Science Advisory Council (SAC)

Report by SAC Sub-Group on 2001 Foot and Mouth Outbreak Carcass Burial

15 March 2017

Contents

Executive Summary

The Foot and Mouth Disease (FMD) carcass burial sites should be managed in a way that ensures the risks to human health and to the environment are negligible in terms of biosecurity and water quality.

The evidence available to inform management decisions comes from the monitoring data for each site. These data are variable in quality and extent and cover chemical parameters alone. They are designed to meet environmental permitting regulations.

To date, the evidence available has not been used to provide reassurance that the sites are: (i) effective at controlling the risk, and (ii) can support decisions needed regarding future risks to biosecurity and water quality. The latter is needed to understand at what point in the future the risk to human health and the environment is sufficiently small that the environmental permits can be surrendered and the liability for ongoing site management on Defra removed.

In relation to **biosecurity and water quality risk**, the advice of the sub-group is:

1. The risk of the FMD virus surviving from the date of the carcass burials in 2001 is *negligible*. Animals that were known to be infected were not buried and the evidence is that the virus in any infected carcases that were buried will not have persisted in the burial sites. Further detail is given at Section D.1
2. Based on the available evidence, the advice of the sub-group is that the overall risk of other notifiable diseases spreading from the sites is *very low*. Further detail is given at Section D.2
3. The risk to water quality risk can be derived from projections of the end-points for the leachate decay curves subject to the completion of a *systematic review* of the monitoring regimes at the burial sites described below. Further detail is given at Section D.3
4. Given the scale and unique status of the 2001 FMD outbreak burial sites, and the likely continued public interest in them, a *systematic review* of the monitoring regimes at all the burial sites should be undertaken. The purpose is to design a robust monitoring programme that provides scientific evidence on water quality risks that is sufficient to establish the remaining liability at the sites. The data emerging from the sites should be analysed regularly, with a view to ensuring the monitoring remains fit for purpose and cost effective. The two pieces of work recently commissioned by Defra, which are based on the advice of the sub-group, are the start of this systematic review and should be used to inform the forward management of the FMD carcass burial sites managed by Defra.

In relation to the **forward management** of the FMD carcass burial sites, the advice of the sub-group is:

1. Defra SAC consider the value of extending the recently commissioned work on water quality risk to the three other burial sites managed by Defra.
2. Biological monitoring is *not* added to any revised monitoring programme for the FMD carcass burial sites because animals buried in the pits were thought not to be infected with FMD virus (FMDV). Even if some infected, but not diagnosed animals had been

buried, the evidence is that the virus will not have persisted. Furthermore, formal notifiable animal disease control at international levels generally operates on the principle that testing is not carried out where disease is not suspected.

3. The systematic review of the water quality monitoring regimes is used to:
    a. Identify any trends/anomalies that would indicate existing contamination of water quality adjacent to the burial sites and at receptors.
    b. Evaluate the risk of burial pit (cell) rupture, including assessment of how many burial pit (cells) would need to rupture for a demonstrable impact on water quality.
    c. Identify the risk to water quality of leaving the physical infrastructure of the sites to degrade “naturally” *vs* intervention to maintain their physical structures.

4. Defra SAC consider a proposal that Defra should commit to not disturbing the burial pits (cells) beyond essential maintenance requirements (noting advice under 3c above). The sub-group identified a small risk that a major disturbance of the site could potentially increase the risk of contamination of spores through the release of microbial material from partially degraded carcasses (Anthrax, Clostridium).

Further detail on the forward management of the sites is given in Section E.

A. Purpose

As part of the response Defra took to managing the 2001 Foot and Mouth Disease (FMD) outbreak, livestock carcasses were buried in five locations in England and Scotland. Defra have operational and management control over four of these sites.[1] In total, some 1.3 million carcasses - around 20% of the total 6 million animals slaughtered during the outbreak, were disposed of by this route.[2] These sites are the largest mass burial of livestock carcasses anywhere in the world: there is no precedent on which to base risk analysis at comparable scales.

In 2015, the National Audit Office (NAO) took the view that Defra has a 100-year financial liability, from the date of the carcass burials, to protect water quality and contain any potential biosecurity breaches arising from the burial of the carcasses. Accordingly, Defra's annual accounts must carry a financial provision for the 2001 FMD outbreak burial sites. **The only way to reduce the provision is to reduce the life of the liability.** The burial sites are managed by contractor(s) at a cost to Defra of approximately £1m per annum for maintenance of the sites, and approximately £1m per annum in clean-up costs.

Prior to 2015, the liability in the financial accounts was 25 years from 2001. The NAO assessment of risk underpinning Defra's liability was not informed by scientific evidence relating to biosecurity and water quality at the 2001 FMD outbreak carcass burial sites. Consequently, a sub-group of Defra's Science Advisory Council (SAC) was established to evaluate the evidence base and provide independent advice and assurance to the Defra Chief Scientific Adviser (CSA) through Defra SAC. The sub-group is not a decision-making body. The terms of reference for the sub-group are given in **Annex A**. The membership of the sub-group is given in **Annex B**.

The purpose of the sub-group is to come to an informed view on the risk to biosecurity and water quality from the carcass burial sites managed by Defra. The sub-group was also asked to provide advice on the possible courses of action to manage the risk, and what evidence is needed to inform the estimated nature and length of the liability with respect to the Environmental Permitting Regulations (EPR).

The advice of the sub-group is considered by Defra SAC and Defra's CSA. Based on their recommendations, Defra officials will then take forward the management needs and regulatory responsibilities for the burial sites. Defra have established guidelines[3] on the the surrender of the EPR permits. On the advice of the sub-group, Defra has commissioned initial work on a conceptual model for one site (Watchtree, Cumbria), which forms part of the evidence needed to support the process of permit surrender.

B. Background

The rationale for the burial of livestock carcasses during the 2001 FMD outbreak is summarised in the NAO (2002) Report.[4] The approach used to manage the risk followed

[1] Watchtree, Cumbria; Tow Law, County Durham; Birkshaw Forest, Dumfries & Galloway and Ridgeway Ground, Worcestershire.
[2] National Audit Office, 2002, p. 74
[3] https://www.gov.uk/government/publications/guidelines-for-environmental-risk-assessment-and-management-green-leaves-iii
[4] National Audit Office (2002) Report: The 2001 Outbreak of Foot and Mouth Disease, 138pp.

Environment Agency (EA) protocols for waste disposal in landfill containing biodegradable wastes.[5] The UK Department of Health defined the environmental monitoring regimes for the burial sites. Together, these regulations determined the parameters monitored at the 2001 FMD outbreak carcass burial sites, and as a consequence, the scientific evidence available on which to test assumptions regarding the residual risk to biosecurity and water quality.

B.1 Estimating residual risk

As carcasses decompose they produce leachate, gas and a residual solid waste mass that follow typical decay curves as the metabolic activity of microorganisms results in changes in the mechanical and hydraulic properties of the waste. **Figure 1a**, illustrates the processes and parameters that are typically measured for municipal solid waste landfills.

Figure 1a: Schematic of the processes taking place during the biodegradation of municipal solid waste together with examples of some of the parameters that are typically measured

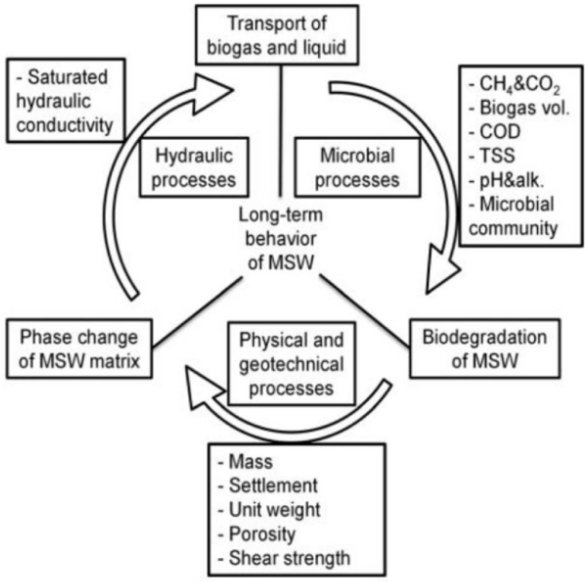

Figure 1a Notes
Biodegradation through the metabolic activity of microorganisms results in changes in the mechanical (physical, geotechnical) and hydraulic properties of the waste. CH_4 = methane. CO_2 = carbon dioxide; COD = chemical oxygen demand; TSS = total suspended solids; pH&alk = pH and alkalinity; MSW = municipal solid waste.

A simple schematic illustrating the pattern and characteristics of leachate and gas production over time arising from the decomposition of biodegradable waste in landfill is shown in **Figure 1b**.

For the carcass burial sites, the decay curve demonstrates the decline in the source term (i.e. maturation of the animal carcass decomposition process in the burial pits) over time. The residual risk, in the event of a release of the liquor to the environment at any time, can be evaluated based on the predicted decay rate. Refer to **Annex C** for technical information on potential chemical, biological and gaseous risks.

[5] UK Environment Agency. (2002). Protocol for the use of licensed landfills for the disposal of animal carcasses during the foot and mouth outbreak. http://www.environmentagency.gov.uk/commondata/105385/126564

Key to providing advice to Defra SAC on the residual risk to water quality and biosecurity from the carcass burial sites is establishing whether there is sufficient evidence to estimate the source term and position on the contaminant decay curve for each burial site. If this evidence exists, it can be compared with the NAO view that Defra has a 100-year liability to protect ***water quality*** at each burial site.

Defra has commissioned the development of a conceptual model to estimate the residual water quality risk using Watchtree, Cumbria as the test site. The same is not applied to ***biosecurity risk*** because the evidence base is that the FMDV does not persist after 15 years in the soil [6]: advice on this risk is thus considered qualitatively.

Figure 1b: Typical decay curves for the biodegradation of municipal solid waste landfills

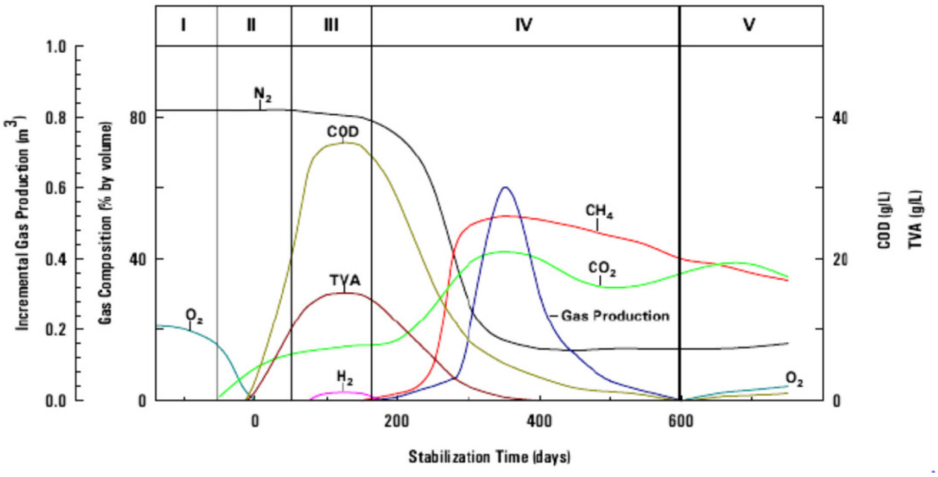

Figure 1b Notes
The burial of solid waste in a landfill initiates a complex series of chemical and biological reactions that can be described in five phases shown in the Figure 1b. The rate and characteristics of leachate produced and biogas generated from a landfill vary from one phase to another, and reflect the microbially mediated processes taking place inside the landfill.

Phase I: Initial adjustment (sometimes described as the lag phase) at the beginning of the decomposition process where aerobic microbes consume moisture within the waste and available oxygen. This phase is typically short in duration.

Phase II: Transition phase as the predominant bacteria switch from aerobic to anaerobic as oxygen is depleted. Total volatile acids (TVA's) start to appear.

Phase III: Acid formation phase - the continuous hydrolysis (solubilisation) of solid waste, followed by the microbial conversion of biodegradable organic content produces intermediate short chain carboxylic acids at high concentrations. The pH of the leachate starts to drop as waste is converted to TVA's and the degradation of organic matter is typically rapid. Leachate has a high chemical oxygen demand (COD) attributable to carboxylic acids. As these acids are biodegradable, the highest Biological Oxygen Demand (BOD not shown on Figure) and COD concentrations in the leachate will be measured during this phase.

Phase IV: Methane fermentation phase as the acids produced in the earlier phases are converted to methane (CH4) and carbon dioxide (CO2). The pH returns to more neutral levels as it is controlled by the bicarbonate buffering system, and consequently supports the growth of methanogenic bacteria. Landfill gas production peaks in this phase, which typically occurs within one year of waste placement.

Phase V: Maturation phase is marked by a significant drop in gas production as the availability of organic matter and nutrients become limiting. Leachate strength stays steady at much lower concentrations as the slow degradation of resistant organic fractions continues. In this phase the BOD/COD is relatively low because dissolved organic matter that is degradable is consumed as rapidly as it is produced. Reappearance of oxygen and oxidized species may be observed slowly.

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[6] Cottral, G. E. (1969) Persistence of Foot-and-Mouth Disease Virus in Animals, their Products and the Environment. *Bull. Off. int. Epiz*. **71** (3-4), 549-568

B.2 Source of risk (source term)

The location of the burial sites, area, and number and type of livestock buried is given in **Table 1 (Annex D).** Around 95,000 tonnes of carcasses were buried in total.[7] The sites were brought into use very quickly. Consequently, the character of the source term is uncertain. Samples collected in the period two days to four months following burial were used to propose source term concentrations for quantitative risk assessment (see **Table 2).** The sampling data showed that leachate composition was roughly consistent with the relative proportions of the same components within whole animal carcasses but highly variable in concentration. The source term concentrations proposed in **Table 2** are at the high end of the typical ranges observed in the sample data after removal of outliers and extremes. The analysis did not take account of other contaminants that may be present. An exponential decline in the source term was initially assumed by regulators.[8]

B.3 Pathways of risk

The exposure pathways that lead to potential risk are: (a) gaseous emissions to the atmosphere; (b) surface runoff, leachate breakout from the burial pits, physical erosion and/or disturbance of the burial pits by animals, and managed discharge; and (c) sub-surface losses to the underlying geological strata, losses from soakaways, and barrier failure.

Rainfall and soil permeability are key drivers of the rate at which contaminants are leached from the mass burial sites to water. The natural attenuation properties of the soils and subsurface strata at each location will determine the potential for decomposition products to reach groundwater, and in the event of this, the potential impact on water quality.

B.3 Receptors at risk

The primary environmental risk from the 2001 FMD outbreak carcass burial sites is the contamination of groundwater or surface waters with the chemical products of carcass decay. The risk to groundwater arises from the potential migration of leachate through unlined burial pits and transport through underlying fractured strata. Shallow wells, spring systems and other surface water bodies are potentially more vulnerable to contamination from the products of carcass decomposition than deep wells or boreholes, due to shorter travel times for contaminant migration. There is potential for gaseous emissions to the atmosphere via vertical migration through the capping layer on the waste mass and lateral migration through fractured media. Gaseous emissions are considered to present a low risk, due to the absence of adjacent receptors (humans) and relatively low gas production.

C. Site Design and summary of the available evidence

The basic design features for the four main 2001 FMD outbreak mass burial sites are given in **Table 3**. All were designed as containment sites, and used synthetic material

[7] UK Environment Agency (2001). The environmental impact of the foot and mouth disease outbreak: an interim assessment. Permalink: http://www.environmentdata.org/archive/ealit:4290

[8] Schlumberger Water Services (2015) Review of Watchtree FMD Disposal Site: Cell Management Review, 54382/R2v2, 44pp.

(liners) and/or the low permeability of the surrounding geological material (e.g. clay) to contain the waste and leachate. Leachate management was part of the design, as was capping of the site to reduce infiltration of rainwater and leachate volumes. Technical **Annex C** provides more detail. **Annex E** provides site drawings for Birkshaw Forest, Tow Law, Ridgeway Ground and Watchtree, along with cross section design sketches for the burial pits at Tow Law, Ridgeway Ground and Watchtree.

Monitoring covers: site performance and behaviour, leachate volumes and composition, and groundwater, surface water and gases/air quality. The water quality parameters measured followed EA landfill monitoring guidance.[9] The water quality evidence available for each site varies but largely constitutes testing for BOD, ammonia, and suspended solids as well as chloride and potassium concentrations. **Biological risks have not been monitored.**

With the exception of annual performance reports produced by the consultants managing the burial sites as required by the surface water discharge consents, **prior to the sub-group being set-up, no evaluation of the data has been carried out to identify trends in contaminant behaviour and their environmental and human health significance.** **Annex F** summarises initial work commissioned by Defra on behalf of the sub-group to gather the evidence and information in relation to water quality risk held for the Watchtree burial site. **Table 4** summarises the data holdings for all the 2001 FMD outbreak carcass burial sites managed by Defra.

D. Sub-group advice regarding the questions posed in the Terms of Reference

The advice below is directed at addressing the questions posed in the terms of reference of the sub-group.

ToR Q1: *Do the burial sites pose any residual risk of FMD or any other notifiable disease of animals?*

D.1 Evidence of residual risk of FMD posed by the burial sites

In principle, decomposing carcasses generate a biological risk that is not limited to the FMD virus alone and includes other pathogens and toxins. The biological risk is greater at burial but this risk decreases significantly over time. The time at which this risk becomes negligible should guide the length of the liability on Defra to protect water quality from, and contain any potential biosecurity risks from each burial site.

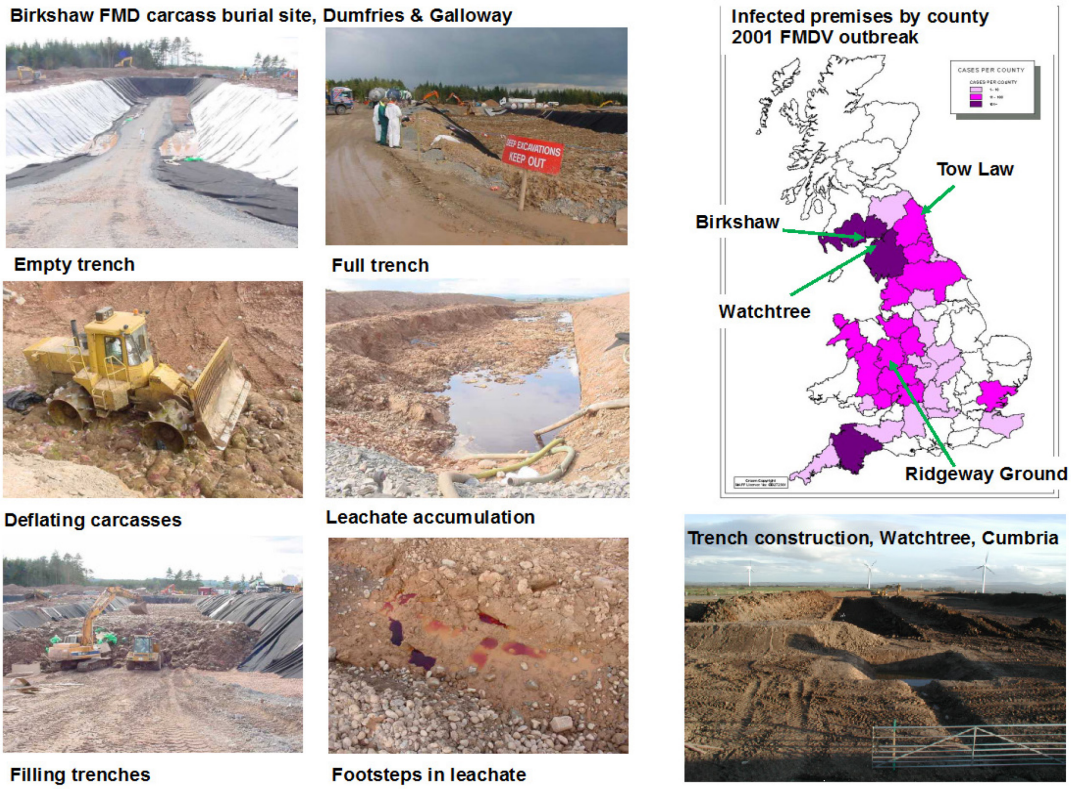
Table 1 shows the number and type of livestock buried at each site. It does not show the ratio of stock infected with FMD *vs* stock culled as a precaution or on welfare grounds, although all animals known to have come from infected farms were incinerated or rendered in Scotland.[10] Similar policies are reported to have been in place in Cumbria, but

[9] EA report guidance NC/02/04/01

[10] The NAO (2002) Report gives some insight e.g. for Birkshaw in Scotland, we know that no animals were buried from confirmed FMD infected premises because 98% of carcasses from FMD infected premises in Scotland were disposed of on-farm by incineration and 2% were disposed of by rendering.

are not recorded officially. That some buried animals were infected cannot be excluded. Published evidence[11][12] suggests FMDV has a 70 to 90 day survival rate, although this varies between tissues in which it is. Technical information in **Annex C** refers. FMDV is rapidly inactivated in muscle as a result of the drop in pH accompanying rigor mortis[13]. It persists longer in tissues protected from such pH changes (e.g. bone marrow, lymph nodes). However, even where a long timescale for risk is quoted for tongue epithelium (see Annex C), the "storage at 4ºC" condition would not have been met at any of the burial sites, especially after such extended periods. Consequently, even if infected carcases had been buried, the virus contained in them would not have been able to persist.

The advice of the sub-group is the risk of the FMD virus surviving in the carcass burial sites since 2001 is *negligible*.



The photo montage above shows the cases of FMD virus (FMDV) at a county level for the UK and the location of the FMD carcass burial sites managed by Defra. The construction phases of the burial pits at Birkshaw, Dumfries and Galloway, are shown together with the initial leachate accumulation prior to the burial pits being covered over. The burial pit construction at Watchtree, Cumbria is also shown.[14]

[11] Kitching, R.P. & Mackay, D. K. (1995) Foot and Mouth Disease. State Veterinary Journal, 5(3). See also Cottral (1969).
[12] Cottral, G. E. (1969) Persistence of Foot-and-Mouth Disease Virus in Animals, their Products and the Environment. *Bull. Off. int. Epiz.* **71** (3-4), 549-568
[13] Gale, 2002, p. 102.
[14] The sub-group would like to thank Colonel Neil Smith MRCVS for sharing the photos

D.2 Evidence of residual risk of other animal notifiable diseases posed by the burial sites

Spore-forming bacteria, especially *Bacillus* and *Clostridium* spp. are known to survive in the environment for very long periods, although clostridial diseases are not notifiable. Dissemination of such organisms from the mass burial sites is dependent on the hydrological and geological properties of location.

Three key **potential biosecurity risks** were identified:

D.2.1 Anthrax. Sporulation of *Bacillus anthracis* requires oxygen and does not occur inside an intact carcass. However, disturbance of burial sites could potentially bring spores to the surface. The reported risk of Anthrax at the time of the livestock burials in 2001 falls within a 5-year period when there were no cases detected. Case History is described in **Annex C**.

The advice of the sub-group is the risks of Anthrax from the burial sites is judged to be *negligible*.

D.2.2 Clostridium spp. are common, spore forming soil and gut-living bacteria that cause a range of non-reportable diseases in cattle and sheep, against which highly efficacious vaccines are commonly used. The sub-group anticipate that these bacteria would be found in possibly large numbers in the burial sites. There is no statutory surveillance for these non-notifiable diseases and vaccination would be expected to protect stock currently grazing there. See **Annex C** for further discussion.

The advice of the sub-group is the risk from Clostridium infection attributable to the burial sites that are managed by Defra is *very low*, although consideration should be given to whether sites risk disturbance by over-grazing or wild animal disturbance.

D.2.3 Prions that cause transmissible spongiform encephalopathies (TSEs) such as BSE in cattle and scrapie in sheep, are highly resistant to inactivation processes (e.g. chemical, thermal ionizing).

Concerning the *source*, for BSE, the risk of undetected infected animals entering the burial sites is considered very low (SEAC).[15] Thus, the risk of onward transmission is negligible, particularly while sites remain undisturbed. Risks of scrapie in sheep are harder to quantify.

[15] Gale, P. (2002) Risk Assessment: Use of Composting and Biogas Treatment to Dispose of Catering Waste Containing Meat. Defra Contract No: 12842-0.

D.2.4 Contaminated soil. The sub-group identified a potential risk at the burial sites if contaminated soil is exposed through disturbance by grazing livestock and/or wild animals. Recent inspection of the burial sites in response to this potential risk suggested no material disturbance or obvious penetration into the burial pits. The presence of susceptible sentinel wild animals (deer) grazing the sites at Ridgeway and Birkshaw, and domestic sheep and cattle grazing the burial site at Tow Law, with no observed ill effects, suggests that these sites have not been a reservoir of contagious/infectious diseases to date. Two sites (Watchtree, Cumbria and Tow Law, Co Durham) are potentially subject to over-grazing and a recently commissioned report will advise further on this potential risk pathway if there is localised increased soil erosion and deeper soil disturbance. **Annex C** **Annex C** references other sources of biological risk considered.

Based on the available evidence, the advice of the sub-group is that the overall risk of other notifiable diseases spreading from the sites is very low.

D.3 Evidence of risk to water quality posed by the burial sites

***ToR Q2**: Based on the evidence available for each site, can the SAC provide an estimate of the current risk to water quality that the burial sites represent: either from an accidental discharge of leachate from containment failure, or from current operational management activities? If evidence is not available or sufficient to make such an estimate, the steps needed to acquire the relevant information (subject to any exclusions)*

To estimate the current risk to water quality from the 2001 FMD outbreak carcass burial sites **a clear understanding of the contaminant source term and decay curve function is needed.** The purpose is to estimate the leachate composition that may impact groundwater quality in the event of a future release from the sites either from an accidental discharge of leachate from containment failure, or from current operational management activities. **Table 4** summarises the carcass burial site data that are available to address this question. To date, these data have not been interrogated beyond annual reporting for regulatory purposes. To move forward, two pieces of work were recently commissioned by Defra on the advice of the sub-group:

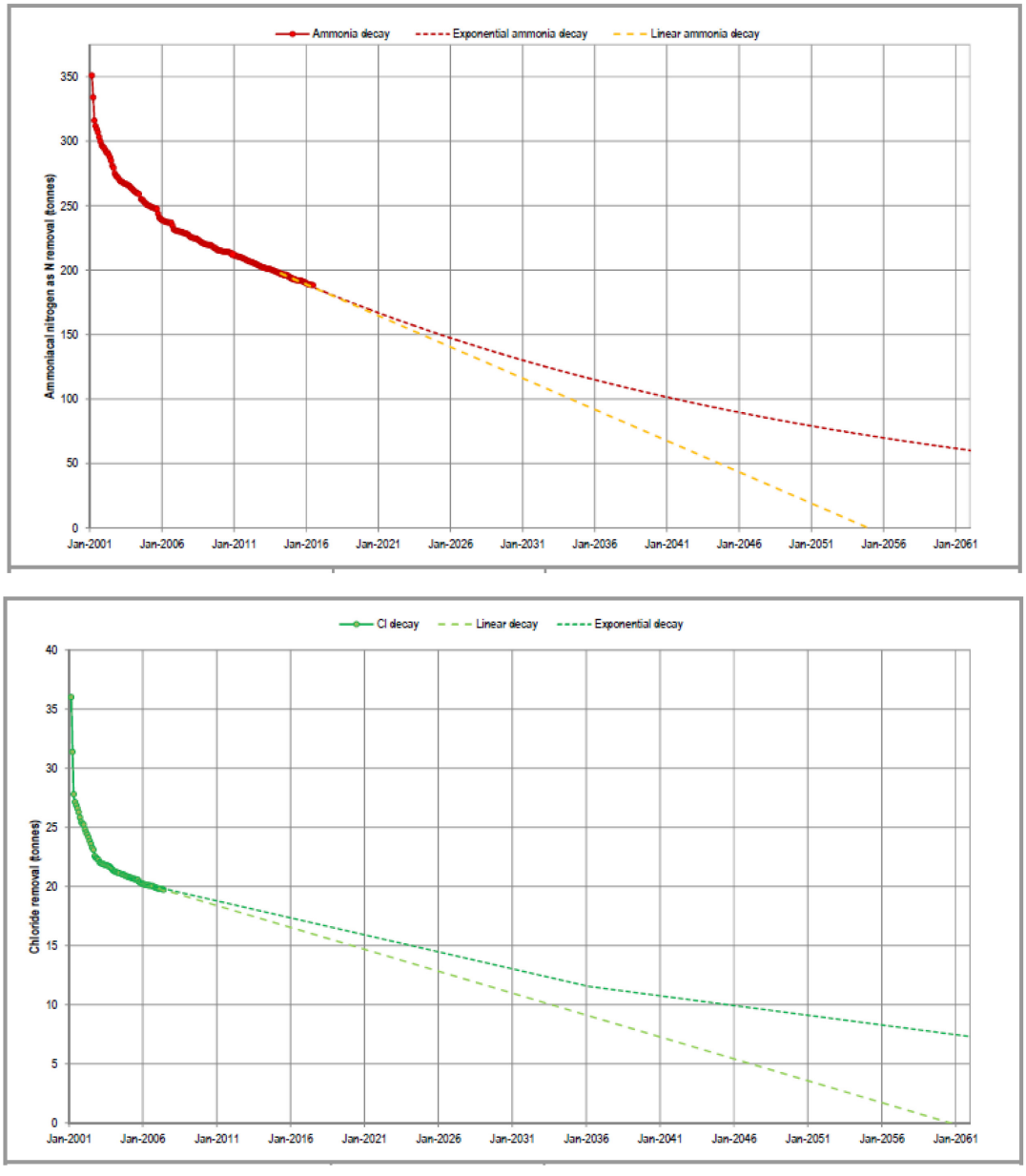
1) Synthesis of the water quality monitoring data from 2001-2016 for all carcass burial sites managed by Defra, and
2) Development of a conceptual model of water quality risk using Watchtree, Cumbria as the test site.

D.3.1 Estimation of leachate decay curve from the water quality monitoring data. To date, only the aggregate and synthesised data for Watchtree, Cumbria have been received by the sub-group, together with some rudimentary material for the three other sites managed by Defra. As an example of a reactive chemical species, **Table 5** summarises the variation in aggregate leachate ammoniacal Nitrogen (N) quality at Watchtree over time (2001-2016). As an example of the behaviour of a conservative (non-reactive)

chemical species, **Table 6** summarises the variation in aggregate chloride (Cl) leachate concentrations over time (2001-2007) for Watchtree. Initial analysis of the variation in leachate chemical composition and water quality for Watchtree suggests that the chemical pollutant source term remains significant, with approximately 53% of the initial ammoniacal nitrogen mass remaining after 15 years.

Figure 2 shows the estimated position on the decay curve for Watchtree for non-reactive (i.e. chloride) and reactive (i.e. nitrogen) species. The observed decay profile is non-linear but the data set is too short in duration to clearly define the long-term decay function. The slope of the decay curve has decreased in recent years, **which may suggest a much lower release of contaminants than assumed initially.** However, the exponential decay implies a much longer release time-scale than that predicted by a linear process, although these predictions are based on very limited monitoring data.

Figure 2: Estimated position on decay curve for Watchtree, Cumbria for ammoniacal Nitrogen and Chloride



Source: Interserve Facilities Management ltd (2016) Watchtree FMD Disposal Site: environmental data analysis, Report 54382/R6v1, 26 September 2016, 73pp

Notes
Each plot shows the observed time-series variation in the chemical species (mass of either NH4 or Cl removed in ***aggregate leachate*** *from the burial pits) from 2001-2016. The predicted future leachate load is based on an assumed linear or exponential decay. The current trend is extended to 2061 only.*

For illustration of the data available for the other 2001 FMD outbreak carcass burial sites managed by Defra, simple plots of the raw water quality data over time are presented in **Figures 3-7.** For Tow Law (**Figure 3**), N shows a rapidly decaying profile to low concentration values, which are sustained to current time and indicate a stabilised source term. A similar trend is reported for Cl (**Figure 4**), and at Ridgeway Ground for N (**Figure 5**) and Cl (**Figure 6**), with steep decline in Cl after 2002. For Birkshaw, the trend for N appears to be more erratic (**Figure 7**), declining to more stable concentrations after 2006.

Figure 3: Ammoniacal Nitrogen concentrations for leachate from individual burial pits, Tow Law, Co. Durham

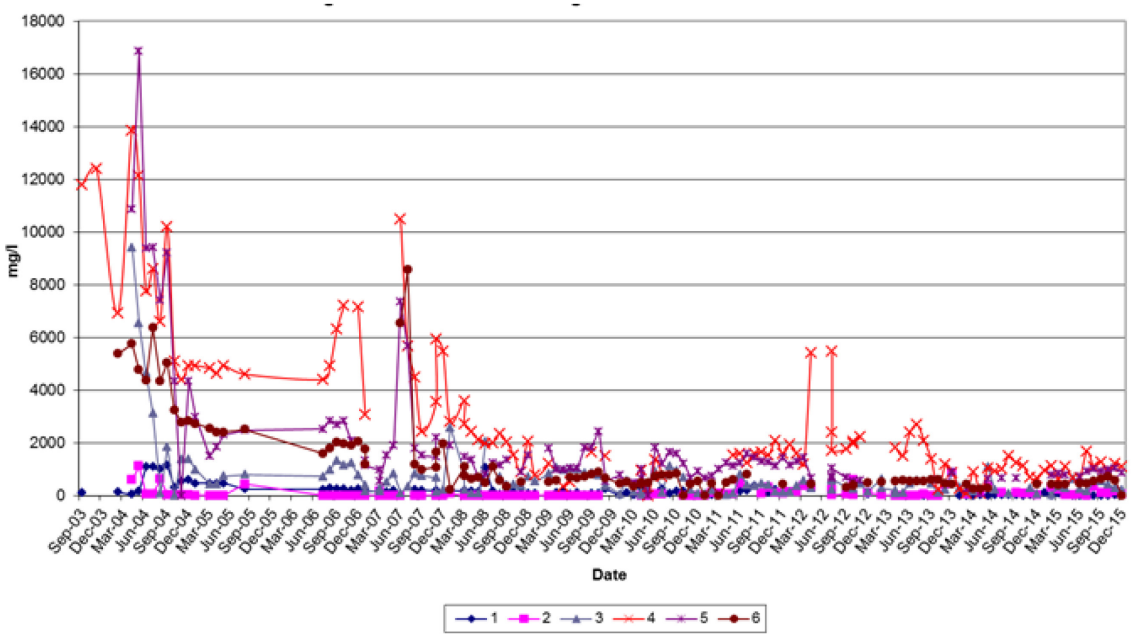
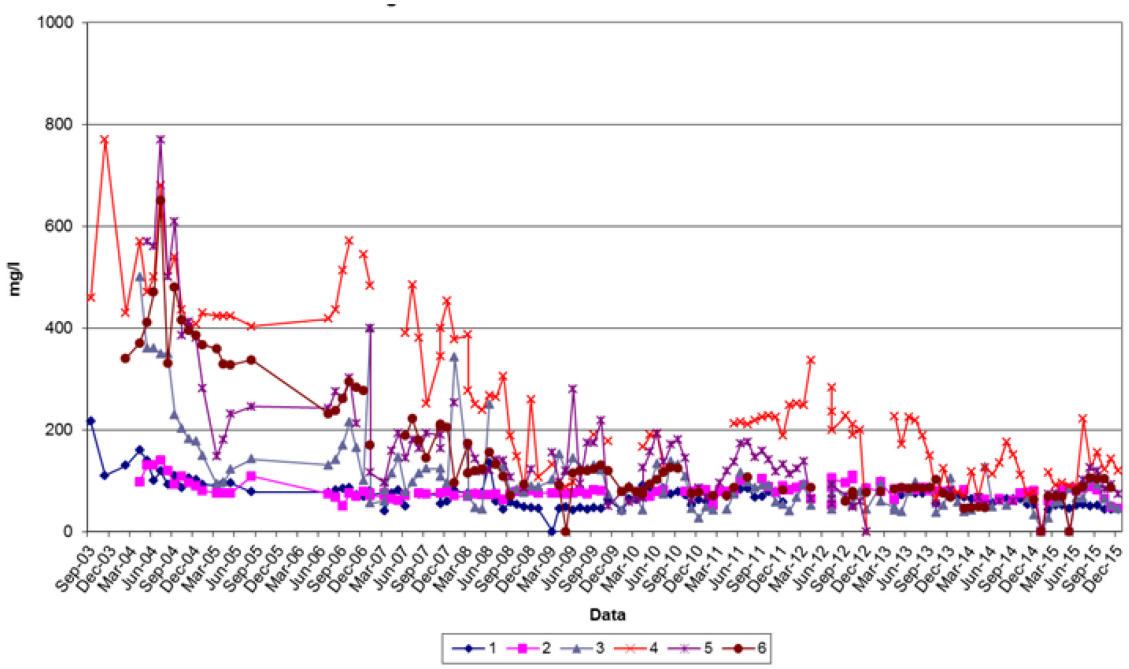


Figure 4: Chloride concentrations for leachate from individual burial pits, Tow Law, Co. Durham



Notes
Plotted lines 1-6 refer to concentrations reported for leachate from individual burial pits. These raw data are not aggregate leachate as used to model the trends shown for Watchtree in Figure 2.

Figure 5: Ammoniacal Nitrogen concentrations for leachate from individual burial pits, Ridgeway Ground, Worcestershire

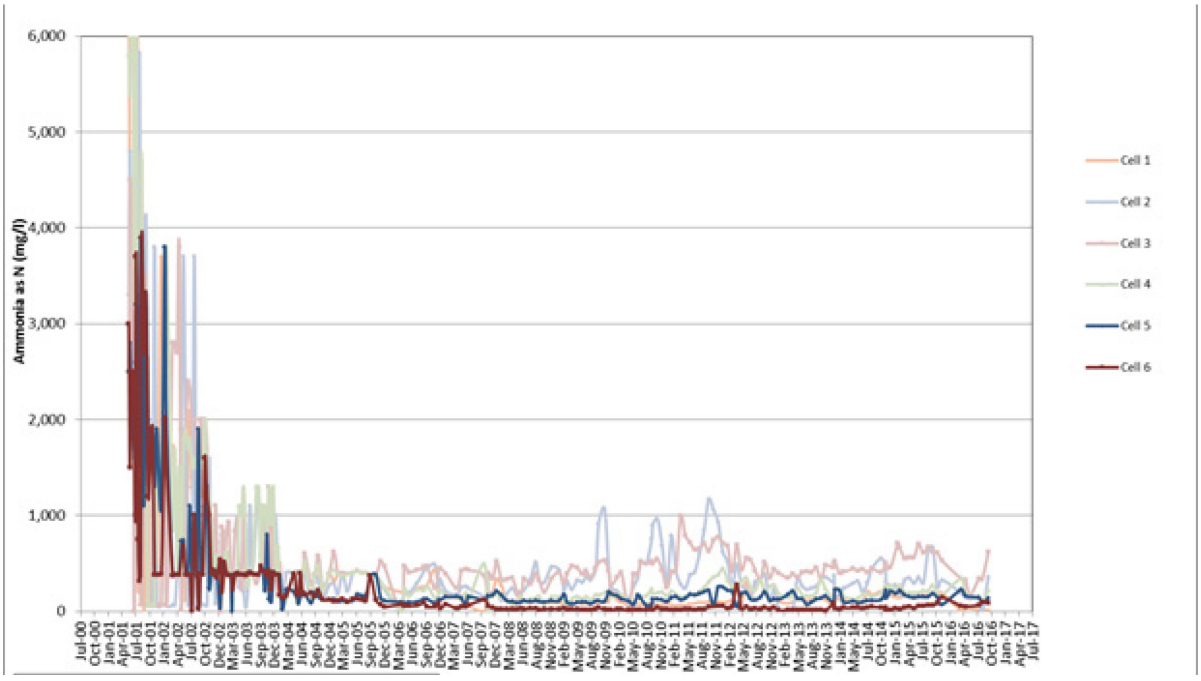
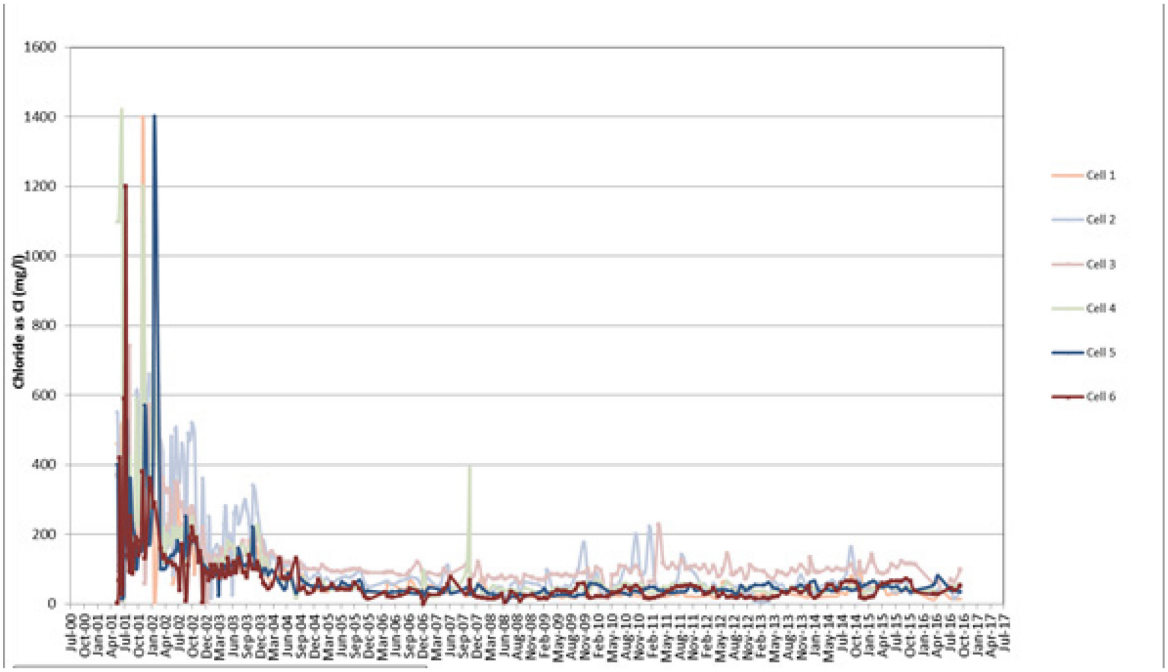
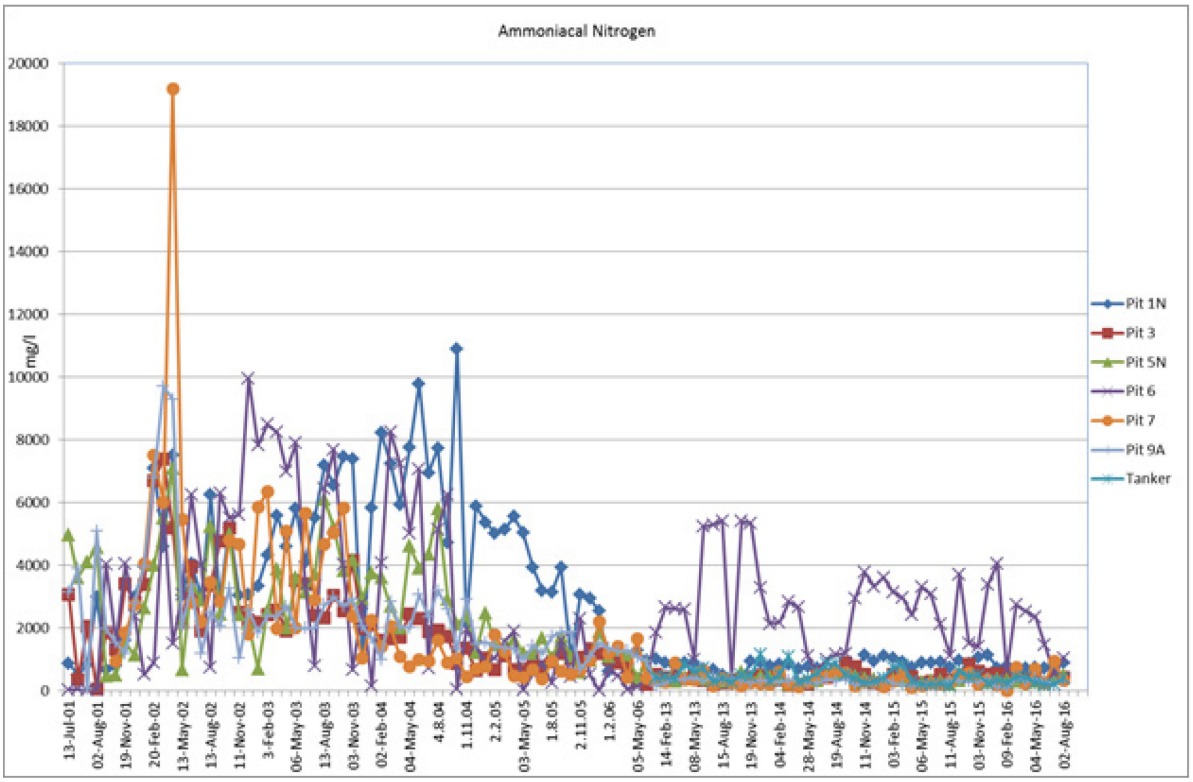


Figure 6: Chloride concentrations for leachate from individual burial pits, Ridgeway Ground, Worcestershire



Notes
Plotted lines for cells 1-6 refer to concentrations reported for leachate from individual burial pits. These raw data are <u>not</u> aggregate leachate as used to model the trends shown for Watchtree in Figure 2.

Figure 7: Ammoniacal N concentrations for leachate recorded from individual burial pits, Birkshaw, Dumfries & Galloway



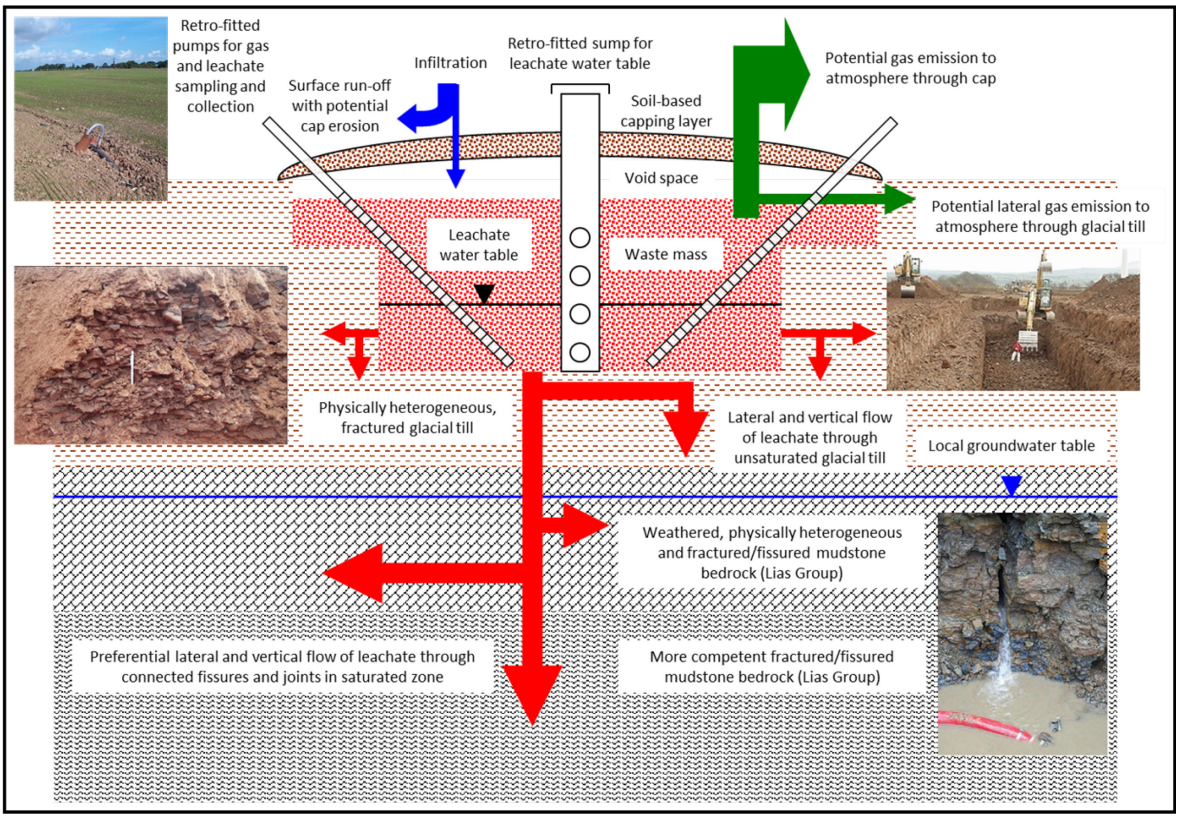
Notes
Plotted lines for pits as numbered refer to concentrations reported for leachate from individual burial pits. These raw data are <u>not</u> aggregate leachate as used to model the trends shown for Watchtree in Figure 2.

The advice of the sub-group is sensible projections could be made of the end-points for the leachate decay curves to understand the liability for water quality risk (see e.g. Figure 2) subject to: (i) appropriate analysis of the current dataset to consider variability in measured parameters (uncertainty assessment), and (ii) collection of further data (possibly scaled down to essential parameters) to verify the predicted trends (see Section E).

D.3.2 Development of a conceptual model is designed to improve the understanding of contaminant fate and potential environmental impacts of leachate and gas releases from the 2001 FMD outbreak carcass burial sites. The model explains the potential pathways for release of leachate from the burial sites to the host environment, including indicative receptors, and the known/potential controls on this release (e.g. integrity of the barrier and host geology). The evidence base to inform this work for Watchtree, Cumbria is summarised in **Annex F**.

The conceptual model can be used with the improved analysis of the leachate decay curves described above to estimate the potential impacts of a leachate release on groundwater quality for the sites. An example conceptual model for an unlined burial pit at Watchtree is shown in **Figure 8**. It illustrates the pathways for release of gas and leachate to the environment and features of the burial pit design and/or host substratum that may influence offsite migration of contaminants. **Technical Annex C refers**.

Figure 8: Example conceptual model for an unlined (Type 1A) 2001 FMD outbreak carcass burial pit at Watchtree, Cumbria



E. Future Management of the 2001 FMD Outbreak Carcass Burial Sites

ToR Q3 *Are there improved or more effective management methods, including revised monitoring procedures that can be applied at the sites to reduce ongoing liability? For example is the current methodology for water management/leachate within individual site burial pit (cells) considered to be the optimum method in terms of continued degradation of carcasses? Can a reduced monitoring plan be developed, based on an evaluation of the data obtained to date, focusing on key points and parameters?*

Given the scale and unique status of the carcass burial sites and the likely continued public interest in them, **the advice of the sub-group is the existing site management is overhauled and reviewed.**

The purpose of the systematic review is to focus monitoring on the parameters that are relevant in defining the residual risk and liability at all four 2001 FMD outbreak carcass burial sites managed by Defra. Because the burial sites are regulated as *landfill,* EA/SEPA guidance defines the process for estimating the future liability and time at which the sites no longer present environmental risks. Any changes to the monitoring programmes need to align with the permit surrender process to ensure they remain fit-for purpose. The commissioned work on the conceptual model is not expected to report until December 2016. Depending on what this analysis shows:

The advice of the sub-group is Defra SAC consider the value of extending the work on water quality risk to the three other burial sites managed by Defra.

This would enable qualitative comparison between sites (recognising that there will be some commonalities) and would provide a more robust analysis of where the sites lie on the leachate decay curve.

Further, the sub-group notes that much of the evaluation of biosecurity risk undertaken for this report relies on the understanding that viruses do not persist at ground surface temperatures for anything like the time that has passed since 2001. [16] Formal notifiable animal disease control at international levels generally operates on the principle that testing is not carried out *where disease is not suspected*.

The sub-group advise that biological monitoring is <u>not</u> added to any revised monitoring programme for the carcass burial sites

[16] Cottral, G. E. (1969) Persistence of Foot-and-Mouth Disease Virus in Animals, their Products and the Environment. Bull. Off. int. Epiz. 71 (3-4), 549-568

ToR Q4 *What advice can the sub-group provide SAC on the ongoing and future management of these sites in the medium to long term to manage any risks to human and animal health, and the environment?*

From the available evidence, only a conservative assessment of the human health and environmental risks posed by the carcass burial sites is possible. **To inform the future management of the 2001 FMD outbreak carcass burial sites, the sub-group advise:**

1. The monitoring data for each site is compiled and reviewed to identify any trends/anomalies that would indicate existing contamination of the environment adjacent to the burial sites and at receptors.
2. The risk of burial pit (cell) rupture is evaluated including assessment of how many burial pit (cells) would need to rupture for a demonstrable impact on the environment: T**his would mean having an appropriate monitoring programme in place to provide evidence to demonstrate impact/no impact**.
3. The risk to water quality and biosecurity of leaving the physical infrastructure of the sites to degrade "naturally" *vs* intervention to maintain their physical structures is understood.
4. If active measures are introduced to shorten the timescales for the source term decay (and hence Defra's liability) that monitoring is in place to provide the evidence to understand the risks to receptors.

ToR Q5 *Would the SAC recommend any further or ongoing analytical investigation to monitor the decomposition of the carcasses?*

The view of the sub-group is there are risks in terms of disturbance in undertaking any sampling within the burial sites rather than of the leachate extracted from the sites, as is current practice. The sub-group identified a small risk that a major disturbance of the site could potentially increase the risk of contamination of spores through the release of microbial material from partially degraded carcases (*Anthrax*, *Clostridium).*

The advice of the sub-group is Defra SAC consider a proposal that Defra should commit to not disturbing the burial pits beyond essential maintenance requirements.

In section **D.1**, the sub-group advises 'negligible risk' in relation both to the FMDV 90-day survival rate and to the policy in place not to bury known infected animals.[17] Given the sub-group advice that disturbance should be avoided, there seem few advantages in internal testing of the burial pits for microbial contamination. Consequently, **the sub-group advice is internal microbial testing in not undertaken**. Further, representative, statistically-based testing of core samples from the sites, given likely heterogeneity in risk posed by any residual infection in the burial pits, would need to be very extensive. Scientific evidence demonstrates that viruses decay and become inactive over time.

[17] National Audit Office (2002) Report: The 2001 Outbreak of Foot and Mouth Disease, 138pp.

Expert opinion draws on this evidence and concluded that the microbiological content relating to the 2001 outbreak remaining in the burial pits negligible. The low risk posed consequently means any further sampling is not justifiable based on the scientific evidence.

The sensitivities in reporting *negligible risk* were noted, and were taken against arguments for disturbing the burial sites and undertaking testing. **The sub-group notes that there is no precedent; available evidence is in the form of published literature with some chemical evidence. The group used their expert judgment to reach the conclusion of negligible risk.**

In reaching any decision regarding disturbance of the burial pits, the SAC should be aware that the regulations for EPR permit surrender may require **intrusive investigation of the burial sites** to demonstrate that the residual risk is negligible before permit surrender. **If EPR requires the burial pits to be disturbed, the advice of the sub-group is any microbiological analysis of the samples is informed by expertise in post-mortem decomposition and includes non-notifiable spore-forming bacteria in addition to notifiable disease risks such as FMDV or Anthrax.**

Annex A: Terms of reference for the sub-group

A Review of scientific evidence underpinning the management of burial sites for carcasses from the 2001 Foot and Mouth Disease (FMD) Outbreak

Background and key aims

The ongoing management of the four burial sites[18] used for animal carcasses during the 2001 FMD outbreak form part of the department's public liability. In the absence of scientific evidence to the contrary, National Audit Office took a view (in 2014/15) that Defra has a 100-year liability to protect water quality and contain any potential biosecurity breaches arising from the burial of these carcasses.

In order to ensure Defra is adequately accounting for future management of these sites, a scientific review of the level of risk to water quality and biosecurity at these sites, and advice on appropriate ongoing management, is now considered appropriate.

Response to the FMD outbreak of 2001

As part of the Department's response to the FMD outbreak in 2001, animal carcasses were buried in four mass burial sites. The decomposition of these carcasses results in bodily fluid and other dissolved components being slowly released in the form of leachate. The leachate has the potential to pollute the environment unless it is carefully managed, including treatment and disposal. The Department publicly committed to actively manage these sites to prevent the discharge of leachate and environmental damage through groundwater pollution and to contain any potential biosecurity risk arising from the spread of pathogens. This work is carried out by a contractor on behalf of Defra, and equates to approximately £1m per annum for the maintenance of the sites, and approximately £1m per annum in clean-up costs[19].

The Department is committed to managing the sites effectively and in a manner that is compliant with national and EU rules on water quality. However, we also recognise that to manage the sites most effectively Defra needs to be mindful of the most up to date scientific advice on managing any potential risk. Defra are engaged with the Environment Agency (EA) and an official from EA will be part of the review process to ensure that recommendations coming forward from the SAC are consistent with environmental policy and current legislation.

Purpose of review

The SAC sub-group on burial sites for FMD carcasses from the 2001 outbreak (SAC-FCB) will be formed of experts from a variety of relevant disciplines, the group will be chaired by Professor Louise Heathwaite, who will support and assure the CSA on evidence relating to FMD burial sites.

[18] There are three in England (Cumbria, County Durham and Worcestershire) and one in Scotland (Dumfries and Galloway).
[19] Which equates to the cost of treating the leachate arising from dissolved substances from the decomposing carcasses.

The group will be convened to address a specific set of questions:

1. Do the burial sites pose any residual risk of FMD or any other notifiable disease of animals?
2. Based on the evidence available for each site, can the SAC provide an estimate of the current risk to water quality that the burial sites represent: either from an accidental discharge of leachate from containment failure, or from current operational management activities? If evidence is not available or sufficient to make such an estimate, the steps needed to acquire the relevant information (subject to any exclusions)
3. Are there improved or more effective management methods, including revised monitoring procedures that can be applied at the sites to reduce ongoing liability? For example is the current methodology for water management/leachate within individual site cells considered to be the optimum method in terms of continued degradation of carcasses? Can a reduced monitoring plan be developed, based on an evaluation of the data obtained to date, focusing on key points and parameters?
4. What advice can SAC provide on the ongoing management of these sites in the medium to long term to manage any risks to human and animal health, biosecurity and the environment
5. Would the SAC recommend any further or ongoing analytical investigation to monitor the decomposition of the carcasses?

In answering these questions, the SAC-FMD review team will:

- provide independent assurance to the Defra CSA in the use of evidence and analysis;
- discuss any issues or gaps in evidence, and advise how they might be addressed;
- provide relevant information from their extended networks that will enable Defra to have the evidence it needs; and
- offer advice.

Membership

The group will be chaired by Professor Louise Heathwaite and will include Defra SAC member, Professor James Wood. A small number of independent academic co-optees will provide additional expertise.

SAC-FCB co-optees are not recruited through open competition, but are appointed based on their specific skills and experience. The SAC-FCB co-optees act independently of any of their other interests.

The SAC-FCB is supported by regulatory and operational expertise in Defra, Scottish Government, EA and SEPA.

Operating procedures

The SAC-FCB will generally operate in accordance with the SAC Handbook[20]. However, notable exceptions are:

- Meetings of the FCB will be convened at the request of the SAC-FCB Chair to address specific issues. Initial analysis suggests that the SAC-FCB will need to meet 2-3 times during the course of its work.
- It is anticipated that the work of the SAC-FMD will be completed within 9-months of the appointment of the external co-optees.
- SAC-FMD will report to SAC through the SAC-FCB Chair.

Outputs

A review report with recommendations to Defra's Chief Scientific Advisor will be presented to Defra SAC within 9 months of commissioning.

Relationship with other parties

Defra estates – John Richards - lead Defra official

EA – involved via Defra estates

SEPA – involved via Defra lead official

Scottish Government – involved via Defra lead official

Duration of sub-group

The expectation is that this sub-group will be closed once it has addressed the specific questions being posed by CSA/Defra.

Reference Documents:

- NAO report on 2001 Outbreak of Foot And Mouth Disease – June 2002
- Bucknall Austin/Unipore Europe Ltd report – July 2006
- Professor Ranald Munro, University of Edinburgh, report – September 2009

1 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449436/sac-handbook-2014-15.pdf

Annex B: Sub-group membership

Sub-Group

Professor Louise Heathwaite (Chair): Professor of Land and Water Science in Lancaster Environment Centre, University of Lancaster and Scottish Government Chief Scientific Advisor (CSA) for Rural Affairs and the Environment. Expertise: Hydrochemistry and diffuse environmental pollution.

Professor James Wood (SAC Member): Alborada Professor of Equine and Farm Animal Medicine and Head of University of Cambridge Vet School. Expertise: Infectious disease epidemiologist.

Professor Jonathan Wastling (Co-opted Member): Pro Vice-Chancellor and Executive Dean, Faculty of Natural Sciences, University of Keele. Expertise: Host-pathogen interactions including viral and bacterial pathogens.

Professor David Rowlands (Co-opted Member): Emeritus Professor of Molecular Virology, University of Leeds. Expertise: FMD virus

Professor Rob Ward (Co-opted Member): Director of Groundwater Science, British Geological Survey. Expertise: Freshwater science, groundwater monitoring and modelling

Professor Steve Thornton (Co-opted Member): Professor in Environmental Engineering Science, Groundwater Protection and Restoration Group, University of Sheffield. Expertise: biodegradation of organic contaminants, dual porosity aquifers, landfill leachate and the design of reactive barriers for landfills.

Regulatory and operational expertise in Defra, Scottish Government, Environment Agency (EA) and Scottish Environment Protection Agency (SEPA)

Martyn Blissitt: Veterinary Adviser (Notifiable Diseases), Animal Health and Welfare Division, Scottish Government

Dr Alwyn Hart Lead Scientist and Research Manager for Air, Land and Water Research, EA

Peter Lang: Landfill Engineering, SEPA

Carol McGinnes: Area Manager within Regulatory Services, SEPA

John Richards (supported by FM & Engineering Technical Lead and FMD FM Operations Lead). Defra Head of Property Strategy

Ref Section B.1 - Estimating residual risk

In general terms, **chemical sources of risk** arising from the process of decomposition might typically include ammonium nitrogen (*up to* 2000mg l^{-1}), chemical oxygen demand (COD) (*up to* 100000 mg l^{-1}) and biological oxygen demand (BOD). **Biological sources of risk** can include foot and mouth disease virus (FMDV), *Escherichia coli (E. coli* O157:H7), *Campylobacter*, *Salmonella*, *Leptospira*, *Cryptosporidium*, Anthrax, *Clostridium* spp. and Bovine spongiform encephalopathy (BSE) & scrapie prions. Finally, **gaseous sources of risk** are primarily carbon dioxide (CO_2) and methane (CH_4) plus trace gases (e.g. hydrogen sulphide, H_2S).

Ref: Section B.2 - Source term

Calculating the initial burial mass

Environment Agency advice is the initial burial mass is calculated as the number of sheep equivalent animals buried in all burial pits multiplied by the mass of a sheep equivalent, taken as 45kg.[21]

For example, at Watchtree, Cumbria, the initial burial mass was calculated as the number of sheep equivalent animals buried in all burial pits (623,417) multiplied by the mass of a sheep equivalent (45kg) giving a total initial tonnage of 28,054.

Note, there is significant uncertainty on the actual mass of carcasses buried at the 2001 FMD outbreak carcass burial sites. Although the exact numbers of sheep, cattle and pigs buried on a burial pit by burial pit basis are known (**Table 1**), **their age profile (and hence average weight) is not**. The advised 45kg mass equivalent reflects juvenile sheep. For the Watchtree burial site, sheep account for 96% of animals buried (**Table 1**). There is anecdotal evidence only that indicates juvenile sheep accounted for the majority of carcasses.

Calculating the initial mass of ammoniacal nitrogen

Is given by multiplying the initial burial mass by the referenced ammoniacal nitrogen composition (1.25%).[22] For Watchtree, this is: 28,054 tonnes x 1.25% = 351 tonnes N.

Estimating the volume of leachate released per animal following death

The rate of animal carcass decomposition is strongly influenced by various endogenous (e.g. putrefaction) and environmental factors (e.g. temperature, moisture, burial depth together with soil type, drainage, rainfall). Body fluids and soft tissues other than fat degrade first, followed by fats, then skin, cartilage, and hair, with bones, horns, and hooves degrading most slowly.

[21] Marsland, P.A., Smith, J.W.N. and Young, C.P., 2001. Foot & Mouth Disease Epidemic. Disposal of culled stock by burial: Guidance and Reference Data for the protection of controlled waters. Draft R&D Technical Report: Version 8: 2 September 2001, National Groundwater & Contaminated Land Centre, Environment Agency.
[22] Unipure Europe Ltd (2006) Ex FMD Disposal Sites: future site management draft report U0409-R7, Defra Estates Division, 22pp.

The volumes of leachate estimated to be released per animal following death were estimated by Munro (2001) using human burial analogues. He concluded that nearly all the immediately available fluid would have drained from a carcass within the first two months but these conditions may not reflect the mass burial of livestock.

Anecdotal evidence from the burial sites indicated that the immediate release of body fluids (including blood and gastro-intestinal fluids) at the burial sites was a problem during carcass disposal. This fluid was estimated to be about 20% of the total body weight of an animal. A further 50% of body weight is intracellular and is released more slowly during decomposition of the carcass. To cope with the volume of leachate, at the four sites managed by Defra, leachate was initially taken off-site by tanker. For example, at Tow Law, initially 50-60 tankers per week took leachate to a treatment facility; reducing to *c.*20 tankers per week. At Watchtree, leachate was initially tankered off-site and discharged into the Irish Sea through a long outfall.

Ref: Section C - site design

Desk-based appraisal of site geology/hydrogeology was carried out rapidly for each site prior to carcass burial, with subsequent site evaluation and risk assessment. Of the four 2001 FMD outbreak carcass burial sites managed by Defra, Watchtree, Cumbria has the highest rate of infiltration and produced up to 150 m^3 leachate per week. It is thought to be the most poorly designed and engineered site of the four sites managed by Defra but the addition of an onsite leachate treatment facility means it is the most complete system. Approximately 30% of the burial site is bunded by a bentonite cut-off wall and the bunded area has a separate leachate extraction system in place to minimise the risk to water quality. At Birkshaw there is little infiltration and at Tow Law and Ridgeway Ground, no infiltration according to Defra estates. Birkshaw produced around 60 m^3 per week, and Tow Law approximately 10 m^3 per week. Frequent blockages of the system at Tow Law were thought to be caused by poor decay of carcass matter.

For all 2001 FMD outbreak carcass burial sites, a design and management plan was produced that set out the rationale for the environmental monitoring programme. Environment Agency landfill monitoring guidance[23] was used to set the minimum measurement parameters: Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), ammonium, chloride, potassium, Total Oxidised Nitrogen (TON), phosphorus, electrical Conductivity and pH. Additional parameters measured in leachate include total solids and total dissolved solids, and for groundwater an additional suite of major ions.

Ref: Section D.1 - Evidence of residual risk of FMD and other infections posed by the burial sites

Deep burial plus associated pressures, oxygen levels and temperatures are assumed to limit the survival of non-spore-forming bacteria but little evidence exists on survival and subsequent dissemination.

An evaluation was conducted in 1985 in Denmark to estimate whether burying animals

[23] EA report guidance NC/02/04/01

infected with FMD would constitute a risk to groundwater[24]. The authors concluded that the probability of groundwater contamination from burial of FMD-infected animals was very small, and that even if virus were able to reach groundwater sources, the concentration would likely be inadequate to present an animal-health risk.

Pre-treatment of leachate from the Ridgeway Ground (Worcestershire) site with lime was discontinued 60 days after burial of the last carcass because FMDV was reportedly unlikely to survive more than 40 days in a burial cell[25]. However, no studies were cited to indicate from what data the 40-day estimate was derived.[26]

Survival of FMD virus[27] (after Kitching and Mackay, 1995[28])

3 days on the surface of soil in summer

6 days in milk at 4ºC

14 days in dry faecal material

28 days on the surface soil in autumn

6 months in slurry in winter

4 – 5 months in carcass lymph nodes at 1ºC

Many years on tongue epithelium stored at 4ºC

Ref: Section D.2.1 Anthrax

The last case of Anthrax in cattle in GB (prior to 2001) was a single case; this was also the last case confirmed in Scotland (a 2 year old heifer in Lanarkshire). There have been no diagnosed cases of Anthrax near any of the burial sites since they were established. The disease is sporadic in nature with 1 confirmed incident in 2002 (1 dairy cow, Wrexham), 2006 (2 cows, Wales) and 2015 (2 cows, Wiltshire).

Ref: Section D.2.2 Clostridium spp.

Vaccination against *Clostridium* spp. for cattle or sheep is not compulsory, so animals grazing on or near the carcass burial sites cannot necessarily be assumed to be protected. The expert opinion of the sub-group is the risk from *Clostridium* spp. attributable to these sites is currently negligible, providing they remain undisturbed. If significant disruption to the sites were to occur (e.g. through renovation/upgrading work) then this advice may need to be revisited, and a general ban on grazing animals in the vicinity might be considered necessary.

Ref: Section D.2.4 Other sources of risk: mummification

[24] Lei, J.C. (1985). Can virus from buried animals with foot and mouth disease constitute a pollution hazard in ground water? An evaluation. Dansk Veterinaertidsskrift, 68 (24), 1263-1274.
[25] Det Norske Veritas, 2003, p. II.21).
[26] Nutsch and Spire (2004) Carcass disposal: a comprehensive review, USDA.
[27] State Veterinary Journal Vol 5, No 3, October 1995
[28] Kitching, R.P. & Mackay, D. K. (1995) Foot and Mouth Disease

Mummification could slow the rate of decay in the burial pits. The guidance issued at the time of burial required carcasses to be pierced, which would have reduced the potential for mummification, and the risks of mummification are considered to be negligible

Ref: Section D.3.2 Conceptual model

The conceptual model integrates and synthesises all available information relating to the carcass burial sites to provide a visual representation of the known conditions. The purpose is to:

i. identify the exposure pathways for the release of contaminants from the site to key receptors in the environment,
ii. deduce the environmental and human health risks related to the current operation of the sites, and
iii. support decision-making on additional investigations and measures that may be required to manage risks.

The source-pathway-receptor approach utilising standard decay functions is designed to test the robustness of the available evidence for estimating the residual risk at that site, which is key to understanding the long-term liability of the site.

Annex D: Tables referred to in main report

Table 1 2001 FMD outbreak mass burial sites, carcass types and carcass volumes

Site	*Area (hectares)*	*Previous use*	*Carcass volume buried (tonnes)*	*Carcass numbers buried*			
				Cattle	*Sheep*	*Pigs*	*Other*
Watchtree, Cumbria	*209*	*airfield*	*29500*	*12,085*	*448,508*	*5,719*	*-*
Ridgeway Ground, Worcestershire	*627*	*farmland*	*15500*	*17,401*	*110,100*	*4,795*	*403*
Widdrington, Northumberland	*25*	*landfill, former open-cast coal*	*-*	*12,056*	*110,261*	*11,438*	*17*
Tow Law, Co. Durham	*97*	*grazed, former open-cast coal*	*4700*	*4,759*	*39,333*	*1,123*	*15*
Eppynt, Powys	*17*	*clay quarry*	*-*	*-*	*18,000*	*-*	*-*
Birkshaw, Dumfries & Galloway	*50*	*commercial forest*	*22900*	*4000*	*490,000*	*Some*	*-*
TOTAL (approx.)			*95,000*	*50,301*	*1,216,202*	*23,075*	*435*

Source: Environment Agency (2003) Foot and Mouth epidemic: Data on leachate chemistry for estimating pollution potential from mass burial sites and pyre ash disposal sites. Report No. NC/02/04/3. Additional data for Birkshaw came from *Capping and Restoration Plan (2001) Final Report, EnvirosAspinwall.*

NOTES

1. Operational and management control is administered by Defra at four sites: Watchtree, Ridgeway Ground, Tow Law and Birkshaw. Two of the sites are owned, one is a long lease, and the Scottish land is subject to a minute agreement (i.e. an occupational easement). Prior to 2006 the sites were run by the veterinary function within Defra; in 2006 they transferred to an estates legacy.
2. At Eppynt, seepage problems leading to groundwater contamination meant the 18,000 carcasses originally buried were exhumed and burnt along with a further 19,500 carcasses.
3. At Widdrington, the land was retained on a short lease under a deed of variation between Defra and UK Coal Mining Limited that ended 2006. Defra has no ownership or control over the site and it not a Defra asset.

Table 2 Indicative initial composition of leachate from 2001 FMD outbreak mass burial sites

All Figures in mg/l except pH.

Determinand	Concentration range	Suggested source term concentration	Concentration in abattoir blood washings
BOD	11,000 - 70,000	40,000	32,000
COD	15,000 - 90,000	50,000	
Ammonium	1,000 - 7,000	4,000	205
Potassium	100 - 2,500	1,000	
Chloride	20 - 1,500	20 - 1,500	4,047
TOC	4 - 51,000	1,000 - 40,000	
TON	<1 - 710	40 - 700	
Phosphorus	10 - 334	(mean = 110 from 7 samples)	
Bacterial indicators			Very low in fresh blood from healthy animals.
pH	5.8 - 9.0	6.0 - 8.0	
Sheep dip chemicals		Propetamphos and diazinon detected at low concentrations	

Source: Environment Agency (2003) Foot and mouth epidemic: Disposal of culled stock by burial - Guidance and reference data for the protection of controlled waters. Report No. NC/02/04/1

Table 3 Summary site design features for the four 2001 FMD outbreak carcass burial sites administered by Defra

Site	Ridgeway Ground	Watchtree	Tow Law	Birkshaw
Carcasses buried (tonnes)	15,500	29,500	4,700	22,900
Number of cells used	6	26	3	6
Approximate dimensions (m) (L x W x D)	50 x 25 x 4	200 x 5 x 2	150 x 30 x 3	40 x 15 x 4
Cell Lining	None	None	Installed Liner	None
Leachate volume (m^3 day^{-1})	13	21	1.3	4.5
Cells capped?	Yes	Yes	Yes	Yes
Leachate collection system	Buried Automatic	Buried Automatic	Buried Automatic	Manual from Surface
Cell management pipework in place?	No	Yes	Yes	No

Source: Unipure Europe Ltd (2006) Ex FMD Disposal Sites: future site management draft report U0409-R7, Defra Estates Division, 22pp.

Table 4 Summary of data held for the 2001 FMD outbreak carcass burial sites managed by Defra

Data Measure	*Sub Measures*	*Watchtree*	*Tow Law*	*Ridgeway Ground*	*Birkshaw*
Site location		Cumbria	Co. Durham	Worcestershire	Dumfries & Galloway
Burial Cells	Number	√	√	√	√
	Location	√	√	√	√
	Layout/Configuration	√	√	√	√
	Construction Design Plans (incl. as built)	√	√	√	√
	Operational schematics	√	√	√	√
Monitoring	Sample point locations	√	√	√	√
Primary Analytical Data	Biologic Oxygen Demand (BOD)	√	√	√	√
	Chemical Oxygen Demand (COD)	√	√	√	√
	Ammonical Nitrogen (NH_3-N)	√	√	√	√
	Leachate Nitrate conc.	√	√	√	√
	Suspended solids	√	√	√	√
Elemental Chemical Data	Potassium	√	√	√	√
	Chloride	√	√	√	√
Field Measurement Parameters	pH	√	√	√	√
	Temperature	√	√	√	√
	Electrical conductivity	√	√	√	√
	Oxygenation reduction potential (redox)	√	√	√	√
	Dissolved oxygen	√	√	√	√
Groundwater Data	Ground water level	√	√	√	√
	Ground water flow (actual or estimated)	√	x	x	x
Gas Monitoring/ Measurement Data	Methane	√	√	√	√
	Carbon Dioxide	√	√	√	√
	Oxygen	√	√	√	√
	Carbon Monoxide	√	x	x	x
	Hydrogen Sulphide	√	√	√	√
Ground Water	Baseline Composition (BOD/COD/NH_3-N)	√	√	√	√
	Quality Analysis	√	√	√	√
Volumetric Measures	Leachate	√	√	√	√
	Rainfall	√ from site	x	x	√ regional source
	Groundwater	√	x	x	x
	Carcass Burial No	√	√ est per cell	√ est	√ est
	Carcass Burial Mass (actual or estimated)	√	x	√ est	√ est
	Carcass Burial by Livestock Unit	√	x	√ est	√ est
Monitoring & Sampling	Frequency	√	√	√	√
Data Integrity[29][30]	Good	√	√	√	√
	Adequate				
	Poor				

[29] 'Good' is majority of data available for analysis; 'Adequate' is a range of data but not a complete data field back to 2001; 'Poor' 'incomplete data across majority of data source from 2001

Table 5 Aggregate leachate quality for ammoniacal Nitrogen for Watchtree carcass burial site, Cumbria

Year (Jan to Dec)	Count of results	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)
2001	33	5	6,210	1,410
2002	59	35	4,650	1,070
2003	46	179	7,280	2,915
2004	47	403	3,260	1,030
2005	47	3	2,770	914
2006	44	10	2,010	636
2007	47	13	691	360
2008	40	173	601	312
2009	13	167	471	294
2010	12	178	479	311
2011	11 [*152*]	170 [*122*]	304 [*406*]	247 [*260*]
2012	12 [*153*]	141 [*111*]	285 [*444*]	191 [*228*]
2013	12 [*140*]	120 [*118*]	274 [*360*]	188 [*236*]
2014	12 [*151*]	99 [*114*]	331 [*518*]	206 [*270*]
2015	12 [*154*]	134 [*159*]	421 [*490*]	198 [*235*]
2016	9 [*88*]	81 [*104*]	175 [*408*]	128 [*207*]

Note:
Values in square brackets indicate onsite laboratory results

Source: Interserve Facilities Management ltd (2016) Watchtree FMD Disposal Site: environmental data analysis, Report 54382/R6v1, 26 September 2016, 73pp

Notes

1. Aggregate leachate is the combined leachate from all the burial pit sumps at Watchtree, Cumbria.
2. Leachate quality is influenced by: (i) dilution due to infiltrating rainfall, (ii) decomposition status of the carcasses and (iii) any degradation/retardation as leachate migrates from the pit to the sump aggregate collections point.
3. Fluctuations in leachate concentration vary seasonally: highest concentrations are recorded in summer during periods of low effective rainfall, and low concentrations during winter months, coinciding with periods of recharge.
4. Varying strengths and volumes of leachate from each burial pit are contributing to the aggregate leachate. There is some correlation with variation in pit design.

Table 6 Aggregate leachate quality for chloride for Watchtree carcass burial site, Cumbria

Year (Jan to Dec)	Count of results	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)
2001*	77*	20*	1,700*	490*
2002	24	53	530	166
2003	46	41	773	264
2004	47	55	256	94
2005	48	23	220	92
2006	44	31	185	64
2007	22	39	78	52
Note: ** No Cl data for aggregate leachate in 2001. Data from individual burial trenches.*				

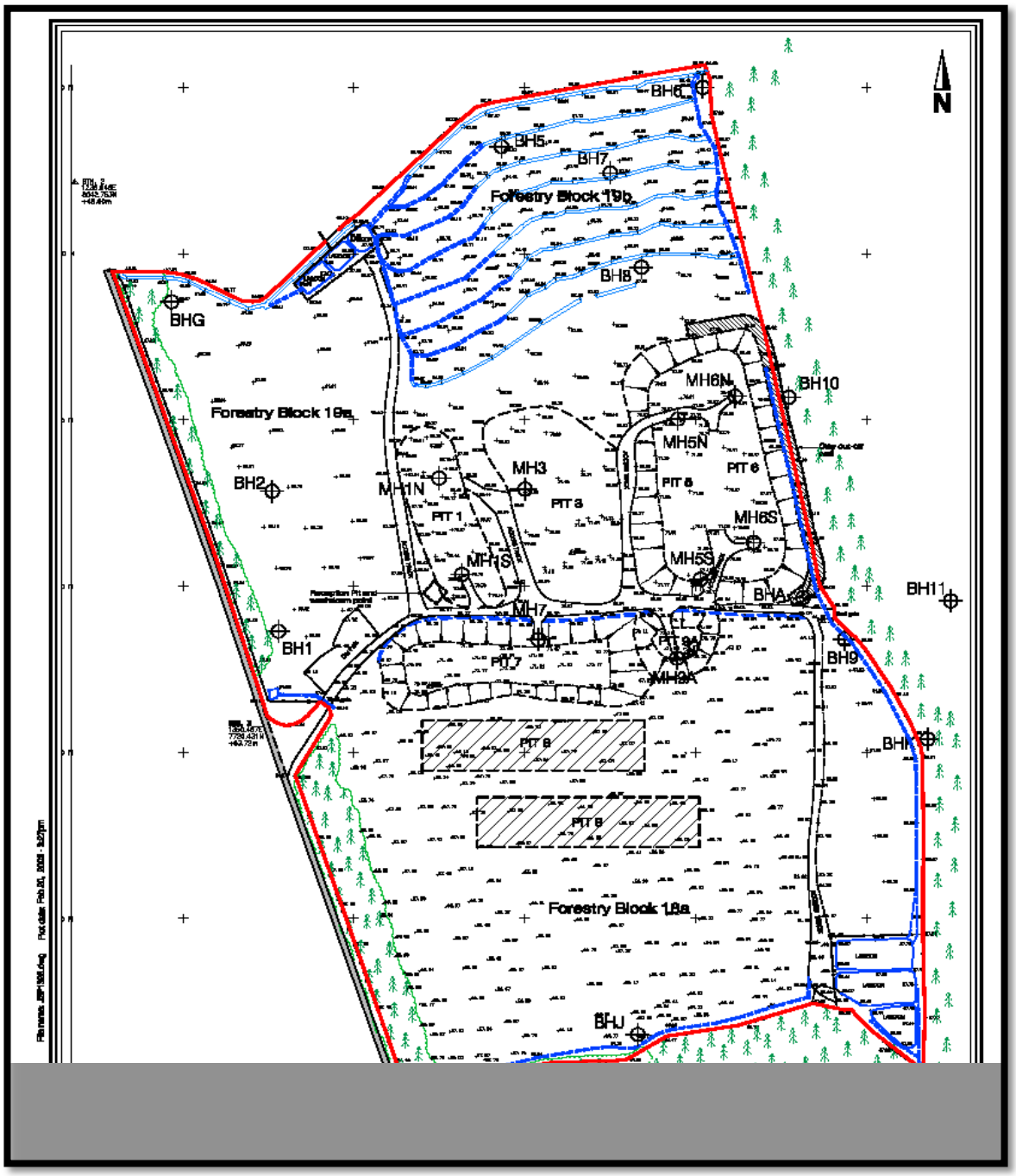
Source: Interserve Facilities Management ltd (2016) Watchtree FMD Disposal Site: environmental data analysis, Report 54382/R6v1, 26 September 2016, 73pp

Notes

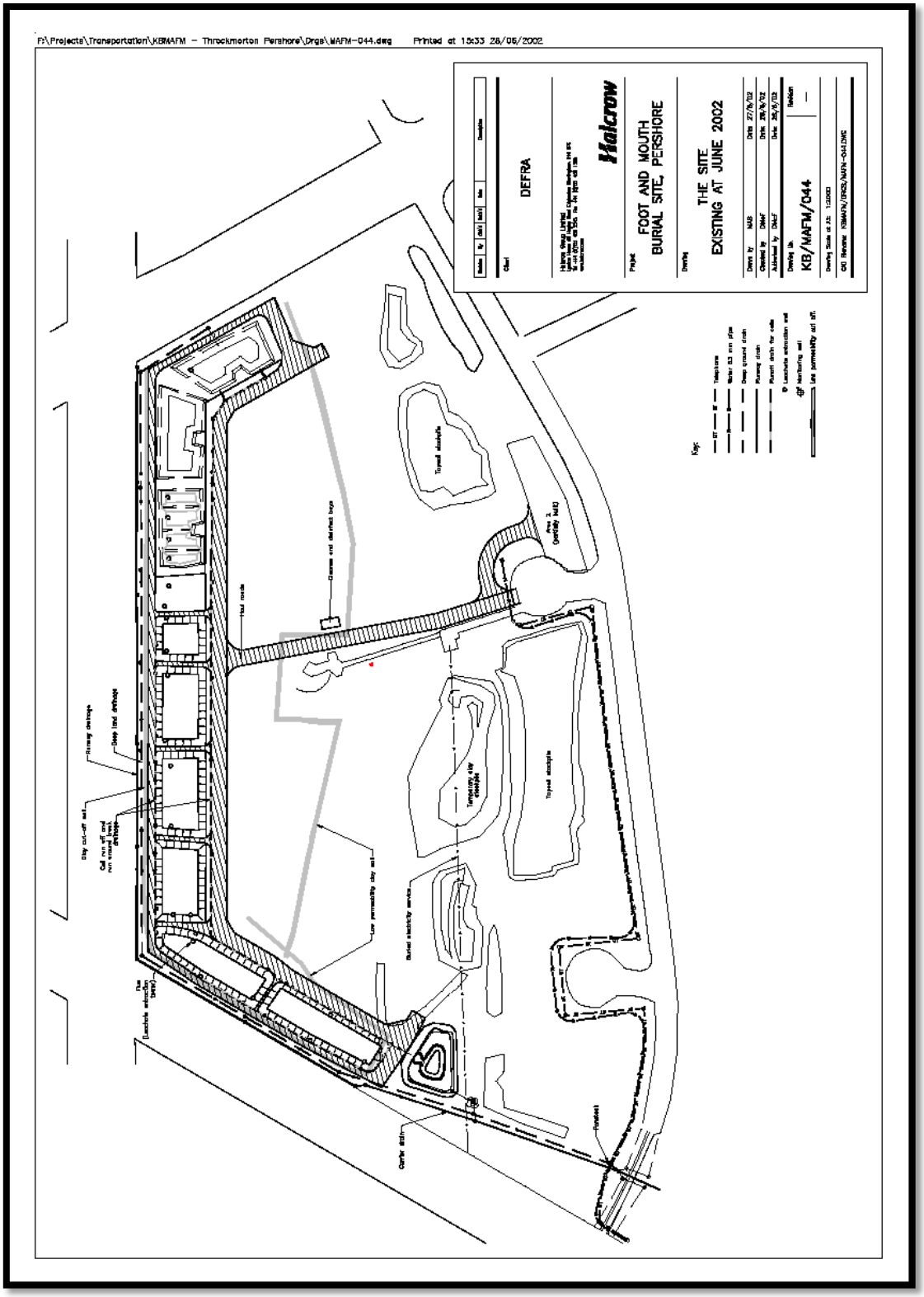
1. Chloride monitoring ceased in 2007.
2. Measurements are correlated with seasonal rainfall: with dilution observed in winter months or for above average rainfall.

Annex E: Site drawings referred to in main report

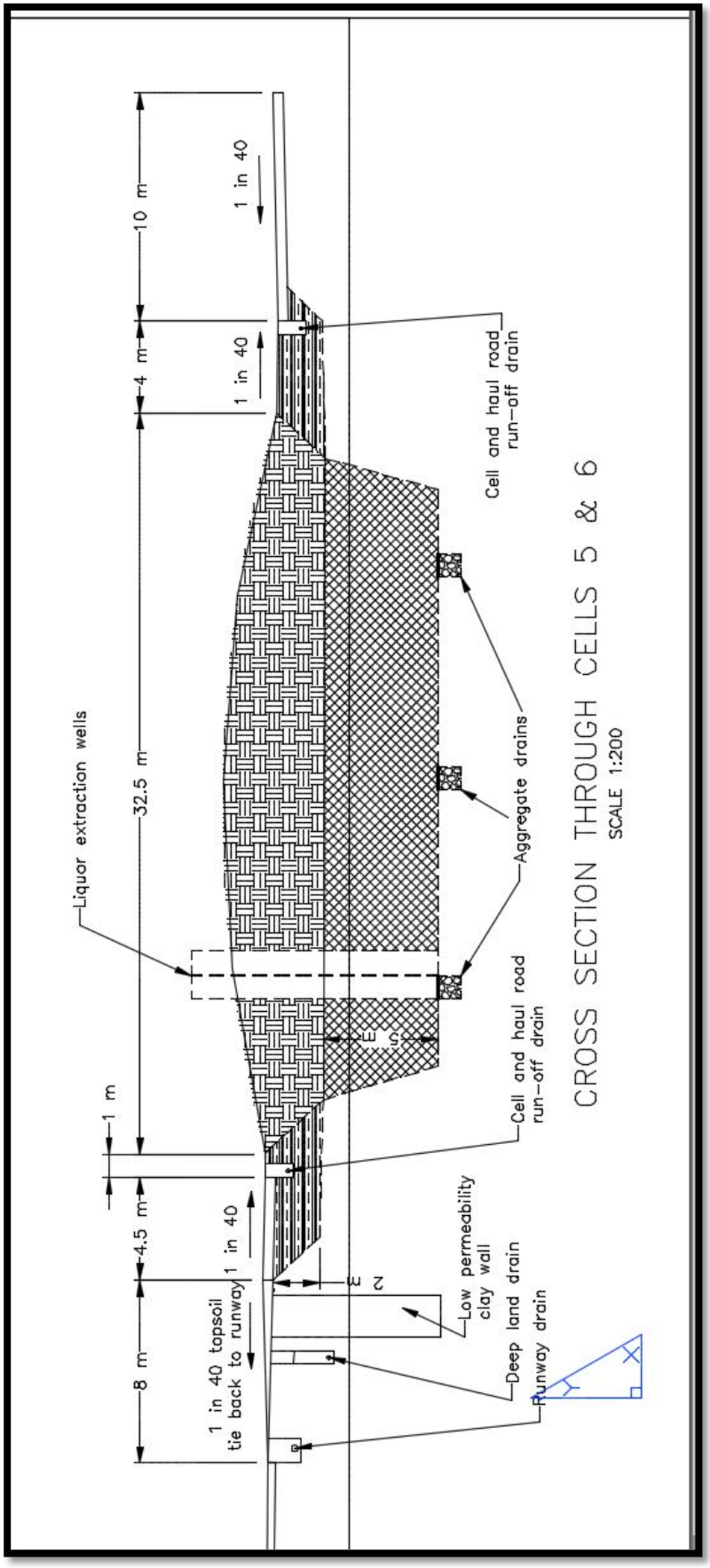
Sketch 1: Site drawing: Birkshaw Forest, Dumfries & Galloway



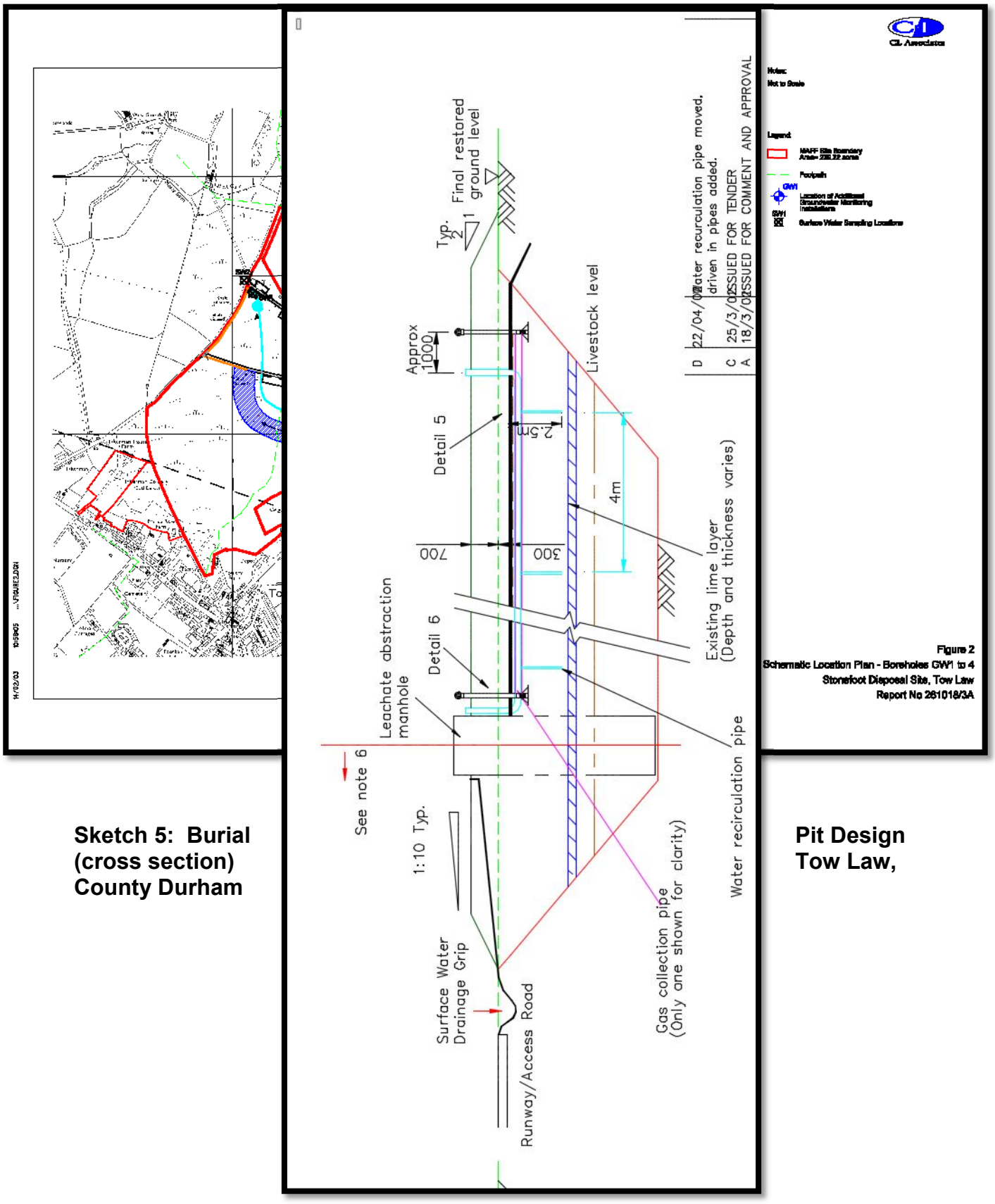
Sketch 2: Site drawing Ridgeway Ground, Worcestershire



Sketch 3: Burial Pit Design (cross section) Ridgeway Ground, Worcestershire

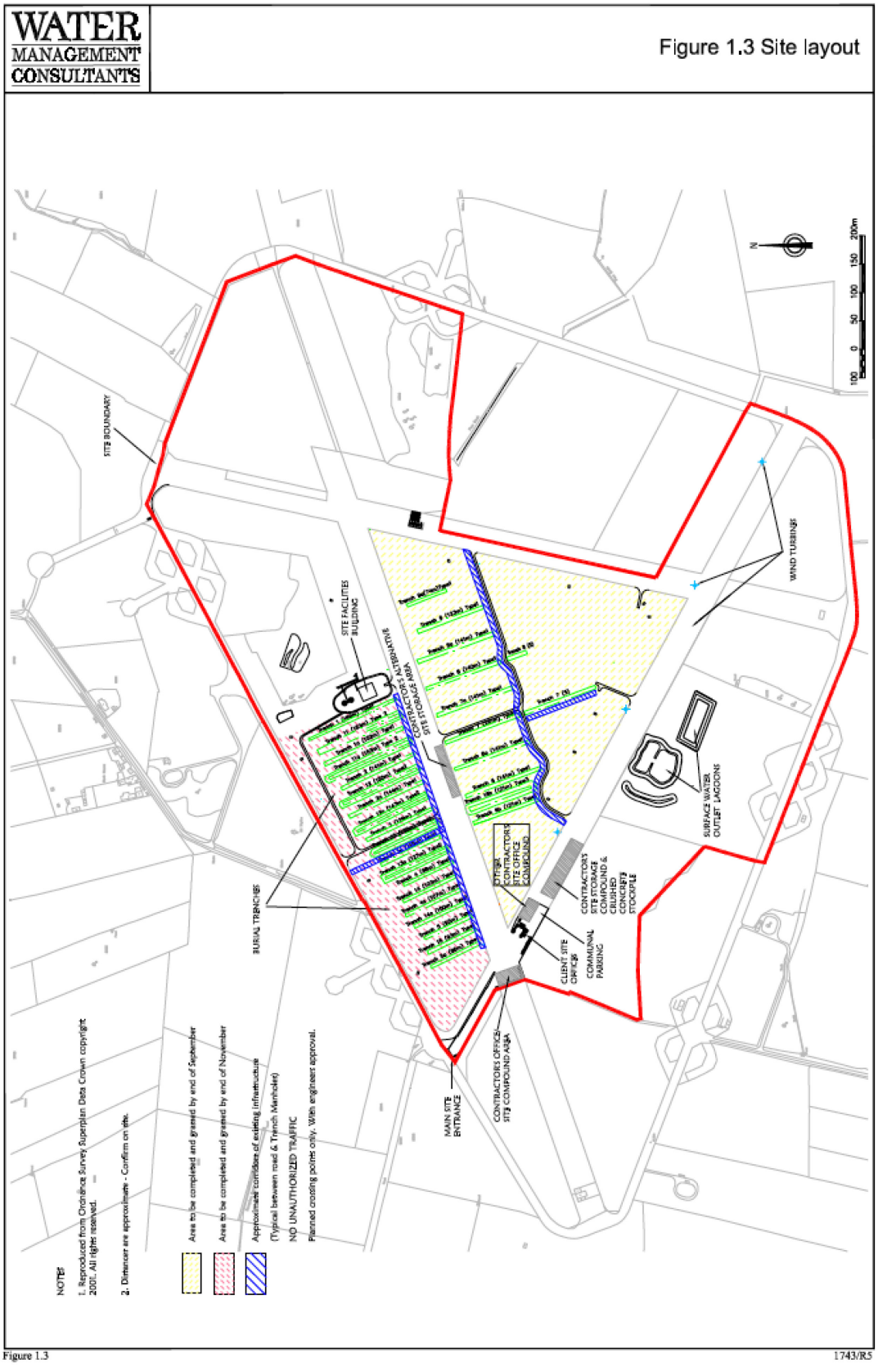


Sketch 4: Site drawing Tow Law, County Durham

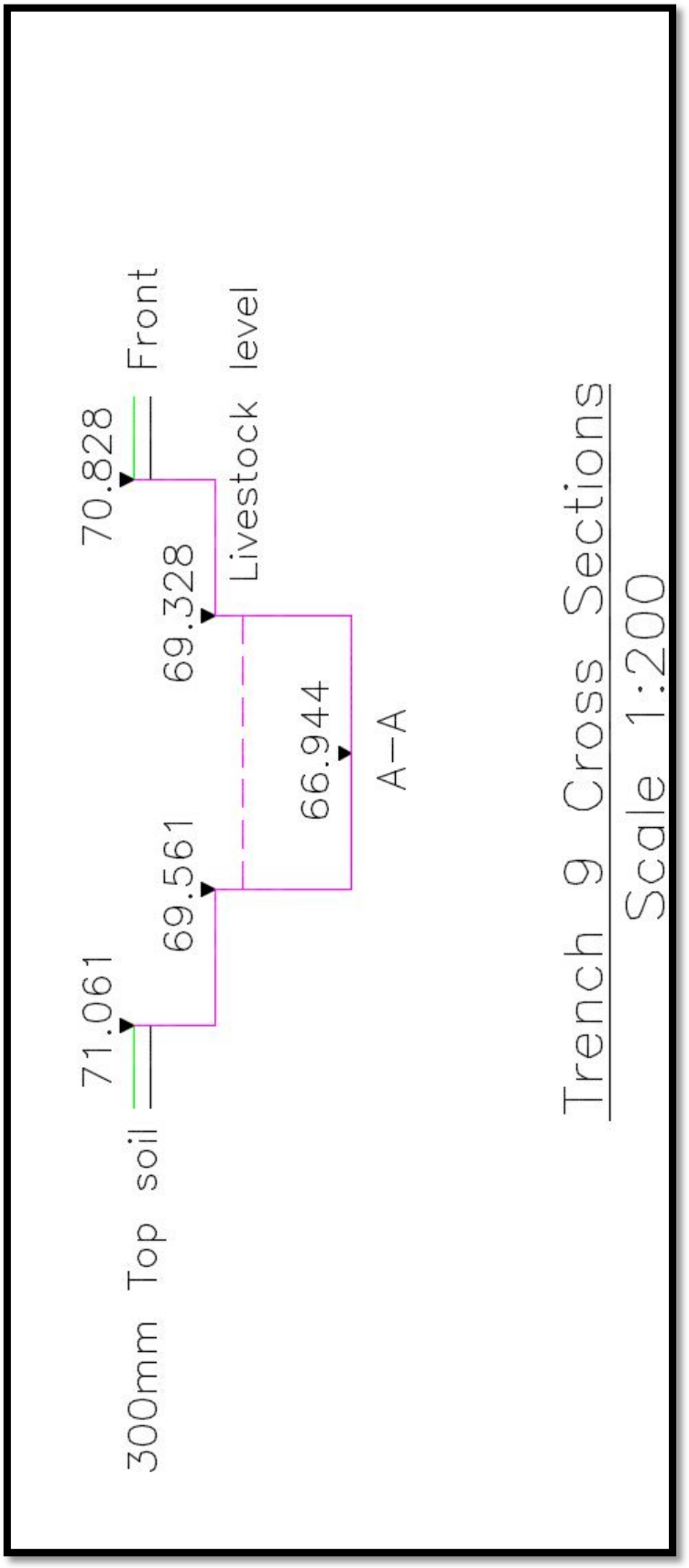


Sketch 5: Burial (cross section) Pit Design Tow Law, County Durham

Sketch 6: Site drawing Watchtree, Cumbria



Sketch 7: Burial Pit Design (cross section) Watchtree, Cumbria



Annex F: Evidence base to inform the conceptual model for Watchtree

Summary of the evidence and information reviewed to compile the evidence base needed to inform the development of the conceptual model(s) for the FMD burial sites. *Note: only Watchtree, Cumbria is being developed as a test model.*

Document type	Document name/number of documents	Other information, e.g. reference numbers if known and name given to file	Burial site
PNG Image Ariel photo by Simon Ledingham	Great Orton airfield burial site in 2005.	Screen shot 2016-8-02 at 09.38.42	Watchtree
Image from GoogleEarth.pdf	Ariel image of Gt Orton Airfield from GoogleEarth	Watchtree. GoogleEarth.pdf	Watchtree
Report by Professor Ranald Munro, October 2006	Decomposition of Cadavers in Foot & Mouth Burial Sites Initial report on examination of samples at Watchtree (Great Orton) 18/10/2006	LH 2009 Munro Advice Decomposition of FD cadavers.doc	Watchtree
I page summary document, no ref or date on doc	Great Orton area, Cumbria	Watchtree- Gt Orton_BGS_Geology_background.doc	Watchtree
Geological site Summary Report , BGS, 2001	Geology of the Great Orton Area	Watchtree- Gt Orton_BGS_GoelReport_EE01_348.doc	Watchtree
Notes of phone conversations	between Rick Brassington, Keith Seymour, Nigel Robinson	Watchtree- Gt Orton_BGS & EA_correspondence.doc	Watchtree
Image, Halcrow Group Ltd	Structural geology	Figure 6.2.pdf	Watchtree
Image, Halcrow Group Ltd	Surface water features, seepages and wells	Figure 6.3.pdf	Watchtree
Image, Halcrow Group Ltd	Conceptual groundwater model	Figure 6.4.pdf	Watchtree
Image, Halcrow Group Ltd	Type 3 burial pit (trench) layout	Figure 7.1.pdf	Watchtree
Image, Halcrow Group Ltd	Type 3 burial pit (trench) liner design	Figure 7.2.pdf	Watchtree
Image, Halcrow Group Ltd	Liquor collection sump	Figure 7.3.pdf	Watchtree
Image, Halcrow Group Ltd	Groundwater control system	Figure 7.4.pdf	Watchtree
Image, Halcrow Group Ltd	Groundwater control system alignment	Figure 7.5.pdf	Watchtree
Image, Halcrow Group Ltd	Groundwater monitoring locations	Figure 9.2.pdf	Watchtree
Image, Halcrow Group Ltd	Surface water monitoring locations	Figure 9.3.pdf	Watchtree
Image, Halcrow Group Ltd	Final land profiles	Figure 10.3.pdf	Watchtree
Image, Halcrow Group Ltd	Conceptual groundwater model	Figure 16.1.pdf	Watchtree
Image, Halcrow Group Ltd	Borehole trail pit locations	Figure 16.2.pdf	Watchtree
Image, Halcrow Group Ltd	Surface water features seepages and wells	Figure 16.3.pdf	Watchtree
Image, Halcrow Group Ltd	Groundwater control system	Figure 16.4.pdf	Watchtree
Image, Halcrow Group Ltd	Groundwater monitoring locations	Figure 16.5.pdf	Watchtree
Image, Halcrow Group Ltd	Surface water monitoring locations	Figure 16.6.pdf	Watchtree
Image, JAF Ltd	Environment monitoring points	1660-P2-0130-Z.pdf	Watchtree
Image, JAF Ltd	Environment monitoring points location plan. Interactive layer map	1660-P2_Watch Tree site map.pdf	Watchtree
Images by Halcrow Group Ltd	List of images followed by all images as already stated	All figures.pdf	Watchtree

Document type	Document name/number of documents	Other information, e.g. reference numbers if known and name given to file	Burial site
Interpretive Annual Monitoring Report, Watchtree 2015-2016 Schlumberger Water Services	Very detailed report, prepared for Interserve (facilities management) by Schlumberger Water Services (24/05/16)	Annual monitoring report for watchtreev1.pdf	Watchtree
Great Orton Disposal Site Hydrogeological Report Sept 2001 (Draft),Water Management Consultants	Great Orton Disposal Site Hydrogeological Report Sept 2001, 1660/R10, DRAFT	Great Orton Disposal Site Hydrogeological Report Sept 2001.pdf	Watchtree
Review of Watchtree FMD Disposal Site: Cell Management Review, 04/09/2015, Schlumberger Water Services	Very detailed report, prepared for Interserve (facilities management) by Schlumberger Water Services	Review of Watchtree FMD site _FINAL-R2v2.pdf	Watchtree
6 pages of badly scanned information Draft report	Great Orton Factual Report MAFN 1037	MAFM1037 Draft of Gt Orton Site investigation report.pdf	Watchtree
Geological Summary Site Report, BGS, 03/11/2016	Geology of the Great Orton Area, prepared for the Environment Agency	BGS site geology report.doc	Watchtree
Report , May 2001, prepared for MAFF by Water Management Consultants Ltd	GREAT ORTON GROUND INVESTIGATION FACTUAL REPORT, May 2001, 1660/R4	1660_R4_SWS_compiled.pdf	Watchtree
Report , May 2001, prepared for MAFF by Water Management Consultants Ltd	GREAT ORTON GROUNDWATER CONTAINMENT DESIGN, May 2001, 1160/R7	1660_R7_SWS compiled.pdf	Watchtree
Report ,Oct 2001, prepared for MAFF by Water Management Consultants Ltd	GREAT ORTON DISPOSAL SITE HYDROGEOLOGICAL REPORT AND GROUNDWATER CONTAINMENT SYSTEM DESIGN, October 2001, R1660/R10	1660_R10_Final-compiled.pdf	Watchtree
Report ,June 2001, prepared for MAFF by Water Management Consultants Ltd	GREAT ORTON ENVIRONMENTAL MONITORING REPORT 1, June2001, 1660/R12	1660_R12_SWS_FINAL compiled.pdf	Watchtree
Powerpoint presentation of photographs of Watchtree FMD site	Carcasses waiting disposal, slaughter shed, trench type 1B, 1A, type III, trench under-drainage system, retro-fitted fluid extraction wells, cattle/sheep disposal, initial fluid release, fluid perimeter ditch, DAF plant, DAF results2001, cut off wall drilling, cut off wall trial		Watchtree
Page Scan from document, and letter 22/11/2001, CL Associates	Key to Explanatory Hole Records	Key to Explanatory Hole Records_Tow Law site.pdf; BH log info detailed	Tow Law
Letter of correspondence Dr James D. Floyd, BGS		TowLaw_BGS_Letter.doc	Tow Law
BGS report 2016	Geological Summary Site Report, 2016	BirkshawForest_BGS_GeolReport_EE01_508.doc	Birkshaw Forest
0.5 page summary	Hydrogeological data for Birkshaw Forest	BirkshawForest_BGS_hydrogeology.doc	Birkshaw Forest
Image, Halcrow Group Ltd	Cross section through a typical burial pit (cell) Ridgeway Grounds	Figure 3.pdf	Ridgeway Grounds

Document type	Document name/number of documents	Other information, e.g. reference numbers if known and name given to file	Burial site
Image, Halcrow Group Ltd	Conceptual Model of Ridgeway Grounds Burial Site	Figure 4.pdf	Ridgeway Grounds
Image, Halcrow Group Ltd	Geological Cross Section of Ridgeway Grounds Burial Site	Figure 6.pdf	Ridgeway Grounds
Image, Halcrow Group Ltd	Interpolated Water Contours, August 2003 for deep boreholes, Ridgeway Grounds Burial Site	Figure 7.pdf	Ridgeway Grounds
Image, Halcrow Group Ltd	Average monitoring well concentrations of TOC, potassium and ammonia, between July 2001 and December 2001, Ridgeway Grounds Burial Site	Figure 12.pdf	Ridgeway Grounds
PNG image	List of Appendix pdfs Ridgeway Grounds data sets for gas, water, groundwater and leachate quality	List of Appendices.png (image only)	Ridgeway Grounds
Geological report, BGS, 25/06/2001	Geological Report of Widdrington Mass Disposal Site	Widdrington_BGS_GoelReport_EE01_541.doc	Widdrington
3 page summary of information, BGS	Hydrogeology records search and possible leachate transport risk: Widdrington Burial Site	Widdrington_BGS_Hydrogeology.doc States that other data needs to be located. No date on document or ref number	Widdrington
Report, July 2001, prepared for DEFRA by Water Management Consultants Ltd	Desk study report on the Widdrington mass burial site and environs, July 2001, 1673/R1	1673_R1.pdf	Widdrington
Report, July 2001, prepared for DEFRA by Water Management Consultants Ltd	Site investigation report on the water environment at the Widdrington FMD Burial Site, , October 2001, 1673/R2A	1673_R2A.pdf	Widdrington
Report, Oct 2002, prepared for DEFRA by Water Management Consultants Ltd	Assessment of risk to controlled waters from the Widdrington FMD burial site, October 2002, 1673/R2B	1673_R2b.pdf	Widdrington
Report, Nov 2002, prepared for DEFRA by Water Management Consultants Ltd	Assessment of the potential for groundwater flow between Widdrington FMD burial site and Steadsburn extension, November 2002, 1673/R3	1673_R3.pdf	Widdrington
Report, Dec 2003, prepared for Bucknall Austin by Water Management Consultants Ltd	Widdrington FMD burial site Annual Monitoring Report– 2003 December 1868/R1	1868_r1.pdf	Widdrington
Technical memorandum, prepared by Schlumberger Water Services for EA and Interserve	Subject: Water Quality Monitoring at the Widdrington Foot and Mouth Burial Site, 14/08/2015	54381TM1v2.pdf	Widdrington
Geological Report, BGS , 02/04/2001	Geological Report for Pershore Airfield	Thockmorton_BGS_GeolRepot.pdf	Pershore Airfield
Word Document (no authorship)	Data and monitoring issues. Further to Martin Griffiths note of 29 April 2001	Data and monitoring requirements _v2.pdf	For all sites in UK
Paper by Department of Health, 31/05/2001, pdf	FOOT AND MOUTH DISEASE: Disposal of Carcasses Programme of Monitoring for the Protection of Public Health	Doh_501.pdf	For all sites in UK
EA report, Dec 2001, pdf. D3.32C(414)	The environmental impact of the foot and mouth disease outbreak: an interim assessment.	Environmental_ impact_ of _the_ foot and_ mouth_ disease_ outbreak_ an interim_ assessment [1].pdf AND Fmd_report.pdf	For all sites in UK

Document type	Document name/number of documents	Other information, e.g. reference numbers if known and name given to file	Burial site
C P Young, P A Marsland and J W N Smith (2001). Draft R&D Technical Report: Version 7, pdf	Foot and Mouth Disease Epidemic: Disposal of culled stock by burial: Guidance and Reference Data for the protection of controlled waters	20001643.pdf	For all sites in UK
Excel spreadsheet	Leach test results_V2_290501.xls	LEach test results_V2_290501.xls	For all sites in UK
Excel spreadsheet	Leach test results_V3_250601.xls	LEach test results_V3_250601.xls	For all sites in UK
P A Marsland, J W N Smith and C P Young (2003). National Groundwater and Contaminated Land Centre, EA report	Foot and mouth epidemic: Disposal of culled stock by burial – Guidance and reference data for the protection of controlled waters	NC_02_04_1(FMD burial).pdf Environment Agency report NC/02/04/1	For all sites in UK
www.defra.gov.uk guidance document, June 2011, pdf	Guidance on applying the Waste Hierarchy	Pb13530-waste-heirarchy-guidance.pdf	For all sites in UK
J.M. Scudamore, G.M. Trevelyan , M.V. Tas, E.M. Varley & G.A.W. Hickman (2002). Journal paper.	Carcass disposal: Lessons from Great Britain following the foot and mouth disease outbreaks of 2001	Review of 2001FMD sites paper by Scudmore et al.pdf	For all sites in UK
Pdf, guidance on completing conceptual models	Annex 4 – Conceptual Model	Annex 4 Conceptual model pdf	For all sites in UK
Pdf, Image of an example of a conceptual model	Conceptual site models : Components	Example of CSM .pdf	For all sites in UK
Report by : DEFRA, Estates Division, Unipure Europe Ltd and Bucknall Austin, 2006 (word document)	Ex FMD Disposal Sites Future Site Management	LH U0409-R7 2006Defra Estates FMD Future site management.doc	For all sites in UK
Excel spreadsheet, monitoring schedules for all sites and reports	Lists of Reports available for all sites throughout years, some from 2002 to 2016 on monthly basis	Annex 4 FMD Sites- Reporting to date 15/03/2016v2.pdf	For all sites in UK
Research Article, 2002	Carcass disposal: lessons from Great Britain following the foot and mouth disease outbreaks of 2001	Review of 2001 FMD sites; Paper by Scudmore et al.pdf	For all sites in UK
Excel spreadsheet	Data Identification Exercise SAC-FCB Sub group	LH Data Identification Exercise SAC-FCB Sub group	For all sites in UK
Data Summary EA report scan	Data Summary, List of reports for all sites and when carried out, reports included are up to 2015 for Watchtree, Tow Law and Throckmorton.	Annex 4 FDM Data Summary.pdf Scottish Environmental Protection Agency, table of some data for Birkshaw Forest, Bengal Farm 2001-2004	For all sites in UK
EA report, Dec 2004	Potential groundwater pollutants from cemeteries	SCH0120BIKR-e-e.pdf	N/A
Published Research Journals, all PDF format	16 papers	General information about cadaver (human)decomposition in terrestrial burial	N/A
Published Research Journal, 2005, Alwyn Heart , pdf	Ammonia shadow of my former self: a review of potential groundwater chemical pollution from cemeteries	Ammonia shadow paper.pdf	N/A
Booklet by EA Science Group: Air, Land & Water, 2004	Assessing the Groundwater Pollution Potential of Cemetery Developments	Cemeteries_apr_790738.pdf	N/A
EA report, Dec 2004	Potential groundwater pollutants from cemeteries	SCH0120BIKR-e-e.pdf	N/A
Working draft March	Global Polio Eradication	GPLN_Guidlines_April2015.pdf	N/A

Document type	Document name/number of documents	Other information, e.g. reference numbers if known and name given to file	Burial site
2015	Initiative, guidelines on environmental surveillance for detection of polioviruses		
Word document	Annex 2 – regulatory issues for Foot and Mouth Disease disposal sites	Annex 2 Regulatory Issues Burial Sites.pdf	N/A
EA Guidance Document, 13/12/2012	Landfill (EPR 5.02) and other permanent deposits of waste How to surrender your environmental permit	Annex 3 permit licence surrender guidance.pdf	N/A
Research Article, 2016	Environmental surveillance of viruses by tangential flow Filtration and metagenomic reconstruction	2016 Furtak et al Euroserv21438.pdf	N/A
Scan of book pages 'Contagious Diseases of' (1900),and 'Prevention and control of Animal Diseases', (1991), (1999), (2006)	Annex 2.	Unclear .no reference; book extracts.Page 66 from 1900's book, Page 2 And 3 from 1991 book, page 2 from 1999 and 2 pages from 2006 book pages not detailed or referenced. Annex 2.pdf	N/A
Book page sections x2. Word document	Annex 3	Unclear .no reference; book extract, Anthrax, Chapter B2 Exotic Disease.	N/A
Book page section. Word document	Anthrax outbreaks in GB	Unclear .no reference; book extracts. Table of Anthrax outbreaks in GB: 1887-1900 and 1992-2015; Anthrax outbreaks in GB SAC.doc	N/A
Email from Kostya Chumakov, text copied to word document	Email from Kostya Chumakov. No date or other info.	Email from Kostya Chumakov, about his research paper and link to another report	N/A
Book scanned information in pdf	Foot and Mouth Disease: The principle Features	Irish Veterinary Journal, 1987, 41:325-327 pdf.	N/A
Book scanned information in pdf, Alex I. Donaldson	Irish Veterinary journal 41:325-327, 1987. Foot-and- Mouth Disease: The principle Features	Jw002.pdf	N/A
Word document, correspondence	Response from Alex Donaldson	Correspondence with book scanned information	N/A
1 page flow chart, BGS	Procedure for IGS(N) Enquiry Response within BGS	FMD_BGS_response flow chart.doc	N/A

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We are grateful to the scientists and regulators that formed the sub-group for their willingness to provide expert opinion and advice, sometimes based on limited or raw data, and their wholly constructive engagement in considering the evidence underpinning our advice.

The Chair of the sub group would particularly like to thank the Defra secretariat for their patience, support and enthusiasm in putting the report together and the Defra estates team for their calm and professionalism in dealing with repeat requests for information and insight, which often meant going back to archived information from many years ago.

Glossary and abbreviations

Term	Meaning
Ammoniacal Nitrogen	Is a measure for the amount of ammonia, a toxic pollutant often found in landfill leachate and in waste products, such as sewage, liquid manure and other liquid organic waste products. The term is used widely in waste treatment and water purification systems.
Anthrax	A fatal infectious disease of mammals and humans caused by a spore-forming bacterium called *Bacillus anthracis*.
Biodegradable wastes	Includes any organic matter in waste which can be broken down into carbon dioxide, water, methane or simple organic molecules by micro-organisms and other living things using composting, aerobic digestion, anaerobic digestion or similar processes. In waste management, it also includes some inorganic materials which can be decomposed by bacteria.
Biological sources of risk	Can include foot and mouth disease virus (FMDV), *Escherichia coli* (E. coli O157:H7), *Campylobacter*, *Salmonella*, *Leptospira*, *Cryptosporidium*, Anthrax, *Clostridium* spp. and Bovine spongiform encephalopathy (BSE) & scrapie prions
Biosecurity	Preventive measures designed to reduce the risk of transmission of infectious diseases.
Bovine spongiform encephalopathy	Is a fatal neurodegenerative disease in cattle that causes a spongy degeneration of the brain and spinal cord.
Carboxylic acids	A carboxylic acid is an organic compound that contains a carboxyl group (C(=O)OH). The general formula of a carboxylic acid is R–COOH, with R referring to the rest of the (possibly quite large) molecule. Carboxylic acids occur widely and include the amino acids and acetic acid.

Chemical sources of risk	Arising from the process of decomposition might typically include ammonium nitrogen, chemical oxygen demand and biological oxygen demand
Environmental permit regulation	Some facilities could harm the environment or human health unless they are controlled. The environmental permitting regime requires operators to obtain permits for some facilities, to register others as exempt and provides for ongoing supervision by regulators.
Gaseous sources of risk	Primarily carbon dioxide (CO2) and methane (CH4) plus trace gases (e.g. hydrogen sulphide, H2S).
Leachate	The decomposition of carcasses results in bodily fluid and other dissolved components being slowly released in the form of leachate. The leachate has the potential to pollute the environment unless it is carefully managed, including treatment and disposal.
Monitoring	Covers: site performance and behaviour, leachate volumes and composition, and groundwater, surface water and gases/air quality
Negligible risk	As defined by The World Organisation for Animal Health (OIE) it means “so rare that it does not merit to be considered”.
Prions	Transmissible spongiform encephalopathies (TSEs), also known as prion diseases are a group of progressive conditions that affect the brain and nervous system of many animals, including humans. Prions cannot be transmitted through the air or through touching or most other forms of casual contact. However, they may be transmitted through contact with infected tissue or body fluids,
Residual risk	Is the risk or danger of an action or an event, a method or a (technical) process that, although being abreast with science, still conceives these dangers, even if all theoretically possible safety measures would be applied (scientifically conceivable measures).

Scrapie	Is a fatal, degenerative disease that affects the nervous systems of sheep and goats. It is one of several transmissible spongiform encephalopathies (TSEs), which are related to bovine spongiform encephalopathy and chronic wasting disease of deer.

Abbreviations

BOD	Biological Oxygen Demand
BSE	Bovine spongiform encephalopathy
COD	chemical oxygen demand
CSA	Chief Scientific Adviser
Defra	Department of Environment, Food and Rural Affairs
EA	Environment Agency
EPR	Environmental Permitting Regulations
FMD	Foot and Mouth Disease
FMDV	Foot and Mouth Disease Virus
NAO	National Audit Office
SAC	Science Advisory Council
SEPA	Scottish Environment Protection Agency
TOC	Total Organic Carbon
TON	Total Oxidised Nitrogen
TSEs	Transmissible spongiform encephalopathies
TVA’s	Total volatile acids