Non-Coal Mining 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 Non-Coal Mining to impact the safety and performance of the Strategic Road Network (SRN). Together with the Non-Coal Mining 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 Non-Coal Mining 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 Non-Coal Mining hazards
Part II: outlines steps in the risk management framework to enhance the network resilience to Non-Coal Mining
Part III: provides further background information specific to Non-Coal Mining, its relevance to the SRN, and key sources of reference

In addition, a detailed commentary on the history, geography and hazards presented by Non-Coal Mining in the UK can be found in the executive summary of the Arup Review of Mining Instability in Great Britain, prepared for the Department of Environment in 1990.

Part I Highways England's approach to managing Non-Coal Mining risks

There is a history of mining various types of rock and minerals within England that have left a legacy of mines, shafts and adits. The history of Non-Coal Mining and its impact on the SRN is summarised in Part III.

For hazards associated with Coal Mining or Brine Extraction refer to the corresponding hazard guidance notes.

The risk presented by the legacy of Non-Coal Mining is not new to Highways England. Any new assessment of the risk should make due consideration of the following factors:

Void in central reservation of M2 due to a chalk mine. Source: Highways England

- At the time of construction of the SRN or at the time of undertaking improvement schemes, Non-Coal Mining 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.

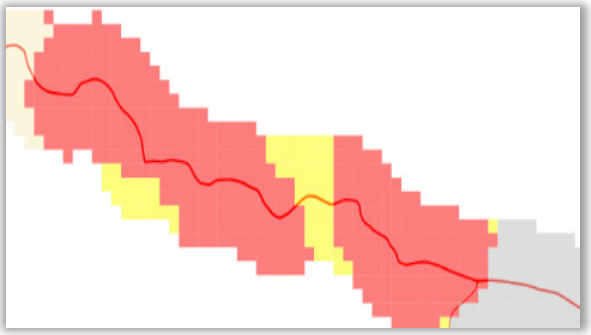
1.0 Current ground risk management requirements:

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 Non-Coal Mining related risk. Consideration of the hazard posed by Non-Coal Mining 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 Non-Coal Mining Hazard Rating Map



Section of the Non-Coal Mining Hazard Rating map

An HE specific Non-Coal Mining 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 Non-Coal Mining obtained over several years from organisations including British Geological Survey, Environment Agency, Ove Arup & Partners, Peter Brett Associates and Wardell Armstrong LLP. The derivation of this map is explained in detail in a hazard assessment note available on the HA GDMS download page: *HAGDMS Non-Coal Mining 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 Non-Coal Mining 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 Non-Coal Mining poses to the Strategic Road Network, or for any other issues associated with ground-related hazards, please contact one of the 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 Non-Coal Mining 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 Non-Coal Mining beneath the SRN, and these present different risks to the network:

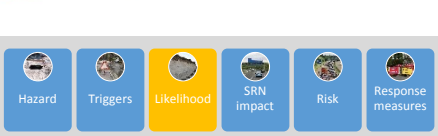
- Collapse of a shallow mine working (may be either sudden or progressive)
- Settlement/subsidence related to presence of deep mines (typically progressive)
- The collapse of a mine shaft or mine adit (typically sudden)
- The appearance of mine water on or adjacent to the SRN

2. Consider potential external triggers of the hazard event

There may be little or no warning of a mine-related failure, 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 Non-Coal Mining hazard event:

- A surface flooding event
- Change in surface water flow and changes in drainage
- Groundwater regime change (refer also to the Groundwater Flooding hazard guidance note)
- Erosion
- Change in surcharging or loading
- Leakage from nearby water mains, sewerage or drainage

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



3. Assess the likelihood of the hazard event occurring

The *hazard rating* given on the Non-Coal Mining 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 Non-Coal Mining, compared to the rest of the network. The Non-Coal Mining 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 mining collapse or related subsidence, the following factors are relevant:

(A) The likely presence of Non-Coal Mining

- Refer to the Non-Coal Mining Hazard Rating map
- Refer to area-specific report records held on HAGDMS
- Indicators that mines would not be captured by records and therefore not included within the Non-Coal Mining Hazard Rating map:
  - Areas of mining pre-1872 – i.e. prior to regulatory registration of mines
  - Areas where mining records are incomplete – such that low confidence that all mines are captured
  - Areas of small mine workings (<12 men) prior to 1993 – registration of mines was not required

(B) Inherent properties, characteristics, and legacy issues

- Age of mining / method of extraction / date of abandonment – indicative of inherent stability and original measure to make the mine safe
- Mineral mined – indicative of construction techniques, geometry and frequency of shafts / adits if not known
- 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 manage the mine
- Brine springs, brine extraction sites, or a hydrogeological regime allowing fresh water flow through an abandoned salt mine – may indicate stability issues relating specifically to salt mines. (A separate guidance note is available addressing the hazards associated directly to Brine Extraction.)

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

These may be considered by the type of triggering mechanism:

- Weakening of the mine structure, as may be indicated by:
  - A history of flooding (refer also to the Groundwater Flooding hazard guidance note)
  - Recent / forecast heavy or prolonged rainfall
  - Blocked / insufficient / absent drainage
  - Water/wastewater pipes in poor condition, e.g. aged or damaged through construction-induced ground movements, and may leak or cause local flooding
  - Groundwater extraction / dewatering, soakaways, irrigation
- Destabilisation through additional loading, as may be indicated by:
  - Traffic loading (volume) increases
  - Construction / demolition activities, excavations, and temporary plant
  - New structures and permanent loads

An understanding of the likelihood of a Non-Coal Mining 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:

- The rate of failure and the amount of warning available – a rapid, catastrophic failure presents the highest safety consequence.
- The size of the potential failure – a large failure presents a much higher safety risk to potentially many more users of the network than a small one would. Estimation of failure size requires local consideration and expert input.
- The location of the potential failure – ground movement directly beneath a main running lane presents both higher safety impact, and higher performance impact than beneath a hard shoulder or beyond.
- 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.
- Presence of technology – smart motorways could be assumed better able to respond to an event in terms of traffic management.

5. What is the risk (considering likelihood and impact) that Non-Coal Mining 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

* 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.

undertaking proactive mitigation. When selecting appropriate measures, there should be early engagement with Geotechnical Specialists from Highways England and service providers.

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 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.
- **Response and recovery:** To respond rapidly to a potentially unexpected hazard event, development of response plans is recommended for areas of known Non-Coal Mining risk. Response plans should include:
    i. Engagement with Highways England technical specialists – named focal points (and responsibilities) should be clearly identified.
    ii. 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).
    iii. 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.
    iv. 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 The legacy of Non-Coal Mining in England

1.0 History

There is a long history of mining in England, having taken place over 5000 years, in varying extents in different counties. Many different raw materials have been extracted from the ground, ranging from precious metals to mining for construction materials such as limestone, sandstone, chalk etc. Chalk was often mined wherever it outcropped – primarily in Southern England. Other rocks including limestone were mined Yorkshire and to a lesser extent in Lancashire, Greater Manchester, Derbyshire, West Midlands, Cumbria and Cleveland. Cornwall was the area most intensively mined for metalliferous ores, but places such as Devon, Somerset, Derbyshire, Staffordshire, the Pennines, Cumbria, Clwyd, Ceredigion and Montgomeryshire also have extensive evidence of historical mining.

Grinkle ironstone mine culvert collapse, North York Moors
(© http://www.geograph.org.uk/profile/22761)

The Arup Review of Mining Instability in Great Britain classified the mineral types into five categories; rocks (e.g. sandstone, limestone), metalliferous (non-ferrous) ores, iron ore outside coalfields, evaporites (e.g. rock salt or potash) and coal and its associated minerals. Coal and associated minerals is addressed within the Coal Mining hazard guidance note, and pumping of brine is addressed within the Brine Extraction hazard guidance note.

Pillar and stall mining of limestone, Gorebridge, 1945. Source: BGS

Mining of chalk was undertaken as a source of lime for agricultural purposes (soil improvement) and for construction materials e.g. lime mortar. These 'deneholes' and 'chalkwells' as the different shaped mines were known, were sunk to extract material throughout England from Medieval times. Shafts would have been 10-20m depth and unlined. Deneholes were frequently capped by placement of an upturned bush into the top and filling over with soil. Limestone was also frequently mined for similar purposes, but it has been mines at greater depths using extraction methods similar to coal mines e.g. pillar and stall.

Bell pits for iron ore extraction were common in 13th – 17th centuries. Metalliferous ores such as lead, zinc, tin and copper often occur in tabular veins within discontinuities in rock. They are typically steeply inclined and the techniques of mining reflect this. Access to the minerals is usually through shafts driven vertically through the vein that are connected through cross cuts. Characteristically there are a large number of veins in one area, which means that it is common for many shafts to be placed adjacent to one another. In other areas minerals do not occur in regular tabular veins. The mining in these areas reflect this irregularity and methods of extraction vary according to the geometry of the deposit.

Mines closed before 1872 will have more incomplete records. After that date, the Metalliferous Mines Regulation Act of Parliament was passed that included the requirement of mine owners to deposit plans with the state after mine closure. Incomplete records signifies an increased likelihood of unidentified and hence untreated mines and mine openings. Furthermore, older mines tended to be shallower, with increased number of shafts. However non-coal mines were not required to deposit plans if there had been less than 12 men employed below ground, and this relaxation was perpetuated in all subsequent legislation until 1993. This means that recent small mines may not necessarily be recorded.

It is also of note that the Coal Authority, whose powers were extended in 2011 to enable support to non-coal mine related issues, has no statutory obligations with respect to Non-Coal Mining, but may offer commercial consulting and response services.

2.0 Non-Coal Mining and the Strategic Road Network

The hazard posed by Non-Coal Mining can be considered to arise the potential for:

- voids beneath the Highways England estate with the potential to either collapse suddenly and catastrophically or to cause subsidence. These voids could be present due to:
  - unidentified, and hence unmanaged, mines or mine shafts (often older mines or mine entries are more difficult to locate)
  - inadequate stabilisation methods (compared to current practice/guidance), which may correlate to the approximate date of works
  - the measures employed have deteriorated subsequently due to changes since the time of works (e.g. chemical, groundwater or surface flooding) or have reached the end of their serviceable life
  - undetected fissuring in certain surface rocks resulting from ground strains caused by longwall mining at depth
- abandoned non-coal mine workings to produce potentially dangerous emissions, such as mine gas or polluting mine waters.
- former mine caverns or cavities to have subsequently been utilised for other purposes e.g. storage of hazardous materials or backfilled with hazardous or contaminated waste.

This note focuses on the potential for voids and subsidence, but the potential for release of hazardous gas or polluted waters or other contaminants should not be ignored – also see the Aggressive / Corrosive Soil and Groundwater hazard guidance note.

The type of hazard that the presence of these mines presents to the SRN is further significantly influenced by the type of material that was mined, and the way in which it was extracted. Broadly speaking, the hazard type can be grouped based on the following categories:

- **Collapse of mine entries (shafts and adits):** mine entries are the most likely cause of mining related subsidence. They can often pass through weathered rocks and weak soils near to the ground surface. Entries may have been treated for stability but both treated and untreated shafts and adits can collapse.
- **Crown holes (localised collapses into mine voids):** These can occur when mines extracted using the pillar and stall method collapse. It is common that when abandoned, mines using this extraction method are uncollapsed or only partially collapsed. Later deterioration of the mine roof and pillars can lead to eventual total collapse. The ground movements due to collapse can take many years to manifest. If they fall into mine voids they can cause crownholes to appear. Most crownholes arise from mines at depths shallower than 30m, there have been recorded incidences of arising from mines at depths greater than 100m.
- **General subsidence:** Several types of mining can cause general collapse. For example if the roof and pillars in a mine collapse the whole overburden can subside. Alternatively total extraction methods can cause general subsidence. Total extraction methods are achieved by either mining the pillars that are left during partial extraction or by mining the mineral on a long face. The general subsidence can take the form of a wide saucer shaped depression of the land surface, which is different from the sharply defined discontinuities that are associated with crownholes. Total extraction can cause this type of subsidence because the overburden is generally allowed to collapse, although in some cases the mine roof is supported in the short term to reduce subsidence effects at the land surface. This subsidence is usually predictable and occurs within a few years of extraction, and is therefore less likely to be of concern for Highways England, although groundwater changes (e.g. climate change related or due to changes in groundwater abstraction) could reinitiate subsidence. Mining subsidence may result in differential settlement across structural geological discontinuities (e.g. faults or major joint sets), which could pose a hazard to surface assets.

At the time of mine abandonment, works such as capping of shafts and backfilling of workings may have been carried out, depending on when the mine was closed. Equally, these activities may have been undertaken at a later stage, for example at the time of construction of the SRN. Historical reports on HAGDMS may provide further information on this and any changes since construction. It is reasonable to assume that if during SRN works a mine was known to be present, there will have been investigation and stabilisation measures undertaken, with the following broad observations:

- Mine stabilisation undertaken before the publication of the CIRIA SP32 (1984) may have been less effective and more ad hoc.
- Mine stabilisation measures implemented before 1984 have now been in place for over 30 years and therefore carry uncertainties about the deterioration due to ageing or other external factors.
- Between 1984 and the first publication of the DMRB in 1992, there should have been an improvement in the investigation and stabilisation of mines based on the level of guidance available.
- Since the publication of the DMRB in 1992, (particularly HD22, management of geotechnical risks) there has been less uncertainty, better records on HAGDMS, and more effective and consistent investigation and stabilisation.
- Where stabilisation has been undertaken in the last 10 years, and has experienced less age-related deterioration the above-mentioned issues of deterioration of stabilisation are less significant, and records should be easily accessible to confirm adequate investigation and stabilisation.

3.0 Key references and further information

Non-Coal Mining Hazard Rating map, 2017, HAGDMS / HAGIS

HAGDMS Non-Coal Mining Hazard Rating data description, 2017

Arup, Review of Mining Instability in Great Britain, 1990

CIRIA SP32 Construction over abandoned mine workings, 1984

CIRIA C758 Abandoned mine workings – publication pending

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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