Technical Appendix I

Flood Risk Assessment

FLOOD RISK ASSESSMENT

LEAPERS WOOD QUARRY

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GENERAL NOTES

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1 INTRODUCTION

1.1 Background

Tarmac Trading Ltd has operated Leapers Wood Quarry, Carnforth for several decades. A Section 73 Planning Application has been prepared for proposed deepening of the existing quarry to -37 metres Above Ordnance Datum (mAOD) to secure a long-term supply of limestone. The Planning Application is also for an extension of time for mineral extraction and restoration operations through the variation of Conditions 1 (timescales), 2 (approved plans), 4 (depth of mineral extraction), 6 (phasing plans), 41 (final restoration scheme) and 43 (water level timescales) placed on Planning Permission 01/09/0360.

The site location and boundary are shown on *Drawing 3037/FRA/01*. The site is over 1 hectare (ha) in extent; therefore a Flood Risk Assessment (FRA) is required, in accordance with the National Planning Policy Framework (NPPF) and associated Planning Practice Guidance (PPG).

Hafren Water has been involved with environmental water management issues within the vicinity of the site for more than 20 years and therefore has a detailed understanding of the local water environment.

1.2 Flood risk and scope of the assessment

The site is entirely designated as Flood Zone 1 for fluvial (river) flooding by the Environment Agency (EA) as shown on *Drawing 3037/FRA/02*. As such it has less than 0.1% chance of flooding in any year. Therefore, the Sequential Test is considered to be passed and the Exception Test is not required.

The EA's 'Risk of Flooding from Surface Water' mapping (*Drawing 3037/FRA/03*) shows that the risk of surface water flooding is confined to minor watercourses in areas to the east, north and south of the quarry boundary.

This FRA considers the likelihood of flooding to and from the site. Consideration is given to the risk from fluvial flooding and rainfall events with a return period of 1 in 100-years, unless otherwise stated.

The applicable climate change allowances for the proposed development are outlined in Section 3.5.

A drainage strategy for the operational phase and restored site is included in Section 9.

1.3 Data sources

The following data sources were used in this assessment:

Tarmac Trading Limited

- Site plans and topographic survey
- Site Permits & Licences

Ordnance Survey (OS)

- 1:25,000 scale series mapping

British Geological Survey (BGS)

- Geological maps, 1:50,000-scale (England & Wales), via the Geology of Britain website

Environment Agency (EA)

- Environment Agency flood mapping
- Hydrology Data Explorer

North West Regional Flood and Coast Committee

- North West SUDS Proforma – July 2020

Lancashire County Council (LCC)

- Consultation Draft Local Flood Risk Management Strategy for Lancashire 2021-2027 – undated
- Joint Lancashire Minerals and Waste Development Framework Core Strategy - February 2009
- Lancashire Area Preliminary Assessment Report - May 2011
- Joint Lancashire Minerals and Waste Local Plan – September 2013
- North West Flood Risk Management Plan – December 2015
- Flood Investigation Reports Summer 2012 and December 2015

Lancaster City Council

- Level 1 Strategic Flood Risk Assessment – October 2017

Hafren Water Ltd

- Hydrogeological Impact Assessment, Leapers Wood Quarry, September 2023

2 PROPOSED DEVELOPMENT

2.1 Mineral extraction

Leapers Wood Quarry is operated for the production of limestone. It is proposed to access additional reserves to a depth of -37 mAOD. This will continue to require dewatering to allow the extraction of mineral from below the watertable. Existing and proposed water management is outlined in Section 5.

The combined working of Leapers Wood Quarry and the adjoining Back Lane Quarry to comprise a single quarry void is proposed. A topographic survey of both quarries is provided as *Appendix 3037/FRA/A1*. The proposed extension will secure additional mineral reserves. The planning boundary area for the combined quarries is approximately 95 ha, with a combined quarry void area of approximately 68 ha.

Future mineral extraction within the combined quarry areas is scheduled to continue until 2077. The proposed operational phasing plans are provided in *Appendix 3037/FRA/A2*.

2.2 Restoration

Progressive restoration of the site will occur, with the final landscaping of both sites being completed by 2078. Restoration of the quarry void will be to open water. Once final extraction depths have been reached, dewatering of the void will cease and the workings will start to fill with water. A waterbody will form within the quarry void, due to ingress of rainfall and groundwater. The rate of inflow will be slow and the timescale for filling of the void commensurately long, due to the low hydraulic conductivity of the limestone and the large capacity of the void. Water levels will be controlled passively and in perpetuity by the creation of an outfall, which will convey water to a natural sinkhole. The water levels will be regulated to 45 mAOD.

The proposed restoration scheme is provided in *Appendix 3037/FRA/A3*.

It is estimated that it will take between 10 and 15 years to reach its final level (HIA, Hafren Water, 2023). The proposed water management in perpetuity is outlined in Section 5.

3 BACKGROUND AND KEY DOCUMENTS

3.1 Local Planning Policy

Lancashire County Council is the Lead Local Flood Authority (LLFA) for this area and is responsible for ensuring local policy is consistent with national policy. Lancaster City Council is the local planning authority for this area. Both Lancashire County Council and Lancaster City Council are responsible for encouraging sustainable development and ensuring adherence to NPPF requirements regarding flood risk management.

Each Planning Authority must produce a Local Plan for its area which will include the objective of contributing to the achievement of sustainable development. The County Council produces Local Plans for minerals, waste management and transport. Local Plans are supported by a Strategic Flood Risk Assessment (SFRA) to guide the preferred location of development by means of a 'Sequential Test'. In this instance a SFRA has been produced for Lancaster City Council (October 2017) that covers the area occupied by the quarry. Flood risk management of 'local' sources is addressed by the County Council under its responsibilities as the LLFA (Preliminary Assessment Report, May 2011).

Planning Applications are considered in accordance with policies in Local Plans.

3.2 Local Policies and Guidance

3.2.1 Lancaster City Council Level 1 SFRA

The NPPF states that Local Plans should be supported by a Strategic Flood Risk Assessment (SFRA), which refines information regarding the probability of flooding, taking all sources of flooding and the impacts of climate change into account. SFRA's provide the foundation for applying the Sequential Test, on the basis of the Flood Zones.

Lancaster City Council prepared a Level 1 SFRA in October 2017 for an area that includes both Leapers Wood and Back Lane Quarries. The SFRA assesses flood risk from groundwater, surface water, sewer and river sources, taking into account the effect of future climate change.

The SFRA makes no specific reference to potential flooding in the area occupied by the quarry. Its recommendations include: a) 'at risk' developments should meet NPPF requirements, developments within Flood Zone 3b should not be permitted, b) flood risk assessments should consider surface run-off and its management by SuDS, and c) that a sequential approach is taken to site layout.

The SFRA raises no concerns for the site.

3.2.2 Level 2 SFRA

The site is not covered by a Level 2 SFRA.

3.2.3 Consultation Draft Local Flood Risk Management Strategy for Lancashire 2021-2027

The need for a LFRMS is governed by the Flood and Water Management Act 2010, which places a statutory duty on LLFA's to develop, maintain, implement and monitor an approach for managing local flood risks in its area.

In accordance with Section 9 of the Flood and Water Management Act the LLFA has developed a Local Flood Risk Management Strategy (LFRMS) to inform how flood risk will be managed and how its duties under the Act will be fulfilled. The LFRMS has focused on 'local sources' of flooding (ordinary watercourses, surface water and groundwater) and has identified priority flood risk areas, none of which overlap the quarry site.

3.2.4 Lancashire Area Preliminary Assessment Report (PFRA)

Preliminary Flood Risk Assessments (PFRA's) were a requirement of the Flood Risk Regulations (2009) and were produced by LLFA's. Their purpose is to provide information on significant historical flood events and summarise future flood risk, from all sources of flooding.

The PFRA does not raise any concerns for the development area.

3.2.5 Joint Lancashire Minerals and Waste Development Framework Core Strategy

This is the strategic document for future minerals and waste development in Lancashire until 2021. It was adopted in March 2009 and outlines the strategic policies required to deliver the vision. This includes Policies CS5 and CS9, which require the selection of sites that will not increase fluvial or surface water flood risk.

3.2.6 Joint Lancashire Minerals and Waste Local Plan

The Minerals and Waste Local Plan contains the Council's vision and objectives for minerals planning. This document provides the policy framework and proposed sites to maintain the supply of minerals and limit the impacts of their working.

The Local Plan does not make specific reference to Leapers Wood Quarry in site allocation and development management policies.

3.3 National Planning Policy and Guidance

This FRA has been undertaken in accordance with the statutory requirements of the NPPF and associated PPG regarding development and flood risk.

The NPPF requires developments to:

- Consider climate change over the longer term to avoid increased vulnerability to the range of impacts arising from climate change
- Ensure new development does not increase flood risk elsewhere
- Avoid inappropriate development in areas at risk of flooding by directing development away from areas at highest risk
- Where development is necessary, make it safe without increasing flood risk elsewhere and direct the most vulnerable development to areas of lowest flood risk
- Be supported by an appropriate site-specific Flood Risk Assessment, where one is required
- Ensure development is appropriately flood resilient and resistant
- Major development should incorporate sustainable drainage systems (SuDS), which should meet the Technical Standards for SuDS. Major development (according to Section 2 of Statutory Instrument 2015 Nº 595, Town and Country Planning of England), includes the winning and working of minerals or the use of land for mineral working deposits, also waste development

3.4 Flood zone and vulnerability classifications

EA mapping shows that the site lies wholly within Flood Zone 1 (low probability of fluvial and tidal flooding) – see *Drawing 3037/FRA/02.* This zone comprises land assessed as having less than a 1 in 1000 annual probability of river or sea flooding in any given year (<0.1%).

In accordance with the NPPF and associated Planning Practice Guidance (PPG), all sites within Flood Zones 2 or 3 or over 1 ha in size must be accompanied by an FRA.

Mineral working and processing is designated as being 'Less Vulnerable' in accordance with the NPPF and PPG. According to Table 3 of the PPG, it is considered appropriate for 'Less Vulnerable' development to be located within Flood Zone 1. The Sequential Test is therefore considered to be passed and the Exception Test does not need to be applied.

3.5 Climate change

In May 2022 the EA published an update on climate change allowances for peak rainfall intensity. The site is within the Lune Management Catchment.

3.5.1 Peak rainfall intensity

Within the UK, projections of future climate change predict that there will be more frequent, short duration, high intensity rainfall events and periods of long duration rainfall. The NPPF recommends that the effects of climate change are incorporated into FRA's. Recommended precautionary sensitivity ranges for peak rainfall intensities are outlined on the Hydrology Data Explorer and are summarised in *Table 3037/FRA/T1* below.

3037/FRA/T1: Lune Management Catchment - peak rainfall allowances				
	30-yr return period		100-yr return period	
	Central	Upper	Central	Upper
2050's	25%	35%	25%	45%
2070's	35%	45%	35%	50%

The restored site will have a lifetime beyond the 2070's. In accordance with the guidance, it is appropriate to use the Central Allowance for 'Less Vulnerable' developments. Therefore, a climate change allowance of 35% is appropriate in this instance. However for robustness, a 50% allowance has been applied within the drainage strategy.

4 SITE DESCRIPTION

4.1 Location and setting

Leapers Wood Quarry is located immediately to the southeast of Carnforth, Lancashire. It is centred on National Grid Reference (NGR) SD 51189 69217 within postcode area LA6 1BP (*Drawing 3037/FRA/01*).

4.2 Topography

Ground elevations at Leapers Wood Quarry are between approximately 40 and 90 mAOD along its western and eastern boundaries respectively. The terrain to the east of the quarry is undulating, decreasing towards the River Lune, 4 km distant. The western quarry boundary parallels the M6 Motorway, beyond which ground elevations broadly decline westwards, towards Morecambe Bay, 2.6 km distant. Ground levels also decrease towards the River Keer 1.5 km to the north of the quarry boundary. The Back Lane Quarry void is located immediately to the south of Leapers Wood Quarry, the two essentially now comprising one large void.

4.3 Hydrology

4.3.1 Rainfall

Long-term average rainfall data were obtained from the EA for the closest gauging station to the quarry. The gauge is located to the east of Peddar Potts Reservoir, approximately 2.4 km northeast of the quarry, (NGR SD 535 705) at an elevation of c90 mAOD. The average monthly rainfall between February 1994 and February 2021 is provided in *Table 3037/FRA/T2* below. The total average annual rainfall is 1137.7 mm.

3037/FRA/T2: Monthly rainfall totals (1994-2021)												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average rainfall (mm)	104.1	92.1	73.9	55.2	69.1	79.8	95.9	108.8	108.2	119.2	109.9	121.5

4.3.2 Watercourses

Water features near the site are shown on *Drawing 3037/FRA/04*.

The closest named watercourse to the site is the Nether Beck. This watercourse is a tributary of the River Keer, which is located approximately 1.5 km to the north of the quarry. Both are classed as Main Rivers by the EA. The Nether Beck originates from a spring situated approximately 200 m to the west of the site boundary. Flow at the headwaters of the Nether Beck (adjacent to SD 50417 69774) is occasionally so low that the reach immediately upstream of SD 50476 70317 becomes dry. The watercourse flows broadly northwards on the western, opposite side of the M6 Motorway to the quarry. The stream flows through Carnforth, where it is conveyed within several culverts, beneath the Lancaster Canal, a sports field and agricultural land, ultimately discharging into the River Keer. The River Keer flows generally westwards and discharges into Morecambe Bay, approximately 2.6 km to the west of the quarry.

The Nether Beck has several tributaries. Effluent from a small sewage treatment works, located approximately 600 m to the north of Leapers Wood, is culverted beneath the M6 and syphoned beneath the Lancaster Canal, discharging to the Nether Beck. In addition, a small ephemeral drainage channel, located 50–100 m west of the site, drains from a culvert outfall beneath the M6 carriageway, located at NGR SD 50470 69623. A laser scan survey of this culvert, undertaken in March 2022, indicates that it is 49.2 m long, with inlet and outlet elevations of approximately 32.26 mAOD and 31.96 mAOD respectively. The culvert diameter is 600 mm. As-built plans of the M6 Motorway, provided by Highways England, record that karst features were intercepted during motorway construction. The plans infer that drainage from these karst features is conveyed via pipes to outfalls on the western embankment of the M6 carriageway. The surveyed culvert is considered to be one of these drainage outfalls.

Land located directly to the southeast of the site is located within the catchment of the River Lune, an EA designated Main River, which is located 4 km to the south. The river flows southwards, ultimately discharging into Morecambe Bay.

Two other watercourses are located in the vicinity of the site; Cote Beck and Swarth Beck. Cote Beck is a tributary of the River Lune and flows southwestwards, 1.5 km to the south of the quarry boundary. Swarth Beck is a tributary of the River Keer and flows northwards, 1.25 km to the east of the site boundary.

An unnamed stream rises from seepages and sinks at Dunald Mill Hole cave (NGR SD 515 676), approximately 1.1 km to the south of the site.

The Lancaster Canal is located approximately 0.75 km to the northwest of the quarry. It passes beneath the M6 Motorway 1 km to the north of the quarry. The canal is located at an elevation of approximately 25 mAOD.

4.3.3 Waterbodies

Several waterbodies exist within the site boundary, which are associated with site water management. There are numerous waterbodies within a 2 km radius of the site, several of which relate to historical mineral extraction. Details of the largest four waterbodies are provided in *Table 3037/FRA/T3*.

3037/FRA/T3: Details of waterbodies				
Waterbody	**NGR**	**Description**	**Distance / direction**	**Approximate elevation**
Overhead Quarry (also known as Jackdaw Quarry)	SD 52877 71392	Restored (flooded) former limestone quarry	2 km / NE	30–31 mAOD
Peddar Potts Reservoir	SD 53360 70422	Stream-supported (Swarth Beck) man-made lake	1.8 km / NE	70-80 mAOD
Waterbody north of Intack Wood	SD 52533 68323	Waterbody, possibly supported by spring seepage from the Pendle Grit Member	820 m / SE	93-106 mAOD
Dunald Mill Quarry	SD 51120 67962	Mothballed (flooded) limestone quarry	540 m / S	31-46 mAOD

4.4 Ground conditions

4.4.1 Geology and hydrogeology

Superficial deposits, which existed at the site prior to mineral extraction comprised glacial till. The EA designates these deposits as 'Secondary undifferentiated' and are considered likely to be Minor or Non-Aquifers.

Bedrock at the site comprises the Park and Urswick Limestone Formations and is classified by the EA as a Secondary 'A' Aquifer. Data from the British Geological Survey (BGS) and field observations note that the limestone bedrock is highly karstified.

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

4.4.2 Groundwater flowpaths

Major groundwater flow paths are likely to be associated with the karst limestone system which is present within the local area. These systems have the potential to transmit and store significant volumes of water, potentially reducing surface run-off where the bedrock is exposed. Tracer tests conducted from the existing (and proposed) quarry discharge locations have demonstrated that the local groundwater flow patterns are dominated by the karst conduit system. The system conveys the majority of groundwater flow northwards and is considered to have developed along this orientation due to the presence of a syncline within the limestone. Groundwater flow within the mass of the limestone is considered likely to follow this flowpath. Conceptual groundwater flow paths are shown on *Drawing 3037/FRA/05*.

At times of prolonged low rainfall, when water levels within the catchment are generally low, sections of the groundwater flowpath may temporarily become disconnected with surface water egress locations.

There is no evidence that water from the proposed discharge locations at either quarry flows to spring resurgences on the coastal plain.

5 WATER MANAGEMENT

5.1 Current water management

At both quarries, water inflow is conveyed to sumps in the base of the quarry void prior to being pumped to lagoons in the west of both sites. At Back Lane Quarry, a licence (EA reference 26/73/622/039) permits water to be abstracted from a silt settlement lagoon, for use in the wheel wash, for dust suppression and asphalt production. At Leapers Wood Quarry, Full Licence reference NW/073/0622/007 permits water to be abstracted from a lagoon, to supply a sprinkler system, dust suppression and a wheel wash.

At Back Lane Quarry, water discharges off-site at two locations. Excess water exits the silt settlement lagoon by gravity outfall to ground (at the location of gravity egress from the lagoon, where water sinks to ground at the base of the exposed rock face within its southwestern corner). The site also holds a discharge consent for an outfall from a French drain (constructed at the site of a historical sinkhole), at the western extent of the quarry (Permit reference 017290438). The consent is for 17,280 m^3/day (720 m^3/hour or 200 l/s) of settled site run-off. Surface water run-off across an area of hardstanding located in the west of the quarry is captured by a sump, located adjacent to the quarry offices. From here water passes through an oil interceptor, prior to discharging into the French drain.

At Leapers Wood Quarry, excess water is pumped to a sinkhole soakaway where it is discharged to ground, under EA Permit reference 017290475/V002. A maximum discharge rate of 2,600 m^3/day (108.4 m^3/hour or 30.1 l/s) is permitted.

5.2 Proposed operational water management

5.2.1 Managing water during operational phase ('average conditions')

Leapers Wood and Back Lane Quarries will be combined into a single void during future mineral extraction. Continuation of mineral extraction beneath the watertable will be required, therefore the current active water management will be maintained. Water management will also be combined for the two, joined, quarries; the proposed water management is shown on *Drawing 3037/FRA/06*. It is proposed to continue using the existing water management systems detailed in Section 5.1 above. Groundwater ingress and incident rainfall across the quarry will collect within one or more sumps within the quarry void. These sump(s) will provide settlement of run-off, reducing the suspended solid content of the water.

Water from the quarry sump(s) and Back Lane settlement lagoon will continue to be used for dust suppression, sprinkler systems and wheel washes at both sites, also for asphalt production at Back Lane Quarry.

For the duration of mineral extraction, excess water from dewatering will be pumped to the existing disposal points. Details of the proposed discharge locations and conceptual flow paths from these locations are provided in *Table 3037/FRA/T4* below and are shown on *Drawings 3037/FRA/05 and 3037/FRA/06*.

3037/FRA/T4: Offsite discharge points			
Location	**NGR Location**	**Elevation (mAOD)**	**Flow path/groundwater egress**
Back Lane Lagoon Sink	SD 50697 69264	~43	Along the Nether Kellet Syncline to a spring (at SD 51138 71293) and the lower reaches of Nether Beck (between NGR SD 50977 70645 and SD 50871 70770), located ~1.25 km north
Leapers Wood Sinkhole	SD 50820 69830	~52	
Back Lane French drain	SD 50570 69600	~43	To the Nether Beck headwaters via M6 drainage (culvert outfall at SD 50470 69623), located 50–100 m west & Along the Nether Kellet Syncline to a spring (at SD 51138 71293) and the lower reaches of Nether Beck (between NGR SD 50977 70645 and SD 50871 70770), located ~1.25 km north

The flow rate at each discharge location is controlled as follows:

- Flow at the Back Lane Lagoon Sink in the corner of the silt lagoon is gravity controlled. The rate of outflow is undefined, however it is controlled by the aperture of the 'receiving' fissure in the bedrock. Water entering the lagoon is pumped at a controlled rate from the dewatering sump in the base of the quarry void. Water is also abstracted from this lagoon for consumptive use on-site; a proportion of this water is settled and recirculated back into the lagoon
- Flow into the Back Lane French drain currently comprises settled surface water run-off only. The future proposed discharge would comprise both dewatering water and surface water run-off. The rate of inflow into the French drain would be controlled by the pump rate or by an engineered structure (ie pipe orifice plate or weir). Discharge of up to 200 l/s is permitted under EA Permit reference 017290438
- Excess water from dewatering is pumped to the Leapers Wood Sinkhole. Discharge at this location is currently permitted at 30.1 l/s under Permit reference 017290475/V002 the daily rate being controlled by pumping duration.

Future water management will require larger volumes of water to be discharged off-site than currently pertain. Under the proposed water management scheme, discharge will be undertaken to one (or more) locations with the maximum allowable being regulated to the greenfield rate.

5.2.2 Flow paths from discharge points

Tracer testing was undertaken in 1999, 2002 and 2023 as part of investigations at Leapers Wood and Back Lane Quarries. Their purpose was to determine the groundwater flow path from discharge locations to egress points. This involved the introduction of dye at the discharge locations (Back Lane Lagoon Sink, the Back Lane French drain/historical sink hole, and the Leapers Wood Sinkhole) and undertaking monitoring before and after the tests at springs and watercourses. The locations of dye resurgence are shown on *Drawing 3037/FRA/05* and are described below.

Tracer testing has demonstrated that water from all three of the proposed quarry discharge points is conveyed rapidly northwards along a discrete flow path, taking between 25-72 hours to issue between 1–1.25 km north of the site. This flow path is considered to be an active conduit system, which probably developed along this orientation due to the presence of a synclinal feature within the limestone (the Nether Kellet Syncline). The majority of discharged water from all three of the proposed quarry discharges, is conveyed along this flow path and reaches a single spring resurgence (NGR SD 51138 71293). Smaller amounts of water egress in downstream reaches of the Nether Beck (between NGR SD 50977 70645 and SD 50871 70770) either at a point spring egress or as a diffuse connection through the streambed. Immediately downstream of this, the receiving watercourses flow through agricultural land within the floodplain of the River Keer.

Sections of the groundwater flow path may become temporarily inactive at times of prolonged low rainfall, due to generally lower groundwater levels within the catchment. Monitoring during the 2023 tracer test indicated that this scenario occurs along the flow path, which connects the quarry discharges to the lower reaches of the Nether Beck (between NGR SD 50977 70645 and SD 50871 70770).

Tracer introduced to the Back Lane French drain was detected within the lower reaches of the Nether Beck and at the single spring resurgence at NGR SD 51138 71293. However, the primary resurgence was detected at the outfall of a concrete culvert under the M6 carriageway at NGR SD 50470 69623, where water enters the Nether Beck headwaters. The rapid transit time from the French drain to this culvert outfall (<3 days) indicates the presence of a discrete flow path, which permits the rapid transfer of water from the French drain towards the Nether Beck. The culvert forms part of the M6 highway drainage system, which is understood to be located above the elevation of the natural conduit system. This M6 drainage probably captures water draining from the ground surface through the limestone in this location, as well as water from the French drain.

The dimensions of the concrete culvert were confirmed by a laser scan survey (see Section 4.3) and will be unchanged by the proposed development. The maximum potential rate of flow into the Nether Beck headwaters will therefore remain unchanged from the existing situation. Using the culvert dimensions and the Hazen Williams approximation, the maximum rate through this culvert is estimated to be 509 l/s (calculation provided as *Appendix 3037/FRA/A4)*. The flow path of the Nether Beck is described in Section 4.3; it ultimately flows across the floodplain of the River Keer.

5.2.3 Water volumes during operational phase ('average' conditions)

The proposed continuation of sub-watertable mineral extraction will necessitate dewatering at an increased rate, to enable safe and dry mineral extraction. Three potential sources of water ingress to the quarry void exist: direct rainfall, diffuse groundwater inflow from the mass of the limestone and groundwater inflow from truncated karst features (conduits). Due to their inherent nature, the locations and connections of karst features, and which of these features transmits flow, cannot be determined definitively. Estimating future dewatering requirements therefore requires consideration of the inherent unpredictability of karst systems.

As it is not possible to definitively determine the complex and temporal, highly variable karst flow systems and whether these systems will be intercepted by the proposed deeper quarry void, an alternative approach has been adopted. The theoretical volume of water that could occur within the karst system and which could enter the quarry void, has been calculated. It is considered that the stream sinking into Dunald Mill Hole Cave system (located approximately at NGR SD 515 676) represents the headwaters of the catchment flowing into the karst system, and that all of this water could potentially be intercepted within Back Lane and/or Leapers Wood Quarries. The maximum, which could be conveyed through the system would in reality, be constrained by the maximum conveyancing capacity of conduits and cave systems (eg the sump which exists within the Dunald Mill Hole Cave system). The calculation method adopted represents a worst case scenario.

It is highly likely that this water would be naturally attenuated or constrained up-catchment by the maximum conveyancing capacity of conduits and cave systems (eg the sump which exists within the Dunald Mill Hole Cave system). However, in a worst-case scenario, if this water entered the quarry, it would be managed by the proposed water management system, outlined in Section 5.2.1.

Calculations estimating the volume of water that will need to be accommodated by the water management system are included within the accompanying Hydrogeological Impact Assessment (HIA, Hafren Water, 2023) and are summarised herein. The volume of such water under 'average' (ie not storm) conditions is provided in *Table 3037/FRA/T5* below. The maximum future discharge requirement, if the karst system was intercepted, is 17,790 m³/day (205.9 l/s) during normal operating conditions (no storm). This is less than the greenfield run-off rate of 232 l/s (see Section 7 below).

3037/FRA/T5: Groundwater ingress and incident rainfall under average conditions (not storm) including inflow from karst system							
Phase of development	**Inflow from incident rainfall [A] (l/s)**	**Inflow from incident rainfall volume (24 hour period) (m³/day)**	**Groundwater inflow [B] (l/s)**	**Groundwater inflow (24 hour period) (m³/day)**	**Flow from karst system[C] (l/s)**	**Inflow from karst system (m³/day)**	**Volume to be managed in a 24-hour period (m³/day)**
Full depth of extraction (-37 mAOD)	27.4	2,367	107.2	9,262	71.3	6,160	17,790

[A] Incident rainfall calculated using 80% December rainfall across the quarry catchment (75.5 ha)
[B] Calculated using the Dupuit-Forcheimer (Thiem-Dupuit) equation
[C] Incident rainfall calculated using 80% December rainfall across the Dunald Mill Hole Cave catchment (196.5 ha)

5.2.4 Managing water run-off during operational phase (storm conditions)

The volumes of rainfall-derived water generated during storm events are significantly greater than those under 'average' rainfall conditions. Although the total volume of water from storm events is not problematic, the temporary storage of storm-derived water requires consideration. Water from storm events would not need to be discharged off-site instantaneously but would be temporarily stored within the quarry void and subsequently discharged off-site, at the greenfield rate (see Section 7 below).

The volume of surface run-off from the site and incident rainfall into the quarry void under different storm return periods has been estimated by the Rational Method. If the karst system was intercepted, a greater volume of groundwater inflow would need to be managed on-site. The volumes of water flowing into the karst system and subsequently into the quarry void during storm events, will be significantly greater than those under 'average' rainfall conditions discussed in Section 5.2.3. It is highly likely that storm flows within the karst system would be naturally attenuated or constrained up-catchment by the maximum conveyancing capacity of conduits and cave systems (eg the sump which exists within the Dunald Mill Hole Cave system). However in a worst-case scenario, if this water entered the quarry, it would not need to be discharged off-site instantaneously, but would be temporarily stored within the quarry void and subsequently discharged off-site, at a restricted rate.

A calculation record is presented in *Appendix 3037/FRA/A5* and considers a conservative approach of no outflow. The results are summarised in *Table 3037/FRA/T6* below. Under the NPPF, the maximum relevant storm, for design purposes, is that which has a return period of 1 in 100-years plus an allowance for 50% climate change (design flood event).

The Rational Method is used to give peak flows (Q_p) and is of the form:

$$Q_p = 2.78\ CiA$$

Where: C = run-off co-efficient (dimensionless)
i = rainfall intensity (mm/hr)
A = catchment area (ha)

The run-off co-efficient, C, varies for different surfaces and values of 0.35, 0.85, 1.0 and 0.70 have been conservatively assumed for vegetated areas, hardstanding, open water and exposed rock/quarry floor surfaces, respectively.

Rainfall intensities have been obtained via the Flood Estimation Handbook (FEH) web service. Rainfall intensity is dependent on storm duration and a period of 6-hours has been assumed in this preliminary drainage analysis, which is a conservative (in terms of volume) estimate of the time for the total catchment to respond OR run-off has been estimated for a range of storm durations. The potential effect of climate change is accommodated by applying a 50% (upper estimate) uplift in design storm rainfall.

Table 3037/FRA/T6 details the total daily volume of water that would need to be attenuated if the karst system was intercepted, under storm conditions. The maximum volume of water required to be attenuated within the quarry void at its maximum operational depth, for the 1 in 100-year event (6-hour duration +50% climate change) is 141,761 m^3. The base of the quarry void area at the lowest sinking (-37 mAOD) will be approximately 275,769 m^2 (27.6 ha). This volume therefore equates to a water depth of 0.5 m, which could be readily accommodated within the quarry void.

3037/FRA/T6: Run-off rates and attenuation storage volumes								
Phase of development	Return period (6-hour duration)	Run-off inflow rate (l/s)	Run-off inflow volume after 6 hours [A] (m³)	Groundwater inflow [B] (l/s)	Groundwater inflow for 24 hours (m³)	[3]Storm inflow from the karst system (l/s)	Storm inflow from the karst system for 6 hours (m³)	Required Attenuation Storage for a 24-hour period (m³)
Full depth of extraction (-37 mAOD)	1 in 2	679	14,659	107	9,262	864	18,653	42,574
	1 in 10	1,035	22,346	107	9,262	1,316	28,434	60,042
	1 in 100	1,800	38,871	107	9,262	2,290	49,461	97,594
	1 in 100 years (+CC 50 %)	2,699	58,307	107	9,262	3,435	74,192	141,761

[A] Rational Method flood peak multiplied by a storm duration of 6 hours OR critical duration for quarry catchment
[B] Calculated using the Dupuit-Forcheimer (Thiem-Dupuit) equation
[C] Rational Method flood peak multiplied by a storm duration of 6 hours OR critical duration for Dunald Mill Hole Cave Stream catchment

5.3 Proposed post-restoration water management

5.3.1 Managing water post-restoration ('average' conditions)

Once final extraction depths have been reached, dewatering of the void will cease and water levels within the quarry void will increase. A waterbody will form within the quarry void due to ingress from rainfall and groundwater. The rate of inflow will be slow and the timescale for filling of the void commensurately long, due to the low hydraulic conductivity of the limestone and the large capacity of the void.

The rest level of the waterbody will be regulated passively by an engineered outfall, from which water will egress by gravity. The outfall will control the lake level to 45 mAOD. It is estimated that it will take between 10 and 15 years to reach its final level.

Variation in groundwater fluxes, combined with the predicted increased storm water inflows due to climate change, is such that the water level of the restoration waterbody will vary by small amounts temporarily. Any overflow would be passively controlled by the proposed engineered structure(s).

Discharge off-site will be limited to the greenfield run-off rate for the combined quarry catchment area; 232 l/s (detailed in Section 7 below).

5.3.2 Managing water post-restoration (storm conditions)

Run-off from the 75.5 ha quarry catchment will enter the quarry void. However, the majority of this area will comprise the restoration waterbody. With a rest surface water elevation of 45 mAOD, the surface area of the waterbody would be approximately 68 ha. Storm generated run-off across the surface of this waterbody and across the remaining 7.5 ha of surrounding restored quarry void will enter the restoration waterbody. The volume of storm run-off into the restoration waterbody has been estimated using the Rational Method, in *Table 3037/FRA/T7*. The calculation record is provided in *Appendix 3037/FRA/A6* and considers a conservative approach of no outflow. The run-off co-efficient, C, varies for different surfaces and values of 0.35 have been conservatively assumed for areas of restored (vegetated) quarry faces and 1.0 for open water respectively.

3037/FRA/T7: Storm run-off: quarry catchment (restoration phase)

Phase of development	Return period (6-hour duration)	Run-off inflow rate (l/s)	Run-off inflow volume after 6 hours [A] (m^3)	Required Attenuation Storage for a 24-hour period (m^3)
Restoration phase (waterbody)	1 in 2	887	19,155	19,155
	1 in 10	1,352	29,199	29,199
	1 in 100	2,351	50,792	50,792
	1 in 100 years (+CC 50 %)	3,527	76,188	76,188

[A] Rational Method flood peak multiplied by a storm duration of 6 hours OR critical duration for quarry catchment

The maximum volume of water required to be attenuated by the restoration waterbody for the 1 in 100-year event (6-hour duration +50% climate change) is 76,188 m^3. Across the surface of the restoration waterbody (680,000 m^2) this volume therefore equates to a water depth of 0.1 m; the height of the controlled engineered structure(s) therefore needs to be in excess of 45.1 mAOD to allow attenuation storage within the waterbody during storm events.

6 FLOOD RISK FROM THE SITE

6.1 Overview

The entire site is designated as Flood Zone 1 by the EA. Water will continue to be actively discharged off-site during mineral extraction and passively thereafter. Operational water management is outlined in Section 5.2 and the proposed water management post-restoration is outlined in Section 5.3. It is proposed to continue discharges off-site at the three current discharge locations; the Back Lane Lagoon Sink, the Back Lane French drain and the Leapers Wood Sinkhole, shown on *Drawing 3037/FRA/06*.

Water discharged at these locations enters the natural karst system and discharges into tributaries of the River Keer. Considerable effort has been made to investigate these subsurface flow paths during the current assessment. Tracer testing has determined the locations at which these discharges egress to surface watercourses. Details of the conceptual flow paths are described in Sections 4 and 5, shown on *Drawing 3037/FRA/05* and are summarised below.

A majority of discharged water from all three of the proposed quarry discharges reaches a single spring resurgence (NGR SD 51138 71293) and to a lesser extent, the downstream reaches of the Nether Beck (between NGR SD 51180 70385 and SD 50800 70800). The receiving watercourses flow through agricultural land within the floodplain of the River Keer. This area is part of the floodplain of the River Keer and is identified on EA flood mapping as Flood Zone 3. The proposed future water management will require larger volumes of water to be discharged off-site than currently occurs and therefore, the discharge to ground reaching these locations will potentially increase as the quarry void depth increases. Under the proposed water management scheme, discharge will be undertaken at one or more of these locations in combination with the maximum regulated to be at or below the greenfield rate.

The maximum volume of water that could be conveyed through the system would be constrained by the conveyancing capacity of karst conduits and cave systems. If flowpaths through the karst were to reach capacity, the system could back up and the ability to dispose of water at the three proposed discharge locations would be reduced. This water would therefore have to be temporarily stored on-site until water levels within the catchment fell, and the disposal of water off-site could be resumed.

A resurgence of water from the discharge to the Back Lane French drain was also recorded at the outfall of a concrete culvert under the M6 carriageway at NGR SD 50470 69623 where water enters the Nether Beck headwaters. This reach of the Nether Beck is identified on EA flood mapping to be in Flood Zone 3. The dimensions of the concrete culvert control the rate of flow into the Nether Beck at this location as described in Section 5.2. It has been estimated that the existing conveyance capacity of the culvert is approximately 509 l/s (Section 5.2), which is greater than the greenfield run-off rate estimated for the site of 232 l/s (see Section 7). These dimensions will remain unchanged by the proposed development. The maximum potential rate of flow into the Nether Beck headwaters will therefore remain unchanged.

6.2 Risk of groundwater and fluvial flooding

Fluvial (river) flooding occurs when a watercourse cannot accommodate the volume of water draining into it from the surrounding catchment. Groundwater flooding occurs when the watertable rises above the ground surface.

The nature of the discharge to ground is such that it is contained within discrete conduits which egress to springs and/or surface watercourses. Therefore, there is no potential for the proposed discharges to impact groundwater levels within the mass of the limestone. There is therefore no potential groundwater flood risk associated with the proposed development or water management scheme.

The volume of water discharged during site operation and restoration will increase from the current scenario due to dewatering, however surface water discharge rates will be at or below the greenfield rate. There is therefore no potential risk of fluvial flooding to the tributaries of the River Keer and mitigation measures are not required.

The maximum potential rate of flow into the Nether Beck headwaters is controlled by an existing culvert outfall, which drains from beneath the M6. This culvert will remain unchanged by the proposed development. The overall risk of fluvial flooding to the headwaters of the Nether Beck during site operation and restoration is therefore unchanged from the greenfield scenario and mitigation measures are not required.

6.3 Flooding of utilities

Sewer flooding occurs when sewers are overwhelmed by heavy rainfall or when pipes become blocked or broken. There is no information to suggest that the proposed discharge locations are linked to discharges from main sewers. Flood risk from sewers and water mains during site operation and restoration is therefore very low.

7 FLOOD RISK TO THE SITE

7.1 Overview

During site operation, active water management will be undertaken by discharging water off-site (to ground) at the existing discharge locations, as described in Section 5.2.

The management of water following storm events is described in Section 5.2. Water from storm events would not need to be discharged off-site instantaneously but would be stored, temporarily, within the quarry void and subsequently discharged off-site, at or below the greenfield rate (see Section 7 below).

Calculations included in Section 5.2, demonstrate that the volume of run-off generated during the 1 in 100-year event (6-hour duration +50% climate change) can be readily accommodated within the quarry void. When the base of the quarry void is at the lowest sinking (-37 mAOD) the volume of storm water will equate to a water depth of 0.5 m, which can be readily accommodated.

Proposed water management following quarry restoration is outlined in Section 5.3. Measures to allow a passive continuation of the proposed operational water management will be installed to control the final rest level of the restoration waterbody to 45 mAOD. Outfalls would be to either the Leapers Wood sinkhole, the Back Lane lagoon sinkhole, the Back Lane French drain or potentially in combination. Engineered structure(s) would control the rate of flow off-site to the greenfield run-off rate for the combined quarry catchment area.

7.2 Fluvial flooding

The EA Flood Map for Planning shown on *Drawing 3037/FRA/02* indicates that the site has a very low flood risk from rivers and is situated in Flood Zone 1, which equates to a chance of flooding of less than 0.1% each year.

The overall risk of fluvial flooding during site operation and restoration is therefore very low and mitigation measures are not required.

7.3 Surface water flooding

Surface water (pluvial) flooding occurs when rainwater does not drain away through the normal drainage system or soak into the ground, but instead lies on or flows over the ground. This can typically happen following high rainfall storm events when a drainage system is unable to accommodate the amount of surface run-off or when ground profiles are uneven and facilitate ponding.

The EA's 'Risk of Flooding from Surface Water' map (*Drawing 3037/FRA/03*) shows that the risk of surface water flooding is confined to minor watercourses in areas to the east, north and south of the quarry boundary.

During mineral extraction, surface water ponding may occur on the floor of the quarry void from where it will be directed to sumps by gravity flow, after which it will be managed by the existing water management system. The overall risk of surface water flooding to the operational site (both existing and proposed) is considered to be very low.

Following quarry restoration it is likely that there will be small and brief rises in the level of the waterbody, as excess surface water run-off flows into the restored void during heavy rainfall. A passive continuation of the proposed operational water management will apply; an outfall will be installed at the western margin of the restoration waterbody within the combined quarry void to regulate its level. The outfall structure(s) would control the rate of flow off-site to the greenfield run-off rate for the combined quarry catchment area.

The overall risk of surface water flooding post-restoration is therefore considered to be very low.

7.4 Surface water flooding due to changes in ground cover

7.4.1 Greenfield run-off

The planning boundary area for the combined quarries is approximately 95 ha, with a combined quarry void area of approximately 68 ha. Run-off from 75.5 ha of the quarry catchment will be managed by the operational water management system; a greenfield run-off rate of 232 l/s has been calculated for this area. The remaining 19.5 ha area is located around the periphery of the site and run-off from these areas is directed away from the quarry void by the existing topography and therefore does not enter the water management system. This will remain unchanged as part of the proposed development.

The peak 'greenfield' run-off rate for the drained area of the site has been estimated using the IH124 method on the HR Wallingford Greenfield Runoff Tool. The IH124 method to give a mean annual peak flow (Q_{BAR}) is of the form:

$$Q_{BAR(rural)} = 0.00108 AREA^{0.89} SAAR^{1.17} SOIL^{2.17} = 232 \text{ l/s}$$

Where: $Q_{BAR(rural)}$ mean annual flood, with a return period of 2.3 years (m^3/s)

AREA catchment area (km^2) = 0.755

SAAR(4170)	Standard Average Annual Rainfall (1941 to 1970) (mm) = 1137
SOIL	soil index = 2

A soil index of 2 has been selected. $Q_{BAR(rural)}$ can be multiplied using the UK Flood Studies Report regional growth curves to produce peak flood flows for any return period (the calculation record is provided in *Appendix 3037/FRA/A7*). An estimate of the greenfield run-off rate from the site is 232 l/s.

7.4.2 Developed site run-off (operational phase)

The volumes of rainfall-derived water generated during storm events are significantly greater than those under 'average' rainfall conditions. The volumes of rainfall-derived water generated from storm events during site operation, which would require attenuation within the quarry void, have been calculated – see Section 5.2. A worst-case scenario has been considered where the karst system was intercepted, when a greater volume of groundwater inflow would need to be managed.

Although the total volume of water from storm events can be readily managed, the temporary storage of storm-derived water requires consideration. Water from storm events would not need to be discharged off-site instantaneously but would be stored temporarily within the quarry void and subsequently discharged off-site, at or below the greenfield rate.

As detailed in *Table 3037/FRA/T6*, the maximum volume of water required to be attenuated within the quarry void at its maximum operational depth, for the 1 in 100-year event (6-hour duration +50% climate change) is 141,760 m^3. The base of the quarry void area at the lowest sinking (-37 mAOD) will be approximately 275,769 m^2 (27.6 ha). This volume therefore equates to a water depth of 0.5 m, which could be readily accommodated within the quarry void.

7.4.3 Developed site run-off (post-restoration)

After the completion of mineral extraction, dewatering will cease and water levels will increase within the quarry void. Surface run-off from the restored quarry will continue to be attenuated by the waterbody within the quarry void. It is proposed to install passive water level control measures at the western extent of Back Lane Quarry void, as described above.

The maximum volume of water required to be attenuated by the restoration waterbody for the 1 in 100-year event (6-hour duration +50% climate change) is 76,188 m^3 (see *Table 3037/FRA/T11*). Distributed across the restoration waterbody (680,000 m^2) this volume therefore equates to a water depth of 0.1 m; the height of the controlled engineered structure(s) therefore needs to be in excess of 45.1 mAOD.

7.5 Groundwater flooding

Groundwater flooding occurs when the watertable rises to meet the ground surface. It is most likely in areas above an aquifer where water levels can rise, following prolonged rainfall.

Groundwater is currently encountered during quarry working and is managed by the installed water management system. The continued operation of this system will manage potential flooding to a low level of risk. In the event of a failure in the system, operations may need to be temporarily suspended. Groundwater ingress into the quarry void would be slow and could readily be attenuated within the base of the quarry void until active water management was re-instated. The risk of groundwater flooding during site operation and restoration is therefore considered to be low.

7.6 Flooding from sewers and water mains

Sewer flooding occurs when sewers are overwhelmed by heavy rainfall or when pipes become blocked or broken. There is no information to suggest that sewer flooding poses a risk to the existing site. Future quarry development will take place within the existing footprint of the quarry and interaction with sewers or water mains is extremely unlikely. Flood risk from sewers and water mains during site operation and restoration is therefore very low.

8 MITITGATION MEASURES

8.1 Flood risk to and from the site

The potential flood risk to and from the site is considered to be low overall and the volumes of water can be readily attenuated on-site or managed by the proposed water management system. Therefore, no additional mitigation measures are required.

9 DRAINAGE STRATEGY

9.1 Overview

The Lead Local Flood Authority (LLFA) requires a detailed water management plan (or drainage strategy), for water generated from dewatering and surface water run-off. The proposed water management and volumes of water that are required to be managed are outlined within Sections 5.2 and 5.3 above and includes details of how water will be managed over the lifetime of the quarry. *Drawing 3037/FRA/06* illustrates the proposed water management and *Drawing 3037/FRA/05* illustrates the conceptual groundwater flow paths from the discharge points.

Further details of how water quality, ecology and exceedance events will be managed are outlined below.

9.2 Run-off quality

The proposed water management system is a continuation of the current operations. Water has been managed effectively for a prolonged period and it is anticipated that the same will apply in the future.

The 'first flush' of rainfall generally has a higher pollutant load than subsequent run-off. This initial flow will be contained within the site. This will be achieved by intercepting groundwater ingress and incident rainfall and directing it to one or more sumps within the quarry void. These sumps will provide settlement capacity, reducing the suspended solid content of the water.

As with all quarries, there is a risk of small-scale accidental release of chemicals or hydrocarbons from mobile plant or other chemicals used on-site. Adherence to the industry best practice pollution control measures will be employed at the site, as detailed on the Government website (https://www.gov.uk/guidance/pollution-prevention-for-businesses). These measures will ensure that any residual risk from hydrocarbon or chemical spills will be removed. Run-off from vehicle parking areas will also pass through an oil-interceptor prior to discharging off-site.

9.3 Ecology

The proposed post-restoration water management will enhance existing habitats and provide new ones within the site wherever possible. The exposed quarry benches will be landscaped and a waterbody will form within the quarry void, providing habitat for aquatic flora and fauna. The ecological potential of the restoration scheme will be maximised by utilising planting and creating a range of habitats.

10 SUMMARY AND CONCLUSIONS

Leapers Wood Quarry has been an operational limestone quarry for several decades. A Section 73 Planning Application has been prepared for proposed deepening of the existing quarry to - 37 metres Above Ordnance Datum (mAOD), to secure a long-term supply of limestone. The Planning Application is also for a time extension for mineral extraction and restoration operations, through the variation of Conditions 1 (timescales), 2 (approved plans), 4 (depth of mineral extraction), 6 (phasing plans), 41 (final restoration scheme) and 43 (water level timescales) of Planning Permission 01/09/0360.

Leapers Wood Quarry and the adjacent Back Lane Quarry, operated by Aggregate Industries, have liaised extensively to ensure that the combined quarry void of the two operations will continue to be managed effectively in all aspects, including practical water management.

Future mineral extraction within the combined quarry areas is scheduled to continue until 2077. Progressive restoration will occur with the final landscaping for restoration of both sites being completed by 2078. In accordance with the PPG, for Less Vulnerable development with a lifetime between 2061 and 2100 the central allowance is applicable. Therefore, a climate change allowance of 35% is appropriate in this instance, however for robustness a 50% allowance has been considered within the drainage strategy for the site.

The proposed water management scheme (drainage strategy) has included settlement capacity and pollution control measures to control the water quality of the discharge off-site.

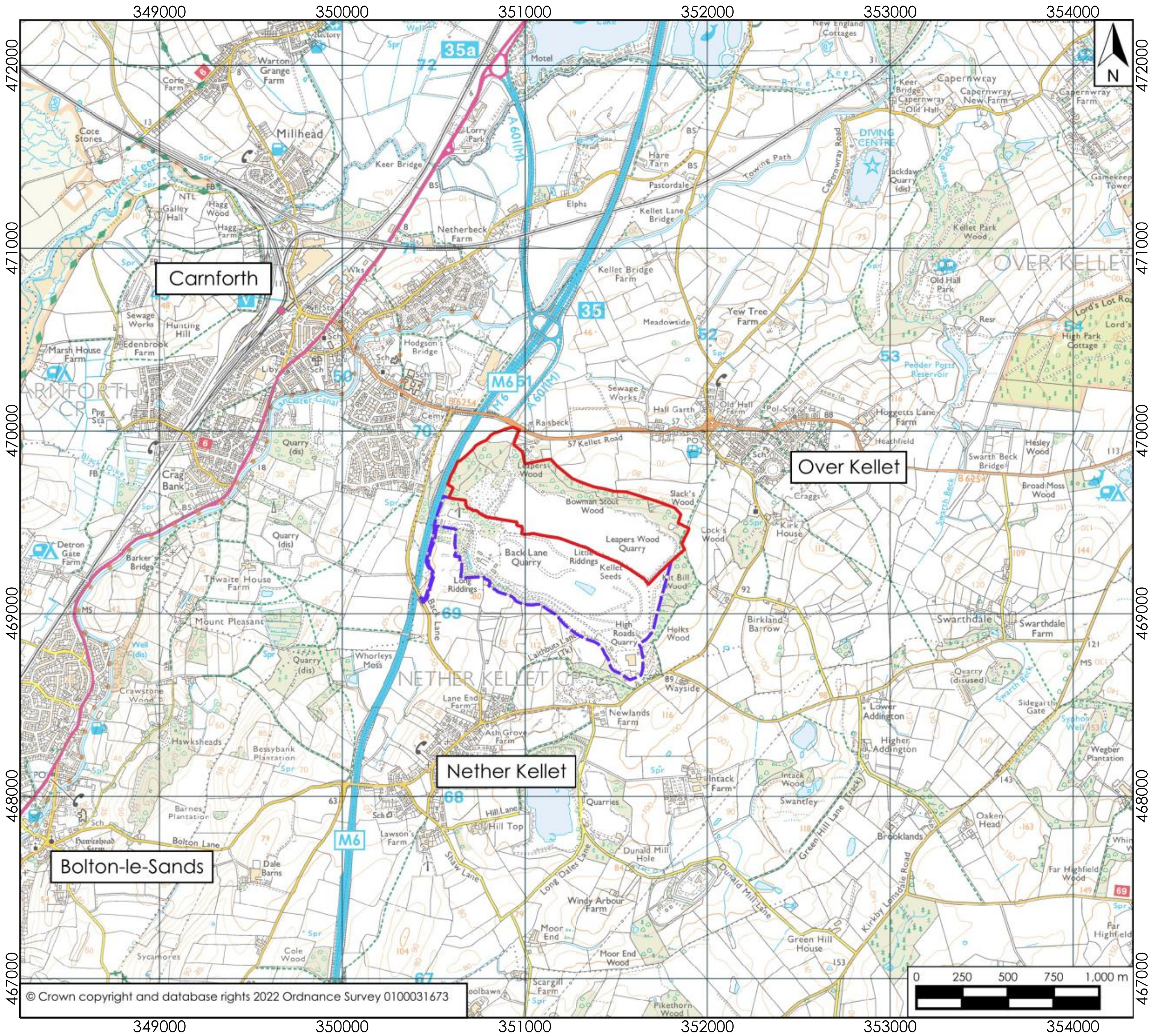
The site is located wholly within Flood Zone 1 and is considered to be at low risk of flooding from all sources. The continuation of mineral extraction at the site is not expected to increase flood risk to the site or external areas.

As the site is at low risk of flooding, there is no requirement for mitigation beyond a continuation of the existing water management regime. Water from storm events would not need to be discharged off-site instantaneously but would be temporarily stored within the quarry void and subsequently discharged off-site, at or below the greenfield rate.

Restoration of the majority of the quarry void will be to open water. Once final extraction depths have been reached, dewatering of the void will cease and the workings will be allowed to fill. A waterbody will form within the quarry void due to ingress from rainfall and groundwater. Passive control measures will be installed at the western extent of Back Lane Quarry, which would control the water level to 45 mAOD. These controls would essentially represent a continuation of the proposed operational water management and will regulate the discharge off-site to the greenfield run-off rate. The elevation of the passive overflow structure will be set to allow attenuation storage within the waterbody during storm events.

It is considered that the proposals are appropriate in terms of flood risk and the site can be suitably drained both during the mineral extraction phase and in perpetuity thereafter.

DRAWINGS



Key

Site Boundary

Back Lane Site Boundary

Scale correct at A4

Client	Tarmac Trading Ltd
Title	Site Location
Project	Leapers Wood Quarry
Drawing	3037/FRA/01
Version	1
Date	Mar 2024
Scale	1:30,000

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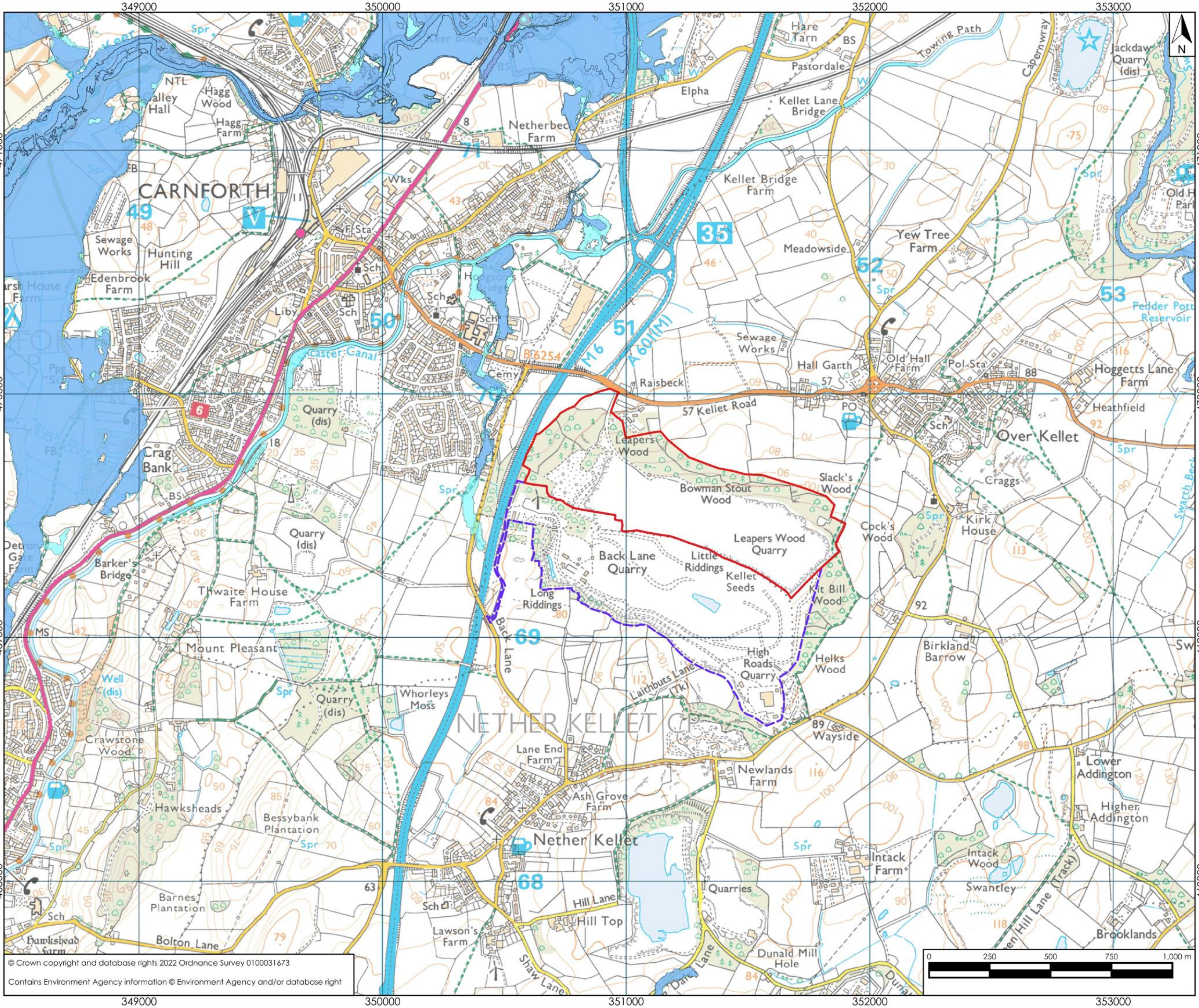

Key

- Site Boundary
- Back Lane Site Boundary
- Flood Zone 2
- Flood Zone 3

Scale correct at A3

Client	Tarmac Trading Ltd
Title	Fluvial Flood Zones
Project	Leapers Wood Quarry
Drawing	3037/FRA/02
Version	1
Date	Mar 2024
Scale	1:15,000

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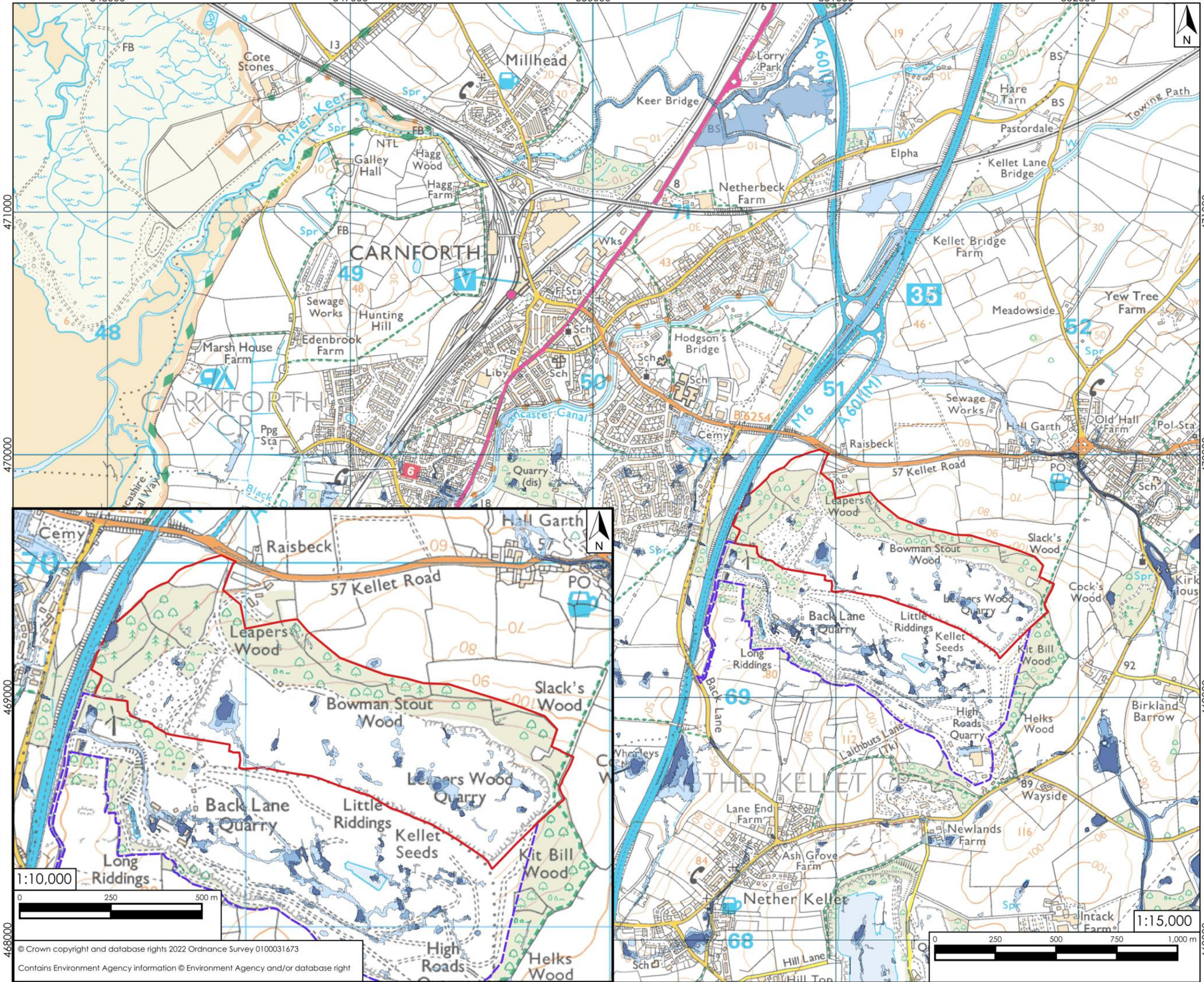

Key

- Site Boundary
- Back Lane Site Boundary
- High Risk (1 in 30 years)
- Medium Risk (1 in 100 years)
- Low Risk (1 in 1000 years)

Scale correct at A3

Client	Tarmac Trading Ltd
Title	Surface Water Flood Risk
Project	Leapers Wood Quarry
Drawing	3037/FRA/03
Version	1
Date	Mar 2024
Scale	See maps

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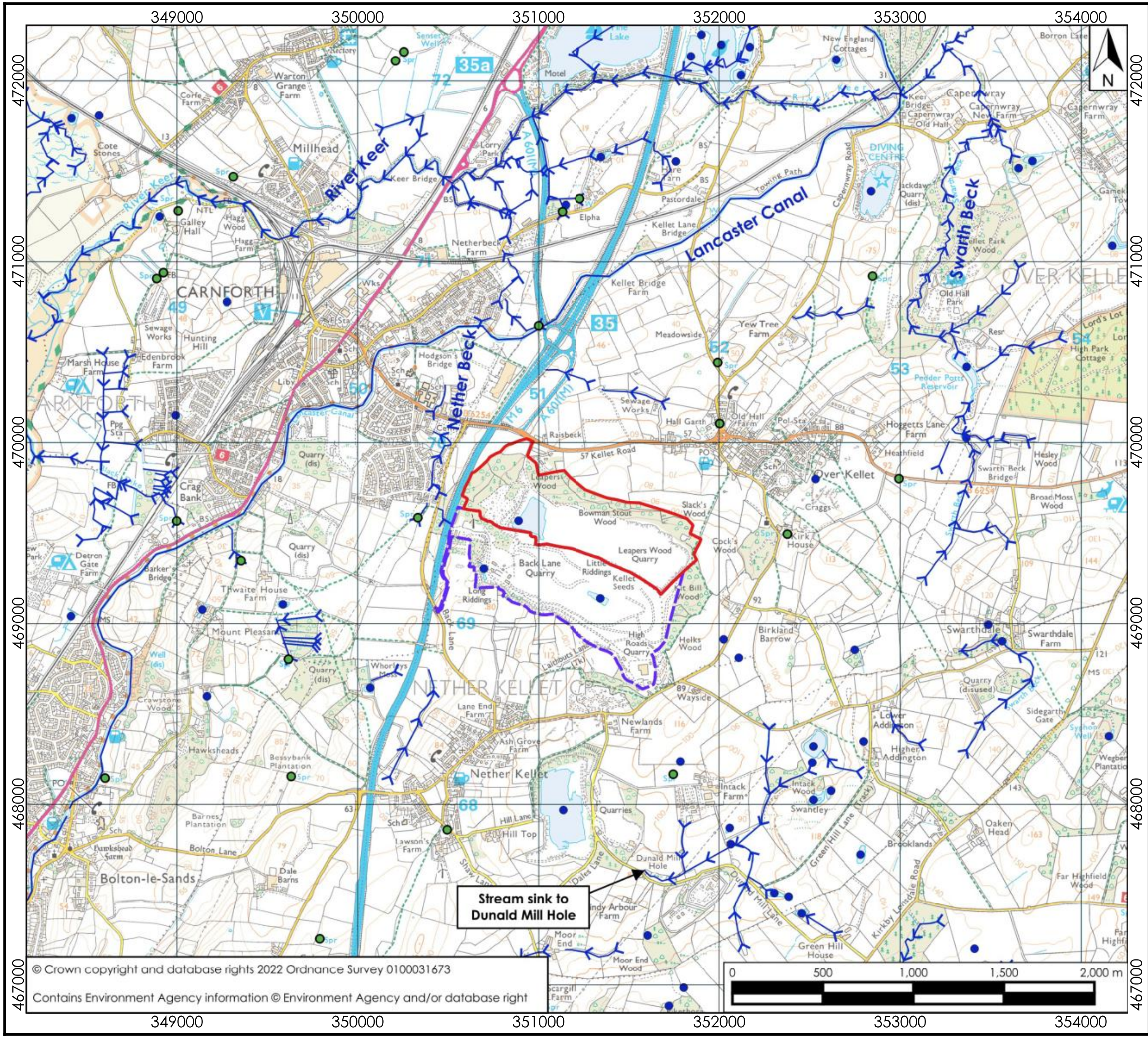

Key

- Site Boundary
- Back Lane Site Boundary
- Watercourse
- Canal
- Spring
- Waterbody

Scale correct at A4

Client	Tarmac Trading Ltd
Title	Water Features
Project	Leapers Wood Quarry
Drawing	3037/FRA/04
Version	4
Date	Mar 2024
Scale	1:30,000

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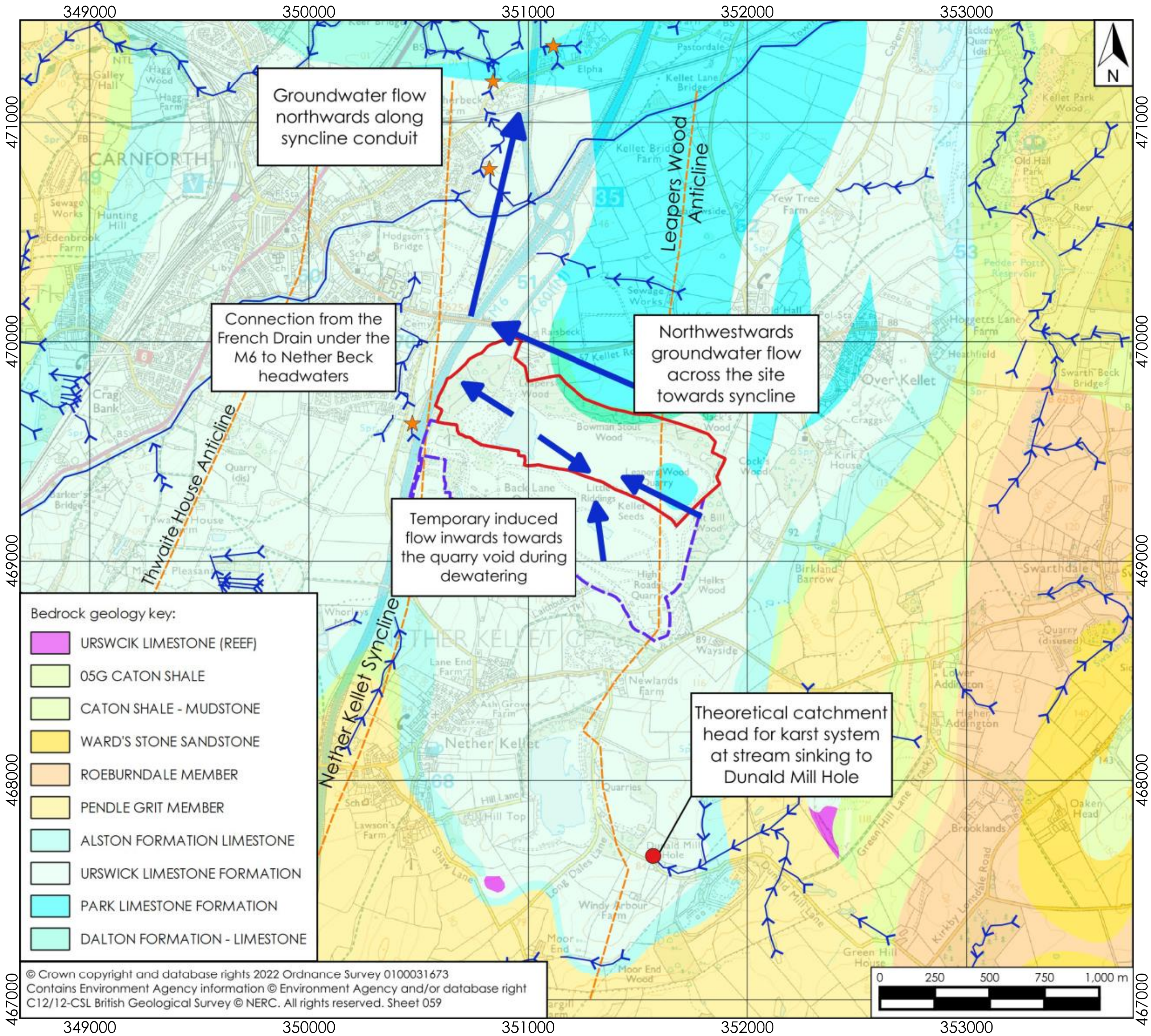

Key

- Site Boundary
- Back Lane Site Boundary
- Watercourse
- Canal
- Fold features
- Tracer test resurgence locations
- Dunald Mill Hole and Cave

Scale correct at A4

Client	Tarmac Trading Ltd
Title	Conceptual Groundwater Flow Paths
Project	Leapers Wood Quarry
Drawing	3037/FRA/05
Version	1
Date	Mar 2024
Scale	1:25,000

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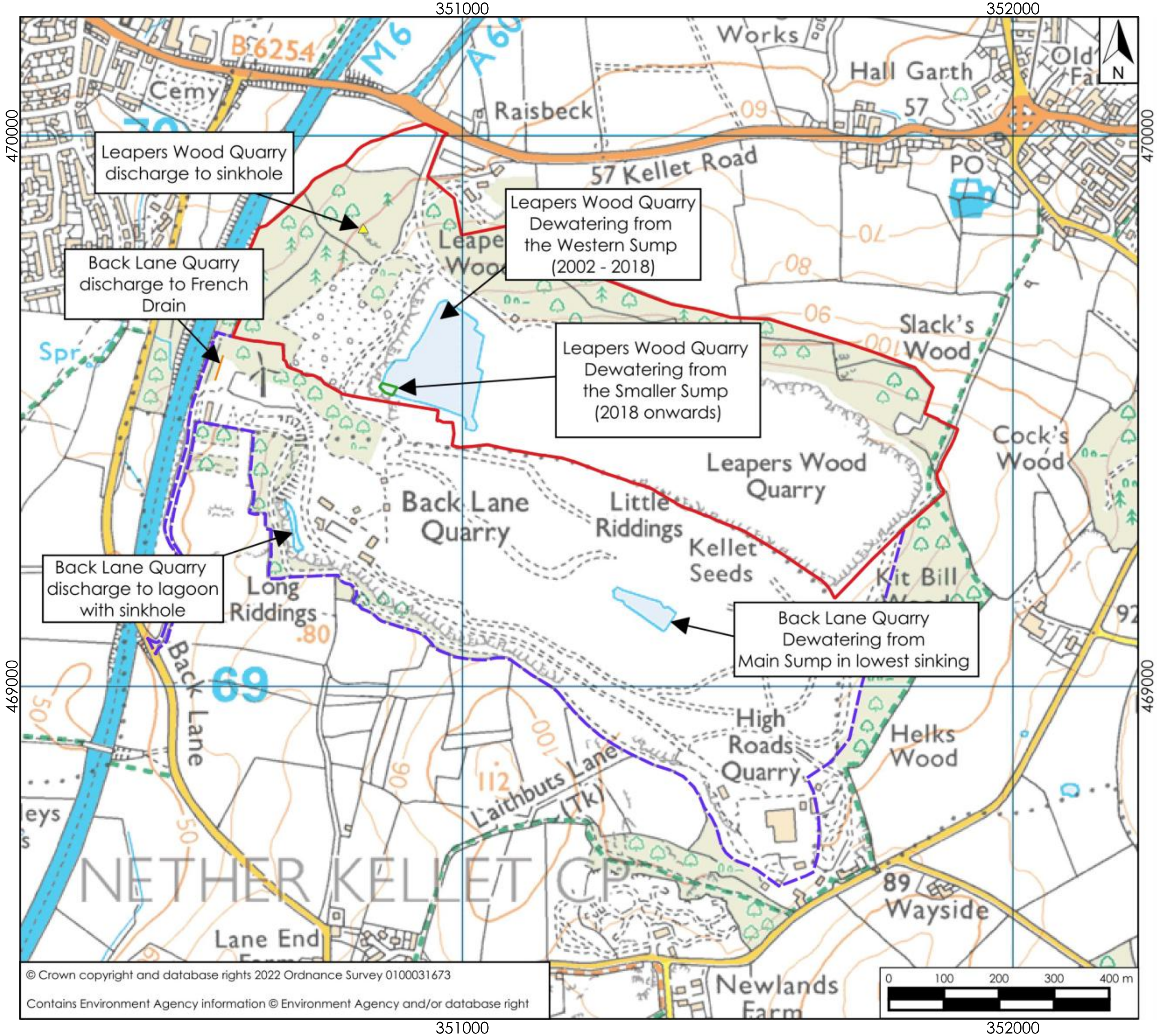

Key

- Site Boundary
- Back Lane Site Boundary
- Sump Areas
- New Sump Location
- Sinkhole
- French Drain

Scale correct at A4

Client	Tarmac Trading Ltd
Title	Fluvial Flood Zones
Project	Leapers Wood Quarry
Drawing	3037/FRA/06
Version	1
Date	Mar 2024
Scale	1:10,000

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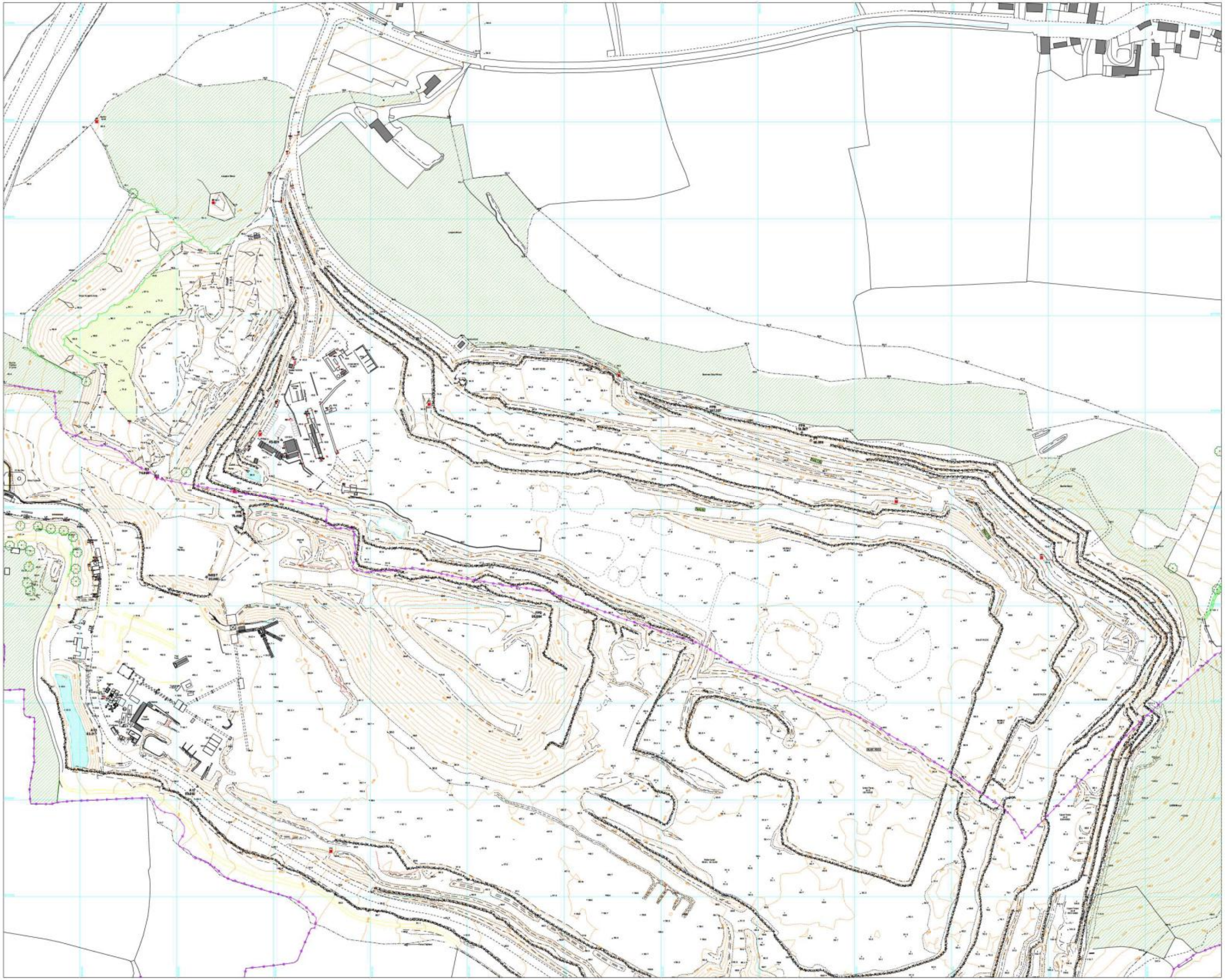
APPENDIX 3037/FRA/A1

Topographic survey



TARMAC
A CRH COMPANY

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L43 LEAPERS WOOD

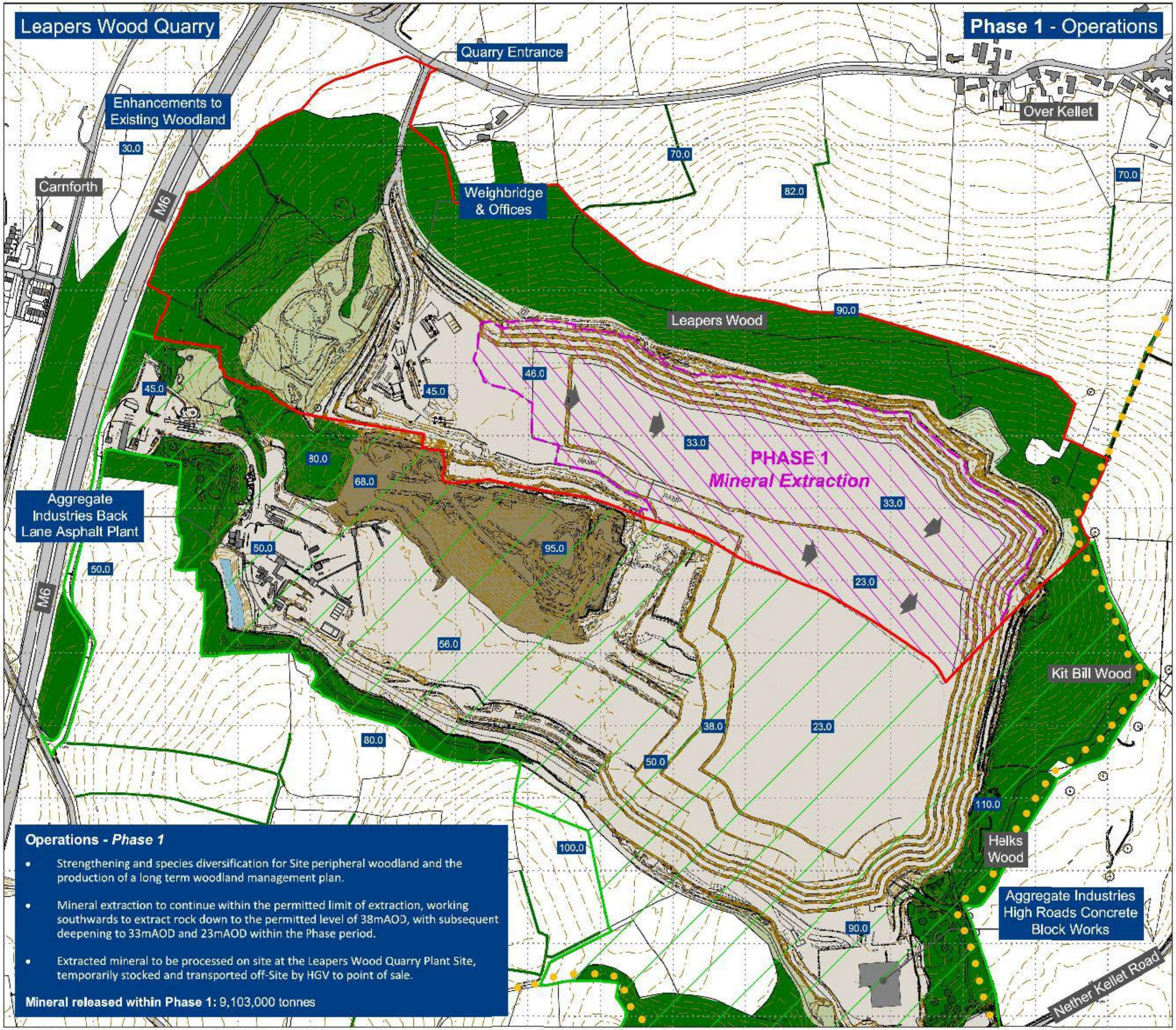
TOPOGRAPHIC SURVEY
22nd APRIL 2022

LIS Models Used To Create Plot
L43 LEAPERS WOOD 2022-04-22 QU

Drawn By	LIS Drawing Number
DWH	L43 - 00048
Scale	Drawing Name
1 : 1250	L43 2022-04-22 QU A0L.PDF

APPENDIX 3037/FRA/A2

Phasing plans



Operations - *Phase 1*

- Strengthening and species diversification for Site peripheral woodland and the production of a long term woodland management plan.
- Mineral extraction to continue within the permitted limit of extraction, working southwards to extract rock down to the permitted level of 38mAOD, with subsequent deepening to 33mAOD and 23mAOD within the Phase period.
- Extracted mineral to be processed on site at the Leapers Wood Quarry Plant Site, temporarily stocked and transported off-Site by HGV to point of sale.

Mineral released within Phase 1: 9,103,000 tonnes

Legend

- *Application Boundary*
- *Other Land Under the Ownership of the Applicant*
- *Back Lane Quarry*
- *Surrounding Woodland*
- *Buildings & Roads*
- *Disturbed Land - Leapers Wood & Back Lane Quarries*
- *Existing Overburden Tip / Landform*
- 70.0 *Contours (2m Intervals) & Spot Heights (m AOD)*
- *Limit of Extraction within Phase 1*
- *Initial Direction of Working (with Subsequent Deepening)*
- *Public Rights of Way (PROW)*

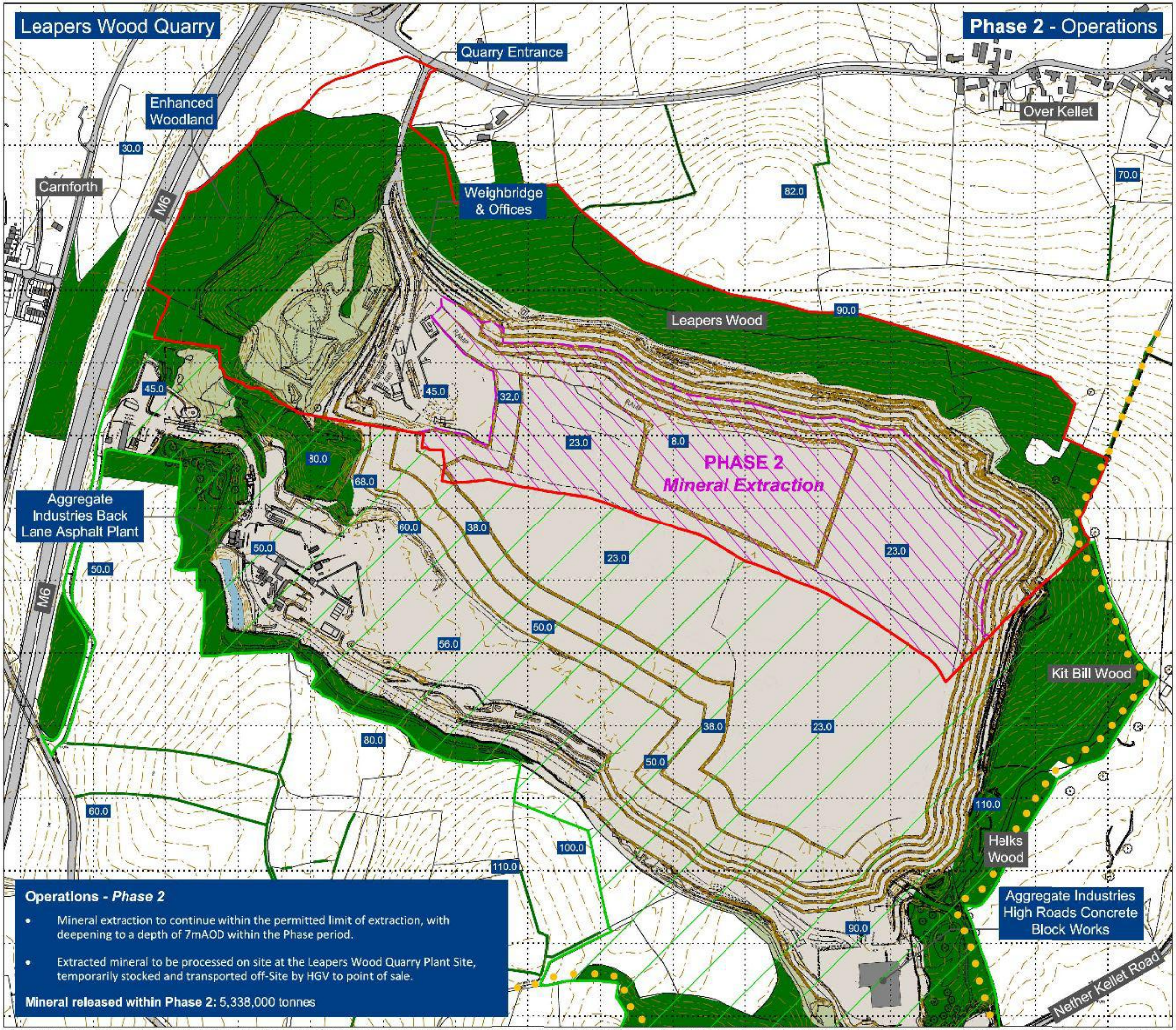
Please Note. Tarmac and AI Geologists have worked together to ensure a fully integrated mineral extraction scheme will progress concurrently for both Leapers Wood and Back Lane Quarries.

KEDD Limited

TARMAC
A CRH COMPANY

Site Name: Leapers Wood Quarry	
Drawing Name: Phase 1 - Operations	
Drawn By: R.Duncan	*Scale @ A3:* 1:5,000
Date: January 2024	*Drawing Number:* KD.BKLN.1.D.019

N



Operations - *Phase 2*

- Mineral extraction to continue within the permitted limit of extraction, with deepening to a depth of 7mAOD within the Phase period.
- Extracted mineral to be processed on site at the Leapers Wood Quarry Plant Site, temporarily stocked and transported off-Site by HGV to point of sale.

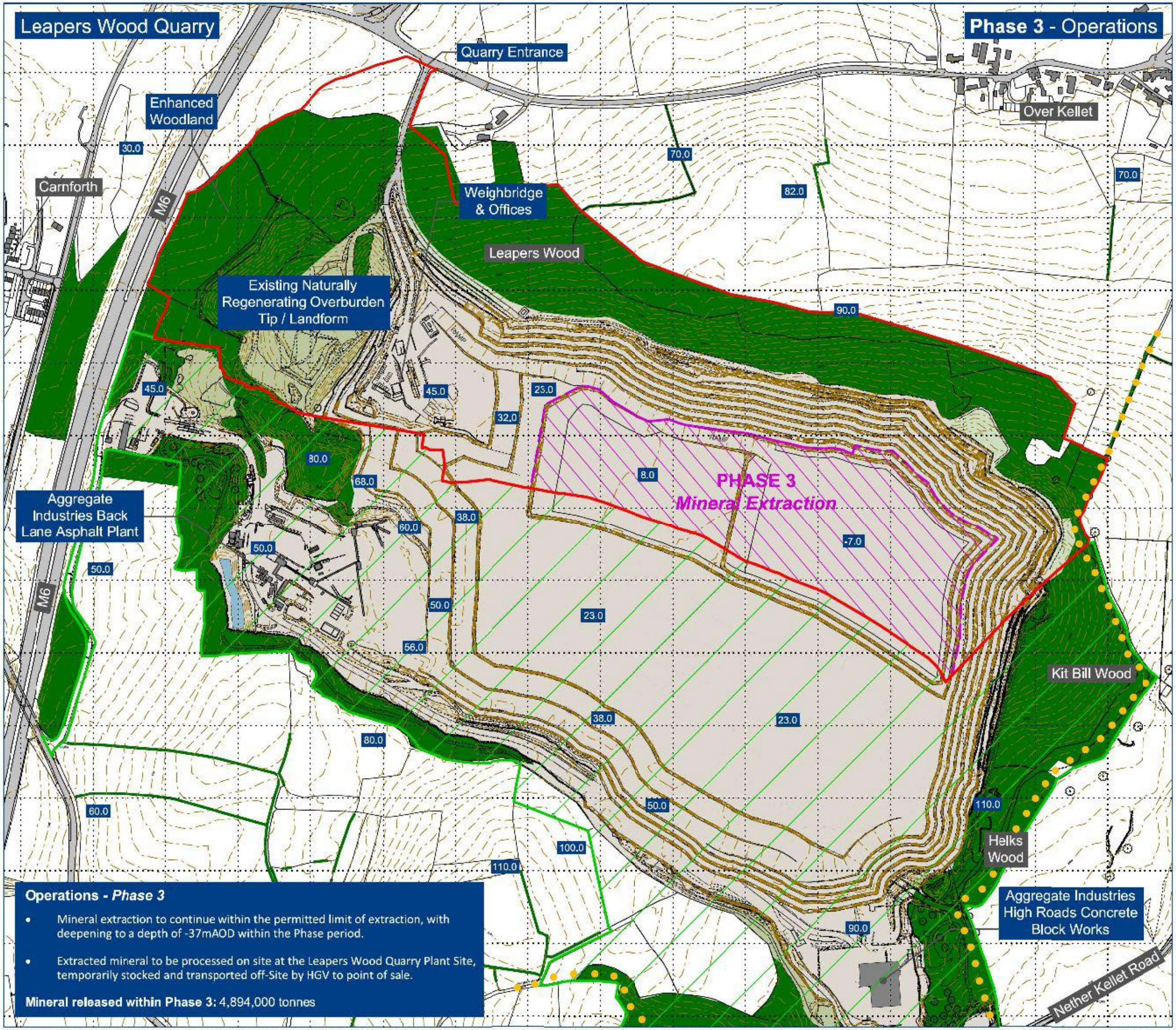
Mineral released within Phase 2: 5,338,000 tonnes

KEDD Limited

TARMAC
A CRH COMPANY

Site Name:	Leapers Wood Quarry
Drawing Name:	Phase 2 - Operations
Drawn By: R.Duncan	*Scale @ A3:* 1:5,000
Date: January 2024	*Drawing Number:* KD.BKLN.1.D.020

N



Operations - *Phase 3*

- Mineral extraction to continue within the permitted limit of extraction, with deepening to a depth of -37mAOD within the Phase period.
- Extracted mineral to be processed on site at the Leapers Wood Quarry Plant Site, temporarily stocked and transported off-Site by HGV to point of sale.

Mineral released within Phase 3: 4,894,000 tonnes

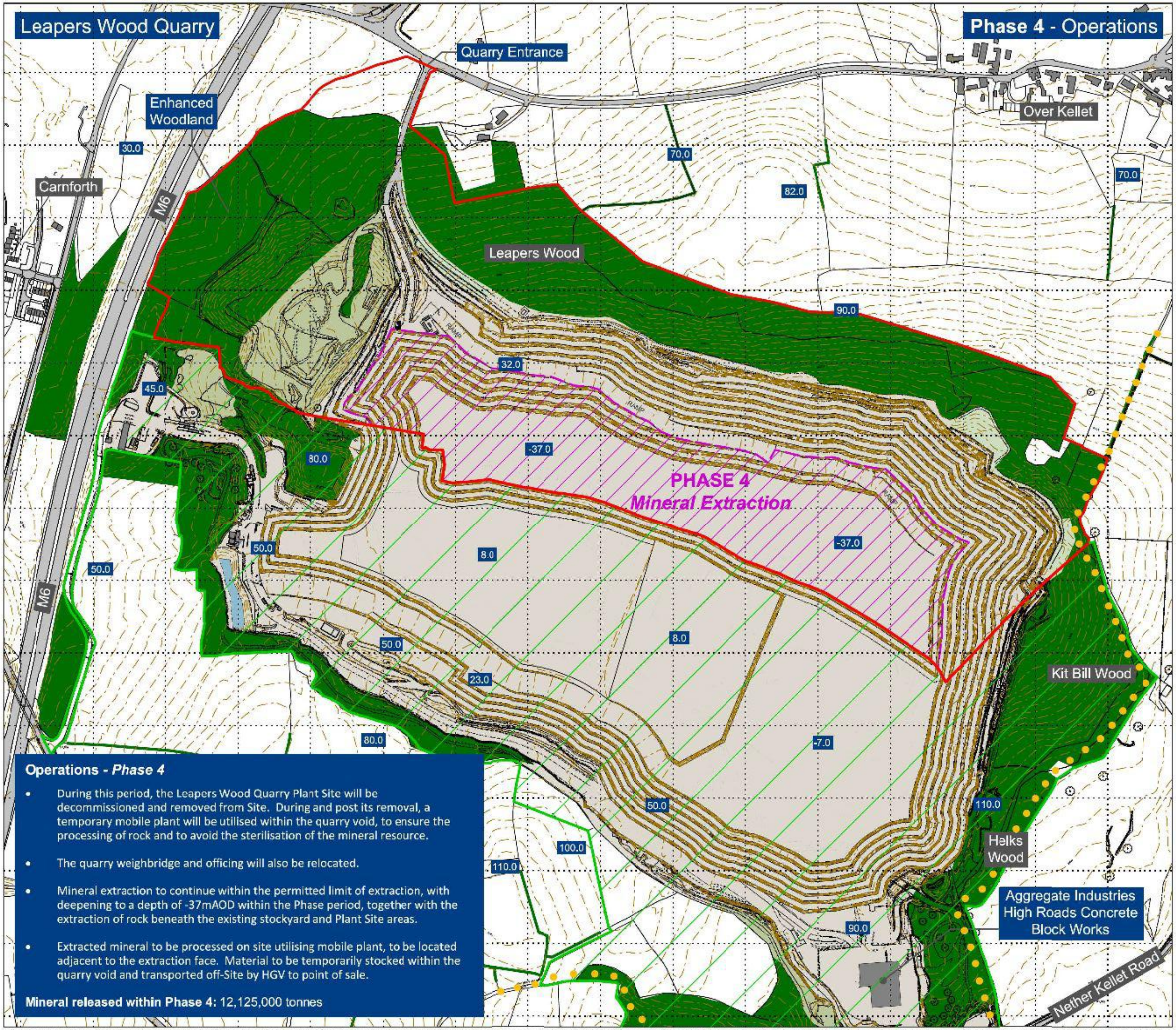
Legend

- Application Boundary
- Other Land Under the Ownership of the Applicant
- Back Lane Quarry
- Surrounding Woodland
- Buildings & Roads
- Disturbed Land - Leapers Wood & Back Lane Quarries
- 70.0 Contours (2m Intervals) & Spot Heights (m AOD)
- Limit of Extraction within Phase 3
- Public Rights of Way (PROW)

KEDD Limited

TARMAC
A CRH COMPANY

Site Name:	Leapers Wood Quarry
Drawing Name:	Phase 3 - Operations
Drawn By: R.Duncan	Scale @ A3: 1:5,000
Date: January 2024	Drawing Number: KD.BKLN.1.D.021



Operations - *Phase 4*

- During this period, the Leapers Wood Quarry Plant Site will be decommissioned and removed from Site. During and post its removal, a temporary mobile plant will be utilised within the quarry void, to ensure the processing of rock and to avoid the sterilisation of the mineral resource.
- The quarry weighbridge and officing will also be relocated.
- Mineral extraction to continue within the permitted limit of extraction, with deepening to a depth of -37mAOD within the Phase period, together with the extraction of rock beneath the existing stockyard and Plant Site areas.
- Extracted mineral to be processed on site utilising mobile plant, to be located adjacent to the extraction face. Material to be temporarily stocked within the quarry void and transported off-Site by HGV to point of sale.

Mineral released within Phase 4: 12,125,000 tonnes

Legend

- Application Boundary
- Other Land Under the Ownership of the Applicant
- Back Lane Quarry
- Surrounding Woodland
- Buildings & Roads
- Disturbed Land - Leapers Wood & Back Lane Quarries
- 70.0 Contours (2m Intervals) & Spot Heights (m AOD)
- Limit of Extraction within Phase 4
- Public Rights of Way (PROW)

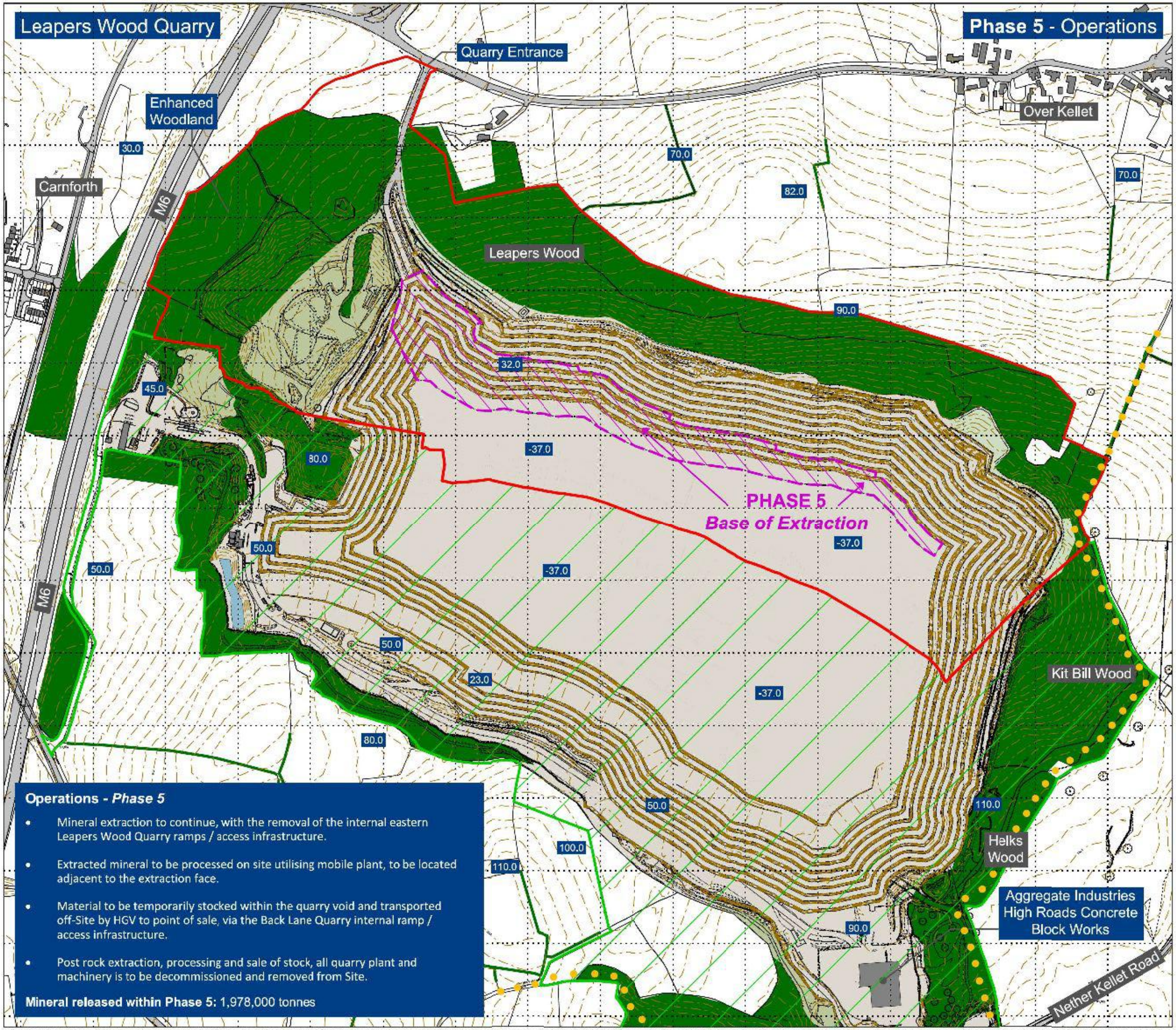
KEDD Limited

TARMAC
A CRH COMPANY

Site Name:	Leapers Wood Quarry
Drawing Name:	Phase 4 - Operations
Drawn By: R.Duncan	Scale @ A3: 1:5,000
Date: January 2024	Drawing Number: KD.BKLN.1.D.022

Leapers Wood Quarry

Phase 5 - Operations



Operations - *Phase 5*

- Mineral extraction to continue, with the removal of the internal eastern Leapers Wood Quarry ramps / access infrastructure.
- Extracted mineral to be processed on site utilising mobile plant, to be located adjacent to the extraction face.
- Material to be temporarily stocked within the quarry void and transported off-Site by HGV to point of sale, via the Back Lane Quarry internal ramp / access infrastructure.
- Post rock extraction, processing and sale of stock, all quarry plant and machinery is to be decommissioned and removed from Site.

Mineral released within Phase 5: 1,978,000 tonnes

Legend

- Application Boundary
- Other Land Under the Ownership of the Applicant
- Back Lane Quarry
- Surrounding Woodland
- Buildings & Roads
- Disturbed Land - Leapers Wood & Back Lane Quarries
- Contours (2m Intervals) & Spot Heights (m AOD) (70.0)
- Limit of Extraction within Phase 5
- Public Rights of Way (PROW)

KEDD Limited

TARMAC A CRH COMPANY

Site Name: Leapers Wood Quarry

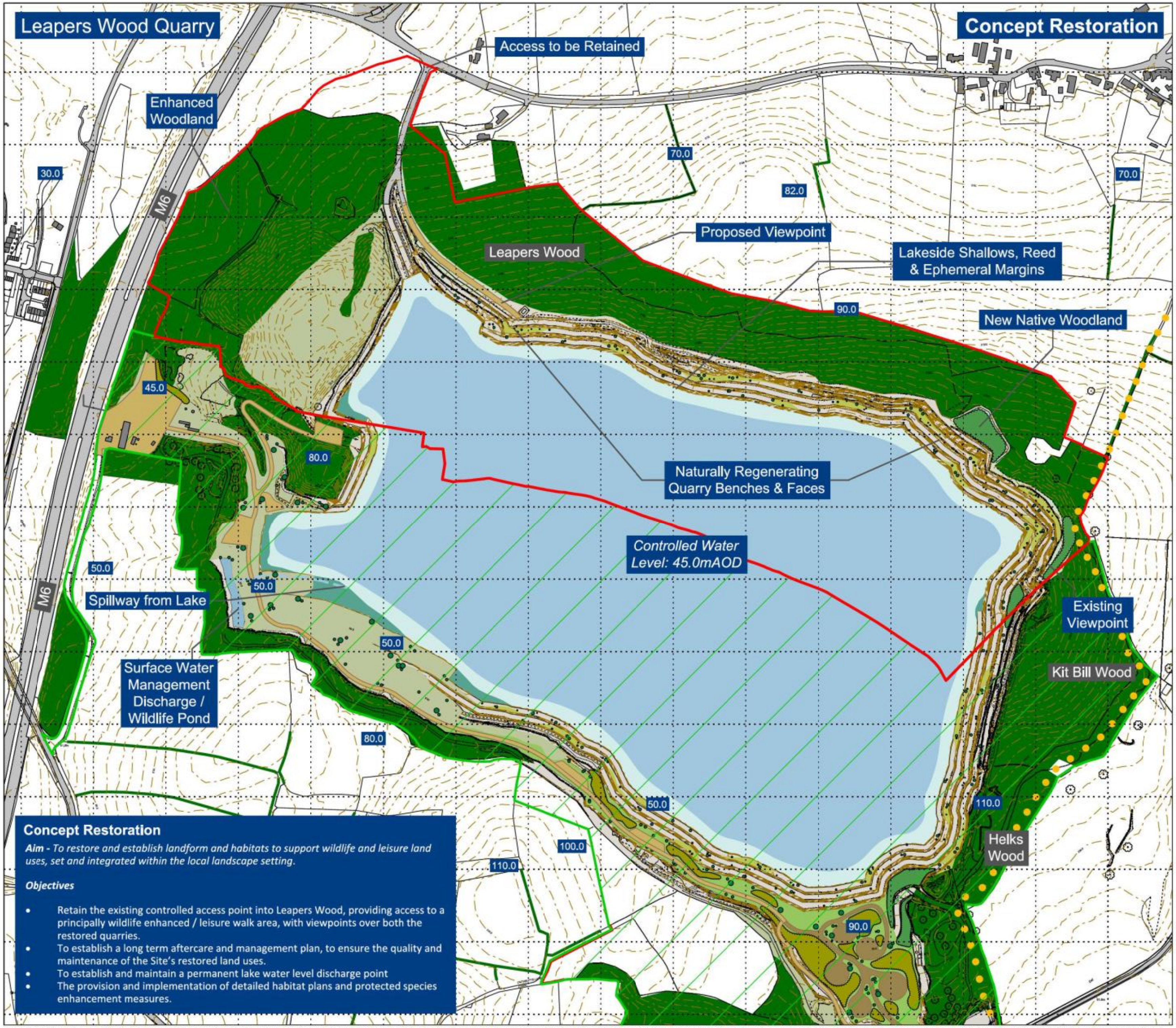
Drawing Name: Phase 5 - Operations

Drawn By:	Scale @ A3:
R.Duncan	1:5,000
Date:	**Drawing Number:**
January 2024	KD.BKLN.1.D.023

N

APPENDIX 3037/FRA/A3

Restoration plan



Concept Restoration

***Aim** - To restore and establish landform and habitats to support wildlife and leisure land uses, set and integrated within the local landscape setting.*

Objectives

- Retain the existing controlled access point into Leapers Wood, providing access to a principally wildlife enhanced / leisure walk area, with viewpoints over both the restored quarries.
- To establish a long term aftercare and management plan, to ensure the quality and maintenance of the Site's restored land uses.
- To establish and maintain a permanent lake water level discharge point
- The provision and implementation of detailed habitat plans and protected species enhancement measures.

Legend

- Application Boundary
- Other Land Under the Ownership of the Applicant
- Back Lane Quarry
- Surrounding Woodland / Vegetation Structure
- Buildings & Roads
- Exposed Quarry Benches & Faces - Natural Regeneration
- Proposed Calcareous Grassland
- Proposed Open Mosaic Habitat
- Proposed Internal Access Infrastructure / Tracks
- Proposed Native Woodland
- Proposed Native Scrub
- Proposed Amenity Lake & Shallow Margins
- Proposed Reed Development / Aquatic Marginals
- 70.0 Contours (2m Intervals) & Spot Heights (mAOD)
- Public Rights of Way (PROW)

KEDD Limited

TARMAC A CRH COMPANY

Site Name: Leapers Wood Quarry	
Drawing Name: Concept Restoration	
Drawn By: R.Duncan	**Scale @ A3:** 1:5,000
Date: January 2024	**Drawing Number:** KD.BKLN.1.D.024

N

APPENDIX 3037/FRA/A4

M6 culvert: pipe flow calculation

hafrenwater
environmental water management

M6 culvert pipe flow calculation

Source: https://www.calctool.org/fluid-mechanics/pipe-flow

Formula: Hazen–Williams equation

Pipe diameter	0.6 m
Material	Concrete
Roughness coefficient	110
Pipe length	49.2 m
Drop	0.3 m
Flow velocity	1.8 m/s
Flow discharge	509 liters /s

Material	Roughness coefficient
Cast iron	100
Concrete	110
Copper	140
Plastic (PVC)	150
Steel	120

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APPENDIX 3037/FRA/A5

Storm run-off: operational phase

Incident rainfall storm runoff calculation

	Vegetated	Hardstanding	Open Water	Exposed bedrock
Runoff Coefficient	0.35	0.85	1.00	0.70
Area Ha	1.5	10.5	0.5	63.0

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

- *C* co-efficient of run-off (dimensionless)
- *i* rainfall intensity (mm/hr)
- *A* catchment area (Ha)

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

Duration	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Runoff from open water *3	Runoff from exposed bedrock *3	Total Runoff	Total Volume
	2 year event							
hours	mm	mm/hr	l/s	l/s	l/s	l/s	l/s	m^3
0.25	6.7	26.9	39	667	37	3295	4039	3635
0.5	9.1	18.2	27	451	25	2226	2729	4912
1	11.9	11.9	17	295	17	1459	1788	6437
2	16.6	8.3	12	206	12	1018	1247	8979
4	22.7	5.7	8	141	8	697	854	12301
6	27.1	4.5	7	112	6	554	**679**	**14659**
8	30.5	3.8	6	95	5	467	572	16482
12	35.6	3.0	4	74	4	364	**446**	**19263**
16	39.5	2.5	4	61	3	303	371	21367
20	42.6	2.1	3	53	3	261	320	23055
24	45.3	1.9	3	47	3	231	283	24483
28	47.6	1.7	2	42	2	208	255	25727
32	49.7	1.6	2	38	2	190	233	26857
36	51.6	1.4	2	36	2	176	215	27896
40	53.4	1.3	2	33	2	164	200	28870
44	55.1	1.3	2	31	2	153	188	29789
48	56.7	1.2	2	29	2	145	177	30665

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

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www.hafrenwater.com

Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 2-year event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries

Date: Sep-23

Incident rainfall storm runoff calculation

	Vegetated	Hardstanding	Open Water	Exposed bedrock
Runoff Coefficient	0.35	0.85	1.00	0.70
Area Ha	1.5	10.5	0.5	63.0

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

C	co-efficient of run-off (dimensionless)
i	rainfall intensity (mm/hr)
A	catchment area (Ha)

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

Duration	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Runoff from open water *3	Runoff from exposed bedrock *3	Total Runoff	Total Volume
	10 year event							
hours	mm	mm/hr	l/s	l/s	l/s	l/s	l/s	m^3
0.25	12.2	48.6	71	1207	68	5963	7309	6578
0.5	16.5	33.0	48	819	46	4046	4959	8925
1	21.6	21.6	32	536	30	2647	3244	11679
2	27.8	13.9	20	345	19	1703	2088	15033
4	35.8	8.9	13	222	12	1097	1344	19360
6	41.3	6.9	10	171	10	844	**1035**	**22346**
8	45.5	5.7	8	141	8	697	854	24591
12	51.6	4.3	6	107	6	528	**647**	**27934**
16	56.2	3.5	5	87	5	431	528	30406
20	59.9	3.0	4	74	4	367	450	32380
24	62.9	2.6	4	65	4	321	394	34035
28	65.6	2.3	3	58	3	287	352	35501
32	68.1	2.1	3	53	3	261	320	36832
36	70.4	2.0	3	49	3	240	294	38071
40	72.5	1.8	3	45	3	222	272	39234
44	74.6	1.7	2	42	2	208	255	40337
48	76.5	1.6	2	40	2	195	240	41387

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 10-year event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries

Date: Sep-23

Incident rainfall storm runoff calculation

	Vegetated	Hardstanding	Open Water	Exposed bedrock
Runoff Coefficient	0.35	0.85	1.00	0.70
Area Ha	1.5	10.5	0.5	63.0

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

C co-efficient of run-off (dimensionless)
i rainfall intensity (mm/hr)
A catchment area (Ha)

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

Duration	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Runoff from open water *3	Runoff from exposed bedrock *3	Total Runoff	Total Volume
	100 year event							
hours	mm	mm/hr	l/s	l/s	l/s	l/s	l/s	m^3
0.25	21.3	85.3	124	2116	119	10455	12814	11533
0.5	29.6	59.3	87	1471	82	7268	8907	16033
1	39.1	39.1	57	970	54	4795	5877	21156
2	49.9	25.0	36	619	35	3061	3751	27009
4	63.4	15.9	23	394	22	1944	2383	34317
6	71.9	12.0	17	297	17	1468	**1800**	**38871**
8	77.8	9.7	14	241	14	1192	1461	42063
12	85.9	7.2	10	178	10	877	**1075**	**46444**
16	91.4	5.7	8	142	8	700	858	49436
20	95.5	4.8	7	118	7	585	718	51664
24	98.8	4.1	6	102	6	505	619	53460
28	101.6	3.6	5	90	5	445	545	54964
32	104.1	3.3	5	81	5	399	489	56322
36	106.4	3.0	4	73	4	362	444	57571
40	108.6	2.7	4	67	4	333	408	58745
44	110.7	2.5	4	62	3	308	378	59865
48	112.7	2.3	3	58	3	288	353	60936

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

hafrenwater environmental water management
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Tel: 01743 355770
www.hafrenwater.com

Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 100-year event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries | Date: Sep-23

Incident rainfall storm runoff calculation

		Vegetated	Hardstanding	Open Water	Exposed bedrock
Runoff Coefficient		0.35	0.85	1.00	0.70
Area	Ha	1.5	10.5	0.5	63.0

Climate change (% rainfall increase)	50	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

- *C* co-efficient of run-off (dimensionless)
- *i* rainfall intensity (mm/hr)
- *A* catchment area (Ha)

	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Runoff from open water *3	Runoff from exposed bedrock *3	Total Runoff	Total Volume
Duration	**100 year event**							
hours	mm	mm/hr	l/s	l/s	l/s	l/s	l/s	m^3
0.25	21.3	85.3	187	3174	178	15683	19221	17299
0.5	29.6	59.3	130	2206	124	10901	13361	24050
1	39.1	39.1	86	1456	82	7192	8815	31734
2	49.9	25.0	55	929	52	4591	5627	40513
4	63.4	15.9	35	590	33	2917	3575	51475
6	71.9	12.0	26	446	25	2202	**2699**	**58307**
8	77.8	9.7	21	362	20	1787	2191	63094
12	85.9	7.2	16	266	15	1316	**1613**	**69667**
16	91.4	5.7	13	213	12	1050	1287	74154
20	95.5	4.8	10	178	10	878	1076	77497
24	98.8	4.1	9	153	9	757	928	80191
28	101.6	3.6	8	135	8	667	818	82446
32	104.1	3.3	7	121	7	598	733	84483
36	106.4	3.0	6	110	6	544	666	86357
40	108.6	2.7	6	101	6	499	612	88118
44	110.7	2.5	6	94	5	463	567	89797
48	112.7	2.3	5	87	5	432	529	91404

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

hafrenwater environmental water management

Barkers Chambers
Barker Street
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Tel: 01743 355770
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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 100-year plus climate change event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries

Date: Sep-23

Storm runoff calculation - Dunald Mill Hole Cave catchment

		Dunald Mill Cave - catchment
Runoff Coefficient		0.35
Area	Ha	196.5

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

Duration	Rainfall *2	Rainfall intensity	Runoff from Dunald Mill Cave - catchment *3	Total Runoff	Total Volume
	2 year event				
hours	mm	mm/hr	l/s	l/s	m^3
0.25	6.7	26.9	5139	5139	4625
0.5	9.1	18.2	3472	3472	6250
1	11.9	11.9	2275	2275	8191
2	16.6	8.3	1587	1587	11426
4	22.7	5.7	1087	1087	15652
6	27.1	4.5	864	**864**	**18653**
8	30.5	3.8	728	728	20973
12	35.6	3.0	567	**567**	**24510**
16	39.5	2.5	472	472	27188
20	42.6	2.1	407	407	29335
24	45.3	1.9	361	361	31152
28	47.6	1.7	325	325	32736
32	49.7	1.6	297	297	34174
36	51.6	1.4	274	274	35496
40	53.4	1.3	255	255	36735
44	55.1	1.3	239	239	37905
48	56.7	1.2	226	226	39020

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CIA$$

Where:

C co-efficient of run-off (dimensionless)
i rainfall intensity (mm/hr)
A catchment area (Ha)

hafrenwater environmental water management	Barkers Chambers Barker Street Shrewsbury, Shropshire SY1 1SB UK Tel: 01743 355770 www.hafrenwater.com	Client:	**Aggregate Industries UK Ltd** **Tarmac Trading Ltd**
Title:	1 in 2-year event runoff rates and volumes for Dunald Mill Hole Cave Catchment		
Project:	Back Lane and Leapers Wood Quarries	Date:	Sep-23

Storm runoff calculation - Dunald Mill Hole Cave catchment

		Dunald Mill Cave - catchment
Runoff Coefficient		0.35
Area	Ha	196.5

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

	Rainfall *2	Rainfall intensity	Runoff from Dunald Mill Cave - catchment *3	Total Runoff	Total Volume
Duration	**10 year event**				
hours	mm	mm/hr	l/s	l/s	m^3
0.25	12.2	48.6	9300	9300	8370
0.5	16.5	33.0	6309	6309	11357
1	21.6	21.6	4128	4128	14860
2	27.8	13.9	2657	2657	19128
4	35.8	8.9	1711	1711	24634
6	41.3	6.9	1316	**1316**	**28434**
8	45.5	5.7	1086	1086	31290
12	51.6	4.3	823	**823**	**35544**
16	56.2	3.5	672	672	38689
20	59.9	3.0	572	572	41202
24	62.9	2.6	501	501	43308
28	65.6	2.3	448	448	45173
32	68.1	2.1	407	407	46866
36	70.4	2.0	374	374	48443
40	72.5	1.8	347	347	49922
44	74.6	1.7	324	324	51327
48	76.5	1.6	305	305	52662

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

C co-efficient of run-off (dimensionless)
i rainfall intensity (mm/hr)
A catchment area (Ha)

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 10-year event runoff rates and volumes for Dunald Mill Hole Cave Catchment

Project: Back Lane and Leapers Wood Quarries Date: Sep-23

Storm runoff calculation - Dunald Mill Hole Cave catchment

		Dunald Mill Cave - catchment
Runoff Coefficient		0.35
Area	Ha	196.5

Climate change (% rainfall increase)	0	%

Outflow rate - not used 0.0 l/s

Groundwater seepage - not used 0.0 l/s

	Rainfall *2	Rainfall intensity	Runoff from Dunald Mill Cave - catchment *3	Total Runoff	Total Volume
Duration	**100 year event**				
hours	mm	mm/hr	l/s	l/s	m^3
0.25	21.3	85.3	16305	16305	14675
0.5	29.6	59.3	11334	11334	20401
1	39.1	39.1	7478	7478	26919
2	49.9	25.0	4773	4773	34367
4	63.4	15.9	3032	3032	43666
6	71.9	12.0	2290	**2290**	**49461**
8	77.8	9.7	1858	1858	53522
12	85.9	7.2	1368	**1368**	**59097**
16	91.4	5.7	1092	1092	62904
20	95.5	4.8	913	913	65740
24	98.8	4.1	787	787	68025
28	101.6	3.6	694	694	69938
32	104.1	3.3	622	622	71666
36	106.4	3.0	565	565	73256
40	108.6	2.7	519	519	74749
44	110.7	2.5	481	481	76174
48	112.7	2.3	449	449	77537

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\,CiA$$

Where:

- *C* co-efficient of run-off (dimensionless)
- *i* rainfall intensity (mm/hr)
- *A* catchment area (Ha)

hafrenwater environmental water management

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 100-year event runoff rates and volumes for Dunald Mill Hole Cave Catchment

Project: Back Lane and Leapers Wood Quarries

Date: Sep-23

Storm runoff calculation - Dunald Mill Hole Cave catchment

		Dunald Mill Cave - catchment
Runoff Coefficient		0.35
Area	Ha	196.5

Climate change (% rainfall increase)	50	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

Duration	Rainfall *2	Rainfall intensity	Runoff from Dunald Mill Cave - catchment *3	Total Runoff	Total Volume
	100 year event				
hours	mm	mm/hr	l/s	l/s	m^3
0.25	21.3	85.3	24458	24458	22012
0.5	29.6	59.3	17001	17001	30602
1	39.1	39.1	11216	11216	40379
2	49.9	25.0	7160	7160	51550
4	63.4	15.9	4549	4549	65499
6	71.9	12.0	3435	**3435**	**74192**
8	77.8	9.7	2788	2788	80283
12	85.9	7.2	2052	**2052**	**88646**
16	91.4	5.7	1638	1638	94356
20	95.5	4.8	1370	1370	98609
24	98.8	4.1	1181	1181	102037
28	101.6	3.6	1041	1041	104907
32	104.1	3.3	933	933	107499
36	106.4	3.0	848	848	109884
40	108.6	2.7	779	779	112124
44	110.7	2.5	721	721	114261
48	112.7	2.3	673	673	116306

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\, CiA$$

Where:

C	co-efficient of run-off (dimensionless)
i	rainfall intensity (mm/hr)
A	catchment area (Ha)

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 100-year plus climate change event runoff rates and volumes for Dunald Mill Hole Cave Catchment

Project: Back Lane and Leapers Wood Quarries | Date: Sep-23

APPENDIX 3037/FRA/A6

Storm run-off: restoration phase

Incident rainfall storm runoff calculation - Restored Phase

		Vegetated restored quarry faces	Open water
Runoff Coefficient		0.35	1.00
Area	Ha	7.5	68.0

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

- *C* co-efficient of run-off (dimensionless)
- *i* rainfall intensity (mm/hr)
- *A* catchment area (Ha)

Duration	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Total Runoff	Total Volume
	2 year event					
hours	mm	mm/hr	l/s	l/s	l/s	m^3
0.25	6.7	26.9	196	5081	5278	4750
0.5	9.1	18.2	133	3433	3565	6418
1	11.9	11.9	87	2250	2336	8411
2	16.6	8.3	61	1569	1630	11733
4	22.7	5.7	41	1075	1116	16073
6	27.1	4.5	33	854	**887**	**19155**
8	30.5	3.8	28	720	748	21537
12	35.6	3.0	22	561	**583**	**25170**
16	39.5	2.5	18	467	485	27919
20	42.6	2.1	16	403	418	30124
24	45.3	1.9	14	356	370	31990
28	47.6	1.7	12	321	333	33616
32	49.7	1.6	11	293	305	35093
36	51.6	1.4	10	271	281	36450
40	53.4	1.3	10	252	262	37723
44	55.1	1.3	9	237	246	38924
48	56.7	1.2	9	223	232	40069

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 2-year event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries | Date: Sep-23

Incident rainfall storm runoff calculation - Restored Phase

		Vegetated restored quarry faces	Open water
Runoff Coefficient		0.35	1.00
Area	Ha	7.5	68.0

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

C co-efficient of run-off (dimensionless)
i rainfall intensity (mm/hr)
A catchment area (Ha)

Duration	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Total Runoff	Total Volume
	10 year event					
hours	mm	mm/hr	l/s	l/s	l/s	m^3
0.25	12.2	48.6	355	9195	9550	8595
0.5	16.5	33.0	241	6238	6479	11662
1	21.6	21.6	158	4081	4239	15260
2	27.8	13.9	101	2627	2728	19642
4	35.8	8.9	65	1691	1757	25297
6	41.3	6.9	50	1302	**1352**	**29199**
8	45.5	5.7	41	1074	1116	32132
12	51.6	4.3	31	814	**845**	**36500**
16	56.2	3.5	26	664	690	39730
20	59.9	3.0	22	566	588	42310
24	62.9	2.6	19	496	515	44473
28	65.6	2.3	17	443	460	46388
32	68.1	2.1	16	402	418	48127
36	70.4	2.0	14	370	384	49746
40	72.5	1.8	13	343	356	51265
44	74.6	1.7	12	320	333	52707
48	76.5	1.6	12	301	313	54078

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 10-year plus climate change event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries

Date: Sep-23

Incident rainfall storm runoff calculation - Restored Phase

	Vegetated restored quarry faces	Open water
Runoff Coefficient	0.35	1.00
Area Ha	7.5	68.0

Climate change (% rainfall increase)	0	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

C	co-efficient of run-off (dimensionless)
i	rainfall intensity (mm/hr)
A	catchment area (Ha)

Duration	Rainfall *2	Rainfall intensity	Runoff from vegetated area *3	Runoff from hardstanding *3	Total Runoff	Total Volume
	100 year event					
hours	mm	mm/hr	l/s	l/s	l/s	m^3
0.25	21.3	85.3	622	16121	16744	15069
0.5	29.6	59.3	433	11206	11639	20950
1	39.1	39.1	285	7393	7679	27644
2	49.9	25.0	182	4719	4902	35291
4	63.4	15.9	116	2998	3114	44840
6	71.9	12.0	87	2264	**2351**	**50792**
8	77.8	9.7	71	1837	1908	54962
12	85.9	7.2	52	1353	**1405**	**60687**
16	91.4	5.7	42	1080	1121	64596
20	95.5	4.8	35	903	938	67508
24	98.8	4.1	30	778	809	69855
28	101.6	3.6	26	686	712	71819
32	104.1	3.3	24	615	639	73594
36	106.4	3.0	22	559	580	75226
40	108.6	2.7	20	513	533	76760
44	110.7	2.5	18	475	494	78223
48	112.7	2.3	17	444	461	79623

*2 Obtained from FEH website

*3 Climate change factored into rainfall intensity at this stage

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Client: **Aggregate Industries UK Ltd**
Tarmac Trading Ltd

Title: 1 in 100-year event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries | Date: Sep-23

Incident rainfall storm runoff calculation - Restored Phase

		Vegetated restored quarry faces	Open water
Runoff Coefficient		0.35	1.00
Area	Ha	7.5	68.0

Climate change (% rainfall increase)	50	%

Outflow rate - not used	0.0	l/s
Groundwater seepage - not used	0.0	l/s

The Rational Method to give peak flow Q_p is in the form:

$$Q_p = 2.78\ CiA$$

Where:

C co-efficient of run-off (dimensionless)
i rainfall intensity (mm/hr)
A catchment area (Ha)

Duration	Rainfall *[2]	Rainfall intensity	Runoff from vegetated area *[3]	Runoff from hardstanding *[3]	Total Runoff	Total Volume
	100 year event					
hours	mm	mm/hr	l/s	l/s	l/s	m^3
0.25	21.3	85.3	933	24182	25115	22604
0.5	29.6	59.3	649	16809	17458	31425
1	39.1	39.1	428	11090	11518	41465
2	49.9	25.0	273	7079	7352	52937
4	63.4	15.9	174	4497	4671	67261
6	71.9	12.0	131	3396	**3527**	**76188**
8	77.8	9.7	106	2756	2863	82443
12	85.9	7.2	78	2029	**2107**	**91031**
16	91.4	5.7	63	1620	1682	96894
20	95.5	4.8	52	1354	1406	101262
24	98.8	4.1	45	1168	1213	104782
28	101.6	3.6	40	1029	1069	107729
32	104.1	3.3	36	923	958	110390
36	106.4	3.0	32	838	871	112839
40	108.6	2.7	30	770	800	115140
44	110.7	2.5	28	713	741	117335
48	112.7	2.3	26	665	691	119434

*[2] Obtained from FEH website

*[3] Climate change factored into rainfall intensity at this stage

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Title: 1 in 100-year plus climate change event runoff rates and volumes

Project: Back Lane and Leapers Wood Quarries

Date: Sep-23

APPENDIX 3037/FRA/A7

Greenfield run-off

Greenfield runoff rate estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Rosie Morrant
Site name:	Leapers Wood/Back Lane
Site location:	Carnforth

This is an estimation of the greenfield runoff rates that are used to meet normal best practice criteria in line with Environment Agency guidance “Rainfall runoff management for developments”, SC030219 (2013) , the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site Details

Latitude:	54.11771° N
Longitude:	2.74673° W
Reference:	1592490029
Date:	May 26 2021 10:01

Runoff estimation approach IH124

Site characteristics

Total site area (ha): 75.5

Methodology

Q_{BAR} estimation method: Calculate from SPR and SAAR

SPR estimation method: Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
HOST class:	N/A	N/A
SPR/SPRHOST:	0.3	0.3

Hydrological characteristics

	Default	Edited
SAAR (mm):	1137	1137
Hydrological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 30 years:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Growth curve factor 200 years:	2.37	2.37

Notes

(1) Is Q_{BAR} < 2.0 l/s/ha?

When Q_{BAR} is < 2.0 l/s/ha then limiting discharge rates are set at 2.0 l/s/ha.

(2) Are flow rates < 5.0 l/s?

Where flow rates are less than 5.0 l/s consent for discharge is usually set at 5.0 l/s if blockage from vegetation and other materials is possible. Lower consent flow rates may be set where the blockage risk is addressed by using appropriate drainage elements.

(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite would normally be preferred for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Q_{BAR} (l/s):	231.95	231.95
1 in 1 year (l/s):	201.79	201.79
1 in 30 years (l/s):	394.31	394.31
1 in 100 year (l/s):	482.45	482.45
1 in 200 years (l/s):	549.72	549.72