A8.1 Land Contamination Assessment

This appendix presents a detailed assessment of land contamination issues summarised in Chapter 8 (Geology, Contaminated Land and Groundwater). The main objective of this appendix is to provide supporting information and assessments to explain how the Conceptual Site Model (CSM) and potential pollutant linkages relevant to the proposed scheme presented in Chapter 8 were derived. It provides the following information:

- **a summary of background information including historical contamination issues and previous investigations;**
- **the preliminary CSM;**
- **an assessment of contamination risks to human health, the water environment, ecological receptors and future structures and services from available ground investigation (GI) data;**
- **an assessment of risks from ground gas; and**
- **the updated CSM based on the outcome from the risk assessment.**

The land contamination study area is shown in Figure 8.4. For the purposes of the land contamination assessment the study are is split into three sections: northern study area (land north of the Firth of Forth), marine study area (the section of the Firth of Forth spanned by the main crossing) and southern study area (south of the Firth of Forth).

1 Background Information

1.1 Historical Land Use

1.1.1 Large areas of land within the study area have undergone industrial development. A summary of historical land uses is presented in Section 8.3 (Chapter 8: Geology, Contaminated Land and Groundwater) of the ES.

1.2 Environmental Setting

1.2.1 Information on the geology of the study area has been sourced from relevant BGS geological maps, previous desk study reports and historical investigations. A detailed description of the geology is presented in Section 8.3 of the ES.

1.2.2 Information regarding the hydrology and hydrogeology of the study area has been gathered from a range of sources. A detailed description of the hydrogeology of the area is presented in Section 8.3 of the ES. The hydrology of the area is discussed in detail in Chapter 9 (Water Environment) of the ES.

1.2.3 Several sensitive land uses have been identified within the study area including the St. Margaret's Marsh Site of Special Scientific Interest (SSSI) and the Firth of Forth SSSI. These areas are further detailed in Section 8.3 of the ES.

1.3 Consultation

1.3.1 Consultation with SEPA during the Stage 2 DMRB Environmental Assessment indicated the potential for low levels of radioactive contamination at St. Margaret's Marsh (Figure 8.4a). St. Margaret's Marsh originally comprised a natural intertidal zone and was artificially infilled prior to the 1960s. The specific nature of the infill material is not known; however, it is believed to comprise marine sediments from the vicinity of the nearby Rosyth Naval Base where low level radioactive waste has been historically discharged. In 2004, SEPA issued a consent certificate for the disposal of low level concentrations of cobalt-60 and tritium into the Firth of Forth approximately 1km upstream of the study area (SEPA, 2004). As part of this consent, SEPA have a monitoring programme in place which tests for the presence of cobalt-60 in sediments upstream of the discharge. To date, no cobalt-60 has been identified above the lab method reporting limit.

1.3.2 Further information regarding landfills to the north of the Firth of Forth was received following consultation with Fife Council. The following information was received for a number of landfills in the Fife area within 250m of the proposed scheme (source references i.e. potential sources of contamination are detailed in Tables 2.1 and 2.2 below):

- Castlandhill Quarry (source reference N21): Exact waste type unknown. A third party Phase 1 site report has been undertaken;
- Ferry Toll Quarry North (source reference N5a): Used by TW Ward Shipbreakers as a landfill for general ship waste from 1961 until an unknown date. In 1979, the site was licensed to accept asbestos and non-hazardous industrial wastes. The site was reportedly closed, covered with soil and seeded in 1994. The site was still actively gassing (above waste management guidelines) in 1999. A third party Phase 1 site investigation report has been undertaken.
- Ferry Toll Quarry South (source reference N5b): Used by TW Ward Shipbreakers as a landfill for general ship waste from 1961 until 1979. In 1979, the site was licensed to accept asbestos and non-hazardous industrial wastes. In 1990, a licence was granted to allow the site to accept compacted paper, plastic, wood, putrescible material, builders waste, hard core and other inert materials. The site was closed, capped and graded in 1991. Gas monitoring records from 1991 were within waste management guidelines. A third party Phase 1 site report has been undertaken.
- Ferry Hills Landfill (source reference N6): The site was filled with commercial, industrial, domestic, construction and demolition waste from approximately 1972 to 1982. The site was still actively gassing (above waste management guidelines) in 1993. A third party Phase 1 site report has been undertaken.
- St. Margaret's Bay Landfill (source reference N2): Anecdotal evidence suggests that the site was used as a general municipal waste tip from 1958 to 1972. Gas monitoring was last undertaken on the site in 2004 with marginally elevated carbon dioxide detected. A third party Phase 1 and Phase 2 study has been undertaken (Envirocentre, 2003; Envirocentre, 2004a) (see paragraph 1.3.3-1.3.12 for further details).

St. Margaret's Marsh and St. Margaret's Marsh Landfill Investigations (source refs N1 & N2)

1.3.3 A number of land contamination investigation reports for the St. Margaret's Marsh were received from Fife Council during the Stage 2 consultation process. The Phase 1 desk study report undertaken by Envirocentre in 2003 focused on the area to the far northeast of the marsh. The report identified the presence of a former landfill in this area that received domestic waste between 1958 and 1972. An intrusive investigation was undertaken in 2004 to assess this further. The works undertaken during this investigation included:

- excavation of 13 trial pits to the base of the made ground;
- excavation of three boreholes within the likely landfill footprint and one borehole outside the landfill area to the south west closer to the shore;
- sampling and analysis of 34 soil samples excavated from the trial pits;
- groundwater and ground gas monitoring from installations within the made ground; and
- sampling and analysis of four groundwater samples for a range of contaminants and field parameters.

1.3.4 The full results of the investigation are detailed in the Phase 2 Interpretive Report (Envirocentre, 2004a, 2004b) and summarised in the following section.

1.3.5 The thickness of made ground was between 1.7 and 3.5m below ground level (bgl) overlying marine clays. Groundwater was encountered within the fill deposits at depths between 1.2 and 2.2m bgl.

1.3.6 During groundwater sampling, a range of water quality measurements were undertaken in-situ as outlined in Table 1.1. Groundwater was determined to flow south towards the Firth of Forth and it was considered likely that groundwater in the area is influenced by tidal fluctuations.

Table 1.1: Summary of 2004 Groundwater Quality Measurements in St. Margaret's Marsh Landfill

Parameter	In landfill area		Outside landfill area	
	Maximum	Minimum	Maximum	Minimum
Electrical conductivity (µS/cm)	6050	18780	34700	37700
Salinity (units)	3.2	10.5	21	23.3
Dissolved oxygen (ppm)	0.3	2.4	1.0	-
pH (units)	7.11	7.16	7.14	-
Redox (mV)	13	16	14	-

1.3.7 During ground gas monitoring rounds, carbon dioxide was identified in the landfill area up to a concentration of 1.7% v/v. No methane gas was identified during the monitoring rounds and no ground gas flow measurements were taken.

1.3.8 Visual evidence of contamination was reported to be present at all excavated trial pits with made ground of up to 3.5m bgl consisting of sands, ash, clays, glass and general refuse waste. Observations of ferrous staining were also reported at the majority of investigation locations. Ferrous staining is often associated with acid mine drainage, however, mining has not been identified during any historic investigations in this area.

1.3.9 Following analysis of soil samples taken during the 2004 investigation (Envirocentre, 2004a), a human health risk assessment was undertaken using assessment values derived using Contaminated Land Exposure Assessment (CLEA) methodology, Dutch Intervention Values (DIVs) and Canadian Environmental Quality Guidelines. The assessment identified a potential risk to human health through exposure to a number of metals including arsenic, cadmium, selenium, copper, lead and zinc. An assessment of the risks posed to the water environment was also undertaken using groundwater analysis results with chromium, copper, thiocyanate, lead and arsenic all found to exceed assessment values.

1.3.10 Further groundwater sampling and ground gas monitoring was undertaken by Envirocentre in the St. Margaret's Marsh landfill area in October 2004 (Envirocentre, 2004b) to confirm the presence of contaminants in the groundwater and the existence of elevated concentration of carbon dioxide. Carbon dioxide was identified to a maximum concentration of 3.4% v/v and chromium concentrations were identified in the groundwater up to 220µg/l (above DIV).

1.3.11 An investigation was undertaken across the full extent of St. Margaret's Marsh in 2007 by Environ UK (Environ, 2007). This investigation was undertaken in order to assess the degree and extent of groundwater contamination associated with the Oil Fuel Depot at the HM Naval Base as previous investigations had identified hydrocarbon contamination across St. Margaret's Marsh. The areas of hydrocarbon contamination were within the west and central areas of St. Margaret's Marsh and not in the area of the proposed B981 realignment. For this investigation, groundwater sampling and monitoring of existing boreholes across St. Margaret's marsh was undertaken. Only one monitoring location was located within the former landfill the far northeast of the marsh.

1.3.12 The data collected during the investigation indicated that the deep groundwater at St. Margaret's Marsh is tidally influenced, with the shallow groundwater tidally influenced near to the shore line. The analysis of groundwater samples from the shallow groundwater across the marsh did not identify any significant hydrocarbon contamination. However, ammoniacal nitrogen concentrations were found to be elevated near to the boundary of the East Tip to the far west of St. Margaret's Marsh, approximately 500m outside of the study area to the west. Low concentrations of hydrocarbons were identified in the deep groundwater; however, it was considered likely that these concentrations were attributable to the low levels of contaminants in the dredging materials used to

in-fill the marsh. The analysis of the deeper groundwater at the former landfill to the north east of the marsh identified elevated concentrations of metals including copper, lead, nickel and zinc.

Additional Information

1.3.13 In addition to previous investigation reports in the St. Margaret's Marsh area, historical borehole logs (obtained from BGS) were also reviewed along the remainder of the length of the proposed scheme. In the south, visual evidence of contamination was only reported at the Stores area (Source Reference S3) at the southern shore and consisted of ash, clay and brick fill. Visual contamination was identified at several locations along the proposed scheme in the northern study area, as detailed on Figure 8.4, and included the presence of brick, ash, wood, glass, cloth and pottery within the made ground.

1.3.14 Following a review of archive records relating to wartime bombing held at the National Archives of Scotland for the study area, a number of potential unexploded ordnance (UXO) locations were identified. This information was incorporated into the health and safety documentation for the 2008 and 2009 Ground Investigation works.

2 Preliminary Conceptual Site Model

2.1 Background

2.1.1 The "suitable for use" approach is a fundamental principle of land use and planning policy in the UK. Risk assessment for the assessment and management of land contamination is central to Part IIA of the Environmental Protection Act 1990, which was implemented through the Contaminated Land (Scotland) Regulations 2000 (as amended). A fundamental principle of this approach is that a risk only exists if a suitable pathway exposes identified receptors to the hazard (or source) in question. This is referred to as a pollutant linkage.

2.1.2 The Part IIA regime and supporting guidance has therefore resulted in the development of a formalised and explicit technical approach to assess risks to humans, the water environment, sensitive ecosystems and buildings (building materials), which is applicable to the assessment and management of land contamination issues.

2.1.3 A conceptual site model (CSM) is a tool used to identify hazards, exposure pathways and potential receptors at the site on which to focus the risk assessment. The CSM represents a network of relationships between potential hazards from within and adjacent to the site area and the receptors that may be exposed to the hazards through linking pathways. A key element of a CSM is that not only does it examine the range of potential exposure pathways that are present; it also eliminates those source-pathway-receptor linkages that are incomplete and therefore cannot pose a risk. This approach is consistent with the current UK policy and guidance as outlined in CLR11 (Environment Agency, 2004).

2.1.4 In line with the DMRB guidance, the CSM presented below considers the pollutant linkages likely to be present as a direct result of the construction of the proposed scheme and associated road structures. These include linkages relating to both during construction and operational phases.

2.2 Potential Contamination Sources

Northern and Southern Study Areas

2.2.1 Potential sources of contamination in the northern and southern study areas are shown on Figure 8.4 and listed in Tables 2.1 and 2.2.

Table 2.1: Potential Contamination Sources – Northern Study Area

Source Reference	Historical Feature	Potential Contamination Identified
Made ground		
N1	St. Margaret's Marsh	• Low level radiation e.g. cobalt-60 in soils and groundwater. • Metals, organic and inorganic contaminants in the sediment used to in-fill reclaimed land.
Refuse tip/landfill		
N2	St. Margaret's Bay Landfill	• Heavy metals, including lead and chromium, in soils and groundwater (identified during previous investigations), possible landfill leachate. • Carbon dioxide (identified during earlier investigations), methane and other ground gases. • Organic and inorganic contaminants in soils and groundwater. • Asbestos in soils.
N5a	Ferry Toll Quarry North Landfill	• Heavy metals, semimetals, inorganic and organic contaminants and leachates in soils and groundwater. • Asbestos in soils. • Methane and other landfill gases.
N5b	Ferry Toll Quarry South Landfill	
N6	Ferry Hills Landfill	
N7	Refuse tip (unnamed)	
N30	East Tip	
Mineral extraction		
N13	Old Quarry 1	• Open face of quarry remains evident but may be partially in-filled. • Contaminants may include heavy metals, inorganic and organic compounds and leachates in soil and groundwater.
N14	Quarry 1	
N15	St. Margaret's Quarry	• Potentially in-filled with contaminated soils. Contaminants may include heavy metals, inorganic and organic compounds and leachate in soil and groundwater. • Asbestos in made ground. • Methane and other landfill gases.
N16	Quarry 2	
N17	Welldean Quarry	
N18	Old Quarry 2	
N19	Old Quarry (whinstone)	
N20	Ferry Toll Quarry	
N21	Castlelandhill Quarry	
N22	Old Quarry 3	
N23	Old Quarry 4	• Open face of quarry remains evident but may be partially in-filled. • Contaminants may include heavy metals, inorganic and organic compounds. Possible landfill leachate. • Methane and other landfill gases.
N24	Old Quarry 5	• Potentially in-filled with contaminated soils. Contaminants may include heavy metals, inorganic and organic compounds in soil and groundwater. Possible landfill leachate. • Asbestos in made ground. • Methane and other landfill gases.
N25	Fairykirk Quarry	• Open face of quarry remains evident but may be partially in-filled. Possible landfill leachate. • Contaminants may include heavy metals, inorganic and organic compounds in soil and groundwater. • Methane and other landfill gases.
N26	Unrecorded coal mines in the Charlestone Main Limestone outcrop	• Potential mine gas (methane, carbon dioxide, carbon monoxide, hydrogen sulphide), associated with former mining. • Metals and inorganic contaminants in the deep groundwater from the mine workings.
Other		
N3	Wastewater treatment works	• Metals and semi-metals, pathogens, inorganic compounds and organic contaminants.

Source Reference	Historical Feature	Potential Contamination Identified
N4	Belleknowes Industrial Estate	• A wide range of metals, semimetals, inorganic and organic compounds in soils and groundwater associated with the varying land use in this area.
N8	Tanks 1	• Unknown contamination source as nature of tanks unknown.
N9	Tanks 2	• Unknown contamination source as nature of tanks unknown.
N10	Former railway lines and tunnels	• Heavy metals, organic contamination, e.g. fuel oils, pesticides and other inorganic compounds in made ground.
N11	Saltpans works	• A wide range of metals, semimetals, inorganic and organic compounds in soils and groundwater associated with the varying land use in this area.
N12	Cemetery	• Heavy metals, inorganic and organic contamination in soils and groundwater.
N29	HM Naval Base	• Metals and semi-metals, inorganic compounds and organic contaminants e.g. hydrocarbons, asbestos.

Table 2.2: Potential Contamination – Southern Study Area

Figure Reference	Historical Feature	Potential Contamination Identified
Refuse Tip/Landfill		
S5	Refuse tip 1	• Heavy metals, semimetals, inorganic and organic contaminants and leachates in soils and groundwater. • Asbestos in soils. • Methane and other landfill gases.
S6	Refuse tip 2	
Mineral Extraction		
S7	Oil shale processing spoil heap	• Heavy metals, semimetals, inorganic and organic contaminants and leachate in soils and groundwater. • Possible acid mine drainage.
S9	Old Quarries	• Potentially in-filled with contaminated soils. Contaminants may include heavy metals, inorganic and organic compounds and leachates in soil and groundwater. • Asbestos in made ground. • Methane and other landfill gases.
S10	Three old Quarry (Lindsay's Craigs)	
S11	Quarry 1	
S12	Quarry 2	
S13	Former oil shale mining area	• Heavy metal and inorganic contamination in groundwater. • Methane and other ground gases. • Possible acid mine drainage.
Other		
S1	Sewerage pumping station	• Metals and semi-metals, pathogens, inorganic compounds and organic contaminants.
S2	Barracks area	• Metals, inorganic and organic contaminants in imported made ground.
S3	Stores area	• Metals, inorganic and organic contaminants in imported made ground. • Storage of fuel oils resulting in hydrocarbon contamination in both soils and groundwater.
S4	Dundas Lime Works	• Heavy metals, semi-metals, inorganic and organic contaminants in soils and groundwater. • Alkaline pH. • Asbestos in soils.
S8	Bonded warehouse	• Hydrocarbons, metals, asbestos.
S15	Oil Storage Depot	• Petroleum hydrocarbons including PAHs, VOCs, SVOCs.
S16	Sewage Works	• Metals and semi-metals, pathogens, inorganic compounds and organic contaminants.

Marine Study Area

2.2.2 Potential contamination in the sediments in the Firth of Forth include radioactive contamination from authorised discharges from the Rosyth Naval Yard, hydrocarbon contamination from sea-going vessels and a wide range of contaminants from the various industrial process that have been present along the shores of the Firth of Forth.

2.2.3 There is regular maintenance and dredging at Rosyth and Port Edgar. Contaminants have the potential to be mobilised from the sediments into the Firth of Forth during these processes.

2.3 Potential Receptors and Pathways

2.3.1 Potential receptors are related to the development of the proposed scheme alignment, the location of the study area relative to sensitive environmental receptors, and the ground and groundwater conditions below the proposed alignment. The following potential receptors have therefore been identified.

Construction Workers

2.3.2 Construction workers may be exposed to shallow soils and perched groundwater via ingestion, inhalation or dermal contact in the short term during the construction works. There is also the potential for short term exposure of construction workers to potentially contaminated arisings excavated from depth during civil engineering works such as piling and drainage construction. In addition, where blasting is required to cut into bedrock during the creation of cuttings, contaminated groundwater may be drawn into the works area, thus exposing the workers to deep groundwater. Construction workers may also be exposed to migrated ground gases, in particular within confined spaces and where blasting is undertaken, and be at risk though explosion or suffocation.

Maintenance Workers

2.3.3 Following construction, maintenance workers may be required to undertake below ground works on the proposed scheme alignment, such as repairing and maintaining services. Workers may be exposed to soils and perched groundwater via ingestion, inhalation or dermal contact up to 2m bgl relatively infrequently but extended over a long term. As with construction workers, maintenance workers may also be at risk from explosive and asphyxiating ground gases when working in confined spaces.

End Users

2.3.4 End users of the site include people using the Main Crossing and associated access roads, i.e. motorists, and those people using footpaths or landscaped areas within the study area. End users may be exposed to contaminated soil reused in embankment structures and landscaping via ingestion, inhalation or dermal contact. It is conservatively assumed that the end users could be in contact with the top 2m of soils beneath ground level extended over a long term for the purposes of this conceptual model.

Off-Site Receptors

2.3.5 Off-site receptors are those people living or working close to the site. Off-site receptors would be exposed via ingestion, inhalation or dermal contact with wind blown dust from the site created during construction. Off-site receptors may also be at risk via lateral migration of groundwater and ground gas into existing buildings, thus putting residents at risk from volatiles, explosion or asphyxiation. Construction activities, such as the laying of drainage channels, may potentially create a preferential pathway to off-site receptors.

2.3.6 The residential towns of Inverkeithing and North Queensferry lie within the study area in the north, with South Queensferry and Kirkliston in the southern study area. In addition, there are a number of industrial areas located in the near vicinity of the proposed scheme alignment.

Shallow Groundwater

2.3.7 Shallow groundwater has been identified during previous investigations in both the northern and southern study areas within made ground and localised sands and gravels. Shallow groundwater could potentially be at risk as a result of the leaching and migration of contaminants from contaminated soils reused within road structures e.g. embankments or disposed of off-site. The shallow groundwater in the study area is assessed to be of low sensitivity except in St. Margaret's Marsh (source reference N1) area where the marsh may be supported by shallow groundwater (Chapter 8: Geology, Contaminated Land and Groundwater).

Deep Groundwater

2.3.8 The geology of the study area consists of both 'impermeable' rock types and moderately permeable aquifers. The background water quality in the study area is largely unknown at present. There is the potential for contaminated shallow groundwater to migrate vertically downwards into the deep bedrock aquifers (e.g. in the South Fife bedrock in the north and in the Edinburgh and Livingston bedrock in the south); however, where the thickness of the cohesive drift layer (mostly firm clays) is significant, this is unlikely. Where engineering structures such as piles, band drains and vibro-stone columns are constructed, a pathway into the lower aquifer through the cohesive layer may be created or contaminated soils may be driven to depth.

2.3.9 In the south study area the drift thickness fluctuates between 2m and 10m in the area of the M9 Junction 1A, between 10m and 31m in the area of Dundas Home Farm (chainage 1490-2000m), between 10m and 18m roughly parallel to the A904 (chainage 2000-3200m) and between 0m and 10m in the northernmost section sloping towards the Firth of Forth (chainage 3200-4600m). A detailed assessment is currently underway for the northern study area.

2.3.10 A number of springs and wells have been identified in both the northern and southern study areas. At the time of writing, the extent to which the deeper aquifer is currently being extracted for private water supply purposes was still under investigation. There are existing springs and wells within the study area where consultation is ongoing.

Surface Water

2.3.11 Several surface water features have been identified within the study area, as outlined in Chapter 9 (water environment) and these features are potentially at risk from the migration of contaminated shallow and deep groundwater. For example the key sensitive surface water receptors identified are:

- Marine study area:
  - i. The Firth of Forth: good water quality, a SSSI and two Special Protection Areas.
- Southern study area:
  - ii. Swine Burn: Good water quality and in hydrological connectivity with the Humbie Reservoir;
  - iii. Humbie Reservoir: Important for local fisheries interest;
  - iv. Niddry Burn: High environmental importance (salmonoid waters); and
  - v. River Almond: High environmental importance (salmonoid waters).

2.3.12 Preferential pathways for the migration of contaminated shallow groundwater to these surface water features may be created during the construction of the proposed scheme. For example,

migration of shallow groundwater in local sands and gravels along drainage channels and associated granular bedding materials.

2.3.13 In addition, deep groundwater contaminated as a result of the vertical migration pathway created during construction, may flow into groundwater supporting surface water features.

2.3.14 Following construction of the proposed scheme, surface waters could potentially be at risk from contaminated surface water draining from the road surface.

2.3.15 It is also important to consider the impacts of blasting on surface water features. During the construction of the proposed scheme, several cuttings into the bedrock are proposed. As a result of the blasting, it is likely that significant quantities of groundwater will be drawn into the cutting area and need to be disposed of. It is currently proposed that the groundwater will be discharged to the Firth of the Forth and therefore there is the potential for contaminated groundwater to directly enter this watercourse.

2.3.16 The Firth of Forth is also potentially at risk from the disturbance, excavation and subsequent disposal of contaminated sediments during construction of the Main Crossing.

Proposed Structures and Services

2.3.17 Future structures constructed for the proposed scheme, for example concrete piles, may be affected by direct contact with contaminated soils and groundwater, particularly where elevated concentrations of sulphates have been identified. Where potable water supply services are laid through contaminated soils, there is the potential for ingress of contaminants into the supply where appropriate pipe materials for the ground conditions have not been used.

Ecological Receptors

2.3.18 Where the proposed alignment runs through environmentally sensitive areas, for example St. Margaret's Marsh SSSI, ecological receptors may be at risk from contaminated soils excavated during construction via the plant uptake, ingestion, inhalation and direct contact pathways.

2.4 Potential Pollutant Linkages

2.4.1 A summary of potential pollutant linkages associated with the study area is provided in Table 8.21, Chapter 8 (Geology, Contaminated Land and Groundwater).

3 Assessment of Land Contamination Risks – Northern Study Area

3.1 Introduction and Methodology

Baseline conditions for the northern study area were identified through the collection and review of information from existing sources, additional survey work, consultation responses, and the results of the 2008 GI (Jacobs Arup, 2009a). A summary of the assessment of the baseline conditions is included in Section 8.3 of Chapter 8 (Geology, Contaminated Land and Groundwater) and detailed description of the ground investigation findings is presented in the 2008 GI Report (Jacobs Arup, 2009a). This includes detailed assessment of the ground conditions underlying the areas investigated. The GI also included the installation of boreholes for groundwater and ground gas monitoring and chemical analysis of soils and groundwater. The factual data including borehole logs and chemical analysis data is included in the Report on a Ground Investigation for Forth Replacement Crossing Detailed GI - North of Forth Estuary (Norwest Holst, 2009).

3.1.1 Ground investigations have identified the presence of metallic, inorganic and organic contaminants in soils underlying the site. It is therefore necessary to determine whether these contaminants pose a significant risk to receptors for a particular source-pathway-receptor linkage, as identified in the preliminary CSM in Section 1.3.

3.1.2 In order to identify the potential risks posed by these contaminants, a range of generic quantitative risk assessments (GQRA) have been undertaken. GQRA is undertaken by comparing chemical analysis or field results with generic assessment criteria (GACs) considered suitable for the proposed end use. GACs are pre-defined concentrations of contaminants derived using conservative assumptions about receptor behaviour and chemical contact, and represent a concentration over which unacceptable risks may be present. If the GAC is not exceeded, the study area can be considered suitable for its intended use. This does not mean that the contaminants are absent, merely that contaminants are at a sufficiently low concentration not to present risks to the relevant receptors. If contaminants exceed the acceptable concentrations then risks may be present, with the seriousness of the risk linked directly to the magnitude of the exceedance. Where contaminants are found to exceed the GAC, these contaminants are considered as potential contaminants of concern (COCs).

3.1.3 The following potential risks are assessed within this section:

- Risks to human health: receptors include end users and off-site receptors (e.g. adjacent residents). The risk to construction and maintenance workers are considered to be short term and are not assessed quantitatively within this report.
- Risks to the water environment: receptors include surface water features, such as the Firth of Forth, and groundwater receptors which are important in their own right and could potentially be used for drinking water abstraction.
- Risks to the ecology: receptors include protected species such as those identified within the St. Margaret's Marsh SSSI.
- Risks to future structures and services: receptors include new road structures and associated drainage and potable water supplies.
- Risks posed by ground gases: receptors include construction workers, maintenance workers, and off-site receptors.

3.1.4 The methodology undertaken for each of these assessments is further discussed within each individual section.

3.2 Risks to Human Health

Conceptual Exposure Model

3.2.1 During and following the construction of the proposed scheme, the following receptors are considered to be at risk from long term exposure to contaminated soils in the northern study area:

- During construction:
  - i. Off-site users e.g. nearby residents and commercial unit workers via ingestion, inhalation and dermal contact with wind blown dust created during excavation works (PL3, Table 8.21 in Chapter 8).
- Post-construction:
  - ii. End-users via ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaping (PL12, Table 8.21 in Chapter 8).
  - iii. Off-site users via ingestion, inhalation and dermal contact with windblown dust from contaminated soils reused within road features such as embankments and landscaping (PL13, Table 8.21 in Chapter 8).

3.2.2 Based on this conceptual exposure model, the most conservative land use scenario that will be considered during the following assessment is the residential land use scenario with the most sensitive receptor a female child under the age of six, as per current CLEA model guidance. This is a highly conservative approach given the proposed end use and has been used for screening purposes as a first stage assessment. It is anticipated that more detailed site-specific risk assessment will be carried out as part of detailed design works.

Human Health Generic Qualitative Risk Assessment Methodology

3.2.3 In order to identify potential areas in the northern study area that may pose a risk to human health, a screening GQRA has been undertaken for all soil samples analysed. In addition, a more detailed GQRA has been undertaken for the St. Margaret's Marsh area where a more extensive data set is available due to the availability of historical investigation data.

3.2.4 In August 2008, the Department for Environment Food and Rural Affairs (DEFRA) issued a series of communications relating to the outcome of the "Way Forward" review exercise that resulted in the withdrawal of Contaminated Land Report (CLR) documents CLR7 to CLR10, and all previously published Soil Guideline Values (SGVs). These documents and SGVs were in widespread use as the basis for the generic quantitative assessment of risks to human health from contaminated soils. Following a three month evaluation period, the England and Wales Environment Agency (EA) subsequently issued a revised Contaminated Land Assessment (CLEA) model and associated practical guidance handbook (on issue as version 1.04, January 2009) (Environment Agency, 2009a), with a proposed schedule for the publication of revised SGV reports, toxicity data and supplementary information for priority contaminants. In parallel, in an effort to speed up the process of obtaining industry-accepted generic screening criteria, there are several non-EA initiatives currently underway to develop generic acceptance criteria using the CLEA model for substances not included in the EA list. DEFRA has stated that CLEA 1.04 is currently the preferred model for the production of risk assessment values for human health protection, however, it is not mandatory to use the CLEA model for human health risk assessments and DEFRA has made no statement as to the likely impacts on previous risk assessments carried out using the now withdrawn documentation. There has been no formal response on any of the above to date from the Scottish Government.

3.2.5 In light of these developments, Jacobs Arup is currently in the process of producing an updated set of assessment values using the new CLEA model. The first new SGV reports for benzene, toluene, ethylbenzene, xylenes, mercury and selenium were published on 31 March 2009. Additional SGVs

and generic acceptance criteria are anticipated to be published by the EA and non-EA groups in Summer 2009. The following assessment has been undertaken using SGVs available at the time of writing (Environment Agency, 2009b-g).

3.2.6 The first assessment undertaken was an initial screen of all soils data within the northern study area (i.e. one data set) against GACs. Where former SGVs are available, these have been used as the GACs. Where SGVs are not available, Chartered Institute of Environmental Health (CIEH) values issued in 2007 or US Risk Assessment Information Systems (RAIS) Preliminary Remediation Goal (PRG) have been used in the initial assessment. These values have been adjusted to take account of the UK context and approach, including the 1:10,000 risk level broadly accepted in the UK. The generic assessment criteria used have assumed the most conservative soil organic matter (SOM) concentration of 1% given the broad range of values found. Full details of the assessment criteria are available on request.

3.2.7 A more detailed assessment has been undertaken for the St. Margaret's Marsh area. All samples taken from the made ground at St. Margaret's Marsh area were screened against GACs. Where analytes exceeded GAC, further statistical interpretation of the data was then undertaken in accordance with CL:AIRE, 2008. The scenario relating to assessments under planning is relevant for this proposed scheme. This involved use of the following tests:

- Outlier test: to identify any statistical outliers which may identify contamination 'hot spots' not part of the statistical population; and
- Comparison against critical concentration: following the removal of any outliers in the dataset, calculation of the "true mean" (95th upper confidence limit of the mean (UCL) and comparison with the critical concentration (CL:AIRE, 2008)).

Data Assessment: Full data set screening

3.2.8 In order to identify potential areas of contamination within the northern study area which may pose a risk to human health, the full data set was screened against relevant GACs. Analysis results were first screened using residential GACs to reflect the most conservative exposure scenario. Following this, the results were then screened against industrial GACs in order to identify areas of increased potential risk. Areas where exceedances of the assessment have been identified are illustrated on Figure 8.4, and a summary of the assessment exceedances is presented in Table 3.1. Full details of the assessment are available on request.

Table 3.1: Human Health Risk Assessment Screen Soil Exceedances (Soils) – Northern Study Area

Analyte	GAC (residential) mg/kg*	No. of samples above GAC (residential)/ number of samples analysed	GAC (industrial) mg/kg*	No. of samples above GAC (industrial)/ number of samples analysed
pH	6.5-9.5 (units)	n/a	n/a	n/a
Arsenic	20	1/60	500	0/60
Lead	450	2/61	750	0/61
Mercury	1.0	1/61	26	0/61
Nickel	75	9/61	5000	0/61
Vanadium	150	9/61	4250	0/61
Naphthalene	6.94	1/38	290	0/38
Phenanthrene	1.3	2/38	29.7	1/38
Pyrene	1.3	2/38	29.7	1/38
Benzo(a)anthracene	1.3	2/38	29.7	1/38

Analyte	GAC (residential) mg/kg*	No. of samples above GAC (residential)/ number of samples analysed	GAC (industrial) mg/kg*	No. of samples above GAC (industrial)/ number of samples analysed
Chrysene	1.3	2/38	29.7	1/38
Benzo(b)+(j) fluoranthene	1.3	2/38	29.7	1/38
Benzo(k)fluoranthene	1.3	1/37	29.7	1/37
Benzo(a)pyrene	1.3	2/38	29.7	1/38
Indeno(1,2,3-cd)pyrene	1.3	1/38	29.7	1/38
Dibenz(a,h)anthracene	1.3	1/38	29.7	0/38
Benzo(g,h,i)perylene	1.3	1/38	29.7	1/38
TPH C10-C40	14.2	49/56	625	2/56
TPH C40-C44	417	1/56	9250	0/56
* mg/kg unless otherwise stated				

3.2.9 The chemical analysis for total petroleum hydrocarbons (TPH) was not speciated into carbon bands and therefore the most conservative GAC (for aromatic short chain compounds) has been used in the assessment. This had led to a large number of exceedances. TPH analysis will need to be speciated to further assess the risks as these are dependent on the TPH fractions present. Similarly, the individual PAH species have been assessed against the GAC for benzo(a)pyrene which is considered to pose the highest risk to human health. Therefore, the assessment of the remaining PAHs is considered to be conservative.

3.2.10 The majority of the exceedances have been identified within areas previously identified as being potentially contaminated due to historical land uses. Assessment results relating to potentially contaminated sites identified from historical maps within the study area are summarised in Table 3.2. A number of additional areas which may pose a risk to human health outwith previously identified potentially contaminated areas are summarised in Table 3.3.

Table 3.2: Human Health Risk Assessment Relating to Historically Contaminated Sites – Northern Study Area

Source Ref	Areas of Contamination Identified in Desk Study in 250m from FDR	2008 GI Locations in Area	Contamination identified from soil analysis?
Made ground			
N1	St. Margaret's Marsh	No investigation undertaken in this area.	
Refuse tip/landfill			
N2	St. Margaret's Marsh Landfill	BHN1010	Lead and PAHs above residential GAC
		BHN1010A	No contamination identified above GAC
		BHN1011	Arsenic and nickel exceed residential GAC
		BHN1012	Nickel exceeds residential GAC
		BHN1013	Vanadium exceeds residential GAC
N5a	Ferrytoll Quarry North Landfill	No investigation undertaken in this area.	
N5b	Ferrytoll Quarry South Landfill		
N6	Ferry Hills Landfill		
N7	Refuse Tip	BHN2034	No samples analysed
N30	East Tip	No investigation undertaken in this area.	
Mineral extraction			
N13	Old Quarry 1		

Source Ref	Areas of Contamination Identified in Desk Study in 250m from FDR	2008 GI Locations in Area	Contamination identified from soil analysis?
N14	Quarry 1	No investigation undertaken in this area.	
N15	St. Margaret's Quarry	BHJN1003	No samples analysed
N16	Quarry 2	No investigation undertaken in this area.	
N17	Welldean Quarry	BHN1010B	No samples analysed
		BHN1008	No contamination identified above GAC
N18	Old Quarry 2	No investigation undertaken in this area.	
N19	Old Quarry (Whinestone)		
N20	Ferry Toll Quarry	BHN1014	No samples analysed
		BHN1014A	No contamination identified above GAC
		BHN1014B	No samples analysed
N21	Castlelandhill Quarry	No investigation undertaken in this area.	
N22	Old Quarry 3		
N23	Old Quarry 3		
N24	Old Quarry 4		
N25	Fairykirk Quarry		
N26	Unrecorded coal mines in the Charlestone Main Limestone outcrop		
Other			
N3	A wastewater treatment works	BHN2005	Nickel and vanadium exceed residential GAC
		BHN2005A	Asbestos detected
N4	Belleknowes Industrial Estate (south end)	BHN1037	No contamination identified above GAC
N8	Tanks 1	No investigation undertaken in these areas.	
N9	Tanks 2		
N10	Former railway lines and tunnels		
N11	Saltpans works		
N12	Cemetery		
N29	HM Naval Base		

Table 3.3: Additional Areas of Contamination Identified – Northern Study Area

Ref	Areas of Contamination Identified in Desk Study in 250m from FDR	Potential Contamination
N27	Welldean Cottage Area	Made ground to 0.85m bgl identified in this area with brick and pottery fill also noted - may be some of the fill used to reclaim land. Exceedances of lead and nickel above residential GAC identified.
N28	TPH hotspot at BHN1015	Made ground to 0.95m bgl with exceedances of the industrial GAC for TPH.
N31	Made ground either side of the existing carriageway (including TPH hotspot at TPN1014/01)	Made ground identified along the proposed scheme and has included metal pieces, brick, wood, glass and pottery (see Figure 8.4a). Vanadium, TPH and PAH concentrations above residential GAC.

Data Assessment: St. Margaret's Marsh

3.2.11 UCLs were calculated for all the metal contaminants. No outliers were identified for any of the metals with only the lead UCL (460mg/kg) exceeding the residential GAC. Lead is therefore a potential contaminant of concern in the St. Margaret's Marsh area and may pose a risk to human health.

3.2.12 The UCL for TPH C10-C40 (391mg/kg) exceeds the residential GAC. However, this is a highly conservative assessment which presumes all the TPH are short chain aromatic compounds. Further assessment of TPH in the area using speciated analysis techniques is required in order to characterise the risks posed by TPH in the St. Margaret's Marsh area.

3.2.13 Due to the small amount of PAH data currently available for the St. Margaret's Marsh area, it was not possible to undertake meaningful statistical analysis on the currently held data. Further analysis will be required in order to fully characterise the PAHs in the soils present.

3.2.14 St. Margaret's Marsh was artificially infilled prior to the 1960s. The specific nature of the infill material is not known; however, it is believed to comprise marine sediments from the vicinity of the nearby Rosyth Naval Base. Low level radioactive waste has been historically discharged from the Rosyth Naval Base. Preliminary monitoring data undertaken during the 2008 GI and monitoring data from the nearby intertidal zone suggest that radiation levels are not elevated above background.

3.2.15 Additional site-specific risk assessment will be required to further evaluate the risks to human health. This will be undertaken following completion of the 2009 GI.

3.3 Risks to the Water Environment

The Water Environment Generic Qualitative Risk Assessment Methodology

3.3.1 The statutory objectives and the general requirements of the Water Framework Directive (European Parliament, 2000) require careful consideration of the on-going effects of construction activities to the water environment. To assess the risks contaminated soils and construction activities will pose to the water environment (PL5, PL6, PL7, PL15, PL16 and PL17, Table 8.21, Chapter 8), groundwater chemical test data has been assessed using the Environmental Assessment Levels (EALs) sourced from statutory and guidance documents. EALs are environmental standards below which there are considered to be no significant risks to the water environment. The most conservative EALs have been used for this initial assessment based on freshwater Environmental Quality Standards (EQS) or UK Drinking Water Standards (DWS).

3.3.2 The available leachate data for the proposed route is limited therefore the extent to which leachable contaminants represent an on-going source affecting groundwater quality cannot be established. It is noted that the concentrations of contaminants in soils at the location of St. Margaret's Marsh are sufficiently high to have the potential to leach into the water environment.

Data Assessment

3.3.3 Assessment exceedances are summarised in Table 3.4. Full details of the assessment are available on request.

Table 3.4: Water Environment Risk Assessment Exceedance – Northern Study Area

Analytes	Maximum concentration	Units	No. of samples exceeding the EAL	EAL
Electrical conductivity	3900	µS/cm	2 of 9	2500
Bromide	3.7	mg/l	1 of 9	0.002
Chloride	1100	mg/l	9 of 10	25
Ammoniacal nitrogen (unionised)	0.02	mg/l	1 of 6	0.015
Sulphate	360	mg/l	3 of 10	250
Potassium	20	mg/l	1 of 9	12
Magnesium	110	mg/l	2 of 10	50
Chromium (total species)	13	µg/l	1 of 2	10
Selenium	12	µg/l	1 of 2	10

Analytes	Maximum concentration	Units	No. of samples exceeding the EAL	EAL
Iron	380	µg/l	4 of 9	200
pH	7.5-8.9	units	n/s	6.5-9.5

3.3.4 Table 3.4 indicates that the majority of the exceedances found relate to major ions and may relate to saline intrusion and/or poor background quality due to historical quarrying and mining activities in the vicinity. No List I substances, such as cadmium compounds, mercury compounds, free cyanide and TPH, have been identified to be present within the groundwater. The discharge of List I substances to groundwater is prohibited under the EU Groundwater Directive, although this does not apply to historically contaminated land. A small number of List II substances have been identified to be present at elevated concentrations in groundwater, including chromium and selenium.

3.3.5 Most of the exceedances, and the highest electrical conductivity, were recorded in the sample from BHN1011 located within the probable boundary of the St. Margaret's Bay Landfill area (source reference N2). This is an area of reclaimed land that has been infilled with marine sediments, most likely in continuity with the Firth of Forth. This would explain the concentrations of iron, potassium and electrical conductivity present above EALs (Table 3.4).

3.4 Risks to Ecological Receptors

Methodology

3.4.1 Where contamination has been identified to be present within an environmentally sensitive area, there is the potential for these soils to pose a risk to local ecology (PL8, PL9, PL20 and PL21, Table 8.21, Chapter 8). In the northern study area, contamination has been identified within the St. Margaret's Marsh SSSI. As a result, it is necessary to assess the risk to ecology in the area following the Ecological Risk Assessment Framework methodology as published by the Environment Agency (Environment Agency, 2008).

3.4.2 For the purpose of this assessment, all soil samples within the St. Margaret's Marsh area have been assessed against soil screening values (SSV) as outlined by the Environment Agency. SSVs are concentrations of chemical substances found in soils below which there are not expected to be any adverse effects on wildlife such as birds, mammals, plants and soil invertebrates, or on the microbial functioning of soils. Where contaminants exceed the SSVs, there is the potential for these soils to pose ecological risks and further investigation should be undertaken.

Assessment Results

3.4.3 A summary of the contaminants which were above GAC are listed in Table 3.5. Full details of the assessment are available on request.

Table 3.5: Ecological Risk Assessment Exceedances – Northern Study Area

Analytes	Maximum concentration	No. of samples exceeding the SSV	SSV
Arsenic	26	40	0.04*
Cadmium	3.2	2	1.15
Chromium	132.6	29	21.1
Copper	710	14	88.4
Lead	1900	14	167.9
Mercury	2.9	22	0.06
Nickel	140	44	25.1
Zinc	1900	34	90.1

Analytes	Maximum concentration	No. of samples exceeding the SSV	SSV
Cyanide (complex)	3.4	8	0.0057*
Cyanide (total)	3.4	9	0.0057*
Phenols(total)	1.3	2	0.136*
Naphthalene	0.3	3	0.0533*
Anthracene	0.7	1	0.02*

Units: mg/kg

* SSV insufficiently reliable but used to give initial indication of potential ecological risk

3.4.4 A number of metals, inorganic and organic compounds were above GAC at St. Margaret's Marsh. The soils in St. Margaret's Marsh therefore pose a potential risk to the ecosystem of the SSSI. However, as the SSSI itself results from reclamation of the area with marine sediments and other materials, the contamination present may not necessarily impact the local ecosystem. This should be evaluated further as part of detailed design and is of particular importance during the construction phase where soils are likely to be excavated from the marsh area and potentially reused on other areas of the marsh. If soils are to be removed from the study area they will need to be analysed for waste acceptance criteria (WAC) and disposed of in accordance with current UK guidance.

3.5 Risk to Future Structures and Services

Guidance

3.5.1 Contamination arising from industrial development may pose a risk to building and civil engineering structures. During any potential future construction associated with the proposed scheme, the activities/structures most likely to interact with contaminated ground are as follows:

- structures and associated foundation construction e.g. concrete piles; and
- construction of services such as water and drainage, electrical cables and gas supply lines.

3.5.2 There are several guidance documents currently available to assist in assessing and mitigating the risks posed as a result of these activities.

3.5.3 In the UK, sulphates and acids, both naturally occurring and man made, are the agents most likely to attack and weaken underground structures. Sulphates at elevated concentrations are aggressive to concrete and may affect future developments on the site. BRE Special Digest 1:2005 (BRE, 2005) recommends precautionary measures with respect to sulphate and acid attack on concrete for a range of concentrations, for both green field and brownfield locations. The guidance also indicates that there is potential for organic compounds, such as phenols, and ammonium ions to attack underground structures at high concentrations.

3.5.4 In areas along the proposed scheme where ground improvement will be required, a ground improvement risk assessment should be undertaken to support the detailed design in line with Environment Agency guidance, Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination, Guidance on Pollution Prevention (Environment Agency, 2001).

3.5.5 Where services are to be laid in a known contaminated site, it is necessary to select suitable materials to comply with current regulations and to prevent pipelines failing prematurely due to aggressive ground conditions. This is particularly important in the case of drinking water supply pipes where permeation and accelerated deterioration of the pipe material can occur due to chemical reactions between the pipe and contaminants in the ground. Information on this can be found in guidance published by the Water Regulations Advisory Scheme (WRAS) (WRAS, 2002).

3.5.6 It is known that there are several other contaminants that may affect building structures, however additional contaminants that affect structures are not anticipated to be present along the proposed scheme.

Structures and Building Materials

3.5.7 In order to identify the potential risks to future structures and buildings (PL18), the soils beneath the site have been assessed in accordance with BRE Special Digest (BRE, 2005). Soluble sulphate concentrations (as SO_4 in 2:1 water/soil extracts) were reported at values up to 1985 mg/l within the soils beneath the site, and pH ranged from 5.5 to 8.7.

3.5.8 The guidance recommends using a characteristic value comprising the mean of the top 20% of soluble sulphate concentrations (for greater than 10 analysis results) to assess the design sulphate class. Due to the low number of samples taken compared to the size of the study area, this assessment should only be used to give an indication of likely soil conditions. The characteristic value for soils at the site has been assessed as 673mg/l.

3.5.9 A characteristic value for pH comprising the mean of the lowest 20% of pH values (for greater than 10 analysis results) is used for assessing the aggressive chemical environment for concrete (ACEC) classification. The characteristic value for pH within the soils at the site has been assessed as 5.9. Further assessment should be undertaken following receipt of the 2009 GI and as part of detailed geotechnical design work.

Water Supply Pipes

3.5.10 Where contamination is present within soils, there is the potential for these contaminants to attack buried structures such as potable water pipes and gas supply lines, dependant on the construction materials used (Table 8.21; PL19). The WRAS Guidance Note 29 outlines a quantitative assessment method to determine the risk to services; however, the assessment values are based on outdated contamination assessment values. As a result, the precautionary approach, as detailed in the guidance has been used in this assessment. As elevated concentration of contaminants have been identified at a number of locations across the study area, it is likely that special protection measures may be required. As a worst case, special measures would involve the use of clean backfill in service trenches or up-rating of the pipe construction (wrapped iron or polythene/aluminium/polythene (PE/Al/PE) compound pipes).

3.6 Assessment of Risks from Ground Gas

Risk Assessment Methodology

3.6.1 A ground gas risk assessment has been undertaken in accordance with CIRIA C665 guidance 'Assessing Risks Posed by Hazardous Ground Gases to Buildings' (CIRIA, 2007). This assessment provides an indication of risk to buildings on or adjacent to the site (PL2, PL4, PL11, PL14 and PL19, Table 8.21, Chapter 8).

3.6.2 Given the proposed end use within the study area the assessment has been carried out for Situation A, as defined in CIRIA C665. Situation A is applicable to all development types other than a low rise building with minimum ventilated under floor void (minimum 150mm). This method uses both gas concentrations and borehole flow rates to define a characteristic situation for a site based on limiting borehole gas volume flow for methane and carbon dioxide, which is known as the Gas Screening Value (GSV), defined as follows:

- Gas Screening Value (litres of gas per hour) = maximum borehole flow rate (l/hr) x maximum gas concentration (% by volume).

3.6.3 The calculation is carried out for both methane and carbon dioxide and the worse case value adopted. The characteristic situation is then determined from Table 8.5 of CIRIA C665. This is a

conservative approach that has been used to provide an initial indication of the level of risk from ground gases on site and to provide a guide as to whether mitigation measures will need to be employed within the study area.

Ground gas risk assessment results

3.6.4 To date, up to three rounds of ground gas monitoring have been undertaken at 14 boreholes located within the near vicinity of St. Margaret's Marsh. Due to the relatively low number of boreholes monitored, an assessment has been undertaken for each individual borehole. Full details of the ground gas readings are available on request. A summary of the gas screening values recorded at each monitoring borehole is outlined in Table 3.7.

Table 3.7: Characteristic Situation Borehole for Methane and Carbon Dioxide – Northern Study Area

Borehole ID	Max CO2 conc. (%)	Max CH4 conc.(%)	Max steady flow rate (l/hr)	GSV-CO2 (L/hr)	GSV-CH4 (L/hr)	Characteristic Situation
BHN1008	0.1	0.2	0.1#	0.0001	0.0002	1-very low risk
BHN1010B	0.1	0.2	0.1#	0.0001	0.0002	1-very low risk
BHN1011	0.1#	0.2	0.1#	0.0001	0.0002	1-very low risk
BHN1001	0.1	0.1	0.1#	0.0001	0.0001	1-very low risk
BHN1017A	0.1	0.1	0.1#	0.0001	0.0001	1-very low risk
BHN1020	0.1	0.1#	0.1#	0.0001	0.0001	1-very low risk
BHN1021	0.1	0.1	0.1#	0.0001	0.0001	1-very low risk
BHN1023	0.1#	0.1#	0.1#	0.0001	0.0001	1-very low risk
BHN1024B	0.1	0.1	0.1#	0.0001	0.0001	1-very low risk
BHN1029	0.1	0.1	0.1#	0.0001	0.0001	1-very low risk
BHN1032	0.1#	0.1	0.1#	0.0001	0.0001	1-very low risk
BHN2017	0.1#	0.1#	0.1#	0.0001	0.0001	1-very low risk
BHN2024	0.1#	0.1#	0.1#	0.0001	0.0001	1-very low risk
BHJN1003	0.1	2.0	0.1#	0.0001	0.002	1-very low risk

Where the concentrations have been less than the detection limit, the detection limit has been used to give the most conservative assessment

3.6.5 The data collected to date indicates that there is a very low risk to buildings associated from methane and carbon dioxide concentrations recorded across a range of strata. Further investigation is currently being undertaken at boreholes located in the vicinity of potential land contamination (BHN1008, BHN1010B and BHN1011) to fully characterise the gas regime in this area. It is also possible that elevated concentrations of ground gas are present in other areas not yet fully investigated and this should be considered as part of detailed design work.

Other gases

3.6.6 Hydrogen sulphide and carbon monoxide were not identified above the instrument detection limits.

4 Assessment of Contamination Risks: Marine Study Area

4.1 Introduction and Methodology

4.1.1 Baseline conditions for the marine study area were identified through the collection and review of information from existing sources, additional survey work, consultation responses, and extracts from the results of the 2008 Marine GI. A summary of the assessment of the baseline conditions is included in Section 8.3 of Chapter 8 (Geology, Contaminated Land and Groundwater).

4.1.2 The intrusive investigations have identified the presence of metallic, inorganic and organic contaminants in sediment in the marine study area. The next stage is to determine whether these contaminants pose a significant risk to receptors for a particular source-pathway- receptor linkage, as identified in the preliminary CSM in Section 1.3.

4.1.3 As outlined in Section 1.4, a GQRA has also been undertaken for the marine study area. The following potential risks are assessed in the following section:

- risks to human health: receptors include end users, maintenance workers and off-site receptors (e.g. adjacent residents). The risk to construction workers are considered to be short term and are not assessed quantitatively within this report;
- risks to the water environment: receptors include surface water features, such as the Firth of Forth, and groundwater receptors which could potentially be used for drinking water abstraction;
- risks to estuarine ecology: receptors include inter-tidal fauna and macroinvertebrates; and
- risks to future structures: receptors include new bridge structures.

4.1.4 The methodology undertaken for each of these assessments is further discussed within each individual section.

4.2 Risks to Human Health

Conceptual Exposure Model

4.2.1 An assessment on risks to human health has been undertaken in the event that dredged material was to be reused along the proposed scheme. However, it is most likely that the dredged sediments will be re-disposed in the Firth of Forth and this has been assessed separately (refer to Chapter 9 (Water Environment)). Should marine sediments be reused along the proposed scheme, the following receptors are considered to be at risk from long term exposure to contaminated sediments in the marine study area:

- During construction:
  - i. Off-site users e.g. nearby residents and commercial unit workers via ingestion, inhalation and dermal contact with wind blown dust from excavated sediments (PL3, Table 8.21, Chapter 8).
- Post-construction:
  - ii. End-users via ingestion, inhalation and dermal contact with wind blown dust from excavated sediments (PL12, Table 8.21, Chapter 8).
  - iii. Off-site users via ingestion, inhalation and dermal contact with windblown dust from excavated sediments (PL13, Table 8.21, Chapter 8).

4.2.2 Based on this conceptual exposure model, the most conservative land use scenario that will be considered during the following assessment is the residential land use scenario with the most sensitive receptor a female child under the age of six, as per current CLEA model guidance.

Human Health Generic Qualitative Risk Assessment Methodology

4.2.3 In order to identify potential areas in the marine study area that may pose a risk to human health, a screening GQRA has been undertaken for all soil samples analysed. A full description of the methodology used for this assessment can be found in Section 1.4.

Data Assessment

4.2.4 The only recorded exceedance is for TPH (C10 to C40) where 13 of the 14 samples analysed exceed the residential GAC. However, the value used for this assessment is highly conservative

and presumes that the hydrocarbons present are short chain aromatics. It is therefore considered unlikely that the sediments located in line with the proposed scheme pose a risk to human health. Full details of the data assessment are available on request.

4.3 Risks to the Water Environment

Water Environment Generic Qualitative Risk Assessment Methodology

4.3.1 The statutory objectives and the general requirements of the Water Framework Directive require careful consideration of the on-going effects of construction activities to the water environment. To assess the risks contaminated sediments and construction activities will pose to the water environment (Table 8.21; PL7 and PL17), soil leachate chemical test data have been assessed using EALs sourced from statutory and guidance documents. EALs are environmental standards below which there are considered to be no significant risks to the water environment, in this case the Firth of Forth. The EALs selected were primarily sourced from the UK Environmental Quality Standards (EQS) for saltwater bodies.

Data Assessment

4.3.2 Analytes failing the assessment are summarised in Table 4.1. Full details of the assessment are available on request.

Table 4.1: Water Environment Risk Assessment Exceedances – Marine Study Area

Analytes	Maximum concentration (mg/l)	No. of samples exceeding the EAL	EAL
Chromium	0.013	6	0.005
Copper	0.038	13	0.005
Lead	0.012	1	0.01
Ammoniacal nitrogen*	3.26	10	0.022

* adjusted for ammoniacal nitrogen (unionised)

4.3.3 A number of metals and ammoniacal nitrogen exceed the EALs, and therefore may potentially pose a risk to the water environment, namely the Firth of Forth. This is of particular importance during construction works where sediments may be disturbed and removed from the river bed.

4.4 Risks to Estuarine Ecology

Background

4.4.1 It is known from earlier studies that the sub-tidal sediments in the Firth of Forth contain metals elevated above background levels, similar to other major estuaries in the UK. During construction of the Main Crossing, piling and dredging activities will result in the re-suspension of sedimentary materials and the redistribution of sediment contaminants. As a result, the construction activities may potentially pose a risk to the inter-tidal and sub-tidal benthic ecology, including sub-tidal fauna and macroinvertebrates, in the Firth of Forth.

4.4.2 As part of the benthic baseline studies undertaken in 2008, sampling of sub-tidal sediments was undertaken which included the analysis of metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). In order to assess the risks posed to estuarine ecology as a result of identified contamination, the analysis results were compared against the following assessment values:

- Threshold Effects Levels (TEL): represents the concentration below which sediment associated chemicals are not considered to represent significant hazards to aquatic organisms;

- Predicated Effects Level (PELs): represents the lower limit of the range of chemical concentrations that have been associated with adverse biological effects; and
- Action Levels: represents the chemical concentration at which mitigation measures may be required.

4.4.3 The methodology of this assessment is provided in Chapter 11 (Estuarine Ecology).

Assessment Summary

4.4.4 The full estuarine ecology risk assessment is detailed in Chapter 11 (Estuarine Ecology).

4.4.5 Given the generally low sediment contaminant concentrations, the re-distribution of sediments and their associated contaminants is unlikely to impact significantly on the receiving inter-tidal and sub-tidal benthic environments.

4.5 Risk to Future Structures

Structures and Building Materials

4.5.1 The presence of sulphate and low pH within sediments could affect structures constructed within the Marine Study Area. This needs to be considered as part of geotechnical design work. An initial assessment has been carried out against BRE Special Digest 1:2005.

4.5.2 Soluble sulphate concentrations (as SO_4 in 2:1 water/soil extracts) were reported at values up to 920 mg/l within the soils beneath the site, and pH ranged from 7.8 to 8.8. The guidance recommends using a characteristic value comprising the mean of the top 20% of soluble sulphate concentrations (for greater than 10 analysis results) to assess the design sulphate class. Due to the low number of samples taken compared to the size of the study area, this assessment should only be used to give an indication of likely sediment conditions. The characteristic value for sediments at the site has been assessed as 587mg/l.

4.5.3 A characteristic value for pH comprising the mean of the lowest 20% of pH values is recommended (for greater than 10 analysis results) for assessing the aggressive chemical environment for concrete (ACEC) classification. The characteristic value for pH within the sediments at the site has been assessed as 8.06. Further assessment should be undertaken following receipt of the 2009 GI. This should include evaluation of the potential for sulphide to oxidise to sulphate during construction.

5 Assessment of Land Contamination Risks: Southern Study Area

5.1 Introduction and Methodology

5.1.1 Baseline conditions for the southern study area were identified through the collection and review of information from existing sources, additional survey work, consultation responses, and the results of the 2008 GI (Jacobs Arup 2009b). A summary of the assessment of the baseline conditions is included in Section 8.3 of Chapter 8 (Geology, Contaminated Land and Groundwater) and detailed description of the ground investigation findings can be obtained in the 2008 GI (Jacobs Arup 2009b). This includes detailed assessment of the ground conditions underlying the areas investigated. The GI also included groundwater and ground gas monitoring, chemical analysis of soils and groundwater, and the installation of boreholes. The factual data including borehole logs and chemical analysis data is included in the Detailed GI South of Forth Estuary, Final Report (BAM Ritchies, 2009).

5.1.2 The intrusive investigations have identified the presence of metallic, inorganic and organic contaminants in groundwater underlying the site. The next stage is to determine whether these

contaminants pose a significant risk to receptors for a particular source-pathway- receptor linkage, as identified in the preliminary CSM in Section 1.3.

5.1.3 A GQRA has been undertaken where possible, as outlined in Section 1.4, in order to assess the following potential risks:

- risks to the water environment: receptors include surface water features, such as local surface water features and groundwater receptors which could potentially be used for drinking water abstraction;
- risks to future structures and services: receptors include new road structures and associated drainage and potable water supplies; and
- risk posed by ground gas: receptors include off-site receptors, construction workers and maintenance workers.

5.1.4 Due to the lack of soils analysis data for the southern study area, no further assessment of the risks to human health could be undertaken (PL3, PL10, PL12 and PL13, Table 8.21, Chapter 8) and an assessment of risks to the water environment from leaching of contaminants was not able to be undertaken. Adequate data will be collected during the 2009 GI to obtain data for further assessment.

5.1.5 As no environmentally sensitive land uses have been identified in the near vicinity of the proposed scheme construction works, the potential risks posed by contaminated soils to ecological receptors has not been further assessed at this stage.

5.1.6 The methodology undertaken for each of these assessments is further discussed within each individual section.

5.2 Risks to the Water Environment

The Water Environment Generic Qualitative Risk Assessment Methodology

5.2.1 The statutory objectives and the general requirements of the Water Framework Directive (European Parliament, 2000) require careful consideration of the on-going effects of construction activities to the water environment. To assess the risks that contaminated soils and construction activities will pose to the water environment (Table 8.21; PL5, PL6, PL7, PL15, PL16 and PL17, Chapter 8), groundwater chemical test data have been assessed using the Environmental Acceptability Levels (EALs) sourced from statutory and guidance documents. EALs are environmental standards below which there are considered to be no significant risks to the water environment. As little information is currently known about the groundwater quality and usage below the site, the most conservative EALs have been used for this assessment.

Data Assessment

5.2.2 Exceedances of EALs are summarised in Table 5.1. Full details of the assessment are available on request.

Table 5.1: Water Environment Risk Assessment Exceedances – Southern Study Area

Analytes	Maximum concentration	Units	No. of samples exceeding the EAL	EAL
Aluminium	35000	µg/l	4 of 4	10
Calcium	272	mg/l	2 of 10	250
Copper	137	µg/l	7 of 10	10
Iron	102000	µg/l	4 of 4	200
Magnesium	93000	µg/l	1 of 5	50000

Analytes	Maximum concentration	Units	No. of samples exceeding the EAL	EAL
Lead	1040	µg/l	8 of 10	10
Nickel	140.8	µg/l	5 of 9	20
Selenium	17	µg/l	1 of 9	10
Vanadium	73.3	µg/l	1 of 9	20
Electrical conductivity	6800	µS/cm	1 of 10	2500
Ammoniacal nitrogen (unionised)	2.59	mg/l	2 of 9	0.015
Chloride	161	mg/l	8 of 10	25
Bromide	127	µg/l	1 of 4	2
Nitrite	0.6	mg/l	1 of 9	0.5
Sulphate	761	mg/l	1 of 10	250
Sulphide	4.3	mg/l	8 of 9	0.00025
Phenols (total)	0.33	mg/l	1 of 9	0.03
TPH>C20-C40	670	µg/l	4 of 8	10
TPH>C6-C40	670	µg/l	4 of 8	10
Anthracene	0.23	µg/l	6 of 8	0.02
Fluoranthene	0.62	µg/l	6 of 8	0.02
Benzo(a)pyrene	0.33	µg/l	4 of 8	0.01
pH	6.8-12.5	units	n/a	6.5-9.5

5.2.3 As the majority of the sampling boreholes are located within open undeveloped ground, the samples demonstrated the background ground water quality in the study area and the possible effects of historical mining in the area. Elevated contaminants have been identified in all of the samples collected from the study area. BHSJ006, located near to the M9 Junction, exhibits particularly elevated concentrations of lead (1020µg/l) and ammoniacal nitrogen (2.6mg/l), elevated conductivity (6800µS/cm) and an alkaline pH (12.5). Samples taken from the borehole located within the developed Shores area contain similar concentrations of contaminants to those samples taken from undeveloped areas.

5.2.4 Groundwater monitoring boreholes located immediately outside the study area in the location of the Echline/Scotstoun junction and the former oil shale mining area exhibited similar elevated contaminant to those recorded for BHSJ006 i.e. elevated ammoniacal nitrogen, alkaline pH and increased conductivity. Although these boreholes are outside the study area, there is the potential for this groundwater to be drawn into the area as a result of earthworks e.g. cuttings.

5.3 Risk to Future Services and Structures

Guidance

5.3.1 Contamination arising from industrial development may pose a risk to building and civil engineering structures. During any potential future construction associated with the proposed scheme, the activities/structures most likely to interact with contaminated ground are as follows:

- structures and associated foundation construction e.g. concrete piles; and
- construction of services such as water and drainage, electrical cables and gas supply lines.

5.3.2 There are several guidance documents currently available to assist in assessing and mitigating the risks posed as a result of these activities.

5.3.3 In the UK, sulphates and acids, both naturally occurring and man made, are the agents most likely to attack and weaken underground structures. Sulphates at elevated concentrations are aggressive to concrete and may affect future developments on the site. BRE Special Digest 1:2005 (BRE,

2005) recommends precautionary measures with respect to sulphate and acid attack on concrete for a range of concentrations, for both green field and brownfield locations. The guidance also indicates that there is potential for organic compounds, such as phenols, and ammonium ions to attack underground structures at high concentrations.

5.3.4 Where services are to be laid in a known contaminated site, it is necessary to select suitable materials to comply with current regulations and to prevent pipelines failing prematurely due to aggressive ground conditions. This is particularly important in the case of drinking water supply pipes where permeation and accelerated deterioration of the pipe material can occur due to chemical reactions between the pipe and contaminants in the ground. Information on this can be found in guidance published by the WRAS (WRAS, 2002).

5.3.5 It is known that there are several other contaminants that may affect building structures; however, additional contaminants that affect structures are not anticipated to be present along the proposed scheme.

Structures and Building Materials

5.3.6 In order to identify the potential risks to future structures and buildings (Table 8.21; PL18), the soils beneath the site have been assessed in accordance with BRE Special Digest 1: 2005. Soluble sulphate concentrations (as SO_4 in 2:1 water/soil extracts) were reported at values up to 280 mg/l within the soils beneath the site, and pH ranged from 5.8 to 8.

5.3.7 The guidance recommends using a characteristic value comprising the mean of the top 20% of soluble sulphate concentrations (for greater than 10 analysis results) to assess the design sulphate class. Due to the low number of samples taken compared to the size of the study area, this assessment should only be used to give an indication of likely soil conditions. The characteristic value for soils at the site has been assessed as 230mg/l.

5.3.8 A characteristic value for pH comprising the mean of the lowest 20% of pH values is recommended (for greater than 10 analysis results) for assessing the aggressive chemical environment for concrete (ACEC) classification. The characteristic value for pH within the soils at the site has been assessed as 6.5. Further assessment should be undertaken following receipt of the 2009 GI.

Water Supply Pipes

5.3.9 Due to the lack of soils analysis data in this area, no assessment of the risks to supply pipes can be undertaken at this point. A risk assessment to water supply pipes will be undertaken when soil data becomes available. These results will be detailed in subsequent reports.

5.4 Assessment of Risks from Ground Gas

Risk Assessment Methodology

5.4.1 A ground gas risk assessment has been undertaken in accordance with CIRIA C665 guidance 'Assessing Risks Posed by Hazardous Ground Gases to Buildings' (CIRIA, 2007). This assessment provides an indication of risk to buildings on or adjacent to the site (Table 8.21; PL2, PL4, PL11, PL14 and PL19).

5.4.2 Given the proposed end use within the study area the assessment has been carried out for Situation A, as defined in CIRIA C665. Situation A is applicable to all development types other than a low rise building with minimum ventilated under floor void (minimum 150mm). This method uses both gas concentrations and borehole flow rates to define a characteristic situation for a site based on limiting borehole gas volume flow for methane and carbon dioxide, which is known as the Gas Screening Value (GSV), defined as follows:

- Gas Screening Value (litres of gas per hour) = maximum borehole flow rate (l/hr) x maximum gas concentration (% by volume).
- The calculation is carried out for both methane and carbon dioxide and the worse case value adopted. The characteristic situation is then determined from Table 8.5 of CIRIA C665.

5.4.3 This is a conservative approach that has been used to provide an initial indication of the level of risk from ground gases on site and to provide a guide as to whether mitigation measures will need to be employed within the study area.

Ground gas risk assessment results

5.4.4 Due to the size of the study area and the relatively low number of boreholes monitored for gas concentrations and flow rate, each borehole has been considered separately for the purpose of this assessment. Full details of the ground gas readings are available on request. A summary of the gas screening values recorded at each monitoring borehole is outlined in Table 5.2.

Table 5.2: Characteristic Situation by Borehole for Methane and Carbon Dioxide – Southern Study Area

Borehole ID	Max CO2 conc. (%)	Max CH4 conc.(%)	Max steady flow rate (l/hr)	GSV-CO2 (L/Hr)	GSV-CH4 (L/Hr)	Characteristic Situation
BHS1013	1.4	0.2	0.1	0.0014	0.0002	1-very low risk
BHS1016A	1.3	89.1	0.2	0.0026	0.1782	4-moderate to high risk*
BHS1018	1.5	0.1	0.1#	0.0015	0.0001	1-very low risk
BHS1019	1.8	0.1#	0.1	0.0018	0.0001	1-very low risk
BHS1021	1.4	7.8	0.1	0.0014	0.0078	3-moderate risk*
BHS1023	2.1	0.1#	0.1	0.0021	0.0001	1-very low risk
BHS1024	0.2	0.1#	0.1#	0.0002	0.0001	1-very low risk
BHS1027A	0.8	0.1	0.6	0.0048	0.0006	1-very low risk
BHS1028	0.3	0.1	0.1#	0.0003	0.0001	1-very low risk
BHS1041	0.1	0.1#	0.1	0.0001	0.0001	1-very low risk
BHS1044	0.5	1.4	0.2	0.001	0.0028	2-low risk
BHS1045	1.0	0.1	0.1	0.001	0.0001	1-very low risk
BHS1100	0.1	0.1#	0.1#	0.0001	0.0001	1-very low risk
BHS2001	1.2	0.1#	0.1#	0.0012	0.0001	1-very low risk
BHSJ012	0.1#	0.1#	0.1#	0.0001	0.0001	1-very low risk

* Based on GSVs these boreholes represent a low risk, however, due to the elevated methane concentrations, (>2.5%) then a moderate or moderate to high risk is used, and a quantitative risk assessment is required.

Where the concentrations have been less than the detection limit, the detection limit has been used to give the most conservative assessment.

5.4.5 Elevated concentrations of methane were identified at BHS1061A and BHS1021, both of which were installed in the drift and bedrock, and additional boreholes monitored prior to the collection of flow rate readings. These elevated concentrations of ground gases may pose a significant risk to construction and maintenance workers, especially in confined spaces. In addition, construction

activities, such as grouting or piling have the potential to cause migration of gases or create pathways for gas movement. It is possible that these elevated gas readings are associated with former oil shale mines understood to exist in the southern study area. Further investigation is currently being undertaken to further characterise the ground gas regime within the study area. It is also possible that elevated concentrations of ground gas are present in other areas not yet fully investigated and this should be considered as part of detailed design work.

Other gases

5.4.6 Hydrogen sulphide concentrations were assessed by comparison with the short-term (10ppm for 15 minutes) and long-term (5ppm for 8 hours) Occupational Exposure Level (OEL) concentrations presented in Table 2.2 of CIRIA C665. Both OELs were considered appropriate to construction workers or maintenance workers who may be at risk from ground gas emissions within the study area. No recorded concentrations of hydrogen sulphide exceeded the OEL.

5.4.7 Carbon monoxide concentrations were assessed by comparison with the short-term (200ppm for 15 minutes) and long-term (30ppm for 8 hours) OEL presented in Table 2.2 of CIRIA C665. Carbon monoxide was found to exceed the long term exposure limits at BH1028, located in the study area close to the southern shore in open ground. In addition, the boreholes located immediately outside of the study area at the Echline/Scotstoun junction exceed both the short and long term exposure levels with concentrations up to 939ppm recorded.

6 Updated Conceptual Site Model

6.1.1 The preliminary CSM presented in Section 1.3 identified the potentially significant pollutant linkages present within the study area. The preliminary CSM has been refined in this section and further assesses the potentially significant pollutant linkages which may pose unacceptable risk. A summary of the assessment for each study area is outlined in Tables 6.1 – 6.3. Any pollutant linkages deemed not to exist for each study area based on the available information to date have been removed from the CSM. These are summarised as follows:

- Pollutant linkages PL3-9 and PL12-21 are not applicable to a large number of study areas (N4, N5a-b, N6-9, N11-16, N21-26, N29-30, S1, S3-12 and S14-16) as no construction works are proposed in these areas or within 200m of these areas. Important potential pollutant linkages for these areas considered in the tables relate to risks to construction and maintenance workers associated with migration of ground gas and/ or groundwater contamination.

6.1.2 Where pollutant linkages have been identified to be potentially present, the level of potential risk has been assessed qualitatively using a simple matrix described in CIRIA 552 (CIRIA, 2001) which defines risk as a combination of:

- the magnitude of potential consequences (or severity) of the risks occurring; and
- the magnitude of the probability (likelihood) of the risk occurring.

6.1.3 In order to make the assessment as site-specific as possible, information from desk-based research and available ground investigation data (as detailed in Sections 3-5 above) has been considered on the assessment of each potential pollutant linkage as follows:

- Risks to human health associated with contaminated soils (PL1, PL3, PL10, PL13): the potential for soil contamination to be present from historical land uses, the results of the human health GQRA reported above together with the potential for excavations to be carried out.
- Risks associated with ground gas (PL2, PL4, PL11, PL18): the potential for ground gas to be present and evidence of elevated concentrations from borehole monitoring, together with the likelihood of below ground works being required and relevant receptors, e.g. residential housing, being present.
- Risks to the water environment (PL5-7, PL15-17): the potential for groundwater to be impacted by historical activities and the elevated concentrations of contaminants found in the 2008 GI,

together with assessment of how the site geology and construction works will affect contaminant mitigation.

- Risks to future building structures and services (PL18, PL19): evidence for soil contamination to be present that could affect such receptors based on the 2008 GI data.
- Risks to ecological receptors (PL8, PL9, PL20, PL21): evidence for potential or actual soil contamination to be present and the proximity to sensitive ecosystems.

6.1.4 It is important to note that this assessment has been undertaken in line with the DMRB guidance and pollutant linkages are only assessed with respect to construction and/or operation phase activities.

6.1.5 The main uncertainties and limitations of the CSM at this stage are as follows:

- not all study areas have been fully investigated and there are limitations in the availability of chemical test data as highlighted in Sections 3-5 above;
- the ground gas regime has not been fully characterised in all areas and under a wide range of atmospheric conditions;
- the groundwater regime and direction of groundwater flow have not been fully established in each area, along with the interactions between shallow and deep groundwater; and
- it is possible that localised areas of contamination exist that have yet to be identified both within and outwith the study areas identified.

6.1.6 Some of these issues are being assessed through supplementary ground investigations recently carried out whereas others will require assessment and mitigation through the detailed design and construction phases as detailed in section 8.5 of Chapter 8 of the ES.

Table 6.1: Marine Study Area Conceptual Site Model

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
M1:Contaminated sediments in the Firth of Forth	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, marine sediments, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. pier construction.	Construction workers	Low	Medium	Moderate/Low
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Unlikely	Medium	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Low
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; • shallow and deep groundwater entering cuttings during blasting; and • contaminated sediments disturbed during the construction of the bridge piers.	Surface water	Low	Mild	Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Low	Medium	Moderate/Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Low	Medium	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. inspections.	Maintenance workers	Unlikely	Medium	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Unlikely	Mild	Very Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies lain as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Medium	Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Medium	Low

Table 6.2: Northern Study Area Conceptual Site Model

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
N7: Refuse tip, N9: Tank 2, N11: Saltpans Works, N12: Cemetery, N13: Old quarry 1, N14: Quarry 1, N15: St. Margaret's Quarry; N16: Quarry 2; N21: Castlelandhill Quarry; N22:Old quarry 3; N23:Old quarry 4; N24: Old Quarry 5; N25: Fairykirk Quarry; N26: Unrecorded coal mines: N30 East Tip (various sources as detailed in Table 2.1).	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Unlikely	Medium	Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling		Unlikely	Severe	Moderate/low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Unlikely	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
N1: St. Margaret's Marsh (excluding landfill): Contaminated soils and/or groundwater: low level radiation e.g. cobalt-60 in soils and groundwater. Metals, organic and inorganic contaminants in the sediment used to in-fill reclaimed land.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Unlikely	Medium	Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Unlikely:	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Medium	Moderate/Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling, or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Low	Mild	Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Low	Medium	Moderate/Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Low	Medium	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Low	Medium	Moderate/Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Medium	Moderate/Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Low	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Low	Medium	Moderate/Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Low	Medium	Moderate/Low
N2: St. Margaret's Marsh Landfill: Metals, organic and inorganic contaminants present due to historical land use as a landfill. Elevated PAHs, lead, arsenic, nickel and vanadium identified during ground investigations.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	High	Severe	Very high
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Likely	Severe	High
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	High	Medium	High
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Likely	Mild	Moderate/Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Likely	Medium	Moderate
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Likely	Medium	Moderate
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	High	Medium	High
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Likely	Severe	High
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Low	Medium	Moderate/Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Low	Medium	Moderate/Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	High	Medium	High
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of : • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack	Proposed structures and buildings	Likely	Minor	Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Likely	Minor	Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Likely	Medium	Moderate
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Likely	Medium	Moderate
N3: Wastewater treatment works: Waste water treatment contaminants including metals, pathogens, inorganic and organic contaminants. Elevated nickel and vanadium identified during ground investigations. Asbestos also identified in made ground.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	High	Medium	High
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Likely	Medium	Moderate
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Low	Medium	Moderate/Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Low	Medium	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	High	Medium	High
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Low	Medium	Moderate/Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Low	Medium	Moderate/Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.	Shallow groundwater	Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.		Likely	Medium	Moderate
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of : • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low likelihood	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack	Proposed structures and buildings	Likely	Minor	Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Likely	Minor	Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Low	Medium	Moderate/Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Low	Medium	Moderate/Low
N4: Belleknowes Industrial Estate: Contaminants from varying land uses including metals, inorganic and organic contaminants and asbestos.	**Construction**					
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.	Construction workers	Unlikely	Severe	Moderate/Low
	Operation					
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.	Maintenance workers	Unlikely	Severe	Moderate/Low
N5a: Ferry Toll Quarry Landfill North, N5b Ferry Toll Quarry Landfill South N6: Ferry Hills Landfill: Waste water treatment contaminants including metals, pathogens, inorganic and organic contaminants.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Unlikely	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
N8: Tank 1: Unknown contamination source as nature of tanks unknown.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Unlikely	Severe	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Unlikely	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
N10: Former Railway lines and Tunnels: Metals, pesticides, fuel oils etc. associated with former land use as railway land.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Unlikely	Severe	Moderate/Low
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Unlikely	Medium	Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Low	Mild	Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
N17: Welldean Quarry Heavy metals, organics and inorganics associated with made ground used for quarry infill.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of : • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
N18: Old quarry 2: Heavy metals, organics and inorganics associated with made ground used for quarry infill.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of : • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
N19: Old Quarry (whinstone): Heavy metals, organics and inorganics associated with made ground used for quarry infill.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
N20: Ferrytoll Quarry: Heavy metals, organics and inorganics associated with made ground used for quarry infill. Made ground identified in the area during the ground investigation. and associated works	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
N27: Welldean Cottages area Made ground to 0.85m bgl identified with elevated metal contaminants present.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Likely	Medium	Moderate
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Medium	Moderate/Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Low	Mild	Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Medium	Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Medium	Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Low	Medium	Moderate/Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Medium	Moderate/Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Low	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Medium	Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Medium	Low
N28: TPH Hotspot at BHN1015: Made ground with TPH contamination and elevated concentrations of heavy metals and containing glass, wood, brick, metal and pottery fragments.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Likely	Medium	Moderate
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Unlikely	Medium	Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Unlikely	Mild	Very Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Low	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
N29: HM: Naval Base	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction Workers	Likely	Medium	Moderate
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Unlikely	Severe	Moderate
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
N31: Made ground either side of the main carriageway	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Likely	Medium	Moderate

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Unlikely	Mild	Very Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Low	Medium	Moderate/Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Very Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Unlikely	Mild	Very Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	High	Minor	Moderate/Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Low	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low

Table 6.3: Southern Study Area Conceptual Site Model

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
S1: Sewerage pumping station; S4: Dundas Lime Works;S5:Refuse Tip 1, S6:Refuse tip 2; S7: Oil shale processing spoil heap;S8 Bonded warehouse; S9: Old quarries; S10: three old quarries;S12:Quarry 2; S14: Identified furnace waste materials] (various sources as detailed in Table 2.2)	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Unlikely	Medium	Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Unlikely	Severe	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Unlikely	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low
S2:Barracks area: Potential metal, inorganic and organic contaminants associated with imported made ground.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors	Low	Medium	Moderate/Low
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater	Low	Mild	Low
	PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer either through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits.	Deep groundwater	Low	Mild	Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Low	Mild	Low
	PL8	Inhalation, ingestion and direct contact with contaminated soils excavated and stored/reused on site during construction.	Ecological receptors	Unlikely	Mild	Very Low
	PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.		Unlikely	Mild	Very Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
	PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users	Unlikely	Medium	Low
	PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors	Low	Medium	Moderate/Low
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.		Low	Severe	Moderate
	PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments.	Shallow groundwater	Low	Mild	Low
	PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater	Unlikely	Mild	Very Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	Low	Minor	Very Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low
	PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors	Unlikely	Mild	Very Low
	PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.		Unlikely	Mild	Very Low
S3: Stores area: Potential metal, inorganic and organic contaminants associated with imported made ground.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Unlikely	Medium	Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Low	Severe	Moderate
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Unlikely	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Unlikely	Severe	Moderate/Low

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
S11: Quarry 1: Metal, inorganic and organic compounds associated with made ground infill.	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Unlikely	Severe	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Low	Medium	Moderate/Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Low	Severe	Moderate
S13: former oil shale mining area: Contaminated ground water and mine gas associated with mine workings and shale processing	**Construction**					
	PL1	Ingestion, inhalation and dermal contact with soils, soil dust, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting.	Construction workers	Low	Medium	Moderate/Low
	PL2	Migration of ground gases into confined spaces during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling.		Likely	Severe	High
	PL4	Migration of ground gases into home/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.	Off-site receptors	Low	Severe	Moderate
	PL7	Migration of: • shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground; • deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction; and • shallow and deep groundwater entering cuttings during blasting.	Surface water	Likely	Mild	Moderate/Low
	Operation					
	PL10	Ingestion, inhalation and dermal contact with soils, soil dust and/or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections.	Maintenance workers	Unlikely	Medium	Low
	PL11	Migration of ground gases into confined spaces e.g. service pits creating an asphyxiation/explosion risk.		Likely	Severe	Moderate

Source	Pollutant Linkage Ref.	Pathway	Receptor	Probability	Consequence	Potential Risk (before mitigation)
	PL14	Migration of ground gases into home/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.	Off-site receptors	Low	Severe	Moderate
	PL17	Migration of: • shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground; • contaminated shallow groundwater through drainage channels and associated granular bedding materials; • contaminated surface water from the new road surface through drainage channels; and • shallow groundwater entering cuttings.	Surface water	Low	Mild	Moderate/Low
	PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings	Unlikely	Minor	Very Low
	PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.		Unlikely	Minor	Very Low

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