REMEDIATION OPTION APPRAISAL

HISTORIC LANDFILL AT BRAY HARBOUR, CO. DUBLIN

MARCH 2017

dlr
Comhairle Contae County Council

FEHILY TIMONEY & COMPANY

REMEDIATION OPTIONS APPRAISAL

BRAY HISTORIC LANDFILL, CO. WICKLOW

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Abstract: Following the findings of the Tier 2 Assessment, this report assesses remediation options for the site in accordance with CIRIA's Guidance on the management of landfill sites and land contamination on eroding or low-lying coastlines and the DLRCC Coastal Protection Strategy

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EXECUTIVE SUMMARY

Fehily Timoney & Co. (FT) was appointed by Dún Laoghaire–Rathdown County Council (DLRCC) to complete an Environmental Risk Assessment of a site in accordance with the Environmental Protection Agency (EPA) Code of Practice (CoP) (2007): *Environmental Risk Assessment for Unregulated Waste Disposal Sites*.

A Tier 1 assessment was completed followed by a Tier 2 assessment which comprised a site investigation and geophysical assessment which were undertaken in July/August 2016 to confirm the type of and depth of waste and to assess potential groundwater contamination. The site investigation comprised the drilling of six boreholes across the site and subsequent landfill gas and groundwater monitoring.

The site investigation identified that the thickness of the waste was up to 8.7 m in the northern portion of the site. The geophysical assessment indicated a volume of waste of approximately 104,028 m^3. The Tier 2 assessment determined that a Low classification (Class C) can be assigned to the site.

However, given that the site is subject to coastal erosion and this is exposing and eroding waste material with particular reference to the finding of small sporadic pieces of asbestos, FT has developed a remediation option appraisal for the site. This includes a review the National Coastal Strategy and DLRCC coastal strategy and assessing the remediation options in the context of the CIRIA's Guidance (C718).

It is concluded that long-term coastal protection is required on the site, however, further assessment is required to determine the impact of engineered coastal protection to erosion and sediment transportation rates adjacent in the wider coastal environment. In the interim, short-term approaches can be adopted at the site to mitigate any potential impacts.

1. INTRODUCTION

1.1. Background

Fehily Timoney and Company (FT) was commissioned by Dún Laoghaire Rathdown County Council (DLRCC) to undertake a remediation option appraisal for the historic landfill north of Bray Harbour. The purpose of this report is to discuss the short-term and long-term remediation options for the site and determine their suitability in the context of environmental pollution risks. The findings of this report will determine the most suitable approach for remediation.

FT has previously undertaken Tier I and Tier 2 environmental risk assessments for the site in accordance with the EPA Code of Practice (CoP) (2007): *Environmental Risk Assessment for Unregulated Waste Disposal Sites*. The appraisal of the remediation options has also been discussed in the context of these guidelines with reference also made to the CIRIA's *Guidance on the management of landfill sites and land contamination on eroding or low-lying Coastlines,* (C718, 2012).

1.2. Scope of Works

The scope of works for this remediation option appraisal includes:

i. Review of the findings of Tier 2 Risk Assessment including volumes of waste and risks identified.
ii. Assessment of coastal erosion and flooding risk for the site, to estimate likely erosion rates at the site and surrounding coastal area. This is to be undertaken in the context of the Office of Public Works Irish Coastal Protection Strategy (2010), the DLRCC Coastal Defence Strategy (2012) undertaken by Malachy Walsh and Partners, and the RPS Options Assessment and Design Reports (2007) undertaken on behalf of Woodbrook Golf Course by RPS.
iii. Review of remediation options for managing the risks identified in the Tier 2 risk assessment in accordance with CIRIA guidance and in the context of the DLRCC Coastal Strategy.
iv. Recommendations for long-term and short-term coastal protection.

2. REVIEW OF TIER 2 RISK ASSESSMENT

2.1. Site Setting

The site is an overgrown disused former landfill site 100 m to the north of Bray Harbour comprising an area of 2.57 hectares. The former Bray Urban District Council (now incorporated as part of Wicklow County Council following the Local Government reform act 2014.) operated the landfill for domestic refuse at this site in the past. Following Local Government boundary changes the majority of this site moved from Wicklow County Council (WCC) administrative area to the administrative area of DLRCC. The site was sold by Wicklow County Council to Woodbrook Golf Club in 1992 and the land is now privately owned by Woodbrook Golf Club. The topography of the site is undulating at elevations ranging from 5 metres above ordnance datum (mOD) to 11 mOD, with the gradient generally rising from south to north, with two steeper areas identified to the north. The site is bounded by the Dublin – Bray railway line to the west, by Woodbrook Golf Club to the north, by the coastline to the east and by a small industrial complex to the south.

Teagasc online mapping describe the soil and subsoil underlying the site as made ground, while the GSI online mapping indicates that the northern portion of the site is underlain by alluvium deposits, while the southern portion of the site is underlain by deposits of gravels derived from limestone. This is underlain by the Maulin Formation, comprising Ordovician dark blue-grey siltstone, slate, phylite and schist.

The groundwater is classified by the GSI online mapping as a 'Locally Important Aquifer' (LI). The closest surface water feature is the Irish Sea adjacent to the eastern portion of the site, while a culverted stream also flows east through the northern section of the site.

2.2. History of the Site

A brief review of historic Ordnance Survey of Ireland (OSI) Mapping on the OSI website indicates that the site was historically undeveloped. Historic 25-inch mapping from 1888 – 1913 identified the site as a low-lying area to the east of the former Dublin-Bray rail tracks, which have now been relocated to the west of the site due to coastal erosion. The site appeared to be influenced by saline intrusion as it is identified as *liable to flooding*.

The exact period of operation as a landfill has not been determined, however, it is known that the landfill was closed in 1968 and was sold to Woodbrook Golf Club in 1992.

Information provided by DLRCC indicated that a small isolated area of asbestos containing material (ACM) was exposed by coastal erosion at the southern cliff face. Inspections were undertaken by DLRCC in early 2015 with the material identified as comprising ACM (roofing materials including roofing felt, small quantities of corrugated asbestos sheeting and various types of roofing slates).

Following consultation with DLRCC, Asbestos Transport Limited was employed by Woodbrook Golf Club to remove any exposed ACM at this location and to monitor the beach for asbestos on a weekly basis. Minor quantities of ACM were uncovered and removed for disposal at an appropriate waste disposal facility. No further ACM was revealed along the coastline during the periods of inclement weather from December 2015 to February 2016.

The location of the site is presented in on Figure 2.1.

2.3. Site Investigation and Waste Characterisation

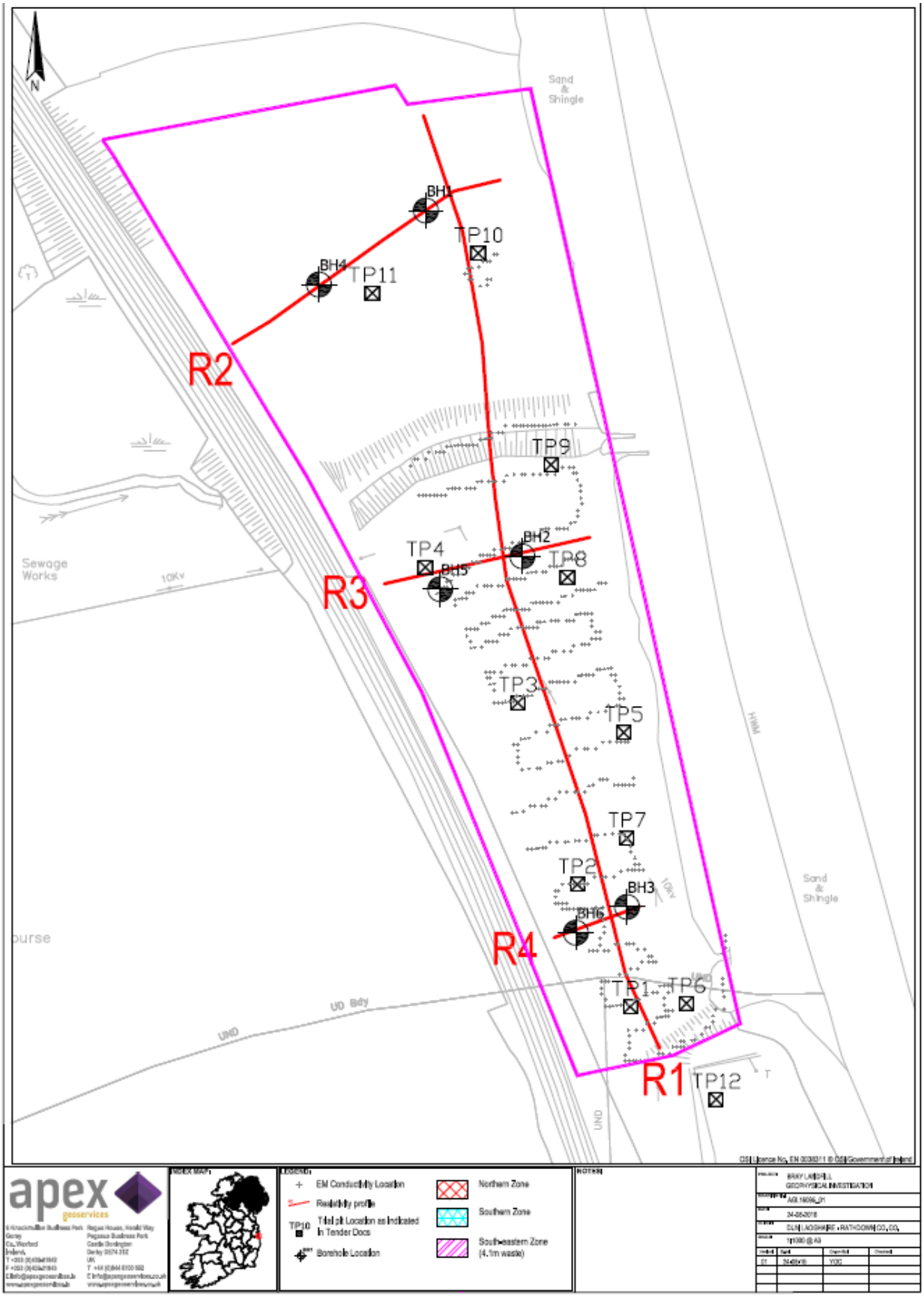
The 2016 site investigation (Tier 2) revealed a much shallower depth of infill material in the boreholes located in the southern and central portion of the site with thickness ranging from 1.8 m at BH5 and BH6 to 3.2 m at BH2, whilst infill material depth was 8.4 m bgl at BH4 and 8.7 m bgl at BH1 at the northern end of the site.

The geophysical assessment undertaken as part of the Tier 2 Assessment calculated a total waste volume of 104,028 m^3 underlying the site. Inert domestic and construction and demolition (C&D) waste were predominantly encountered to the south of the site with thicknesses ranging from 1.2 - 3.3 m, whilst a small pocket of thicker material up to 4.1 m was also encountered in the south-east.
The northern portion of the site encountered fill thickness up to 8.7 m with evidence of inert domestic waste and possible industrial waste increasing with depth.

The site investigation location plan is presented in Figure 2.2 overleaf.

Source: GSI Maps, Site boundary outlined in red

Figure 2.1: Aerial Photograph of Site



Source: FT Tier 2 Environmental Risk Assessment Report, 2016 APEX Geoservices,

Figure 2.2: Site Investigation Location Plan

2.4. Environmental Assessment

2.4.1. Evidence of Contamination

As noted, the majority of the waste encountered was C&D waste, with organic and industrial type waste increasing with depth. No significant contamination was noted during the site investigation, however a slight creosote odour was encountered in BH1 from 2.2 to 2.8 m bgl. A sheen was also noted in the groundwater / leachate sample.

Asbestos containing material (ACM) was not encountered during the drilling works, however, sporadic ACM fragments were encountered in the shallow soils during the site clearance in close proximity to BH1, BH2 and BH4. Approximately 8 small ACM roof tile fragments were identified and subsequently double-bagged and removed off-site for disposal. No visual or olfactory evidence of contamination was noted in the natural ground during the site investigation.

2.4.2. Risk Assessment

Following the site investigation, a Tier 2 risk assessment was undertaken to determine the level of risk to human health and environmental receptors.

Soil samples retrieved during the site investigation were analysed for a broad range of contaminants, with the results were screened against the CIEH / LQM and Dutch List assessment criteria. No exceedances were noted and therefore no significant risk to the current site users. The samples were screened for asbestos with no fibres detected. However as noted in Section 2.4.1, sporadic ACM fragments were identified during the site clearance in the central and northern portion of the site.

One round of gas monitoring detected a low risk of low carbon dioxide concentrations (max 10.0 % v/v). No methane was detected.

The leachate and groundwater sampling at BH1 and BH4 returned several elevated concentrations of ammoniacal nitrogen, potassium and TPH. However, given the low permeability of the underlying natural clayey silt, the risk to deeper groundwater and sea water receptor is considered low. Furthermore, the closest groundwater abstraction point is located 300 m southwest of the site (up-gradient) and given that groundwater flow is to the east the risk is low.

Additional gas monitoring and groundwater monitoring was recommended to be undertaken on the site to fully determine the risk.

The Tier 2 assessment identified the site as having a low risk classification (Class C) in accordance with the risk based methodology adopted from the *EPAs CoP: Environmental Risk Assessment for Unregulated Waste Disposal Sites (2007)*. The waste material within the landfill does not present a risk if left undisturbed, however, given that the site is subjected to coastal erosion, the waste material is being released onto the foreshore and into the water environment during storm events, therefore creating a potential risk to users of the foreshore / beach. The unmitigated risk to users of the beach / foreshore has therefore been classified as moderate due to the potential exposure of asbestos.

As outlined above, the site investigation identified exposure of waste material (with particular reference to asbestos) as a risk due to coastal erosion. The risk at the site can be mitigated by removal of either; the source, pathway or receptor. The scenarios for managing the risk though a site specific remediation strategy, based on source, pathway or receptor removal, are discussed in Section 4.

3. SITE IN CONTEXT OF COASTAL FLOODING AND EROSION

3.1. Strategic Assessment of Coastal Flooding and Erosion

A Strategic Assessment of the Coastal Flooding and Erosion Extents was undertaken by RPS on behalf of the Office of Public Works in 2010. This study estimated the likely future positions of coastlines in the years 2030 and 2050 given the current predicted erosion rates.

A review of the Irish Coastal Protection Strategy Study for the South-East Coast available on the OPW website[1] indicates the extent of the estimated future position of the coastline in proximity to the site. The map presented in Figure 3.1, indicates that the site is subjected to coastal erosion, with the cliff-face predicted to retreat approximately 20 m to the west by 2050 without any coastal protection. This would cause additional risk to the railway track that bounds the site to the west and the gas mains. The report has medium confidence (55 – 70%) in this estimated erosion extent.

Additionally, the Irish Coastal Protection Strategy Study Phase 2 - South East Coast undertaken on behalf of the OPW[2] indicates that the site is not likely to be subjected to 1 in 200 flooding based on evidence of the high water mark (cliffs).

3.2. Wave and Tidal Conditions at the Site

In 2007, RPS undertook an Options Assessment in Response to Section 55 Notice issued by DLRCC on behalf of Woodbrook Golf Course. This report undertook a review of the 2005 site investigation, assessed the historic erosion rates at the site and also undertook a wave and tidal condition assessment for the site.

The report indicated an erosion rate of approximately 0.6 m per year with a total retreat of 30 m over the next 50 years.

Wave modelling was undertaken in this report to determine the wave climate conditions for the site, with the data derived from the UK Met Office European Water Waves Model from 1990 – 2000. The waves were modelled using Mike21 Nearshore Spectral Windwave model.

Following an assessment of the tidal conditions and wave climate, the RPS report concluded that the erosion at this site is driven and dominated by wave action, in particular extreme wave action (i.e. during storms). It outlined that '*during these events large water levels are expected, which will cause significant run up to the shore and erosion to the toe of the cliff, with collapse at the higher part, Significant erosion might only be observed under these events with less or no retreats for periods in between.'*

It should be noted that the data derived to create this model does not include information post 2000.

3.3. DLRCC Coastal Strategy

Malachy Walsh and Partners was commissioned by DLRCC to develop a coastal strategy for the management of the Coastline in 2010 and this study was formally adopted by the Council. DLRCC has indicated that any coastal protection works proposed in this area will have to be presented in the context of this Coastal Strategy.

The aim of study was to develop a strategy for the management of coastal defence related issues within the DLRCC functional area relating to the risks from coastal erosion, cliff instability and tidal flooding, while determining the appropriate options for each discrete length of coastline and recommendation of the extent and type of coastal defences.

[1] http://www.opw.ie/en/media/ICPSS_Appendix8_Erosion_Mapping_Final.pdf
[2] http://www.opw.ie/en/media/ICPSS_Appendix7_Flood_Mapping_Final_Part1.pdf

3.3.1. DLRCC Coastal Study – Risk to Site

Section 5.4 identified the site (Landfill, South of Woodbrook Golf Club) as an area that required a Stage 3 Assessment. The report outlines that generally *an area undergoing a Stage 3 assessment was considered to have a more immediate risk or a potentially higher value of assets at risk than the Stage 2 areas*.

Section 5.4.1 detailed the site's coastline which typically comprised gravel type material mixed with landfill material. The cliff typically has a crest level of 10m ODM, with a slope of 0.49 horizontal to 1 vertical. Erosion and cliff instability are the two mechanisms at work causing landfill material to be exposed along the coastline, fall into the sea and spread along the shore by waves and tides. In order to prevent this from occurring the report indicates it will be necessary to prevent erosion and stabilise the cliff.

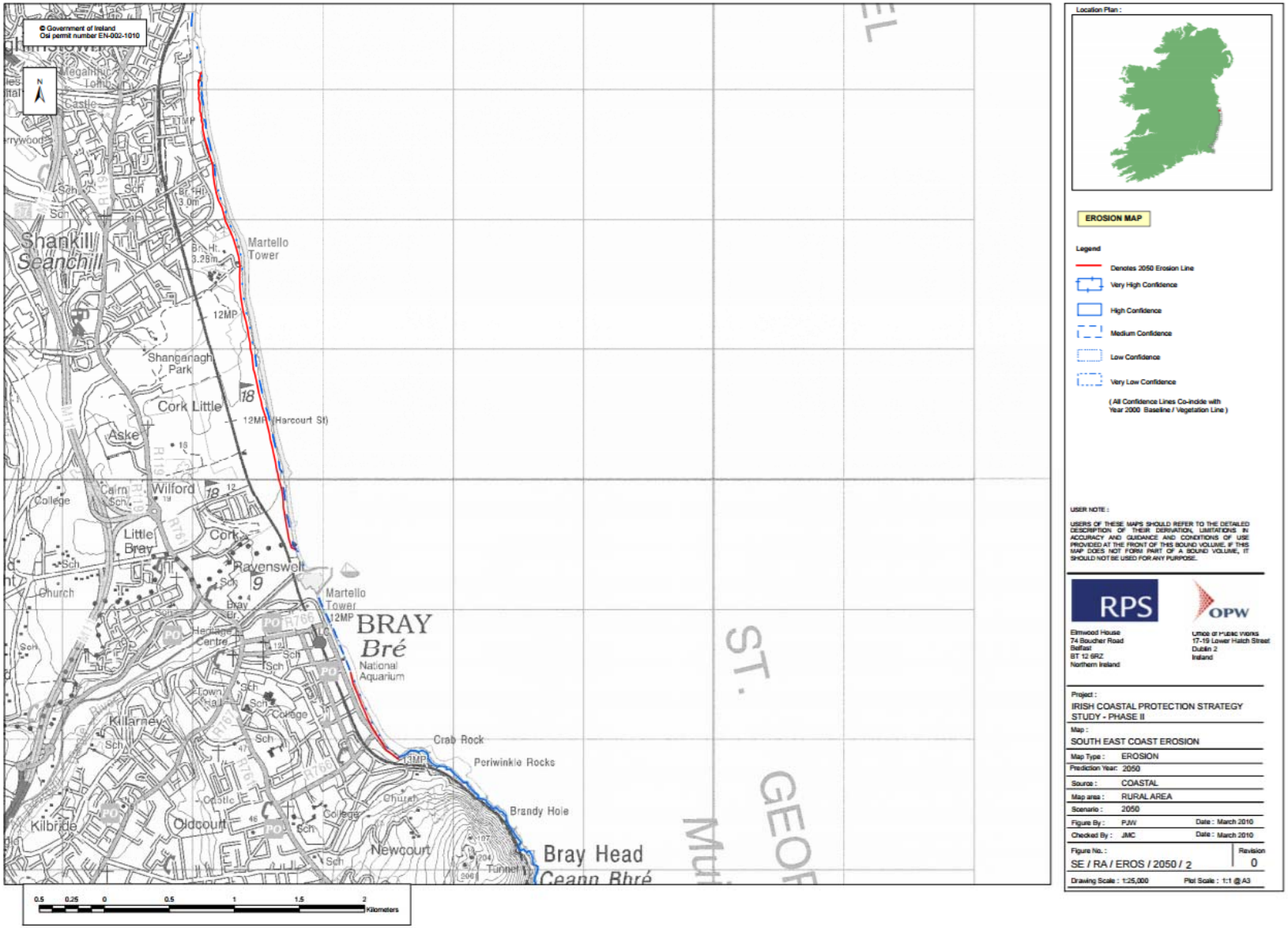
The report outlines that the risk from cliff failure is principally to the environment, including the amenity value of the shoreline in this area and the loss of land. It also outlines that the potential environmental impact of the landfill material depends on the 'material type and level of contamination'. As noted in Section 2.4, the Tier 2 assessment identified the main risk from the site is the exposure of the waste material (with particular reference to asbestos) along the cliff-face and beach with particular due to increased coastal erosion, during periods of stormy weather.

3.3.2. DLRCC Coastal Study – Estimated Erosion Rates for the Site

In 2010, the immediate erosion risk included 11,443 m^3 of inappropriate material falling into the sea, equivalent to 3,939 m^2 of land area with best estimate erosion rate of 0.34 m/year. 56,100 m^3 of material is at risk of being eroded onto the beach over the next 50 years in this area, equivalent to 5,100 m^2 of land. The risk line relating to cliff instability extends 13.13 m behind the line of the existing cliff crest, with erosion risk during the next 50 years extending the current risk line a further 17 m west.

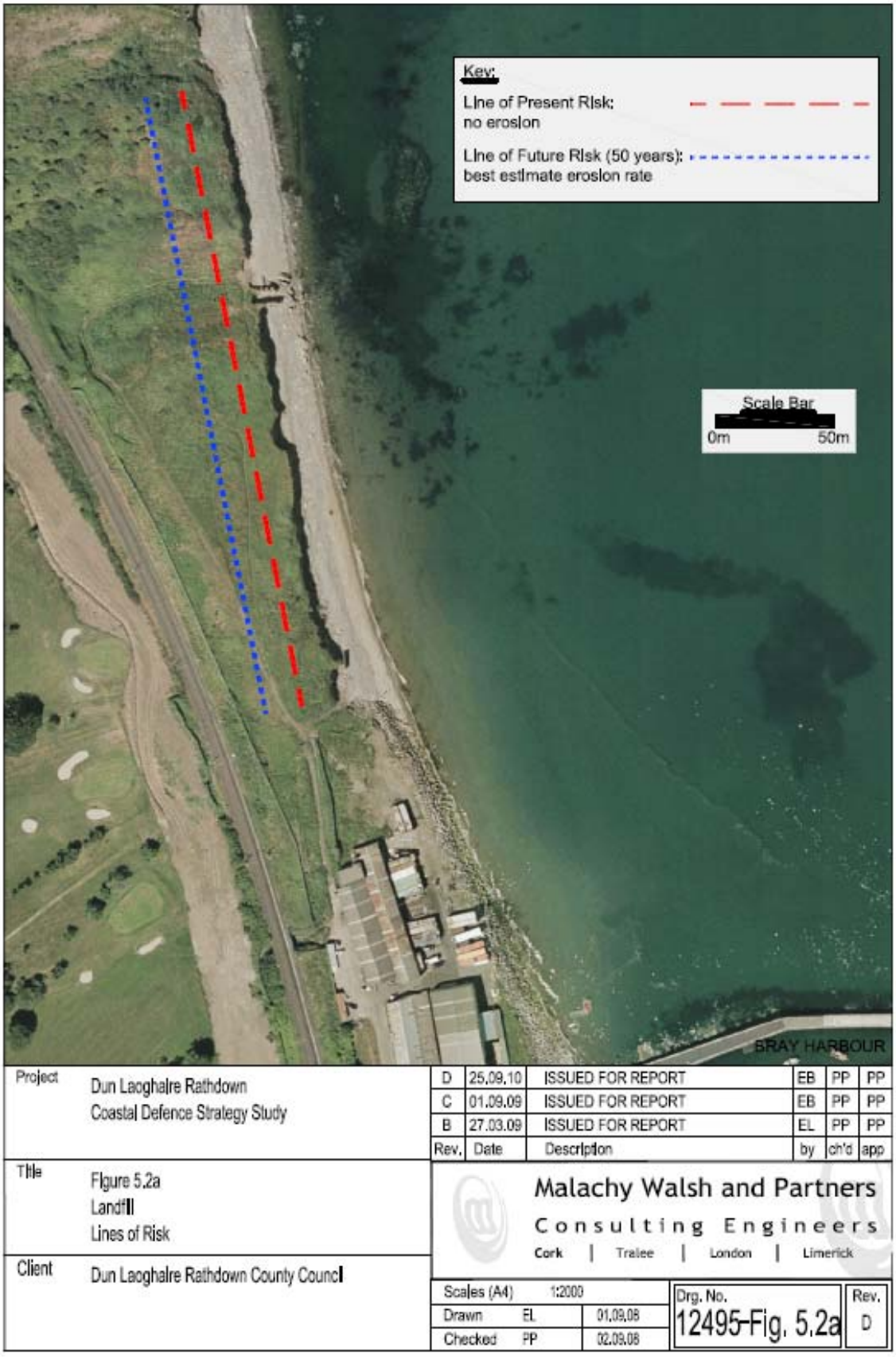
The values provided in this report are based on best estimates of erosion rates and mid values of potential long term stable slopes.

The erosion rates for the site is illustrated in Figure 3.3.



(Source: OPW Irish Coastal Protection Strategy, South East Coast Erosion, 2010 Figure: SE / RA / EROS / 2050 / 2)

Figure 3.1: Lines of Coastal Erosion Risk - 2050



(Source: DLRCC Coastal Strategy Report, Figure 5.2a)

Figure 3.2: Lines of Coastal Erosion Risk

3.3.3. DLRCC Coastal Study Evaluation of Options

The DLRCC coastal study undertook an assessment of the options to be considered for the site. These options included:

A. Do nothing
B. Assess the level of contamination in the landfill
C. Protect the toe of the existing cliff
D. Protect the cliff toe and soil nail the cliff face
E. Protect the cliff toe and re-grade the cliff face
F. Remediate the landfill site

These options are presented in the extracted Table 3.1 below, and are discussed in Section 4 in the context of the CIRIA C718 guidance.

Table 3.1: DLRCC Coastal Strategy – Study of Feasible Options for the Site

(Source: DLRCC Coastal Defence Study, Section 8.2.1 Table 8.1)

Landfill: Summary Evaluation of Feasible Options

Option Description	Cost PV	Economic Benefits	Environmental Impact	Technical Requirements	Comment
Do Nothing –A	None	N/A	Adverse impact on beach and adjacent area	Does not satisfy	Not Preferred
Assess Landfill site for hazardous materials – B	€10 to 20k	N/A	None	Does not Satisfy	Required to assess hazard
Protect Toe of Cliff with rock armour revetment – C	€1.03m	N/A	Adverse impact on beach and adjacent area – but much less than with do nothing option.	Reduction in volume of landfill escaping into sea. Leachate and some landfill material reach the beach. Unremediated material remains	Not Preferred, as some 2500m^3 of potentially contaminated material can continue to fall from the cliff face.
Protect toe of cliff with rock armour revetment and stabilise cliff with soil nails, Option D Figure 8.1	€2.7m	N/A	Lesser impact on beach, contaminated land remains however.	Leachate reaches the beach. Unremediated material remains	Minimises disturbance to landfill material. Not the most cost effective option:
Protect toe of cliff with rock armour revetment and stabilise cliff by regrading. Option E, Figure 8.1	€2.3m	N/A	Low impact	Only leachate reaches the beach. Unremediated material remains	Likely optimum- if landfill material is inert.
Remediate site by removing landfill and defend remainder from wave action using Option E - Option F	€6 to 12m depending on extent and volume of hazardous materials plus cost of cliff toe protection (E)	N/A	Low impact – must also consider potential impact of removing material	Satisfied	If landfill material is contaminated remediation will be required. And the remediated area is likely to require protection from wave action

4. REMEDIAL OPTIONS FOR MANAGING THE RISK

The CIRIA guidelines on the management of contaminated and landfill sites on eroding or low-lying coastlines appraises the suitable management options with regards to short-term and long-term strategic coastal management planning. The guidance discussed the importance of considering the viability and sustainability of the options and the importance of communicating with stakeholders (e.g. adjacent landowners / DLRCC / Wicklow Council / coastal engineer etc.). The guidance discusses five main scenario options for managing the risk:

1. Do nothing.
2. Inspection and surveillance.
3. Remove the source of the risk.
4. Break the pathway between the source and the receptor.
5. Remove the receptor to the risk.

Each of these scenarios are discussed below in the context of the risk from the landfill. Additionally, the options evaluated by the DLRCC Coastal Strategy are discussed where applicable.

4.1. Do Nothing

The guidance outlines that usually it is necessary to assess the 'Do Nothing' option as it would provide a base case to compare the other options against. In the context of coastal erosion, the DLRCC report indicates that doing nothing will lead to the continuing erosion of landfill material into the sea, and possible lowering the amenity value of the beach in the immediate and adjacent areas due to landfill material possibly being transported to these areas.

Section 7.6 of the DLRCC Coastal Strategy outlines that coastal protection should be minimised along the area from Bray to Shanganagh due to potential sediment transport impacts and should only be undertaken when necessary and where alternatives have been exhausted. However, in the context of the site, Section 8.2.1 indicates that once the level of contamination has been identified '*it is a requirement that material from the site should be prevented from entering the sea and the preferred coastal defence option should be used*.'

The Tier 2 assessment identified the possibility of ACM being exposed during coastal erosion as a risk. The 'Do Nothing' scenario would only be viewed as a viable option for the site if it could be verified that there was no longer a risk that ACM would be exposed during coastal erosion. Given the age of the landfill, it is unlikely that any documentation exists confirming the location of specific waste in the landfill. No ACM was revealed along the foreshore during 2016, however, sporadic fragments were noted in close proximity to BH1, BH2 and BH4 during the site investigation works.

This option is not considered feasible given the risk of continued erosion identified in the DLRCC report and the possibility that ACM will be exposed during coastal erosion and therefore presenting a risk to users of the foreshore / beach and possible coastal transportation down shore.

4.2. Inspect and Surveillance

As outlined above in Section 2.2, following consultation with DLRCC, Woodbrook Golf Club initiated a monitoring and inspection programme along the foreshore in 2015. This was undertaken by a specialised contractor to assess for the presence of any ACM fragments and remove any identified fragments.

The continuation of these visual inspections is recommended on a weekly / bi-weekly basis by a relevant DLRCC / WCC / Woodbrook Golf Club representative / independent contractor. The frequency of inspections undertaken should be increased after periods of adverse weather. Any ACM identified during the inspections should be removed from site and disposed of accordingly.

Additionally, it may also be prudent for an independent consultant to undertake quarterly inspections and soil sampling in close proximity to area(s) where ACM was identified.

As part of the continued monitoring these samples would be screened for the presence of asbestos fibres and therefore quantifying if there is a risk to site users.

4.3. Remove the Source of the Risk

The removal of the pollution source eliminates the risk from the site. The Tier 2 assessment identified the risk of landfill material (with particular reference to ACM) being exposed along the foreshore as a risk to beach users.

The guidance outlines that removing the source of the risk can be achieved through one of the following:

- Removing the waste or contaminated material
- On-site treatment
- Off-site treatment

Removal the waste / contaminated material: The site investigation identified very limited contamination, with the majority of the material likely to be inert or non-hazardous. Groundwater / leachate contamination was marginal and therefore the risk to groundwater and seawater receptors is considered low. The main risk identified was from ACM being exposed during coastal erosion. Minor quantities of ACM fragments were identified in close proximity to BH1, BH2 and BH4 during the site preparation works.

As noted, the landfill closed in 1968 and it is unlikely that there are any records on the locations where ACM was infilled. The geophysical assessment identified that the landfill comprises 104,028m^3 of material, with approximately 45% of the material likely to be inert. No significant contamination was identified during the site investigations with all of the samples classified as non-hazardous. It is therefore likely that a very small quantity of this material would be considered as hazardous.

To commence with a programme of excavation and removal would involve the excavation of all of the waste material, which would be subsequently screened to remove the asbestos. The screened material would then be backfilled and re-compacted. As outlined in Table 3.1, this option would be a very costly operation given that the volume of the waste on site.

Furthermore, the logistics of this operation would be impractical due to the access restrictions to the site. Any excavation works would also involve significant health and safety risks which include the risk of undermining the cliffs and the railway tracks during the works and the risks posed from the services on the site (e.g. electrical pylons and gas mains). It would therefore be considered logistically impractical to commence with a programme of excavation and removal.

Additionally, excavating a large volume of infilled material could cause significant environmental risks. This includes creating a void that may leave the remainder of the site in an unstable condition and increase the likelihood of sea flooding. Furthermore, the waste body is currently acting as coastal protection for the railway track.

The removal of the waste material is considered impractical given the above health, safety and environmental risks outlined above and therefore the preferred solution is for waste to remain in situ with mitigating measure adopted to prevent any further material being eroded and falling onto the foreshore and sea.

On-site / off-site treatments: On-site treatments (e.g. biological treatment, treatment of leachate / groundwater, soil vapour extraction etc.) and off-site treatments (e.g. chemical extraction, chemical reduction / oxidation, thermal desorption etc.) are not considered suitable for mitigating the potential risk from ACM.

4.4. Break the Pathway between the Source and Receptor

The risk to the receptor can also be mitigated through breaking the pathway between the source and receptor. The CIRIA C718 Guidance indicates that the principal methods for breaking the pathway are discussed below.

- clean-up operations
- cover systems
- cut-off walls
- coastal defences

Clean up Operations

The guidance outlines that the pathway can be broken by regularly monitoring the site and foreshore for signs of material release and, if found, clearing it away using specialist contractors. Woodbrook Golf Club implemented this approach in 2015 as a short-term solution. The CIRIA guidance indicates that this may be a preferred approach where the risk to human health and the natural environment is considered low, *'where erosion rates are low and episodic or where the material being released is inert or non-hazardous and causes an aesthetic effect only'*.

The erosion rates are episodic (i.e. during winter storms) and the majority of the material released is considered non-hazardous. However, a risk of further ACM being exposed on the along the beach / foreshore due to coastal erosion has been identified and therefore this approach may not be considered a long-term solution.

Cover Systems

The guidance outlines that a cover system (cap) can be used to create a physical barrier using a natural, synthetic or combination (natural / synthetic) liner. A cover system would, however, need to be installed with additional coastal defence structures as a cover system on its own would not be sufficient due to the impact of coastal erosion.

Cut-off Walls

Cut-off walls are subsurface barriers constructed by backfilling a trench with a suitable material (bentonite, concrete etc.). The purpose of a cut-off wall is to create a low permeability barrier in the ground to contain or direct groundwater or leachate. The Tier 2 assessment revealed that the risk to groundwater / surface water receptors is considered low, therefore this method is not considered applicable.

Coastal Defences

In the context of the site, the installation of a coastal defence or physical barrier along the shoreline may be adopted to prevent the further erosion and exposure of the landfill material. The preferred approach adopted at a site will depend heavily on the robustness of the solution required, its desired design life and the physical setting (CIRIA, 2012). Furthermore, any long-term coastal protection should be designed in the context of impacts to the overall coastline. Possible long-term engineering solutions that could be adopted include:

i. Walls of stone-filled gabion baskets
ii. Clay embankments
iii. Installation of concrete sea wall
iv. Installation of driven sheet pile retaining walls
v. Installation of concrete sloping revetments or rock (armour) revetments

Each of these options are briefly discussed below.

i. **Stone-filled gabions basket:** This protection mechanism comprises of wire mesh baskets filled with cobbles or crush rock. They are most appropriate at sandy beach sites suffering periodic moderate to severe erosion where backshore assets are at risk.

They provide reasonable fixed defences with their permeable face absorbs wave energy and encourages upper beach stability, but have a limited life of 5 to 10 years due to deterioration of the baskets.

The 2010 RPS report indicated that this option was the preferable option given that redevelopment in the near future may occur in close proximity to the site under the Bray Development Plan. Therefore, more expensive long-term protective structures (e.g. rock revetments) would be at risk of being made redundant. However, given that no planning is in place and that the majority of site is located within DLRCC, any protection on the site must be undertaken in the context of the DLRCC Coastal Protection Strategy.

ii. **Clay Embankment:** This option not be considered practical as the embankment may fail as a result of '*direct frontal erosion by wave action, flow through the fissured zone causing a shallow sump to occur on the landward face of the wall, scour on the back of the wall by overtopping or rotational slip'* (Engineering Geology and Construction, BGS, 2004).

iii. **Concrete Sea Wall:** A concrete sea wall is a structure built parallel to the shore which provides a high degree of protection from erosion, reducing the risk of landfill material being exposed. It is seen as an effective coastal protection mechanism that can improve slope stability and dissipate wave energy on sandy coasts. However, disadvantages of this methodology includes wave reflection and increased sediment transport offshore, while scour occurs at the toes of eroded beaches. Furthermore, it should be constructed along the whole coastline as erosion may occur on the adjacent coastline if not.

Information provided by DLRCC indicated that the landfill was historically protected by a sea wall. No information on the details of the seawall were provided, however, it is unlikely that it was constructed in accordance with coastal erosion specifications given that has been eroded.

iv. **Sheet Piling:** The installation of interlocking driven sheet piles along the coast of the landfill is also another option that would provide a high degree of protection from coastal erosion with medium to long-term protection. The structural integrity of the protection may also require toe protection and anchoring. Disadvantages of this option include its high cost, increased scour at the toe due to its vertical face and increased erosion immediately down drift.

v. **Rock Armour Revetment:** A revetment can also afford protection against coastal erosion, with rock more commonly used than concrete. The BGS guidance outlines that one of the key factors in the selection of revetment is the selection of stone size, to guard against erosion between stones / rocks, with coarse rip-rap isolated from the earth embankment by one or more coarse filter stones. Revetments do not provide protection to adjacent areas, which may experience increased erosion as a result of wave reflection from the structure, however, this effect is less than with seawalls and piles. Additionally, if rock revetment / armouring does cause adverse impacts it can be removed more easily and is less costly than sea walls / sheet-pile walls.

Table 3.1 extracted from the DLRCC Coastal Defence Study summarised the feasibility of options for the site. The report concluded that the preferable option was option E - *Protect the cliff toe and re-grade the cliff face.* This option consists of placing of a rock armour revetment at the toe of the cliff and the stabilising of the cliff face above by regrading to a long term stable slope. This option would involve the removal of a considerable amount of landfill material from the cliff face (possibly to a licensed landfill). The regraded face could be protected by gabion mattresses or top soiling and seeding. The effectiveness of this option is similar to that of the revetment and soil nail option in that landfill material no longer enters the sediment transport system.

The report outlines that *Option E* is only preferable if leachate is not determined as a potential environmental impact from the landfill due to potential migration pathway from the landfill to the seawater. *Option B Assess the level of contamination in the landfill* was undertaken as part of the Tier 2 Environmental Risk Assessment. The Tier 2 indicated that the risk from leachate to the seawater and underlying groundwater was considered low.

Other variants of the revetment design include riprap revetment plus launching apron given that erosion is predominantly during storm events.

It should be noted that adopting one of these 'hard' coastal defence options would need to be undertaken in the context of the DLRCC Coastal Strategy and in consultation with a suitably experienced coastal engineer. This may also require a further coastal erosion assessment for the site and the implications to the wider coastal environment.

In the interim, 'softer' engineered coastal protection mechanisms could be adopted to prevent erosion. These options include:

- Beach replenishment / recharge along the foreshore
- Installation of layers of sand-filled geo-textile bags

These options could prevent further coastal erosion in the short-term, and in situations where the risk presented by the release of materials is relatively low (i.e. low likelihood of occurrence and / or low consequence). Beach replenishment offers adequate coastal protection without hard structures and is usually best suited in areas of high value amenity beaches.

The beach replenishment could be undertaking through beach recycling i.e. utilising inert sand / silt dredging along the foreshore. It should be noted that the nourishment material should be as similar as possible to the indigenous sediment. Furthermore, all recycled dredging would have to suitably clean and from a verified source, with appropriate chemical analysis undertaken prior to placement to ensure that no further contamination.

Consideration should also be taken to the most effective position to place the nourishment to achieve optimum protection. The upper beach / cliff face would be the most obvious as it would protect the coast immediately, however, *'if the sediment is primarily sand, it will be rapidly redistributed alongshore or across the beach face by waves and currents to form a new equilibrium profile. (Scottish National Heritage, 2000)'*[3]

Guidance outlines that the replenished material should be installed approximately 1m above the maximum wave run up level (SNH, 2000). However, given the unpredictable height of the wave level during stormy periods this may require significant quantities of material which may be quite costly and ineffective.

Any scheme should be designed by competent coastal consultants, following preliminary studies of the physical, natural and human environment. Schemes are best implemented in the spring and early summer when work windows are least restricted and the nourishment has the greatest chance to stabilise before winter storms start to erode and redistribute the beach.

Additionally, it would be recommended that a coastal habitat survey is undertaken prior to the placement of fill material as direct placement of sediments and increased turbidity may impact the organisms that inhabit the area.

As noted, beach recharge is a short-term option with periodic replenishments needed to maintain its effectiveness. This will require regular re-investment but this can be viewed as a maintenance cost, such as those associated with hard engineered structures. These options also have their limitations which include the access restrictions for plant and material, possible requirement for a foreshore licence and the uncertainty regarding the how effective these approaches would be to prevent further erosion (e.g. the additional sand barrier may be eroded during the first winter storm).

4.5. Remove the Receptor to the Risk

If the receptor is removed from the area of risk the material will continue to be released but it will not come into contact with the receptor. The Tier 2 assessment identified users of the adjacent foreshore as the main receptors due to the exposure of waste material.

The CIRIA guidance outlines that methods that could be adopted to remove the receptor to the risk include the installation of warning signage and barrier fence preventing the public from coming into contact with the source. A vehicular barrier is already in place along the laneway access to the site, however, the site is still accessed by the general public.

[3] http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.7.shtml

Possible preventative methods would include the installation of a temporary barrier fence approximately 2.0 m in height along the access point to the south of the site along with warning signs indicating the risks of landfill material being exposed due to coastal erosion. This would be a short-term solution to prevent pedestrian access to the foreshore / beach area while a long-term solution is designed and constructed. Furthermore, this will also offer the in-situ monitoring points protection from damage due to anti-social behaviour.

Further consultation will be required with WCC to assess the feasibility of this approach as a short-term solution given that this section of the landfill is located within the WCC functional area.

5. RECOMMENDATIONS

5.1. Long Term

This appraisal has outlined the possible remediation options for the site. Any long-term solution adopted must take into consideration both the National and DLRCC Coastal Strategies.

Section 7.6 of the DLRCC Coastal Strategy outlines that coastal defences should only be undertaken when necessary to protect valuable assets, and only when alternatives have been exhausted given the impact on sediment transport down shore. In the context of the site, the report also outlines that coastal protection would not result in a significant reduction in the overall sediment budget, with a loss of about 5% of sediment from these cliffs. It further states that the cliff height in this area has been artificially raised by the landfill and it is not appropriate for such landfill material to enter the sediment transport regime.

The report states that coastal protection should be undertaken once the risk from contamination at the site has been determined. Possible minor quantities of ACM as well as other non-hazardous landfill material are at risk of being eroded onto the beach and entering the sea.

The following options are considered the most viable to, prevent landfill material entering the sea / beach and to prevent coastal erosion at the site:

- Protect toe of cliff with rock armour revetment and stabilising cliff by regrading (Option E in the Malachy Walsh and Partners, DLRCC Coastal Defence Strategy Study, 2012 report).

- Riprap rock armour revetment protection with launching apron.

It is recommended that a further study is undertaken to assess the viability of these options and to determine if there would be any adverse impact to the adjacent coastlines and coastlines down shore. This would involve undertaking a detailed design of the appropriate coastal protection methods and modelling the potential impacts these may have on coastal erosion and sediment transportation. Furthermore, it may be appropriate to use a similar coastal modelling tool as adopted in the previous assessments.

A coastal erosion specialist must be consulted during the design and throughout the construction phase to ensure the impact to the adjacent and down shore coastal environments is minimised. Furthermore, landowners and relevant stakeholders within the wider coastal environment should also be consulted.

5.2. Short Term

In the short-term, DLRCC, WCC and Woodbrook Golf club could implement a combination of several of the options outlined in Section 4 of this report to minimise the potential risk to the receptor.

Inspection and Surveillance: Similar to the programme previously initiated by Woodbrook Golf Club in 2015 when the ACM was first encountered. The continuation of these visual inspections is recommended on weekly / bi-weekly basis by a relevant DLRCC / WCC / Woodbrook Golf Club representative / independent contractor. The frequency of inspections undertaken should be increased after periods of adverse weather. Any ACM identified during the inspections should be removed from site and disposed of accordingly.

Additionally, it would also be prudent for an independent consultant to undertake quarterly inspections and sampling in close proximity to the cliff-face where ACM was identified. As part of the continued monitoring these samples would be screened for the presence of asbestos fibres and therefore quantifying the risk to site users.

Clean-up Operation: As noted above, the inspection and surveillance operation will also include a clean-up operation during the weekly inspections. Any ACM identified during the inspections will be removed, double-bagged and disposed of at a licensed waste facility. If, during periods of adverse weather, inspection rounds do identify more contamination hotspots, a team of suitably qualified ACM removal operatives may be required to undertake the clean-up operation.

Remove the Receptors: DLRCC / WCC / Woodbrook Golf Club could 'remove the receptors' from the risk by erecting warning signage outlining the risk of landfill material being exposed during erosion and installing 2.0 m high barrier fence to prevent public access to the landfill area and the beach. Further consultation with key stakeholders i.e. Woodbrook Golf Club as site owners / WCC may be required to assess the feasibility of this approach.

Installation of Short-term Coastal Defence: As an interim measure, DLRCC/WCC could install 'soft' coastal defence along the foreshore to prevent exposure of waste material. As noted, beach nourishment is a short-term option with periodic re-nourishments required to maintain its effectiveness, which may also be eroded during the first significant storm. It also has limitations which include access restrictions to the site, and possible delays due to requirement for a foreshore licence and habitat study.

6. CONCLUSION

The landfill site has been identified as having a high risk from coastal erosion and cliff instability with landfill material also at risk of being eroded and transported down shore. The Tier 2 assessment indicated that a potential moderate risk exists to users of the adjacent site (foreshore / beach), in the absence of mitigation measures due to ACM being exposed during coastal erosion.

Methods of long-term coastal protection possibly applicable to the site include rock armour revetment and stabilising cliff by regrading or riprap rock armour revetment protection with launching apron. A further assessment is required to determine the viability of these options which would include modelling the potential impacts these options may have to coastal erosion and sediment transportation in the coastal environment.

It is recommended that DLRCC, WCC and Woodbrook Golf Club undertake some remedial measures in the interim. This includes a resumption of the *inspection and surveillance programme* by DLRCC / WCC / Woodbrook Golf Club. Any ACM material identified should be removed through a *clean-up operation*. Furthermore, the removal of the receptors from the site could be achieved through the installation of temporary barrier fence and signage however further consultation may be required to determine its feasibility.

7. REFERENCES

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