Perth Seawater Desalination Plant 2 Construction Impact Assessment

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BMT Eastern Australia Pty Ltd Level 8, 200 Creek Street Brisbane Qld 4000 Australia PO Box 203, Spring Hill 4004 Tel: +61 7 3831 6744 Fax: + 61 7 3832 3627 ABN 54 010 830 421 www.bmt.org	**Document:**	R.B22253.004.Construction_Impact_Assessment.02.docx
	Title:	Perth Seawater Desalination Plant 2 Construction Impact Assessment
	Project Manager:	Michael Barry
	Author/s:	Ian Teakle, Jonah Chorley
	Client:	Water Corporation
	Client Contact:	Bree Atkinson
	Client Reference:	N/A

Synopsis: This report is an assessment of Perth Seawater Desalination Plant expansion pipeline trenching plumes.

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1 Introduction

1.1 Background

Water Corporation propose to construct a second seawater desalination plant – Perth Seawater Desalination Plant 2 (PSDP2) - adjacent to the existing Perth Seawater Desalination Plant to increase the amount of supply from climate independent sources. The existing Perth Seawater Desalination Plant (PSDP1) is located at Kwinana Industrial Area on the Eastern Shore of Cockburn Sound, receiving intake water and discharging its brine effluent to Cockburn Sound. The proposed PSDP2 will require dredging works associated with the installation of the intake and outfall pipes.

The PSDP2 dredging requirements have been assessed and summarised in a BMT technical note (Tn-WAT_1334_10_003-02, 12/03/2019). The proposed works are:

- Dredging of separate intake and outlet pipe trenches ~180,341m^3.
- Installation of intake & outlet pipes.
- Placement of rock protection, pea gravel & armour rock ~59,521m^3.
- Backfilling pipe trench with sand fill ~79,260m^3.

Potential marine impacts from the proposed construction works have been identified. Adverse impacts which may be caused by dredging activity include:

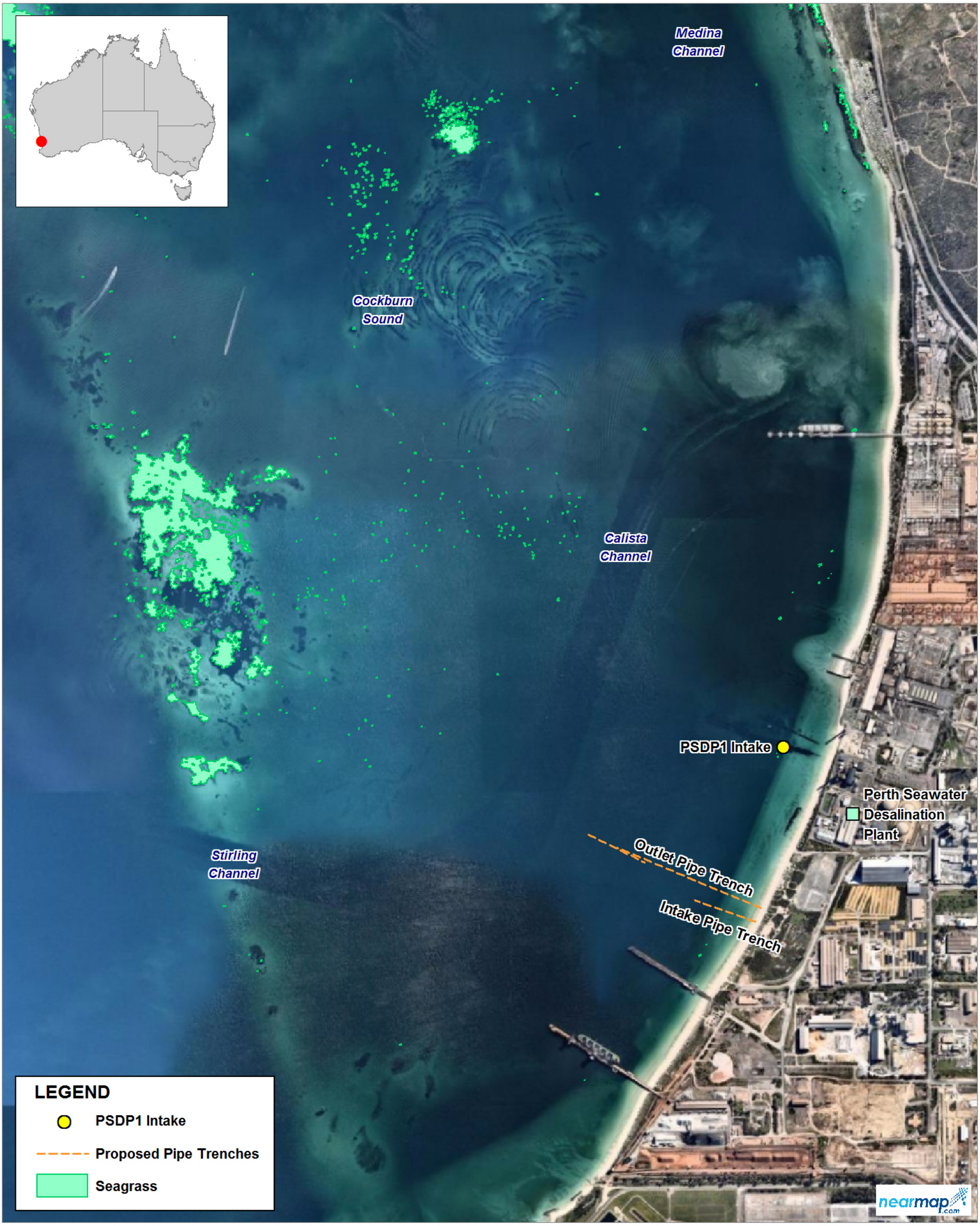
- Impact on PSDP1 plant efficiency due to reduced intake water quality; and
- Shading of seagrasses due to sedimentation and light attenuation in the water column.

The location of the nearby receptor sites sensitive to Total Suspended Sediment (TSS), PSDP1 intake & seagrass area, relative to the proposed PSDP2 pipe trenches are shown in Figure 1-1.

1.2 Study Objective and Scope

The objective of this study is to assess the marine impacts associated with the intake and outfall construction works with the purpose of informing decisions on construction methodology and the Environmental Impact Assessment (EIA) process. As part of the impact assessment, an existing numerical model of Cockburn Sounds was used to simulate the advection and dispersion of sediment plumes generated by the proposed construction works. The impact assessment scope is as follows:

- Analysis of meteorological and hydrodynamic processes likely to influence sediment plume advection and dispersion to create typical and worst-case design conditions for construction.
- Investigation into suitability of potential dredging options for the construction works.
- Simulation of sediment plume advection and dispersion for Backhoe Dredger option, with rock protection and backfilling via backhoe placement.
- Comparison of simulated Total Suspended Sediment (TSS) at sensitive receptor sites (seagrass and PSDP1 intake) against nominal threshold values.



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Proposed PDSP2 Intake and Outlet Pipe Trench Locations

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Approx. Scale

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2 Numerical Model Description

2.1 Hydrodynamics (TUFLOW FV)

The hydrodynamic modelling component of these assessments was undertaken using the TUFLOW FV software, which is developed and distributed by BMT. TUFLOW FV is a numerical hydrodynamic model for the two-dimensional (2D) and three-dimensional (3D) Non-Linear Shallow Water Equations (NLSWE). The model is suitable for simulating a wide range of hydrodynamic systems ranging in scale from open channels and floodplains, through estuaries to coasts and oceans. The three-dimensional model was deployed in this study.

The Finite-Volume (FV) numerical scheme employed by TUFLOW FV solves the NLSWE on both structured rectilinear grids and unstructured meshes comprised of triangular and quadrilateral elements. The flexible mesh allows for seamless boundary fitting along complex coastlines or channels as well as accurately and efficiently representing complex bathymetries with a minimum number of computational elements.

The current assessment utilized the existing TUFLOW FV Cockburn Sounds hydrodynamic model which was constructed and validated as per the BMT Perth Desalination Plant Discharge Modelling Report (BMT, 2018a).

2.2 Waves (SWAN)

Wave modelling was included in the assessment to capture sediment resuspension and dispersion from wave action in shallow areas, likely to be significant in determining sediment plume behaviour. The wave modelling component of these assessments has been undertaken using the spectral wave model SWAN. SWAN (Delft University of Technology, 2006) is a third-generation spectral wave model, which can simulate the generation of waves by wind, dissipation by whitecapping, depth-induced wave breaking, bottom friction and wave-wave interactions in both deep and shallow water. SWAN simulates wave/swell propagation in two-dimensions, including shoaling and refraction due to spatial variations in bathymetry and currents. This is a global industry standard modelling package that has been applied with reliable results to many investigations worldwide.

For sediment re-suspension and dispersion modelling the SWAN wave model was coupled with the 3D TUFLOW FV hydrodynamic and advection-dispersion models. This required the wave simulations to be completed separately, with the model output stored at hourly intervals on regular grids. During the subsequent sediment re-suspension and dispersion simulations, the wave conditions were linearly interpolated spatially from the grids to the TUFLOW FV mesh.

2.2.1 Model Domain

A fixed grid spatial discretization with a resolution of ~50m was adopted for the SWAN model, extending ~25km offshore and covering Cockburn Sound with Rottnest Island at the Northern boundary and Warnbro Sound at the Southern boundary. The SWAN model domain is shown in Figure 2-1.

2.2.2 Model Parameters

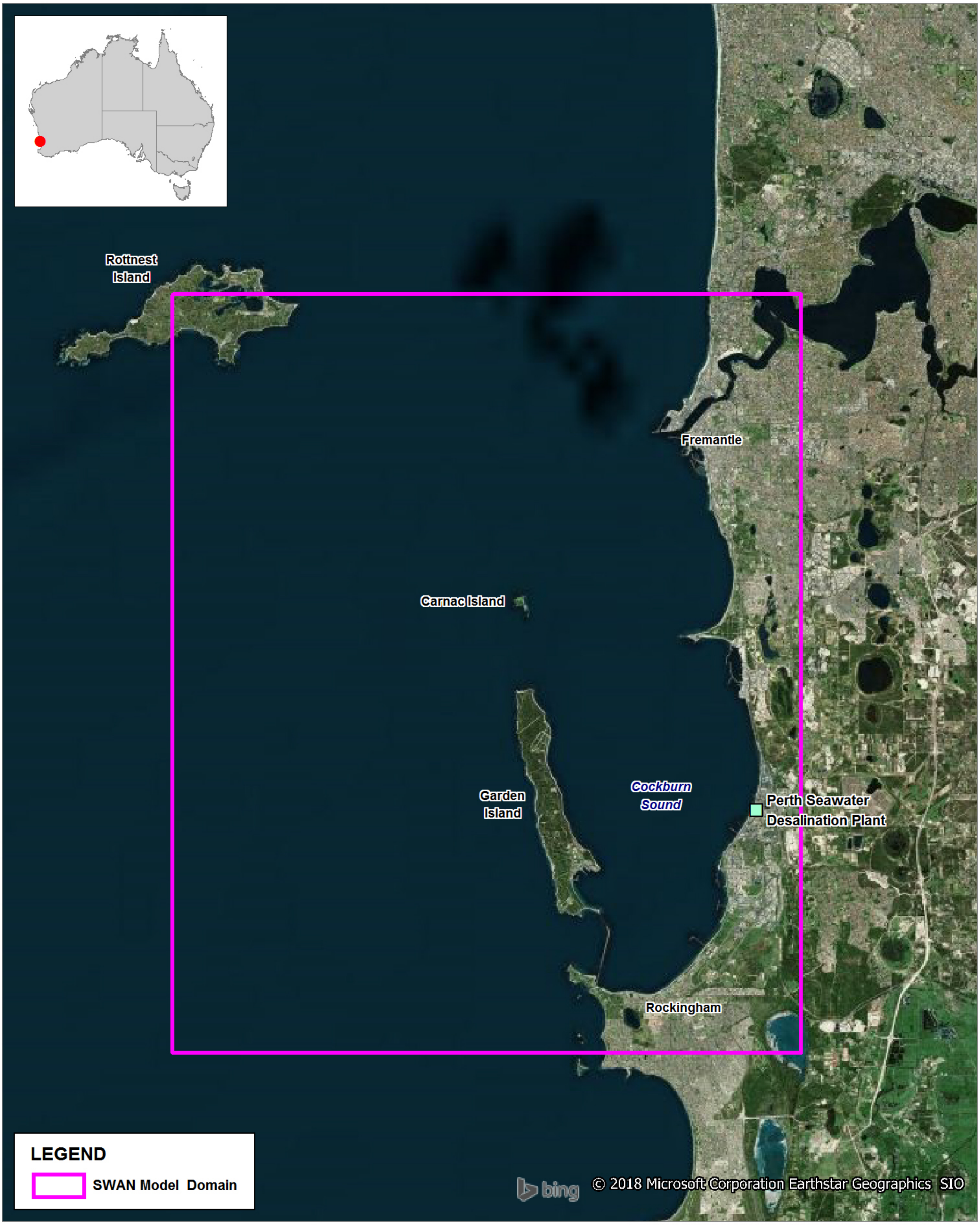
The following parameters were adopted for the SWAN model:

- 3rd generation source terms, whitecapping and depth-limited breaking (default parameters);
- Collin friction formula, with C_D = 0.015 (default);
- Directional spectra resolution, 10º; and
- Frequency spectra resolution, 25 frequencies from 0.04 < f < 1.00 Hz.

2.2.3 Boundary Conditions

An offshore swell boundary condition was derived from the NOAA WaveWatch III global hindcast dataset (Chawla et al, 2011).

The wind boundary condition was derived from the NOAA CFSR and CFSv2 global model datasets (Saha et al, 2011; 2014). The data applied to the model was a 10-m elevation, 10-minute average wind vector.



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SWAN Model Domain

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2.3 Sediment Transport (ST)

This study has simulated the additional resuspension, dispersion and settling of sediment released into the water column and placed on the bed by proposed dredging activities using the TUFLOW FV ST module coupled with the wave and hydrodynamic models.

The ST module allows for the simulation of multiple sediment fractions in suspension and within the bed. Sediments have been represented by four (4) fractions ranging from cohesive clays and silts to non-cohesive sand fractions.

Bed shear stress is calculated in the ST model from the non-linear interaction of currents and waves using the procedure of Soulsby (1997). A Root-Mean-Square combined wave-current bed shear stress is used as the representative value in the sediment erosion and deposition calculations.

The modelled rate of sediment deposition, Q_d (g/m^2/s), is a function of the near-bed sediment concentration (TSS), the still-water fall velocity and the bed shear stress (τ_b), according to Equation 2-1. As such, sediment settling may be reduced below its still water value by the action of bed shear stress and associated mixing in the water column. Non-cohesive sediment fractions were modelled without a critical shear stress for deposition, meaning that they have the potential to settle at all times independent of the bed shear stress.

$$Q_d = w_s.TSS.\max\left(0,1 - \frac{\tau_b}{\tau_{cd}}\right)$$

Equation 2-1

The rate of erosion, Q_e (g/m^2/s), is calculated according to Equation 2-2. Erosion will occur in response to the combined wave-current driven bed shear stress (τ_b) when this exceeds a critical threshold (τ_{ce}).

$$Q_e = E.\max\left(0, \frac{\tau_b}{\tau_{ce}} - 1\right)$$

Equation 2-2

It is commonly considered that the behaviour of sand-mud mixtures with sand content >90% will be dominated by the sand processes, with the fines being released from or trapped within the sand interstices (e.g. Whitehouse et al., 2000). Sediments with >5-15% fines content will tend to become cohesive with behaviour dominated by the finer fraction (e.g. Mitchener & Torfs, 1996). Most surficial bed sediments within the study area comprise sandy-clay mixtures (>55% fines content). A common critical erosion threshold and rate-coefficient was applied across both cohesive and non-cohesive sediment fractions.

2.3.1 Sediment Transport Model Parameters

Four (4) sediment fractions have been simulated within the model representing cohesive materials (clays, fine-silts and coarse-silts) and non-cohesive materials (fine-sands). It is assumed that coarser sediments (coarse-sands to gravel) will not form sediment plumes as is relevant to the water quality assessments. Table 2-1 presents the parameterisation of the three modelled sediment fractions. The critical shear stress for erosion and erosion rate constant have been based on literature values (Whitehouse et al, 2000). The adopted critical shear stress for deposition is based on literature parameter values (Mehta, 2014) and is consistent with calibrated parameter sets from similar dredge plume impact assessments where ambient sediment modelling has been undertaken and compared with in-situ suspended sediment measurements (BMT WBM, 2016; BMT, 2018b).

Table 2-1 Sediment transport properties

Material Fraction	Settling Velocity (m/s)	Critical Shear Stress for Erosion (N/m^2)	Critical Shear Stress for Deposition (N/m^2)	Erosion Rate Constant (g/m^2/s)
Fine Sand	1.0×10^{-2}	0.20	-	0.01
Coarse Silt	3.0×10^{-3}	0.20	0.18	0.01
Fine Silt	1.0×10^{-3}	0.20	0.18	0.01
Clay	1.0×10^{-4}	0.20	0.18	0.01

3 Sediment Plume Impact Assessment

The following section describes the methodology and results of numerical modelling assessments of water quality impacts at sensitive receptor sites due to sediment plumes generated during pipe trenching and backfilling of the proposed PSDP2 intake and outfall pipes. The PSDP2 dredging requirements have been assessed and summarised in a BMT technical note (Tn-WAT_1334_10_003-02, 12/03/2019).

In the following section of this report the sediment plume modelling methodology and assumptions are described in detail followed by the presentation of the model results.

3.1 Geotechnical Assumptions

Available geotechnical information was reviewed in order to derive properties for the dredge material. Geotechnical reports detailing material characteristics in proximity to the subject area include Oceanica (2009) and Golder Associates (2008). Further assumptions have also been made regarding the characteristics of the backfill material.

3.1.1 Oceanica Report

The Oceanica Sediment sampling and analysis implementation report was undertaken in October 2009 for the proposed Kwinana Quay Development and Kwinana Bulk Berth No.1 projects for Fremantle Ports. The purpose of this investigation was to assess the suitability of sediment for use in land reclamation and offshore disposal.

Two different sampling techniques were used to obtain material from the seabed surface down to below dredge design depths. A diver survey was undertaken in August 2008 to assess the top 1m of sediment using a PVC core. A geotechnical survey undertaken in late 2008 and early 2009 was carried out using a ‘PQ3 triple tube’ drill string set up.

Based on Oceanica’s field observations, the sedimentary material characteristic was described as having particles in the top 0-50 cm and bottom 50-100 cm of mainly silt and clay, followed by fine sand with some shell, occasional rocks and seagrass rhizome remnants. The particle size distribution data is presented in Table 3-1.

Table 3-1 Oceanica (2009) PSD data

Location	Fines (%)		Coarse (%)					
	<38µm	>38µm	>63 µm	>125 µm	>250µm	>500 µm	>1000 µm	>2000 µm
BH1_top	53.1	7	16.8	8.3	4.9	2.9	2.3	4.7
BH1_bot	63	6.8	7.4	4	3.6	3.5	6.2	5.5
BH2_top	56.8	10.3	13.6	4.4	3.4	2.1	1.7	7.6
BH15_top	51.7	13.1	21.1	6.5	1.7	0.5	0.3	5.1
BH16_top	39	9.2	18.2	8	6.7	3.9	2.5	12.6
BH16_bot	32.7	7	22.2	7.2	5.3	4.9	4	16.6
BH17_top	25.2	3.7	8.2	4.3	4.2	4.1	4	46.3
Average	45.93	8.16	15.36	6.1	4.26	3.13	3	14.06

3.1.2 Golder Associates Report

The Golder Associates geotechnical site investigation factual report was completed in June 2009 for the proposed Outer Harbour development at the Port of Fremantle. The purpose of this investigation was to determine the subsurface conditions in the channel and berthing areas known to be shallower than the design depths. J&S Drilling were commissioned directly to carry out the drilling programme using an Edson 3000 drilling rig and jack up barge.

As described in the report, the marine sediment observed over the site were generally up to 2.5m thick and composed of sandy clay with low plasticity, fine grained sand and abundant shell fragments. It is stated that below the marine sediments, a siliceous calcarenite, calcarenite and calcisiltite (limestone) layer was encountered. These sediments were very weakly to well cemented, fine to medium grain with abundant large shell fragments and pale grey to pale yellow in colour.

The particle size distribution data is presented in Table 3-2.

Table 3-2 Golder Associates (2008) PSD Data

Location (Depth)	Fines (%)	Coarse (%)				
	<75 µm	<150 µm	<300 µm	<425 µm	<1180 µm	<2360 µm
K3 (-12.25m)	82	7	3	1	1	6
OH17 (-13.2m)	46	27	8	2	3	14
OH18 (-12.3m)	45	29	17	3	2	4
OH18 (-13.5m)	25	12	8	3	5	47
Average	49.5	18.75	9	2.25	2.75	17.75

3.1.3 Selection of Material Characteristics

In the absence of more detailed site-specific geotechnical data a single material characterisation has been used to represent the in-situ dredge volume. Review of available geotechnical investigations indicate the material is a sandy-clay, with a high fraction of fines (Oceanica 2009). Based on the observed particle size distributions at the subject site, the relative quantities of the four (4) different sediment size fractions were estimated. Lower bound assumptions regarding grain size were made, giving a conservative representation of the distribution of fines between clay and fine silt.

In addition, assumptions regarding the sediment fractions of the backfill material have been made. The coarse gravel and rock material are assumed to have a small fraction of fines (1%) attached to the large aggregates. The sand backfill material, likely to be used as a substitute for the in-situ dredge material, is also assumed to have a low fines content (1%). The adopted sediment fractions are shown in Table 3-3.

It has been assumed the hard calcisiltite limestone layer at ~17m depth CD is not within the dredge envelope and hence potential consequences of this have not been considered.

Table 3-3 Nominal material sediment fractions

Material	Dry Density (kg/m^3)	Clay (%)	Fine Silt (%)	Coarse Silt (%)	Fine Sand (%)	Coarser Aggregates (%)
Marine Sediment (in-situ)	1590	55	10	10	25	-
Coarse Aggregate Backfill (Pea Gravel, Filter Rock, Armour Rock)	1590	1	-	-	-	99
Sand Backfill	1590	1	-	-	-	99

3.2 Dredging Methodology Assumptions

The assessment of marine impacts associated with the PSDP2 intake and outfall construction works required the development of representative dredging methodology scenarios. Two (2) scenarios were schematised and investigated, relating to two (2) different potential dredging options, the options are outlined below.

- Option 1: Backhoe Dredging (BHD) - using a backhoe to excavate/remove marine sediment to the required designed dredging depth.
- Option 2: Cutter suction dredging (CSD) - using a medium sized CSD vessel equipped with a 'cutting head' to remove the marine sediment.
- Use of mounted backhoe/excavator for placement of rock, gravel and sand backfill materials is proposed for both options.

Preliminary investigation into Option 2 (CSD) indicated that the CSD would not be a feasible dredging methodology due to the generation of much higher intensity plumes than the BHD option. Therefore Option 1 (BHD) is the preferred methodology. Details on the preliminary investigation into both Option 1 and 2 are included as Appendix A. Further details on the assumptions used to schematise the BHD dredging campaign and associated backfill operation are provided in the following sections.

3.2.1 Backhoe Dredge

The modelled scenario considers a backhoe/excavator mounted on a barge, similar to the dredge vessel *Total Support*, where excavated material will be loaded onto hopper barges which travel to an approved nearby land back wharf facility for offloading. High productivity has been assumed for the backhoe dredge option, in which a fixed 6.0 hours of standby time is assumed to occur daily, centred on midnight. The backhoe dredge productivity assumptions are detailed in Table 3-4.

Table 3-4 Backhoe dredge productivity assumptions

Material	Design Dredge Volume (m^3)	Production Rate (in-situ m^3/operational hour)	Efficiency (i.e. % of time working)	Estimate Dredge Campaign Duration (days)
Marine Sediment	180,341	102.5	75	~97

3.2.2 Rock Protection and Backfilling

For rock protection and backfilling, the same mounted backhoe/excavator will be used to facilitate the placement of material into the pipe trench. High productivity has been assumed for both the rock placement and backfilling, in which a fixed 6.0 hours of standby time is assumed to occur daily, centred on midnight. The backhoe productivity assumptions and fill volumes for the rock placement and backfilling phases are detailed in Table 3-5.

Table 3-5 Backfill assumptions

Material	Design Fill Volume (m^3)	Fill Rate (in-situ m^3/ hour)	Efficiency (i.e. % of time working)	Estimate Duration (days)
Pea Gravel	30,174	71.5	75	23.5
Filter Rock	9,151	71.5	75	7.1
Armour Rock	20,197	71.5	75	15.7
Sand Backfill	79,260	95.3	75	46.2
Total	138,781	-	-	~93

3.3 Plume Generation Assumptions

Numerical simulation of dredge and dump plumes requires specification of sediment plume boundary conditions, i.e. source terms describing temporal and spatial release of suspended sediment fractions into the water column.

Plume release rates are typically expressed as a fraction of the in-situ production rate (Becker et al, 2015; Kems & Massini, 2017). The release rates used in the plume modelling relate to the far-field (passive) plumes, which have the potential to be transported by currents beyond the immediate dredging footprint. Near-field dynamic plumes are not included in the dredge/dump plume modelling as they do not extend beyond the immediate dredge/dump footprint.

Assumed plume-release rates for the various source terms are detailed in Table 3-6. The plume-release rates represent the passive plume quantity released at the dredge/dump point. It was assumed that the plume release would be vertically well mixed due to turbulence generated by the dredging equipment.

The dry densities in Table 3-3 and production rates from Table 3-4 and Table 3-5 were used in calculating the instantaneous release rates for the respective plume sources. The plume source PSDs have been based on the source material characteristics (Table 3-3). Only the clay, fine-silt, coarse-silt and fine-sand fractions were included in the dredge plume modelling, as other, coarser, aggregates in the nominal material will settle immediately to the seabed.

Derived plume source rates are summarised in Table 3-6. Only the source terms related to fine sediment fractions (clay and fine silt) are included in the summary table as these will represent the majority of plume material to disperse outside the dredge footprint.

Table 3-6 Summary of plume source rates (Clay & Fine Silt Fractions Only)

Source	Source Material	Plume-Release Rate (%)	Fines Mass Flux (kg/s)	Total Mass Fines (Tonnes)
Backhoe Dredge	Marine Sediment	3.0	0.87	5,468
Barge Dumping	Coarse Aggregate Backfill	20	0.06	189.3
Barge Dumping	Sand Backfill	20	0.08	252.0

3.4 Design Conditions and Simulation Period Ensemble

Based on the nominal backhoe methodology for dredging and backfilling, the period in a given year for the intake and outfall construction works will be 1st February to 15th August (190 days).

Given the relatively low tidal amplitudes, wind is the main forcing mechanism in Cockburn Sound. Therefore, potential impact to sensitive receptors may vary in response to wind conditions encountered during construction.

An ensemble of simulation periods was selected in order to analyse the sediment plume behaviour under a number of atypical (worst case scenario) and typical design wind conditions for the respective dredge scenarios. The following section describes the analysis and selection of wind conditions for the simulation ensemble.

3.4.1 Description of Summer Wind in Cockburn Sound

Winds in the summer and early autumn period, notably December to March, are characterised by a diurnal offshore/onshore signal. Movement of the subtropical ridge South and movement of the Monsoon Trough North, combined with heating of the land in the morning, generate warm, offshore, easterly winds of up to 5 m/s in Cockburn Sound (BMT 2018a).

As the land mass further heats towards midday, differential land-sea heating produces afternoon sea breezes of up to 15 m/s. Coriolis forcing, causes the onshore winds experienced in Cockburn Sound to be typically from the south to southwest. Although the sea breeze in Perth is a year-round feature, it is more prevalent and energetic in the summer months and is responsible for producing northward currents along the coastline from afternoon to the early evening (BMT 2018a).

Analysis of wind data at the Bureau of Meteorology (BOM) Garden Island Weather Station, from 2002-2018, is consistent with this description. Inter-annual and inter-daily averages of hourly wind speed and direction for the February/March period are show in Figure 3-1 as a representative wind time series for a typical summer day. The diurnal signal is evident in the time series, with notably stronger southerly winds in the afternoon.

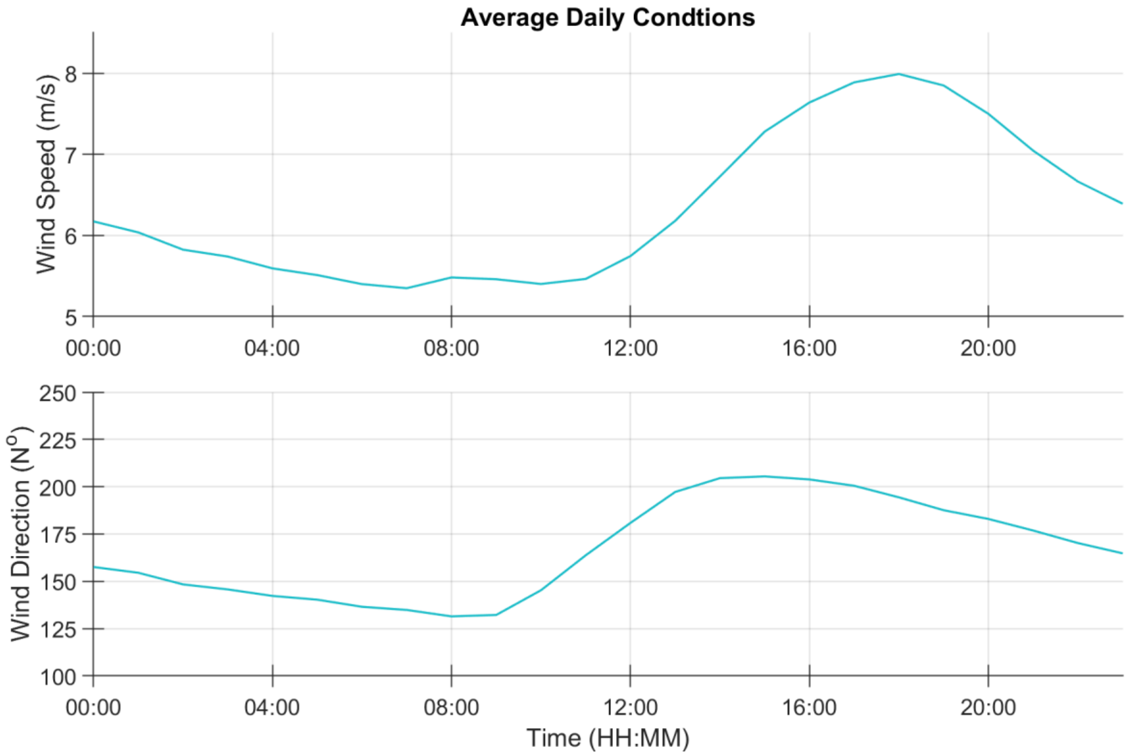

Figure 3-1 Typical Summer diurnal wind pattern in Cockburn Sound

Atypical wind conditions in Cockburn Sound arise from the genesis of the west coast trough, a low-pressure band with an axis aligned from north to south which is generated from the combination of warm easterly winds and cool sea breezes. When the trough forms inland, the sea breezes are more active in the coastal area, conversely, when the West Coast trough forms offshore, it acts as a blockage of oceanic airflow, and the corresponding sea breezes are weaker (and sometimes may not even form).

3.4.2 Scenario Wind Conditions

Based on the potential wind states described, three scenarios have been identified for analysing potential dredging impacts at the two sensitive receptor sites. The conditions are outlined below:

- Typical diurnal summer winds, oscillating between easterlies and southerlies, with stronger southerlies.
- Easterly dominated summer winds, southerly winds blocked by offshore formation of west coast trough. Expected increase in westward advection and dispersion of sediment plume towards seagrass relative to typical conditions.
- Southerly dominated summer winds, west coast trough forms inshore increasing southerly intensity. Expected increase in northward advection and dispersion of sediment plume towards PSDP1 intake relative to typical conditions.

3.4.3 Simulation Ensemble

Summer wind conditions across individual years from 2002 to 2018 were analysed to select three (3) summer periods representative of the design conditions outlined above, forming the simulation ensemble for assessing potential construction impacts. The selection of simulation periods for the ensemble are shown below, wind roses for full day, A.M and P.M conditions, for the respective ensemble periods, are shown in Figure 3-2, Figure 3-3 and Figure 3-4.

- Typical summer wind conditions, February/March 2007 (Figure 3-2);
- Easterly dominated summer wind conditions, February/March 2011 (Figure 3-3); and
- Southerly dominated summer wind conditions, February/March 2004 (Figure 3-4).

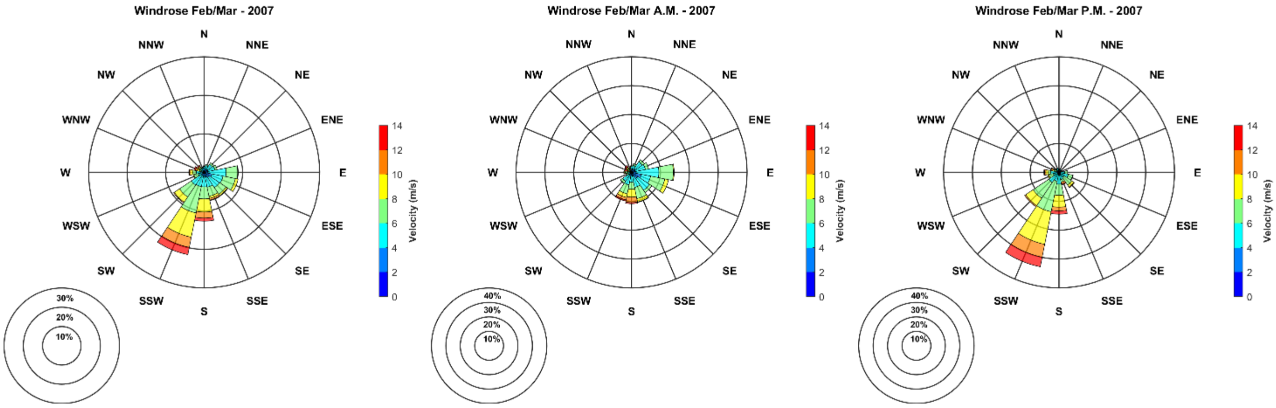

Figure 3-2 2007 Period Garden Island wind rose – Typical Summer wind conditions

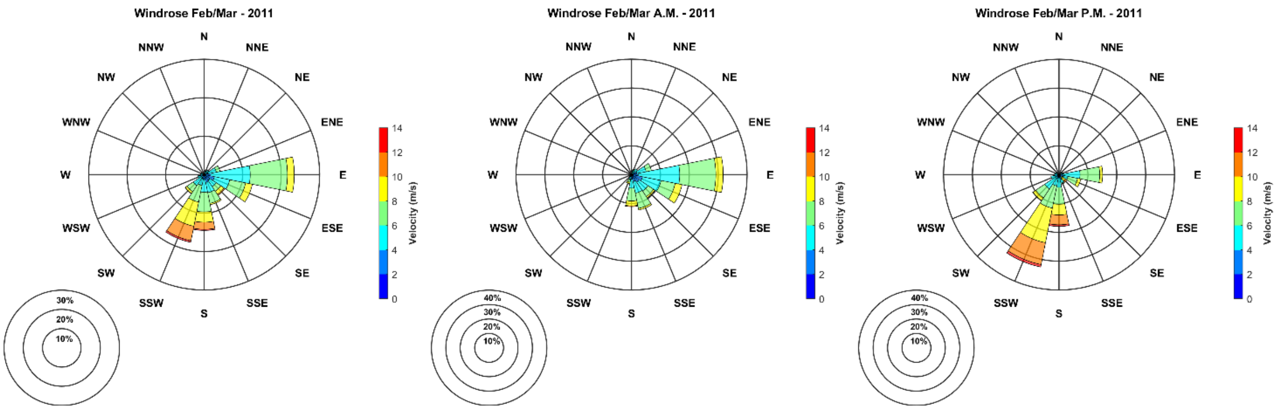

Figure 3-3 2011 Period Garden Island wind rose – Easterly dominated Summer wind conditions

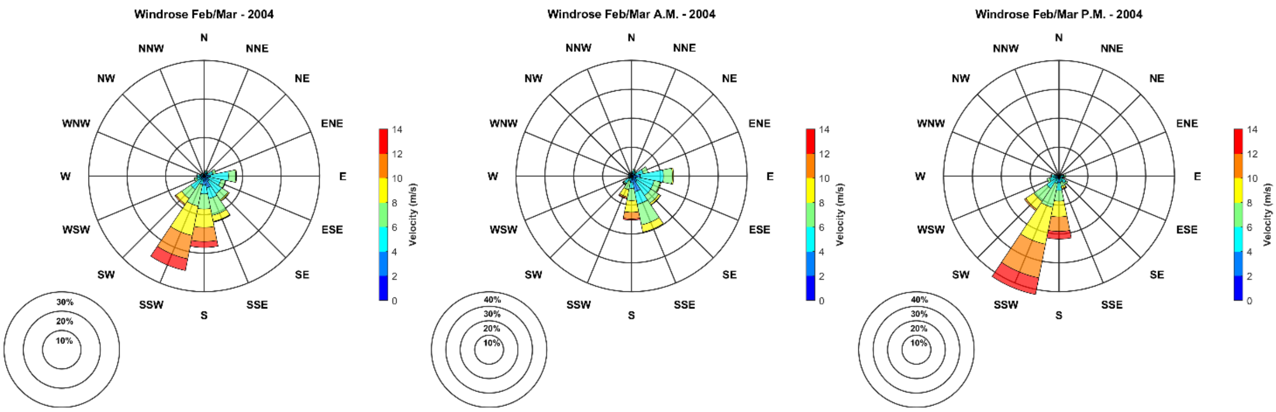

Figure 3-4 2004 Period Garden Island wind rose – Southerly dominated Summer wind conditions

3.5 Results

The dredge plume modelling results from the ensemble simulations have been processed as timeseries and spatial plots for assessing impact in terms of Total Suspended Sediment (TSS) concentration above threshold values. Spatial plots of sediment deposition have also been included to inform impacts. Threshold values of TSS concentration for the PSDP1 intake were derived from the EQG for Total Suspended Solids (EPA 2017).

The rolling median concentration of total suspended solids adjacent to the Perth Seawater Desalination Plant intake (PSDP1), calculated over a period not exceeding four weeks, should not exceed 4.5 mg/L and no individual total suspended solids value should exceed 9 mg/L at any time.

Assessment of potential dredging impacts to benthic primary producers was undertaken in-line with EPA (2016). Predicted dredge-generated elevations (above background) in TSS were examined using nominal threshold values of 2, 5 and 20 mg/L, where:

- 2 mg/L approximates a visible plume (but no impact);
- 5 mg/L approximates a low risk of impacts to seagrass health (potential for moderate impact); and
- 20 mg/L approximates a high risk of impacts to seagrass health (potential for permanent impact).

These threshold values are with respect to the metrics of maximum exceedance level 95th and 99th percentile values of TSS across any 30-day period. These TSS metrics have been used in previous EIAs of dredging campaigns (e.g. Mangles Bay; Strategen 2012) and have been accepted by the regulator for demonstrating changes in marine quality.

3.5.1 Sensitive Receptor TSS Time Series

The instantaneous and 'rolling median' depth averaged TSS were extracted from the ensemble simulations as time series at the two (2) sensitive receptor sites. Figure 3-5 shows the TSS time series at the PSDP1 intake for the respective ensemble periods. In all scenarios the instantaneous threshold value of 9 mg/L is exceeded during the dredging campaign. Only in the 2007 'typical summer wind conditions' period is the rolling median threshold value of 4.5 mg/L exceeded.

The results indicate that the most severe impacts to PSDP1 intake water quality occur under typical wind conditions (2007 ensemble period), where maximum TSS values of ~20mg/L can be expected, with frequent exceedance of the instantaneous TSS threshold and a sustained exceedance of the rolling median threshold. Typical wind conditions appear to produce the most severe impacts at PSDP1 due to the P.M. onshore southerly winds advecting the dredge plume to the PSDP1 intake. While the stronger southerly wind scenario (2004 ensemble period) also advect the plume towards the PSDP1 intake, the stronger currents induce more dispersive mixing of the plume with the consequence of slightly reducing peak concentrations. Mitigation strategies will need to be implemented during the dredge campaign to manage the elevated concentrations at the PSDP1 intake.

At the seagrass sensitive receptor site, time series plots in Figure 3-6 demonstrate the instantaneous TSS is effectively <2mg/L across the entire dredge campaign, indicating potential for a visible plume at this location without any adverse impacts.

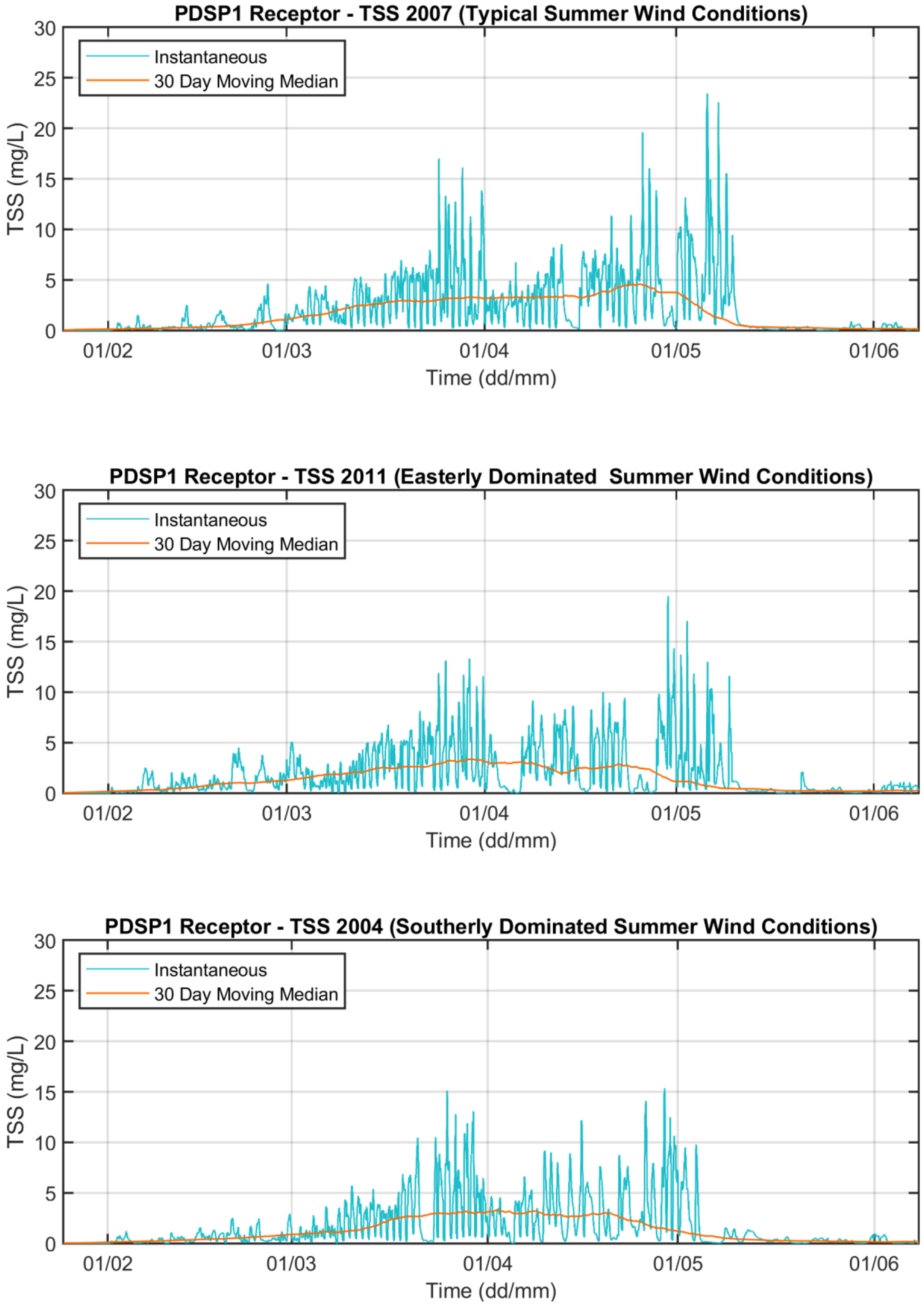

Figure 3-5 PSDP1 sensitive receptor TSS time series plots, (a) 2007 – Typical wind conditions, (b) 2011 – Easterly dominated wind, (c) 2004 – Southerly dominated wind

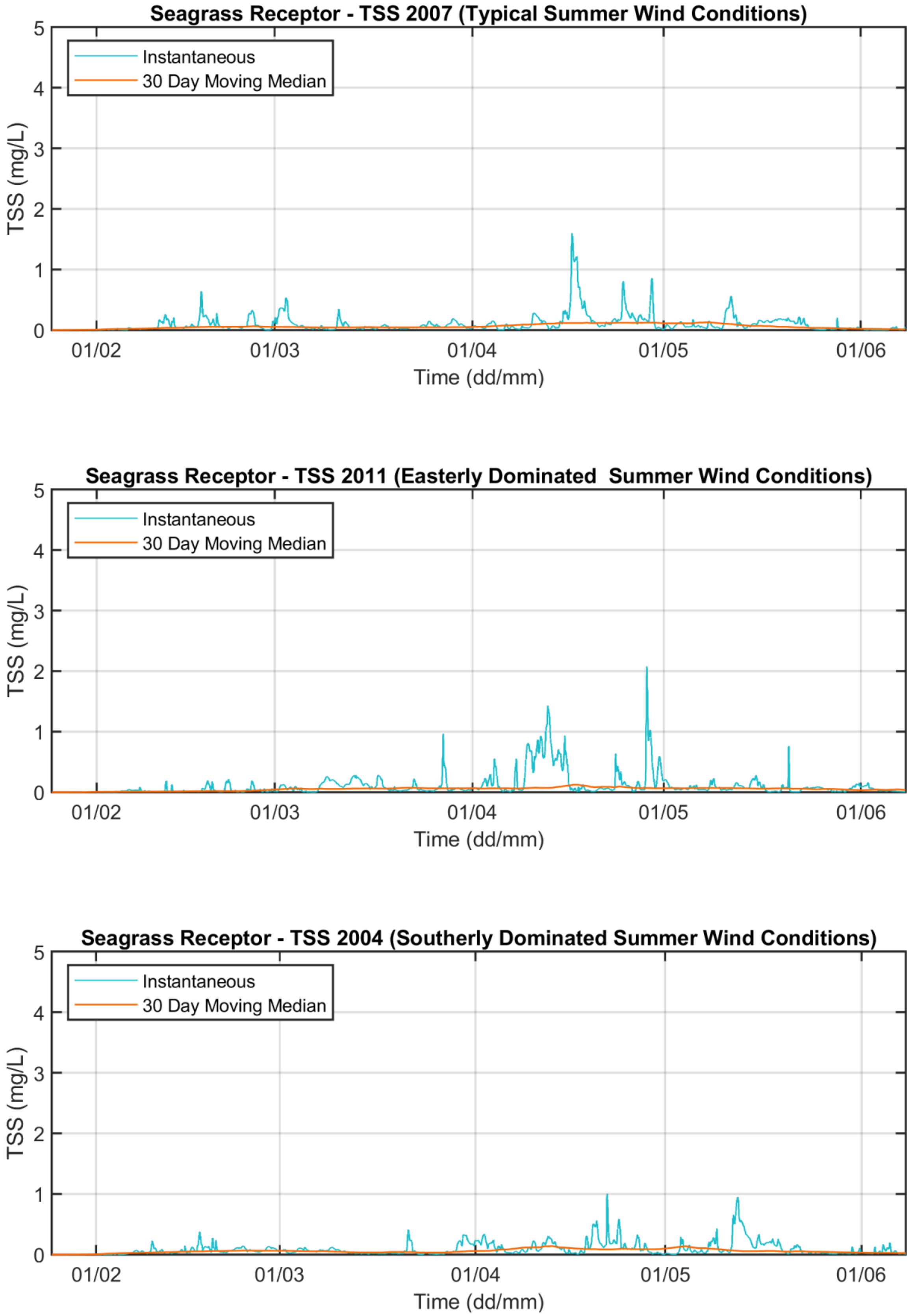

Figure 3-6 Seagrass sensitive receptor TSS time series plots, (a) 2007 – Typical wind conditions, (b) 2011 – Easterly dominated wind, (c) 2004 – Southerly dominated wind

3.5.2 TSS Percentiles

Acute exceedance level 99th percentile TSS plots are shown for *Expected Case* (average of ensemble periods) and *Worst Case* (maximum of ensemble periods) in Figure 3-7 and Figure 3-8, respectively.

The 99th percentile TSS contours under average conditions show a tendency for the sediment plume to advect north-west along the coastline. This behaviour is likely due to elevated wave induced bed shear stress in the shallow areas along the coastline preventing fine sediment from settling, in combination with the stronger P.M. southerly winds encountered in the summer. As discussed above, the summer afternoon seabreeze is an adverse condition for construction plume connectivity with the PSDP1 intake.

Worst case 99th percentile TSS contours indicate TSS values ~10mg/L at the PSDP1 intake, and TSS values < 2mg/L across most of the seagrass area, consistent with the timeseries data in section 3.5.1.

3.5.3 Sediment Deposition

The 99th percentile of sediment deposition rate is shown for average conditions (average of ensemble periods) and worst case (peak of ensemble periods) in Figure 3-11 and Figure 3-12 respectively. Plots showing the final distribution of net sedimentation across the simulation period for the average conditions and the worst case are shown in Figure 3-15 and Figure 3-16, respectively.

The worst-case deposition rate and net deposition plots indicate that acute levels of deposition will only occur in the immediate vicinity of, and to the South – West of, the dredge area.

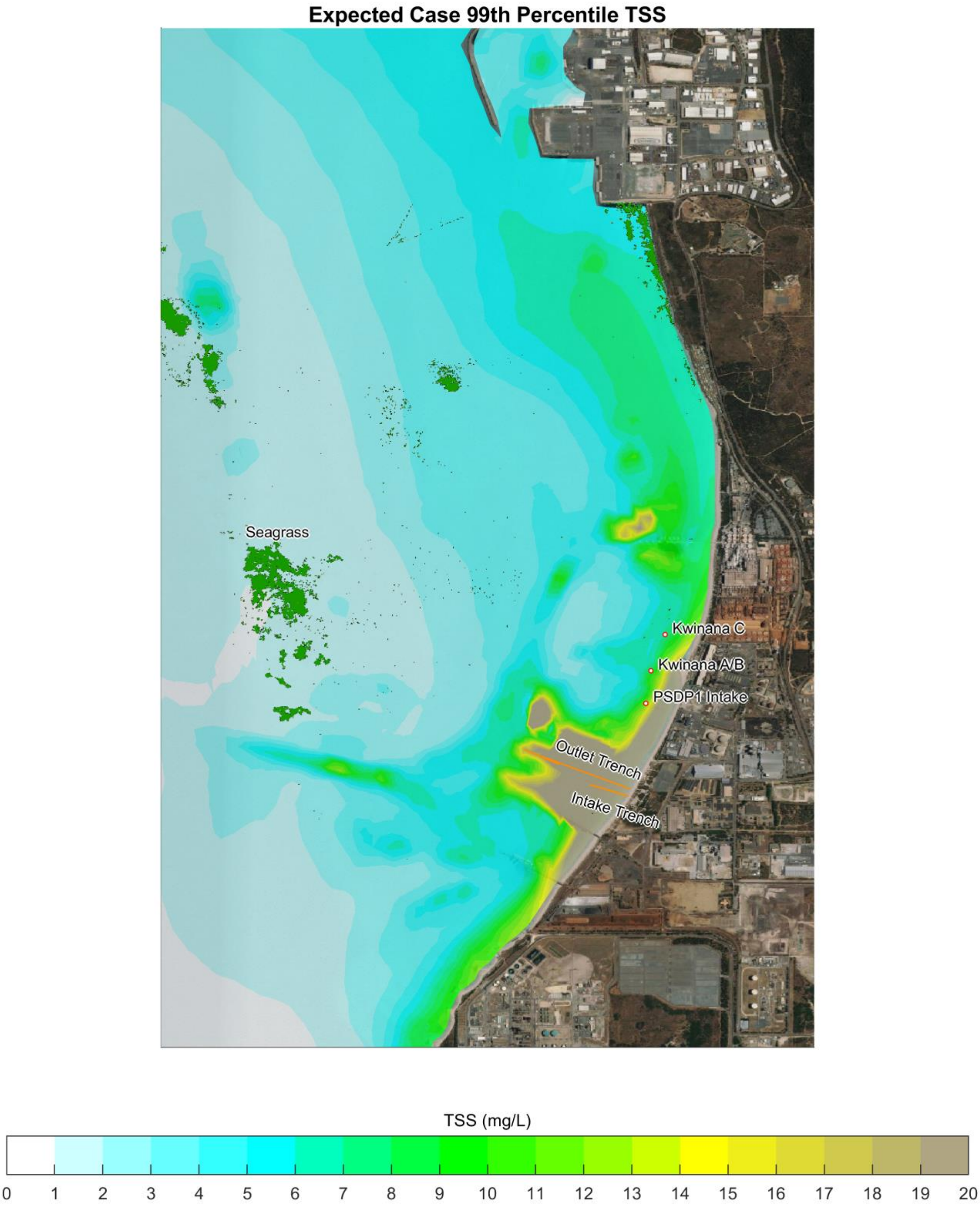

Figure 3-7 Expected Case 99th percentile TSS contours

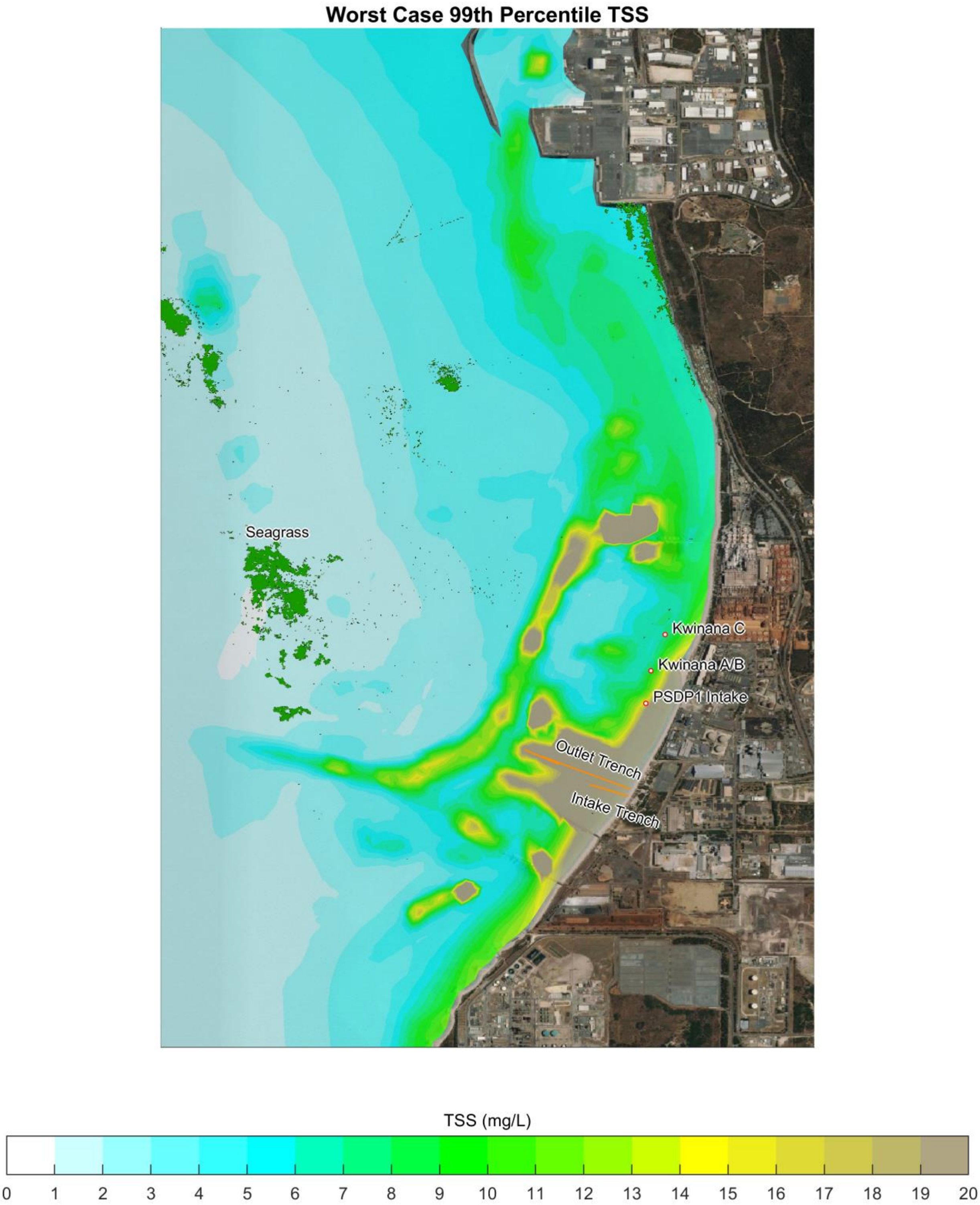

Figure 3-8 Worst Case 99th percentile TSS contours

Figure 3-9 Expected Case 95th percentile TSS contours

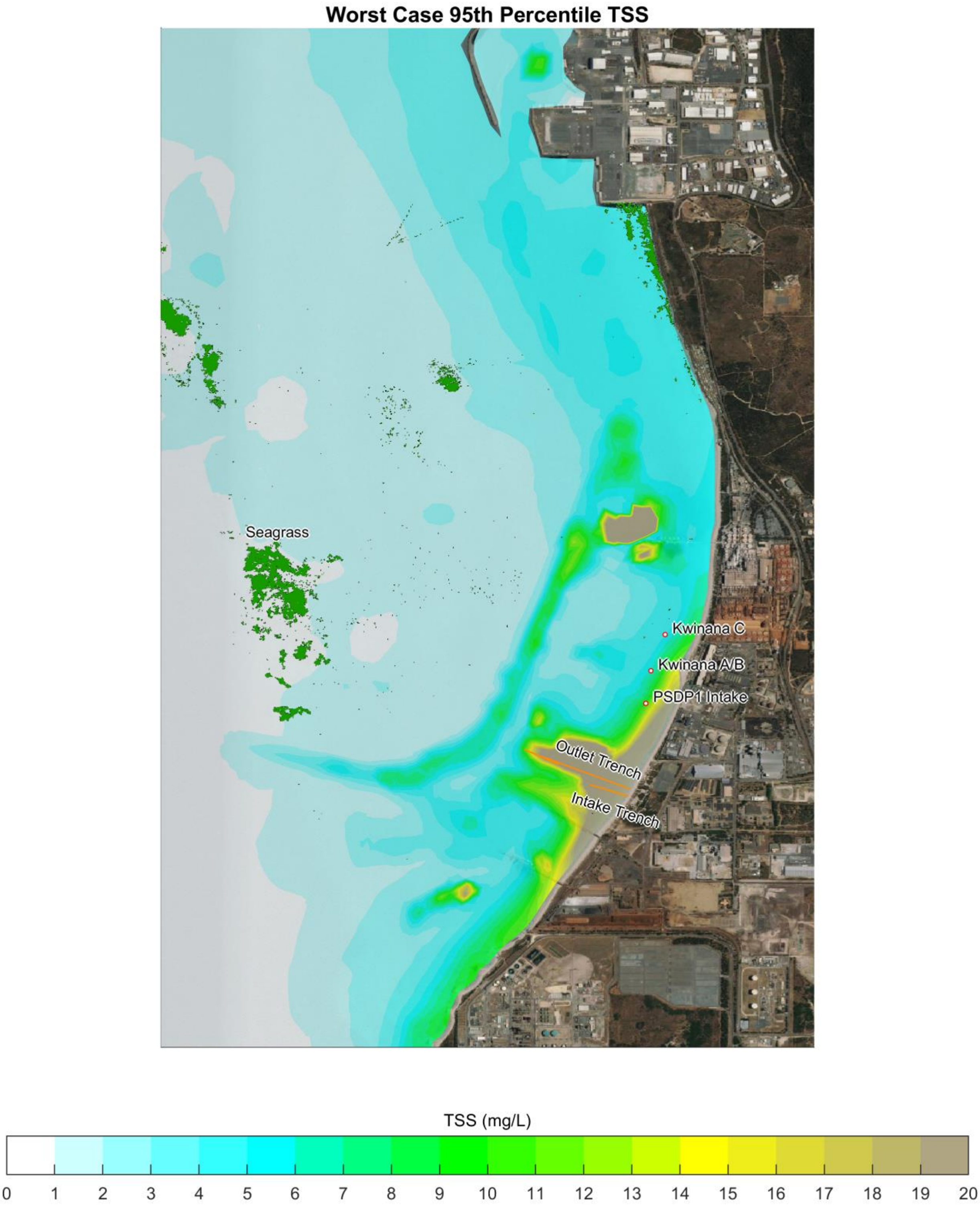

Figure 3-10 Worst Case 95th percentile TSS contours

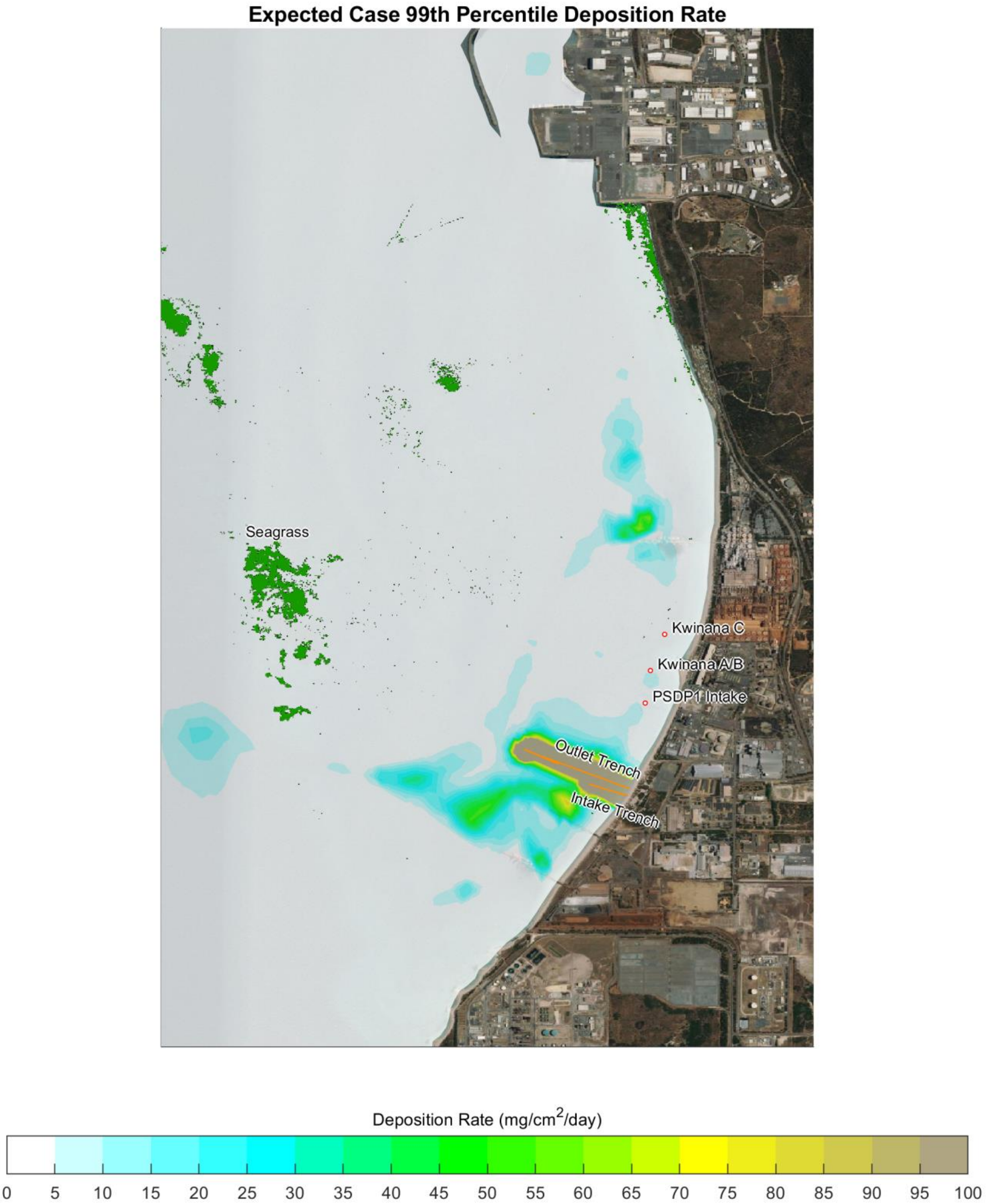

Figure 3-11 Expected Case 99th percentile deposition rate contours

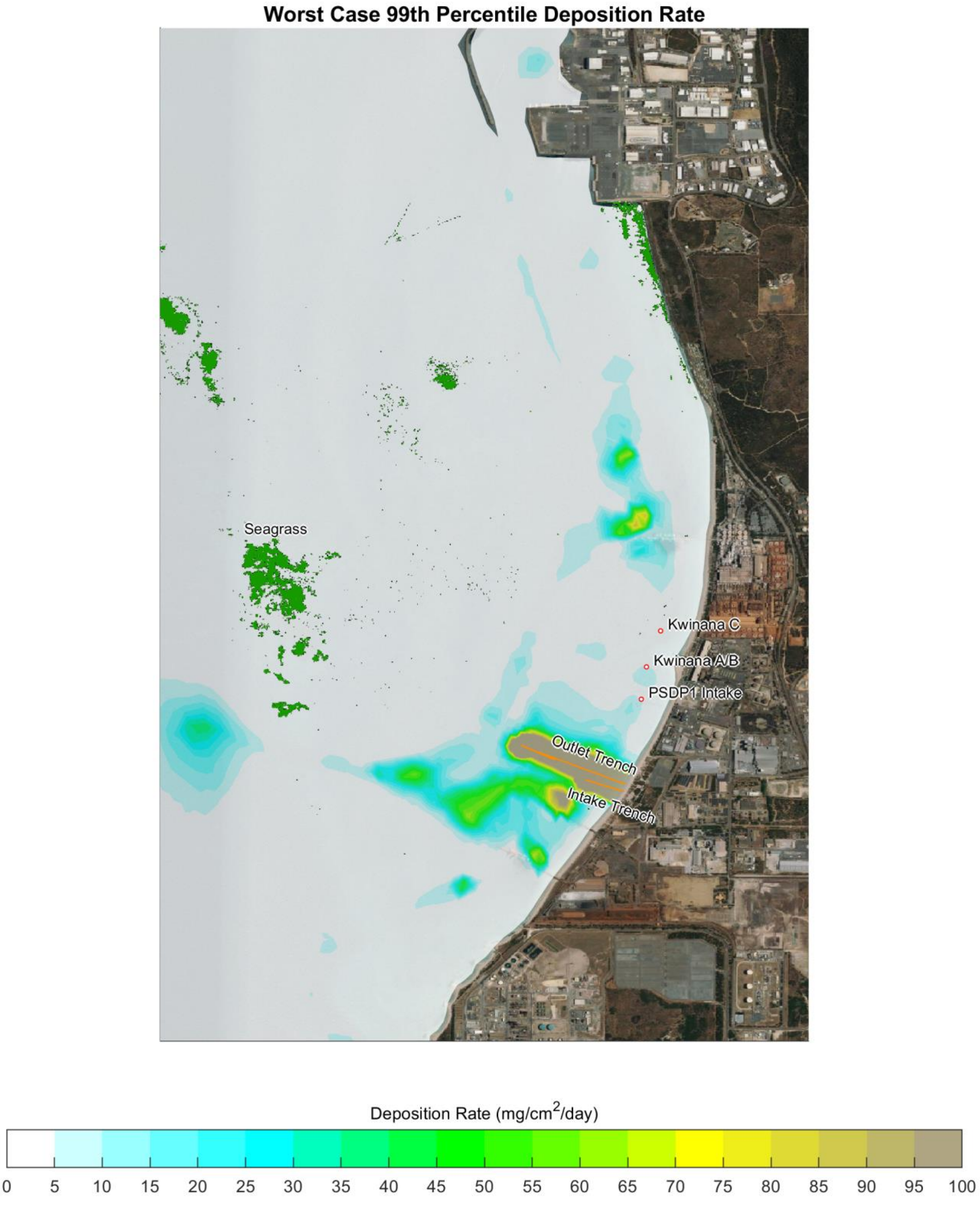

Figure 3-12 Worst case 99th percentile deposition rate contours

Figure 3-13 Expected case 95th percentile deposition rate contours

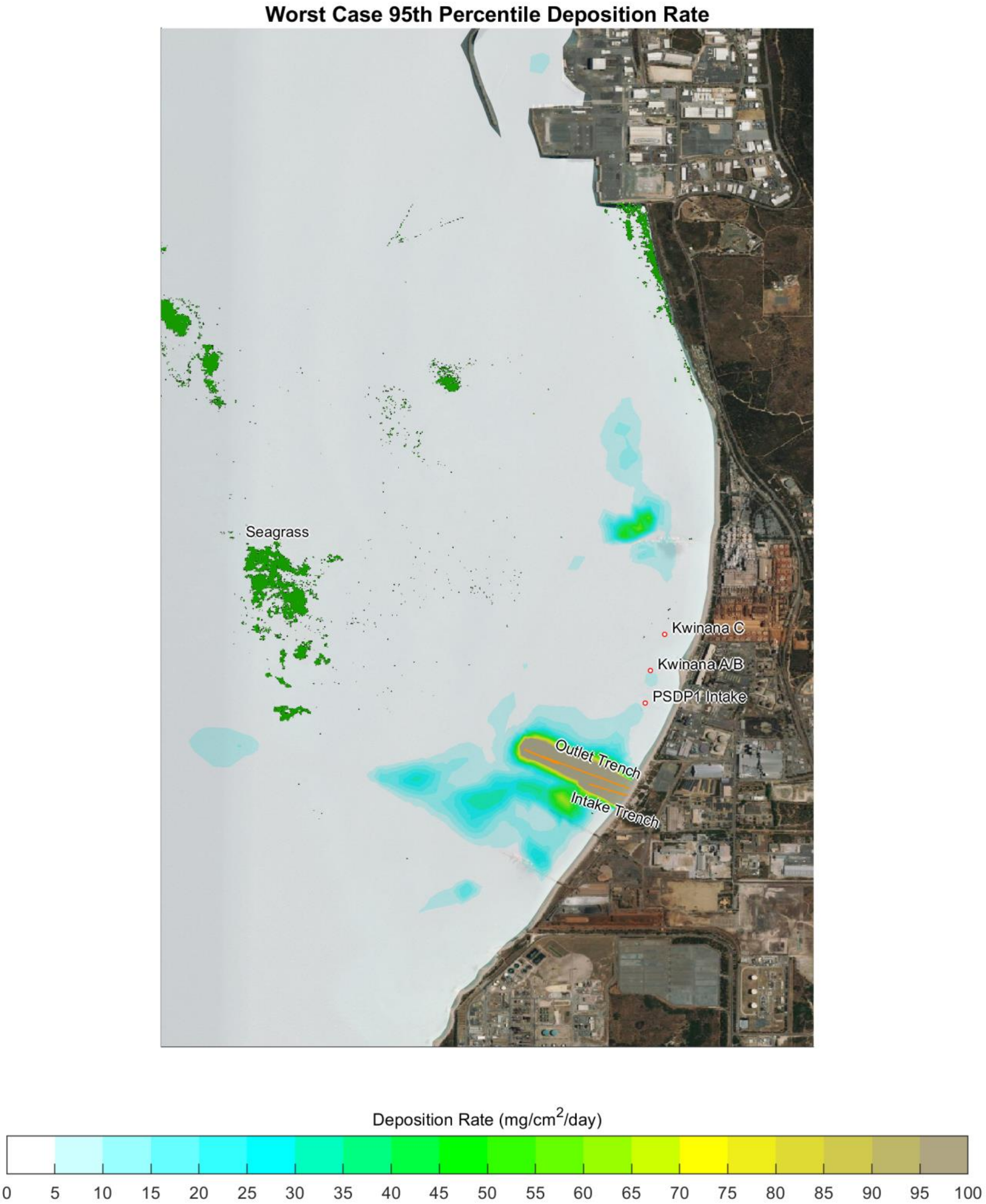

Figure 3-14 Worst case 95th percentile deposition rate contours

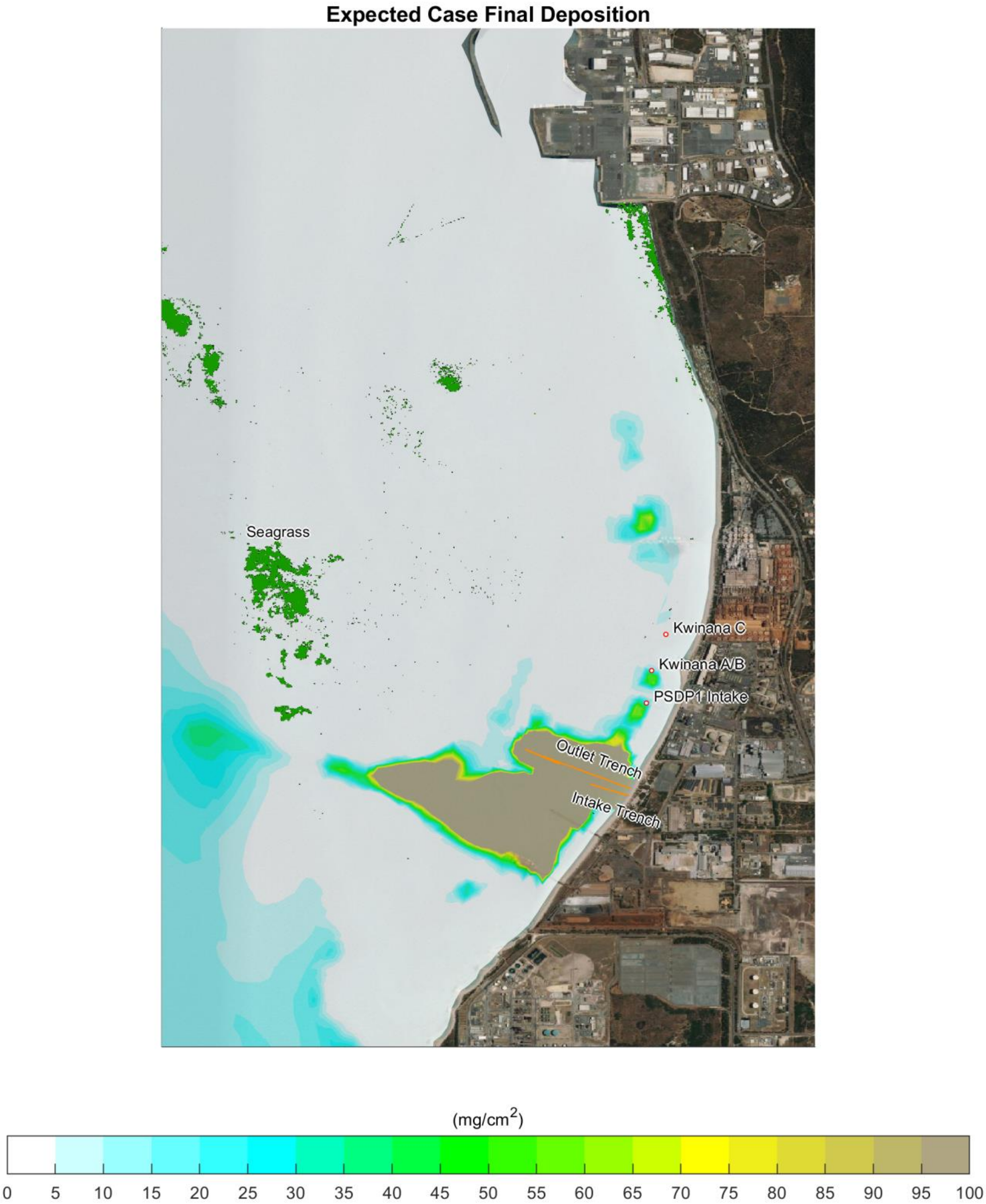

Figure 3-15 Expected case net deposition

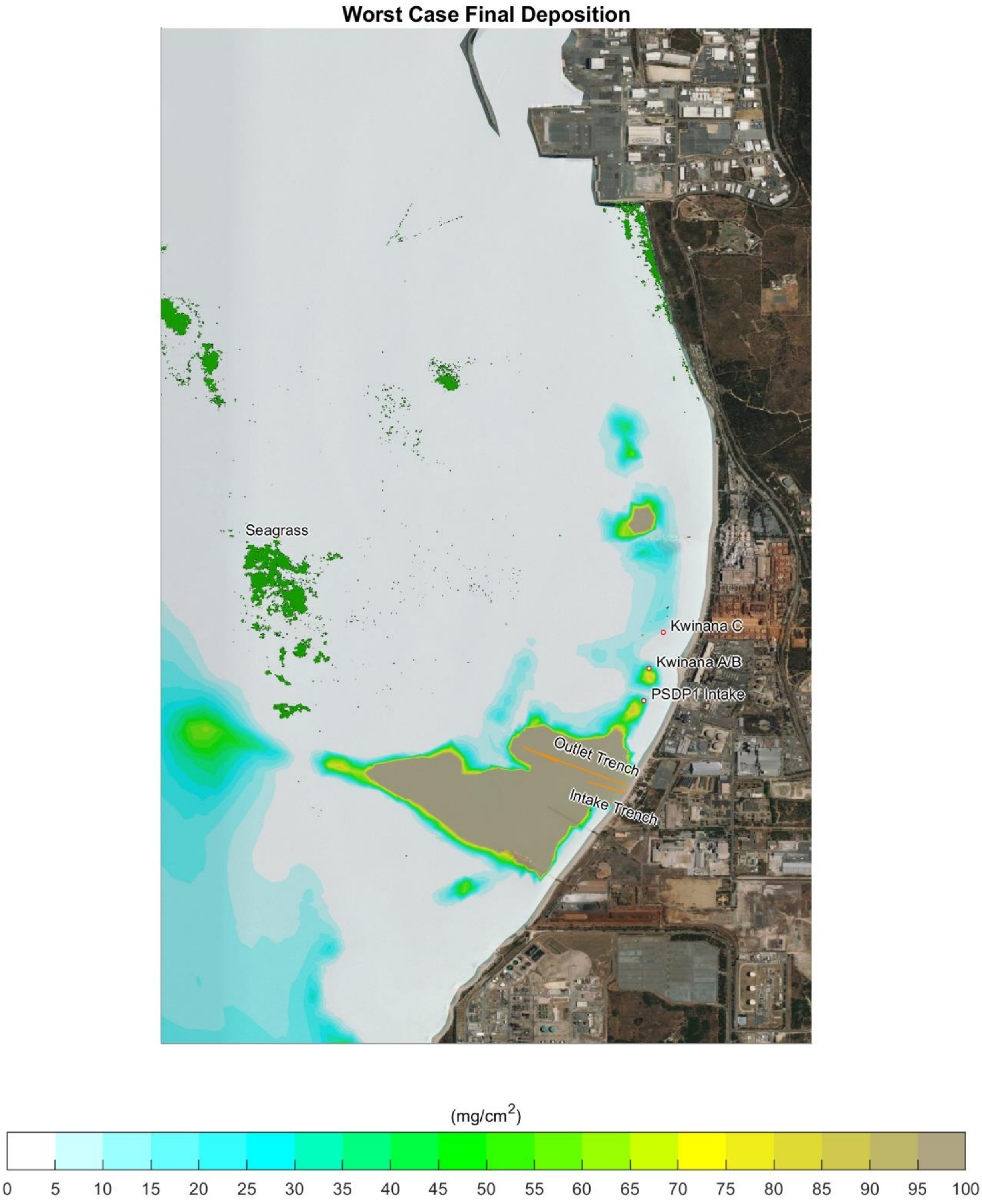

Figure 3-16 Worst case net deposition

4 References

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Appendix A Cutter Suction Dredge Option Investigation

As part of preliminary investigation into potential dredging options a Cutter Suction Dredger was considered, with pilot modelling of both the Cutter Suction Dredger and Backhoe Dredger options. It was proposed a medium sized cutter suction dredger, similar to the dredge vessel *Eastern Aurora*, where dredged material will be collected by the vessel hydraulic pumping system and passed through a series of pipeline into a dredge material placement area (DMPA). High productivity was assumed when assessing this option, in which a fixed 9.6 hour down time is assumed to occur daily, centred on midnight. The cutter suction dredge productivity assumptions are detailed in Table A-1.

Table A-1 Cutter suction dredge productivity assumptions

Material	Design Dredge Volume (m^3)	Production Rate (in-situ m^3/operational hour)	Efficiency (i.e. % of time working)	Estimate Dredge Campaign Duration (days)
Marine Sediment	113,670	1,040	0.6	8

This option assumed that a plot of land will be available to adequately contain/hold the dredged material during and post dredging works, from where supernatant water (dredge tailings) will be allowed to be discharge back into the sea. The dredge tailings assumptions are detailed in Table A-2. The TSS in the tailings water is assumed to comprise of 100% clay.

Table A-2 Cutter suction dredge tailings assumptions

Total Tailings Volume (m^3)	Tailings Release Rate (m^3/s)	TSS Concentration (mg/L)	Duration of Tailings Discharge (days)
1.3×10^6	1.0	150	15

Derivation of plume source rates are as per section 3.3. Derived plume source rates are summarised for the CSD option in Table A-3 below. Only the source terms related to fine sediment fractions (clay and fine silt) are included in the summary table as these will represent the majority of plume material to disperse outside the dredge footprint.

Table A-3 Cutter suction dredge plume source rates (Clay and Silt Fraction Only)

Source	Source Material	Plume-Release Rate (%)	Mass Flux (kg/s)	Total Mass – Fines Only (Tonnes)
Cutter Suction Dredge	Marine Sediment	7.5	22.4	8,817
DMPA Tailwater	-	-	0.15	195

The nominal southerly dominated summer wind condition period of February/March 2004 was selected for the pilot simulations of the CSD option. Time series plots at the sensitive receptor sites are shown in Figure A-1. During dredging TSS exceeds the instantaneous threshold value of 9 mg/L for impacts at PSDP1 by a factor ~25. Therefore, the CSD option is not feasible based on the likely effects incurred to the intake water quality of PSDP1.

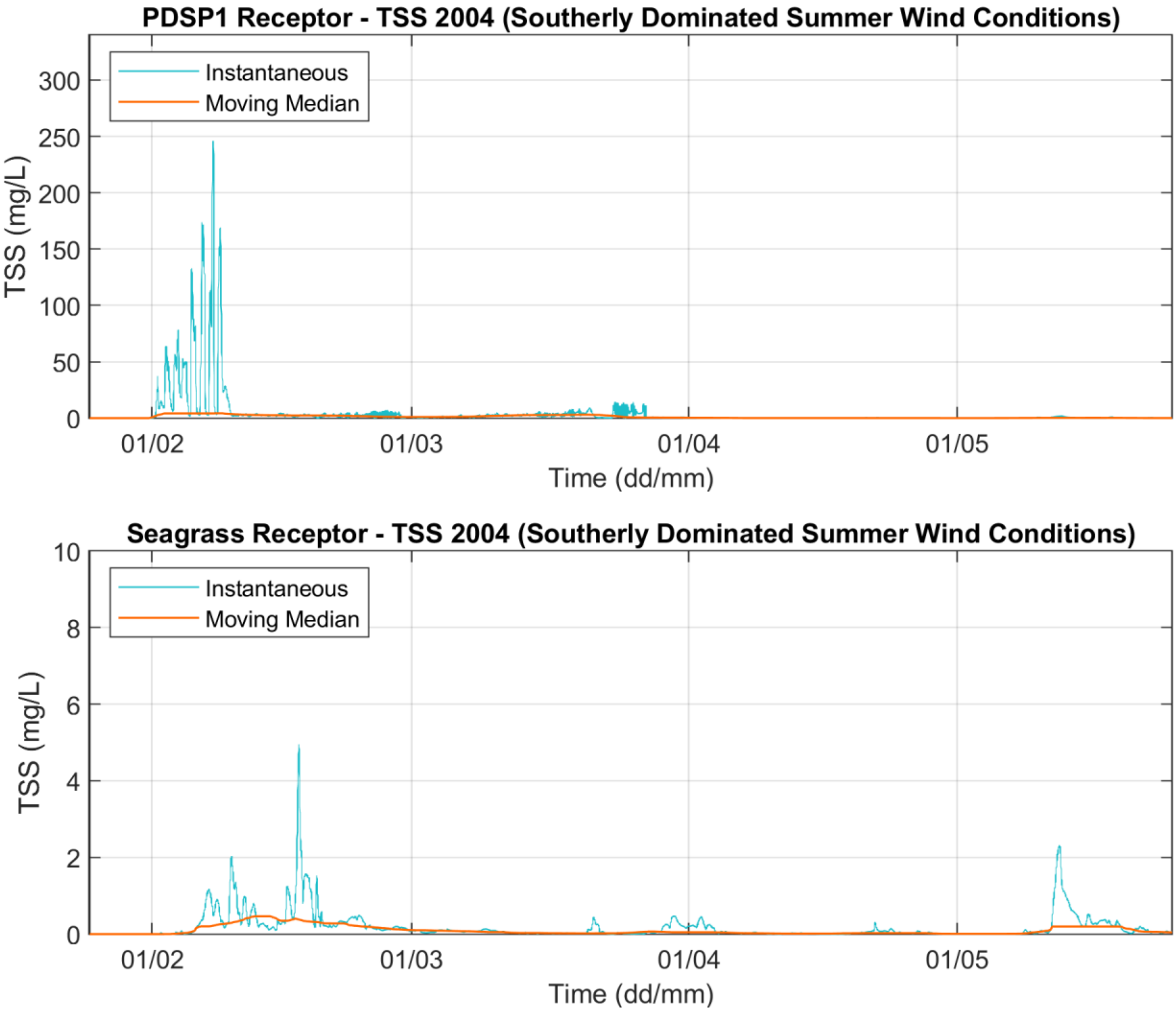

Figure A-1 2004 Typical summer wind conditions TSS time series plots, (a) PSDP1 intake sensitive receptor, (b) Seagrass sensitive receptor

Appendix B Total Suspended Sediment and Deposition Spatial Plots

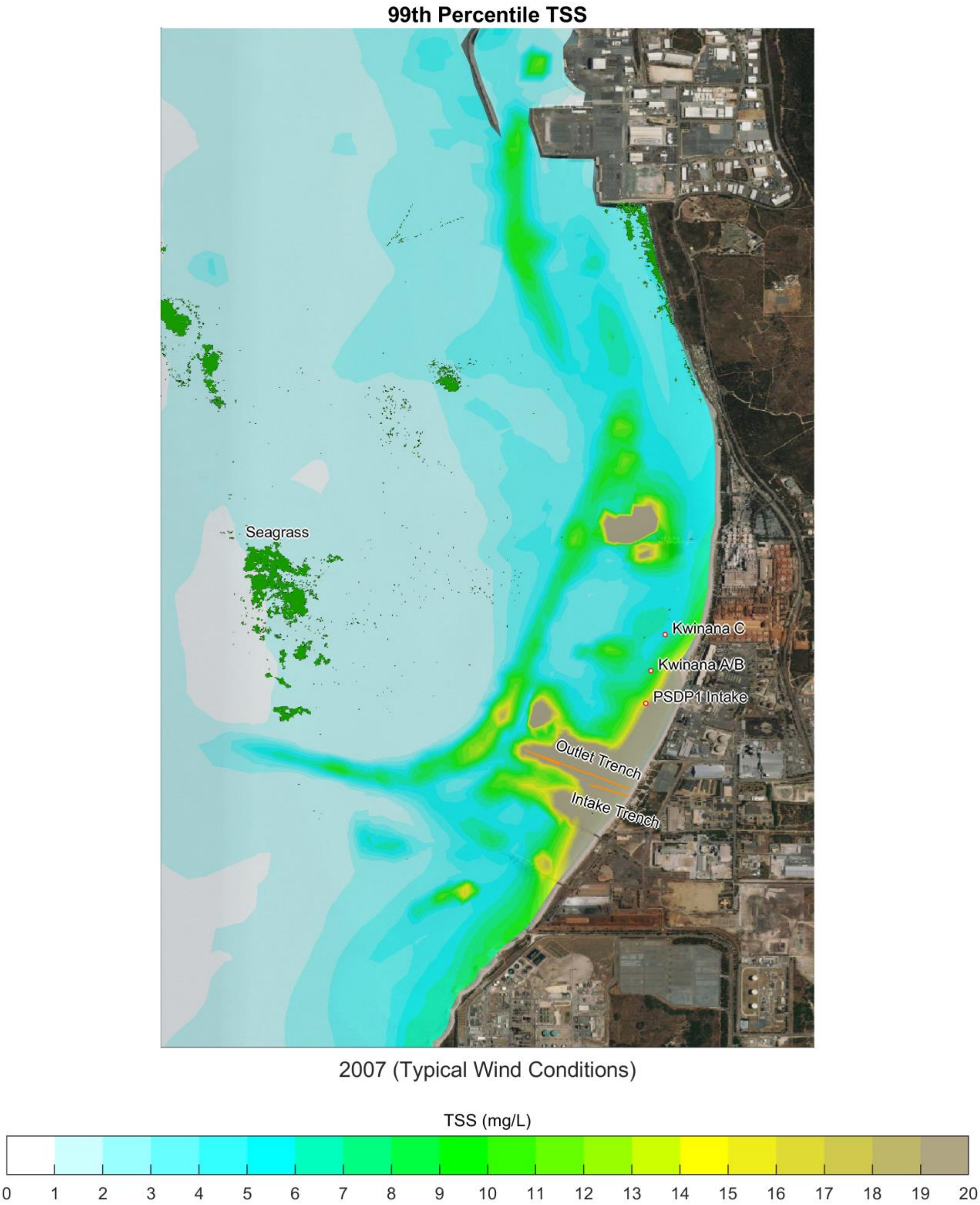

Figure B-1 2007 typical summer wind conditions 99th percentile TSS contours

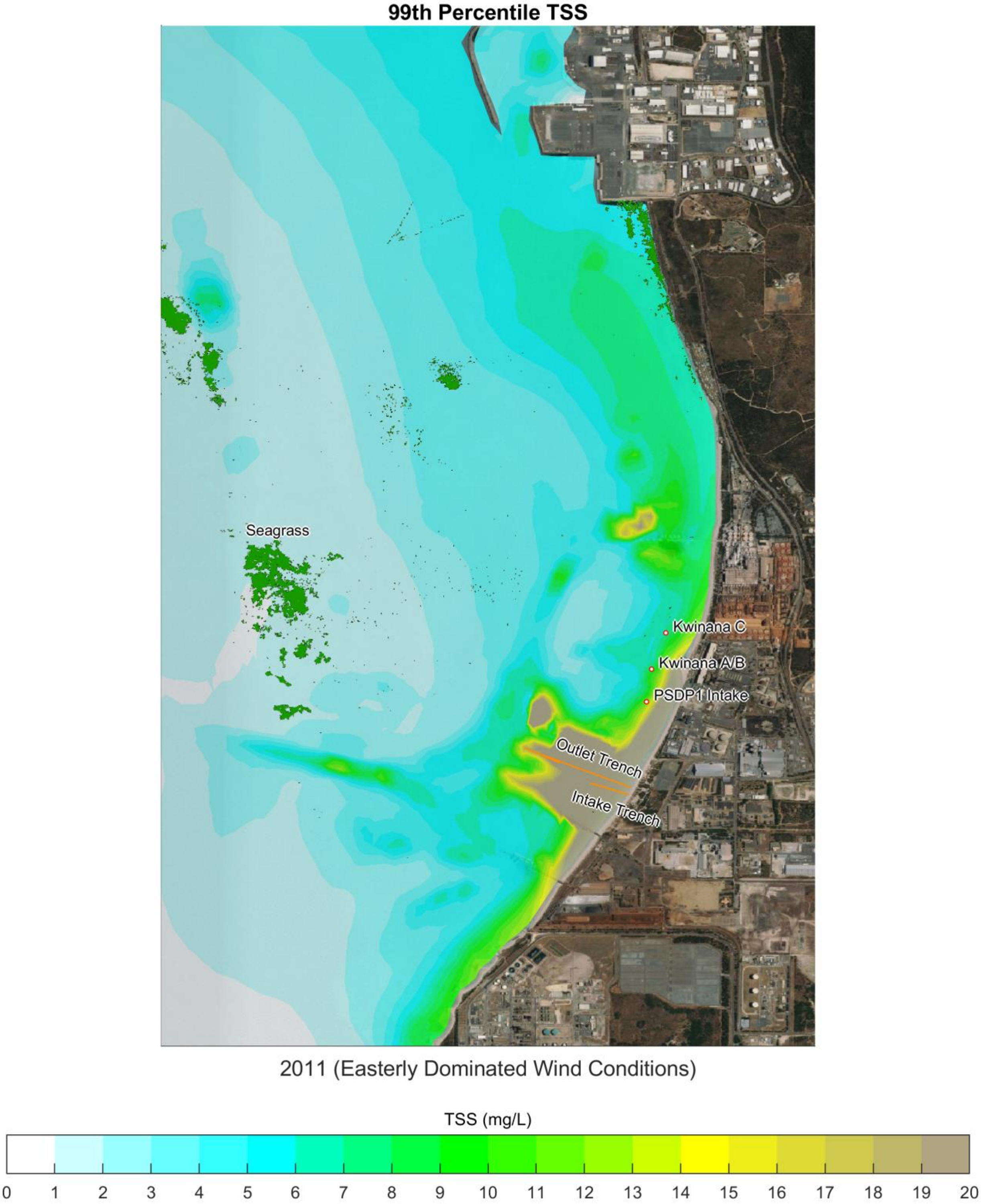

Figure B-2 Easterly dominated summer wind conditions 99th percentile TSS contours

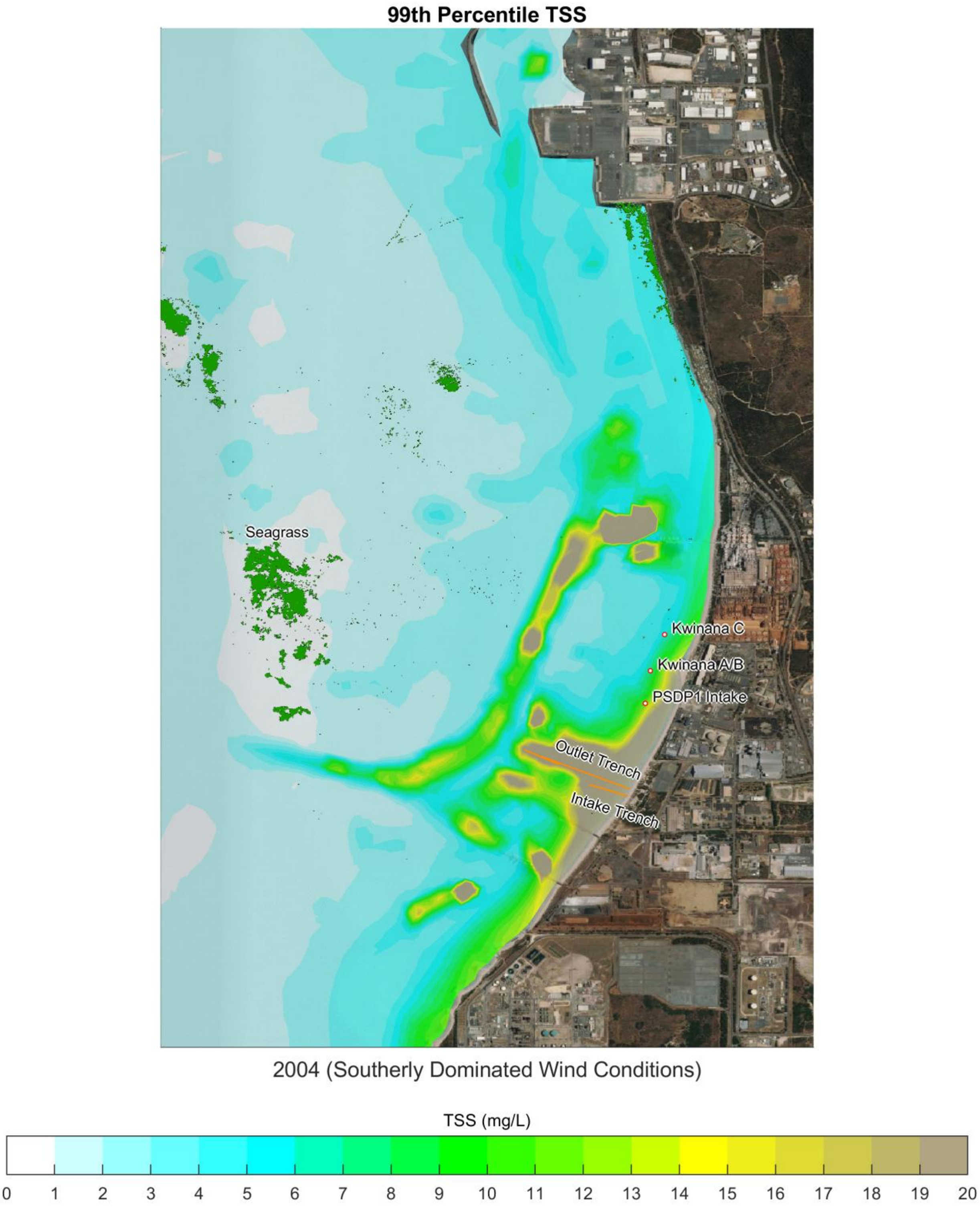

Figure B-3 Southerly dominated summer wind conditions 99th percentile TSS contours

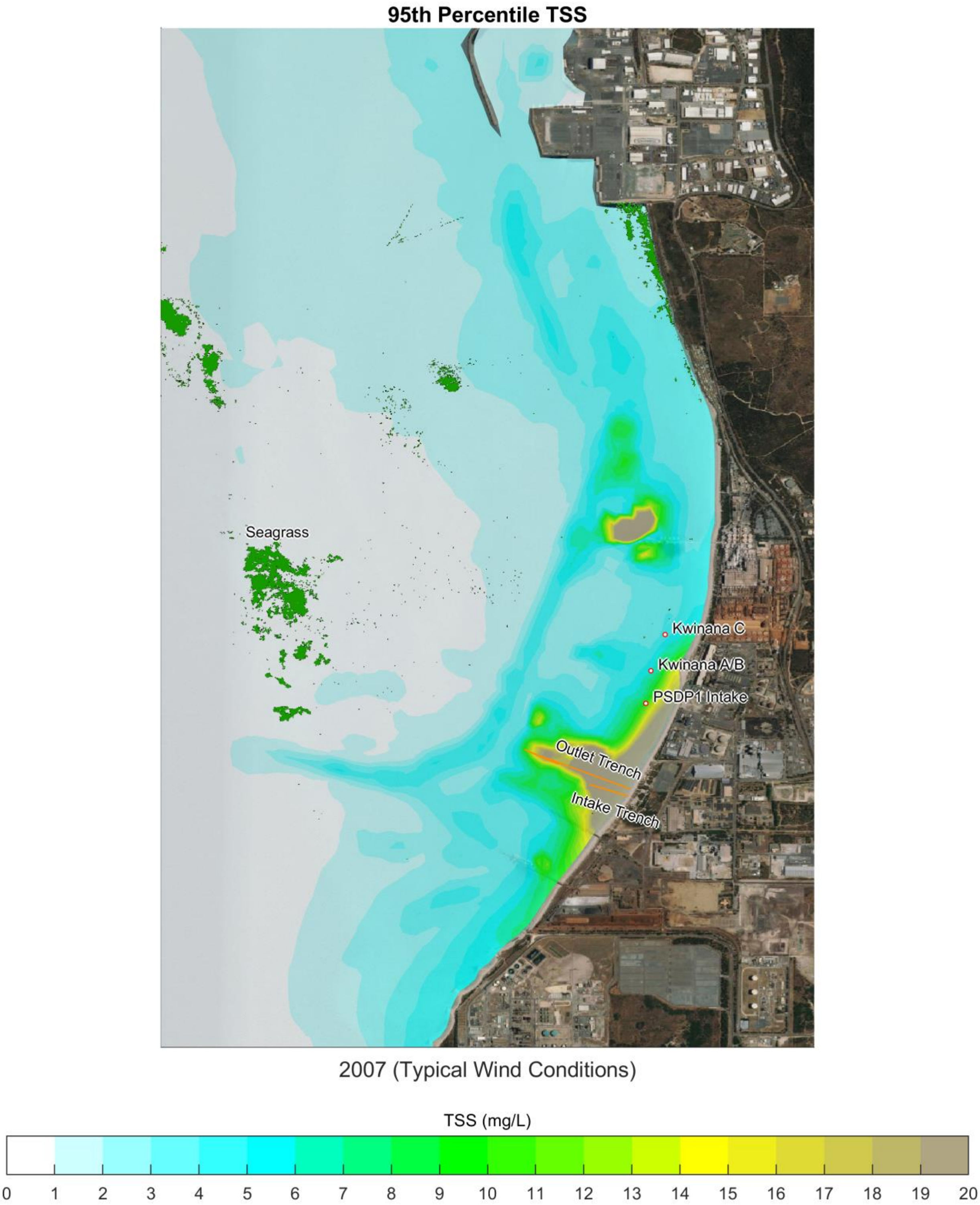

Figure B-4 Typical summer wind conditions 95th percentile TSS contours

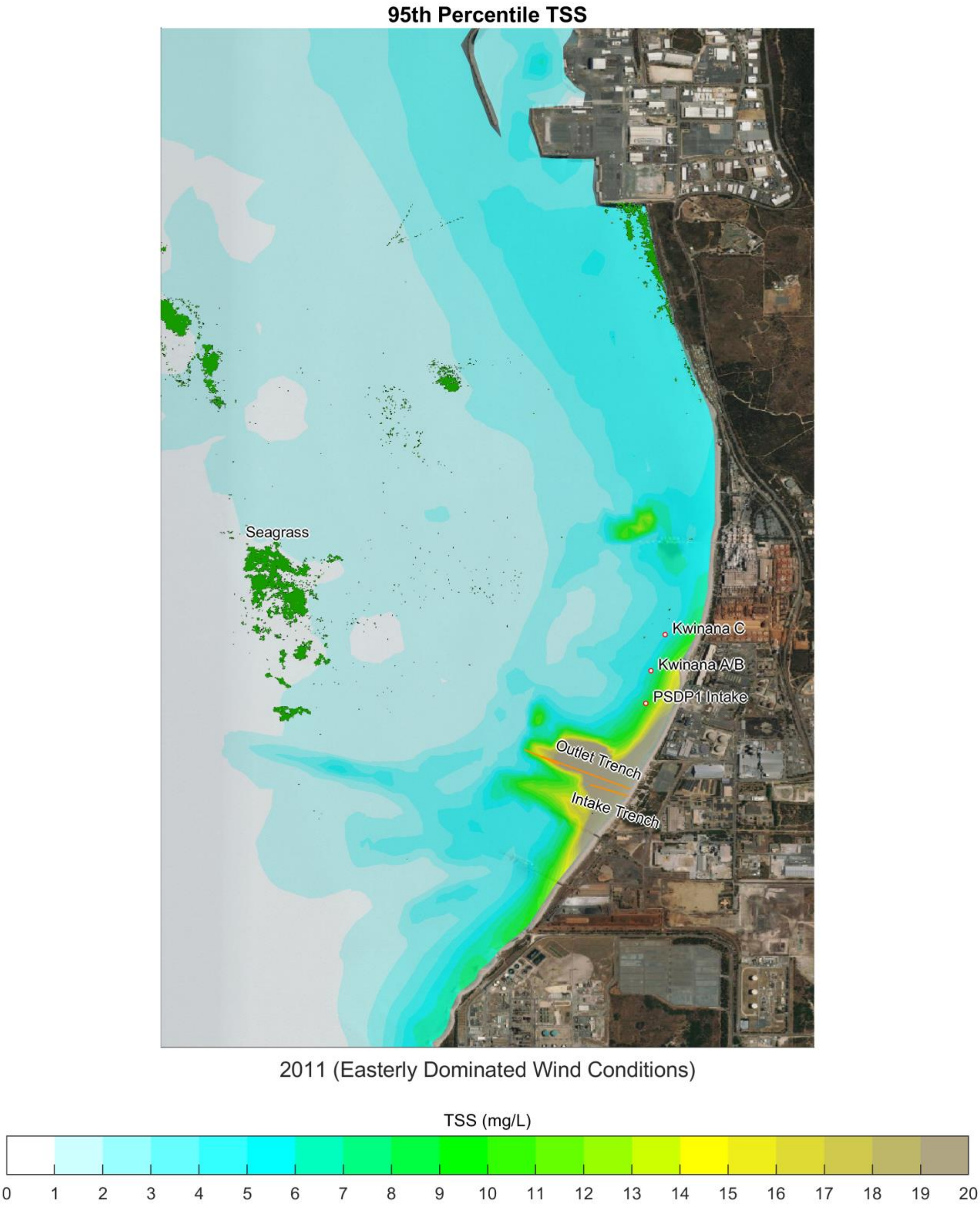

Figure B-5 Easterly dominated summer wind conditions 95th percentile TSS contours

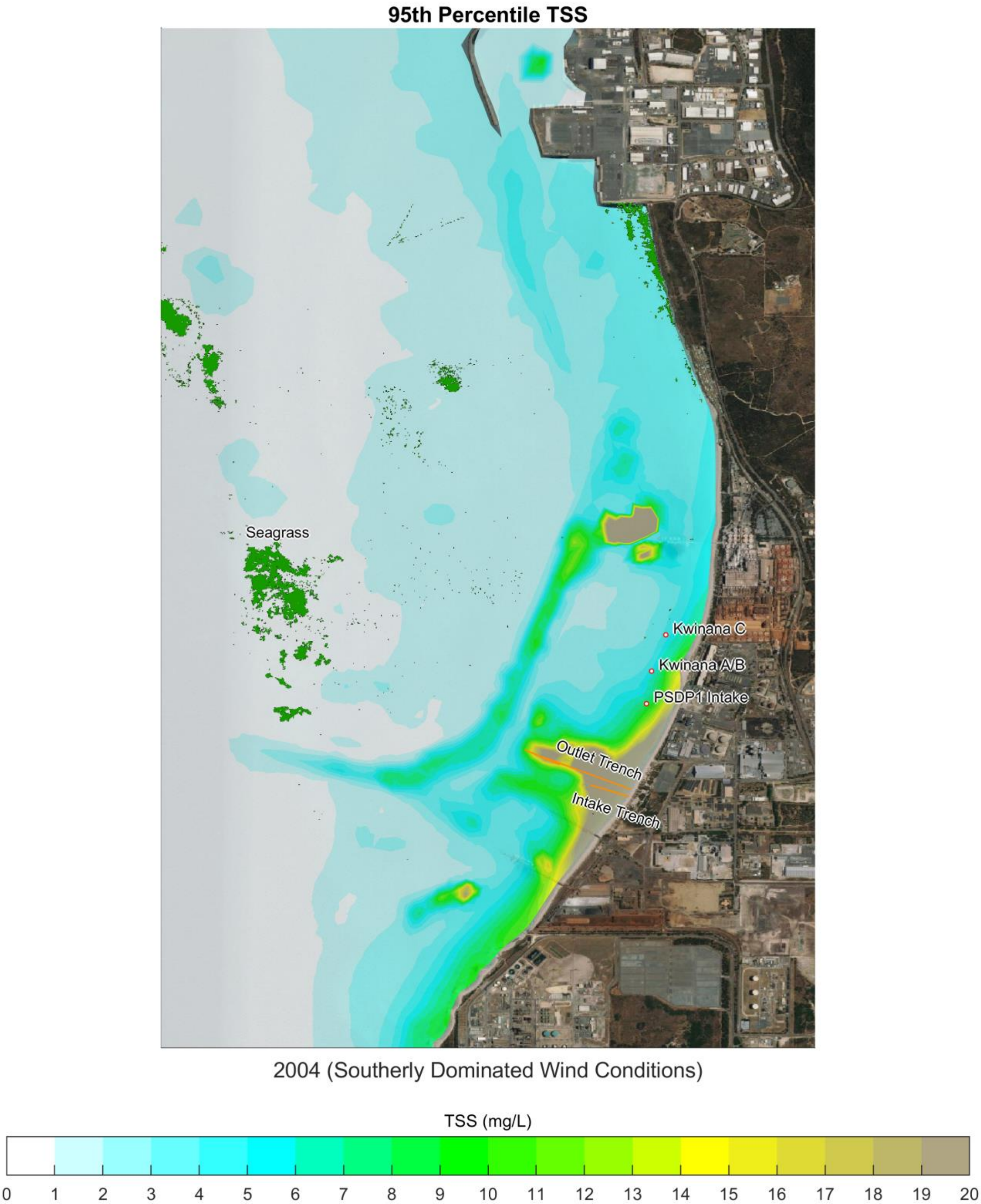

Figure B-6 Southerly dominated summer wind conditions 95th percentile TSS contours

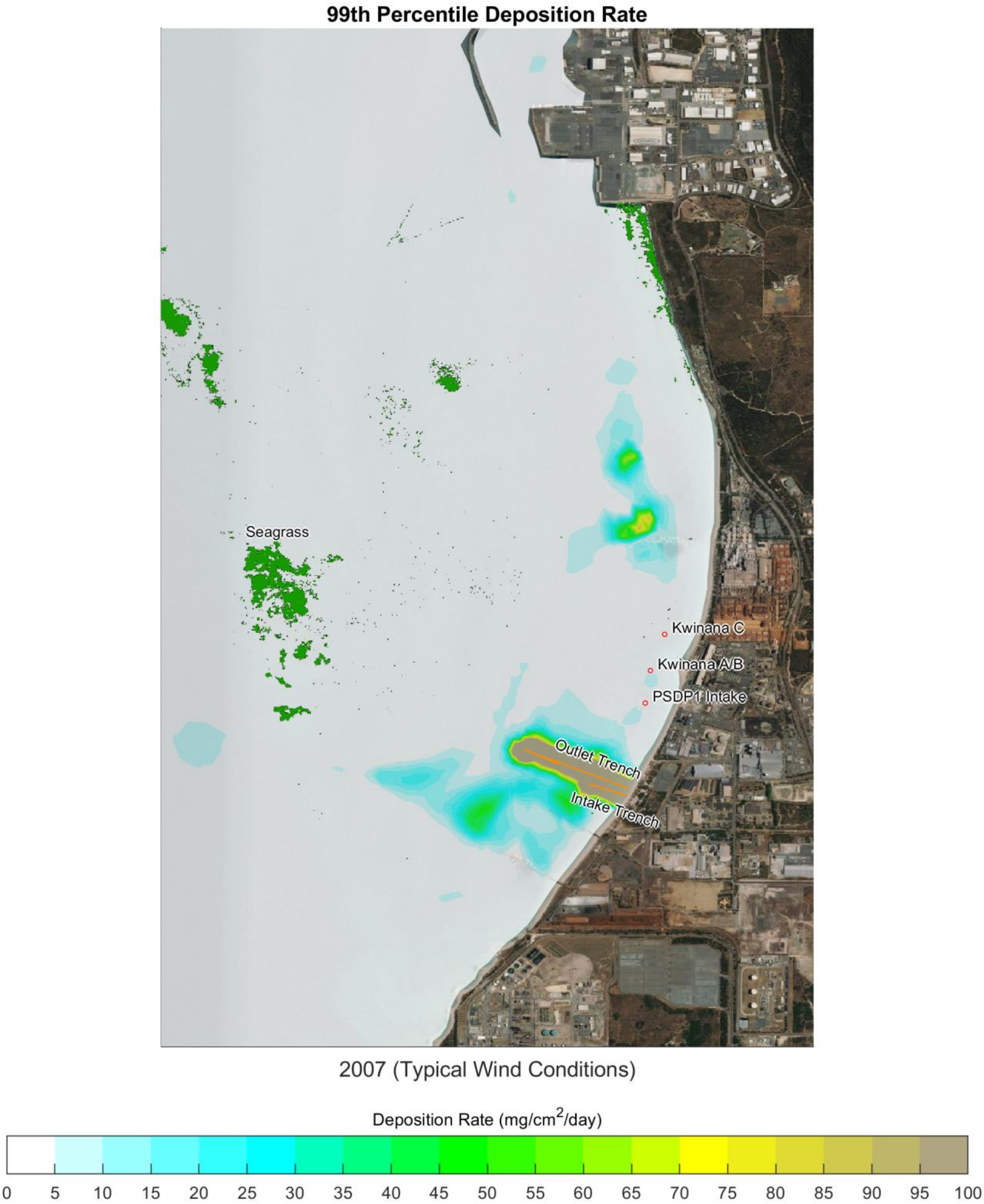

Figure B-7 Typical summer wind conditions 99th percentile deposition rate contours

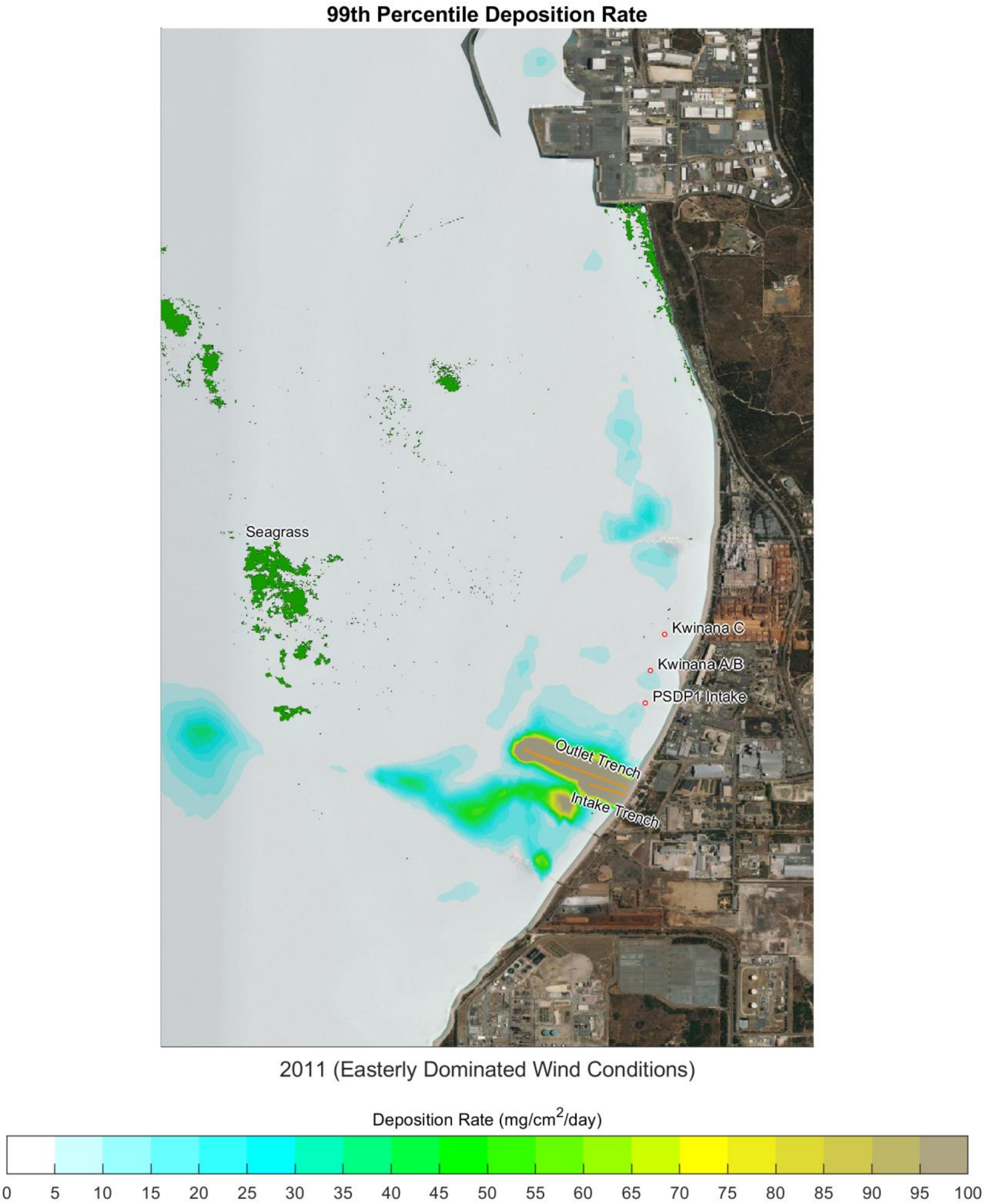

Figure B-8 Easterly dominated summer wind conditions 99th percentile deposition rate contours

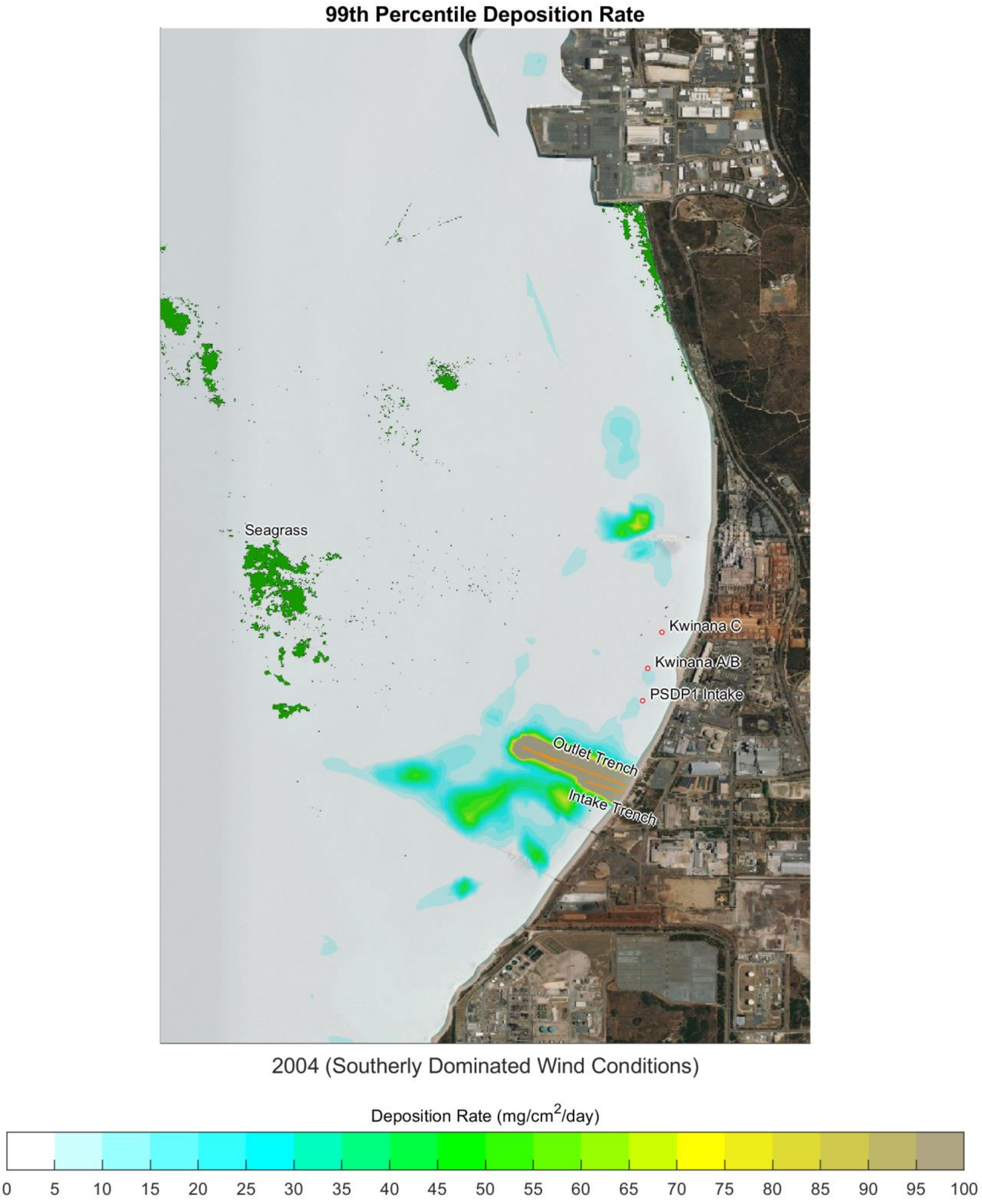

Figure B-9 Southerly dominated summer wind conditions 99th percentile deposition rate contours

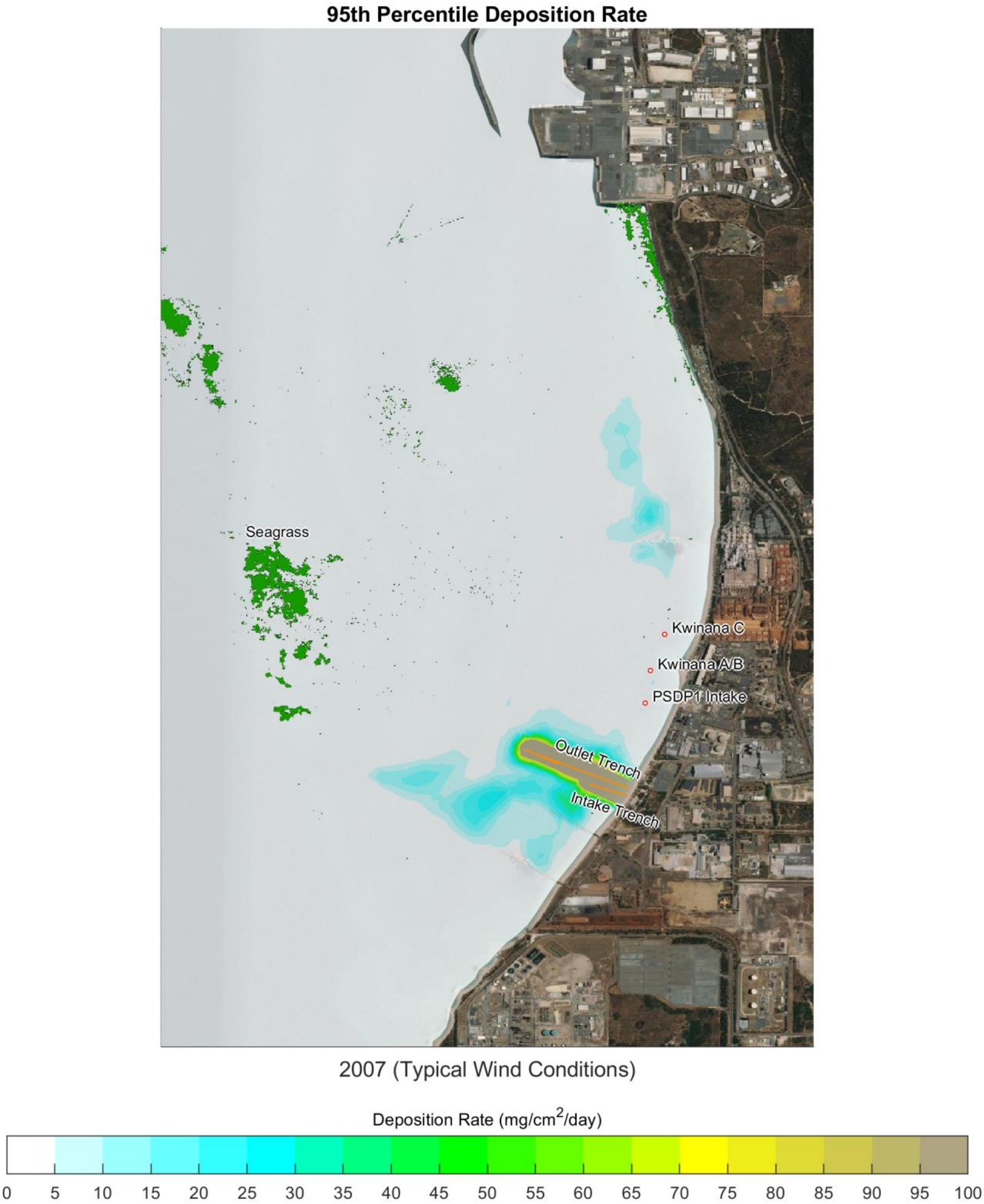

Figure B-10 Typical summer wind conditions 95th percentile deposition rate contours

Figure B-11 Easterly dominated summer wind conditions 95th percentile deposition rate contours

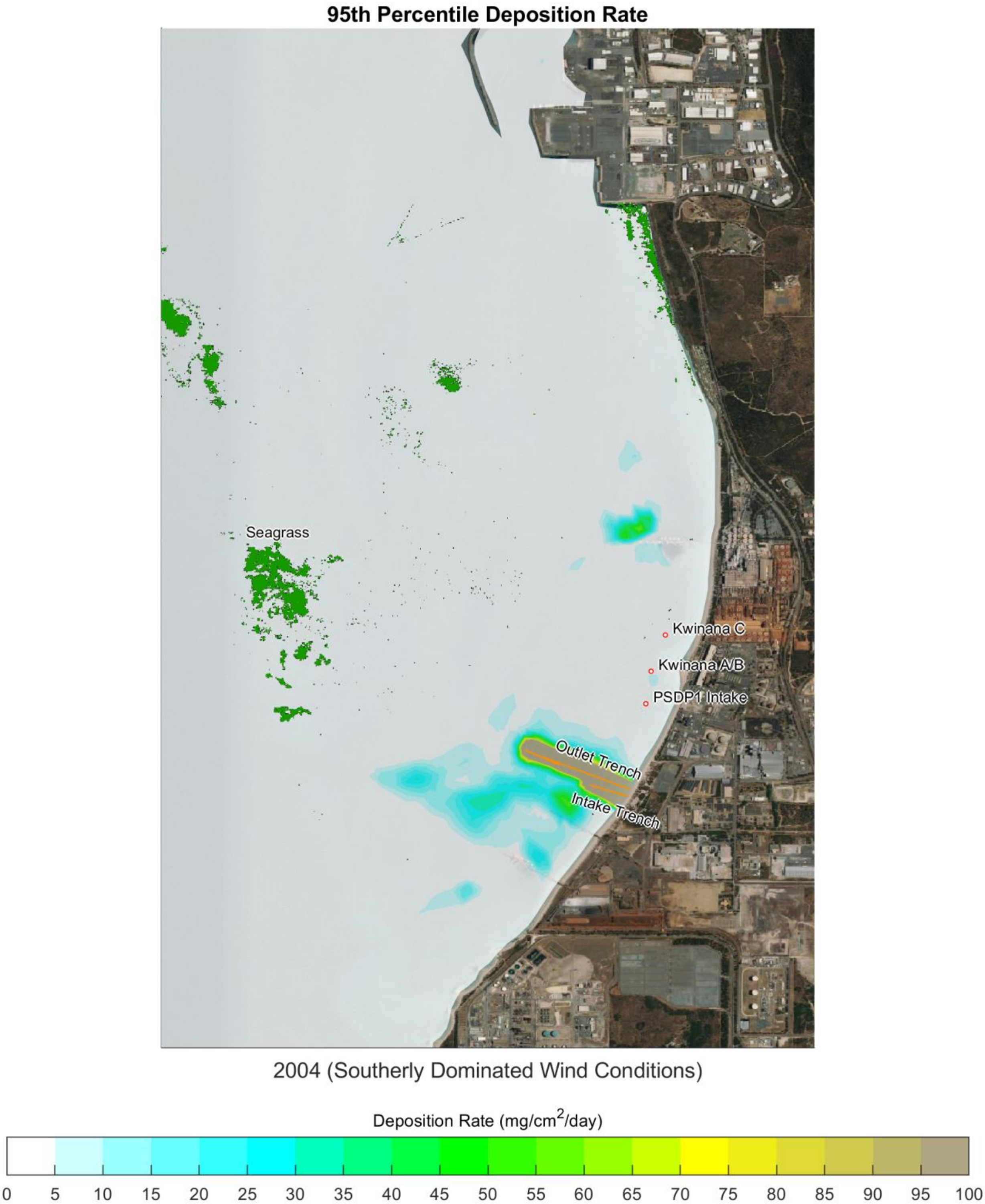

Figure B-12 Southerly dominated summer wind conditions 95th percentile deposition rate contours

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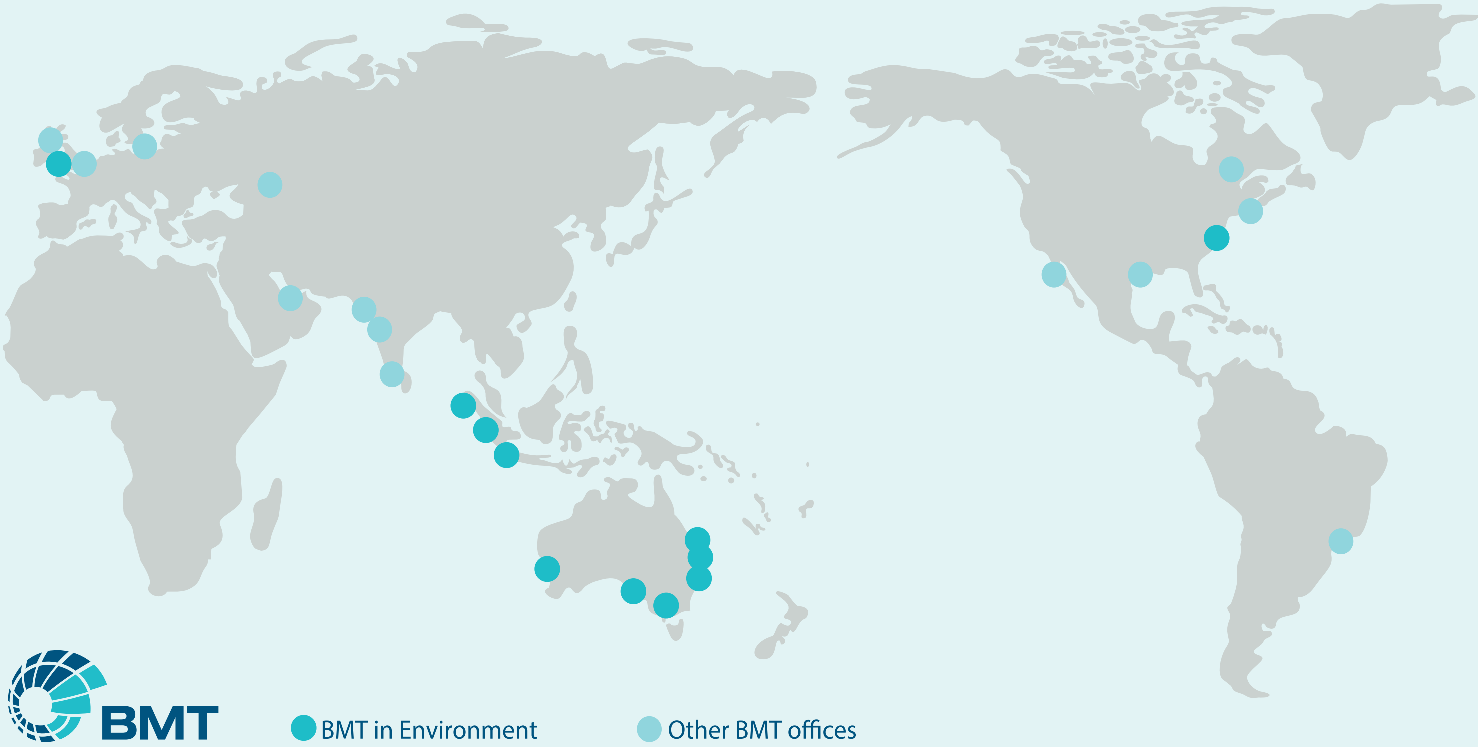

Brisbane
Level 8, 200 Creek Street
Brisbane Queensland 4000
PO Box 203 Spring Hill Queensland 4004
Australia
Tel +61 7 3831 6744
Fax +61 7 3832 3627
Email brisbane@bmtglobal.com

Melbourne
Level 5, 99 King Street
Melbourne Victoria 3000
Australia
Tel +61 3 8620 6100
Fax +61 3 8620 6105
Email melbourne@bmtglobal.com

Newcastle
126 Belford Street
Broadmeadow New South Wales 2292
PO Box 266 Broadmeadow
New South Wales 2292
Australia
Tel +61 2 4940 8882
Fax +61 2 4940 8887
Email newcastle@bmtglobal.com

Adelaide
5 Hackney Road
Hackney Adelaide South Australia 5069
Australia
Tel +61 8 8614 3400
Email info@bmtdt.com.au

Northern Rivers
Suite 5
20 Byron Street
Bangalow New South Wales 2479
Australia
Tel +61 2 6687 0466
Fax +61 2 6687 0422
Email northernrivers@bmtglobal.com

Sydney
Suite G2, 13-15 Smail Street
Ultimo Sydney New South Wales 2007
Australia
Tel +61 2 8960 7755
Fax +61 2 8960 7745
Email sydney@bmtglobal.com

Perth
Level 4
20 Parkland Road
Osborne Park Western Australia 6017
PO Box 2305 Churchlands Western Australia 6018
Australia
Tel +61 8 6163 4900
Email wa@bmtglobal.com

London
1st Floor, International House
St Katharine's Way
London
E1W 1UN
Tel +44 (0) 20 8090 1566
Email london@bmtglobal.com

Aberdeen
Broadfold House
Broadfold Road, Bridge of Don
Aberdeen
AB23 8EE
UK
Tel: +44 (0) 1224 414 200
Fax: +44 (0) 1224 414 250
Email aberdeen@bmtglobal.com

Asia Pacific
Indonesia Office
Perkantoran Hijau Arkadia
Tower C, P Floor
Jl: T.B. Simatupang Kav.88
Jakarta, 12520
Indonesia
Tel: +62 21 782 7639
Fax: +62 21 782 7636
Email asiapacific@bmtglobal.com

Alexandria
4401 Ford Avenue, Suite 1000
Alexandria
VA 22302
USA
Tel: +1 703 920 7070
Fax: +1 703 920 7177
Email inquiries@dandp.com