Breen Resources Pty Ltd

Breen Resources Facility - EIS
Contamination Status Report

April 2021

Executive summary

Breen Resources Pty Ltd (Breen) owns and operates the Breen Resources Facility at 330 Captain Cook Drive, Kurnell (the Proposal Site). The Breen Resources Facility is situated on an area which has been subject to extensive sand mining in the past, and currently receives excavated materials and selected construction and demolition (C&D) waste. Breen carries out Proposal Site restoration by application of these materials to land. Construction and demolition waste recycling operations are also carried out at the Proposal Site.

Breen has commissioned an environmental impact statement (EIS)is being prepared to support a development application for approval of the following under Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act 1979* (the EP&A Act) (the Proposal):

- Construction and operation of a resource management facility, comprising:
  - A New Resource Recovery Facility on the eastern part of the Proposal Site (Lot 5), including consolidation of existing waste management activities within this part of the Proposal Site.
  - A waste disposal facility, being the continuation of current land restoration, landfilling and contouring operations at the Proposal Site by permanent application of some of the residual waste materials from the New Resource Recovery Facility to land on Lot 5.
- Use of suitable material processed by the New Resource Recovery Facility to cap, contour and re-profile areas of the Proposal Site and to construct the Embellished Marang Parklands on Lots 1122, 1123 and Lot 6.
- Re-profiling of parts of the Proposal Site within Lots 1122, 1123 and 6, with some existing waste materials from those lots.
- Delivery of an activated and integrated community space in the form of the Embellished Marang Parklands on Lots 1122,1123 and Lot 6, to provide a superior parkland to that proposed under the VPA as detailed in Section 4.4.3 of the EIS (referred to as the Embellished Marang Parklands). This would include, among other things, integrated water usage and management and utilising personnel, plant, material and infrastructure across the whole of the Site.

To enable the above Proposal, the Existing Breen Resources Facility infrastructure on Lots 1122, 1123 and 6 (this includes those parts of Lot 1122 and 1123 and Lot 6 that will comprise the Playing Fields) will be demolished and/or relocated (as required) to Lot 5.

This report has been prepared by GHD to characterise baseline contamination status at the Proposal Site as an input to the EIS. The purpose of this report is to address the Secretary of the NSW Department of Planning and Secretary's Environmental Assessment Requirements (SEARs; SSD-10412) dated 14 February 2020.

The objectives of this report are to:

- Characterise baseline contamination status at the Proposal Site to assess potential impacts related to the Proposal.
- Address the SEARs related to contamination.
- Assess potential ecological and human health risks associated with identified contamination on site and in the Proposal Site's vicinity

The scope of works for this report included:

- Desk study and review of publicly available information, and previous soil, landfill gas and surface water investigations.
- Completion of a Proposal Site visit to better understand Proposal Site activities and contamination issues.
- Collection of surface water samples from on-site and off-site, and five off-site sediment pore water samples from Towra Point Nature Reserve to the north, and subsequent analysis for a broad suite of contaminants of potential concern (COPC).
- Review of historical monitoring and assessment reports and interpretation of existing soil, surface water and soil gas data.
- Development of a Conceptual Site Model (CSM) for current and proposed Proposal Site uses in the context of contamination.
- Assessment of data gaps and potential constraints posed by contamination to the Proposal.

The primary source of contamination at the Proposal Site is mainly derived from landfilling activities within the western portion, which has occurred after historical sand mining pits were backfilled with VENM and PASS (below the groundwater table). Placement of waste has resulted in leachate generation as well as production of ground gases such as methane and carbon dioxide, which is typical of landfill sites.

Available soil data from stockpiled recovered fines/ recovered aggregate analysis indicate that contaminant concentrations meet the analytical thresholds in their respective exemptions, and are all below adopted human health criteria for current and future use (recreation / public open space and commercial). Concentrations are also generally below adopted ecological criteria for future use.

Leachate/groundwater samples within the waste mass show impacts with nutrients, (most notably ammonia) and moderate concentrations of heavy metals and petroleum hydrocarbons. Other organic contamination such as PAHs, phenols and pesticides have not been detected.

These impacts are reflected, to a lesser extent, in groundwater at perimeter monitoring locations around the Proposal Site, with the greatest concentrations of ammonia (a leachate indicator) in BH5A to the north, towards Towra Point Nature Reserve. However, surface water data collected from on-site locations, apart from the lined leachate pond, did not show significant nutrient impacts, although concentrations of heavy metals were above adopted ecological criteria.

Off-site surface water sampling to the south did not indicate the likelihood for any significant impacts to fresh water ponds, with virtually all contaminant concentrations below adopted freshwater ecological criteria; only one duplicate copper result slightly exceeded the trigger value.

Off-site surface water and pore water to the north indicated impacts in both media from nutrients and heavy metals in excess of 95% species protection for marine ecological receptors. However, analysis of the relationship between surface water, pore water and up-gradient groundwater concentrations does not clearly link the observed surface water impacts to groundwater migrating from the Proposal Site, as in most cases the pore water concentrations are greater than measured upgradient groundwater concentrations for COPC.

Given the extensive industrial use of Botany Bay which continues to the present, background sources of impacts cannot be precluded, and are in fact, likely.

Ground gases (methane and carbon dioxide) are present above adopted trigger levels in the waste mass. However, surface monitoring, indoor accumulation monitoring and perimeter in-ground monitoring do not indicate that gases are migrating off-site or into confined spaces and posing a risk.

Data gaps have been identified and evaluated; these primarily relate to the potential for minor localised contamination to be present from Proposal Site operations, the potential for asbestos to be present, and the potential for contaminants other than those specified in EPL 4608 to be present in leachate (PCBs, TBT and PFAS). These data gaps have been assessed as generally low significance, with the potential exception of PFAS, which is a known presence in landfill leachates, and is an emerging contaminant with uncertainty in respect of environmental effects.

It is also noted that Botany Bay is an NSW EPA PFAS investigation area due to the many potential sources of PFAS associated with industrial use.

Review of potential source-pathway-receptor linkages for the current use does not identify any that are, or are likely to be, complete, with the possible exceptions of:

- Aesthetic (odour) issues for off-site receptors
- Leaching from waste to on-site groundwater resources
- Direct contact to potential localised contamination (if present) for transient wildlife on-site
- Exposure to leachate by Proposal Site workers on-site by direct contact, if applicable.
- Possible migration of contaminants via groundwater to Towra Point Nature Reserve
- Potential for exposure to hazardous ground gases by intrusive maintenance workers for any excavation work into waste materials.

In respect of future land use (recreational /open space in the western portion and commercial industrial at the proposed New Resource Recovery Facility in the east), the landfilling areas of the Proposal Site will be capped in accordance NSW EPA landfill closure requirements, which include mitigation of ground gases and specifications for clean capping materials in the final landform.

With this in mind, the review of potential source-pathway-receptor linkages for the future use can be split into three areas:

- Area 1 - Capped areas of landfilled waste in the west which will be public open space / recreational
- Area 2 - New cell B11 (with geosynthetic liner) in the central eastern portion of the Proposal Site, which will be operational for the next few years
- Area 3 - New Resource Recovery Facility in the east of the Proposal Site (being Lot 5), which will be primarily sealed.

Source-pathway-receptor linkages for these future scenarios are not identified to be complete, or likely to be complete based on the available data, with the exception of the following:

- Leaching from waste (Area 1 only) to on-site groundwater resources. The potential for this is likely to be reduced post capping due to infiltration reduction.
- Potential for exposure to hazardous ground gases by intrusive maintenance workers (Area 1 only) for any excavation work over capped waste.

No significant contamination constraints to the Proposal have been identified based on the available data. The potential linkages identified are considered to be manageable by implementation of the Proposal Site Capping Plan and associated post closure environmental monitoring. It is considered that the Proposal Site can be made suitable for its intended uses (including for the purposes of SEPP55) subject to the mitigation measures described in this document being implemented. This will need to include the development and implementation of a Proposal Site Closure Plan in accordance with NSW EPA guidelines. It is noted that appropriate closure of non-operational portions of the Proposal Site in accordance with NSW

EPA requirements will result in a large overall reduction in the generation of leachate associated with the Proposal as opposed to existing conditions, which is expected to result in groundwater of improved water quality and lower volume migrating off-site (GHD 2021).

While there does not appear to be a direct link between leachate impacts (most notably ammonia, but also to a lesser extent heavy metals) in groundwater at the Proposal Site with off-site surface water, the data suggests that leachate from the Proposal Site is likely to have migrated beyond the northern Proposal Site boundary in groundwater in excess of adopted criteria. This issue has been, and will continue to be, discussed with the EPA.

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Definitions/terminology

Term	Definition
ACM	Asbestos containing material
AHD	Australian Height Datum
AMP	Asbestos management plan
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ASS	Acid sulphate soil
ASSMP	Acid sulphate soil management plan
BaP	Benzo-a-pyrene
BoM	Bureau of Meteorology
Breen	Breen Resources Pty Ltd
BTEX	Benzene, toluene, ethylbenzene and xylene
C&D	Construction and Demolition Waste including excavated material such as rock and soil, waste asphalt, bricks, concrete, plasterboard, timber and vegetation, asbestos and contaminated soil
C&I	Commercial and Industrial Waste, being mixed waste sourced from manufacturers, shops and businesses.
CEMP	Construction Environmental Management Plan
CLM Act	Contaminated Land Management Act 1997
COC	Chain of custody
COPC	Contaminants of potential concern
CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
CRP	Concrete recycling pond
CSM	Conceptual site model
DQI	Data quality indicators
EIL	Ecological investigation levels
EIS	Environmental Impact Statement
EP&A Act	New South Wales (NSW) Environmental Planning and Assessment Act 1979
EPL	Environment Protection Licence issued by the Environment Protection Authority under the *Protection of the Environment Operations Act 1997*
Embellished Marang Parklands	The Marang Parkland as now proposed to be delivered as part of this SSDA, which contain a range of improvements and embellishments over and above the 2010 Voluntary Planning Agreement commitments.
Existing Breen Resources Facility	Existing facility owned by Breen Property Pty Ltd and operated by Breen Resources Pty Ltd at 330 Captain Cook Drive, Kurnell which receives excavated materials and selected C&D waste, and carries out Proposal Site restoration by application of these materials to land in accordance with DA269/90 on: • Lot 1122 in DP794114 (Lot 1122); • Lot 1123 in DP794114 (Lot 1123); • Lot 5 in DP1158627 (Lot 5); Lot 6 in DP1158627 (Lot 6).
ESL	Ecological screening levels

Term	Definition
Former Landfill Area	Parts of the Existing Breen Resources Facility that were formally managed under one license as one site and used for landfilling pursuant to DA269/90 and EPL 4608, but where landfilling has since ceased, comprising parts of Lots 1122, 1123 and Lot 6 (noting that landfilling remains active on Lot 5).
HSL	Health screening levels
HWWWP	Historic western wheel wash pond
Landfill	A landfill is an engineered, in-ground facility for the safe and secure disposal of waste by applying the waste to the land.
LEL	Lower explosive level
LEP	Local environmental plan
m bgl	Metre below ground levels
m btoc	Metre below top of casing
Marang Parklands	The regional recreation facilities and parklands proposed under the 2010 Voluntary Planning Agreement (VPA).
NAPL	Non aqueous phase liquid
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
New Resource Recovery Facility	Proposed new facility on Lot 5 DP1158627 to receive and process up to 650,000 tonnes per year of C&D and non-putrescible C&I wastes. The New Resource Recovery Facility comprises: • Waste processing building – incorporating the Recycling Plant and light residuals processing • Soils processing building – incorporating soil processing plant • Concrete processing building – incorporating processing plant for concrete, aggregate, brick, tiles, rock and other similar materials. • Three weighbridges and an internal weighing zone • Proposal Site office and administration building • Workshop • Parking area • Three wheel washes • Two recovered water basins • Internal roadways • Fencing and visual screening • Stockpiles and storage areas Skip bin storage area
NHMRC	National Health and Medical Research Council
NSW EPA	NSW Environment Protection Authority
NWQMS	National Water Quality Management Strategy
OCP/OPP	Organochlorine and organophosphate pesticides
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PFAS	Per- and polyfluoroalkyl substances
Playing Fields	The playing fields and associated works approved under: • DA11-0665; • DA11-0941; • DA12-0083; • DA12-0439; and

Term	Definition
	DA12-1066
POEO Act	Protection of the Environment Operations Act 1997
Proposal Site	The entirety of the Existing Breen Resources Facility, being Lot 1122 and Lot 1123, and Lot 5 and Lot 6.
QA/QC	Quality assurance/quality control
QA/QC	Quality assurance and quality control
Recycling plant	Part of the New Resource Recovery Facility and located within the processing building. Includes plant and equipment to pre-process incoming C&D and C&I waste streams and separate waste into various recyclables using size, density and other separation technology.
RRO	Resource Recovery Order
SEARs	Environment's Environmental Assessment Requirements. In this case SSD-10412 dated 14 February 2020.
SEPP 55	State Environmental Planning Policy 55
SSDA	State significant development application
SWL	Standing water level
The Proposal	• Construction and operation of a resource management facility, comprising: - A resource recovery facility on Lot 5 to process up to 650,000 tonnes per year of C&D and non-putrescible C&I wastes, including consolidation of existing waste management activities within this part of the Proposal Site. - A waste disposal facility being the continuation of landfilling, land rehabilitation operations and contouring by permanent application of some of the residual waste materials from the New Resource Recovery Facility to land on Lot 5. • Demolition and/or relocation to Lot 5 (as required) of the Existing Breen Resources Facility on Lots 1122, 1123 and 6 (this includes those parts of Lots 1122, 1123 and 6 that will comprise the Playing Fields). • Capping, closing and contouring areas within Lots 1122, 1123 and Lot 6 with suitable material recovered from the New Resource Recovery Facility and the material currently stockpiled on site that meets a relevant 2014 resource recovery orders, This includes ensuring a consistent and appropriate land form between the Embellished Marang Parklands and Lot 5. Some specific material would be imported to the Proposal Site for capping and covering, such as low permeability clay. Delivery of activated community space in the form of the Embellished Marang Parklands on Lots 1122, 1123 and Lot 6.
TRH	Total recoverable hydrocarbons
VENM	Virgin Extracted Natural Material

Term	Definition
VPA	The Voluntary Planning Agreement entered into between Breen Holdings Pty Ltd (subsequently novated to Breen Property), Australand Kurnell Pty Ltd (now renamed Frasers Property Australia Limited) and Sutherland Shire Council in June 2010 which requires: • A staged transfer of 91 ha of land to public ownership for the purpose of environmental conservation and public open space. • Construction of regional recreation facilities, including 10 playing fields, a skate park, 3 amenities buildings, walking and cycling tracks, picnic facilities and associated parking for over 400 cars. • Rehabilitation and landscaping of degraded land previously dredged for sand mining to support an ecological 'green corridor' stretching from the Towra point Nature Reserve to the ocean at Wanda Beach.
WWP	Wheel wash pond
DA269/90	A consent applying across the Proposal Site which provides for the establishment of a depot to receive excavated materials and selected demolition materials (including bricks, tiles and concrete spall), and for the restoration of the land by application of the materials to the land.
DA11-0665	A consent applying across part of the Proposal Site (i.e. parts of Lot 1122, Lot 11223, Lot 5 and Lot 6) as well as adjacent land, which provides a masterplan for the construction of playing fields in accordance with VPA. DA11-0665 is a Staged Development Consent, and subsequent detailed approvals are provided under the following related consents: • DA11-0941 for Stage 1B playing fields bulk earthworks • DA12-0083 for Stage 2 playing fields and the roads, services and landscaping for Stage 1B. • DA12-0439 for Stage 3 playing fields. • DA12-1066 for Stage 1C skate park. DA11-0665 also included the detailed development consent for the first stage of works, being the development of the Stage 1A playing fields on Lot 1 DP1101922.
DA11-0941	A consent applying across part of Lot 1122 for the development of the Stage 1B playing fields bulk earthworks. DA11-0941 is a Stage 2 consent, related to the partial delivery of the masterplan approved under Staged Development Consent DA11-0665.
DA12-0083	A consent applying across part of Lot 1122 and part of Lot 6 for the development of the Stage 2 playing fields and the roads, services and landscaping for Stage 1B playing fields. DA12-0083 is a Stage 2 consent, related to the partial delivery of the masterplan approved under Staged Development Consent DA11-0665.
DA12-0439	A consent applying across part of Lot 1122 for the development of the Stage 3 playing fields. DA11-0439is a Stage 2 consent, related to the partial delivery of the masterplan approved under Staged Development Consent DA11-0665.
DA12-1066	A consent applying on Lot 1 DP1101922 for the development of the Stage 1C skate park. DA11-0941 is a Stage 2 consent, related to the partial delivery of the masterplan approved under Staged Development Consent DA11-0665.

1. Introduction

1.1 Background

Breen Resources Pty Ltd (Breen) owns and operates the Existing Breen Resources Facility at 330 Captain Cook Drive, Kurnell (comprising Lot 1122 and Lot 1123 DP794114, and Lot 5 and Lot 6 DP1158627; here after referred to as Lot 1122, Lot 1123, Lot 5 and Lot 6). The Existing Breen Resources Facility currently receives excavated materials and selected construction and demolition (C&D) waste, and carries out Proposal Site restoration by application of these materials to land. Construction and demolition waste recycling operations are also carried out at the Proposal Site; for more details refer to Section 3.

Parts of the Existing Breen Resources Facility (Lot 1122, Lot 1123, and Lot 6) are also subject to a Voluntary Planning Agreement (VPA) which requires the future provision of regional recreation facilities and parklands (named by Sutherland Shire Council as the Embellished Marang Parklands).

The Existing Breen Resources Facility infrastructure is located on land that will be developed as, subject to approval of this SSD, the Embellished Marang Parklands. Separate consents provide approval for delivery of Stages 2 and 3 of the Playing Fields on a portion of this land as well.

To deliver the Embellished Marang Parklands and part of the Playing Fields on Lots 1122 and 1123, parts of the Existing Breen Resources Facility need to be demolished. Breen is therefore proposing to construct and operate a new integrated resource recovery facility to consolidate all functional recycling activities within the eastern part of the Proposal Site (on Lot 5).

Together with the continuation of landfilling on the residual parts of Lot 5, the New Resource Recovery Facility and the delivery of the Embellished Marang Parklands comprise the Proposal.

The Proposal will allow Breen to deliver this activated recreational space and other publicly accessible parklands in the western part of the Proposal Site to the community in accordance with the VPA.

The Proposal would contribute to the delivery of quality green, open and public space at Kurnell, supporting the Premier's priority to "increase the tree canopy and green cover across Greater Sydney by planting one million trees by 2022" and support the delivery of the Sydney Green Grid Objectives. The Proposal would also contribute to achieving the NSW Government's resource recovery targets as outlined in both the National Waste Policy: Less waste more resources and the NSW "Waste and Resource Recovery Strategy 2014-2021" by investing in technology to improve the quality of recycling activities at the Proposal Site, a key priority for the NSW Environmental Protection Authority (EPA).

1.2 Purpose

Ethos Urban has been engaged by Breen to author an environmental impact statement (EIS) to support a development application for approval of the Proposal under Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act 1979* (the EP&A Act). The EIS is being prepared in accordance with the provisions of the EP&A Act.

This report has been prepared by GHD to characterise baseline contamination status at the Proposal Site as an input to the EIS. The purpose of this report is to address the Secretary of the NSW Department of Planning and Secretary's Environmental Assessment Requirements (SEARs; SSD-10412) dated 14 February 2020. The SEARs are presented in Section 1.7.

1.3 Objectives

The objectives of this report are to:

- Characterise baseline contamination status at the Proposal Site in order to assess potential impacts related to the Proposal.
- Address the SEARs related to contamination.
- Assess potential ecological and human health risks associated with identified contamination on site and in the Proposal Site's vicinity.

1.4 The Proposal Site

1.4.1 Location

The Proposal Site is located within the Sutherland Shire Local Government Area, approximately 12 kilometres south of the Sydney Kingsford Smith Airport. The Proposal Site is situated on the Kurnell Peninsula, positioned between Quibray Bay (within Botany Bay) to the north and Bate Bay (being Cronulla and Wanda beaches) to the south. It is currently accessible from Captain Cook Drive and Lindum Road.

Figure 1-1 shows the location of the Proposal Site.

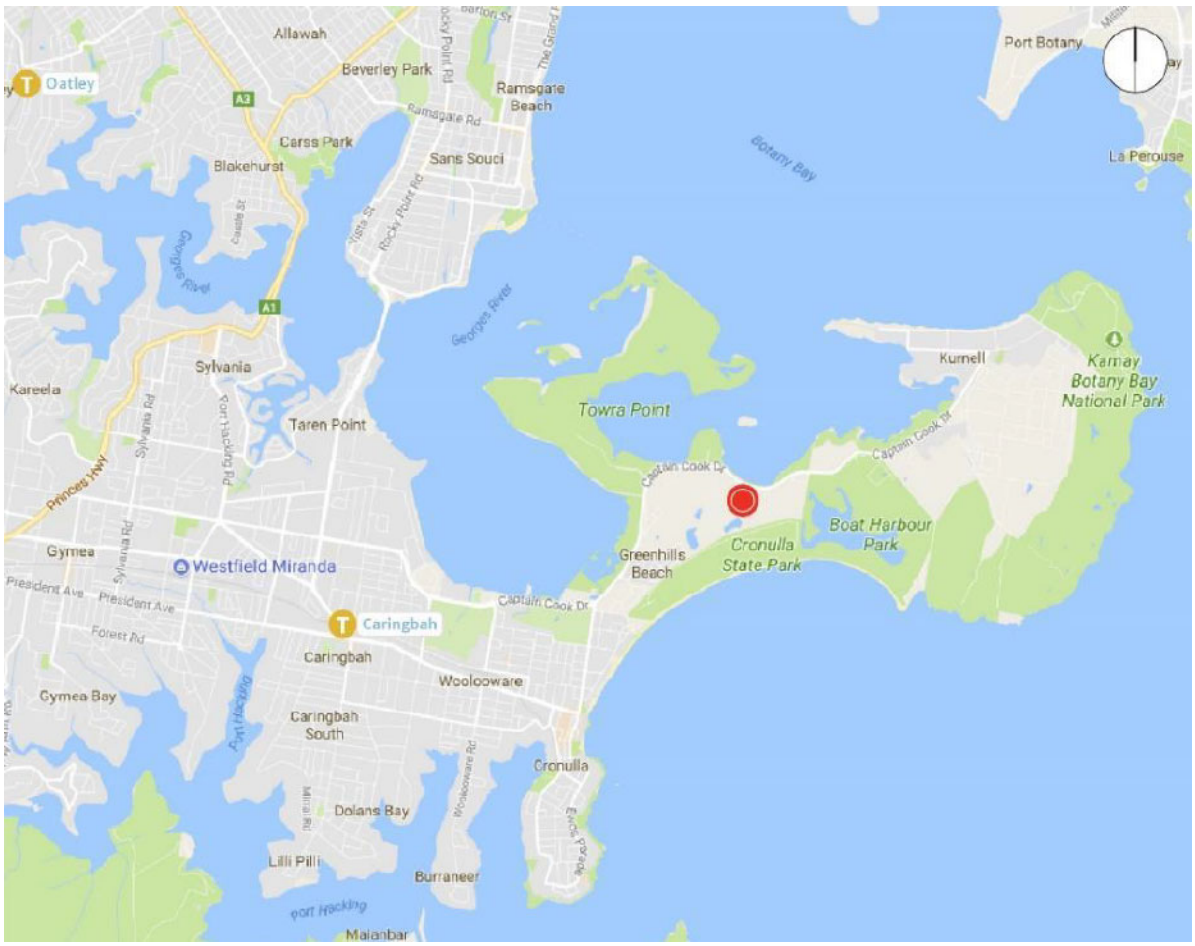

Figure 1-1 Proposal Site location

1.4.2 Proposal Site context

The Proposal Site is generally bounded to the north by Captain Cook Drive, which provides access from North Cronulla through to the village of Kurnell, as well as the main access to the existing Breen Resources Facility. Further to the north of Captain Cook Drive are the foreshores and waters of Botany Bay, including the Towra Point Nature Reserve.

Near the eastern end of the Proposal Site, Sporting Field No. 1 and the Skate Park have recently been constructed on Lot 1 DP 1101922 and are now operational. This new recreational area represents the closest existing sensitive receptor to the eastern part of the Proposal Site, where the resource recovery facility is proposed to be located.

An electricity transmission line easement runs along this boundary, between the Proposal Site and the Sporting Field No. 1 and Skate Park recreational area. The easement contains Ausgrid 132kV overhead electricity transmission lines. Further to the west, Hockey Fields No. 2 and No. 3 have also already been constructed on Lot 111 DP777967 and part of Lot 1123 DP794114, and are now operational.

To the south, the Proposal Site adjoins the Heritage Sand Dune and Cronulla State Park, which leads to Wanda Beach, fronting onto Bate Bay.

To the east, the Proposal Site is bounded by an unconstructed extension of Lindum Road, within which a pedestrian footpath has been constructed for beach and foreshore access. Beyond the Lindum Road reserve is a sand mining site that is being progressively mined for construction sand and backfilled with virgin excavated natural materials.

To the west, the Proposal Site adjoins Charlotte Breen Memorial Reserve and Sydney Water's Cronulla wastewater treatment plant. Beyond Charlotte Breen Memorial Reserve to the south west is the new residential suburb of Greenhills Beach, comprising low density residential housing. This area was also subject to extensive sandmining in the past. More broadly, this area of the Kurnell peninsula also includes other large scale industrial use, notably the Sydney Desalination Plant (approximately 1.8 km east) and the Caltex Kurnell Terminal (and former refinery – approximately 2 km east)

1.5 Proposal overview

1.5.1 Key infrastructure components

The Existing Breen Resources Facility is located on land that will, subject to the approval of this application, be developed as the Embellished Marang Parklands. Stages 2 and 3 of the Playing Fields will also be developed on a part of this land under separate consents already obtained.

To deliver the Embellished Marang Parklands on Lots 1122 and 1123 and Lot 6, the Existing Breen Resources Facility infrastructure needs to be demolished and/or relocated.

Breen is therefore proposing to construct and operate a new integrated resource recovery facility to consolidate all functional recycling activities within the eastern part of the Proposal Site, being on Lot 5. This will allow Breen to deliver the recreational space and other publicly accessible Embellished Marang Parklands in the western part of the Proposal Site to the community. It will also provide improved recycling capability in line with NSW Government priorities and targets to increase resource recovery from the C&D and C&I sectors.

The Proposal is comprised of the delivery of the Embellished Marang Parklands, the continuation of landfilling on the residual parts of Lot 5 and the construction of the New Resource Recovery Facility.

Specifically, the Proposal involves the following key integrated components:

- Construction and operation of a New Resource Recovery Facility, comprising:

  - A New Resource Recovery Facility on Lot 5 to process approximately 650,000 tonnes per year of construction and demolition (C&D) and commercial and industrial (C&I) wastes, including consolidation of existing waste management activities within this part of the Proposal Site.
  - -A waste disposal facility, being the continuation of current land restoration, landfilling and contouring operations at the Proposal Site by permanent application of some of the residual waste materials from the New Resource Recovery Facility to land on Lot 5;
- Use of suitable material processed by the New Resource Recovery Facility to cap, contour and re-profile areas of the Proposal Site and to construct the Embellished Marang Parklands on Lots 1122, 1123 and Lot 6.
- Re-profiling of parts of the Proposal Site within Lots 1122, 1123 and 6, with some existing waste materials from those lots.
- Delivery of an activated and integrated community space in the form of the Embellished Marang Parklands on Lots 1122 and 1123 and Lot 6). This will include, among other things, integrated water usage and management and utilising personnel, plant, material and infrastructure across the whole of the Proposal Site.

To enable the above Proposal, the Existing Breen Resources Facility infrastructure on Lots 1122, 1123 and 6 (this includes those parts of Lot 1122 and 1123 and Lot 6 that will comprise the Playing Fields) will be demolished and/or relocated (as required) to Lot 5.

Figure 1-2 shows key features of the Proposal.

Figure 1-2 Proposal – key components

1.6 Definitions

The following terms are used within this report:

- The ‘Proposal Site’ refers to Lot 1122, Lot 1123, Lot 5 and Lot 6 .

1.7 Secretary's environmental assessment requirements

Table 1 presents the key issues provided by the SEARs related to soil and water, and where they are addressed in this report and/or other documents.

Table 1 SEARs key requirements addressed in this report

Requirements/key issues	Where addressed in this report
Soil and Water – the EIS must address the following specific matters:	
Characterisation of the nature and extent of any contamination of the Proposal Site based on the historic use as a landfill and a description of proposed measures.	Sections 8, 9 and 10. Mitigation measures are discussed in Section 11.
An assessment of potential impacts to soil and water resources, topography, hydrology, groundwater, drainage lines, watercourses and riparian lands on or nearby the Proposal Site, including mapping and description of existing background conditions and cumulative impacts.	Sections 9 and 10. Also refer to Groundwater Impact Assessment report (GHD 2021) and Surface Water Management Assessment (Cardno, 2021)
Characterisation of water quality at the point of discharge to surface and/or groundwater against the relevant water quality criteria (including details of the contaminants of concern that may leach from the waste into the wastewater and proposed mitigation measures to manage any impacts to receiving waters and monitoring activities and methodologies).	Section 9 and Groundwater Impact Assessment (GHD, 2021) and Surface Water Management Assessment (Cardno, 2021)
The assessment must include details of proposed surface and groundwater monitoring.	Groundwater impact assessment (GHD, 2021) and Surface Water Management Assessment (Cardno 2021)

1.8 Agency requirements

Agency requirements considered to have relevance to this report are summarised in Table 2.

Table 2 Agency recommendations

Requirements/key issues		Where addressed in this report
NSW Department of Planning Industry and Environment (DPIE) – Climate Change and Sustainability	9.0 The EIS must map the following features relevant to water and soils including: Acid Sulphate Soils (Class 1, 2, 3 or 4 on the Acid Sulphate Soil Planning Map). Rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method) Wetlands (as described in s4.2 of the Biodiversity Assessment Method). Groundwater Groundwater dependent ecosystems	Section 3 (Overview where other specialist reports cover in more detail)
	10.0 The EIS must describe background conditions for any water resource likely to be affected by the development, including: Existing surface and groundwater Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	Existing surface water and groundwater conditions are addressed in Section 8 and 9 Water quality objectives are

Requirements/key issues		Where addressed in this report
	Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions http://www.environment.nsw.gov.au/research-and-publications/publications-search/risk-based-framework-for-considering-waterway- health-outcomes-in-strategic-land-use-planning	discussed on Section 6. Also reference Groundwater Impact Assessment (GHD, 2021), Surface Water Impact Assessment (Cardno 2021), Biodiversity Development Assessment Report (Eco Logical, 2021)
NSW Environment Protection Authority (EPA)	B Proposal 2.0 Description of the proposal Water Provide details of the project that are essential for predicting and assessing impacts to waters including: The quantity and physio-chemical properties of all potential water pollutants and the risks they pose to the environment and human health, including the risks they pose to Water Quality Objectives in the ambient waters (as defined on http://www.environment.nsw.gov.au/ieo/index.htm, using technical criteria derived from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, ANZECC 2000)	Sections 8 to 10. Also reference Groundwater Impact Assessment (GHD, 2021) and Surface Water Impact Assessment (Cardno 2021)
	E The Environmental Issues 4. Water Describe baseline conditions Describe existing surface and groundwater quality – an assessment needs to be undertaken for any water resource likely to be affected by the proposal and for all conditions (e.g. a wet weather sampling program is needed if runoff events may cause impacts). Note: Methods of sampling and analysis need to conform with an accepted standard (e.g. Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC 2004) or be approved and analyses undertaken by accredited laboratories). State the ambient Water Quality and River Flow Objectives for the receiving waters. These refer to the community's agreed environmental values and human uses endorsed by the Government as goals for the ambient waters. These environmental values are published on the website: http://www.environment.nsw.gov.au/ieo/index.htm. The EIS should state the environmental values listed for the catchment and waterway type relevant to your proposal. NB: A consolidated and approved list of environmental values are not available for	Sections 8 and 9 Also reference Groundwater Impact Assessment (GHD, 2021) and Surface Water Impact Assessment (Cardno 2021) Section 7 (Also reference Groundwater Impact Assessment (GHD,

Requirements/key issues		Where addressed in this report
	groundwater resources. Where groundwater may be affected the EIS should identify appropriate groundwater environmental values and justify the choice.	2021) and Surface Water Impact Assessment (Cardno 2021)
	State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the ANZECC 2000 Guidelines for Fresh and Marine Water Quality (http://www.environment.gov.au/water/publications/quality/nwqms-guidelines-4-vol1.html) (Note that, as at 2004, the NSW Water Quality Objectives booklets and website contain technical criteria derived from the 1992 version of the ANZECC Guidelines. The Water Quality Objectives remain as Government Policy, reflecting the community's environmental values and long-term goals, but the technical criteria are replaced by the more recent ANZECC 2000 Guidelines1). NB: While specific guidelines for groundwater are not available, the ANZECC 2000 Guidelines endorse the application of the trigger values and decision trees as a tool to assess risk to environmental values in groundwater.	Section 7 (Also reference Groundwater Impact Assessment (GHD, 2021) and Surface Water Impact Assessment (Cardno 2021)
	State any locally specific objectives, criteria or targets, which have been endorsed by the government e.g. the Healthy Rivers Commission Inquiries or the NSW Salinity Strategy (DLWC, 2000) (http://www.environment.nsw.gov.au/salinity/government/nswstrategy.htm).	Reference Surface Water Impact Assessment (Cardno 2021)
	Describe the state of the receiving waters and relate this to the relevant Water Quality and River Flow Objectives (i.e. are Water Quality and River Flow Objectives being achieved?). Proponents are generally only expected to source available data and information. However, proponents of large or high risk developments may be required to collect some ambient water quality / river flow / groundwater data to enable a suitable level of impact assessment. Issues to include in the description of the receiving waters could include: A lake or estuary flushing characteristics A specific human uses (e.g. exact location of drinking water offtake) A sensitive ecosystems or species conservation values A description of the condition of the local catchment e.g. erosion levels, soils, vegetation cover, etc	Section 8 to 9 ((Also reference Groundwater Impact Assessment (GHD, 2021) and Surface Water Impact Assessment (Cardno 2021)

[1] ANZECC (2000) has been revoked by an online resource prepared by the Australian and New Zealand and Australian State and Territory Governments (ANZG) in 2018.

1.9 Scope of works and structure of the report

1.9.1 Scope of the report

The scope of works for this report comprised:

- Desk study and review of specific information including published information (e.g. topographic, geological, soil landscape, acid sulfate soil risk maps), aerial photographs; search of WaterNSW groundwater bore database, NSW Environment Protection Authority (EPA) databases, and previous soil, landfill gas and surface water investigations.
- A review of relevant information including:
  - Legislative documents that inform the assessment of Proposal Site contamination.
  - The project description and design plans.
  - Previous modification documentation.
  - Current land use activities and details of the proposed works.
- Completion of a Proposal Site visit to better understand Proposal Site activities and contamination issues.
- Collection of five surface water samples from on-site surface water features (SW1 to SW5); and three off-site surface water samples (SW6, SW7 and SW8); and five off-site sediment pore water samples (PW01 to PW04 and PW07) from Towra Point Nature Reserve to the north of the Proposal Site.
- Analysis for a broad suite of contaminants of potential concern (COPC) at a laboratory accredited by the National Association of Testing Authorities (NATA), Australia.
- Review of historical monitoring and assessment reports and interpretation of existing soil, surface water and soil gas data.
- Assessment of baseline contamination status using a conceptual model based approach developed using the information collated for the works outlined above.
- Assessment of data gaps.
- Assessment of potential constraints posed by contamination to the Proposal.
- Conceptual development of mitigation measures, including monitoring procedures, to mitigate conceptual data uncertainties, delineate the emergence of impacts and respond appropriately to emerging impacts.
- Development of this contamination assessment to document the findings of the investigation.

1.10 Limitations

This report: has been prepared by GHD for Breen Resources Pty Ltd and *may only be used and relied on by Breen Resources Pty Ltd for the purpose agreed between GHD and the Breen Resources Pty Ltd as set out in Section 1.2 of this report.*

GHD otherwise disclaims responsibility to any person other than Breen Resources Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation

to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Breen Resources Pty Ltd and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Proposal Site conditions at other parts of the Proposal Site may be different from the Proposal Site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular Proposal Site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant Proposal Site features and conditions may have been identified in this report.

Proposal Site conditions (including the presence of hazardous substances and/or Proposal Site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the Proposal Site conditions. GHD is also not responsible for updating this report if the Proposal Site conditions change.

2. Legislative and policy context

A summary of NSW legislative and policy context in respect of contamination is presented below.

2.1 Contaminated Land Management Act 1997

The *Contaminated Land Management Act 1997* (CLM Act) is one of the main regulatory tools in NSW to control investigation and remediation of contaminated sites.

The CLM Act defines when a site is contaminated to the point in which it requires regulation. Regulation is required when a site is declared 'significantly contaminated land' or when it is under a management order. The CLM Act defines a legal structure which allows the NSW EPA to regulate the investigation and clean-up of a regulated site. Under the CLM Act, the NSW EPA can provide guidelines for fulfilling the requirements provided by the CLM Act.

Contaminated sites that are not regulated under the CLM Act are managed under relevant authorities such as local councils.

2.2 Protection of the Environment Operations Act 1997

The primary function of the Protection of the Environment Operations Act 1997 (POEO Act) is to protect, restore and enhance the quality of the environment, in recognition of the need to maintain ecological sustainable development.

The *POEO Act* provides for an integrated system of licensing and contains a core list of activities requiring Environment Protection Licenses (EPL) from the EPA. These potentially polluting activities are called 'scheduled activities' and are listed in Schedule 1 of the *POEO Act*. EPLs can stipulate conditions, such as environmental monitoring requirements for which non-compliance can result in penalties. The *POEO Act* also provides the power for regulatory authorities (typically Councils or EPA) to issue prevention, prohibition and clean-up notices under the *POEO Act* for polluting activities or pollution incidents.

Correspondingly, there is a provision in the *POEO Act* that requires notification of the EPA and other relevant authorities for certain pollution incidents causing material harm.

The *POEO Act* defines 'waste' for regulatory purposes and establishes management and licensing requirements for waste in conjunction with the POEO (Waste) Regulation 2014. This includes procedures for the classification of waste, the definition of offences and penalties in relation to waste management.

The *POEO Act* also includes requirements for the protection against water, air and noise pollution and incident reporting requirements for actual or potential pollution incidents.

2.2.1 Environmental protection licences

The Proposal Site holds two environmental protection licences (EPLs) which have been issued to Breen. Details about the EPLs are provided below.

Environment Protection Licence - 4608

The EPL authorises 'resource recovery' (any general waste recovered) and 'waste disposal by application to land under the *POEO Act*. A list of acceptable waste is provided in the EPL and comprise immobilised wastes able to be landfilled; virgin excavated natural material; waste tyres; paper or cardboard; glass, plastic, rubber, plasterboard, ceramics, bricks, concrete or metal; building and demolition waste; asphalt waste (including asphalt resulting from road

construction and waterproofing works); ferric sludge (from the Sydney Desalination Plant); dredge spoil; and soils.

The following operational conditions and obligations were noted:

- 'Surface waters must be diverted away from any area where waste is being or has been landfilled'.
- 'The landfill surface must be contoured to prevent the run-on of surface waters onto areas where waste has been landfilled except during storm events of not less than a 1 in 10 year recurrence interval of 24 hours duration'.
- 'Make all efforts to contain any discharge, spill or run-off from the licensee's premises'.
- 'Remediate and rehabilitate any exposed areas of soil and/or waste'.
- 'At the request of the EPA monitor surface water leaving the licensee's premises'.
- 'At the request of the EPA monitor groundwater beneath the licensee's premises and its potential to migrate from the licensee's premises'.

Environment Protection Licence – 20697

The EPL authorises 'resource recovery' (recovery of general waste) and 'waste storage' (waste storage – other types of waste) under the *POEO Act 1997*. A list of acceptable wastes is provided in the EPL and comprise: grit and screenings from potable water and water reticulation plants that has been dewatered so that it does not contain free liquids; wood waste; cured concrete waste from a batch plant; synthetic fibre waste (from materials such as fibreglass, polyesters and other plastics) being waste that is packaged securely to prevent dust emissions, but excluding asbestos waste; grit, sediment, litter and gross pollutants collected in, and removed from, stormwater treatment devices or stormwater management systems, that has been dewatered so that it does not contain free liquids; waste collected by or on behalf of local councils from street sweeping; household waste from municipal clean-up that does not contain food waste; waste tyre; soils; asphalt waste (including asphalt resulting from road construction and waterproofing works); building and demolition waste; glass, plastic, rubber, plasterboard, ceramics, bricks, concrete or metal; paper or cardboard; and virgin excavated natural material.

Operational conditions and obligations are in line with EPL 4608.

2.2.2 Resource Recovery Orders

A number of resource recovery orders have been issued by the NSW EPA under the Resource Recovery Order Part 9, Clause 93 of the *Protection of the Environment Operations (Waste) Regulation 2014* has been issued by the NSW EPA. Two resource recovery orders applicable to the Proposal Site have been reviewed.

The orders define requirements that must be met by suppliers of recovered material.

Recovered aggregate

The *Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014 – Recovered aggregate order 2014* (recovered aggregate order 2014) applies to recovered aggregate. The definition of recovered aggregate, as provided by the NSW EPA, is 'material comprising of concrete, brick, ceramics, natural rock and asphalt processed into an engineered material. This does not include refractory bricks or associated refractory materials, or asphalt that contains coal tar'. The order applies to who supplies the material. It does not apply to the supply of recovered aggregate to a consumer of the material.

Sampling and testing is required to classify materials as recovered aggregate. Details regarding sampling, analytical testing and record keeping are provided in the order which can be found at

https://www.epa.nsw.gov.au/your-environment/recycling-and-reuse/resource-recovery-framework/current-orders-and-exemption. In summary, limits are imposed for heavy metals (mercury, cadmium, arsenic, lead, chromium, copper, nickel, and zinc), electrical conductivity and anthropogenic materials (metal, plaster, rubber, plastic, paper, cloth, paint, wood and other vegetable matter).

The Proposal Site holds statements of compliance which certify that specific materials produced on-site comply with the requirements of the recovered aggregate order 2014.

Recovered fines (Continuous)

The *Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014 – The "continuous process" recovered fines order 2014* (continuous fines order 2014) applies to fines recovered from continuous processes. The definition of "continuous process" recovered fines, as provided by the NSW EPA, is 'a soil or sand substitute with a typical maximum particle size of 9.5 mm that is derived from the continuous processing of mixed construction and demolition waste including residues from the processing of skip bin waste'. The order applies to who supplies the material. It does not apply to the supply of recovered fines to a consumer of the material.

Sampling and testing is required to classify materials as "continuous process" recovered fines. Details regarding sampling, analytical testing and record keeping are provided in the order which can be found at https://www.epa.nsw.gov.au/your-environment/recycling-and-reuse/resource-recovery-framework/current-orders-and-exemption. In summary, limits are imposed for heavy metals (mercury, cadmium, lead, arsenic, chromium, copper, nickel and zinc), total organic carbon, electrical conductivity, pH, total PAH, benzo(a)pyrene, TPH, individual chlorinated hydrocarbons, individual OCPs, individual PCBs, anthropogenic materials (glass, metals, plastics) and particle size.

The Proposal Site holds statements of compliance that certify specific materials produced on-site comply with the requirements of the recovered continuous fines order 2014.

2.3 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act) provides the overarching framework for development approvals in NSW. The EP&A Act institutes a system for environmental planning and assessment, including approvals and environmental impact assessment requirements for proposed developments.

Implementation of the EP&A Act is the responsibility of the Minister for Planning, statutory authorities and local councils. The EP&A Act contains three parts that impose requirements for planning approval. These are generally as follows:

- Part 4 provides for control of "development" that requires development consent from the local councils, a regional planning panel or the state government.
- Part 5 provides for control of 'activities' that do not require approval or development consent under Part 4.
- Part 5.1 provides for control of State Significant Infrastructure.

The need or otherwise for development consent is set out in environmental planning instruments including State Environmental Planning Policies (SEPPs) and Local Environmental Plans (LEPs) which are developed in accordance with Part 3 of the EP&A Act.

In relation to contaminated land, State Environmental Planning Policy 55 – Remediation of land (SEPP55) provides for a state wide planning approach to the remediation of contaminated land

and aims to promote the remediation of contaminated land for the purpose of reducing the risk of harm to human health or any other aspect of the environment by:

a) specifying when consent is required, and when it is not required, for a remediation work,

b) specifying certain considerations that are relevant in rezoning land and in determining development applications in general and development applications for consent to carry out a remediation work in particular,

c) requiring that a remediation work meet certain standards and notification requirements.

The policy states that land must not be developed if it is unsuitable for a proposed use due to contamination. If the land is unsuitable, remediation must take place before the land is developed. SEPP 55 also includes provisions specifying when a remediation work requires consent in its own right (Category 1) or is permissible without consent (Category 2).

2.4 Waste Avoidance and Resource Recovery Act 2001

This Act promotes waste reduction and encourages resource recovery (recycling) where appropriate with the objective of reducing environmental impact and encouraging sustainable development.

2.5 State Environmental Planning Policy (SEPP) 55

SEPP 55 provides for a State-wide planning approach to the remediation of contaminated land. In particular, the SEPP aims to promote the remediation of contaminated land for the purpose of reducing the risk of harm to human health or any other aspect of the environment.

According to clause 7 of SEPP55, contamination and remediation need to be considered in determining a development application as follows:

"(1) A consent authority must not consent to the carrying out of any development on land unless:

(a) it has considered whether the land is contaminated, and

(b) if the land is contaminated, it is satisfied that the land is suitable in its contaminated state (or will be suitable, after remediation) for the purpose for which the development is proposed to be carried out".

2.6 National guidelines

2.6.1 National Environment Protection (Assessment of Site Contamination) Measure 1999

The main objective of the National Environment Protection Council (NEPC) (2013) *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM) is to provide a nationwide consistent methodology to assess and mange contaminated sites. It aims at defining environmental management standards and practices to be followed by regulators, environmental auditors and the rest of the community (e.g. the industry and developers). The NEPM is executed by state and territories legislation and guidelines.

With respect to the Proposal, the NEPM provides a framework for the change of land use at a site that has a history indicative of potential contamination. It provides health and ecological criteria suitable for generic land uses, including commercial/industrial and open space. Assessment criteria adopted from NEPM are discussed in Section 7

2.6.2 National water quality management strategy

The *National Water Quality Management Strategy* (NWQMS) provides the basis for management and protection of water quality depending on desired uses, values, and environmental conditions. It aims at reaching sustainable use of water resources by enhancing water quality and supporting economic and social development. The NWQMS provides a range of tools and guidelines to manage water quality and contamination.

The NWQMS provides water quality assessment criteria for specific water use and protection of specific values. These criteria are based on scientific evidence and include the National Health and Medical Research Council (NHMRC) 2011, *Australian Drinking Water Guidelines*, and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG) 2018. They were used in this investigation.

2.6.3 Australian and New Zealand Guidelines for fresh and marine water quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) form part of the NWQMS. The ANZG provide strategies to manage current and future environmental values for both natural and semi-natural water systems.

The ANZECC (2000) provides assessment criteria – referred to as trigger values and expressed as concentrations – which are used to assess potential environmental issues. The criteria identify different levels of protection for different aquatic ecosystem conditions: high concertation or ecological value systems; slightly to moderately disturbed systems; and highly disturbed systems.

The ANZECC (2000) has been revised in 2018 to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018). The revised guidelines are available at www.waterquality.gov.au/anz-guidelines. These criteria have been adopted to assess ecological receptors such as Botany Bay, Towra Point Nature Reserve and water bodies surrounding the Proposal Site.

State specific guidelines for NSW are listed in Section 7.

3. Proposal Site operations

The current operations at the Proposal Site comprise:

1. Landfill operations
2. Construction and demolition (C&D) waste recycling operations

All incoming material passes over the weighbridge and undergoes initial inspection prior to being directed to the landfill or to the appropriate area of the C&D recycling operations.

The existing Proposal Site layout is depicted on Figure 1 in Appendix A.

3.1 Landfill operations

The landfill is licenced to accept General Solid Waste (non-putrescible) and waste tyres (Special Waste). No putrescible, hazardous or green/garden organics is accepted at the Proposal Site or landfill.

The entire Proposal Site, including the landfill is currently operated pursuant to EPLs 4608 and 20967. The newest landfill cell (known as B11 Stage B under EPL 4608 and depicted on Figure 1 in Appendix A) is lined with a geosynthetic clay liner (GCL), whilst the older former cells are understood to be clay lined.

3.1.1 C&D recycling operations

The existing C&D recycling operations include:

- Weighbridge
- Wheel wash and standpipe
- C&D recycling plant
- Concrete recycling – operated by Concrete Recyclers
- Plasterboard processing – operated by Regyp
- Soil recycling
- VENM sand stockpile
- Skip bin storage
- Metals recovery
- Recovered fines and aggregates stockpiles
- Aggregate drying area

Weighbridge

Access to the Proposal Site for material drop off is gained via the weighbridge. The weighbridge is elevated and this allows for both the weighing of vehicles/loads and a first material inspection point. Once loads have been inspected and weighed, they are directed to the C&D recycling plant or (for source-separated materials) to Concrete Recyclers or Regyp. Loads may also be directed to the landfill as applicable for permitted waste materials.

The weighbridge is used for external and internal materials weighing and tracking.

Wheel wash and stand pipe

The wheel wash is used for removing soil/dust from public and commercial vehicles prior to departure from Proposal Site and includes a stand pipe used by Proposal Site water cart for water transport to and use at various Proposal Site operations.

The sedimentation, infiltration, and recovered water basin serves the wheel wash and stand pipe.

C&D recycling plant

The existing C&D recycling plant processes approximately 45,000 tonnes per year of light, mixed C&D waste which is delivered to the Proposal Site in skip bins and truck by various collection contractors or by the public in small vehicles.

Incoming loads are inspected to determine the appropriate drop off locations at the plant. Waste is then dropped directly onto the concrete tip and inspect slabs where directed by staff to either the:

- Heavy waste stockpile – recycling plant feed
- Light waste stockpile
- Skip bin unload area
- Brick and concrete hand unload area
- General storage area for hand unload

Currently, the sorting process consists of:

- Preliminary sort by excavator(s) with finger claws and some sorting by Proposal Site personnel by hand
- Mechanical screening via trommels into three size fractions
- Manual sorting of the largest size fraction (picking station)
- Residual waste is shredded for additional recovery of soil, aggregate and recoverable waste. Residual waste is then baled for transport to landfill.

The smallest fraction (0-25 mm) is recovered as ‘fines’, while much of the largest fraction (>80 mm) is recovered via the manual sorting line. The mid-size fraction (25-80 mm), which comprises 30-40% of the waste stream, is currently disposed to landfill.

Outputs from the trommel (screening) process include:

- Brick and concrete
- (-) 80 mmm aggregate
- (-) 25 mm aggregate

Outputs from the manual/mechanical sorting process include:

- Timber
- Cardboard
- Metals
- Carpet
- Timber pallets
- Oversize brick and concrete

- Unexpected finds eg;
  - Green waste
  - Batteries
  - Gas bottles

Recovered concrete from the C&D recycling plant is directed to the concrete crushing operations on site. Recovered timber is sent off-site for further processing. Recovered metal (ferrous and non-ferrous) is sent off-site to Sell and Parker for recycling. The >80 mm fraction that is not recovered is currently stockpiled on site at the aggregate drying area.

Concrete recycling

Concrete Recyclers operates a concrete crushing and processing operation on the Proposal Site under contract to Breen. It receives recovered concrete that comes into the Proposal Site pre-sorted or which is recovered from the onsite C&D recycling plant or soil recycling operation.

Concrete Recyclers processes the recovered concrete and produces a variety of aggregate products (concrete and brick drainage aggregate, crushed concrete, crushed brick, crushed sandstone or blocks and bedding sand).

This area also contains a number of stockpiles, with processing undertaken based on customer orders.

Plasterboard processing

Regyp operates a plasterboard recycling operation. It receives pre-sorted plasterboard and other gypsum wastes. Regyp processes these incoming materials to produce gypsum products for return to manufacturers, as well as fertilizer and soil amendment products.

Soil recycling

The soil recycling area receives:

- soil material classified as general solid waste (non-putrescible)
- (-) 80 mm aggregate from the C&D recycling plant
- (-) 25 mm aggregate from the C&D recycling plant

The input material is processed through mechanical separation and crushing equipment to produce recovered fines and recovered aggregate.

Skip bin storage

A skip bin storage area is provided for customers to store empty skip bins.

Metals processing

A separate flow of metals processing occurs within the Proposal Site boundaries for recovery of ferrous and non-ferrous metals.

Recovered fines and aggregate stockpiles

Recovered fines and aggregate from the C&D recycling plant are stockpiled on site for future use as part of the Greenhills Parklands grading, with the remaining material for regrading to come from the future New Resource Recovery Facility.

Aggregate drying area

The existing C&D recycling operations includes an aggregate drying area. The >80 mm material from the C&D recycling plant is stockpiled here. The material (which contains MDF, timber, foam, and others) needs drying before it can be processed.

This area currently includes stockpiles of the >80 mm material and a drying shelter. The shelter comprises shipping container walls with an attached steel structure and fabric roof. The shelter is 25 m in width.

3.2 Proposal Site infrastructure

Proposal Site infrastructure currently includes:

- Parking area
- Proposal Site office
- Workshop
- Sedimentation, infiltration, and recovered water basin
- Proposal Site access/egress and internal roadways
- Weighbridge
- Wheel wash and standpipe
- Additional structures

Parking area

The existing parking area is used for both Proposal Site personnel and visitors. Additional parking exists also adjacent to the eastern side of the Proposal Site office.

The parking area surface is granular and spacing is not defined for vehicle parking.

Proposal Site office

The Proposal Site office is formed from two demountables and includes a lunch room, office, and ablutions. The Proposal Site office is serviced by a septic system.

Workshop

There are two workshops on the Proposal Site;

- One workshop consisting of three-walled covered steel structure is used for various Proposal Site maintenance activities (approximately 20 m x 15 m)
- The smaller workshop is approximately 9 x 14 m.

Sedimentation, infiltration, and recovered water basin

The two sedimentation, infiltration, and recovered water basins are used for a variety of purposes:

- The basin receives Proposal Site stormwater runoff for sedimentation and infiltration
- The basin is excavated to below groundwater level and allows for water recovery and reuse, primarily via the wheel wash/stand pipe and Proposal Site operations

Proposal Site access/egress and internal roadways

The Proposal Site access is via the weighbridge from Captain Cook Drive. The Proposal Site egress is via the wheel wash to Captain Cook Drive.

The Proposal Site includes multiple internal roadways established for traffic to and from the Proposal Site operations. Signage is erected to direct onsite traffic to/from Proposal Site operations.

Additional structures

There are additional structures located in the vicinity of the Proposal Site office, consisting of a former workshop and a small number of containers/trailers.

4. Environmental setting

4.1 Proposal Site identification

A Proposal Site locality plan is provided in Figure 1 in Appendix A. A summary of key Proposal Site location details is provided in Table 3.

Table 3 Proposal Site information summary

Item	Details
Address	330 Captain Cook Drive, Kurnell, NSW 2231
Lot/DPs	112/DP794114; 1123/DP794114; 6/DP1158627; 5/DP1158627
Proposal Site use	Existing Breen Resources Facility operated by Breen Resources Pty Ltd
Area	71 hectares (approximate)
Perimeter	4.8 km (approximate)
Land zoning	It is understood that the Proposal Site is zoned under the *State Environmental Planning Policy (Kurnell Peninsula) 1989* (NSW) as 7(b) Special Development.

4.2 Surrounding land use

The Proposal Site is located on the Kurnell Peninsula which lies partially within the Botany Bay National Park. The surrounding land use is as follows:

- North: To the north is the Towra Point Nature Reserve which is an area of environmental conservation with an area of zoned for public recreation in which is located the Greenhills Hockey Complex and Greenhills Skate Park.
- East: Directly to the east is an area of deferred matter land, which has not yet been zoned. Further to the east is an area of industrial land including Sydney Desalination Plant and the Caltex Kurnell Terminal and beyond this the Botany Bay National Park, which is an area of environmental conservation.
- South: Land to the south is zoned as environmental conservation and includes the Cronulla sand dunes, Cronulla State Park and Cronulla Beach.
- West: To the west land is predominantly undeveloped and zoned as environmental conservation land. Located within this area is the Cronulla Wastewater Treatment Plant.

4.3 Topography

The Proposal Site's topography is shown in Figure 2 in Appendix A. The Proposal Site is generally flat, with elevations of less than 4 m. Based on the 2 m contours of the Proposal Site, the area of highest elevation on site is located at the western end of the Proposal Site where the maximum elevation is 36 m relative to Australian Height Datum (AHD). An area of increased elevation is also present on the southern boundary of the Proposal Site with elevations up to 18 m AHD. To the north and south the land slopes away to 0 m AHD at Quibray Bay and Cronulla

Beach respectively. To the east the land is of similarly low elevation, predominantly less than 4 m AHD. To the west the land is of higher elevation with elevations up to 38 m AHD.

4.4 Proposal Site walkover

A GHD Technical Director attended the Proposal Site with a representative of Breen on 4 August 2020. The Proposal Site visit included a drive around active areas of the Proposal Site and inspections at various points. The following is noted:

- The Proposal Site is accessed from Captain Cook Drive. The Proposal Site offices comprise a number of demountable buildings close to the entrance in a generally unsealed area. All of the roads on Proposal Site are unsealed.
- Adjacent to the office complex to the east are two hockey playing fields and associated amenities that form part of the Embellished Marang Parklands development.
- Between the hockey pitches and the Proposal Site office complex is the Proposal Site access / exit route, which includes a wheel wash.
- Adjacent to the Proposal Site office complex to the west is a surface water pond, understood to be Infiltration Point 1.
- Further west again, the heavy and light waste and material processing area is present. Due to active operations, access was subject to safety restrictions.
- Past the material processing area, the topography slopes steeply upwards due to the present of a large stockpile of recovered fines (northern portion) and recovered aggregate (southern potion). To the south west of this stockpile is a cleared area where concrete recycling takes place.
- In the central southern portion of the Proposal Site is a cleared gypsum recycling area.
- East of the gypsum recycling area is a general solid waste and soil recycling area. The topography here slopes steeply upwards towards the east above a landfilled area known as Cell ‘B10’ pursuant to EPL 4608 and depicted on Figure 1 in Appendix A. Some landfill odour was notable at this location.
- East of Cell B10 and at a much lower elevation, a large landfill cell in construction was evident (known as B11 under EPL 4608 depicted on Figure 1 in Appendix A), with liner exposed.
- North of Cell B10 and the new cell (B11) was a long rectangular leachate pond adjacent to another access road. The leachate pond was approximately half full. Further infiltration ponds were visible to the north of the leachate pond.
- The eastern portion of the Proposal Site (the location of the proposed New Resource Recovery Facility) is largely low lying and unused. A number of surface water features were observed. It was noted that areas of standing water above the infilled former pond were lying at a slightly higher elevation than the surface water features in natural Botany Sands, indicating that infill materials likely had a lower permeability.
- No indicators or significant of widespread gross contamination were observed at the portions of the Proposal Site visited.

4.5 Geology

4.5.1 Regional geology

The Proposal Site and surrounding area is located within the Permo-Triassic Sydney Basin. The Sydney Basin is a 64,000 km^2 convergent margin foreland sedimentary basin on the central eastern coast of Australia.

The basin overlies the Lachlan Fold Belt and Late Carboniferous volcanoclastic sediments. The basin itself comprises interbedded sedimentary strata with a succession comprising lower sequence of interbedded marine-deposited strata, overlain by local Permian coal-bearing sequences, then additional marine and terrestrial strata. Within the sedimentary sequence are intrusions of Jurassic, Mesozoic and Cenozoic age volcanics. The pre-Quaternary succession is overlain by Quaternary sediments, primarily of alluvial origin.

4.5.2 Proposal Site geology

The Proposal Site is located within the region covered by the 1:100,000 Wollongong-Port Hacking Geological Map (Stroud et al. 1985). The stratigraphic units encountered in the Proposal Site are discussed below. The surface geology is depicted in Figure 3 in Appendix A.

Fill / landfill

No detailed bore records are available within the historical landfilling of the sand mining operations, however the available information indicates that the sand was excavated to depths of approximately – 23 m AHD. This indicates that filling on site is likely to extend to 25 to 26 m bgl. The base of the sand pits were understood to have been lined with clay prior to filling, and capped with up to 1 m of clay at the completion of filling. A clay cap at the top of historical filled pits has been confirmed in some locations, eg LW01, LW02, LW03, LW05 and LW06 (CES, 2020f). The material below the cap was only penetrated in LW01, and below a thin (0.1 m) layer of wood fragments, the top one metre of material encountered prior to termination was reported as sand fill with cobbles and gravel of sandstone, with no observed foreign materials. It is understood that backfilling of the sand pits primarily comprised virgin excavated natural materials (VENM). Anecdotally, potential acid sulphate soils (PASS) have also been placed below the water table in accordance with EPL 4608 (licence variation dated 24 May 2005). Breen has advised that the PASS is likely to be less than 1% of the total backfill.

Following infilling of the old sand pits, filling has been undertaken on site in accordance with EPL 4608. Based on the stratigraphy encountered in the wells installed on-site, the fill thickness varies up to at least 27.8 m and is generally comprised of a mixture of wood (timber and manufactured wood), brick, concrete, metal, plastic and ceramic fragments with trace clay, sand and gravel (CES 2020f).

Quaternary sediments

The Quaternary sediments primarily consist of unconsolidated to semi-unconsolidated permeable sands. These are interspersed with lenses and layers of peat, peaty sands, silts and clays (low permeability). These sediments are identified as medium to fine marine quartz sand and podsols (Qbd) and marine quartz sand (Qmd).

Bedrock

The alluvium, marine deposits and residual soils overlie Hawkesbury Sandstone. The Hawkesbury Sandstone is composed of medium to coarse-grained quartz sandstone, with very minor shale and laminate lenses. The Hawkesbury Sandstone outcrops at the eastern end of the Kurnell peninsula.

4.6 Soil landscape

Based on the Soil Landscapes of Sydney, collated by Lotsearch (2020; Appendix B), the Proposal Site is within the soil landscape: Podsol (Cb27). This is characterised of “coastal sand plains and dunes, lagoons and swampy areas: chief soils are leached sands. Associated are dunes of siliceous sands and/or calcareous sands fringing the coastline; and swampy areas of soils and soils with peaty surfaces.

4.6.1 Acid sulphate soils

Acid sulphate soils (ASS) are naturally occurring soils containing iron sulphides. When exposed to air, the oxidisation of the sulphides produces sulphuric acid. Acid sulphate soils commonly occur in coastal areas and wetlands, and along waterways and drainage channels.

There is the potential for ASS to be present on the Proposal Site with classifications ranging from Class 2 to Class 5 within the Proposal Site and surrounding area. Table 4 presents the acid sulphate classification of locations within the Proposal Site (Sutherland Shire LEP, 2015). An acid sulphate soil map is provided in Figure 4 in Appendix A.

Table 4 Acid sulphate soil classifications

Location	Class
Lot 1122 DP 794114	2, 3, 4 and 5
Lot 1123 DP 794114	
Lot 6 DP 1158627	3 and 5
Lot 5 DP 1158627	3 and 4

Class 2 are classified as ASS likely to be found below the natural ground surface. Any works beneath the natural ground surface or works which are likely to lower the water table, will trigger the requirement for assessment and may require management.

Class 3 are classified as ASS are likely to be found beyond 1 metre below the natural ground surface. Any works that extend beyond 1 metre below the natural ground surface, or works which are likely to lower water table beyond 1 metre below the natural ground surface, will trigger the requirement for assessment and may require management.

Class 4 are classified as ASS are likely to be found beyond 2 metres below the natural ground surface. Any works that extend beyond 2 metres below the natural ground surface, or works which are likely to lower water table beyond 2 metres below the natural ground surface, will trigger the requirement for assessment and may require management.

Class 5 are classified as unlikely to find ASS. However, they are adjacent to Class 1, 2, 3 and 4 land and therefore consideration is needed if lowering of the water table will affect the neighbouring areas.

4.7 Hydrogeology

Review of available data collated by Lotsearch (2020), presented in Appendix B, identified two registered extractive bores on site and 13 registered groundwater wells used for domestic, recreational, irrigation, industrial or experiment purposes within a one kilometre radius of the Proposal Site. The majority of the wells are shallow (<20 metres in depth) and expected to be screened within the Botany Sands. A summary of these wells is provided in Table 5. Figure 5 in Appendix A shows registered groundwater bores within 1 km of the Proposal Site, as well as the Proposal Site’s groundwater monitoring well network.

Table 5 Summary of nearby groundwater bores within 500 m

ID	Purpose	Distance from Proposal Site	Drilled depth (mbgl)	Screened lithology	SWL (bgl)	Salinity (mg/L)	Yield (L/s)
GW104134	Industrial	On-site	15.20	Sand and clay	-	4.90	-
GW110548	Industrial	On-site	2.00	-	-	-	-
GW107432	Domestic	75 m east	4.00	Sand	2.00	good[2]	0.5
GW109177	Industrial	89 m east	3.00	-	-	-	-
GW102032	Experimental/research	103 m south west	7.5	Sand and marine clay	1.04	-	2.5
GW071908	Irrigation	281 m south east	29.3	-	3.4	500	8.8
GW107820	Recreation	290 m south west	-	-	-	-	-
GW109383	Industrial	324 m east	7	Sand	-	-	-
GW109178	Industrial – sand & gravel	335 m South east	3	-	-	-	-
GW107771	Stock	336 m east	5	-	-	-	20
GW071694	Irrigation	458 m east	15.00	-	0-500	-	-
GW108847	Industrial – sand & gravel	482 m south west	3.00	-	-	-	-

A number of surface water features surround the Proposal Site including Towra Point Nature reserve, Quibray Bay, Weeney Bay and Botany Bay to the north of the Proposal Site; Georges River and Woolooware Bay to the west; and Bate Bay to the south. Figure 6 in Appendix A shows the locations of these surface water features.

[2] This terminology has been transcribed from the driller's log

4.8 Climate

Based on the Bureau of Meteorology (BOM) Australian Climate Classification Map, the climate of the region is temperate with no dry season and a warm summer (BOM, 2001). The nearest BOM station that records monthly climate statistics is 066037 at Sydney Airport. The mean annual maximum temperature is 22.4 ºC and the mean annual minimum temperature is 13.5 ºC, as recorded over the period 1939 to 2020. Mean annual rainfall for the period 1929 to 2020 is 1077.4 mm, with an average of 95.6 days of rain per year.

4.9 Regulatory information

4.9.1 Overview

GHD obtained a Lotsearch report for the Proposal Site on 22 May 2020 which is presented in Appendix B. The Lotsearch report brings together searches of databases with information pertinent to the contamination status of the Proposal Site. These databases include databases of regulatory information relating to the Proposal Site. GHD reviewed the information in the report which is summarised in the following sections.

4.9.2 EPA records

Under provisions of the NSW *CLM Act* (Section 58, Subsection 2 'CLM' Act) a public register of current NSW declarations and orders in force is maintained by the EPA. Under the NSW *POEO Act*, a register of current and surrendered licences is also maintained by the EPA. A search of these datasets was provided in the Lotsearch report (Appendix B) and reviewed by GHD.

Contaminated sites register and records of notice

The Contaminated Land Record of Notices under the CLM Act, is a public record of contaminated land which displays:

- Orders made under Part 3 of the CLM Act;
- Approved voluntary management proposals under the CLM Act that have not been fully carried out and where the approval of the EPA has not been revoked;
- Site audit statements provided to the EPA under Section 53B of the CLM Act that relate to significantly contaminated land;
- Where practicable, copies of anything formerly required to be part of the public record; and
- Actions taken by the EPA under Section 35 or 36 of the Environmentally Hazardous Chemicals Act 1985 (EHC Act).

Two sites were identified on the list of contaminated sites notified to the EPA within 1 km of the Proposal Site. They are shown in Figure 7 in Appendix A. Both sites have activity listed as chemical industry. The former Phillips Imperial Chemicals site is located 620 m to the east and regulation under CLM Act not required and Abbott Australasia is located 976 m to the east of the Proposal Site and is listed as having contamination that was formerly regulated under the CLM Act.

Neither of the above sites are considered to be located up hydraulic gradient of the Proposal Site, and are therefore not considered to be off-site sources that warrant further consideration.

POEO license register

The POEO license register identifies premises that are licensed for certain activities under the POEO Act. Information of particular relevance to this assessment which is listed on the register

includes site location, activity type, relevant clean up notices, non-compliance information and load-based licensing data.

Each licence provides information on potential point and non-point sources of soil and groundwater contamination that may be generated on-site through standard operations, accidental spills and leaks.

A search returned eight active EPA Authorisations (covered by five EPLs) within one kilometre of the Proposal Site. A review of these is provided in Table 6.

Table 6 Summary of current EPA licensed activities

EPL	Organisation/Name	Activity	Status	Distance from Proposal Site
4608	Breen Resources Pty Ltd/Kurnell Land Fill Company	Recovery of general waste	Issued	On-site
4608	Breen Resources Pty Ltd/Kurnell Land Fill Company	Waste disposal by application to land	Issued	On-site
20697	Breen Resources Pty Ltd	Recovery of general waste; Waste storage – other types of waste	Issued	On-site
20697	Breen Resources Pty Ltd	Recovery of general waste; Waste storage – other types of waste	Issued	On-site
1728	Sydney Water Corporation/Cronulla Sewage Treatment System	Sewage treatment processing by large plants	Issued	19 m west
3629	All Sands Pty Ltd/Rocla Pty Ltd	Crushing, grinding or separating	Issued	20 m east
3629	All Sands Pty Ltd/Rocla Pty Ltd	Other land-based extraction	Issued	20 m east
5658	Besmaw Pty Ltd/Besmaw Pty Ltd trading as Holt Land Rehabilitation Centre	Other activities	Issued	20 m east

4.9.3 Waste management and liquid fuel facilities

National Waste Management Site Database

GHD reviewed the search of the register undertaken by Lotsearch on 22 May 2020. The search identified an operational landfill operating as Kurnell Landfill Company near the Proposal Site. It is understood that Breen previously conducted landfilling operations under that name, and the register may not be up to date. The search did not show any other premises within a one kilometre radius of the Proposal Site.

National Liquid Fuel Facilities

GHD reviewed the search of the register undertaken by Lotsearch on 22 May 2020. The search identified no premises on the register within a one kilometre radius of the Proposal Site.

4.9.4 Per- and polyfluoroalkyl substances (PFAS) investigation and management programs

EPA PFAS Investigation Program

GHD reviewed the search of the register undertaken by Lotsearch on 22 May 2020. The search identified that the Proposal Site is within the Botany Bay and Georges River area, which are part of the NSW EPA PFAS investigation program.

Defence PFAS Investigation Program

GHD reviewed the search of the register undertaken by Lotsearch on 22 May 2020. The search did not show any premises within a one kilometre radius of the Proposal Site.

Defence PFAS Management Program

GHD reviewed the search of the register undertaken by Lotsearch on 22 May 2020. The search did not show any premises within a one kilometre radius of the Proposal Site.

Air services Australia National PFAS Management Program

GHD reviewed the search of the register undertaken by Lotsearch on 22 May 2020. The search did not show any premises within a one kilometre radius of the Proposal Site

5. Proposal Site history

5.1 General

The Kurnell peninsula has been subject to extensive sand mining historically, with estimates in excess of over 170 million tonnes of sand extracted since the 1930s (https://www.ssec.org.au/our_environment/our_bioregion/kurnell/issues/sandmining.htm). The Proposal Site has been used for sand extraction since the 1960s. Sand extraction activities produced dredge ponds surrounded by a relatively flat area. The Proposal Site was delimited to the north, south and west by areas elevated up to approximately 30 m relative to Australian Height Datum (AHD), based on CES (2020f).

Breen began landfilling activities in 1990. Landfill clay liners were installed at the bottom of excavations in Lot 1122, and Lot 1123 DP794114, and Lot 6 DP1158627 (CES, 2020f). Construction details of the liners are not available. Based on the limited information available, liners were most likely installed at depths between 18 and 20 m below the 2017 level of waste (CES, 2020f). Excavations produced by sand extraction activities are understood to have been filled with virgin excavated natural materials and potential acid sulphate soils (below the water table) in accordance with EPL 4608.

5.2 Aerial photography

A selection of aerial photographs was examined in order to ascertain past activities and land uses at the Proposal Site and on the surrounding land. Photographs from 1956, 1961, 1965, 1970, 1978, 1984, 1990, 1994, 2000, 2007, 2014 and 2019 were examined. They are presented in the Lotsearch report in Appendix B.

A review of the aerial photography is summarised in Table 7.

Table 7 Review of aerial photographs

Year	Features
1956 (black & white)	Proposal Site and surrounds are undeveloped with a road along the north of the Proposal Site in the current location of Captain Cook Drive.
1961 (black & white)	Mostly unchanged from 1956, two access tracks cut across the Proposal Site location from north to south, and an access track is visible to the south of the Proposal Site. Possible evidence of sand extraction at east of Proposal Site.
1965 (black & white)	As 1961 with additional evidence of sand extraction in the eastern portion of the Proposal Site.
1970 (black & white)	Much of the Proposal Site and surrounds remains undeveloped. Additional tracks are present across the Proposal Site, with a surface water feature in the western half of the Proposal Site and expanded sand extraction in the east. Development had commenced to the west of the Proposal Site in the location of the current Cronulla Wastewater Treatment Plant.
1978 (black & white)	The area appears similar to 1974, with the expansion of the surface water features in the western portion of the Proposal Site, and an additional surface water feature to the south-west of the Proposal Site.
1984	Generally unchanged from 1978

Year	Features
(colour)	
1990 (colour)	Similar to 1984, with reconfiguration of the surface water feature in the western portion of the Proposal Site and expansion of the on-Proposal Site works.
1994. (colour)	Generally unchanged from 1990
2000 (colour)	Proposal Site configuration has changed from 1994 with the infilling of the surface water feature in the western portion and a new surface water feature in the eastern portion of the Proposal Site. Beyond the Proposal Site to the east the area is no longer unaltered with surface water features present. Further development has occurred in the location of the current Cronulla Wastewater Treatment Plant, which is now similar in configuration to the present.
2007 (colour)	The on-site configuration is similar to 2000 and development has started to the south-west of the Proposal Site.
2014 (colour)	The on-site configuration is similar to 2000 and 2007. The development to the south-west of the Proposal Site has expanded and the surface water to the east of the Proposal Site has reduced in area.
2019 (colour)	The Proposal Site appears to be in same configuration as present. In comparison to 2014, the Proposal Site is similar in configuration with the addition of the Greenhills Hockey Complex in the north/centre of the Proposal Site and a sports field to the north east.

5.3 Previous investigations

A summary of previous, relevant groundwater, leachate, soil (i.e. recovered material produced at the Proposal Site) and landfill gas monitoring reports and data made available to GHD is provided below. Locations of main sampling points are shown in Figure 8 in Appendix A.

Based on information provided to GHD, the groundwater monitoring well network on-site was first developed by URS. Wells BH1 to BH7 were installed in 1992, BH8 to BH9 in 1993, BH10 to BH13 in 1994 and BH14 and BH15 in 1996. Replacement wells BH8A and BH9A were installed in 1996, and BH4A and BH7A in 1998, to replace BH8 and BH9, and BH4 and BH7 respectively. Wells BH3A, BH5A, BH12A and BH13A replaced BH3, BH5, BH12 and BH13 in 2000, when a new well, BH17 was also installed. Replacement wells BH6A and BH10A were installed in 2001 to replace BH6 and BH10. New bores BH7B and BH8B were installed next to BH7 and BH8. BH19A was understood to have been replaced by BH19B in March 2019 as per EPL 4608, although it is noted that BH19A was still sampled in 2020.

Between 2011 and 2020, Consulting Earth Scientists (CES) installed the following wells:

- Leachate monitoring well LB02 to replace well LB01, which was no longer serviceable (CES 2011, *Installation report for leachate monitoring well LB02, Kurnell Landfill Facility: Captain Cook Drive, Kurnell NSW* (dated 7 April 2011)). It is noted that LB02 was installed to a depth of approximately 20 mbgl.

- Groundwater monitoring wells BH10A, BH14 and BH19 were replaced by new wells, which retained the same names (CES 2014, *Kurnell Landfill, Captain Cook Drive, Kurnell, NSW - Groundwater Monitoring Well Replacement Report* (dated 18 August 2014)).
- Groundwater monitoring well BH25 to the west of BH12A (CES 2020a, *Groundwater Monitoring Well Installation – Kurnell Landfill, Captain Cook Drive, Kurnell, NSW*).
- In 2017, CES installed six leachate monitoring bores (LW01 to LW06).

During well installation, the following lithology was observed:

- At location LB02, the general stratigraphic sequence was described as “compacted clay line(r) overlying waste layers comprising sandy clay with a significant proportion of waste inclusions, consisting of decomposed wood, aluminium and steel”. The recorded leachate level post installation was 19.17 mbgl..
- At BH10A, BH14 and BH19, fill comprising clayey sand and clay to a depth between 2.5 m bgl and 5.8 m bgl, followed by medium grained sand to a maximum investigation depth of 6.8 m bgl.
- At BH25, fine to medium sand from the surface to the well installation depth of 15 m bgl.
- At LW01 to LW06, the general sequence was described as sand or clay cover material, overlying waste up to 27.8 m thick. This was in turn underlain by clay /sandy clay cap in some locations up to 0.9 m thick.

Resource recovery orders have been applied on site to produce certified recovered aggregate and recovered fines (continuous) as described in Section 2.2.2. A weekly sampling regime has been implemented to characterise and verify the recovered materials. Based on CES (2020b) and CES (2020c), laboratory results indicated that materials met all requirements set out by relevant orders. Analytical data provided to GHD are summarised in Appendix G.

5.3.1 Assessment reports

One assessment report was available to GHD for review: URS 2004, *Ecotoxicological Assessment of Groundwater Quality*, Kurnell Landfill, 2004 Sampling Program.

The objective of the investigation was to assess ecotoxicity of groundwater at the Proposal Site and to evaluate risks posed by contaminants, particularly arsenic, ammonia and total petroleum hydrocarbons. The scope of work comprised sampling of groundwater from four wells (BH8A, BH9A, BH11 and BH13A), chemical analyses and ecotoxicological testing.

Of the four groundwater samples tested, the highest concentrations of arsenic and ammonia were in groundwater from BH9A (1.7 mg/L and 13.3 mg/L respectively). Nitrate concentrations were highest (1.22 mg/L) in well BH13A.

Findings indicated that groundwater within the landfilled area had the potential to pose adverse ecotoxicological risks to algal growth and to waterflea life cycle. However, groundwater collected from a sampling point closer to the Proposal Site boundary towards Quibray Bay (BH13A) did not show ecotoxicological risks.

Groundwater migrating off the Proposal Site was expected to present lower contaminant concentrations compared to on-site groundwater. A decrease in concentrations would be the result of dispersion, dilution and/or degradation processes. Based on data recorded along the Proposal Site’s boundary, groundwater was concluded to be unlikely to pose a risk to neighbouring aquatic ecosystems. In addition, risks to surrounding open surface waters, such as Botany Bay and Towra Point Nature Reserve, would be reduced by dilution with estuarine water.

5.3.2 Monitoring reports

Groundwater monitoring

Groundwater monitoring has been undertaken on a quarterly and yearly basis on between 21 and 26 monitoring wells, 22 of which are prescribed by EPL 4608. In addition, eight leachate wells have been historically monitored at irregular intervals. The quarterly analytical suite was limited to pH, electrical conductivity, total dissolved solids, major anion and ions, nutrients and arsenic. The annual analytical suite, in addition to the analytes above, contains heavy metals (Al, Ba, Cd, Cr, Co, Co, Fe, Pb, Mn, Mg, Hg, Zn), phenolic compounds, organochlorine and organophosphate pesticides (OCP/OPP), polycyclic aromatic hydrocarbons (PAH), total recoverable hydrocarbons (TRH), benzene, toluene, ethylbenzene and xylene (BTEX) volatile organic compounds.

GHD has reviewed available reports and provided a brief summary of objectives, scope and results in Table 8.

Table 8 Summary of groundwater monitoring reports

Report name	Objectives and main findings
URS 2007, *Groundwater Monitoring Program, Quarterly Report January 2007* and URS 2007, *Groundwater Monitoring Program, Annual Report January 2007*	Objective: to assess groundwater, surface water and leachate at the Proposal Site. Scope: gauging and sampling of 21 groundwater monitoring wells and one leachate well using bailers; and sampling of four surface water bodies (the concrete recycling pond (CRP), historic western wheel wash pond (HWWWP), wheel wash pond (WWP) and the pond in Lot 1124). Analysis for water pH, electrical conductivity, total dissolved solids, major anion and ions, nutrients and arsenic. Main findings: • Groundwater flow direction was inferred to the north-east. • Arsenic concentrations above the adopted trigger values were detected in 11 groundwater monitoring wells. Mild arsenic contamination was present down gradient of the southern landfill area most notably near well BH10A (0.113 mg/L). No increasing concentration trends were noted. • In groundwater, copper concentrations exceeded the adopted trigger value in one well (BH4A – 0.002 mg/L), and zinc in six wells (up to 0.043 mg/L in BH20). The remaining analytes were not detected or showed concentrations lower than the adopted assessment criteria. • Ammonia was detected in groundwater downgradient of the southern landfill area (up to 7.69 mg/L at BH10A). • In leachate monitoring well LB01, ammonia (60.4 mg/L), cobalt (0.005 mg/L) and copper (0.002 mg/L) concentrations exceeded the adopted trigger values.

	The remaining analytes were not detected or showed concentrations lower than the adopted assessment criteria. • In surface water, analyte concentrations fluctuated within the normal range for the Proposal Site.
URS 2007, *Groundwater Monitoring Program, Quarterly Report April 2007* (Draft)	Objective: to assess groundwater, surface water and leachate at the Proposal Site. Scope: gauging and sampling of 21 groundwater monitoring wells and one leachate well using bailers; and sampling of three surface water bodies. Analysis for water pH, electrical conductivity, total dissolved solids, major anion and ions, nutrients and arsenic. Main findings: • Groundwater flow direction was to the north-east. • Mild arsenic concentrations above the adopted trigger values was detected in 12 groundwater monitoring wells. Arsenic contamination was present down gradient of the southern landfill area with a maximum of 0.118 mg/L in BH9B. No increasing concentration trends were noted. • Ammonia was detected in groundwater at minor concentrations in the southern landfill area, up to 11.9 mg/L in BH9B. Potential increasing trends in ammonia concentrations were detected in groundwater monitoring wells BH5A and BH10A. • In surface water, analyte concentrations fluctuated within the normal range for the Proposal Site.
CES 2018, *Groundwater assessment report, Breen Landfill and waste management facility, 330 Captain Cook Drive, Kurnell, NSW 2231* (dated 21 November 2018)	Objective: to provide a groundwater assessment statement in relation to the proposed works at the Existing Breen Resources Facility. Works comprised: increase in landfill volume on Lots 5 and 6 of DP 1158627; relocation of existing waste management infrastructure; and installation of environmental mitigation structures to reduce environmental impacts related to waste management activity. Scope: monitoring of 22 groundwater monitoring wells and one leachate well (LB02), on a quarterly and yearly basis in accordance with EPL 4608. Samples were analysed for pH, electrical conductivity, dissolved oxygen, redox, dissolved and suspended solids, metals, cations, anions, nutrients, OCP/OPP, PAH, TRH, BTEX and volatile compounds. In line with the Proposal Site EPL the scope of the monitoring reports did not require comparison of results to assessment criteria, but rather a qualitative trend analysis for key parameters. Main findings: no discernible temporal trend in ammonia concentrations between 2009 and 2018 were identified. Proposed works at the Proposal Site were considered unlikely to produce adverse groundwater impacts. The ongoing quarterly

	and annual groundwater monitoring in accordance with the EPL was considered adequate to meet Development Application (DA) requirements. Historical groundwater results, collected between 2009 and 2018, should be used as a baseline to assess potential groundwater impacts associated with the proposed works.
CES 2019, *Quarterly water environmental monitoring report for Kurnell Landfill Facility: October 2019*	Objectives: to monitor groundwater and leachate quality. Scope: monitoring of 22 groundwater monitoring wells and one leachate well; measuring of field parameters and analysis of samples for the analytical suit prescribed in EPL No. 4608. In line with the Proposal Site EPL the scope of the monitoring reports did not require comparison of results to assessment criteria, but rather a qualitative trend analysis for key parameters. Main findings: Results were considered consistent with previous monitoring round. It is noted that the scope of the monitoring reports did not require comparison of results to assessment criteria as per the EPL. The highest ammonia concentrations were detected in leachate well LB02 (160 mg/L) located in the landfilled area, and groundwater monitoring wells BH5A (23 mg/L) and BH9C (17 mg/L) located in the northern/north-western and central portions of the Proposal Site, respectively. Several wells installed along the Proposal Site perimeter showed ammonia concentrations above a 95% species protection ecological criterion (0.9 mg/L), and were generally lower than 5.6 mg/L.
CES 2020e, *Quarterly water environmental monitoring report for Kurnell Landfill Facility: January 2020*	Objectives: to monitor groundwater and leachate quality. Scope: monitoring of 23 groundwater monitoring wells and one leachate well; measuring of field parameters and analysis of samples for the analytical suit prescribed in EPL 4608. In line with the Proposal Site EPL the scope of the monitoring reports did not require comparison of results to assessment criteria, but rather a qualitative trend analysis for key parameters. Main findings: An increase in ammonia concentrations from 1.7 mg/L in October 2019 to 13 mg/L in January 2020 was reported. Overall, it was considered that results and trends were consistent with the October 2019 monitoring round. It is noted that the scope of the monitoring reports did not require comparison of results to assessment criteria as per the EPL. The highest ammonia concentrations were detected in leachate well LB02 (300 mg/L) located in the landfilled area, and groundwater monitoring wells BH5A (19 mg/L) located in the northern/north-western portions of the Proposal Site. Several wells installed along the Proposal Site perimeter showed ammonia concentrations above a 95% species protection ecological criterion (0.9 mg/L), and were generally lower than 13 mg/L.

CES 2020f, *Breen Resource Recovery Facility - Leachate Management Strategy for Landfilled Areas,* 15 October 2020.	Objectives: to provide an overview of leachate management systems. It is noted that this report also includes results from a 2016/2017 leachate study as appendices. Based on the data contained within the report, petroleum hydrocarbons were detected in leachate up to 21.5 mg/L (C_6-C_{36}). Volatile petroleum fractions (<C_{10}) and BTEX compounds were generally not detected apart from 24 ug/L benzene in LW05 (December 2016) and 100 ug/L TRH C_6-C_{10} in LW06 (December 2016). PAH compounds were generally not detected apart from naphthalene (LW05 and LW06 up to 8 ug/L) and were below adopted criteria. Heavy metals exceeded adopted criteria at one or more locations for arsenic (up to 32 ug/L; LW06), chromium (up to 98 ug/L; LW06), and nickel (up to 30 ug/L; LW06). Ammonia was present in all leachate bores up to 830 mg/L in LW06.

Gas monitoring

Gas (methane) monitoring is currently carried out at five bores, BH4A, BH8B, BH12A, BH13A and BH18 to satisfy Proposal Site's EPL (No 4608) requirements. Eleven documents containing monitoring data collected between 2007 and 2020, were provided to GHD at the following link http://www.consultingearth.com.au/results/breen-resources. Data are reported in Appendix G and discussed in Section 9.3 of this report. Table 9 summarises the available landfill gas reports (as opposed to raw data).

Table 9 Summary of landfill gas monitoring reports

Report name	Objectives, scope and main findings
URS 2007, *Landfill Gas Monitoring Program, Quarterly Report January 2007* dated April 2007	Objective: to assess surface, sub-surface and infiltration landfill gases concentrations at the Proposal Site. Scope: monitoring of 17 ground gas bores, assessment of surface gas at Lot 1123 and Lot 1122, and monitoring of gas accumulation in four buildings. Methane concentrations were reported as percentage (%) relative to LEL. Main findings: • During surface gas monitoring, methane concentrations were lower than the adopted assessment criterion of 1% v/v for methane. • Sub-surface gas monitoring undertaken at 17 locations showed low methane concentrations and higher levels of oxygen and carbon dioxide. Elevated methane concentrations, up to 608 % LEL (or approximately 30 % v/v), were detected in bores BH9B and BH11; however, these bores are located within the landfill area. Infiltration and accumulation of landfill gasses within the Proposal Site's buildings were not detected.

URS 2007, *Landfill Gas Monitoring Program, Quarterly Report April 2007* dated June 2007	Objective: to assess surface, sub-surface and infiltration landfill gases (i.e. methane, carbon dioxide and oxygen) concentrations at the Proposal Site. Scope: monitoring of 17 ground gas bores, assessment of surface gas in Lot 1123 and Lot 1122, and monitoring of gas accumulation in four buildings. Main findings: • During surface gas monitoring, methane concentrations were lower than the current assessment criterion of 1% v/v for methane. • Sub-surface gas monitoring undertaken at 17 locations showed low methane concentrations and higher levels of oxygen and carbon dioxide. Elevated methane concentrations, up to 546 % lower explosive level (LEL) (or 27.3% v/v), were detected in bores BH9B and BH-11; however, these bores are located within the landfill area. • Infiltration and accumulation of landfill gases within the Proposal Site's buildings were not detected.
CES 2020d, *Quarterly landfill gas monitoring report, Kurnell landfill facility: January 2020, Captain Cook Drive, Kurnell NSW*	Objectives: to assess the concentration of landfill gases in nominated monitoring wells around the perimeter of the Proposal Site and buildings situated on site. Scope: monitoring of five subsurface ground gas (only methane) sampling locations and monitoring of gas accumulation in five buildings. Main findings: • Methane concentrations in sub-surface gas and within buildings were lower than the methane assessment criterion of 1% v/v. • Carbon monoxide, carbon dioxide and hydrogen sulphide in the sub-surface posed low to negligible risks. • Results indicated that risks related to gas accumulation in buildings were low to very low.
CES 2020f, *Breen Resource Recovery Facility - Leachate Management Strategy for Landfilled Areas,* 15 October 2020.	Objectives: to provide an overview of leachate management systems. It is noted that this report also includes results from a 2016/2017 leachate study as appendices. Based on the available results, GHD noted that methane (up to 63.6% v/v) and carbon dioxide (up to 34.7% v/v) concentrations in exceedance of the NSW EPA (2016) Environmental Guidelines – Solid Waste Landfills criteria of 1% v/v for methane and 1.5% v/v for carbon dioxide, were detected in six leachate observation wells (LW01 to LW06) sampled in December 2016 and January 2017. Sampling locations were within the landfilled area.

5.3.3 Asbestos testing

Data was provided to GHD by Breen for random asbestos testing carried out for incoming loads. It is noted that this testing is not required by the Proposal Site EPLs. Twenty-eight soil and aggregate samples collected between March and July 2020 were tested for asbestos presence/absence. Asbestos was not identified in any sample. All samples contained organic fibres. Information regarding sample origin, such as location and depth, was not provided to GHD.

A list of the relevant laboratory certificate of analyses, produced by Envirolab Services Pty Ltd (Envirolab), is provided in Section 13 (References) under Envirolab 2020. These reports can be provided on request.

5.3.4 Other information

Digital data

Available soil (i.e. recovered material produced at the Proposal Site under resource recovery orders described in Section 2.2.2), surface water, groundwater, leachate and soil gas results have been collated from previous reports and excel tables provided to GHD and are presented in Appendix G. They are discussed in Section 9.

Correspondence

In 2018 NSW EPA sent a letter to Breen (Annual Return Monitoring Data & Inspection Follow-up, ref DOC18/846710 dated 19 November 2018. The following was noted:

- Ammonia concentrations were well above ANZECC[3] guidelines which set an ammonia trigger value of 0.9 mg/L[4]; BH5A with an average of 11.725 mg/L and BH9C with an average of 40 mg/L.
- Elevated ammonia levels were expressed to be of concern as they show that the integrity of the landfill liner may be in question and that the landfill may be discharging leachate. The discharge may be affecting the groundwater quality in the nearby vicinity.
- NSW EPA required that Breen engage a suitably qualified expert to review the water quality data from the boreholes and determine if any follow up action is required as a result of the findings.

Breen subsequently engaged CES to prepare a response which was documented in Re: Response to EPA Correspondence – Annual Return Monitoring Data & Inspection Follow-up dated 21 December 2018 (CES 2018b). The following are key points from the response:

- CES stated that an appropriate guideline value for ammonia based on a receiving marine environment pH of 8 should be 3.91 mg/L in accordance with ANZG (2018). It was further noted that the default ammonia guideline value was classified as a moderate reliability guideline and therefore could be over-conservative.
- Leachate at the Proposal Site was characterise by ammonia concentrations well in excess of 3.91 mg/L, up to 830 mg/L with a mean of 358 mg/L.
- Leachate was also characterised by elevated concentrations of bicarbonate alkalinity, total recoverable hydrocarbons (TRH), potassium, total dissolved solids (TDS) and total organic carbon (TOC). These were adopted by CES as “leachate marker chemicals”.

[3] Now superseded by ANZG 2018
[4] It is noted that this is the trigger level for 95% species protection for both freshwater and marine environments

- Ammonia concentrations in BH5A and BH9C were not considered to exhibit a “constant definable trend” with considerable fluctuations in concentrations, and were typically an order of magnitude less then leachate concentrations.
- Leachate marker chemicals in BH5A, BH9C and surrounding bores were typically not detected (TRH, although some detections marginally above the practical quantitation limit (PQL) did occur), were consistent and within expected ranges for groundwater (bicarbonate alkalinity; except for two isolated spikes at BH9C in 2014 and 2015 and potassium, except for an isolated spike between April and October 2017 at BH9C) and demonstrated considerable variability with no discernible trends (TDS). TOC was determined to have “remained consistent” with the exception of elevated concentrations in BH9C between October 2014 and October 2016 and an isolated spike in BH3A (considered anomalous).
- CES did not consider there was a definitive connection between leachate marker chemicals and elevated concentrations of ammonia in BH5A and BH9C, nor did they identify elevated ammonia concentrations in nearby wells BH3A, BH4A, BH12A, BH13A and BH17.
- CES identified that elevated ammonia concentrations could be from local sources such as mangroves, Proposal Site compound (workshop, weighbridge, wheelwash and amenities block), Captain Cook Drive or off-site sources.

6. Fieldwork program

6.1 Overview

To supplement existing data at the Proposal Site and to address SEARs requirements, GHD carried out the following:

- A Proposal Site walkover with Breen staff
- Gauging of accessible groundwater monitoring wells
- Hydraulic conductivity testing in selected wells
- Sampling of surface water features at five on-site and three off-site locations.
- Sampling of sediment pore water at five off-site locations to the north of the Proposal Site (Towra Point Nature Reserve).

6.2 Methodology

Investigation methodologies utilised in the works are consistent with all relevant GHD, NSW EPA and Australian Standard guidance, and are presented in detail in Appendix C. Groundwater gauging and hydraulic testing methodologies are also included in Appendix C.

6.3 Data quality objectives

Data quality objectives (DQOs) provide a framework for the investigation and are presented in Appendix D.

6.4 Fieldworks

A summary of the field works is provided in Table 10.

Table 10 Summary of fieldworks

Item	Description
Date of Proposal Site walkover	4 August 2020
Scope of surface water and pore water sampling	Collection of five on-site surface water samples (SW1 to SW5) plus three off-site samples (SW6, SW7 and SW8) with measurement of field parameters (pH, electrical conductivity, redox potential, total dissolved solids and dissolved oxygen). In addition, five pore water samples were collected from the shoreline of Towra Point Nature Reserve. Sampling locations are shown in Figure 9 in Appendix A.
Date of surface water sampling and groundwater gauging	3 August 2020 groundwater gauging. 11 June 2020 for on-site surface water samples SW1 to SW5 26 August 2020 for off-site surface water sample SW6 11 September 2020 for off-site surface water samples SW7 and SW8; and sediment pore water samples PW01 to PW04 and PW07.
Number of primary surface water samples collected and description of sampling locations	8 – Identified as SW1 to SW8: SW1 – infiltration pond located in the north-eastern portion of the Proposal Site (referred to as Infiltration Point 3 in the groundwater impact assessment (GHD, 2021)). Sample was collected from the north-eastern corner of the pond. This infiltration point is serviced by a drain running along the northern Proposal Site boundary from immediately west of the leachate ponds. This drain may or

Item	Description
	may not be in direct connection with the Botany Sands Aquifer. The pond is expected to receive surface water run-off from northern areas of the Proposal Site that are located to the east of new waste Cell B11. During a Proposal Site visit on 4 August 2020 perched surface water was observed to be present in a number locations in this area of the Proposal Site. Ponding around the infiltration pond itself was observed to be much higher than in the infiltration pond itself indicating that the landfill material in this location was of distinctly lower permeability than the Botany Sands that were intersected by the infiltration pond. SW2 – located near the eastern boundary. Sample collected from the eastern bank. The pond appears to be formed by parched water potentially connected to the pond where SW3 was collected. SW3 – Infiltration pond located near the eastern boundary (referred to as Infiltration Point 4 in the groundwater impact assessment (GHD, 2021)). Sample collected from the northern end of the pond. This infiltration pond is a drainage line that is approximately 400 m long and extends along Lindum Road before extending west, along the southern Proposal Site boundary to landfill Cell B11. This infiltration point is connected via a culvert to a large ponded area (associated with a low topography) located in the southern portion of the Proposal Site and east of Cell B11. Due to the depth of the culvert draining the pond the water levels in this area and the infiltration pond were observed to be similar during the Proposal Site visit on 4 August 2020. SW4 – leachate ponds. The sample was collected from the northern bank. The ponds are lined with an impermeable membrane and are not hydraulically connected with the underlying groundwater system. The ponds receive leachate from a leachate collection system associated with landfill cell B10. They are designed to be evaporation ponds and have no discharge off site. SW5 – infiltration pond located in the northern portion of the Proposal Site (referred to as Infiltration Point 2 in the groundwater impact assessment (GHD, 2021)). Sample collected from the eastern bank. This pond is serviced by a drain running along the south eastern boundary of the hockey complex. During the Proposal Site visit it was reported by Proposal Site personnel that this pond received run-off from the landfill mound (Cell B10) and soil recycling area to the west of Cell B10. SW6 – Off-site freshwater pond to the south-west of the Proposal Site (Lot 1056). Based on visual observations from the Proposal Site on 4 August 2020, the pond appeared to be clear with vegetation in apparently good condition. There was a relatively steep fall down to the lakes from the Proposal Site boundary. SW7 and SW8 – off-site within Towra Point Nature Reserve (Weeney Bay). This is a marine ecosystem. Pore water samples PW01, PW02, PW03, PW04 and PW07
Number of primary pore water samples collected and description of sampling locations	Five – identified as PW01 to PW04 and PW07. Sampling locations are shown in Figure 9 in Appendix A. All pore water samples were collected from mangrove swamp areas near the high tide mark, to a depth of about 300 mm..
Primary surface water and pore water analysis selected	TRH, BTEX, PAH, OCP, polychlorinated biphenyls (PCBs); phenols, 12 heavy metals and alkali metals; and nutrients. TRH silica clean-up was performed on samples PW02, PW03 and PW04 to investigate the nature of TRH in pore water.

Item	Description
Duplicate surface water and pore water samples analysed	Two surface water duplicates were collected - FD01 collected at sampling location SW1; and QC04 collected from sampling location SW8. One pore water duplicate – QC02 collected from sampling location PW04. Samples were analysed for the same analytical suite as for primary samples.
Groundwater gauging	The monitoring wells were gauged using an oil/water interface probe to measure static water levels (SWL) and assess for the potential presence of non-aqueous phase liquid (NAPL).The locations of monitored groundwater monitoring wells are shown in Figure 8 in Appendix A. Equipment calibration certificates are provided in Appendix E.
Groundwater gauging notes	Strong leachate odours were noted in well LW02. Moderate to slight leachate odours were noted in wells BH11A, BH9C, LW03, LW04, LB02 and LW05. No odours were recorded in the remaining wells. Orange staining was observed in wells LW05, BH9C and LW3. A grey-brown sediment was noted in well BH6A.
Sample handling and transport	Surface water samples were immediately placed on ice and stored in an esky prior to being forwarded to the analytical laboratories along with a chain of custody (CoC) form.
Laboratory details	The primary laboratory was Eurofins A secondary laboratory was used only for pore water samples. The selected laboratory was ALS. Laboratory results are summarised in Appendix F and certificates of analysis and COC forms are included in Appendix H.
Quality assurance and quality control (QA/QC)	A Proposal Site based QA/QC sampling procedure was implemented and further details are described in Appendix I.

7. Basis for assessment

7.1 Regulatory framework

The following guidelines were referenced for the Proposal Site assessment.

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG) (2018). Australian and New Zealand Governments and Australian State and Territory Governments, Canberra ACT, Australia.
- National Environment Protection Council (NEPC) (2013) *The National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM).
- CRC CARE (2011) *Health Screening Levels for petroleum hydrocarbons in soil and groundwater.* Technical report series No. 10. Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE). Friebel, E. and Nadebaum, P., 2011.
- CRC CARE 2017, *Risk-based management and remediation guidance for benzo(a)pyrene*, CRC CARE Technical Report no. 39, CRC for Contamination Assessment and Remediation of the Environment, Newcastle, Australia.
- National Health and Medical Research Council (NHMRC) (2011), Australian Drinking Water Guidelines version 3.5 updated 2018.
- National Health and Medical Research Council (NHMRC) (2008) Guidelines for Managing Risks in Recreational Water.
- Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.
- NSW EPA (2016) *Environmental Guidelines – Solid Waste Landfills* (Second edition, 2016).

The guideline values are shown in the results summary tables contained in Appendix F and Appendix G. Application of guidelines is summarised below.

7.2 Identified receptors

The assessment criteria were selected to allow decisions to be made for the following identified receptors:

- Future construction and intrusive maintenance workers during the Proposal Site development and for ongoing maintenance.
- Current and future recreational users of the Proposal Site (e.g. users of sport facilities and parklands).
- Current and future commercial Proposal Site users e.g. the New Resource Recovery Facility.
- Ecological receptors down-gradient of the Proposal Site such as Botany Bay and Towra Point Nature Reserve which are located approximately 100 m to the north of the Proposal Site; and the ponds located immediately to the south-west of the Proposal Site.
- Potential beneficial users of groundwater.
- Potential recreational users of the ponds to the south-west of the Proposal Site. It is noted that recreational access to Towra Point Nature Reserve to the north is restricted, and recreational use is not anticipated to be a sensitive receptor in this water body. As such,

recreational use in Towra Point Nature Reserve is not considered to be a plausible pathway for sensitive human receptors.

- There are active oyster leases in the area of Towra Point Nature Reserve.

7.3 Assessment criteria

7.3.1 Soil

The assessment of risks to human health for future construction workers, maintenance workers and recreational users was undertaken in accordance with NEPM and CRC Care (2011). For soils the adopted human health criteria was based on the proposed land use as recreational facility. The selected assessment criteria were the following:

- NEPM health investigation levels (HIL) for recreational land uses (HIL C).
- NEPM health investigation levels (HIL) for commercial/industrial land uses (HIL D).
- NEPM health screening levels (HSL) for recreational land uses (HSL C)
- NEPM health screening levels (HSL) for commercial/industrial land uses (HSL D)
- CRC CARE (2011) HSL for Intrusive Maintenance Workers in shallow trenches.
- Direct contact HSLs for recreational and commercial/industrial land uses, and intrusive maintenance workers were adopted from CRC CARE (2011) as they are not published in the NEPM.

BTEXN and the TRH F1 and F2 fractions were not analysed in soil samples during previous investigations and, therefore, hydrocarbon contamination cannot be directly compared to HSLs. Historical data report hydrocarbons measured as TPH C_6-C_9 and TPH >C_{10}-C_{36} fractions. GHD has indicatively compared the TPH C_6-C_9 and TPH >C_{10}-C_{36} fractions to HSLs for F1 and F2 for qualitative purposes. This comparison is indicative only, but is considered suitable for a screening exercise.

The adopted ecological criteria were based on the following:

- NEPM ecological investigation levels (EIL) for urban residential and public open space land uses (EIL C).
- NEPM ecological investigation levels (EIL) for commercial and industrial land uses (EIL D).
- NEPM ecological screening levels (ESL) for urban residential and public open space land uses (ESL C).
- NEPM ecological screening levels (ESL) for commercial/industrial land uses (ESL D).

Based on the measured recycled soil pH >7.5, the selected EIL added contaminant limit for copper was 800 mg/kg for urban residential/public open space; and 1,200 mg/kg for commercial/industrial. Similarly, the selected EIL – added contaminant limit for zinc was 230 mg/kg for urban residential/public open space; and 360 mg/kg for commercial/industrial.

7.3.2 Groundwater, surface water and pore water

Health screening levels (HSLs) for selected petroleum compounds and fractions published in the NEPM were applied to assess vapour inhalation risks for recreational land-use from groundwater impacts encountered at depths greater than 2 m below ground level (bgl). Sand was selected as the Proposal Site lithology.

The adopted groundwater assessment criteria are summarised in Table 11.

Table 11 Adopted groundwater and surface water assessment criteria

Beneficial use	Adopted assessment criteria
Protection of human health	The NEPM health screening levels for vapour intrusion in recreational setting (HSL C) and commercial/industrial (HSL D) in a sand setting and at depths greater than 2 m bgl. CRC CARE (2011) - groundwater HSL for vapour intrusion, intrusive maintenance workers.
Water dependent ecosystems and species	ANZG 2018 maintenance of ecosystems: slightly to moderately disturbed systems (95% species protection) (fresh water) for ponds to the south; and 95% species protection (marine) for Towra Point Nature Reserve. ANZG 2018 – Unknown level of species protection for marine water and fresh water. ANZECC (2000) – estuaries; and freshwater lake and reservoir. It should be noted that these criteria represent typical ranges for unimpacted systems. They are not considered to be trigger values in terms of potential risk. ANZECC (2000) Toxicant guidelines for the protection of aquaculture species (Marine aquaculture guidelines)
Water based recreation (primary contact recreation)	NHMRC (2008), *Guidelines for Managing Risk in Recreational Water* (based on latest ADWG)
Drinking water	Australian Drinking Water Guidelines (ADWG) 2011 Health.
Aesthetic criteria	ADWG (2011) Aesthetic (v3.5 updated 2018).

7.3.3 Soil gas

The assessment criteria for soil gas were adopted from the following documents:

- NSW EPA (2016) *Environmental Guidelines – Solid Waste Landfills* (Second edition, 2016).
- NSW EPA (2020) *Assessment and management of hazardous ground gases – Contaminated Land Guidelines.*

8. Results

8.1 Field observations

8.1.1 Groundwater gauging

Standing water level (SWL) was measured by GHD between 1.772 m below top of casing (bTOC) and 23.293 m bTOC. Two of the gauged wells were leachate wells.

Groundwater gauging results are presented in Table 12. Locations of the groundwater and leachate monitoring wells are shown in Figure 8 in Appendix A. Additional information are provided in the groundwater impact assessment (GHD, 2021).

Table 12 Groundwater gauging results

Location	Stick up (m agl)	SWL (mbTOC)	Base of well (mbTOC)	Bore diameter (mm)	Comment
BH19A	0.57	3.009	6.505	50	No odour
BH19B	0.82	4.024	7.008	50	No odour
BH4A	1.005	3.86	6.845	50	No odour
BH20	0.7	1.772	6.301	50	No odour
BH6A	0.7	13.72	19.89	50	Grey-brown with sediment
LW05	0.68	11.475	15.325	50	Leachate. Orange-brown, with moderate leaching odour
BH11A	0.85	23.293	26.041	50	Moderate leachate odour. No cap.
BH9C	0.865	5.179	10.099	100	Orange. Weak leachate odour.
LW04	0.576	17.469	18.003	50	Weak leachate odour.
LW03	0.91	20.12	24.009	50	Orange. Weak leachate odour
LB02	0.24	14.774	18.254	50	Moderate leachate odour
LW02	0.91	18.79	19.21	50	Dark. Strong leachate odour.
BH10B	-0.7	2.625	4.613	50	No odour. Plus 4.06 m of casing removed to gauge.
BH25	gatic	7.004	14.801	50	No odour.
BH12A	gatic	10.001	11.517	50	No odour.
BH17	0.59	5.297	8.054	50	No odour.

Notes: m agl = metre (m) above ground level; mbTOC = m below top of casing.

8.1.2 Surface water and pore water quality parameters

Field parameters recorded during GHD surface water and pore water sampling are presented in Table 13. Sampling locations are shown in Figure 9 in Appendix A.

Samples SW1 to SW5 were collected on site, while SW6 to SW8 were collected off site. Pore water samples PW01 to PW04 and PW07 were collected off site in the intertidal zone and mangrove forest of Weeney Bay, located across Captain Cook Drive and approximately 20 m to the north of the Proposal Site at its closest point.

Table 13 Surface water field quality parameters

Sampling location	Temperature °C	Electrical conductivity µS/cm	pH unitless	Dissolved oxygen ppm	Redox* mV	Total dissolved solids mg/L
Surface water samples						
SW1	15.6	221.6	8.0	7.2	357.7	175.5
SW2	16.7	420.9	7.8	7.6	345.2	333.5
SW3	15.4	495.8	7.9	8.5	345.8	392.6
SW4	17.4	2,245	8.0	8.1	322.1	1,709.5
SW5	17.5	373.6	8.2	9.5	337.5	285.75
SW6 (off-site)	14.1	413.7	8.9	7.9	201.7	-
SW7 (off-site)	18.3	27,335	7.5	5.2	236.3	-
SW8 (off-site)	19.1	30,230	7.5	6.7	236.0	-
Pore water samples						
PW01	15.4	13,341	6.7	0.9	117.6	-
PW02	15.3	23,669	6.7	0.4	351.7	-
PW03	15.6	13,718	6.8	0.3	73.5	-
PW04	15.6	17,830	7.1	2.1	253.9	-
PW07	15.8	16,004	7.3	1.0	212.7	-

* Redox readings collected in the field using a silver chloride electrode were corrected to standard hydrogen electrode values by adding 199 mV.

On-site surface water (SW1 to SW5) and the off-site pond located to the south-west of the Proposal Site (SW6) were generally fresh (with the exception of SW4 – leachate pond), slightly alkaline and well oxygenated. Surface water samples collected form Towra Bay Nature Reserve (SW7 and SW8) were marine (highly saline), generally neutral in pH and oxygenated.

Pore water samples were saline, although with electrical conductivities lower than marine surface water samples, neutral in pH and poorly oxygenated to anoxic.

8.2 Conductivity testing

Results of the hydraulic conductivity testing are presented below in Table 14. For further information refer to the Groundwater Impact Assessment (GHD, 2021).

Table 14 Conductivity testing results

Monitoring well	Standing water level (mBTOC)	Screened interval (mBTOC)	Transmissivity (m^2/day)	Saturated water column (m)	Hydraulic conductivity (m/day)
BH9C	5.3866	3.75 – 9.75	18.63	4.735 (7.103)*	4.27
BH17	5.307	2.0 – 8.0	31.89	2.653 (3.98)*	8.01
BH22	2.665	1.4 – 7.5	128.8	4.495 (6.742)*	19.10

* Multiplied by 1.5 to capture the inflow into the well.

8.3 Surface water sampling analytical results

Surface water analytical results are presented in Tables F1 to F4 in Appendix F. Exceedances of the adopted assessment criteria are provided on a Proposal Site plan in Figure 10 in Appendix A.

Off-site freshwater pond SW6 did not exceed any of the adopted criteria in primary samples. One intra-laboratory duplicate for copper returned an anomalous result of 0.013 µg/L above the adopted criterion of 0.0014 µg/L. Taking the hardness measured at SW6 into account (140 mg/L) the adjusted criterion for copper is 0.005 µg/L, which is still below the duplicate concentration.

Off-site surface marine water samples SW7 and SW8, collected from Towra Point Nature Reserve showed exceedances of ecological criteria, comprising marine aquaculture and ANZG (2018) marine water (95% species protection) guidelines for a number of analytes, with SW7 typically indicating higher concentrations than SW8. These exceedances were total suspended solids (SW7 and SW8), total nitrogen (SW7), phosphorous (SW7), chromium (total – SW7), copper (SW7 and SW8), iron (SW7), lead (SW7 and SW8), manganese (SW7) and zinc (SW7 and SW8). In addition, analysis detected low concentrations, of the same order of magnitude as the LOR, of mid to heavy TRH fractions in the surface water samples collected from locations SW7 and SW8. These are likely related to high organic material content rather than to petroleum-derived hydrocarbons based on silica gel clean-up results for pore water samples (see Section 0). Endosulfan, a pesticide, was detected in sample SW7 at concentrations just above LOR.

No adopted human health criteria were exceeded in the marine surface water samples.

On-site, exceedances of the assessment criteria for freshwater (95% level of species protection) and/or marine (95% level of species protection) ecosystems (ANZG, 2018) were detected in all on-site surface water samples for copper and chromium (III+VI). Freshwater and/or marine criteria were exceeded for lead and zinc in samples SW4 and SW5. Concentrations of metals were generally of the same order of magnitude as assessment criteria and similar in all on-site ponds. Exceedances of the cyanide and ammonia (as nitrogen) freshwater and marine assessment criteria (ANZG, 2018) were only detected for sample SW4, which was collected from the leachate pond.

Aesthetic and drinking water criteria were also exceeded in one sample, SW4 (leachate), for total dissolved solids, hardness (as $CaCO_3$), sodium and chloride. The remaining analytes showed concentrations lower than the adopted assessment criteria. TRH, BTEX, PAH, PCB, and OCP were not detected in any surface water samples.

8.4 Sediment pore water analytical results

Pore water analytical results are presented in Tables F3 to F4 in Appendix F. Exceedances of the adopted assessment criteria are provided on a Proposal Site plan in Figure 11 in Appendix A.

Recreational criteria were exceeded in sample PW02 for lead and B(a)P. Ecological criteria, comprising marine aquaculture and ANZG (2018) marine (95% species protection) guidelines, were exceeded in pore water samples for total dissolved solids (all samples), ammonia (PW01, PW03 and PW07; with only PW03 showing a concentration of 14 mg/L in exceedance of the ANZG (2018) marine criterion of 0.91 mg/L), total nitrogen (all samples), heavy metals aluminum (PW04 and PW07), arsenic (PW02), cadmium (PW02 and PW04), chromium (PW02, PW03, PW04 and PW07), copper (PW02, PW03, PW04 and PW07), iron (PW01, PW02, PW04 and PW07), lead (PW02, PW03, PW04 and PW07), manganese (all), zinc (PW02, PW03, PW04 and PW07) and mercury (PW02).

TRH were detected in all pore water samples, particularly for mid to heavy TRH fractions, at levels two to three orders of magnitude higher than the limit of reporting but below the adopted criteria. The highest concentration was measured at PW04 – collected in the mangrove swamp to the north of the Proposal Site – where the TRH C_{16}-C_{34} fraction was 3,000 µg/L. As significant levels of non-petroleum hydrocarbons (e.g. organic matter, polar metabolite compounds) were suspected in pore water in this organic rich environment, TRH silica gel clean-up was performed on the samples showing the higher TRH concentrations, namely PW02, PW03 and PW04. Following silica gel clean-up, TRH were detected only in sample PW04, at approximately half the original concentration.

PAHs such as fluoranthene and pyrene were detected in all samples except for PW07 which is located to the north-west of the Proposal Site. Endosulfan was detected in sample PW04 at the detection level of 0.1 µg/L. No other pesticides, phenols or PCBs were detected.

Nitrogen concentrations, expressed as total N, were greater than the adopted ecological assessment criteria of 1 mg/L (ANZECC 2000, marine aquaculture) in all pore water samples. The highest total nitrogen concentration, 72 mg/L, was detected in PW02; the remaining pore water samples showed levels ranging from 1 mg/L to 16 mg/L. Ammonia concentrations exceeded ecological the assessment criteria for marine water (95% level of species protection, 0.91 mg/L) only in PW03. The latter sample showed the highest ammonia concentration, 14 mg/L, among all pore water samples. In contrast, nitrate, nitrite and total oxidised nitrogen were not detected.

9. Discussion

9.1 Sediment pore water

Pore water was collected from mangrove swamps located to the north and north east (i.e. down gradient) of the Proposal Site, along the littoral areas of Towra Point Nature Reserve in order to evaluate potential groundwater impacts discharging into the surface water environment. The decreased salinities observed in the pore water samples are considered to support that the samples are representative of a fresh water / salt water mixing zone within the intertidal sediments.

While all pore water samples showed exceedances of one or more criteria, in relative terms the background sample PW01 on the north-eastern shore of Quibray Bay, generally had the lowest concentrations of contaminants. Groundwater from the Proposal Site is considered highly unlikely to discharge as far north as the PW01 location.

9.1.1 Quibray Bay locations (Towra Point Nature Reserve)

Sample locations PW02, PW03 and PW04 were all collected from the southern shore of Quibray Bay, and from the stretch of down-gradient coastline closest to the Proposal Site. They are also located down-gradient of monitoring bores BH17, BH13A, BH3A and BH4A. PW03 had the highest concentration of ammonia recorded in pore water samples at 14 mg/L; PW02 was below LOR and PW04 was slightly above aquaculture guidelines but below marine 95% species protection criterion.

Oxidisable nitrogen, including nitrate and nitrite, was not detected in any sample. With the exception of sample PW03, ammonia (as N) accounted for less than 6% of the total nitrogen concentration, indicating that the remaining nitrogen was most likely bound to organic matter. However, at PW03, the ammonia concentration accounted for 93% of total nitrogen.

The PW03 ammonia concentration is higher than groundwater concentrations at up-gradient monitoring wells BH17, BH13A, BH3A and BH4A, which have not exceeded 3.8 mg/L in the last two years of monitoring. The closest well with similar order of magnitude concentrations of ammonia is BH5A, which has consistently recorded 19 to 23 mg/L over the last two years. However, BH5A is unlikely to be hydraulically up-gradient of PW03. As such, the concentrations of ammonia in PW03 appear to be unlikely to be related to groundwater migration from the Proposal Site, but other sources of ammonia measured in PW03 cannot be ruled out from the available data. It is noted that CES (2018b) ascribed the potential for ammonia to be present in anoxic sediments in proximity to the mangroves. While this may not be the case for BH5A, which is upgradient and above the mangrove swamp, PW03 is within the mangrove intertidal zone.

Similarly, the concentrations of TRH recorded in PW04 do not appear to be related to groundwater sources as represented by BH3A and BH4A which are up-hydraulic gradient. Historical data for TRH at these locations is limited; however, no detections have been identified with the most recent data available at BH4A in January 2020. This would appear to rule out the former Proposal Site wheelwash pond, which is up-hydraulic gradient, as a likely source. However, localised hydrocarbon run-off impacts from general use of Captain Cook Drive could be a contributing source of the TRH detected at PW04.

For heavy metals, PW02 generally displayed the highest concentrations relative to PW03 and PW04. Wells up-gradient of this location (BH17, BH13A) exceeded marine criteria (95% species protection) for copper, manganese and zinc over the last two years. However the recorded concentrations in groundwater at these wells (refer Section 9.3.1) for copper and zinc are an order of magnitude lower than PW02 which would be inconsistent with a conceptual Proposal

Site model for leachate impacted groundwater discharging into the mixing zone where dilution would occur.

Mangrove muds are also typically rich in organic material which would provide a much greater degree of affinity for metals sorption compared to siliceous sands, which would mean that dissolved phase metals in groundwater should partition to organic matter in the mixing zone within the mangrove swamps, and would also tend to move out of the dissolved phase with increasing pH. It is therefore likely that the measured heavy metal concentrations in the pore water samples could have other background or historical sources.

Based on the available data, there is no conclusive evidence that groundwater impacts from the Proposal Site are linked to elevated pore water concentrations in down-gradient Quibray Bay, although this cannot be ruled out.

9.1.2 Weeny Bay (Towra Point Aquatic Reserve)

One pore water sample was collected in Weeny Bay, north-west of the Proposal Site (PW07). Upgradient groundwater monitoring wells from this sampling point are considered to comprise BH25 only. Groundwater at BH25 only exceeded adopted ecological criteria for zinc (0.013 mg/L; ANZG 2018 freshwater 95% species protection) in the most recent data provided to GHD. The zinc concentration at PW07 was 0.046 mg/L, which exceeds the adopted ecological criterion for marine water of 0.015 mg/L (ANZG, 2018 at 95% species protection) but is also substantially higher than in the groundwater source up-gradient at BH25. Similarly, exceedances for chromium, copper and lead concentrations in PW07 were not mirrored by corresponding exceedances I BH25 As noted above, this is not considered to be consistent with a CSM for groundwater impacts from the Proposal Site migrating through quaternary sands and discharging into surface water via marine muds, and other sources of heavy metals may be present. There is not considered to be any evidence that impacted groundwater from the Proposal Site is posing an unacceptable risk to Weeny Bay.

9.2 Surface water

Results of surface water sampling undertaken by GHD in June, August and September 2020 are presented in Tables F1 to F4 in Appendix F.

Analytical results indicate that surface water within the monitored on-site and off-site samples is not likely to pose any unacceptable risks to human health in respect of current workers or future recreational users of the Proposal Site. Contaminant concentrations were lower than recreational and drinking water assessment criteria (where applicable).

On-site, the only aesthetic water quality exceedance was for total dissolved solids at SW4 (leachate pond).

Surface water within the on-site ponds may pose potential risks to sensitive off-site ecological ecosystems, such as Botany Bay and Towra Point Nature Reserve (marine receptors), which are located approximately 100 m to the north of the Proposal Site; and the ponds (fresh water receptors) located immediately to the south-west of the Proposal Site. Potential risks are related to heavy metal, particularly copper and chromium (total), concentrations in exceedance of the freshwater and marine assessment criteria (ANZG, 2018) in all on-site ponds.

The criteria were also exceeded for cyanide in sample SW4 – which has been collected from a leachate pond lined with high-density polyethylene – which is not connected with the aquifer. GHD understands that surface water contained in the leachate pond will be disposed in accordance with NSW regulations. As such, it is unlikely that it will pose risks to surrounding ecological receptors via infiltration to groundwater or run-off to surface water systems.

The remaining on-site ponds are infiltration ponds, and observed contaminants are likely to reflect a mixture of groundwater impacted by leachate and surface run-off from landfilled materials. Hence, water characterised by heavy metal concentrations exceeding freshwater and marine assessment criteria (ANZG, 2018) may percolate from infiltration ponds into the aquifer and migrate towards ecological receptors. In terms of the off-site fresh water pond to the south-west (SW6), one exceedance – for copper (0.013 mg/L) detected in duplicate sample QC01 – of the freshwater criterion of 0.005 mg/L (hardness modified) was observed. However, the primary sample, SW6, showed a copper concentration lower than the detection limit. Taking hardness into account (140 mg/L) the adjusted 95% freshwater trigger value is 0.005 mg/L, which is still slightly below the duplicate value. It should be noted that one exceedance does not necessarily indicate a risk, as the criteria are based on long term average concentrations, and seasonal variations are unknown.

The off-site marine environment to the north (Towra Point Nature Reserve) is an ecological reserve situated in Botany Bay, which has had extensive industrial use which continues to the current day. As such, background contamination is likely. Surface water samples in the marine environment to the north of the Proposal Site (SW7 in Quibray Bay and SW8 in Weeny Bay) exceeded these adopted ecological criteria (ANZGG, 2018) for several heavy metals, with SW8 exhibiting fewer exceedances than SW7, and by smaller margins.

The data from pore water sampling showed similar impacts, which did not appear to be related to groundwater impacts migrating from the Proposal Site, as groundwater quality migrating towards the shoreline was less impacted than the pore water measurements. The surface water concentrations were generally lower than measured pore water concentrations at the corresponding locations.

While this is logically the case, reflecting the tidal flushing of the system and the significant attenuation of any impacts arising from groundwater discharge (if present), the degree of attenuation was much lower than would be expected, and in fact many concentrations, particularly heavy metals, would be within acceptable precision limits if samples had been collected in duplicate from the same location. A comparison of attenuation factors between paired pore water and surface water results for exceedances which were identified in both samples is presented in Table 15

Table 15 Attenuation factor (AF) comparison – marine surface water and pore water

Analyte	SW7 (mg/L)	PW03 (mg/L)	AF	SW8 (mg/L)	PW07 (mg/L)	AF
Ammonia	0.75	14	18.7	0.05	0.23	4.6
Nitrogen	5.89	15	2.5			
Phosphorus	0.14	0.03	**0.2**			
Chromium	0.02	0.02	0	0.002	0.019	9.5
Copper	0.016	0.012	**0.8**	0.005	0.011	2.2
Lead	0.025	0.030	1.2	0.003	0.023	7.7
Manganese	0.024	0.063	2.6			
Mercury	0.0002	0.0002	**1**			
Zinc	0.057	0.056	**1**	0.009	0.046	5.1

*__Bold__ denotes SW concentration equal to or higher than PW.

It is noted that in general the Quibray Bay surface water sample results were more impacted than Weeny Bay. While there is insufficient data to be conclusive, Weeny Bay may be more

sheltered from the rest of Botany Bay, and in particular, from potential historical impacts arising from heavy industries to the east of the Proposal Site along the Kurnell Peninsula.

Similar to the ecological exceedances, ANZECC (2000) marine aquaculture guidelines were exceeded for a number of metals and nutrients at SW7 and/or SW8. Insufficient data is available to confirm whether the concentrations measured in this assessment are indicative of long term averages, or whether there are seasonal fluctuations. While the measured data indicate potential adverse effects to aquaculture in Towra Point Nature Reserve, such as Oyster Leases, evaluation of the data suggests that some, if not all, impacts may be associated with sources other than the Proposal Site.

The potential linkages between on-site surface water and off-site surface water bodies are also assessed by examining the groundwater quality and potential impacts migrating off-site in Section 9.3.1.

9.2.1 Historical surface water data review

Historical surface water results are presented in Tables G2a and G2b in Appendix G. Surface water samples have been historically collected from the following locations:

- Concrete recycling pond (CRP).
- Historic western wheel wash pond (HWWWP).
- Wheel wash pond (WWP).
- Lot 1124.

Exceedances of the adopted ecological assessment criteria for freshwater and marine water (ANZG, 2018) were detected at all sampling locations for metals (arsenic, chromium, copper and lead) during most of the sampling rounds. Metal concentrations were generally of the same order of magnitude of samples collected by GHD in 2020 (see Section 8.3). Ammonia concentrations exceeded the adopted ecological assessment criteria (ANZG, 2018 and ANZECC, 2000) in most samples.

Historical ammonia concentrations were of the same order of magnitude as samples collected by GHD, except for SW4 (leachate pond), which was two orders of magnitude higher than the other samples, as would be expected for leachate. Electrical conductivity and pH consistently exceeded the ANZECC (2000) criteria in most samples.

Drinking water and aesthetic assessment criteria for arsenic, pH and ammonia were exceeded in isolated cases in all ponds. Total dissolved solid ecological criteria (ANZG, 2018) were frequently exceeded in the wheel wash pond (WWP) and, to a lesser extent, in the concrete recycling pond (CRP) and the historic western wheel wash pond (HWWWP). Noting that these ponds are no longer present, potential linkages to identified receptors are no longer plausible.

Based on the available data, current surface water quality at the Proposal Site is considered unlikely to pose unacceptable risks to identified receptors.

9.3 Historical data

Historical groundwater, leachate, soil and ground gas data are discussed in the following sections. Breen has provided the data in in electronic format and GHD collated them. Data are provided in Appendix G.

9.3.1 Groundwater

Comparison of available groundwater data to adopted criteria is provided in Table G1a and Table G1b in Appendix G. Exceedances of the adopted assessment criteria presented in

Section 7.3.2 for the Q1 monitoring round in 2020 are presented in Figure 11 in Appendix A. For assessment of baseline contamination status with respect to the Proposal, the last two rounds of data (Q1 and Q2 monitoring rounds in 2020) are discussed in detail in this section.

Human health receptors

In respect of evaluating potential abstraction for drinking water, only one bore within 500 m of the Proposal Site is licensed for domestic abstraction – GW107432 approximately 75 m east of the Proposal Site. The nearest groundwater bores to this point are BH22, and BH15, which are potentially up hydraulic gradient of GW107432. Exceedances of adopted human health criteria (potable) were not observed at BH15 or BH22 for any parameters in the 2020 dataset, indicating that the potential for off-site migration of COPC to this off-site bore at concentrations exceeding human health criteria is very low. It is further noted that the area to the east is subject to sand mining and there are no domestic properties present. It is therefore considered very unlikely that groundwater is abstracted for potable purposes.

Licensed groundwater abstraction for industrial / irrigation / recreational purposes is also mapped off site to the east at GW109177 (89 m), the south-east at GW071908 (281 m) and to the south-west GW107820 (290 m). The closest perimeter bores at the Proposal Site representing groundwater quality in respect of potential off-site migration are BH15 (GW109177), BH16 and BH23 (GW071908) and BH7A (GW107820). No exceedances of recreational criteria were observed at any of these bores in the 2020 dataset. It is therefore considered unlikely that measured concentrations of COPC in groundwater at the Proposal Site have the potential to pose unacceptable risk to off-site groundwater abstraction for recreational purposes.

None of the on-site groundwater wells exceeded vapour intrusion criteria for petroleum hydrocarbons, indicating that the potential for vapour intrusion risk into current or proposed future structures on the Proposal Site is low. It should be noted that recreational criteria for vapour intrusion are non-limiting for all petroleum hydrocarbons (i.e. groundwater concentrations cannot exceed unacceptable risk thresholds before solubility limits are reached).

Ecological receptors

Off-site ecological receptors are present to the north (Towra Point Nature Reserve – marine) and to the south (un-named freshwater ponds). Perimeter monitoring wells considered to represent groundwater quality in respect of potential off-site migration to these receptors are:

- BH8A and BH7A (off-site fresh water ponds to the south)
- BH25, BH12A, BH5A, BH17, BH13A, BH3A, BH4A, BH9C, BH10B, BH19A, BH19B, BH14A, BH20 and BH15 (Towra Point Nature Reserve)

For identified marine receptors, exceedances of adopted ecological criteria at sentinel wells were recorded for:

- Ammonia – all wells; up to 22 mg/L in BH5A
- Chromium – BH4A, BH19A, BH19B (0.017 mg/L)
- Cobalt – BH5A, BH12A, BH13A, BH20 (maximum of 0.003 mg/L in BH12A)
- Copper – BH5A, BH9C, BH12A, BH13A, BH17, BH19B, BH20 (maximum of 0.018 mg/L in BH9C)
- Manganese – BH5A, BH10B, BH12A, BH13A, BH17, BH20, (maximum of 0.7 mg/L in BH5A)
- Zinc – all wells except BH15 (maximum of 0.19 mg/L in BH19A)

No other COPC, including organic contaminants, were detected in excess of the adopted criteria.

The ammonia and metals exceedances at down gradient sentinel wells, suggest that there is potential for impacts on sensitive ecological receptors in Towra Point Nature Reserve. However, as noted above, any groundwater impacts from Proposal Site reaching the marine environment would be expected to be significantly attenuated at the point of discharge due to the tidal environment. This has been further evaluated by review of off-site pore water and surface water sampling data in Towra Point Nature Reserve (Section 9.1 and 9.2). Notably, ammonia concentrations in shallow surface water samples within the intertidal zone do not exceed the adopted ecological criterion of 0.9 mg/L (95% species protection) indicating than unacceptable ammonia impacts to surface water are unlikely to be occurring.

For identified freshwater receptors, exceedances of adopted freshwater ecological criteria at sentinel wells were recorded for:

- Copper (BH7A)
- Zinc (BH7A

BH8A is not tested for heavy metals, pesticides or other organic contaminants. Review of the SW6 data (nearest off-site surface water sample to the south) does not indicate any significant impact from landfill derived COPC from on-site, apart from a single exceedance of copper in a quality assurance (duplicate) sample. The risk to off-site fresh water receptors from impacted groundwater is therefore considered likely to be low and acceptable.

Groundwater trends

A detailed review of contaminant trends in groundwater over time has been undertaken in the Groundwater Impact Assessment (GHD 2021). With regard to ammonia, monitoring wells BH9C and BH5A located on the north western boundary of the Proposal Site, have the highest concentrations of ammonia compared to the other wells. Monitoring well BH9C is located near the current entrance of the Proposal Site and monitoring well BH5A is located off-site along Captain Cook Drive near the western portion of the Proposal Site. Monitoring well BH12A, the next well west of BH5A, also has high concentrations of ammonia (approximately 9 mg/L relative to the adopted criterion of 0.9 mg/L). These two wells appear to have had recent upward trends that may be associated with historical variability or indicative of a longer-term trend associated with Proposal Site activities. Ammonia concentrations in monitoring well BH10B have increased rapidly over the last three rounds to approximately 18 mg/L. The trend analysis plots indicate that ammonia concentrations in groundwater appear to pulse, which may be associated with climatic variations and the observed upward trends at some wells across the Proposal Site may be part of that pattern.

9.3.2 Leachate

Historical leachate results have been collated and compared to assessment criteria relevant to this investigation (Section 7.3.2). Samples had been collected between 2002 and 2020 from leachate sampling points. Results are summarised in Table G3a and Table G3b in Appendix G.

Since 2017, leachate has only been sampled in LB02 in the central western portion of the Proposal Site. However, during 2017, leachate was also measured in a number of additional wells spatially distributed across the western and central areas; i.e. LW01 to LW06. No leachate has been assessed in the eastern portion of the Proposal Site, where anecdotally only virgin excavated natural materials have been used to fill the former pond.

To assess the baseline contamination status of the Proposal Site, the leachate data from 2017 and subsequently from LB02 has been examined in detailed below. In general, leachate on the

Proposal Site has been characterised by elevated concentrations of dissolved salts, nutrients (notably ammonia – up to 830 mg/L in LW06 in 2017), some petroleum hydrocarbons (little or no BTEX, but up to 23 mg/L TRH in LW06 (mostly heavy end in the C_{16}-C_{34} fraction). No other organic contaminants (where analysed – mostly for LB02 in January 2020) have been detected, including PAHs, phenols and pesticides.

Human health receptors

Leachate will not be abstracted on site for potable purposes in current or future uses of the Proposal Site. The potential for leachate to impact off-site groundwater and potential domestic abstraction off site has been evaluated in Section 9.3.1. Further comparison of leachate quality to potable criteria is not considered to be relevant. However it is understood that leachate irrigation for dust suppression may be used as a potential for leachate management in future (CES 2020f).

While no recreational criteria were exceeded for the 2018-2020 leachate data set, it is noted that ammonia does not have a health criterion due to insufficient data (ADWG, 2018). There could be a potential risk to human health posed by direct contract to extracted leachate which would require management under any irrigation scenarios. Anecdotal information provided by Breen indicates that some leachate is re-injected within lined cell B10 and exclusion zones are present to avoid personnel coming into contact with leachate.

No exceedances of vapour intrusion criteria for petroleum hydrocarbons were observed (where analysed), indicating that there is a low potential for vapour intrusion risk into current or proposed future structures on the Proposal Site. It should be noted that recreational criteria for vapour intrusion are non-limiting for all petroleum hydrocarbons (i.e. groundwater concentrations cannot exceed unacceptable risk thresholds before solubility limits are reached).

Ecological receptors

Exceedances of the ANZG (2018) ecological criteria in the leachate have been limited to heavy metals and ammonia. The potential for these contaminants to impact on-site and off-site ecological receptors in Towra Point Nature Reserve and fresh water ponds to the south via groundwater migrations and subsequent discharge is considered low and has been discussed in Sections 9.1, 9.2 and 9.3.1.

9.3.3 Soils

Soil samples were collected from on-site stockpiles to classify the material as recovered aggregate or recovered fines (continuous) as described in CES (2020b and 2020c). The classifications were successful.

GHD has compared results provided against assessment criteria relevant to the current Proposal Site setting and proposed Proposal Site setting (as described in Section 7.3.1). They are presented in Table G4 in Appendix G.

Human health receptors

All sample data showed contaminant concentrations lower than commercial/industrial and recreational open space health investigation levels and health screening levels. Concentrations were also lower than the adopted direct contact assessment criteria. This indicates that recovered aggregate and recovered fines (continuous) present on site are unlikely to pose human health risks during current Proposal Site use or future redevelopment works and future land use as recreational facilities and parklands.

Ecological receptors

Of the 95 sample data available, three exceeded EILs for open space land use, none exceeded the commercial/industrial EILs, 10 exceeded open space ESLs, and four exceeded commercial/industrial ESLs. Exceedances were typically detected for nickel, zinc and benzo(a)pyrene. However, calculated 95% upper confidence levels (UCL) were lower than EILs and ESLs for all analytes with one exception: benzo(a)pyrene (95% UCL = 1.2 mg/kg) marginally exceeded the ESL for urban residential/public open space land use (0.7 mg/kg).

For BaP, CRC CARE Technical Report 39 (2017) provides ESLs with higher reliability compared to those reported in the NEPM. ESLs provided by CRC CARE (2017) have been based on more species and a larger dataset providing a greater confidence in the calculated criteria. For urban residential and public open space, the CRC CARE ESL for BaP is 33 mg/kg; which is well in excess of the results from all soil samples from the Proposal Site. It is therefore considered unlikely that BaP will pose a material ecological constraint to Proposal Site redevelopment as public open space.

Overall, material classified as recovered aggregate and recovered fines (continuous) is considered unlikely to pose ecological and/or human health risks during future works and during future use of the Proposal Site as open space land based on the available data. It is noted however, that although load inspections are carried out for asbestos, confirmatory analysis for asbestos is not required under the Proposal Site EPL. Asbestos analyses on aggregate material have been undertaken between March and July 2020 and showed no asbestos. GHD understands that Breen's acceptance and material inspection processes have been consistently applied throughout the term these products were produced.

9.3.4 Landfill gas

Historical ground gas results collected between July 2017 and January 2020 are presented in Table G5 in Appendix G. Figure 13 in Appendix A shows a ground gas exceedance plan based on the highest methane and carbon dioxide concentrations detected since 2016 (refer to Section 5.3.2).

Methane and carbon dioxide concentrations in excess of the NSW EPA (2016) Environmental Guidelines – Solid Waste Landfills criteria were detected in six leachate observation wells (LW01 to LW06) sampled in December 2016 and January 2017 (see Figure 13 in Appendix A). Concentrations of methane ranged up to 63.6% v/v (LW06), and carbon dioxide ranged up to 34.7% v/v (LW06). Hydrogen sulphide was also detected up to 460 ppm (LW05). Flow rates within the landfilled area were up to 13.4 L/hr (LW06).

For ground gas sampling points located along the Proposal Site perimeter, methane concentrations were below the adopted assessment criterion of 1% for available monitoring event data. Minor concentrations were detected at the limit of reporting of 0.1% in few occasions. Carbon dioxide was not measured. Maximum borehole flow rates ranged from -0.7 L/hr to 1.3 L/hr.

Based on available data, ground gases are present within the landfilled areas at concentrations that require management actions and mitigation as part of Proposal Site closure and redevelopment.

In contrast, ground gas levels measured along the Proposal Site perimeter were lower than adopted assessment criteria. Off-site migration of ground gas under current Proposal Site conditions is therefore considered unlikely to pose an unacceptable risk. However, capping of the landfilled areas may result in changed ground gas conditions It is also noted that the extent of potential ground gas impacts in the eastern portion of the Proposal Site, while unlikely, are not well understood. It is understood that a Proposal Site Closure Plan will be developed in

accordance with NSW EPA guidelines which will include consideration of gas management strategies and monitoring requirements.

9.4 Quality assurance and quality control (QA/QC)

A quality assurance and control (QA/QC) assessment was completed for surface water and pore water analytical sample data. The objective was to determine whether data are of suitable quality on which to base the Proposal Site investigation. This included the collection and review of three intra-laboratory duplicate, one inter-laboratory duplicate, three trip blank, two trip spike and one rinsate blank samples. Results are presented in Appendix I.

The QA/QC assessment found that GHD QA/QC data quality indicators (DQIs, presented in Appendix D) were within the specified requirements. The data are therefore considered to be valid and of sufficient quality to rely on for the purpose and objectives of this assessment. A copy of the detailed QA/QC report is provided in Appendix I. Comments on third party QA/QC are provided in Appendix I.

10. Conceptual site model

10.1 General

Based on available information, the following preliminary conceptual site model (CSM) has been developed for the Proposal Site. The purpose of the CSM is to provide an understanding of the nature and extent of previous and current contamination impacts and contaminant migration mechanisms. This includes exposure pathways by which identified receptors may be exposed to contamination from the Proposal Site. The CSM also serves as a framework to assess risks to human health and environmental receptors.

For an ecological or human health risk to be present, there must be a complete linkage between contamination sources and receptors. The linkage is represented by a migration mechanism which is also referred to as pathway. When data show that contamination has migrated from a source, through a pathway and to a receptor, the contamination linkage is referred to as complete.

Graphical CSM representations along three different cross sections for the Proposal Site are presented in Figures 14 to 18. Two graphical CSMs were prepared for each cross section; one for the current Proposal Site conditions and one in respect of future development.

10.2 Contamination sources

The most significant identified primary contamination source is the waste mass placed on site as part of landfilling pursuant to EPL 4608. Other primary sources might include localised contamination associated with the landfilling and recycling operations on site, such as minor fuel spills.

10.3 Contaminants of potential concern

Contaminants of potential concern (COPC) are considered to include (in accordance with the EPL monitoring requirements):

- TRH
- BTEX
- PAH
- OCP and OPP
- Heavy metals including As, Ba, Cd, Co, Cr, Cu, Hg, Pb, Ni, Mn, Mg and Zn.
- Major cations and anion including carbonate, chloride, calcium, fluoride, potassium, sodium, sulphate
- Total dissolved solids and total suspended solids
- Total organic carbon
- Total phenolics
- Nutrients including ammonia, total nitrogen, nitrate, nitrite and total phosphorus.
- Conductivity
- pH
- Ground gasses (primarily methane and carbon dioxide).

Additionally, asbestos is considered to be a potential contaminant due to the nature of material entering the Proposal Site, including construction and demolition waste. Cyanide was also detected in surface water samples.

10.4 Receptors

Receptors were identified for the current land use as a landfill, including future redevelopment works, and for future land use as recreation facilities and parklands.

Identified receptors for the current land uses of the Proposal Site (Lot 1122, Lot 1123, Lot 5 and Lot 6, are:

- Workers/users of the Proposal Site including intrusive maintenance workers.
- Off-site users (commercial/industrial)
- Ecological receptors down-gradient of the Proposal Site such as Botany Bay and Towra Point Nature Reserve which are located approximately 100 m to the north of the Proposal Site; as well as the fresh water ponds located immediately to the south-west of the Proposal Site and Cronulla Beach.
- Marine aquaculture (oyster leases in Towra Point Nature Reserve).
- Groundwater resources.
- Potential beneficial users of groundwater.

Identified receptors for future land uses of the Proposal Site are:

- Future recreational users of the Proposal Site (e.g. users of sport facilities).
- Future workers at the Proposal Site (commercial/industrial and intrusive maintenance workers).
- Off-site users (commercial/industrial).
- Ecological receptors down-gradient of the Proposal Site such as Botany Bay and Towra Point Nature Reserve which are located approximately 100 m to the north of the Proposal Site; as well as the ponds located immediately to the south-west of the Proposal Site and Cronulla Beach.
- Groundwater resources.
- Potential beneficial users of groundwater.

Of note, the setting of the area to the north of the Proposal Site restricts access to the Towra Point Nature Reserve for recreational users. As such, recreational receptors in Towra Point Nature Reserve were not considered to be plausible.

10.5 Potential pathways

The identified pathways by which receptors could potentially be exposed to the sources of contamination based of the current and future land uses which have been considered are:

- Leaching of wastes or contaminated soils to groundwater.
- Lateral migration of groundwater and leachate and subsequent discharge.
- Groundwater extraction.
- Direct contact with impacted soil, surface water and leachate, including uptake by flora and fauna.
- Consumption of aquatic species exposed to contaminated surface water.

- Volatilisation of volatile contaminations in soil, groundwater or leachate to indoor and outdoor environments.
- Dust inhalation
- Accumulation of explosive or oxygen excluding gases in confined spaces

10.6 Source-pathway-receptor linkage assessment

Table 16 and Table 17 provide assessments of potential source-pathway-receptor linkages for the current status of the Proposal Site and for its future use as set out in the Proposal. Linkages are categorised as complete, possible, unlikely or incomplete based on available data.

Table 16 Source-pathway-receptor linkages (current use)

Potential Source	Pathway	Receptor	Pathway complete?
Stockpiled / processed soils / recycled materials and landfilled waste	Odours (aesthetic considerations)	Off-site users	**Possible** – some odours identified during Proposal Site walkover, however no sensitive residential receptors nearby
	Volatilisation to indoor air and subsequent inhalation	On-site users	**No** – no exceedances of vapour intrusion criteria, and no structures with indoor air spaces adjacent to stockpiled material.
		Off-site users	**No** – no exceedances of vapour intrusion criteria, and no structures with indoor air spaces adjacent to stockpiled material.
	Volatilisation to outdoor air and subsequent inhalation	Proposal Site workers	**No** - soil concentrations are below the adopted HSL D in all samples.
		Intrusive maintenance workers	**No** - soil concentrations are below the adopted CRC Care HSL Intrusive Maintenance Worker in all samples
	Direct Contact	Proposal Site workers	**No** – all measured soil concentrations are below the adopted criteria for direct contact
		Ecological receptors (flora/fauna)	**No** – the vast majority of results were below adopted ecological criteria.
	Dust generation (asbestos)	Proposal Site workers	**Unlikely** – Resource recovery order testing requirements do not include analysis of asbestos. However, all loads are inspected and random asbestos analyses on aggregate material have been undertaken between March and July 2020 and showed no asbestos in recovered aggregate. While the potential for asbestos to be present cannot be completely excluded, significant asbestos impacts are unlikely.
		Off-site users	**Unlikely** – Resource recovery order testing requirements do not include analysis of asbestos. However, all loads are inspected and random asbestos analyses on aggregate material have been undertaken between March and July 2020 and showed no asbestos in recovered aggregate. While the potential for asbestos to be present cannot be completely excluded, significant asbestos impacts are unlikely.

Potential Source	Pathway	Receptor	Pathway complete?
	Leaching to groundwater	Groundwater resources	**Yes** – analysed contaminant concentrations are generally low. As is common with landfills, leachate is however being generated and ammonia is present in groundwater wells, including off-site, at concentrations in excess of adopted criteria.
Localised surface contamination from Proposal Site operations (recycling, filling) eg vehicle fuel spills	Direct contact	Proposal Site workers	**Unlikely** – Proposal Site workers wearing PPE and following safe work procedures
		Ecological receptors	**Possible** – the Proposal Site is large and does contain native vegetation and abuts ecological reserves. However, operational areas where localised contamination might be present are likely to host transient fauna only.
	Run-off to ponds	Ecological receptors	**Unlikely** – on site ponds (other than leachate pond) show minor impacts for dissolved metals only.
	Leaching to groundwater	Groundwater beneficial use	**Unlikely** –localised spot contamination on the surface unlikely to have a material impact on groundwater relative to landfilling activities. Groundwater/leachate quality does not indicate significant contaminants other than nutrients (ammonia) metals, and some medium to long chain hydrocarbons.
Dissolved phase contaminants in groundwater / leachate	Volatilisation to indoor air and subsequent inhalation	On-site workers	**No**– there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below HSL D vapour intrusion criteria
		Off-site users	**No**– there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below HSL vapour intrusion criteria
	Volatilisation to outdoor air and subsequent inhalation	On-site workers	**No**– there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below vapour intrusion criteria
		Off-site users	**No**– there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below vapour intrusion criteria
	Lateral migration of groundwater and leachate, and direct contact	On-site workers	**Possible –** Recreational criteria have been exceeded in five groundwater monitoring wells (AB01 BH7, BH9 BH10A and BH11A) and two leachate wells (LD002 and LW05) for arsenic and/or benzene. There is the potential for direct contact with leachate and groundwater, for example using leachate or leachate impacted groundwater. Anecdotal information from Breen indicate that leachate is not currently

Potential Source	Pathway	Receptor	Pathway complete?
			used for irrigation or dust suppression. Standing water level was measured between 1.772 m below top of casing (bTOC) and 23.293 m bTOC. Direct contact with subsurface groundwater and leachate is therefore considered unlikely in the course of Proposal Site operations.
		Off-site recreational users	**No –** Recreational criteria were exceeded in groundwater beneath the Proposal Site, however all off-site surface water results were below recreational criteria. Recreational access to Towra Point Nature Reserve to the north is restricted.
		Marine ecological receptors (off-site - north)	**Possible** – concentrations of metals and ammonia in groundwater exceed marine ecological criteria along the Proposal Site's northern perimeter. However, surface water samples in Towra Point Nature Reserve are still below adopted criteria and the relationship between boundary groundwater quality and off-site surface water indicates that background impacts cannot be ruled out and are possibly a significant factor.
		Freshwater ecological receptors (off-site – south)	**Unlikely** – concentrations of metals and ammonia in groundwater exceed fresh water ecological criteria. However, in the off-site pond to the south (down gradient) of the Proposal Site all concentrations are below the freshwater assessment criteria apart from one copper exceedance (in a duplicate sample).
	Groundwater extraction	Groundwater users (direct contact and ingestion) off-site	**Unlikely –** Groundwater samples collected along the Proposal Site's boundary in the direction of beneficial abstraction bores showed contaminant concentrations in the most recent rounds below drinking water and recreational criteria. The closest bore licensed for domestic purposes is 75 m east of the Proposal Site, with the closest irrigation / recreational bores >250 m south east and south-west of the Proposal Site.
Hazardous ground gases	Accumulation and explosion / asphyxiation	Proposal Site workers / intrusive maintenance workers	**Possible** – intrusive maintenance works into waste has to the potential to create a confined space. However, for conventional Proposal Site workers it is considered **unlikely** as surface and indoor monitoring has not indicated any exceedances.
		Off-site users	**No** – perimeter gas monitoring has not indicated any exceedances of adopted criteria for ground gases

Table 17 Source-pathway-receptor linkages (future use)

Potential Source	Pathway	Receptor	Pathway complete?
Landfilled waste in western portion of the Proposal Site, stockpiled / processed soils / recycled materials used for landscaping	Odours (aesthetic considerations)	Off-site users	**No** – The final landform is expected to be capped with suitable material.
	Volatilisation to indoor air and subsequent inhalation	Future recreational users and Proposal Site workers	**No** – no identified exceedances of vapour intrusion criteria for recreational use (HSL C) and commercial/industrial use (HSL D) were detected.
		Off-site users	**No** – no identified exceedances of vapour intrusion criteria were detected.
	Volatilisation to outdoor air and subsequent inhalation	Future recreational users and Proposal Site workers	**No** – no identified exceedances of vapour intrusion criteria for recreational land use (HSL C).
		Intrusive maintenance workers	**No** – soil concentrations are below the adopted CRC Care HSL Intrusive Maintenance Worker in all samples
	Direct Contact	Future recreational users and Proposal Site workers.	**No** – all measured soil concentrations are below the criteria for direct contact for recreational and commercial/industrial use (HSL D) land uses.
		Intrusive maintenance workers	**No** – all measured soil concentrations are below the criteria for direct contact for commercial/industrial land use and intrusive maintenance workers.
		Ecological receptors (flora/fauna)	**No** – proposed fill materials stockpiled on-site are generally below adopted ecological criteria, and final landform is also anticipated to be capped by suitable material / growing medium.
	Dust inhalation (asbestos)	Future recreational users of the Proposal Site and workers, and off-site users	**No** – widespread asbestos contamination is considered unlikely in waste received at the Proposal Site, and soil will be capped with validated material.
		Intrusive maintenance workers	**Unlikely –** Intrusive maintenance workers could be exposed to asbestos (if present) during intrusive works (e.g. excavations). Intrusive works would require management under WH&S requirements for any excavations into capped waste materials.
	Leaching to groundwater	Groundwater resources	**Yes** – analysed contaminant concentrations are generally low. Leachate is however being generated and ammonia is present in groundwater wells in excess of adopted criteria. However, infiltration and leachate generation are expected to be greatly reduced following capping of the western portions of the landfilled areas,

Potential Source	Pathway	Receptor	Pathway complete?
			and operation of Cell B11 which is fully lined with a leachate management strategy.
Localised surface contamination from Proposal Site operations (New Resource Recovery Facility) in eastern portion of the Proposal Site) – eg vehicle fuel spills	Direct contact	Proposal Site workers in the eastern portion of the Proposal Site (New Resource Recovery Facility)	**Unlikely** – Proposal Site workers wearing PPE and following safe work procedures
		Ecological receptors	**Unlikely** – the Proposal Site contains native vegetation and abuts ecological reserves. However the risk is likely to be less in the future scenario as recycling activities will be concentrated into a smaller area.
	Run-off to surface water	Ecological receptors	**Unlikely** – future development will have improved run-off controls
	Leaching to groundwater	Groundwater beneficial use	**Unlikely** – Proposal Site will be sealed localised spot contamination on the surface during operations at the New Resource Recovery Facility unlikely to have a material impact on groundwater relative to historical landfilling activities.
Dissolved phase contaminants in groundwater / leachate	Volatilisation to indoor air and subsequent inhalation	Future recreational users and Proposal Site workers	**No** – there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and available results are below HSLs for recreational and commercial/industrial land use.
		Intrusive maintenance workers	**No** – there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below HSLs for vapour intrusion for intrusive maintenance workers.
	Volatilisation to outdoor air and subsequent inhalation	Future recreational users of the Proposal Site and workers	**No** – there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below vapour intrusion criteria. HSL-C is also non-limiting for all volatile petroleum compounds.
		Off-site users (commercial/industrial)	**No**– there is no evidence suggesting significant concentrations of volatile contaminants in leachate or groundwater, and results are below vapour intrusion criteria
	Lateral migration of groundwater and leachate, and direct contact	Future recreational users of the Proposal Site	**No –** access to leachate or groundwater by recreational users is not expected to be available in the final landform.
		Proposal Site workers / Intrusive maintenance workers	**Unlikely –** recreational criteria were exceeded in some groundwater and leachate monitoring wells. There could be a potential risk to human health posed by direct contact to leachate

Potential Source	Pathway	Receptor	Pathway complete?
		(recreational area and new recycling area)	which would require WH&S management under any future irrigation scenarios.
		Off-site recreational users	**No –** Recreational criteria were exceeded in groundwater beneath the Proposal Site, however all off-site surface water results were below recreational criteria. Recreational access to Towra Point Nature Reserve to the north is restricted.
		Marine ecological receptors (off-site - north)	**Unlikely** – while concentrations of metals and ammonia in groundwater exceed marine ecological criteria along the Proposal Site's northern perimeter, ammonia exceedances in off-site marine surface water were not present. The relationship between boundary groundwater quality and off-site surface water indicates that background impacts, especially for metals, cannot be ruled out. Capping in the future land use scenario is likely to reduce infiltration and groundwater impacts (refer to Groundwater Impact Assessment Report, GHD 2021)
		Freshwater ecological receptors (off-site – south)	**Unlikely** – concentrations of metals and ammonia in groundwater exceed fresh water ecological criteria. However, in the off-site pond to the south (down gradient) of the Proposal Site all concentrations are below the freshwater assessment criteria except for one copper exceedance (in a duplicate sample).
	Groundwater extraction	Groundwater users (direct contact and ingestion) off-site	**Unlikely** – Groundwater samples collected along the Proposal Site's boundary in the direction of beneficial abstraction bores showed contaminant concentrations below drinking water and recreational criteria. The closest bore licensed for domestic purposes is 75 m east of the Proposal Site, with the closest irrigation / recreational bores >250 m south east and south-west of the Proposal Site.
Hazardous ground gases	Accumulation and explosion / asphyxiation	Future recreational users of the Proposal Site	**Unlikely** – Ground gases within waste above adopted criteria are present in the landfilled areas. Ground gas management will be considered in the Proposal Site Closure Plan which is required to be developed in accordance with NSW EPA guidelines, and risks in future open space areas would be negligible. However, the design of any above ground structures (eg BBQs) may require further assessment post capping in respect of ground gases.

Potential Source	Pathway	Receptor	Pathway complete?
		Proposal Site workers (New Resource Recovery Facility)	**Unlikely** – backfilling of the ponds in on the is understood to comprise VENM with a small proportion of PASS in accordance with EPL 4608, and waste has not been landfilled in this area. While the lateral extent of gas impacts from waste in the western and central portions if the Proposal Site have not been delineated, lateral migration is considered unlikely as new cell B11 (with synthetic liner) creates a break in the pathway to landfilled waste to the west.
		Intrusive maintenance workers	**Possible** – any maintenance work would require management under WH&S requirements for any excavations into capped waste materials.
		Off-site users	**No** – perimeter gas monitoring has not indicated any exceedances of adopted criteria for ground gases

10.7 Data gaps

Data gaps were identified based on available information and its consolidation into the conceptual site model. They are presented in Table 19, which also provides recommended on the significance of the data gaps.

Table 18 Data gaps and potential significance

Data gap identified	Potential significance
Localised contamination may have occurred during current Proposal Site use. Based on the environmental protection licences hold by the Proposal Site, GHD has not identified activities that could result in major contamination. A limited Proposal Site walkover undertaken by GHD has not identified widespread contamination at the Proposal Site's surface.	As discussed in the CSM the potential for localised contamination to pose a major constraint to Proposal Site redevelopment is considered low, especially in the context of the proposed earthworks to raise Proposal Site levels, which would effectively cap any potential contamination.
There is potential for asbestos containing material (ACM) to be present in waste received at the Proposal Site. Resource recovery order testing requirements do not require analysis of asbestos. However, it is noted that inspections of all incoming loads are carried out, and random asbestos testing data made available to GHD has not indicated any asbestos.	The presence of significant asbestos is considered unlikely based on operational protocols. However, the potential for asbestos to be present in a portion of waste and recycled materials received at the Proposal Site cannot be entirely discounted. It is expected that there would be contingency plans in place during construction to manage the possible presence of asbestos and any other unexpected finds during earthworks. As such, this data gap should not pose a major constraint to Proposal Site redevelopment, especially in the context of having a validated capping layer in the final landform (which will need to be detailed in a Proposal Site Closure Plan in accordance with NSW EPA guidelines), which would effectively prevent any potential exposure to contaminants in

Data gap identified	Potential significance
	waste (including asbestos, if present) to future users.
Potential contaminants not assessed in groundwater under the Proposal Site EPL	The following potential COPC have not been assessed in groundwater under the Proposal Site EPL: • PCBs – potentially present in C&D waste which could have been contaminated by light fittings or transformer oils. However, no PCBs have been detected in surface water sampling (including leachate pond) which indicates that the potential is low. • Tributyltin (TBT). Waste in cell B10 may include dredge spoil contaminated with this anti-foulant. However this cell is emplaced on a clay liner, limiting the potential for this contaminant to enter groundwater. • Per-and polyfluorinated alkyl substances (PFAS). PFAS is frequently reported in landfills with C&D waste (Gallen *et al* 2017). It is noted that ecological criteria at the time of writing are extremely low, and the Towra Point Nature Reserve is a sensitive receptor in close proximity to the Proposal Site. However, it should also be noted that Botany Bay is an NSW EPA PFAS investigation area, with a number of potential PFAS inputs.

11. Mitigation measures

This section provides indicative measures to reduce risks and impacts related to identified contamination and data gaps described in this report.

The objective of these measures is to describe how potential risks posed by contamination to human health and the environment can be reduced to acceptable levels. Contamination risks should be reduced by:

- Implementing mitigation measures described in the following sections.
- Implementing other mitigation measures described in relevant technical reports prepared for the Proposal Site, such as the Groundwater Impact Assessment (GHD, 2021).
- Designing and undertaking the project to reduce risks related to soil, groundwater, surface water, leachate and ground gas contamination.
- Undertaking additional contamination investigations to address any data gaps, as described in Section 10.7.
- Managing contamination risks in line with relevant legislation (Section 2).
- Undertaking construction activities in line with the Blue Book (Landcom, 2004).
- Preparing, and implementing a Proposal Site Closure Plan in accordance with NSW EPA guidelines.

Mitigation measures should be developed for the contamination, design, construction and operation of the Proposal Site. Potential measures are discussed in Table 19.

Table 19 Mitigation measures for potential contamination

Issue	Mitigation measure
Addressing identified data gaps	Additional environmental investigations could be carried out for the data gaps in Section 10.7 and in accordance with NEPM and other regulations.
Ground gas management and monitoring	Procedures to manage hazardous ground gases need to be included in a Proposal Site Closure Plan, which outlines Proposal Site closure requirements to meet NSW EPA guidelines. Construction of any future structures (eg BBQ facilities) on will be required to be completed in accordance with the Proposal Site Closure Plan.
Managing potential risks posed during construction	A CEMP should be developed for construction works to outline how the project will avoid, reduce or mitigate effects on the environment. The CEMP should consider a number of subjects applicable to the redevelopment such as – but not limited to – groundwater, surface water, soil and air quality, dust generation, noise and vibration, waste and drainage. The CEMP should include an unexpected contamination finds protocol to be implemented during construction. If signs of contamination are encountered during construction, such as odours, staining and ACM, work in the area should be stopped and contamination managed in accordance with an unexpected contamination finds procedure.
Acid sulphate soil	While most of the Proposal Site has already been disturbed and mined, some ASS may be present in undisturbed areas and on site boundaries. Disturbance of these areas is not understood to be included in the

Issue	Mitigation measure
	Proposal, due to heritage constraints. Should disturbance of natural ground be required in future, an acid sulphate soil management plan (ASSMP) should be developed in line with the Acid Sulfate Soil Manual (Stone at al., 1998).
Validation of the Proposal Site capping system	Capping of the landfilled waste will need to meet NSW EPA landfill closure requirements and a Proposal Site Closure Plan will also be required to detail capping aspects.
Long-term management and monitoring	Long-term, ongoing environmental management requirements will need to be identified within a Proposal Site Closure Plan; to be prepared in accordance with NSW EPA Guidelines.

12. Conclusions

Based on the scope of work undertaken (Section 1.9), the data and assumptions described in this report, and subject to the limitations in Section 1.10, the following conclusions are reached.

This investigation has assessed the current contamination status of the Proposal Site using available soil, groundwater, ground gas, pore water and surface water data and evaluated the potential for complete source-pathway-receptor linkages that might exist in the context of current Proposal Site use and the proposed future use, which includes recreation/public open space in the western portion of the Proposal Site and a New Resource Recovery Facility in the eastern portion.

The primary source of contamination at the Proposal Site is mainly derived from landfilling activities within the western portion, which has occurred after historical sand mining pits were backfilled with VENM and some minor amounts of PASS (below the groundwater table) in accordance with EPL 4608. Placement of waste has resulted in leachate generation as well as production of ground gases such as methane and carbon dioxide, which is typical of landfill sites.

Available soil data from stockpiled recovered fines/ recovered aggregate analysis indicate that contaminant concentrations meet the analytical thresholds in their respective exemptions, and are all below adopted human health criteria for current and future use (recreation / public open space and commercial). Concentrations are also generally below adopted ecological criteria for future use.

Leachate/groundwater samples within the waste mass show impacts with nutrients, (most notably ammonia) and moderate concentrations of heavy metals and petroleum hydrocarbons. Other organic contamination such as PAHs, phenols and pesticides have not been detected.

These impacts are reflected, to a lesser extent, in groundwater at perimeter monitoring locations around the Proposal Site, with the greatest concentrations of ammonia (a leachate indicator) in BH5A off-site to the north, towards Towra Point Nature Reserve. However, surface water data collected from on-site locations, apart from the lined leachate pond, did not show significant nutrient impacts (i.e. ammonia concentrations did not exceed the ANZG (2018) marine water criteria, except in the lined leachate pond SW4), although concentrations of heavy metals were above adopted ecological criteria.

Off-site surface water sampling to the south did not indicate the likelihood for any significant impacts to fresh water ponds, with virtually all contaminant concentrations below adopted freshwater ecological criteria; only one duplicate copper result slightly exceeded the trigger value.

Off-site surface water and pore water to the north indicated impacts in both media from nutrients and heavy metals in excess of 95% species protection for marine ecological receptors (ANZG, 2018). However, analysis of the relationship between surface water, pore water and up-gradient groundwater concentrations does not clearly link the observed surface water impacts to groundwater migrating from the Proposal Site, as in most cases the pore water concentrations are greater than measured upgradient groundwater concentrations for COPC. Given the extensive industrial use of Botany Bay which continues to the present, background sources of impacts cannot be precluded, and are in fact, likely.

Ground gases (methane and carbon dioxide) are present above adopted trigger levels in the waste mass. However, surface monitoring, indoor accumulation monitoring and perimeter in-ground monitoring do not indicate that gases are migrating off-site or into confined spaces and posing a risk.

Data gaps have been identified and evaluated; these primarily relate to the potential for minor localised contamination to be present from Proposal Site operations, the potential for asbestos to be present, and the potential for contaminants other than those specified in EPL 4608 to be present in leachate (PCBs, TBT and PFAS). These data gaps have been assessed as generally low significance, with the potential exception of PFAS, which is a known presence in landfill leachates, and is an emerging contaminant with uncertainty in respect of environmental effects. It is also noted that Botany Bay is a NSW EPA PFAS investigation area due to the many potential sources of PFAS associated with industrial use.

Review of potential source-pathway-receptor linkages for the current use does not identify any that are, or are likely to be, complete, with the possible exceptions of:

- Aesthetic (odour) issues for off-site receptors
- Leaching from waste to on-site groundwater resources
- Direct contact to potential localised contamination (if present) for transient wildlife on Proposal Site
- Possible migration of contaminants via groundwater to Towra Point Nature Reserve
- Potential for exposure to hazardous ground gases by intrusive maintenance workers for any excavation work into waste materials.

In respect of future land use (recreational /open space in the western portion and commercial industrial at the New Resource Recovery Facility in the east), the landfilling areas of the Proposal Site will be capped in accordance NSW EPA landfill closure requirements, which include mitigation of ground gases and specifications for clean capping materials in the final landform.

With this in mind, the review of potential source-pathway-receptor linkages for the future use can be split into three areas:

1. Area 1 - Capped areas of landfilled waste in the west which will be public open space / recreational
2. Area 2 - New cell B11 (with geosynthetic liner) in the central eastern portion of the Proposal Site, which will be operational for the next few years
3. Area 3 - New Resource Recovery Facility in the east of the Proposal Site (being Lot 5), which will be primarily sealed.

Source-pathway-receptor linkages for these future scenarios are not identified to be complete, or likely to be complete based on the available data, with the exception of the following:

- Leaching from waste (Area 1 only) to on-site groundwater resources. The potential for this is likely to be reduced post capping due to infiltration reduction.
- Potential for exposure to hazardous ground gases by intrusive maintenance workers (Area 1 only) for any excavation work over capped waste.
- Potential exposure to leachate by Proposal Site workers on-site by direct contact during use for irrigation, if applicable, at Cell B11 (Area 2), which can be managed by WH&S protocols.

While there does not appear to be a direct link between leachate impacts (most notably ammonia, but also to a lesser extent heavy metals) in groundwater at the Proposal Site with off-site surface water, the data suggests that leachate from the Proposal Site is likely to have migrated beyond the northern Proposal Site boundary in groundwater in excess of adopted criteria (for example, see historical groundwater analytical ammonia results for wells BH3A, BH5A and BH12A). This issue has been, and will continue to be, discussed with the EPA. It is

noted that appropriate Proposal Site closure of non-operational portions of the Proposal Site in accordance with NSW EPA requirements will result in a large overall reduction in the generation of leachate associated with the Proposal as opposed to existing conditions, which is expected to result in groundwater of improved water quality and lower volume migrating off-site (GHD 2021).

No significant contamination constraints to the Proposal have been identified based on the available data. It is considered that the Proposal Site can be made suitable for its intended uses (including for the purposes of SEPP55) subject to the mitigation measures described in this document being implemented. This will need to include the development and implementation of a Proposal Site Closure Plan in accordance with NSW EPA guidelines, which outlines requirements for capping, landfill gas management and long-term environmental monitoring.

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