Upton House
Market Street
Charlbury
Oxfordshire, OX7 3PJ
United Kingdom
tel +44 (0)1608 810374
fax +44 (0)1608 810093
e-mail info@gwp.uk.com
www.gwp.uk.com

BOW FARM HYDROGEOLOGICAL RISK ASSESSMENT TO SUPPORT A DEPOSIT OF WASTE FOR RECOVERY ENVIRONMENTAL PERMIT APPLICATION

For

MORETON C CULLIMORE (GRAVELS) LIMITED

November 2025

GWP Consultants LLP
Registered No. OC326183
Registered Office: Upton House, Market Street, Charlbury, Oxfordshire, OX7 3PJ, UK

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CONTENTS

1. INTRODUCTION 1
1.1 Report Context 1
1.1.1 Operator of the Proposed Development 1
1.1.2 Agent who Completed this Report 1
1.1.3 Outline of the Proposed Development 1

2. CONCEPTUAL HYDROGEOLOGICAL MODEL 2
2.1 Site Location 2
2.2 Site Layout 2
2.2.1 Site context and rural designations 3
2.2.2 Historical landfilling 7
2.3 Climate 7
2.4 Geological Setting 8
2.4.1 Bedrock Deposits 8
2.4.2 Superficial Deposits 8
2.5 Hydrological Setting 10
2.5.1 Surface Water Features 10
2.5.2 Description of Local Water Courses 10
2.5.3 Waterbodies 10
2.5.4 Springs 10
2.5.5 Flows within Local Water Courses 10
2.5.6 Flood Risk and the Presence of Indicative Floodplains 11
2.5.7 Surface Water Abstractions 11
2.5.8 Consented Discharges 12
2.5.9 Surface Water Quality 12
2.6 Hydrogeological Setting 12
2.6.1 Aquifer Characteristics 12
2.6.2 Groundwater Flow and Levels 13
2.6.3 Groundwater Recharge 14
2.6.4 Groundwater Discharge 14
2.6.5 Groundwater Quality 15

3. CONCEPTUAL SITE MODEL 15
3.1 Sources 15
3.2 Pathways 16
3.3 Receptors 17

4. HYDROGEOLOGICAL RISK ASSESSMENT 17
4.1 The Nature of the Hydrogeological Risk Assessment 17
4.1.1 Risk Screening 18
4.2 The Proposed Assessment Scenarios 19

5. GENERIC QUANTITATIVE RISK ASSESSMENT 19
5.1 The Priority Contaminants to be Modelled 19
5.2 Numerical Modelling 20
5.2.1 Model Parameters 20
5.2.2 Model Results 24
5.3 Rogue Load Assessment 25
5.4 Qualitative Assessment of Accidents and Their Consequences 26
5.4.1 Failure of Leachate Management System 26
5.4.2 Stability and Integrity of Artificial Geological Barrier (AGB) 26
5.4.3 Diesel Fuel Storage Tank Qualitative Assessment 27

5.4.4 Rogue Loads 27
5.5 Emissions to Groundwater 27
5.5.1 Hazardous Substances 27
5.5.2 Non-hazardous Pollutants 28
5.5.3 Surface Water Management 28
5.6 Hydrogeological Completion Criteria 29
6. REQUISITE SURVEILANCE 29
6.1 Review of Technical Precautions 29
6.2 Leachate Monitoring 30
6.3 Groundwater Monitoring 30
6.4 Groundwater Quality Compliance Limits 31
6.5 Surface Water Monitoring 32
7. CONCLUSIONS 32
7.1 Compliance with the Landfill Directive 32
7.2 Compliance with the Groundwater Regulations 33
7.3 Summary 33
8. REFERENCES 33

TABLES

Table 1 Rural designations/potential receptors
Table 2 Waste types
Table 3 Priority contaminants modelled
Table 4 Input concentrations for GQRA and Rogue Load models
Table 5 Model Domain and fill cell input parameters for 'Inert Waste – Phases 1 to 9'
Table 6 Infiltration input parameters
Table 7 Unsaturated pathway input parameters
Table 8 Half-life values from available literature
Table 9 K_d value parameters
Table 10 Partition to organic carbon parameters for Toluene
Table 11 Aquifer pathway input parameters
Table 12 GQRA LandSim model results – 95th percentile concentration of modelled hazardous substance at base of unsaturated zone
Table 13 GQRA LandSim model results – 95th percentile concentrations of modelled non-hazardous determinands at monitoring point
Table 14 Rogue Load LandSim model results – 95th percentile concentration of modelled hazardous substance at base of unsaturated zone
Table 15 Rogue Load LandSim model results – 95th percentile concentrations of modelled non-hazardous determinands at monitoring point
Table 16 Groundwater monitoring schedule
Table 17 Proposed compliance limits for down-gradient boreholes WM5, WM6 and WM8

DRAWINGS

Drawing Number	Drawing Title	Version
BOWFEPR2511-1	Site location	a
BOWFEPR2511-2	Site context	a
BOWFEPR2511-3	Approved Planning boundary and EPR Permit application boundary	a
BOWFEPR2511-4	Site plan	a
BOWFEPR2511-5	Land use receptors	a
BOWFEPR2511-6	Cultural and heritage receptors	a
BOWFEPR2511-7	Ecological receptors	a
BOWFEPR2511-8	Components of the site model	a
BOWFEPR2511-9	Conceptual hydrogeological model	a

APPENDICES

Appendix 1a	Groundsure Enviro Insight report
Appendix 1b	Groundsure Geo Insight report
Appendix 2	Daily rainfall graphs
Appendix 3	River Severn at Saxons Lode daily flow and level graphs
Appendix 4	Borehole logs – WM1 to WM8
Appendix 5	Groundwater level data for boreholes WM3 to WM8
Appendix 6	Site groundwater quality monitoring data
Appendix 7	LandSim model and result files – GQRA
Appendix 8	LandSim model and result files – Rogue Load Assessment
Appendix 9	*Bow Farm Pollution Control and Incident Response Plan* report (GWP Report No. 240526)
Appendix 10	*Bow Farm Sustainable Drainage Systems (SuDS) Management Plan* report (GWP Report No. 240522)
Appendix 11	*Bow Farm Flood Storage Compensation Scheme* (GWP Report No. 241008)
Appendix 12	Proposed groundwater quality compliance limits for down-gradient borehole

BOW FARM HYDROGEOLOGICAL RISK ASSESSMENT TO SUPPORT A DEPOSIT OF WASTE FOR RECOVERY ENVIRONMENTAL PERMIT APPLICATION

1. INTRODUCTION

1.1 Report Context

The works approved by Planning Permission 19/000048/CM (Worcestershire County Council) and Planning Permission 19/0081/TWMAJM (Gloucestershire County Council) provide for, *inter alia*, site restoration using imported inert fill material at Bow Farm, Ripple, Worcestershire (the site).

Planning Permission 19/0081/TWMAJM was approved by Gloucestershire County Council through the successful appeal (Appeal Ref. APP/T1600/W/23/3324695) by the applicant following initial refusal of Planning Permission 19/0081/TWMAJM.

Completion of the approved site restoration scheme, involving the restoration of the mineral extraction areas requires 1.4Mm^3 (approximately 2.45Mt using a standard conversion factor of 1.75t/m^3) of imported inert fill material within Phases 1 to 9 of the excavation area in the main site area.

The approved site restoration scheme also provides for excavation and low-level restoration of Flexible Working Areas A and B in the west of the site. Flexible Working Areas A and B will only be excavated seasonally during non-high flow periods of the River Severn. The River Severn is located *c.* 25m to the west at its closest approach. Restoration of Flexible Working Areas A and B will be to wetlands and water features using only site derived mineral waste (silts and clays) and will have a final landform below pre-extraction ground levels. No imported inert fill material will be placed in Flexible Working Areas A and B.

An application is being made for a Bespoke Environmental Permit (use of waste in a deposit for recovery activity). The applicant is Moreton C Cullimore (Gravels) Limited.

The EPR Permit application is submitted on the basis that the permanent deposit of imported inert fill material within excavation area Phases 1 to 9 at the site to achieve the approved restoration scheme is a deposit for recovery activity and not a waste disposal activity.

This report presents a Hydrogeological Risk Assessment (HRA) and has been prepared to support an EPR Permit application to provide for the permanent deposit of imported inert fill material at the site as a deposit for recovery activity to achieve the approved restoration landform.

1.1.1 Operator of the Proposed Development

Moreton C Cullimore (Gravels) Limited, Netherhills, Whitminster, Gloucestershire, GL2 7PD.

1.1.2 Agent who Completed this Report

GWP Consultants LLP, Upton House, Market Street, Charlbury, Oxfordshire, OX7 3PJ.

1.1.3 Outline of the Proposed Development

The works approved by Planning Permission 19/000048/CM (Worcestershire County Council) and Planning Permission 19/0081/TWMAJM (Gloucestershire County Council) provide for, *inter alia*, site restoration using imported inert fill material at Bow Farm, Ripple, Worcestershire.

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The approved site restoration scheme also provides for excavation and low-level restoration of Flexible Working Areas A and B in the west of the site. Flexible Working Areas A and B will only be excavated seasonally during non-high flow periods of the River Severn, located *c.* 25m to the west of the site at its closest approach. Restoration of Flexible Working Areas A and B will be to wetlands

and water features using only site derived mineral waste (silts and clays) and will have a final landform below pre-extraction ground levels. No imported inert fill material will be placed in Flexible Working Areas A and B.

Details of the site setting and development design are presented in the Environmental Setting and Site Design (ESSD) report prepared by GWP Consultants LLP (GWP Report No. 251039) which accompanies the EPR Permit application (Appendix Gii of the Permit application documentation) and which should be read in conjunction with this report.

2. CONCEPTUAL HYDROGEOLOGICAL MODEL

2.1 Site Location

The application site is located at Bow Farm, Ripple, Worcestershire (National Grid Reference SO 87565 36504).

Drawing No. BOWFEPR2511-1 shows the site location and Drawing No. BOWFEPR2511-2 shows the different areas of the site, including the excavation area Phases 1 to 9 where imported inert fill material will be placed under the EPR Permit. Drawing No. BOWFEPR2511-3 shows the EPR Permit application area within the context of the site approved under the Planning Permissions.

The total site area covers *c.* 65ha, straddling the county boundary between Worcestershire and Gloucestershire. An area of *c.* 45ha of land has been approved for mineral extraction in the north and centre of the site (this is located entirely within Worcestershire). The approved mineral extraction areas are made up of excavation area Phases 1 to 9 (*c.* 30.9ha), Flexible Working Area A (*c.* 8.8ha) and Flexible Working Area B (*c.* 5.3ha). The processing plant and access route will be located in Gloucestershire (eastern part of the site).

A site plan is presented as Drawing No. BOWFEPR2511-4.

The Phases 1 to 9 excavation area in the north of the main part of the site is located *c.* 500m south of the village of Ripple. The processing plant and main access road is located *c.* 300m south of the village of Puckrup and *c.* 900m southwest of the village of Twyning. The town of Tewkesbury is located *c.* 2.5km to the south of the site.

From a geomorphological terrain perspective, the site can be split into three areas:

- a flat low lying (<10mAOD) area south of Ripple Quarry Lake;
- a raised north-west south-east trending 300m wide, 1000m long ridge rising to 14mAOD, separated from the Ripple Quarry area by the Napps Local Wildlife Site (LWS) wetland area (a former osier bed); and
- a hill side slope rising to >30mAOD, above the River Severn valley, separated from the southern end of the raised ridge and floodplain by a small stream named the Ripple Brook.

The Ripple Brook valley has an elevation of 9mAOD to 11mAOD adjacent to the site and divides the site in two.

The site is accessed from the A38 to the east of the site.

An Enviro Insight report and a separate Geo Insight report for the site, both obtained in November 2024, are presented in Appendix 1a and Appendix 1b, respectively.

2.2 Site Layout

The approved design and operation of the site reflects the three areas' different elevations and proximities to the River Severn (*c.* 25m to the west of the EPR Permit Application area and *c.* 400m west of the Phases 1 to 9 excavation area).

The north-south ridge in the centre of the site, approved under Planning, is where excavation area Phases 1 to 9 are situated. Phases 1 to 9 is the location for year-round sand and gravel extraction and is the area of the site where the imported inert fill material will be placed with restoration back to pre-extraction ground levels. The Phases 1 to 9 area of the site is the focus of the deposit for recovery Environmental Permit being applied for, as this is the part of the site where the imported inert fill material will be used to restore the site.

The elevated hill slope area in the east of the site will be the location for the processing plant, main site office and weighbridge, silt settlement lagoons associated with the processing plant/mineral washing and the site access road from the A38.

The low-lying area of Flexible Working Areas A and B, located *c.* 25m to the east of the River Severn at its closest approach, will only be excavated seasonally during non-high flow periods of the river. Restoration of Flexible Working Areas A and B will be to wetlands and water features using only site derived mineral waste (silts and clays) and will have a final landform below pre-extraction ground levels. No imported inert fill material will be placed in Flexible Working Areas A and B.

2.2.1 Site context and rural designations

The EPR Permit application is to provide for site restoration using imported inert fill material within excavation area Phases 1 to 9 at Bow Farm as a deposit for recovery activity.

The following distances from the Environmental Permit application boundary have been used to identify rural designations/potential receptors:

- 1km radius – European ecological important sites including RAMSAR sites, Special Areas of Conservation, Local Wildlife Sites and Special Protection Areas;
- 1km radius – potentially sensitive receptors of ecological importance and sites of cultural and natural heritage. These include National Nature Reserves, Local Nature Reserves, Sites of Special Scientific Interest and Scheduled Monuments;
- 500m radius – all other potentially sensitive receptors *e.g.* residential, commercial, industrial, agricultural and surface water receptors.

Rural designations/potential receptors are detailed in Table 1 and are shown on Drawing Nos. BOWFEPR2511-5, 6 and 7.

Table 1 – Rural designations/potential receptors

Receptor name	Receptor type	Receptor direction from site	Approximate distance from application boundary
Land use receptors within 500m of the application boundary (Drawing No. BOWFEPR2511-5)			
Puckrup Hall Farm	Industrial/Commercial/Residential Property	Centre/East (of excavation area Phases 1 to 9)	Adjacent
Bow Farm	Industrial/Commercial	East (of excavation area Phases 1 to 9)	50m
Ripple Quarry (restored)	Industrial/Commercial	West (of excavation area Phases 1 to 9)	Adjacent
All Seasons Cars Taxi Service	Commercial	Southeast (of plant and access road area)	250m
The Crown Inn at Shuthonger	Commercial	Southeast (of plant and access road area)	450m
Tewkesbury's Hand Car Wash	Commercial	Southeast (of plant and access road area)	450m
3C Legal Limited	Commercial	East (of plant and access road area)	350m

Hilton Puckrup Hall, Tewkesbury	Commercial (accommodation and leisure)	North (of plant and access road area)	50m (to golf course grounds)
Hill View Lakes (Fishing Lakes)	Commercial/Leisure	Northeast (of plant and access road area)	320m
Tewkesbury Riding School	Commercial/Leisure	Northeast (of plant and access road area)	450m
Glebe Cottage Bed & Breakfast	Commercial/Residential	East (of plant and access road area)	400m
Properties along Bow Lane	Residential Properties	East (of excavation area Phases 1 to 9)	50m (closest)
Properties along Puckrup Lane	Residential Properties	Northeast (of connection between excavation area Phases 1 to 9 and plant and access road area)	200m (closest)
Properties within Shuthonger	Residential Properties	Southeast (of plant and access road area)	240m (closest)
Properties within Puckrup	Residential Properties	North (of plant and access road area)	300m (closest)
Properties within Church End	Residential Properties	South (of plant and access road area)	200m (closest)
Property along Bow Lane to the north of the M50	Residential Property	North (of excavation area Phases 1 to 9)	400m
Bow Lane	Local Transport Network	East (of excavation area Phases 1 to 9)	Adjacent
Puckrup Lane	Local Transport Network	East (of excavation area Phases 1 to 9)	100m
M50	Local Transport Network	North (of excavation area Phases 1 to 9)	20m
A38	Local Transport Network	East (of access road area)	Adjacent
Owls Lane	Local Transport Network	Southeast (of plant and access road area)	200m

Church End	Local Transport Network	East (of plant and access road area)	300m
River Severn	Surface Water Feature	West (of excavation area – Flexible Working Area A)	25m
		West (of excavation area Phases 1 to 9)	400m
Ripple Brook	Surface Water Feature	North to south, crossing the site between the main site area and plant and access road area	Crosses the site between the connection between excavation area and plant and access road area
Mythe Brook	Surface Water Feature	Southeast (of excavation area Phases 1 to 9)	110m
Bushley Brook	Surface Water Feature	West (of excavation area – Flexible Working Area A)	350m
Drain between Flexible Working Areas A and B	Surface Water Feature	North to southeast, crossing the site between Flexible Working Areas A and B	Crosses the site between Flexible Working Areas A and B
Pond and surface water drain/wetland areas	Surface Water Feature	West (of excavation area Phases 1 to 9)	Adjacent
Ripple Quarry Lake (restored)	Surface Water Feature	West and north (of excavation area Phases 1 to 9)	50m (closest)
Ponds at Hilton Puckrup Hall Hotel and Golf Club	Surface Water Features	North (of plant and access road area)	50m (closest)
Twyning Cricket Club	Open Ground (leisure)	North (of plant and access road area)	380m
Agricultural land	Open Ground	North, east, south and west of whole site	Adjacent (closest – south)
Cultural and heritage receptors within 1km of the application boundary (Drawing No. BOWFEPR2511-6)			
Puck Cottage	Listed building (closest)	East (of excavation area Phases 1 to 9)	50m

Towbury Hill camp	Scheduled Monument	East (of excavation area Phases 1 to 9)	250m
Ripple village cross	Scheduled Monument	North (of excavation area Phases 1 to 9)	630m
Cross north of St Mary's Church	Scheduled Monument	North (of excavation area Phases 1 to 9)	650m
Uckinghall cross	Scheduled Monument	North (of excavation area Phases 1 to 9)	950m
Churchyard cross in St Nicholas's churchyard	Scheduled Monument	West (of excavation area Phases 1 to 9)	1km
Church End Twyning	Historical Conservation Area	East (of plant and access road area)	300m
Ecological receptors within 1km of the application boundary (Drawing No. BOWFEPR2511-7)			
Ripple Lake and the Napps	Local Wildlife Site	On-site (western edge of excavation area Phases 1 to 9)	On-site
Ripple Brook	Local Wildlife Site	North to south, crossing the site between the main site area and plant and access road area	On-site
Ripple Meadow	Local Wildlife Site	Northwest (of excavation area – Flexible Working Area A)	Adjacent
		West (of excavation area Phases 1 to 9)	430m
River Severn	Local Wildlife Site	West (of excavation area – Flexible Working Area A)	25m
		West (of excavation area Phases 1 to 9)	400m
Queenhill Brickpit	Local Wildlife Site	Northwest (of excavation area Phases 1 to 9)	900m
Mythe Composite Site	Gloucester Key Wildlife Site	Northeast (of plant and access road area)	860m

Mythe Railway	Gloucester Key Wildlife Site	Northeast (of plant and access road area)	980m
Brockeridge Common	Gloucester Key Wildlife Site	Northeast (of excavation area Phases 1 to 9)	830m
Priority Habitat Inventory – Deciduous Woodland	Protected Woodland	Northwest (of excavation area Phases 1 to 9)	Adjacent (closest)
Priority Habitat Inventory - Traditional Orchards	Protected Woodland	East (of plant and access road area)	230m (closest)
Priority Habitat Inventory - Coastal and Floodplain Grazing Marsh	Protected Grassland	On-site (adjacent to the north of excavation area – Flexible Working Area B)	On-site (closest)
		West (of excavation area Phases 1 to 9)	125m
Priority Habitat Inventory - Good quality semi-improved grassland	Protected Grassland	East (of excavation area Phases 1 to 9)	250m
Priority Habitat Inventory - Lowland Dry Acid Grassland	Protected Grassland	South (of plant and access road area)	830m
Priority Habitat Inventory - Lowland Meadows	Protected Grassland	East (of excavation area Phases 1 to 9)	300m
Woodpasture and Parkland BAP Priority Habitat	Woodpasture and Parkland	North (of plant and access road area)	60m (closest)

2.2.2 Historical landfilling

Historical landfilling within the vicinity of the site is detailed in Section 3 of the Enviro Insight report presented in Appendix 1a.

There are two historical landfills located within 1km of the site:

- Ripple Landfill Site located *c.* 850m northeast of the main excavation/proposed imported inert fill area; and
- Twyning Pit (split into two areas) closest area is located *c.* 370m east of the main access route to the site off the A38.

2.3 Climate

According to the Flood Estimation Handbook (FEH) Web Service, average annual rainfall (SAAR6190) at the site is 622mm.

The Defra Hydrology Data Explorer data platform has been used to obtain daily rainfall data from three rain gauges located approximately equidistant from the site to the southwest, west and northeast, respectively. The rain gauges and associated rainfall data ranges are as follows:

- Over Farm, located *c.* 17km southwest of the site. Data from 2009 to 2024;
- Ledbury (Ledbury Road), located *c.* 17km west of the site. Data from 1982 to 2024; and
- Sheriffs Lench, located *c.* 18km northeast of the site. Data from 2001 to 2024.

The average rainfall over the monitoring period at Over Farm is 773mm. The average rainfall recorded over the monitoring period at Ledbury is 684mm. The average rainfall recorded over the monitoring period at Sheriffs Lench is 699mm. Daily rainfall graphs for the three rain gauges are provided in Appendix 2. The average rainfall between the three rain gauges is 719mm, which is slightly higher than the average annual rainfall given for the area by the FEH Web Service. The nearest of the available rain gauges outlined above is *c.* 17km away from the site and so variation in rainfall amounts compared to the site location can be expected.

The direction of the prevailing wind is from the southwest (national prevailing wind direction).

2.4 Geological Setting

The geological setting of the site has been determined based on a review of published information and historical and recent site investigation information.

The general geological setting of the site is shown in Sections 1.3 (Superficial geology) and 1.5 (Bedrock geology) of the Geo Insight report presented in Appendix 1b.

2.4.1 Bedrock Deposits

The solid geology underlying the site comprises the Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group which consists of a sequence of red-brown mudstones and siltstones.

The Tewkesbury Fault crosses the site access road to the east of the processing plant area. The fault is therefore situated to the east of the Phases 1 to 9 excavation area of the EPR Permit application area. The Tewkesbury Fault has a north-south trend and juxtaposes limestone and shale of the younger Jurassic Rugby Limestone Member against the Branscombe Mudstone Formation.

2.4.2 Superficial Deposits

The bedrock mudstone is overlain by a series of stepped river Terrace Deposits of sand and gravel formed during the Pleistocene by the early River Severn system. The Terrace Deposits are believed to have formed in a braided river environment in which lateral variation from clay or silty channel fill to gravel islands can be expected. Erosion of the bedrock clay may lead to thickening of Terrace Deposits.

The Terrace Deposits collectively belong to the Severn Valley Formation. The youngest Terrace Deposit at Ripple is concealed beneath alluvial sediment of the modern River Severn.

The four lowest (youngest) of the River Severn terrace sand and gravel deposits are present on the site:

Kidderminster Station Member (BGS 4th Terrace of the River Severn)

The Kidderminster Station Member is the oldest terrace deposit on site. The upper surface level is *c.* 32mAOD to 33mAOD and is found only at the eastern boundary of the full site area east of Ripple Brook where it caps the higher ground above the location of the processing plant. The British Geological Survey (BGS) memoir records that at Twyning, 4.1m of sandy gravel was proven in a borehole in which Bunter Sandstone gravel predominated.

Window Sampling of this terrace was carried out in 2018 and descriptions indicate that the terrace deposit comprises predominantly brown and red brown silty sand with pockets of fine and coarse gravel beneath a thin soil cover. The maximum thickness intersected was to the east of the processing plant area, where 4.7m of reddish-brown silty sand with rare gravel present.

Historic investigations showed that the base of the terrace gravel is at 26mAOD to 28mAOD leaving a step in the bedrock levels of approximately 10m to 11m, forming the hillside above the Holt Heath Member below.

Holt Heath Member (BGS 3rd Terrace or Main Terrace of the River Severn)

The Holt Heath Member underlies the level ground lying at *c.* 15-17mAOD between the processing plant area and Puckrup Lane, to the east of the Phases 1 to 9 excavation area, which is largely

occupied by the golf course at the Hilton Puckrup Hall Hotel and Golf Club. The extent continues into the site area to include the footprint of the processing plant area.

A wedge shaped remnant of this terrace also lies between the northern site boundary and Ripple Brook, extending north of the M50 as far as Ripple Village. It is evident that part of the terrace has been excavated in the past, possibly during construction of the M50 bridge in 1960.

The levels of the top of bedrock mudstone in exploratory boreholes, located outside of the northeastern part of excavation area Phases 1 to 9, reflect the step up in levels of bedrock (Mercia Mudstone) from the base of the Worcester Member along the site boundary in this area. There appears to be an overlap between the two terraces which may represent encroachment of material from the higher terrace over the slope.

Worcester Member (BGS 2nd Terrace of River Severn)

The Worcester Member is the main sand and gravel resource on the site within the Phases 1 to 9 excavation area and forms a prominent landform 3 to 4m above the floodplain. On the site, the front edge of the terrace forms a well-defined slope between the top of the terrace deposit at 12mAOD to 14mAOD and the floodplain at 9mAOD to 10mAOD.

South of Bow Farm the terrace was incised by the Ripple Brook which passes behind the back edge of and through the terrace. The area between the processing plant location and Ripple Brook is a remnant of this terrace.

The base of the terrace deposit is inferred to slope towards the river from *c.* 9.5mAOD at the eastern edge of the Phases 1 to 9 excavation area, to *c.* 6.5mAOD at the western edge of the same area, at a gradient of 1v in 90h to 1v in 120h. The underlying bedrock (mudstone) level rises at the back (east) of the terrace.

The terrace deposit appears to be continuous but thins to the edge of the site area against the rising bedrock mudstone adjacent to Bow Lane. A thickness of 5.5m of terrace deposit was intersected in the Trial Pits dug in 1987, however previous modelling indicates that the greatest thickness may exceed 6m close to the front edge (west) of the terrace.

The Member consists of medium dense, reddish-brown slightly clayey and occasionally pebbly fine to medium sand. The gravel and clay content varies between boreholes installed in the deposit, but the terrace deposit is always predominantly sand.

Overburden is between 0.4m and 0.8m thick across the terrace and comprises firm red-brown very sandy clay beneath thin sandy topsoil.

Power House Member (BGS 1st Terrace of River Severn)

The current channel and floodplain of the River Severn are cut into the Power House Member, the youngest of the terrace gravel deposits of the Severn Valley Formation. The deposit is entirely obscured by silty clay alluvium and overbank sediments. The approved development allows for excavation of this terrace in Flexible Working Areas A and B only.

Historic trial pits excavated within Flexible Working Areas A and B in 1987 did not reach the base of the gravel. An estimate of the level of the base of the terrace has been made by extrapolating from the neighbouring Ripple Quarry site to the north of Flexible Working Areas A and B, where levels between 2.7mAOD and 4.8mAOD were recorded. It is likely that a thin horizon of gravel continues beneath the current river channel.

The maximum thickness of sand and gravel intersected on site through previous site investigations was 3.3m in the east of Working Area B. This is consistent with reported thickness from data from the adjacent Ripple Quarry site which reported an average thickness of 3.19m over the proposed extraction area with a maximum of 6.25m and minimum of 1.5m. Similar variation is expected at Bow Farm.

Investigations at the adjacent Ripple Quarry describes the material as *'brown medium to fine grained sandy gravel'*. The average composition was reported to be 41% gravel, 49% sand and 10% silt.

Overburden above the Power House Terrace comprises river alluvium and ranges in thickness from 2m to over 4.3m. Ground levels rise from *c.* 9.5mAOD to over 11mAOD towards the existing River Severn flood embankment to the west of Working Area A over a distance of 200m and the thickness

of overburden is inferred to increase accordingly. There are no descriptions of alluvium from the site.

2.5 Hydrological Setting

2.5.1 Surface Water Features

Surface water features are identified in Sections 7.1 (Water Network), 7.2 (Surface water features), 7.3 (WFD Surface water body catchments) and 7.4 (WFD Surface water bodies) of the Enviro Insight report presented in Appendix 1a and are shown on the Hydrology map on Page 53 of the Enviro Insight report.

2.5.2 Description of Local Water Courses

The closest watercourses to the site are the River Severn and the Ripple Brook. The River Severn is located *c.* 25m to the west of the full site area and *c.* 400m to the west of the Phases 1 to 9 excavation area. The River Severn is affected by high tides and tidal gates on the River Avon at Tewkesbury.

The Ripple Brook flows from north to south and separates the Phases 1 to 9 and Flexible Working Areas A and B excavation areas from the processing plant area to the east. The Ripple Brook joins the Mythe Brook, which in turn flows into the River Severn *c.* 1.5km south of the site.

2.5.3 Waterbodies

The nearest external surface water bodies are ponds and surface water drain/wetland features located adjacent to the west of the excavation areas in the north of the site and the restored Ripple Quarry Lake feature to the west of the site.

Ponds are also situated within the grounds of the Hilton Puckrup Hall Hotel and Golf Club to the north of the eastern part of the site (processing plant area).

2.5.4 Springs

There are no identified springs located within *c.* 500m of the site.

2.5.5 Flows within Local Water Courses

Daily flow and water level information and data for the River Severn measured at Saxons Lode (Station No. 54032), located *c.* 2.1km north of the site, has been obtained from the National River Flow Archive (NRFA) and the Defra Hydrology Data Explorer. The data are presented in graphs within Appendix 3. The NRFA reports that the River Severn Catchment to Saxons Lode is 6,850km^2 and that river flows have been measured since January 1970, initially using a velocity area station during 1970-1987, and a multipath ultrasonic gauge since 1987.

The catchment has a minimum elevation of 9.5mAOD (at the gauging station), a maximum elevation of 826.2mAOD and a median elevation of 130.8mAOD. Over 50% of the catchment bedrock is inferred to be of low permeability, and 20% of the catchment bedrock is described as high permeability. This suggests that river flows are significantly influenced by surface water runoff. However, a Base Flow Index (BFI) of 0.58 gives evidence that a significant proportion of river flow is derived from stored sources (*i.e.* groundwater from the bedrock and superficial deposits).

Between 1970 and 2024 average flow of the River Severn at Saxons Lode is reported to have been 89.8m^3/s with a 95% exceedance (Q_{95} baseflow) of 15.5m^3/s. Over the same period, Q_{50} was 54.0m^3/s and Q_{10} was 233m^3/s. The maximum measured flow rate was recorded as 546m^3/s on 12th February 2014. The NRFA reports that this ultrasonic station is reliable at low and medium flows, but it becomes progressively less reliable once stage exceeds about 4m. The station is affected by high tides and tidal gates on the River Avon at Tewkesbury.

The Ripple Brook is a tributary of the River Severn. Data from an EA station at the Ripple Brook (Station No. 2624 – now closed – located *c.* 900m to the south of the site) reported water levels between 0.63m and 2.55m during 90% of the time over the monitoring period (November 2012 to March 2016).

The catchment area of the Ripple Brook immediately downstream of the Application Site is *c.* 24.3km^2. High (extreme) flows for the Ripple Brook at this location have previously been estimated

for extreme rainfall events with return periods of 1:100, 1:30, and 1:1 years as 10.8m^3/s, 8.5m^3/s and 4.1m^3/s, respectively[1].

The excavation of the mineral and placement of inert waste into Phases 1 to 9 will require the excavation area to be dry and devoid of water.

A clay cut-off will be installed around the perimeter of the site and keyed into the underlying weathered bedrock clay/mudstone to create an impermeable hydraulic seal between the Phase 1 to 9 excavation area and the surrounding sand and gravel aquifer.

The placement of the impermeable seal will prevent the groundwater flow (estimated to be 1 l/s to 5 l/s) from passing westwards through the Phases 1 to 9 excavation area. The River Severn, with a Q_{95} baseflow of 15.5m^3/s (*c.* 15,500 l/s), will not be affected by a derogation of 1 l/s to 5 l/s.

The Ripple Brook is located up-gradient of the excavation and infilling areas. Flows within the Ripple Brook will not be affected by the development.

Flows within the River Severn and the Ripple Brook will be unaffected by the restoration of the Phases 1 to 9 excavation area using site-derived quarry waste and imported inert waste. Accordingly, it is considered that assessments of flows in the River Severn and the Ripple Brook are not required for the purposes of the EPR Permit application.

2.5.6 Flood Risk and the Presence of Indicative Floodplains

The majority of the Phases 1 to 9 excavation area is located is situated within fluvial flood risk Flood Zone 1 (less than 0.1% annual chance of flooding from rivers) and Flood Zone 2 (between 0.1% and 1% annual chance of flooding from rivers). Only the outer extremities of the Phases 1 to 9 area is located in Flood Zone 3 (annual chance river flooding is greater than 1%). Flood defences exist on the banks of the River Severn and the Mythe Brook.

Flexible Working Areas A and B are situated within Flood Zone 3. Part of the site situated in Gloucestershire, to the east of Ripple Brook, is also located within fluvial flood risk Flood Zone 3.

The majority of the EPR Permit Application area is situated within a low (between 0.1% and 1% annual chance of flooding from surface water) or very low (less than 0.1% annual chance of flooding from surface water) pluvial flood risk area. The EPR Permit Application area is not at risk of pluvial flooding.

Flood risk maps are provided in Sections 8, 9 and 10 of the Enviro Insight report presented in Appendix 1a.

2.5.7 Surface Water Abstractions

Details of surface water abstractions are provided in Section 6.7 of the Enviro Insight report presented in Appendix 1a.

There are 10 No. identified licensed surface water abstractions within *c.* 1km of the site. Where surface water abstractions have a shared ID within the Enviro Insight report then these have been counted as one abstraction.

According to the Enviro Insight report, the closest surface water abstraction is on site, however this record covers a reach of the River Severn and is represented by a line between the two extremities which intersects the site boundary. The closest surface water abstraction is therefore not on the site, but *c.* 25m to the west of the full site boundary.

Other surface water abstractions exist *c.* 45m to the south of the site access road to the excavation Phases 1 to 9 area at the Ripple Brook and also to the north of the processing plant area, to the east of the excavation area Phases 1 to 9. All of the surface water abstraction records within 1km of the site are for spray irrigation and most are of a historical status and have been present for several years/decades.

[1] Bow Farm Sand and Gravel Quarry Development Hydrogeological and Hydrological Impact Assessment and Flood Risk Assessment. GWP Consultants LLP. Report No. 190714 v.02. August 2019.

2.5.8 Consented Discharges

Details of licensed discharges are provided in Section 4.13 of the Enviro Insight report presented in Appendix 1a.

The only consented discharge within *c.* 1km of the site was from the Ripple Quarry site *c.* 420m northwest of the site for site drainage trade discharge, however this licence was revoked in June 2018.

2.5.9 Surface Water Quality

The River Severn (confluence of River Teme to confluence of River Avon) Water Body was given a 'Moderate' ecological status for 2022 according to the Environment Agency's (EA's) Catchment Data Explorer. The chemical status was classed as 'does not require assessment'.

The Ripple Brook (source to confluence of River Severn) Water Body was given a 'Moderate' ecological status for 2022 according to the EA's Catchment Data Explorer. The chemical status was classed as 'does not require assessment'.

The River Severn has been monitored for 17 No. determinands by the EA at Uckinghall *c.* 750m northwest (upstream) of the site through 2023 and 2024. The River Severn has also been monitored at (Upper) Tewkesbury, c. 2.4km downstream (southeast) of the site between 2000 and 2025, with over 100 determinands sampled for during this time.

The Ripple Brook has been monitored for 34 determinands at Bow Bridge *c.* 75m to the east of the site between 2000 and 2021 and also at its tributary upstream of Mythe Pools, downstream of the site. The location upstream of Mythe Pools was monitored during 2021 and 2025 for 17 No. determinands.

Given the inert nature of the imported waste and the strict waste acceptance procedures and protocols, it is considered that no hydrological risk is posed to the River Severn and Ripple Brook, or any surface water dependent sites of ecological sensitivity from the restoration with site-derived quarry waste material and imported inert fill within excavation area Phases 1 to 9.

During operations, direct rainfall and associated surface water runoff within the progressive Phases 1 to 9 void will be pumped out and clarified through the use of temporary silt lagoons. This cleaned water will then be transferred to infiltration basins along the western perimeter of Phases 1 to 9 to allow it to infiltrate back into the sand and gravel aquifer. Details of the surface water management scheme are provided in Section 5.5.3.

2.6 Hydrogeological Setting

2.6.1 Aquifer Characteristics

Aquifer characteristics and maps are provided in Sections 6.1 (Superficial aquifer) and 6.2 (Bedrock aquifer) of the Enviro Insight report presented in Appendix 1a.

The superficial deposits, including the Worcester Member (2nd Terrace), at the site and the surrounding area is classified by the EA's Aquifer Designation Dataset for England and Wales map, accessed through the Defra Magic Map application, as a 'Secondary A' superficial aquifer, defined as 'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of baseflow to rivers'.

The bedrock at the site and the surrounding area is shown on the Aquifer Designation map as a 'Secondary B' aquifer, defined as 'mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers'. Site investigations have shown the solid geology underlying the site comprises the Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group which consists of a sequence of red-brown mudstones and siltstones. The existence of the mudstone dominated bedrock at the site means it does not transmit groundwater flow.

The site is not located within a groundwater Source Protection Zone (SPZ).

Details of licensed groundwater abstractions are provided Section 6.6 of the Enviro Insight report presented in Appendix 1a.

There are 5 No. identified licensed groundwater abstractions within *c.* 500m of the site. Where surface water abstractions have a shared ID within the Enviro Insight report then these have been counted as one abstraction.

According to the Enviro Insight report, the closest of the groundwater abstractions is an area within the extent of the restored Ripple Quarry Lake *c.* 80m from the site at its closest point. This abstraction is for direct spray irrigation up to 30,000m^3 per year.

Other groundwater abstraction locations exist to the east of the Phases 1 to 9 excavation area. The closest of these is a licence for general farming and domestic purposes *c.* 210m to the east of the site.

Similarly to the surface water abstractions, most of the groundwater abstractions are for use in direct spray irrigation, with some under active status (relating to current regulations) and others under historical status.

2.6.2 Groundwater Flow and Levels

Previous reporting (GWP Report No. 190714 v.02)[1] on the groundwater flow regime indicates that the regional groundwater flow direction within the Worcester Member (2nd Terrace) is to the west, towards the River Severn.

Eight piezometers (WM1 to WM8) were installed during October 2010 within the Worcester Member (2nd Terrace) on the perimeter of approved excavation area Phases 1 to 9 in the main site area. The locations of the groundwater monitoring boreholes are shown on Drawing No. BOWFEPR2511-2. Borehole logs for the monitoring boreholes are provided in Appendix 4 (borehole references in the logs go from BH1 to BH 8, which numerically correspond to references WM1 to WM8).

Groundwater level data is available from boreholes WM3 to WM8 between December 2010 to June 2019, with additional monitoring undertaken between May 2024 and September 2025. The groundwater levels recorded by the applicant between December 2010 and June 2019 were initially on roughly a quarterly basis and then approximately monthly between early 2014 and June 2019. Following the acquisition of the data so far during 2024 and 2025, it is planned to continue the groundwater level monitoring on a monthly basis. All available groundwater level data for these boreholes is included in Appendix 5. Boreholes WM1 and WM2, located on the northeastern perimeter of the site, are always dry.

The data before late 2013 is somewhat irregularly measured, and that during 2014 and 2015 is firstly affected by a flooding event in early 2014 and then evidently is affected by off-site de-watering in late 2014 and throughout 2015.

Since early 2016, groundwater levels have stabilised (presumably after restoration and de-watering cessation of other off-site gravel extractions) and a consistent seasonal fluctuation of between 0.5m and 1.0m can be observed.

A more detailed comparison of the groundwater hydrograph elevations with the reported base of the sand and gravel deposit shows that WM3 is actually seasonally dry every year (when readings must reflect measurements in the top of the underlying weathered clay) and WM4 can be dry all year round although more frequently can become partially saturated during the wettest months.

Therefore, during the summer months there are only groundwater level readings sitting within the sand and gravel deposit on the western side of the site. Groundwater level contours cannot be illustrated for this time given the 4 No. monitoring boreholes that remain partially saturated are all on the western perimeter (with groundwater levels of typically 8.9mAOD). However, it is self-evident given the elevation of the underlying surface of the impermeable mudstone and unsaturated sand and gravel to the east, that groundwater flow is towards and across the western boundary of the site.

For the winter months, WM3 does become sufficiently saturated to enable groundwater level interpolation and estimation of a hydraulic gradient across the site. WM1, WM2 and WM4 (depending on the year) remain unsaturated, confirming groundwater flow has to follow the surface of the underlying impermeable clay strata to the west.

A hydraulic gradient of 6.6 x 10^{-4} between WM3 and monitoring boreholes WM6, WM7 and WM8 on the western boundary, is shallow and indicates either high permeability or low groundwater flux. Given there is no sand and gravel aquifer up-gradient of WM3 and the geological description is of

predominantly sand (and not gravel), then the low gradient is likely to reflect proximity to the eastern up-gradient boundary of the deposit and low groundwater flux.

Assuming an average sand and gravel thickness of 3m, a cross-section sand and gravel length of 1,100m (north to south), the hydraulic gradient of 6.6 x 10^{-4} and a permeability of 5 x 10^{-4} m/s, the groundwater through-flow can be calculated as 1 litre per second (94 m^3/d or 34,343 m^3/year).

If the hydraulic gradient is instead assumed to equate to the slope of the underlying surface of the impermeable clay (2 x 10^{-3}) then the groundwater flow rate increases to 3.3 l/s. This doubles to 6.6 l/s if the saturated thickness is increased to the maximum possible within the Worcester Member (2nd Terrace) of 6m.

2.6.3 Groundwater Recharge

Average annual rainfall for the site is estimated to be between 622mm/year (FEH Web Service) to 719mm/year (Defra Hydrology Data Explorer data) (see Section 2.3). Assuming 30% of rainfall infiltrates as direct recharge then the typical pre-development average annual recharge rate can be estimated as between 187mm/year and 216mm/year.

Using the conservative lower recharge estimate, over the *c.* 35 hectares of the excavation area east of Ripple Lake and the Napps LWS, this equates to 65,450 m^3/yr (179m^3/d or 2.1 l/s). This is consistent with the estimate of groundwater through-flow across the site (see Section 2.6.2).

Groundwater recharge will also enter the perched higher elevation terraces east of the site. Groundwater recharge inflows will be limited given the small area of these raised terraces, and therefore may not sustain year-round perched groundwater bodies - WM1 and WM2 confirm the higher terrace east of the proposed excavation area yields no groundwater as these monitoring points have always been monitored as 'dry'.

2.6.4 Groundwater Discharge

There are 5 No. licensed groundwater abstractions within 1km of the site. Details of licensed groundwater abstractions are provided Section 6.6 of the Enviro Insight report presented in Appendix 1a. Of the identified abstractions, two near Twyning are reported to abstract groundwater from a hydraulically separate gravel terrace and hydraulically separate bedrock to those at the site, and is used for irrigation. The historical abstraction at Bowbridge Farm *c.* 210m to the east of the Phases 1 to 9 excavation area is from an isolated area of the Holt Heath Member superficial deposits, separate to the Worcester Member sand and gravel in the Phases 1 to 9 excavation area.

The groundwater abstraction reported to be *c.* 80m to the west of the site is recorded as abstracting from a lagoon and not a borehole. It is also reported as owned by a farm in Ryall 4km north of the site and is used for spray irrigation in summer months. It is possible the abstraction location is misplaced, although equally, satellite images appear to show abstraction infrastructure in the northern end of Ripple Quarry Lake. The licence has an annual limit of 30,000m^3/year (equivalent to 1 l/s) and a maximum daily limit of 1,600m^3/d (equivalent to 18 l/s).

A groundwater abstraction in this area would be consistent with the lower groundwater levels observed at the northern most WM8 borehole when compared to the other monitoring boreholes.

There are no reported unlicensed/private groundwater abstractions within 1km of the site.

Discharges of groundwater from the lower western edges of the elevated and perched sand and gravel terraces on the high ground to the east of the site can be expected. However, given the small areas covered by these individual terraces (see Section 1.3 (Superficial geology) of the Geo Insight report presented in Appendix 1b) of typically 25 hectares, then groundwater through-flow is likely to be no more than 1.5 l/s.

Groundwater flowing across the approved excavation area in the main site area flows in a westerly direction during the current pre-development scenario. Groundwater elevations of 9m AOD to 10mAOD demonstrate it is possible for these groundwaters to discharge through the alluvial overburden and into Ripple Lake and the Napps LWS, Ripple Quarry Lake and/or the River Severn.

Given the inert nature of the waste and the strict waste acceptance procedures and protocols, it is considered that restoration of excavation area Phases 1 to 9 using site-derived quarry waste material and imported inert fill under a deposit for recovery scheme will have no significant or measurable detrimental impact on the hydrogeological setting of the site and the surrounding area.

2.6.5 Groundwater Quality

Available groundwater quality monitoring data has been collected from existing boreholes on site between May 2024 and August 2025.

Groundwater monitoring locations are shown on Drawing No. BOWFEPR2511-2. Groundwater quality monitoring data for boreholes monitoring up-gradient (WM3) and down-gradient (WM5, WM6 and WM8) of the excavation area Phases 1 to 9, is provided in Appendix 6.

This monitoring data has been used to establish baseline groundwater quality conditions at the site.

Given the inert nature of the waste and the strict waste acceptance procedures and protocols, it is considered that restoration of excavation area Phases 1 to 9 using site-derived quarry waste material and imported inert fill under a deposit for recovery scheme will have no significant or measurable detrimental impact on the hydrogeological setting and groundwater quality of the site and the surrounding area.

Despite this, groundwater quality monitoring will be undertaken in accordance with a monitoring scheme agreed with the EA. Details of the proposed monitoring scheme and proposed compliance limits are provided in Sections 6.3 and 6.4.

3. CONCEPTUAL SITE MODEL

The conceptual hydrogeological model is illustrated on Drawing No. BOWFEPR2511-9.

3.1 Sources

The imported inert fill capacity to be provided for by the deposit for recovery EPR Permit is *c.* 1.4Mm^3. The imported inert fill material is to be placed within Phases 1 to 9 of the excavation area in the north and centre of the main site area. No imported inert fill material will be placed in Flexible Working Areas A and B in the west of the site. Restoration of Flexible Working Areas A and B will be to wetlands and water features using only site derived mineral waste (silts and clays) and will have a final landform below pre-extraction ground levels.

The waste types associated with imported inert fill material to be placed within excavation area Phases 1 to 9, and provided for by the EPR Permit application are listed below in Table 2 (it should be noted that the waste types provide for the importation of uncontaminated wastes from brownfield developments).

The recovered waste will be imported inert fill material sourced from construction sites within the general Tewkesbury area. To ensure that the recovered waste material is suitable for its intended use, the works will be managed by staff having the appropriate level of technical competence with relevant qualifications gained from one of the accepted industry schemes. Waste Acceptance Criteria inspection procedures will be in place to ensure that the inert fill material used in the works is as described on Waste Transfer Notes, is permitted by the Environmental Permit and is fit for purpose.

17 05 04 waste will be sourced from greenfield sites and/or will be waste of 'greenfield quality' sourced from brownfield sites (*i.e.* naturally occurring material for which there is no suspicion of contamination based on specific source specific environmental risk assessment, supported as necessary by laboratory analysis).

The waste will be Landfill Directive inert Waste Acceptance Criteria (WAC) compliant *i.e.* the waste will comply with the leaching values for waste acceptable at landfills for inert waste set out in Section 2.1.2 of *'Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC'*.

The imported waste will be Landfill Directive inert WAC compliant, however the EPR Permit application is submitted on the basis that the permanent deposit of imported inert fill material within excavation area Phases 1 to 9 at the site to achieve the approved restoration scheme is a deposit for recovery activity and not a waste disposal (landfill) activity.

Despite the inert nature of the imported waste, this material represents the 'source' for the purposes of this HRA. This HRA addresses the small risk of contaminants being contained in the imported inert waste and being leached out into water infiltrating through the waste material.

A clay cut-off wall will be installed around the full perimeter of the excavation areas. The presence of this clay cut-off wall will prevent the groundwater within the river terrace sand and gravel deposits

up-gradient of the site from being transmitted through the sand and gravel aquifer on site. Notwithstanding this, a side slope Artificial Geological Barrier (AGB) will be constructed on a phased basis against the perimeter walls of excavation area Phases 1 to 9, where the imported inert fill material is to be placed.

The side slope AGB will be constructed on a phased basis in order to provide protection to soil, groundwater and surface water at least equivalent to that resulting from an attenuation barrier/liner with a minimum thickness of 1.0m and a maximum permeability of 1 x 10^{-7} m/s.

Site investigations have shown the solid geology underlying the site comprises the Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group which consists of a sequence of red-brown mudstones and siltstones. The existence of the mudstone dominated bedrock at the site means it does not transmit groundwater flow and forms an adequate natural basal geological barrier.

The side slope AGB will be constructed in accordance with a Construction Quality Assurance Plan approved by the EA. The Construction Quality Assurance Plan (GWP Report No. 250927) is provided as Appendix M of the EPR Permit application.

Table 2 – Waste types

Waste types	
Exclusions Wastes having any of the following characteristics shall not be accepted: - consisting solely or mainly of dusts, powders or loose fibres - hazardous wastes - wastes in liquid form	
EWC Waste Code	**Description**
01	**WASTES RESULTING FROM EXPLORATION, MINING, QUARRYING AND PHYSICAL AND CHEMICAL TREATMENT OF MINERALS**
01 01	**wastes from mineral excavation**
01 01 02	wastes from mineral non-metalliferous excavation
01 04	**wastes from physical and chemical processing of non-metalliferous minerals**
01 04 08	waste gravel and crushed rocks other than those mentioned in 01 04 07
01 04 09	waste sand and clays
17	**CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)**
17 01	**concrete, bricks, tiles and ceramics**
17 01 01	concrete
17 01 02	bricks
17 01 03	tiles and ceramics
17 01 07	mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06
17 05	**soil (including excavated soil from contaminated sites), stones and dredging spoil**
17 05 04	soil and stones other than those mentioned in 17 05 03

3.2 Pathways

The following pathways exist between the Phases 1 to 9 excavation area where the imported inert fill material will be placed and potential receptors:

- through the engineered clay cut-off/side slopes AGB;
- the saturated Terrace Deposits of the River Severn sand and gravel aquifer;
- discharge of surface water (which will comprise an admixture of surface water runoff from the imported inert waste and surface water otherwise collecting within the excavation void) from the

excavation void through infiltration ponds/basins. Details of the surface water management scheme are provided in Section 5.5.3.

Despite construction of the clay cut-off wall and the installation of the side slope AGB which will occur prior to the placement of imported inert waste within excavation area Phases 1 to 9, the saturated Terrace Deposits of the River Severn sand and gravel has the potential to transport contaminants in the direction of groundwater flow towards receptors. The characteristics of the superficial Terrace Deposits aquifer, including the Worcester Member (2nd Terrace), are discussed in Section 2.6 and are illustrated in the conceptual hydrogeological model shown on Drawing No. BOWFEPR2511-9.

Natural groundwater flow around the site is inferred to be to the west, towards the River Severn. Groundwater elevations of 9mAOD to 10mAOD (see Section 2.6.4) demonstrate it is possible for these groundwaters to discharge through the alluvial overburden and into Ripple Lake and the Napps LWS, Ripple Quarry Lake and/or the River Severn. For the purposes of the risk assessment within this HRA, it is assumed there is a hydraulic connection between the site and the Ripple Lake and the Napps LWS, Ripple Quarry Lake and/or the River Severn through the aquifer during development and post-development, as a worst-case scenario.

3.3 Receptors

The groundwater present within the superficial Terrace Deposits sand and gravel aquifer, including the Worcester Member (2nd Terrace), is considered to be the primary receptor, hence the requirement for an engineered clay cut-off and side slopes AGB to be installed within excavation area Phases 1 to 9. No basal AGB will be required at the site due to the presence of an adequate natural geological barrier comprising the underlying Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group.

Natural groundwater flow around the site is inferred to be to the west, towards the River Severn. Groundwater elevations of 9mAOD to 10mAOD (see Section 2.6.4) demonstrate it is possible for these groundwaters to discharge through the alluvial overburden and into Ripple Lake and the Napps LWS, Ripple Quarry Lake and/or the River Severn. For the purposes of the undertaking of the HRA, Ripple Lake and the Napps LWS, Ripple Quarry Lake and the River Severn are treated as potential receptors. The closest of these receptors is the water-dependent Ripple Lake and the Napps LWS, situated just inside the site boundary to the west of excavation area Phases 1 to 9, but outside of the approved excavation and subsequent infilling area in this part of the site.

Water collecting within the excavation void of Phases 1 to 9 during the deposit for recovery infilling activity will comprise an admixture of surface water runoff from the imported inert waste and surface water otherwise collecting within the excavation void. This water will be pumped out and clarified through the use of temporary silt lagoons. This cleaned water will then be transferred to infiltration basins along the western perimeter of Phases 1 to 9 to allow it to infiltrate back into the sand and gravel aquifer. Details of the surface water management scheme are provided in Section 5.5.3.

4. HYDROGEOLOGICAL RISK ASSESSMENT

The imported inert fill capacity to be provided for by the deposit for recovery EPR Permit is *c.* 1.4Mm^3. The imported inert fill material is to be placed within Phases 1 to 9 of the excavation area. No imported inert fill material will be placed in Flexible Working Areas A and B in the west of the site. Restoration of Flexible Working Areas A and B will be to wetlands and water features using only site derived mineral waste (silts and clays) and will have a final landform below pre-extraction ground levels.

Therefore, this HRA presents an assessment of the hydrogeological risks posed by the deposit for recovery activity associated with the placement of imported inert fill material within the Phases 1 to 9 excavation area of the site.

4.1 The Nature of the Hydrogeological Risk Assessment

EA guidance proposes a tiered approach to risk assessment whereby the complexity of the assessment reflects the potential risk posed by a particular site, the sensitivity of the site settings and the probability of a risk being realised.

An initial Tier 1 Risk Screening Assessment has been undertaken. This is a qualitative assessment which involves the development of a robust conceptual model and subsequent risk screening. If the outcome of this Tier 1 assessment highlights potentially unacceptable risks to groundwater, then a

Tier 2 (quantitative) approach must be taken. If this Tier 1 approach does not identify any potentially unacceptable risks, then the EA guidance indicates that no further risk assessment is required.

The EPR Permit application is submitted on the basis that the permanent deposit of imported inert fill material within excavation area Phases 1 to 9 at the site to achieve the approved restoration scheme, is a deposit for recovery activity and not a waste disposal activity. Notwithstanding, the same tiered based risk assessment approach has been undertaken as for an inert landfill waste disposal application.

4.1.1 Risk Screening

Compliance with Groundwater (England and Wales) Regulations

Given the inert nature of the waste and strict Waste Acceptance Procedures and Protocols to be employed at the site, it is considered that the quantity and concentration of any hazardous substances or non-hazardous determinands within any leachate (defined here as water coming into contact with the waste) will be minimal, hence the site falls outside the scope of the Groundwater (England and Wales) Regulations.

Collection of leachate

As the imported waste will be inert, it is considered (in accordance with EA guidance) that there is no requirement to collect and manage leachate. Therefore, there is no requirement for leachate drainage layers.

Artificial Geological Barrier

A side slope Artificial Geological Barrier (AGB) will be constructed on a phased basis within excavation area Phases 1 to 9 in order to provide protection to soil, groundwater and surface water at least equivalent to that resulting from an attenuation barrier/liner with a minimum thickness of 1.0m and a maximum permeability of 1×10^{-7} m/s.

Details of the components of the AGB are illustrated on Drawing No. BOWFEPR2511-8.

The Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group underlying the site forms an adequate natural basal geological barrier.

Site location

The site is located within the superficial sand and gravel Terrace Deposits (see Section 2.6 above).

The EA classifies the superficial deposits, including the Worcester Member (2^{nd} Terrace), as a 'Secondary A' superficial aquifer, defined as 'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of baseflow to rivers'.

The bedrock at the site and the surrounding area is classified as a 'Secondary B' aquifer, defined as 'mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers'. Site investigations have shown the solid geology underlying the site comprises the Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group which consists of a sequence of red-brown mudstones and siltstones. The existence of the mudstone dominated bedrock at the site means it does not transmit groundwater flow.

The site is not located within a groundwater Source Protection Zone (SPZ).

There are 5 No. identified licensed groundwater abstractions within *c.* 500m of the site. It is anticipated that all but one of the abstractions are hydraulically separated from the Worcester Member superficial deposits on site (see Section 2.5.4) and will therefore be unaffected by the deposit for recovery activity.

In addition, given the inert nature of the waste and the strict waste acceptance procedures and protocols, it is considered that site restoration using imported inert fill under a deposit for recovery scheme will have no significant or measurable detrimental impact on the hydrogeological setting of the site and the surrounding area.

4.2 The Proposed Assessment Scenarios

Risk screening detailed in Section 4.1.1 above establishes that infilling Phases 1 to 9 of the excavation area with imported inert fill material poses little hazard to groundwater quality and would normally fall outside of the scope of the Groundwater (England and Wales) Regulations. However, due to the location of the site within the 'Secondary A' superficial aquifer and proximity of identified potential receptors in the form of Ripple Lake and the Napps LWS, Ripple Quarry Lake and the River Severn, a Tier 2 Generic Quantitative Risk Assessment (GQRA) approach has been undertaken for this HRA.

5. GENERIC QUANTITATIVE RISK ASSESSMENT

5.1 The Priority Contaminants to be Modelled

As part of the GQRA for the site, groundwater quality/contaminant transport modelling has been undertaken. Priority contaminants have been chosen and included within the quantitative modelling, with justifications based on the potential presence of hazardous substances and non-hazardous determinands.

The imported waste will be Landfill Directive inert Waste Acceptance Criteria (WAC) compliant. Modelled contaminants which are listed with inert WAC thresholds have therefore been selected, except for Ammoniacal Nitrogen. Ammoniacal Nitrogen is a contaminant that would not be expected to be generated from inert waste, which is shown by its absence from the schedule of inert WAC. It can however, signify the presence of biodegradable material if this were to be placed at the site and so has been included within the analysis.

The modelled contaminants are presented in Table 3.

Table 3 – Priority contaminants modelled

Contaminant	Description	Hazardous/Non-Hazardous	Justification
Toluene	Hydrophobic organic	Hazardous	BTEX constituent and a hazardous substance
Ammoniacal Nitrogen	Inorganic cation	Non-hazardous	Signifies presence of biodegradable material
Chloride	Inorganic anion	Non-hazardous	Conservative – not retarded, no degradation
Cadmium	Metallic ion	Non-hazardous	Associated with contaminated land
Nickel	Metallic ion	Non-hazardous	Mobile metal

WAC limits for inert waste are provided in mg/kg. These values have been converted to leachate concentrations in mg/l by dividing by 10 for use as input values. As described above, Ammoniacal Nitrogen is not included within the inert WAC schedule, nor is it covered by Section 2.1.2.1 of the Council Decision Annex 2003/33/EC. The input concentration for Ammoniacal Nitrogen has therefore been chosen based on Groundwater Generic Assessment Criteria (GAC), which is equivalent to the UK Drinking Water Standard (DWS).

Table 4 sets out the input concentrations proposed for selected contaminants based on the WAC criteria. As a conservative estimate, all input concentrations are presented as single values at the inert WAC limit (or equivalent), as opposed to probabilistic distribution functions.

Table 4 – Input concentrations for GQRA and Rogue Load models

Determinand	Hazardous/Non-Hazardous	GQRA input concentration (mg/l)	Rogue load input concentration (mg/l)
Toluene	Hazardous	0.6	0.84
Ammoniacal Nitrogen	Non-hazardous	0.5	0.7
Chloride	Non-hazardous	80	118
Cadmium	Non-hazardous	0.004	0.0056
Nickel	Non-hazardous	0.04	0.048

5.2 Numerical Modelling

Analytical models of 'leachate' migration through the AGB into the Terrace Deposits sand and gravel aquifer and dispersion in the hydrogeological environment, and probabilistic analysis, have been used to provide an evaluation of the possible likelihood and consequences of 'leachate' release and migration from the imported inert waste placement within excavation area Phases 1 to 9 under the deposit for recovery development.

For the purposes of the GQRA, the term 'leachate' is used to describe rainfall falling on the area of the imported inert fill mass, infiltrating through the surface and percolating through/coming into contact with the inert fill mass. The constituents of this 'leachate' will be different from traditional leachate associated with landfill developments. Therefore, no traditional leachate management or monitoring infrastructure is required and none is proposed (see ESSD report (GWP Report No. 251039) which accompanies the EPR Permit application (Appendix Gii of the Permit application documentation)).

The Golder Associates' LandSim 2.5[(1)] modelling software has been used to assess the risks to the local groundwater and surface water environment from the placement of imported inert fill material within excavation area Phases 1 to 9. The likelihood and magnitude of leakage rates and potential contaminant concentrations at receptor locations for hazardous substances and non-hazardous determinands has been evaluated. In order to determine these outcomes, the concentration of substances within the imported inert material was assumed to decline over time after placement *i.e.* a declining source term. Appropriate declining source terms are dictated by Kappa value constants *m* and *c* which are provided in LandSim 2.5.

The calculated concentrations at the designated receptors, at what is modelled as infinite time, thus represents a conservatively high estimate of the concentrations that could develop at the receptor given the scenario assessed. In reality, any reduction in the leachate source concentration over time will reduce the ultimate concentration that could reach and impact on receptors.

Uncertainty in the natural processes of leachate migration through AGB liner and contamination transportation in groundwater were incorporated in the modelling process by the inclusion of stochastic values to represent certain controlling parameters.

The stochastic values were defined by probability density functions based on site-specific data and appropriate supporting published public information. Single, uniform, triangular, log uniform and log triangular distributions (log distributions used where data has varying orders of magnitude) have been used for parameter values in the modelling analysis.

The results of the modelling have been presented probabilistically to apply levels of confidence. The 95th percentile represents the value for which there is only a 5% probability of exceedance; this 5% probability is considered as unlikely. In order to provide reasonable results, 501 iterations of the model were carried out in the probabilistic sampling.

5.2.1 Model Parameters

This has included details related to the following:

- The nature of the parameterisation process including all model inputs, probability density functions and model calibration where appropriate.

- The justification for using model defaults against providing field measurements.

Model parameterisation is presented below.

Model Domain and Waste Cells

The approved scheme involves the permanent placement of a total *c.* 1.4m^3 imported inert fill material within excavation area Phases 1 to 9 at the site, which will be undertaken as a deposit for recovery activity. Site derived mineral waste (silts and clays) will also be placed within excavation area Phases 1 to 9 as part of the approved restoration scheme. The use of site derived material to partly restore the excavation area Phases 1 to 9 will not pose increased risk to the local hydrological or hydrogeological environment. Therefore, for the purposes of the modelling, only the volume of imported inert waste is included.

Within the LandSim model the infill area has been called 'Inert Waste – Phases 1 to 9'. All of the proposed inert fill material has been conservatively included as one 'phase' within LandSim.

The geometry of the inert fill mass within the LandSim model has been orientated so that the inert fill area has the bolted-on 'monitoring well' at the downstream edge. Due to the westerly groundwater flow direction, the downstream perimeter of the inert fill area is at the western boundary of the Phases 1 to 9 area in reality. To be able to model this scenario in LandSim, the waste area has been rotated as the software has a fixed flow direction.

Fill thicknesses at the site have been input as log triangular distributions for the minimum, most likely and maximum values within the modelled area. Model Domain and fill cell input parameters are presented in Table 5.

The engineered side slope AGB to be constructed at the site will separate any saturated River Terrace sand and gravel surrounding the excavation area from the imported inert fill material and will therefore act as the unsaturated pathway. This means the model does not incorporate an engineered barrier system (EBS), even though a natural basal geological barrier (Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group) and engineered side slope AGB will actually be present at the site. This represents a conservative approach.

The log triangular distributions for the inert fill area have been input for the head on EBS parameters, to reflect fully saturated fill thickness; however, this does not have any effect on the output results as the model does not incorporate an EBS, as outlined above.

Table 5 – Model Domain and fill cell input parameters for 'Inert Waste – Phases 1 to 9'

Parameter	Value	Unit	Justification
Final Waste Thickness	LOGTRIANGULAR(0.01, 4.53, 7.5)	m	Range of planned fill thicknesses at the site
Waste Porosity	SINGLE(0.25)	Fraction	From lab tests undertaken on inert fill for GWP
Waste Field Capacity	SINGLE(0.1)	Fraction	From lab tests undertaken on inert fill for GWP
Waste Dry Density	SINGLE(1.6)	kg/l	From lab tests undertaken on inert fill for GWP
Head when surface breakout occurs	LOGTRIANGULAR(0.01, 4.53, 7.5)	m	Final fill thickness as per above, representing ground surface level
Head on EBS	LOGTRIANGULAR(0.01, 4.53, 7.5)	m	See text explanation above

Infiltration

The average rainfall for the area, based on rainfall data collected at three rainfall stations surrounding the site, is *c.* 719mm (see Section 2.3). Under pre-development conditions it is assumed that 30% of rainfall infiltrates as direct recharge into the River Terrace sand and gravel superficial deposits, which would equate to a typical annual recharge rate estimate of up to *c.* 216mm/year.

No cap is to be placed over the fill to reduce infiltration as the approved scheme does not require capping, however the imported inert fill material will be of lower permeability than the *in situ* sand

and gravel material, typically in the order of 1 x 10^{-8} to 1 x 10^{-10} m/s, compared to the 5 x 10^{-4} m/s for the Terrace Deposits (see Section 2.6.2).

Therefore, the effective infiltration has been selected as 15% of the average annual rainfall of 719mm. This equates to 108mm/year. This is conservative as evapotranspiration has not been accounted for.

Infiltration input parameters are given in Table 6.

Table 6 – Infiltration input parameters

Parameter	Value	Unit	Justification
Infiltration to open waste	SINGLE(108)	mm/year	Recharge - 15% of average rainfall

Unsaturated Pathway

The main unsaturated pathway input parameters are outlined in Table 7.

Table 7 – Unsaturated pathway input parameters

Parameter	Value	Unit	Justification
Geological unit	Clay	-	Unsaturated pathway treated as side slopes AGB (see 'Model Domain and Waste Cells')
Flow model	Porous Medium	-	-
Unsaturated pathway length	SINGLE(1)	m	Minimum side slope AGB thickness of 1m
Moisture content	TRIANGULAR(0.19, 0.25, 0.31)	Fraction	Range for nearest Jurassic clay. Table 3 in Manger, 1963[2]
Hydraulic conductivity	LOGUNIFORM(1x10^{-9}, 1x10^{-7})	m/s	Conservative range for engineered clay and includes maximum allowable permeability of side slope AGB of 1x10^{-7}m/s
Longitudinal dispersivity	SINGLE(0.1)	m	Nominal 10% of travel distance

Biodegradation

For certain determinands, biodegradation in the unsaturated pathway and/or the aquifer pathway has been simulated. For the other determinands, no decay has been assumed.

Table 8 below lists the half-life values obtained from a review of relevant literature.

Table 8 – Half-life values from available literature

Determinand	Half-life value	Unit	Justification
Ammoniacal Nitrogen	Unsaturated pathway - SINGLE(1x10^{9}) Aquifer pathway - UNIFORM(5, 10)	years	Table 4.2 in NGWCLC, 2003[3]
Toluene	SINGLE(0.65)	years	Equivalent to 238 days. Table 17 in USGS, 2006[4]

Retardation

K_d (sorption coefficient) values dictate the partition of 'contaminants' between the liquid (groundwater) and solid (unsaturated pathway) phases.

Table 9 sets the K_d values used for the modelling based on suitable LandSim defaults for clay for the unsaturated pathway (side slope AGB).

Table 9 – K_d value parameters

Determinand	K_d value – Unsaturated zone	K_d value - Aquifer	Unit	Justification
Ammoniacal Nitrogen	SINGLE(3.2)	LOGUNIFORM (0.5, 2)	l/kg	ConSim values
Chloride	0	0	l/kg	No sorption assumed
Cadmium	SINGLE(222.2)	SINGLE(240)	l/kg	ConSim values
Nickel	SINGLE(85.7)	SINGLE(66)	l/kg	ConSim values

As Toluene is an organic constituent, a partition to organic carbon (koc) value is used rather than a K_d value for retardation. The koc input parameters for Toluene are given in Table 10.

Table 10 – Partition to organic carbon parameters for Toluene

Parameter	Value	Unit	Justification
Partition to organic carbon	SINGLE(190)	ml/g	Table 3.1 in Environment Agency, 2002[5]
Fraction of organic carbon – Unsaturated zone	SINGLE(0.05)	Fraction	Table 2.3 in Environment Agency, 2002[5]
Fraction of organic carbon – Aquifer	LOGTRIANGULAR(0.0002, 0.0017, 0.012)	Fraction	Table 2.3 in Environment Agency, 2002[5]
Pathway density – Unsaturated zone	UNIFORM(1.8, 2.2)	kg/l	Table 3 in Manger, 1963[2]
Pathway density – Aquifer	UNIFORM(1.5, 2.0)	kg/l	Table 4 in Manger, 1963[2]

Aquifer Pathway

The aquifer pathway input parameters for the River Terrace Deposits sand and gravel are presented in Table 11.

Table 11 – Aquifer pathway input parameters

Parameter	Value	Unit	Justification
Geological unit	River Terrace Deposits sand and gravel	-	-
Pathway Width ('Inert Waste – Phases 1 to 9')	SINGLE(1100)	m	Conservative width of waste mass perpendicular to flow. See Section 2.6.2
Mixing zone thickness	TRIANGULAR(0, 3.0, 6.0)	m	Saturated aquifer thickness. See Section 2.6.2
Conductivity	SINGLE(0.0005)	m/s	See Section 2.6.2
Regional gradient	LOGUNIFORM(0.00066, 0.002)	-	See Section 2.6.2
Pathway porosity	UNIFORM(0.30, 0.35)	Fraction	30-35% porosity for seasonal groundwater fluctuations of 0.5 to 1.0m in sand and gravel with 30% rainfall recharge.
Longitudinal dispersivity	SINGLE(110)	m	Nominal 10% of maximum pathway width
Transverse dispersivity	SINGLE(3.3)	m	Nominal 3% of longitudinal dispersivity

5.2.2 Model Results

Model results from the LandSim analysis for hazardous substances and non-hazardous determinands are presented below. All model output concentrations are recorded to the 95th percentile. The LandSim model (.sim) and result (.rst) files are presented in Appendix 7.

Hazardous Substances

The HRA must demonstrate that the technical precautions would "*prevent hazardous substances from entering groundwater*". Consequently, it must consider whether there is likely to be a discernible discharge of hazardous substances to groundwater. The test shall be applied at the point at which leachate enters groundwater and shall not take account of the effect of dilution in the groundwater.

The predicted concentration for the hazardous substance Toluene, a representative hydrocarbon, has been reported at the base of the unsaturated zone (the outside edge of the side slope AGB).

The result has been compared against the Environmental Assessment Limit (EAL) for Toluene – the limit of detection (1µg/l, or 0.001mg/l if converted to mg/l) based on pre-development baseline monitoring data undertaken at the site. The baseline monitoring data showed no records of Toluene above the limit of detection for this determinand. The result is also below the Limit of Quantification (LoQ) for Toluene of 0.0002mg/l as given in the Technical report on Groundwater Hazardous Substances by the UK Technical Advisory Group on the Water Framework Directive (UKTAG, 2016)[6]. The result is presented in Table 12.

Table 12 – GQRA LandSim model results – 95th percentile concentration of modelled hazardous substance at base of unsaturated zone

Determinand	GQRA input concentration (mg/l)	'Inert Waste – Phases 1 to 9' concentration at base of unsaturated zone (mg/l)	EAL (mg/l)
Toluene	0.6	4.44 x 10^{-8}	0.001

Based on the model result, the predicted concentration of hazardous substance Toluene is below the EAL at the compliance point. The proposed development will therefore prevent hazardous substances

from entering groundwater and will not be detrimental to the local groundwater or surface water environments, or any downstream receptor, through the acceptance and placement of imported inert waste at inert WAC limits.

Non-hazardous pollutants

The HRA must demonstrate that the technical precautions would *"limit the introduction of non-hazardous pollutants into groundwater so as to avoid pollution".* Consequently, it must consider whether the predicted concentrations of non-hazardous pollutants are likely to exceed relevant environmental quality criteria, or cause an unacceptable deterioration in water quality, in the groundwater following dilution.

Predicted concentrations of non-hazardous pollutants have been reported at the downstream boundary of the inert fill mass. The downstream boundary has been defined by the bolted-on 'monitoring well' within LandSim. Results have been compared against the respective EALs for each determinand. The EALs set for non-hazardous pollutants are the proposed compliance limits which have been based on the pre-development baseline monitoring data undertaken at the site. The proposed compliance limits are discussed in Section 6.4. The results are presented in Table 13.

Table 13 – GQRA LandSim model results – 95th percentile concentrations of modelled non-hazardous determinands at monitoring point

Determinand	GQRA input concentration (mg/l)	'Inert Waste – Phases 1 to 9' concentration at monitoring point (mg/l)	EAL (mg/l)
Ammoniacal Nitrogen	0.5	0.087	0.78
Chloride	80	26.4	53.3
Cadmium	0.004	3.29×10^{-5}	0.00066
Nickel	0.04	0.0032	0.015

Based on the model results, predicted concentrations of non-hazardous determinands at the compliance point are lower than the EAL values. The proposed development will therefore not be detrimental to the local groundwater or surface water environments, or any downstream receptor, through the acceptance and placement of imported inert waste at inert WAC limits.

5.3 Rogue Load Assessment

In addition to the numerical modelling undertaken to evaluate the possible likelihood and consequences of leachate release and migration from the deposit for recovery activity at the site, a quantitative rogue load risk assessment has been completed.

The LandSim model (.sim) and result (.rst) files for the rogue load assessment are presented in Appendix 8.

Completion of the rogue load risk assessment in no way suggests or infers that such a load is anticipated to arrive on the site and be placed in the deposit for recovery restoration scheme. Strict Waste Acceptance Criteria and Procedures will be employed at the site to minimise the potential for rogue loads to be accepted on site and placed within the inert fill mass (see Appendix Giii of the Permit application documentation).

A modified set of input concentrations for the chosen determinands were selected using a weighted average, where 90% of the waste is assumed to be at inert WAC limit concentrations and 10% of the waste is at the C_0 values (first eluate of percolation test at L/S = 0.1 l/kg) provided within Section 2.1.2.1 of Council Decision 2003/33/EC, where applicable. As Ammoniacal Nitrogen and Toluene do not have C_0 values, a conservative method has been applied for setting rogue load input concentrations using a weighted average where 90% of the waste is at inert WAC limit concentrations and the remaining 10% has concentrations at five times the input values for these determinands used in the GQRA model in Appendix 7. This accords with similar differences between the inert WAC

values and C_0 values for the other determinands. Rogue load input concentrations are presented in Table 4.

The methodology has been used to assess the impact of rogue loads of non-inert imported material deposited at the site and also acts as a sensitivity analysis.

The rogue load input concentration and result for the hazardous substance, compared to the same EAL applied in the GQRA model in Section 5.2.2 and Table 12, are presented in Table 14.

Table 14 – Rogue Load LandSim model results – 95th percentile concentration of modelled hazardous substance at base of unsaturated zone

Determinand	Rogue load input concentration (mg/l)	'Inert Waste – Phases 1 to 9' concentration at base of unsaturated zone (mg/l)	EAL (mg/l)
Toluene	0.84	6.21×10^{-8}	0.001

The rogue load input concentrations and results for non-hazardous determinands, compared to same EALs applied in the GQRA model in Section 5.2.2 and Table 13, are presented in Table 15.

Table 15 – Rogue Load LandSim model results – 95th percentile concentrations of modelled non-hazardous determinands at monitoring point

Determinand	Rogue load input concentration (mg/l)	'Inert Waste – Phases 1 to 9' concentration at monitoring point (mg/l)	EAL (DWS) (mg/l)
Ammoniacal Nitrogen	2.5	0.121	0.78
Chloride	460	38.7	53.3
Cadmium	0.02	4.24×10^{-5}	0.00066
Nickel	0.12	0.0035	0.015

Based on the rogue load model results, predicted concentrations of hazardous and non-hazardous determinands at the compliance points are below the respective EALs. Accordingly, it is concluded that the proposed development will not be detrimental to the local groundwater and surface water environments, or any downstream receptor. The local water environments will be adequately protected against the potential impact of rogue load material by strict Waste Acceptance Criteria and Procedures and a side slope AGB.

5.4 Qualitative Assessment of Accidents and Their Consequences

A qualitative consideration of the impact of accidents is given below.

5.4.1 Failure of Leachate Management System

Given the inert nature of the waste material no traditional leachate will be generated. Therefore, no leachate management infrastructure is required.

5.4.2 Stability and Integrity of Artificial Geological Barrier (AGB)

A Stability Risk Assessment (SRA) of the side slope AGB has been completed (GWP Report No. 251042) and is provided as Appendix Gv of the EPR Permit application.

The SRA has established the adequacy of the design and the associated stability and integrity of the side slope AGB.

The side slope AGB will be constructed in accordance with a CQA Plan approved by the EA. The CQA Plan (GWP Report No. 250927) is provided as Appendix M of the EPR Permit application.

5.4.3 Diesel Fuel Storage Tank Qualitative Assessment

Any diesel fuel storage tanks at the site will be located on hardstanding and away from the main infilling operations.

The principal accident preventative measures are that any diesel tanks used at the site will be steel, double skinned manufactured to industry standards and bunded to EA guidelines. The tanks will be located above ground, with bunding on a concrete base with a capacity of 110% of the tank capacity.

In addition, the following water quality impact mitigation measures will be implemented at the site:

- All plant, machinery and vehicles will be routinely maintained to industry standards;
- All vehicles will be parked overnight on an impermeable hardstanding, draining to an oil interceptor;
- All vehicle and mobile machinery maintenance will be undertaken in an off-site facility;
- All required chemicals and oils will be stored in a bespoke high hazard watertight container/shed, located on an impermeable pad drained to an oil interceptor;
- Wastewater will be collected to an industry standard septic tank, which will be routinely emptied by vacuum road tanker to an off-site disposal facility;
- The site will operate site spill kits and follow industry standard accidental spillage and clear up procedures.

In addition, further details of pollution management are provided in the *Bow Farm Pollution Control and Incident Response Plan* report (GWP Report No. 240526), prepared separately to discharge Condition 25 of Planning Permission Number 19/000048/CM (Worcestershire County Council). Discharge of Condition 25 was subsequently permitted by Worcestershire County Council on 2nd June 2025 through Condition discharge application 24/000035/DIS. The Pollution Control and Incident Response Plan report is included in Appendix 9.

5.4.4 Rogue Loads

Strict Waste Acceptance Criteria and Procedures will be employed at the site to minimise the potential for rogue loads to be accepted on site and placed within the inert waste mass. The Waste Acceptance Criteria and Procedures document is included as Appendix Giii of the EPR Permit application.

The quantitative rogue load risk assessment completed as part of this HRA (see Section 5.3) concludes that the groundwater environment will be adequately protected against the potential impact of rogue load material by strict Waste Acceptance Criteria and Procedures and a side slope AGB.

5.5 Emissions to Groundwater

The HRA has demonstrated that the predicted discharge from the deposit for recovery activity complies with the requirements of the Groundwater (England and Wales) Regulations for both hazardous substances and non-hazardous determinands. The total leachability and pollutant content of the deposited material and the ecotoxicity of the leachate will be insignificant and in particular will not endanger the quality of groundwater. There will be no deleterious emissions to groundwater from the site.

5.5.1 Hazardous Substances

The predicted concentrations of hazardous substances at the point where they enter groundwater (the outside edge of the side slope AGB) have been shown to be below EALs based on the numerical modelling undertaken.

All materials that are to be deposited within the EPR Permit application area will either conform to those wastes categorised as inert (referenced in the Environmental Permitting (England and Wales) Regulations), or which undergo testing to demonstrate compliance with the Waste Acceptance Criteria for inert landfill. As only demonstrably inert material will be deposited, there will be no increase in the concentration of hazardous substances due to its presence.

5.5.2 Non-hazardous Pollutants

The predicted concentrations of non-hazardous determinands at the site boundary have been shown to be below respective EALs based on the numerical modelling undertaken.

All materials that are to be deposited within the EPR Permit application area will either conform to those wastes categorised as inert (referenced in the Environmental Permitting (England and Wales) Regulations), or which undergo testing to demonstrate compliance with the Waste Acceptance Criteria for inert landfill. As only demonstrably inert material will be deposited, there will be no increase in the concentration of non-hazardous determinands due to its presence.

5.5.3 Surface Water Management

All surface water associated with the deposit for recovery scheme will be managed initially within the EPR Permit area.

Operational Phase

As outlined in Section 3.1, a clay cut-off wall will be installed around the full perimeter of the Phases 1 to 9 excavation area. The presence of this clay cut-off wall will prevent the groundwater within the river terrace sand and gravel deposits up-gradient of the site from being transmitted through the sand and gravel aquifer on site but will be routed to the west of the site through the installation of perimeter groundwater interception ditches. Therefore, water collecting within the excavation void will be rainfall-derived surface water only (no groundwater dewatering will be required). Sump pumps will be used inside the excavation pit to remove rainfall.

Surface water runoff generated within excavated areas of Phases 1 to 9 will progressively infiltrate or will be internally managed within the site area. Surface water runoff will be captured and routed from areas outside of excavations, including temporary bunds and stockpiles, to prevent turbid water entering local water courses.

There will be no direct discharge of water from the EPR Permit application area into any local surface water receptors.

During operations, direct rainfall and associated surface water runoff within the progressive Phases 1 to 9 void will be pumped out and clarified through the use of temporary silt lagoons. This cleaned water will then be transferred to infiltration basins along the western perimeter of Phases 1 to 9 to allow it to infiltrate back into the sand and gravel aquifer. Details of the surface water management scheme are provided in the *Bow Farm Surface Water Drainage Scheme* report (GWP Report No. 240707), prepared separately to discharge Condition 20 of Planning Permission Number 19/000048/CM (Worcestershire County Council). Discharge of Condition 20 was subsequently permitted by Worcestershire County Council on 2nd June 2025 through Condition discharge application 24/000035/DIS. The Surface Water Drainage Scheme report is included in Appendix 3 of the ESSD report (GWP Report No. 251039) provided as Appendix Gii of the EPR Permit application.

Restoration and Post-Development Phase

Restoration of excavation area Phases 1 to 9 will be back to pre-extraction ground levels (*via* site derived materials and importation of inert waste). Restoration of Flexible Working Areas A and B will be to water bodies and wetland (using site derived mineral waste only) below pre-extraction ground levels. Thus, all the site area will be restored to or below pre-excavation ground levels, providing a net gain in floodplain storage and conveyance.

The removal of the sand and gravel from excavation area Phases 1 to 9 and their replacement with low permeability inert waste contained within a low permeability side wall liner will result in increased surface water runoff from these areas. Mitigation measures are therefore required to ensure no negative impact in terms of drainage and risk of flooding within and/or around the site area.

A runoff attenuation scheme, approved under Planning Permissions 19/000048/CM and 19/0081/TWMAJM, will be included as part of the restored site layout. The approved surface water runoff management scheme consists of a single elongated restoration infiltration basin along the western boundary of excavation Phases 1 to 9. The feature is described as an infiltration basin as its purpose is not to convey flow but to store it and, to a large extent, allow runoff infiltration. Excess runoff will be discharged from the restoration infiltration basin (*via* an overflow orifice) into a proposed wetland area that sits within the Application Site. The runoff attenuation scheme is outlined in detail within the *Bow Farm Sand and Gravel Quarry Development Hydrogeological and Hydrological*

Impact Assessment and Flood Risk Assessment report (GWP Report No. 190714), included in Appendix 4 of the ESSD report (GWP Report No. 251039) provided as Appendix Gii of the EPR Permit application. The phasing of the construction of the restoration infiltration basin is also detailed within the Surface Water Drainage Scheme report included in Appendix 3 of the ESSD report.

In addition to the Surface Water Drainage Scheme report, the *Bow Farm Sustainable Drainage Systems (SuDS) Management Plan* report (GWP Report No. 240522), prepared separately to discharge Condition 21 of Planning Permission Number 19/000048/CM (Worcestershire County Council), includes details for the management of the infiltration ponds/basins which will form the SuDS features on site. The use of infiltration features to discharge surface water to ground at the site is in accordance with the SuDS discharge hierarchy. Discharge of Condition 21 was subsequently permitted by Worcestershire County Council on 2nd June 2025 through Condition discharge application 24/000035/DIS. The SuDS Management Plan report is included in Appendix 10.

The *Bow Farm Flood Storage Compensation Scheme* (GWP Report No. 241008), prepared separately to discharge Condition 19 of Planning Permission Number 19/000048/CM (Worcestershire County Council), provides the scheme for flood storage compensation at the site, including the principles behind the movements of soil stripped from areas on site and how flood storage betterment is provided through the life of the development. Discharge of Condition 19 was subsequently permitted by Worcestershire County Council on 2nd June 2025 through Condition discharge application 24/000035/DIS. The Flood Storage Compensation Scheme report is included in Appendix 11.

Given the inert nature of the imported waste, the strict waste acceptance procedures and protocols, and the findings of the quantitative HRA above, it is considered that no hydrological risk is posed to the River Severn and Ripple Brook, or any surface water dependent sites of ecological sensitivity (including Ripple Lake and the Napps LWS, Ripple Lake LWS and the River Severn) from the restoration of excavation area Phases 1 to 9 with imported inert fill.

5.6 Hydrogeological Completion Criteria

Hydrogeological completion criteria refer to the conditions that must be met before an EPR Permit can be surrendered, *i.e.* EPR Permit completion attained. Completion relating to hydrogeological risk will have been achieved when there is no longer any unacceptable risk of pollution from the waste mass, *i.e.* the site complies with the Groundwater (England and Wales) Regulations without any active leachate management.

Inert fill material poses no threat to the groundwater environment either during infilling or post completion since, by definition, the total leachability and pollutant content of the wastes and the ecotoxicity of the leachate will be insignificant and in particular will not endanger the quality of groundwater. There will be no risks of pollution of groundwater resulting from the presence of the inert fill material within excavation area Phases 1 to 9 at the site.

As excavation area Phases 1 to 9 of the site will receive inert waste only and unacceptable discharge is therefore unlikely, it is considered that hydrogeological completion criteria will not be the controlling factor in the ultimate surrender of the Environmental Permit. EA guidance (Landfill and deposit for recovery: aftercare and permit surrender) indicates that for inert waste infilling permitted under the Landfill Directive *'you should be able, through waste records, to demonstrate that the waste accepted was genuinely inert'*, and this will form the basis for EPR Permit surrender.

6. REQUISITE SURVEILANCE

6.1 Review of Technical Precautions

Due to the inert nature of the imported fill material which will be placed within excavation area Phases 1 to 9, it is considered that the proposed technical precautions detailed below are appropriate and sufficient to prevent any unacceptable discharge from the site:

- strict control of waste types sourced and accepted;
- strict adherence to compliance criteria and testing;
- provision of a side slope AGB in compliance with the Landfill Directive;
- progressive restoration to a profile to encourage surface water runoff from the waste mass and minimise water ingress into the inert waste mass;

- provision of ditches or berms, where required, to minimise surface water runoff into the deposit for recovery area.

It is considered that leachate monitoring and management is not required due to the inert nature of the imported inert fill.

6.2 Leachate Monitoring

Given the inert nature of the imported fill material which will be placed within excavation area Phases 1 to 9, no leachate will be generated. Therefore, no leachate management or monitoring infrastructure is required and none is proposed.

A side slope AGB will be constructed to provide sufficient attenuation between the inert fill material source within excavation area Phases 1 to 9 and any potential receptor. The AGB will be constructed to achieve a minimum thickness of 1.0m and maximum permeability of 1 x 10^{-7} m/s in accordance with a Construction Quality Assurance Plan approved by the EA. The Construction Quality Assurance Plan (GWP Report No. 250927) is provided as Appendix M of the EPR Permit application.

6.3 Groundwater Monitoring

Given the inert nature of the waste and the strict Waste Acceptance Procedures and Protocols, it is considered that no hydrogeological risk is posed from the approved site restoration using imported inert waste within excavation area Phases 1 to 9 under a deposit for recovery scheme.

Furthermore, the results from the quantitative modelling presented in Sections 5.2.2 and 5.3 demonstrate that no unacceptable levels of hazardous substances or non-hazardous pollutants are predicted to be within the groundwater at the respective compliance points.

Groundwater will be monitored within existing boreholes up-gradient and down-gradient of the excavation area Phases 1 to 9 for levels and quality to assess the integrity of the performance of the site and to ensure that there is no impact on groundwater.

The groundwater monitoring points that have been used to monitor baseline groundwater levels and quality during 2024 and 2025 (see Sections 2.6.2 and 2.6.5) shall be used to monitor groundwater once the Environmental Permit has been issued by the EA. These are up-gradient borehole WM3 and down-gradient boreholes WM5, WM6 and WM8.

Groundwater monitoring borehole locations are shown on Drawing No. BOWFEPR2511-2.

It is proposed that groundwater levels are monitored on a monthly basis.

It is proposed that the same determinands that have been monitored for during the baseline groundwater quality monitoring period (see Section 2.6.5 and Appendix 6) are monitored for once the Environmental Permit has been issued. However, it is proposed that the frequency of groundwater quality monitoring is quarterly for some determinands and annually for others. This is because of the low risk posed to the groundwater environment from the placement of imported inert waste within excavation area Phases 1 to 9 under a deposit for recovery scheme – due to the inert nature of the waste, the strict Waste Acceptance Procedures and Protocols that will be employed at the site and the presence of the clay cut-off that will create an impermeable hydraulic seal between the Phase 1 to 9 excavation area and the surrounding sand and gravel aquifer.

The following schedule of groundwater monitoring is proposed in Table 16.

Table 16 – Groundwater monitoring schedule

Monitoring points	Determinands	Monitoring frequency
Up-gradient - WM3 Down-gradient – WM5, WM6, WM8	Groundwater level	Monthly
	pH, Electrical Conductivity, Ammoniacal Nitrogen, Chloride, Sulphate, Cadmium (dissolved), Chromium (dissolved), Lead (dissolved), Nickel (dissolved), Total Organic Carbon (TOC), BTEX Compounds, Total Petroleum Hydrocarbons (TPH)	Quarterly
	Boron (dissolved), Calcium (dissolved), Copper (dissolved), Iron (dissolved), Magnesium (dissolved), Manganese (dissolved), Mercury (dissolved), Potassium (dissolved), Sodium (dissolved), Zinc (dissolved), Alkalinity as $CaCO_3$, Total Oxidised Nitrogen (TON), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Polycyclic Aromatic Hydrocarbons (PAHs – 16 No.)	Annually

The monitoring data will be provided to the EA on a quarterly basis following Permit issue.

Groundwater quality compliance limits for down-gradient monitoring boreholes WM5, WM6 and WM8 are proposed in Section 6.4. The proposed compliance limits are based on a review of the baseline groundwater quality monitoring data undertaken at the monitoring boreholes at the site.

The compliance limits will be revised, if necessary and in agreement with the EA, once one year's worth of monitoring data has been collected following the issue of the Environmental Permit.

Given that the acceptance of inert waste at the site will be strictly controlled using robust waste acceptance criteria and protocols, it is considered that site restoration using imported inert waste within excavation area Phases 1 to 9 at the Bow Farm site under a deposit for recovery scheme will not result in any significant or measurable detrimental impact on the hydrogeological setting of the site and surrounding area.

6.4 Groundwater Quality Compliance Limits

Compliance limits for down-gradient monitoring boreholes WM5, WM6 and WM8 have been proposed based on a review of the data from the baseline groundwater quality monitoring from up-gradient monitoring borehole WM3 and down-gradient boreholes WM5, WM6 and WM8.

Compliance limits have been proposed for determinands included in the GQRA, except for Toluene. Baseline concentrations of Toluene have not been recorded above the limit of detection.

The proposed compliance limits within down-gradient boreholes WM5, WM6 and WM8 for Ammoniacal Nitrogen, Chloride, Cadmium and Nickel have been selected as the EAL concentrations applied in the GQRA in Section 5.2.2 (Table 13).

The proposed compliance limits for Ammoniacal Nitrogen, Cadmium and Nickel for the down-gradient boreholes have been selected as the baseline down-gradient maximum concentrations plus two standard deviations as the baseline down-gradient maximum concentrations are greater than the baseline up-gradient maximum concentrations.

The proposed compliance limit for Chloride for the down-gradient boreholes has been selected as the baseline up-gradient geometric mean concentration plus three standard deviations.

The proposed compliance limits are presented in Table 17. Associated groundwater monitoring data used for the setting of the limits is provided in Appendix 12. Limit values within Table 17 may have been rounded based on the actual data supplied within Appendix 12.

Table 17 – Proposed compliance limits for down-gradient boreholes WM5, WM6 and WM8

Determinand	Unit	Min.	Max.	Geometric Mean	Standard Deviation	Compliance limit
Ammoniacal Nitrogen	mg/l	<0.03	0.492	0.08	0.14	0.78
Chloride	mg/l	16.5	45.4	24.7	9.5	53.3
Cadmium	mg/l	<0.0001	0.0005	0.00011	0.00008	0.00066
Nickel	mg/l	<0.0004	0.01	0.0007	0.0023	0.015

Note: Minimum, maximum, geometric mean and standard deviation results for Ammoniacal Nitrogen, Cadmium and Nickel are from down-gradient boreholes WM5, WM6 and WM8 as these values have been used in setting the compliance limits for these determinands.

Note: Minimum, maximum, geometric mean and standard deviation results for Chloride are from up-gradient borehole WM3 as these values have been used in setting the compliance limit for this determinand.

The compliance limits will be revised, if necessary and in agreement with the EA, once one year's worth of monitoring data has been collected following the issue of the Environmental Permit.

6.5 Surface Water Monitoring

Given the inert nature of the imported waste to be placed in excavation area Phases 1 to 9 and the strict waste acceptance procedures and protocols that will be employed on site, it is considered that no hydrological risk is posed to the River Severn and Ripple Brook, or any surface water dependent sites of ecological sensitivity (including Ripple Lake and the Napps LWS, Ripple Lake LWS and the River Severn), from the restoration of excavation area Phases 1 to 9 with imported inert fill.

Furthermore, the results from the quantitative modelling presented in Section 5.2.2 and 5.3 demonstrate that no unacceptable levels of hazardous substances or non-hazardous determinands are predicted to be within the groundwater at the compliance points, prior to any discharge into any surface water body.

The quality of groundwater between the site and any surface water receptors (Ripple Lake and the Napps LWS, Ripple Lake LWS and the River Severn) will be monitored (see Section 6.3).

Surface water will be managed in accordance with the *Bow Farm Surface Water Drainage Scheme* report (GWP Report No. 240707), prepared separately to discharge Condition 20 of Planning Permission Number 19/000048/CM (Worcestershire County Council). Discharge of Condition 20 was subsequently permitted by Worcestershire County Council on 2nd June 2025 through Condition discharge application 24/000035/DIS. The Surface Water Drainage Scheme report is included in Appendix 3 of the ESSD report (GWP Report No. 251039) provided as Appendix Gii of the EPR Permit application.

7. CONCLUSIONS

7.1 Compliance with the Landfill Directive

The EPR Permit application provides for the permanent deposit of *c.* 1.4Mm^3 of imported inert fill material within Phases 1 to 9 of the excavation area in the main site area as a deposit for recovery activity and not a waste disposal activity. Site derived mineral waste (silts and clays) will also be placed within excavation area Phases 1 to 9 as part of the restoration under the approved scheme.

No imported inert fill material will be placed in Flexible Working Areas A and B in the west of the site. Restoration of Flexible Working Areas A and B will be to wetlands and water features using only site derived mineral waste (silts and clays) and will have a final landform below pre-extraction ground levels.

Notwithstanding, a side slope AGB will be constructed on a phased basis within excavation area Phases 1 to 9 in order to provide sufficient attenuation between the source and any receptors (the underlying Triassic Branscombe Mudstone Formation of the Mercia Mudstone Group provides an adequate natural base AGB) as would be required in order to ensure compliance with the Landfill Directive in circumstances where an inert landfill waste disposal activity was being applied for.

Given the inert nature of the imported fill material and site derived mineral waste (silts and clays) which will be placed within excavation area Phases 1 to 9, no leachate will be generated. Therefore, no leachate management or monitoring infrastructure is required and none is proposed.

7.2 Compliance with the Groundwater Regulations

The HRA has demonstrated that under operational and post-operational phases of the development, hazardous substances will not be present in groundwater down-gradient of the site in discernible concentrations and non-hazardous determinands will not be present in concentrations such that pollution of groundwater is caused. It is considered therefore that the site is and will be compliant with respect to the Groundwater (England and Wales) Regulations.

7.3 Summary

Given that the acceptance of imported inert waste within excavation area Phases 1 to 9 at the site will be strictly controlled using robust Waste Acceptance Criteria and Protocols, and having regard to the findings of the quantitative HRA, it is considered that completion of the approved site restoration scheme as a deposit for recovery activity, requiring *c.* 1.4Mm^3 (approximately 2.45Mt using a standard conversion factor of 1.75t/m^3) of imported inert fill material within the excavation area Phases 1 to 9, will not result in any significant or measurable detrimental impact on the hydrogeological or hydrological setting of the site and surrounding area.

8. REFERENCES

1. LandSim Version 2.5 manual. 2004. Golder Associates.
2. Manger, G.E. 1963. *Porosity and Bulk Density of Sedimentary Rocks*, Geological Survey Bulletin 1144-E.
3. National Groundwater and Contaminated Land Centre (NGWCLC). 2003. *Review of Ammonium attenuation in soil and groundwater, National Groundwater and Contaminated Land Centre*, NGWCLC Report NC/02/49.
4. United States Geological Survey (USGS). 2006. *Description, properties and degradation of selected volatile organic compounds detected in groundwater*.
5. Environment Agency. 2002. *The Effects of Contaminant Concentration on the Potential for Natural Attenuation*, R&D Technical Report P2-228/TR.
6. UK Technical Advisory Group on the Water Framework Directive (UKTAG). 2016. *Technical report on Groundwater Hazardous Substances*.

GWP CONSULTANTS
NOVEMBER 2025

APPENDIX 1a

Groundsure Enviro Insight report

APPENDIX 1b

Groundsure Geo Insight report

APPENDIX 2

Daily rainfall graphs

APPENDIX 3

River Severn at Saxons Lode daily flow and level graphs

APPENDIX 4

Borehole logs – WM1 to WM8

APPENDIX 5

Groundwater level data for boreholes WM3 and WM8

APPENDIX 6

Site groundwater quality monitoring data

APPENDIX 7

LandSim model and result files - GQRA

APPENDIX 8

LandSim model and result files – Rogue Load Assessment

APPENDIX 9

Bow Farm Pollution Control and Incident Response Plan report
(GWP Report No. 240526)

APPENDIX 10

***Bow Farm Sustainable Drainage Systems (SuDS) Management Plan report* (GWP Report No. 240522)**

APPENDIX 11

Bow Farm Flood Storage Compensation Scheme **(GWP Report No. 241008)**

APPENDIX 12

Proposed groundwater quality compliance limits for down-gradient borehole