Empire Bay Marina

Sediment Delineation Investigation

PREPARED FOR

DEPARTMENT OF PLANNING, HOUSING AND INFRASTRUCTURE - CROWN LANDS AND PUBLIC SPACES

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Empire Bay Marina

Sediment Delineation Investigations

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ACRONYMS AND ABBREVIATIONS

Acronyms	
ACM	Asbestos Containing Material
ADWG	Australian Drinking Water Guidelines
AHD	Australian height datum
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand
ANZG	Australian and New Zealand Guidelines
ASC NEPM	National Environment Protection (Assessment of Site Contamination) Measure
bgl	below ground level
BTEXN	Benzene, toluene, ethylbenzene, xylenes and naphthalene
CCC	Central Coast Council
COC	Chain of Custody
CoPCs	Constituents of potential concern
CSM	Conceptual Site Model
Cu	Copper
DO	Dissolved oxygen
DP	Douglas Partners
DGV	Default Guideline Value
DQIs	Data Quality Indicators
DQO	Data Quality Objectives
DSI	Detailed Site Investigation
EC	Electrical Conductivity
EIL	Ecological investigation levels
ERM	Environmental Resources Management Australia Pty Ltd
GME	Groundwater Monitoring Event
HHERA	Human Health and Ecological Risk Assessment
HIL	Health Investigation Levels
HSL	Health Screening Levels
LNAPL	Light Non-Aqueous Phase Liquid
LOR	Limit of Reporting
m AHD	metres Australian height datum
m bgl	Meters below ground level
m BTOC	Metres below Top Of Casing
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council

Acronyms	Description
NEPM	National Environmental Protection Measure
NHMRC	National Health and Medical Research Council
ORP	Oxidation reduction potential
PAH	Polycyclic aromatic hydrocarbons
PFAS	Per- and Polyfluorinated Substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
QA / QC	Quality assurance / quality control
RAP	Remediation Action plan
RPD	Relative percentage difference
SAQP	Sampling Analysis and Quality Plan
SCI	Supplementary Contamination Investigation
Sn	Tin
SOP	Standard Operating Procedures
SPR	Source-Pathway-Receptor
TBT	Tributyltin
TDS	Total dissolved solids
TRH	Total recoverable hydrocarbons
UPSS	Underground petroleum storage system
UST	Underground storage tank
VMP	Voluntary Management Proposal
Zn	Zinc

EXECUTIVE SUMMARY

Environmental Resources Management Australia Pty Ltd (ERM) was contracted by the Department of Planning, Housing and Infrastructure - Crown Lands and Public Spaces (referred to as Crown Lands herein) to complete further investigation and delineation of sediment contamination at the former Empire Bay Marina, located at 16B Sorrento Road, Empire Bay NSW (the Site).

The Site is located on a Crown reserve and Crown waterway (Brisbane Water) and historically consisted of a locally heritage listed timber boatshed, jetties, slipway and refueling facilities. It operated as a commercial marina from 1949 to 2020, however, has been vacant for approximately three years and is under the care, control, and management of Crown Lands. The boatshed and jetties were demolished, UPSS removed and Crown Lands has agreed to a Voluntary Management Proposal (VMP) with the NSW EPA to manage contamination at the Site.

ERM recently completed a Supplementary Contamination Investigation (SCI) covering soil, groundwater, surface water and sediments. Although concentrations of contaminates of concern were detected in soil and groundwater, the issues appeared to be centralised to the former marina infrastructure and were vertically and laterally delineated. The investigations reported Tributyltin (TBT) exceedances of DGVs primarily localised around the slipway, former boat shed and former jetties. Lateral delineation of impacts was not achieved to the north-east (offshore), north (cross shore) and south (cross shore).

The overall objective of the Sediment Delineation Investigation was to further delineate the vertical and lateral extent of TBT and metals contamination at the Site in order to provide sufficient information for the Health and Ecological Risk Assessment (HERA) and Remediation Action Plan (RAP) (if required).

Based on gauging data, groundwater onsite is shallow (<2m below ground level). Groundwater flow direction was determined to be to the hydraulically to the west (away from the Cockle Channel), which is not consistent with previous events, however field parameters are indicative of fresh water indicating that there is tidal influence at the shoreline but overall groundwater is flowing to the east and discharging to the water body, rather than being tidally influenced to any significant extent inland from the shoreline. Groundwater analytical data was largely consistent with previous investigations, with exceedances of ecological screening criteria recorded for TBT, PFOS, copper, lead, mercury and zinc.

Sediment results exceeded DVGs for TBT at seven locations, with the most significant concentrations recorded in proximity to the former slipway. Sediment impact confirmed to be largely located approximately within 20m of the shoreline at depths <0.5m below seabed (with the exception of the historical channel leading to the former slipway). Delineation was achieved to the north in nearshore locations and offshore toward deeper, higher flow zones of the channel.

Offsite exceedances were recorded to the north-east and south within third party vessel moorings. It is unknown whether offsite detections are Site sourced or related to the vessel moorings located along the shoreline both north and south of the Site. It is likely that the third party vessel moorings represent numerous additional offsite sources of TBT.

Porewater results for TBT have previously been recorded exceeding DGVs in surface sediments within the footprint of the former boat shed, where surface sediment concentrations are elevated, however no porewater result from this investigation exceeded the DGVs.

All surface water samples collected reported results below the laboratory LOR and the adopted screening criteria with the exception of PFOS which presented exceedances of ANZG (2018) Marine Water - High ecological/conservation value in all locations sampled. It appears that the primary source of PFAS concentrations in the Cockle Channel is not Site related based on the consistency of up and downstream concentrations, however PFAS in onsite groundwater could be interacting with surface water.

Overall, the findings generally support the conclusions of the DP 2021 DSI and ERM 2024 SCI, that historical marina activities at the Site have resulted in contamination which may present a risk to the environment. The primary source of impact at the Site appears to be the former slip way, where antifouling of vessels was likely undertaken, however offsite private vessel moorings appear to be resulting in offsite impacts which are not distinguishable from onsite sources.

The information collected was reviewed in conjunction with previous Site data and used to refine the Sites Conceptual Site Model (CSM). Potentially complete SPR linkages have been identified for ecological receptors in contact with organotin impacted sediments, primarily in the footprint of the former marina infrastructure. Onshore ecological and recreational direct contact linkages may be present currently or in the future under a public foreshore open space land use scenario based on identified onshore soil and groundwater impacts.

Based on the potentially complete SPR linkages identified as part of this SDI, further remediation and/or management may be required to mitigate recreational and/or ecological risks related to organotin contamination in nearshore sediments and also onshore heavy metals, asbestos and PFOS impacts. The data available is considered sufficient to be used to inform a Human Health and Ecological Risk Assessment (HHERA) and RAP (if required following HHERA).

1. INTRODUCTION

1.1 OVERVIEW

Environmental Resources Management Australia Pty Ltd (ERM) was contracted by the Department of Planning, Housing and Infrastructure - Crown Lands and Public Spaces (referred to as Crown Lands herein) to complete additional investigation and delineation of sediments contamination at the former Empire Bay Marina, located at 16B Sorrento Road, Empire Bay NSW (the Site).

The Site location is presented in **Figure 1, Appendix A.**

1.2 BACKGROUND

The Site is located on a Crown reserve and Crown waterway (Cockle Channel within Brisbane Water) and historically consisted of a locally heritage listed timber boatshed, jetties, slipway and refueling facilities. It operated as a commercial marina from 1949 to 2020, however, was vacant for approximately three years until demolition in October 2023. The Site is under the care, control, and management of Crown Lands.

In October 2023, the boatshed & jetties were demolished and underground storage tanks (USTs) removed under a demolition order issued by Central Coast Council (CCC). Crown Lands has agreed to a Voluntary Management Proposal (VMP) with the NSW EPA to manage contamination at the Site. Crown Lands engaged Lange Jorstad of Geosyntec Consultants as NSW EPA Accredited Site Auditor for the Site. A Human Health and Ecological Risk Assessment (HHERA) is also being produced by SAGE Environmental Services, which will ultimately inform the requirement for remediation.

ERM recently completed a Supplementary Contamination Investigation (SCI) in accordance with the Douglas Partners (DP) SAQP and is summarised in **section 1.3** below.

1.3 SUMMARY OF SCI OUTCOMES

The SCI works covered soil, groundwater, surface water and sediments. Although concentrations of contaminates of concern were detected in soil and groundwater, the issues appeared to be centralised to the former marina infrastructure and were vertically and laterally delineated. Surface water results reported below the laboratory limit of detection which were appropriate to the assessment criteria selection. Based on this information, sufficient data exists to make decisions on the nature and extent of contamination in soil, groundwater and surface water in relation to the Site.

Discrete sediment samples collected at each location from either 0.25m or 0.3m depth (based on depth of core) were collected to provide additional vertical characterisation of sediments. In locations where TBT was recorded at 0.1m in excess of criteria, the deeper sample also generally exceeded. Therefore, the organotin impacts are considered to be vertically undelineated.

Tributyltin (TBT) reported was reported at concentrations exceeding Default Guideline Value (DGVs) at eight sediment locations. These exceedances were primarily localised around the slipway, former boat shed and former jetties.

Regarding lateral delineation of impacts, the status of characterisation following the SDI can be summarised as follows:

- North East (offshore): Impacts in sediment appeared to be delineated offshore by sediment locations SED129 and SED130;
- North (cross shore): impacts were noted in excess of DGVs at the northern sediment locations (SED126 and SED135); and
- South (cross shore): Shoreline impacts were delineated to the south by location SED132, however location SED128 which was approximately 10m offshore recorded concentrations exceeding DGVs.

No discernable pattern was present in the vertical distribution of TBT, with approximately half of the relevant locations exhibiting decrease in concentrations with depth and others increasing. Furthermore, reanalysis of all samples taken at 0.25/0.3m indicated that concentrations were variable between runs of laboratory analysis of the same sampled and therefore the distribution of TBT was likely to be highly variable. The concentrations in sediments at 0.3m require confirmation in order to refine the data that will be utilised in the risk assessment phase.

The ERM report then concluded that organotins in near shore sediments may potentially pose risk to receptors and impacts are undelineated vertically and laterally.

1.4 DATA GAPS SUMMARY OF SCI

Based on the information collected to date, the following key data gaps exist for organotins in sediments:

- Organotins are vertically undelineated across the majority of the impacted area (footprint of the former marina and jetties);
- Organotins are laterally undelineated to the North, both at shoreline and nearshore from the end of the footprint of the northern most former jetty;
- Organotins are laterally undelineated to the south in near shore sediments (~10-15m from shore); and
- Multiple rounds of analysis on individual sediment samples has yielded inconsistent results. Therefore, the magnitude of concentrations of organotins in sediment needs to be confirmed.

A Sediment Delineation Investigation has been scoped to provide further information on the identified data gaps, as outlined in **Section 1.6** below.

1.5 OBJECTIVES

The overall objective of the Sediment Delineation Investigation is to further characterise and delineate the extent of organotin contamination in sediments at the Site both laterally and vertically in order to provide sufficient information for the Human Health and Ecological Risk Assessment (HHERA) and (Remediation Action Plan) RAP (if required).

1.6 SCOPE OF WORK

1.6.1 SEDIMENT ASSESSMENT

ERM produced a Scoping Document (ERM, 2024) to outline the scope of works for review and endorsement by the Auditor. Based on the requirements of the Scoping Document, the scope for the nearshore Sediment Assessment and Analysis was undertaken:

- Collection of sediment samples at 13 locations to a target depth of 1m beneath the bed by hydraulic handheld vibro-core (locations are illustrated on ***Figure 3, Appendix A*).** Dedicated plastic core liners were used to minimise cross contamination;
- Photograph and log the lithology of each core;
- Collection of sediment samples as per the SAP in *Appendix A* as follows:
  - three samples per bore (0.3, 0.5m and 1.0m) at 6 locations;
  - four samples per bore (surface, 0.3, 0.5m and 1.0m) at 7 locations ;
  - each primary sample required two 250ml soil jars to be collected to allow for sample re-analysis if required;
  - Refusal was encountered at 0.2 m on oysters and dense sand at sample location SED_2_122_2 and could not be sampled; and
  - SED_2_140 was split into two locations, with an additional location SED_2_140a about 10 meters further offshore. Although collected at different locations, both locations represent one planned location in relation to the SDI scoping (ERM, September 2024) and the depth sampled.
- Additional bulk grab samples were collected by Van Veen sampler or large diameter push core (150mm) for the purpose of collecting additional sample sufficient for pore water analysis (min 5kg). Pore water samples were collected at all locations with the exception of previously completed location SED_2_222_2 and SED_2_223_2 (12 locations total); and
- Submission of sediment samples to a NATA accredited laboratory under chain of custody (COC) for analysis of:
  - organotins (monobutyltin, dibutyltin, tributyltin and elemental tin) on the -2mm fraction. Each extraction will be 6 gram of sample, which is an increase from the standard 2 gram;
  - Organic Carbon %; and
  - Pore water analysis for organotins.

1.6.2 SURFACE WATER ASSESSMENT

A surface water sampling event was completed, which included locations SW136 – SW140, which were also sampled as part of the SCI, as follows.

- Samples were collected prior to any sediment sampling for representative samples not influenced by any disturbance;
- Samples were collected by extendable sampling arm from approximately 10cm below the water surface;
- Locations SW136, SW137, SW139 and SW140 were collected from the bank and location SW138 was sampled from the support vessel;
- Surface water samples were laboratory analysed for the following suite:
  - Organotins; and
  - PFAS.
- Submission of surface water samples to a NATA accredited laboratory.

1.6.3 Groundwater Monitoring Event

The remaining groundwater monitoring wells (MW3, MW6 and MW102) were sampled as per methodology utilized during the SCI and previously conducted events. Groundwater monitoring activities included:

- Gauging of three groundwater monitoring wells using an interface probe to measure groundwater depth and the presence / absence of light non aqueous phase liquid (LNAPL);
- Purging and sampling of three groundwater wells using low flow sampling (peristaltic pump);
- A water quality meter recorded groundwater quality parameters prior to sampling of recovered water. Field parameters included temperature, pH, oxidation reduction potential (ORP), EC and DO;
- Groundwater was purged until field parameters stabilised, primary samples and field QC samples were then collected in laboratory-prepared bottle and vials, for analysis of the identified COPCs:
  - BTEX;
  - TRH;
  - Metals (Cu, Ni, Pb, Hg, Sb, Sn, Zn);
  - PAHs;
  - Organotins; and
  - PFAS.
- Submission of groundwater samples to a NATA accredited laboratory.

2. SITE IDENTIFICATION AND SETTING

The following sections provide a brief summary of the Site setting information gathered and reviewed for the Site.

2.1 SITE IDENTIFICATION

TABLE 2-1 SITE IDENTIFICATION

Item	Description
Site Name	Empire Bay Marina
Site Address	16B Sorento Road, Empire Bay, NSW,
Site ownership	NSW Crown Lands
Legal Description	Part of Lot 7036 in DP 1058756, Part of Lot 486 in DP 727270 and Part of Brisbane Water (Cockle Channel)
Latitude/longitude	-33.492495, 151.363086
Local Government Area	Central Coast Council
Site area	2,050 m^2
Current Zoning	RE1 Public Recreation and W2 Recreational Waterways
Current land use	Empire Bay Marina – Closed to the public following demolition.

Source:
Douglas and Partners (2022) Sampling Analysis and Quality Plan for a Supplementary Contamination Investigation.
Google Earth (accessed March 2024)

2.2 SITE DESCRIPTION

The Site currently consists of vacant land, with numerous hardstand and support structures along the surface. The jetty has since been removed although pilings remain in place. An overview of the Site features is presented in **Figure 2, Appendix A.** Photographs of the Site are presented in **Appendix E.**

As shown in **Figure 2, Appendix A**, the Site consists of on shore and near shore areas. The onshore area, within the western half of site, consists of grassed surface and hardstand. The remnants of building support structures, and UPSS infrastructure, including the old boat ramp, with slipway rails which extend into the water are evident within the footprint of the former marina. Onshore areas are demarcated by temporary fencing.

The nearshore portion of the Site extends approximately 30m out from the shoreline. This area consists of remnant pilings which were used to support the marina shed and two jetties, and rails which extend from the boat ramp on shore out into the water. This area is demarcated by a silt screen within the water**.**

The Site boundary was determined based on historical marina activities, and where impacts would most like be present based on the use/storage of equipment and mooring of boats.

2.3 SITE SETTING

The Site setting information is presented within Table 2-2 below:

TABLE 2-2 SITE SETTING

Item	Description
Current Land Use	• The Site is currently vacant, slip way and pilings related to the former jetties remaining. • The onshore areas of site consists of hardstand, and grass surface and building infrastructure remaining in the hardstand.
Surrounding Land Use	The current uses surrounding the Site include: • **North:** Public waterfront reserve, which includes a playground 60m to the north. • **East**: Directly east of Site is the Cockle Channel within Brisbane Water, with the suburb of Davistown approximately 450m further north-east on the bank opposite to Site. • **South**: Directly south of the Site is a public waterfront reserve. The Empire Bay Wharf and public boat ramp is located 110 m to the southeast. • **West**: Directly west of the Site is a public easement, with residential properties 20m west.
Site Elevation	• Approximately 2 m relative to Australian Height Datum (AHD)
Topography (Onshore)	• The Site and the broader Empire Bay township area is generally flat and low lying and is surrounded on three sides (north, east and west) by the Brisbane Water estuary and/or estuarine wetland areas connected to Brisbane Water. • An elevated ridge is situated to the south of Empire Bay, which rises from approximately 600m to the south of the Site to a maximum elevation of 125m AHD.
Nearshore Water depths and description	• The water depth grade from approximately 0.5-1m within 5-10m of the shoreline and drops off to approximately 4 m below the water level towards the center of Cockle Channel (varying depending on tide levels).
Hydrology	• Surface water would generally be expected to runoff into the unsealed onshore surfaces in the locality of the Site or drain into Cockle Channel / Brisbane Water.
Geology, Soils and Sulfate Soils	• Review of the local geology mapping indicates that the onshore areas of the Site are underlain by estuarine tidal-delta flat deposits described as fine to medium-grained lithic-carbonate-quartz sand (marine-deposited), silt, clay, shell material, polymictic gravel (Douglas Partners, 2021). • The mapping indicates that Site soils would generally comprise Holocene sediments of predominantly coarse to fine quartz sand with shell fragments and occasionally silt (Douglas Partners, 2021). • The near shore areas of the Site are mapped as being underlain by possibly a mix of estuarine tidal delta flat (subaqueous) and estuarine channel deposits (subaqueous). Both estuarine deposits are described as fine to medium-grained lithiccarbonate-quartz sand (marine-deposited), silt, clay, shell material and gravel. The local acid sulfate risk mapping indicates that both the onshore and overwater areas are mapped as having a high probability of occurrence of acid sulfate soils.

Item	Description
Hydrogeology	• A search of the publicly available registered groundwater bore database (BOM, 2024) indicated that there are three registered groundwater bores within 500m of the Site. GW201592- 130m southwest, GW107255- 340m northwest and GW202201- 481m northeast. All bores are registered for domestic purposes, however given the availability of municipal drinking water in the Empire Bay area, it is considered unlikely that groundwater within the area is used for drinking purposes. • Douglas partners (2021) concluded that a permanent groundwater table is present at relatively shallow depth (i.e. less than 1 m depth) and it is anticipated that there may be a flow direction beneath the Site toward Brisbane Water (i.e. north-east towards Cockle Channel). It was also noted, groundwater levels are potentially transient and can be affected by factors such as soil permeability, recent weather conditions and tidal conditions within Brisbane Water.

Sources:
Douglas and Partners (2021) Detailed Site Investigation (Contamination). Rehabilitation of Empire Bay Marina.
Bureau of Meteorology (BOM) (2024) Australian Groundwater Explorer. Accessed 13 March 2024.

3. DATA QUALITY OBJECTIVES

3.1 OVERVIEW

For the purposes of this assessment, the following Data Quality Objectives (DQOs) were adopted to define the type and quality of data required to achieve the project objectives outlined in Section 1.5. The DQOs have been prepared in line with the seven-step approach outlined in National Environment Protection (Assessment of Site Contamination) Measure (the ASC NEPM) (NEPC, 1999) (as amended 2013).

The DQO process is validated, in part, by the quality assurance and quality control (QA/QC) procedures and assessment presented in **Appendix G** of this report. The seven steps of the DQO process, and how they were applied to this assessment, are presented in the following subsections.

3.2 STEP ONE: STATE THE PROBLEM

Based on the outcomes of previous investigations (ERM 2024), contamination is present at the Site in soil, groundwater and nearshore sediments. The primary source of impact at the Site appears to be the former slip way, where antifouling of vessels was likely undertaken with TBT and heavy metals being the prevalent contaminants of concern, byproducts of such activity.

Following a review of the source pathway receptor (SPR) and data collected as part of the SCI, ERM considers that a risk to onshore recreational and ecological receptors in contact with sediments in the footprint of the former marina infrastructure may exist under a future public foreshore open space land use scenario.

The organotin contamination in sediments at the Site is undelineated both laterally and vertically. Furthermore, data related to multiple rounds of analysis on individual samples demonstrates high heterogeneity. Increased certainty around the values used for characterising, risk assessment and determine the most appropriate actions for future Site management in required.

3.3 STEP TWO: IDENTIFY THE DECISION

Overall, the principal decision to be made is the determination of the contamination extent at the Site associated with previous Site operations. Additional decisions to be made include:

- Is the data of sufficient quality to be relied on for the characterisation of impacts?
- What is the extent of impact to sediment, surface water and/or groundwater?
- Does contamination present warrant remediation or further management?

In order to make an informed decision regarding the extent of potential contamination, sediment, surface water and groundwater samples were collected and submitted for laboratory analysis, with the results being reviewed in addition to the SCI findings and against applicable screening criteria.

3.4 STEP THREE: IDENTIFY INPUTS TO THE DECISION

The inputs required to adequately make a decision regarding the nature and extent of soil and groundwater contamination at the Site include the following:

- scope of works as outlined in Section 1.6;

- relevant environmental data made available to ERM by Crown Lands at the time of reporting and through searches completed by ERM as outlined in Section 2;
- direct measurement and observations of environmental variables during sediment sampling including soil type, odours, and staining;
- laboratory measurement of sediment, surface water and groundwater samples for one or more of the identified CoPCs;
- field and laboratory quality assurance / quality control data;
- the relevant sediment, surface water and groundwater quality criteria; and
- assessment of whether the concentrations of the contaminants of potential concern (CoPCs) are greater than, equal to or less than the adopted screening criteria.

3.5 STEP FOUR: DEFINE THE BOUNDARIES OF THE STUDY

3.5.1 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundaries of the study are as per the description of the Site as shown in **Figure 1** and **Figure 2, Appendix A**. The investigation was limited to sediment, surface water and groundwater beneath the Site. Four sediment sampling locations were added to the north, one for northeast, one for south and one for south east in to refine the delineation of the SCI.

Vertical boundaries of the investigation were limited to sediment (<1.0 m bgl which was the maximum depth of investigation) and the depth of the groundwater monitoring wells.

Temporally, the study was intended to provide an assessment of the nature and extent of contamination as at the time of the investigation (14 and 15 October 2024).

3.5.2 STUDY CONSTRAINTS

Constraints on the delivery of the Site Investigation within the study boundaries included:

- Capability of vibrocore sample tube to retain sample in water column;
- Ground conditions restricting vibrocorer penetration beyond obstructions; and
- Location of pilings remaining insitu in the nearshore portion of the Site.

3.6 STEP FIVE: DEVELOP A DECISION RULE

The DQOs were designed to facilitate the collection of adequate data to address the decisions in Step Two of the DQO process.

Results of laboratory analysis were compared to published environmental criteria to establish whether identified environmental and human health values have been protected in the context of its current approved zoning and land use.

The current zoning of the Site is RE1 Public Recreation and W2 Recreational Waterways within the Central Coast Council Local Government Area. The waterway is considered to be of high ecological value. ERM has applied the relevant screening criteria as a preliminary tool for assessing any current and / or potential future unacceptable risk for the identified Site receptors.

Lateral delineation plan was based on the SCI findings to further investigate areas of concern with additional sample locations extending beyond the investigation extent of the SCI. Vertical delineation was assessed extending delineation from 0.3m up to 1m in all sampling locations.

3.6.1 FIELD AND LABORATORY QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

The suitability of data was assessed based on comparison with acceptable limits for field and laboratory QC samples outlined in relevant guidelines made or approved under the NEPC 1999 (April 2013) National Environment Protection (Assessment of Site Contamination) Measure.

The scope of the Sediment Delineation Investigation has been developed in strict accordance with the Quality Assurance and Quality Control (QA/QC) requirements stipulated in the NEPM. Key aspects QA/QC requirements have been highlighted below:

- Quality control analysis was developed to include:
  - Intra laboratory duplicates at a rate of 1:10 samples (requiring 5 intra laboratory samples);
  - Inter laboratory duplicates at a rate of 1:10 samples (requiring 5 inter laboratory samples);
  - In addition to the above list duplicates, each primary sample was collected as two x250ml soil jars and logged as separate laboratory samples to allow more flexibility in the reanalysis of samples;
  - one rinsate blank per day of sampling; and
  - one trip blank/spike pair per sample batch (analysed for TRH / BTEX as standard, one blank accompanying sediment samples will be analysed for TBT).
- The field program was developed taking into consideration all relevant legislative requirements and guidance; and
- The primary laboratory (Eurofins) and secondary laboratory (ALS) which have been selected to deliver the laboratory analytical component of the project are NATA-accredited for all laboratory analysis proposed as part of this investigation.

A summary of the QA / QC procedures and assessment is presented in **Appendix G.**

3.6.2 ASSESSMENT CRITERIA

Sediment and groundwater data was compared to the relevant screening criteria as outlined in Section 4. Exceedance of the screening criteria were not necessarily considered indicative of a requirement for remediation or of a risk to human health and / or the environment. If individual concentrations exceeded the screening criteria, consideration was given to the extent of the impact, the potential for receptors to be exposed and regulatory compliance. Further details on the screening criteria adopted for soil and groundwater are provided in Section 5.

3.6.3 APPROPRIATENESS OF LABORATORY LIMIT OF REPORTING

Comparison of the laboratory Limit of Reporting (LOR) to the screening values has been undertaken, confirming that the laboratory LORs are appropriate to the adopted screening criteria. Minor laboratory LORs are predominantly lower than the adopted screening criteria and those exceptions were noted and are discussed further in the QA / QC Report presented in **Appendix G.**

3.7 STEP SIX: SPECIFY LIMITS ON DECISION ERRORS

This step establishes the decision maker's tolerable limits on decision errors, which provide performance goals for limiting uncertainty in the data. Data generated during this project must be appropriate to allow decisions to be made with confidence.

Specific limits for this project have been adopted in accordance with the appropriate guidance from the NEPM (2013), appropriate data quality indicators (DQIs) used to assess data QA / QC and standard ERM procedures for field sampling and sample handling.

To assess the usability of the data prior to making decisions, the data will be assessed against pre-determined DQIs for precision, accuracy, representativeness, comparability and completeness. The DQI decision errors of measure are presented in table below.

The pre-determined DQIs established for the project are discussed below in relation to precision, accuracy, representativeness, comparability, completeness and sensitivity.

- **Precision** – measures the reproducibility of measurements under a given set of conditions. The precision of the laboratory data and sampling techniques is assessed by calculating the Relative Percent Difference (RPD) of duplicate samples;
- **Accuracy** – measures the bias in a measurement system. The accuracy of the laboratory data that are generated during this project is a measure of the closeness of the analytical results obtained by a method to the 'true' value. Accuracy is assessed by reference to the analytical results of laboratory control samples, laboratory spikes and analyses against reference standards;
- **Representativeness** - expresses the degree with which sample data accurately and precisely represent a characteristic of a population or an environment condition. Representativeness is achieved by collecting samples on a representative basis across the Site, and by using an adequate number of sample locations to characterise the Site to the required accuracy;
- **Comparability** – expresses the confidence with which one data set can be compared with another. This is achieved through maintaining a level of consistency in sampling techniques, analytical techniques and reporting methods;
- **Completeness** – is defined as the percentage of measurements made which are judged to be valid measurements. The completeness goal is set at there being sufficient valid data generated during the study; and
- **Sensitivity** – expresses the appropriateness of the chosen laboratory methods, including the limits of reporting, in producing reliable data in relation to the adopted assessment criteria.

If any of the DQIs are not met, further assessment will be necessary to assess whether the non-conformance will significantly affect the usefulness of the data. Corrective actions may include requesting further information from samplers and / or analytical laboratories, downgrading of the quality of the data or alternatively, re-collection of the data.

TABLE 3-1 DQI DECISION ERRORS

Data Quality Objectives		
Precision		
Blind duplicates (intra laboratory)	1 / 20 samples	30% RPD
Blind duplicates (inter laboratory)	1 / 20 samples	30% RPD
Accuracy		
Surrogate spikes	All organic samples	70-130%
Laboratory control samples	1 per lab batch	70-130%
Matrix spikes	1 per lab batch	70-130% Lower recoveries may be acceptable for OCPs, OPPs, PCBs and phenols and were assessed according to USEPA protocols.
Representativeness		
Sampling appropriate for media and analytes	NA	Follow laboratory requirements for sample containers and transport.
Samples extracted and analysed within holding times.	NA	organics (14 days), inorganics (6 months)
Rinsate blank	1 per day where non-dedicated equipment is used. Samples are to be analysed for main CoPCs other than asbestos	<LOR
Trip spike	1 per day (water samples; BTEX only)	70-130%
Method blank	1 per lab batch	<LOR
Comparability		
Standard operating procedures for sample collection and handling	All samples	All samples
Standard analytical methods used for all analyses	All samples	All samples
Consistent field conditions, sampling staff and laboratory analysis	All samples	All samples
Completeness		
Sample description and COCs completed and appropriate	All samples	All samples

Data Quality Objectives	Frequency	Data Quality Indicator
Appropriate documentation	All samples	All samples
Satisfactory frequency and result for QC samples	All QA / QC samples	-
Data from critical samples is considered valid	NA	Critical samples valid
Sensitivity		
Limits of reporting appropriate and consistent	All samples	All samples

3.8 STEP SEVEN: OPTIMISE THE DESIGN FOR OBTAINING DATA

The DQOs were developed based on a review of existing data, and discussions with the stakeholders. The aim of establishing the DQOs outlined above was to ensure the accuracy, precision, comparability, representativeness and completeness of the data generated.

Investigation locations and sampling frequencies were based on a judgmental and targeted approach to assess contamination as a result of the potential sources, but also placed to achieve suitable Site coverage to assess the contamination at the Site.

4. INVESTIGATION METHODOLOGIES

The following subsections describe the field work methodology undertaken for the investigation activities.

Works were generally conducted in accordance with ERM Standard Operating Procedures (SOPs). The SOPs describe methodologies designed to be consistent with relevant and current national and state-based guidelines related to the investigation, assessment and reporting onsite contamination. Additionally, for the purposes of this assessment, DQOs were adopted as outlined in Section 3 to define the type and quality of data required to achieve the project objectives outlined in Section 1.5.

The investigation locations included in this SDI are illustrated in **Figure 3, Appendix A.**

Specific details are described in the subsections that follow.

4.1 RATIONALE FOR SELECTION OF SAMPLING DESIGN

The investigation locations were specified in the Auditor endorsed scoping document (ERM, 2024) and extended to the north, northeast, south and southeast from the SCI sediments investigation locations. The sampling design was selected in order to define the lateral extent of impacts in sediments, groundwater, and surface water.

4.2 SEDIMENT SAMPLING METHODOLOGY

Sediment sampling activities were undertaken exclusively by ERM professionals by drilling the sediment cores. Fourteen sediment cores were sampled during the works within and surrounding the Site, as presented on **Figure 3, Appendix A**. Sediment sampling occurred 14 and 15 October 2024.

- The sediment samples were collected beneath the bed by hydraulic barge mounted vibro-core via lifting mechanism guided by hand and dedicated plastic core liners were used to minimise cross contamination. Cores were removed with minimal water ingress into the plastic tube to prevent mixing of lithology;
- Three sediment samples per bore were collected (0.3, 0.5m and 1.0m below sea bed / or base of core) at locations SED_2_223_2, SED_2_225_2, SED_2_226_2, SED_2_228_2 SED_2_231_2, SED_2_235_2 and four samples per bore (surface, 0.3, 0.5m and 1.0m / or base of core) at locations SED_2_136 to SED_2_142;

  It is to be noted that fall out during extraction of samples, refusal and sample compaction from vibration from vibro-core resulted in different core lengths being retrieved;
- Additional bulk grab samples were collected by Van Veen sampler for the purpose of collecting additional sample sufficient for pore water analysis (min 2kg) for the sediment surface samples;

  Van Veen sampler was also used for targeted location in the scope of work, if duplicate and triplicate were required at surface and when not enough material was available for sampling from the vibro-core. The equipment was pushed at 0.2 mm for shallow sampling with one advance to collect the necessary volume;
- Collected samples from Van Veen sampler and vibro-core were disposed directly adjacent to each other when extracted;

- Samples were collected by subcontractors form the barge and immediately processed on shore by ERM staff;
- Samples were processed into laboratory containers, lithology logged, and cores photographed, presented in photologs and core logs (**Appendix E and F**); and
- Primary samples and field QC samples were collected into laboratory-prepared bottle and vials, for analysis of the identified COPCs.

4.3 SURFACE WATER SAMPLING METHODOLOGY

Surface water samples were taken from five locations (SW136 – SW140) within and surrounding the Site, as shown in **Figure 3** and **Figure 7, Appendix A**. Surface water samples were collected on 15 October 2024. Field methods were undertaken as follows:

- Each sample was taken approximately 10 cm below the surface of the water by extendable sampling arm;
- SW136, SW137, SW139 and SW140 were collected from the bank and location SW138 was sampled from the support vessel;
- A water quality meter recorded water quality parameters prior to sampling of recovered water. A dedicated parameters sampling container was collected on the vessel, with field parameters recorded on shore. Field parameters included temperature, pH, oxidation reduction potential (ORP), electrical conductivity (EC) and dissolved oxygen (DO); and
- Surface water samples were collected within the appropriate laboratory supplied containers, including PFAS, which were sealed and immediately placed in an insulated cooler, on ice, and stored to reduce the potential for loss or degradation of COPCs prior to analysis.

4.4 GROUNDWATER SAMPLING METHODOLOGY

ERM gauged and sampled three groundwater monitoring wells (MW3, MW6, MW102). Groundwater sampling occurred on 15 October 2024. Groundwater monitoring activities involved:

- Gauging of three groundwater monitoring wells using an interface probe to measure groundwater depth and the presence / absence of light non aqueous phase liquid (LNAPL);
- Purging and sampling of three groundwater wells using low flow sampling (peristaltic pump);
- A water quality meter recorded groundwater quality parameters prior to sampling of recovered water. Field parameters included temperature, pH, oxidation reduction potential (ORP), EC and DO;
- Field observations were noted during groundwater sampling procedures to check for the presence of odours (hydrocarbon, organic, etc.) and / or sheen; and
- Once field parameters stabilised, primary samples and field QC samples were collected in laboratory-prepared bottle and vials, for analysis of the identified COPCs.

A water quality meter recorded groundwater quality parameters prior to sampling of recovered water. Field parameters included temperature, pH, oxidation reduction potential (ORP), EC and DO. Groundwater samples, including PFAS, were collected within the appropriate laboratory supplied containers, which were sealed and immediately placed in an insulated cooler, on ice, and stored to reduce the potential for loss or degradation of COPCs prior to analysis.

Gauging data collected prior to groundwater sampling is included in **Table 1, Appendix B.** Groundwater quality parameters recorded prior to sample collection are included in **Table 2, Appendix B** and on the field sheets provided in **Appendix C.**

4.5 LABORATORY ANALYSIS

Samples, including intra-laboratory duplicate samples, were analysed by Eurofins and inter-laboratory duplicates were analysed by ALS laboratories. Samples collected during the investigation were analysed for the following primary analytical suite which were considered CoPCs for the Site, in accordance with the Investigation Plan (ERM, 2024).

TABLE 4-1 SCHEDULE OF ANALYSIS

Matrix	COPCs
Groundwater	• BTEX • TRH • Metals (Cu, Ni, Pb, Hg, Sb, Sn, Zn) • PAHs • Organotins • PFAS
Surface Water	• Organotins • PFAS (noting an LOR was marginally above the PFOS screening level)
Sediment	All Samples: • Organotins • Organic carbon • Pore water analysis (TBT) - selected samples

A summary of the laboratory analyses undertaken for groundwater samples, as well as chain of custody documents, sample receipt notification and certificates of analysis, are included in **Appendix D.**

4.6 WASTE COLLECTION AND DISPOSAL

Purged groundwater and excess sediment core material generated during the investigation was stored in one secure 20 L drum and will be disposed of by a licensed waste contractor at a licensed facility in accordance with the relevant legislation and guidelines.

5. ASSESSMENT CRITERIA

Groundwater and sediment samples collected as part of this SDI were assessed in accordance assessment with the following guidance documents and published criteria:

- Australian and New Zealand Guidelines (ANZG), 2018 for Fresh and Marine Water Quality, Trigger values for the protection of marine ecosystems at the 99% protection level;
- National Environment Protection Council (NEPC) National Environment Protection (Assessment of Site Contamination) Measure, 1999 amended 2013 (ASC NEPM), NEPC, Canberra;
- Australian and New Zealand Guidelines (ANZG), 2018 for Fresh and Marine Water Quality, Default Guideline Values for Toxicants in Sediment;
- CSIRO 2013, Revision of the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) Sediment Quality Guidelines;
- National Health and Medical Research Council (NHMRC) 2008 Guidelines for Managing Risks in Recreational Water; and
- US EPA (2023) Regional Screening Levels.

5.1 GROUNDWATER AND SURFACE WATER INVESTIGATION LEVELS

To assess the potential risk to environmental values, environmental data representative of the Site condition is screened against investigation levels.

The adopted groundwater investigation levels are shown in **Table 5-2** below, and **Table 4, Appendix B.**

TABLE 5-1 GROUNDWATER INVESTIGATION LEVELS

Environmental Values	Groundwater Investigation Level	Comments
Onshore Recreational Use (groundwater only)	• NEPM (1999) HSL C (Sand <2m).	Onshore vapour inhalation under a recreational/open space setting (see **Appendix J** for Extension Model HSL calculations).
Water dependent ecosystems and species	• ANZG[1] 2018: Marine Water (99%) species protection. • NEMP (2020) Interim Marine (99%).	The ANZG (2018/2023), and NEMP (2020) guidelines are applicable to receiving waters. The nearest receptor is Cockle Channel/Brisbane Water located adjacent to the Site. Criteria for High ecological/conservation value ecosystems has been applied due to the Site location on an estuary.
Water-based recreation (direct contact recreation)	• ADWG[3], (NHMRC) Guidelines for Managing Risk in Recreational Water (2008). • NEMP (2020) Recreational Water.	The guideline recommends application of a factor of 10 to 20 to the ADWG when assessing for recreational use, as such a factor of 10 has been adopted. Note - It is considered unlikely that groundwater is being utilised for drinking purposes on the basis of the availability of municipal drinking water in the Central Coast area. However, given a number of bores in the surrounding area are present, and the groundwater classified as good-fair, as a conservative measure drinking water guidelines have been adopted.

Environmental		

Notes:
[1]ANZG: Australian and New Zealand Guidelines for Fresh and Marine Water Quality
[2]ANZG: Toxicant default guideline values for aquatic ecosystem Protection Perfluorooctane sulfonate (PFOS) in freshwater Technical brief (May 2023).
[3]ADWG: Australian Drinking Water Guideline, National Health and Medical Research Council (NHMRC), 2008
ASC, NEPM: National Environment Protection (Assessment of Site Contamination) Measure 1999 (2013).

5.2 SEDIMENT INVESTIGATION LEVELS

Sediment samples were assessed against assessment criteria published in the following documents:

- US EPA (2023) Regional Screening Levels – Resident Soils;
- Australian and New Zealand Guidelines (ANZG), 2018 for Fresh and Marine Water Quality; Default Guideline Values for Toxicants in Sediment; and
- CSIRO 2013, Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines.

As the tributyltin (TBT) SGV was calculated to be protective of exposure of organisms to TBT in the dissolved phase (Simpson et al. 2013), specifically a water chronic value of 7.4 ng TBT/L, the SGV can be adjusted based on site soil organic carbon (OC). For the adjustment, the average of the OC samples analysed during this SDI has been used (0.5% w/w). As the SGV was modelled from the water chronic value assuming partition to a sediment with 1% OC. Correcting for the low OC of 0.5%, which indicates lower partitioning to sediments results in lowering the SGV from 9 ug Sn/kg to 4.5 ug Sn/kg. Similarly, the SGV-High would be reduced to 35 ug Sn/kg.

6. INVESTIGATION RESULTS

Field observations and analytical results obtained as part of the Site Investigation are summarised in the following subsections. Field notes and the photographic log from the field program are provided in **Appendix C** and **Appendix E.**

6.1 FIELD OBSERVATIONS

6.1.1 SEDIMENT

Investigation locations are presented on **Figure 3, Appendix A**. A photographic log illustrating conditions encountered during investigation works is presented within **Appendix E**. Core logs detailing the stratigraphic conditions encountered during coring of sediment are presented in **Appendix F**.

- The lithology noted varied between silty sand and sandy silt from 0 to 1.0 mbgl (maximum depth of investigation);
- Depth of cores varied from 0.2 to 1.3m into the sediments based on the operator's ability to advance the cores;
- Significant visual or olfactory indicators of contamination such as staining, odours or sheen were not observed to be present during sampling of sediment. Potential paint flakes were observed at location SED_2_139;
- Refusal was encountered at 0.2 m on oysters and dense sand at sample location SED_2_122_2 and could not be sampled; and
- SED_2_140 was split into two locations, with additional location SED_2_140a about 10 meters further offshore. Although collected at different locations, both locations represent one planned location in relation to the SDI scoping (ERM, September 2024) and the depth sampled.

6.1.2 SURFACE WATER

Field activities associated with the surface water sampling were undertaken on 15 October 2024. The following observations were made in the field as part of the sampling.

Field quality parameters including pH, EC, DO, temperature and redox were measured during the surface water sampling. A summary of field parameters collected prior to sampling is provided below:

- No odours or hydrocarbon sheens were noted during surface water sampling activities;
- SW139 location surface water was slightly turbid with brown sediment suspensions;
- pH ranged from slightly alkaline to neutral; and
- Electrical conductivity was high, ranging between estuarine and marine.

Table 3, Appendix B, presents field parameters, sampling method and sampling comments (current) for surface water samples.

6.1.3 GROUNDWATER

The following observations were made in the field as part of the groundwater monitoring event (GME):

- Gauged depth to groundwater ranged from 0.620 m AHD (MW3) to 1.745 m AHD (MW6);

- No measurable and / or detectable LNAPL was recorded at any of the locations during groundwater gauging or sampling activities;
- No hydrocarbon sheens were noted during the groundwater sampling activities; and
- No odours where were considered indicative of contamination were noted during groundwater sampling activities;
- Groundwater flow direction was reported to be hydraulically to the west (away from the Cockle Channel), which is not consistent with previous events however given the tidal nature of the area fluctuations are not unexpected; and
- Field groundwater quality parameters including pH, EC, DO, temperature and redox were measured during the groundwater purging. The conclusions made from the field parameters were that the pH was neutral to slightly acidic. The electrical conductivity indicated that groundwater was relatively fresh for an estuarine area, indicating that the groundwater has a minimal interaction with the channel. The exception to this was MW3, located at the edge of the shoreline, which demonstrated higher electrical conductivity values reflective of saline water (between 1,000 to 10,000 µS/cm). MW6 measurements are indicative of fresh water indicating that there is tidal influence at the shoreline but its overall not pushing inland as far as MW6.

Overall, field parameters from the July event suggested that the groundwater at the Site is relatively fresh with minimal tidal influence at the locations gauged.

Table 1, Appendix B, presents a summary of groundwater gauging results and ***Table 2, Appendix B***, presents field parameters, sampling method and sampling comments (current).

TABLE 6-1 TIDES LEVELS FROM BRISBANE WATER REPORTING FOR THE COCKLE CHANNEL ENTRANCE – TIDE TIMES AND HEIGHTS

14/10/24	15/10/24
2:05 AM 0.18m	2:51 AM 0.15m
8:07 AM 0.88m	8:56 AM 1m
1:42 PM 0.26m	2:45 PM 0.2m
8:18 PM 1.18m	9:10 PM 1.21m

Source : Brisbane Water - Cockle Channel Entrance Tide Times, NSW - WillyWeather

6.2 ANALYTICAL RESULTS

6.2.1 SEDIMENT ANALYTICAL RESULTS

Sediment analytical results are presented in **Table 7, Appendix B**, and exceedances are presented on **Figure 6, Appendix A**.

The SDI included laboratory analysis of discrete sediment samples were collected at each location from either the surface and 0.3 m, 0.5 m and 1.0 depth (based on depth of core) to provide additional vertical characterisation of sediments as per detailed in section 4.2 above.The laboratory analyses specific to support assessment of sediment ecological risks based following the ANZG (2018) guidance were:

- Total Organic Carbon (TOC) – to refine the DGV's which are dependent on organic carbon %;
- Organotins analysis on the <2 mm sediment particle size fraction which is recommended for comparison with sediment quality guideline values (ANZG 2018); and
- Porewater soluble metals analysis on the <2 mm sediment particle size fraction which is considered more representative of the bioavailable fraction available to benthic biota and can be compared to sediment water screening levels where available (ANZG 2018 and Simpson et al. (2013).

Organic carbon (OC%) was analysed for all samples to give a more comprehensive overview for the purposes of screening value calculation. Overall, OC% decreased with grain size and generally with depth (i.e. deeper and higher sand content sediments were associated with lower OC%). The average OC% was 0.5%, and therefore this value was applied to the SDG.

Sediments samples were collected in duplicate as 'A' and 'B' samples, outside of the QAQC program. Each sample was analysed to assess consistency of results. All 'A' samples were analysed on October 16 2024 (report number 1149444-S-V2) and 26 selected 'B' samples on November 1st 2024 (report number 1156247-S) following a review of the initial results. The 'B'' samples analysed were selected based on either the overall importance of individual results to the delineation of organotins, or 'A' samples where data appeared potentially anomalous based on either the known or likely distribution of contamination.

An assessment of the two batches of samples was completed to determine the compatibility of the data. Both the 'A' and 'B' samples are presented in **Table 7, Appendix B**. The results were primarily similar with four of the 26 results identified as materially dissimilar to the extent that the characterisation of the nature and extent of contamination in sediments may be influenced. These samples were as follows:

- SED_2_125_2_0.3;
- SED_2_131_2_0.3;
- SED_2_138_0.3; and
- SED_2_142_0.5.

In all cases, the higher of the results have been used for the purposes of this assessment as a conservative measure.

In general, sediment analytical results were reported below the limit of reporting (LOR) or adopted screening criteria with the exception of those presented below in **Table 6-4**. Where multiple data points are available for a location/depth, the highest concentration is shown.

TABLE 6-2 SEDIMENT ANALYTICAL RESULTS

Analyte	Location	Concentration (µg/kg)	Criteria Exceeded
Tributyltin	SED_2_125_2_1.0 B SED_2_136_0.0 (QC202) SED_2_138_2_0.0 SED_2_139_0.0 B SED_2_139_0.3_A	17 9.8 17 22 52	• ANZG (2018) DGV -– Sediment Quality
Tributyltin	SED_2_123_2_0.3 B SED_2_123_2_0.5 B SED_2_123_2_1.0 A SED_2_125_2_0.3 B SED_2_125_2_0.5 B SED_2_126_2_0.3 A SED_2_131_2_0.3 B SED_2_138_2_0.3A SED_2_142_0.0 (QC205) SED_2_142_0.3 B SED_2_142_0.5 A	81 640 480 1500 55 340 86 110 140 1000 230	• ANZG (2018) DGV -– Sediment Quality • ANZG (2018) GV-High -– Sediment Quality

All pore water samples results were below the adopted screening criteria. MBT, DBT and /or TBT were however detected in the majority of sediment pore water sampled during this SDI with the exception of SED_2_139_PORE_20241015 which recorded results below LOR for all organotins. Note that porewater samples were collected from the seabed surface only due to constraints around collecting sufficient sample volume at depth. Since surface samples in impacted areas were not collected during this SDI for sediment analysis, a direct comparison between total and leached organotins is not possible for data analysed during this investigation.

6.2.2 SURFACE WATER ANALYTICAL RESULTS

Surface water analytical results are presented in **Table 5, Appendix *B.*** All surface water samples collected reported results below the laboratory LOR or the adopted screening criteria with the exception of PFOS which presented exceedances of ANZG (2018) Marine Water - High ecological/conservation value in all locations sampled.

TABLE 6-3 SURFACE WATER ANALYTICAL RESULTS

Analyte	Location	Concentration (mg/L)	Criteria Exceeded
PFOS	SW136_20241015 SW137_20241015 SW138_20241015 SW139_20241015 SW140_20241015	0.0009 0.0008 0.0008 0.0012 0.0008	• NEMP (2020) Interim Marine Water - High ecological/conservation value

PFOS concentrations were not reported to exceed screening criteria during previous investigations, however the LORs were raised during previous works and likely masked exceedances. PFOS also exceeded criteria in onsite groundwater at concentrations up to two orders of magnitude higher than surface water (see Section 6.2.3 below).

The surface water concentrations were consistent for samples collected onsite and both upstream and downstream, indicating a regional issue not entirely related to the groundwater onsite.

6.2.3 GROUNDWATER ANALYTICAL RESULTS

Groundwater analytical results are presented in **Table 4, Appendix B**, and groundwater exceedances are presented on **Figure 5, Appendix A**.

In general, groundwater analytical results were reported below the limit of reporting (LOR) or adopted screening criteria with the exception of those presented below in .

TABLE 6-4 GROUNDWATER ANALYTICAL RESULTS

Analyte	Location	Concentration (mg/L)	Criteria Exceeded
Copper (Filtered)	MW102_20241015 MW3_20241015 QC101_20241015 (MW6)	0.013 0.03 0.015	• ANZG (2018) Marine Water - High ecological/conservation value
Lead (Filtered)	MW102_20241015 MW3_20241015	0.003 0.003	• ANZG (2018) Marine Water - High ecological/conservation value
Mercury (filtered)	MW6_20241015	0.0002	• ANZG (2018) Marine Water - High ecological/conservation value
Zinc	MW102_20241015 MW3_20241015 MW6_20241015 QC101_20241015 (MW6) QC201_20241015(MW102)	0.016 0.032 0.015 0.016 0.182	• ANZG (2018) Marine Water - High ecological/conservation value
Tributyltin	MW3_20241015	0.008	• ANZG (2018) Marine Water - High ecological/conservation value
PFOS	MW102_20241015 MW3_20241015 MW6_20241015 QC101_20241015 (MW6)	0.096 0.011 0.044 0.032	• NEMP (2020) Interim Marine Water - High ecological/conservation value

Overall, the results are consistent with the findings of the SCI report. TRH and BTEX were undetected in all three monitoring wells sampled during the DSI, re-confirming the SCI conclusions that USTs have not resulted in significant onshore petroleum hydrocarbon impacts in groundwater.

However historical Site activities have likely resulted in the presence heavy metals concentrations in groundwater with exceedances for Copper and Zinc in all monitoring wells, lead in MW102 and MW3 and mercury in MW6.

Note that the LOR was above the screening criteria for Anthracene, Benzo(a)pyrene and Phenanthrene.

TBT was detected in MW3, exceeding ecological and conservation criteria and was undetected at this location during the SCI. TBT was undetected in MW6 and MW102 as per previous sampling round during the SCI. However, detection limit was higher (than the criterion) during the SCI compared to the SDI.

PFOS was detected in groundwater at concentrations exceeding the NEMP (2020) Interim Marine Water - High ecological/conservation value in all groundwater monitoring wells, which is consistent with the results from the previous SCI.

6.3 QAQC

6.3.1 FIELD QC RESULTS

The field QC results (including intra laboratory duplicates, inter laboratory duplicates, trip spikes, trip blanks and rinsate blanks) were generally reported within acceptable limits. Any outliers observed are discussed within the QA/QC assessment presented in **Appendix G**.

6.3.2 LABORATORY QC RESULTS

Laboratory QC analytical results for groundwater investigation were generally reported within acceptable limits. Laboratory QC reports are provided in **Appendix D**, any outliers are discussed within the ERM QA/QC assessment presented in **Appendix G**.

7. CONCEPTUAL SITE MODEL

The development of a Conceptual Site Model (CSM) is the fundamental step that describes the source of contamination, exposure route or pathway and potential linkage to the receptor (i.e. source pathway receptor (SPR) linkages). The linkages between these elements in the CSM examines if a complete, potential or incomplete exposure pathway exists.

The status of the exposure pathway determines the presence of risk to environment and/or human health. Potential exposure pathways are evaluated for completeness based on the existence of:

- a source of contamination / impact;
- a mechanism for release of contaminants from identified sources;
- a contaminant retention or transport medium (e.g. soil, air, groundwater, etc.);
- potential receptors of contamination; and
- a mechanism for chemical intake by the receptors at the point of exposure.

The following CSM is based on ERM's understanding of the general area and background information gathered as part of previous investigations, including ERM's SCI, and updated with the finding of this investigation.

7.1 POTENTIAL SOURCES OF CONTAMINATION

The following potential onsite sources of contamination were identified at the Site during the Site Investigation. Potential onsite sources have been illustrated on **Figure 2**, **Appendix A**.

7.1.1 PRIMARY

- Potential storage / use of PFAS containing materials such as Aqueous Film Forming Foams (AFFF);
- Spills and leaks during fuel unloading activities around bowsers and USTs;
- Fill material underlying the Site;
- Vessel Maintenance and anti-fouling both onsite and at third party offsite vessel moorings; and
- Leaching chemical (TBT) from paint flakes, boating activities both onsite and at third party offsite vessel moorings.

7.1.2 SECONDARY

- Residual soil impact associated with previous activities at the Site;
- Vertical seepage of released petroleum fuels through soil to the groundwater table from primary sources identified;
- Vertical seepage of petroleum fuel dissolved phase hydrocarbons or chemicals originating from surface spills and leaks from leaking tanks, fuel lines and fuel pumps, through surface soil into the underlying lithology (creating a soil smear zone) and then dissolving into groundwater;
- Leaching chemical (TBT) from paint flakes, boating activities both onsite and at third party offsite vessel moorings; and
- Lateral migration of impacted groundwater flow via subsurface lithology.

7.2 NATURE AND EXTENT OF IMPACTS

Impacts at the Site have been confirmed to be present primarily in sediments, however, notable onshore source areas were present (USTs/onshore vessel maintenance).

TRH and BTEX were undetected in all monitoring wells sampled during both SCI and DSI investigations with the exception of benzene detected in groundwater monitoring well MW101 in February 2024 located in close proximity to the former USTs. This confirms that USTs have not resulted in significant onshore petroleum hydrocarbon impacts in groundwater. In general, it appears that the most significant risk driver at the Site is TBT, which has likely been sourced from onshore stripping and re-application of antifouling paints as well as hull cleaning of vessels at mooring.

Specific details on nature and extent of impact in soil, groundwater, sediments and surface water are included in the subsections that follow.

7.2.1 SOILS

Soil impacts were not further characterised as part of the SDI investigation, however the nature and extent of soil impacts has been considered in this CSM for completeness. Results from the SCI investigations reported that soil impacts were primarily limited to heavy metals, organotins (TBT) and asbestos.

Heavy metals (copper, lead, nickel and zinc) in shallow soils exceeded ecological criteria and were likely related to historical maintenance and storage and vessels and equipment. Lead exceeded the human health criteria for human health direct contact at one location (TP105) located within the footprint of the slipway. TBT was also identified in soil, however these were at concentrations below the USEPA RSLs.

TBT impacts in soils are present across two areas of the Site; in the vicinity of the slipway, and in a localised area near the driveway/entrance into the former maintenance shed. Note that the screening criteria used to identify impacts are designed for application to sediments rather than soils and are likely to be highly conservative. These criteria were applied as an initial data screen. The impacts are likely sourced from onshore vessel maintenance. The concentrations and distribution were generally consistent with DP (2021), though at lower maximum concentrations. DP 2021 reported TBT concentrations up to 10,000 mg/kg at in the vicinity of the slipway at 0.3 m bgl. The concentrations of TBT in these areas area expected to be heterogeneous, which is to be expected from an incidental and depositional source.

DP (2021) identified several asbestos fragments immediately to the south of the former boat shed. This area and the remainder to the Site was assessed extensively for the presence of asbestos through survey/inspection and test pitting. During this investigation a single fragment was identified and removed from the Site. Therefore, whilst asbestos may be present at the Site, it does not appear to be in significant quantities.

Hydrocarbons were generally not detected in soils and therefore significant onshore impacts (soil and groundwater) related to the onsite USTs are not considered to be present.

7.2.2 GROUNDWATER

Groundwater at the Site is shallow (<0.5m bgl). Finding of this field investigation indicated that electrical conductivity was low for an estuarine area, indicating that the groundwater has a minimal interaction with the channel ash hydraulic head data indicated an inland groundwater flow to the west. However geochemical data (namely EC) indicates overall flow is toward the Cockle Channel with minor tidally influenced at the banks.

The primary onshore source areas, being the USTs and the slipway, are located immediately adjacent to the shoreline and therefore any impacts related to these sources are likely to migrate directly towards the Cockle Channel to the east, rather than extend any significant distance inland.

The groundwater monitoring network was designed to primary monitor for impacts related to the USTs, however based on the overall groundwater flow towards the Cockle Channel it is likely that all locations are hydraulically up to cross gradient and in the intertidal zone. It is to be noted that all USTs have been removed from the site and the surrounding areas surrounding have been remediated and validated. Hence, two groundwater monitoring wells were no longer available for ERM sampling as they were removed after remediation (Douglas Partner, 2024).

All three wells sampled during this investigation recorded concentrations of heavy metals exceeding ecological criteria, which were comparable to observations made in shallow soils during the SCI. Exceedances of ecological criteria were noted for copper, lead, mercury and zinc. TBT was detected at MW3 and also exceeded ecological criteria which is located behind the former boat shed and next to slip way.

DP (2021) confirmed that TBT is present in groundwater monitoring well MW3 in close proximity to the shoreline in concentrations exceeding ecological criteria but did not extend to the upgradient location. Groundwater impact would be expected to be present in a similar pattern to TBT in soils and sediments, which was primarily detected in locations near to the shoreline.

PFAS was detected at all locations in groundwater at concentrations below human health criteria but above ecological 99% protection criteria, indicating that a historical PFAS source existed at the Site.

7.2.3 SEDIMENT

TBT has been reported exceedances of DGVs at a number sediment locations. The impacts primarily localised around the slipway, former boat shed and former jetties, which is consistent with the finding of previous investigations. The most significant impacts are located at the former slipway and the access channel to the slipway, with results up to 1500 µg/kg recorded during this investigation and up to 20,000 µg/kg recorded historically at the same location (DP 2021). TBT impacts appear to be at the highest magnitude in sediments at 0.3m below seabed. Surface sediments reported generally lower concentrations, with the exception of locations advanced around the footprint of the former boat house during the ERM SCI (2024).

Porewater results for TBT have been recorded exceeding DGVs in surface sediments in within the footprint of the former boat shed, where surface sediment concentrations are elevated.

No porewater result from this investigation exceeded the DGVs, however due to constraints around sample volume requirements for the porewater analysis, no samples could be collected at 0.3m where concentrations are most significant. Based on the results of the SCI, TBT concentrations should be considered to be leachable.

TBT sediment contamination is considered to be largely vertically delineated vertically at 0.5m below seabed. Onsite exceptions were SED_2_123 and SED_2_125, which are located within the channel which historically ran between the former jetties to access the slip way. TBT at these locations were undelineated at 1.0m below seabed. The sediments at SED_2_123 in particular were noted during vibro-coring to be comparatively soft fine grain sands to the depth of the core, as opposed to the more typical increase in grain size observed at other locations. This indicates that a deeper historical dredged channel may have been present to facilitate vessel access to the slip way. which has refilled with sediments since marina maintenance activities ceased. Based on the core log for SED_2_123, the channel the fine grain sediments extent to at least 1.4m below the seabed. Vertical delineation is not considered to be completed at SED_121 and SED_122 due to a lack of data for those locations and will need to be inferred from the surrounding data points.

Impacts in sediment appear to be delineated laterally offshore toward deeper, higher flow zones of the channel by locations SED_2_140 and SED_2_141. Delineation has also been achieved to the north by SED_2_137, and also near shore locations SED_2_135 and SED_2_136.

Offsite TBT exceedances were reported to the north of the former jetties at locations SED_2_138_2 (at 0.3m) and SED_2_139_2 (at seabed surface) and offsite south at location SED_2_142_2 (0.3m and 0.5m). All offsite impacts were vertically delineated. Whilst is it possible that these offsite impacts are related to the Site, it is noted that all locations were within the footprint of current or historical third party vessel moorings, which may represent TBT sources. ERM have been advised of instances of long-term submerged vessels at moorings in the vicinity of the Site, specifically the mooring to the south of the Site where SED_2_142 was advanced. These vessels have been salvaged, however historical presence of deteriorated vessels potentially represent TBT sources. It is noted that during the ERM SCI (2024) an exceedance for TBT of the DGV was also recorded at 0.3m sediment depth near to the boat ramp/jetty facilities ~100m to the south. It is unknown whether offsite detections are Site sourced or related to vessel moorings located along the shoreline both north and south of the Site. It is likely that the third party vessel moorings represent numerous additional offsite sources of TBT. Overall, a number of interrelated factors are likely to be influencing the distribution of TBT from both onsite and offsite sources, including location of infrastructure/ historical activities/moorings, water flow velocity, water depth and sediment grain size.

Copper was noted to be present in concentrations exceeding the DGV during the ERM SCI (2024), with three copper result also exceeding the GV-High (SED120_0.1, SED122_0.3 and SED125_0.3). Lead also exceeded the DVG at a single location. The heavy metals distribution onsite is similar to the TBT distribution described above.

Petroleum hydrocarbons were also noted to be present at low concentrations across the nearshore area of the Site during the ERM SCI (2024), with one location in the vicinity of the USTs exceeding the DGV. It is noted that Sediments can be very high in natural biogenic polar hydrocarbon compounds which may be detected in standard TRH analysis.

However, given the presence of the USTs, the groundwater flow direction toward the Cockle Channel and the distribution of impacts, it is likely that the TRH in sediments are petroleum hydrocarbons related to the USTs at the Site. However, USTs have been removed from site and their area decontaminated, and TRH have not been analysed during the SDI so the presence or absence could not be determined.

7.2.4 SURFACE WATER

All surface water samples collected reported results below the laboratory LOR and the adopted screening criteria with the exception of PFOS which presented exceedances of ANZG (2018) Marine Water - High ecological/conservation value in all locations sampled. PFOS also exceeded criteria in onsite groundwater at concentrations up to two orders of magnitude higher than surface water. The surface water concentrations were consistent for samples collected onsite and both upstream and downstream, indicating a regional issue.

Whilst the TBT impacts in sediments may be leachable, it appears that the rate of leaching is not sufficient to detect CoPCs in surface water at the LOR.

7.3 POTENTIAL RECEPTORS

The following potential receptors have been identified in association with the Site:

- Human Receptors:
  - future onshore recreational users of the Site; and
  - Current/future recreational users of Cockle Channel within Brisbane Water.
- Ecological Receptors:
  - ecological receptors of Cockle Channel within Brisbane Water; and
  - Future onshore terrestrial ecological receptors.

7.4 EXPOSURE AND MIGRATION PATHWAYS

Based on information collected to date, the following exposure pathways have been considered and updated:

- Human Health:
  - dermal contact and / or incidental ingestion (direct) of groundwater, sediments and/or surface water; and
  - outdoor vapour inhalation.
- Ecological:
  - uptake via direct contact by flora and fauna in sediments and/or surface water.

Groundwater Extraction and Use has been considered and excluded from the exposure pathways. All potential areas where groundwater may be beneficially used is upgradient of all sources of contamination based on previous groundwater SWLs and geochemical data. Therefore impact is unlikely to extent to any registered or potential nearby unregistered abstraction bores.

7.5 POTENTIALLY COMPLETE SPR LINKAGES

A source pathway receptor linkage is present when a pathway links a source with a receptor. These linkages explain when there may be risks to the receptor, either now or in the future. below outlines the potential complete SPR linkages updated with the DSI findings. Exposure pathway categories are summarised as follows:

Complete: All elements are present. Actual risk is likely to exists based on the available data;

Potentially Complete: One or more of the elements may not be present, and/or information is insufficient to eliminate or exclude the element. The potential for risk exists; and

Incomplete: One or more of the elements are absent.

TABLE 7-1 SPR LINKAGES ASSESSMENT

Contaminant Source	Exposure Pathways	Potential Receptor	Linkage?	Comment
Impacted Soil	Direct contact	Ecological receptors	Potentially Complete	• Findings of the SCI indicated that ecological screening criteria was exceeded for TBT, copper, zinc and lead. ACM was also detected at one location (TP115) on the sand along the eastern edge of Site. • Given the current use of the Site, and the land surrounding, there is a risk to recreational and ecological receptors due to the proximity to the Brisbane Water and interaction between recreational users and shallow soils and groundwater.
	Direct contact, inhalation, incidental, ingestion, Vapour intrusion, Residual contamination leachage	Future onsite recreational and ecological receptors	Potentially Complete	• The Site is currently fenced and vacant, with institutional controls in place for access. • Given the planned future use of the Site, and the land surrounding as public foreshore, there may a risk to recreational users and/or ecological receptors accessing shallow soils on the foreshore due to the presence of TBT, heavy metals, asbestos.
Impacted Groundwater	Direct contact, Outdoor vapour inhalation, incidental, ingestion	Onsite recreational receptors / Groundwater Users	Incomplete	• It is feasible future recreational receptors could contact groundwater due to its shallow nature, however no recreational direct contact criteria were exceeded and therefore no linkage exists for recreational users. • Outdoor inhalation of vapours in considered unlikely to be a viable pathway given the concentrations of hydrocarbons observed. • Groundwater extraction and use does not currently occur onsite, and searches of registered groundwater bores indicated 3 upgradient bores within a 500m radius of the Site. • Although groundwater was classified as 'good' to 'fine' based on Total dissolved solids (TDS) values, due to the availability of municipal water in the Central Coast Council area, it is unlikely these wells are used for drinking purposes, therefore pose a low risk.
	Direct contact	Future ecological receptors	Potentially Complete	• Onsite groundwater is shallow (<0.5m bgl) and interacts with the Cockle Channel. • Exceedances of ecological screening criteria have been recorded for TBT, PFOS, copper, lead mercury and zinc. • It is possible the future onsite ecological receptors may contact groundwater either onshore in or nearshore environments, however sediment and surface water data are more appropriate indicators of ecological risk at the site.
Impacted Sediment	Direct contact	Ecological receptors (nearshore)	Complete	• The Cockle Channel represents ecological habitat. • The sediment and sediment pore water results indicate levels of tributyl tin (TBT), copper and TRH exceeding the sediment DGVs and in some cases the DGV-High and are indicative of potential ecological risks for benthic biota within the general footprint of the former marina infrastructure. • Concentrations have previously been demonstrated to be bio-accessible and therefore a potentially completed SPR linkage exists for ecological receptors.
	Direct contact, incidental ingestion,	Recreational receptors - users of Cockle Channel	Incomplete	• TBT concentrations are below the most appropriate available human health direct contact criteria and therefore a linkage does not exist for recreational users of the Cockle Channel
Impacted Surface water	Direct contact	Ecological receptors	Feasible	• The Cockle Channel represents ecological habitat. • All surface water analytical results were reported under the adopted human health and ecological screening criteria for the second round of assessment with the exception of PFOS which presented exceedances of ANZG (2018) Marine Water - High ecological/conservation value in all locations sampled. • It is likely that the primary source of PFAS concentrations in the Cockle Channel is not Site related based on the consistency of up and downstream concentration, however PFAS in onsite groundwater could be interacting with surface water.
	Direct contact, incidental ingestion,	Recreational receptors - users of Cockle Channel	Incomplete	• It is likely the Cockle Channel is used for recreational purposes, however no human health based criteria have been exceeded and therefore no linkage exists for recreational receptors.

8. CONCLUSIONS

ERM consider that the objectives of this investigation have been met, with the data collected enabling an assessment and refinement of the delineation of impacts on current onsite groundwater conditions, near shore sediment and surface water conditions both on and offsite.

In order to achieve the above stated objectives, ERM completed a GME which included sampling of three groundwater monitoring well, collection of sediment samples by vibrocore and Van Veen Sampler at 14 locations and surface water sampling at five locations. The findings of this investigation are summarised below as follows:

Groundwater:

- Exceedances of ecological screening criteria were recorded in groundwater for TBT, PFOS, copper, lead mercury and zinc; and
- Groundwater flow direction was determined to be to the hydraulically to the west (away from the Cockle Channel), which is not consistent with previous events, however field parameters are indicative of fresh water indicating that there is tidal influence at the shoreline but overall groundwater is flowing to the east and discharging to the water body, rather than being tidally influenced to any significant extent inland from the shoreline.

Nearshore Sediments:

- Sediment results exceeded DVGs for TBT at seven locations, with the most significant concentrations recorded in proximity to the former slipway;
- Generally, the highest observed concentrations (where detected) are present across the investigation area at approximately 0.3m;
- Porewater results for TBT have previously been recorded exceeding DGVs in surface sediments within the footprint of the former boat shed, where surface sediment concentrations are elevated, however No porewater result from this investigation exceeded the DGVs;
- Vertical delineation was largely achieved at 0.5m below seabed, with the exception of locations in the historical channel leading to the former slipway where unconsolidated fine grain sediments were present to at least 1.4m;
- Delineation was achieved offshore toward deeper, higher flow zones of the channel, with sediment impact confirmed to be located approximately within 20m of the shoreline;
- Delineation was achieved to the north in nearshore locations; and
- Offsite exceedances were recorded to the north-east and south within third party vessel moorings. It is unknown whether offsite detections are Site sourced or related to the vessel moorings located along the shoreline both north and south of the Site. It is likely that the third-party vessel moorings represent numerous additional offsite sources of TBT.

Surface Water:

- All surface water samples collected reported results below the laboratory LOR and the adopted screening criteria with the exception of PFOS which presented exceedances of ANZG (2018) Marine Water - High ecological/conservation value in all locations sampled; and

- It is likely that the primary source of PFAS concentrations in the Cockle Channel is not Site related based on the consistency of up and downstream concentrations, however PFAS in onsite groundwater could be interacting with surface water.

Overall, the findings generally support the conclusions of the DP 2021 DSI and ERM 2024 SCI, in that historical marina activities at the Site have resulted in contamination which may present a risk to the environment. The primary source of impact at the Site appears to be the former slip way, where antifouling of vessels was likely undertaken, however offsite private vessel moorings and possible sunken vessels appear to be resulting in offsite impacts which are not distinguishable from onsite sources.

Following a review and update of the CSM, potentially complete SPR linkages exist for ecological receptors in contact with organotin impacted sediments, primarily in the footprint of the former marina infrastructure. Onshore ecological and recreational direct contact linkages may be present currently or in the future under a public foreshore open space land use scenario based on identified onshore soil and groundwater impacts.

Although PFOS concentrations in surface water of the Cockle Channel may be indicative of a complete SPR linkage for ecological receptors, the distribution of PFOS in surface water is not indicative of an onsite source and therefore a complete SPR linkage has not been flagged for the Site.

Based on the potentially complete SPR linkages identified as part of this SDI, further remediation and/or management may be required to mitigate recreational and/or ecological risks related to organotin contamination in nearshore sediments and also onshore heavy metals, asbestos and PFOS impacts. The data available is considered sufficient to be used to inform a HHERA and RAP (if required following HHERA).

9. REFERENCES

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US EPA (2023) Regional Screening Levels.

10. STATEMENT OF LIMITATIONS

This report was prepared in accordance with the scope of work outlined within this report and subject to the applicable cost, time and other constraints. ERM performed the services in a manner consistent with the normal level of care and expertise exercised by members of the environmental profession. ERM makes no warranty concerning the suitability of the Site for any purpose or the permissibility of any use, development, or re-development of the Site. Except as otherwise stated, ERM's assessment is limited strictly to identifying specified environmental conditions associated with the subject site and does not evaluate structural conditions of any buildings on the subject site. Lack of identification in the report of any hazardous or toxic materials on the subject site should not be interpreted as a guarantee that such materials do not exist on the Site.

This assessment is based onsite inspection conducted by ERM personnel, sampling and analyses described in the report, and information provided by NSW Crown Lands ("the client") or other people with knowledge of the Site conditions. All conclusions and recommendations made in the report are the professional opinions of the ERM personnel involved with the project and, while normal checking of the accuracy of data has been conducted, ERM assumes no responsibility or liability for errors in data obtained from such sources, regulatory agencies or any other external sources, nor from occurrences outside the scope of this project.

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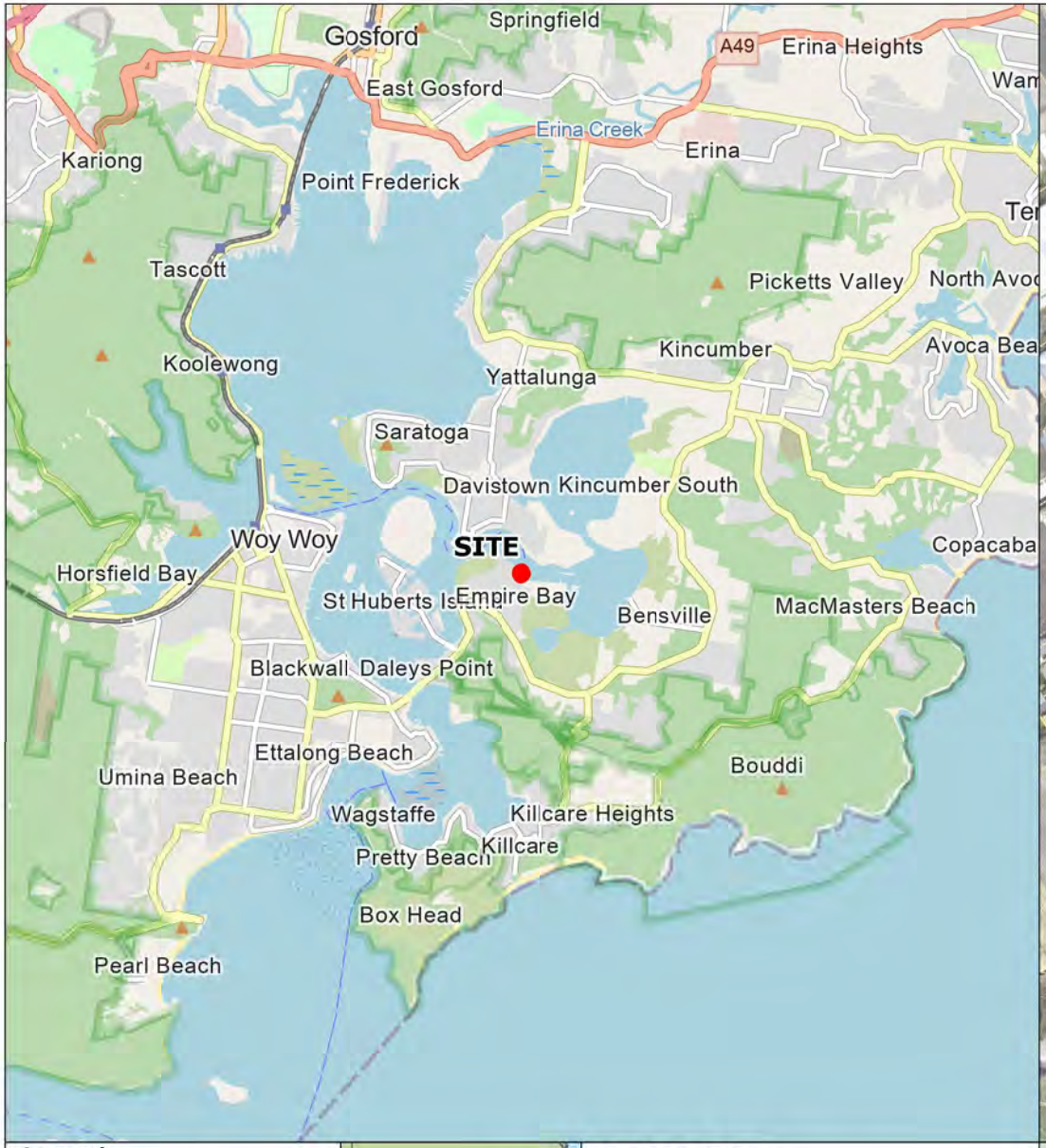
APPENDIX A FIGURES



Legend

Site Boundary

Cadastre

Data Source:
Nearmap Imagery October 2024
Esri OpenStreetMap 2024
NSW DFSI, DCDB/DTDB 2024

Coordinate System:
GDA 1994 MGA Zone 56

Date: 10/01/2025

Created By: MF / GC

Drawing Size: A4

0 10 20 30m

1:1,100

F1 - Site Location

Empire Bay Marina SDI

NSW Government – Crown Lands

ERM

0720932_EmpireBay_G001_R0.aprx

F2 - Site Layout

Empire Bay Marina SDI

NSW Government – Crown Lands

ERM

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0720932_EmpireBay_G003_R0.aprx

F4 - Groundwater Flow Direction

Empire Bay Marina SDI

NSW Government – Crown Lands

ERM

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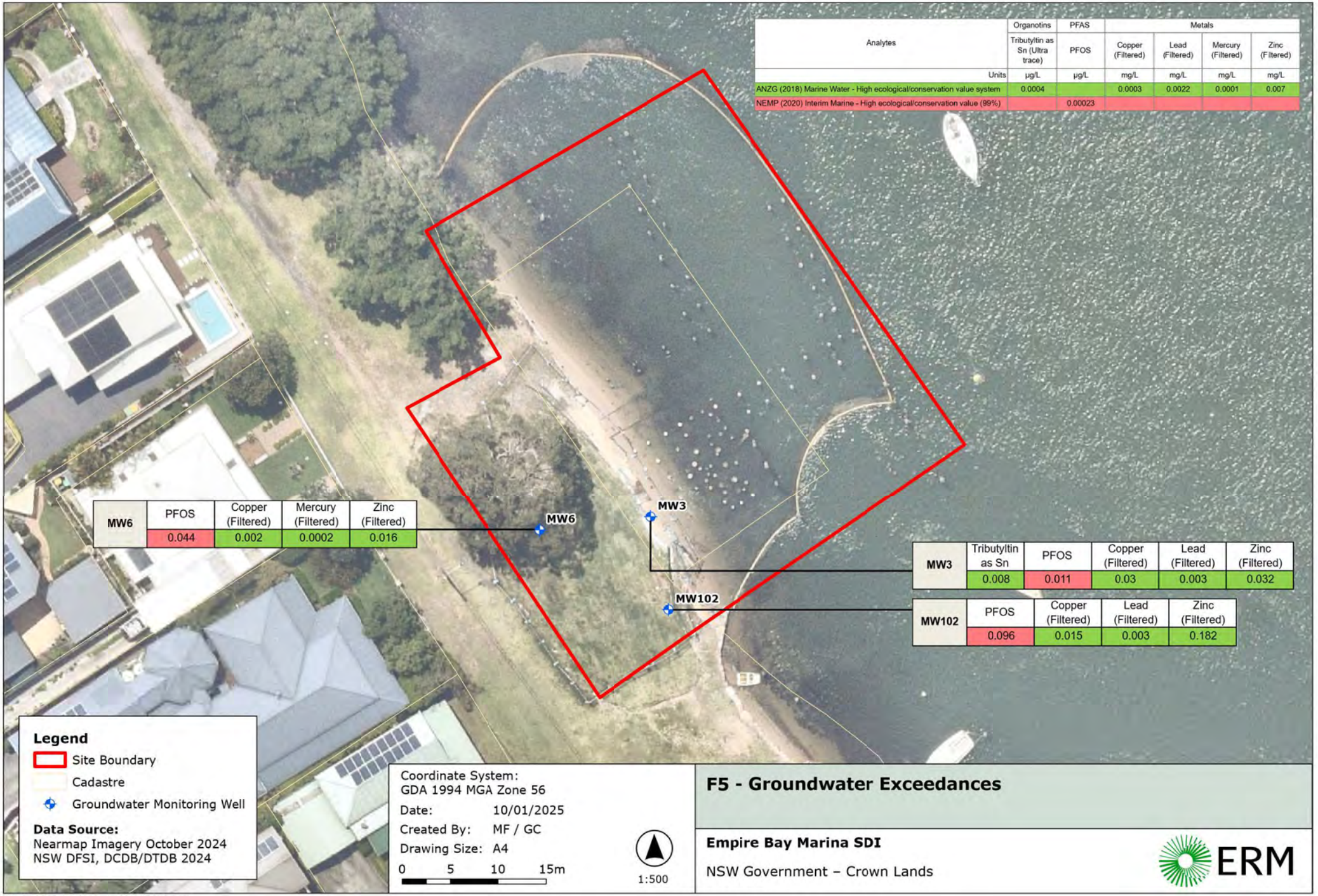

F5 - Groundwater Exceedances

Empire Bay Marina SDI

NSW Government – Crown Lands

ERM

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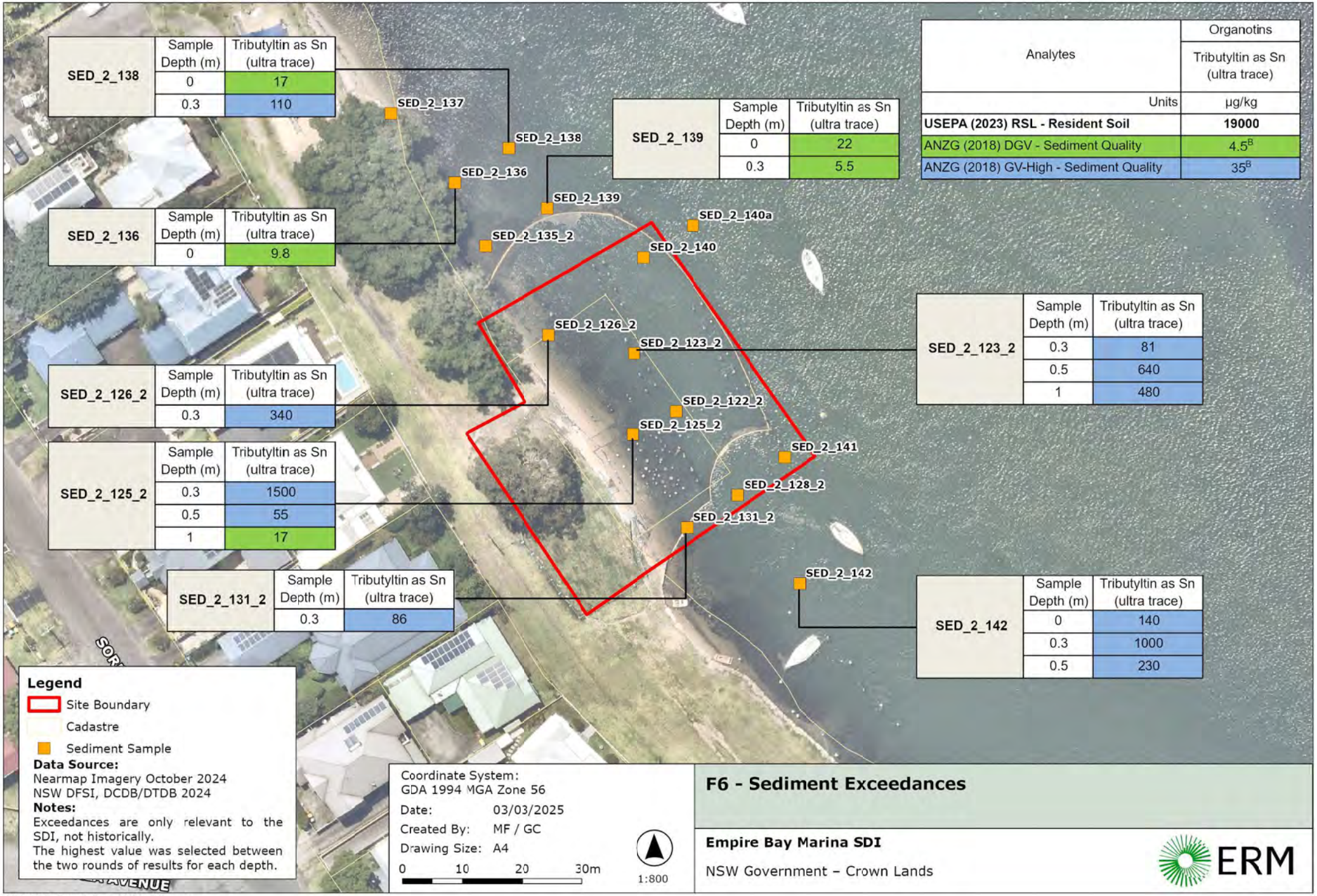

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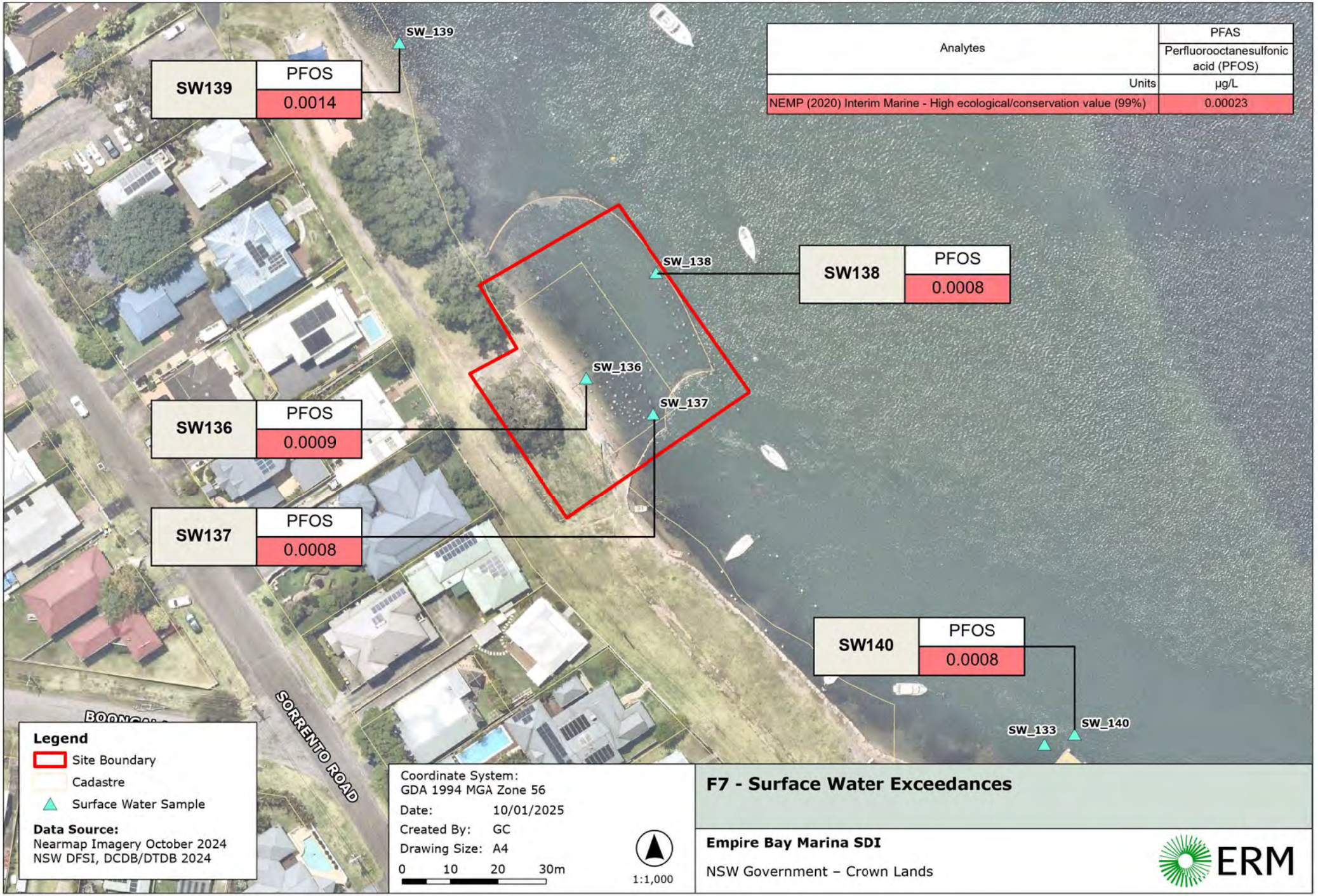

Analytes	PFAS
	Perfluorooctanesulfonic acid (PFOS)
Units	µg/L
NEMP (2020) Interim Marine - High ecological/conservation value (99%)	0.00023

Coordinate System:
GDA 1994 MGA Zone 56
Date: 10/01/2025
Created By: GC
Drawing Size: A4
0 10 20 30m
1:1,000

F7 - Surface Water Exceedances

Empire Bay Marina SDI

NSW Government – Crown Lands

ERM

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