

IPSEN EAST, PILING RISK ASSESSMENT REPORT

3037/01

VERSION 1

19 DECEMBER 2023

FINAL

Prepared for:



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This report has been prepared by GroundSolve Ltd with all reasonable care and diligence, within the best practice and guidance current at the time of issue within the proposed redline boundary and proposed Site end use as presented by the Client.

This report is confidential to the Client and GroundSolve Ltd accepts no responsibility whatsoever to third parties to whom this report is presented.

Version No.	Description of Issue / Revision	Date of Issue	Author	Reviewed By	Approved By
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1 INTRODUCTION

GroundSolve Ltd (GSL) were commissioned by Ipsen Biopharm Ltd requested by Lovelock Mitchell Architects to undertake a Piling Risk Assessment Report for an area of land to the east of the Main Ipsen Biopharm facility (the “Site”).

This report has been devised to generally comply with the relevant principles and requirements of a range of guidance including:

- Part IIA of the Environment Protection Act, 1990;
- BS5930:2015 +A1:2020 “Code of practice for site investigations”;
- BS10175: 2011 +A2:2017 “Investigation of Potentially Contaminated Sites - Code of Practice”;
- The Building Regulations 2010. Part C (HM Government 2013)
- Environment Agency: Land Contamination Risk Management (LCRM), Version 3, October 2020;
- Environment Agency (2017) “The Environment Agency’s Approach to Groundwater Protection” November 2018 Version 1.2;
- Environment Agency - Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention National Groundwater & Contaminated Land Centre report NC/99/73 May 2001.

1.1 OBJECTIVES

The scope of this report is to meet the requirements to provide information for planning purposes and for design of the development. The specific activities carried out are as follows:

- Carry out a piling risk assessment to determine and assess the risk to sensitive controlled water receptors from piling works on site.

1.2 PROPOSED DEVELOPMENT

The proposed development plan (see Figure 1 below) comprises the construction a large commercial building with vehicle parking areas and service provisions.

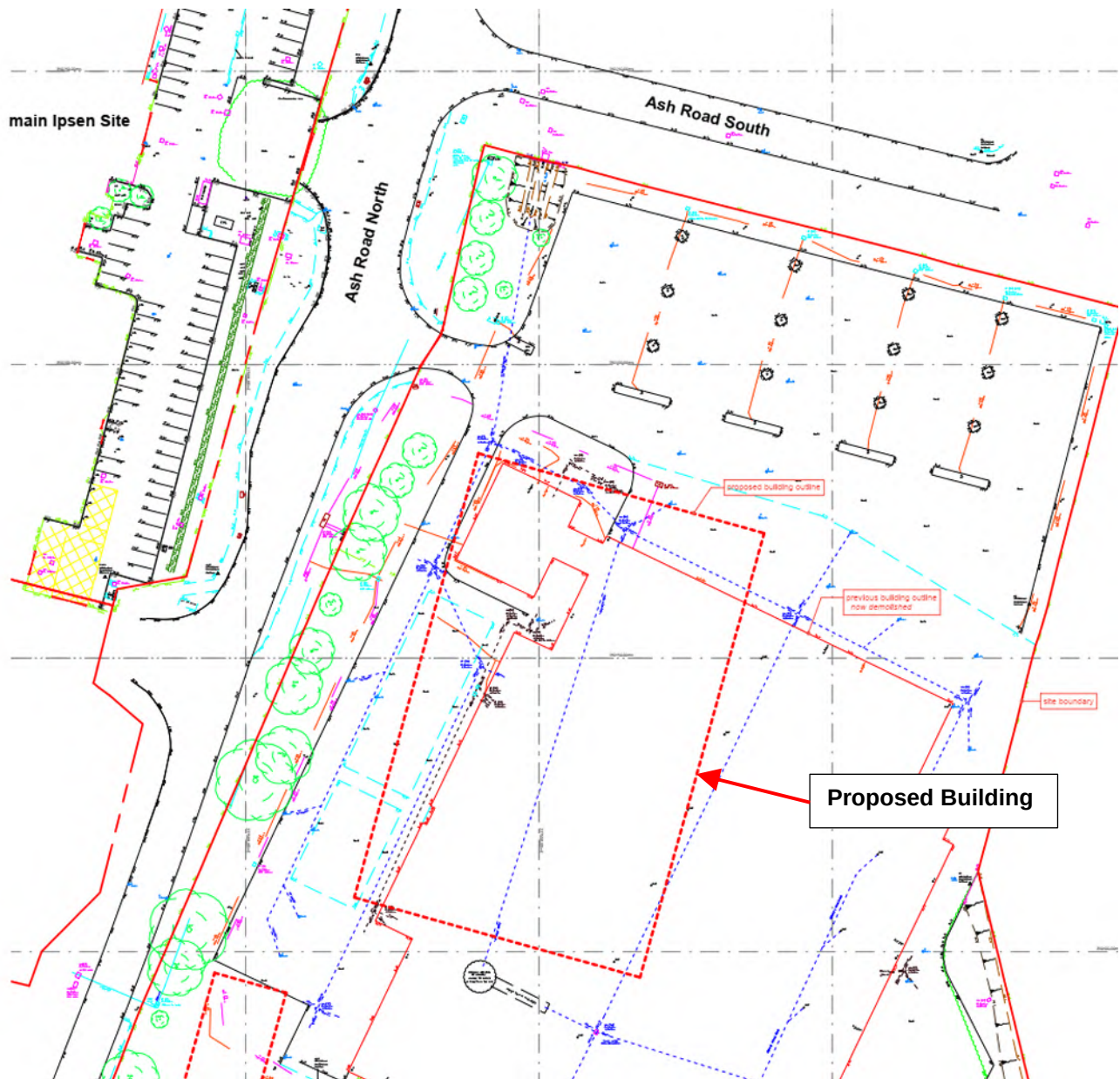


Figure 1: Extract of Drawing 2227-9501-P1 Building Location on Topo – 01/05/2023 - Lovelock Mitchell Architects

1.3 PREVIOUS REPORTS

A number of previous investigations have been carried out by Groundsolve Ltd. The findings of the previous reports are summarised in **Section 3**.

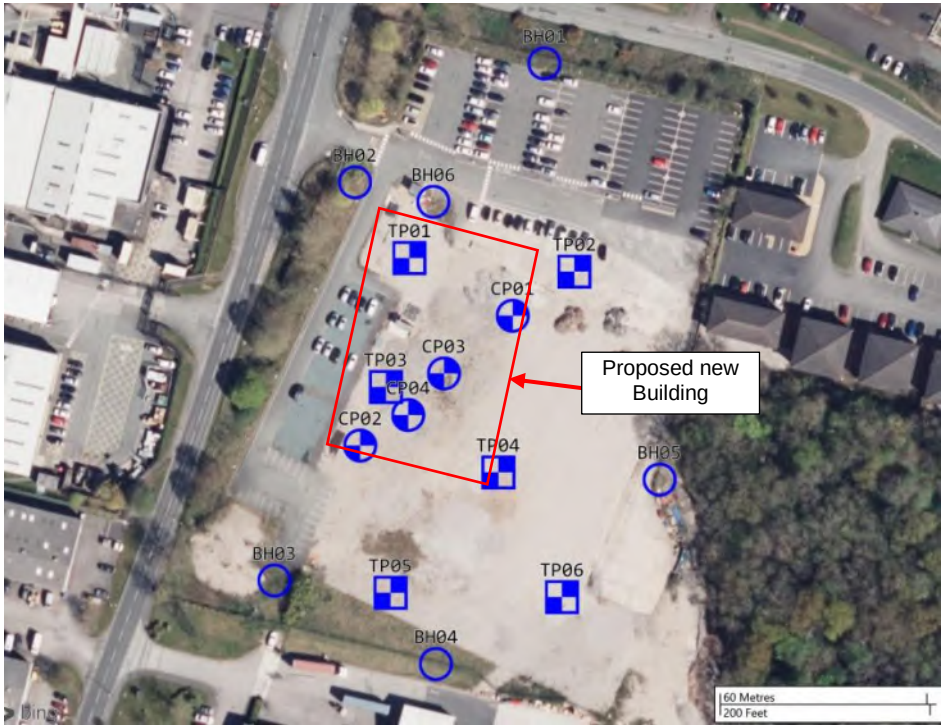
1.4 ASSUMPTIONS

The following assumptions are made in this report:

1. It is assumed that ground levels will not change significantly from those described in this report or as shown on proposed development drawings. If this is not the case, then amendments to the recommendations made in this report may be required.
2. Any references to observations of suspected asbestos-containing materials are for information only and should be verified by a suitably qualified asbestos specialist and/or confirmed by laboratory analysis.
3. The use of the term 'Topsoil' within this report is based on a visual identification only and that these materials have not necessarily been classified in accordance with BS3882:2015.
4. The comments and opinions presented in this report are based on the findings of the desk study and Intrusive investigation performed by GroundSolve Ltd. There may be other conditions prevailing on the Site which have not been revealed by this investigation and which have not been taken into account by this report at this stage.
5. Responsibility cannot be accepted for any conditions not revealed by this investigation. Any diagram or opinion on the possible configuration of the findings is conjectural and given for guidance only. Confirmation of ground conditions should be undertaken if deemed necessary.
6. The report has not assessed the suitability of the chosen foundation design but only assessed the risk to controlled waters.
7. This report has been prepared for the sole use of the Client. No other third party may rely upon or reproduce the contents of this report without the written approval of GroundSolve Ltd. If any unauthorised third party comes into possession of this report, they rely on it entirely at their own risk.

2 SITE DETAILS AND DESCRIPTION

Table 2.1 – Current Site Overview

Site name	Ipsen East
Site address	Former Proserve Logistics Ltd, 12 Ash Rd N, Wrexham LL13 9JT
National Grid Reference (NGR)	337558, 350127
	
Approximate Site area	1.30 Ha
Site shape	Rectangular
Current land use on the Site	The site is currently undeveloped land on the grounds of the former Proserve Logistics building, which was demolished in 2016.
Surrounding land uses	The site is surrounded by commercial properties and vehical parking.
General topography and ground levels	The site is relatively flat ranging from 36.80m (north) OD to 36.90m OD (south).

Relevant site photographs are presented in **Appendix B**.

3 PREVIOUS REPORT REVIEW

A Phase 1 and Phase 2 Site Investigation Report was prepared by GroundSolve Ltd for the site in March 2018. The main findings of the report are summarised in **Table 3.1** below.

No other reports have been provided to GroundSolve Ltd for review.

Table 3.1: Summary of Main Findings of Previous Reports

Geological Setting	Artificial deposits are mapped across the site and the surrounding area. The site is underlain by drift deposits comprising Glacial Till (Clay). The underlying bedrock is the Salop Formation, of Carboniferous age, mainly comprising mudstone and siltstone, which in turn are underlain by the Coal Measures at significant depth. A fault trending in a northeast-southwest orientation passes through the northern corner of the site but outside the footprint of the proposed building. The Triassic Kinnerton Sandstone is present to the NW of the fault.
Mining	A Coal Authority mining report was obtained for the adjacent Ipsen site, the main points are summarised below. • The site is not within a surface area that could be affected by past underground mining; • The site is not within a surface area that could be affected by present underground mining; • There are no known coal mine entries within, or within 20m of, the site boundary; • The site lies within an area where a notice to withdraw support was given in 1972; • The property lies outside the Cheshire Brine Compensation District. Based on the Coal Authority report and the underlying geology of the area, the site is not considered at risk from coal mining related hazards.
Ground Conditions	A number of site investigations have been carried out, which include 4No. Cable Percussion boreholes varying between 14.50m and 26.50m, 6No window sample boreholes and trial pits. Made Ground is relatively typically less than 1.00m in thickness and is predominantly brick and concrete granular fill over reworked natural deposits. No visual or olfactory evidence of contamination was noted during the fieldwork. TP04 and TP05 were located approximately in the location of the former mineral railway. No evidence of the railway was encountered. Glacial Till comprises Firm becoming stiff slightly sandy slightly gravelly Clay ranging in thickness from 13.00m to 16.90m. SPT N values range between 9-32. Loose / very loose brown slightly silty fine to coarse sand from 16.90m (BH03) and 17.20m (BH04) becoming medium dense with depth. Groundwater has been encountered ranging from 11.00m (BH02) and 17.20m (BH04). Artesian groundwater was encountered within BH03. The initial groundwater strike was at 16.50m rising to 15.00m, however rose up to 1.25m above ground level within the monitoring well the following day.

4 ENVIRONMENTAL SETTING

4.1 GEOLOGY

Table 4.1 - Geological Summary

Made ground / artificial ground	Previous investigation has shown thin Made Ground typically less than 1.00m predominantly comprising reworked natural deposits.
Drift geology	Glacial Till over Glacial silty Sand.
Solid geology	Carboniferous Salop Formation, mainly comprising mudstone and siltstone.
Faults	A fault trending in a northeast-southwest orientation between the Carboniferous and Triassic units. The fault is outside the proposed building footprint.
Coal seams	N/A

4.2 HYDROGEOLOGY

Table 4.2 - Groundwater Occurrence and Abstraction

	Presence/location	Comments
Environment Agency aquifer designation – Superficial Deposits	Secondary Undifferentiated Medium Vulnerability	
Environment Agency aquifer designation – Bedrock	Secondary A – Carboniferous Medium Vulnerability	
Anticipated groundwater depth(s)	Between 11.00m to 17.20m	Artensian groundwater conditions within the deeper sand deposits.
Direction of flow	NR	
Current licensed abstractions – potable	NR	
Source Protection Zones	NR	
Springs	NR	

NR - none recorded.

For definition of Source Protection Zones, see **Appendix A**.

4.3 HYDROLOGY

Table 4.3 - Surface Water Features

	Presence/location	Comments
Nearest surface water feature	Unnamed stream	100m to north (culverted)
Other surface water features	N/A	
Canals, ponds, lakes, etc.	N/A	
Licensed surface water abstractions	Closest 288m NE	Non-Evaporative Cooling. Downstream of site

Environment Agency GQA assessments: A = very good to E = poor

4.4 SOIL CONTAMINATION

Soil Contaminants (for a Human Health receptor) identified during the previous ground investigations comprised;

- No elevated metal, PAHs or TPH within the Made Ground.
- 1 No. sample from 12No. recorded positive asbestos result. Chrysotile fibres were in BH4-0.80m with the quantification recorded to be 0.0252%.

4.5 GROUNDWATER CONTAMINATION

Soil Contaminants from leachability testing (for a Controlled Water receptor) identified during the 2023 ground investigation comprised;

- pH above 11 within the Made Ground.
- No elevated metals, PAHs or TPH recorded within Made Ground or natural deposits.

4.6 GROUND GAS REGIME

The phase 1 risk assessment has shown there is no credible ground gas source on site, including Radon. No deep organic rich made ground was encountered during the ground investigation. There is no evidence of any hydrocarbon spills on the site.

4.7 REMEDIATION WORKS

The results of site investigation and laboratory analysis indicates that there is low concentrations of potential contaminants at the site and there are no potential off-site sources that will affect the development.

Therefore there is a negligible risk to:

- (i) human health,
- (ii) controlled waters,
- (iv) adjoining land,
- (v) ecological systems, and
- (vi) archaeological sites and ancient monuments.

No specific precautions are required with respect to landfill type ground gases, hydrocarbons or the potential risk from radon for the development. Protection measures will also not be required due to the potential risk from radon. All below ground concrete should be designed to meet the requirements of ACEC Class AC-1s. Therefore no specific remedial measures are required.

4.8 GEOTECHNICAL CONSIDERATIONS AND GROUND IMPROVEMENT REQUIREMENTS

It is understood that the developer is proposing to use a piled foundation solution for the proposed development.

5 PILING METHOD

Justification of the preferred method has been provided by the piling contractor:

- The use of 436No. Driven Precast 250mm diameter Square Piles to a maximum design depth of 17.00m.
- Groundwater strikes have been encountered between 11.00m to 17.00m. Artesian groundwater was encountered within BH03.
- Solid cylindrical piles are able to form a seal when driven through a clay layer with a thickness of at least two pile diameters.
- Solid driven piles with a square cross-section are likely to seal just as well as cylindrical piles, given the similarity of observed deformation mechanisms.
- As the clay layer extends by circa 15.00m it is far more than the required 2 x the pile diameter (250mm square) required for the above scenario to be in effect. Therefore the water table should not be at risk from the driven precast piles.
- Please note that approximately 1,100No. Vibro Stone Columns will also be installed on this project, however these columns will be installed to a maximum depth of 3.00m and therefore will have no effect on the water table.

6 POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

No significant contamination sources have been identified on or adjacent to the proposed development. However the following environmental impacts should be considered during the construction:

- Creation of preferential pathways, including through a low permeability layer, to cause contamination of groundwater in an aquifer.
- Creation of preferential pathways to allow migration of contaminant vapours to surface.
- Direct contact with contaminated soil arisings which have been brought to the surface.
- Direct contact with contaminated soil or leachate causing degradation of pile materials.
- The driving of solid contaminants down into an aquifer during pile casing driving.
- Contamination of groundwater and, subsequently, surface waters by concrete, cement paste or grout.

7 JUSTIFICATION OF FINAL SELECTED METHODOLOGY

7.1 CREATION OF PREFERENTIAL PATHWAYS - GROUNDWATER

Driven displacement piles may drag down contaminated material as they penetrate underlying strata through a frictional mechanism along the shaft of the pile, or by pushing the material ahead of the pile shoe. However, research on driven piles has shown that both these effects are minimal (Hayman et al, 1993; Boutwell et al; 2000). Material dragged down by shaft friction is unlikely to be displaced by more than a few centimetres, and very little soil may be pushed ahead of the pile shoe as the primary mechanism of soil displacement during pile installation is horizontal. It is also the case that this would imply soft material is carried with the pile right to set, bringing the load-bearing capacity of the pile into doubt. It is therefore considered unlikely that in practice this occurs (NC/99/73 EA 2001).

Driving the precast square piles through the soils as they are progressed will cause minimal drag down of soils with depth. The soils are under increasing overburden pressure with depth and as such shaft friction begins to build up soon after installation.

The site conditions comprise reworked Made Ground typically 1.00m over Glacial Till and Glacial sand overlying Carboniferous Mudstone at depth. It is assessed that there is a negligible risk of the driven piles forming a migration pathway.

7.2 CREATION OF PREFERENTIAL PATHWAYS - VAPOURS

The sides of the pile are sealed by the pressure of soils against the pile wall. This will limit the vapour pathway. There is no contamination source encountered on site.

7.3 DIRECT CONTACT WITH CONTAMINATED SOIL ARISING

Due to the piling method selected, direct contact with Made Ground and any unforeseen contaminated material will not be a risk as driven piles will not produce arisings.

All piling operatives will be required to wear the appropriate PPE for the expected contaminants on site.

7.4 DIRECT CONTACT WITH CONTAMINATED SOIL CAUSING PILE DEGRADATION

The appropriate pile construction materials (precast, reinforced and concreted piles) have been selected by the piling contractor with respect the expected ground conditions. The ground conditions will not degrade the concrete after installation (No hydrocarbons/VOCs source have been identified, which could affect concrete prior to setting).

7.5 DRIVING SOLID CONTAMINANTS INTO UNDERLYING AQUIFER

No contamination has been encountered. Made Ground is directly underlain by firm becoming stiff Glacial clay overlying Glacial Sand. The sides of the piles will be sealed by the pressure of soils against the outer pile. It is assessed that there is a negligible risk of the driven precast piles forming a migration pathway.

7.6 CONTAMINATION OF GROUNDWATER BY PILING MATERIALS

Because of the chosen piling method (precast square driven piles), there will be no onsite mixing of materials i.e. concrete, cement, grout. Strict housekeeping on site and assessment of the piling contractors methods statements will ensure the risk to groundwater or subsequently, surface waters by site materials will be minimal.

7.7 QA/QC MEASURES

The proposed piling subcontractor has reviewed the site investigation information primarily CP01 to CP04 when developing their design. The best way to provide a foundation solution for this type of development and ground conditions is to use precast driven piles. The soils are under increasing overburden pressure with depth and as such shaft friction begins to build up soon after installation of the pile. The sides of the pile are sealed by the pressure of soils against the pile wall.

Appropriate site supervision and QA/QC measures on site during the post-remediation piling works will mitigate any potential environmental, geotechnical and financial impacts of the works.

8 PILING RISK ASSESSMENT SUMMARY

Precast 250mm diameter driven piles will be advanced through the shallow Made Ground into the Glacial Clay and potentially into the top of the Glacial Sand deposits.

It is assessed that there is a negligible risk from this process to the aquifer at depth due to a combination of mitigating factors including:

- The made ground has shown no significant contamination sources on or adjacent to the proposed development.
- The site currently does not lie within a designated groundwater Source Protection Zone.
- There is no spoil returned to surface during the piling which limits any risk of contaminated soils impacting the site surface and surface water sources.
- The soils are under increasing overburden pressure with depth and as such shaft friction begins to build up soon after installation. The sides of the pile are sealed by the pressure of soils against the pile wall, reducing the likelihood of a migration pathway being formed.
- The sides of the pile are sealed by the pressure of soils against the pile wall. This will limit the vapour pathway.
- The site has been redeveloped post WWII, which has since been demolished prior to redevelopment during this construction. The Zetica UXO risk mapping indicates that the site has low bomb risk.

9 REFERENCES

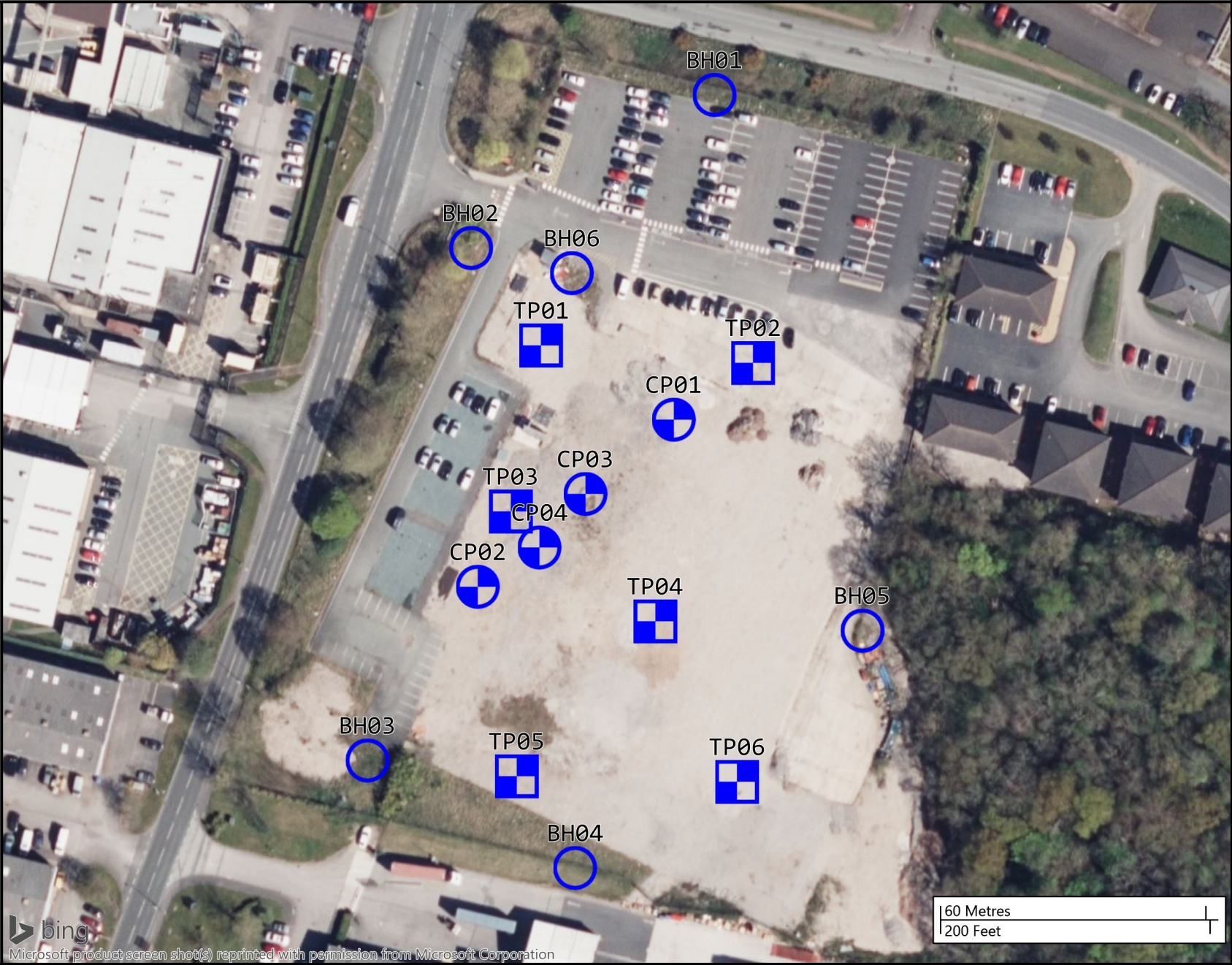
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DRAWINGS

Project Id: 3023
Project Title: Ipsen East Site - Additional Borehole
Location: Wrexham Business Park
Client: Ipsen

Title: Site Plan
Scale: 1:1250
Engineer: Ross Page
Dwg No.: GSL3023-1-001

- Legend Key
- Locations By Type - CP
 - Locations By Type - TP
 - Locations By Type - WLS



APPENDIX A – ENVIRONMENTAL RISK ASSESSMENT METHODOLOGY & TERMINOLOGY

Environmental Risk Assessment Methodology & Terminology

LEGISLATION OVERVIEW

This report includes hazard identification and environmental risk assessment in line with the risk-based methods referred to in relevant UK legislation and guidance. Government environmental policy is based upon a “suitable for use approach,” which is relevant to both the current use of land and also to any proposed future use. The contaminated land regime is the statutory regime for remediation of contaminated land that causes an unacceptable level of risk and is set out in Part 2A of the Environmental Protection Act 1990 (“EPA 1990”). The main objective of introducing the Part IIA regime is to provide an improved system for the identification and remediation of land where contamination is causing unacceptable risks to human health, or the wider environment given the current use and circumstances of the land. Part IIA provides a statutory definition of contaminated land under Section 78A(2) as:

“any land which appears to the Local Authority in whose area it is situated to be in such a condition, by reason of substances in, on, or under the land, that:

a) Significant harm is being caused or there is a significant possibility of such harm being caused;

or

b) Pollution of controlled waters is being, or is likely to be, caused.”

In order to assist in establishing if there is a “significant possibility of significant harm” there must be a “contaminant linkage” for potential harm to exist. That means there must be a source(s) of contamination, sensitive receptors present and a connection or pathway between the two. This combination of contaminant-pathway-receptor is termed a “contaminant linkage or CPR linkage.”

Part IIA of The Environmental Protection Act 1990 is supported by a substantial quantity of guidance and other Regulations. Key implementing legislation of the Part 2A regime includes the Contaminated Land (England) Regulations 2006 (SI 2006/1380) as amended by the overarching legislation for the contaminated land regime, which implements the provisions of Part IIA of the Environmental Protection Act 1990 (as inserted by section 57 of the Environment Act 1995), came into force on 14th July 2000 together with recent amended regulations: Contaminated Land (England) (Amendment) Regulations 2012 (SI 2012/263). Revised Contaminated Land Statutory Guidance was published by DEFRA in April 2012. Part IIA defines the duties of Local Authorities in dealing with it. Part IIA places contaminated land responsibility as a part of planning and redevelopment process rather than Local Authority direct action except in situations of very high pollution risk.

In the planning process guidance is provided by National Planning Policy Framework (NPPF) of July 2018 which requires that a site which has been developed shall not be capable of being determined “contaminated land” under Part IIA. In practice, Planning Authorities require sites being developed to have a lower level of risk post development than the higher level of risk that is required in order to determine a site as being contaminated in accordance with Part IIA. This is to ensure that there is a suitable zone of safety below the level for Part IIA determination and prevent

recently developed sites becoming reclassified as contaminated land if there are future legislative or technical changes (e.g., a substance is subsequently found to be more toxic than previously assessed this increases its hazard).

The criteria for assessing concentrations of contaminants and hence determining whether a site represents a hazard are based on a range of techniques, models and guidance. Within this context it is relevant to note that Government objectives are:

- a) to identify and remove unacceptable risks to human health and the environment;
- b) to seek to bring damaged land back into beneficial use;
- c) to seek to ensure that the cost burdens faced by individuals, companies and society as a whole are proportionate, manageable and economically sustainable.

These three objectives underlie the "suitable for use" approach to risk management and remediation of contaminated land. The "suitable for use" approach focuses on the risks caused by land contamination. The approach recognises that the risks presented by any given level of contamination will vary greatly according to the use of the land and a wide range of other factors, such as the underlying geology of the site. Risks therefore should be assessed on a site-by-site basis.

The "suitable for use" approach then consists of three elements:

- a) ensuring that land is suitable for its current use - in other words, identifying any land where contamination is causing unacceptable risks to human health and the environment, assessed on the basis of the current use and circumstances of the land, and returning such land to a condition where such risks no longer arise ("remediating" the land); the contaminated land regime provides the regulatory mechanisms to achieve this;
- b) ensuring that land is made suitable for any new use, as planning permission is given for that new use - in other words, assessing the potential risks from contamination, on the basis of the proposed future use and circumstances, before official permission is given for the development and, where necessary to avoid unacceptable risks to human health and the environment, remediating the land before the new use commences; this is the role of the town and country planning and building control regimes; and
- c) limiting requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to the current use or future use of the land for which planning permission is being sought - in other words, recognising that the risks from contaminated land can be satisfactorily assessed only in the context of specific uses of the land (whether current or proposed), and that any attempt to guess what might be needed at some time in the future for other uses is likely to result either in premature work (thereby running the risk of distorting social, economic and environmental priorities) or in unnecessary work (thereby wasting resources).

The mere presence of contaminants does not therefore necessarily warrant action, and consideration must be given to the scale of risk involved for the use that the site has and will have in the future.

OVERALL METHODOLOGY

The work presented in this report has been carried out in general accordance with recognised best practice as detailed in guidance documents such as in the EA online guidance: Land Contamination: Risk Management (LCRM) (Environment Agency, 2020), and BS10175:2011+A2 2017. Important aspects of the risk assessment process are transparency and justification. The particular rationale behind the risk assessments presented is given in this appendix.

The first stage of a two-staged investigation and assessment of a site is the Preliminary Investigation (BS 10175:2011), often referred to as the Phase 1 Study, comprising desk study and walk-over survey, which culminates in the Preliminary Risk Assessment. A preliminary conceptual site model (CSM) is developed which identifies potential geotechnical and geo-environmental hazards and the qualitative degree of risk associated with them. From the geo-environmental perspective, the Hazard Identification process uses professional judgement to evaluate all the hazards in terms of potential contaminant linkages (of contaminant source-pathway-receptor). Potential contaminant linkages are potentially unacceptable risks in terms of the current contaminated land regime legal framework and require either remediation or further assessment. These are normally addressed via intrusive ground investigation and generic risk assessment.

The second stage is the Ground Investigation, Generic Risk Assessment and Geotechnical Interpretation. This represents the further assessment mentioned above. The scope of the Ground Investigation is based on the findings of the Preliminary Risk Assessment and is designed to reduce uncertainty in the geotechnical and geo-environmental hazard identification. The Ground Investigation comprises fieldwork, laboratory testing and usually also on-site monitoring. The Ground Investigation may include the Exploratory, Main and Supplementary Investigations described in BS 10175:2011+A2 2017. The results of the Ground Investigation reduces uncertainty in the geotechnical and geo-environmental risks. Depending on the findings more detailed investigations or assessments may be required.

PRELIMINARY RISK ASSESSMENT

Current practice recommends that the determination of potential liabilities that could arise from land contamination be carried out using the process of risk assessment, whereby “risk” is defined as:

- “(a) The probability, or frequency, or occurrence of a defined hazard; and
- (b) The magnitude (including the seriousness) of the consequences.”

The UK’s approach to the assessment of environmental risk is set out in by the Department of the Environment Transport and the Regions (2000) publication “A Guide to Risk Assessment and Risk Management for Environmental Protection” (also called Greenleaves II). This established an iterative, systematic staged process which comprises:

- a) Hazard identification;
- b) Hazard assessment;
- c) Risk estimation;
- d) Risk evaluation;
- e) Risk assessment;

At each stage during the development process, the above steps are repeated as more detailed information becomes available for the site.

For an environmental risk to be present, all three of the following elements must be present:

- Source/Contaminant: hazardous substance that has the potential to cause adverse impacts;
- Receptor: target that may be affected by contamination: examples include human occupants/users of site, water resources (rivers or groundwater), or structures;
- Pathway: a viable route whereby a hazardous substance may come into contact with the receptor.

The absence of one or more of each component (contaminant, pathway, receptor) would prevent a contaminant linkage being established and there would be no significant environmental risk.

The identification of potential contaminant linkages is based on a Conceptual Model of the site, which is subject to continual refinement as additional data becomes available. As part of a Preliminary Risk Assessment (Desk Study and site walk over) a Preliminary Conceptual Site Model (PCSM) is formed. Based on the PCSM, potential contaminant linkages can be assessed. If the PCSM and hazard assessment indicate that a contaminant linkage is not of significance then no further assessment or action is required for this linkage. For each significant and potential linkage, a risk assessment is carried out. The linkages which potentially pose significant risks may require a variety of responses ranging from immediate remedial action or risk management or, more commonly, further investigation and risk assessment. This next stage is termed a Phase II Main Site Investigation and should provide additional data to allow refinement of the Conceptual Site Model and assess the level of risk from each contaminant linkage.

Definition of Risk Assessment Terminology

CIRIA Report C552, Contaminated Land Risk Assessment A Guide to Good Practice, 2001 sets out a methodology for estimating risk. The methodology for risk evaluation is a qualitative method for interpreting the output for the risk estimation stage of the assessment. It involves the classification of the:

- Magnitude of the potential consequence (severity) of risk occurring.
- Magnitude of the probability (likelihood) of the risk occurring.

The classification of consequence and probability are set out in table B1 and B2 below:

Table B1 Classification of Consequence

Classification	Definition	Examples
Severe (Sv)	Short term (acute) risk to human health likely to result in “significant harm” as defined by the Environment protection Act 1990, Part IIA. Short term risk of pollution of controlled waters. Catastrophic damage to buildings / property. A short-term risk to a particular ecosystem, or organism forming part of such ecosystem	High concentrations of cyanide on the surface of an informal recreation area Major spillage of contaminants from site into controlled water. Explosion causing building collapse (can also equate to a short-term human health risk if buildings are occupied.)
Medium (Md)	Chronic damage to Human Health (“significant harm”). Pollution of controlled waters. A significant change in a particular ecosystem, organism forming part such ecosystem.	Concentrations of contaminants from site exceeding generic or site-specific screening criteria. Leaching of contaminants into a major or minor aquifer. Death of species within a designated nature reserve.
Mild (Mi)	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures, and services. Damage to sensitive buildings / structures / services or the environment.	Pollution of non-classified groundwater. Damage to building, rendering it unsafe to occupy (e.g., foundation damage resulting in instability)
Minor (Mr)	Harm, although not necessarily significant harm, which may result in a financial loss, or expenditure to resolve. Non-permanent health effects to human health (easily prevented by measures such as protective clothing etc). Easily repairable effects of damage to buildings, structures, and services.	The presence of contaminants at such concentrations that protective equipment is required during site work. The loss of plants in a landscaping scheme. Discolouration of concrete.

The classification of consequence does not take into account the probability of the consequence being realised. Therefore there may be more than one consequence for a particular pollutant linkage. Both a severe and medium classification can result in death. Severe relates to short term (acute) risk while medium relates to long term (chronic) risk. Mild relates to significant harm but to

less sensitive receptors. Minor classification relates to harm which is not significant but could have a financial cost.

Table B2 Classification of Probability

Classification	Definition
High likelihood (Hi)	There is a pollutant linkage and an event that either appears very likely in the short term and almost inevitable in the long term, or there is evidence at the receptor or harm or pollution.
Likely (Li)	There is a pollutant linkage, and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low likelihood (Lw)	There is a pollutant linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such event would take place and is less likely in the short term.
Unlikely (Ul)	There is a pollutant linkage, but circumstances are such that it is improbable that an event would occur even in the very long term.

The classification gives a guide as to the severity and consequence of identified risk when compared with other risk presented on the site. It should be noted that if a risk is identified it cannot be classified as “no risk” but as “very low risk”. Differing stakeholders may have a different view on the acceptability of a risk.

Once the consequence and probability have been classified these can be compared using a matrix (**Table B3**) to identify an overall risk category. These categories and the actions required are categorised in **Table B4**.

Table B3 Risk Evaluation Matrix

		Consequence			
		Severe (Sv)	Medium (Md)	Mild (Mi)	Minor (Mr)
Probability	High likelihood (Hi)	Very High Risk (VH)	High Risk (H)	Moderate Risk (M)	Mod/Low Risk (M/L)
	Likely (Li)	High Risk (H)	Moderate Risk (M)	Mod/Low Risk (M/L)	Low Risk (L)
	Low likelihood (Lw)	Moderate Risk (M)	Mod/Low Risk (M/L)	Low Risk (L)	Very Low Risk (VL)
	Unlikely (Ul)	Mod/Low Risk (M/L)	Low Risk (L)	Very Low Risk (VL)	Very Low Risk (VL)

Table B4 Risk Categorisations

Very High Risk (VH)	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, OR there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not undertaken already) and remediation are likely to be required.
High Risk (H)	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer-term.
Moderate Risk (M)	It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the longer-term.
Low Risk (L)	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low Risk (VL)	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

GENERIC QIANTITATIVE RISK ASSESSMENT

In the following sections the current UK guidance on risks to the following receptors are discussed: human health, plant life and controlled waters

Human Health

The overall methodology for assessing the risk to human health from potential contaminants in soil is set out in the Environment Agency's guidance "Using Soil Guideline Values" SC050021/SGV Introduction, March 2009 and using the CLEA 1.06 model software (and CLEA 1.071 for nickel). The generic assessment criteria are in accordance with the following:

- Science Report SC050021/SR2: Human health toxicological assessment of contaminants in soil;
- Science Report SC050021/SR3: Updated technical background to the CLEA model;
- Science Report SC050021/SR4: CLEA Software (Version 1.071, 2014) & Handbook;
- Toxicological reports and SGV technical notes;
- Toxicological data published by LQM/CIEH (2009) and CL:AIRE/EIC/AGS (2009);
- DEFRA Development of Category 4 Screening Levels for assessment of land affected by contamination - SP1010 (December 2013);
- LQM/CIEH Suitable 4 Use Levels (S4ULs) for Human Health Risk Assessment; and,
- Toxicology review published by the European Food Safety Authority for nickel (2015).

In March 2014 six 'proposed' Category 4 Screening Levels (pC4SL) were issued by Defra. These screening values are considered to be within Category 4 as defined in the Contaminated Land Statutory Guidance and indicate safe levels for new developments passing through the planning system. The SGV for lead has been withdrawn, and the pC4SL for lead has been derived using current best practice. In January 2015 LQM/CIEH published S4ULs for 89 contaminants in accordance with the C4SL methodology.

Note that groundwater contamination may pose a risk to human health but that there are no relevant generic assessment criteria available for comparison. GroundSolve has derived our own assessment criteria for this.

Phytotoxic Risks

Generic assessment of phytotoxicity is by comparison with guideline values presented in the British Standard for Topsoil and the MAFF document "Code of Good agricultural practice for the protection of soil", October 1998. This is in accordance with LCRM's reference to DEFRA notice CLAN 4/04.

Controlled Waters

Risks to controlled waters (groundwater and surface waters) from contaminants are assessed in accordance with the EA documents "The Environment Agency's Approach to Groundwater Protection" (2017) and Remedial Targets Methodology (RTM, 2006). Pollutant inputs from

contaminated land sites are considered as passive inputs under the European Water Framework Directive (2000/60/EC) (WFD) and its daughter Directives, and as such are regulated under the Environment Agency's 'limit' pollution objective. Acceptable water quality targets (WQT) are defined for protection of human health (based on Drinking Water Standards (DWS)) and for protection of aquatic ecosystems (Environmental Quality Standards (EQS)). The risk posed to controlled waters from total soil concentrations cannot be directly assessed. The risk is assessed either by comparison of results of leachate tests carried out on soil samples, or from the direct testing of samples of groundwater to screening criteria. Leachate testing generally forms a conservative assessment and is not appropriate for organic contaminants.

CURRENT GUIDANCE ON INTERPRETATION OF CHEMICAL ANALYSIS OF SOILS

Contaminated land is defined under law through Part IIA of the Environmental Protection Act 1990, implemented through Section 57 of the Environment Act 1995. This supports a 'suitable for use' based approach to the risk assessment of potentially contaminated land. The site-specific risk assessment is based upon assessment of plausible contaminant linkages, referred to as the contaminant-pathway- receptor model, based upon the current or proposed use of the site.

Before undertaking a risk assessment, a conceptual site model is devised in order to identify the potential contaminants, pathways and receptors. The individual contaminants, pathways and receptors then need to be further investigated in order to refine the initial assessment and risk assessment undertaken.

In March 2002, the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency published the Contaminated Land Exposure Assessment (CLEA) Model and a series of related reports. These were designed to provide a scientifically based framework for the assessment of chronic risks to human health from contaminated land. These reports (CLR7-10) together with associated "SGV" documents were withdrawn and the following documents have been published as revised guidance to the CLEA assessment:

- Environment Agency : 2008: Using Soil Guideline Values SC050021/SGV Introduction, March 2008.
- Environment Agency : 2008: Science Report SC050021/SR2: Human health toxicological assessment of contaminants in soil.
- Environment Agency : 2008: Science Report SC050021/SR3: Updated technical background to the CLEA model.
- Environment Agency : 2008 : Compilation of Data for Priority Organic Contaminants for Derivation of Soil Guideline Values Science report SC050021/SR7
- Environment Agency : Science Report SC050021/SR4: CLEA Software (Version 1.071, 2015) & Handbook.
- DEFRA Development of Category 4 Screening Levels for assessment of land affected by contamination - SP1010 (December 2013).
- LQM/CIEH Suitable 4 Use Levels for Human Health Risk Assessment.

Additional guidance on statistical assessment replacing CLR 7 is partly provided in:

- CL:AIRE: 2009: Guidance on Comparing Data With a Critical Concentration

A different approach to the statistical appraisal of data is required depending on whether the assessment of risk is to assess whether land is Contaminated Land in accordance with regulations, or whether the assessment is to assess whether the site is suitable for new development in according with Planning guidance. This is discussed further in CL:AIRE: 2009 "Guidance on Comparing Data With a Critical Concentration".

The introduction of the Contaminated Land (England) (Amendment) Regulations 2012 and Contaminated Land Statutory Guidance (DEFRA, 2012) reassessed the CLEA Model and the derived SGVs (and associated GACs calculated using the model). This re-assessment concluded that the SGVs/GACs were conservative screening criteria for determining the suitability of soil with regard to the risk to human health under the planning regime and defined a new upper limit for planning purposes which is the boundary between the new Category 3 and 4. In March and September 2014 DEFRA issued guidance on these new Category 4 Screening Levels (C4SL) and these are discussed further below.

Soil Guideline Values

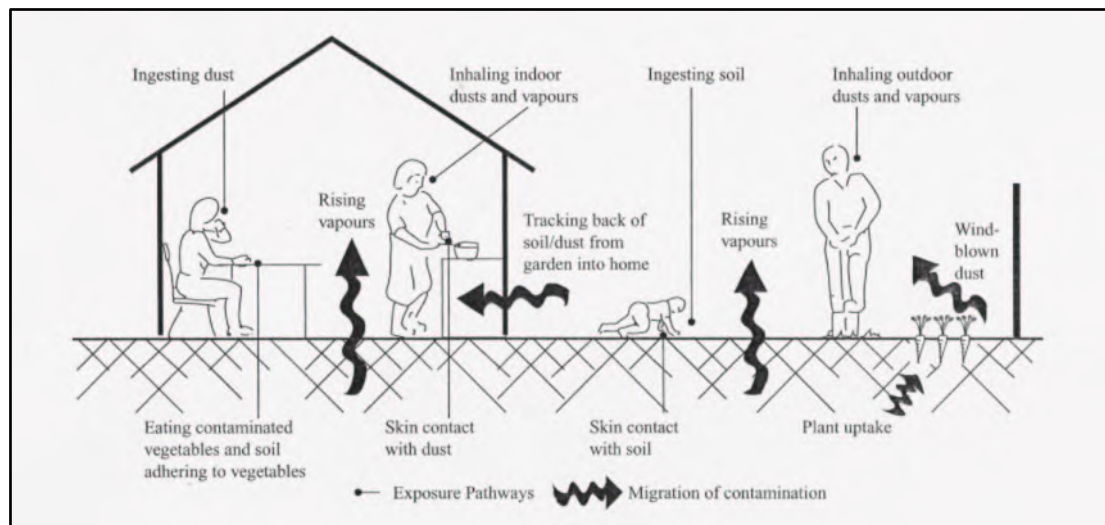
A program for the derivation of SGVs based on the above guidance is provided by the Environment Agency and is entitled “CLEA Software Version 1.06”. These reports, together with supporting toxicology reviews (“Tox” or Supplementary Information Reports) for individual substances (which will be gradually updated), Soil Guideline Value Reports and other guidance referred to in the above documents, provide guidance and the scientific basis for assessing the risk to human health from potential contaminants. Soil Guideline Value Reports (SGV Reports) have been published for a number of contaminants and these are published on the Environment Agency website. Eventually the reports will include SGVs for:

- heavy metals and other inorganic compounds: arsenic, cadmium, chromium, cyanide, lead (now withdrawn), mercury nickel (now withdrawn), and selenium;
- benzene, ethylbenzene, toluene, and xylenes;
- phenol;
- dioxins and dioxin-like polychlorinated biphenyls (PCBs);
- polycyclic aromatic hydrocarbons (PAHs) – 11 substances.

In September 2015, CLEA was re-issued as ‘CLEA Version 1.071’. Currently, the software has been used to produce an in-house GAC for nickel, following with withdrawal of the SGV.

In addition, CIEH through LQM and the EIC have published generic assessment criteria (GACs) for a wide variety of other parameters including metals, hydrocarbons, chlorinated aliphatic compounds, PAHs and explosive substances for three standard land uses. These have been produced to supplement the Environment Agency guidance. These GACs will be replaced by SGVs when or if the Environment Agency publishes any more SGVs.

The CLEA model has been developed to calculate an estimated tolerable daily soil intake (TDSI) for site users given a set ‘default’ exposure pathways. Ten human exposure pathways are covered in the CLEA model as presented below:



- Ingestion:
 - ingestion of outdoor soil;
 - ingestion of indoor dust;
 - ingestion of home-grown vegetables;
 - ingestion of soil attached to home grown vegetables.
- Dermal Contact:
 - dermal contact with outdoor soil;
 - dermal contact with indoor dust.
- Inhalation:
 - inhalation of outdoor dust;
 - inhalation of indoor dust;
 - inhalation of outdoor soil vapour;
 - inhalation of indoor soil vapour.

It should be noted that there are other potential exposure pathways on some sites not included in the CLEA model e.g., certain organic compounds can pass through plastic water pipes into drinking water supply.

The presence and/or significance of each of the above exposure pathways are dependent on the type of land use being considered and the nature of the contaminant under scrutiny. Accordingly, the CLEA model considers for principle ‘default’ land use types and makes a series of ‘default’ assumptions with regard to human exposure frequency, duration and critical human target groups for each land use considered:

- residential land use;
- allotments;
- commercial and industrial land use.

The land use categories defined in the CLEA are detailed below.

Residential: This land use category assumes that people live in a variety of dwellings including terraced, detached and semi-detached houses up to two storeys high. The structure of buildings varies. Default parameters for building materials and building design are included in CLEA documents to calculate the relevant multi-layer diffusion coefficients for vapour intrusion and to model indoor vapour intrusion. The CLEA model assumes that regardless of the style of housing the residents will have access to either a private garden or community open space nearby, and that soil tracked into the home will form indoor dust. It allows for the ingestion pathways from home grown vegetables.

Allotments: The CLEA model incorporates an assessment of land provided by local authorities specifically for people to grow fruit and vegetables for their own consumption. Consumption of such fruit and vegetables present several exposure pathways; plants absorb contaminants mainly via water uptake through roots, the contaminants move to edible portions of plants via translocation and contaminated soil particles become trapped in the skin and between leaves. At present the model fails to account for exposure through the consumption of animals, and their products (e.g., eggs), which have been reared on contaminated land.

Commercial/Industrial: Although there are a wide variety of workplaces and work-related activities, the CLEA assessment of this land-use assumes that work occurs in a permanent, three-storey structure, where employees spend most time indoors, conducting office-based or light physical work. The model assumes employees sit outside during breaks for most of the year. Limitations in applying this land-use to different industries is detailed in EA publication “Updated technical background to the CLEA model” (2011). The generic model assumes that the site would not be covered by hard standing. Risk of exposure to contaminants would be clearly less where commercial land is essentially all buildings and hard standing.

Based on the assumptions of each land use and the associated applicable exposure pathways, a ‘Soil Guideline Value’ (SGV) may be calculated for each contaminant under consideration for a particular land use in order to determine whether certain contaminant soil concentrations pose a significant risk to human health. The primary purpose of the CLEA SGVs are as ‘trigger values’ – indicators to a risk assessor that soil concentrations below this level require no further assessment as it can be assumed that the soil is suitable for the proposed use. Where soil concentrations occur above the SGV then further assessment of the results is required. The Contaminated Land (England) (Amendment) Regulations 2012 and Contaminated Land Statutory Guidance (DEFRA, 2012) which came into force in early April 2012 provides new clarity on the assessment of risk where soil concentrations exceed the SGV. The guidance introduces a four-stage classification system relating to concentration of contaminants and the assessed risk which indicates appropriate actions. Category 1 and 2 sites are classified as “Contaminated Land” as defined in Part IIA of The Environmental Protection Act (1990). Category 3 and 4 sites are not considered as “Contaminated Land” in accordance with the Act. This can be explained using the figure on the following page.

There are also difficulties in establishing soil concentrations of contaminants beyond which risks from exposure to these contaminants would be ‘unacceptable’ and that they would lead to “significant possibility of significant harm” as defined in Part IIA of The Environmental Protection Act (1990) and determine that the land is “contaminated.” This ultimately requires detailed ‘toxicological’ information of the health effects of individual contaminants and also a scientific judgement on what constitutes an ‘unacceptable’ risk. It is for local authorities or the

Environment Agency to determine whether a particular site is contaminated land, and it is for local Planning Authorities to determine whether land affected by contamination can be redeveloped.

Given the SGVs have been derived only for a limited number of contaminants and there was little prospect of further SGVs being published, two professional groupings have produced Generic Assessment Criteria (GACs) in accordance with the CLEA model for a large number of additional contaminants. These GACs were recognised in the new Contaminated Land Statutory Guidance (DEFRA, 2012) and have been produced as follows:

- *LQM/CIEH : 2009 Nathaniel CP, McCaffrey C, Ashmore MH, Cheng NPS GROUP, Gillett A, Ogden R & Scott D : 2009 . The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment (2nd edition). Land Quality Press, Nottingham.*
- *CL:AIRE/EIC/AGS: 2009 : Soil Generic Assessment Criteria (GAC) for Human Health Risk Assessment. Contaminated Land: Applications in Real Environments, Environment Industries Commission & Association of Geotechnical and Environmental Specialists. December 2009.*

Category 4 Screening Levels and LQM/CIEH Suitable 4 Use Levels

For new developments progressing through the planning regime, it is desirable that the soil concentrations are within Category 4 where there is a valid contaminant linkage. The upper boundary between Category 4 and 3 is not defined in the guidance. This boundary can also be better defined by carrying out a Detailed Quantified Risk Assessment (DQRA) and this is discussed later in this appendix.

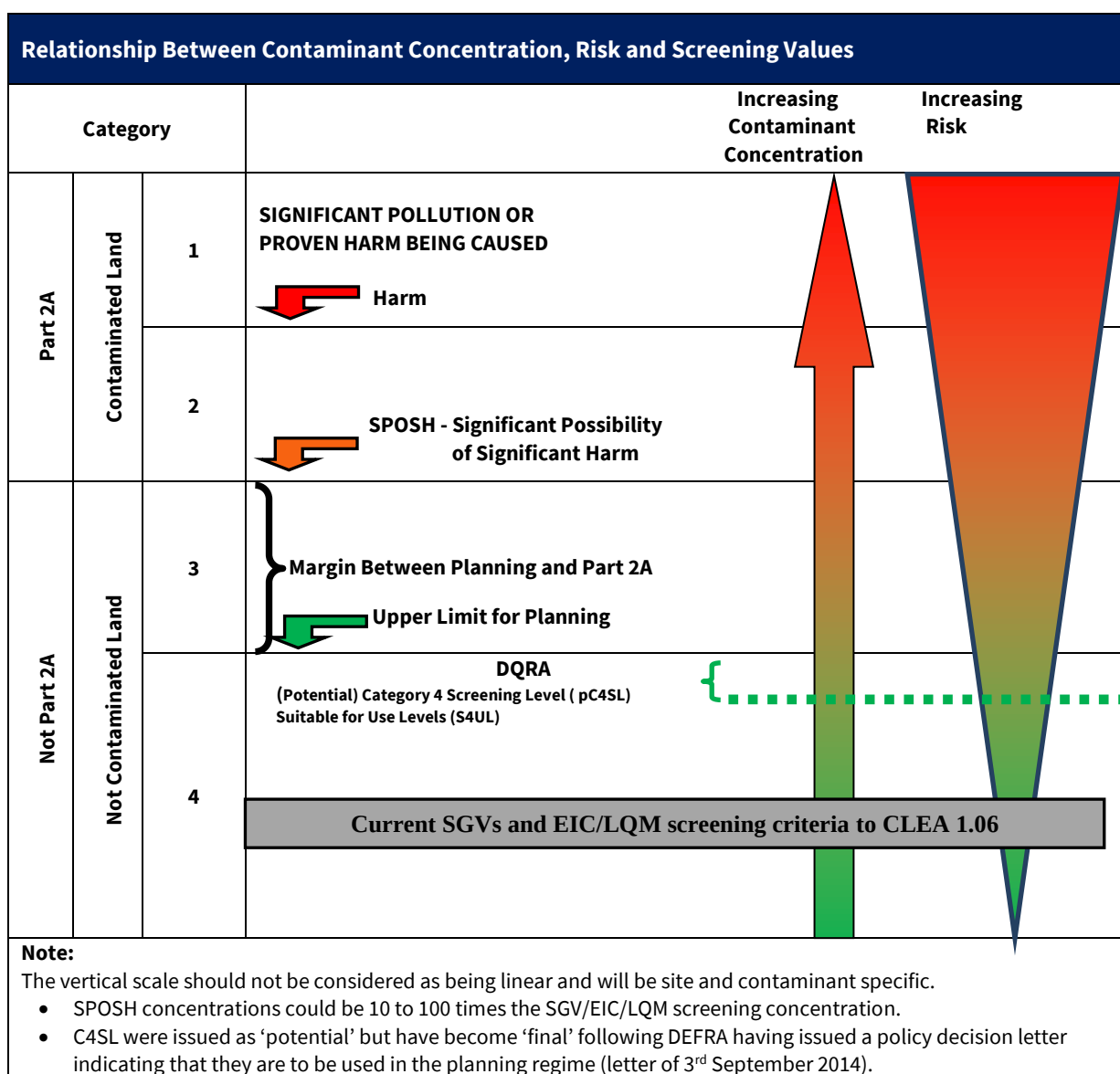
In December 2013 Defra issued the findings of a research project undertaken by CL:AIRE to set out the framework by which potential Category 4 Screening Levels (pC4SL) may be derived. The report was not designed to produce 'final' C4SL as the steering group producing the report believes that final C4SL should be set by a 'relevant authority' (e.g., Defra), the toxicological framework proposed has not been reviewed by the Committee on Toxicity and the document has yet to be subject to peer review.

In March 2014, appendices to the main Defra report were published detailing the derivation of pC4SL for 6 contaminants and other appendices regarding a review of the CIEH/CL:AIRE statistics guidance and sensitivity analysis. For each contaminant, a range of pC4SL have been produced relating to modifying toxicological parameters only, modifying exposure parameters only or by modifying both. It should be noted that the pC4SL produced for lead (the SGV was withdrawn in 2011) has undertaken a relatively large toxicological review in relation to modelling blood lead concentrations. pC4SL have been produced for:

- Arsenic;
- Benzene;
- Benzo(a)pyrene (as a surrogate marker for PAHs);
- Cadmium;
- Chromium (VI); and
- Lead

As previously discussed the values were initially published as 'potential' C4SL but have become 'final' following DEFRA having issued a policy decision letter indicating that they are to be used in the planning regime (letter of 3rd September 2014). It is considered that the pC4SL provide a

simple test for deciding whether land is suitable for use without any remediation. The pC4SL represent a new set of screening levels that are more pragmatic (but strongly precautionary) compared to the existing soil guideline values (SGVs and the other GACs calculate in accordance with the existing CLEA methodology). The pC4SL provide cautious estimates of contaminant concentrations in soil that are still considered to present an acceptable level of risk, within the context of Part 2A, by combining information on toxicology, exposure assessment and normal levels of exposure to these contaminants. pC4SL values should not be seen as ‘SPOH values.’ Exceeding a pC4SL means that further investigation is required, not that the land is necessarily contaminated. In January 2015, LQM published Suitable 4 Use Levels (S4ULs) for a further 89 contaminants using the Defra C4SL methodology. In a similar manner to the pC4SLs, no authoritative review has been undertaken although the approach and quality of the work undertaken is widely accepted as being of high quality.



Lead:

The SGV for lead was withdrawn in 2011 and is not used in this report. The pC4SL for lead provides a technically robust and conservative assessment tool using significantly updated toxicological modelling in line with current scientific understanding of lead toxicology.

Nickel

The SGV for nickel was withdrawn in 2015 and is not used in this report. In-house GACs for nickel have been produced using the updated toxicological review by the EFSA and the CLEA 1.071 software.

Public Open Space

The Defra report (December 2013) has also introduced exposure scenarios for two other commonly occurring land uses which require assessment (under the planning and Part 2A regimes) on a relatively frequent basis. These exposure scenarios are:

- Public Open Space – Space Near Residential Housing (POS_{resi}); and,
- Public Open Space – Public Park (POS_{park}).

Potential use of pC4SL relating to Public Open Space (POS) require care due to the significant variability in exposure characteristics. For example, POS may include:

- Children's play areas, public parks where children practise sport several times a week and teenagers only once a week;
- Grassed areas adjacent to residential properties which are rarely used;
- Dedicated sports grounds where exposure is only to players and groundworkers; and,
- Nature reserves or open ground with low level activity (for example, dog walking).

Within the Defra report (December 2013) the following exposure scenarios have been modelled as these are considered the most important for potential exposure for the critical receptor i.e., young children:

- Green open space close to housing, including tracking back of soil (POS_{resi}); and
- Park-type scenario where distance is considered sufficient to discount tracking back of soil (POS_{park}).

Detailed Quantified Risk Assessment (DQRA)

SGVs, GACs, pC4SL and S4ULs are based on a number of basic assumptions. There are two main options for developing Site Specific Assessment Criteria (SSAC) by adjusting the CLEA model so that they have greater relevance to the site:

- **Simple adjustment of the generic SGV / C4SL model.** Such adjustment is restricted to the choice of exposure routes selected for the generic land use, building type, soil type and soil organic matter content within the CLEA software.
- **Detailed adjustment.** It may be relevant to make greater modifications to the model due to the specific use of the land in question. This can include modification to any parameter value, including exposure assumptions, building parameters, and the choice and application of fate and transport models. This is equally relevant to site-specific modifications of existing generic land uses, the development of new land uses, and the inclusion of additional exposure pathways. Much of this can be undertaken using the CLEA software. Depending on the complexity of the detailed adjustments required, it may be necessary to use other tools either alone or in conjunction with the CLEA software. Both options should follow established protocols for DQRA and require sufficient justification and supporting information for the adjustments made. Detailed adjustments are likely to require substantially greater technical justification and supporting documentation, especially if modifications are based on information not contained within the SGV framework documents.

The two choices present the risk assessor with three options/decisions:

1. Use a published SGV/GAC/pC4SL/S4UL if it can be demonstrated that the assumptions inherent in the value are appropriate to the site in question. If they are not, proceed to either option 2 or 3 below.
2. Make simple site-specific adjustments to the generic exposure model used to derive the SSAC. Three examples of when this could be appropriate are:
 - a. High density residential development with no exposed contaminated soil at surface. It is appropriate in this case to consider the relevance of direct contact pathways and consumption of homegrown produce.
 - b. Soil type is significantly different (specifically when soil type is likely to be less protective e.g., made ground) to that assumed in the SGV/GAC/pC4SL/S4UL.
 - c. Soil organic matter content is significantly different to that assumed in the derivation of the SGV/GAC/pC4SL/S4UL.
3. If simple adjustments are not sufficient to reflect site conditions, undertake a DQRA. This may be undertaken using the CLEA software or by using an alternative risk assessment methodology that is relevant, appropriate, authoritative, and scientifically based. Changes to toxicological end points may also be considered, although this should only be undertaken by a toxicology expert. In the context of this guidance, simple adjustments of a generic land use scenario for soil type or SOM content for example are not considered sufficient to be classed as a DQRA.

DQRAs should be conducted with the agreement of the local authority (or the Environment Agency) since it is the authority that determines whether land is Contaminated Land or whether Planning Permission for a new development may be granted.

Representative Data

The type, quantity and quality of the available soil data influence the method chosen to obtain a site representative soil concentration that is compared with an SGV/GAC/pC4SL/S4UL in the screening process. The soil data should be representative of the exposure scenario being considered. This can include factors such as:

- Averaging area over which exposure occurs;
- Sample depth; and,
- Heterogeneity of soil.

where the ‘averaging area’ is defined as:

“That area (together with a consideration of depth) of soil to which a receptor is exposed or which otherwise contributes to the creation of hazardous conditions”.

Site investigations take discrete samples from a given area (and to a certain depth). It has to be assumed that these samples are to some degree representative of the contaminant concentration throughout that volume of soil. The critical soil volume (taking into account area and depth) which might be usefully compared with an SGV/GAC/pC4SL/S4UL is a site-specific decision, but a starting point is the generic land use scenarios used in the derivation of the SGV/GAC/pC4SL/S4UL. The critical soil volume depends on two factors:

- Contaminant distribution and vertical profile (bands of highly contaminated material or lateral hot spots should not necessarily be averaged out with more extensive cleaner areas of soil without justification)
- Contribution to average exposure underpinning the SGV. Direct contact exposure pathways depend on the adult or child coming into contact with near-surface soils and the area over which that exposure occurs is usually important (i.e., the averaging area). Vapour pathways are less dependent on surface area, for example vapour intrusion may result from a highly concentrated hot spot beneath a building leading to elevated average indoor air concentrations. For the three standard land uses for which SGVs are derived, relevant considerations are:
- For the standard **residential or allotment land use**, the critical soil volume is the area of an individual garden, communal play area or working plot from the surface to a depth of between 0.50m and 1.00m. This is the ground over which children are most likely to come into contact with soil or from which vegetable and fruit produce will be harvested. In the case of volatile contaminants, it may also be appropriate to consider the volume of soil underneath the footprint of the building although vapour intrusion may be driven by a soil volume much smaller than this if the contaminant source is highly concentrated.
- For the standard **commercial land use**, the critical soil volume has to be decided on a case-by- case basis due to the wide range of possible site layouts. However, for non-volatile contaminants, landscaped and recreational areas around the perimeter of office buildings are likely to be most important. For volatile contaminants, the footprint occupied by the building itself should also be considered.

- For **most exposure pathways**, the contamination is assumed to be at or within one metre of the surface.

The use of averaging areas must be justified on the basis of relevance to the exposure scenario. SGVs are relevant only when the exposure assumptions inherent in them are appropriate for the identified exposure averaging area. Further guidance on critical soil volumes and the consideration of averaging exposure areas can be found in:

- *Secondary model procedure for the development of appropriate soil sampling strategies for land contamination* (Environment Agency, 2000);
- *Guidance on comparing soil contamination data with a critical concentration* (CIEH/CL:AIRE, 2009); and
- *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination – Appendix I* (Defra December 2013, March 2014)

It is the mean soil concentration for the individual contaminant within an individual averaging area, which is compared to the SGV. However, as contaminant concentrations vary across a site, and sampling and analysis will introduce measurement errors, the comparison between measured mean concentration and the SGV must take this uncertainty into account.

There are two principal options available to obtain site representative soil concentrations from a site investigation dataset; statistical and non-statistical methods. Data objectives, quality and quantity are likely to determine which approach is most appropriate. If statistical methods such as those presented in CIEH/CL:AIRE (2011) are to be used, sufficient data need to be available or obtained. No one single statistical approach is applicable to all sites and circumstances. The wider range of robust statistical techniques developed by organisations including the US Environmental Protection Agency (USEPA) are also important tools. Risk assessors should choose an appropriate statistical approach on the basis of the specific site and the decision that is being made. For further guidance on the appropriate use of statistical approaches, refer to USEPA 2006 or good environmental monitoring statistics textbooks.

When statistical approaches are inappropriate (this will depend on the objectives of the site investigation), individual or composite samples should be compared directly to the SGV. Guidance on use of alternative data handling approaches such as the use of composite sampling can be found in documents such as:

- *Verification of remediation of land contamination* (Environment Agency, 2010);
- *Sampling and testing of wastes to meet landfill Waste Acceptance Criteria* (Environment Agency, 2005);
- *Guidance on choosing a sampling design for environmental data collection* (USEPA, 2002); and,
- *Soil Quality – Sampling, ISO 10381 series* (ISO, 2002–2007).

The statistical tests should not be used as arbiters for decisions under Part 2A. They are an additional, useful line of evidence to assist in decision-making. The implications of the basis for the derivation of the site representative soil concentration must be taken into account in any decision-making process and clearly documented.

Where the statistical tests are conducted in accordance with the method described in CL:AIRE 2009:

- For the Planning situation, it has to be demonstrated that the concentration of contaminants is low compared to the pC4SL/S4UL or SSAC. All of the test data should be below the screening criteria and no statistical analysis is required or if there are exceedances of the criteria then a statistical assessment is required. For the statistical assessment this decision is based on whether there is at least a 95% confidence level that the true mean of the dataset is lower than the screening criteria.
- For the Part 2A scenario the regulator needs to determine whether the concentration of contaminants is greater than the SGV/GAC/pC4SL/S4UL or SSAC. This decision is based on whether there is at least a 95% confidence level that the true mean of the dataset is higher than the SSAC. However, the regulator may proceed with determination if there is just a 51% probability, “on the balance of probabilities.”

If the screening levels are exceeded then more sophisticated quantitative risk assessment can be undertaken or remedial action may be taken to break the contaminant linkages. The benefits of undertaking a quantitative risk assessment must be weighed against the likelihood that it will bring about cost savings in the proposed remediation. Further information about the use of soil guideline values is provided in Environment Agency : 2008: Using Soil Guideline Values SC050021/SGV Introduction, March 2008.

GENERIC RISK ASSESSMENT CRITERIA FOR RISK TO PLANTS

Soil contaminants, if present at sufficient concentrations, can have an adverse effect on the plant population. Phytotoxic effects can be manifested by a variety of responses, such as growth inhibition, interference with plant processes, contaminant-induced nutrient deficiencies and chlorosis (yellowing of leaves). All chemicals are probably capable of causing phytotoxic effects. Thus, the phytotoxic potential of substances is dependent on the concentrations capable of having adverse effects on plants and the concentrations likely to be found at contaminated sites. Phytotoxicity is a difficult parameter to quantify given that experimental techniques vary widely, and variations exist in plant tolerances, soil effects and synergistic/antagonistic reactions between chemicals. Contaminants may be taken up and accumulated by plants through a range of mechanisms. The principal pathways are active and/or passive uptake through the plant root, adsorption to root surfaces and volatilisation from the soil surface followed by foliar uptake. After plant uptake, contaminants may be metabolised or excreted, or they may be bioaccumulated and this is highly species dependant. Many of the substances capable of adversely affecting vegetation exert this effect because of their water solubility, a characteristic that could result in their transport from contaminated sites into adjacent locations where the chemical may generate a phytotoxic response. This could be important if, for example, the adjacent site has important conservation status.

The concentration in soil at which substances become phytotoxic depend on a range of factors including plant type, soil type, pH, the form and availability of the contaminant and other vegetation stress factors that may be present (such as drought). Some plants (including some rare plants) will only grow in soils where there are relatively high concentrations which would be phytotoxic to other species. Whilst many contaminants may be phytotoxic, data are limited. Some heavy metals are essential as trace elements for plant growth but may become toxic at higher concentrations.

GroundSolve has carried out a review of a number of current and former guidance documents and other texts on phytotoxicity. It is not possible to produce a definitive list of phytotoxic substances on account of the variables mentioned above. However, a number of metals are repeatedly cited as commonly occurring priority pollutants. As a result, the following list is adopted by GroundSolve as indicators of the potential for phytotoxicity: As, Cr, Cu, Ni and Zn (note that Boron has been excluded from this list because the more modern studies do not assess this).

As the CLEA framework is a risk-based approach, applied to humans, an alternative strategy is required to assess the risk to plants from substances that are phytotoxic. Reference to published criteria and background concentrations can help put site data into context. Published assessment criteria for the protection of plant life from a number of countries are given in the following Table. The most authoritative source is the British Standard for topsoil, but this only lists three elements. LCRM states that the ICRL Guidance Note 70/90 can be used for initial screening criteria. This approach has been adopted by GroundSolve where BS3882 is lacking, but where an ICRL 70/90 criterion is lacking, the lowest criterion in Table below from, firstly UK, and, secondly, European and then other worldwide criteria. The adopted criteria are highlighted in the table 3.8. The MAFF value of 250 mg/kg has been chosen for As over the ICRL value of 50 mg/kg as MAFF explains the 50 is applicable to vegetables and human health, whereas 250 is applicable to the plants themselves.

Table B.5: Published Assessment Criteria for Phytotoxic Elements (mg/kg)							
Reference	As	CR (Total)	Cr (III)	Cr (VI)	Cu	Ni	Zn
British Standard for topsoil (BS3882:2007)	-	-	-	-	200 (pH >7) 135 (pH 6-7) 100 (pH 5.5-6.0)	110 (pH >7) 75 (pH 6-7) 60 (pH 5.5-6.0)	300 (pH >7) 200 (pH 6-7) 200 (pH 5.5-6.0)
MAFF Code of Good Agricultural Practice for the Protection of Soil (1998)	250	-	400 for sites containing sewage and sludge	-	500 (grass) but may fall to 250 for clover and sensitive species (at pH>6)	110 (pH>7) 75 (pH 6-7) 60 (pH 5.5-6.0)	1000 (clover & grass at pH 6), may fall to 300 for sensitive species (at pH 6-7)
ICRCL 59/83 (1987) now withdrawn for human health assessment	-	-	-	-	130	70	300
ICRCL 70/90 (1990) threshold trigger value	50	-	-	25 *	250	-	1000
Dutch ecotoxicological intervention value (Swartjes 1993 & 1994)	40	230	-	7	190	-	-
Australian Guideline B(1) (1999), Interim Urban Ecological Investigation Level (EIL). Soils not generally considered phytotoxic below these EILs.	20	-	400	1	100	60	200
New Zealand guidelines for timber treatment sites (1977), estimated based on Cu bioavailability *	-	-	-	-	500 - 1000 clay soils	-	-
New Zealand guidelines for timber treatment sites (1977), soil criteria for protection of plant life (residential/ agricultural setting)	10-20	-	600	25	130	-	-
Note: * Cr (VI) is only likely to be present in as a significant proportion of total Cr where pH >12 so this does not routinely need to be tested for regarding plant health.							

CURRENT GUIDANCE FOR CONTROLLED WATERS RISK ASSESSMENT

Summary of Regulatory Context

Government policy is based upon a “suitable for use approach,” which is relevant to both the current use of land and also to any proposed future use. When considering the current use of land, Part IIA of the Environment Protection Act 1990 ^[4] (EPA 1990) provides the regulatory regime, which was introduced by Section 57 of the Environment Act 1995 ^[5], which came into force in England on 1 April 2000. The main objective of introducing the Part IIA regime is to provide an improved system for the identification and remediation of land where contamination is causing unacceptable risks to human health, controlled waters or the wider environment given the current use and circumstances of the land. Part IIA provides a statutory definition of contaminated land under Section 78A(2) as:

“any land which appears to the Local Authority in whose area it is situated to be in such a condition, by reason of substances in, on, or under the land, that:

- a) *Significant harm is being caused or there is a significant possibility of such harm being caused; or,*
- b) *Pollution of controlled waters is being, or is likely to be, caused.”*

Part IIA provides a statutory definition of the pollution of controlled waters under Section 78A(9) as:

*“the entry into controlled waters of **any** poisonous, noxious or polluting matter or **any** solid waste matter”*

Part IIA is supported by a substantial quantity of guidance and other Regulations, especially for England, The Contaminated Land (England) (Amendment) Regulations 2012 and Contaminated Land Statutory Guidance (DEFRA, 2012) which came into force in early April 2012. The document re-confirms the duties of Enforcing Authorities in dealing with contamination including the role of the Environment Agency which has powers under Part 7 of The Water Resources Act (1991) to take action to prevent or remedy the pollution of controlled waters, including circumstances where the pollution arises from contamination in the land.

Part IIA introduces the concept of a contaminant linkage; where for potential harm to exist, there must be a connection between the source of the hazard and the receptor via a pathway. Risk assessment in contaminated land is therefore directed towards identifying the contaminants, pathways and receptors that can provide contaminant linkages. This is known as the contaminant-pathway-receptor link (CPR or contaminant linkage).

Part IIA places contaminated land responsibility as a part of the planning and redevelopment process rather than Local Authority or Environment Agency taking direct action except in situations of very high pollution risk or where harm is occurring. In the planning process guidance is provided by National Planning Policy Framework (NPPF) of March 2012. This requires that a site which has been developed shall not be capable of being determined “contaminated land” under Part IIA. Therefore, appropriate risk-based investigation is required to identify the contaminant

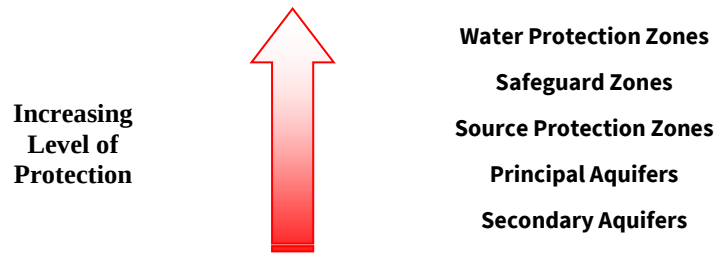
linkages that can then be assessed, and then mitigated using methods that can be readily agreed with the planners.

Environment Agency Guidance

Legislation and guidance surrounding the protection of controlled waters in the UK is numerous and can be complex. The Environment Agency's overall position on groundwater is *"To protect and manage groundwater resources for present and future generation in ways that are appropriate for the risks that we identify"* (The Environment Agency's Approach to Groundwater Protection, 2017). In brief, the core objectives of the existing legislation serve to enforce this position.

In 1992, the National Rivers Authority published their Policy and Practice for the Protection of Groundwater (PPPG), this document was influential as it provided a focus for key developments such as Source Protection Zones (SPZs) and Groundwater Vulnerability Maps. The Policy was then revised in 1998, since which there have been substantial changes in legislation, driven by Europe. Key European Directives relating to groundwater include the Groundwater Directive (80/68/EEC) and the Water Framework Directive (2000/60/EC). Aspects of these directives are controlled by primary UK legislation such as the Water Resources Act 1991 as amended by the Water Act 2003. Further to legislative changes, gaps identified in the 1998 PPPG required addressing. These changes are reflected in the Environment Agency Policy document *The Environment Agency's Approach to Groundwater Protection* of March 2017.

The Environment Agency follows a tiered, risk-based approach to drinking water protection, and this should be taken into account when carrying out controlled waters risk assessment:



Tools available for Risk Assessment of Controlled Waters

In order for a developer of a potentially contaminated site to fulfil their obligations under the legislation, a site assessment would be required to be undertaken in order to identify any potential risks to controlled waters and to derive suitable clean-up criteria if necessary to ensure the protection of controlled waters. A number of tools are available for this purpose.

Three main stages apply to any risk assessment of controlled waters, these are:

- i. Risk Screening (devise Conceptual Site Model, making reference to groundwater vulnerability maps, site setting etc)
- ii. Generic Risk Assessment (using the EA Remedial Targets Methodology – Tier 1 - Comparison of groundwater data with relevant standards)
- iii. Detailed Quantitative Risk Assessment (Consideration of aquifer properties and site-specific parameters, using the EA Remedial Targets Methodology - Tiers 2 & 3)

The Environment Agency developed a spreadsheet-based code to support the Remedial Target Methodology, and the code is capable of undertaking assessments for Tiers 1 to 3. Tier 4 assessment is not supported by the spreadsheet-based code.

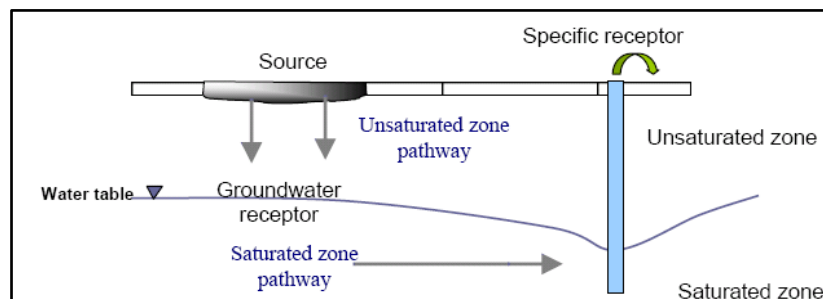
A more advanced code, ConSim 2, developed on behalf of the Environment Agency to support the Remedial Targets Methodology, allows for the introduction of additional geological horizons and is used mainly to determine the concentrations reaching a receptor and the timescales over which this may happen.

The codes assess only the dissolved phase contaminants. There are many further codes commercially available for use in controlled waters risk assessment, particularly for more complex situations, however, these should be used with caution and only once agreement has been obtained from the Environment Agency. All have the overall aim of the estimation of risk from contaminant linkages and the protection of controlled waters.

General notes on each stage of the controlled waters risk assessment process

Risk Screening

The understanding of the Conceptual Site Model (CSM) is the key to assessing any site. Using a robust CSM, potential pathways or receptors may be screened out from any further assessment at an early stage. For example, if the pathway through the unsaturated zone is blocked by the presence of a significant thickness of low permeability clay. A greater understanding of the CSM is achieved with each tier of risk assessment. An example of a basic Source-Pathway-Receptor concept is given below (taken from the Environment Agency GP3, 2006):



Generic Risk Assessment

When undertaking the Generic Hydrogeological Risk Assessment (EA Remedial Targets Methodology Tier 1), comparison of chemical analytical results is made with screening criteria. Published values of screening criteria with which chemical test results can be compared are published in the following guidance:

There is a hierarchy of screening criteria which is as follows:

- Updated Recommendations on Environmental Technical Standards, River Basin Management (2015-21), April 2012 by the UK Technical Advisory Group on the Water Framework Directive;
- Environmental Quality Standards (EQS) for freshwaters based on The EC Dangerous Substances Directive (76/464/EEC and Daughter Directives);

- Surface Waters (Abstraction for Drinking Water)(Classification) Regulations (1996)
- Surface Waters (Fishlife) (Classification) Regulations (1997)
- UK Drinking Water Standards (DWS) (Water Supply (Water Quality) Regulations 2000);
- Dutch Ministry of Housing, Spatial Planning and Environment (2001) Intervention Values and Target Values – soil quality standards;
- World Health Organisation Guidelines for Drinking Water (2004)

Should the Level 1 or 2 assessments indicate threshold levels to be exceeded, then there are three alternative ways in which to proceed:

- To devise suitable remedial solutions;
- To carry out more investigation, sampling and analysis;
- To conduct a site-specific Detailed Quantitative Risk Assessment (DQRA) to whether or not the soil materials are suitable for their site-specific intended use or to devise a site-specific clean-up level.

Detailed Quantitative Risk Assessment (DQRA)

The decision to carry out a DQRA will be dependent on the extent and implications of the initial qualitative and generic assessment. The scope of any such assessment will be accurately defined by the outcomes of the former two stages. The CSM will be sufficiently refined by this stage that only certain contaminants of concern, certain pathways and certain receptors will require further assessment, the remainder having been screened out.

Additional site-specific data is normally required for this stage of assessment, as explained above, more processes that are capable of affecting contaminant concentrations are considered (such as dilution and attenuation).

Remediation criteria derived will therefore be specific to each site and will be based on a detailed assessment of the potential impact at the identified receptor or *compliance point*. A greater level of confidence can be placed on the predicted impact on the compliance point following a DQRA.

Definition of Controlled Waters

The term ‘controlled waters’ is defined in Section 104 of the Water Resources Act 1991 as:

“Territorial Waters...which extend seawards for three miles..., coastal waters..., inland freshwaters, waters in any relevant lake or pond or of so much of any relevant river or watercourse as is above the freshwater limit, and ground waters, that is to say, any waters contained in underground strata.”

Note that the definition of groundwater under the Water Resources Act 1991 includes all water within underground strata (including soil / pore water in the unsaturated zone). The definition of groundwater under the Groundwater Directive however is limited to water in the saturated zone. For the purposes of Part IIA of the Environmental Protection Act 1990, the Environment Agency

recommends that the groundwater within the saturated zone only is considered as the receptor (rather than soil / pore water).

Environment Agency's Aquifer Designations

The Environment Agency have classified different types of aquifers from which groundwater can be extracted. The aquifer designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply) but also their role in supporting surface water flows and wetland ecosystems. The aquifer designation data is based on geological mapping provided by the British Geological Survey.

The maps are split into two different types of aquifer designation:

- **Superficial (Drift)** – permeable unconsolidated (loose) deposits.
- **Bedrock (Solid)** – solid permeable formations e.g., sandstone, chalk, limestone.

The aquifer designations displayed on the Environment Agency maps are as follows:

- **Principal Aquifers (formerly termed Major Aquifers)** – These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as a major aquifer.
- **Secondary Aquifers (formerly termed Minor Aquifers)** – These include a wide range of rock layers or drift deposits with an equally wide range of water permeability and storage. Secondary aquifers are subdivided into two types:
 - **Secondary A** - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers;
 - **Secondary B** - predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.
 - **Secondary Undifferentiated** - has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.
- **Unproductive Strata (formerly termed Non-Aquifer)** – These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

Hazardous and Non-Hazardous Substances

The Groundwater (England and Wales) Regulations 2009 control the disposal to the hydrogeological environment of potentially polluting substances which are divided into Hazardous Substances and Non-hazardous Contaminants (this roughly approximates to the former List 1 and List 2 substances).

Hazardous Substances are the most damaging and toxic and must be prevented from directly or indirectly entering the groundwater environment. Hazardous Substances include mineral oils and hydrocarbons, pesticides, biocides, herbicides, solvents and some metals. Discharge of Hazardous Substances to Controlled Waters must be prevented.

Non-hazardous Pollutants are any contaminants other than Hazardous Substances. Non-hazardous Pollutants are potentially toxic but are less harmful than Hazardous Substances, but their direct discharge to groundwater is generally not permitted and any indirect discharge to groundwater must be limited and be controlled by technical precautions in order to prevent pollution. Non-hazardous Pollutants include ammonia and nitrites, many metals and fluorides.

MANAGEMENT OF CONTAMINATED LAND

When risk assessment of the site has been completed and this indicates that remedial works are required, the main guidance in managing this process is set out in the DEFRA/EA online guidance LCRM (2020) “Land Contamination: Risk Management” The stages of managing remediation are as follows:

- (a) Options Appraisal and develop Remediation Strategy;
- (b) Develop Implementation Plan and Verification Plan;
- (c) Remediation, Verification and Monitoring.

The Remediation Strategy sets out the remediation targets, identifies technically feasible remedial solutions and presents an evaluation of the options so that these can be assessed enabling that the most suitable solution is adopted. An outline of the proposed remedial method should be presented. Agreement should be sought of the appropriate statutory bodies for the Remediation Strategy before proceeding to the next stage.

The Implementation Plan is a detailed method statement setting out how the remediation is to be carried out including stating how the site will be managed, welfare procedures, health and safety considerations together with practical measures such as details of temporary works, programme of works, waste management licences and regulatory consents required. Agreement should again be sought of the appropriate statutory bodies for this Plan.

The Verification Plan sets out the requirements for gathering data to demonstrate that the remediation has met the required remediation objectives and criteria. The Verification Plan presents the requirements for a wide range of issues including the level of supervision, sampling and testing regimes for treated materials, waste and imported materials, required monitoring works during and post remediation, how compliance with all licenses and consents will be checked etc. Agreement should again be sought of the appropriate statutory bodies for the Verification Plan. On completion of the remediation a Verification Report should be produced to provide a complete record of all remediation activities on-site and the data collected as required in the Verification Plan. The Verification Report should demonstrate that the remediation has met the remedial targets to show that the site is suitable for the proposed use.

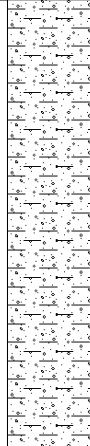
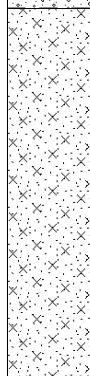
GLOSSARY

TERMS		UNITS	
AST	Above Ground Storage Tank	m	Metres
BGS	British Geological Survey	km	Kilometres
BSI	British Standards Institute	%	Percent
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes	%v/v	Percent volume in air
CIEH	Chartered Institute of Environmental Health	mb	Milli Bars (atmospheric pressure)
CIRIA	Construction Industry Research Association	l/hr	Litres per hour
CLEA	Contaminated Land Exposure Assessment	ha	Hectare (10,000m ²)
CSM	Conceptual Site Model	µg/l	Micrograms per Litre (parts per billion)
DNAPL	Dense Non-Aqueous Phase Liquid (chlorinated solvents, PCB)	ppb	Parts Per Billion
DWS	Drinking Water Standard	mg/kg	Milligrams per kilogram (parts per million)
EA	Environment Agency	ppm	Parts Per Million
EQS	Environmental Quality Standard	mg/m ³	Milligram per metre cubed
GAC	General Assessment Criteria	Mg/m ³	Megagram per metre cubed
GL	Ground Level	µg/m ³	Microgram per metre cubed
GSV	Gas Screening Value	m bgl	Metres Below Ground Level
HCV	Health Criteria Value	m bcl	Metre Below Cover Level
LNAPL	Light Non-Aqueous Phase Liquid (petrol, diesel)	mOD	Metres Above Ordnance Datum (sea level)
ND	Not Detected	kN/m ²	Kilo Newtons per metre squared
LMRL	Lower Method Reporting Limit	kPa	Kilo Pascal – same as kN/m ²
NR	Not Recorded	µm	Micro metre
OD	Ordnance Datum		
PAH	Poly Aromatic Hydrocarbon		
PCB	Poly-Chlorinated Biphenyl		
PID	Photo Ionisation Detector		
PCSM	Preliminary Conceptual Site Model		
SGV	Soil Guideline Value		
TPH (CWG)	Total Petroleum Hydrocarbon (Criteria Working Group)		
SPT	Standard Penetration Test		
SVOC	Semi Volatile Organic Compound		
UST	Underground Storage Tank		
VCCs	Vibro Concrete Columns	VSCs	Vibro Stone Columns
VOC	Volatile Organic Compound		

APPENDIX B – EXPLORATORY HOLE LOGS

GroundSolve Ltd				Cable Percussion Drilling Record						CP01	
Project Name: Ipsen East Site, Wrexham				Client: Ipsen Biopharm Ltd.				Date: 08/02/2023 - 09/02/2023			
Location: Wrexham Industrial Estate				Contractor: Cheshire Drilling				Co-ords: E337579.76 N350152.44			
Project No. : 2867				Crew Name: GC and DB				Drilling Equipment: Dando 2000			
Borehole Number CP01		Hole Type CP		Level 37.12m AoD		Logged By JP		Scale 1:50		Page Number Sheet 1 of 2	
Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description			
		Depth (m)	Type	Results							
		0.30	D	N=6 (2,2/2,1,1,2)	0.50	36.62		Very dense greyish brown sandy angular to subangular fine to coarse GRAVEL of brick, concrete, and metal. (MADE GROUND) Stiff brown slightly sandy slightly gravelly CLAY. Gravel is angular to subangular fine to coarse of concrete, limestone, and sandstone. (MADE GROUND)		1	
		1.00	D								
		1.20	SPT								
		2.00	D	N=16 (1,1/3,4,4,5)	1.85	35.27		Stiff reddish brown mottled grey slightly sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine to medium of quartzite. (GLACIAL TILL)		2	
		2.00	SPT								
		3.00	SPT	N=15 (2,2/3,3,4,5)					3		
		4.00	U								
		5.00	B	N=28 (3,3/5,6,8,9)					5		
		5.00	D								
		5.00	SPT								
6.00	U	N=22 (3,4/5,5,6,6)			Less mottling and no gravel from 8.00m bgl.		6				
7.50	SPT										
9.00	D										
9.00	U						9				
									10		
Hole Diameter		Casing Diameter		Chiselling				Inclination and Orientation			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth Top	Depth Base	Inclination	Orientation
15.00 15.45	150 50	14.50	150								
Remarks										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH	
Terminated at 15.45m bgl due to reaching target depth. Groundwater encountered at 13.00m bgl.											

Project Name: Ipsen East Site, Wrexham		Client: Ipsen Biopharm Ltd.		Date: 08/02/2023 - 09/02/2023	
Location: Wrexham Industrial Estate		Contractor: Cheshire Drilling		Co-ords: E337579.76 N350152.44	
Project No. : 2867		Crew Name: GC and DB		Drilling Equipment: Dando 2000	
Borehole Number CP01	Hole Type CP	Level 37.12m AoD	Logged By JP	Scale 1:50	Page Number Sheet 2 of 2

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
		10.50	SPT	N=20 (3,3/4,5,5,6)	13.00	24.12		Stiff reddish brown mottled grey slightly sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine to medium of quartzite. (GLACIAL TILL)	11
		12.00 12.00	D U						12
		13.50 13.50	D SPT	N=12 (2,3/2,3,3,4)	15.45	21.67		Medium dense brown silty fine to medium SAND. (GLACIAL TILL)	13
		15.00	SPT	N=17 (3,3/4,4,4,5)					14
		End of Borehole at 15.450m							15
									16
									17
									18
									19
									20

Hole Diameter		Casing Diameter		Chiselling				Inclination and Orientation			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth Top	Depth Base	Inclination	Orientation
15.00 15.45	150 50	14.50	150								

Remarks Terminated at 15.45m bgl due to reaching target depth. Groundwater encountered at 13.00m bgl.										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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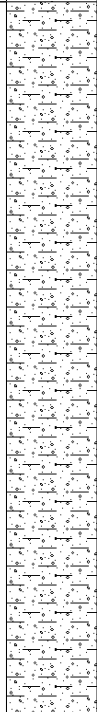
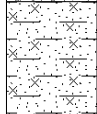
Project Name: Ipsen East Site, Wrexham		Client: Ipsen Biopharm Ltd.		Date: 09/02/2023 - 10/02/2023	
Location: Wrexham Industrial Estate		Contractor: Cheshire Drilling		Co-ords: E337534.67 N350115.09	
Project No. : 2867		Crew Name: GC and DB		Drilling Equipment: Dando 2000	
Borehole Number CP02	Hole Type CP	Level 37.14m AoD	Logged By JP	Scale 1:50	Page Number Sheet 1 of 2

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
		0.10	D		0.55	36.59		Very dense greyish brown sandy angular to subangular fine to coarse GRAVEL of brick, concrete, and metal. (MADE GROUND)	1
		0.80	D					Firm becoming soft brown slightly sandy slightly gravelly CLAY. Gravel is angular to subangular fine to coarse of concrete, limestone, and sandstone. (MADE GROUND)	
		1.20	SPT	N=12 (5,4/3,2,3,4)					
		2.00	SPT	N=6 (2,1/1,2,1,2)	2.00	35.14		Soft becoming stiff reddish brown mottled grey slightly sandy slightly gravelly CLAY. Gravel is subangular to rounded fine to medium of quartzite. (GLACIAL TILL)	2
		2.50	D						
		3.00	SPT	N=21 (3,3/4,5,6,6)					3
		4.00	U						4
		5.00	D						
		5.00	SPT	N=24 (4,4/5,6,6,7)					5
		6.00	U						6
		7.00	D						7
		7.50	SPT	N=24 (4,4/4,6,7,7)				Less mottling and no gravel from 7.50m bgl.	8
		10.00	D						10

Hole Diameter		Casing Diameter		Chiselling				Inclination and Orientation			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth Top	Depth Base	Inclination	Orientation
15.00 15.45	150 50	3.00	150								

Remarks Terminated at 15.45m bgl due to reaching target depth. Groundwater encountered at 11.00m bgl.										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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Project Name: Ipsen East Site, Wrexham		Client: Ipsen Biopharm Ltd.		Date: 09/02/2023 - 10/02/2023	
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Project No. : 2867		Crew Name: GC and DB		Drilling Equipment: Dando 2000	
Borehole Number CP02	Hole Type CP	Level 37.14m AoD	Logged By JP	Scale 1:50	Page Number Sheet 2 of 2

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
		10.50	SPT	N=16 (3,3/3,4,4,5)				Soft becoming stiff reddish brown mottled grey slightly sandy slightly gravelly CLAY. Gravel is subangular to rounded fine to medium of quartzite. (GLACIAL TILL)	
								<u>Damp from 11.00m bgl.</u>	11
		12.00	U						12
		12.50	D						13
		13.50	SPT	N=17 (3,3/4,4,4,5)					14
		15.00	SPT	N=26 (4,5/6,6,7,7)	14.70	22.44		Dense brown slightly clayey silty fine to coarse SAND. (GLACIAL TILL)	15
					15.45	21.69		End of Borehole at 15.450m	16
									17
									18
									19
									20

Hole Diameter		Casing Diameter		Chiselling				Inclination and Orientation			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth Top	Depth Base	Inclination	Orientation
15.00 15.45	150 50	3.00	150								

Remarks Terminated at 15.45m bgl due to reaching target depth. Groundwater encountered at 11.00m bgl.										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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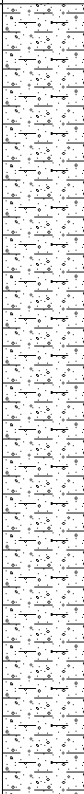
Project Name: Ipsen East Site - Additional Borehole		Client: Ipsen		Date: 13/11/2023 - 14/11/2023	
Location: Wrexham Business Park		Contractor: Cheshire Drilling		Co-ords: E337559.40 N350135.85	
Project No. : 3023		Crew Name: GC		Drilling Equipment: Dando 2000	
Borehole Number CP03	Hole Type CP	Level 37.15m AoD	Logged By RP	Scale 1:50	Page Number Sheet 1 of 3

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					0.70	36.45		Dense brown grey sandy fine to coarse angular subangular GRAVEL of brick concrete (MADE GROUND)	
		1.20	SPT	N=6 (1,1/1,1,2,2)				Firm brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse (MADE GROUND)	1
		2.00	SPT	N=9 (1,2/2,2,2,3)	2.20	34.95		Firm brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse of Sandstone. (GLACIAL TILL)	2
		3.00	U		3.00	34.15		Stiff brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse of Sandstone. (GLACIAL TILL)	3
		4.00	SPT	N=21 (4,4/5,5,5,6)					4
		5.00	U						5
		6.00	SPT	N=23 (2,3/4,5,6,8)					6
		7.50	U						7
		9.00	SPT	N=23 (5,4/4,5,6,8)					9
									10

Hole Diameter		Casing Diameter		Chiselling				Progress			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth of Hole	Depth Casing	Depth Water	Date
		16.50	200					0.00	0.00	Dry	13/11/2023 08:00:00
		25.00	150					17.00	17.00	3	13/11/2023 18:00:00
								16.90	16.50	3	14/11/2023 08:00:00
								19.50	19.00	8	14/11/2023 12:00:00
								19.50	19.00	8	15/11/2023 08:00:00

Remarks 1) Groundwater encountered at 16.5m rising to 15.0m after 20mins 2) Monitoring well installed with response zone between 16.5m-25m 3) 17/11/23 - artesian groundwater recorded in monitoring well - upto 1.25m above GL										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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Project Name: Ipsen East Site - Additional Borehole		Client: Ipsen		Date: 13/11/2023 - 14/11/2023	
Location: Wrexham Business Park		Contractor: Cheshire Drilling		Co-ords: E337559.40 N350135.85	
Project No. : 3023		Crew Name: GC		Drilling Equipment: Dando 2000	
Borehole Number CP03	Hole Type CP	Level 37.15m AoD	Logged By RP	Scale 1:50	Page Number Sheet 2 of 3

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description		
		Depth (m)	Type	Results						
		10.50	SPT	N=17 (2,3/3,4,4,6)	15.30	21.85		Stiff brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse of Sandstone. (GLACIAL TILL)	11	
		12.00	SPT	N=19 (3,3/4,4,5,6)				12		
								13		
		13.50	SPT	N=22 (3,4/5,5,6,6)				14		
								15		
		15.00	SPT	N=17 (3,4/4,4,4,5)				16		
			16.50	SPT	N=9 (2,2/3,2,2,2)	16.90	20.25		Stiff brown slightly sandy slightly gravelly CLAY with brown fine to coarse SAND lenses. Gravel is fine to coarse (GLACIAL TILL)	17
			18.00	SPT	N=0 (0,0/0,0,0,0)	18.00	19.15		Medium dense brown silty fine to coarse SAND (FLUVIOGLACIAL DEPOSITS)	18
										19
			19.50	SPT	N=7 (1,1/2,1,2,2)	19.50	17.65		Very loose brown slightly silty fine to coarse SAND (FLUVIOGLACIAL DEPOSITS)	20

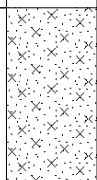
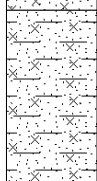
Hole Diameter		Casing Diameter		Chiselling				Progress			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth of Hole	Depth Casing	Depth Water	Date
		16.50	200					26.90	26.00	4	15/11/2023 18:00:00
		25.00	150								

Remarks

- 1) Groundwater encountered at 16.5m rising to 15.0m after 20mins
- 2) Monitoring well installed with response zone between 16.5m-25m
- 3) 17/11/23 - artesian groundwater recorded in monitoring well - upto 1.25m above GL

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Chester Road
Bretton
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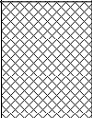
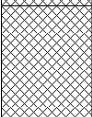
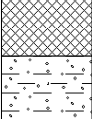
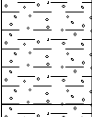
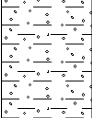
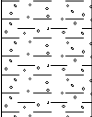
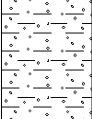
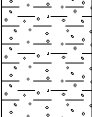
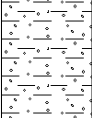
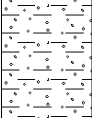
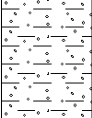
Project Name: Ipsen East Site - Additional Borehole		Client: Ipsen		Date: 13/11/2023 - 14/11/2023	
Location: Wrexham Business Park		Contractor: Cheshire Drilling		Co-ords: E337559.40 N350135.85	
Project No. : 3023		Crew Name: GC		Drilling Equipment: Dando 2000	
Borehole Number CP03	Hole Type CP	Level 37.15m AoD	Logged By RP	Scale 1:50	Page Number Sheet 3 of 3

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
		21.00	SPT	N=16 (3,2/2,3,4,7)	21.20	15.95		Loose brown slightly silty fine to coarse SAND (FLUVIOGLACIAL DEPOSITS)	21
								Medium dense brown silty clayey fine to coarse SAND (FLUVIOGLACIAL DEPOSITS)	22
		22.50	SPT	N=13 (2,3/3,4,2,4)					23
		24.00	SPT	N=21 (5,4/4,5,6,6)					24
		25.50	SPT	N=24 (3,4/5,5,6,8)					25
					26.50	10.65		End of Borehole at 26.500m	26
									27
									28
									29
									30

Hole Diameter		Casing Diameter		Chiselling				Progress			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth of Hole	Depth Casing	Depth Water	Date
		16.50 25.00	200 150								

Remarks 1) Groundwater encountered at 16.5m rising to 15.0m after 20mins 2) Monitoring well installed with response zone between 16.5m-25m 3) 17/11/23 - artesian groundwater recorded in monitoring well - upto 1.25m above GL										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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Project Name: Ipsen East Site - Additional Borehole		Client: Ipsen		Date: 16/11/2023 - 18/11/2023	
Location: Wrexham Business Park		Contractor: Cheshire Drilling		Co-ords: E337548.86 N350123.83	
Project No. : 3023		Crew Name: GC		Drilling Equipment: Dando 2000	
Borehole Number CP04	Hole Type CP	Level 37.15m AoD	Logged By RP/AB	Scale 1:50	Page Number Sheet 1 of 2

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					0.80	36.35		Dense brown grey sandy fine to coarse angular subangular GRAVEL of brick concrete (MADE GROUND)	
								Firm brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse of brick and sandstone (MADE GROUND)	1
					1.90	35.25		Firm brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse sandstone (GLACIAL TILL)	2
					3.00	34.15		Stiff brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse sandstone. (GLACIAL TILL)	3
									4
									5
									6
									7
									8
									9
									10

Hole Diameter		Casing Diameter		Chiselling				Progress			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth of Hole	Depth Casing	Depth Water	Date
		17.20	200					0.00	0.00	Dry	16/11/2023 08:00:00
		18.50	150					10.00	10.00	Dry	16/11/2023 18:00:00
								10.00	10.00	Dry	17/11/2023 08:00:00
								18.95	19.00	1	17/11/2023 18:00:00

Remarks 1) Borehole terminated due to potential artesian groundwater conditions 2) Groundwater encountered at 17.2 rising to 5.5m after 20mins 3) Blowing sand from 17.2m up to 12m 4) Groundwater in continuity with CP03. Groundwater changes noted in both boreholes simultaneously										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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Project Name: Ipsen East Site - Additional Borehole		Client: Ipsen		Date: 16/11/2023 - 18/11/2023	
Location: Wrexham Business Park		Contractor: Cheshire Drilling		Co-ords: E337548.86 N350123.83	
Project No. : 3023		Crew Name: GC		Drilling Equipment: Dando 2000	
Borehole Number CP04	Hole Type CP	Level 37.15m AoD	Logged By RP/AB	Scale 1:50	Page Number Sheet 2 of 2

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
								Stiff brown slightly sandy slightly gravelly CLAY. Gravel is subangular subrounded fine to coarse sandstone. (GLACIAL TILL)	11
									12
									13
									14
									15
									16
									17
		17.20 - 18.00 17.20	B SPT	N=0 (0,0/0,0,0,0,0)	17.20	19.95		Very loose brown silty fine to coarse SAND (FLUVIOGLACIAL DEPOSITS)	18
		18.00	SPT	N=10 (1,1/3,2,3,2)	18.00	19.15		Medium dense brown silty fine to coarse SAND (FLUVIOGLACIAL DEPOSITS)	19
		18.50	SPT	N=16 (6,3/3,4,4,5)					20
					18.95	18.20		End of Borehole at 18.950m	

Hole Diameter		Casing Diameter		Chiselling				Progress			
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth of Hole	Depth Casing	Depth Water	Date
		17.20 18.50	200 150								

Remarks 1) Borehole terminated due to potential artesian groundwater conditions 2) Groundwater encountered at 17.2 rising to 5.5m after 20mins 3) Blowing sand from 17.2m up to 12m 4) Groundwater in continuity with CP03. Groundwater changes noted in both boreholes simultaneously										GroundSolve Ltd Unit 1 Well House Barns Chester Road Bretton CH4 0DH
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APPENDIX C – PILING INFORMATION



Project Name:	Wrexham - Ash Road North	Page :	1
Project No:	CR0024	Date:	13/12/2023
Engineer:	AT	Checker:	MMM

CR0024 - Wrexham - Ash Road North - Mitigation of Risk to Ground Water

The purpose of this document is to address the potential risk to ground water caused by the proposed piling and ground improvement works for the Ipsen NDP, Ash Road North, Wrexham. These proposed works include the installation of 436 Driven Precast 250mm Square Piles to a maximum design depth of 17m. As per Cable Percussive Boreholes CP03 and CP04 as provided by *Factual Ground Investigation: Ipsen East* by Roundsolve Ltd (Ref No. - GSL3023R01) the top of water table is located at approximately 16.5m.

Both Boreholes show that the ground material is primarily made up of Clay from approx 2.0m - 17.0m. Due to the presence of clay, it is unlikely that the proposed driven precast piles will be at risk to the water table with reference to the below extract from Page 56 of *Piling in Layered Ground: Risks to Ground Water and Archaeology* by the Environment Agency (Ref No. - SC020074/SR):

"Solid cylindrical piles are able to form a seal when driven through a clay layer with a thickness of at least two pile diameters, although this result may not hold for heavily overconsolidated clays. Where the clay is less than two pile diameters thick, substantial changes in overall vertical permeability can occur. Also, piles with re-entrant sections, such as H-section piles, seal less well than solid ones due to partial plugging with overlying soil. The effect of pile driving is equivalent to the creation of an additional seepage pathway in a column of overlying soil (Figure 4.18). A normalised diagram (Figure 4.19) shows the effects observed in the model tests, although further research is needed to test the validity of the normalisation."

"Solid driven piles with a square cross-section are likely to seal just as well as cylindrical piles, given the similarity of observed deformation mechanisms"

As the clay layer extends by circa 15.0m it is far more than the required 2 x the pile diameter (250mm square) required for the above scenario to be in effect. Therefore the water table should not be at risk from the driven precast piles.

Please note that approximately 1,100 Vibro Stone will also be installed on this project, however these columns will be installed to a maximum depth of 3.0m and therefore will have no effect on the water table.