Technical Annexes 14 – Ground Conditions

Contents

Buro Happold

007838 Hayle Harbour Redevelopment

Master Planning

Volume 1 Contamination Report

Job no 007838 August 2007

Revision 2

author	**Simon Pilkington/Matthew Parry**
signature	
date	**August 2007**
approved	**Justin Phillips**
signature	
date	**August 2007**

Contents

1 Introduction

ING Real Estate propose to redevelop much of Hayle Harbour and its associated quays and have appointed Buro Happold Limited to advise on site wide geotechnical and contamination issues.

This report deals with contamination, geotechnical issues are discussed in the accompanying Volume 2 (1). It should be noted that “contamination” is taken throughout the report to mean the “presence of one or more potentially harmful substances as a result of human activity”. However, naturally elevated concentrations of potentially harmful substances (PHSs) may also be of concern (see Box 1). It should be noted that “contamination” can have different meanings under different regulatory regimes; for example, planning (2), the Building Regulations (3), and Part IIA of the Environmental Protection Act (see Boxes 1 & 2).

Box 1: Contamination and contaminated land in a planning context

Annex 2 of Planning Policy Statement 23 (2) states that:

- To avoid confusion with the statutory term “contaminated land” and its definition [i.e. in Part IIA of the Environmental Protection Act 1990] and to reflect the different context of planning control, this Annex uses the wider term “land affected by contamination”. This is intended to cover all cases where the actual or suspected presence of substances in, on or under the land may cause risks to people, property human activities, or the environment, regardless of whether or not the land meets the statutory definition in Part IIA.

Annex 2 also states:

- Potentially hazardous substances, such as radon, methane or elevated concentrations of metallic elements may also be present in the ground due to the underlying geology. Since these may pose a risk to human health or to the environment, their presence is a material consideration.

Box 2: The Building Regulations – Approved Document C (3)

Contamination is dealt with in requirement C1 which concerns `Preparation of site and resistance to moisture'.

C1(1) requires that:

> *The ground to be covered by the building shall be reasonably free from any material that might damage the building or affect its stability, including vegetable matter, top-soil and pre-existing foundations.*

C1(2) requires that:

> *Reasonable precautions shall be taken to avoid danger to health and safety caused by contaminants on or in the ground covered or to be covered by the building and any land associated with the building.*

C1(3) requires that:

> *Adequate sub-soil drainage shall be provided if it is needed to avoid –*
>
> *a) the passage of ground moisture to the interior of the building;*
>
> *b) damage to be building, including damage through the transport of water-borne contamination to the foundations of the building.*

Contaminant is defined as (C1(4)):

> *Any substance which is or may become harmful to persons or buildings, including substances which corrosive, explosive, flammable or radioactive or toxic.*

The “building and land associated with the building” means:

> *The building and all land forming the site subject to building operations which includes land under the building and the land around it which may have an effect on the building or its users.*

Requirement C1(2) applies to new construction and under Regulation 6, whenever there is a “material change of use” of the whole building. “Material change of use” is defined in Regulation 5

2 Scope of Report

This report provides a brief summary of the investigation carried out by Buro Happold (for a fuller description see the geotechnical report (1)), summarises the results of the investigation, and provides an assessment of risk to human health, the water environment and some other potential receptors.

The aim of the investigation was to provide sufficient data to support a planning application for master planning rather than detailed design, the latter will require further ground investigation and risk assessment where necessary (see Section 8.7).

The approach to the investigation has followed the Contaminated Land Report (CLR) 11, Model Procedures for the Management of Land Contamination (4), and the R&D Technical Report P5-066/TR, Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination (5).

CLR11 sets out an iterative process of risk assessment that becomes progressively more refined starting with the initial desk study and culminating with the completion of any remedial and protective works, by which time any risks identified earlier should have been reduced to acceptable levels. A process is also described for setting the remedial objectives, identifying the options for achieving these objectives, collecting any additional information that might be required, and developing the most appropriate overall remediation strategy. Guidance is provided on the implementation of the remediation strategy which is completed once appropriate verification sampling, testing and monitoring has been carried out.

A preliminary risk assessment was carried out as part of the desk study and ground investigation planning stage. This report includes risk assessment to tier 2 only, the Generic Quantitative Risk Assessment. This level of assessment uses generic assumptions and assessment criteria. Site specific assessment criteria have only been used where generic ones have not been published. This level of risk assessment is considered to be appropriate for master planning purposes. Detailed design will require further information about the site and will allow the development of the more refined detailed quantitative risk assessment.

This report also includes a limited discussion on identifying feasible remediation.

P5-066/TR has been used to establish the sampling strategy. The complex site history and size of each development zone led to a sampling strategy based on an approximate 50m grid, with some additional targeted sampling on areas highlighted by the walkover and desk study information. The nominal grid spacing means that there is potential for large features to have gone undetected in this phase of the survey. Following P5-066/TR this grid has a 40% probability of detection of a 100m2 circular feature and an 80% probability of detection of a 2000m2 circular feature. The EA and Penwith District Council were consulted during the planning of the ground investigation and both indicated that they considered this sampling strategy to be appropriate.

The entire site has been assessed in terms of the following:

- Risks to human health and plants from contaminated soil
- Risks to groundwater from leaching contaminants
- Existing groundwater contamination and risks to surface water due to migration of groundwater
- Ground gas/vapour

It is important to recognise that contamination, for example from a small spill of oil, may be very localised and that no investigation, however comprehensive, is capable of finding such occurrences other than by chance. Furthermore, it was not possible to investigate the areas already covered by the existing buildings. Thus, the possibility of small areas of contamination existing on the site, not found during the investigation, or being present at greater concentrations than found during the investigation, cannot be entirely ruled out.

Some areas have not been sampled due to difficult access, this includes the large area of fill to the west of South Quay, and land beneath the extensive stockpiles in the old power station area.

Occasionally access was limited by dense vegetation, for example the eastern part of the sand dune area. As the ground investigation was carried out during the spring extensive vegetation clearance was not possible due to the legal requirement of not disturbing nesting birds.

Following telephone conversations with the area petroleum officer from Cornwall County Fire Brigade, there are no records held of any active or non-active petroleum stations or storage facilities within the site boundary. This is confirmed by the Envirocheck Report. Cornwall Country Fire Brigade do not retain information on private fuel storage facilities and as a result the petroleum officer was not able to provide information relating to potential fuel storage facilities associated with historical industrial uses.

The stockpiled materials in the area of the disused power station have not been sampled as it is understood that this material is owned by Lello and will be removed before development.

Localised instances of fly tipping have not been sampled or assessed.

No testing of the harbour waters was included in the contamination testing.

No testing of the estuarine sediments (excluding the man made Cockle Bank) have been undertaken.

After the site work and the majority of the laboratory testing work was complete it was decided to add a further area to the master planning application. The area is to the NE of North Quay and the proposed use is residential with gardens. For master planning purposes the approach to this extra area is to carry out a desk study and make recommendations for ground investigations to be undertaken in support of the detailed planning application. Details are contained in Appendix Q of this report.

3 Site Description and History

3.1 Site Description

The town of Hayle is located on the north coast of Cornwall, approximately 10km north east of Penzance, in the administrative area of Penwith County Council (Figure 1). The Hayle Estuary is the most south westerly estuary in Britain and includes the mouths of the Hayle and Angarrack Rivers. The town itself includes a large harbour and has a long history of industrial development. The historical development of the town has led to its current division into the western Foundry and eastern Copperhouse areas. The layout of the harbour is dominated by two tidal water storage lagoons, Copperhouse Pool and Carnsew Pool constructed to flush sediment from the harbour.

The National Grid Reference for the centre of the site is SW 557 377.

The land owned by ING in Hayle is extensive and includes much of Hayle Harbour. A general plan showing the layout of the site is included in Figure 1.

In general the quay sides are approximately 4.5m above Ordnance Datum (m AOD) and the majority of the site is below 5.5m AOD. To the north of North Quay a line of cliffs separates the generally flat quay side from undulating wind blown sand dunes. The cliffs are up to 15m high whilst the sand dunes rise to approximately 35m AOD.

In general the site is bounded to the east and south east by the town of Hayle. To the south west and west are the open waters of the estuary. To the north of the sand dunes are the Hayle Cricket Club grounds and chalets of the Riviere Towans. In the north western part of the site is a large area (approximately 10,800m2) owned and operated as a sub-station by Western Power. Numerous over ground electricity cables enter the substation from the north west, whilst cables to the south west of the substation exist underground, some of which cross the estuary towards the village of Lelant.

A series of site photographs are included in Appendix A.

North Quay and Dunes

The area covered by North Quay is approximately 47,200m2 including the Harbour Masters office, Chieftain's Yard, Lello's recycling site and the former chemical works buildings.

Much of North Quay is disused and is clear of buildings. The surface is generally granular hard standing with areas of concrete and brick flooring. Several railway lines are still present particularly in the north eastern area.

The only notable structures are:

- The former bromide works buildings in the central northern part of North Quay, these are generally 2 storey buildings with flat roofs (and reported to have at least 1 storey basements) and are of reinforced concrete construction.
- The former Sulphur Store, now used as a topsoil store by Lello's recycling operation
- The former arsenic calciner Chimney towards the north western part of North Quay
- A ramshackle single storey listed structure towards the east of North Quay that includes some scoria block construction.
- A reinforced concrete wall running parallel to the quay at the western end of North Quay

The current economic uses for North Quay include the following:

- Hayle Harbour Management Ltd
- Lello's recycling operation
- Various fishing activities with a few boats based on North Quay landing catches and storing equipment
- The former chemical works buildings house the following: electric motor sales and service business; printers; café,
- Informal boat store on the concrete hard standing at the eastern end of North Quay.

To the north east of the quay is an area of sand dunes, these cover and area of approximately 55,400m2.

The only business operating in this area is Cook haulage and servicing garage.

South Quay

South Quay is approximately 40,400m2 including the area between the B3301 Carnsew Road and the railway viaduct.

South Quay is largely disused and only has one small standing building to the south. This is a small single storey flat roofed concrete house known as Blue Hayles.

The only economic activities on this quay are small scale fishing operations.

The western part of the South Quay area consists of fill mounded up to 2m above the general level of the quay.

During the ground investigation areas of Japanese Knotweed were noted around the central parts of South Quay around the margins of the large filled area.

The area between Carnsew Road and the railway viaduct is generally gravel hard standing and is used as an informal car park and access to the foundry buildings to the south of the viaduct. Relatively small volumes of tipped material exist in this area.

East Quay

East Quay comprises approximately 12,200m2 although not all the land on East Quay is under ING ownership.

Current economic activities on East Quay include, Philps Bakery, ATS vehicle servicing, a shellfish merchant, boat building and repairs, textile manufacture.

Disused Power Station

Much of this area is owned and operated by Western Power and includes a number of transformers and buildings of unknown use together with some partially demolished buildings. The land owned by ING comprises approximately 16,000 m2 and has been extensively used for the stock piling of building demolition material apparently both pre and post processing.

Triangular Spit

The Triangular Spit is part of the Hayle Estuary and Carrack Gladden Site of Special Scientific Interest (SSSI). It is a generally a flat area of land approximately 30,500m^2 with no buildings. The surface is generally gravel hard standing with some areas of rough vegetation, towards the western margin there is some blown sand and dune development. A rare and protected species of petalwort has been found in this area.

Other sites

The railway site and Lelant Quay are covered in separate reports and hence are not included here. ING also own the Riviera Farm, however no ground investigation work has been undertaken to date.

Cockle Bank

At low tide the Cockle Bank is approximately 360m x 60m whilst at high tide the bank is almost completely submerged. To the NE of the bank is North Quay, to the E and SE are East Quay and South Quay, to the NW lies the harbour entrance, and to the SW is a spit of land that separates Lelant Water from the main harbour. The top of the bank is generally 2m above low tide level gradually rising at the NW and SE extremities to approximately 3m above low tide level. The surface is generally sandy with some seaweed cover and occasional more muddy areas especially on the SW side. The NW and SE extremities have more gravel, boulders and cobbles at the surface, both extremities are marked by large wooden posts that were apparently used for turning boats in the harbour.

Various electric cables cross beneath the harbour entrance to the NW of the bank trending approximately N-S.

3.2 Site History

Hayle has a long industrial history and the subject is covered in a number of books and studies, the most notable being Cahill 2000 (6). Hayle developed into a major port in the 18th centaury and was home to two of the largest early 19th century mine engine foundries in the world (Harvey's 1779-1903 and Copperhouse 1820-1869). In the 19th century the rivalry between these two companies were largely responsible for the expansion of the town and harbour. In the early 20th centaury the port continued to flourish and was used for building and dismantling ships as well as the production of bromide for aviation fuel.

Commercial shipping ceased in the 1970's and sluicing operations ceased in 1979, and at present the harbour is only used by relatively small businesses.

Historical maps are included with the Envirocheck Report in Appendix B. The maps are at 1:2,500 and 1:10,000 scales and date from 1878. Extracts of earlier maps are available from the Cahill 2000 (6) report.

A summary of the historical land use is presented in Figure 2 and Table 1 below. Only the significant industrial uses are identified below.

Area	Details	Dates
North Quay	Coal yard for Power Station	1910-1977
Chieftain's Yard	Life Boat station Esso storage tanks	1906-1920 pre 1963 – 1965+
Lello's recycling yard/Chemical Works	Arsenic calciner Glass works Chemical works	1907 1917 - 1925 Late 1930s – 1973
Old Power Station	Power Station, coal fired	1910 – 1977
Dunes	Land surface modified between Chieftain's Yard and the existing chemical works buildings	1908 – 1963
East Quay	Gas works	1888 - ?
South Quay	Ore hutches Ship building and breaking Gas works Timber yards	1943 - 1888
SSSI	Boat building and breaking	

Table 1: Summary of historical land use.

North Quay and Dunes

Development of the quay started in the east and progressively extended to the west away from the town. By 1810 the quay extending from the custom house to Chieftain's yard was complete. By 1842 development had extended as far as the coal yard, and by 1877 the final existing western end section had been completed.

The area now known as Chieftain's Yard is currently used as a fisherman's storage and repair area. This was originally a quarry owned by the Cornish Copper Company. A lifeboat station from approximately 1906 to 1920 and for Esso storage tanks from pre 1936 until at least 1965. The maps show that this quarry was never backfilled.

The historical maps show that the area of land between Chieftain's Yard and the existing chemical works buildings has been modified. The hatching on the 1908 map is markedly different to that on the 1936 map.

The area to the north of the western part of the quay is shown as a *Gravel Pit* on the 1878 1:2,500 map and an *Old Gravel Pit* on the 1908 1:2,500 map. A *Rifle Range* with 100, 200 and 300 yard targets is shown on the 1879 map, *Old Targets* are shown further north on the 1908 map. The maps show that this area was not backfilled before being developed further.

The existing circular stone chimney marks the location of the *Pentowan Calcining Works* shown on the 1907 map. The site was re-used as a glass works from 1917 to 1925. Calciners smelted tin ore, and the resulting toxic fumes condensed on the flume walls as arsenic trioxide where it was chipped off by hand and sold.

The chemical works in the central northern part of the quay were constructed in the late 1930's and produced bromine from sea water using the hot water and electricity from the power station. The operation continued until 1973. The operation was initiated by the military, set up by ICI for the British Ethyl Corporation and then taken over by Associated Octel.

The power station area is shown as a *Sand Pit* on the 1878 and 1908 1:2,500 maps. The maps show that the pit was not infilled before further development. The coal fired power station became operational in 1910 from which time the western part of the quay would have been used as a coal yard. This probably continued to 1977 when the power station was decommissioned. The original cold water inlet exists to the east of North Quay between low and high water and is shown on the 1964 1:2,500 map. A second cold water inlet was constructed between 1939 and 1941 in Carnsew Pool (see below). Hot water from the power station was used by the chemical works, it is understood that this was discharged at the eastern end of North Quay through a culvert.

In 1996 a Hayle trawler was broken up on North Quay.

East Quay

By 1810 only the north eastern part of East Quay had been constructed, this included Bristolmen's Dock that was infilled by 1877. By 1842 the majority of the quay had been constructed. The area now occupied by Philp's Bakery (not part of the site) was infilled between 1936 and 1964 (see historical maps).

Ore hutches are shown on along the south western part of the quay on the 1878 1:2,500 map and date from at least 1842.

A gas works was in operation on East Quay from 1888. The historical maps indicate that it was constructed in 2 phases with the western half shown on the 1908 1:2,500 map and both the western and eastern halves shown on the 1936 map. The gas holders were demolished by 1979 but the buildings remain.

1960's warehouses exist on the western part of the quay.

South Quay

South Quay was built about 1819. Initially a pre-existing causeway ran beneath the northern part of the quay through an arch or tunnel. The location of the tunnel is marked by the sheet piled section of wall on the eastern side of the quay and on the west side by an area of infill masonry (see Appendix C for information from the Hayle Archive).

South Quay used to include ore hutches towards its northern end (shown on the 1879 1:2,500 maps). The western part of the quay and quayside was used by Harvey for shipbuilding. Initially the boats were wooden then steel, the largest, built in 1891, was the 4000 tonne SS Ramleh. The same area was used for ship breaking with a number of WWI boats dismantled between 1919 and 1923. Ship breaking continued after WWII up until the 1970's when at least 3 trawlers were broken up. This area was infilled by 1979.

Towards the southern end of the quay were boiler works, a timber shed, a wrights yard and buildings, the steamer's office and yard, a drawing office, a coal house, saw pit, a carpenter's shop, a wagon shed, a chain store and a shoeing shop. Timber yards were located on the eastern side of the quay and are clearly seen on the aerial photos included in Appendix A.

The area between Carnsew Road and the railway viaduct was used as a gas works from 1843 to 1888. Various buildings and a gas holder shown on the 1879 1:2,500 map. Various buildings still shown on the 1964 1:2,500 map but were apparently completely demolished by 1976.

Carnsew Quay

Carnsew Quay, up to a point midway between the lock gates and sluice, was built in 1758, it was then extended in the 1830's to form the spit that separates the mouth of the River Hayle and the harbour.

To the west of Carnsew Quay, near the location of the present Jewson, a lime kiln in shown on the 1879 map and is depicted as an old lime kiln until 1964.

Cockle Bank

The Cockle Bank is understood to have been created in the 1830's to aid the flushing of sediment from the harbour by increasing the flow of water released from the Copperhouse and Carnsew Pools. The source of material for the bank is unknown but there is clearly potential for mine waste, industrial waste and locally dredged material to be used in its construction. A record dated 1832 obtained from the Hayle Archive entitled "Expense of making an embankment at Hayle" indicates that the bank is constructed of sand covered in clay, however the record refers to a weir and also lists the cost of rail road, sluice gates etc. so it is possible the that record actually relates to the construction of Carnsew Pool or the spit.

Numerous vessels are known to have foundered on Cockle Bank in the late 18 and early 19C. Posts, presumably for navigation are shown on the earliest map until the 1964 map.

Triangular SSSI

The eastern margin of the triangular SSSI, the spit that extends to the north, and the bank enclosing Carnsew Pool were all constructed in the 1830's. The triangular area to the north of Carnsew Pool was infilled between 1936 and 1964. This may have resulted from natural silting up or it may be where the dredged spoil from the dredging of Carnsew Pool was dumped. Carnsew Pool was deepened to provide a permanent source of cold water for the power station between 1939 and 1941.

A number of slipways on the western margin of the SSSI area are visible on the aerial photographs included in Appendix A. It is understood that these were used for the construction of landing craft or support barges for use in the D-Day invasions.

Mining and Buried Ordnance

Mining and the risks of buried ordnance are discussed in the accompanying geotechnical report.

3.3 Geology

Historical borehole records and details of the findings of the 2005 ground investigation are presented in the accompanying geotechnical report. A summary of ground conditions is given below.

The BGS 1:50,000 Solid and Drift Penzance Sheet 351 & 358 (7) shows the majority of the site to be underlain by Marine and Estuarine Alluvium. This in turn is underlain by the Gramscatho Beds of the Devonian Period; these are well graded turbiditic sandstones in beds up to 2m thick with interbedded slates. This strata is shown to outcrop at the surface south of Carnsew Road, on the spur to the south east of East Quay and to the north of North Quay on the power station, chemical works, and Chieftain's Yard areas. The higher ground to the north and west of these areas is shown to consist of Quaternary Blown Sand overlying the Gramscatho Beds.

3.4 Hydrology, Hydrogeology and Water Quality

The Groundwater Vulnerability Map, Sheet 53 (8), shows the site to lie on a minor aquifer.

The Environment Agency (EA) have informed Buro Happold Limited that there are no specific Environmental Quality Standards (EQSs) for Hayle Harbour. The EA correspondence together with monitoring results is included in Appendix D.

3.5 Summary of Envirocheck Data

The Envriocheck Report in Appendix B includes Data Sheets that detail the environmental setting, the economic activities and some of the basic geological and hydrological risks on the site. The key issues are summarised below:

Water abstractions

One lapsed licence on site for use by the CEGB, presumably for cooling water, 7 licences over 700m from the site boundary, for irrigation and general use.

Discharge consents

5 onsite, 8 over 700m from the site boundary

Waste

The old power station is shown to be a BGS recorded landfill. The old chemical works area (Lello's recycling yard) is shown to be a Licensed Waste Management Facility and a Registered Waste Treatment or Disposal Site. There is a Local Authority Recorded Landfill 460m south of the site boundary.

Geological Risks

The report states that the site is in an area affected by mining, see also Volume 2 (1).

10-30% of homes are above the National Radiological Protection Board Action Level, this means that full radon protection measures are required.

3.6 Site Walkover Observations

A thorough site walkover was made on 2nd and 3rd December 2004. Observations not already made in the site description and site history sections (3.1 and 3.2) are listed below:

- In several locations groundwater can be seen to be flowing down the cliff face that separates North Quay from the dunes.
- There has been extensive fly tipping across much of the site
- Suspected asbestos cloth was noted on the triangular SSSI area and on Lelant Quay
- Some brightly coloured staining was noted on the surface of the infilled western margin of South Quay

4 Scope of Investigations

4.1 Previous Investigations

Ground conditions across the site have been investigated a number of times. The following reports were made available:

- Gibb and Partners, Sept 1988, Hayle Harbour Development: Engineering Appraisal. This includes no contamination data.
- Babtie, Feb 2001, Final Geotechnical Desk Study. This includes no contamination data.
- WSP Environmental, March 1998, Environmental Assessment of Proposed Dredging Works. This includes some contamination data for the intertidal and submerged soils including Cockle Bank and the main parts of the Harbour, but not including Penpol Creek and Carnsew Quay

The following was not available:

- Soil Mechanics, March 2003. Factual Report on Preliminary Ground Investigation. Report Number J2113.

This work was carried out under the instruction of the Hayle Harbour Company and supervision of the Babtie Group.

4.2 Buro Happold 2004-2005 Investigation

The following sources of information were reviewed for the desk study:

- Envirocheck report for Hayle Harbour (included in Appendix B) Dated 10 December 2004 Report Reference 8080801-1-1
- Information available from the Hayle Archive (included in Appendix C)
- Aerial Photographs from the English Heritage National Monuments Record (included in Appendix A)
- Information gathered from the site walkover
- Information available from Hayle Library
- Information available from the Hayle Harbour Management Office
- Information available from the internet
- Existing borehole records provided by the British Geological Survey (included in the geotechnical report)
- 1:50,000 Solid and Drift Penzance Sheet 351 & 358 Geological Map
- Environment Agency (formerly National Rivers Authority) Groundwater Vulnerability Map
- Department of Environment Industry Profiles
- The results of a number of previous investigations (not all of which were undertaken specifically to investigate contamination).

Following coalition and review of the desk study data a conceptual ground model was produced, this is included as Figure 3.

The ground investigation was carried out by CJ Associates in four phases:

- 29/09/2004 to 30/09/2004 Preliminary trial pitting investigation of Cockle Bank
- 29/03/2005 to 22/04/2005 Main phase of ground investigation
- 16/05/2005 to 23/05/2005 Return to site to complete rotary coring
- 07/06/2005 to 09/06/2005 Additional dynamic probing in Penpol Creek for a revised master plan

In total this included 128 machine dug trial pits, 35 cable percussion boreholes (including 6 drilled in intertidal areas), 4 rotary cored holes, 9 rotary open holes, 16 window sample holes, 28 dynamic probes, a parallel seismic test and a day trial of ground probing radar. Hand dug trial pits on the beach deposits were included in order to obtain samples for the testing of natural back ground levels of contamination.

The layout of the exploratory holes are shown in Figure 4 and full details of the results are contained in CJ Associates Factual Report (9).

Sampling and Testing Strategy

The locating of the holes on an approximate 50m grid is discussed in Section 2.

Contamination laboratory testing on soil, leachate and groundwater samples was carried out by TES Bretby and all results are included in their factual report (10). The testing suites was derived from a study of the previous industrial usage across the site, the soil, leachate and water suites are included in Appendix E. Additional physiologically based extraction tests (PBETs) for arsenic were carried out on samples from Cockle Bank and the dunes area. A number of EDTA 'extractable' metals tests were also carried out on samples form Cockle Bank together with tests on sieved fractions.

Groundwater and gas monitoring standpipes with slotted screens were installed in the majority of cable percussion and rotary cored boreholes by CJ Associates. These enabled the recording of groundwater levels during and after the fieldwork period and to take gas and groundwater samples for laboratory tests.

Four rounds of gas and groundwater sampling and monitoring were carried out by Soil Mechanics on behalf of TES Bretby. These results are included in TES Bretby's Factual Report.

CJ Associates undertook one round of groundwater monitoring and a 12 hour monitoring period measuring the fluctuation of water level in selected standpipes over a tidal cycle as close as practical to spring tides. This data is included in CJ Associates factual report (9).

Findings of Ground Investigation

In general the ground investigation confirmed the geological sequence as predicted by the geological maps (see Section 3.3). Most of the site has a layer of made ground at the surface. A map showing the thickness of made ground encountered at each exploratory hole is included in Volume 2 (1). The made ground is highly variable but is generally granular and includes widespread ash and clinker.

Notable details of features encountered in the made ground for each of the main site areas are listed in Table 2 below:

Area	Details	Hole Ref
North Quay	Thickness very variable, generally thicker towards quay wall. Very strong hydrocarbon odour and black staining	 TP122 from 2.5m
Chieftain's Yard	Up to 2m of made ground, some areas of reinforced concrete up to 0.45m thick Hydrocarbon contamination observed, oil noted.	 BH108 from 0.4m TP121 from surface WS108 below 0.6m
Lello's Yard/Chemical Works	3.4m of building demolition material including brick, concrete blocks up to at least 1m diameter, timber and metal. Old foundations and below ground structures encountered.	TP104 TP105 A-D
Old Power Station	A large amount of building demolition material including brick, concrete blocks, metal sheets, wire rope, smooth reinforcing bars etc. Some in-situ concrete walls and an in-situ vertical I beam were also encountered and these pits are assumed to have been dug in backfilled basement areas of the old power station. A 3ft diameter cast iron pipe exposed that is assumed to be one of the water inlet or outlet pipes for the power station.	TP516 TP516A TP518 TP520

Table 2: Notable features encountered in the made ground. Continued on next page.

Area	Details	Hole Ref
Dunes	In general the made ground in the dune area is restricted to the top 2-300mm of material and consists of sand and ash, notable exceptions are discussed below.	
	Infilled concrete structure 2.4m deep	TP206
	An area of ash and clinker fill up to 7m deep was encountered in the dune area to the north of North Quay. SPT's carried out in BH505 show this material to be very loose.	TP535 TP539 BH505 BH505R BH509R BH510R BH511R
East Quay	Up to 4.7m made ground, generally non-cohesive material but with some cohesive horizons. No notable contamination observed on logs	
South Quay	Generally non-cohesive material up to 6.5m deep very variable including cohesive and non-cohesive material	
SSSI	Up to 3.7m thick,	
Cockle Bank	Up to 4.5m thick, generally gravelly sands.	

Table 2: Notable features encountered in the made ground. Continued from previous page.

Further details including descriptions, thicknesses and properties for each of the stratums encountered are included in the accompanying geotechnical report (1).

Groundwater

Groundwater was encountered in the majority of boreholes and in some of the deeper trial pits. Full details are included in CJ Associates Factual Report (9). CJ Associates also undertook a 12 hour round of tidal monitoring, and the results are tabulated in their report and the tidal ranges recorded are presented graphically in the accompanying geotechnical report (1). TES Bretby undertook 4 monitoring visits to measure levels of gas and groundwater in the standpipes and to sample the groundwater for contamination testing, full details are included in TES Bretby's report (10).

The highest recorded water levels are generally 3 to 4m below ground level across most of the quays. In the dune area the highest recorded water levels are somewhat deeper, varying from 5m below ground level on the lowest parts of the dunes to 17m below ground level on the highest parts. Most of the standpipes in the quay areas showed a direct correlation between their standing water levels and the level of water in the harbour. Over a 12 hour period levels in the boreholes varied by approximately 1 to 3.5m compared to a recorded tidal range of 4.2m. Details are presented in graphically in the accompanying geotechnical report (1).

5 Proposals

The proposed development is of mixed use and includes the following elements:

- residential areas with gardens
- residential areas without gardens
- commercial/business areas
- retail units
- hotels
- restaurants/cafes/pubs
- industrial areas
- college
- leisure/galleries
- marina and fisherman's harbour
- new bridges and barrage
- landscaped car parking

FSP Architects and Planners have produced a number of designs for the master plan. This report has used the version dated 13/08/07 and this is reproduced as Figure 5.

In general there is only limited excavation and filling proposed. The aim would be to have no offsite disposal of material (with the exception of Cockle Bank). Some re-profiling of the quays to provide adequate flood defence is expected, together with the dredging of Penpol Creek.

The proposals include the removal of Cockle Bank to make way for a marina. This will involve the removal of approximately 120,000m3 of material depending on the final levels of excavation and the details of the approved scheme.

Details for the residential areas without gardens are not available, however our current assumptions are that they will be of several storeys surrounded mainly by hard standing with isolated areas of soft landscaping.

Where possible shallow foundations will be used. Piled foundations will be used where structures are near quay walls, where the thickness of made ground is high, or where the building loads are high and the rock surface is deep.

6 Assessment Criteria

6.1 Assessment criteria for soil contaminants

Site Assessment Criteria (SAC) for different land use scenarios are listed in Table 3 together with their source, reasons of concern and the receptors to which they apply. Detailed discussions regarding these criteria and the ones used in respect of the water environment are provided in subsequent sections.

The considered critical receptors vary according to each final land use and type of contaminants. For commercial and industrial sites the critical receptor is an adult worker, while for residential sites a female child. As zinc and copper are mainly toxic to plants (phytotoxic contaminants) the assumed critical receptors are plants. Further information is given on the Environment Agency guidance CLR10 (11).

Determinand		Assessment Criteria (mg/kg)			Source / Model	Reasons of concern	Primarily Assessed for
		Residential with plant uptake	Residential without plant uptake	Commercial			
Metals	Antimony	31			USEPA	Toxic and Phytotoxic (toxic to plants)	Plants
	Beryllium	1			USEPA	Carcinogen	Human health
	Arsenic	20	20	500	SGV	Carcinogen and toxic	Human health
	Cadmium	8	30	1400	SGV (pH = 8)	Toxic	Human health
	Chromium	130	200	5000	SGV	Toxic	Human health
	Copper	130			ICRCL	Phytotoxic	Plants
	Lead	450	450	750	SGV	Toxic	Human health
	Mercury	8	15	480	SGV	Toxic	Human health
	Nickel	50	75	5000	SGV	Toxic and phytotoxic	Human health
		70			ICRCL	Toxic and phytotoxic	Plants
	Selenium	35	260	8000	SGV	Toxic	Human health
	Tin	900			Dutch Indicative Level of serious contamination	Not dangerous but may be toxic at very high concentrations	Human health
	Zinc	300			ICRCL	Phytotoxic	Plants
PAHs	Benzo (a) pyene	0.85	0.95	9.0	CLEA	Carcinogen	Human health
	Dibenzo(ah) anthracene	0.85	0.95	9.0	From relative cancer potencies compared to benzo(a)pyrene (US EPA 1993)	Carcinogen	Human health
	Benzo(a) anthracene	8.5	9.5	90			
	Benzo(b) fluoranthene	8.5	9.5	90			
	Benzo(k) fluoranthene	8.5	9.5	90			
	Indeno(123c d) pyrene	8.5	9.5	90			
	Anthracene	85	95	900			
	Chrysene	85	95	900			
	Benzo(ghi) perylene	85	95	900			
	Naphthalene	0.45	0.45	3.0	SNIFFER and RISC database	Carcinogen	Human health

Table 3: Assessment Criteria for Soils. Continued on next page.

BTEX	Benzene	0.54	0.54	**	Derived with RISC	Carcinogen	Human health
	Ethyl benzene	9.0	16	48,000	SGV (for 1% SOM)	Carcinogen	Human health
	Toluene	3.0	3.0	150	SGV (for 1% SOM)	Carcinogen	Human health
	Xylenes	9.4	9.4	***	Derived with RISC	Carcinogen	Human health
Petroleum hydrocarbons	Total GRO	30	30	310	Canada Standards for Petroleum Hydrocarbons, C6-C10, for coarse grained soils	Carcinogen	Human health
	DRO (C8 to C10)	30	30	310	Canada Standards for Petroleum Hydrocarbons, C6-C10, for coarse grained soils	Carcinogen	Human health
	DRO (C10 to C16)	150	150	760	Canada Standards for Petroleum Hydrocarbons, C10-C16, for coarse grained soils	Carcinogen	Human health
	DRO (C16 to C35)	400	400	1700	Canada Standards for Petroleum Hydrocarbons, C16-C34, for coarse grained soils	Carcinogen	Human health
PCBs	Total of 7 Congener PCBs	1	1	1	EA - Guidance On National Interim Waste Acceptance Procedures (Inert Waste)	Carcinogen	Human health
Other organics	Phenol (Index)	78	21,900	21,900	SGV (value dependant on soil organic mater, lowest values used here)	Toxic and irritant	Human health

Table 3: Assessment Criteria for Soils. Continued from previous page.

Key

SGV	Soil Guideline Value
ICRCL	Interdepartmental Committee for the Redevelopment of Contaminated Land - Limits for phytotoxic compounds
CLEA	Contaminated Land Exposure Assessment model
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Poly Chloride Biphenyls
BTEX	Benzene-Toluene-Ethyl benzene-Xylene
GRO	Gasoline Range Organics
DRO	Diesel Range Organics
**	Assessment Criteria for commercial land use not derived for benzene as no results exceed the residential without plant uptake value
***	Assessment Criteria for commercial land use not derived for xylene as only 1 result exceed the residential without plant uptake value, see also Section 8

6.2 Human Health

General

Site-specific assessment criteria have been derived using the CLEA (Contaminated Land Exposure Assessment), SNIFFER (12) or RISC (13) methodologies for some determinands for which there are no published Soil Guideline Values (see Box 3). In other cases, appropriate criteria have been drawn from other authoritative sources. The criteria employed are in all cases appropriate to the intended end use.

Environment Agency guidance CLR7 (14) suggests the use of 95% Upper Confidence Limits (UCLs) and the Maximum Value Test to detect outliers when applying the published Soil Guideline Values. However, this is only applicable when the sampling locations are sufficient in number and evenly spaced (e.g. on a regular grid) and the samples have all come from strata with similar characteristics or origins. This is not the case for the data assessed in this report and thus whilst 95% UCLs are included in the Tables in Appendix I, they are not used in the assessment (see also Section 7.1).

Metals

The published Soil Guideline Values (SGVs – see Box 3) for different land uses (residential with or without plant uptake, commercial/industrial) and the ICRCL threshold limits for those elements regarded as toxic to plants (phytotoxic) have been used.

Although the ICRCL Threshold Trigger Concentrations (TTCs) in respect of the phytotoxic elements copper, nickel and zinc were withdrawn by DEFRA with the other TTCs in December 2002, they remain a sound basis for initial assessments. Buro Happold is not aware of any other guideline values concerned with phytotoxicity available in jurisdictions other than the UK. Where there are specific concerns about phytotoxicity it is customary to determine "plant available" concentrations or to use the range of British/International Standards intended for direct determination of toxicity (e.g. root elongation and germination tests.).

For total tin, the Dutch Indicative Level for serious contamination (15) of 900mg/kg was used as assessment criteria. 8 soil samples were tested for the organic tin compounds of dibutyl tin, tributyl tin (TBT) and tri-phenyl tin. The results were all below the detection limits. TBT is a List 2 dangerous substance in the EC Dangerous Substances Directive (76/464/EEC), the Environmental Quality Standard (EQS) for TBT in estuarine waters is 0.002 ug/l. This level is below the detection limits available hence no testing for TBT in leachates and waters has been carried out.

Arsenic Bioavailability Tests

The high natural levels of arsenic have been of concern especially for the possible re-use of material on residential areas with gardens.

Bioaccessibility tests were carried out on 9 soil samples in order to estimate the "bioaccessible" amount of arsenic (i.e. the fraction of the chemical that can be adsorbed by the body through the gastrointestinal system) and therefore allow for a more detailed risk assessment.

Results of bioaccessibility tests can be found on Appendix M and are expressed both as concentrations and percentage of total arsenic.

The testing method was the Physiologically Based Extraction Test (PBET), designed to recreate the conditions found in the gastrointestinal tract of a 2-3 year old child. It is this group that is considered to be most at risk from accidental soil ingestion. The laboratory's PBET is based upon that proposed by Rodriguez et al (16).

The percentage of biologically available arsenic varies from 1 to 30 making the results of limited use in this assessment.

PAHs

In the absence of published SGVs it has been necessary to derive site-specific criteria using the CLEA model as made available by DEFRA (see Box 4). Using the same general assumptions as used to derive the published SGVs a site-specific assessment criterion (SSAC) has been derived for benzo(a)pyrene for residential and commercial/industrial developments. The criterion is 0.85 mg/kg for residential with plant uptake, 0.95mg/kg for residential without plant uptake and 9.0mg/kg for commercial/industrial. The output from the CLEA model including the assumptions made is provided in Appendix F. Criteria for a number of other PAHs also regarded as proven or probable human carcinogens have also been derived by using available published data of Relative Cancer Potencies compared to that of benzo(a)pyrene (see Box 4). Assessment criteria were not derived for PAHs with extremely low cancer potencies (a thousand times less than benzo(a)pyrene).

Criteria for naphthalene were derived for residential and commercial scenarios using the SNIFFER methodology (12). The indoor air exposure route dominates in the derivation of criteria for volatile contaminants and it is thus important to exclude this exposure route when there are no buildings to be occupied. The output spreadsheets are included as Appendix G. The toxicological information has been obtained from the EA/DEFRA report (17) and the physical properties from the Environment Agency compilation (18).

Box 3: Soil Guideline Values

The Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency have published Soil Guideline Values (SGVs) and the associated toxicological information for the following potential contaminants:

Arsenic	**Mercury (inorganic)**	**Ethyl benzene**
Cadmium	**Nickel**	**Toluene**
Chromium (VI)	**Selenium.**	
Lead		

Toxicological information for benzene; benzo(a)pyrene; inorganic cyanide; naphthalene; 1,1,2,2-tetrachlroethane; 1,1,1,2-tetrachloroethane; 1,1,1-trichloroethane; trichloroethene, vinyl chloride; xylenes and "dioxins, furans and dioxin-like PCBs" has also been published. In addition, the Environment Agency has issued a consultation paper on the assessment of human health risks from petroleum hydrocarbons.

SGVs are a screening tool for use in the assessment of land affected by contamination. They can be used to assess the risks posed to human health from exposure to soil contamination in relation to land use. They represent "intervention values": indicators to an assessor that concentrations above this level might present an unacceptable risk to the health of site-users and that further investigation and/or remediation is required.

SGVs have been provided for four scenarios (land uses): allotments, residential with plant uptake, residential without plant uptake and commercial/industrial.

The SGVs replace the corresponding "tentative threshold trigger concentrations" promulgated by the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL) in ICRCL 59/83 (second edition) published in 1987.

Guidance on the application of SGVs is provided in DEFRA CLR7 (14).

Benzene - Toluene - Ethyl benzene - Xylene (BTEX)

The respective published Soil Guideline Values (SGVs – see Box 3) for 1% of Soil Organic Matter have been used for the different land uses (residential with and without plant uptake, commercial/industrial).

No SGVs are currently available for benzene and xylenes. Site specific assessment criteria for a residential with plant uptake scenario were derived using the RISC model (13), which is more suitable than SNIFFER when inhalation is the dominating pathway, as for BTEX compounds. Input and output sheets from the RISC model are included in Appendix H.

Petroleum hydrocarbons

When considering contamination with hydrocarbons such as fuel oils and petroleum it is important to take note of site observations (e.g. regarding odours, the appearance of samples and on-site measurement of vapour concentrations) as well as analytical results. It should also be noted that it is difficult to obtain entirely reliable results for volatile organic compounds such as benzene using disturbed samples, particularly when these are taken from trial pits as there is ample opportunity for loss of vapours to occur.

Assessments are commonly made using broad parameters such as EPH/DRO (extractable petroleum hydrocarbons/diesel range organics), mineral oils and PRO/GRO (petroleum/gasoline range organics) and/or individual compounds such as the BTEX and MTBE (methyl-tertiary-butyl-ether) compounds. The use of the broad parameters is made difficult because different analytical methods give different results, the carbon ranges reported sometime differ and the terminology is not necessarily used in a consistent way. For example, "mineral oil" is sometimes taken as the aliphatic components of EPH but may be determined directly, for example by thin-layer chromatography. A combination of methods has been used in the investigations of the Hayle Harbour site. Individual petroleum hydrocarbons have not generally been determined.

The criteria used in the assessment are listed in Table 3. Assessment criteria have been chosen for total determinands (total EPH/DRO, mineral oil and total GRO) and single hydrocarbon bands, by reference to generic guidelines used in Canada (19) (see Box 5).

Volatile Organic Compounds (VOCs) are highly toxic and some are proven carcinogens. No test results pose a problem, assuming they were well sampled/stored and volatiles have not been lost in transit or storage.

Box 4: Derivation of Criteria for PAHs

PAHs are variously toxic and/or carcinogenic. For example, benzo(a)pyrene is a proven human carcinogen. It has been customary in the past to compare the "total concentration of PAHs", calculated as the sum of 16 individual compounds (the 16 USEPA[A] PAHs), with the ICRCL threshold trigger concentrations (TTCs) for residential developments and allotments (50 mg/kg) or for commercial/industrial developments as appropriate. In January 2002, DEFRA proclaimed that the ICRCL value had been withdrawn and that only SGVs derived using the CLEA model should be used in future. However, SGVs for neither total PAHs nor individual compounds have been published. Although toxicological information for benzo(a)pyrene has been published (20) no SGV has been published.

In the absence of published SGVs a site-specific assessment criterion (SSAC) has been derived using the CLEA model as made available by DEFRA. The model contains data for benzo(a)pyrene. Using the same general assumptions as used to derive the published SGVs, criteria of 0.85mg/kg, 0.95mg/kg and 9mg/kg have been derived for a residential with plant uptake, residential without plant uptake and commercial/industrial developments respectively. The outputs from the model including the assumptions made, which were similar to those used to derive the published SGVs, are provided in Appendix F.

A number of other PAHs are also regarded as proven or probable human carcinogens. However, no input data are available for other PAHs in the CLEA model at present. However, the USEPA has suggested (21) that these compounds have relative cancer potencies as shown in table below. It is possible to derive criteria for the other PAHs from the SGV for benzo(a)pyrene.

Compound	Potency relative to benzo(a)pyrene	Derived Criteria* (mg/kg)
Benzo (a) anthracene	0.1	8.5 / 9.5 / 90
Benzo (b) fluoranthene	0.1	8.5 / 9.5 / 90
Benzo (a) pyrene	1.0	0.85 / 0.95 / 9.0
Indeno (1,2,3-cd) pyrene	0.1	8.5 / 9.5 / 90
Dibenzo (a,h) anthracene	1.0	0.85 / 0.95 / 9.0

* Limits refer to: Residential with plant uptake / Residential without plant uptake / Industrial-Commercial

The criteria have been derived using similar assumptions (see Appendix F) to those employed in deriving the published SGVs, i.e. for commercial/industrial use for a female adult worker and assuming a sandy soil with a 5% organic matter content. The "availability" of PAHs can vary depending on such factors as soil type (e.g. sandy, loam, clay) and organic matter content but is not sensitive to the pH. The criteria increase with organic matter content and clay content. It should be noted that the 5% organic matter content is a conservative assumption, being less than the mean of the available laboratory data. In addition, it should be noted that in practice the percentage of organic matter in the soil may reduce with time due to biodegradation of humic materials thus increasing the availability of PAHs.

Phenols

The published Soil Guideline Values (SGVs – see Box 3) for different land uses (residential with or without plant uptake, commercial/industrial) have been used. The SGV for phenol varies with the percentage of soil organic matter. For this assessment the most conservative values, relating to 1% soil organic matter have been used.

The ICRCL TTC was 5 mg/kg for all land use scenarios. This was based on possible tainting of potable water supplies were phenols to penetrate plastic pipes or contaminated soil come into contact with water, for example as a result of back-siphoning into a leaking pipe. This concern should be taken into account of water supply pipes are to be laid in soil contaminated with phenols.

Box 5: Comparison with Generic Guideline Values from Canada (19)

Canada has developed Tier-1 assessment criteria for petroleum hydrocarbons for a variety of land uses and different carbon bands. Separate criteria are provided for near-surface soils (0-1.5 m) and sub-surface soils (>1.5 mbgl). A further distinction is made between "fine-grained" and "coarse-grained" soils. Separate values are provided for different exposure pathways for humans and for protection of groundwater.

Levels of petroleum hydrocarbons for different carbon fractions were compared with the Canadian limits below (for coarse-grained soil):

Fraction 1: nC6 to nC10	30mg/kg Residential 310mg/kg Commercial
Fraction 2: >nC10 to nC16	150mg/kg Residential 760mg/kg Commercial
Fraction 3: >nC16 to nC34	400mg/kg Residential 1700mg/kg Commercial

Total values of Diesel Range Organics (DRO) and mineral oil were compared with the limit for Fraction 3, while total Gasoline Range Organics (GRO) were compared with the limit for Fraction 1.

Asbestos

Asbestos screening was carried out on all soil samples to identify the presence of fibres above the 0.001% limit.

For the five samples found above this limit, the form of asbestos was also identified (see Appendix M). More information about the location of these five samples can be found on section 7.1.

6.3 Groundwater and Leachates

There are no generic guidance values in the UK specifically applicable to contamination of groundwater. A number of guidelines developed for other purposes have been used and adjustments made where necessary to bring those values into the context of a contaminated land risk assessment. The following criteria have been used:

- Environmental Quality Standards (EQS) for "dangerous substances" in estuarine waters (22), see Box 6). All the limits refer to an annual average.
- The Water Supply (Water Quality) Regulations 2000[28] (23) values governing the quality of drinking water in the UK. Only those values that are relevant to this assessment have been used. These values are referred to as Drinking Water Limits (DWLs).
- Dutch Intervention Values (15), or New Zealand Drinking Water Standards (24), when no other UK sources were available.

In addition, a value of 1000 mg/kg EPH/DRO (C10-C40) has been used as a screening value for potential leaching of hydrocarbons into groundwater.

Box 6: Environmental Quality Standards

EQSs have been derived under the requirements of the Dangerous Substances European Directive which classifies substances as List I and List II. Standards for List I substances have been defined in "daughter" Directives to the EC Dangerous Substances Directive. The scientific justification for the standards is not available. The Dangerous Substances Directive required that standards for List II substances are derived by the member states. For each of the List II substances, reports are available which describe the data used to derive the standards and any uncertainties in the derivation. Where there are uncertainties arising from a lack of information on effects on saltwater organisms, larger safety factors have been used in the derivation of the EQS.

Compound		Assessment Criteria (micrograms/l)	Source
Metals	Antimony	5.0	DWLs
	Arsenic	10 25 (Dissolved)	DWLs EQS
	Cadmium	5 2.5 (Dissolved)	DWLs EQS
	Chromium	50 15 (Dissolved)	DWLs EQS
	Copper	2,000 5 (Dissolved)	DWLs EQS
	Lead	25 25 (Dissolved)	DWLs EQS
	Mercury	1 0.3 (Dissolved)	DWLs EQS
	Nickel	20 30 (Dissolved)	DWLs EQS
	Selenium	10	DWLs
	Tin (Inorganic)	10	EQS
	Tributyl Tin (TBT)	0.002 (maximum conc.)	EQS
	Zinc	40 (Total)	EQS
Inorganics / parameters	Total Cyanide	50	DWLs
	Ammoniacal Nitrogen	500 (as ammonium)	DWLs
	pH	6 – 8.5	EQS

Table 4: Assessment Criteria for groundwater and leachate. Continued on next page.

Compound		Assessment Criteria (micrograms/l)	Source
PAHs	Benzo (a) pyene	0.01 0.7	DWLs WHO
	Naphthalene	5 (annual average)	EQS
	Fluoranthene	4	NZL
	PAHs (sum of 4): Benzo(b)fluoranthene, Benzo(ghi)perylene Benzo(a)pyrene indeno(1,2,3-cd) pyrene.	0.1	DWLs
BTEX	Benzene	1 30 (annual average)	DWLs EQS
	Ethyl benzene	150	Dutch Intervention Value
	Toluene	40 (annual average)	EQS
	Xylenes	30 (annual average)	EQS
Petroleum Hydrocarbons	Total PRO (C4-C10)	1600	New Zealand Drinking Water Standard
	Total DRO (C10-C40)	350	New Zealand Drinking Water Standard
	Total Petroleum Hydrocarbons	1,950	Sum of total DRO/PRO
Other Organics	Methyl Tertiary-Butyl Ether (MTBE)	15	EA, *The fuel additive MTBE – A groundwater protection issue (value based on taste rather than toxicity)*

Key

DWLs	UK Drinking Water Limits
EQS	Environmental Quality Standards from the Environment Agency (Estuarine waters)
NZL	New Zealand drinking water standards

Table 4: Assessment Criteria for groundwater and leachate. Continued from previous page.

6.4 Gas

For the purpose of master planning the principal guidance used to determine if carbon dioxide and methane concentrations are at levels that might require protective measures is: Building Regulations -Approved Document C (1992 Edition) (25) which suggests that consideration of the need for specific protective measures should be made if the methane concentration exceeds 0.5% or the carbon dioxide concentration exceeds 1.5%. The revised Approved Document published in 2004 advocates a risk-based approach to evaluation of the presence of methane and carbon dioxide etc. The revised document also highlights the need to consider gas concentrations across the entire level designated for redevelopment, not just buildings, e.g. ensuring ground gas does not migrate beneath buildings from the surrounding area.

Depleted oxygen concentrations are also of concern. These are commonly, but not always associated with elevated concentrations of carbon dioxide and/or methane. A screening concentration of 18% oxygen has been used (the concentration in normal air is about 21%).

6.5 Building Materials

The assessment criteria used to assess the potential for sulphate attack on concrete are:

- 500 mg/l water-soluble sulphate as SO_4 in a 1:2 extract.
- 400 mg/l sulphate as SO_4 in groundwater

The both of these are taken from BRE SD1- Concrete in Aggressive Ground 2005 (26).

For the deeper ground, the assessment is best made using the analytical data for groundwater.

As the pH values were all greater than 5.5 chloride is not considered to be aggressive to concrete. Concrete exposed to seawater (with approximately 18 000 mg/l chloride) should be designed according to BS 6349-1 for maritime structures and to BS 8500-1.

A value of 5000mg/l has been used for sulphide as a typical limiting value for aggregates used in concrete.

There are no specific guideline values for hydrocarbon contaminated soils, for example in respect of potential attack on plastics materials but the significance of these is considered in qualitative terms in Section 7.

6.6 Cockle Bank

Where the end use is of a standard type, i.e. residential with or without plant uptake or commercial then the assessment criteria discussed above may be used. However, there is a proposal to use the material from Cockle Bank as a soil conditioner on farm land. In this scenario the following assessment criteria from ICRCL Guidance Note 70/90 (27) have been used. This reference gives guidance on farming on soil contaminated with the same contaminants as those found in Cockle Bank, the "Maximum (Action Trigger) Concentrations" are set out below in Table 5.

Element	**Maximum (Action Trigger) Concentrations for Total Element Concentration mg/kg**		**Guide values for extractable (EDTA) metals mg/dm3**
	For grazing livestock	For crop growth	
Arsenic	500	1000	None
Copper	500	250	70
Lead	1000	-	None
Zinc	3000	1000	130

Table 5: ICRCL Guidance Note 70/90 Maximum (Action Trigger) Concentrations

6.7 Preliminary Waste Acceptance Criteria

Each of the zones (see Section 7) have been assessed in terms of the Landfill Waste Acceptance Criteria for granular wastes (see Appendix P). The assessment criteria used are as published in Table 2.1 of the Guidance on Sampling and Testing of Wastes to Meet Landfill Waste Acceptance Procedures Version 1, April 2005, published by the Environment Agency (29).

7 Results

Full analytical results are provided in the report provided by TES Bretby (10). The results are summarised in the tables provided in Appendices I to L subdivided in to zones and depth ranges as detailed below.

For assessment the site has been divided into 9 geographical zones based on the distribution of the proposed end use. These zones are summarised in Table 6 below and are illustrated in Figure 6:

Zone	Geographical Area
1. Industrial/Business	Old power station and adjacent dunes
2. Hill Top Residential	Sand dunes to NE of North Quay
3. Marina Residential	Majority of North Quay excluding W and E extremities
4. Marina Business	Western part of North Quay
5. Cockle Bank	Central part of harbour waters
6. Hotel, leisure/galleries, business	East Quay and land around Harbour Masters Office
7. Landscaped Car Park	Triangular Spit
8. Retail and residential	South Quay and Carnsew Quay
9. Health Centre/College	Area south of Carnsew Road
10. Beach Deposits	Hayle beach

Table 6: Geographic Assessment Zones

The area designated as Zone 11 was added to the masterplan area following the completion of the ground investigation and this report. As a result a desk based study of the existing information for the site was undertaken and recommendations for additional ground investigation to be undertaken in support of the detailed planning application within this area of the site were provided. This desk based study is presented in Appendix Q.

The depth ranges have been selected to enable assessment as detailed in Table 7 below.

.

Depth Range (metres below ground level)	Assessment implications
0.0-0.5	Indicative of: exposed surface with which casual visitors might have contact, source of dust, source of material that might be trafficked around site during works. Zone in which plants might root
0.5-1.5	Indicative of zones likely to be disturbed during installation of services or shallow foundation and other minor works.
>1.5	Zones in which there will be exposure only in the event of deeper excavation.

Table 7: Depth range divisions for assessment purposes

7.1 Soils

The results of soils analysis are tabulated in Appendix I and results above the relevant assessment criteria are detailed in Table 8 below.

Figures 7 to 13 show the geographical distribution of the highest soil analysis for arsenic, copper, lead, zinc, naphthalene, benzo(a)pyrene and EPH. It is these determinants which have been identified as the contaminants of concern.

For most areas commercial limits have been used as the assessment criteria. Exceptions to this are for the hilltop residential area and the beach sand area where the residential with gardens assessment criteria have been used and for the residential areas without gardens where the residential without plant uptake assessment criteria have been used.. The results for Cockle Bank are discussed separately in section 7.4 below.

Chemical symbols have been used in the following tables as follows:

As – Arsenic
Cd - Cadmium
Cr – Chromium
Cu – Copper
Ni - Nickel
Pb – Lead
Sn – Tin
Zn - Zinc

Development Zone	Depth Range (m)	Observations: Number of samples above Assessment Criteria (AC)/Number of samples tested				
		Metals > AC	PAHs > AC	Petroleum Hydrocarbons	Other Contaminants	Comments
Zone 1 Industrial/Business Commercial/Industrial AC	0-0.5	Cu 28/28 Pb 2/34 Zn 2/34	1/34 Benzo(a)pyrene	none > AC	None > AC	Cu and Zn results represent risk to plants. Pb and PAHs represent risk to human health.
	0.5-1.5	Pb 1/10 Cu 10/10 Zn 2/10	1/10 Naphthalene 1/10 Benzo(a)pyrene	none > AC	None > AC	
	>1.5	Cu 2/10	none > AC	none > AC	None > AC	
Zone 2 Hill Top Residential Residential With Plant Uptake AC	0-0.5	As 22/30 Cr 1/30 Cu 4/30 Pb 3/30 Ni 16/30 Zn 3/30	4/30 Benzo(a)pyrene	none > AC	None > AC	Cu, Ni and Zn results represent risk to plants. As, Cr, Pb and PAHs represent risk to human health
	0.5-1.5	As 4/6 Ni 4/6 Zn 1/6	1/6 Naphthalene 1/6 Benzo(a)pyrene	none > AC	None > AC	
	>1.5	As 2/3 Ni 1/3	none > AC	none > AC	None > AC	
Zone 3 Marina Residential Residential With Plant Uptake AC	0-0.5	As 11/11 Cd 1/11 Cu 8/11 Pb 4/11 Zn 6/11	1/11 Naphthalene 7/11 Benzo(a)pyrene	1/11 Aliphatics >C12 - C16	None > AC	Cu, and Zn results represent risk to plants. As, Cd, Pb, PAHs and hydrocarbons represent risk to human health
	0.5-1.5	As 9/9 Pb 4/9 Sn 1/9 Cu 8/9 Zn 7/9	2/9 Naphthalene 3/9 Benzo(a)pyrene 2/9 Dibenzo(ah)anthracene	Elevated GRO and TPH results for 2/9	None > AC	
	>1.5	Cu 1/1 Zn 1/1	none > AC	Elevated GRO and TPH results for 1/1	None > AC	

Table 8: Summary of soil results above the relevant assessment criteria (AC) continued on next page …

Development Zone	Depth Range (m)	Observations: Number of samples above Assessment Criteria (AC)/Number of samples tested				
		Metals > AC	PAHs > AC	Petroleum Hydrocarbons	Other Contaminants	Comments
Zone 4 Marina Business Commercial/Industrial AC	0-0.5	8/17 Cu 6/17 Zn	4/17 Naphthalene 1/17 Benzo(a)pyrene	1/17 Aliphatics 12-16	None > AC	Cu, and Zn results represent risk to plants. As, PAHs and hydrocarbons represent risk to human health
	0.5-1.5	1/10 As 6/10 Cu 4/10 Zn	2/10 Naphthalene	none > AC	None > AC	
	>1.5	2/3 As 3/3 Cu 2/3 Zn	none > AC	none > AC	None > AC	
Zone 5 Cockle Bank AC varies with end use		Elevated As, Cu, and Zn. Isolated elevated Pb	none > AC	none > AC	None > AC	Discussed separately below in sections 7.4 and 8.7
Zone 6 Hotel, leisure/galleries, business Commercial/Industrial AC	0-0.5	2/8 As 8/8 Cu 1/8 Pb 8/8 Zn	1/8 Benzo(a)pyrene	none > AC	None > AC	Cu, and Zn results represent risk to plants. As and PAHs represent risk to human health
	0.5-1.5	2/7 As 4/7 Cu 4/7 Zn	none > AC	none > AC	None > AC	
	>1.5	1/6 As Pb 1/6 6/6 Cu 4/6 Zn	none > AC	Elevated xylene 1/6	None > AC	
Zone 7 Landscaped Car Park Commercial/industrial AC	0-0.5	4/8 As 5/8 Cu 2/8 Pb 4/8 Zn	none > AC	none > AC	Asbestos (chrysotile) in 3 samples	Cu, and Zn results represent risk to plants. As and Pb represent risk to human health
	0.5-1.5	1/3 As 2/3 Cu 2/3 Zn	none > AC	none > AC	None > AC	
	>1.5	2/3 Cu 2/3 Zn	none > AC	none > AC	None > AC	

Table 8: Summary of soil results above the relevant assessment criteria (AC). Continued from previous page and onto next page.

Development Zone	Depth Range (m)	Observations: Number of samples above Assessment Criteria (AC)/Number of samples tested				
		Metals > AC	PAHs > AC	Petroleum Hydrocarbons	Other Contaminants	Comments
Zone 8 Retail and residential Commercial/industrial AC	0-0.5	2/24 As 17/24 Cu 6/24 Pb 19/24 Zn	3/24 Benzo(a)pyrene	none > AC	Asbestos (chrysotile) in 1 sample	Cu, and Zn results represent risk to plants. As, Pb, PAHs and asbestos represent risk to human health
	0.5-1.5	1/15 As 10/15 Cu 10/15 Zn	1/15 Naphthalene 2/15 Benzo(a)pyrene	none > AC	Asbestos (chrysotile and crocidolite) in 1 sample	
	>1.5	1/18 As 5/18 Cu 1/18 Pb 7/18 Zn	1/18 Naphthalene 1/18 Benz(a)anthracene 1/16 Benzo(a)pyrene 1/18 Dibenzo(ah)anthracene	none > AC	None > AC	High PAH results all from the same sample, TP311 at 4.0m.
Zone 9 Health Centre Commercial/industrial AC	0-0.5	3/3 Cu 2/3 Pb 3/3 Zn	none > AC	none > AC	None > AC	Cu, and Zn results represent risk to plants. As and Pb represent risk to human health
	0.5-1.5	1/3 As 1/3 Cu 2/3 Zn	none > AC	none > AC	None > AC	
	>1.5	3 tested none > AC	none > AC	none > AC	None > AC	
Zone 10 Beach Deposits Residential without plant uptake AC		4/5 As	none > AC	none > AC	None > AC	As represents risk to human health

Table 8: Summary of soil results above the relevant assessment criteria (AC). Continued from previous page.

It is noted that for the hill top residential area and the beach sand results the metal results are considerably lower than for the areas around the quays and Cockle Bank. This is probably a combination of the fact that the harbour areas are more industrial and that the natural deposits in this area have been sourced from and are closely connected to local mineralised soil and rocks. The beach and dune deposits are sourced from a wider area that includes all of St Ives Bay as a minimum and probably includes a much wider section of the coast, these deposits also have a significantly lower amount of fines (clay and silt sized particle), suggesting that the contaminants may be concentrated in the finer fraction.

The results indicate only isolated samples are contaminated with chrysotile (white) and crocidolite (blue) asbestos . Previous reports available from the Hayle Archive and included in Appendix C suggest that the occurrence of asbestos is more wide spread, especially across South Quay, “Hayle Weir” (taken to be the triangular SSSI area, and Lelant Quay. The spacing of exploratory holes in the 2005 investigation could potentially have missed some large areas of asbestos contamination, alternatively the asbestos may be concentrated in the near surface deposits.

7.2 Leachate Results

The results of leachate analysis are tabulated in Appendix J and results above the relevant assessment criteria are detailed in Table 9 below.

Development Zone	Observations			
	Metals > AC * none > AC	Petroleum Hydrocarbons	Other Contaminants	Comments
Zone 1 Industrial/Business	2/4 As > EQS 2/4 Cu > EQS	None > AC	None > AC	High conductivity due to brackish conditions
Zone 2 Hill Top Residential	1/5 As > EQS 3/5 Cu > EQS 1/Zn > EQS	None > AC	1/5 pH < EQS	High conductivity due to brackish conditions
Zone 3 Marina Residential	1/7 Cu > EQS 2/7 Zn > EQS	None > AC	None > AC	High conductivity due to brackish conditions
Zone 4 Marina Business	3/7 As > EQS 2/7 Cd > EQS 5/7 Cu > EQS 1/7 Ni > EQS 1/7 Sn > EQS 2/7 Zn > EQS	None > AC	1/7 pH < EQS	High conductivity due to brackish conditions
Zone 5 Cockle Bank	2/4 As > EQS 3/4 Cu > EQS 1/4 Zn > EQS	None > AC	None > AC	High conductivity due to brackish conditions
Zone 6 Hotel, leisure/galleries, business	None tested	None tested	None tested	
Zone 7 Landscaped Car Park	5/6 As > EQS 3/6 Cu > EQS 1/6 Sn > EQS 1/6 Zn > EQS	None > AC	None > AC	High conductivity due to brackish conditions
Zone 8 Retail and residential	4/6 As > EQS 3/6 Cu > EQS 1/6 Sn > EQS 4/6 Zn > EQS	None > AC	None > AC	High conductivity due to brackish conditions
Zone 9 Health Centre	None tested	None tested	None tested	
Zone 10 Beach Deposits	None tested	None tested	None tested	

Table 9: Summary of leachate results above the relevant assessment criteria (AC).

7.3 Groundwater Results

The results of water analysis are tabulated in Appendix K and results above the relevant assessment criteria are detailed in Table 10 below.

Development Zone	Observations				
	Metals > AC * none > AC	PAHs > AC	Petroleum Hydrocarbons	Other Contaminants	Comments
Zone 1 Industrial/Business	None tested	None tested	none > AC	none > AC	High conductivity due to brackish conditions
Zone 2 Hill Top Residential	5 Samples tested *	2/2 Flouranthene > AC 2/2 Benzo(a)pyrene > AC 2/2 Sum 4 PAH > DWL	none > AC	none > AC	High conductivity due to brackish conditions
Zone 3 Marina Residential	1/1 As > EQS 1/1 Cu > EQS 1/1 Zn > EQS	None tested	none > AC	none > AC	High conductivity due to brackish conditions
Zone 4 Marina Business	4/6 As > EQS 5/6 Cu > EQS	3/3 Flouranthene > AC 3/3 Benzo(a)pyrene > AC 3/3 Sum 4 PAH > DWL	none > AC	none > AC	High conductivity due to brackish conditions
Zone 5 Cockle Bank	None tested	None tested	None tested	None tested	
Zone 6 Hotel, leisure/galleries, business	3/3 As > EQS 3/3 Cu > EQS 2/3 Zn > EQS	1/1 Benzo(a)pyrene > AC Sum 4 PAH > DWL	none > AC	none > AC	High conductivity due to brackish conditions
Zone 7 Landscaped Car Park	5/9 As > EQS 9/9 Cu > EQS 3/3 Zn > EQS	3/3 Flouranthene > AC 3/3 Benzo(a)pyrene > AC 3/3 Sum 4 PAH > DWL	none > AC	none > AC	High conductivity due to brackish conditions
Zone 8 Retail and residential	1/14 As > EQS 8/14 Cu > EQS 1/14 Ni > EQS 5/14 Zn > EQS	5/5 Benzo(a)pyrene > AC 5/5 Sum 4 PAH > DWL	none > AC	none > AC	High conductivity due to brackish conditions
Zone 9 Health Centre	1/3 As > EQS 1/3 Cu > EQS	None tested	none > AC	none > AC	High conductivity due to brackish conditions
Zone 10 Beach Deposits	None tested	None tested	None tested	None tested	

Table 10: Summary of water results above the relevant assessment criteria (AC).

7.4 Cockle Bank

As the end use for the Cockle Bank has not been defined in the Master Plan comparison against any particular assessment criteria is not possible. The results are discussed separately in conjunction with the assessment and recommendations section 8.5.

7.5 Ground Gas

The ground gas monitoring results are included in Appendix L.

No methane was recorded on the monitoring visits. Elevated levels of carbon dioxide (>0.5%) were recorded in boreholes 102, 103 107, 108, 504, 506, 507. The highest carbon dioxide level was recorded at 1.9 % volume on 11 October 2005 in BH108 (Zone 3), which is potentially related to the hydrocarbon contamination in this area. Reduced oxygen levels were also recorded in BH107 and BH108.

Radon gas concentrations cannot be monitored during the ground investigation, therefore the site has been assessed in terms of data on the number of homes affected in the vicinity (availably in the Envirocheck Report in Appendix B and in the Radon Atlas of England and Wales (30)).

8 Assessment and Recommendations

8.1 General

This contamination risk assessment has been undertaken in support of the ING Masterplan for Hayle Harbour. The findings of this report are also based on the current version of the Masterplan, which at the time of writing is dated 13/08/07 (see Figure 5).

In general the ground investigation has adopted a 50 metre sampling grid with targeted exploratory work being undertaken where previous or current land use suggested areas of specific ground contamination issues may exist. To aid the risk assessment process the site has been zoned by intended land use.

This report addresses the contamination issues pertinent to the Masterplan. An accompanying report describes the geotechnical issues (Volume 2) and should be read in conjunction with the document. Separate combined interpretative geotechnical and contamination reports will be provided for Lelant Quay and the area referred to as 'The Sidings'.

Factual data is held in separate reports provided by CJ Associates (9) and TES Bretby (10).

The key findings of the contamination assessment are as follows:

8.2 Site Wide Issues

Given the extent of historic land use and the potential for contamination the site is considered to be generally suitable for the development as planned. Bearing in mind the sample grid spacing the investigation did not encounter areas of widespread or significant contamination (except in parts of North Quay and South Quay discussed in Section 8.3 below) and this is broadly supported by the chemical laboratory results for soil, leachate and groundwater. This general conclusion is also subject to the following recommendations as well as the proposals for further investigations when the design is further developed.

8.2.1 Soils

Contaminants of concern include arsenic, copper and zinc which are widespread across the development area and in some zones (3, 4, 6 and 7) are at noticeably high concentrations. Their occurrence appears to be most attributable to mineralization associated with the local geology and mine workings upstream, but some contribution from industrial activities on site is also likely, particularly around the Quays. Lower concentrations were noted in the Hilltop residential zone and from samples collected from Hayle Beach and where appropriate the reduced concentrations have been taken into account in the risk assessment and remediation advice given below.

Arsenic is both toxic and carcinogenic. Attempts have been made in this investigation to assess the bio-availability (via bio accessibility tests to represent potential human uptake via ingestion) but this has demonstrated a wide scatter in the % of 'available' arsenic from total arsenic. Given the results their application to this project has been discounted.

Copper and zinc are primarily phytotoxic but at very high concentrations can also be toxic to humans. At Hayle such high copper and zinc concentrations are generally not encountered and it is the protection of plant life that is the primary concern.

Elevated lead concentrations have been recorded in several zones, in some cases exceeding screening values for less sensitive land uses such as the industrial/commercial developments.

Present evidence suggests that the elevated concentrations of heavy metals are associated with the finer soil fraction, i.e. silt or clay grade. Further work is required to substantiate this (see Section 8.6).

Chemical test results have noted a fairly widespread distribution of naphthalene and benzo (a) pyrene.

Naphthalene is a suspected carcinogen and as a semi-volatile is a primary risk in vapour form. Risks arising from naphthalene vapours beneath buildings are adequately covered by the proposed measures to address radon gas (see below). Naphthalene concentrations within open spaces are not significant and no special measures are necessary.

Measures to address benzo (a) pyrene in sensitive residential areas are also adequately addressed by the solutions adopted to deal with arsenic (section 8.5).

Elevated concentrations of Diesel Range Organics and Petrol Range Organics have been encountered in North and South Quay, ie in areas in designated for residential and retail land uses. Elevated concentrations in North Quay appear to be linked to a former Oil Storage area (Chieftain's Yard). It is assumed that the occurrences on South Quay are most likely to be attributable to the former scrap yards and ship building/breaking areas. Further discussion is given in Section 8.3.

Sporadic occurrences of asbestos (chrysotile and crocidolite) have been encountered in near surface deposits around South Quay and the landscaped car park and are consistent with other findings. Typically asbestos is in a woven fabric form. Limited remediation is required to protect current site users/visitors (see below 8.4). Otherwise subject to the future investigations outlined in Section 8.6, particularly vigilance during construction, there are no other remedial measures required for the existing site.

Sporadic occurrences of cadmium, nickel, antimony and beryllium have also been recorded but not at concentrations requiring specific action.

Mass loss on ignition tests (c.31% by volume, included in CJ Associates factual report (9)) indicate the potential risks from combustible soils within the predominantly ashy soils that have been used to infill a noticeable depression within the Hilltop Residential Zone. Further testing of Calorific Value is required to fully determine the extent and degree of risk, although given the age of infill and that the form of development should not significantly aerate the soil, the risks should remain low.

There are no major concerns associated with Tin (or organo tin), Antimony, Beryllium, Chloride, Volatile Organic Compounds (VOCs), Phenols or PCB.

8.2.2 Beach Sands

Chemical test results for soil samples collected from Hayle beach recorded a notably higher soil quality than any part of the Masterplan area. Only Arsenic was marginally elevated (mean 22 mg/kg, compared to the SGV of 20 mg/kg) above current guidance for the most sensitive forms of land use.

8.2.3 Groundwater and Leachates

Electrical conductivity readings for both leachate and groundwater reflect a water of poor drinking quality, most likely attributable to varying degrees of salinity.

As for soil arsenic, copper and zinc exceed the recommended guidance for leachate and groundwater in most tested samples. Occasional exceedances of selenium, antimony and nickel are also found in groundwater samples.

The groundwater tests did not record any elevated concentrations of either Diesel Range or Gasolene Range hydrocarbons which might indicate the presence of significant plumes of hydrocarbon contamination, although again the coarseness of the sampling grid needs to be remembered. The results for Polyaromatic Hydrocarbons (PAHs) consistently exceed the Drinking Water Standards, particularly for Zone 2 and Zone 4. The results are typical for brown field sites and indicate that the groundwater is not suitable for drinking water. This is not an immediate cause for concern as there are no abstraction points for potable water in the vicinity, and remediation is not required. However, further standpipes are recommended in order to validate the existing results over a more closely spaced grid and to determine if there is an elevated background level of PAH or if elevated results are related to a particular source.

In terms of leachate testing, sporadic elevated concentrations of cadmium, lead and nickel reflect similar occurrences within the soil tests. Of particular interest to the Hayle area there are no significant issues with respect to organo tin compounds.

In general the results do not indicate significant widespread man-made contamination, although the heavy metal concentrations and general salinity obviously preclude any potential for potable water supplies.

The EA Environmental Quality Standards (EQS) identify Cadmium as a List I substance. Arsenic is a List II substance. The presence of cadmium, albeit an isolated basis in a leachable form, requires further groundwater quality monitoring to support a general assumption of low risk (see Section 8.6).

8.2.4 Gas

Gas monitoring has not detected elevated concentrations of methane or carbon dioxide or reduced oxygen levels that require specific protection measures. The development is however within an area where 10-30% of homes are potentially above the action limit of 200Bq/m3 of radon gas within residential homes.

It is therefore necessary to design all residential properties with full radon protection measures as given in BRE Report BR 211 (31). This will entail passive venting measures (e.g. a granular layer or voided area beneath ground floor slabs) supported by a well-detailed and constructed damp proof membrane. Brick lined sumps should also be constructed beneath each individual private dwelling or at least every 250m2 for larger development footprints. Dwellings should be monitored post construction to more precisely reflect actual ventilation conditions within buildings. Where the action level is exceeded small electric fans placed in unobtrusive locations should activate the radon venting system. Further details are given in the BRE guidance document.

Radon guidance for non residential uses is generally less specific. As a precautionary measure all other, commercial and industrial land uses should install the passive measures described above and monitored in a similar fashion to the residential units. The requirement to activate the protection system in this case can be based on radon levels exceeding 400Bq/m3.

Radon protection measures should also be sufficient to address the sporadic elevated concentrations of naphthalene found across the site.

8.2.5 Buried Concrete Design

For general site wide use the results of soluble sulfate and pH tests and where relevant chloride and ammoniacal nitrogen tests have been used to derive a site wide ACEC of AC3. It should be noted that the use of BRE SD 1 (25) is not applicable to the design of concrete for marine structures or for assessing the potential for chloride attack on steel reinforcement (see also Section 6.5) which falls outside of the confines of this report.

8.2.6 Soil Disposal

As it is the general intention of the project to recycle or treat site won materials within the development it is not envisaged that there will be widespread offsite disposal soils to landfill. However, where necessary an assessment is required to determine whether the waste is inert, non-hazardous or hazardous. In this case a preliminary assessment using the procedures outlined in the EA ‘Guidance on sampling and testing of wastes to meet landfill waste acceptance procedures (Version 1 April 2005) has been carried out.

The preliminary assessment suggests that arisings disposed to landfill would be predominantly classified as inert or non-hazardous, although further testing is required to justify an ‘inert’ rating. Some areas (zones 3, 4, 6 and 7) recorded a number of results leading to Hazardous status. This is particularly attributable to arsenic trioxide concentrations, but is also occasionally linked to mineral oil or lead. In general it is not possible to differentiate any soils on site that are attributable to Hazardous Waste, except for the obvious hydrocarbon hot spots and a degree of dilution with the prevailing inert/non-hazardous material will inevitably occur. Nevertheless, further testing, particularly in these 4 zones, is required to validate the waste classifications.

Further discussion on material arising from the dredging of Cockle Bank is given in section 8.5.

8.2.7 Construction Issues

Site workers should be provided with adequate PPE, protective gloves and hygiene facilities.

Toolbox talks should focus on raising awareness of particular contaminants of concern, namely pervasive arsenic, copper, zinc, lead, PAHs, as well as the more concentrated hotspots of GROs and DROs or asbestos.

During dry spells adequate dampening down of dry exposed surfaces should be undertaken.

Dust monitoring should also be undertaken during dry spells to protect site workers and surrounding neighbours.

8.2.8 Japanese knotweed

Japanese knotweed is suspected on South Quay (and has been identified by the Environment Practice on Lelant Quay and the railway land). This should be managed in accordance with the Environment Agency Guidance 32) which gives advice on herbicides and acceptable disposal options both on and offsite. It should be noted that it normally takes at least three years to kill Japanese Knotweed with herbicides, and if taken offsite it will be classified as hazardous waste.

8.3 Hydrocarbon Hotspots in North & South Quay

Section 4.2 records visual and olfactory evidence of hydrocarbon contamination encountered during the recent ground investigation. Subsequent chemical testing indicates diesel/soil contamination in TP121 at shallow depths (c.0.5m below ground level) whilst at TP122 it is petrol range organics that exceed published criteria for a residential without plant uptake land use at a depth of 2.5m. Other minor diesel concentrations were recorded at TPs 104, 117 and WS108. At the Master Plan stage remediation is considered prudent in these areas (see Section 8.4).

Further investigation and risk assessment is required to refine current assumptions regarding volumes of soil required for disposal or treatment in known areas. Further investigation is also required to reduce the sample grid spacing to minimise the potential for further contaminated hotspots, particularly around North and South Quay. Section 8.6 provides further details.

8.4 Remediation

To protect current site users, near surface asbestos fragments/fabric should be removed from South Quay and the landscaped car park by a competent/licensed contractor. All material should be disposed to an appropriate licensed landfill.

Given the widespread concentrations of arsenic, copper, zinc and to a lesser degree lead it is necessary to opt for a simple cover system to protect end users from contact with contaminated soil. The thickness and make up of the cover system is dependent on land use and the mean contaminant soil concentrations found in these areas. The guidance offered by the BRE and AGS (32) has been used to establish the appropriate thickness.

The results enclosed within Appendix O suggest a general 600mm of cover should be applied to all proposed land uses because of the concentrations of arsenic, copper or zinc. The results of further testing recommended in Section 8.6 may permit reductions in the overall thickness of the cover system in selected areas at a later stage.

In the areas designated for commercial and industrial use the plan extent of a cover system is notably reduced by the prevailing cover of building aprons or external hardstanding. The area requiring the greatest extent of simple cover is the Hilltop Residential Zone where private gardens are planned.

The simple cover system can be catered for by importing clean sub and topsoil with a soil quality that is at least 50% lower than the SGVs for the contaminants of concern. As an alternative to importing material or perhaps as a partial solution, consideration can be given to ex-situ soil washing to remove the finer more contaminated fraction in the near surface material. The finer fraction will, however, potentially require offsite disposal or treatment before reuse on site. Further discussion on this aspect is given under section 8.5.

The pervasive occurrence of heavy metals and in some cases particularly high concentrations of arsenic and lead allied to widespread PAHs and sporadic hotspots of DRO and PRO suggest it is prudent to install all new services within purpose built trenches backfilled with clean inert granular fill. The Master plan provides the opportunity to design trenches that accommodate a variety of utilities to achieve potential economies. As the ground is predominantly granular new service trenches are unlikely to create new pathways for contaminants.

For the purposes of the Master plan and initial costing exercises it should be assumed that known DRO and GRO hydrocarbon ‘hotspots’ in North and South Quay (see Section 8.3) are excavated and disposed to landfill or are bio-remediated on site and reused in suitable areas of the development. Alternatively if logistics allow the hydrocarbon ‘hotspots’ could potentially be remediated with the soil washing plant proposed as a treatment option for the material arising from the excavation of Cockle Bank. Preliminary waste assessments suggest that the hydrocarbon ‘hotspot’ material, if taken off site, would be classified as Hazardous.

For initial costing purposes an allowance of 5,000m^3 should be made for the adequate remediation of known hotspots. The coarseness of the sampling grid makes accurate estimates of the volume of soil requiring treatment difficult and it is essential for detailed investigations described in section 8.6 to fully validate any initial assumptions and to more accurately determine whether remediation of known hotspots is actually necessary and to what extent (via EA R&D P20 methodology (34)) or can remain in-situ. Validation testing would also be required for any treated hotspots to adequately demonstrate to the Regulators that sufficient action has been taken.

Further investigation is also required to increase the certainty that further hydrocarbon ‘hotspots’ do not exist, particularly around North Quay (see Section 8.6).

8.5 Cockle Bank

The results of *leachate* tests from the Bank contrast with the elevated concentrations of arsenic, copper and zinc found in soils within the Bank and also with the leaching results from the surrounding land. Within the Bank it is only copper (3 out of 4 samples) and zinc (1 out of 4 samples) leachate that exceed the published EQS values. Current evidence suggests that the elevated metal concentrations are associated with the finer soil fraction. The relatively low leaching potential when compared to the surrounding soils may in part be explained by the constant flushing of tidal waters over a lengthy time.

On the whole the results of leaching tests do not indicate a significant risk to the environment should Cockle Bank remain in situ.

Consideration is being given to reusing the dredgings from Cockle Bank on agricultural land. However, at the time of writing no details have been given to the location(s) and intended agricultural uses.

An assessment of potential agricultural reuse has been based on ICRCL Guidance Note 70/90 ‘Notes on the Restoration and Aftercare of Metalifferous Mining Sites for Pasture and Grazing’ (see also section 6 for further details) which provides a useful basis for similar forms of contamination being reused for the intended purpose. It should be recognised however that the ICRCL guidance is specifically intended for redevelopment of metalliferous waste sites and other guidance, standards or legislation may also apply. For example the Environmental Protection Act (EPA) Part IIa may apply if the receiving site exhibits notably lower concentrations of arsenic, copper and zinc.

With reference to Table 5 (section 6.6) the results of soil tests suggest that the mean concentrations of arsenic and zinc from Cockle Bank are generally at acceptable levels for planting and grazing. In some instances however the levels of total copper concentrations in the soil exceed the recommended guidance. A similar picture emerges for the plant available concentrations of copper where 4/16 tests exceed the recommended 70mg/kg. The recommended value is an indicator that increased concentrations may inhibit plant growth. It should be noted that copper is not readily taken up into the leafy parts of the plant but may accumulate in the roots with limited translocation above ground. Soil pH also plays a part in plant uptake, with more acidic conditions (i.e. < 6) increasing root uptake, e.g. a concentration of 250 mg/kg is likely to cause phytotoxicity to clover at a pH of 6. With a pH of more than 6 (which is the case with the Cockle Bank soils) a copper concentration in soil of 500 mg/kg would be acceptable for productive grasses, but above this level may be toxic to sheep and lambs. About 15% of the test results for copper in soil are higher than the 500 mg/kg action level, although this reduces to 0% if the finer clay and silt fraction is removed (see Appendix N). Comparison using the ICRCL Guidance Note 70/90 assessment criteria is a highly conservative approach as it does not take into account the dilution of contamination that will occur as the Cockle Bank material is spread onto farmland.

Although the results are generally supportive of an agricultural use the elevated copper levels (in solid and leachable form) suggest that the intended land use needs to be identified before reuse in an existing untreated form can be accepted to all cases offsite. It is also necessary to discuss the current test results in line with the specific land use proposals with the Environment Agency, who would act as the Waste Regulatory Authority. Some toxicity may be tolerable, if some loss of productivity or amenity is acceptable to all of the relevant stakeholders. It would also be necessary to implement a system of monitoring, agreeable with the EA at all receiving sites. The existing sewage Sludge Regulations (35) are the most appropriate framework for considering the testing of soil at the receiving sites and the rates of addition of toxic elements including zinc, copper and lead.

Additional guidance for the addition of arsenic addition is given in the Code of Practice for Agricultural Use of Sewage Sludge 36). Further specific testing may also be required to support particular land uses, eg germination and root elongation tests to directly assess toxicity to specific plant forms.

Overall the Environment Agency will need to be reassured that soil will be improved by the addition of Cockle Bank material, be it untreated or treated. There will be a balance between adding enough material to improve the physical properties of the soil, but not so much as to damage the soil chemically. The volumes added per area will need to be assessed on a site by site basis as they will depend on the chemistry of the receiving site.

If the dredgings cannot be used in their current form for all intended land uses without a pre treatment there are a number of options that could still be adopted for the most sensitive of receiving sites:

- Use the dredgings as a drainage layer in areas of poor drainage. This would require the topsoil to be stripped and replaced, but would have no adverse effects on the root zone of plants
- Incorporate organic matter
- Raise the pH with lime

Both organic and pH additives would require periodic topping up to maintain levels.

Irrespective of heavy metal concentrations the dredgings are notably saline and some form of washing may be required before widespread agricultural use can be considered.

Until the EA discussions are concluded it should be assumed for the purposes of the Masterplan and for initial costing that some form of pre-treatment is necessary in some instances. The sieved fraction results (included in Appendix N) indicate that the heavy metals are associated with the finer soil fraction. Therefore it is recommended that soil washing be considered where this is necessary.

In essence soil washing involves removing the fine fraction from the soil using appropriate physical properties. Further testing will be required for the detailed design of the soil washing plant, for example, is material to be separated on a size or specific gravity basis, are abrasive techniques required, are polymers required to coagulate and flocculate the fine fraction to the resulting filter cake. The technique works best on soils with a high granular content, with fines making up 30% or less, such as at Hayle.

The process would leave a relatively clean sand fit for a variety of agricultural or onsite purposes, along with a smaller residue of material that has to be either taken offsite/disposed to landfill or is reused on site, possibly after further treatment. Soil gradings suggest that up to 10% of the volume of dredged material may be left in the residue. Assuming that up to 50% of dredged material requires pre-treatment because of a sensitive land use then a volume up to 5,000m^3 maybe produced as residual filter cake.

The residue is likely to be of a poor physical and chemical composition and may require pre-treatment if reused on site or even if taken to landfill. The residue would also require further testing in line with the EA procedures for Waste Acceptance before establishing if it is Hazardous, Non Hazardous or Inert. If taken offsite untreated then it is possible on the basis of current findings that the residue would be classified as Hazardous Waste, primarily on grounds toxicity and ecotoxicity.

For the purposes of the Master plan however, it is preferable to reuse the residue on site, eg it could be stabilised/solidified within a cement and PFA mixture and used as an improved subgrade beneath hardstanding and road pavements.

Soil washing will require the appointment of a competent contractor with the requisite Mobile Plant Licence. Current changes to the Waste Management Regulations will enable a contractor to port a licence from one site to another for the same plant, rather than on an individual site basis. This should speed up the application process, which can take up to 3-6 months. Soil stabilisation/solidification would require a further Mobile Plant Licence.

Guidance given in Schedule III of the Waste Management Licensing Regulations, 1994 (clause 7) suggests that agricultural reuse maybe exempt from Waste Management Licensing, but this again requires clarification from the EA. It is likely that the EA would also consult with DEFRA in this regard.

As an alternative to agricultural use the dredgings may also be considered for reuse within the development, but this would require a simple cover of clean fill as described in section 8.4.

The dredgings (washed or unwashed) are not considered suitable for beach replenishment materials.

8.6 Further Work

A more closely spaced soil sampling grid should support detailed design, this should be directly linked to both historical use and end use. The following sampling spacing should be adopted, taking into account the existing sampling distribution:

- Residential with private gardens (Hilltop Residential): 10-15 metres
- All other areas: 25 metres

A more focused chemical testing suite should also be used at the additional sampling points. This should include As, Cu, Zn, Pb, Cd, DRO, PRO, PAH and asbestos, the latter particularly around South Quay and the landscaped car park. Plant availability tests for Cu and Zn should also be undertaken. The additional testing will help to:

- refine cover system thickness,
- validate existing assumptions about heavy metals being associated with the finer soil fractions,
- delineate hydrocarbon hotspots to establish what can be left in situ or what volumes require disposal/treatment

The present results suggest that the bulk of any further soil sampling and testing can also be concentrated on the upper 1.5 metres of soil.

Further groundwater monitoring wells should be installed, particularly in North, South Quay and residential hill top areas where some elevated hydrocarbon contamination and PAH results have been recorded. A grid spacing of 25 metres in these areas offset from the existing pattern of monitoring stations is recommended to reduce the size of potential hot spots/plumes. A wider spacing can be applied in other areas. In all cases a specific suite of tests should be undertaken on water samples: DRO/GRO/PAH/As and Cd.

As part of the additional groundwater monitoring proposed above, it is recommended surface water samples are taken from Hayle Estuary at locations both upstream and downstream of the site. This will enable current baseline conditions to be assessed and to potentially determine whether areas of contamination identified within the site are having a deleterious effect on the quality of water within the estuary.

It is recommended that the Environment Agency is consulted over the selection of controlled waters assessment criteria for TPH, DRO & PRO prior to the combined interpretation of existing and future datasets.

If offsite disposal is required in any area then further leachate soil testing in line with the EA guidance (ref) is recommended to fully establish appropriate volumes of inert, non-hazardous and hazardous waste. This is particularly essential where it is essential to distinguish between Inert and Non Hazardous materials which prevail at the site. Such tests would need to include the 2 part leachate tests as described by CEN PrEN12457-3. Further waste acceptance criteria tests are also required in zones 3, 4, 6 and 7 to support existing assumptions that the presence of hazardous material is limited and effectively diluted by the prevailing inert/non-hazardous soils.

Additional sampling of Cockle Bank and the harbour sediments is required to determine the effects of dredging on water quality.

Further risk assessment (using the EA R&D P20 methodology (33)) should be undertaken to confirm or otherwise the need to remediate and delineate known hydrocarbon hotspots currently assumed for offsite disposal or ex-situ bio remediation. An allowance should also be given for a similar exercise to any further hotspots encountered during the reduced grid investigations.

It is anticipated this additional work will require a detailed assessment of the hydrogeological relationship between the potentially contaminated groundwater and the estuarine receiving water.

Validation testing will need to support all hotspot removals/process based remediation.

Periodic (say monthly for at least 6 months) gas monitoring should be continued to support existing assumptions regarding limited gas protection measures and can be undertaken with the additional groundwater quality testing. This is in line with current best practice.

Any agricultural land intended to receive dredgings from Cockle Bank will require sampling and testing to ensure that imported material will not adversely affect soil quality. Further testing of the exported Cockle Bank dredgings will also be required to support existing findings. Specific testing to evaluate germination/root elongation on particular plants from soils derived from Cockle Bank may also assist in maximising reuse on agricultural sites.

The probing exercise devised to estimate rock head level within Penpol Creek did not facilitate soil sampling. Bed sampling should be undertaken to determine soil chemistry in order to determine appropriate re-use or treatment requirements. Testing for tributyl tin (TBT) should be included.

Calorific Value tests should be undertaken on the deep ash fill within the Hilltop residential zone to validate current assumptions of a low risk from combustion.

9 References

1. Buro Happold, September 2005. Volume 2 Hayle Harbour Redevelopment Master Planning Geotechnical Report.
2. Office of the Deputy Prime Minister, Planning Policy Statement 23: Planning and Pollution Control – Annex 2: Development on Land Affected by Contamination. ODPM (London) 2004.
3. Office of the Deputy Prime Minister, Building Regulations 2000, Approved Document C – Site Preparation and Resistance to Contaminants and Moisture, The Stationery Office (London) 2004
4. Contaminated Land Report 11, 2004. Model Procedures for the Management of Land Contamination, DEFRA and Environment Agency
5. R&D Technical Report P5-066/TR, 2000. Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination, Environment Agency
6. Cahill, N. July 2000. Hayle Historical Assessment, Cornwall. Published by Cornwall Archaeological Unit for English Heritage. Available at http://www.historic-cornwall.org.uk/cisi/hayle/hayle.htm
7. BGS 1:50,000 Solid and Drift Penzance Sheet 351 & 358
8. Environment Agency, 1996, Policy and Practice for the Protection of Groundwater, Groundwater Vulnerability of West Cornwall, Sheet 53
9. C.J. Associates, June 2005. Hayle Harbour Redevelopment. Site Investigation No. S0209 Factual Report TES Bretby report
10. TES Bretby, November 2005. Hayle Harbour Analysis Report
11. CLR10, 2002: Contaminated Land Exposure Model (CLEA): Technical Basis and Algorithms. EA/DEFRA 2002
12. Method for Deriving Site-specific Human Health Assessment Criteria for Contaminants in Soil, SNIFFER, 2003
13. RISC Version 4.03a October 2003
14. Department of Environment, Food & Rural Affairs/ Environment Agency, R & D Publication CLR 7: Assessment of Risks to Human Health from Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research, DEFRA/EA 2002
15. Dutch Soil and Water quality Standards (2000) - Target Values and Intervention Values for Soil Remediation
16. Rodriguez and Basta et al (1999) An In Vitro Gastrointestinal Method to Estimate Bioavailable Arsenic in Contaminated Soils and Solid Media. Environmental Science and Technology, 33, 642-649
17. Department of Environment, Food & Rural Affairs/ Environment Agency, R & D Publication TOX20 Contamination in Soil: Collation of Toxicological Data and Intake Values for Humans - Naphthalene, DEFRA/EA 2003.
18. Environment Agency, Draft Technical Report P5-079/TR1: Review of Fate and Transport of Selected Contaminants in the Soil Environment, Environment Agency, 2003.
19. Council of Canadian Ministers of the Environment, Canada-wide Standard for Petroleum Hydrocarbons (PHCs) in Soil. CCME (Winnipeg) 2001.
20. Department of Environment, Food & Rural Affairs/ Environment Agency, R & D Publication TOX 2: Contamination in Soil: Collation of Toxicological Data and Intake Values for Humans - Benzo(a)pyrene, DEFRA/EA 2002.
21. US Environmental Protection Agency, *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons*, USEPA (Washington DC) 1993. Document EPA/600/R-93/099
22. EC Dangerous Substances Directive (76/464/EEC)
23. The Water Supply (Water Quality) Regulations (England and Wales) (2000) - Statutory Instrument 2000 No. 3184
24. Ministry of Health of New Zealand (2000) – Drinking Water Standards for New Zealand. http//www.moh.govt.nz
25. Department of the Environment and The Welsh Office (1992). Approved Document C (1992 edition): Site Preparation and Resistance to Moisture. HMSO, London
26. BRE Special Digest 1, 2005. Concrete in Aggressive Ground.

27. ICRCL Guidance Note 70/90, First Edition February 1990. Notes on the Restoration and Aftercare of Metalliferous Mining Sites for Pasture and Grazing.

28. Building Regulations -Approved Document C (1992 Edition)

29. Guidance on Sampling and Testing of Wastes to Meet Landfill Waste Acceptance Procedures Version 1, April 2005, published by the Environment Agency

30. National Radon Protection Board, 2002, Radon Atlas of England and Wales

31. BRE BR221, 1999, Radon: Guidance on Protective Measures for New Dwellings

32. Environment Agency, May 2001. Code of Practice for the Management, Destruction and Disposal of Japanese Knotweed.

33. BRE BR 465, 2004, Cover systems for land regeneration, Thickness of cover systems for contaminated land

34. Environment Agency R&D Publication 20, 1999. Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources

35. The Sludge (Use in Agriculture) Regulations, 1989, and Amendment, 1990.

36. Code of Practice for Agricultural Use of Sewage Sludge, ISBN 185112005X, Department of the Environment.

10 Figures