Randwick City Council
Interim Human Health Risk Assessment for Asbestos

Little Bay Beach
4R Coast Hospital Road,
LITTLE BAY, NSW

7 October 2020
59811-132997 (Revision A)
JBS&G Australia Pty Ltd

www.jbsg.com.au

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List of Abbreviations

Term	Definition
ACM	Asbestos Containing Material
AEC	Area of Environmental Concern
AF/FA	Asbestos Fines / Fibrous Asbestos
AHD	Australian Height Datum
bgl	Below Ground Level
COPC	Contaminant of Potential Concern
CoS	City of Sydney
Cr	Chromium
CSM	Conceptual Site Model
DA	Development Application
DQI	Data Quality Indicator
DQO	Data Quality Objectives
DP	Deposited Plan
DPI Water	NSW Department of Primary Industry - Water
EPA	NSW Environment Protection Authority
Ha	Hectare
HIL	Health-based Investigation Level
HSL	Health Screening Level
JBS&G	JBS&G Australia Pty Ltd
LOR	Limit of Reporting
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
OEH	NSW office of Environment and Heritage
PIL	Phytotoxicity Based Investigation Level
QA/QC	Quality Assurance/Quality Control
RCC	Randwick City Council
RME	Reasonably Maximum Exposed
RPD	Relative Percentage Difference
SAS	Site Audit Statement
SAR	Site Audit Report
SCS	Significantly Contaminated Site
SWA	Safe Work Australia
UR	Unit Risk
VENM	Virgin Excavation Natural Material (as defined in POEO Act)

Executive Summary

JBS&G Australia Pty Ltd (JBS&G) was engaged by Randwick City Council (Council, the client) to complete an interim health risk assessment of the potential health risk posed by the occurrence of asbestos impact at Little Bay Beach accessed from 4R Coast Hospital Rd Little Bay NSW. A range of earlier contamination assessments and remedial works as completed by Trinitas Group Pty Ltd (Trinitas) have identified significant asbestos impact, occurring as fibre cement sheet fragments, across the extent of the Beach. The Trinitas works, with the assessment of health risk as completed here, have been restricted to the area legally described as Lot 97 DP270427.

The interim health risk assessment has been requested to be undertaken on the basis of data currently available from Trinitas investigations, to determine whether levels of asbestos as estimated on Little Bay Beach are potentially present at a level that poses an unacceptable health risk to an ongoing recreational use of the Beach / Golf Course areas in proximity and/or Little Bay residents in proximity of the Beach. A sensitivity analysis undertaken of the risk assessment process has found that risk estimates are appropriately conservative and suitable for decision making as to the suitability of the site. The assessment has been undertaken as an interim stage using available data with conservative assumptions prior to the availability of a detailed site characterisation.

In accordance with the limitations provided as **Section 11**, levels of asbestos on the site have not been found to pose a potentially unacceptable health risk to current / future users of the Beach as consistent with a recreational land-use, Golf Course users nor occupants of residential properties in proximity of the site.

The fate and transport assessment has estimated the potential worse case airborne concentration of asbestos fibres on the site. This has been found to be well below a level of 0.01 f/ml as identified in *Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997*, 2015, NSW EPA as a potential trigger to warrant reporting under the *Contaminated Lands Management Act 1997*. Further recent respirable fibre monitoring undertaken by Trinitas during site assessment / remediation works has not identified airborne levels of fibres equal to or exceeding 0.01 f/ml. It is concluded on this basis that there is not a requirement to report asbestos impact to the NSW EPA.

Notwithstanding the conclusions in respect of the potential human health risk, soils on the site are impacted with asbestos. Requirements with respect to asbestos as informed to the *Work Health and Safety Regulation 2017* (WHS Reg) do not differentiate as to whether levels of asbestos are sufficient to pose a health risk.

As noted, a detailed site investigation is proposed to be undertaken on the Beach. This interim health risk assessment will require to be updated with the detailed quantification data as generated by the future investigation. The requirements of the WHS Reg as relevant to the Beach will be able to be considered in more detail on availability of the investigation results.

1. Introduction and Background

1.1 Background

JBS&G Australia Pty Ltd (JBS&G) was engaged by Randwick City Council (Council, the client) to complete an interim health risk assessment of the potential health risk posed by the occurrence of asbestos impact at Little Bay Beach accessed from 4R Coast Hospital Rd Little Bay NSW. A range of earlier contamination assessments and remedial work reports as completed by Trinitas Group Pty Ltd (Trinitas) have identified significant asbestos impact, occurring as fibre cement sheet fragments, across the extent of the Beach. The Trinitas works, with the assessment of health risk as completed here, have been restricted to the area legally described as Lot 97 DP270427.

The interim health risk assessment has been requested to be undertaken on the basis of data currently available from Trinitas investigations. It is anticipated that detailed site investigations will be undertaken on the Beach in the near future, and an updated health risk assessment will be prepared following the receipt of the detailed site characterisation data.

The risk assessment has been undertaken by a process of initially estimating the worse-case concentration of each form of asbestos as able to be estimated from the extent of investigations and data reported to date. Fate and transport modelling has been undertaken of potential asbestos emissions from the site and considered with toxicological review and exposure assessment to estimate levels of health risk. Site specific factors to assist in fate and transport calculations have also been considered here.

Risk assessment is the process of estimating the potential impact of a chemical, physical, microbiological or psychosocial hazard on a specified human population or ecological system under a specific set of conditions and for a certain timeframe. The risk assessment here is restricted to the consideration of asbestos based materials present in soil (i.e. beach sands and overlying rock platforms) within the site and the potential interactions with current and future human populations as may occur with the ongoing use of the site for recreational purposes, and further potentially sensitive receptors in proximity of the site (i.e. residents on Murra Murra Place Little Bay).

The risk assessment has been undertaken by the methodology outlined in *Environmental Health Risk Assessment Guidelines for assessing human health risks from environmental hazards*, 2012, Department of Health and Ageing and enHealth Council (enHealth 2012) and *National Environment Protection (Assessment of Site Contamination) Measure*, 2013, National Environment Protection Council (NEPC 2013).

1.2 Objectives

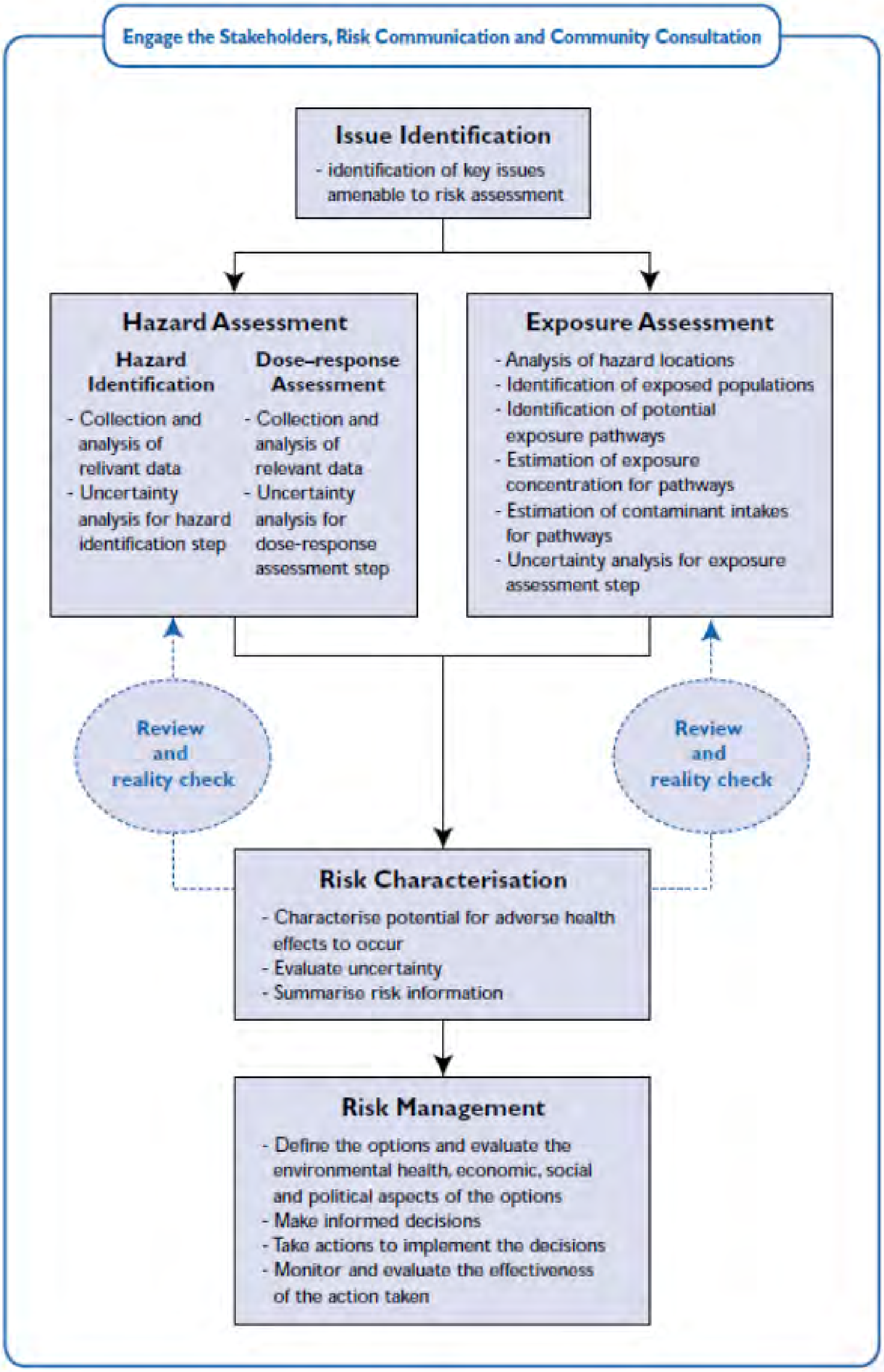
The objective of the HHRA is to determine whether levels of asbestos present within the extent of Little Bay Beach site pose a potential human health risk as per an ongoing recreational / open space use of the site and to further determine if levels pose a potential health risk to potentially sensitive receptors in proximity of the site. An additional objective has been to determine whether the occurrence of asbestos impact poses a significant enough risk to necessitate a duty to report under section 60 of the *Contaminated Lands Management Act 1997*.

1.3 Risk Assessment Process

Risk assessment is the process of estimating the potential impact of a chemical, physical, microbiological or psychosocial hazard on a specified human population or ecological system under a specific set of conditions and for a certain timeframe. A schematic of the risk assessment process is shown in the diagram below (source: enHealth 2004).

- Issue Identification identifies issues amenable to the risk assessment and assists in establishing a context for the risk assessment by a process of identifying the problems that the risk assessment needs to address. This includes the selection of Constituents of Potential Concern (COPC's) for the site and each identified potential exposure population.
- Hazard Assessment including toxicological assessment and dose-response assessment. Toxicological assessment involves determining what types of (adverse) health effects might be caused by the agent; and how quickly the adverse health effects might be experienced and their duration. Dose-response assessment considers both qualitative and quantitative toxicity information to determine 'the incidence of adverse effects occurring in humans at different exposure levels'.
- Exposure Assessment involves the determination of the frequency, extent, duration and character of exposures in the past, currently, and in the future. There is also the identification of exposed populations, particularly sensitive sub populations, and potential exposure pathways.
- Risk Characterisation provides a qualitative and / or quantitative estimate, including attendant uncertainties, of the nature, severity and potential incidence of effects in a given population, based on the hazard identification and exposure assessments.

The risk assessment has specifically considered a range of potential human receptors who may use the site in the future, and existing and future human receptors in proximity of the site.


Engage the Stakeholders, Risk Communication and Community Consultation
Issue Identification
- identification of key issues amenable to risk assessment
Hazard Assessment
Hazard Identification
- Collection and analysis of relivant data
- Uncertainty analysis for hazard identification step
Dose-response Assessment
- Collection and analysis of relevant data
- Uncertainty analysis for dose-response assessment step
Exposure Assessment
- Analysis of hazard locations
- Identification of exposed populations
- Identification of potential exposure pathways
- Estimation of exposure concentration for pathways
- Estimation of contaminant intakes for pathways
- Uncertainty analysis for exposure assessment step
Review and reality check
Review and reality check
Risk Characterisation
- Characterise potential for adverse health effects to occur
- Evaluate uncertainty
- Summarise risk information
Risk Management
- Define the options and evaluate the environmental health, economic, social and political aspects of the options
- Make informed decisions
- Take actions to implement the decisions
- Monitor and evaluate the effectiveness of the action taken

1.4 Site Identification

The location of the site is shown in **Figure 1**, and the site extent is shown in **Figure 2**. Site details are summarised in **Table 1.1**.

Table 1.1: Summary Site Details

Lot/DP	Lot 97 DP270427
Address	4R Coast Hospital Road Little Bay NSW
Local Government Authority	Randwick City Council
Site Zoning	Open Space / Recreational
Current Use	Little Bay Beach, open space / recreational / car parking
Proposed Use	Ongoing open space / recreational
Geographical Co-ordinates	E338461, N6238749 (MGA56)
Area of the site	Approximately 1 hectare

1.5 Current Site Condition

A detailed site description has been provided to Trinitas (2020i) which has been confirmed by JBS&G site inspection as appropriate. The site is referred to as northern, western and southern sections, as shown on **Figure 3**.

The Northern Beach area (approximately 3600 m^2):

- A feature referred to as Crown Gully 1 runs from the northern golf course, where a historical retaining wall forms a barrier with stormwater outlet;
- A channel with boulders runs from the retaining wall towards the Bay. Anthropogenic materials were observed in this area inclusive of several fibre cement sheet fragments;
- Fill materials such as building rubble and solid waste (including plastic, tiles, rubber, tyre, bricks) were observed along the edge of the hill slope;
- Visible fibre cement sheet fragments were identified throughout the whole beach sand area;
- The eastern section of Northern Beach under the cliff was characterised with a sandstone platform and abundant boulders;
- Visible fibre cement sheet fragments were identified under the rock platform immediately adjacent to the low tide water line; and
- Up to the Golf Course between Crown Gully 1 and Crown Gully 2, fibre cement sheet fragments were observed as scattered with disturbed and eroded soil (land bush clearance, golf car drive path, stormwater runoff channels, fill slopes).

The Western Beach area (approximately 1200 m^2):

- Fill material was observed to include a feature referred to as Crown Gully 2. A stockpile of old bricks and concrete were observed to have been placed at the outlet of the gully; and
- Fibre cement sheet fragments were identified and confirmed on the gully soil ground and in buried demolition material.

The Southern Beach area (approximately 5300 m^2):

- A feature referred to as Crown Gully 3 was located in the southwest section with a stormwater pipe (around 80 cm in diameter) observed;
- Bush clearance works in August 2020 (over an area of approximately 60 m^2) had identified fibre cement sheet fragments at around 50 m upstream of the concrete stormwater pipe;
- Soil erosion was observed at the slope of the golf course;

- Fibre cement sheet fragments were identified and confirmed around the channel outlet and further distributed across the whole beach sand; and
- Fibre cement sheet was reported to consist of super 6 corrugated sheeting chunks, flat ACM sheeting and highly polished ACM fragments.

Rock outcrops and platforms separate Western Beach and Southern Beach. However, there is no apparent physical boundary between Northern Beach and Western Beach.

1.6 Surrounding Land Uses

The surrounding land uses have been identified as comprising:

- North – A golf course is present adjoining the northern portion of the Beach. Existing residential dwellings are located further to the north, an approximate distance of 300 m from the northern extent of the beach;
- East – Little Bay and the Pacific Ocean are located adjoining the east of the beach, as consistent with the coastline;
- South – The Golf Course is present adjoining the immediate south of the site, with parking and club house facilities located an approximate distance of 200 m from the southern extent of the Beach;
- West – The golf course is present at the immediate west of the Beach, consisting of fairway and green areas. Residential areas of Little Bay are located further to the west, being an approximate distance of 50 m from the western extent of the Beach.

The nearest potentially sensitive human exposures can be identified as the recreational users of the Beach and Golf Course, commercial workers (i.e. Greenskeepers) to the Golf Course, maintenance workers to the Beach (i.e. cleaning the beach) and residential dwellings located in closest proximity to the west of the Beach.

1.7 Topography

Trinitas (2020i) reports that reference to the Bondi 9130-2S topographic map (1:25000) indicates that the Site is situated under the cliffs in the north and in the south. The Site steeply slopes toward the Bay. The approximate elevation of the timber entry to the beach is 20 m(AHD).

1.8 Geology

Soils on the site have been observed to generally consist of a shallow depth of sands overlying a sandstone bedrock. The sandstone can be observed to outcrop in several areas of the site, particularly in proximity of the boundary with the Ocean. Fill materials are potentially present adjoining the Beach as associated with the steep elevation to the Golf Course / embankment adjoining the Beach.

1.9 Site History

A brief site history as relevant to the occurrence of asbestos has been provided to Trinitas (2020i). The beach is noted as being in proximity of the historical Prince Henry Hospital. Prince Henry Hospital is reported to have been initially used as a quarantine facility in the late 19th century. Following this, it was known as the Coast Hospital, with a golf course additionally developed surrounding in 1922.

The hospital closed in 1988, and was subsequently demolished, with part of the lands used for residential development, and the golf course remaining operational. Golf course facilities and buildings have been regularly renovated through the operational history which continues until today.

Anecdotal evidence further presented in Trinitas (2020i) reported that potential asbestos containing materials had been present on the beach for many years, and there was a potential history of illegal dumping / filling having occurred adjoining the Beach that was the potential source of the asbestos containing materials.

1.10 Meteorology

A review of average climatic data for the nearest comprehensive Bureau of Meteorology monitoring location (Sydney Airport) indicates the site is located within the following meteorological setting:

- Average minimum temperatures vary from 7.2 in July to 19.1 in February;
- Average maximum temperatures vary from 17.0 in July to 26.5 in January;
- The average annual rainfall is approximately 1083.7 mm with rainfall greater than 1 mm occurring on an average of 95.9 days per year; and
- Monthly rainfall varies from 60.3 mm in September to 122.5 mm in June with the wettest periods occurring on average in March and June.

1.11 Previous Investigations

Council has made available a range of assessments to advise the risk assessment. This includes:

- *Asbestos Identification Report*, 3 August 2020, Trinitas Group (Trinitas 2020a);
- *Asbestos Clearance Inspection and Clearance Certificate (northern section)*, 4 August 2020, Trinitas Group (Trinitas 2020b);
- *Asbestos Clearance Inspection and Clearance Certificate (western section)*, 4 August 2020, Trinitas Group (Trinitas 2020c);
- *Asbestos Clearance Inspection and Clearance Certificate*, 5 August 2020, Trinitas Group (Trinitas 2020d);
- *Asbestos Clearance Inspection and Clearance Certificate*, 6 August 2020, Trinitas Group (Trinitas 2020e);
- *Asbestos Daily Air Monitoring Report*, 6 August 2020, Trinitas Group (Trinitas 2020f);
- *Asbestos Clearance Inspection and Clearance Certificate*, 7 August 2020, Trinitas Group (Trinitas 2020g);
- *Asbestos Daily Air Monitoring Report*, 7 August 2020, Trinitas Group (Trinitas 2020h);
- *Preliminary Technical Brief for Potential Asbestos Contamination at Little Bay Beach, Little Bay NSW*, 24 August 2020, Trinitas Group (Trinitas 2020i);
- *Request for Quotation – Detailed Site Investigation 1A for Three Sand Areas at Little Bay Beach, Little Bay NSW*, 25 August 2020, Trinitas Group (Trinitas 2020j);
- *Asbestos Clearance Inspection and Clearance Certificate*, 2 September 2020, Trinitas Group (Trinitas 2020k);
- *Asbestos Daily Air Monitoring Report*, 2 September 2020, Trinitas Group (Trinitas 2020l);
- *Asbestos Clearance Inspection and Clearance Certificate*, 9 September 2020, Trinitas Group (Trinitas 2020m);
- *Asbestos Daily Air Monitoring Report*, 9 September 2020, Trinitas Group (Trinitas 2020n);
- *Asbestos Clearance Inspection and Clearance Certificate*, 11 September 2020, Trinitas Group (Trinitas 2020o);

- *Asbestos Daily Air Monitoring Report*, 11 September 2020, Trinitas Group (Trinitas 2020p);
- *Asbestos Clearance Inspection and Clearance Certificate*, 15 September 2020, Trinitas Group (Trinitas 2020q);
- *Asbestos Daily Air Monitoring Report*, 15 September 2020, Trinitas Group (Trinitas 2020r);
- *Asbestos Clearance Inspection and Clearance Certificate*, 18 September 2020, Trinitas Group (Trinitas 2020s);
- *Asbestos Daily Air Monitoring Report*, 18 September 2020, Trinitas Group (Trinitas 2020t);
- *Asbestos Clearance Inspection and Clearance Certificate*, 23 September 2020, Trinitas Group (trinitas 2020u);
- *Asbestos Daily Air Monitoring Report*, 23 September 2020, Trinitas Group (Trinitas 2020v);
- *Asbestos Clearance Inspection and Clearance Certificate*, 25 September 2020, Trinitas Group (Trinitas 2020w); and
- *Asbestos Daily Air Monitoring Report*, 25 September 2020, Trinitas Group (Trinitas 2020x).

The works and findings of each of these assessments is summarised following.

1.11.1 Asbestos Identification (Trinitas 2020a)

The works undertaken consisted of a walkover inspection of two areas of Little Bay Beach reported as northern beach near the gully and adjacent western beach near the gully. A number of asbestos fibre cement sheets were identified, generally described as being highly polished. The sheets typically appeared to consistent of 4 mm thick fibre cement sheet with dimensions of 20 mm to 100 mm. Asbestos was confirmed by laboratory analysis to be present as chrysotile and crocidolite forms

The description of 'highly polished' fragments has been interpreted by JBS&G to be indicative of weathering of the fibre cement sheets being evident.

1.11.2 Clearance Inspection and Certificate (Trinitas 2020b and 2020c)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the western section and northern section of Little Bay Beach. The picking works were undertaken on the 4th August 2020. Similarly sized fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.3 Clearance Inspection and Certificate (Trinitas 2020d)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 5th August 2020. Smaller fragments than those presented in Trinitas (2020a) are shown as present, with fragments as small as 10 mm. A covering email reported that seven fragments were removed from the three sections of the Beach.

1.11.4 Clearance Inspection and Certificate (Trinitas 2020e and 2020f)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 6th August 2020. Smaller fragments than those presented in Trinitas (2020a) are shown as present, with fragments as small as 10 mm. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.5 Clearance Inspection and Certificate (Trinitas 2020g and 2020h)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 7th August 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.1 fibres/ml.

1.11.6 Technical Brief (Trinitas 2020i)

Trinitas (2020i) has reported site identification and background information for the site as has been summarised in the earlier sections to this report. Trinitas (2020i) has also summarised the asbestos assessment and removal works as completed to the issue of the report in last August. The works have included / identified:

- Suspected asbestos containing fibre cement sheet fragments were identified across the Beach area;
- All fragments suspected of containing asbestos and submitted for laboratory analysis have confirmed the presence of asbestos (17 samples);
- Over 200 fragments of fibre cement sheet were collected from the Beach area over the period 4th to 21st August 2020 at the Northern and Western Beach areas;
- Approximately 1 kg of fibre cement sheet fragments were collected on the 21st August as an accumulation adjacent to a stormwater pipe outlet in the southern beach area;
- The fibre cement sheet fragments were observed to be distributed throughout the Beach area, with Trinitas (2020i) reporting no obvious decreasing trend of fragments through the three specific areas assessed (**Figure 3**); and
- Fibre cement sheet fragments are visually characterised as being highly polished, which is inferred to be characteristic of the weathering of the fragments.

1.11.7 Detailed Site Investigation Brief (Trinitas 2020j)

Trinitas (2020j) contains a summary of all background / available information for the asbestos assessment and remedial works as completed at the Little Bay beach. The beach is reported as currently and proposed to be used for an open space / recreational land use.

It is reported that the works completed between the 4th and prior to the 21st August (Trinitas 2020a to 2020f) had resulted in the collection / removal of 200 fragments of ACM. Works as undertaken on the 21st August (Trinitas 2020g and 2020h) resulted in the removal of 1 kg of fibre cement sheet fragments.

1.11.8 Clearance Inspection and Certificate (Trinitas 2020k and 2020l)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 2nd September 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. It is reported that over 1 kg of fibre cement fragments have been removed by the works which equated to 40 fragments. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.1 fibres/ml.

1.11.9 Clearance Inspection and Certificate (Trinitas 2020m and 2020n)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 9th September 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.10 Clearance Inspection and Certificate (Trinitas 2020o and 2020p)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 11th September 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.11 Clearance Inspection and Certificate (Trinitas 2020q and 2020r)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 15th September 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.12 Clearance Inspection and Certificate (Trinitas 2020s and 2020t)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 18th September 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.13 Clearance Inspection and Certificate (Trinitas 2020u and 2020v)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 23rd September 2020. Smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

1.11.14 Clearance Inspection and Certificate (Trinitas 2020w and 2020x)

Emu picking of suspected fibre cement fragments has been reported as being undertaken at the northern, western and southern sections of Little Bay Beach. The picking works were undertaken on the 25th September 2020. Similarly sized and smaller fragments to those reported in Trinitas (2020a) are shown as being present. Air monitoring as undertaken during the works have reported all levels of respirable fibres below 0.01 fibres/ml.

2. Conceptual Site Model

National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No.1) (NEPC 2013) identifies a conceptual site model (CSM) as a representation of site related information regarding contamination sources, receptors and exposure pathways between those sources and receptors. The development of a CSM is an essential part of all site assessments.

NEPC (2013) identified the essential elements of a CSM as including:

- Known and potential sources of contamination and contaminants of concern including the mechanism(s) of contamination;
- Potentially affected media (soil, sediment, groundwater, surface water, indoor and ambient air);
- Human and ecological receptors;
- Potential and complete exposure pathways; and
- Any potential preferential pathways for vapour migration (if potential for vapours identified).

The CSM has been defined following as restricted to the potential occurrence of asbestos impact.

2.1 Known and Potential Sources of Contamination

Asbestos impact has been identified occurring as fibre cement sheet debris as present across the site. Laboratory analysis of the fibre cement sheet fragments has confirmed that they contain asbestos (i.e. are asbestos containing material, ACM). No analysis has been undertaken to determine if soils / sands on the beach are impacted by asbestos fibres / asbestos fines / friable asbestos.

2.2 Extent of Environmental Impact

Asbestos has been identified across the area of the Beach. No distribution or otherwise other controls have been reported as per the extent of asbestos, and the impact is taken to be broadly evenly distributed across the assessment area.

Recent extensive works have been undertaken to remove the fibre cement sheet fragments from the Beach area (Trinitas 2020a to 2020x). While these works will have been effective at reducing the point in time occurrence of ACM, they have not been effective in removing all ACM. It is inferred from the number of repeat events that sub-surface ACM is likely present on the site and is caused to become visible at the surface by the movement of sands in response to wind and wave action, as well as overland stormwater discharge flows. Or otherwise / additionally is being caused to continually migrate to the extent of the Beach.

Where ACM has been observed, it typically occurs with construction and building wastes, and present as fibre cement sheet fragments. This indicates that historically asbestos impacted material has been imported to the proximity of the site and used as fill material, or has otherwise been sourced from historical demolition activities as undertaken in proximity of the site. The site is noted to downstream of overland flows from the Little Bay suburb, and historical Prince Henry Hospital.

No definitive quantitative data has been provided to Trinitas (2020a to 2020x). However the extent of data available has been interrogated to determine a basis to estimate an extent of ACM on the Beach area. The following data has been used:

- A total of 200 fragments of ACM having been removed from the Beach area by initial works (Trinitas 2020i and 2020j);

- A total of 1 kg of fragments of ACM having been removed from the stormwater outlet at the southern beach (Trinitas 2020i and 2020j);
- 40 fragments of ACM equates to 1 kg of ACM (Trinitas 2020k); and
- Each of the picking / inspection events have resulted in the removal of all visible / surface ACM.

On the basis of the available data, it has been assumed that a typical fragment of ACM present on the Beach weighs 25 grams. On the basis of asbestos fibre cement sheet having a typical density of 1000 kg/m^3 a typical fragment will have a volume of $2.5*10^{-5}$ m^3 Based on the observation of typically 4 mm thickness fragments, an ACM fragment would be characterised as having an area of $6.25*10^{-3}$ m^2 (equivalent 80 mm length and width). Observation of photos of works would indicate a significant range either side of this typical estimate.

Where 200 fragments is equivalent to 5 kg of ACM, and an additional 1 kg was collected form near to a stormwater outlet during the initial mobilisations, it can be estimated that 6 kg of ACM was present during the initial works. NEPC (2013) advises that asbestos content of ACM can be up to 15%. Where it is further assumed, based on typical minimum dimensions of sheets observed being 10 mm, that these fragments were restricted to the upper 5 mm of soils observed, the extent of the northern, southern and western beach area (**Section 1.5**) is 10 000 m^2, and the beach sands are a typical density of 1500 kg/m^3, then an asbestos (in a bonded form) in soil concentration of 12 mg/kg is estimated.

Based on the number of repeat events, it is likely that asbestos picking works have not been completely efficient. The efficiency of ACM collection / identification cannot be readily estimated from the Trinitas assessments. However the comparison of Trinitas (2020i and 2020j) and Trinitas (2020k) estimates indicates that significant ACM is not being identified / removed. For the purposes of this assessment, an extremely conservative collection / identification efficiency of 50% (i.e. half) has been estimated for the removal of asbestos. Applying the factor to the estimate of bonded asbestos present, an asbestos concentration of 24 mg/kg is estimated. Noting that no previous remedial / asbestos removal works are known to have taken place prior to Trinitas (2020a to 2020j) this can be considered indicative of a potential maximum extent of ACM historically present, and likely present, on the Beach in the future.

Asbestos has only been identified as bonded asbestos. No assessments have been completed for free asbestos fibres / asbestos fines / friable forms of asbestos.

2.3 Potential and Complete Exposure Pathways

Future human receptors on and in immediate proximity of the site can be characterised as consisting of:

- Recreational users of the Beach and Golf Course adjoining;
- Landscapers / gardening personnel as more likely retained on the Golf Course adjoining, but also potentially engaged within the Beach (periodic clean up / maintenance works); and
- Potential future sub-surface maintenance / excavation workers.

Receptors will be potentially exposed to soil contaminants by oral, dermal and inhalation pathways. Oral and dermal exposures have not been considered any further as asbestos is not toxic by these pathways. Inhalation exposures will potentially occur by the release of fibres from impacted soils into human breathing zones.

Where asbestos fibres are released from soils on the site there is a potential that residential occupants in proximity of the site may be affected. Potentially complete exposure pathways may occur where airborne respirable asbestos fibres migrate to the extent of these properties. Residential dwellings are located in close proximity to the west on Murra Murra Place Little Bay.

2.4 Preferential Pathways

A range of preferential pathways are currently present on the site as associated with sandy soil horizons and potential services present across the site area (i.e. stormwater outlet at southern Beach etc.). A significant preferential pathway is the steep slope of the potential asbestos soils / materials adjoining the boundary of the Beach.

These preferential pathways are not considered significant as asbestos occurs as a solid and is not readily transportable within the sub-surface. However gravity / overland run-off assisted processes can cause increased movement of ACM down the steep slope and onto the Beach.

2.5 Complete Source-Pathway-Receptor Linkages

Potentially complete source-pathway-receptor linkages are considered to be limited to potential inhalation exposures of fibres of on-site receptors, and recreational areas and residential properties in proximity of the site.

3. Issue Identification

Issue identification is the first step of the risk assessment process.

3.1 Issue Identification

Issue identification determines whether risk assessment is useful, and establishes a context for the risk assessment by a process of identifying the concerns the risk assessment needs to address. Issue identification draws on all relevant lines of information.

Issue identification comprises several phases:

1. Identification of environmental health issues (or an individual issue) and determining whether there are hazards amenable to risk assessment. This will involve demarcating ‘hazards’ from ‘issues’ and may require environmental sampling;
2. Putting the hazards into their environmental health context (clarification and prioritising of problems and hazards);
3. Identification of potential interactions between agents; and
4. Stating clearly why risk assessment is needed and the scope and objectives of the risk assessment. This will involve identifying problems for which information is, or can be, available to undertake adequate risk assessments and problems which risk assessment cannot assist.

3.2 Identification of Environmental Hazards

Environmental health hazards may be caused by physical, chemical, biological or social factors in the environment. Physical factors include heat, cold, noise, mechanical hazards etc. Chemical factors include synthetic and naturally occurring substances. Biological factors include viruses, prions, bacteria, parasites and vermin.

Environmental impact is currently widespread in soils and sands across the Beach, reported to be consequent of historical placement of fill materials in proximity of the Beach and the release by weathering / erosion process of asbestos containing anthropogenic material.

The sands within the extent of the Beach are impacted at least with bonded forms of asbestos, and potentially further impacted with asbestos fibres. Bonded ACM products have been observed distributed across the surface of the Beach.

3.3 Environmental Sampling and Analysis

Environmental sampling and analysis are a key factor in identifying the agents that may be present, their concentrations and distributions. Environmental sampling and analysis should be targeted to address the identified potential environmental hazards.

Environmental sampling and analysis has been detailed in previous investigations (Trinitas 2020a to 2020x) as reported in **Section 1.11**.

3.4 Putting Hazards into their Environmental Health Context

Putting the hazards into their environmental context entails a consideration of:

- Whether the hazard has single or multiple sources;
- Whether the type of environmental impact affects multiple environmental media;
- How stakeholders perceive the problem including the consideration of different groups; and
- How do the hazards compare to other environmental hazards affecting the community.

The environmental hazards across the open space / parkland are restricted to the impacted Beach sands and associated near surface soils within the Beach which have been historically disturbed on the site, or otherwise impacted from off-site locations.

The risk assessment takes into consideration the ongoing use of the site as per the current recreational setting. The major human stakeholders identified for the ongoing use of the Beach include recreational users, landscapers, Beach surface maintenance / cleaning and maintenance workers of above-ground and sub-surface services in proximity. Potential exposures of further recreational and residential receptors in proximity of the site have also been identified.

As the environmental hazards present on the Beach are generally related to commonly occurring commercial / industrial contaminants, (i.e. asbestos) and are also commonly identified on urban development site in established areas of Sydney and/or commonly used in a range of processes, it can be assumed that the environmental hazard does not pose a unique hazard to the community. However, the presence of these contaminants in uncontrolled locations, potentially in proximity of sensitive populations, may serve to increase the exposure of the community and/or the environment to the environmental hazard.

3.5 Identification of Potential Interactions between Agents

There may be interactions between the physical, chemical, biological and social hazards that require identification and consideration as part of a risk assessment. There are several potential types of interactions between hazardous agents which include: additive effects; synergistic effects; potentiation effects and antagonistic effects.

It is widely acknowledged that activities such as smoking can increase the susceptibility of a person to the potential effects of some carcinogens. To this effect, it will be required to be ensured that conservatively derived data and reasonably maximum exposed receptors are used as the basis for any risk assessment.

3.6 Why is Risk Assessment Needed?

The occurrence of environmental hazards in a site sub-surface is unique for every site and location. Further, the particular populations exposed to an environmental hazard are unique for every occurrence of the environmental hazard. Regulatory authorities within NSW do not provide comprehensive guidance for the assessment of the range of contaminants identified within the reserve site as an environmental hazard. The limited guidance available is considered unsuitable to be solely applied to the ongoing use of the site, as based on potential human exposures. For example, the guidance provided for asbestos in NEPC (2013) and endorsed by the NSW EPA for investigation purposes, is based on assumptions derived from substantially drier Western Australian soils and very simplistic estimates as to potential exposures.

The requirement, and method, for remediation/management for an environmental hazard needs to be determined. The extent of this potential requirement must be determined by the assessment of the presence of an environmental hazard; the degree of potential harm posed by the environmental hazard (in an isolated environment); and the likely exposure of the environment to the environmental hazard. Only through the assessment of all these factors can the true impact of the environmental hazard be assessed. The risk assessment process is designed to include all of these factors to determine a site-specific estimate of the risk posed by the level of asbestos present in soils on the Beach.

3.7 Limitations and Uncertainties

Potential limitations and uncertainties that may occur in the risk assessment process include:

- Information gaps, e.g. effects of mixtures, low level and variable exposures over time, relative contribution of 'lifestyle' factors;
- Poor exposure information, e.g. complex mixtures of hazards with complex behaviours in the environment; limited knowledge about the actual or potential sub-population;
- Limitations of toxicological or epidemiological research, e.g. small populations and limited exposure information, multifactorial causes of many diseases on health impacts; 'background noise' affecting research into common diseases or symptoms; population heterogeneity;
- Complexity, e.g. large numbers of combinations of hazards, exposures and health states;
- Confidentiality of health and commercial information;
- Charged atmosphere of fear, antagonism and distrust; and
- Value conflicts.

The risk assessment requires a thorough sensitivity analysis subsequent to the provision of the risk outcomes. The sensitivity analysis will take these matters into account, testing the outcome of the risk assessment of reasonable upper and lower bounds of each. Sensitivity analysis of all assumptions has been undertaken throughout the risk assessment. Risk assessment outcomes may require to be modified where sensitive parameters are observed to have large reasonable potential deviations.

4. Selection of Constituents of Potential Concern

The risk assessment has been restricted to the assessment of asbestos. Asbestos has been identified as bonded asbestos only and occurring in the form of fibre cement sheet fragments. No assessment of free asbestos fibres / asbestos fines / friable asbestos has been undertaken.

5. Toxicological Assessment

There are two elements to the toxicological review for the human health risk assessment: hazard identification (using toxicological studies) and dose-response assessment. The Australian approach to each is discussed in detail following.

5.1 Hazard Identification

Hazard identification examines the capacity of an agent to cause adverse health effects in humans and other animals. The dose-response assessment examines the quantitative relationships between exposure and the effects of concern.

Hazard identification uses:

- Animal data. This is usually assessed by toxicological methods;
- Human data. This usually assessed by epidemiological methods when groups of people are involved, or by toxicological methods when using case studies and acute chamber studies; and
- Other data. This includes structure data such as structure activity data or in vitro data assessed by toxicologists.

Hazard identification mostly relies on the results of in vitro toxicity studies conducted according to standard protocols (e.g. OECD Test Guidelines). The following types of studies are defined:

- Acute toxicity studies are studies which investigate the effects of single doses of a substance. The standard acute toxicity studies include tests for: acute, oral, dermal and inhalational toxicity, eye irritation, skin irritation and skin sensitisation;
- Sub-chronic toxicity studies are short term repeat-dose studies. The main purpose of sub-chronic testing is to identify any target organs and to establish dose levels for chronic exposure studies;
- Chronic toxicity studies, or long-term studies, are defined as studies lasting for the greater part of the lifespan of the test animals. The protocol for these studies may cover the investigation of chronic toxicity or carcinogenicity, or both;
- Reproductive toxicity studies are studies designed to provide general information about the effects of a test substance on reproductive performance in both male and female animals;
- Developmental toxicity studies are studies which examine the spectrum of possible in utero outcomes for the conceptus, including death, malformations, functional deficits and developmental delays; and
- Genotoxicity studies are designed to determine whether test chemicals can perturb genetic material to cause gene or chromosomal mutations.

The essential purpose of toxicity studies is the detection of valid biological evidence of the hazard potential of the substance being investigated. The evaluation of the weight of evidence produced by toxicity studies is that process which considers the cumulative data pertinent to arriving at a level of concern about the potential adverse effects of a substance. In assessing toxicological studies and hazard analysis, judgement and supporting rationale are provided for:

- The acceptability of the study and its database;
- The existence of biologically important adverse effects;
- The relevance of any factors noted during the evaluation which might have had some bearing on the outcomes of the study and modified the findings in some way; and

- The likelihood that any of the observed effects were induced by the administered substance.

Toxicology assessments are often complemented with epidemiological studies in hazard assessment. Epidemiology is the direct human evidence component of the assessment. Epidemiological studies are used to investigate the cause of adverse health effects; the natural history of health conditions; the description of the health status of populations; and to evaluate the health status of populations; and to evaluate health related interventions.

5.2 Dose-Response Assessment

There are different ways of characterising dose-response relationships including:

- Effect levels (e.g. LD50, LC50, ED10) and no observed adverse effect levels (NOELs);
- Margins of safety;
- Therapeutic indices; and
- Models to interpolate high dose experimental data to the low doses likely to be experienced in the environment.

There are often limited human exposure data, animal bio-assay data are most often used for dose-response assessment. The use of these data requires extrapolations from animals to humans and interpolations from high doses to low doses.

Dose-response assessments and calculations are generally undertaken by either of a threshold approach or a non-threshold approach. Each is described in further detail following.

5.2.1 Threshold Approaches

A threshold is considered to occur because of biological mechanisms such as the ability to metabolise or excrete a toxin to repair damage up to a certain dose.

The approach with these models is to derive exposure limits such as an Acceptable Daily Intake (ADI), Tolerable Daily Intake (TDI) or Reference Dose (RfD). This approach makes no attempt to calculate a level of risk at low exposures. Rather, it derives a dose which is apparently without effect in a human population or suitable animal model, and then applies a factor to derive an exposure which has a high likelihood that no effect will occur in the general human population.

These exposure limits are first derived by determining the No Observed Adverse Effect Level (NOAEL) or, if the NOAEL cannot be determined, the Lowest Observed Adverse Effect Level (LOAEL) and dividing the value by factors to account for:

- Interspecies differences (extrapolating from animals to humans);
- Intraspecies differences (differing sensitivities between individuals);
- The severity of the adverse effect; and
- The quantity and quality of the scientific data.

Traditionally, safety factors for intraspecies and interspecies differences have each been assigned values of ten, and the other two have been assigned values between 1 and 10. An additional factor of ten is sometimes used if the NOAEL was not established in the study. The individual factors are then multiplied to determine an overall safety factor by which the NOAEL is divided to give the ADI, TDI or RfD.

Historically, the most common overall factor used by a number of regulatory bodies is 100, if a large toxicological database has been assessed, although the overall factor can range from 10 to 10,000. From the data available on humans and experimental animals, it appears that interspecies and intraspecies differences are in general less than 10, hence the often used safety factor of 100 for these two factors is conservative and adequately protective of public health.

5.2.2 Non-Threshold Approaches

These approaches do not recognise the possibility of a threshold effect and are appropriate for radiation and some genotoxic carcinogens. It is, as a science policy decision, applied to all carcinogens by the US EPA.

Non-threshold models assume linearity between the lowest experimentally derived dose and the zero dose (the origin). This implies that there is a calculable probability of an adverse effect (risk) no matter how small the dose. This does not mean that there is no dose that could be considered safe unless safety must be equated with zero risk.

Numerical estimates of risk probabilities are generated by fitting one or more mathematical models to the data in the experimental dose range and extrapolating to the low environmental exposure doses. For example, low-dose extrapolation using a linear model is a default approach for cancer risk assessment in the USA and is one approach which has been used by the WHO for genotoxic carcinogens in deriving water quality guidelines.

The outcomes are estimates of either:

- The dose at a predetermined acceptable risk level (note that this requires some judgement on what constitutes an acceptable level of risk); or
- The estimated risk level at any particular dose.

It has been recognised by IARC and other European based agencies that not all carcinogens have genotoxicity as their prime mode of action, the dose-response curve is assumed to be non-threshold for genotoxic carcinogens and threshold for non-genotoxic carcinogens. Accordingly, the Australian approach is to apply non-threshold and threshold models to genotoxic and non-genotoxic carcinogens.

5.3 Sources of Toxicological and Tolerable Intake Data

NEPC (2013) provides toxicological data sources that are considered to provide information that is compliant with Australian requirements for setting public health standards in the context of assessing potential human health risks. These sources include:

1. National Health and Medical Research Council documents (e.g. Australian Drinking Water Guidelines);
2. National Environmental Protection Council documents (e.g. NEPM Air Toxics, NEPM Ambient Air Quality and Air Quality Standard Setting Methodology);
3. Other Australian government sources of toxicity data (e.g. ADI list from the Therapeutic Goods Administration, enHealth Council documents and National Environmental Health Forum documents distributed by the Commonwealth Department of Health and Ageing);
4. South Australian Health which has published a series of workshops on risk assessment of contaminated land;
5. World Health Organisation (WHO) documents. Australia is a party to the WHO process and has incorporated their material in a variety of environmental health criteria. A range of documents include those from the WHO/ILO/UNEP International Programme on Chemical Safety (IPCS) which produces Environmental Health Criteria monographs and Concise International Chemical Assessment documents (CICADs). Documents detailing international Acceptable Daily Intakes (ADI's), Tolerable Daily Intakes (TDI) or Tolerable Weekly Intakes (TWI) may be found in evaluations by the WHO/FAO Joint Meeting on Pesticide Residues (JMPR) and by the Joint FAO/WHO Expert Committee on Food Additives (JECFA);
6. International Agency for Research on Cancer (IARC) documents;

7. US Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels and toxicological reviews;
8. Other Governmental sources of information (e.g. NICNAS, USEPA IRIS database and European Government Guidance);
9. Other sources of peer reviewed toxicity criteria (US EPA's PPRTV/HEAST, Cal EPA toxicity values and OEHHA); and
10. Peer reviewed journals for which robust justification is required if information is to be sourced as they generally are not compliant with the requirement for having carried out an extensive literature review.

Where physical and chemical data are necessary requirements in the risk assessment process, the following sources, in order, are recommended:

1. ORNL (Oak Ridge National Laboratory) Risk Assessment Information System (RAIS);
2. ATSDR toxicological profiles; and
3. Peer reviewed journals.

5.4 Review of Published Hazard Data

Available toxicological, epidemiological studies and dose-response studies have been reviewed for asbestos, as identified in **Section 4**, by the protocols established in **Section 5.1**. Consequently, citing the relevant agencies, there has been no requirement in this risk assessment to further review and comment upon the hazard studies reviewed by each organisation, or those that may be available elsewhere that are not endorsed by these organisations.

Instead, the pertinent toxicological effects identified for asbestos by the agencies has been reviewed and summarised. Risk / hazard factors and guideline values have also been identified from these sources.

5.5 Asbestos

Asbestos has been selected as a contaminant of potential concern (COPC) for the assessment of potential human health impacts. A brief summary of the toxicological data available for asbestos has been provided following. The summary has been generated by a review of the available data held by the agencies outlined in **Section 5.3**, as summarised in **Table 5.1**.

Table 5.1: Summary of Published Hazard Data for Asbestos

Organisation	Availability	Reference
NHMRC	YES	'Lung Cancer', Section 1, Epidemiology. http://www.nhmrc.gov.au/publications/synopses/_files/cp97_1.pdf 'Asbestos Related Diseases' http://www.nhmrc.gov.au/your_health/issues/asbestos.htm
NEPC	YES	NEPC (2013) 'Schedule B1: Soil and Groundwater Investigation Levels'
Therapeutic Goods Administration	No	
WHO	YES	'Elimination of Asbestos Related Diseases' http://whqlibdoc.who.int/hq/2006/WHO_SDE_OEH_06.03_eng.pdf 'Asbestos in Drinking Water' http://www.who.int/water_sanitation_health/dwq/asbestos.pdf Air Quality Guidelines, 2nd Edition, Section 6.2, 'Asbestos'. http://www.euro.who.int/document/aiq/6_2_asbestos.pdf 'Environmental exposure to asbestos and the exposure–response relationship with mesothelioma' http://www.emro.who.int/publications/emhj/1501/PDF/03.pdf
enHealth	YES	'Management of Asbestos in the Non-Occupational Environment' http://www.nphp.gov.au/enhealth/council/pubs/pdf/asbestos.pdf
NEHF	No	
S.A Health	No	
IARC	No	
WHO/FAO JMPR	No	
NICNAS PEC	YES	'Chrysotile Asbestos Priority Existing Chemical No. 9' http://www.nicnas.gov.au/publications/CAR/PEC/PEC9/PEC_9_Full_Report_PDF.pdf
ATSDR	YES	'ToxFAQs™ for Asbestos' http://www.atsdr.cdc.gov/tfacts61.html 'Regulations and Advisories' http://www.atsdr.cdc.gov/toxprofiles/tp61-c8.pdf
NTP	YES	Lifetime Carcinogenesis Studies of Amosite Asbestos in Syrian Golden Hamsters http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr249.pdf Toxicology and Carcinogenesis Studies of Crocidolite Asbestos in F344/N Rats http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr280.pdf Toxicology and Carcinogenesis Studies of Chrysotile Asbestos in F344/N Rats http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr295.pdf
OECD SIDS SIAR	No	
US EPA	YES	'Asbestos (CASRN 1332-21-4)' http://www.epa.gov/NCEA/iris/subst/0371.htm US EPA (December 2014) 'Toxicological Review of Libby Amphibole Asbestos'

NHMRC

NHMRC define asbestos as a carcinogen with no clearly delineated limiting threshold, and support a cumulative exposure model for risk as defined by exposure. Asbestos has been found to cause pleural disease, asbestosis, lung cancer and mesothelioma.

NEPC

NEPC (2013) has adopted the asbestos criteria as provided in *Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia*, 2009, Western Australian Department of Health (WA DoH, 2009).

WA DoH (2009) provide assessment levels for asbestos cement products and free asbestos fibres in soils. The assessment criteria are based on the work of Swartjes et al (2003) and Swartjes & Tromp (2008), WHO risk figures for mesothelioma and division by a factor of ten, to account for greater dryness and dust generating potential of WA soils and treating all forms of asbestos as being of equivalent toxicity. The soil investigation criteria provided by WA DoH (2009) are listed as follows:

- 0.001% asbestos for all site uses, based on free asbestos fibres and asbestos fines;

- 0.01% asbestos for residential use, based on ACM;
- 0.04% asbestos for residential use with minimal soil access, based on ACM;
- 0.02% asbestos for parks, public open spaces, playing fields, based on ACM; and
- 0.05% asbestos for commercial / industrial based on ACM.

It is noted that only residential criterion are based on toxicology and risk based assessments using exposure parameters and unit risk levels. The other criteria are derived from the residential criteria using adopted exposure ratios which are loosely based on comparative exposure durations on the assessed populations.

WHO

WHO classify asbestos (actinolite, amosite, anthophyllite, chrysotile, crocidolite and tremolite) as carcinogenic, based on a statement by the International Agency for Research on Cancer. Exposure to amosite, anthophyllite, chrysotile or crocidolite results in the increased risk of lung cancer, while occupational exposure to crocidolite, amosite, tremolite and chrysotile has resulted in mesotheliomas. The risk of bronchial cancer also increases, as may that of cancers of the larynx and gastrointestinal tract.

WHO finds that the occurrence of asbestos-related diseases is related to fibre type, size and dose, and to the industrial procession of that asbestos, while cigarette smoking increases the associated risk. Fibres with a diameter greater than 3 µm are not respirable; fibres shorter than 5 µm and thicker than 2 µm elicit little response, while those longer than 10 µm and thinner than 0.5 µm yield the highest response.

Asbestosis has only been found related to occupational asbestos exposure, while non-occupational asbestos exposure does not appear sufficient. The incidence of mesothelioma has been shown to increase with increased exposure.

WHO studies have not found asbestos to be teratogenic or mutagenic in mice, while there is no conclusive evidence that ingested asbestos is carcinogenic. Drinking water containing high levels of asbestos have not been shown to be carcinogenic.

WHO (2000) provides estimates of mesothelioma risk resulting from lifetime inhalation exposure to asbestos with a best estimate of a risk of $2 * 10^{-5}$ for a lifetime exposure to 100 f/m^3 ($1 * 10^{-4}$ f/ml). WHO (2000) further provides an estimate of $2.2 * 10^{-5}$ risk of lung cancer for a non-smoker exposed to a fibre concentration of 100 f/m^3. These values are each equivalent to an approximate unit risk of 0.2 (f/ml)$^{-1}$. The unit risk is a measure of the incremental lifetime risk of cancer associated with lifetime exposure to a unit concentration (1 f/ml)$^{-1}$ of asbestos in air. Unit risk factors are derived from the cancer slope factor for the inhalation of carcinogenic chemicals.

enHealth

enHealth defines asbestos as a carcinogen, with amphibole fibres (crocidolite, tremolite and amosite) considered more dangerous and the primary agents in the increased incidence of mesothelioma. enHealth quotes studies suggesting there is a direct correlation between exposure and risk, with chronic exposure being the largest contributor to asbestos related health risks, with significantly increased mortality rates reported in exposed workers with cumulative exposure estimates greater than 25-100 f/mL-years. A further study estimated a 1 per cent increase in the standardised mortality ratio for lung cancer per year of exposure to 1 f/mL

The shape and length of asbestos fibres are also found to alter health risks, with fibres >20 µm <100 µm consider to be most carcinogenic, while in terms of shape, those with fibres >8 µm long and <0.25 µm diameter, with an aspect ratio (length/width) ≥10 appear to be most dangerous.

For non-occupational risk, studies of a crocidolite mining town showed a mesothelioma rate of 260 per 100 million person-years, while the mesothelioma rate for residents living near an asbestos cement factory was 73 (female) and 114 (male) per million person-years, as compared to a background incidence rate of one per million person-years. enHealth quotes guidelines for asbestos exposure as 0.1 f/mL for occupational exposure in Australia, and para-occupational sampling if using a limit of detection of 0.01 f/mL, while there is a proposed standard of 0.033f/mL for ambient air in Tasmania. Further, Australia has set a cut-off of 0.1 per cent by weight asbestos in products for the purpose of carcinogenic classification of the products.

NEHF/NICNAS

NICNAS has declared chrysotile a Priority Existing Chemical (PEC) as it is prevalent and a known human carcinogen, causing asbestosis, mesothelioma, and lung cancer. No estimate is given as to a limiting threshold, but lung cancer occurrence estimates for the Australian friction material manufacturing industry are given as 1 to 2 cases from exposure to 1 f/mL, 1 case at 0.5 f/mL and 0.2 case at 0.1 f/mL, per 1000 workers. The PEC also cites the 1999 national exposure standard (TWA) for chrysotile as 1 f/mL, but suggests that monitoring methods do not distinguish between types of asbestos and a limit of 0.1 f/mL would protect against other forms of asbestos.

ATSDR

ATSDR recognizes asbestos as a carcinogen responsible for mesothelioma and lung cancer. They quote the US EPA as proposing a concentration limit of 7 million fibres per litre of drinking water for long fibres (lengths greater than or equal to 5 µm), while the Occupational Safety and Health Administration has set a limit of 100,000 f/m^3 with lengths greater than or equal to 5 µm for workplace air for 8-hour shifts and 40-hour work weeks. A number of sources are quoted as given US standards for limits, typically 0.1 – 1.0 f/mL.

NTP

NTP studies on hamsters and rats show that asbestos is not carcinogenic from ingestion.

US EPA

The US EPA established asbestos as a human carcinogen based on consistently higher mortality rates and cancers among occupationally exposed workers. Inhalation was identified as the primary cause, while evidence for carcinogenicity from ingestion remains inconclusive, as studies on white rats resulted in the development of benign polyps. A synergistic interaction between asbestos exposure and cigarette smoking, contributing to the development of lung cancer but not mesothelioma, was identified.

The US EPA identifies the Inhalation Unit Risk as 0.23 $(f/mL)^{-1}$. The unit risk is a measure of the incremental lifetime risk of cancer associated with lifetime exposure to a unit concentration (1 f/ml)-1 of asbestos in air. Unit risk factors are derived from the cancer slope factor for the inhalation of carcinogenic chemicals. The US EPA unit risk factor is very similar to the unit risk as derived from WHO reports.

Air Concentrations at Specified Risk Levels as provided by the US EPA are summarised following:

Risk Level	Concentration
E-4 (1 in 10,000)	$4*10^{-4}$ f/mL
E-5 (1 in 100,000)	$4*10^{-5}$ f/mL
E-6 (1 in 1,000,000)	$4*10^{-6}$ f/mL

Different types and fibre sizes of asbestos appear to have different health impacts, with fibre size and processing method appearing to impact relative risk as much as the specific type of asbestos. Evidence remains inconclusive as to the exact nature of these differences.

US EPA (2014) provides a further discussion of potential noncancer effects of exposure to amphibole forms of asbestos. These have been found to include pleural abnormalities, asbestosis, and reduced lung function as well as increased mortality from noncancer causes. Experimental animal studies are further reported to have demonstrated increased collagen deposition consistent with fibrosis following intratracheal instillation of asbestos fibre in mice as well as increased markers of pulmonary inflammation in a rat model for human cardiovascular disease.

US EPA (2014) nominates a reference concentration (RfC) of $9*10^{-5}$ f/ml for amphibole forms of asbestos as based on observations of increased pleural thickening (localized and diffuse) and signs of interstitial fibrosis (i.e. small opacities) in occupationally exposed workers. Localized pleural thickening (LPT) was selected as the critical effect due to its higher prevalence for the purposes of deriving an RfC. The RfC is intended to be applied on the basis of continuous exposure (i.e. 24 hours/day, 365 days/year, with exposure beginning at birth and continuing for 70 years). The derivation of the RfC is reported to have included three uncertainty factors (UF) for a composite UF of 300 (comprising an intraspecies UF of 10 and a database UF of 10). The RfC is reported to be applied by calculating the average concentration over a lifetime period – that is the RfC is intended to be applied to an averaging time of a lifetime exposure.

US EPA (2014) also present an estimate of unit risk, on the basis of combined mesothelioma and lung cancer mortality from exposure to amphibole asbestos on the basis of the workers assessed. The unit risk value of 0.17 $(f/ml)^{-1}$ provided for amphibole asbestos is similar to the unit risk of 0.23 $(f/ml)^{-1}$ recommended by the US EPA IRIS database for all forms of asbestos.

5.6 Adopted Value to Assess Risk of Asbestos

Potential toxicological effects of asbestos exposure will be assessed by the WHO recommended unit risk of 0.2 $(f/ml)^{-1}$. Asbestos is not toxic by oral or dermal exposure pathways. The unit risk to assess non-threshold effects, has been demonstrated as being suitably conservative to account for potential threshold effects of exposure to amphibole forms of asbestos.

6. Exposure Assessment

Exposure assessment involves the determination of the magnitude, frequency, extent, character and duration of exposures currently and into the future. This includes the identification of exposed populations and potential exposure pathways. The exposure assessment has derived exposure scenarios that are the most potentially conservative for the site and the surrounding area.

6.1 Potential Exposure Pathways and Populations

On the basis of preceding discussion, the potential receptors of concern for further assessment are:

- Recreational users of the Beach;
- Landscapers / Gardeners / Beach maintenance workers;
- Sub-surface maintenance / excavation workers; and
- Residents adjoining / in proximity of the site.

Recreational users will potentially undertake a range of surface activities across the Beach, as consistent with the locality and open space nature of the site. It is noted that these would be anticipated to be of short duration in nature as consistent with the absence of any fixed equipment, camping etc within the extent of the Beach.

Landscapers are understood to be occupationally engaged to maintain the adjoining Golf Course and likely undertake minor works associated with the maintenance / upkeep of the Beach. Though these are a commercial / industrial receptor, exposure durations will not be consistent with the duration of commercial / industrial exposures, as only a minor amount of landscaping / maintenance works are required for the grassed / open areas in proximity of the Beach – or otherwise for the limited works required to maintain / clean the area of the Beach. There are no significant garden / landscaped areas within the Beach that would warrant detailed works from a gardener / landscaper. However particular factors as unique to landscaping / gardening works may potentially cause increased exposures.

Periodic sub-surface / excavation works may be required in proximity of the site as associated with future maintenance of services (i.e. stormwater services known to pass through the Beach, irrigation systems on the adjoining Golf Course etc). These exposures would be anticipated to be of short duration and intermittent. However, as noted for landscapers there is a potential for unique factors within these works that may potentially cause increased exposures to airborne asbestos fibres. Sub-surface maintenance worker exposures may further be caused to be highly localised, and assessment should be undertaken to maximum concentrations of constituents to remain conservative.

Asbestos fibres as potentially generated from exposed asbestos fibres within the beach may potentially migrate to affect residential properties in proximity. The residential properties will likely have sensitive receptors present. Further exposure durations within residential properties would be anticipated to be greater than exposure durations of recreational users on the Beach. The risk assessment also requires to consider the potential levels of asbestos as may be caused at these adjoining residential properties. This will require additional factors to be considered in the fate and transport assessment, inclusive of the proportion of time that a residence may be downwind of the site, dispersion and associated reduction in concentration of airborne fibres between the Beach and the residential dwelling / property, and reductions of indoor to outdoor levels of respirable particles/ fibres.

6.2 Exposure Estimation

Exposure estimation has been undertaken by the consideration of a reasonable maximum exposure (RME) on a particular site (USEPA, 1989a). The goal of RME is to combine upper bound and average exposure factors in a manner such that the result represents an exposure scenario that is both protective and reasonable. This is not one which is the absolute worst case but that which represents a reasonable maximum exposure.

The approach for exposure assessment used here is based on the procedures developed by the US EPA (1989a and 1991). In general, assumptions employed in risk assessments are based on information presented by local authorities (i.e. enHealth (2001) 'Exposure Scenarios and Settings'), precedents established in previous risk assessments and recommendations by the US EPA.

The estimated exposure (or intake) of a person is normalised for time and body weight and is generally calculated as:

$$\text{Intake} = \frac{\text{Concentration x Contact Rate x Exposure Frequency x Exposure Duration}}{\text{Body Weight x Averaging Time}}$$

As an alternative to deriving criteria based on RME, probabilistic techniques such as Monte Carlo analysis can be used to account more realistically for variability and uncertainty. However, there is generally insufficient information available in an Australian context to allow reliable Monte Carlo analysis to be undertaken. Monte Carlo analysis has not been undertaken here.

6.3 Exposure Factors

The exposure factors adopted for the purposes of assessing risks from the site are consistent with those adopted in NEPC (2013) in the first instance. Where insufficient guidance is provided in NEPC (2013), further reference has been made to enHealth (2012) '*Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards*', enHealth (2012b) '*Australian Exposure Factor Guidance: Guidelines for assessing human health risks from environmental hazards*' and CRC CARE (2011) '*Technical Report no.10: Health Screening Levels for Petroleum Hydrocarbons in Soil and Groundwater*' where available. For some exposure scenarios, specific or appropriate exposure factors have not been provided in enHealth (2012) or CRC CARE (2011). In these cases, available literature has been reviewed to determine the parameters that are most appropriate for an Australian context. Additional parameters, where required, are based on an RME receptor.

Exposure factors are summarised for each of these populations in the following **Tables 6.1** to **6.4**.

Table 6.1: Exposure Parameters – Recreational User

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	365	NEPC (2013), assumed continuous
Exposure Duration	Years	70	NEPC (2013), assumed lifetime
Exposure Time	Hours	2	NEPC (2013), as recommended for recreational exposure durations
Averaging Time – non Threshold	Years	70	NEPC (2013)

Table 6.2: Exposure Parameters – Gardener / Landscaper

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	52	Assumption of one day per week, 52 weeks per year. Protective of exposures on the Beach, or otherwise exposures in close proximity on the Golf Course
Exposure Duration	Years	30	NEPC (2013), commercial / industrial exposure duration
Exposure Time	Hours	8	NEPC (2013)
Averaging Time – non Threshold	Years	70	NEPC (2013)

Table 6.3: Exposure Parameters – Adult Sub-Surface Maintenance Workers

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	15	Assumption of maximum time spent undertaking maintenance works, three weeks.
Exposure Duration	Years	10	Based on 10 repeat events
Exposure Time	Hours	8	NEPC (2013)
Averaging Time – non Threshold	Years	70	NEPC (2013)

Table 6.4: Exposure Parameters – Adjoining Resident

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	365	NEPC (2013)
Exposure Duration	Years	35	enHealth (2012), 95% RME time at single residence.
Exposure Time	Hours	20	enHealth (2012)
Averaging Time – non Threshold	Years	70	NEPC (2013)

6.4 Estimation of Inhalation Exposure

When deriving screening levels for asbestos, inhalation exposures have been estimated by the approach in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*, January 2009, US EPA. Equations are provided here for estimating exposure concentrations for assessing cancer risks and for calculating hazard quotients from chronic exposures as per the following:

EC = (CA * ET * EF * ED)/AT (cancer risks)

EC = (CA * ET * EF * ED)/AT (hazard quotients)

Where: EC – exposure concentration (µg/m^3);

CA – contaminant concentration in air (µg/m3);

ET – exposure time (hours/day)

EF – exposure frequency (days/year)

ED – exposure duration (years)

AT – averaging time, cancer risks (lifetime in years * 365 days/year * 24 hours/day)

AT – averaging time, hazard quotient (ED in years * 365 days/year * 24 hours/day)

Table 6.5, summarises each of the adjustment factors to be used for each of the receptors assessed by the risk assessment.

Table 6.5: Summary of Factors to Adjust Airborne Concentrations for Inhalation Exposure

Receptor	Cancer Risks (EC)
Recreational Site User	EC = 8.33×10^{-2} * CA
Landscaper / Gardener	EC = 2.04×10^{-2} * CA
Sub-Surface Maintenance Worker	EC = 1.96×10^{-3} * CA
Adjoining Resident	EC = 0.417 * CA

6.5 Asbestos Fibre Fate and Transport

Environmental assessment works undertaken have identified asbestos as present on the site as summarised in **Sections 1.11** as restricted to assessment of asbestos occurring as bonded ACM. The quantitative data as generated from the assessments to date has presented a concentration of bonded asbestos present in site soils of 24 mg/kg (**Section 2.3**). However potential exposures require to be based on airborne concentrations of asbestos. On this basis, a fate and transport assessment has been completed to estimate potential airborne levels of asbestos from the site, as generated from known levels of asbestos in site soils.

6.5.1 Level of Asbestos in Site Soils

A typical level of asbestos in site soils has been estimated as 24 mg/kg of bonded asbestos as present in site soils as per **Section 2.3**. This is adopted as the typical average level of asbestos across the site.

There is a potential that higher localised concentrations may be present in areas of preferential asbestos disposition / occurrence. These have not been definitively identified within the previous Trinitas (2020a to 2020x) assessments, but may occur in areas of the gullies and/or at the stormwater outlet. For the basis of this risk assessment, it has been assumed that maximum concentrations of up to 2.5 times the adopted average level may be present on the site. This is consistent with the guidance for typical maximum values in contaminated soil data sets advised in NEPC (2013). A maximum concentration of asbestos (bonded) of 60 mg/kg has been adopted for the assessment.

6.5.2 Fibre Release from Contaminated Soils

Two published studies are available which have attempted to quantify the rate of asbestos fibre release from soils. These include Addison, J., Davies, L.S.T., Robertson, A., and Willey, R.J, 1988, '*The Release of Dispersed Asbestos Fibres from Soils Technical Memoranda',* TM/88/14, Institute of Occupational Medicine: 50, Edinburgh, UK (Addison et al 1988) and Swartjes, F.A., Tromp, P.C., , 2008, 'A Tiered Approach for the Assessment of Human Health Risks of Asbestos in Soils'*, Soil and Sediment Contamination*, Volume 14, Issue 4, pp. 137 – 149 incorporating Swartjes F.A, Tromp P.C, Wezenbeek J.M, 2003, '*Assessment of the Risks of Soil Contamination with Asbestos',* National Health and Environmental Institute, Netherlands, RIVM Report 711701034/2003 (Swartjes and Tromp 2008), as discussed below.

<u>Addison et al (1988)</u>

Assessment of the potential for asbestos fibre generation from asbestos contaminated soils has been undertaken in Addison et al (1988). This study assessed the potential generation of free asbestos fibres from asbestos contaminated soils.

It was found that potentially high concentrations of asbestos fibres could be present in dust as generated from contaminated soils. It was found that soils with a concentration of free asbestos fibre of 1% by weight could generate airborne fibre concentrations greater than 20 f/ml where dust levels were below 5 mg/m^3. Dry loose soils with 0.001% asbestos fibres reported respirable asbestos concentrations greater than 0.01 f/ml while dust levels were below 5 mg/m^3.

The potential generation of asbestos fibres was found to be reduced for chrysotile forms of asbestos when compared to amphibole forms. Increasing moisture content of soils reduced potential asbestos fibre generation. Clayey soils generated less asbestos fibres than loose sandy soils.

On the basis of the tests completed by Addison et al (1988) a relationship between the normalised airborne fibre concentration (f/ml / mg/m^3) and the proportion of asbestos in soil was produced (**Diagram 6.1**).

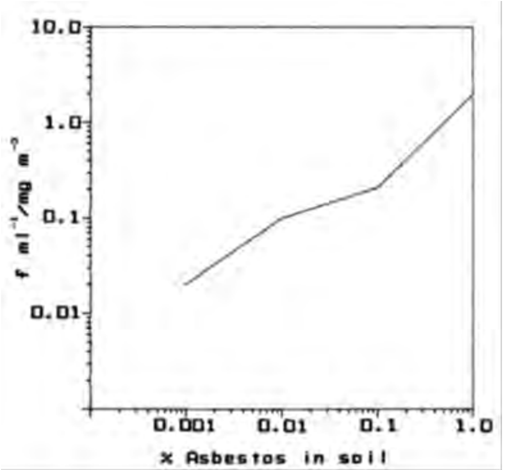


Diagram 6.1: *The relationship between the normalised airborne fibre concentration (f/ml / mg/m^3) and the proportion of asbestos in soil; average results from all test runs (Addison et al 1988)*

Swartjes et al (2003) and Swartjes & Tromp (2008)

A more recent assessment than Addison et al (1998) of the generation of asbestos fibres from soils has been undertaken by Swartjes & Tromp (2008) as incorporating the findings of Swartjes et al (2003). An inventory of more than 1000 measurements of asbestos fibre generation from asbestos impacted soils is reported to have been reviewed. These data resulted from:

- Worst case simulation experiments (wind blower with dry soil and loose asbestos fibres);
- Field experiments consisting of daily practice activities including driving on contaminated roads, digging and dumping and sifting of humid soil on sites contaminated with:
    - Friable asbestos in soils; and
    - Bound asbestos (i.e. ACM) in soils.

Diagram 6.2 shows the data obtained by Swartjes et al (2003) and Swartjes & Tromp (2008) showing the relationship between soil and air concentrations of asbestos. The graph shows the airborne asbestos concentration during the simulation experiments and field measurements with friable and bound asbestos impact in soils. 95% confidence intervals are also shown. The lower fitted line is based on field measurements of asbestos fibre generation from impacted soils, and the upper fitted line is based on simulations of worst case asbestos fibre dispersal from impacted soils (i.e. lab based trials).

It is noted by the authors in the preparation of the graph that the worst case simulation experiments (i.e. lab based) give higher airborne asbestos concentrations. This is shown by the higher of the fitted lines on **Diagram 6.2**.

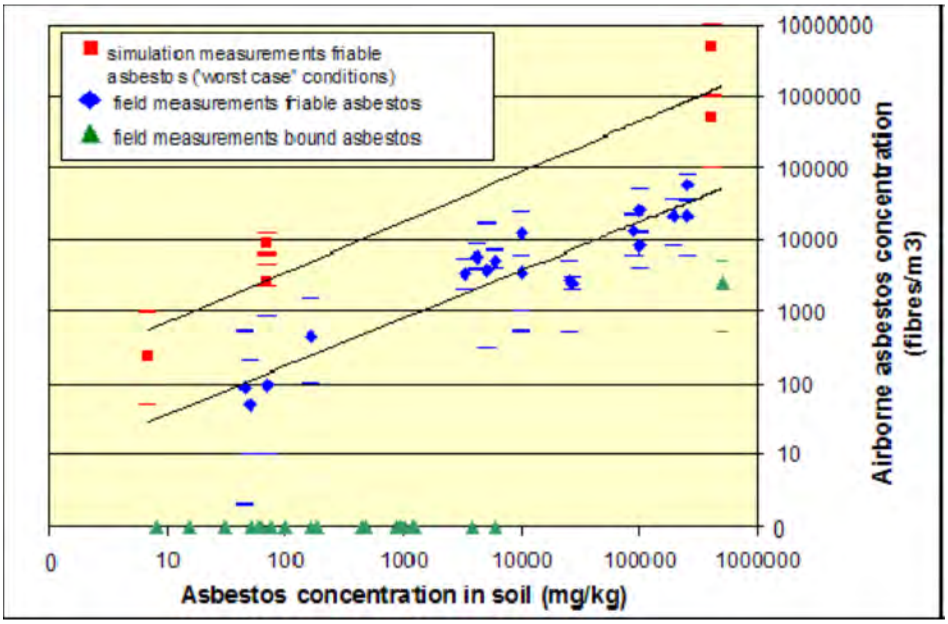


***Diagram 6.2**: Results showing the relationship developed between soil and air concentrations of asbestos*

Preferred Method

The Swartjes and Tromp (2008) method has been adopted to estimate potential airborne asbestos concentrations as caused by fibres in soils. This method is considered appropriately conservative for adoption on the site on the basis of:

- The asbestos fibre generation measurements in the field based data set have been collected during daily practice activities where soils are being actively agitated. Examples of the sort of agitation works being undertaken on the soils includes driving on contaminated roads and digging, dumping and sifting of humid soil. These activities will typically not be undertaken within the Beach, or will be highly localised and of short duration when undertaken. This causes the estimated levels of asbestos over the chronic timescale of the majority of exposure assessed to be highly conservative;
- Soil moisture content is reported to control asbestos emissions as discussed further in **Section 6.5.3**. The Dutch soils on which the Swartjes and Tromp (2008) emissions data are based are reported to have a typical soil moisture content of 10% (MHSP&E 2000). Noting that the site is a beach area, and is subject to regular inundation and further drainage outflows, this is a conservative characterisation of the actual levels of soil moisture that will be present, and ensures that underestimates of asbestos fibre release will not occur. This confirms that Dutch data is appropriate to characterise the potential future behaviour of soils on the site. A basis to estimate reduced asbestos emissions with increasing soil moisture, as will be relevant to the context of the Beach being assessed here, is also provided (discussed further in **Section 6.5.4**);
- It is assumed with application of the method that exposures occur in direct proximity of the asbestos fibres. However, Swartjes and Trompe (2008) reports substantial reductions in airborne levels of asbestos fibres at small distances from the source of the fibres. These have not been considered in the assessment; and
- For the purposes of the modelling, it has been assumed that all asbestos fibres are present in near surface soils and are available to be released into the atmosphere. This is again highly conservative as it assumes that asbestos fibres are relocated to the upper surface

layer of soils only and no vegetation is present in landscaped areas of the site, or otherwise present over the remainder of the site.

6.5.3 Locations of Asbestos Exposure

It has been assumed that recreational users, landscapers / gardeners and sub-surface excavation / intrusive workers will be exposed to asbestos fibres in soils consistent with the predicted airborne concentration above the asbestos fibres. There is also a potential that asbestos fibres may blow into nearby residential dwellings (in closest proximity to the west).

Langley & Sobardo (1996) 'Exposure factors in risk assessment' in Langley, Markey & Hill (eds) The health risk assessment and management of contaminated sites: proceedings of the Third National Workshop on the Health Risk Assessment and Management of Contaminated Sites, Contaminated Sites Monograph Series No. 3, South Australia Health Commission reports that 'inspirable particulates inside a house will be 75% of the level of inspirable particulates outdoors'. On this basis, it has been assumed that the 0.75 of the maximum concentration of asbestos fibres will occur within the residential buildings in proximity of the site.

It is further noted that the nearest residence is located at least 50 m from the boundary of the Beach. Reduction in airborne concentrations of asbestos fibres would occur over this distance by dispersion of any asbestos emissions from the Beach. Reductions in concentrations as caused by these dispersion processes have not been considered in the risk assessment, causing estimated airborne concentrations at adjoining residents to be conservative.

6.5.4 Reduced Asbestos Exposure during Rain Days

Review of meteorological data for the Sydney region indicates that the area is subject to rainfall approximately 96 days per year as discussed in **Section 1.10**. Significant asbestos fibre emissions are not anticipated to occur during periods of rainfall. Consistent with the guidance provided in Swartjes and Trompe (2008) and shown on **Diagram 6.3**, emissions of asbestos fibres substantially reduce with increased levels of soil moisture. This is particularly the case for sandy soils, as are observed on the site.

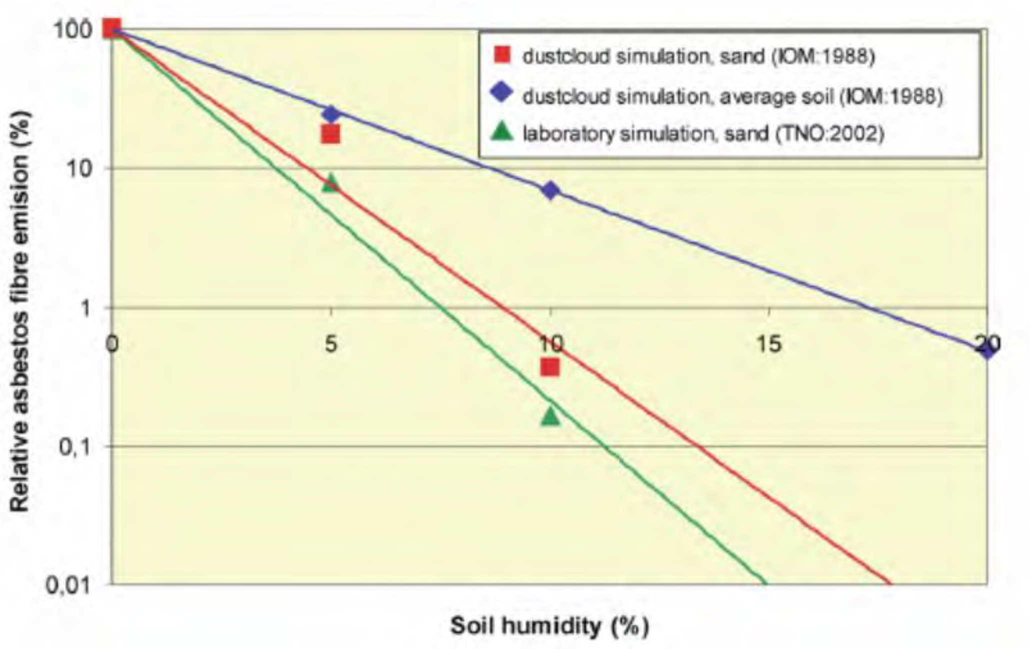


Diagram 6.3: *Comparison of Soil Moisture and Relative Level of Asbestos Fibres Released*

On this basis, it has been assumed that no significant emissions of asbestos fibres will occur on rainy days. The potential assessment of long term exposures have been reduced by a factor consistent with (365-96)/365 days.

No correction has been made for the increased soil moisture, anticipated to be significantly greater than 10%, that would be present within beach sands. The higher moisture content of soils on the Beach would mitigate the potential release of asbestos fibres.

6.5.5 Reduced Asbestos Exposure based on Wind Direction

For human exposure to occur to asbestos emissions, the receptor is required to be downwind of the source of the asbestos fibres. However, for the risk calculations undertaken here, it has been assumed that the on-site receptors are constantly downwind of the source of asbestos fibres.

For the residential receptors in proximity, an adjustment factor of two has been adopted to occur for periods when the residential dwelling is cross-wind or otherwise upwind of the Beach.

6.5.6 Potential Increased Exposure of Excavation Workers and Gardeners

It is noted that some of the factors as summarised in **Section 6.5.2** to support the use of the Swartjes and Trompe (2008) relationship as conservative for the risk assessment may not apply to short duration excavation worker exposures and works where significant soil agitation may occur (i.e. raking of beach sands to remove wastes, excavations near stormwater pipes etc). On this basis, an additional order of magnitude safety factor has been adopted with these receptors, including potential intrusive / excavation workers and site maintenance staff / gardeners / landscapers in estimating potential levels of asbestos fibres.

6.5.7 Asbestos Release from Bonded Asbestos

All detected asbestos on the site occurs in a bonded matrix. As can be observed from the green data points on **Diagram 6.2**, asbestos emissions do not occur from bonded matrices. For asbestos emissions to occur from bonded asbestos, the bonded matrix is required to break down to release the asbestos fibres into the soils.

A minimum thickness of fibre cement sheet fragment of 4 mm has been observed on the site by the interpretation of the assessments completed. A fibre cement sheet weathering rate of 0.024 mm/year has been reported in *Asbestos fibre release by corroded and weather asbestos-cement products*, 1989, Spurney K R in IARC Science Publication. On the basis of 30, 35 and 70 year duration exposures in proximity of the site, this would indicate that between 18, 21 and 42% of asbestos fibres caused to be released and occur as asbestos fines. This would preclude a substantial portion of the asbestos detected from being considered to potentially be present as fibres, and excluded from the risk assessment calculations

However, it is noted that no assessment of potential levels of free asbestos fibres / asbestos fines / friable asbestos has been completed with the assessments completed to date (Trinitas 2020a to 2020x). On this basis, and to again ensure conservatism of the interim risk assessment stage, it has been assumed that all asbestos present on the site occurs as free asbestos fibres.

6.5.8 Summary of Exposure Concentrations

On the basis of the preceding sections, the potential exposure adjusted asbestos fibre concentration as estimated from the level of asbestos fibres in soils, is summarised for each of the site receptors in **Table 6.7**. This has been undertaken by the adopted concentrations of asbestos fines / free asbestos fibres.

Table 6.7: Summary of Exposure Concentrations for Airborne Asbestos Fibres for Each Receptor Type Based on Asbestos Fines

Factor	Recreational User	Landscaper / Gardener / Beach Maintenance	Sub-Surface Excavation Worker	Adjoining Resident
Free Asbestos in Soils, mg/kg	24	60	60	24
Estimated Airborne Concentration (Swartjes and Tromp), f/m^3	80	105	105	80
Rain day adjustment	0.74	0.74	1	0.74
Excavation works adjustment	1	10	10	1
Outdoor-Indoor Air adjustment	1	1	1	0.75
Wind direction adjustment	1	1	1	0.5
RAGS F Exposure Adjustment	0.0833	0.0204	0.00196	0.417
Exposure Concentration (f/ml)	$4.9*10^{-6}$	$1.6*10^{-5}$	$2.1*10^{-6}$	$9.3*10^{-6}$

It is noted that an additional order of magnitude conservative factor was provided for potential excavation worker, beach maintenance worker and landscaper / gardener exposures only, which is a substantial adjustment to the exposure level of these populations. Consistent with the discussion in **Section 6.5.2**, the data used to premise the estimate of the release of asbestos fibres from the site soils has been based on data collected from active excavation / earthworks / remediation sites. These activities are not consistent with normal site activities as associated with the anticipated chronic duration exposures for normal site users (i.e. passive beach use under high moisture content conditions). However these activities may be consistent with a significant duration of intrusive / maintenance worker exposures and/or increased rates of soil agitation by beach maintenance, and the additional factor of ten has been adopted here to ensure a conservative approach to exposure characterisation.

It is further noted that only the maximum estimated concentration of asbestos fibres / asbestos fines has been considered in the potential exposure of sub-surface maintenance / excavation workers and beach maintenance workers. This is cognisant of maintenance / excavation works potentially being localised to small areas of the site, and unlikely to be exposed to the full extent of the site. On this basis the estimated average of the site level of asbestos is not appropriate.

7. Criteria for Assessment of Risk

7.1 Risk Measurement

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The slope factor (SF) converts estimated daily intakes averaged over a lifetime of exposure directly to incremental risk of an individual of developing cancer. Because relatively low intakes (compared to those experienced by test animals) occur with exposures on most contaminated sites it can generally be assumed that the dose response relationship is linear in the low-dose portion of the multistage model dose-response curve. Under this assumption the slope factor is constant and risk is directly related to intake. Thus the following linear based carcinogenic risk equation is used:

Risk = CDI * SF

where: Risk – unitless probability of an individual developing cancer;

CDI – chronic daily intake averaged over 70 years (mg/kg-day); and

SF – slope factor expressed in $(\text{mg/kg-day})^{-1}$.

The slope factor is often an upper 95% percentile confidence limit of the probability of response based on experimental animal data used in the multistage model. Consequently, the carcinogenic risk estimate will often be an upper bound estimate (US EPA, 1989a).

For the case of estimating risk from asbestos exposure the following linear based carcinogenic risk equation is used:

Risk = Cadj * Unit Risk

where: Risk – unitless probability of an individual developing cancer;

C_{adj} – adjusted asbestos fibre air concentration (f/ml); and

Unit Risk – equal to 0.2 $(\text{f/ml})^{-1}$ for asbestos fibres based on WHO increased incidence of mesothelioma and/or lung cancer.

7.2 Adopted Risk Criteria

Acceptable risk guidelines are available from a range of national and international environmental agencies. These include:

- US EPA (1991) states that "Where the cumulative site risk to an individual based on a reasonable maximum exposure for both current and future land use is less than 10^{-4}, action is generally not warranted unless there are adverse environmental impacts". Where the level of risk exceeds 10^{-4} it is recommended that remediation goals are developed based on a 10^{-6} cancer risk;
- WHO (2004b) 'Guidelines for Drinking Water Quality' are based on a risk of 1 in 100,000 (1 x 10^{-5}); and
- NHMRC/ARMCANZ (2011) 'Australian Drinking Water Guidelines' nominate a negligible level of risk of 1 in 1,000,000 (1 x 10^{-6}).

Risk based criteria have been derived by the risk assessment. Guidance for the Australia approach to the derivation of risk based criteria for the assessment of contaminated sites can be observed in NEPC (2013). To this extent, the worked examples provided to NEPC (2013) for the derivation of risk based criteria adopt a target risk of $1*10^{-5}$. The derivation of risk based criteria for benzene in CRC CARE (2011), as adopted in NEPC (2013), has adopted a target risk of $1*10^{-5}$. The guidelines for human health risk assessment as provided to NEPC (2013) further instructs that when using non-threshold TRV as dose-response criteria, the recommended acceptable incremental lifetime risk of developing cancer arising from exposure to single or multiple carcinogens is 1 in 100,000 (10^{-5}).

For the purposes of this risk assessment an acceptable level of risk is defined as risk less than 1 x 10^{-5} incremental lifetime risk of cancer.

8. Assessment of Risk

Estimates of carcinogenic risk have been prepared for each of the nominated receptors on the basis of the exposure concentrations as summarised in **Table 6.7** and the unit risk adopted for asbestos inhalation. The estimates of carcinogenic risk for each of the receptors assessed are summarised within **Table 8.1** following.

Table 8.1: Estimate of Carcinogenic Risk for Each Receptor

Receptor	Cancer Risk Estimate
Recreational User	$9.9*10^{-7}$
Landscaper / Gardener / Beach Maintenance Worker	$3.2*10^{-6}$
Sub-Surface Maintenance Worker	$4.1*10^{-7}$
Adjoining Resident	$1.9*10^{-6}$

Each of the estimated levels of risk are well below the adopted acceptable level of risk for the site.

It is further noted that there is a likelihood that a resident located in the Little Bay residential area, including the residence in closest proximity to the Beach, may further use the Beach for recreational purposes. As per this scenario, the incremental risk estimated for 'adjoining resident' and 'recreational user' scenarios should be added. The sum of these risk estimates is $1.4*10^{-6}$ which is still well below the adopted risk criterion.

On this basis, restricted to the assessment of asbestos on the site and the interim estimate of asbestos that may be present, it is considered that the levels of asbestos as present on the Beach will not pose an unacceptable health risk to ongoing / potential future users of the site and/or potentially sensitive populations in proximity of the site.

9. Sensitivity Analysis

An assessment has been required to be undertaken of the sensitivity of the risk assessment outcomes. Risk assessment calculations can be observed to have been based on:

- Levels of COPCs (free asbestos fibres / asbestos fines and bonded asbestos) as estimated by soil sampling programs completed on the site;
- Toxicological parameters used to characterise COPCs;
- Anticipated and assessed current and future land-uses;
- Exposure parameters used to characterise future population behaviours on the site;
- Physical parameters used to characterise site areas and buildings where exposures may occur; and
- Equations and related relationships used to estimate levels of COPCs from reported levels in soils and groundwater to points of exposure.

Each of these are discussed as follows.

9.1 Sampling Programs

Analytical data used for the risk assessment have been obtained from assessment and remediation programs recently undertaken and reported in Trinitas (2020a to 2020x). The principal assumptions in the use of this data, and further the potential sensitivity of the assumptions, include:

- 6 kg of asbestos based fibre cement sheet fragment was removed from the Beach area over a three week period. It was assumed that this was 50% of the total ACM as present on the Beach and further present at the site surface. This has resulted in subsequent estimates of asbestos concentrations being doubled. A more appropriate factor would have been derived by the comparison of the 1 kg of additional asbestos reported to have been collected in Trinitas (2020k) following completion of works reported in Trinitas (2020i and 2020j). This would indicate that the amount of ACM is being underestimated by a significantly lower factor of approximately 17%, which would of resulted in a lower estimate of asbestos.

  It is also noted that there is a possibility that smaller fragments of ACM have not been identified / removed. However where present, due to their small size, they would not affect the adopted concentration of asbestos significantly

  Further it has been assumed that the Beach area will persist with a level of contamination that was present prior to the recent remedial works. No allowance has been made for the extensive removal of ACM as has been recently completed on the Beach, again causing the estimated level of asbestos to exceed the actual level now present;
- All asbestos assumed to be present and/or caused to be removed by the site remedial works is restricted to the upper 5 mm of the soils profile only. It has been assumed that ACM below this depth has not been able to be identified. The assumption of 5 mm is highly conservative, and a depth as consistent with the smallest ACM fragments recovered (i.e. 10 mm) would have been more appropriate. Where 10 mm had of been adopted, then the estimated asbestos concentrations would be halved; and
- Asbestos has been identified in a fibre cement sheet matrix only, which has been described as non-friable. No assessment for free asbestos fibres / asbestos fines has been undertaken. In lieu of this, it has simply been assumed that all asbestos present is present as free asbestos fibres. This has resulted in a substantially higher estimate of potential airborne

asbestos fibres that what would of otherwise been estimated by the characterisation of fibre cement sheet weathering as proposed in **Section 6.5.7**. For the residential receptor, this has resulted in an increased estimate of risk of an approximate order of magnitude.

Further, the assessment of a sub-surface excavation / maintenance worker has been based on a maximum concentration, which has been estimated at an even higher level than the conservative estimate of the average level of asbestos discussed above.

It is considered that the use and selection of environmental data has caused the interim risk assessment to derive overly conservative estimates of risk.

It is finally noted that a repeat health risk assessment is proposed to be undertaken on the availability of detailed quantitative data as proposed to be collected from the Beach. It is anticipated that this data will confirm the highly conservative estimates adopted in the risk assessment.

9.2 Toxicological Parameters

Toxicological data are generally derived by the conversion of dose factors as developed based on animal studies to appropriate levels for human exposure. The conservatism of these values is achieved through the use of uncertainty factors. An uncertainty factor of 100 is commonly applied in converting measured animal toxicity data for use for humans, comprising:

- A factor of 10 to allow for differences that affect the way a chemical behaves in humans rather than the animal species tested; and
- Another factor of 10 adequate to allow for differences in the way the chemical might affect different people, to allow for the most sensitive individuals.

Though the two processes most likely act in two separate ways, indicating a summed factor of 20 should be used, the factors are multiplied to generate an uncertainty factor of 100. It is also noted that most agencies will incorporate an additional factor of 10 where long term toxicity data are not available for a particular constituent, resulting in a total factor of 1 000.

Actual conversion factors used in the derivation of toxicological values has been extensively detailed in **Section 5**. Toxicological data used in the risk assessment has incorporated these uncertainty factors. This is considered an appropriately conservative process for the site.

9.3 Land-Use

The risk assessment outcomes are only valid for the assumed future land-use of the site. The risk assessment would need to be revised where the site was used for a future use other than what has been considered in this assessment.

It is noted that it has been assumed in the fate and transport assessment that the whole of the site is unpaved and clear of vegetation, and all asbestos within Beach sands is potentially accessible to surface wind processes and in a general dried condition. With particular respect to the moisture content, this is a highly conservative assumption. Sand moisture contents will be substantially higher than the level of 10% that asbestos emission rates have been based on.

9.4 Exposure Parameters

Exposure parameters have been derived for the range of receptors as based on published guidance provided in Australian guidelines. Exposure parameters are based on reasonably maximum exposed persons and are considered to be conservative.

Risk results are generally found to adjust linearly with adjustments in exposure parameters.

9.5 Air Monitoring Data

It is noted that several air monitoring events for airborne asbestos fibres have been completed on the site as reported across Trinitas (2020a to 2020x). Levels of potential respirable fibres have been reported below 0.01 fibres/ml in the majority of events. Though these results are encouraging, the detection limit of 0.01 fibres / ml (1000 fibres/m^3) is substantially above the level of airborne asbestos fibres as predicted by the risk assessment.

9.6 Conclusion

There are several factors which may have caused the risk and hazard estimates provided in this risk assessment to be underestimated. However, it is more than likely that any underestimation caused by the risk assessment process and limitations of available data and modelling techniques has been overcome by the use of conservative assumptions throughout the assessment. Examples of conservative assumptions provided in this assessment include:

- Adoption of a conservatively characterised dataset to estimate levels of free asbestos fibres as present in beach sands;
- Consideration of estimated maximum values for asbestos contaminant concentrations across the whole of the Beach in the characterisation of potential exposure levels of occupationally engaged receptors;
- Used of a conservative modelling approach and associated physical parameters to characterise fate and transport of asbestos; and
- Use of RME (reasonable maximum exposed) based exposure parameters for receptors where locally available data is not present.

It is concluded that the risk estimates provided are overestimates of actual risk levels and can be used for future decision making for the site.

Notwithstanding, the risk assessment must be repeated and reconsidered on the availability of quantitative data as proposed to be collected with the upcoming detailed site investigation works. It is highly likely that the availability and use of this data will preclude the requirement for several of the highly conservative assumptions adopted, and will further result in a lower estimate of health risk.

10. Conclusions and Recommendations

A human health risk assessment has been undertaken to determine whether the levels of asbestos as estimated on Little Bay Beach are potentially present at a level that poses an unacceptable health risk to an ongoing recreational use of the site / sites in proximity and/or residents in proximity of the site. A sensitivity analysis undertaken of the risk assessment process has found that risk estimates are appropriately conservative and suitable for decision making as to the suitability of the site. The assessment has been proposed as an interim stage using available data with conservative assumptions prior to the availability of a detailed site characterisation.

In accordance with the limitations provided as **Section 11**, levels of asbestos on the site have not been found to pose a potentially unacceptable health risk to current / future users of the site as consistent with a recreational land-use, recreational uses in proximity of the site, nor occupants of residential properties in proximity of the site.

The fate and transport assessment has estimated the potential worse case airborne concentration of asbestos fibres on the site. This has been found to be well below a level of 0.01 f/ml as identified in *Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997*, 2015, NSW EPA as a potential trigger to warrant reporting under the *Contaminated Lands Management Act 1997*. Further recent respirable fibre monitoring undertaken by Trinitas during site assessment / remediation works has not identified airborne levels of fibres equal to or exceeding 0.01 f/ml. It is concluded on this basis that there is not a requirement to report asbestos impact to the NSW EPA.

Notwithstanding the conclusions in respect of the potential human health risk, soils on the site are impacted with asbestos. Requirements with respect to asbestos as informed to the *Work Health and Safety Regulation 2017* (WHS Reg) do not differentiate as to whether levels of asbestos are sufficient to pose a health risk.

It is understood that a detailed site investigation is proposed to be undertaken on the Beach. This interim health risk assessment will require to be updated with the detailed quantification data as generated by this investigation. The requirements of the WHS Reg as relevant to the Beach will be able to be considered in more detail on availability of the investigation results.

11. Limitations

This report has been prepared for use by the client who commissioned the works in accordance with the project brief only and has been based in part on information obtained from other parties. The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

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Sampling and chemical analysis of environmental media is based on appropriate guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements and site history, not on sampling and analysis of all media at all locations for all potential contaminants.

Limited sampling and laboratory analyses were undertaken as part of the investigations, as described herein. Ground conditions between sampling locations may vary, and this should be considered when extrapolating between sampling points. Chemical analytes are based on the information detailed in the site history. Further chemicals or categories of chemicals may exist at the sites, which were not identified in the site history and which may not be expected at the site.

Changes to the subsurface conditions may occur subsequent to the investigations described herein, through natural processes or through the intentional or accidental addition of contaminants. The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown sources of contamination, JBS&G reserves the right to review the report in the context of the additional information.

Figures

Legend:

Approximate Site Extent

Job No: 59811

Client: Randwick City Council

Version: R01 Rev A	Date 7/10/2020
Drawn By: AS	Checked By: MP

Scale 1:15,000

0 200 400
metres

Coord. Sys. GDA 1994 MGA Zone 56

Little Bay Beach,
2 Coast Hospital Road,
Little Bay Road, NSW

SITE LOCATIONS

FIGURE 1

File Name: N:\Projects\Randwick City Council\59811 Little Bay Asbestos\GIS\Maps\R01 Rev A\59811_01_SiteLocation.mxd
Reference: © OpenStreetMap (and) contributors, CC-BY-SA

Legend:
- Approximate Site Extent
- NSW Cadastre (DFSI, 2020)

JBS&G

Job No: 59811

Client: Randwick City Council

Version: R01 Rev A	Date 7/10/2020
Drawn By: AS	Checked By: MP

Scale 1:1,500

0 20 40
metres

Coord. Sys. GDA 1994 MGA Zone 56

Little Bay Beach,
2 Coast Hospital Road,
Little Bay Road, NSW

SITE EXTENT

FIGURE 2

File Name: N:\Projects\Randwick City Council\59811 Little Bay Asbestos\GIS\Maps\R01 Rev A\59811_02_Site Extent.mxd
Reference: Nearmap, www.nearmap.com - Imagery 26-09-2020

Legend:

Approximate Site Extent

Beach Assesment Areas

NSW Cadastre (DFSI, 2020)

JBS&G

Job No: 59811

Client: Randwick City Council

Version: R01 Rev A	Date 7/10/2020
Drawn By: AS	Checked By: MP

Scale 1:1,500

0 20 40

metres

Coord. Sys. GDA 1994 MGA Zone 56

Little Bay Beach,
2 Coast Hospital Road,
Little Bay Road, NSW

BEACH ASSESSMENT AREAS

FIGURE 3

File Name: N:\Projects\Randwick City Council\59811 Little Bay Asbestos\GIS\Maps\R01 Rev A\59811_03_BeachAssessmentAreas.mxd
Reference: Nearmap, www.nearmap.com - Imagery 26-09-2020

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		Name	Name	Signature	Date
A	Matt Parkinson CEnvP (SC)	Michael Samuel LAA		Draft for client review	07/10/2020