Landfill Sites Hazard on the Strategic Road Network of England

This guidance note is intended for non-specialists of ground-related hazards and describes the potential of Landfill Sites to impact the safety and performance of the Strategic Road Network (SRN). Together with the Landfill Sites Hazard Rating map and corresponding hazard assessment note on Highways England's Geotechnical Data Management System / Geographical Information System (HAGDMS / HAGIS), the three products support effective management of the Landfill Sites risk to the network.

This guidance note does not replace the need for local and site-specific assessment by Highways England's geotechnical specialists.

How to use this guidance note:

Part I: provides an overview of Highways England's risk management of Landfill Sites hazards
Part II: outlines steps in the risk management framework to enhance the network resilience to Landfill Sites
Part III: provides further background information specific to Landfill Sites, its relevance to the SRN, and key sources of reference

Part I Highways England's approach to managing Landfill Sites risks

Landfills are areas of land used to deposit waste material which are then covered over. Landfills may be sited within excavations (often filling former quarries) or mounded and landscaped over ('land raising'). They represent a long-term presence of potential contaminants that must be contained in accordance with UK law, and where the SRN is built on top of or adjacent to landfills, their stability poses a hazard to the road network. The background of Landfill Sites and its impact on the SRN is summarised in Part III.

Landfill under construction.
Source www.geograph.co.uk

The risk presented by the instability and subsidence of Landfill Sites is not new to Highways England. Any new assessment of the risk should make due consideration of the following factors:

- At the time of construction of the SRN or at the time of undertaking improvement schemes, Landfill Sites and related risks should have been investigated and mitigated appropriate to the standards or advice that applied at the time. Where available, relevant records are held in HE's geotechnical database held on HAGDMS.
- The Geotechnical Risk Management procedures were introduced in the 1990s. Specifically, *HD22 Managing Geotechnical Risk* was first published within the *Design Manual for Roads and Bridges* (DMRB) in 1992. It is therefore reasonable to assume that for schemes post 1992 there is an improvement in the reliability of information captured and retained, along with increased standardisation in investigation, design, and mitigation methodologies across schemes.

1.0 Current ground risk management requirements:

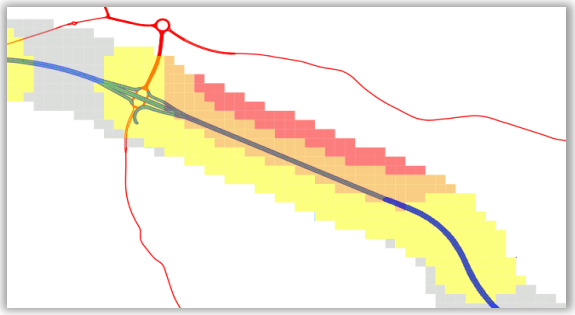
HD22/08 (DMRB Volume 4) presents a framework for geotechnical risk management and is a mandated requirement on all highway schemes where a ground investigation or geotechnical design is required. It establishes the principles of early risk identification and continuity of the geotechnical risk register through the project life cycle from concept to handover.

HD41/15 (*Maintenance of Highway Geotechnical Assets*) provides guidance on the identification and management of 'At Risk Areas' including those of potential Landfill Sites related risk. Consideration of the hazard posed by Landfill Sites to the existing SRN should form a part of the GeoAMP (Geotechnical Asset Management Plan) process. The GeoAMP is

prepared by the Operations service provider, reviewed on an annual basis (at a timeframe agreed with Highways England), and is submitted for agreement by HE.

For guidance on the application of current requirements please refer to the Advice contacts below.

2.0 The Highways England Landfill Sites Hazard Rating Map



Section of the Landfill Sites Hazard Rating map

An HE specific Landfill Sites Hazard Rating map for a 1km corridor centred on the Strategic Road Network has been prepared. This can be accessed on HAGDMS / HAGIS. Version 1 of the hazard map is a synthesis of information relating to Landfill Sites obtained from datasets including Environmental Agency Historic Landfill Sites and Environmental Agency Authorised Landfill Sites. The derivation of this map is explained in detail in a hazard assessment note available on the HA GDMS download page: *HAGDMS Landfill Sites Hazard Rating data description (April 2017).*

The map is intended as a high level hazard awareness map only. **It does not replace the need to seek expert advice** from within Highways England and undertake site-specific studies. As noted above, consideration of Landfill Sites along with all other ground-related hazards is an inherent part of risk management within Highways England's geotechnical standards.

3.0 Further advice

To obtain further advice on the hazard Groundwater Flooding poses to the Strategic Road Network, or for any other issues associated with ground-related hazards, please contact the following:

- Environmental Advisors available within Environment (& Drainage) Group and
- Geotechnical Advisors available within Highways England's Geotechnics and Pavement Group.

Role of Highways England's Geotechnical Advisors:

- Technical oversight of schemes, to ensure the technical input is appropriate, complies with HE standards and delivers good value.
- Cascading local knowledge and good or bad experiences from other projects
- Evaluating and supporting innovation opportunities to promote efficient delivery.
- Providing asset data and information management services.
- Managing knowledge improvement for the geotechnical discipline, including Standards and Advice Notes and supporting Integrated Asset Management in Highways England.

Part II Using the Landfill Sites Hazard Rating map to enhance resilience of the SRN

Resilience of the Strategic Road Network comes from both adequate design and maintenance, mitigation of hazards, and having appropriate response and recovery measures in place should the hazard occur. Selection of appropriate mitigation (proactive, pre-event) measures versus response and recovery (reactive, post-event) cannot be prescriptive, but the guidance below can be used to support risk-based decision making.

1. Define the hazard event

A hazard 'event' can be defined as '*the event that could occur due to the presence of the hazard*'. The following are different hazard events related to the presence of Landfill Sites along the SRN, and these present different risks to the network:

- Collapse or settlement/subsidence of the landfill beneath the SRN (may be sudden or progressive)
- Differential settlement – particularly where spanning across the edge of landfill site (the 'high wall')
- Release of leachate, gas and/or other hazardous waste related components into the SRN environment (including drainage system) or to third party land

2. Consider potential external triggers of the hazard event

There may be little or no warning of a landfill-related hazard event, but if specific triggers have been identified, these can be monitored to improve the management of the risk. The following are potential external triggers of a landfill-related hazard event:

- Vibration or disturbance, e.g. due to traffic, construction activities and excavation
- Groundwater regime change (refer also to the Groundwater Flooding hazard guidance note)
- A surface flooding event
- Leakage from nearby water mains, sewerage or drainage
- Sudden collapse of a void-containing waste element (e.g. a refrigerator that has not been properly pre-crushed)

Note that the above water related triggers (surface or groundwater, flooding etc.) may be exacerbated by climate change.

The following are also potential external triggers specifically related the release of contamination:

- Puncturing of containment layers
- Puncturing, rupture or failure of leachate / gas collection pipework and system

The *hazard rating* given on the Landfill Sites Hazard Rating map is not an absolute indicator of the likelihood of a hazard event occurring, but a relative indicator of the potential presence of Landfill Sites, compared to the rest of the network. The Landfill Sites hazard rating is not directly comparable to hazard ratings derived for other hazard types.

To undertake a qualitative assessment of the likelihood of either a subsidence or contamination leakage, the following factors are relevant:

(A) The likely presence of Landfill Sites

- Refer to the Landfill Sites Hazard Rating map
- Evidence of leachate seepages on slopes or within drainage systems

(B) Inherent properties, characteristics, and legacy issues

- Age (and design life) of the landfill – indicative of engineering design standards followed and operator management, plus potential degradation of lining materials. The introduction of the Landfill Directive in 2002 represents best available techniques for landfilling. Other milestone changes in legislation are summarised in Part III.
- Type of landfill – indicative of both the waste mass ability to break down (e.g. organic material) and the potential to generate contaminants (with age also being relevant)
- A history of problems, instability, contamination leakages
- Location of landfill – contamination leakage to a sensitive receptor (SRN environment / protected aquifer, third party land) is less likely when the landfill is more remote
- Age or construction/maintenance records of the SRN – indicative of the types, current effectiveness (including age degradation) and completeness of any investigations and measures undertaken to stabilise landfills and address potential contamination issues

(C) Presence of any mitigating / exacerbating features

- A hydrogeological regime allowing water flow around a landfill perimeter – potentially promoting contaminant mobility

(D) Indicators that a triggering action (as listed in Step 2: Triggers) is likely to occur

- A history of flooding (also refer to the groundwater flooding hazard guidance note)
- Recent / forecast heavy or prolonged rainfall
- Tap roots and deep roots that could potentially penetrate a landfill capping layer
- Animal burrowing (where capping layer is not sufficiently thick / deep – which may be possible with older landfill constructions)
- Traffic loading (volume) increases
- Construction / demolition activities, excavations and deep drilling, and temporary plant – particularly relevant for improvement schemes (especially 'Technology' schemes)
- New structures and permanent loads
- Blocked / insufficient / absent drainage
- Water/wastewater pipes in poor condition, e.g. aged or damaged through construction-induced ground movements
- Groundwater extraction / dewatering, soakaways, irrigation

An understanding of the likelihood of a Landfill Sites hazard event occurring may also be assessed from historical records and frequency of similar problems on the strategic road network and the surrounding area. Where HAGDMS contains report records* demonstrating that this hazard was assessed in accordance with current risk management procedures and standards it is reasonable to assume a lower likelihood of a hazard event. There is planned research and development into the use of sensing techniques and other data to identify the presence of ground-related hazards, which could support the likelihood assessment described above.

4. Consider the potential impact on the safety and/or performance of the SRN

A quantitative assessment of impact on a national scale is not possible, but at a local level, the following factors should be considered to understand the potential impact:

(A) Factors specific to the hazard event:

- For landfill stability: the nature (or rate) of failure and the amount of warning available – a rapid, catastrophic event presents the highest safety consequence.
- For landfill stability: the size of the potential failure – a large collapse presents a much higher safety risk to potentially many more users of the network than a small collapse would. Estimation of collapse size requires local consideration and expert input.
- For landfill stability: heterogeneity of material – differential settlement caused by softer or harder masses within the waste material results in more damage to overlying pavement or structures compared to uniform settlement. The rigid 'high wall' at the edge of a landfill is likely to be a point of significant differential settlement.
- For landfill failure: The location of the potential failure – a collapse in a main running lane presents both higher safety impact, and higher performance impact than one in a hard shoulder or beyond.
- For contamination: The type of the waste – landfills are currently classed as either inert, non-hazardous or hazardous. Landfills constructed prior to 1974 were not subject to any classification requirements and could contain a variety of different types of material. In addition, some substances such as asbestos are considered toxic (but only as of 1985) but stable such that they do not represent a mobile (waterborne / airborne) contamination risk.
- Consideration of potential investigation and remedial works – the longer these could take, the longer the performance impact.

(B) Factors specific to the location of the hazard event on the network:

- The speed and volume of traffic using the road – where higher it typically correlates to an increased safety impact.
- The type of pavement – a sudden/catastrophic failure is more likely where there is loss of support beneath by a rigid pavement whereas a flexible pavement show early signs of a failure.
- The type of road – smart motorways being the most important in terms of performance, down to All Purpose Trunk Roads (APTR) being the least.
- Proximity to environmental protection sites or protected aquifers – higher sensitivity to contamination and any remediation required will be more onerous
- Presence of technology – smart motorways could be assumed better able to respond to an event in terms of traffic management.

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* The Topic Search tool within HAGDMS facilitates a search across several of the system's databases for information related to a particular topic, for a chosen location. Topics are pre-defined by the System Administrator and currently cover a number of ground-related hazards and therefore the databases searched are focused on geotechnics rather than drainage.

- Receptor space for potential contamination – harmful gases such as methane entering confined spaces, e.g. sewers will have a much a much more concentrated human safety impact than if released into open spaces.

5. What is the risk (considering likelihood and impact) that Landfill Sites presents to the SRN?

This can be qualitatively assessed, and should inform subsequent decision making. Uncertainty should be recognised and decisions should typically be cautious, particularly where there are high levels of uncertainty (or lack of data).

6. Select appropriate measures to mitigate risk and enhance resilience

Measures taken to mitigate risk and enhance resilience may be either proactive or reactive. Typically, the greater the safety or performance risk to the SRN in terms of both likelihood and impact of an event, the greater the benefits of undertaking proactive mitigation. When selecting appropriate measures, there should be early engagement with Environmental and Drainage, and Geotechnical Specialists from both Highways England and service providers and where appropriate the Environmental Agency.

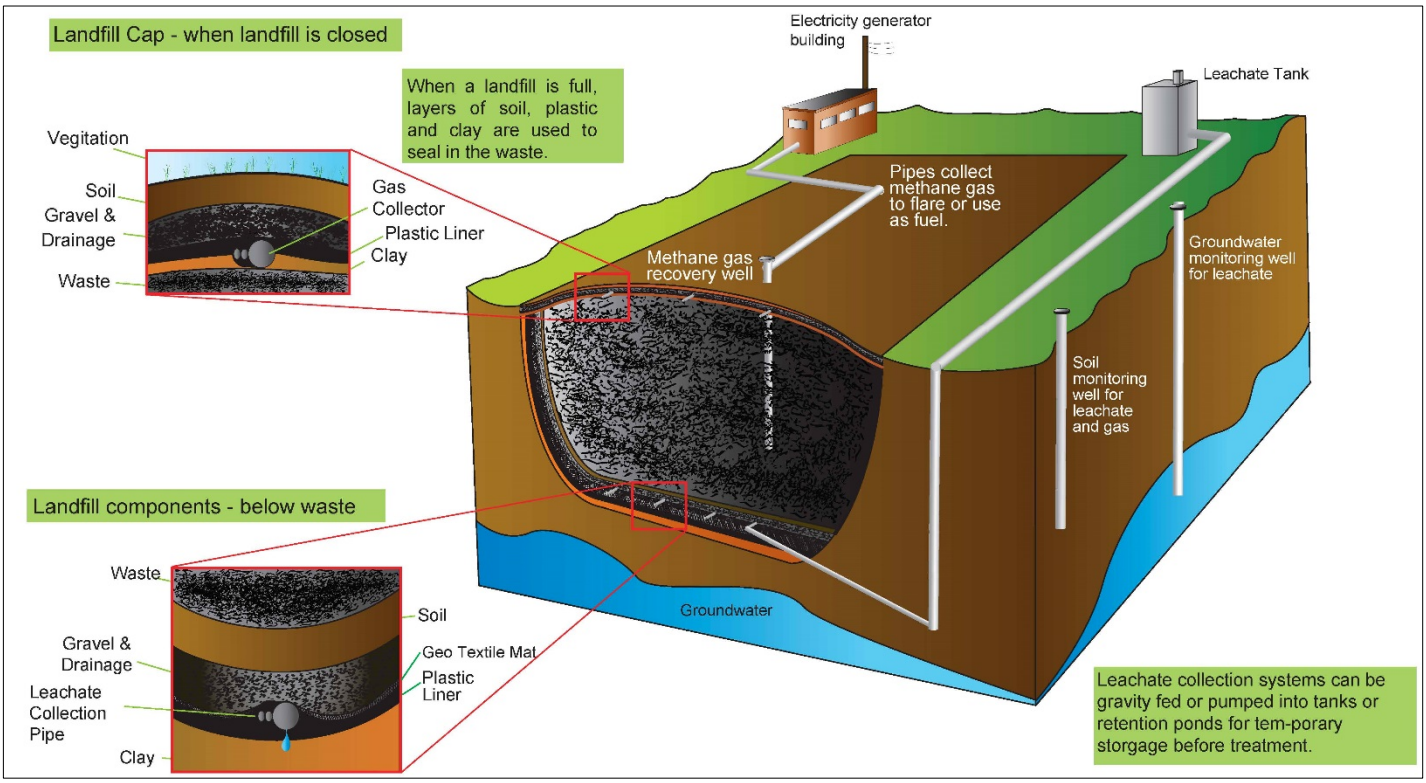
High level risk management measures are likely to be specific to both the hazard event and whether it is a construction and/or on-going operations risk, but all measures would fall into one of the following categories:

- **Investigation:** To understand the current condition and therefore likelihood of the hazard event. Investigation may reduce the uncertainty and hence reduce the need for additional mitigation measures.
- **Intervention:** Where there is an evident cost-benefit in implementing measures (barriers) to prevent the hazard event from occurring, or mitigating measures to limit the impact should it occur.
- **Monitoring:** To allow appropriate operational responses to be implemented in anticipation of a potential hazard event. (Leachate is included as a specific observation item within geotechnical inspections)
- **Response and recovery:** To respond rapidly to a potentially unexpected hazard event, development of response plans is recommended for areas of known Landfill Sites risk. Response plans should include:
    i. Engagement with Highways England technical specialists – named focal points (and responsibilities) should be clearly identified.
    ii. Identification of third party land owners where the landfill is located outside the SRN boundary. Also procedures for gaining access where required to third party land.
    iii. Being prepared to close lanes and/or implement diversions, and have an understanding of the potential duration of these measures until the SRN may be fully operational – this includes a broad range of communications, such as Highways England's suppliers, road users and the general public. These should be linked to Incident Response Plans (IRPs).
    iv. Likely response options should be identified – based on the particular hazard events and anticipated consequences. The time and resources that would be required to implement the options should also be considered.
    v. Incident recording – following initial recovery, a full record of the mitigation works (as part of Health and Safety file recording), the cause of the event assessed, the risk of similar events occurring elsewhere on the network evaluated, and appropriate actions taken to manage the incident should be recorded. All geotechnical events must be recorded on HAGDMS.

Part III An overview of Landfill Sites in England

1.0 Basic components of a modern landfill construction

The figure below shows the main features of a typical landfill constructed today. The presence, quality and durability of the encapsulation system of older landfill sites can only be expected to be in accordance with the legislative requirements at the time of construction, and subject to subsequent age deterioration.



Construction of a modern landfill. Source: www.re3.org http://www.geograph.co.uk/

Landfill Sites are susceptible to volume changes (reduction) as materials break down and liquids (leachate) and gas (e.g. air, methane, etc.) are expelled from the waste mass. Subsidence follows the construction initially as voids within the waste mass or voids within waste elements collapse simply under the landfill's own weight or any initial surcharge load that is applied. There is then volume reduction as the self-weight / surcharge squeezes out leachate. Subsequently, there is further volume reduction as the load is taken directly by the solid waste elements which rearrange and crush, decompose and expel more leachate/gas. The rate and degree to which the waste mass volume can reduce depends on the type of waste contained (e.g. municipal, industrial, organic, etc), the geometry of the landfill, and the surcharge loads and groundwater pressures applied.

2.0 Environmental legislation

There is a significant amount of primary and secondary environmental legislation that concerns landfills as well as wider waste management and pollution control. The specific obligations and requirements placed by UK law (for instance, the requirement for Materials Management Plans during construction) are beyond the scope of this guidance note; however the Highways England Environment (& Drainage) Group should be contacted directly for further information and advice.

The following describes the role of key legislation as is relevant to the improvement in standards in the engineering of landfills and the control of contamination:

(A) Legislation covering the construction of landfills:

The Control of Pollution Act 1974 (COPA) was the first piece of legislation that introduced the requirement for landfill sites to be licensed. Local authorities became the regulatory bodies to administer the Act. Licenses required operators of landfills to control the escape of landfill gas and discharges of water from the site, and a licence could be refused in the event that such pollution was likely. Landfills built prior to this Act and even for many years after were likely to contain toxic contamination with no containment engineering for pollution control. Further, certain materials treated as toxic waste today were not always considered so in the past; for example blue and brown asbestos was not banned until 1985.

In terms of the stability of the landfills, the publication of Waste Management Paper 26 in 1986 by the former Department of the Environment, although not statutory guidance, effectively established initial standards for landfill engineering. It described the main engineering components of landfills that continue to be important in current design, including:

- bulk earthworks
- underdrainage
- liners - mineral and synthetic
- leachate / gas management
- monitoring

However, planning authorities were not required to consider the impact of the landfills on the local environment until 1999, when Environmental Impact Assessment Regulations (SI 1999 No 293) came into effect. This was followed by the introduction of the Pollution Prevention and Control (PPC) 1999 Act that has changed the environmental permitting of industrial activities including landfill, that have a pollution potential. The principle of PPC is through the application of Best Available Techniques (BAT), which sets out standards of operation that are acceptable on an industrial sector basis.

Implementation of the Landfill Directive via the Landfill Regulations (2002) is considered to constitute BAT for landfilling. All new PPC permits for landfills have to comply with the technical measures outlined within Annex I of the Directive. Schedule 2 of the Landfill (England and Wales) Regulations 2002 sets out the containment measures required at landfill sites. These set out some minimum requirements, including the following:

- siting of landfills where a geological barrier is provided
- provision of a two component lining system
- no unacceptable discharge from the waste throughout the lifetime
- construction of a barrier in a manner to ensure that it remains stable

A detailed history of the development of landfill legislations is available from www.gov.uk – *Stability of Landfill Lining Systems: Report No. 1 Literature Review*, R&D Technical Report P1-385/TR1.

(B) Legislation concerning the management of contaminated land:

Management of contaminated land is closely linked to issues relating to landfill sites. The primary legislation was introduced in 1995 as an amendment to the Environmental Protection Act 1990 and became effective from 2000. The following is a summary of the legislation taken from 'Dealing with contaminated land in England' published by the Environment Agency in April 2016.

It [Part 2A of the Environmental Protection Act 1990] *provides a framework for identifying land where historical contamination has resulted in an unacceptable risk to human health or the environment, and aims to ensure land identified as 'contaminated land' under the regime will be remediated where possible. Local councils are the lead regulators for Part 2A.*

The overarching objectives of the Government's policy on contaminated land and the Part 2A regime are to:

(a) Identify and remove unacceptable risks to human health and the environment.
(b) Seek to ensure that contaminated land is made suitable for its current use.
(c) Ensure that the burdens faced by individuals, companies and society as a whole are proportionate, manageable and compatible with the principles of sustainable development

The Part 2A statutory guidance requires local councils to write an inspection strategy for their areas. Inspections involve local councils looking at previous land uses and activities that may have caused contamination and assessing the potential risks from these to people and the environment. Part 2A provides a legal definition of contaminated land. The accompanying statutory guidance introduces the idea of significant contaminant linkages that must be present in order to define land as contaminated land. Where all of these conditions are met, a local council can then determine the site to be contaminated land under Part 2A.

Once a site has been determined as contaminated land decisions can be taken about how to deal with it and who should pay. In some specific circumstances (that are defined in the Contaminated Land (England) Regulations 2006) the Environment Agency becomes the enforcing authority. This happens when a site is designated by the local council as a special site.

In either case, remediation should be carried out by the appropriate person(s). There are two classes of appropriate person:

1. *Class A: those persons who caused or knowingly permitted the pollution*
2. *Class B: a site owner or occupier – but would only be liable if a Class A appropriate person cannot be found for a particular significant contaminant linkage.*

The provision for remediation follows the 'polluter pays' principle. Where an appropriate person may be unable to pay for remediation, the regulators must consider hardship. The regulator may also be able to recover costs if they do the remediation. However, where no appropriate person can be found the cost of remediation may be met by taxpayers.

Remediation can be achieved by breaking the source-contaminant-receptor linkages. For example, removing or reducing the source of contamination, blocking the pathway between the contamination and the receptor, reducing the exposure of the receptor to the contamination or removing the receptor all together. The remedial actions are documented. Enforcing authorities have a duty to maintain a public register that records regulatory action taken regarding the remediation of contaminated land.

3.0 Landfill Sites and the Strategic Road Network

The hazard posed by Landfill Sites can be considered to arise from the potential for:

- instability of a landfill adjacent to or beneath the Highways England estate to either collapse suddenly and catastrophically or to cause settlement/subsidence. Instability could result from:
  - unidentified, and hence unmanaged, landfills
  - inadequate compaction and stabilisation methods (compared to current practice/guidance), which may correlate to the approximate date of works
  - the stabilisation measures employed have deteriorated subsequently due to changes unforeseen at the time of treatment (e.g. chemical, groundwater changes or surface flooding) or there has been further material decomposition and expulsion of leachate / gas
  - new unassessed landfill related activities
- failure to contain leachate / gas within the landfill or treatment plant, releasing harmful or toxic substances into the SRN environment or, where the landfill is under HE management, into third party land. Mobility of any released leachates in particular will be further increased where there is flooding or groundwater flow around landfill.

Management activities carried out for a landfill may have been undertaken by the original operator of the site, or subsequently, for example such works may have been included in the construction or subsequent maintenance of the SRN. The age of the landfill, and the age of the SRN can be useful guides to indicate the scope of works that may have been carried out and to what degree of effectiveness, in particular in relation to the regulations that applied at the time. For existing sections of the SRN, it is reasonable to assume that remediation has taken place where contaminated ground has previously been identified.

When constructing new roads, specialist advice may be required to identify sites that could become classed as 'contaminated land' where the change in use increases likelihood of exposure. In such instances, it can be a grey area to determine who is responsible for remediation.

This note focuses on the potential failure of pre-existing landfills, but potential hazard associated with the construction of new landfill site should not be ignored.

4.0 Key references and further information

Landfill Sites Hazard Rating map, 2017, HAGDMS / HAGIS

HAGDMS Landfill Sites Hazard Rating data description, 2017

Guidance on the management of landfill sites, CIRIA, 2012

Remedial engineering for closed landfill sites, CIRIA, 2001

Stability of Landfill Lining Systems: Report No. 1 Literature Review, Environment Agency, 2003

Dealing with contaminated land in England, Environment Agency, 2016

Acknowledgement and contact details

This work has been informed by two tasks currently being undertaken as part of HE's Innovation Programme: Task 1-085 *Resilience enhancement measures for geotechnical assets* and Task 1-062 *Geotechnical Hazard Knowledge*.

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