consists of plume characteristics including centreline dilution, rise-rate, width, centreline height and plume diameter. Dilution is reported as the “effective dilution”, the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner *et al.* (1994).

The near-field zone ends where the discharged plume reaches a physical boundary or assumes the same density as the ambient water.

Figure 2.1 shows a conceptual diagram of the dispersion and fates of a negatively buoyant discharge and the idealised representation of the discharge phases.

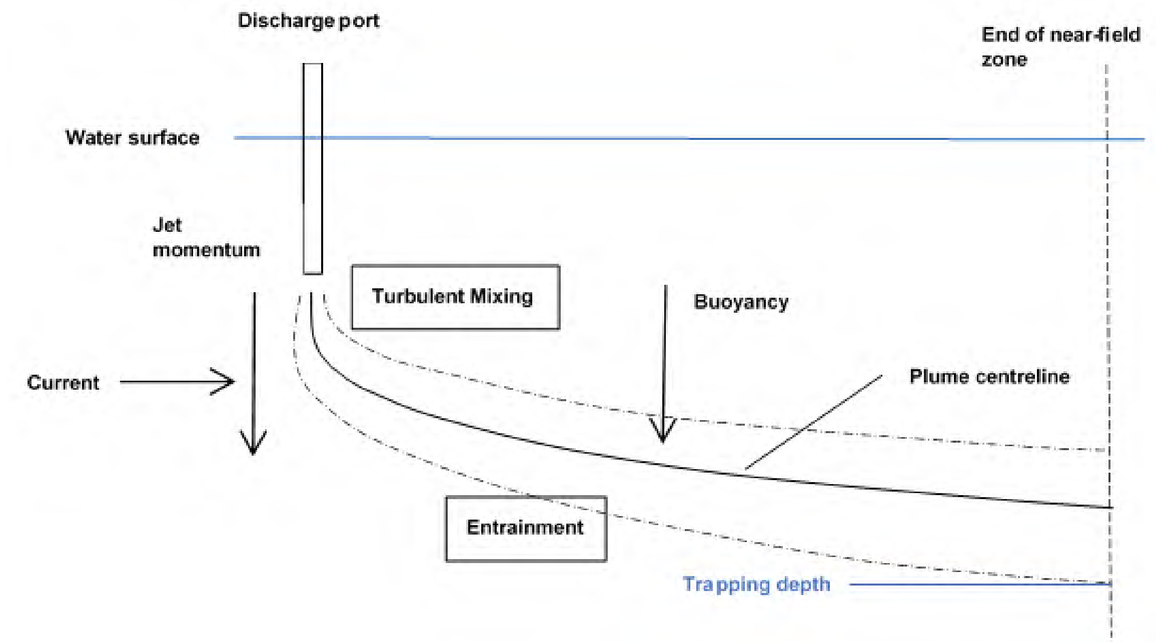

Figure 2.1 Conceptual diagram showing the general behaviour of negatively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The PW discharge characteristics for Cases P1 to P3 are summarised in Table 2.1. Cases P1, P2 and P3 were assumed to occur at depths of 0 m below mean sea level (BMSL), 10 m BMSL and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 0.2 m diameter at a rate of 95 m^3/d and have a salinity and temperature of 40.5 parts per thousand (ppt) and 40 °C, respectively.

Concentrations of the constituent of interest (TPH) within the discharges are described in Table 2.2, along with the required dilution factor to reach the defined threshold concentration (Advisian, 2018).

Table 2.1 Summary of PW discharge characteristics.

Parameter	Case P1	Case P2	Case P3
Flow rate (m^3/d)		95	
Outlet pipe internal diameter (m) [in]		0.2 [7.9]	
Outlet pipe orientation		Vertical (downwards)	
Depth of pipe below sea surface (m)	0	10	30
Discharge salinity (ppt)		40.5	
Discharge temperature (°C)		40	

Table 2.2 Constituent of interest within the PW discharges and criteria for analysis of exposure.

Constituent	Source Concentration (mg/L)	Threshold Concentration (mg/L)	Required Dilution Factor
Total Petroleum Hydrocarbons (TPH)	29	0.07	414.3

2.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the UM3 model included a vertical profile of temperature and salinity, along with constant current speeds and general direction. The temperature and salinity profiles are required to accurately account for the buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the PW plume. These inputs are described in the following sections.

2.1.3.2.1 Ambient Temperature and Salinity

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration, NOAA) and its co-located World Data Center for Oceanography (Levitus *et al.*, 2013).

Table 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 m to 50 m. This data can be considered representative of seasonal conditions at the FPU location.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth. Salinity levels are generally more consistent and exhibit a vertically well-mixed water body (34.7-34.8 practical salinity unit, PSU), irrespective of season or depth.

Table 2.3 Average temperature and salinity levels adjacent to the proposed FPU location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	27.8	34.7
	20	27.3	34.8
	50	26.2	34.8
Transitional	0	26.0	34.7
	20	25.7	34.7
	50	25.1	34.7
Winter	0	26.4	34.7
	20	26.3	34.7
	50	26.2	34.7
Annualised	0	26.6	34.7
	20	26.3	34.7
	50	25.8	34.7

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-year hindcast data set of combined large-scale ocean (BRAN) and tidal currents. The data was statistically analysed to determine the 5th, 50th and 95th percentile current speeds. These statistical current speeds can be considered representative of seasonal conditions at the FPU location.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 5th percentile current speed: weak currents, low dilution and slow advection.
- 50th percentile (median) current speed: average currents, moderate dilution and advection.
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2.4 Adopted ambient current conditions adjacent to the proposed FPU location.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	2.5	0.041	0.158	0.326
	22.7	0.049	0.154	0.312
	56.7	0.044	0.138	0.267
Transitional	2.5	0.045	0.177	0.375
	22.7	0.045	0.173	0.369
	56.7	0.043	0.157	0.322
Winter	2.5	0.044	0.172	0.395
	22.7	0.043	0.166	0.375
	56.7	0.039	0.156	0.341
Annualised	2.5	0.043	0.170	0.374
	22.7	0.045	0.164	0.361
	56.7	0.042	0.151	0.320

2.2 Far-Field Modelling

2.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh & Chang, 1973; Khondaker, 2000).

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals/constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al.*, 1999; King & McAllister, 1997, 1998).

2.2.3 Stochastic Modelling

A stochastic modelling procedure was applied in the far-field modelling to sample a representative set of conditions that could affect the distribution of constituents. This approach involves multiple (25) simulations of a given discharge scenario and season, with each simulation being carried out under a randomly-selected period of currents. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents at the discharge location. Once the stochastic modelling is complete, all simulations are statistically analysed to develop the distribution of outcomes based on time and event.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

Two PW discharge scenarios were modelled as a continuous discharge using 25 simulations for each season. Once the simulations were complete, they were reported on a seasonal basis: (i) summer (December to February); (ii) transitional (March and September to November) and (iii) winter (April to August). The PW discharge characteristics for the selected cases (P1 and P3) are summarised in Table 2.5. These cases were chosen to cover the full range of proposed discharge depths.

Table 2.5 Summary of far-field PW discharge modelling assumptions.

Parameter	Case P1	Case P3
Hindcast modelling period	2006-2015	
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August) Annual	
Flow rate (m^3/d)	95	
Discharge depth (m)	0	30
Discharge salinity (ppt)	40.5	
Discharge temperature (°C)	40	
Number of simulations	75 (25 per season)	
Simulated discharge type	Continuous	
Simulated discharge period (days)	5	

2.2.4.2 Mixing Parameters

The horizontal and vertical dispersion coefficients represent the mixing and diffusion caused by turbulence, both of which are sub-grid-scale processes. Both coefficients are expressed in units of rate of area change per second (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations faster. Increasing the vertical dispersion coefficient spreads the discharge across the vertical layers (or depths) faster.

Spatially constant, conservative dispersion coefficients of 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the PW plume in the horizontal and vertical directions, respectively. Each of the mixing parameters was selected following extensive sensitivity testing to recreate the plume characteristics predicted by the near-field modelling. It would be expected that the in-situ mixing dynamics would be greater under average and high energy conditions by a factor of 10 (King & McAllister, 1997, 1998) and thus the far-field model results are designed to produce a worst-case result for concentration extents.

2.2.4.3 Grid Configuration

MUDMAP uses a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). Due to the rapid mixing and small-scale effect of the effluent discharge, it was necessary to use a fine grid with a resolution of 5 m x 5 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 5 km (longitude or x-axis) by 5 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Background

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the island groups stretching from the Dampier Archipelago to the North West Cape. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have greater influence upon the net trajectory of slicks over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of pollutants can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is critical to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration of pollutants. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.2.5.2 Mesoscale Circulation Model

Representation of the drift currents that affect the area were available from the output of the BRAN (Bluelink ReANalysis; Oke *et al.*, 2008, 2009; Schiller *et al.*, 2008) ocean model, which is sponsored by the Australian Government through the Commonwealth Bureau of Meteorology (BoM), Royal Australian Navy, and Commonwealth Scientific and Industrial Research Organisation (CSIRO). BRAN is a data-assimilative, three-dimensional ocean model that has been run as a hindcast for many periods and is now used for ocean forecasting (Schiller *et al.*, 2008).

The BRAN predictions for drift currents are produced at a horizontal spatial resolution of approximately 0.1° over the region, at a frequency of once per day, averaged over the 24-hour period. Hence, the BRAN model data provides estimates of mesoscale circulation with horizontal resolution suitable to resolve eddies of a few tens of kilometres' diameter, as well as connecting stream currents of similar spatial scale. Drift currents that are represented over the inner shelf waters in the BRAN data are principally attributable to wind induced drift.

There are several versions of the BRAN database available. The latest BRAN simulation spans the period of January 1994 to August 2016. From this database, time series of current speed and direction were extracted for all points in the model domain for the years 2006-2015 (inclusive). The data was assumed to be a suitably representative sample of the current conditions over the study area for future years.

Figure 2.2 shows the seasonal distribution of current speeds and directions for the BRAN data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The data shows that current speeds and directions vary between seasons. In general, during transitional months (March and September to November) currents have the strongest average speed (0.22 m/s with a maximum of 0.56 m/s) and tend to flow south-east. During winter (April to August), current flow conditions are more variable, with lower average speed (0.21 m/s with a maximum of 0.53 m/s). During summer (December to February), the current flow occurs in a predominantly south/south-westerly direction with the lowest average speed (0.20 m/s with a maximum of 0.46 m/s).

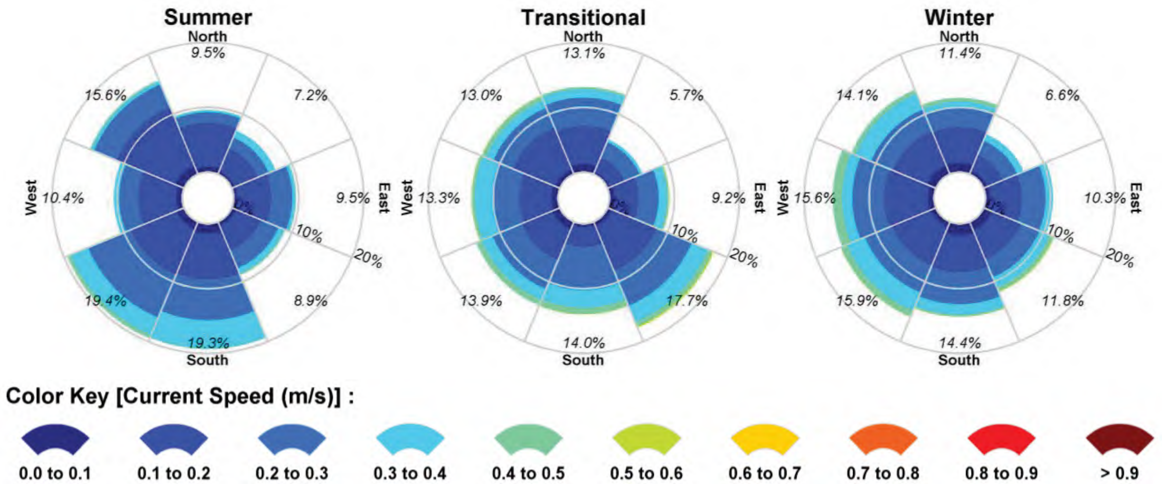

Figure 2.2 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Circulation Model

As the BRAN model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 25 years (Isaji & Spaulding, 1984, 1986; Isaji *et al.*, 2001; Zigic *et al.*, 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.3).

Four layers of sub-gridding were applied to provide variable resolution throughout the domain. The resolution at the primary level was 15 km. The finer levels were defined by subdividing these cells into 4, 16 and 64 cells, resulting in resolutions of 7.5 km, 3.75 km and 1.88 km. The finer grids were allocated in a step-wise fashion to areas where higher resolution of circulation patterns was required to resolve flows through channels, around shorelines or over more complex bathymetry. Approximately 98,600 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office. Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992-2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone *et al.*, 1998; Matsumoto *et al.*, 2000; Kostianoy *et al.*, 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

For the purpose of verification of the tidal predictions, the model output was compared against independent predictions of tides using the XTide database (Flater, 1998). The XTide database contains harmonic tidal constituents derived from measured water level data at locations around the world. Of more than 40 tidal stations within the HYDROMAP model domain, ten were used for comparison.

Water level time series for these locations are shown in Figure 2.4 for a one-month period (January 2005). All comparisons show that the model produces a very good match to the known tidal behaviour for a wide range of tidal amplitudes and clearly represents the varying diurnal and semi-diurnal nature of the tidal signal.

The model skill was further evaluated through a comparison of the predicted and observed tidal constituents, derived from an analysis of model-predicted time-series at each location. A scatter plot of the observed and modelled amplitude (top) and phase (bottom) of the five dominant tidal constituents (S_2, M_2, N_2, K_1 and O_1) is presented in Figure 2.5. The red line on each plot shows the 1:1 line, which would indicate a perfect match between the modelled and observed data. Note that the data is generally closely aligned to the 1:1 line demonstrating the high quality of the model performance.

Figure 2.6 shows the seasonal distribution of current speeds and directions for the HYDROMAP data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The current data indicates cyclical tidal flow directions along a northeast-southwest axis, with maximum speeds of around 0.09 m/s.

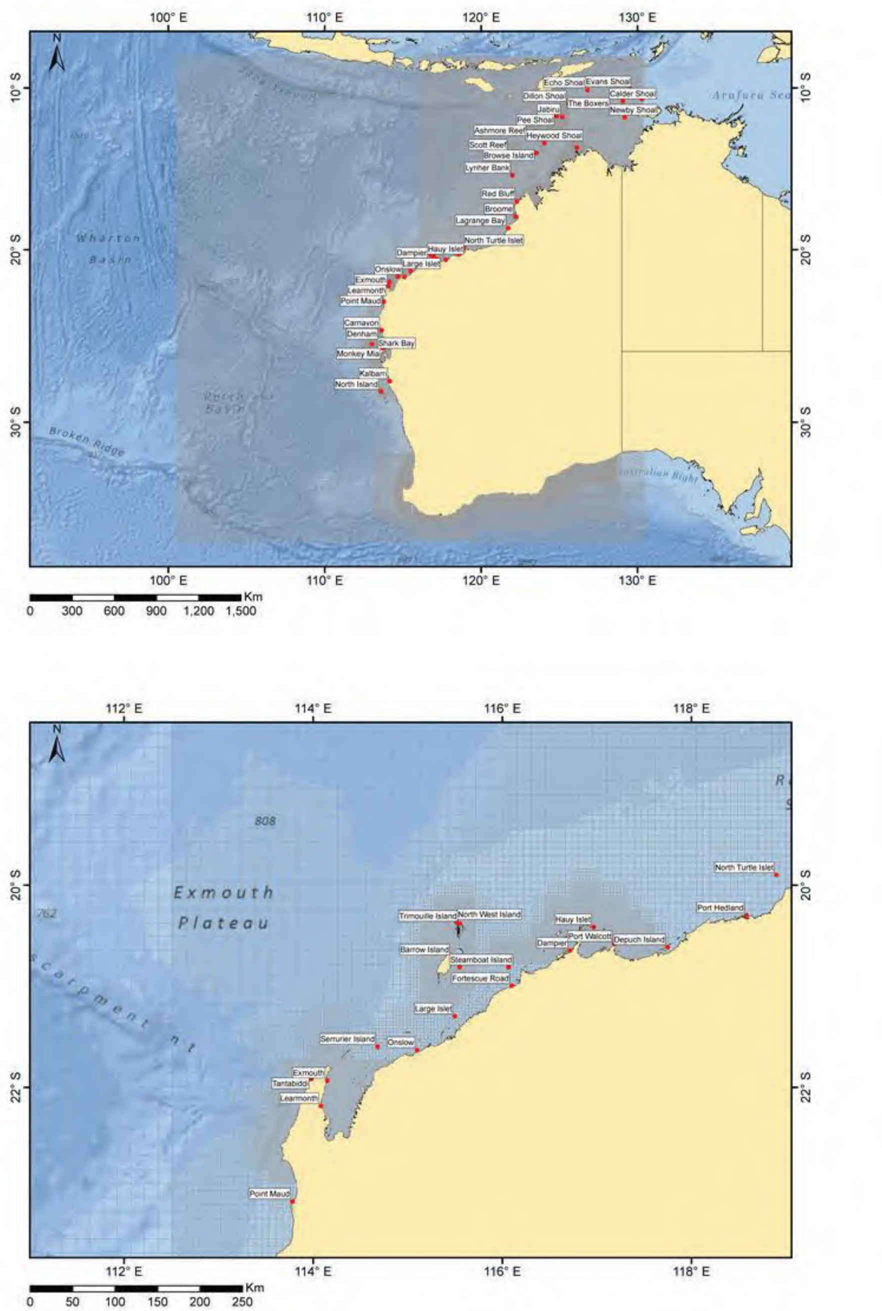

Figure 2.3 **Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing locations available for tidal comparisons (red labelled dots). The top panel shows the full domain in context with the continental land mass, while the bottom panel shows a zoomed subset near the discharge locations. Higher-resolution areas are indicated by the denser mesh zones.**

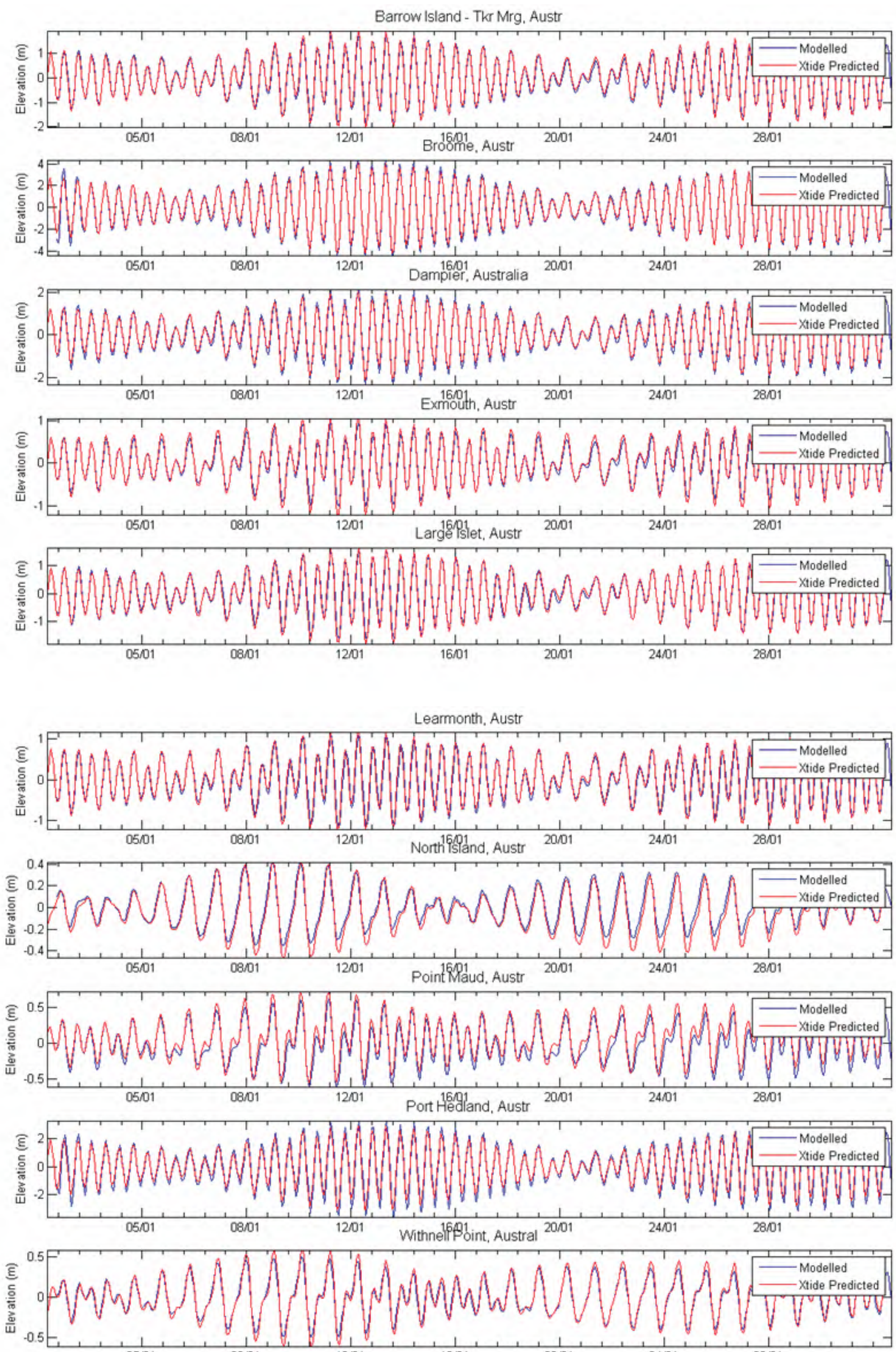

Figure 2.4 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at ten locations in the tidal model domain for January 2005.

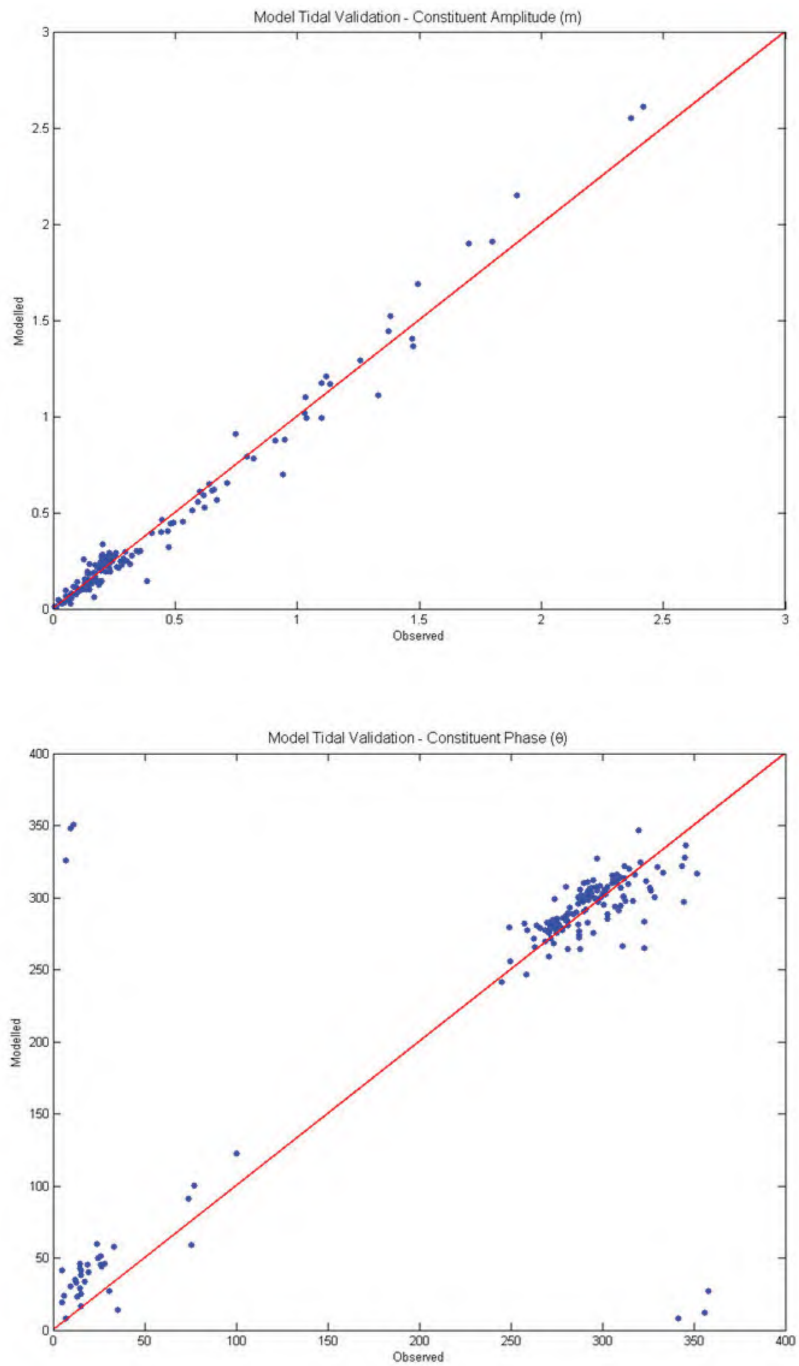

Figure 2.5 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all stations in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

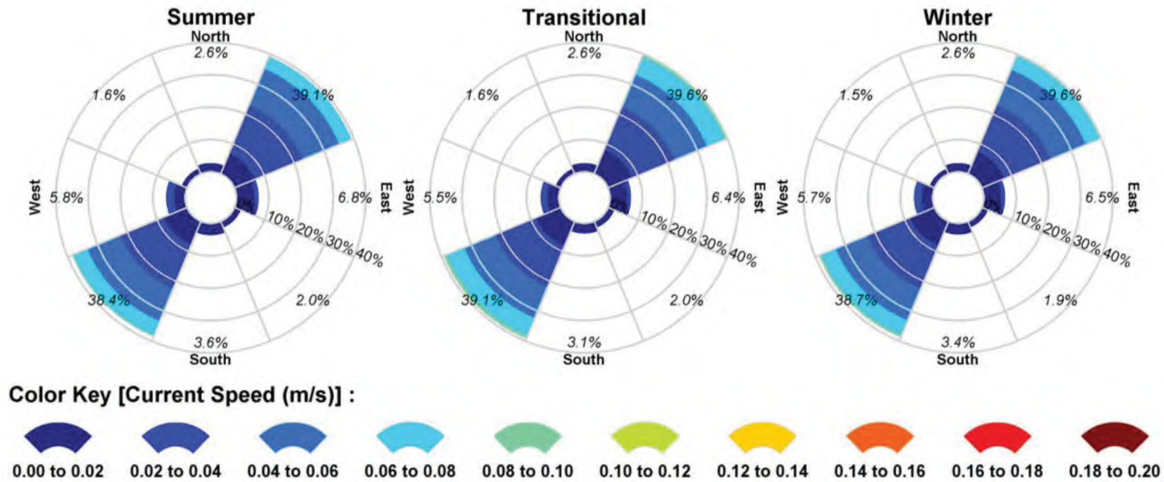

Figure 2.6 **Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.**

3 MODELLING RESULTS

3.1 Near-Field Modelling

3.1.1 Overview

In the following sections, information for each of the modelled discharge cases is presented first in a table summarising the predicted plume characteristics in the near-field mixing zone under varying current speeds, and then in further tables summarising the concentrations of TPH at the end of the near-field mixing zone, the concentration threshold, and the amount of dilution for each season and for the annual period. Any dilution rates indicated in red show that suitable dilution is not achieved during the near-field stage for at least one current-speed case.

Figure 3.1 to Figure 3.12 (note the differing x-axis and y-axis aspect ratios) show the change in average dilution and temperature of the plume under varying discharge depths (0 m, 10 m and 30 m), seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

In each figure, the plots have been arranged to demonstrate the variation in predicted outcomes for the same discharge at different depths under identical current conditions.

The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 0 m, 10 m and 30 m below the water surface (Cases P1, P2 and P3, respectively). The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column. For Case P1, the plume is predicted to plunge between 0.1 m and 4.4 m below the sea surface depending on season. For Cases P2 and P3, the plumes are predicted to remain at approximately the discharge depth: 9-11 m below the surface for Case P2 and 29-31 m below the surface for Case P3, depending on season. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

Table 3.1, Table 3.6 and Table 3.11 show the predicted plume characteristics for the varying discharge depths, seasonal conditions and current speeds. High annualised currents push the plume to maximum horizontal distances of 866 m and 123 m for the Case P1 and Case P3 discharges, respectively.

The diameter of the plume at the end of the near-field zone ranged from 0.4 m to 3.7 m for Case P1, 0.5 m to 1.8 m for Case P2 and 0.6 m to 1.7 m for Case P3. Increases in current speed serve to restrict the diameter of the plume.

For most combinations of season and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution (Table 3.1, Table 3.6 and Table 3.11). The average dilution levels of the plume upon reaching the trapping depth under medium and strong currents are predicted to be 1:1,519 and 1:3,616 for Case P1, 1:88 and 1:140 for Case P2, and 1:43 and 1:181 for Case P3, respectively. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under medium and strong currents are predicted to be 1:390 and 1:929 for Case P1, 1:22 and 1:36 for Case P2, and 1:11 and 1:46 for Case P3. Note that these predictions rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

The results for the Case P1 (Section 3.1.2; Table 3.2 to Table 3.5), Case P2 (Section 3.1.2.2; Table 3.7 to Table 3.10) and Case P3 (Section 3.1.2.3; Table 3.12 to Table 3.15) discharges indicate that the TPH constituent of the PW discharge is not expected to reach the required levels of dilution in the near field mixing zone.

3.1.2 Results – Tables

3.1.2.1 Discharge Case P1: Flow Rate of 95 m^3/day at 0 m Depth (Surface)

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	3.5 [2.7]	27.83	0.03	91	351	16.8
	Medium (0.16)	3.4 [2.6]	27.81	0.01	339	1,321	124.1
	Strong (0.33)	3.5 [2.6]	27.80	0.00	725	2,821	376.9
Transitional	Weak (0.05)	0.3 [0.2]	32.84	6.84	1	2	0.9
	Medium (0.18)	0.4 [0.2]	26.91	0.91	4	15	4.2
	Strong (0.38)	0.3 [0.2]	26.47	0.47	7	30	7.9
Winter	Weak (0.04)	0.4 [0.2]	31.03	4.63	1	3	0.4
	Medium (0.17)	3.6 [2.6]	26.41	0.01	412	1,601	325.7
	Strong (0.40)	0.4 [0.2]	26.74	0.34	10	40	11.8
Annual	Weak (0.04)	0.4 [0.2]	29.83	3.23	1	4	0.8
	Medium (0.17)	3.5 [2.6]	26.61	0.01	390	1,519	255.0
	Strong (0.37)	3.7 [2.6]	26.60	0.00	929	3,613	866.3

Table 3.2 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 351, 1,321 and 2,821, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		351x Dilution	1,321x Dilution	2,821x Dilution		
TPH	29	$8.3*10^{-2}$	$2.2*10^{-2}$	$1.0*10^{-2}$	0.07	414.3

Table 3.3 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2, 15 and 30, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2x Dilution	15x Dilution	30x Dilution		
TPH	29	14.5	1.9	$9.7*10^{-1}$	0.07	414.3

Table 3.4 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 3, 1,601 and 40, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		3x Dilution	1,601x Dilution	40x Dilution		
TPH	29	9.7	$1.8*10^{-2}$	$7.2*10^{-1}$	0.07	414.3

Table 3.5 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 4, 1,519 and 3,613, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		4x Dilution	1,519x Dilution	3,613x Dilution		
TPH	29	7.3	$1.9*10^{-2}$	$8.0*10^{-3}$	0.07	414.3

3.1.2.2 Discharge Case P2: Flow Rate of 95 m^3/day at 10 m Depth

Table 3.6 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	1.8 [11.3]	27.73	0.14	25	99	7.5
	Medium (0.16)	1.2 [10.8]	27.69	0.09	42	163	28.4
	Strong (0.33)	1.0 [10.5]	27.67	0.06	56	220	58.1
Transitional	Weak (0.05)	1.0 [9.5]	26.28	0.43	8	32	4.2
	Medium (0.18)	0.7 [9.9]	26.07	0.23	16	61	27.2
	Strong (0.38)	0.7 [10.0]	25.93	0.10	36	141	83.2
Winter	Weak (0.04)	0.7 [9.8]	27.36	0.12	3	12	1.8
	Medium (0.17)	0.8 [10.3]	26.41	0.18	19	76	41.3
	Strong (0.40)	0.7 [10.2]	26.34	0.11	32	127	67.1
Annual	Weak (0.04)	0.5 [10.0]	28.17	1.74	2	8	1.3
	Medium (0.17)	0.9 [10.4]	26.58	0.16	22	88	35.5
	Strong (0.37)	0.7 [10.2]	26.52	0.09	36	140	67.3

Table 3.7 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 99, 163 and 220, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		99x Dilution	163x Dilution	220x Dilution		
TPH	29	$2.9*10^{-1}$	$1.8*10^{-1}$	$1.3*10^{-1}$	0.07	414.3

Table 3.8 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 32, 61 and 141, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		32x Dilution	61x Dilution	141x Dilution		
TPH	29	$9.1*10^{-1}$	$4.8*10^{-1}$	$2.1*10^{-1}$	0.07	414.3

Table 3.9 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 12, 76 and 127, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		12x Dilution	76x Dilution	127x Dilution		
TPH	29	2.4	$3.8*10^{-1}$	$2.3*10^{-1}$	0.07	414.3

Table 3.10 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8, 88 and 140, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8x Dilution	88x Dilution	140x Dilution		
TPH	29	3.6	$3.3*10^{-1}$	$2.1*10^{-1}$	0.07	414.3

3.1.2.3 Discharge Case P3: Flow Rate of 95 m^3/day at 30 m Depth

Table 3.11 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.04)	1.7 [31.1]	27.29	0.17	20	79	7.9
	Medium (0.16)	1.1 [30.7]	27.23	0.10	34	134	28.9
	Strong (0.33)	0.9 [30.5]	27.21	0.08	48	186	58.5
Transitional	Weak (0.05)	1.4 [29.2]	25.66	0.25	14	57	6.01
	Medium (0.18)	0.9 [29.7]	25.55	0.15	25	99	30.3
	Strong (0.38)	0.8 [29.9]	25.49	0.09	41	160	75.2
Winter	Weak (0.04)	1.1 [29.5]	26.21	0.41	8	34	4.2
	Medium (0.17)	0.7 [29.9]	26.01	0.22	16	62	25.5
	Strong (0.40)	0.7 [30.0]	25.88	0.10	38	147	86.3
Annual	Weak (0.04)	0.9 [29.6]	26.61	0.62	6	23	2.9
	Medium (0.17)	0.6 [30.0]	26.31	0.33	11	43	19.8
	Strong (0.37)	0.8 [30.0]	26.05	0.07	46	181	122.7

Table 3.12 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 79, 134 and 186, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		79x Dilution	134x Dilution	186x Dilution		
TPH	29	$3.7*10^{-1}$	$2.2*10^{-1}$	$1.6*10^{-1}$	0.07	414.3

Table 3.13 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 57, 99 and 160, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		57x Dilution	99x Dilution	160x Dilution		
TPH	29	$5.1*10^{-1}$	$2.9*10^{-1}$	$1.8*10^{-1}$	0.07	414.3

Table 3.14 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 34, 62 and 147, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		34x Dilution	62x Dilution	147x Dilution		
TPH	29	$8.5*10^{-1}$	$4.7*10^{-1}$	$2.0*10^{-1}$	0.07	414.3

Table 3.15 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 23, 43 and 181, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		23x Dilution	43x Dilution	181x Dilution		
TPH	29	1.3	$6.7*10^{-1}$	$1.6*10^{-1}$	0.07	414.3

3.1.3 Results – Figures

3.1.3.1 Flow Rate of 95 m^3/day at Varying Depths

3.1.3.1.1 Annualised

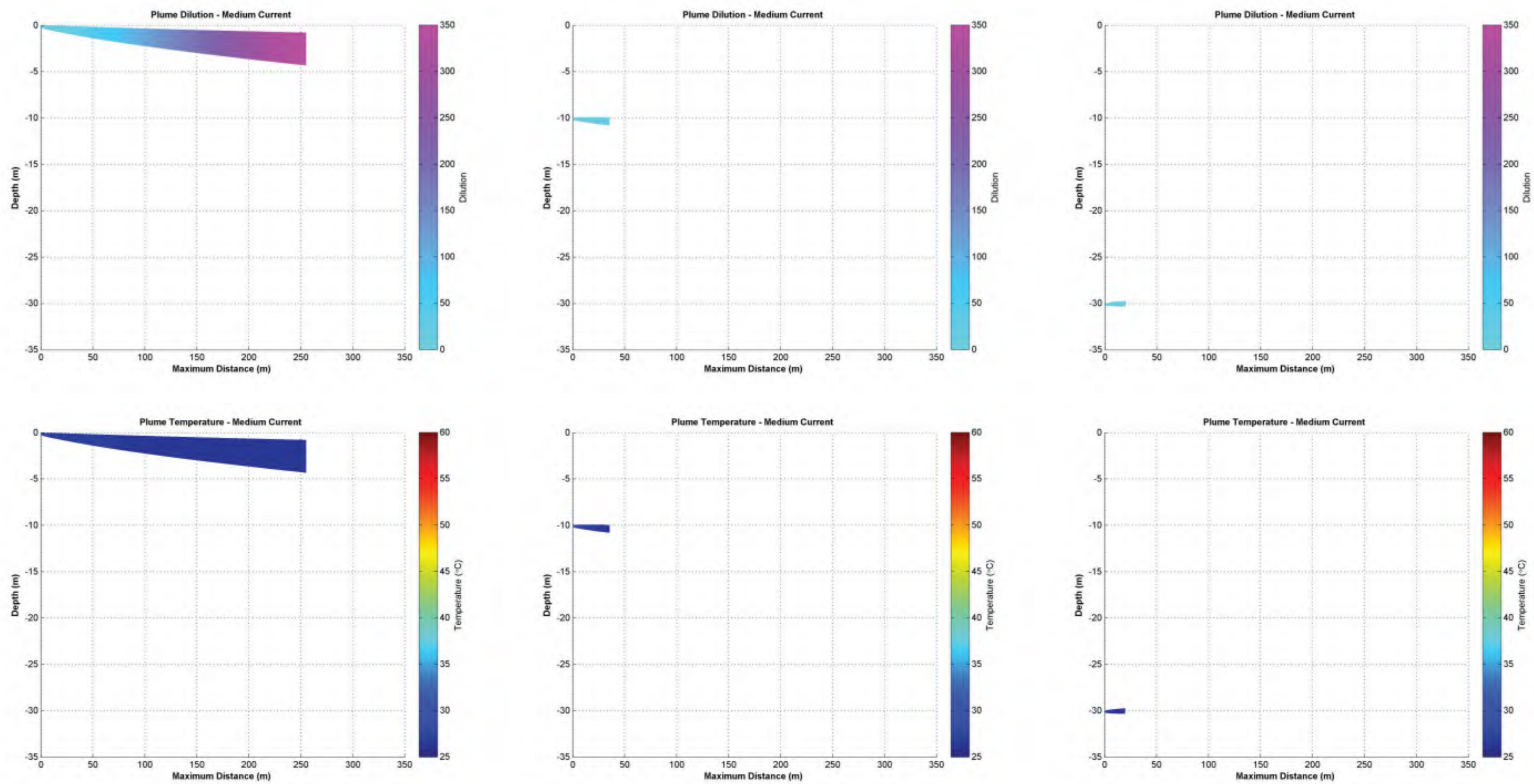

Figure 3.1 **Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

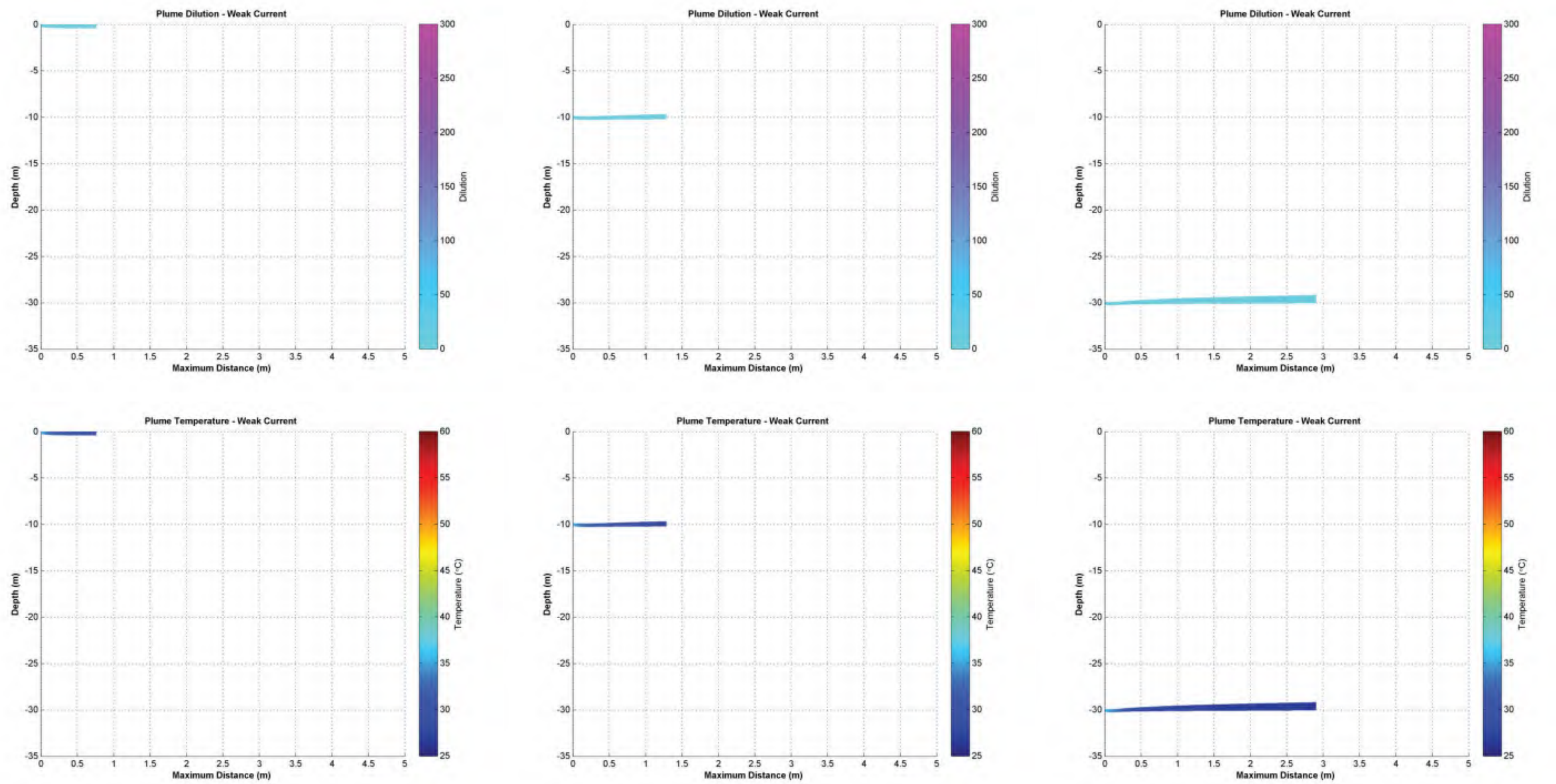

Figure 3.2 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

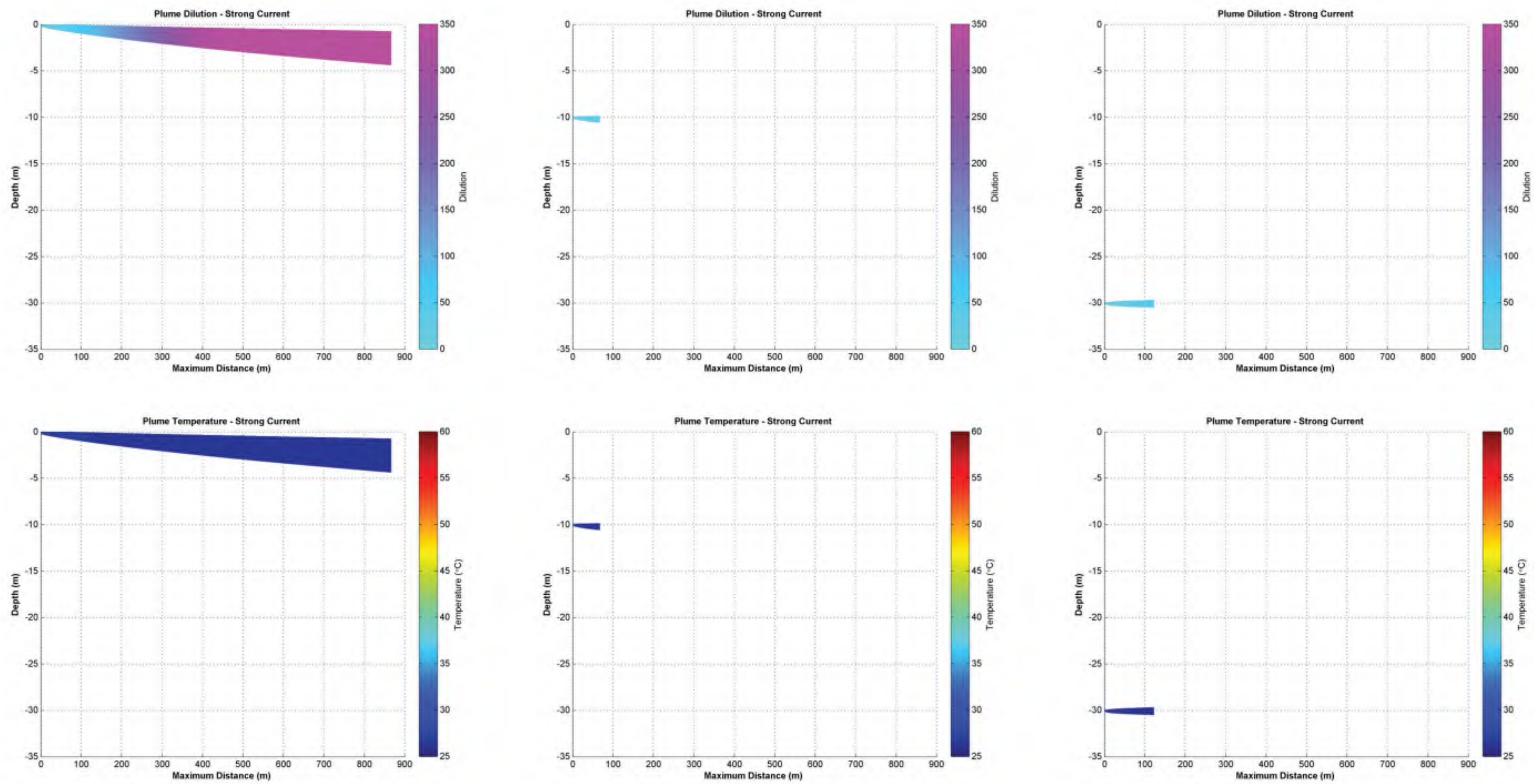

Figure 3.3 Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

3.1.3.1.2 Summer

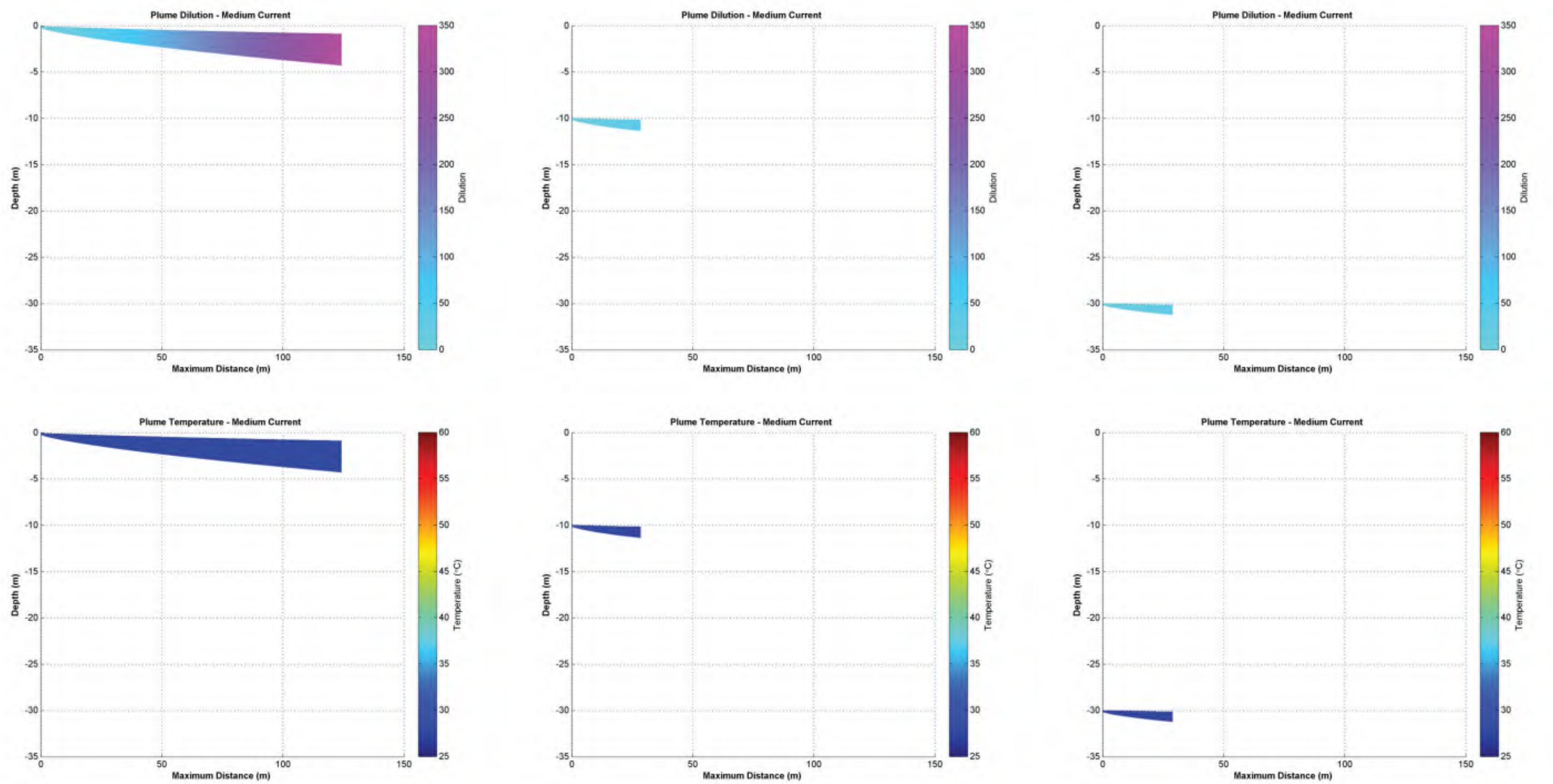

Figure 3.4 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

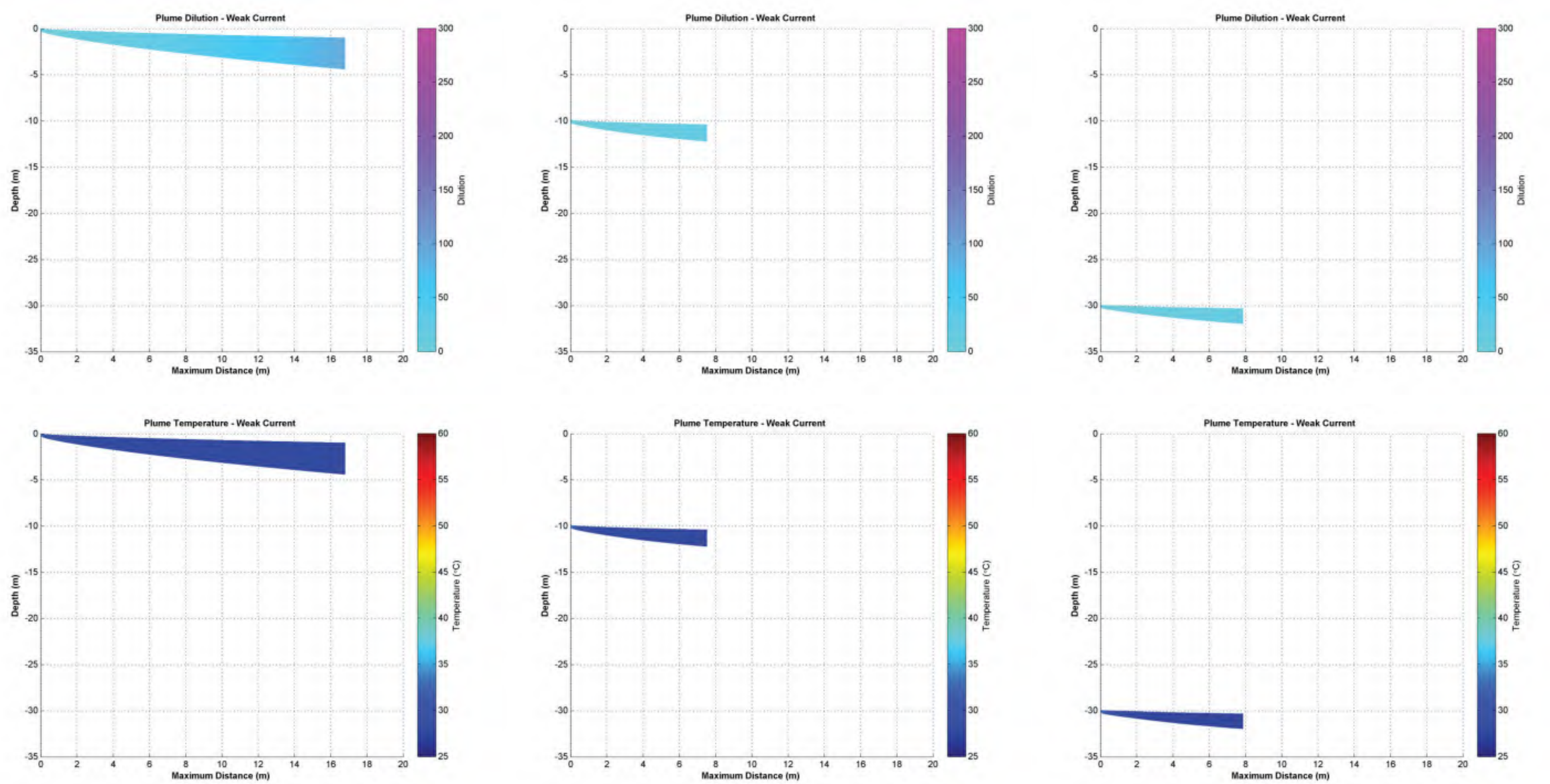

Figure 3.5 Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

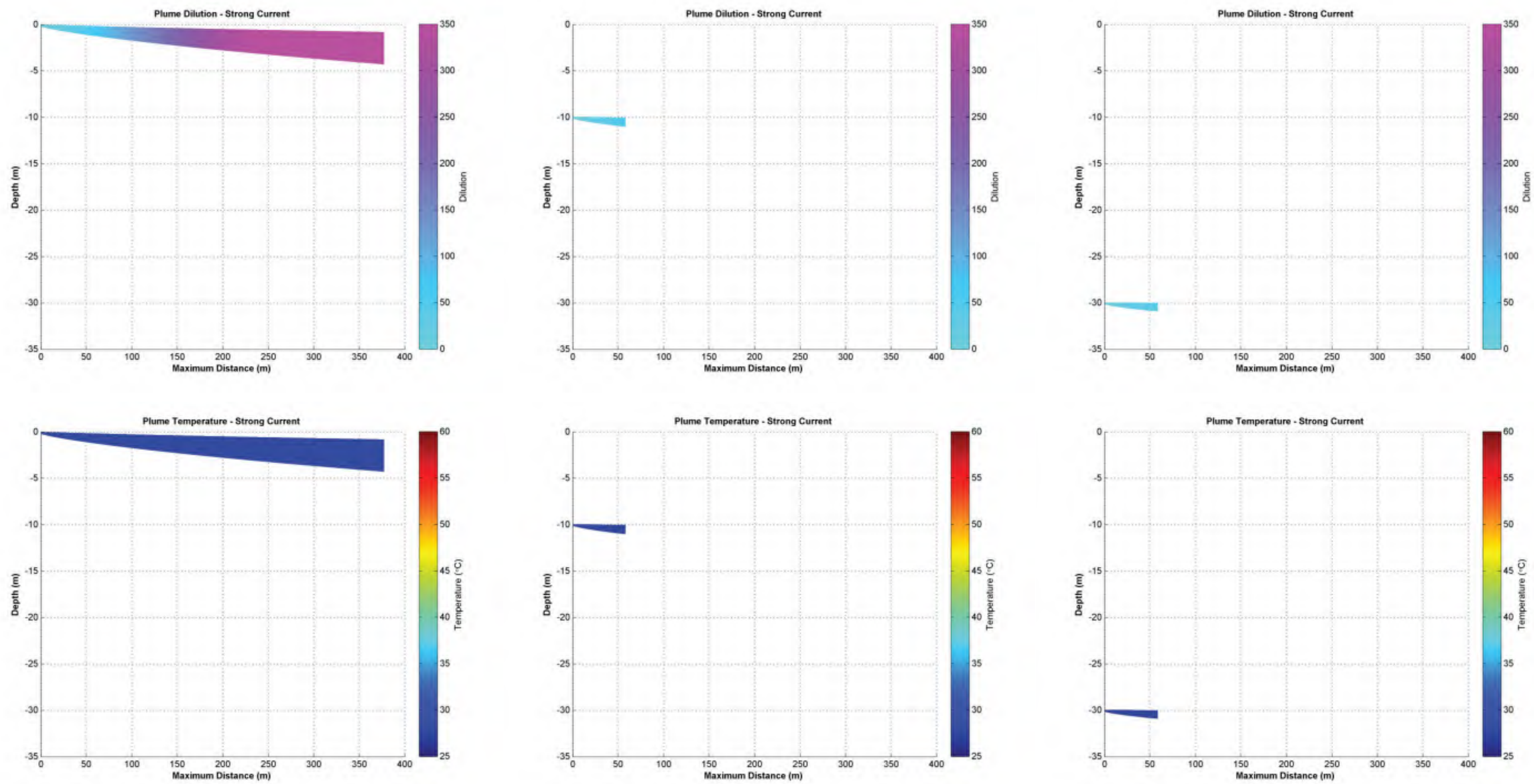

Figure 3.6 Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

3.1.3.1.3 Transitional

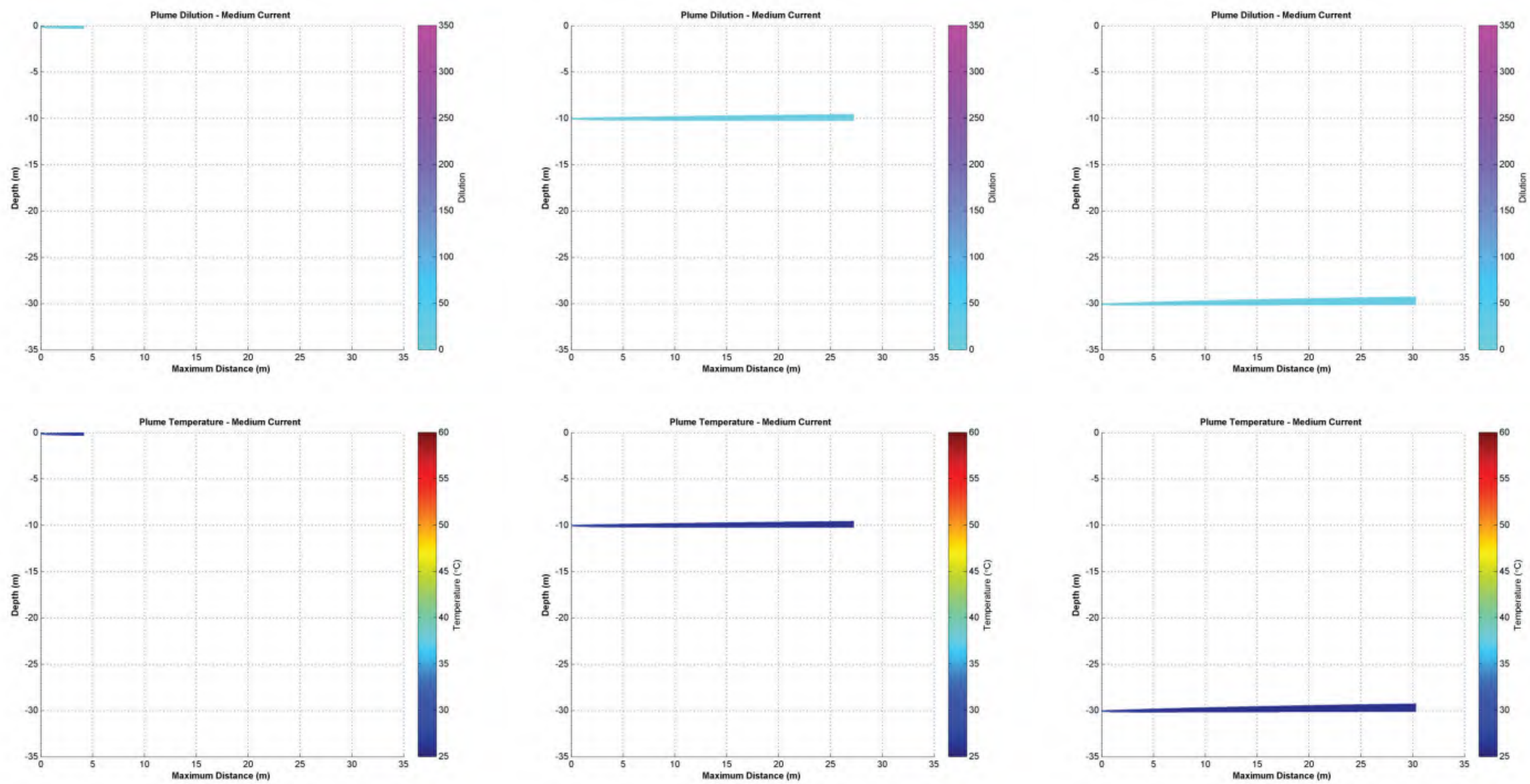

Figure 3.7 **Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

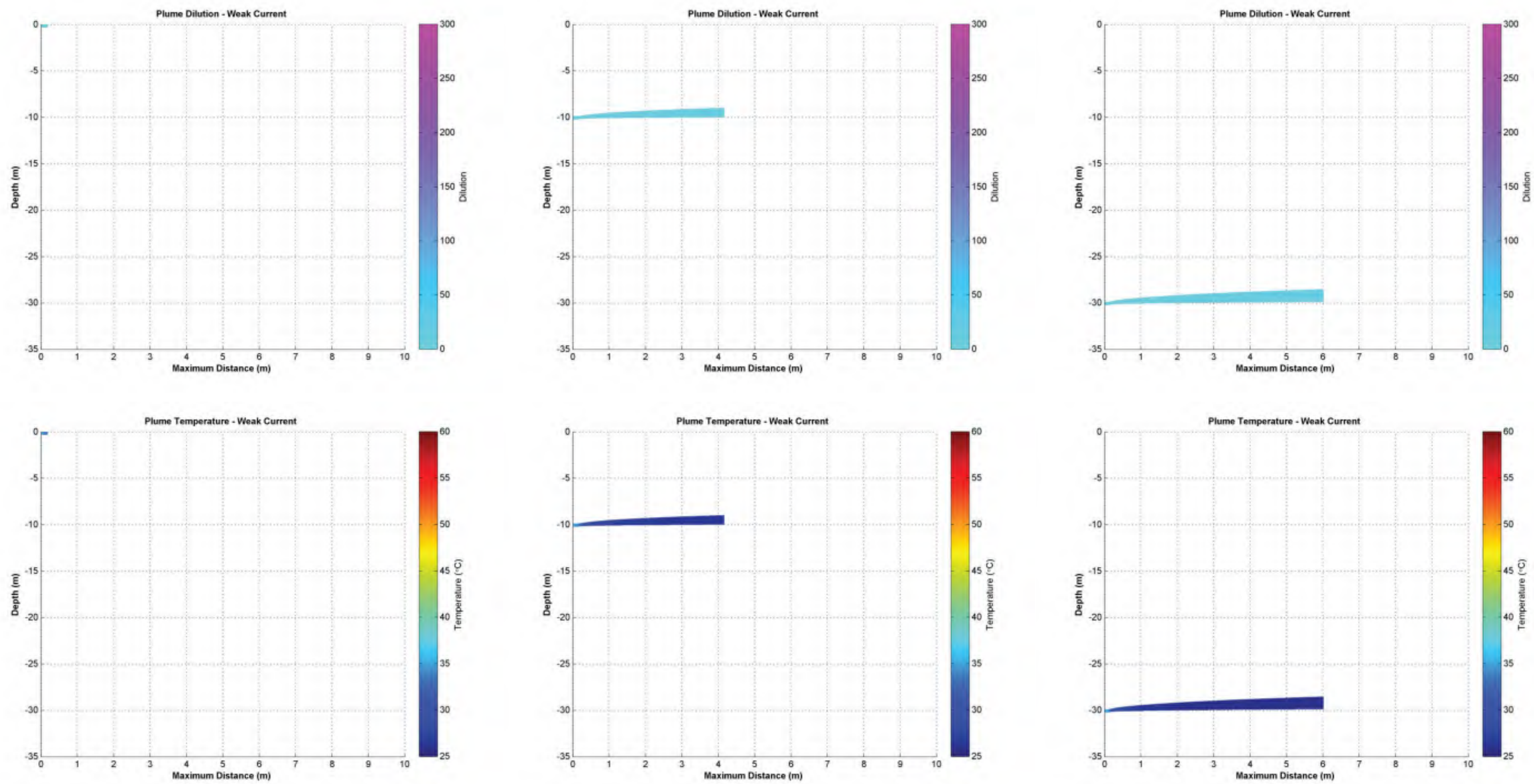

Figure 3.8 **Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

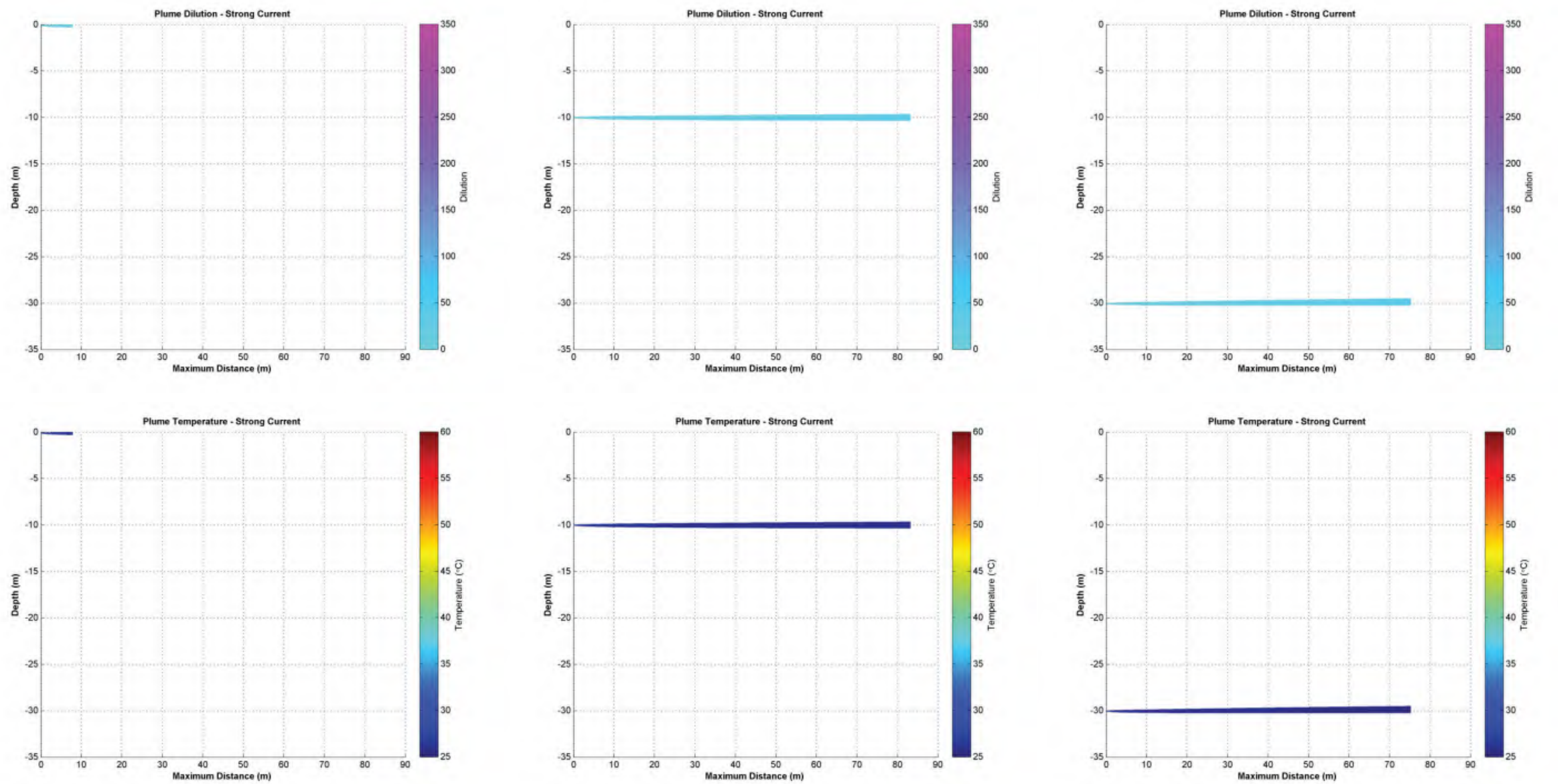

Figure 3.9 Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

3.1.3.1.4 Winter

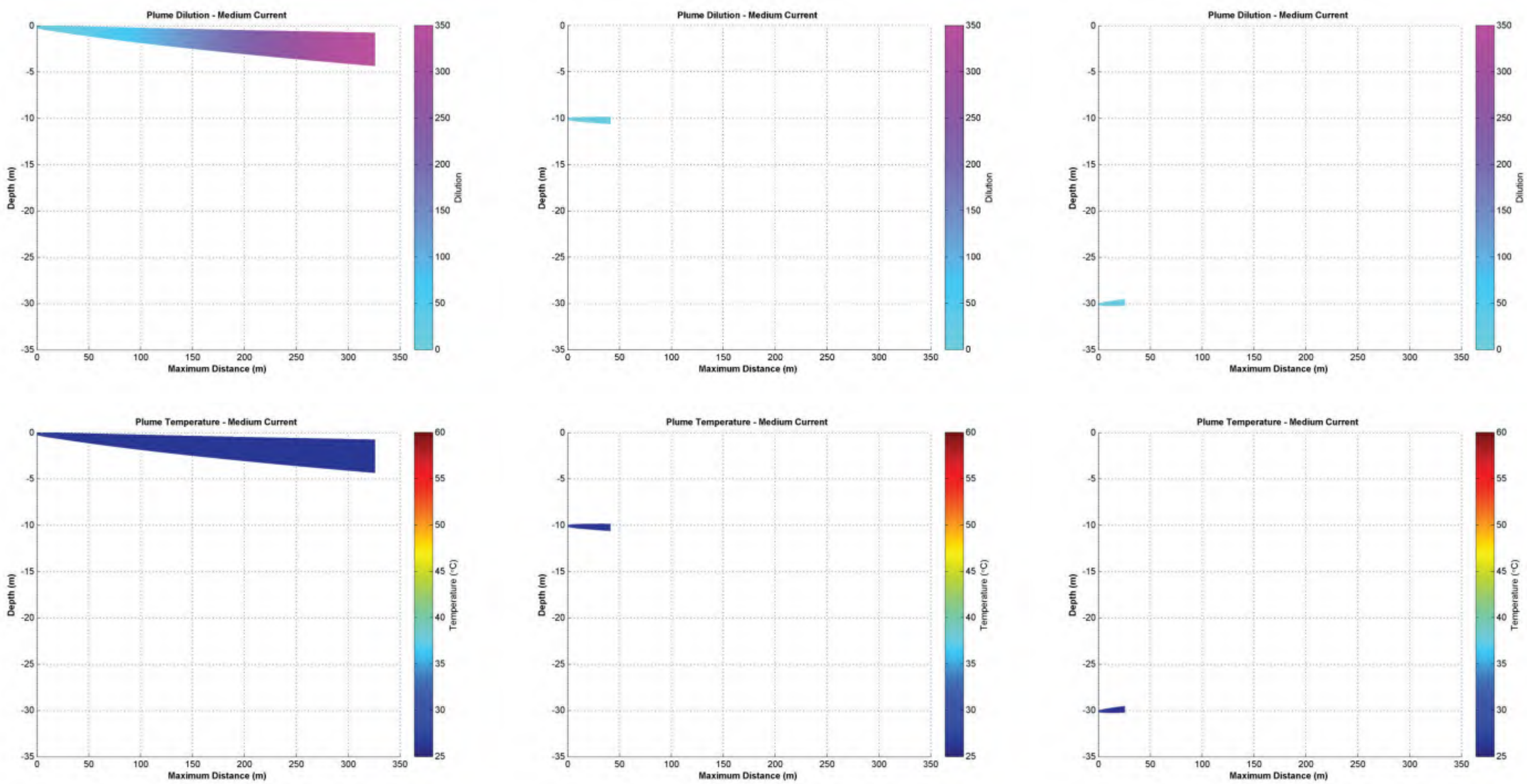

Figure 3.10 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

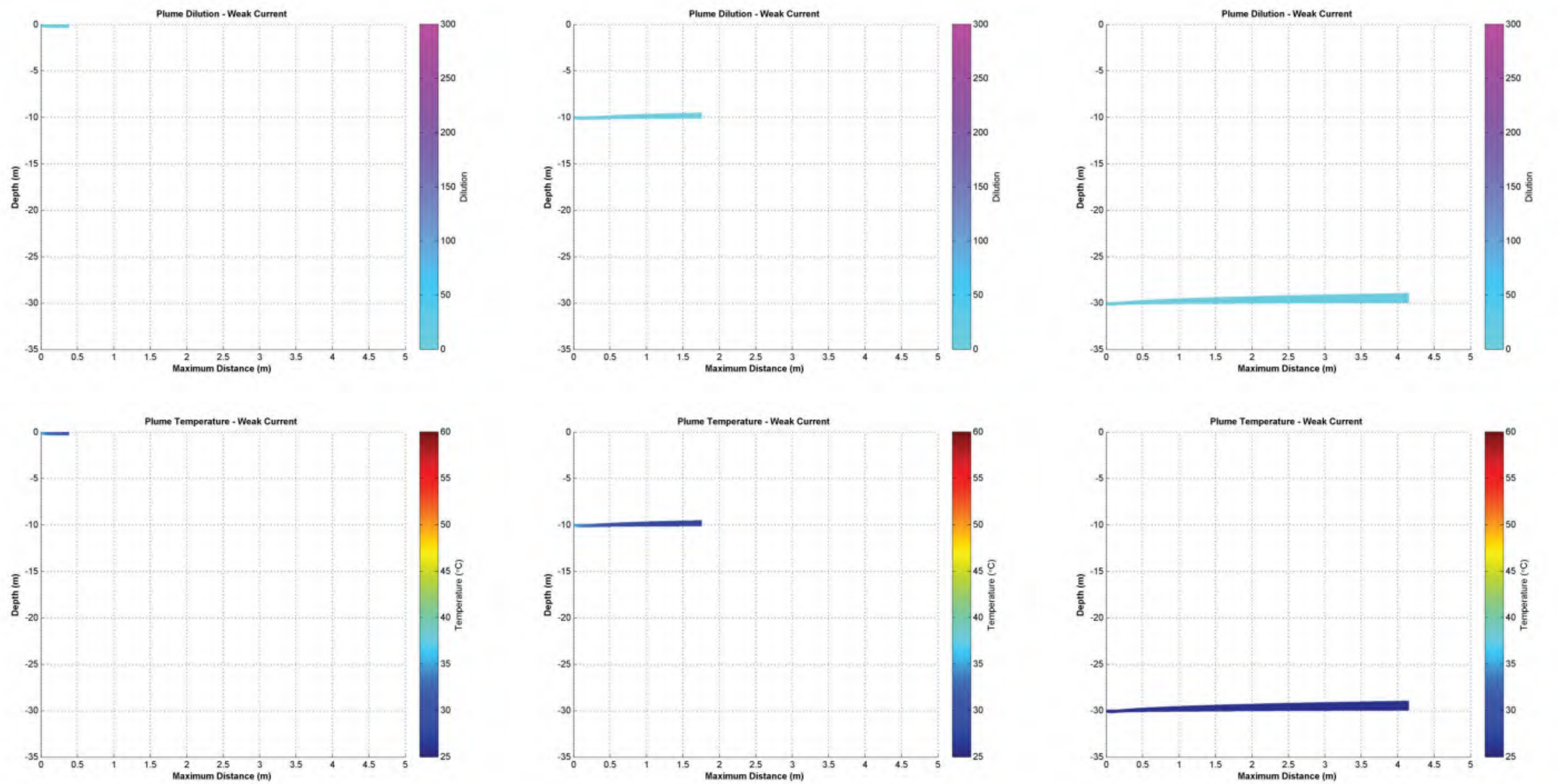

Figure 3.11 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

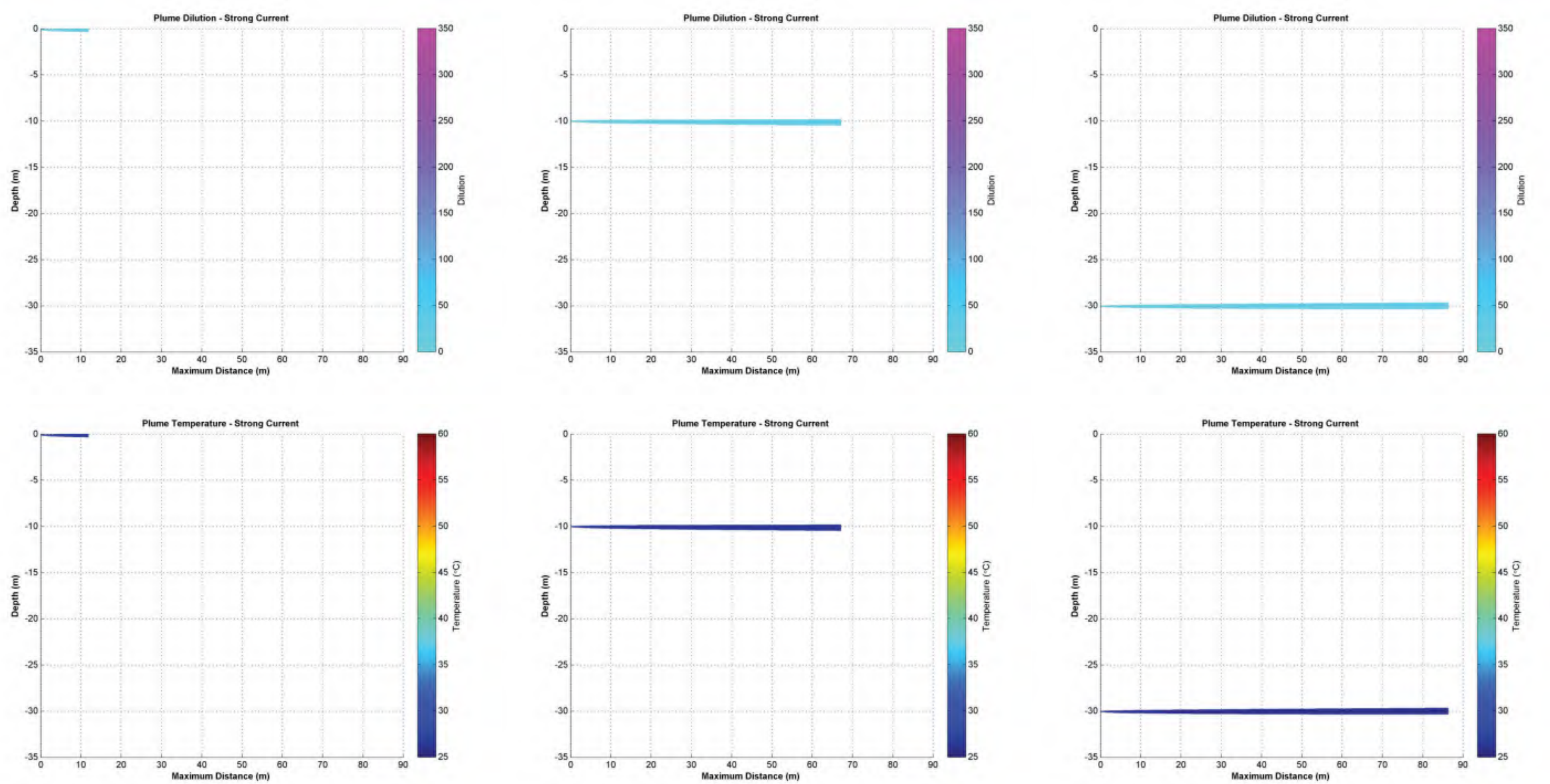

Figure 3.12 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

3.2 Far-Field Modelling

3.2.1 Overview

It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario. The far-field results included episodes of pooling of the discharge plume under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location when the pooled plume was advected away. Episodes of recirculation – where the plume moved back under the discharge at some later time due to the oscillatory nature of the tide – were also observed, compounding the pooling effect and further lowering the dilution values.

3.2.2 Interpretation of Percentile Dilution Contours

For each of the modelled discharge cases, the results for all simulations were combined and a statistical analysis performed to produce percentile contours of dilution. In the following sections, outcomes based on 95^{th} and 99^{th} percentile dilution contours are presented.

Calculation of 95^{th} and 99^{th} percentile statistics is a common approach to assessing the impact of dispersing plumes and captures the variability in outcomes, for all but the most ephemeral and extreme forcing conditions, in the data set under consideration. Impact assessment criteria for water quality are often defined using similar statistical indicators.

Note that the percentile figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that particular dilution values occur across all replicate simulations and time steps. For example, if the 95^{th} percentile minimum dilution at a particular location in the model domain is predicted as a value of 100, this means that for 95% of the time the dilution level will be higher than 100 and for only 5% of the time the dilution level will be lower than 100. A comparison of the plume extents shown in Figure 3.13 with those shown in Sections 3.2.4 and 3.2.5 demonstrates the significant difference between an instantaneous snapshot and a cumulative estimate of coverage over several days and many individual simulations.

Dilution contours are calculated from the ratios of dispersing contaminant concentrations in the receiving waters to the initial concentration of the contaminant in the discharge. Note that this assumes the background concentration of the constituent in the receiving waters is zero and there is no significant biodegradation of the discharged constituent over the short duration of the dispersion process.

Table 3.16 summarises the initial concentrations of TPH, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200 and 1:400). These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

Table 3.16 Initial concentrations of TPH and equivalent concentrations at example dilution levels.

TPH Parameter	TPH Concentration (mg/L)
Initial concentration in discharge	29.0
Initial concentration in receiving waters	0.0
Concentration at 1:100 dilution	0.29
Concentration at 1:200 dilution	0.145
Concentration at 1:400 dilution	0.0725

3.2.3 General Observations

Figure 3.13 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 10:00 on 29th December 2008 to 01:00 on 30th December 2008. This simulation – selected merely to be representative of typical conditions – considers the Case P1 discharge at 0 m BMSL. The spatially-varying orientation of the plume with the currents and the rapidly-varying nature of the concentrations around the source can be observed. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

These snapshots illustrate that the dilutions (and in turn concentrations) become more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) are predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume has a more continuous appearance, with higher-concentration patches moving as a unified group. These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.

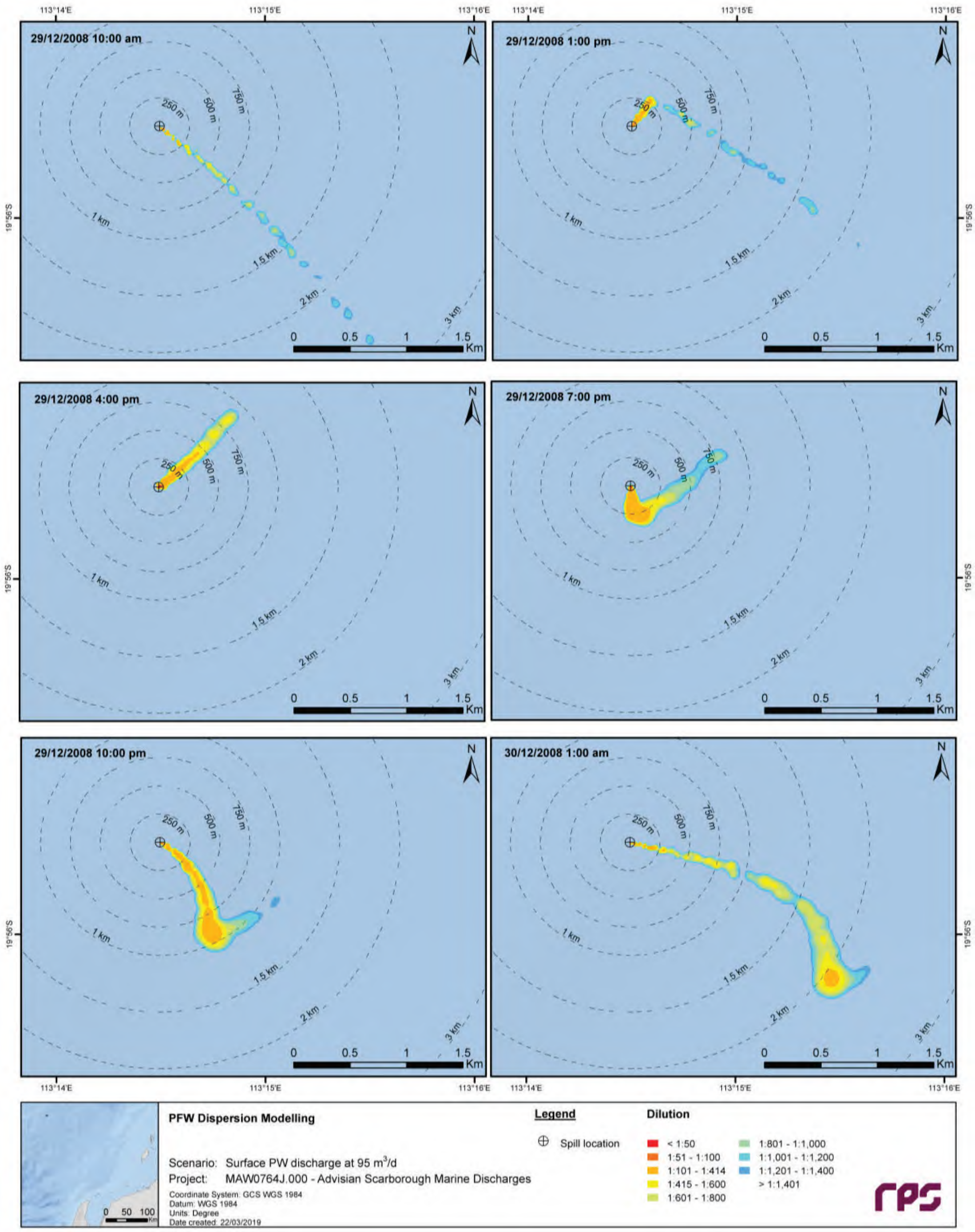

Figure 3.13 Snapshots of predicted dilution levels, at 3-hour intervals from 10:00 on 29th December 2008 to 01:00 on 30th December 2008, for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

3.2.4 Seasonal Analysis

The model outputs over the ten-year hindcast period (2006-2015) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to surrounding sensitive receptors whilst considering inter-annual variability in ocean current conditions.

Table 3.17 and Table 3.18 summarise, for Cases P1 and P3 respectively, the minimum dilution achieved at specific radial distances from the discharge location for each season and percentile.

Table 3.19 and Table 3.20 provide, for Cases P1 and P3 respectively, summaries of the maximum distances from the discharge location to achieve 1:414 dilution for each season and percentile. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion within the ambient environment. For Case P1, dilution to reach threshold concentration is achieved for TPH within an area of influence ranging from 181 m to 221 m at the 95th percentile across all seasons (Table 3.19). For Case P3, the maximum spatial extents of the relevant dilution contour vary from 184 m to 229 m at the 95th percentile across all seasons (Table 3.20). The greatest spatial extents are observed in winter.

Table 3.21 and Table 3.22 provide, for Cases P1 and P3 respectively, summaries of the total area of coverage for the 1:414 dilution contour for each season and percentile. For Case P1, the area of exposure defined by the relevant dilution contour is predicted to reach maximums of 0.03 km^2 to 0.04 km^2 at the 95th percentile (Table 3.21). For Case P3, the corresponding maximum areas of exposure vary from 0.03 km^2 to 0.07 km^2 at the 95th percentile (Table 3.22).

Table 3.23 and Table 3.24 provide, for Cases P1 and P3 respectively, summaries of the maximum depths from the discharge location to achieve 1:414 dilution for each season and percentile. Maximum depths are observed in winter, with predictions of 5 m and 33 m for Case P1 and Case P3, respectively.

For Cases P1 and P3, Figure 3.14 to Figure 3.25 show the aggregated spatial extents of the minimum dilutions for each season and percentile. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

Table 3.17 Minimum dilution achieved at specific radial distances from the PW discharge location in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Summer	1:79.2	1:148.3	1:256.9	1:459.5	1:607.7	1:793.0	1:884.7	1:1,050.1	1:1,309.4	1:1,386.7	1:1,789.6	1:1,904.4
	Transitional	1:79.3	1:145.4	1:242.6	1:414.6	1:600.5	1:790.5	1:1,004.8	1:1,221.4	1:1,429.3	1:1,606.9	1:1,931.5	1:2,150.9
	Winter	1:73.4	1:149.4	1:232.7	1:394.5	1:512.1	1:646.6	1:767.1	1:973.7	1:1,094.8	1:1,287.1	1:1,442.2	1:1,606.2
99th	Summer	1:46.6	1:87.6	1:146.5	1:239.4	1:310.1	1:389.3	1:452.1	1:532.2	1:604.6	1:662.5	1:752.2	1:829.3
	Transitional	1:47.6	1:86.4	1:144.5	1:226.1	1:286.1	1:366.0	1:436.0	1:509.9	1:587.9	1:646.4	1:716.0	1:760.1
	Winter	1:64.9	1:107.2	1:187.5	1:317.0	1:381.7	1:522.9	1:550.6	1:643.5	1:785.5	1:837.8	1:912.2	1:1,033.8

Table 3.18 Minimum dilution achieved at specific radial distances from the PW discharge location in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Summer	1:67.8	1:142.2	1:246.1	1:426.6	1:592.1	1:778.0	1:930.0	1:1,123.1	1:1,219.0	1:1,411.4	1:1,537.3	1:1,665.0
	Transitional	1:69.1	1:135.2	1:252.9	1:447.6	1:611.5	1:808.7	1:949.0	1:1,099.4	1:1,281.0	1:1,443.8	1:1,622.0	1:1,729.4
	Winter	1:57.3	1:133.4	1:226.5	1:385.0	1:513.3	1:681.2	1:825.9	1:1,002.6	1:1,227.7	1:1,445.2	1:1,534.8	1:1,860.0
99th	Summer	1:42.9	1:87.7	1:142.0	1:225.8	1:297.3	1:361.4	1:431.9	1:479.0	1:521.9	1:578.4	1:598.9	1:666.9
	Transitional	1:43.7	1:83.5	1:143.1	1:236.6	1:302.9	1:375.4	1:434.6	1:517.9	1:552.4	1:605.8	1:665.7	1:687.6
	Winter	1:37.6	1:76.2	1:123.5	1:187.5	1:232.9	1:272.0	1:277.7	1:307.6	1:381.1	1:408.7	1:474.9	1:496.6

Table 3.19 Maximum distance from the PW discharge location to achieve 1:414.3 dilution in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	181
	Transitional	194
	Winter	221
99th	Summer	426
	Transitional	452
	Winter	543
100th	Summer	2,190
	Transitional	3,231
	Winter	3,005

Table 3.20 Maximum distance from the PW discharge location to achieve 1:414.3 dilution in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	191
	Transitional	184
	Winter	229
99th	Summer	482
	Transitional	432
	Winter	810
100th	Summer	3,244
	Transitional	3,244
	Winter	3,406

Table 3.21 Total area of coverage for 1:414.3 dilution in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.033
	Transitional	0.034
	Winter	0.042
99th	Summer	0.301
	Transitional	0.340
	Winter	0.419
100th	Summer	1.973
	Transitional	2.266
	Winter	3.313

Table 3.22 Total area of coverage for 1:414.3 dilution in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.046
	Transitional	0.034
	Winter	0.065
99th	Summer	0.370
	Transitional	0.348
	Winter	0.623
100th	Summer	4.673
	Transitional	5.204
	Winter	3.406

Table 3.23 Maximum depth from the PW discharge location to achieve 1:414.3 dilution in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	4
Transitional	4
Winter	5

Table 3.24 Maximum depth from the PW discharge location to achieve 1:414.3 dilution in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	33
Transitional	33
Winter	34

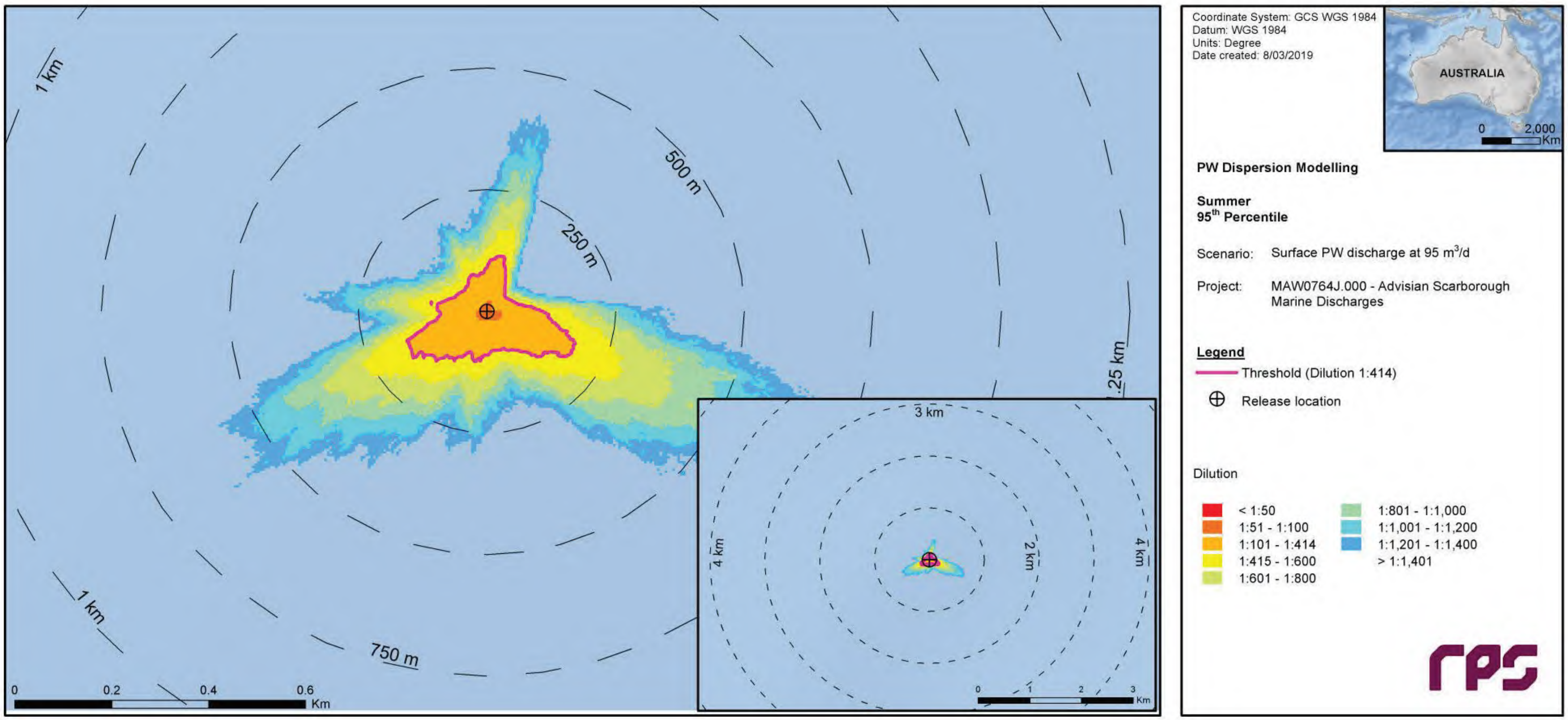

Figure 3.14 Predicted minimum dilutions at the 95th percentile under summer conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

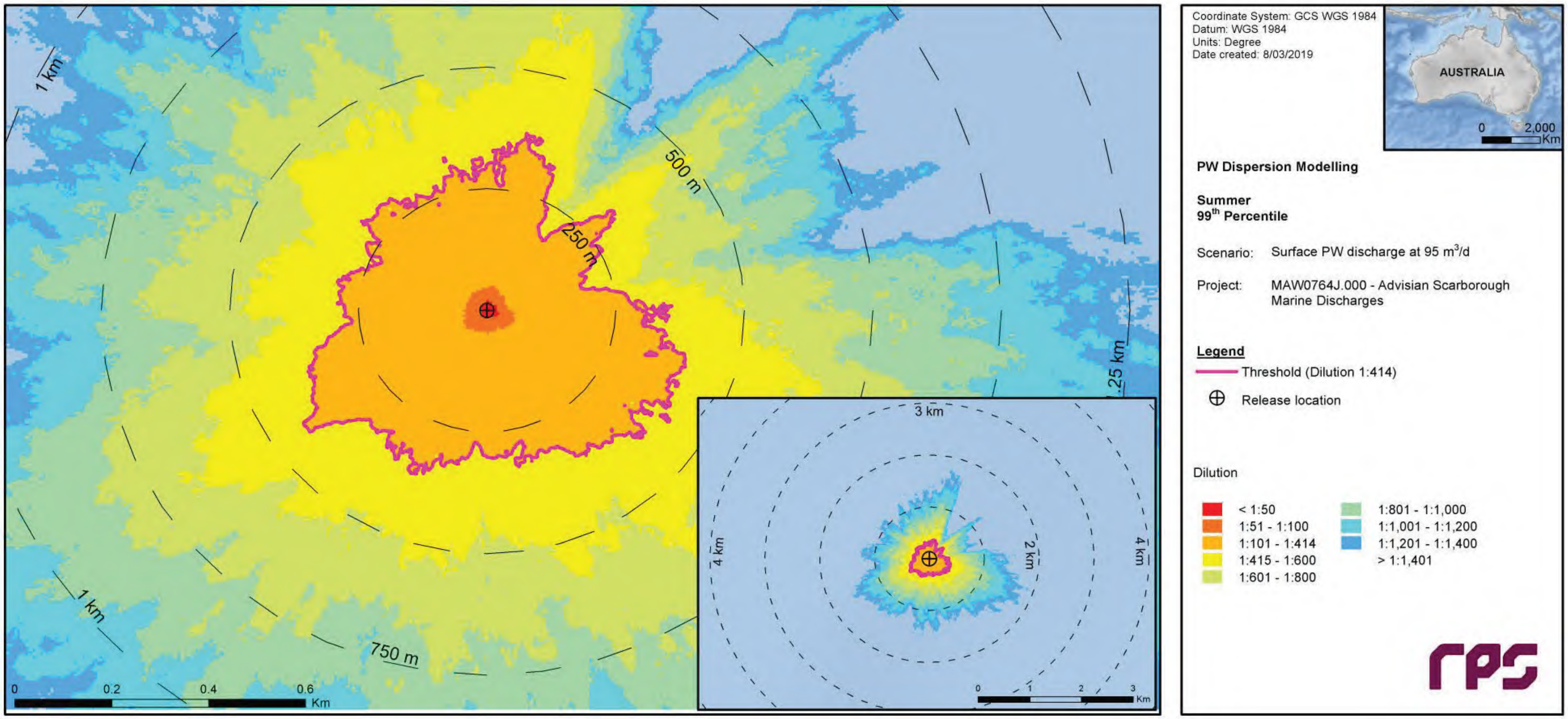

Figure 3.15 Predicted minimum dilutions at the 99th percentile under summer conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

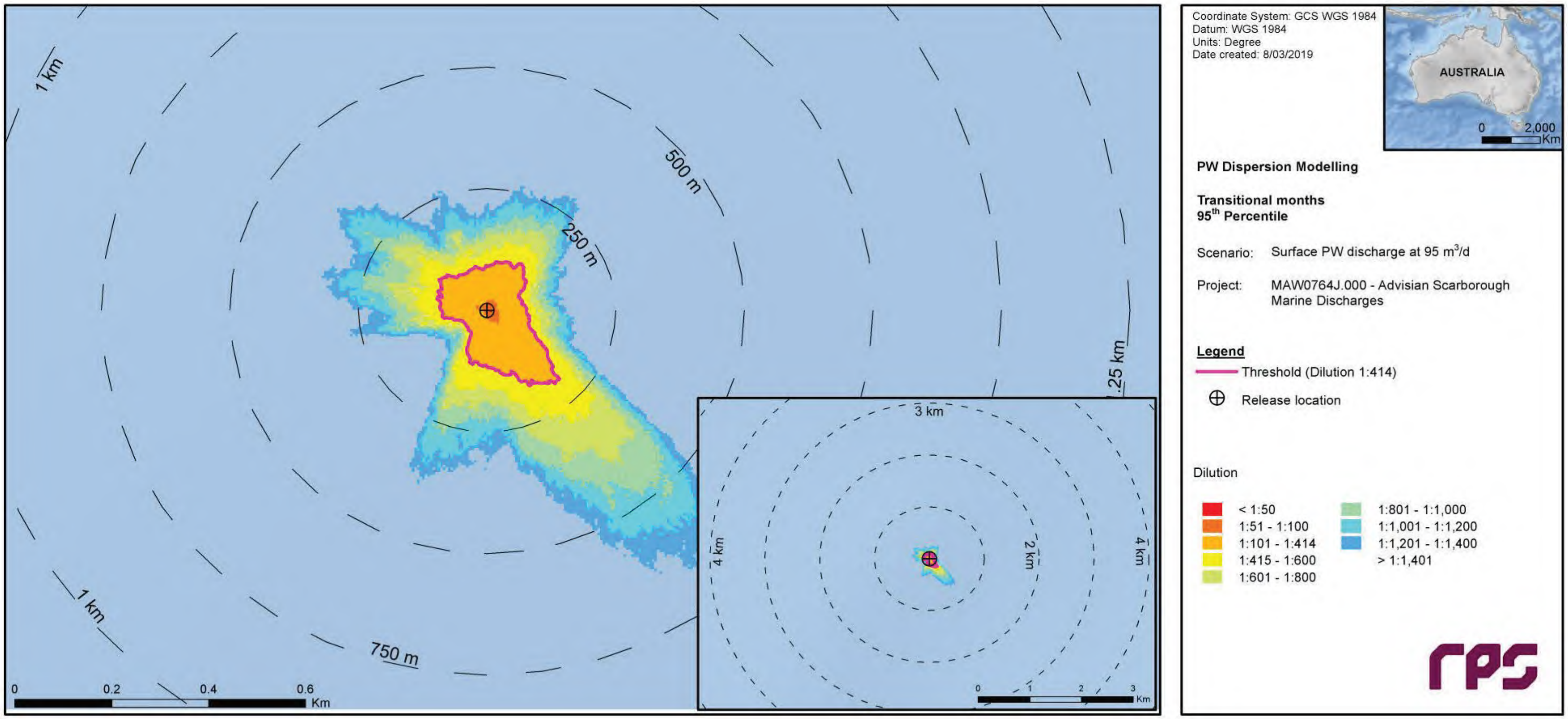

Figure 3.16 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

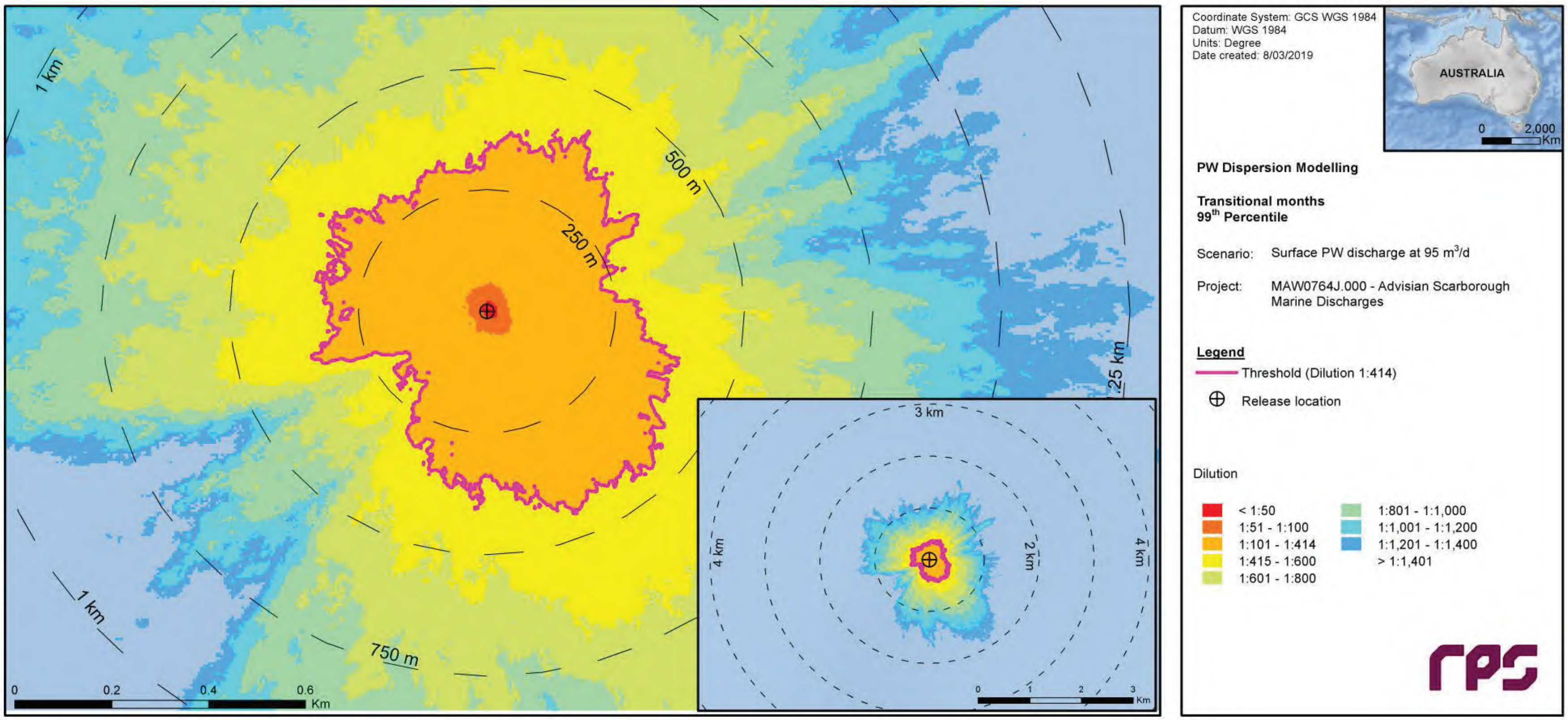

Figure 3.17 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

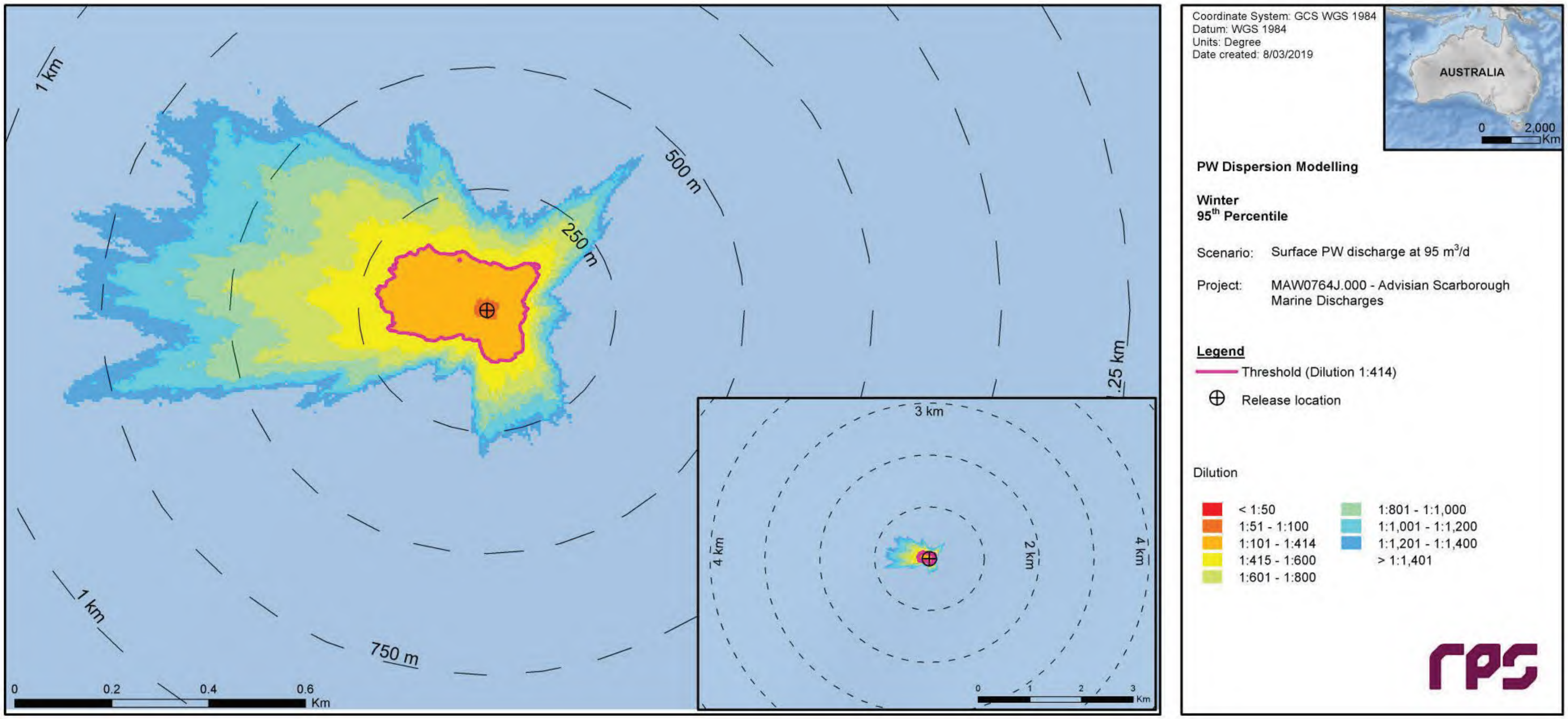

Figure 3.18 Predicted minimum dilutions at the 95th percentile under winter conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

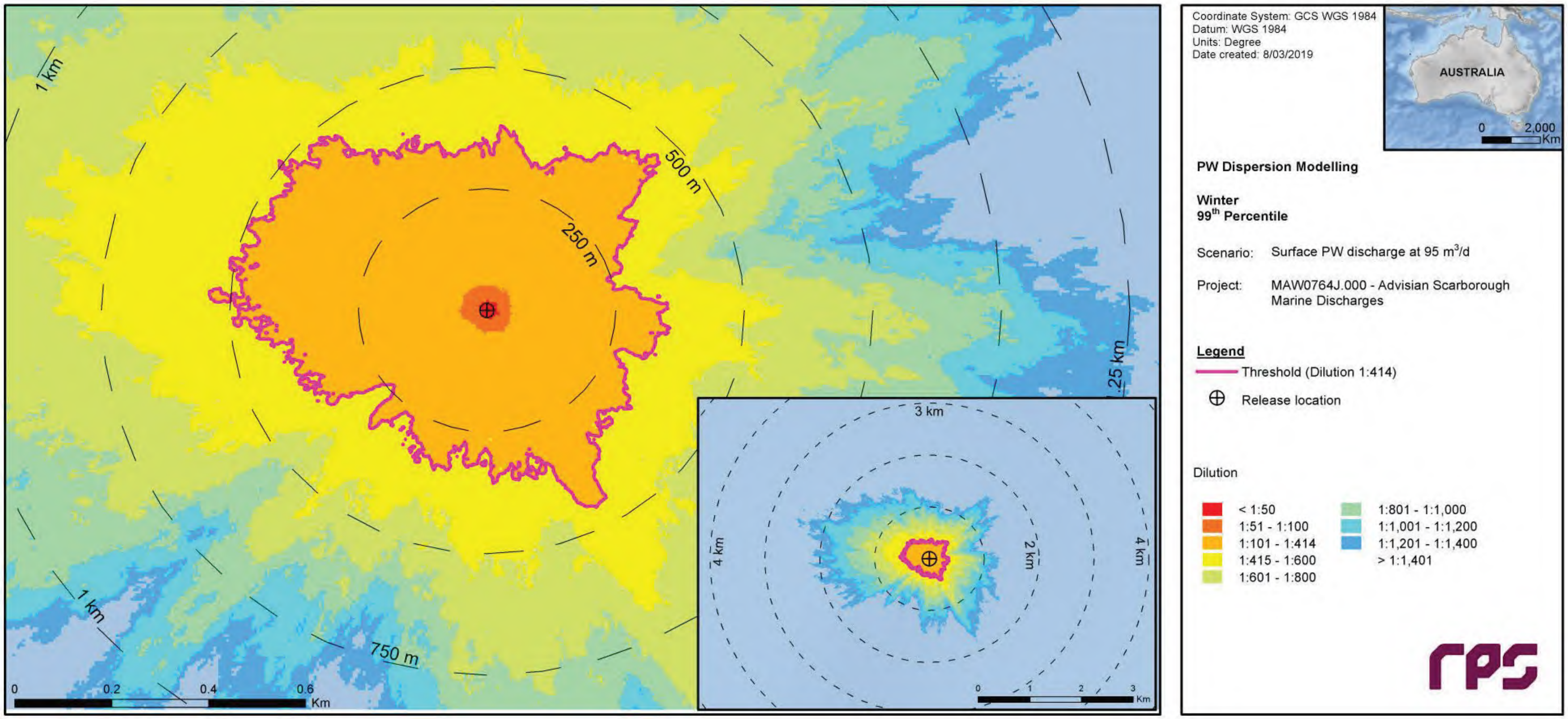

Figure 3.19 Predicted minimum dilutions at the 99th percentile under winter conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

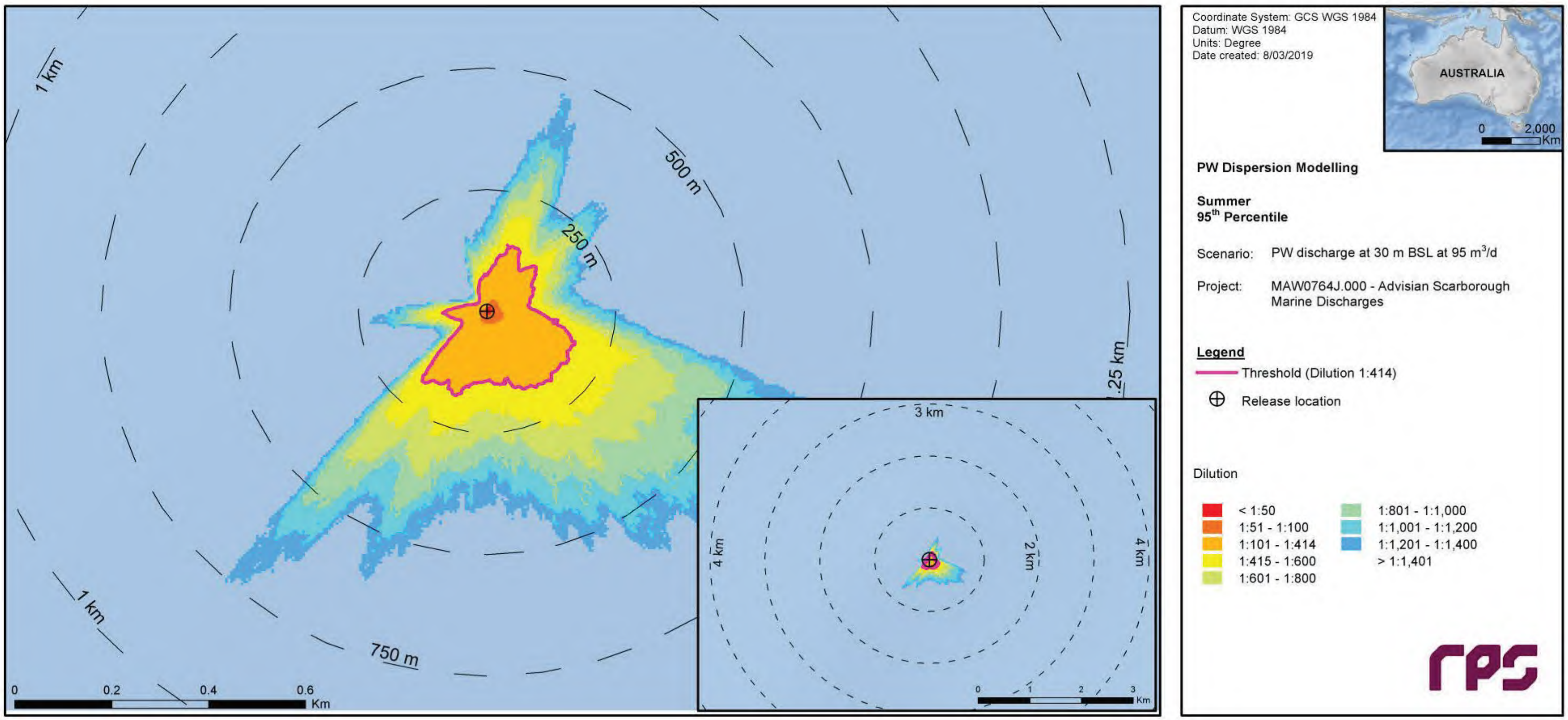

Figure 3.20 Predicted minimum dilutions at the 95th percentile under summer conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

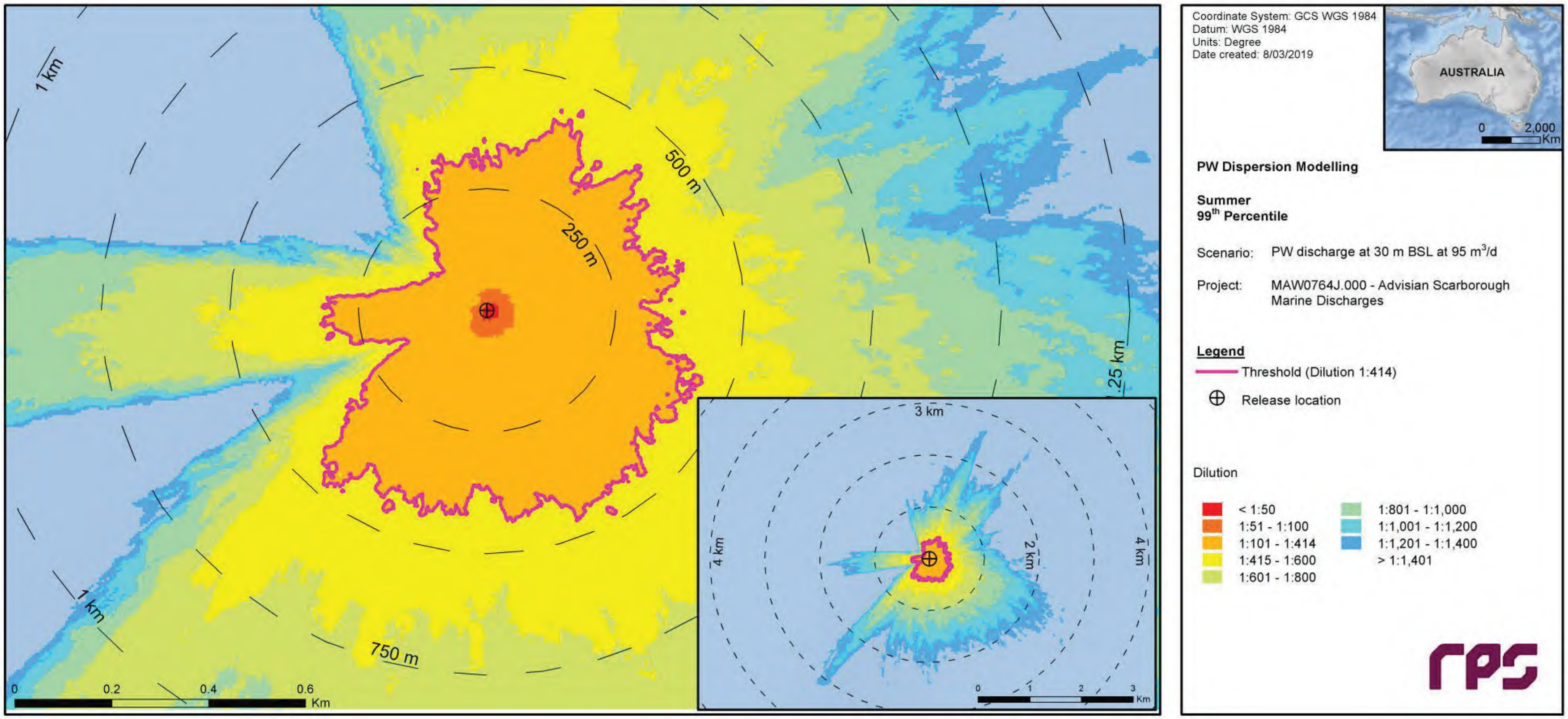

Figure 3.21 Predicted minimum dilutions at the 99th percentile under summer conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

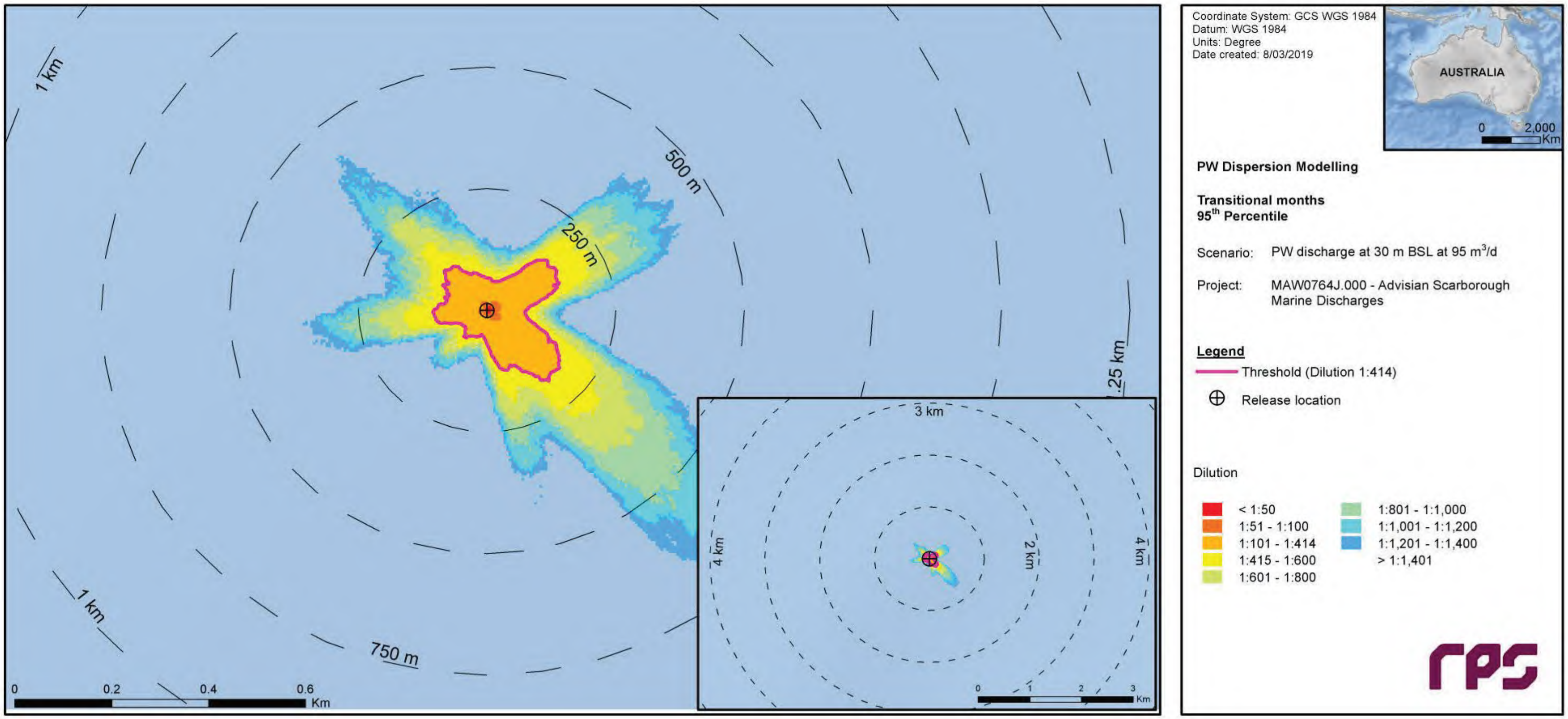

Figure 3.22 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

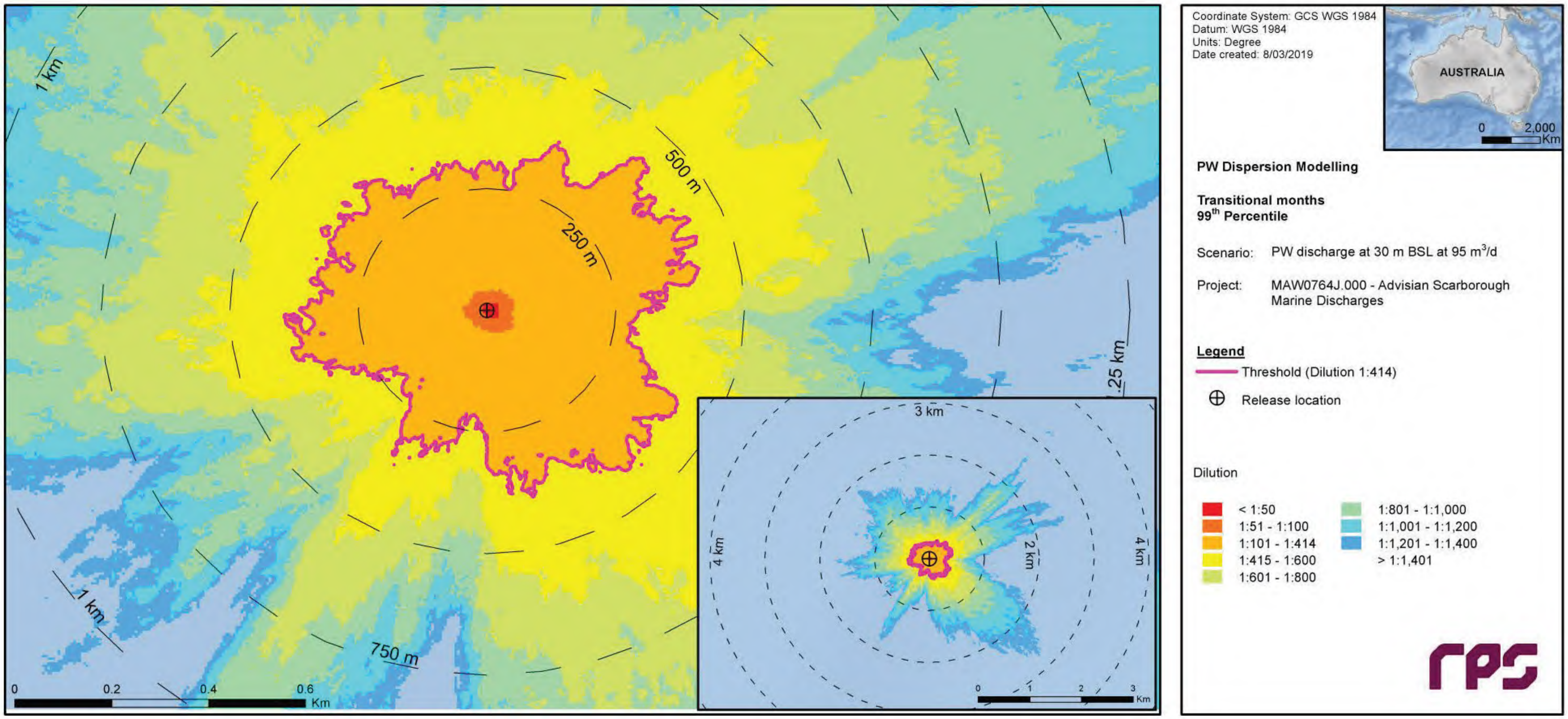

Figure 3.23 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

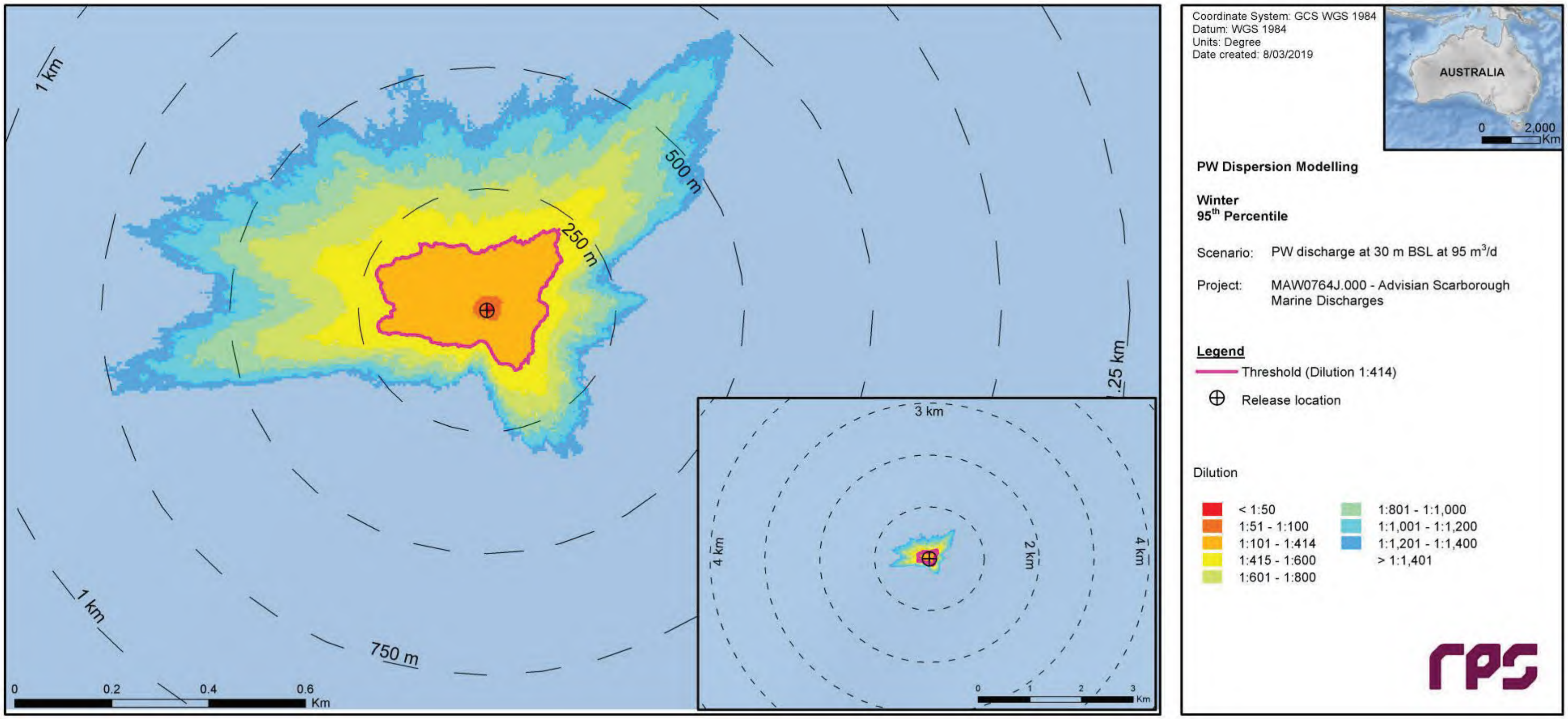

Figure 3.24 Predicted minimum dilutions at the 95th percentile under winter conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

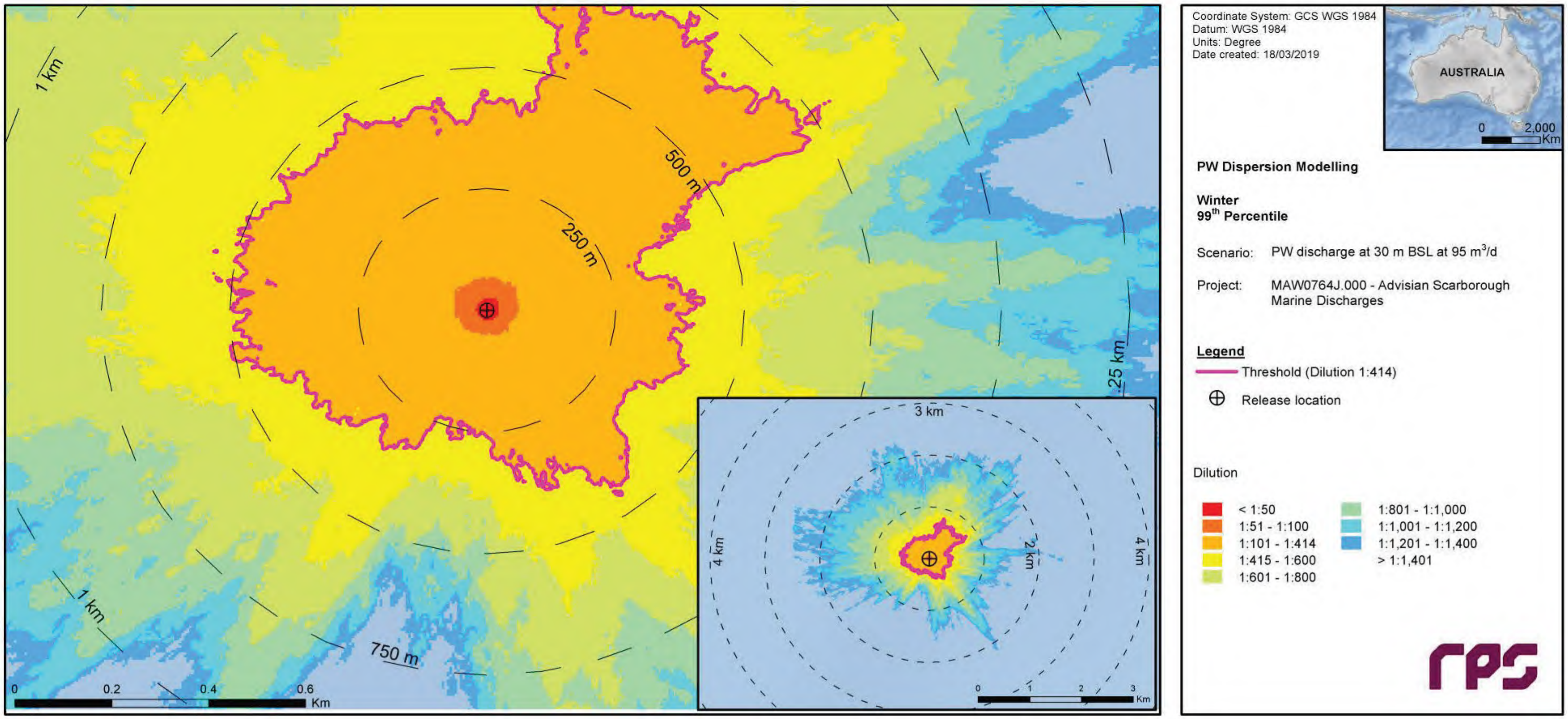

Figure 3.25 Predicted minimum dilutions at the 99th percentile under winter conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

3.2.5 Annualised Analysis

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2006-2015) were combined and analysed on an annualised basis.

Table 3.25 and Table 3.26 summarise, for Cases P1 and P3 respectively, the minimum dilution achieved at specific radial distances from the discharge location for each percentile over the annual period.

Table 3.27 and Table 3.28 provide, for Cases P1 and P3 respectively, summaries of the annualised maximum distances from the discharge location to achieve 1:414 dilution for each percentile. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion within the ambient environment. Dilution to reach threshold concentration is achieved for TPH within a maximum area of influence of 543 m (Case P1) and 810 m (Case P3) at the 99^{th} percentile, this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season.

Table 3.29 and Table 3.30 provide, for Cases P1 and P3 respectively, summaries of the total area of coverage for the 1:414 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach maximum values of 0.48 km^2 (Case P1) and 0.70 km^2 (Case P3) at the 99^{th} percentile in any season.

For Cases P1 and P3, Figure 3.26 to Figure 3.29 show the aggregated spatial extents of the minimum dilutions for each percentile. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

Table 3.25 Annualised minimum dilution achieved at specific radial distances from the PW discharge location for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Annual	1:79.2	1:145.4	1:232.7	1:394.5	512.1	1:646.6	1:767.1	1:973.7	1:1,094.8	1:1,287.1	1:1,442.2	1:1,606.2
99th		1:46.6	1:86.4	1:144.5	1:144.5	1:286.1	1:366.0	1:436.0	1:509.9	1:587.9	1:646.4	1:716	1:760.1

Table 3.26 Annualised minimum dilution achieved at specific radial distances from the PW discharge location for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Annual	1:57.3	1:133.4	1:226.5	1:385.0	1:513.3	1:681.2	1:825.9	1:1,002.6	1:1,219.0	1:1,411.4	1:1,534.8	1:1,860.0
99th		1:37.6	1:76.2	1:123.5	1:187.5	1:232.9	1:272.0	1:277.7	1:381.1	1:381.1	1:408.7	1:474.9	1:496.6

Table 3.27 Annualised maximum distance from the PW discharge location to achieve 1:414.3 dilution for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95^{th}	Annual	221
99^{th}		543
100^{th}		3,231

Table 3.28 Annualised maximum distance from the PW discharge location to achieve 1:414.3 dilution for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95^{th}	Annual	229
99^{th}		810
100^{th}		3,406

Table 3.29 Annualised total area of coverage for 1:414.3 dilution for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95^{th}	Annual	0.067
99^{th}		0.479
100^{th}		4.014

Table 3.30 Annualised total area of coverage for 1:414.3 dilution for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95^{th}	Annual	0.087
99^{th}		0.702
100^{th}		9.910

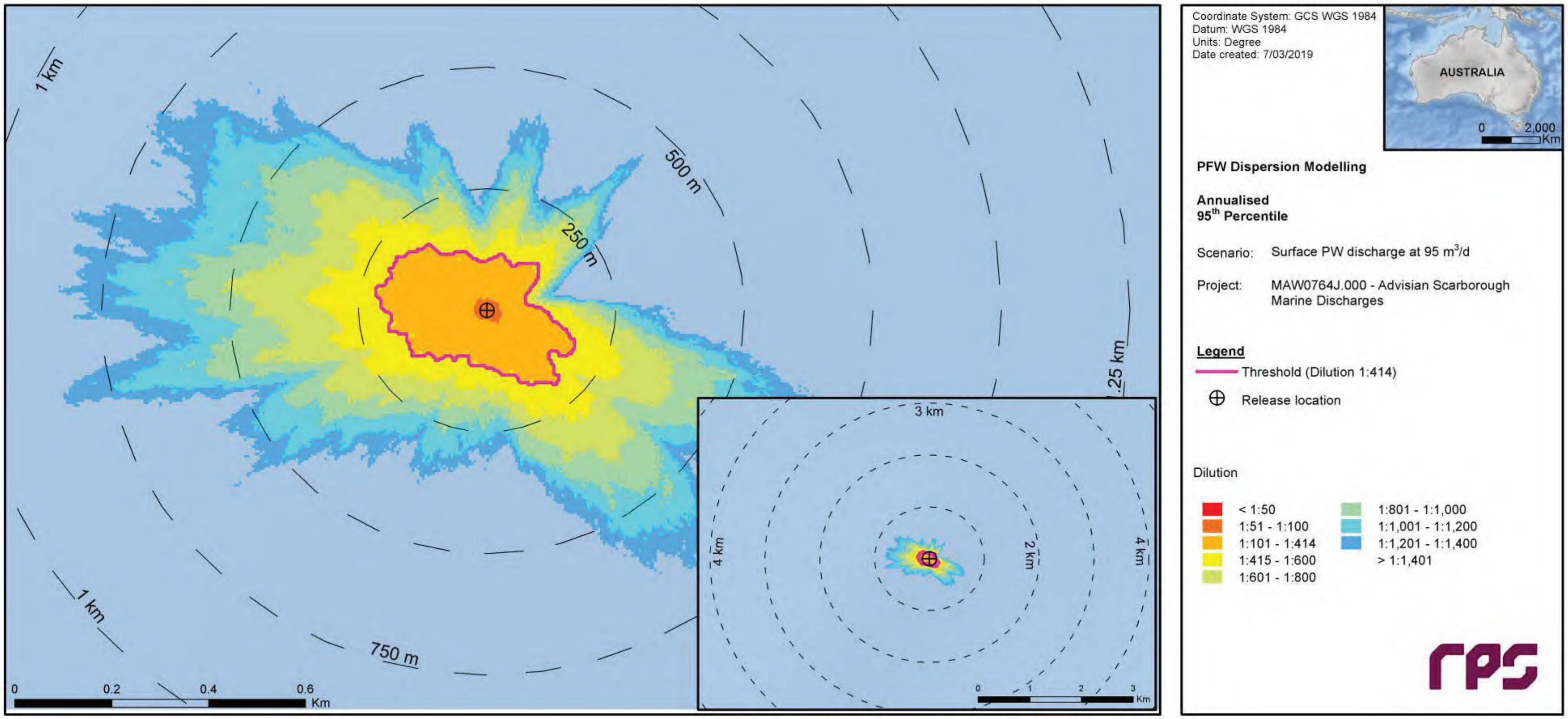

Figure 3.26 Predicted annualised minimum dilutions at the 95th percentile for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

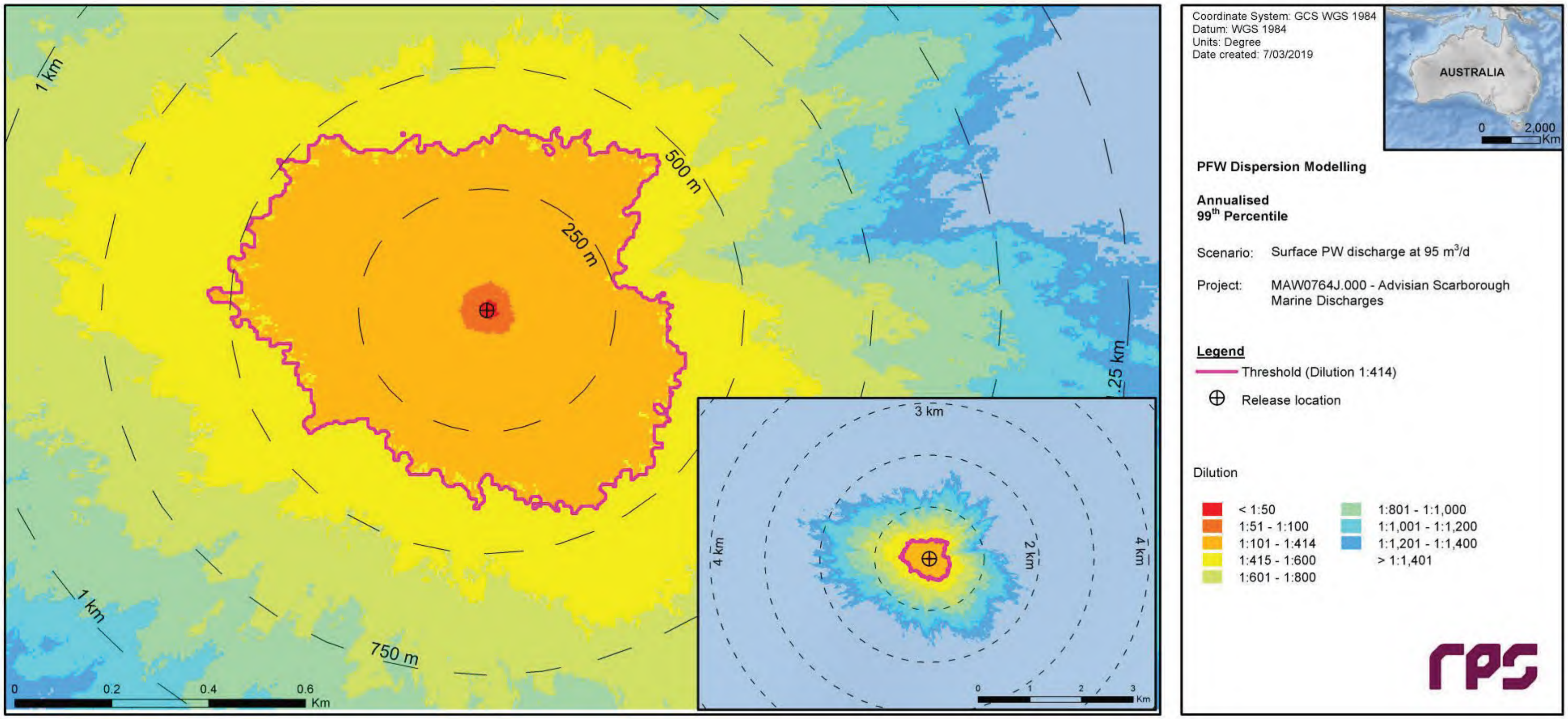

Figure 3.27 Predicted annualised minimum dilutions at the 99th percentile for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

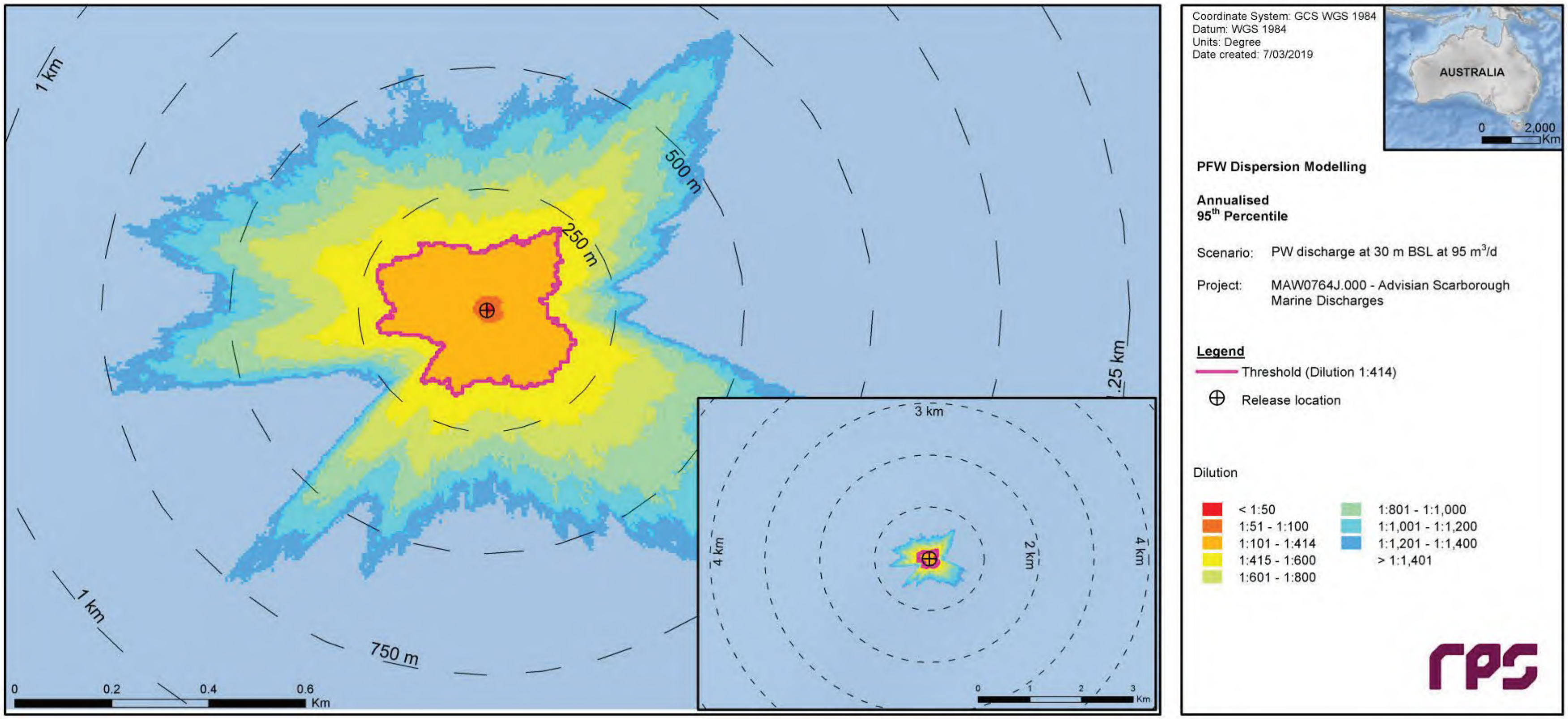

Figure 3.28 Predicted annualised minimum dilutions at the 95th percentile for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

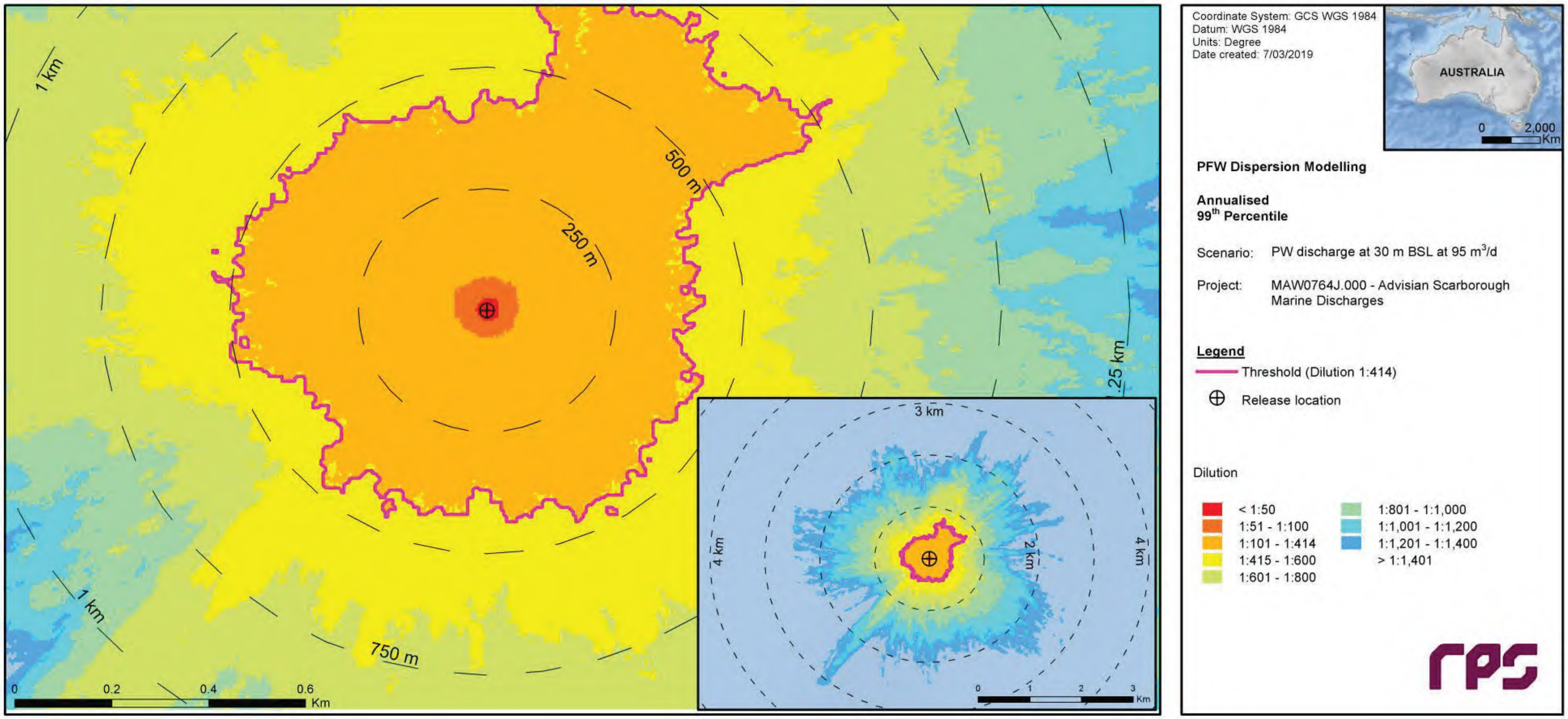

Figure 3.29 Predicted annualised minimum dilutions at the 99th percentile for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

4 CONCLUSIONS

The main findings of the study are as follows:

Near-Field Modelling

- The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 0 m, 10 m and 30 m below the water surface (Cases P1, P2 and P3, respectively). The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column.
- For Case P1, the plume is predicted to plunge up to 4.4 m below the sea surface. For Cases P2 and P3, the plumes are predicted to remain at approximately the discharge depth: up to 11 m below the surface for Case P2 and up to 31 m below the surface for Case P3.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For a discharge at a 95 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 0 m depth as 255 m. The dilution level for this case is predicted as 1:1,519.
- The maximum diameter of the plume at the end of the near-field zone was predicted as 3.7 m for Case P1, 1.8 m for Case P2 and 1.7 m for Case P3. Increases in current speed serve to restrict the diameter of the plume.
- For each discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.
- The average dilution levels of the plume upon reaching the trapping depth under average current speeds are predicted to be 1:1,519 for Case P1, 1:88 for Case P2 and 1:43 for Case P3. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under average current speeds are predicted to be 1:390 for Case P1, 1:22 for Case P2 and 1:11 for Case P3.
- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.
- The results for the Case P1, P2 and P3 discharges indicate that the TPH constituent of the PW discharge is not expected to reach the required levels of dilution in the near field mixing zone.

Far-Field Modelling

- For Case P1, dilution to reach threshold concentration is achieved for TPH within an area of influence extending up to 543 m at the 99th percentile. For Case P3, the maximum spatial extents of the relevant dilution contour are up to 810 m at the 99th percentile.

- For Case P1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum of 0.48 km^2 at the 99th percentile. For Case P3, the corresponding maximum area of exposure is up to 0.70 km^2 at the 99th percentile.
- Maximum depths reached by the discharges are predicted as 5 m and 33 m for Cases P1 and P3, respectively.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents will promote the highest levels of mixing and dilution.
- Because the discharge will be initially negatively buoyant, it will sink in the water column and even a surface discharge is unlikely to resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.

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