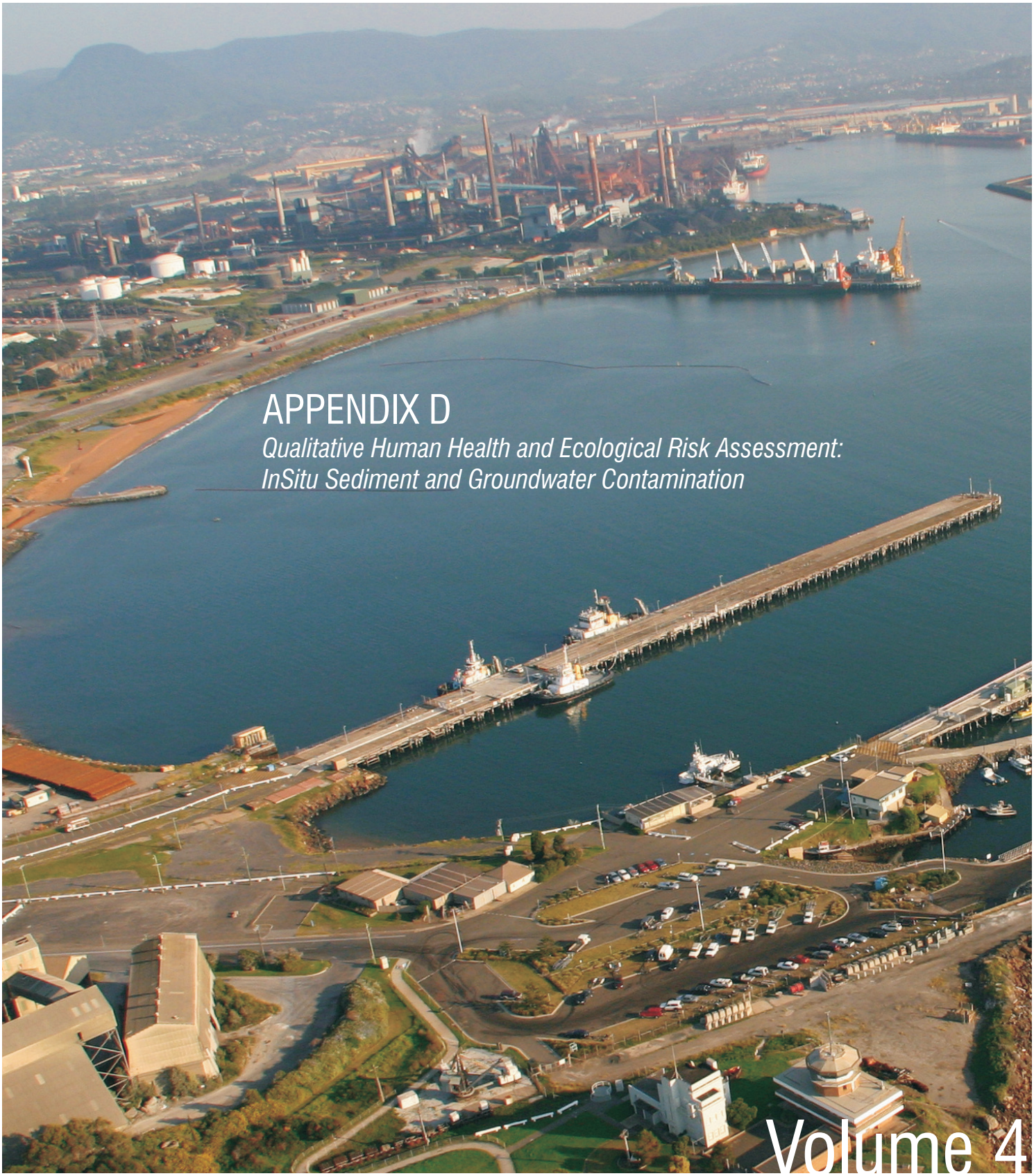

APPENDIX D

Qualitative Human Health and Ecological Risk Assessment: InSitu Sediment and Groundwater Contamination

Volume 4

F I N A L

Qualitative Human Health and Ecological Risk Assessment - In Situ Sediment and Groundwater Contamination

Port Kembla Outer Harbour Port Kembla, NSW

Qualitative Human Health and Ecological Risk Assessment - In Situ Sediment and Groundwater Contamination

Port Kembla Outer Harbour Port Kembla, NSW

Prepared for

Port Kembla Port Corporation

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Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature

Contents

Glossary of Terms

AHD	Australian Height Datum
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CMA	Catchment Management Authority
CoPC	Chemical of Potential Concern
CSM	Conceptual Site Model
DECC	Department of Environment and Climate Change
DoP	Department of Planning
IRIS	Integrated Risk Information System
LOAELs	Low Observed Adverse Effect Level
mBGL	metres Below Ground Level
MW	Monitoring Well
NHMRC	National Health & Medical Research Council
NOAELs	No Observed Adverse Effect Levels
NSW	New South Wales
OCP	OrganoChloride pesticides
OPP	Organophosphate Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PEA	Preliminary Environmental Assessment
PKPC	Port Kembla Port Corporation
PKOH	Port Kembla Outer Harbour
PPE	Personal Protective Equipment
QA/QC	Quality Assurance/Quality Control
QHHERA	Qualitative Human Health and Ecological Risk Assessment
RSLs	Regional Screening Levels
SPOCAS	Suspension Peroxide Oxidation Combined Acidity & Sulfur
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
WCC	Wollongong City Council
WHO	World Health Organisation

Executive Summary

AECOM has undertaken a qualitative assessment of the nature and extent of reported sediment and groundwater contamination within the Port Kembla Outer Harbour (PKOH) and Outer Harbour Lands, and developed a conceptual model describing contaminant transport and exposure pathways by which human and ecological receptors may be exposed to reported sediment and groundwater contaminants.

Based on the assessment, the following conclusions and recommendations are provided:

Potential Human Health Risks

Potential risks to human receptors have been assessed as low or moderate for most receptor/exposure pathway combinations. Potential human health risks which are assessed as potentially 'moderate' include those associated with the following:

- Direct contact with surface water by recreational users or dredging workers
  - The moderate risk rating for these exposures is due to significantly elevated cadmium concentrations reported in a couple of isolated harbour surface water samples. It appears that the cadmium analytical results may be erroneous based on other harbour surface water, sediment and elutriate analytical results as part of this investigation and historical water quality data in the Outer Harbour
- Direct contact with groundwater by intrusive workers
  - While risks were assessed as moderate for these receptors, the extent of exposure is considered likely to be very low for any individual receptor, and potential risks can be managed with the use of appropriate personal protective equipment/clothing and hygiene procedures.

Potential Human health risks assessed as potentially 'high' (on a qualitative basis) if uncontrolled by appropriate design of the dredging work include the following:

- Ingestion of edible fish tissue with elevated Chemical of Potential Concern (CoPC) concentrations due to foraging/exposure in the PKOH
  - The potentially high risk rating for these exposures has been based on significantly elevated concentrations of CoPC reported in sediments.
  - It is considered that potential risks associated with this exposure pathway warrants further qualitative assessment prior to the commencement of dredging works. This further assessment would be based on detailed design of the dredging works and specific environmental management techniques which aim to minimise and control the dispersal of contaminated sediment

Potential Ecological Risks

Potential risks to a number of ecological receptors have been assessed as potentially high based on reported elevated concentrations of CoPC in harbour sediments and the presence of ecological receptors within surface water and sediment. However it should be noted that the overall aquatic ecological environment within PKOH is already highly modified due to:

- Physical modifications of the harbour (e.g., construction of breakwaters and jetties and dredging and reclamation activities) associated with development of the port;
- The industrial nature of the surrounding area;
- Reported presence of pest species due to ballast discharge with the PKOH; and
- The high level of boat/shipping activity within the PKOH.
- The ecological value of the PKOH area itself is therefore considered to be generally low.

The majority of dredging for the total development will be undertaken as part of Stage 1. Dredging within Stage 1 would include areas between the multi-purpose terminals and the container terminals, and east of the container terminals. A combination of dredging types will be employed for the dredging campaigns for Stage 1, similar to previous dredging campaigns undertaken within the Inner Harbour.

Dredging and dumping operations will require the installation of silt curtains around the dredging area directly in front of the grab/backhoe dredge. Silt curtains utilised during the dredging activities will be woven geotextile or other similar suitable material. In addition to the silt curtain for dredging operations, silt curtains will be used within each of the active reclamation areas.

An existing spoil emplacement area, bounded in part by underwater bunds constructed from slag material, overlaps with the proposed berth basin between the multi-purpose and container terminals. This emplacement area was

constructed using slag bund walls to contain the dredge spoil from the Inner Harbour. Some of the previously deposited material will require extraction during the dredging operations for construction of both permanent and temporary edge structures and to provide adequate vessel keel clearance.

Material to be extracted/ dredged is proposed to be incorporated within the reclamation footprint for the proposed development and will be transferred to a series of bunded enclosures to serve as a longer term consolidating material. Relocation of this dredged material within the bunds will occur during Stage 1a and Stage 1c construction activities. A basic methodology to relocate these contaminated sediments to bunds within the reclamation footprint has been proposed.

Further qualitative assessment of potential ecological risks should be based on detailed design of the dredging works and specific environmental management techniques which aim to minimise and control the dispersal of contaminated sediment. The qualitative assessment would have regard to the higher value receptors/areas which may be indirectly affected by sediment contamination within the PKOH such as indirect risks to human health and the marine aquatic ecosystem.

Recommendations

The assessment concludes that the potential risks identified for workers and the public may be managed by consideration of the nominated exposure pathways, and through suitable design of construction methodologies (e.g. sediment curtain, wet emplacement of dredged materials, an environment management plan for construction worker personnel protective equipment). Ecological community risks are considered manageable through consideration of the nominated exposure pathways, and suitable design of dredging methodologies and adoption of appropriate environmental management measures (e.g. sediment curtains, piping of sediment to the emplacement area).

Based on the results of the QHHERA, the following recommendations are provided:

- Potential risks to intrusive maintenance or construction workers due to direct contact with groundwater in the Outer Harbour Lands should be managed and minimised through the use of personal protective equipment/clothing and hygiene procedures;
- The issue of contaminated sediment dispersal with respect to effect on potential ingestion of CoPC in edible fish be subjected to further qualitative assessment prior to commencing dredging works. This assessment to be based on detail design of the dredging works and specific environmental management safeguards aimed at minimising and containing contaminated sediment dispersal;
- Given the highly modified nature of the aquatic environment with the PKOH (and therefore the inferred relatively low ecological value of the area) a further qualitative assessment of contaminated sediment dispersal is undertaken prior to commencing dredging works to assess potential risks to ecological receptors. This assessment to be based on detail design of the dredging works and specific environmental management safeguards aimed at minimising and containing contaminated sediment dispersal.
- PKPC should consider the final chosen design of suitable dredging technologies and use of sediment curtains or other environmental mitigation measures to minimise the dispersal of contaminated sediments during dredging;
- PKPC should confirm that dredged sediment which is to be reclaimed is placed in a suitably constructed containment area to minimise interaction (slumping or leaching) with the surrounding harbour waters;
- PKPC should undertake water quality and turbidity monitoring in the Outer Harbour prior to and during the proposed dredging works.

1.0 Introduction

AECOM was commissioned by Port Kembla Port Corporation (PKPC) to undertake a Qualitative Human Health and Environmental Risk Assessment (QHHERA) of *in-situ* sediment and groundwater contamination within the Port Kembla Outer Harbour (PKOH, hereafter referred to as 'the Site'). This QHHERA is part of an Environmental Assessment (EA) and associated specialist studies being undertaken in the context of a proposed development of the Outer Harbour to accommodate multi-purpose and container terminal facilites (also being prepared and managed by AECOM).

Port Kembla Port Corporation is seeking concurrent Concept Plan approval for the total development and Major Project approval for Stage 1 of the development. The Major Project sits within, and is part of, the overarching Concept Plan framework. A brief description of the Concept Plan and Major Project is provided below. Further discussion on the framework of the Concept Plan and Major Project is presented in Sections 5 and 6 of the Environmental Assessment report.

Concept Plan Outline

The Outer Harbour development is to be constructed in three discrete stages over the next 30 years with an anticipated completion date of 2037. Concept Plan approval is being sought for the total development. Construction of the Concept Plan would be staged to meet the needs of prospective customers, to cater for growing port needs and regional development, and to increase the potential to address the needs of new industry for 30 plus years into the future.

The Concept Plan provides a framework for the progressive completion of the Outer Harbour development and comprises creation of land dedicated to port activity. The reclaimed land will be divided into two main areas, one devoted to the import and export of dry bulk, break bulk and bulk liquid cargoes (multi-purpose terminals) and one devoted to container trade (container terminals).

Once the Concept Plan is completed, the reclamation footprint of the development will extend from the existing Port Kembla Gateway jetty in the north to Foreshore Road in the south, the boat harbour to the east and existing rail sidings to the west.

Major Project Description

Major Project Approval is being sought to construct and operate Stage 1 of the Concept Plan. Construction of the Major Project would be divided into three sub-stages, identified as Stage 1a, Stage 1b and Stage 1c. Construction elements of Stage 1 comprise demolition of No.3 and No.4 Jetties, and reclamation and dredging for the footprint of the total development, with the following exceptions:

- An area in the vicinity of the Port Kembla Gateway.
- Expansion of the current swing basin area (ship turning circle).

At the completion of Stage 1 the central portion of the multi-purpose terminals would be operational. Road and rail infrastructure to support the first multi-purpose berth would also be constructed

The Major Project application sits within, and is part of, the overarching Concept Plan. Stage 1 is proposed to be constructed between 2010 and 2018. Major Project Approval would allow PKPC to commence reclamation and dredging for the multi-purpose and container terminals and construct and commence operations for the first multi-purpose berth. Major Project Approval for Stages 2 and 3 of the Concept Plan would be subject to separate applications for Project Approval made at a later date.

Outlines of both the Concept Plan and the Major Project Plan have been considered in this qualitative risk assessment, with the Major Project description providing a focus for the detailed aspects of the risk assessment report. The Concept Plan approval includes the activities of the Major Project Approval as well as:

- Construction and operation of the balance of the second multi-purpose terminal
- Construction and operation of the balance of the container terminal
- Associated berthing facilities, road and rail infrastructure

The focus of this QHHERA includes identified sediment contamination within the PKOH, and identified groundwater contamination in the PKOH Lands. It is noted that groundwater contamination has been considered with respect to potential discharge to sediment and surface water.

The Site comprises the area proposed for development of the multi purpose terminal and container terminal. The location of the Site is illustrated on **Figure F1**, and the area considered in this QHHERA is shown as proposed dredged areas and reclamation areas in **Figure F2**.

1.1 Objectives

The objectives of the QHHERA included the following:

- Qualitative assessment of the potential for adverse human health or environmental risks associated with identified *in-situ* chemical contamination within PKOH sediments;
- Qualitative assessment of the potential for adverse human health or environmental risks associated with identified chemical contaminants in groundwater in the PKOH Lands; and
- Qualitative assessment of the potential risks associated with redistribution or dispersal of contaminants during dredging or emplacement of sediment in the reclamation areas following dredging.

This risk assessment, by agreement with the DECC, focuses on sediment and groundwater contamination risks at the subject site.

1.2 Scope of Work

The scope of work undertaken to achieve the above objectives included the following:

- Consideration of previous environmental assessment reports relevant to sediment and groundwater quality within the PKOH area;
- Identification of the nature and extent of sediment and groundwater contamination;
- Identification of chemicals of potential concern (CoPCs) in sediment and groundwater, based on comparison of chemical concentrations reported in previous assessment reports to relevant investigation or screening levels for protection of human or ecological receptors;
- Development of conceptual exposure assessments for human and ecological receptors, describing the pathways by which these receptors may be exposed to CoPCs in or deriving from sediment or groundwater;
- Qualitative consideration of potential risks to human and ecological receptors associated with sediment and groundwater contamination, based on considerations such as:
    - The nature and concentrations of contaminants exceeding relevant investigation or screening levels.
    - The expected nature and frequency of exposure by identified receptors.
    - The relevance of the adopted screening or investigation levels to the receptors and/or exposure pathways of concern.
- Preparation of this report summarising the results of the above, and providing conclusions and recommendations regarding potential risks associated with *in-situ* sediment and groundwater contamination in the PKOH and mitigation measures to move those risks.

It is noted that the data available upon which to base the QHHERA is limited primarily to in-situ sediment and groundwater data, and data relating to potential elutriation of contaminants from sediment following exposure to seawater. Additional data required to further assess potential risks associated with alteration of sediment chemistry, toxicity or benthic community structure during dredging (e.g., sediment and/or pore water toxicity tests) are not available at this time.

2.0 Site Identification

2.1 Site Description and Current Land Use

Port Kembla (the Port) is located in the Wollongong Local Government Area and is approximately 80 km south of Sydney's CBD and 60 km from Sydney's south western suburbs. The Port is considered to be one of NSW's three main international trade ports.

The PKOH extends from the southern shoreline to the northern and eastern breakwaters and is defined as the bed of the PKOH. The Port Kembla eastern breakwater lies at the eastern extent of the PKOH and the land based area of the PKOH is bounded by Foreshore Road and Old Port Road to the south and west. The existing shipping channel and northern breakwater lie in the northern portion of the PKOH.

The Site consists of a body of water enclosed on the south and west by the foreshore and the north and east by the northern and eastern breakwaters.

The Site and the immediate surrounding area is characterised by a mixture of both the built environment and natural features (refer to AECOM 2009a, **Figure F2**), which include:

- Three jetties (identified as No. 3, No. 4 and No. 6 Jetties) and an inflammable liquids berth. No. 6 jetty is located in the south western area of the Site and extends from the foreshore in a north easterly direction into the Site and is approximately 200 m in length. This jetty is currently under a long term lease to Gateway and the wharf structure has undergone major strengthening works over the past 15 years. Jetties No. 3 and No. 4 are located in the south eastern corner of the Site. Jetty No. 3 was strengthened and modified in 2000 and currently serves as a tug berth for all tugs operating in the Harbour. Jetty No. 4 underwent major modifications in 1998 and currently serves as a non flammable bulk liquids jetty;
- A saltwater intake channel that supplies cooling water for BlueScope Steel operations located on the south eastern corner of the entrance to the Inner Harbour ;
- A concrete lined storm water drain, identified as Darcy Road drain, located adjacent to lots currently occupied by Brick and Block and Sydney Water;
- Salty Creek, which extends from an area adjacent to the Port Kembla railway station and flows via a culvert under Old Port Road and discharges to the PKOH;
- A small recreational boat harbour and boat ramp located adjacent to the eastern breakwater;
- A number of commercial and industrial operations on and immediately adjacent to the Site's foreshore include PKPC, Port Kembla Gateway Pty Ltd, Brick and Block manufacturing structural masonry products, Morgan Cement, BlueScope Steel, Orica Chemnet, Port Kembla Copper and BHP Billiton;
- An existing rail network (including rail corridor and sidings) located between Darcy Road and Foreshore Road, Old Port Road and Five Islands Road, recently acquired by PKPC; and
- Port Kembla Heritage Park located on the southern headland adjacent to the Site, south of the eastern breakwater. Heritage Park has been developed to conserve military, cultural and historic heritage in the area.

2.2 Surrounding Land Use

The Site is surrounded by commercial/industrial properties to the south and south west of the Site. The closest residential and commercial properties to the south west of the Site are located along Wentworth Road, approximately 400 m from the Site's foreshore. Housing is also located to the south along Electrolytic Street, approximately 600 m south of Foreshore Road.

The Five Islands Nature Reserve, a cluster of Islands, which include Flinders Islet, Bass Islet, Martins Islet, Big Island and Rocky Island are located between 1.5 km and 2.0 km to the south east and east of the Port. The Islands provide habitat to breeding and feeding sea birds which include endangered species (the southern giant petrel and sooty tern).

Wollongong sewage treatment and recycling plant is located approximately 2 km north of the northern breakwater. The 1 km long discharge pipe for the plant extends in a south eastern direction towards the breakwaters. The Port Kembla storm sewage treatment plant is located on Red Point approximately 2 km south of the Site.

2.3 Sea Bed Conditions and Stratigraphy

Sediments within the Site are affected by both natural processes, such as tidal flushing and longshore drift and to a lesser extent mechanical mixing from deep draft vessels and tug boat movements.

The bed profile at the Site comprises a layer of marine estuarine sediments which comprise silty clays, sandy silts and silty sandy clays with fine to coarse gravels. Based on previous studies the Site is characterised by a grain size gradient with coarse sand and fine gravels present around the breakwatersand central area of the Site with fine grained silty, sandy clays present towards the entrance to the Inner Harbour.

The surficial sediments are underlain by stiff alluvial clays and shallow bedrock. Rock contours indicate a rock level of RL-17 m just below the PKOH turning basin which grades upwards towards the south west of the Site and varies between RL-7m to RL -15m under the shoreline. Other key features include a valley present beneath Jetty No. 3 and a ridge of high rock located in the western portion of the Site toward the Port Kembla Gateway Jetty (Jetty No. 6) and an area of high rock close to the shoreline near Jetty No. 3.

An underwater emplacement (disposal) area is also present in the western portion of the Site nearest the shoreline. Prior to construction of the underwater emplacement area the water depth in this area increased rapidly from the shoreline. The underwater emplacement area contains a variety of material types, generated from historical dredging campaigns in the Inner Harbour and is discussed further in this report.

2.4 Aquatic Ecology

The main habitats for aquatic flora and fauna at the Site are the soft, deposited bottom sediments, the extensive constructed rocky revetments and the water column.

2.4.1 Flora

Sediments

Neither mangroves nor sea grasses have been recorded in previous studies of the Site. Wave action and high turbidity do not provide a suitable habitat for their occurrence.

Low levels of cysts of the potentially toxic dinoflagellate *Alexandrium* have been found in all bottom sediments. When disturbed, these cysts can develop into algal blooms causing toxins to accumulate in shellfish and leading to Paralytic Shellfish Poisoning in humans.

Revetments

Many species of macroalgae (seaweed) have been found in PKOH on hard substrata. The existing revetment walls provide potential habitat for macroalgae at shallower depths where light penetration is adequate. Macroalgae provide habitat for invertebrates and fishes. No introduced macroalgae species have been found in PKOH.

Water Column

There is no evidence of a toxic bloom having occurred in harbour waters although concern has been expressed that this may occur if cysts present in bottom sediments are disturbed during times when ambient conditions are suitable for germination.

2.4.2 Fauna

Sediments

The lack of sea grass and mangrove habitat limits the assemblage of marine organisms to benthic invertebrates, such as worms and bivalves, in the soft sediments. These organisms provide food for fish and, despite contamination, these sediments would be regarded by NSW Fisheries as feeding habitat for fish.

Revetments

The rock revetments have been identified as potential habitat for juveniles of one threatened fish species, the black cod (*Epinephelus daemelii).* However, the species has not been observed within the Outer Harbour. The revetments support a range of attached and mobile (e.g. starfish) invertebrate species which provide food for other species. A variety of pest species also colonize hard substrata in the Harbour as a result of the discharge of ballast water. These include sponges, anemones, hydrozoans, bryozoans, polychaete worms, barnacles, crustaceans, ascidians and pest fish (goby) species.

Water Column

A large number of fish species have been recorded feeding in PKOH. None of the recorded fish are listed under the NSW *Fisheries Management Act*.

3.0 Nature and Extent of Contamination

3.1 Previous Investigation Results

At least 75 reports and/or data sets potentially relevant to the site were identified by PKPC, and 32 were provided to AECOM by PKPC for review. Of these 32 reports, only those undertaken after 2002 (i.e., after implementation of the current NSW guidelines and regulations relating to contamination assessment) were reviewed for this investigation. Those investigations with data pertinent to sediment and groundwater quality within the PKOH (sediment) or the Port Kembla Outer Harbour Lands (groundwater) are summarised below.

3.2 Sediment Quality

3.2.1 Report on Sediment Sampling and Analysis, Port Kembla Port (Douglas Partners, 2002)

Douglas Partners was commissioned by PKPC to undertake a sediment investigation of a proposed maintenance dredging area for disposal purposes. Of the 74 sediment cores retrieved, only one sediment core on which very limited analysis was undertaken was determined to be specific to the Site. It is AECOM's opinion that whilst the report provides generic information on sediment quality within the maintenance dredging area, it does not provide specific data which can be relied on for the Site.

3.2.2 MPB3 & EB4 Dredging and Disposal to the Outer Harbour Environmental Assessment (Patterson Britton 2005a)

The purpose of this investigation was to assess the sediment quality of material proposed to be dredged from the Inner Harbour and disposed to the Outer Harbour, as well as to assess its suitability for sea disposal. Samples were retrieved using a combination of vibracoring and sediment grabs.

Reported chemical concentrations in sediment samples were assessed against the ANZECC (2000) Interim Sediment Quality Guidelines (ISQGs), the results of which indicated the following:

- Sediments from the Site comprised very soft dark grey to black silty clay;
- Concentrations of arsenic, cadmium, chromium, nickel, tributyltin (TBT) and total polycyclic aromatic hydrocarbons (PAH) exceeded the ISQG-Low;
- Concentrations of copper, lead, mercury, silver, zinc, and naphthalene exceeded the ISQG-Low;
- Comparison of the results indicated that for the majority of compounds tested, concentrations of contaminants in the Site's sediments were similar to or higher than the dredged material from the Inner Harbour;
- Concentrations of arsenic, copper, lead, mercury, silver and TBT were reported to be higher than those of the dredged sediments from the Inner Harbour whilst concentrations of chromium, zinc and PAH were greater in the dredged sediments.

AECOM notes that 12 sample locations in the area of the proposed development do not provide sufficient coverage or sampling locations in the areas proposed for dredging as part of the Major Project area. Given the limited set of data for the proposed Major Project area, AECOM proposed a broad grid based and targeted sampling program as part of the 2009 sediment investigation across the proposed dredging footprints for the Major Project Approval of the Site's expansion (see **Section 3.2.4)**.

3.2.3 Port Kembla Outer Harbour Reclamation Area Sediment Sampling and Testing (Patterson Britton 2005b)

This investigation was undertaken on behalf of PKPC at the Site. The objective of the sediment investigation was to assess the potential impacts of disposal within the proposed PKOH development reclamation area.

The scope of work included collection and laboratory analysis of sediment samples from 12 locations at the Site including both surface (grab) and subsurface (vibracore; maximum depth of 500 mm) samples.

The results of the investigation indicated the following:

- The 95% Upper Confidence Limit (UCL) of the mean concentration for most analytes (metals, total petroleum hydrocarbons, PAHs, polychlorinated biphenyls, organochlorine pesticides and organotins) were generally above the ISQG-Low;
- The 95% UCL's for copper lead, mercury, silver zinc and naphthalene were above the ISQG-High.

3.2.4 Sediment Investigation, Outer Harbour Port Kembla (AECOM, 2009a)

AECOM undertook a sediment investigation including collection and analysis of sediments from three areas: the eastern dredge footprint, central dredge footprint and the emplacement area. The objectives of this investigation

included characterisation of the lateral and vertical distribution of contaminated sediments in the proposed dredging area and collection of data for the qualitative human health and ecological risk assessment (this investigation).

Sediment samples from the anoxic and oxidic layers were collected based on a systematic grid sampling pattern within locally biased sampling areas (i.e., sampling areas were selected to include potential contamination hotspots). Sampling was conducted by piston core, vibracore and modified Smith-McIntyre grab methods.

The results of the sediment investigation indicated the following:

- Heavy metals contamination (concentrations exceeding their respective ISQG-Low trigger values) was identified across the majority of the sediment investigation (SI) area within the shallow sediments (approximately 0-0.3 m below sediment surface);
- The highest heavy metals concentrations (with concentrations greater than their respective ISQG-High) were identified predominantly within the top 1.0 m of the emplacement area at locations VC03 (between 0 and 1.3 m bgs), VC04 (between 0.2 and 0.8 m bgs), VC07 (between 0.2 and 0.4 m bgs), VC08 (between 0.5 and 2.8 m bgs) and VC09 (between 0.3 and 0.8 m bgs);
- Copper and lead concentrations (and to a lesser degree arsenic) exceeded the NEPM Health Investigation Levels 'F' (commercial/industrial) criteria in relatively localised areas at the southern end of the eastern dredge footprint (in the vicinity of PC22) and also in the vicinity of the Darcy Road Drain (the PC34 area);
- PAH contamination (concentrations exceeding their respective adopted assessment criteria) was identified across the majority of the SI area within the shallow sediments (approximately 0-0.3 m bgs);
- The highest PAH concentrations (concentrations greater than their respective ISQG-High) were identified within the emplacement area at locations VC01, VC05, VC06, VC07, VC08, VC09, PC64, PC53, PC38, PC39, PC42, PC43, PC45 and PC63. The concentrations generally correlated with field observations within this area where possible hydrocarbon/chemical and hydrogen sulphide odours were noted during sampling activities;
- Isolated PAH concentrations exceeding the ISQG-High were identified to the maximum investigation depths of 0.53 and 0.35 at PC19 and PC25 respectively within the proposed eastern most dredging area;
- PAH contamination was generally identified to the maximum depth of sediment sampling, which varied between 0.05 and 3.3 m bgs;
- The extent of TBT contamination (concentrations greater than the ISQG-Low and High) appeared to be confined to the southeastern-most corner of the SI area adjacent to the eastern breakwater and centred around location PC20 and extending to PC22, PC31, PC19 and SG1 (refer AECOM 2009a, **Figure F17**). Other isolated areas of TBT exceeding the ISQG-Low were identified at PC56, PC54, PC34, PC38, PC39, PC49 and PC50;
- Elutriate results indicated the following:
    - There is a potential for copper, arsenic, vanadium and zinc to be released into the water column during dredging at concentrations above relevant ANZECC (2000) 95% Marine Trigger Values;
    - Vanadium and zinc exceedences were reported to be isolated and were restricted to only a few locations located beneath the proposed multi purpose terminal;
    - Arsenic exceedences were reported in 39 out of 51 samples, including those collected across both the central and eastern proposed dredging areas;
    - Copper concentrations in elutriate samples were reported up to 11 µg/L, or approximately ten times background concentrations in seawater (1 to 2 µg/L).

3.3 Groundwater Quality

3.3.1 Groundwater Monitoring Well Installation & Groundwater Monitoring Program, Proposed Hyrock Site, Eastern Corner, Old Port Road and Christy Drive Port Kembla New South Wales, (Absolute Environmental 2004)

Hyrock commissioned Absolute Environmental to install four groundwater monitoring wells and undertake two groundwater monitoring events (GME's) at the proposed Hyrock Site at the eastern corner, Old Port Road and Christy Drive, prior to redevelopment of the Site.

The objective was to assess current groundwater conditions in the area of the site reported to be down hydraulic gradient of an identified area of soil impacted with heavy metals and PCB's.

The scope of works included installation of four groundwater monitoring wells at the PKOH Site and two rounds of groundwater sampling and analysis.

The groundwater investigation results indicated the following:

- Groundwater flow direction was from west to east;
- Arsenic concentrations above laboratory quantitation limits (EQLs) were detected in all wells on the Site at concentrations between 2 µg/L and 75 µg/L;
- Arsenic concentrations in regional groundwater for the Port Kembla area were reported to range from 100 µg/L to 200 µg/L, with a maximum peak of 500 µg/l;
- Zinc concentrations above laboratory EQL were detected in all wells on the Site at concentrations from 39 µg/L to 120 µg/L;
- Reported arsenic concentrations in groundwater were reported to be likely due to background levels resulting from natural sedimentary soils at the Site;
- Reported zinc concentrations in groundwater do not warrant remediation, however future groundwater monitoring undertaken by PKPC as part of their water quality management program should include the Hyrock site and wells located along the foreshore between No. 3 and No. 6 Jetties along, Old Port Road, Christie Drive and Foreshore Road.

3.3.2 Lot 201, Old Port Road, Port Kembla, NSW (SKM 2004)

SKM was commissioned by the SRA to undertake a combined preliminary and detailed site investigation at Lot 201, Old Port Road, Port Kembla, NSW. The scope of work relevant to groundwater quality included installation of four groundwater monitoring wells, and sampling and analysis of groundwater samples.

Concentrations of cobalt, copper, nickel and zinc were reported in groundwater at the Site above the ANZECC (2000) Marine Trigger Values (95%).

3.3.3 Phase II Environmental Site Assessment Port Kembla Port Corporation Inner and Outer Harbour Soil and Groundwater Assessment Port Kembla NSW (URS 2004)

URS was commissioned by PKPC to undertake a Soil and Groundwater Assessment of the Inner and Outer Port Kembla Harbour. The primary objective of the investigation was to assess the soil and groundwater conditions of the Port.

The scope of work relevant to groundwater quality included the installation of 20 groundwater monitoring wells and collection and analysis of groundwater samples for metals and PAHs.

Reported concentrations of copper, lead, nickel and zinc in groundwater at the Site exceeding the nominated investigation guidelines (ANZECC [2000] 95% Marine Trigger Values). Highest concentrations of these metals were reported in eastern portion of the Site.

3.3.4 Port Kembla Port Corporation Outer Harbour Groundwater Monitoring Event Port Kembla NSW (URS 2006)

URS was commissioned by PKPC to further assess groundwater conditions at the Site.

The scope of work relevant to groundwater quality included the collection and laboratory analysis of groundwater samples from 19 existing monitoring wells. The analytical suite included metals and PAHs.

Reported concentrations of cadmium, copper, lead, nickel and zinc in groundwater at the Site exceed the nominated investigation guidelines (ANZECC [2000] 95% Marine Trigger Values). Highest concentrations of these metals were reported in the area around Jetty No. 3 to the west of the storm water canal. Reported concentrations of copper, nickel and zinc were also reported above adopted assessment criteria in off site monitoring wells on Foreshore Road.

3.3.5 Report on Soil and Groundwater investigation, Outer Harbour Lands, Port Kembla (Douglas Partners 2009)

Douglas Partners was commissioned by PKPC to undertake a groundwater investigation in the Outer Harbour Lands (OHLs) of the Port Kembla Harbour. The aim of the investigation was to collect updated information for environmental and occupational health and safety purposes during re-development and reclamation of the OHL.

The scope of work for the investigation relevant to groundwater quality included collection and analysis of 16 groundwater samples from wells installed within the Outer Harbour Lands of the Port Kembla Harbour.

The groundwater analytical results indicated the following:

- Exceedances of adopted Groundwater Investigation Levels (GILs) were reported for copper, zinc, arsenic III, arsenic V, cadmium, lead and nickel. AECOM notes that the adopted assessment criteria (GIL's) for metal and metalloid concentrations in groundwater have been derived from the Port Kembla Environmental Group Trigger values provided to DP by PKPC. AECOM also notes that the report makes an assessment of the

potential risk of harm to the environment using the ANZECC (2000) 95% trigger values of protection for Marine Quality;

- Arsenic V concentrations (ranging between 7-154 µg/l) exceeded the GIL's for all samples submitted for laboratory analysis;
- The report provided a summary and comparison of groundwater data to historical groundwater results from up and down hydraulic gradient wells, which suggested the following:
  - Arsenic concentrations in MW15 (located close to Foreshore Rd) were consistently higher than at any other well in the network and this trend has continued through monitoring in the Outer Harbour Lands;
  - Cadmium concentrations were generally higher in the up gradient wells;
  - Chromium concentrations were generally consistent with down gradient wells;
  - Copper concentrations were generally higher in up gradient wells;
  - Lead concentrations were generally consistent with down gradient wells;
  - Nickel and zinc concentrations were generally higher in up gradient wells;
- TPH, BTEX and PAH concentrations were not considered to pose a risk to the receiving water of the Site.

Recent reviews of historical groundwater data indicate that contamination in groundwater appears to represent regional groundwater effects (URS 2004, Maunsell, 2008b); that groundwater impacts in the Port Kembla area are a regional, rather than local, issue; and that groundwater contamination appears to be migrating towards the PKOH from up-gradient sources.

Available data are insufficient to assess the extent to which groundwater discharge to the marine environment has impacted, or may impact in the future, receiving sediments and surface water. Available monitoring data indicate that concentrations of groundwater contaminants (arsenic, cadmium, lead, nickel) are not elevated within Port Kembla Outer Harbour surface water, likely due to dilution and dispersion. However, the extent to which groundwater contamination has impacted, or may impact in the future, sediments within Port Kembla Outer Harbour cannot be determined based on the available data.

3.4 Analytical Results Summary and Chemicals of Potential Concern

3.4.1 Sediment

The maximum concentrations of chemical contaminants reported in sediment based on previous investigations are summarised along with relevant screening levels for protection of human health (NEPC, 1999; HIL 'F' values) and ecological receptors (ANZECC (2000) ISQG values) in **Table 1** below. The number of guideline exceedences reported during the AECOM (2009a) sediment investigation are also shown.

Table 1: Sediment Results Summary

COPC	HILF guideline (NEPC 1999a) mg/kg	ANZECC 2000 Sediment Quality Guidelines - Low mg/kg	ANZECC 2000 Sediment Quality Guidelines - High mg/kg	AECOM 2009a mg/kg	PB 2005 mg/kg	DP 2002 mg/kg
Antimony	-	2 (25/175)	25 (1/175)	**47.4** (PC22_0.3-0.5)	**3.3** (SOH8)[a] **2.2** (4E)	<LOR
Arsenic	500 (1/175)	20 (70/175)	70 (41/175)	***844*** (PC34, 0-0.27m)	**140** (SOH8)[a] 60 (4E)[b]	**21** (2-3)
Cadmium	100 (0/175)	1.5 (10/175)	10 (6/175)	**25.9** (PC34, 0-0.27m)	**6.5** (SOH8) **3.6** (9E)	1 (2-3)
Chromium	500 [d] (1/175)	80 (370/175)	370 (1/175)	**539** (VC1_1.3-1.4)	**140** (SOH6) **220** (9E)	94 (2-3)

COPC	HILF guideline (NEPC 1999a) mg/kg	ANZECC 2000 Sediment Quality Guidelines - Low mg/kg	ANZECC 2000 Sediment Quality Guidelines - High mg/kg	AECOM 2009a mg/kg	PB 2005 mg/kg	DP 2002 mg/kg
Copper	5000 (3/175)	65 (270/175)	270 (92/175)	***16600*** (PC34, 0-0.27m)	**4100** (SOH8) **450** (4E)	340 (2-3)
Lead	1500 (21/175)	50 (220/175)	220 (95/175)	***8700*** (PC22, 0.3-0.5)	***1500*** (SOH8) **500** (4E)	210 (2-3)
Mercury	75 (0/175)	0.15 (127/175)	1 (55/175)	**6.9** (PC34_0.0-0.27)	**3.8** (SOH8) **2.5** (9E)	0.82 (3-2)
Nickel	3000 (0/175)	21 (71/175)	52 (12/175)	**423** (PC34, 0-0.27m)	**66** (SOH8) **23** (9E)	16 (2-3)
Selenium	-	-	-	392 (PC34, 0-0.27m)	35 (SOH8) 6.7 (9E)	4 (2-3)
Silver	-	1 (79/175)	3.7 (29/175)	**137** (PC34_0.0-0.27)	**14** (SOH8) **1.2** (4E)	<LOR
Zinc	35000 (0/175)	200 (139/175)	410 (127/175)	**6420** (PC34, 0-0.27m)	**2400** (SOH8) **1500** (9E)	**800** (2-3)
Tributyltin	-	5 (15/80)	70 (2/80)	**2,170** (PC20, 0.-0.17m)		
BTEX	-	-	-	<LOR	<LOR	<LOR
Total TPH	1,000[e] (10/72)	-	-	*2,080* (PC63 0.95-1.05)	*1475* (SOH4) *2198* (9E)	<LOR
Benzo(a)pyrene	5 (0/91)	0.43 (61/91)	1.6 (13/91)	**3.81** (VC8 (2.7-2.8)		
Total PAH	100 (1/91)	4 (70/91)	45 (6/91)	**150** (VC8 (2.7-2.8)	Multiple exceedences	48.04 (2-3)

[a] SOH refers to surface samples. SOH8 is located close to Jetty 3.

[b] XE refers to vibrocore samples. 9E is located in the middle of the harbour between Jetty 3 and 6.

[c] (OHMW30) filled with material different to the characteristic of the site to a depth of 5.5mBGL

[d] Value is for chromium VI.

[e] Value is that for TPH C_{10}-C_{36} from NSW EPA (1994) for sensitive land use scenarios (in absence of other guideline value).

NS sediment not sampled

NA COPC not analysed

( ) Numbers in brackets indicate the sample location code. **Bold** indicates exceedence of ANZECC 2000 sediment interim guidelines low

Underline indicates exceedence of ANZECC 2000 sediment interim guidelines high

Italics indicates exceedence of Health Investigation Level (HIL) F Industrial/Commercial Land Use (NEPC 1999a)

Based on the results presented in **Table 1** above, chemicals of potential concern (CoPC) in sediment with respect to human and ecological (aquatic) health are summarised in **Table 2** below.

A chemical was selected as a CoPC if it was reported to be present above the relevant adopted screening criterion consistently (greater than a few percent of samples). Where chemicals were reported above screening criteria in less than two percent of samples, and provided that the maximum reported concentration did not exceed two times the screening criteria, chemicals were not considered to be present at concentrations of concern.

Table 2: Chemicals of Potential Concern in Sediment

Chemical	Human Health	Ecological Receptors
Antimony	-	X
Arsenic	- [a]	X
Cadmium	-	X
Chromium	- [a]	X
Copper	X	X
Lead	X	X
Mercury	-	X
Nickel	-	X
Silver	-	X
Zinc	-	X
Tributyltin	-	X
TPH	X	-
Benzo(a)pyrene	-	X
Total PAH	- [a]	X

X = Chemical selected as CoPC based on exceedence of generic screening levels.

- = Chemical not selected as CoPC based on non-exceedence of generic screening levels.

[a] While maximum reported concentration of chemical exceeded relevant screening level, chemical was not selected based on low exceedence frequency (less than two percent of grid-based samples) and low exceedence magnitude (less than two times the adopted screening level). It is therefore considered unlikely that average concentrations of the chemical to which receptors may be exposed will exceed generic screening criteria.

3.4.2 Groundwater

The maximum concentrations of chemical contaminants reported in groundwater or sediment during previous investigations are summarised together with relevant screening levels for protection of human health (ANZECC, 2000; guidelines for recreational water quality) and ecological receptors (ANZECC (2000) 95% Marine trigger values) in **Table 3** below.

It is noted that, as further described in **Section 4.0** below, human or ecological receptors are not expected to come into direct contact with groundwater at the Site, with the exception of maintenance or construction workers who may contact shallow groundwater in the Outer Harbour Lands during intrusive maintenance or construction activities. Rather, receptors may be indirectly exposed to groundwater contamination following discharge to waters within the PKOH. Thus, reported groundwater concentrations in excess of the generic screening levels summarised below does not necessarily suggest a potential adverse risk to human or ecological receptors, unless resulting concentrations in receiving water body surface water or sediments are elevated. Potential impacts to sediment from contaminated groundwater have been assessed based on reported concentrations within PKOH sediments, as described above. In order to assess the extent to which groundwater has impacted surface water within the PKOH, reported chemical concentrations in PKOH surface water (AECOM, 2009a) are also shown below in **Table 3** and compared to adopted screening criteria.

Chemical concentrations in sediment elutriate water (AECOM, 2009a) are also shown below in **Table 3** in order to provide an indication of the extent to which uncontrolled sediment dredging may result in release of contaminants to the surface water column.

Table 3: Groundwater, Harbour Water and Sediment Elutriate Results Summary

COPC	ANZECC (2000) Recreational Guidelines mg/L	ANZECC 95% Protection Marine Water Guidelines mg/L	AECOM 2009a (harbour water) mg/L	AECOM 2009 a (sediment elutriate) mg/L	DP 2009 mg/L	URS 2006 mg/L	URS 2004 mg/L
Antimony	NA	0.270 (low reliability)	<0.0005	0.0067	NA	NA	NA
Arsenic	0.05	0.0023 (low reliability As III)	0.0021	**0.0671**	**0.154** (MW15) [a]	**0.473** (MW15)	**0.329** (MW1)
Cadmium	0.005	0.0055	**65.4**	0.0006	**0.0061** (MW16)	**0.0684** (MW7)	0.005 (MW16)
Chromium	0.05	0.0044 (Cr VI)	<0.0005	0.0007	NA	<LOR	0.002 (OHMW29)
Copper	1	0.0013	**0.002**	**0.011**	**0.430** (MW32)	**0.486** (MW1)	**0.468** (MW1)
Lead	0.05	0.0044	0.0006	0.0026	**0.015** (OHMW27)	**0.101** (MW3)	**0.065** (MW3)
Mercury	0.001	0.0004	<0.0001	<0.0001	NA	<LOR	<LOR
Nickel	0.1	0.07	0.0008	0.0054	**0.330** (MW32)	**0.430** (MW1)	NA
Selenium	0.01	0.003	<0.002	0.002	**0.075** (OHMW27)	NA	NA
Silver	0.05	0.0014	<0.0001	<0.0001	NA	NA	<LOR
Zinc	5	0.015	<0.005	0.018	**29** (MW32)	**3.54** (MW3)	**1.57** (MW3)
Tributyltin	NA	0.000006	NA	NA	NA	NA	NA
BTEX	0.01 (benzene)	0.5 (low reliability)	NA	NA	<LOR	NA	NA
Total TPH	NA	0.0007 (low reliability)	NA	NA	<LOR	NA	NA
Benzo (a)pyrene	0.00001	0.0002	0.000005	<0.00005	Some detections >LOR	NA	<LOR

[a] Arsenic III and V analysed separately, the highest concentration of the two was selected for comparison, value of 154 is for As V

NS groundwater not sampled

NA COPC not analysed

Bold indicates exceedence of ANZECC 2000 freshwater quality guidelines.

Underline indicates exceedence of ANZECC 2000 recreational quality guidelines.

Based on the results presented in **Table 3** above, chemicals of potential concern (CoPC) in groundwater with respect to human and ecological (aquatic) health are summarised in **Table 4** below.

A chemical was selected as a CoPC if it was reported to be present above the relevant adopted screening criterion in both upgradient groundwater and in PKOH surface waters or sediment elutriate samples (i.e., at relevant exposure points for human and ecological receptors; see Section **4.0** below). It is noted that other chemicals (namely lead, nickel and selenium) have not been reported in PKOH harbour water or sediment elutriate water above adopted screening criteria, but have been reported to be elevated in groundwater upgradient of the PKOH. Thus, while existing data suggest that attenuation and dilution of groundwater upon mixing with PKOH surface waters is currently reducing concentrations of these chemicals at the point of exposure (i.e., within PKOH surface waters) to acceptable levels, the potential for adverse effects associated with continued uncontrolled discharge of these chemicals to the PKOH is noted.

Table 4: Chemicals of Potential Concern in Groundwater

Chemical	Human Health	Ecological Receptors
Antimony	-	-
Arsenic	X	X
Cadmium	X	X
Chromium	-	-
Copper	- (*)	X
Lead	- (*)	- (*)
Mercury	-	-
Nickel	- (*)	- (*)
Selenium	- (*)	- (*)
Silver	-	-
Zinc	-	-
Tributyltin	**	**
TPH	-	-
Benzo(a)pyrene	-	-
Total PAH	-	-

X = Chemical selected as CoPC based on exceedence of generic screening levels.

- = Chemical not selected as CoPC based on non-exceedence of generic screening levels.

(*) = While chemical has not been reported in PKOH harbour water or sediment elutriate water above adopted screening criteria, chemical has been reported in groundwater upgradient of PKOH above screening criteria. Thus, while existing data suggest that attenuation and dilution of groundwater upon mixing with PKOH surface waters is currently reducing concentrations at the point of exposure (i.e., within PKOH surface waters) to acceptable levels, the potential for ongoing groundwater impacts to PKOH surface water may warrant further consideration.

It is noted that tributyltin (TBT) concentrations are reported to be elevated in sediments (see **Table 1**) but have not been analysed in surface waters or elutriate samples.

4.0 Conceptual Exposure Assessment

4.1 Human Exposure

An overview of exposure pathways by which human receptors may be exposed to CoPC in sediment and groundwater is provided in Table 5 below. The human receptors considered in **Error! Reference source not found.** include the following:

- Commercial or industrial workers at properties within the Outer Harbour Lands
  - These include workers involved with terminal activities, loading and unloading of freight, etc., as well as workers in surrounding commercial and industrial properties.
- Recreational users of PKOH
  - These include recreational receptors that may swim or wade in the PKOH, although given the industrial nature of the area, the frequency and duration of exposure by these receptors is considered to be low;
  - Potential recreational fishers are also include in this receptor category (even though fishing may occur outside the site/PKOH, ingested fish may have bioaccumulated CoPC from PKOH sediments or surface water).
- Dredging workers
  - These include workers involved in sediment dredging operations as part of the Outer Harbour redevelopment.
- Intrusive maintenance or construction workers, including:
  - Workers who may conduct intrusive works as part of service or utility installation or maintenance activities;
  - Workers involved in construction of port facilities, either as part of the proposed Outer Harbour redevelopment, or during future development activities.

Contaminant migration and exposure pathways by which the above receptors may be exposed to identified CoPC in sediment and groundwater within the PKOH are shown in Table 5, together with classification of contaminant transport/exposure pathways as either:

- potentially complete and potentially significant;
- potentially complete but likely to be insignificant; or
- incomplete and/or not applicable.

Based on the exposure assessment, human exposure pathways identified as potentially complete and potentially significant are considered to be the following:

- Ingestion of edible fish which have bioaccumulated CoPC present in PKOH sediments or surface water.

Exposure pathways considered to be potentially complete, but not likely to result in significant exposure to CoPC, are considered to be the following:

- Incidental ingestion and/or dermal absorption of CoPC in sediment or surface water by recreational users of the PKOH (based on the industrial nature of the PKOH area such that recreational use and exposures are not expected to be significant);
- Incidental ingestion and/or dermal absorption of CoPC in sediment or surface water by dredging workers (based on expectation that dredging activities will be managed such that direct contact with sediment or surface water by workers will be minimal);
- Incidental ingestion and/or dermal absorption of CoPC in groundwater following accumulation in a maintenance trench or construction pit (based on expectation that contact will incidental, of low frequency and short duration, and that appropriate PPE and hygiene procedures would be used to mitigate potential risks).

Other exposure pathways by which human receptors may be exposed to CoPC deriving from sediment or groundwater are considered to be either incomplete or not applicable.

Table 5: Conceptual Model for Contaminant Exposure - Human Receptors

Source Medium	Transport Mechanism	Exposure Medium	Exposure Pathway	Receptor	Pathway Complete?	Notes
Sediment	NA	Sediment	Direct contact[a]	Industrial Workers	X	Workers not expected to swim or wade in harbour.
				Recreational Users/Visitors	○	Based on industrial nature of the Site, recreational activities and receptors are minimal. Frequency or duration of swimming or wading is expected to be minimal.
				Workers Involved in Dredging	○	Dredging activities are expected to be managed such that direct contact with sediment or surface water is minimal.
	Leaching, diffusion or discharge to surface water (from in-situ sediments or during dredging)	Surface Water	Direct contact[a]	Industrial Workers	X	Workers not expected to regularly swim or wade in harbour.
				Recreational Users	○	Based on industrial nature of the Site, recreational activities and receptors are minimal. Frequency or duration of swimming or wading is expected to be minimal.
				Dredging Workers	○	Dredging activities are expected to be managed such that direct contact with sediment or surface water is minimal.
	Bioaccumulation through food chain	Edible fish	Ingestion	Industrial Workers	X	Workers not expected to ingest fish.
				Recreational Users	●	Sediment CoPC, particularly metals and PAHs are potentially bioaccumulative, and fish have been reported to forage in the PKOH.
				Dredging Workers	X	Workers not expected to ingest fish.
Ground-water	Extraction	Water	All	All	X	Registered bores within 5 km of site are reported to be used for investigation and dewatering purposes only (AECOM, 2009b). Also, high dissolved solids (up to 5,000 mg/L; URS, 2006) content generally precludes extractive use of groundwater.

Source Medium	Transport Mechanism	Exposure Medium	Exposure Pathway	Receptor	Pathway Complete?	Notes
	Accumulation in maintenance trench or construction pit	Water	Direct contact[a]	Intrusive maintenance pr construction workers	○	Contact likely to be incidental, of low frequency and short duration, and it is expected that appropriate PPE and hygiene procedures would be used to mitigate potential risks.
	Volatilisation through vadose zone and release to indoor or outdoor air	Air	Inhalation	Intrusive maintenance pr construction workers	X	CoPC are not volatile.
	Discharge to PKOH and accumulation in sediments	Sediment	All	All	See sediment exposure pathways above.	
	Discharge to PKOH surface water	Surface Water	All	All	See surface water exposure pathways above.	

[a] Includes incidental ingestion and dermal absorption of chemicals from exposure medium.

● = Pathway considered to be complete and potentially significant.

○ = Pathway considered to be potentially complete but likely to be insignificant.

X = Pathway considered to be incomplete and/or not applicable.

4.2 Ecological Exposure

An overview of exposure pathways by which ecological receptors may be exposed to CoPC in sediment and groundwater is provided in **Table 6** below.

The broad ecological receptor groups which are considered to be potentially present within the PKOH, and therefore which have been considered include the following:

- Benthic invertebrates (e.g., worms, bivalves, etc) which may burrow and feed in the soft sediments of PKOH;
- Benthic deposit feeders (e.g., benthic fish, crabs, etc) which may feed on benthic invertebrate or plant species;
- Benthic micro-flora (e.g., diatoms and other microscopic algae species) which may be present in the soft sediments of the PKOH;
- Hard substratum macroalgae (seaweed) on existing constructed revetment/breakwater walls along the north and east borders of the PKOH development area (see AECOM 2009a, **Figure F2**);
- Hard substratum mobile (e.g., starfish) and sessile (e.g., starfish, sponge, anemone, hydrozoans, bryozoans, polychaetes, etc) invertebrates;
- Pelagic organisms (primarily fish) which may reside in the PKOH surface waters.

With respect to ecological receptors, the following is noted:

- Macroscopic flora (e.g., mangroves and sea grasses) have not been recorded to be present in the soft sediments of the PKOH based on previous studies of the Site (Maunsell, 2008b), and wave action and high turbidity from boat operations in the harbour are considered to result in minimal suitable habitat for these species;
- Low levels of cysts of the potentially toxic dinoflagellate *Alexandrium* have been reported in all bottom sediments in the PKOH. When disturbed, these cysts can develop into algal blooms causing toxins to accumulate in shellfish and leading to Paralytic Shellfish Poisoning in humans, and to general adverse effects to aquatic ecological receptors. There is no evidence of a toxic bloom having occurred in harbour waters

including dredging works in the Inner Harbour although concern has been expressed that this may occur if cysts present in bottom sediments are disturbed during times when ambient conditions are suitable for germination. While these micro-algae are not considered to be receptors of concern with respect to impacts from sediment or groundwater contamination, the algae can be considered to be agents of potential concern with respect to their impact on human or ecological receptors.

Contaminant migration and exposure pathways by which the above receptors may be exposed to identified CoPC in sediment and groundwater within the PKOH are shown in **Table 6**, together with classification of contaminant transport/exposure pathways as either:

- potentially complete and potentially significant;
- potentially complete but likely to be insignificant; or
- incomplete and/or not applicable.

Based on the exposure assessment, ecological exposure pathways considered to be complete and potentially significant are considered to be the following:

- Direct contact exposure (i.e., incidental ingestion and dermal contact) to CoPC in sediments by:
  - Benthic invertebrates
  - Benthic microalgae
  - Benthic fish
- Direct contact exposure (i.e., incidental ingestion and dermal contact) to CoPC in sediment pore waters by:
  - Benthic invertebrates
  - Benthic microalgae
  - Benthic fish
- Direct contact exposure (i.e., incidental ingestion and dermal contact) to CoPC in surface water by:
  - Benthic invertebrates
  - Benthic microalgae
  - Benthic fish
  - Pelagic fish
  - Hard substratum species (algae and invertebrates)
- Ingestion of bioaccumulated CoPC within algae, invertebrates and/or other fish by:
  - Benthic invertebrates
  - Benthic fish
  - Pelagic fish
  - Hard substratum invertebrates

Exposure pathways considered to be potentially complete, but not likely to result in significant exposure to CoPC, are considered to be the following:

- Direct contact exposure (i.e., incidental ingestion and dermal contact) to CoPC in sediments by:
  - Pelagic fish/organisms
- Direct contact exposure (i.e., incidental ingestion and dermal contact) to CoPC in sediment pore waters by:
  - Pelagic fish/organisms

Other exposure pathways identified in **Table 6** by which ecological receptors may be exposed to CoPC deriving from sediment or groundwater are considered to be either incomplete or not applicable.

Table 6: Conceptual Model for Contaminant Exposure – Ecological Receptors

Source Medium	Transport Mechanism	Exposure Medium	Exposure Pathway	Receptor	Pathway Complete?	Notes
Sediment	NA	Sediment	Direct contact[a]	Benthic invertebrates	●	Receptors expected to be in close contact with contaminated sediments.
				Benthic microalgae	●	Receptors expected to be in close contact with contaminated sediments.
				Benthic fish	●	Receptors may ingest sediment during feeding.
				Pelagic organisms/fish	○	Receptors expected to only intermittently contact sediments .
				Hard substratum species	X	Hard substratum species are not expected to contact sediments
Sediment	Leaching to pore water	Sediment pore waters	Direct contact[a]	Benthic invertebrates	●	Receptors expected to be in close contact with pore water.
				Benthic microalgae	●	Receptors expected to be in close contact with pore water.
				Benthic fish	●	Receptors expected to be in close contact with pore water.
				Pelagic organisms/fish	○	Receptors expected to only intermittently contact sediment pore water.
				Hard substratum species	X	Hard substratum species are not expected to contact sediment pore waters.
Sediment	Leaching, diffusion or discharge to surface water (from in-situ sediments or	Surface Water	Direct contact[a]	Benthic invertebrates	●	Receptors may be in close contact with surface water at the sediment/water interface.
				Benthic microalgae	●	Receptors may be in close contact with surface water at the sediment/water interface.
				Benthic fish	●	Receptors reside within exposure medium.

Source Medium	Transport Mechanism	Exposure Medium	Exposure Pathway	Receptor	Pathway Complete?	Notes
	during dredging)			Pelagic organisms/fish	●	Receptors reside within exposure medium.
				Hard substratum species	●	Receptors reside within exposure medium.
Sediment	Bioaccumulation through food chain	Edible plants, invertebrates, fish, etc.	Ingestion	Benthic invertebrates	●	Receptors may feed on other algal or invertebrate species.
				Benthic microalgae	X	Ingestion not relevant exposure pathway for primary producers
				Benthic fish	●	May feed on benthic algae or invertebrates.
				Pelagic organisms/fish	●	May feed on algae, invertebrates or other fish.
				Hard substratum algae	X	Ingestion not relevant exposure pathway for primary producers.
				Hard substratum species	●	Receptors may feed on other algal or invertebrate species.
Ground-water	Discharge to PKOH and accumulation in sediments	Sediment	All	All	●	See sediment exposure pathways above
	Discharge to and dispersion in PKOH surface water	Surface Water	All	All	●	See surface water exposure pathways above

[a] Includes incidental ingestion and dermal absorption of chemicals from exposure medium.

● = Pathway considered to be complete and potentially significant.

○ = Pathway considered to be potentially complete but likely to be insignificant.

X = Pathway considered to be incomplete and/or not applicable.

5.0 Risk Characterisation

Qualitative assessment of potential risks to human and ecological receptors associated with sediment and groundwater contamination has been undertaken, primarily based on the following considerations:

- The nature and concentrations of contaminants exceeding relevant investigation or screening levels;
- The expected nature and frequency of exposure by identified receptors;
- The relevance of the adopted screening or investigation levels to the receptors and/or exposure pathways of concern.

5.1 Human Health Risk Characterisation

The assessment of potential risks to human receptors associated with identified sediment and groundwater contamination is summarised below in **Table 7**.

Potential risks to human receptors have been assessed as low or moderate for most receptor/exposure pathway combinations. Potential risks assessed as 'moderate' include those associated with the following:

- Direct contact with surface water by recreational users or dredging workers
  - The moderate risk rating for these exposures is due to significantly elevated cadmium concentrations reported in a couple of isolated harbour surface water samples. It appears that the cadmium analytical results may be erroneous based on other harbour surface water, sediment and elutriate analytical results as part of this investigation and historical water quality data in the Outer Harbour
- Direct contact with groundwater by intrusive workers
  - While risks were assessed as moderate for these receptors, the likely extent of exposure is considered to be very low for any individual receptor, and potential risks can be managed with the use of appropriate personal protective equipment/clothing and hygiene procedures.

Risks assessed as potentially 'high' include the following:

- Ingestion of edible fish tissue with elevated Chemical of Potential Concern (CoPC) concentrations due to foraging/exposure in the PKOH
  - The potentially high risk rating for these exposures has been based on significantly elevated concentrations of CoPC reported in sediments.
  - It is considered that potential risks associated with this exposure pathway warrants further qualitative assessment prior to the commencement of dredging works. This further assessment would be based on detailed design of the dredging works and specific environmental management techniques which aim to minimise and control the dispersal of contaminated sediment.

Table 7: Qualitative Risk Summary - Human Receptors

Receptor/ Exposure Pathway	Potentially Significant Exposure Pathway?[a]	Reported CoPC and Relative Concentrations[b]	Notes/ Other Considerations	Potential Qualitative Risk Rating
Recreational Users – Direct Contact with Sediment	Unlikely or Low	Copper (Moderate) Lead (Moderate) TPH (Low)		Low
Dredging Workers – Direct Contact with Sediment	Unlikely or Low	Copper (Moderate) Lead (Moderate) TPH (Low)		Low
Recreational Users – Direct Contact with Surface Water	Unlikely or Low	Arsenic (Low) Cadmium (High)	Elevated cadmium concentrations (greater than 10,000 time screening criteria)	Moderate

Receptor/ Exposure Pathway	Potentially Significant Exposure Pathway?[a]	Reported CoPC and Relative Concentrations[b]	Notes/ Other Considerations	Potential Qualitative Risk Rating
Dredging Workers – Direct Contact with Surface Water	Unlikely or Low		reported in harbour water samples only during high tide within middle and outer most portions of harbour. Reported concentrations are greater than those reported in groundwater, and source is therefore not known. Other chemicals reported at low concentrations in both harbour water and sediment elutriates.	
Recreational Receptors – Ingestion of Edible Fish	Possible	Arsenic (High) Copper (High) Lead (High) Silver (High) Zinc (High) Tributyltin (High) Other metals (Low to Moderate)	Potential for bioaccumulation of sediment contaminants in edible fish tissue. The extent to which fish which forage in PKOH are ingested by human receptors, warrants further consideration based on detailed design of dredging works and specific environmental management techniques which aim to minimise and control dispersal of contaminated sediment. Bioavailability may limit extent to which CoPC bioaccumulate in fish.	High
Construction or Maintenance Workers – Direct Contact with Groundwater within an Excavation	Unlikely or Low	Arsenic (High) Cadmium (High) Lead (High) Nickel (Low) Selenium (Moderate) Zinc (Low)	Potential risks expected to be managed with appropriate protective equipment and hygiene procedures.	Moderate

[a] See **Table 5**.

[b] CoPC concentrations have been assessed as "Low" (maximum concentration less than five times screening level), "Moderate" (maximum concentration five to ten times screening level or "High" (maximum concentration greater than ten times screening level). See Table 1 and Table 3.

5.2 Ecological Risk Characterisation

The assessment of potential risks to ecological receptors associated with identified sediment and groundwater contamination is summarised below in **Table 8**.

While potential risks to some ecological receptors have been assessed as potentially high based on reported elevated concentrations of CoPC in harbour sediments and the presence of ecological receptors within surface water and sediment, it should be noted that the overall aquatic ecological environment within PKOH is highly modified due to:

- Physical modifications of the harbour (e.g., construction of breakwaters and jetties and dredging and reclamation activities) associated with development of the port;
- The industrial nature of the surrounding area;

- Reported presence of pest species to ballast discharge with the PKOH;
- The high level of boat/shipping activity within the PKOH.

The results of the benthic community survey recently undertaken (UNSW 2009) and of other reports (primarily Maunsell, 2008b) indicate that:

- Resuspension and deposition of sediments could have temporary impacts on the soft sediment infauna through smothering and a change in the composition of sediments;
- Species diversity varies at different locations within PKOH (e.g. at Salty Creek);
- Localised fish populations likely to be affected by the resuspension and deposition of sediments may be able to relocate to other areas within the Outer Harbour;
- None of the species identified during the surveys are listed as threatened or protected in NSW; and
- While the proposed development of Port Kembla Outer Harbour has the potential to cause brief local extinctions of species within the proposed development area, recruitment processes will likely result in a rapid recovery once construction works have ceased.

The ecological value of the PKOH area itself is therefore considered to be generally low.

Further qualitative assessment of potential ecological risks should be based on detailed design of the dredging works and specific environmental management techniques which aim to minimise and control the dispersal of contaminated sediment having regard to the higher value receptors/areas which may be indirectly affected by sediment contamination within the PKOH such as indirect risks to human health and the marine aquatic ecosystem.

Table 8: Qualitative Risk Summary – Ecological Receptors

Receptor/ Exposure Pathway	Potentially Significant Exposure Pathway?[a]	Reported CoPC and Relative Concentrations[b]	Notes/ Other Considerations	Potential Qualitative Risk Rating
Benthic Invertebrates, Microalgae and Fish – Direct Contact with Sediment and/or Pore Waters	Possible	Arsenic (High) Copper (High) Lead (High) Silver (High) Zinc (High) Tributyltin (High) Other metals (Low to Moderate)	Pore water concentrations not known. Sorption, speciation and bioavailability effects likely to impact on overall risk.	High
Pelagic Organisms – Direct Contact with Sediment and/or Pore Waters	Unlikely or Low		Pelagic organisms expected to only intermittently contact sediments or pore water.	Moderate
All Aquatic Receptors – Direct Contact with Surface Water	Possible	Arsenic (High) Cadmium (High) Copper (Low) Tributyltin (Unknown)	Elevated arsenic reported in elutriate samples, but not in PKOH surface water, suggesting potential risks may be associated with dredging operations, but not with release from in-situ sediment and groundwater. Elevated cadmium concentrations (greater than 10,000 time screening criteria) reported in harbour water samples only during high tide within middle and outer most portions of harbour. Source is not known. Tributyltin has been reported to be elevated in PKOH sediment samples	High

Receptor/ Exposure Pathway	Potentially Significant Exposure Pathway?[a]	Reported CoPC and Relative Concentrations[b]	Notes/ Other Considerations	Potential Qualitative Risk Rating
			but has not been analysed in harbour water or elutriate samples. Other chemicals reported at low concentrations in both harbour water and sediment elutriates.	
Aquatic Fauna – Ingestion of Edible Flora, Invertebrates or Fish	Possible	Arsenic (High) Copper (High) Lead (High) Silver (High) Zinc (High) Tributyltin (High) Other metals (Low to Moderate)	Bioaccumulative potential of CoPC varies. Sorption, speciation and bioavailability effects likely to impact on overall risk.	High

[a] See **Table 6.**

[b] CoPC concentrations have been assessed as "Low" (maximum concentration less than five times screening level), "Moderate" (maximum concentration five to ten times screening level or "High" (maximum concentration greater than ten times screening level). See Table 1 and Table 3.

6.0 Conclusions and Recommendations

AECOM has undertaken a qualitative assessment of the nature and extent of reported sediment and groundwater contamination within the PKOH and Outer Harbour Lands, and developed a conceptual model describing contaminant transport and exposure pathways by which human and ecological receptors may be exposed to reported sediment and groundwater contaminants.

Based on the assessment, the following conclusions and recommendations are provided:

6.1 Potential Human Health Risks

Potential risks to human receptors have been assessed as low or moderate for most receptor/exposure pathway combinations. Potential human health risks assessed as potentially 'moderate' include those associated with the following:

- Direct contact with surface water by recreational users or dredging workers
  - The moderate risk rating for these exposures is due to significantly elevated cadmium concentrations reported in a couple of isolated harbour surface water samples. It appears that the cadmium analytical results may be erroneous based on other harbour surface water, sediment and elutriate analytical results as part of this investigation and historical water quality data in the Outer Harbour
- Direct contact with groundwater by intrusive workers
  - While risks were assessed as moderate for these receptors, the likely extent of exposure is considered likely to be very low for any individual receptor, and potential risks can be managed with the use of appropriate personal protective equipment/clothing and hygiene procedures.

Human health risks assessed as potentially 'high' (on a qualitative basis) include the following:

- Ingestion of edible fish tissue with elevated CoPC concentrations due to foraging/exposure in the PKOH.
  - The potentially high risk rating for these exposures has been based on significantly elevated concentrations of CoPC reported in sediments. It is noted that the actual levels of receptor exposure (i.e., quantity of potentially impacted fish which could be ingested) and levels of CoPC concentrations in fish tissue are not known.
  - It is considered that potential risks associated with this exposure pathway warrants further qualitative consideration.

6.2 Potential Ecological Risks

While potential risks to a number of ecological receptors have been assessed as potentially high based on reported elevated concentrations of CoPC in harbour sediments and the presence of ecological receptors within surface water and sediment, it should be noted that the overall aquatic ecological environment within PKOH is highly modified due to:

- Physical modifications of the harbour (e.g., construction of breakwaters and jetties and dredging and reclamation activities) associated with development of the port;
- The industrial nature of the surrounding area;
- Reported presence of pest species due to ballast discharge with the PKOH;
- The high level of boat/shipping activity within the PKOH.

The ecological value of the PKOH area itself is therefore considered to be generally low. Further consideration of potential ecological risks may be limited to higher value receptors/areas which may be indirectly affected by sediment contamination within the PKOH, e.g.:

- Potential indirect risks to human health due to toxic dinoflagellate blooms or bioaccumulation of contaminants into edible fish or shellfish;
- Potential indirect adverse effects or risks to the broader marine aquatic ecosystem or communities (i.e., outside the modified and heavily impacted PKOH area).

It is noted that dredging works have been successfully undertaken by PKPC in the Inner and Outer Harbours over an extended number of years without creation of such dinoflagellate blooms.

6.3 Recommendations

The assessment concludes that the potential risks identified for workers and the public may be managed by consideration of the nominated exposure pathways, and through suitable design of construction methodologies (e.g. sediment curtain, wet emplacement of dredged materials, an environment management plan for construction worker personnel protective equipment). Ecological community risks are considered manageable through consideration of the nominated exposure pathways via suitable design of construction methodologies (e.g. the dredging and curtained areas representing a limited proportion of the wider harbour habitat, sediment piping or barging to the emplacement area, and minimisation of dispersal of contaminated sediment to harbour waters).

The following environmental management framework is considered appropriate for each discrete stage of works:

- Preparation of the Dredging Environmental Management Plan to minimise impacts associated with the dispersal of sediments during dredging.
- Undertaking regular water quality and turbidity monitoring before and during dredging works.
- Preparation of a Site Management Plan to manage handling of potential contaminated soil.

Based on the results of the QHHERA, the following recommendations are provided:

- The elevated cadmium concentrations reported in the Site Investigation report AECOM (2009) within PKOH surface waters be subject to additional monitoring as recommended by the Sediment Investigation (AECOM, 2009a) to clarify the reported elevated cadmium concentrations;
- Potential risks to intrusive maintenance or construction workers due to direct contact with groundwater in the Outer Harbour Lands should be managed and minimised through the use of personal protective equipment/clothing and hygiene procedures;
- The suitability of sediment curtain application and minimisation of contaminated sediment dispersal be subjected to further qualitative human health risk assessment, prior to commencing dredging works, with respect to effect on potential ingestion of CoPC in edible fish ;
- Ground and surface waters quality should be monitored in the OH area prior to and during construction;
- Given the highly modified nature of the aquatic environment within the PKOH, and therefore the inferred relatively low ecological value of the area, a further qualitative assessment of the detailed dredging design with respect to potential risks to ecological receptors be undertaken prior to commencing dredging works and also consider the following:
    - Potential indirect adverse effects or risks to the broader marine aquatic ecosystem or communities (i.e., outside the modified and heavily impacted PKOH area);
    - Potential indirect risks to human health due to toxic dinoflagellate blooms or bioaccumulation of contaminants into edible fish or shellfish;
    - The extent to which protected or recreationally important species are present within the PKOH.
- A recommendation of this qualitative risk assessment is that further detailed consideration of these benthic community characteristics be included in a proposed further qualitative risk assessment upon the description of specific dredging plans and locations and prior to the commencement of dredging works. This approach is consistent with advice from the DECCW regarding the approach required for the risk assessment process.
- It is recommended that prior to commencing dredging works, a more detailed assessment of the potential risk issues identified above be undertaken, to support minimization of risks to humans and the ecosystem Through appropriate design of the dredging works and suitable environment impact mitigation measures.

7.0 References

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PORT KEMBLA OUTER HARBOUR DEVELOPMENT

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