Contract Completion Report

Former Bayer CropScience Site
Hauxton
Cambridgeshire

December 2012

On behalf of:

Harrow Estates Plc

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REPORT TITLE:	**Contract Completion Report, Former Bayer CropScience Site, Hauxton, Cambridgeshire**
REPORT NUMBER:	907BRI/RevB
CLIENT NAME:	**Harrow Estates Plc**

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Issue:1	Final Revision A	21/05/12
Issue: 2	Final Revision B	11/12/12

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1 Introduction

1.1 General

Vertase FLI Limited (VertaseFLI) was appointed by Harrow Estates (Client) to undertake remedial works at the Former Bayer Crop Science Agrochemical Works, Cambridge Road, Hauxton, Cambridgeshire (Site).

1.2 Relevant Reports

The purpose of this document is to provide factual information relating to the completion of the remediation of soils and groundwater at the site, detailing the methods employed for remediation of the site and the validation data collected by VertaseFLI. The ultimate purpose of this report is to satisfy the regulators that remediation works have been undertaken to an appropriate level of detail to remove the pollutant linkages that were once present, as the site was designated under Part 2a of the Environmental Protection Act 1990 and in accordance with Planning Consent S/2307/06/F issued by South Cambridgeshire District Council (later superseded by Planning Consent S/2269/10). This report also demonstrates that works have been completed in accordance with all relevant reports relating to the site, specifically:

- VertaseFLI (2009), 'Remediation Method Statement – Former Bayer Crop Science Site, Hauxton Cambridgeshire', April 2009 – Revision 6.
- VertaseFLI (2011), 'Validation Protocol, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', February 2011 – Revision 4.
- VertaseFLI (2011), 'Remediation Proposal for the Bentonite Wall, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', April 2011.
- VertaseFLI (2012), 'Post Remediation Quantitative Risk Assessment for Controlled Waters, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', December 2012 – Revision B.

In addition to the reports listed above, the client's independent environmental consultant Atkins Global (Atkins) has produced the following reports which all relate to Contaminants Not Previously Identified (hereafter referred to as CNPI):

- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton, Harrow Estates, Protocol for assessment and reporting of Characterisation Samples showing Contaminants Not Previously Identified', July 2010 – Revision 0.

- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified', 8th July 2010.
- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cells H10,I10, J10, K10 NAPL, K11, K12, K13 sand & gravel, K13 chalk, L11, L12 and L13', 18th August 2010.
- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cells J12, J13', 14th September 2010.
- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cells H14, H15, I11, I12, I13, I14, I15 and J14', 22nd September 2010.
- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cell H11, H12, H13 and J15 (CNPI Letter No. 5)', 27th October 2010.
- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cells G12, G13, G14, G17 and H17 (CNPI letter No. 6)', 22nd November 2010.
- Atkins Ltd (2010), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cells G10-G11, G15, I6, L4-L5, M4-M9, N3-N6 (CNPI Letter No. 7)', 30th November 2010.
- Atkins Ltd (2011), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Grid Cells D14, D15, E12, E13, E14, E15, F11, F12, F13, F15 and F16 (CNPI letter No. 8)', 21st February 2011.
- Atkins Ltd (2011), 'Former Bayer Crop Science, Hauxton: Risk Assessment of Contaminants Not Previously Identified; Treatment Bed TB100 and Grid Cells J13, K12 and K13 (CNPI letter No. 9)', 24th May 2011.

This report should be read in conjunction with the above reports. It is assumed that the reader is familiar with the various site investigations undertaken at this site. However, a further reading list is included in VertaseFLI (2009), 'Remediation Method Statement – Former Bayer Crop Science Site, Hauxton Cambridgeshire', April 2009 – Revision 6 (Hereafter referred to as the RMS).

2 The Site

The site has been determined as a Special Site under Part IIa of the Environmental Protection Act (EPA) 1990 due to the identified significant pollutant linkages with respect to groundwater and surface water. The site was used for the storage and production of agrochemicals from the 1940's through to ceasing production in 2004. The site was used primarily for the synthesis, formulation, packaging and storage of agrochemicals (both herbicides and pesticides). A selection of historical photos is displayed between *figures 1* and *6* in Appendix B. It is this former historical use that led to the contamination of soil and groundwater at the site. The site will be developed primarily for residential use post remediation.

2.1 Site Condition Pre-works

Upon deployment in March 2010 the site was in a demolished state. Most above ground structures had been demolished, processed and cleared by Squibb and Davies Ltd in 2008. Remaining buildings included Mill House (listed building), four single storey electricity sub-stations and part of the high bay warehouse to the south of the site. These structures are shown on Drawing number D907_03A in the RMS. The removal of the sub-stations, high bay warehouse, concrete slabs and foundations formed part of the remediation works at the site. An indicative view of the site in its pre-works condition is shown in *figure 7* in Appendix B.

2.2 Summary of Remediation Works

The works can be summarised into two separate sections: preparation and enabling works (outside of the Mobile Treatment Licensing / Environmental Permitting framework); and remedial works (covered under MTL / EP framework):

Preparation Works:

1. Background Monitoring;
2. Mobilisation to site and site compound set-up;
3. Review, upgrading and commissioning of effluent treatment plant;
4. Mobilisation and set-up of site infrastructure, telecoms etc;

5. Continuation of groundwater control;
6. Decommissioning of site facilities from foul drainage;
7. Establishing traffic management plans;
8. Removal of vegetation and general site clearance;
9. Securing of perimeter;
10. Disconnection of services;
11. Provision of power and alternative services as required;
12. Diversion of existing footpaths.

Remediation Works:

13. Breaking, uplifting, crushing and sampling of concrete slabs;
14. Excavation, breaking crushing and sampling of underground obstructions;
15. Pumping and treatment of shallow groundwater and perched waters;
16. Services diversions;
17. Excavation of contaminated soils;
18. Sorting, classification, processing and segregation of soils;
19. Preparation of soils for treatment;
20. Treatment of contaminated soils;
21. Removal of all preferential pathways e.g. pipelines, drainage runs;
22. Re-instatement of soils;
23. Validation testing;
24. Re-instatement of site;
25. Removal of plant and equipment;
26. Finalisation of site model to assess any residual risks;
27. Reporting.

All processing and remediation of contaminated materials were undertaken in accordance with Environmental Permit ERP/QP3293FY (formally Mobile Treatment Licence EAWML26145), for which a site specific deployment form was submitted to the Environment Agency and approved in June 2008.

2.3 Site Set Up

VertaseFLI mobilised to site in March 2010. The Site layout was generally as described in the RMS, which in summary included:

- Personnel and visitor vehicle entrance from the A10, which remained locked at all times and opened on request. Car parking was provided on site for visiting vehicles.
- Large plant and materials entrance from the A10, which remained locked at all times and opened on request.
- No public pedestrian access to the site.
- Site welfare units and decontamination facilities with a ‘clean’ and ‘dirty’ zoning system active throughout the duration of the remediation works on site.
- The ‘dirty’ area on site used for treatment and processing.

A proposed site layout prior to mobilisation is shown in drawing D907_21 of the RMS. Due to practicalities and health and safety on site, slight amendments were made to this plan in the first season of works (March 2010 – December 2010) as shown in drawing D907_199 in Appendix A. In order to enable the progression of works in the second season (January 2011 – November 2011) the site welfare units and main site entrance were relocated as shown in drawing D907_200 in Appendix A. The site layout changed a final time to allow completion of works in the autumn of 2011 as shown in drawing D907_201 in Appendix A.

2.4 Phasing of Works

The original excavation was scheduled to be undertaken as shown on drawing D907_12B in the RMS. The phasing of the excavation onsite is displayed in drawing D907_202 in Appendix A.

The first phase of excavation was required to create on site lagoons, allowing collection of contaminated waters thus allowing progression of the remediation works. Following this, excavation commenced in the north of the site in the first season (phases 2 through 4). The excavation works progressed directly through the former sites main processing facilities. As a result, this season entailed the most extensive excavations and was when the most contaminated materials excavated on site were encountered. Excavation of phases 2 through 4 was completed in September 2010. No further excavation took place in the first season as the remaining areas of the site were covered in treatment beds.

During the second season, treatment beds were reinstated in the north and the site offices relocated, allowing the advancement of the excavation to the east and north and the removal of the bentonite wall (phases 5, 6, 8 and 10). As part of the bentonite wall excavation clean site won materials were excavated from two borrow pits for reinstatement in Zone 1 (phases 7 and 9).

Further investigation works to the south and north-west of the site indicated that in general, materials met targets and that mass excavation in the same manner as previous phases was not required. These areas were overturned by a mechanical excavator to remove any structures (phases 12 and 13) and to ensure that both soils and groundwater were validated and no previously unidentified contamination was present.

This exercise revealed a hotspot in grid squares E19 and F19. This hotspot was excavated in the summer of 2011 (phase 11).

Works were completed when the offices were relocated for a final time in the Autumn of 2011 and services under Mill Lane were diverted, allowing the excavation of Mill Lane and the service road (phase 14).

3 Remedial Targets

3.1 Development of the DQRA for the 23 Contaminants of Concern

An initial conceptual site model, human health risk assessment and a groundwater risk assessment were produced by Atkins and presented for regulatory approval 2008. These were approved by the regulators in February 2010. The initial Atkins risk assessments were based on the extensive and numerous site investigations carried out on the site and provided initial screen targets for 23 contaminants of concern (hereafter referred to as COC). However, there were limitations to the initial conceptual site model and risk assessments, as noted in the RMS. From the onset of the remediation project it was the expressed intention to revise the Conceptual Site Model (CSM) and Risk Assessment to accurately reflect post remediation site conditions. A brief summary of the risk assessments is provided below.

Development of the CSM and groundwater risk assessment took place in 2 phases during the period of site works. An initial risk assessment was carried out to supplement the original Atkins Risk Assessment. VertaseFLI (2011) 'Further Quantitative Risk Assessment for Risks to Groundwater and Surface Waters, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', February 2011 included a reassessment of 5 specific COC. This was superseded by VertaseFLI (2011), 'Further Quantitative Risk Assessment for Controlled Waters and Preliminary Post Remediation Validation Model, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', July 2011 – Revision B. (Hereafter referred to as the DQRA), which used site specific chemical, hydrogeological and geotechnical data. It was the remedial targets produced in this DQRA that were used to facilitate the completion of works on site.

As stated in the RMS, it is intended that a final post remediation conceptual model and groundwater risk assessment will now be completed to reflect conditions on site post remediation. This will be reported under separate cover and will be supplemented by a minimum 6 month groundwater validation monitoring period.

3.2 Remedial Targets for COC

The remedial targets for groundwater developed from the VertaseFLI DQRA for the COC are presented in table 1a in Appendix C.

The VertaseFLI groundwater DQRA was designed with four spatial zones with varying distances from the receptor (detailed in drawing D907_163 in Appendix A), each with its own set of remedial targets for groundwater/leachate and soil concentrations:

- Zone 1. A 20 metre linear zone along the eastern site boundary adjacent to the Riddy Brook - the primary groundwater receptor. Remediation targets in this zone are the most stringent.
- Zone 2N. The northern section of the site, excluding Zone 1.
- Zone 2S. Covering the central area of site, excluding Zone 1.
- Zone 3. Covering the majority of the southern section of site, excluding Zone 1.

Within each spatial zone on site the remedial targets were segregated further depending on the type of material and its characteristics:

- Type A (Predominantly granular and semi cohesive soils i.e. Made Ground and sand and gravel).
- Type B (West Melbury Marly Chalk Formation (hereafter referred to as WMMCF and cohesive Made Ground));
- Type C (Cohesive, i.e. Gault Clay).

Within Zone 1 of the site, a number of contaminants had soil remediation targets below the commercially available laboratory limits of detection (LOD). Where this was the case, leachate testing has been undertaken to compare against leachate targets produced in the VertaseFLI DQRA. Groundwater/leachate targets are presented in table 1b in Appendix C.

3.3 CNPI Risk Assessment

3.3.1 Atkins Screen Values

In the initial risk assessment process, Atkins carried out a P20 risk assessment on each contaminant identified in the previous site investigation work. This totalled approximately 217 individual contaminants. Through this process Atkins produced a shortlist of 23 COC that posed a significant risk to controlled waters.

In accordance with conditions 4 and 9 of the planning conditions S/2307/06/F (South Cambridgeshire District Council, 5th February 2010) for the remediation of the site, analytical screening was undertaken on soil samples taken on site in order to identify any potential CNPI that may represent risks to controlled waters and/or human health receptors.

The protocol for identifying CNPI can be viewed in full in the Atkins (2010) 'Former Bayer Crop Science, Hauxton, Harrow Estates, Protocol for Assessment and Reporting of Characterisation Samples showing Contaminants Not Previously Identified', Rev0, July 2010. In summary, the identification process involved:

- The taking of one representative characterisation soil sample per site grid square. This sample was required to be representative of the contamination levels and the geology in each grid square.
- The analysis of this sample for the CNPI protocol test by the independent laboratory.
- All significant compounds identified in addition to the 23 COC were reported by the independent laboratory.
- Any reported additional compounds were sent to Atkins for review against the original 217 compounds.
- Further risk assessment of any additional compounds identified that were not part of the 217 originally identified. Atkins carried out a provisional risk assessment for those compounds using the conceptual site model and methodology approved for the original 217 contaminants.
- The derivation of preliminary targets for the additional contaminants.

Subsequently, all future samples from a grid square containing CNPI were tested for the CNPI identified in that grid square. This was tracked throughout the remediation process to ensure that all treatment beds excavated from a grid square containing CNPI were tested for those CNPI in addition to the original 23 COC.

The characterisation tracker compiled by Atkins can be viewed in Appendix C (table 4). This tracker includes: all individual grid square characterisation samples; the report number of each sample; all additional peaks identified per grid square; whether or not each compound had been previously assessed by Atkins and therefore, did not pose a significant risk to controlled waters. If a compound had not previously been assessed it also gives brief details of the risk assessment and if a previously unidentified compound was found to pose a significant risk to controlled waters, a remedial target. Using this tracker, it is possible to identify all CNPI, the grid square/s in which they were discovered and the treatment beds that they present in. Characterisation sample laboratory certificates can be viewed in Appendix H.

3.3.2 VertaseFLI CNPI DQRA

Of the CNPI identified nine exceeded the preliminary screening values with respect to controlled waters. In accordance with the methodology set out in Environment Agency (2004), 'The Model Procedures for the Remediation of Contaminated Land, Contaminated Land Report 11' VertaseFLI carried out further detailed quantitative risk assessment (DQRA) for these nine contaminants: VertaseFLI (2011) 'Further Quantitative Risk Assessment for Contaminants Not Previously Identified, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', November 2011, (Hereafter referred to as the CNPI DQRA). This assessment utilised the methodology approved for the original 23 COC in the VertaseFLI DQRA.

It had previously been established that no soil material impacted with CNPI would be placed in Zone 1. At the time that the VertaseFLI CNPI DQRA was written (August 2011), soil material had been reinstated across Zone 2N. None of the reinstated soil material in Zone 2N exceeded the Atkins CNPI preliminary remedial targets. In addition, no CNPI exceeding the Atkins preliminary remedial targets were identified in Type A soil material. As a consequence of the above, targets for the 9 CNPI assessed in the VertaseFLI DQRA were derived for Zones 2S and 3 only and for type B and C materials only.

The targets derived from this process subsequently became the formal remediation targets for these CNPI within Zones 2S and 3.

3.4 Remedial Targets for CNPI

Preliminary targets derived by Atkins for CNPI are displayed in table 2 in Appendix C.

Site specific remedial targets for CNPI derived in the VertaseFLI CNPI DQRA and subsequently adopted for nine CNPI are displayed in table 3 in Appendix C. As the backfill of Zone 2N predated the

VertaseFLI CNPI DQRA, CNPI containing materials and validation faces were required to meet the Atkins preliminary targets for CNPI within Zone 2N.

3.5 Remedial Targets for Human Health

Supplementary to remediation targets with respect to the protection of controlled waters, a human health risk assessment was undertaken by Atkins to account for soils within the top 1m of the site surface that may affect end users of the site. Remedial targets were designed to be protective of both human health and controlled waters and therefore, the lowest appropriate site derived remedial target (for human health or controlled waters) was used.

Remediation targets derived for human health apply to the top metre of soil only with the exception of certain compounds identified as volatile, see appendix T of the RMS for further details. No material has been placed within the final metre of the site during remediation works as per the RMS. Therefore, no reference is made to human health targets as they are outside the scope of this geoenvironmental report. Such issues will be addressed in a separate Human Health Report.

4 Demolition and Processing of Structures

4.1 Asbestos Surveys, Removal and Disposal

Prior to the demolition of existing buildings on site (detailed in 2.1) they were subjected to a full Type 3 Asbestos Survey. Asbestos Containing Materials (ACM) and suspected ACM were removed and sent for offsite disposal prior to demolition of the remaining structures. All works were carried out by a licensed asbestos contractor and the Health and Safety Executive were notified of the works. The relevant survey reports and re-occupation reports were provided to the Construction Design and Management Co-ordinator (CDMC) prior to the demolition of the structures. All waste arisings were disposed of offsite in compliance with current waste regulations.

4.2 Remaining Demolition, Breakout and Processing of Hardstanding

4.2.1 Remaining Demolition

VertaseFLI undertook the demolition of remaining structures on site as per the phases below:

- Phase 1 structures incorporated the remaining sub-stations on site. Services were disconnected prior to subsequent demolition of the structures when necessary to facilitate the advancement of excavation works on site. Demolition works were carried out under an appropriate risk assessment and method statement, as stipulated in the RMS.
- Phase 2 structures. This category incorporated the High Bay Warehouse and the eastern boundary wall. The High Bay Warehouse was retained onsite at the request of VertaseFLI in order to facilitate in the processing of contaminated materials under cover to aid in the control of particularly odorous materials. This structure was demolished under an appropriate risk assessment, method statement and a Section 80/81 Demolition Notice by Squibb Group Demolition in the second season of the remediation works. Only once VertaseFLI deemed that the warehouse was no longer required to control odorous materials was the building demolished.

4.2.2 Concrete Slab

The breaking out of the concrete hard standing onsite was carried out in a phased manner, as stipulated in the RMS. Broken concrete was separated from metalwork, tarmac and other deleterious materials before being processed to a 6F5 type material (see *figures 8* to *10* in Appendix B). This material was validated for the COC prior to subsequent reuse onsite as a hard to dig layer on top of remediated soils. Details of validation of aggregate materials are included in table 13 and table 14 in Appendix G. Laboratory certificates can be found in Appendix H.

In the first season of works concrete fines were separated from the crushed aggregate and were later added to selected treatment beds in order to improve their geotechnical properties. Chemical results for the concrete fines prior to blending with treatment beds are included in table 13 and table 14 in Appendix G. The treatment beds that were improved geotechnically by the addition of concrete fines are shown in the soil audit in Appendix D.

4.2.3 Tarmac

Large areas of tarmac were excavated, processed using crushing plant, and then stockpiled separately onsite. This material was sampled to a ratio of one sample per 22x22m grid square. Material was either reused on site or removed from site for re-use. Validation sampling results are included in table 13 in Appendix G. Details of tarmac reuse/removal are included in the soil audit in Appendix D.

4.2.4 Metalwork

All metal was separated from other excavated materials and sent for offsite recycling as stipulated in the RMS.

4.2.5 Underground Structures

All underground structures were identified and excavated or broken out as indicated in the RMS. Deep pile foundations were broken out to a minimum depth of 3 metres below original ground level. Anything below this depth was recorded and left in situ, unless soil contamination dictated that deeper excavation in these areas was required. A number of pile like structures were located in grid square F12. These were left unbroken, as it was suspected that they may have been previously decommissioned boreholes (see *figures 14* and *15* in Appendix B). Remaining underground structures and their approximate depth above ordnance datum levels are displayed in drawing D907_193 in Appendix A.

Hard materials from underground structures were segregated from contaminated soils and were then processed along with the concrete slab. The validation data incorporates data for both surface concrete and underground structures.

In addition to the above, a drain was discovered approximately 5.5 metres below ground within the Gault Clay in grid square D16 (see *figures 11* to *13* in Appendix B). Materials in this area were not significantly contaminated and the drain was only discovered as it was a suspected artesian well. The drain was decommissioned and sealed with bentonite before backfill.

4.3 Borehole Decommissioning

A large number of monitoring boreholes existed on site prior to the remedial works. The majority of these were excavated during the remediation works, however, a small number were retained on the boundary of the site for post remediation validation. These are displayed in drawing D907_193 and D907_196 within Appendix A along with the new monitoring boreholes installed onsite for post remediation validation.

Three artesian wells suspected to penetrate the Lower Greensand aquifer were discovered during the site remedial works. The location of these wells is shown in drawing D907_193 in Appendix A. Additionally, a fourth semi-artesian feature was identified in D16 but further investigations confirmed this to be a historic drainage feature as discussed in section 4.2.5 above. All artesian wells were decommissioned by experienced drilling sub-contractors in accordance with Environment Agency (2012) 'Good practice for decommissioning redundant boreholes and wells' January 2012. Documentation of this process is included in Appendix I.

4.4 Retained Structures and Services

Mill House is a grade II listed building and has been retained onsite in accordance with the RMS. Live services (gas, water and electric) were disconnected at the site boundary during the remediation works. Disconnection points on the site boundary are shown on drawing D907_193 in Appendix A. A live water main and a live high voltage electricity cable were subsequently diverted within the site boundary to the north-west of the site and are indicated on drawing D907_193.

A temporary sump and pipeline have been installed onsite for surface water management during the post remediation validation phase of the works. These are also shown on drawing D907_193.

5 Excavation

5.1 General

The purpose of this section of the report is to provide a factual account of the excavation works on site and the subsequent validation of those excavations prior to restoration. A total of approximately 171,983m^3 was excavated during the remediation works, 116,561m^3 of which required treatment with an additional volume of 2,000m^3 exported from site for off-site disposal.

Due to the size of the site and the magnitude of the excavation works anticipated, a site grid referencing system was established in order to facilitate the collection and representation of data, as described in the RMS. Each grid is 22 by 22 metres in size. The data collection requirements for each grid square are presented in the RMS and further expanded upon in the validation protocol. Validation data was compared to the site specific remedial targets derived from the VertaseFLI DQRA (Appendix C). The site grid and VertaseFLI DQRA zones are displayed in drawing D907_163 in Appendix A for reference.

5.2 Excavation Process Summary

All excavations and hotspots were dealt with in accordance with the RMS and Validation Protocol, which in summary included:

- All contaminated liquids (including groundwater and surface waters) were collected on site and pumped to the on-site lagoons through a silt remover, before being pumped to the offsite Waste Water Treatment Works (WWTW) for treatment and discharge under consent to the River Cam (Granta). Validation data for discharged effluent was provided to the relevant authorities throughout the remediation works.
- Gross contamination (free product and drums of pesticides/herbicides for example) segregated from soil arisings and exported to quarantine area on site prior to disposal to a suitable licensed off site facility.
- All soils with visual or olfactory evidence of contamination were excavated under the direct supervision of a VertaseFLI Environmental Engineer. These materials were appropriately classified into various treatment beds or stockpiles depending on their physical characteristics. Stockpile validation is covered in section 8.0.

5.3 Soil Audit

Throughout the remediation works, all soils and aggregates that were excavated were tracked through the site soil audit. This audit identifies the following information:

- Treatment bed (requiring treatment) or stockpile (no treatment required) reference;
- Source of excavated material (grid square);
- Geology;
- VertaseFLI DQRA material type (A, B or C);
- VertaseFLI RMS material classification (1-6);
- Presence or absence of CNPI;
- Date excavated;
- Treatment bed/stockpile volume;
- Number of turns (treatment beds only);
- Amendment addition (treatment beds only);
- Whether or not the bed was subjected to force ventilation treatment (treatment beds only);
- Whether or not the treatment bed was disposed offsite or reinstated;
- Location of reinstatement.

The Soil Audit is included within Appendix D and can be used to track material from its point of excavation, through its specific treatment train to its subsequent fate (mainly on site restoration with a limited amount of offsite disposal).

5.4 Zone 1

5.4.1 General

Zone 1 extends for 20 metres from the site boundary along the entire north and eastern site boundary (see D907_163 in Appendix A). As a result, the area is subject to significant variations in geology, hydrogeology, contamination and subsequently excavation.

Excavation works took place between April 2011 and October 2011. This was an exceedingly challenging zone for excavation works due to the proximity of the Riddy Brook to the site boundary. Prior to the commencement of works on the Bentonite Wall an investigation of the structure and surrounding materials was undertaken followed by an options appraisal in accordance with the requirements set out in a particular planning condition. The works to remove the wall are detailed separately in section *5.5 Bentonite Wall*.

5.4.2 Excavation

Excavation depths within Zone 1 are illustrated in drawing D907_207A in Appendix A.

The section between K5 and F11 in Zone 1 was subject to extensive excavation works to remove a significant volume of impacted materials. Excavation depths averaged around 4-5.5mbgl and generally extended into the Gault Clay. During the excavations in Zone 1 a 10m standoff was delineated along the northeast site boundary to maintain the integrity of the Bentonite Wall during the works. The Bentonite Wall was later excavated as a separate task (see section 5.5). In this standoff area only limited excavation of Gault Clay occurred due to the proximity of the Riddy Brook and the risk of excavation collapse and dewatering of the Brook.

Although contamination levels were generally low in soils between F11 and C17, excavation of the Made Ground and WMMCF was required due to the stringent validation criteria developed for Zone 1, as a result of its proximity to the controlled water receptor. Excavation did not extend beyond the top of the Gault Clay in this area due to the significant risk of excavation face collapse and dewatering of the Riddy Brook onto site. Deeper excavation would have compromised the stability of the excavation face adjacent to the Riddy Brook. Therefore, excavation depths in the eastern limb of Zone 1 extended between 3.5 and 4.5mbgl.

During the supervised excavation between F11 and C17 two hotspots were identified. These were within grid squares F12 and E13. These materials were segregated and sent for chemical analysis and treatment where necessary.

Contamination was present in low concentrations within the Made Ground between C17 and A18. As a consequence, the Made Ground was removed to a maximum depth of 1.5mbgl. Investigation and subsequent validation of the remaining strata was carried out by a trial pitting exercise along this area.

A former underground storage tank was discovered in grid A17. The tank and concrete base were excavated and the tank was subsequently sent for offsite disposal. Visual inspection of the tank did not provide any evidence of remaining contaminating liquids. Equally, there was no significant visual or olfactory evidence of contamination within the excavation. Photographs can be viewed between *figures 16* and *18* in Appendix B.

During the excavation of Zone 1, two historic discharge pipes that led from site, directly into the Riddy Brook were discovered. The first of these pipes was discovered in grid square C15 within the base of the Riddy Brook. This pipe was mostly buried beneath the bed of the Riddy Brook, although the top of the pipe was exposed (*figure 137,* Appendix B). The drainage pipe entered the site approximately 1.2mbgl at the base of the Made Ground (top of the WMMCF). In order to prevent dewatering of the Riddy Brook, the drainage pipe was decommissioned in situ within the Riddy Brook under the approval and supervision of the Environment Agency. The drainage pipe was sealed with a pipe bung from the Riddy Brook side and backfilled with low permeability material from the site side.

The second of the two former discharge pipes entered the Riddy Brook adjacent to the public footbridge in grid square L4. This was historically decommissioned when the former site owners redesigned the site surface water catchment system; however it still posed a potential pathway for migration. The pipe was excavated to depth on site and the remaining pipe within the bank of the Riddy Brook was blocked with a bentonite/cement mix and sealed with a pipe bung. Bentonite was placed around the outside of the pipe in order to eliminate this pathway. Photographs of this process can be viewed between *figures 138* and *141* in Appendix B.

5.4.3 Pre-Remediation/Excavation Geology and Hydrogeology

The geology of Zone 1 varied spatially along the north and eastern boundary of site. The section of Zone 1 between N3 and K5 (D907_207A) was characterised by top soil over natural WMMCF. Previous site investigation work had found that this area was not significantly impacted by contamination. As a result, this area was not subjected to mass excavation and was validated in-situ via a trial pitting exercise (see section 6.1.2). Groundwater was encountered within a more permeable horizon within the natural WMMCF above the Gault Clay between grid squares N3 and K5 between approximately 2.0-3.0mbgl. Trial Pit logs are presented in Appendix E.

The section of Zone 1 between K5 to G11 (D907_207A) was predominated by extensively reworked WMMCF and Made Ground as described in the RMS. Sand and gravel was encountered as infrequent lenses (approximately 0.0-0.3m thick) and was generally reworked extensively within Made Ground horizons or WMMCF. Undisturbed natural stratum were encountered throughout the area at approximately 3.5mbgl, this being the Gault Clay.

The section of Zone 1 between grid squares F13 to C17 (D907_207A) was dominated by areas of both natural and reworked WMMCF on top of Gault Clay. A layer of Made Ground was present on the surface. Groundwater was encountered infrequently as perched water within the Made Ground in this section of Zone 1.

The final section of Zone 1 between B17 to C25 (D907_207A) was characterised by a layer of sand and gravel varying from 1.0 to 2.5 metres in depth. This covered natural, fractured WMMCF with high calcareous mudstone content. Gault Clay was present in the very north of this section, but rapidly dipped to the south and was not encountered south of grid square A18. Significant groundwater was encountered within the fractured WMMCF approximately 1.5 metres below ground level in the northern part of this section.

5.4.4 Contamination

The soils between K5 and G10 were generally characterised by high levels of Chlorinated Solvents, Chlorinated Phenols, Bis2-(Chloroethyl)ether, 4-Chloro-2-Methylphenol, Ethofumesate and Schradan. CNPI were present within some of the grid squares within this area. Due to the high levels of contamination any groundwater/surface runoff encountered was yellow to dark brown in colour.

A number of broken drums containing and surrounded by a black oily liquid were discovered buried in the poorly consolidated Made Ground within grid square H7, no more than 20 metres from the Riddy Brook (see *figures 19* and *20* in Appendix B). Under the direction of a VertaseFLI Environmental Engineer the drums and all stained material were isolated and stored in a lined area subject to testing. Chemical analysis of the black material presented low concentrations of volatile and semi-volatile compounds. The drums were disposed of offsite whilst black stained material entered the site treatment train. Chemical analysis results are displayed in Appendix G.

Generally, the soils between F11 and C17 contained low levels of contamination. The only major contaminant discovered in the area was Petroleum Hydrocarbons bands C8-C14. This area was subject to an exploratory trial pitting exercise, after which the soils were deemed acceptable for reuse in other DQRA zones on site, with the exception of the hotspots described in section 5.4.2.

The soils in Zone 1 were generally free of contamination between grids N3 and K5 and also grids C17 and C25. Groundwater between N3 and K5 had a light undistinguishable odour where encountered and varied from clear to translucent yellow. Groundwater encountered in trial pits between C17 and C25 was found to be clear and odourless. As a result, these areas were not subjected to excavation and were validated in-situ via a trial pitting exercise (see section 6.2.). Excavation in these areas was limited to an over dig to remove structures and identify any contamination before re-compaction of materials.

5.5 Bentonite Wall

5.5.1 General

The Bentonite Wall was located to the north-east of the site, running along the boundary of the site between grids K5 and G10, then diverting on to site as shown in drawing D907_207A in Appendix A. The Bentonite Wall was dealt with as a separate entity due the planning conditions applicable to the structure. An intrusive investigation was carried out to assess the geotechnical and chemical conditions of the Bentonite Wall. Following this an options appraisal was conducted that concluded it was necessary to remove the Bentonite Wall as it posed a potential risk to controlled waters. Removal of the Bentonite Wall was carried out in full compliance with VertaseFLI (2011), 'Remediation Proposal for the Bentonite Wall, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', April 2011, which in summary included:

- Demolition of the eastern boundary wall.
- Erection of a suitable boundary fence to the east of the Riddy Brook.
- Erection of a debris net along the Riddy Brook.

- Excavation of the Bentonite wall and surrounding soils to the Gault Clay using a 36 tonne excavator. Excavation took place in sections no more than 20m in length along the Bentonite Wall at any one time to ensure the western bank of the Riddy brook remained stable during the works. Materials were excavated into site at an acceptable angle of repose in 1 metre sections in order to allow constant assessment of the stability of the excavation face adjacent to the Riddy Brook.
- Immediate backfill using appropriately validated site won materials.

Excavation of the Bentonite wall was carried out between August 2011 and September 2011.

5.5.2 Excavation

Excavation of the Bentonite Wall adjacent to the Riddy Brook did not extend beyond the top of the Gault Clay. This was a necessity to ensure that the angle of repose was sufficient to provide stability during the excavation and backfill works, in order to prevent collapse and dewatering of the Riddy Brook. Therefore, excavation depths in the area of the Bentonite wall adjacent to the Riddy Brook extended between 3.5 and 4.5mbgl. Where the Bentonite Wall was keyed into the Gault Clay, trial pits were carried out to determine the extent of the wall into the Gault Clay. Subsequently these sub-Gault sections were excavated further to completely remove all Bentonite out of the Gault Clay, resulting in complete removal of the Bentonite Wall in this area. A photographic log detailing the excavation of the Bentonite Wall adjacent to the Riddy Brook is presented in Appendix B between *figures 21* and *28*.
The Bentonite Wall 'dog legs' into Zone 2S in grid square G10 (see drawing D907_207A Appendix A). Within Zone 2S, excavation levels extended below the base of the Bentonite Wall. This was necessary in order to achieve validation criteria at the base of the excavation within Zone 2S. As a result, the Bentonite Wall was subject to total removal within Zone 2S.

5.5.3 Pre-Remediation/Excavation Geology and Hydrogeology

The geology of the Bentonite Wall between K5 to G10 was similar to that observed in the adjacent Zone 1. Therefore, the geology was predominated by extensively reworked WMMCF and Made Ground. On the site side of the Bentonite Wall there were extensive pockets of reworked sand, WMMCF and Gault Clay. The Gault Clay was encountered at approximately 3.5-4.5 mbgl. Areas of Gault directly adjacent to and below the Bentonite Wall appeared to be undisturbed natural stratum.

Perched water was not encountered on the site side of the Bentonite wall, as it had drained from the excavation faces prior to removal. There were frequent seepages from the face of the excavation at the interface between the Gault and the WMMCF and in alluvial deposits above the WMMCF between 1.4-2.0mbgl in the offsite strata beyond the Bentonite Wall (under the bank of the Riddy Brook).

5.5.4 Contamination

Two historic rudimentary soakaways were located adjacent to the Bentonite Wall between grids H8 and G9. F*igures 27* and *28* in Appendix B show these to be in poor condition at the time of excavation. *Figure 27* shows a metal tank with holes around the base. The soakaway displayed in *figure 28* comprised of an open hole with wooden shuttering. The differing design of these two soakaways suggests that they were installed in different time periods. Both soakaways were connected by a network of drainage pipes that extended within the Made Ground into adjacent areas onsite. These features were situated in heavily reworked WMMCF and Made Ground and were located approximately 3 metres from the Riddy Brook (on the site side of the Bentonite Wall). These were excavated separately prior to the removal of the Bentonite wall. Grossly contaminated materials from around the soakaway and tank were sent to treatment bed for bioremediation.
The soils between H7 and G10 (in the locale of the soakaways described above) were generally characterised by high levels of Chlorinated Solvents, Chlorinated Phenols, specifically Bis2-(Chloroethyl)ether and 4-Chloro-2-Methylphenol. CNPI's were present within some of the grid squares within this area. Soils were frequently heavily stained and discoloured due to the high levels of contamination in the area.

A dark brown/black viscous liquid was present in seepages in the offsite strata between the Gault Clay and WMMCF in grid G10 (see *figure 24* in Appendix B).

The soils excavated between K5 and I6 were characterised by low levels of contamination. This area was subject to an exploratory borehole and trial pitting exercise as part of the Bentonite Wall investigation, after which the soils were deemed acceptable for reuse in other risk assessed zones on site.

5.6 Zone 2N

5.6.1 General

Zone 2 North (2N) is located to the north of the site. Zone 2N largely incorporates an area that was directly below the main production facilities and is the area where the greatest levels and extent of contamination was encountered during the remediation works.

Excavation works took place between April 2010 and November 2011 and were ongoing throughout the majority of the remediation works. The previous site investigation work indicated that contamination in this area was not as extensive as was actually encountered. Resulting excavation works in this area exceeded what was initially anticipated and included significant excavation into the Gault Clay at depth. As contamination was not initially thought to be as extensive in this zone, part of the area was used as a location for the clean zone set up – incorporating site offices, car park, storage area and maintenance area for site plant. Subsequently, the site facilities were moved in the second season to enable the completion of excavation in Zone 2N.

5.6.2 Excavation

Excavation depths within Zone 2N are illustrated in drawing D907_207A in Appendix A.

With the exception of the car park area, Zone 2N was subject to mass excavation. Excavation was carried out by 35 and 45 tonne excavators. Excavation was carried out in a phased manner with type A materials being removed first, followed by type B materials and finally type C materials if required. Material types were segregated and sent to separate treatment beds.

The central and eastern area is the main area of excavation within Zone 2N. This is delineated by grid squares K13, H10, I7, K6 and L10 (see drawing D907_207A in Appendix A for reference). Excavation depths in this area varied from approximately 4.0mbgl to 7.0mbgl depending on contamination levels within each grid square (refer to D907_207A in Appendix A). Excavation in the first season started in grid square K7 and advanced in a south and easterly direction. In the second season, after the relocation of the site facilities, excavation advanced north from grid squares 8 towards the boundary with Zone 1. In the majority of grids within this area, excavation extended into the Gault Clay. A photographic log of the excavation in this area is displayed between *figures 29* and *36* in Appendix B.

A vast network of surface water drainage pipes, manholes and soakaways existed on site. This network consisted of a number of generations of drainage pipes, ranging from ceramic pipes, to cast iron pipes and plastic pipes. During excavation this network of surface water drainage pipes was observed to be in poor condition, older pipework being generally more deteriorated. This network, extended not just across Zone 2N, but across the northern section of Zone 2S and the sections of Zone 1 (below the main works) adjacent to these two zones. In general this network was located within the top 2 metres of site strata and was therefore, largely located in poorly consolidated Made Ground and extensively reworked strata. This network was excavated as works progressed across site. Individual man holes and/or pipework is not referenced in detail as a contaminant source as excavation in these zones was at a minimum down to the base of the WMMCF. Therefore, materials were excavated to a greater depth than the drainage network due to generally high levels of contamination in the WMMCF and Made Ground. Only where drainage pipes were unexpectedly discovered at depth have they been specifically referenced in this document.

A surface water drain and sump was located running between grids K7 and L7. Significant excavation was undertaken below this drain in order to achieve the initial remediation criteria. The base of the excavation was approximately 8.0-10.0mbgl. The location of this excavation is displayed in drawing D907_209 in Appendix A. A photograph of the excavation is displayed in *figure 37* in Appendix B.

A second sub-surface drain was discovered at approximately 3.5mbgl within the Gault Clay in grid K6. This drain was excavated and a base sample was taken from the drainage sump. A photograph of the excavation is displayed between in *figure 38* in Appendix B.

Towards the end of the second season the main site entrance was permanently closed to site visitors and staff in order to enable excavation beneath the former site access road (grid squares K15 to M11). Made Ground was excavated from beneath the site access road after the removal of the bitumen macadam. The Made Ground here had passed the relevant chemical criteria during an investigatory trial pit exercise. However, the material was poor geotechnically and was excavated to a maximum depth of 1.5 metres to the top of the WMMCF. Photographs are provided in *figures 39* and *40* in Appendix B.

The service trench beneath Mill Lane was excavated after the services were disconnected and diverted. Excavation works were completed in the final week of site works (November 2011) with Mill

Lanes closure and excavation. Generally the excavation in this trench extended to the Gault Clay at approximately 2.5mbgl. In grids M9 and M10 excavation was terminated in the WMMCF at approximately 1.5mgl as there was little significant visual or olfactory evidence of contamination at this depth. Photographs are provided in *figures 41* and *42* in Appendix B.

An historic well was discovered in grid M5 (drawing D907_209 in Appendix A). The well was pumped dry before targeted excavation. A validation sample was taken from the base of the excavation; however, there was no significant visual or olfactory evidence of contamination in the excavation. The well prior to excavation can be viewed in *figures 43* and *44* in Appendix B.

5.6.3 Pre-Remediation/Excavation Geology and Hydrogeology

The pre-remediation geology and hydrogeology was observed and logged during excavation works. The geology of Zone 2N was predominated by extensively reworked WMMCF and Made Ground. Made Ground varied in thickness, generally being between 0.3-1.5 metres. Reworked WMMCF was present throughout the area between 0.3-5.0mbgl. Sand and gravel was encountered as infrequent lenses and was generally reworked extensively within Made Ground horizons or WMMCF. Natural stratum was encountered between 2.0-5.0mbgl throughout the area in the form of the Gault Clay, although in some areas the upper strata of the Gault Clay was suspected to have been reworked. There was an area of natural WMMCF to the north-west of Zone 2N. This area was beneath the former works car park (area defined by grid squares N3, M9 and L5).

Groundwater was encountered infrequently as perched water within the Made Ground in this area; however, a limited amount of groundwater was encountered within the natural WMMCF in the north-west corner of Zone 2N. Groundwater was encountered within a more permeable horizon within the natural WMMCF above the Gault Clay.

5.6.4 Contamination

Zone 2N was generally characterised by high levels of Chlorinated Solvents, Chlorinated Phenols, Bis2-(Chloroethyl)ether, 2-Methyl-4,6-Dinitrophenol (DNOC), 4-Chloro-2-Methylphenol and Ethofumesate. Zone 2N also had the greatest presence of CNPI of any zone onsite. Due to the high levels of contamination and the presence of DNOC, large quantities of reworked strata and Made

Ground were stained yellow and any groundwater/surface runoff encountered was yellow to dark brown. Examples of typical contamination in this area are displayed between *figures 45* and *48* in Appendix B.

Previous site investigation work had found that the area beneath the former car park was not significantly impacted by contamination. Further trial pitting was undertaken to provide validation in situ (see section 6.2.). Excavation in this area was then limited to an over dig to remove structures and to identify any previously unidentified contamination before re-compaction.

During excavation of grid square L10 a small amount of black, oily, highly viscous liquid was discovered. The substance was identified in the face of the L10 excavation in the Made Ground (top 1 metre). Under the direction of a VertaseFLI Engineer the free phase product was excavated and stored in a lined bunded area for testing before offsite disposal. Characterisation sample results for this free phase product are displayed in table 12 in Appendix F and show that this contains a number of components including high concentrations of Dinoseb. Photographs are displayed between *figures 49* and *51* in Appendix B.

During excavation of grid L7 a dark brown/black oily fluid was discovered at the base of the marl (*figure 46,* Appendix B). Free Product was recovered from the excavation after sampling. Residual product was excavated with the Gault Clay and entered the treatment process.

5.7 Zone 2S

5.7.1 General

Zone 2 South (2S) is the largest DQRA area and extends from the centre of site to the eastern boundary. During progression through Zone 2S there were significant variations in contamination levels and geology encountered. The area to the north of grid squares 17 (drawing D907_207A Appendix A) was below the main production facilities as with the area described in 2N. Similarly to the area in Zone 2N, this is where the highest levels of contamination were encountered. The area of Zone 2S to the south of grid squares 17 generally contained low levels of contamination.

The bulk of excavation works to the north of Zone 2S commenced in September 2010 and were completed in August 2011. However, the lagoon excavation took place in March 2010, as the lagoon was required to facilitate the remediation works.

The major difficulty in excavation works in this area was a lack of space to stockpile treatment beds on site due to the extensive excavation in Zone 2N. As a consequence, excavation of 2S was limited to turning Made Ground and reworked WMMCF in situ in the first season of works. Excavation could only be advanced in the second season once materials were reinstated to Zone 2N – freeing space on site for the further creation of treatment beds.

5.7.2 Excavation

Excavation depths within Zone 2S are illustrated in drawing D907_207A in Appendix A. Due to the significant variations in geology, contamination and subsequent excavations between the north and south of Zone 2S, they are presented in separate subsections.

5.7.2.1 Zone 2S (Northern Section)

The northern excavation area within Zone 2S (delineated by grid squares K13, H10 and G12) is an extension of the main excavation from Zone 2N. This area was directly below the main production facilities and is the area where the greatest levels and extent of contamination was encountered during the remediation works. Excavation depths in this area varied from approximately 4.0mbgl to 6.0mbgl depending on contamination levels within each grid square. In the majority of grid squares within this area, excavation extended into the top of the Gault Clay (see *figures 52* and *53* in Appendix B).

The area delineated by grid squares J13, J15, H13 and H15 defines a point in the main site where general contamination concentrations start to decrease towards the south of the area beneath the main processing plants. Excavation depths in this area are correspondingly less deep, being generally no more than 3.5 metres in this area. In general, excavation did not advance beyond the Gault Clay, with the exception of a sub-surface drain discovered and subsequently excavated at approximately 3.0mbgl within the Gault Clay in grid I14.
A further sub-surface drain was discovered at approximately 4.0mbgl within the Gault Clay in grid G14. This drain was excavated out of the Gault Clay. Photographs of the drain and excavation are displayed in *figures 54* and *55* in Appendix B.

There was a deeper excavation encompassing grid squares G14-G16 and H16 (see drawing D907_207A in Appendix A). Excavation was to a maximum of 4.5mbgl in this corridor due to the level of the Gault Clay dipping to the east of H13, H14 and H15. Excavation into the Gault Clay was required, possibly because contamination had historically pooled in this low in the Gault Clay.

The lagoon excavation (grid squares K14 and K15) was the first excavation undertaken onsite in order to install the onsite waste water lagoons and facilitate the remediation works. As this excavation predated the VertaseFLI DQRA, significant excavation was undertaken in this excavation – relative to the surrounding area – in order to achieve the initial Atkins COC criteria. The excavation extended to a maximum of 4.5mbgl into the top of the Gault Clay. Photographs of the excavation, construction of the lagoon and decommissioning of the lagoon are displayed between *figures 56* to *62* in Appendix B.

The south-eastern area of Zone 2S (northern section) (delineated by grids H17, F17, F14 and D17) defines another significant change in contamination concentrations encountered as excavation works moved southward, away from the former main processing areas. Generally, contamination was present in low concentrations within the Made Ground/sand and gravels in this area. Excavation was limited to Made Ground/Sand Gravel removal to a maximum depth of 2.0mbgl (see *figure 63* in Appendix B). Investigation and subsequent validation of the remaining strata was carried out by a trial pitting exercise.

The Bentonite Wall 'dog legs' into Zone 2S between grids G10-G13. This is discussed in detail in section 5.5.2.

5.7.2.2 Zone 2S (Southern Section)

Generally excavation in this area was limited to removal of the concrete slab with the majority of grid squares in this area investigated and subsequently validated through trial pits.

A trial pit in grid square E19 revealed unexpected contamination running beneath a suspected foul sewer drain. The pipe was exposed by an excavator before the extent of contamination was established using a Photo Ionisation Detector (PID). Contamination extended approximately 20 metres from the centre of grid square E19 into grid square F19 as shown by the excavation extent in drawing D907_207A in Appendix A. Once the lateral extent of the contamination had been established the pipe was broken out and removed and the contamination below the pipe was excavated.

The vertical extent of contamination was greatest beneath one end of the pipe in E19. Here the excavation extended to approximately 4.5mbgl into the WMMCF. Gault Clay was not encountered at this depth; however, groundwater was present at approximately 4.2mbgl. Contamination was not evident below the sand and gravel deposits approximately 2.5mbgl in grid square F19. Therefore, excavation was terminated at the WMMCF in this grid square. Groundwater was not encountered in grid square F19. Photographs of the excavation are provided between *figures 64* to *69* in Appendix B.

An excavation extending to approximately 3.0mbgl can be observed crossing between Zone 2S and Zone 3 in grid squares G20, H20 and I20 (drawing D907_207A in Appendix A). This excavation was a consequence of the development of the High Bay Warehouse. The excavation depths here represent the base of the High Bay Warehouse after the concrete slab was removed. The area was validated through trial pits in the base of the warehouse, with no further excavation required (see *figures 70* and *71* in Appendix B).

A deep excavation can be seen in the south eastern section of Zone 2S. This is related to borrow pitting activities to generate suitable materials for Zone 1 restoration.

5.7.3 Pre-Remediation/Excavation Geology and Hydrogeology

The following sections summarises the ground conditions prior to remediation and/or excavation.

5.7.3.1 Zone 2S (Northern Section)

Geology to the north of 2S was generally characterised by extensively reworked WMMCF and Made Ground with varying thickness, generally being between 0.3-1.5 metres. Reworked WMMCF was present throughout the area between 0.3-5.0mbgl. Sand and gravel was encountered as infrequent lenses and was generally reworked extensively within Made Ground horizons or WMMCF.

To the south of grid squares G15 and H15 Type A material, typically comprising Made Ground and slightly clayey to clayey sand and gravel became thicker with deposits typically up to 1.0-2.0 metres thick. This corresponds with increased thickness of Type A material to the south of Zone 2S and in Zone 3. Undisturbed Gault Clay was encountered between 2.0-5.0mbgl throughout the area. Generally the Gault Clay rose to the south of the northern area of Zone 2S.

Groundwater was encountered infrequently as perched water within the majority of the northern area of Zone 2S.

5.7.3.2 Zone 2S (Southern Section)

The geology of Zone 2S south was characterised by deposits of Type A material (clayey sand and gravel with some reworked WMMCF) to maximum depths between 1.0 and 2.5 m over natural WMMCF with a high calcareous mudstone content. Sand and gravel deposits became thicker and less clayey to the southeast. The Gault Clay was encountered to the north of Zone 2S South. However, the Gault Clay was not encountered in the majority of Zone 2S as it dips to the south in line with the regional geological dip. Drawing D907_211 in Appendix A displays the maximum depths of trial pits in this area without encountering Gault Clay.

A significant groundwater body is present within the fractured WMMCF in Zone 2S (southern section). Groundwater levels are observed to be between approximately 1.5-2.5mbgl to the north and west of Zone 2N but drop off significantly to the south east coincident with the fall of the Gault Clay.

5.7.4 Contamination

5.7.4.1 Zone 2S (Northern Section)

Zone 2S North was generally characterised by high levels of Chlorinated Phenols, Bis2-(Chloroethyl)ether, 2-Methyl-4, 6-Dinitrophenol (DNOC), 4-Chloro-2-Methylphenol and Ethofumesate. Schradan and Chlorinated Solvents were present in concentrations to the north east of the area. Zone 2S North also had a large number of CNPI. Due to the high levels of contamination and the presence of DNOC, large quantities of reworked strata and Made Ground were stained yellow and any groundwater/surface runoff encountered was yellow to dark brown. Examples of typical contamination in this area are displayed in *figures 72* and *73* in Appendix B.

Red powder was discovered buried in the Made Ground within H16. Under the direction of a VertaseFLI Engineer the barrel and any surrounding visually contaminated material was excavated and stored in a bunded and lined area for testing before offsite disposal. Photographs of this are displayed in *figures 74* and *75* in Appendix B.

Purple powder was discovered buried in the Made Ground within H10 (*figure 76* in Appendix B). Under the direction of a VertaseFLI Engineer the barrel and any surrounding visually contaminated material was excavated and stored in a bunded and lined area for testing before offsite disposal.

Characterisation sample results for both of these substances show them to be mixtures of pesticides that could not be treated on site. These results are displayed in table 12 in Appendix F.

5.7.4.2 Zone 2S (Southern Section)

No significant contamination was identified within Zone 2S (Southern Section). Most grid squares exhibited low to trace levels of contamination limited to the sand and gravels and upper levels of the WMMCF. The hotspot in E19 and F19 was characterised by high CNPI concentrations, specifically Trichlorotoluene and Dichlorotoluene. Chlorinated Solvents were also present in significant concentrations within this hotspot.

Groundwater was observed to be clear and non-odorous within Zone 2S (Southern Section), with the exception of groundwater in the E19 hotspot which was observed to have a strong solvent odour.

5.8 Zone 3

5.8.1 General

Zone 3 is located to the south of site, incorporating an area of former houses and gardens on Church Road and the High Bay Warehouse and storage areas. The area was generally found to have low to trace levels of contamination in the extensive site investigations. No unexpected contamination or hotspots were discovered in Zone 3 during the turnover exercise and excavations. Trial pit logs of pre-remediation conditions are presented in Appendix E.

Due to the volume of material requiring treatment from Zone 2N especially, Zone 3 was covered in treatment beds between May 2010 and August 2011. As stated in section 4.2.1 the High Bay Warehouse was retained in order to control remediation of more odorous materials meaning excavation works took place between August 2011 and October 2011.

5.8.2 Excavation

Excavation depths within Zone 3 are illustrated in drawing D907_207A in Appendix A.

Two large scale excavations are shown on drawing D907_207A within Zone 3. Material was excavated from these two Zone 3 borrow pits for reinstatement and reuse in Zone 1. Pictures of the borrow pits are displayed between *figures 77* and *80* in Appendix B.

5.8.3 Pre-Remediation/Excavation Geology and Hydrogeology

The encountered geology of Zone 3 is characterised by a 1.0 to 2.5 metre layer of Type A material typically comprising slightly clayey to clayey sand and gravel over natural WMMCF with high calcareous mudstone content. The Gault Clay was not encountered at all within Zone 3, apparently continuing the observed dip to the south noted in Zone 2S. It should be noted that investigations undertaken by Atkins Ltd in 2006 detailed in their report 'Remediation of Former Bayer Site, Hauxton, Preliminary Conceptual Model', dated August 2006) confirmed the presence of the Gault Clay underlying the WMMCF at depths typically between 4.2 and 4.9 m bgl. The only exception was in the extreme southeastern corner of the site (approximate grid square D26) where the depth to the Gault clay was 10.3 m bgl.

A significant groundwater body is present within the fractured WMMCF in Zone 3. Groundwater levels are observed to be between approximately 1.0-2.0mbgl to the north and west of Zone 3 but drop off significantly to the south east coincident with the fall of the Gault Clay.
There was a small quantity of reworked WMMCF around the locations of piles in the footprint of the High Bay Warehouse.

5.8.4 Contamination

No significant contamination was identified within Zone 3 of the site. Grid squares were generally free of contamination, although some grid squares to the west of the area exhibited low to trace levels of contamination limited to the sand and gravels and upper levels of the marl.

Groundwater was observed to be clear and non-odorous within Zone 3.

Due to the nature of materials in within Zone 3, grid squares in this area were investigated and subsequently validated through trial pit investigation (see section 6.1.2).

6 Validation of Excavations

6.1 General

Initial excavation depths were determined on site by a VertaseFLI Environmental Engineer using visual and olfactory evidence as well as a photo ionisation detector (PID) to identify any volatile contamination. Once excavated to a potentially clean validation base validation samples were taken. All validations were carried out in accordance with the RMS and VertaseFLI (2011), 'Validation Protocol, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', February 2011 – Revision 4 (hereafter referred to as the Validation Protocol), which in summary includes:

- A minimum of 1 basal sample per grid square.
- Where more than 1 base existed within a grid square (i.e. excavation terraces) 1 sample was taken per base (i.e. more than 1 base sample per grid).
- Where excavation side / faces existed within a grid square, 1 sample was taken per face.
- Where a potential source or pathway/hotspot was excavated from the base of a mass excavation, isolated subsurface drains for example, additional side and basal validation were taken as required at the ratios described above.

Sample analysis results were compared with the validation targets for the specific DQRA zone in which the grid square was located, for example: validation samples for grid square I9 were screened against Zone 2N criteria; validation samples for grid square G16 were compared to Zone 2S criteria etc.

Where CNPI existed within a grid square these results were assessed to VertaseFLI DQRA values or Atkins screen values if the VertaseFLI DQRA values were not available. Validation of CNPI followed the same methodology as the original 23 COC as stated in the RMS and validation protocol.

It was not always practical to excavate an entire site grid square in one excavation phase due to onsite restraints (such as space, location of site offices, location of structures etc). As a consequence some grid squares were excavated in multiple excavation phases. For example, materials to the south of grid L7 were excavated in the first season of works, whereas materials to the north of the grid were excavated in the second season after the site offices were relocated. As a result, two base validations that pass the relevant criteria exist for this grid square, one for the excavation base exposed in the first season and one for the excavation base exposed in the second season. In the case of L7, further base samples exist where a trench was dug in order to excavate contaminated material directly below a drain. Where this has occurred, more than one set of validation data exists for the affected grid square. Indeed, some grid squares have multiple validation samples associated to them.

In addition to the above, further excavation was required in a number of grid squares which failed initial validation tests. Once additional excavation was completed, further validation samples were taken as specified above.

Once all validation samples had passed within a grid square, results for that grid were checked by the independent on site Atkins engineer, prior to backfill and restoration with appropriate materials.

Table 7 in Appendix F is a diagram showing the report number of all validation reports taken in each grid square, including all base validations, side validations, failures, subsequent passes and validation trial pits. Tables 8 and 9 in Appendix F show all validation results. Laboratory certificates for validation data can be viewed in Appendix H.

6.2 Trial Pit Validation

Some areas of in-situ materials across the site were, following further site investigation, suspected to be clean and not requiring excavation or remediation. These areas are covered in detail in sections 5.4, 5.6, 5.7 and 5.8, and in summary incorporates the car park area to the north west of the site in Zone 2N, large areas within Zone 2S South and Zone 3. These areas were investigated and subsequently validated in situ through detailed validation sampling. Following the validation sampling, theses areas were being “turned over” to a depth of 1.5 m bgl to remove obstructions and any preferential contaminant pathways. The trial pit logs are presented in Appendix E.

Trial pits were excavated to a minimum of 1 pit per grid square in these areas. Trial pits were advanced to the maximum practical depth (between 3.0-6.0mbgl) and were terminated for one or a combination of the following reasons: groundwater strike; clean Gault Clay layer; trial pit collapse; maximum reach of excavator reached (between 5.0-6.0 metres).

A range of samples were taken from each trial pit in order to establish as large a data set as possible to ensure the validation process undertaken in this manner was sufficiently robust. In general, a minimum of one sample per strata type was taken. All trial pits were carried out under the direction of a VertaseFLI Environmental Engineer, supervised by an Atkins Engineer. A representative selection of Trial Pit photographs are displayed between *figures 81* and *82* (Zone 2S and 3) and *83* and *84* (Zone 2N north-west) in Appendix B.

6.3 Gross Contamination

It should be noted that where gross contamination was discovered (including red powder, purple powder, black tar and barrels, as described in section 5) additional validation samples were not required as mass excavation in the grids they were discovered in extended to a significant depth below their origin within the Made Ground. Validation samples were taken at the base of these excavations as described in 6.1.

6.4 E19/F19 Hotspot

Following excavation of all soils exhibiting visual or olfactory evidence of contamination in E19 and F19 the excavation was left open for a week to allow groundwater to be pumped in order to check for evidence of pure phase NAPL. After one week there was no evidence of contamination in the sump. As a consequence, pumping was terminated and validation samples were taken from each side of the excavation and from the base of the excavation in the two grid squares. The validated excavation was subsequently backfilled.

6.5 Lagoon

Upon decommissioning of the lagoons the excavation sides and base were re-validated as required in order to confirm that there had been no significant cross contamination from the presence of contaminated liquor within the lagoons. All hard materials that were originally placed as a base to the lagoon were removed, validated and reused on site, followed by excavation validation and restoration in this area.

6.6 Bentonite Wall Validation

As the Bentonite Wall was subject to specific planning conditions, additional validation samples were taken from the corresponding grid squares in Zone 1. Therefore an extra basal sample was taken for each grid square in which the Bentonite Wall was excavated; in addition side validation samples were taken from the site boundary excavation in each grid square. Validation of the Bentonite Wall followed the methodology and frequencies stated in the RMS and Validation Protocol. Immediate backfill followed validation of the Bentonite Wall excavation as stipulated in VertaseFLI (2011), 'Remediation Proposal for the Bentonite Wall, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', April 2011. This was to prevent collapse of the banks of the Riddy Brook.

All validation results for the Bentonite Wall northern limb within Zone 1 were compared to Zone 1 remediation criteria as defined by the DQRA. Due to the site boundary and the presence of the Riddy Brook, further excavation to the north and east beyond the site boundary was not possible.

Table 7 in Appendix F shows the report number of all validation reports applicable to each grid square of the Bentonite Wall excavation, including base validations and side validations. Table 10 and Table 11 in Appendix F show all validation results. Laboratory certificates for validation data can be viewed in Appendix H.

Extra validation samples from the Bentonite Wall southern limb within Zone 2S were not necessary. This was because the excavation in Zone 2S extended below the base of the Bentonite Wall. Validation samples were taken from the base of the excavation in each grid square as per the RMS. These results are displayed within the validation data for Zone 2S in Appendix F.

6.7 Southern Site Boundary Bund

The southern site boundary bund is displayed in figure D907_209 in Appendix A. This bund has been retained at the request of the client. Exploratory investigation using an excavator was not possible due to its location outside of the working site boundary. This bund was not suspected to be contaminated, to confirm this one sample was taken from the bund per grid square using a hand auger. A selection of photographs is included between *figures 85* and *88* in Appendix B.

6.8 Excavation in the Gault Clay

During deeper excavations within particularly Zone 2N, it was noted that chlorinated solvent concentrations still exceeded groundwater risk assessment criteria in a limited number of grid squares. Following discussion with the regulators it was agreed that due to the fact that the Gault Clay is a 'non-aquifer' groundwater targets may not be relevant within this strata. Once excavating had been progressed as deep as practical into the Gault Clay (6.0-7.0mbgl) a risk assessment was undertaken to assess remaining contamination. This assessment determined the need to characterise residual contamination for further post remediation DQRA. This process was necessary in grid squares K9, K10 and I9.

6.9 Asbestos Contamination

During excavation works, buried asbestos was encountered in the Made Ground within grid squares M10, F13, I11, H14 and H15. Made Ground containing asbestos containing materials (ACM) was segregated out from surrounding materials, stockpiled, wetted and covered. Where possible, ACM was removed by hand under the guidance of a VertaseFLI Environmental Engineer. Where the presence of ACM was significant and too difficult to segregate from the Made Ground, the stockpile was removed from site to a licensed landfill. Asbestos report numbers can be tracked through table 7 in Appendix F to the relevant laboratory certificates, located in Appendix H.

7 Treatment Validation

All soils excavated during the site works were placed into Treatment beds for preliminary testing. Subject to this preliminary analysis (classed t_0 sample), soils were either deemed suitable for re-use or were designated for further processing and ex-situ bio-remediation treatment.

Treatment beds were subjected to processing and remediation as per the site treatment train described in the RMS, which in is summarised in the following sections.

7.1 Phase Separation

The first phase was to separate the liquid and solid phases. All liquids encountered were pumped using portable pumps to the main site lagoons prior to transfer the WWTW for treatment, prior to consented discharge to The Cam (Granta).

7.2 Soils Excavation, Segregation and Processing.

Materials were excavated under the direction of a VertaseFLI Environmental Engineer and were segregated according to their material type (Type A, type B, Type C – see soil audit). Soils were further segregated based on visual and olfactory evidence of contamination into one of 6 categories defined in the RMS (see soil audit):

1. Group 1 Material: Granular soils not requiring treatment. These materials were sent to stockpile for validation sampling and reuse.
2. Group 2 Material: Granular material requiring treatment.
3. Group 3 Material: Cohesive or semi-cohesive material not requiring treatment. These materials were sent to stockpile for validation sampling and reuse.
4. Group 4 Material: Cohesive or semi-cohesive material requiring treatment.
5. Group 5 Material: Oversize hard materials. These aggregates were either derived from the excavation or from the screening/turning of Group1 to 4 materials. These were sent to the Concrete stockpile for crushing (see section 4.2.2.).

6. Group 6 Material: Unsuitable materials. These materials were unsuitable for treatment and were quarantined onsite prior to offsite disposal. Materials include asbestos and gross contamination as described in section 5.0.

In the first season, all materials were classified as Group 2, Group 4, Group 5 or Group 6 materials. Therefore, the majority of soils were impacted by contamination to a greater or lesser extent.

7.2.1 Season 1 (March 2010-December 2010)

In the first season all materials were transferred by articulated dump truck (ATD) to the soils processing area (High Bay Warehouse), where they were processed/screened and classified into the 6 groups described above. The purpose of processing/screening process was primarily for: the removal of large clasts and aggregates; homogenisation of material to improve engineering properties and to aid in the remediation. Materials were then transferred to the treatment area where they were formed into appropriately sized treatment beds (windrows).

7.2.2 Season 2 (January 2011-November 2011)

In the second season materials were classified into the 6 groups described by a VertaseFLI engineer as they were excavated. Type 2 and type 4 materials were sent to a treatment area where they were processed/screened and formed into appropriately sized treatment beds. Processing/screening was carried out in treatment bed due to the space restrictions on site in the second season.

7.3 Ex-situ Biological Treatment

7.3.1 General

All materials requiring treatment were constructed into treatment beds for biological treatment. Beds were mechanically turned in order to: further homogenise materials by breaking down larger clasts, increasing the surface area of material to aeration; and ensure regular aeration of the materials. These were important processes in aiding biological treatment.

The first sample taken from a windrow was designated as a t_0 sample, and was taken within a day of the original excavation of the treatment bed. Subsequent t (representing time) samples (t_1, t_2, t_3, etc.) were taken from each individual treatment windrow thereafter. Only when a treatment windrow achieved appropriate validation criteria was it then deemed suitable for re-use. Each treatment bed was reinstated in a certain zone and a certain layer according to the criteria it had passed specified in the DQRA and the material type. Spreadsheets for each treatment bed showing failures and subsequent validation following processing are included in Appendix G. Laboratory certificates are located in Appendix H. The Soil Audit in Appendix D shows the origin, material type, and presence of CNPI, number of times the treatment bed was processed, amendments and destination of each treatment bed.

The soil audit indicates that the average treatment bed had a volume of 617m^3 and was mechanically turned 9 times before analysis demonstrated it was successfully remediated. There are large variations in this for individual beds, depending on contamination levels in specific beds and also the remediation targets that were being used to validate material at the time. For example, TB5 was mechanically processed 24 times before it was successfully validated. This is not solely a reflection of high contaminant concentrations within TB5, but more a reflection on the remedial targets utilised and the nature of the material. Treatment bed 69D had high levels of contamination and was processed 22 times to meet the VertaseFLI DQRA values.

There were a total of 1620 mechanical turns /processing during the entire remediation process, resulting in almost an aggregated 1,000,000m^3 of material passing through the treatment buckets during mechanical turning.

As stipulated in the RMS, it was intended that one sample would be taken per 90m^3 of treated material onsite. Ultimately, 1795 samples were taken from all treatment beds on site during the remediation process. This equates to one sample per 65m^3 of treatment bed material. This includes all individual samples for COC, CNPI and leachate.

There were significant difficulties associated with the treatment of particular windrows, due to odours generated from the windrows. It was necessary to cover the majority of windrows, especially in the first season of the works due to the odorous nature of the excavated materials from Zone 2N and the northern section of Zone 2S (see section 5.0.). This inhibited the treatment process by reducing the amount of oxygen available to the stockpiles whilst covered and reducing the amount of sunlight that the stockpiles received, which is important for heating the treatment beds enhancing biological degradation. Ultra violet light also degrades a number of the contaminants, a process that is inhibited by covering.

A selection of treatment bed photographs are displayed between *figures 89* and *95* in Appendix B.

7.3.2 Treatment Amendments

Where contaminants were suspected to be recalcitrant within individual treatment beds, amendments were added to enhance the remediation process. Spent mushroom compost was added to a number of treatment beds (refer to soil audit in Appendix D). Compost was added to a maximum of 3% of the total treatment bed volume. Spent mushroom compost aids biological treatment via the introduction of additional organic carbon and conditioning the soil. Beds subjected to treatment amendment are displayed in the soil audit. *Figure 96* in Appendix B demonstrates the addition of amendments to a treatment bed.

In total 76 of 179 treatment beds had amendments added to them equating to 42% of all treatment beds. These 76 treatment beds totalled 48,528m^3 (42% of total material treated on site).

7.4 Photo-degradation

Some of the COC (especially the herbicides) are susceptible to breakdown under UV light. Photo-degradation is likely to have been more effective in the second season when less odorous materials were not required to be covered.

7.5 Ex-situ Assisted Bio-treatment

A number of grossly contaminated soil beds were sent for treatment via force-ventilation, post-processing and conditioning. These beds were homogenised and dried as much as possible on site in order to increase the amount of connected void spaces through which air could flow. The beds were added to the force-ventilation vapour extraction plant and then covered. This is a necessity of the force-ventilation vapour extraction process, and was beneficial in the control of more odorous treatment beds. The force-ventilation vapour extraction process increases the degradation of volatile and to a lesser extent semi-volatile organic compounds by circulating air within the treatment beds. Volatile compounds were extracted and then filtered through a biological filter. The biological filter was monitored on a daily basis by a VertaseFLI Environmental Engineer with a PID to ensure that there was no volatile breakthrough. Photographs between *figure 97* and *99* demonstrate the force ventilation vapour extraction plant in operation.

Biological filters have an advantage over traditional granular activated carbon filters, as contaminants sorbing to carbon within the biological filter can then be degraded in situ by bacteria native to the biological media. Biological filters are self replenishing and are more sustainable in comparison to granular activated carbon. Spent mushroom compost was added to treatment beds in the force ventilation vapour extraction plant to aid in the biological treatment (see section 7.3.2.).

In total 13 treatment beds were treated in the force ventilation vapour extraction unit, equating to 7% of all treatment beds. These 13 treatment beds totalled 7,165m^3 (6.15% of all material treated onsite).

7.6 Offsite Disposal

Two treatment beds (TB84 and TB100) contained gross contamination that could not be treated onsite. In accordance with the RMS, these beds were removed from site to an appropriate offsite disposal facility. These two treatments beds equate to only 1% of all treatment beds. TB84 and TB100 totalled 2,682m^3 (2.3% of material treated on site). Photographs of TB84 and 100 are displayed in *figures 100* and *101* in Appendix B.
The red powder found in grid square H16 (section 5.7.4.1), purple powder located found in grid square H10 (section 5.7.4.1) and the Dinoseb containing tar found in grid square L10 (section 5.6.4) were all disposed of offsite.

All offsite disposal was carried out in accordance with the relevant waste regulations.

7.7 In-situ Treatment

There was no in-situ remediation carried out on site, as ground conditions were not suitable for this type of treatment.

7.8 Contaminant Degradation

7.8.1 Concentration Reduction Curves

Concentration reduction curves for 12 of the 23 COC are displayed between *figures 136* and *136.e* in Appendix J. A description of the concentration reduction curves is included in table 7.8.1 on the following page.

The 12 contaminants have been selected on the basis that they are consistently present in high concentrations across a wide range of treatment beds – allowing trends to be established from the data. 11 COC were not selected as they were not consistently present across site or within individual treatment beds and therefore, trends could not be easily established. The curves display the trends in contaminant concentration reduction only.

Concentration reduction curves have been compiled to show representative trends for the selected contaminants. In doing this it is key to select beds that have as many samples as practical in order to establish a trend. All beds used to compile the curves must have the same number of samples. All beds with 7 samples (t_0-t_6) have been considered in assembling the curves. All other beds have been disregarded.
In compiling curves for individual contaminants, beds were only used if there were frequent detects of that contaminant. For example, if a treatment bed had 7 samples but did not show Ethofumesate in those samples, then it was not selected to compile the concentration reduction curve for Ethofumesate. Once appropriate treatment beds had been selected to compile a curve, the data for each sampling point in time (t_0, t_1, t_2 etc) was averaged for all beds to generate a representative concentration reduction curve.

The treatment beds selected to compile the individual curves are recorded in table 15 in Appendix J.

Table 7.8.1. Description of degradation curves displayed in *figure 136* in Appendix J.			
	Period 1 (0-2months)	**Period 2 (2-4 months)**	**Period 3 (4-6 months)**
Bed Characteristics	Bed is ***Heterogeneous***. Material freshly excavated still has large variation in characteristics across the bed, especially in cohesive materials. Discrete pockets of gross contamination exist within treatment beds. These pockets are toxic to bacteria where concentrations are high.	Bed is ***Homogenising.*** Material has been repeatedly processed with mechanical turning buckets. Cohesive material is breaking down and becoming more granular enhancing aeration, volatilization and bacterial activity. Discrete pockets of gross contamination have been redistributed throughout the bed.	Bed is fully ***Homogenised.*** Material has been extensively processed and is ready for reinstatement.
Bacteria	Bacteria in excavated material are exposed to oxygen increasing bacterial activity. Bacterial populations rapidly beginning to establish and are increasing the bio-accessibility of target contaminants.	Bacterial populations now well established in most treatment beds. Rapid initial decrease of toxic levels of volatile contaminants is enabling the establishment of bacterial populations. Bacteria are degrading the contaminants, starting with the least complex as energy release is most efficient.	Bacteria no longer getting sufficient energy from most contaminant sources as they have degraded. Some bacteria are now degrading/latter stages of degrading more complex contaminants. Bacterial populations starting to deactivate as majority of contaminants are no longer viable energy sources.
Chlorinated Solvents (*fig. 136.a.*)	Solvents generally exhibit an initial increase up to t1 as they become more bio-accessible before rapid degradation, through volatilization and biodegradation.	Solvents exhibiting rapid degradation which starts to tail off at the end of this period as concentrations reach residual levels.	Residual solvent concentrations are exhibiting slow degradation, with the exception of Bis(2-Chloroethyl)ether which is exhibiting moderate decline, although well below remedial targets.
BTEX (*fig. 136.b.*)	BTEX compounds exhibit a significant and rapid initial increase in concentration as they become bio-accessible. Volatilization	BTEX compounds rapidly degrading through biodegradation and volatilization. Toluene and Xylene reach residual levels at t3, just half the total	Residual Toluene and Xylene concentrations remain although have been nearly totally degraded. Residual

	potentially limited in the first phase due to bed characteristics. 1,2-dichlorobenzene exhibiting rapid degradation through volatilization and biodegradation.	treatment time of the bed. 1,2-dichlorobenzene exhibits a slight rebound, potentially as bacterial populations switch from more easily degraded sources that have been exhausted.	1,2-dichlorobenzene degrades at a moderate/slower rate.
Chlorinated Phenols (*fig. 136.c.*)	Chlorinated phenols exhibit an initial slight increase followed by rapid degradation to t2.	Chlorinated phenols exhibit a slight rebound followed by gradual degradation to residual levels.	Residual Chlorinated Phenols continue to degrade at a slow rate.
Acid Herbicides (*fig. 136.d.*)	Acid herbicides exhibit rapid degradation in the first period down to a trough at t2. Mecoprop rises to t1 as it becomes more bio-accessible. Degradation is primarily by biodegradation.	Acid herbicides experience a rebound, possibly as bacterial populations switch from more easily degraded sources that have been exhausted. Rapid degradation continues after t3.	Rapid degradation tails off after t5 as residual concentrations of acid herbicides are not a viable energy source.
Organo-phosphates/ Organo-nitrates (OP/ON) (*fig. 136.e.*)	OP/ON type contaminants experience a slight decrease in concentration (significant decrease for Ethofumesate), before significant increases in concentrations as bacteria adapt to the more complex contaminants on-site and start to increase their bio-accessibility.	OP/ON type contaminants continue to increase in concentration as they become more bio-accessible. Some bacteria switch from more easily degraded sources. Subsequently Ethofumesate starts to degrade rapidly after t3. Simazine continues to accumulate.	Ethofumesate degrades to residual concentrations, after which bacteria populations start to switch to degrading Simazine. The degradation of Simazine is moderate although concentrations are well below remedial targets.

7.8.2 Mass Degradation Calculations

Mass calculations have been carried out to quantify contaminant degradation onsite. Mass calculations were carried out on all treatment beds. First it was necessary to calculate the mass of the treatment bed using the following calculations:

$$(V * d) * 1000 = m$$

Where:

V is the volume of the treatment bed (m^3)

d is the density of the treatment bed (kg/m^3)

m is the mass of the treatment bed (kg)

Each treatment bed volume was surveyed on site. The density of treatment beds was measured for geotechnical purposes in an independent laboratory. Where bed specific density was not available, an average for the material type (A, B or C) was used.

Calculations for the mass of each individual contaminant were then carried out:

$$\frac{tmax * m}{1000{,}000{,}000} = mmax$$

Where:

tmax is the highest recorded concentration of the target contaminant within a treatment bed (µg/kg)

mmax is the total mass of the target contaminant within the treatment bed (kg)

The final mass of the target contaminant (***mmin***) was calculated by replacing ***tmax*** with ***tmin*** (concentration of target contaminant in final sample) in the above equation. Mass degradation for the target contaminant was calculated by subtracting ***mmin*** from ***mmax***.

An example of the calculation for all 23 COC in treatment bed 83 is included in table 16 in Appendix J.

In order to ascertain the total mass degradation of contamination during the remediation works, the sum of mass degradation for all 23 COC was calculated and then totalled with the mass degradation for all 179 treatment beds.
Mass degradation parameters for each treatment bed are included in table 17 (type A), table 18 (type B) and table 19 (type C) in Appendix J.

The final calculation of mass degradation onsite is included in table 20 in Appendix J. The calculation shows that the total contaminant mass pre-remediation was approximately 20.84 tonnes. The residual contaminant mass of approximately 1.99 tonne indicates that a total of 18.84 tonne of the 23 COC was degraded during the remediation works. This equates to a 90% reduction in contaminant mass in soils through treatment.

It is important to note that this calculation only applies to contaminants dispersed in soils in the treatment beds and does not account for losses to air during excavation, free product recovered and treated or disposed of offsite or contamination in recovered water treated in the waste water treatment works. In addition, the calculation does not include CNPI.

The contaminant mass calculation for treatment beds disposed of offsite (TB84 and TB100) indicates that 14.96 tonnes of contamination (COC only) was present in these treatment beds immediately before offsite disposal. This indicates that 42% of the original total contaminant mass in all treatment beds only was contained within these two beds (2.3% of total treatment bed volume).

Seven 18 tonne loads of gross contamination (Dinoseb containing tar, red powder, purple powder) and cross contaminated soils were disposed of offsite. At an estimated contaminant concentration of 3.5% this equates to 4.41 tonnes of contamination sent to landfill in addition to TB84 and TB100. In summary therefore including all the above a total of 40.21 tonnes (excluding free product, losses to air and CNPI were reduced to 1.99 tones resulting in at least a 95% reduction in contaminant mass at the site.

8 Stockpile Validation

Excavated materials that did not require remediation or had completed remediation were shaped in to stockpiles rather than treatment beds to save space on site, prior to their reuse. The details of all stockpiles can be viewed in the soil audit in Appendix D. There were three types of stockpile on Hauxton:

- Type 1: Treatment beds that had passed remedial targets following treatment and were combined in preparation for reinstatement. Such beds were only combined into stockpiles when they met all relevant chemical criteria including the COC and CNPI and if they were the same material type. An example is Stockpile A, which was a combination of a number of Gault Clay beds.
- Type 2: Material that was excavated and subsequently did not require treatment. An example is the uncontaminated stockpile bund that separated the works from the gardens and houses in the south of the site (stockpile J).
- Type 3: Material that was sampled in-situ through trial pitting and was subsequently validated for re-use in either less stringent DQRA areas or more stringent DQRA areas without further treatment.

Validation data for Type 1 stockpiles can be tracked from the soil audit to the individual beds that the stockpile is made up of. Validation data for type 2 stockpiles is included in tables 13 and 14 in Appendix G. Validation certificates are included in Appendix H. Validation data for Type 3 stockpiles can be tracked from the soil audit to the trial pit data for individual grid squares that the material was excavated from. Trial pits for material that was validated in-situ prior to excavation and reuse elsewhere was carried out as described in section 6.1.2 Trial Pit Validation.

Extra soil samples were required from trial pits for materials intended to be directly used as fill materials in other parts of the site. To prove the appropriateness of material for reuse samples were taken to a ratio of one sample per 500m^3 within each grid square, as stated by the RMS for validation of site won materials to be reinstated on site. This equates to a minimum of 1 sample per metre depth in each 22x22m grid square. The two stockpiles that fall into this category are SP D and SP M. These comprise the two borrow pits from which WMMCF was won on site that passed criteria for reinstatement within Zone 1. As an extra level of conservatism all materials were excavated from borrow pits under the supervision of a VertaseFLI Environmental Engineer in order to ensure that there was no unexpected contamination within the material.

In some areas within Zone 1 materials had to be excavated as they failed remedial targets within their native DQRA zone. However, remediation of this material was not required as it passed targets for less stringent risk assessed zones around the site. These areas are referenced in section 5.0 and can be tracked through the soil audit.

9 Reinstatement

9.1 General

All excavations were reinstated with clean stockpiles, remediated treatment beds and site won crushed aggregate as outlined in the RMS.

Specific zones and depths for remediated treatment beds and stockpiles were stipulated prior to reinstatement based on the material type and the chemical data. Treatment beds were only reinstated in specific DQRA zones if they passed the required specific remediation targets for that zone.

During the reinstatement process, material was placed in 200mm layers and compacted as per the RMS, Appendix G. All reinstatement works were supervised and assessed by on-site geotechnical engineers, these works were monitored by the independent Atkins representative who ensured compliance with the specification. A photographic log of site reinstatement is included in Appendix B between *figures 102* and *120*.

A final as-built drawing showing the new topography together with any residual features is enclosed in Appendix A (D907_196). A selection of as-built photographs is displayed between *figures 130* and *135* in Appendix B.

9.2 Reinstatement in Location of Former Bentonite Wall

Reinstatement in the location of the excavated Bentonite Wall was as described above, in line with the RMS and VertaseFLI (2011), 'Remediation Proposal for the Bentonite Wall, Former Bayer Crop Science Site, Hauxton, Cambridgeshire', April 2011. Reinstatement began as soon as the excavation was completed and validation samples had been taken. This was important in order to provide support for the excavation face given the proximity of the Riddy Brook to the site boundary. A photographic log of reinstatement along this area is displayed between *figures 121* and *129* in Appendix B.

9.3 Restoration Validation

Comprehensive classification and in-situ geotechnical validation testing was undertaken and recorded by the onsite Geotechnical Engineer pre, during and post compaction of materials. In summary, this data included the following:

- Compaction conditions including: Date compacted; condition of previous layer; thickness of placed layer prior to compaction; number of passes required to achieve compaction; weather conditions and a visual assessment of the compacted layer.
- Nuclear Density Gauge (NDG) tests to assess moisture content and density of the compacted layer.
- Porosity testing involving the collection of U100 samples;
- Classification testing including Particle Size Distribution, bulk density, moisture content and Atterberg Limits.
- Hydraulic Conductivity assessment of Type B soils using a permeameter. Hydraulic conductivity was measured at different depths in reinstated soils over the site and where possible in *in-situ* natural WMMCF.
- Final thickness of material type (Type A, B and C).

The above data is presented in Appendix K (data CD).

In order to add further assurance and refinement of the VertaseFLI DQRA, data generated from the compaction testing was used to calculate the following aquifer properties, as per the validation protocol:

- Source thickness (m).
- Water filled effective porosity (%).
- Air filled porosity (%).
- Mixing zone thickness (m).
- Hydraulic conductivity (m/s)
- Dry bulk density (weight volume).

The above data is presented in the final DQRA for the site.

9.4 As Built Geology

Following remediation at the site, twenty on-site validation boreholes were drilled at locations agreed and approved by the Environment Agency to provide post remediation groundwater data. The boreholes provide a record of the post remediation ground conditions, the positions of the boreholes are shown in drawing D907_226, Appendix A and the borehole logs are presented in Appendix L.
Cross sections across the site showing the as built geology following remediation are presented on drawing D907_236 at Appendix A

9.4.1 Type C Material (Gault Clay)

The restored levels of Gault Clay can be viewed in drawing D907_212 in Appendix A and can be compared to the Gault Clay levels as encountered during excavation in drawing D907_211 (Appendix A).

In accordance with the RMS, all Gault Clay was reinstated first at the base of excavations before restoration of type B and type A materials above, replicating as close as possible the natural geology of the site.

Gault Clay was not encountered in the south of the site during excavation or trial pitting. Drawing D907_211 shows the spatial distribution and limit of Gault Clay to the south, however, the presence of the underlying Gault Clay was confirmed by Atkins (2006). This is consistent with Gault Clay dipping to the south in line with the regional geological dip.

In the north and central sections of the site, Gault Clay was generally reinstated to original levels, being tied in to the Gault Clay exposed in excavation faces where appropriate.

9.4.2 Type B Material

Type B materials comprised all WMMCF and cohesive Made Ground. Type B material was reinstated above the Gault Clay (type C) and below type A in all backfill areas on site, replicating the original site geology, as per the RMS. The level to which WMMCF material was reinstated is illustrated in drawing D907_213A in Appendix A.

As noted in sections 5.4, 5.6, 5.7 and 5.8, some areas of in-situ materials across the site passed validation criteria and did not require excavation or remediation. Where materials were not excavated, the level and relief of type B materials (drawing D907_213A) represent the original, undisturbed WMMCF as encountered during site investigations. In summary, these areas incorporate the car park area to the north west of the site in Zone 2N, areas within Zone 2S South and Zone 3.

9.4.3 Type A Material

Type A material comprised granular and semi-cohesive materials with hydrogeological parameters that fell outside the range specified for type B materials in the VertaseFLI DQRA. The reinstated Type A material was predominantly semi-cohesive with geotechnical testing (see Appendix K) classifying much of the material as cohesive. Areas of Type A material reinstatement are displayed in Drawing D907_224. The reinstated Type A was only placed over cohesive soils and not placed in contact with any *in-situ* Type A. The maximum thickness of the Type A was approximately 1 m with the majority of reinstated Type less than 0.5 m thick.

Type A materials were not reinstated in Zone 1, with the exception of a 2.0-2.5 metre thick layer between grid squares F11 and C17.The layer of sand and gravel was included due to a shortage of appropriate cohesive material on the site which met the stringent remediation criteria for Zone 1. This layer of sand and gravel has been incorporated into the VertaseFLI DQRA which demonstrated that its inclusion would not present a risk to the Riddy Brook.

In the south of the site, remaining undisturbed natural type A material is present to the southeast and southwest and comprises sand and gravel with some clayey deposits varying between 0.5-2.5 metres in thickness (see drawing D907_213AA). It is important to note that excavations in the south of the site (grid squares to the south of grid line 22) including the borrow pit area (grid square D22-D24-F22-F24) removed the natural sand and gravel and replaced it with Type B material.

9.4.4 No Dig Layer

The crushed concrete no dig layer is detailed in drawing D907_215. This layer is 0.3m thick on average across the site. The layer increases in depth to approximately 0.5 metres in between grid columns 22 and 25 in the south (D907_215). Crushed concrete was not placed within 10 metres of the Riddy Brook along the north and north eastern boundary as this is outside of the residential development footprint.

10 Post Remediation Considerations

The following is a list of post remediation considerations that should be considered prior to future use/redevelopment of the site:

10.1 Import of Soil

As detailed in the RMS, in it will be necessary to import a minimum 1m thick capping layer comprising subsoil and topsoil onto site in order to raise levels for flood protection and in order to provide appropriate growing media within garden areas. Any material imported for this purpose should be tested in accordance with the planning conditions and must meet the risk assessed human health targets for the site.

10.2 Structures and Materials Remaining on Site

Remaining structures onsite are discussed in detail in section 4.4 and include:

- A Grade II listed building (Millhouse) (drawing D907_193);
- Surface water management system incorporating a lagoon and pipeline, which must be maintained during the post remediation validation phase to control surface water runoff (drawing D907_193);
- An electricity distribution box (drawing D907_193);
- Retaining wall along the site bund to the south-east;
- Hard-standing around the main site entrance (including remnants of old tarmac entrance road).
- Four footbridges crossing the Riddy Brook. The bridges serving the public footpath must be maintained and all bridges must be considered in any bank re-profiling works;
- Retaining wall along the banks of the Riddy Brook to the north-east of site. This should be considered in any bank re-profiling works;

Stockpiled materials onsite comprise:

- A site won sand and gravel stockpile suitable for reuse onsite within the top 1m or as engineered fill beneath.

- A stockpile (TB179) of type B material with low residual levels of contamination which was excavated and treated post the main remediation phases due to a delay in the disconnection of services in this area of the site this material is now suitable for reuse onsite inside of Zone 2N and Zone 3 below the capping layer which will be re-instated by VertaseFLI before handover the site to the client.
- A stockpile of crushed tarmac suitable for reuse as haul roads during construction on site.

10.3 Remaining Sub-surface Structures

Structures remaining below the surface are discussed in sections 4.25, 4.3 and 4.4, detailed in drawing D907_193 and include:

- Live services running in site from main site entrance to Mill Lane entrance, including gas and water mains and a low voltage electricity cable.
- Live services diverted along north-west boundary including a live water main and a live high voltage electricity cable.
- Historic piled foundations cut off at approximately 3 metres below finish levels.
- Three decommissioned artesian groundwater abstraction wells.
- Post remediation validation monitoring wells. These will need to be decommissioned or retained following the validation monitoring period.
- Surface water sump and ducting next to the main site entrance. This has been retained as part of the surface water management system and must be maintained until an alternative drainage system is installed post validation monitoring.
- A pipeline running from the surface water sump (discussed above), beneath the A10 and to the WWTW. This has been retained as part of the surface water management system and must be maintained until an alternative drainage system is installed post validation monitoring.

10.4 Installation of Structures and Services in Remediated Soils

During redevelopment of the site it may be necessary to excavate below the crushed concrete no-dig layer currently present above remediated soils on the site. In this event the following issues must be considered:

- Before any excavation below the crushed concrete no-dig layer an appropriate risk assessment should be carried out.
- Remediated soil arising from excavations on site for foundations or drainage for example must be stockpiled and handled in accordance with the RMS. Soil arisings may be reused onsite provided they are reinstated within their Zone of origin and beneath the hard-dig layer. Additional assessment careful materials management should be undertaken at this stage.
- The handling of groundwater pumped from any excavations during the redevelopment works. It is possible that impacted but treated groundwater will collect in any open excavations. In this event, groundwater should be pumped from excavations and be controlled and handled in accordance with the RMS. Water quality testing will determine the disposal route.
- During the excavation of remediated soils there may be some residual odour. In the event of this, material must be handled and controlled in order to minimise the risk of nuisance to local residents.
- If piling is proposed for any part of the development, the proposed piling methodology should be submitted to and approved by the Environment Agency prior to works commencing and a planning condition exists in relation to this.
- In the unlikely event of unforeseen contamination being discovered during construction works, works should be suspended and advice sought from a suitably qualified person. This may also entail further discussion with South Cambridgeshire District Council and the Environment Agency.
- Due to the presence of low level residual contamination, potable water services may need to be upgraded from standard MDPE pipe. Exact specification should be agreed with the local water provider.
- Consideration should be given to the design of new services and drainage to ensure that they do not provide preferential pathways to the Riddy Brook or River Cam.

10.5 Future Works Beyond the Remediation Boundary

In addition to the onsite considerations discussed above, the following considerations may be required for works outside of the remediated site boundary:

- There is potential for impacted materials to be present in offsite strata adjacent to and below the A10, as the former works may have extended as far as the pavement. This should be considered when installing services and whilst making any road improvements.
- The full extent of the remediation works has been governed by the existence of the Riddy Brook. There is the potential for residual contamination, subsurface structures, including drainage pipes and foundation piles within the bank of the Riddy though it should be noted this is outside the former boundary wall of the site. Any re-profiling of the banks will require care and appropriate management to minimise risk to the Riddy Brook from such works.