Final Project Report (to be submitted by 14th September 2022)

Instructions:

- Document length: maximum 10 pages, excluding this cover page and the last page on project tags.
- We welcome the submission of Annexes (i.e. bachelor or master thesis, references, species lists, maps, drawings, pictures) to further HeidelbergCement's understanding and future use of your findings, however they will not be reviewed by the Jury, and we kindly ask for these to be sent separately to the National Coordinators.
- Please use the attached template for species data collected during the project and submit with the project report.
- Word/PDF Final Report files must be less than 10 MB.
- If you choose to submit your final report in your local language, you are required to also upload your final report in English if you wish to take part in the international competition.
- To be validated, your file must be uploaded to the Quarry Life Award website before **14th September** 2022 (midnight, Central European Time). To do so, please log in, click on 'My account'/ 'My Final report'.
- In case of questions, please liaise with your national coordinator.
- You should not publish additional private information in your final report (e.g.: address, day of birth, email-address, phone number), just complete the categories we ask for below under "Contestant profile".

1. Contestant profile

Contestant name:	**David Ryves**
Contestant occupation:	Professor of Environmental Change
University / Organisation	Loughborough University
Number of people in your team:	**4**

2. Project overview

Title:	Secrets from the Deep: Sediment archives of Biodiversity and Pollution in New Quarry Lakes
Contest: (Research/Community)	Research
Quarry name:	Barton-under-Needwood, UK

Abstract (max 0.5 page)

High biodiversity quarry lakes are very desirable systems that contribute much to regional biodiversity in river-floodplain environments and the Barton-under-Needwood quarry lake system provides a rare opportunity to explore the development of an ecosystem type which is increasingly rare in the UK (and in many other anthropogenically modified landscapes globally). This project provides valuable long-term data for a largely neglected and yet important artificial aquatic habitat by examining the naturally deposited sediment archive from two lakes over the last ~30 years, focussing on (1) the development of the sedimentary diatom (algal) community as an indicator of changing aquatic biodiversity over time, and (2) applying the novel research field of microplastic/fibre pollution by assessing the inventory of these relatively recent anthropogenic markers in these sediments. Results indicate that the diatom community in a lake directly connected with the nearby and polluted River Trent has been mesotrophic-eutrophic since the lake was created in 1992, dominated by small centric species, but the assemblage has changed over time, reflecting changes in nutrient availability (e.g. silica) and the growth of macrophyte coverage across the lake. Microfibres (both plastic and cotton) were found throughout both lake records, and suggest inputs are dominated by flows from the River Trent. Concentrations and total fibre length peak at the start of both records (usggesting input from the immediate catchment as well as river inputs), and during years of known major River Trent flooding through the system (e.g. a major summer flood that breached the flood berms and allowed significant river flow through the entire system during the very wet year of 2012). Such sedimentary analyses from quarry lakes are essential to establish the longer-term ecological development of these ecosystems in the absence of regular and frequent monitoring data, and can provide integrated evidence of catchment as well as riverine influences, key for their sustainable management. Such wetland-lake complexes, as at Barton, provides multiple roles of biodiversity, aesthetic value, ecosystem services, flood prevention and alleviation, and pollution sinks, and approaches interrogating the sediment archive can inform the optimal management of these important regional and national systems across Europe and globally.

Final report (max 9 pages)

Introduction

Lakes and wetlands are hotspots of biodiversity in the landscape (Williams *et al*. 2003). They support complex communities of fauna and flora and providing important ecosystem services for the wetland and wider catchment (Knight *et al*. 2005). These services include water purification, sediment filtration, pollutant sinks (such as microplastics and microfibres), biogeochemical cycling and nutrient storage (e.g. phosphorus, carbon) and recreational facilities. They also provide resources and habitats beyond the aquatic communities themselves and attract a wide range of fauna including wading and migrating birds, amphibians, mammals and insects with aquatic larval stages. Recent work on ponds shows that the biodiversity of artificial and natural sites can be equally high when good quality freshwater is available (Williams *et al*. 2010, Hill et al. 2019).

Quarry excavations, both deep and shallow, can provide excellent opportunities for the creation of wetland and lake ecosystems (HeidelbergCement 2010) that offset the dramatic disappearance of these habitats through agricultural drainage and urban development over the last 150 years. Mineral extraction sites such as exhausted quarries. The biological characteristics of small lowland lakes, natural or artificial, are principally determined by nutrient loading: importantly nitrogen (N) and phosphorus (P), in compounds derived from agricultural land drainage, domestic and industrial waste and sewage treatment effluent. High nutrient levels support dense phytoplankton blooms (eutrophication) which can have serious consequences for aquatic biodiversity. Undesirable effects include reduced water transparency, water deoxygenation and fish kills and loss of rooted aquatic vegetation leading to steep declines in biodiversity. There are also more recent threats from microplastic and anthropogenic natural fibre pollution from human activities (mainly from industrial and domestic water effluent, especially from washing machines), which can enter quarry lakes through atmospheric input as well as from adjacent rivers where sewage treatment is often unable to filter out such particles (such as the River Trent at Barton).

This project follows on from previous initial investigations at the Barton-under-Needwood system but extends the research into new areas by focussing on the sediment records from two lakes. By focussing on the sediment archives that accumulate in the bottom of these quarry lakes since their creation ~30 years ago, we explore the possible role that frequent, if irregular, River Trent flooding has in terms of nutrient supply and ecosystem quality, using the record of diatom communities (as a proxy for algal primary producers) preserved in the sediments, as well as examining the accumulation of microplastics and natural fibres in these lakes as recorded in lake sediments. Major River Trent flood events may leave signals in the sediments themselves, in terms of altered diatom communities or abundance, distinct sedimentation type (e.g. coarser, fluvial sediments; a short-term reduction in organic carbon content of the sediment) and spikes in the delivery of microplastic and natural fibres.

The analysis of artificial microplastics and fibres in the environment is a novel and exciting area of research (Stanton *et al.* 2019, 2020a, 2020b), as microplastics and natural fibres from clothes can have adverse affects on aquatic fauna through their direct ingestion (by invertebrates, fish and birds and mammals for example) and possible toxic effects of chemicals associated with them (such as dyes and other pollutants associated with these particles). Diatom records can show the extent of nutrient pollution (and potentially the role of the River Trent in this) and provide a history of the development of diatom (and by proxy, overall) algal biodiversity in these lakes, and how this has changed over time. As diatoms are key primary producers and, with other algae, form the base of the aquatic food chain, highly biodiverse diatom communities are indicative of greater biodiversity amongst algae more generally, and hence biodiversity across higher trophic levels such as invertebrates, fish, aquatic birds and mammals.

A key question concerns lake ecosystem development and ecological trajectories. Do these lakes start off as relatively “pristine”, highly biodiverse aquatic ecosystems with a rich benthic diatom flora that slowly become less diverse, and dominated by planktonic taxa (typical of the progression of more eutrophic, nutrient rich lakes) as pollutants enter the system (likely carried by the River Trent at this site), or are they from their creation already impacted by higher nutrient loadings from groundwater, or connection through the gravel bed with River Trent water? How do they subsequently develop along a trophic and pollutant trajectory? In combination with diatom analyses, microplastic/natural fibre analysis will shed light on an increasingly important aspect of aquatic and environmental pollution from human activity, and as such may also be an important marker for the role of River Trent flooding on lake development and algal biodiversity. This will in turn inform the long-term management of the site to optimise biodiversity, reduce pollution inputs while still maintaining a connection with the River Trent (essential for flood control as well as seasonal inundation of wet woodland zones).

Methods

Sediment cores were collected from two lakes across the system, chosen along a gradient of influence from the River Trent (Lakes A and C), which are among the oldest lakes at the site, created in 1992 and 1993 respectively (Figure 1). Basic water chemistry of these sites and the River Trent (conductivity, total nitrogen (TN), total phosphorus (TP)) from earlier investigations demonstrates that these lakes are both eutrophic (Lake A) or hypereutrophic (Lake C), with Lake C having significantly higher summer nutrient concentrations for both TN and TP than Lake A (TP ~300 µg L^{-1}, TN ~4 mg L^{-1} for Lake C and TP ~100 µg L^{-1} and TN ~2 mg L^{-1} for Lake A; D. Ryves, unpublished data). In comparison, River Trent water at Barton is extremely nutrient enriched (summer values of TP ~650 µg L^{-1}, TN ~7.5 mg L^{-1}; D. Ryves, unpublished data).

Sediment cores were collected using a HON-Kajak gravity corer (Renberg 1991) to collect ~35 cm of sediment from an inflatable boat in the deepest parts of both lakes (~4.5 – 5 m water depth) from coring sites located on Figure 1. Lake C was cored in October 2021 and Lake A in August 2022. Sediment cores were vertically extruded on site into 1 cm slices and stored in re-sealable plastic bags, kept cool in cold boxes and transported back to the laboratories at Loughborough University for storage in dark refrigeration until analysis during two MSc Dissertation projects. Care was taken when sampling for microplastics and microfibres to ensure minimal contamination by minimising exposure to any cotton or artificial fibre clothing by making sure outer jackets (generally of material that sheds few such fibres) were zipped up over underlayers. Sediment cores could not be radiometrically dated (using ^{210}Pb for such recent sediments) due to funding constraints, but given the known age of both lakes (31 years for Lake A and 30 years for Lake C) and changes in sediment composition that indicated that both cores reached the initial phase of infill, with coarser sediment with distinctly lower water content in basal layers, a linear sediment accumulation rate (of ~1 cm/year) at both lakes was assumed.

Diatom analyses from Lake C were carried out at Loughborough University using standard methods of sediment processing using concentrated hydrogen peroxide (30%) and the water bath method (Renberg 1990). Briefly, ~0.1 g of wet sediment was added to glass test tubes and heated in a water bath at 90°C for up to 6 hours to remove organic matter. Permanent diatom slides were made from strewn coverslips settled overnight and fixed in a high refractive-index mountant (Naphrax). Diatoms were enumerated under high-power phase-contrast microscope at x1000 (Leica DM) and a minimum of 300 diatom valves identified to species level for every sample, using a range of diatom floras and online identification resources.

Microplastic/fibre analysis from both Lake A and Lake C was carried out at Loughborough University using a method adapted from Turner *et al.* (2019) designed to reduce contamination as far as possible. All analyses were carried out in a closed laboratory room, with the analyst wearing white cotton clothing and a freshly laundered white laboratory coat, with latex gloves worn at all times. Given the prevalence of white fibres in laboratory settings (from laboratory coats), white fibres were ignored in the analysis of microfibres Before opening sample bags, laboratory surfaces were thoroughly cleaned down with moistened laboratory roll, which was repeated at regular intervals during the analysis process. All sediment samples were around 50 cm^3 wet volume given the internal diameter of the coring tube and the sediment slice thickness, with ~1 cm^3 put aside from each sample for diatom analysis (see above). Sample weights used for the microfibre analysis were calculated by subtracting the weight of the dried and empty sample bag from the sample bag with sediment. The remaining sediment sample from each 1 cm slice was removed from its sample bag using a metal spatula, following which the sample bag was rinsed with distilled water into a recently autoclaved glass beaker (covered with aluminium foil until needed). All this material was then sieved through a 350 µm metal sieve using distilled water, and the material left on the sieve back washed with distilled water into a vacuum filtration unit. These washings were then vacuum filtered onto a glass microfibre filter paper (GF/F; 0.45 µm) and then filter papers were removed and dried overnight at 40°C under watch glasses in a heating cabinet. The entire filter paper was scanned at x40 (and at up to x80 where more detailed observation was needed) under a stereo microscope and all fibres encountered were recorded, in terms of type (microplastic fibre or cotton), colour and an estimate of length (based on the known width of a field of view at x40 which was 6 mm). Any white fibres were ignored in this analysis. All equipment used was washed three times with distilled water between samples and the sieve was also backwashed with distilled water.

At the beginning of each day and every 5 samples, a blank was run following the identical procedure to the sediment samples (by washing distilled water through the sieve and filtering the backwash onto a GF/F filter paper). The entire filter paper from these blanks was also scanned at x40 for any non-white microfibres. Very few of the blanks showed any microfibres, but if there were any found, the sum and type was deducted from the analyses of samples counted at the same time. Images were taken of all fibres counted to aid identification and colour. This process minimises possible contamination which has been shown if methods to remove organic matter are employed, such as using concentrated hydrogen peroxide (which can break down fibres into smaller fragments, that may then be missed under sieving).

While it is acknowledged that some smaller microplastics and microfibres may be missed using this method (i.e. if they pass through the 350 µm sieve), this is thought to be minimal (see Turner *et al.* 2019), and treating all samples in the same way allows for a reliable comparison to be made between samples within the same core and from different cores (and so from different lakes). Results from the diatom and microfibre analyses are currently being written up by the two analysts for their MSc dissertations as part of their MSc programme (for which the deadlines are in later autumn) and so, while preliminary findings from both analyses are presented here, there are clear patterns in both datasets that are clearly evident and initial conclusions can be made from both analyses.

Preliminary results and discussion

<u>Diatom analysis</u>

Diatom assemblages from Lake C are dominated by planktonic species that are typical of nutrient enriched lakes (such as *Stephanodiscus parvus, S. hantzschii*, *S. medius*, *Cyclostephanos tholiformis* and *Aulacoseira granulata*), with only a minority of taxa from non-planktonic habitats (though the full range of species encountered was substantial; see Table 1). This likely is result both of the nature of the lake shape (bathymetry) and the coring location in the deepest part of the lake, some distance from the shore and the shallower, periphytic and macrophyte-dominated habitats there. All lakes in the Barton system have been modified from their original form as gravel quarries, which would have had essentially very steeply sloping edges, and have been smoothed to allow a more natural deepening profile away from the shore, but nonetheless the littoral areas of Lakes A and C are steeper than would be expected in natural lakes of this size and depth.

The diatom record also shows a clear change in diatom assemblage since the lake was created, notably with a decline in *Stephanodiscus parvus* and increase in *Aulacoseira granulata*. Both of these species are typical of eutrophic waters (with an optimum total phosphorus value of 134 µg L^{-1} TP for *S. parvus* and 154 µg L^{-1} TP for *A. granulata* as found within the 152 lake training set across north-west Europe by Bennion *et al.*, 1996), but have significant differences in autecology. While *Stephanodiscus parvus* is a small, lightly silicified diatom that blooms under conditions of high phosphorus availability compared to silica (low Si:P ratio), *A. granulata* is much more heavily silicified and requires a high Si:P ratio. Given its greater weight from thicker silica cell walls, this diatom often indicates turbulent conditions of water column mixing in deeper lakes. However, given the depth of these lakes (and hence likely sufficient light penetration throughout the water column except during periods of intense algal blooms), and its ability to tolerate lower light levels (in part likely an adaption due to an association with deeper, mixed water columns), this may not indicate greater water column mixing in more recent years but rather perhaps an increase in nutrient (TP) concentrations, and relatively greater availability of Si, as the lake has developed over the last 30 years. One possible explanation for the increase in phosphorus in Lake C is from the use of bait by recreational fishing activities, which is popular at this lake (David Southgate, pers. comm.);

previous studies (as mentioned earlier) found that Lake A (while still eutrophic) was less nutrient rich than hypertrophic Lake C, and (as well as being further from the very nutrient rich River Trent), there is far less recreational fishing at this lake (David Southgate, pers. comm.). However, the role of the River Trent (which has very high concentrations of TP at Barton; see earlier) is likely of more importance, as this is directly connected to Lake C and as it is adjacent to the channel, likely also contributes TP- (and TN-) rich water through seepage via highly porous gravel-rich sediments that separate Lake C from the river.

It can be expected that silica concentrations are relatively low in the initial stages of the lake's life, if the major supply of water (and Si) is the River Trent, but as diatoms remove silica from the lake water and bury a portion in the sediment (as preserved diatom valves), over time the sediment itself can become an important source of silica for overlying waters through diatom dissolution and Si diffusion to overlying water (Ryves *et al.* 2013)(and given the shallow water depths, the water column will be mixed for most of the year, except for periods during the summer). Groundwater may also be a significant source of Si to the lake, as there is evidence of higher conductivity water at the base of the water column, observed during water column profiling during October 2021, and may explain the fact that conductivity in Lake A is ~1100 μS cm^{-1}, significantly higher than in Lake C (~690 μS cm^{-1}; D. Ryves, unpublished data).

The diatom results also indicate that there has been a change in the availability of different aquatic habitats in Lake C over the course of the last 30 years. Taxa that prefer non-vegetated substrates (such as rock, sand or mud surfaces) decline in relative abundance, such as *Surirella* species and some *Gomphonema* taxa, while those indicating greater macrophyte coverage increase (such as *Cocconeis* species, which are often found attached to plant stems and are good indicators of submerged macrophytes). The total abundance of non-planktonic taxa is relatively low, however, throughout the record, suggesting that these habitats are of less importance than the open water (planktonic) for diatom communities. This is to be expected in lakes with high phosphorus concentration, as algal blooms (of diatoms but also other planktonic algae, such as cyanobacteria [blue-green algae]) will tend to shade out benthic habitats especially in deeper parts of the lake. Additionally, planktonic taxa often respond rapidly to high phosphorus availability and outcompete often slower-growing benthic taxa (forming large blooms, such as *S. parvus* and *S. hantzschii* in the early part of the lake's history, and *A. granulata* in later phases). Finally, previous surveys (D. Ryves, unpublished data) found that the littoral zone in Lake C is relatively narrow (as evidenced by the extent of submerged vegetation), in part due to the relatively steeper slopes at this lake as well as its turbidity reducing the photic depth.

Microfibre analysis

Preliminary analysis of the microfibre data demonstrate that both lakes have been impacted by microfibre pollution throughout their history, demonstrating the pervasive nature of this type of pollution (i.e. microfibres were not just found in Lake C, adjacent to the River Trent and with a direct connection via pipes). Most samples contained at least one non-white fibre, with some containing several. The results from Lake C suggest an increase in microfibres at around 12-14 cm, which assuming a linear sedimentation rate of about 1 cm/year, would match with the known major flood event of the River Trent through the system in summer 2012. This further supports the role of the river as a source of pollutants, both nutrients but also microfibres (and presumably other plastic debris). While the dominant fibre type for all samples from both lakes was synthetic blue fibres, there were also cotton fibres observed (from clothing, as the process of manufacture of cotton garments alters the cotton fibre in clear ways; Stanton *et al.* 20). Other fibre colours were also recorded, with pink and green non-cotton microfibres being found.

Recent research in the East Midlands has suggested that cotton microfibres are dominant in atmospheric sources and in rivers (Stanton *et al.* 2019), while results here suggest that plastic microfibres are the dominant fibre type in these lake sediments. Pathways for transport of cotton fibres may differ however, as these fibres are denser than artificial (plastic) fibres, which may lead to a relatively greater loss of cotton fibres as distance from the river source increases (especially as flood waters will be preferentially from the upper water column of the river). However, given the dominance of natural fibres over plastic fibres found in contemporary river environments (which included the River Trent at Stoke-on-Trent; Stanton et al, 2019) as well as in regional atmospheric deposition, the relatively low proportion of cotton fibres found here is still somewhat unexpected, while there can be large variations in fibre flux in both time and space (Stanton *et al.* 2020a). Further research from other lakes at Barton, as well as sampling the River Trent around Barton-under-Needwood, may help elucidate the reasons for this apparent discrepancy.

Added value of the project for science and quarrying companies

Results from the research on lake sediments, once full data are available, will be published in peer-reviewed scientific journals wherever possible, and results will also be disseminated to the scientific community through conferences, meetings and workshops and to community groups through Citizen Science outreach. The findings will also be made available to the Barton site managers for dissemination through their channels, including for example putting up information posters at the site for the public to share in our findings. Further analysis of the microfibres may also be possible at Loughborough University to characterise the fibres according to material using Raman spectroscopy (Stanton *et al.* 2019), which will add to the value for both scientific outputs as well as furthering our understanding of the relative importance of different materials producing microfibres present in the environment over the last 30 years.

Future work could build on this with continued monitoring of the site, with water quality testing, algal community sampling, sampling of the River Trent and Barton lakes for microplastic/fibre inputs, sediment trap work and further sediment core work on other lakes. Real-time monitoring during a River Trent flood event would be extremely interesting in terms of inputs of nutrients, sediments, plastics/fibres to the system and how these travel through the system and enter the lakes themselves. It would also act as a direct test of the hypothesis of the role of River Trent flooding events as a major source of pollutants and especially microfibres and microplastics to these systems. The lakes chosen here could also be re-cored in future years to assess change in subsequent years and how that is preserved in the sediment archive.

The project has also provided valuable training opportunities for two MSc students at Loughborough University, as analyses conducted here are the basis for their MSc Dissertations, In particular, the student undertaking the microfibre project will take this new knowledge, skills and understanding back to Nigeria on his return after the MSc programme, where plastic pollution is a major but understudied (and to some extent ignored) environmental problem. This knowledge transfer will be applied to the Nigerian context where there is a pressing need to understand the scope and nature of the problem (e.g. see Stanton *et al.* 2020b), and should lead to real impact through dissemination of techniques and ultimately with the aim to influence policy for environmental monitoring and control of the problem.

Recommendations and guidance

It is recommended that this approach could be adopted at other quarry lake sites in the UK and elsewhere in the HeidelbergCement portfolio (and indeed across the industry), as work investigating the sediment inventories and ecological history of such lakes would shed light on how these lakes develop. Diatom analysis for example can be used to investigate the initial trophic (nutrient) status of these lakes when first created, and the extent to which such lakes subsequently change (becoming more or less nutrient enriched, depending on inputs to the systems from the catchment, local rivers and recreational activities such as fishing). Microplastic and microfibre analysis of lake sediments (especially in terms of microfibre/plastic pollutant history from sediment cores) is still comparatively novel, and there is exciting potential to use such sediment records to investigate local pollutant histories of such lakes, and the role that rivers may play in delivering pollutants (nutrients and sediments, as well as microplastics/fibres) to them. Management decisions and practice can then be tailored to the individual situations at each quarry lake system, in terms of the competing demands to create aquatic systems of high ecological quality (with clear water lakes, abundant macrophyte coverage, and a rich benthic flora and fauna) and their use as long-term pollutant and sediment sinks, as well as allowing river flood waters to be stored in quarry lakes for flood alleviation further downstream. It may be that, in any given system, some lakes are employed for their ecosystem services of pollutant trapping and flood alleviation, while others can be protected from river inflows (through the building of berms for example) and maintained for ecosystem quality (maximising biodiversity and amenity value for the wider public). Where lakes are directly connected to the river through pipes (as at Lake C), filters that are regularly maintained can be installed to reduce microfibre pollution. This would also allow quantification of the role of the river as an agent for such pollutants to the system.

Shallow lake systems in largely agricultural landscapes and floodplains are relatively rare across much of Europe as farming has sought to maximise land for crops or animal and many such naturally occurring lakes (such as oxbow lakes) have been infilled, while those that remain are often nutrient enriched due to the application of fertilisers to cropland, inputs of animal slurries, or (as at Barton), the regular inflow of nutrients from neighbouring rivers, hence creating and maintaining low nutrient lakes will add value to the landscape. Biodiverse wetlands and lakes not only provide habitat and resources for non-aquatic fauna but are also important for migratory birds, providing a range of ecosystem services to the surrounding landscape. Society can benefit recreationally and educationally by the creation of species-rich wetlands in otherwise often low biodiversity areas. Added biodiversity value has clear benefits for those stakeholders interested in fishing, bird watching and education. Restored lake and wetland habitats have significant added value (including financial), and are an asset in their own right. However, clearly a balance has to be found between the different, and competing, uses that such systems provide.

Conclusions

Examining the history and development of diatom biodiversity and microplastic/fibre pollution from two quarry lakes since they were created 30 years ago has revealed how their initial status has changed over this time, and the role of the River Trent in this (especially the impact of flood events as sources of sediments, nutrients and microfibres). Diatom data from one lake directly linked to the River Trent shows that the lake has always been nutrient enriched (likely reflecting its initial infilling with River Trent water), and has become more enriched over time, perhaps linked to local recreational activities of fishing (adding nutrients through bait) as well as a change in nutrient dynamics through internal lake processes. The diatom data also evidence the development of (limited) submerged macrophytes in the littoral zone at the lake over time. The novel application of microfibre analysis was also carried out on sediment records from both lakes. Microfibres (both cotton and artificial) were found in both lakes throughout their records, evidencing the pervasive nature of these pollutants, and show patterns that support the key role of the River Trent as a source (especially during flood events).

By increasing the knowledge base, results from this project can aid management of these potentially key wildlife reserves by identifying where improvements are needed for water quality (e.g. encouraging ground water over river water supply; and possible solutions to install filters in pipes connecting the site to the Trent to reduce microplastic/fibre inputs), but also recognising that some lakes within the system may need to remain well connected to the river to act as pollutant sinks and for flood alleviation.

Appendices

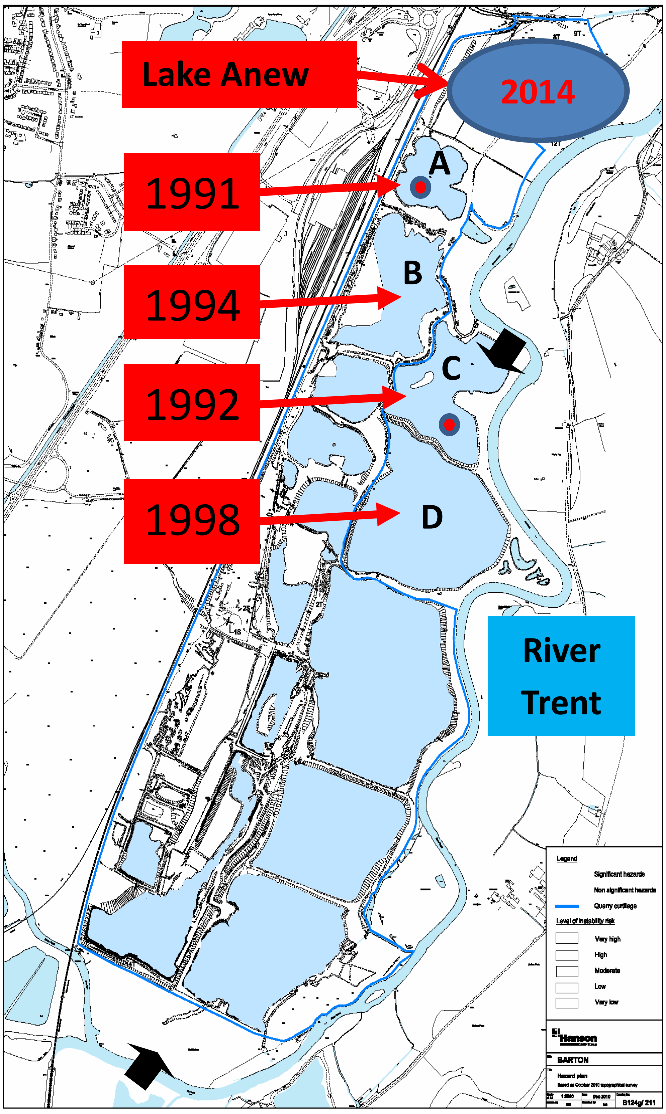

Figure 1. LEFT: Map of the Barton Quarry site, oriented north-south. RIGHT: Map with highlighted codes (A to D) of four lakes with dates of creation; note the new lake created in summer 2014 (Lake Anew). Red dots in Lake A and Lake C indicate coring locations. Black arrows indicate where River Trent inflows can occur. River Trent flows from south to north. The distance from southernmost lake to north side of Lake Anew is about 3 km.

References

Bennion, H., Juggins,S. & Anderson, N.J. (1996) Predicting epilimnetic phosphorus concentrations using an improved diatom-based transfer function and its application to lake eutrophication management. Environmental Science and Technology 30, 2004–2007.

HeidelbergCement (2010) 'Promotion of Biodiversity at the Mineral Extraction Sites of HeidelbergCement'. Eds M. Rademacher & U. Traenkle. HeidelbergCement AG. 83 pp.

Hill, M.J., Wood, P.J., White, J.C. & Ryves, D.B. (2019) Environmental factors are primary determinants of different facets of pond macroinvertebrate alpha and beta diversity in a human-modified landscape, Biological Conservation, 237, 348-357.

Knight, T. M., McCoy, W. M., Chase, J. M., McCoy, K. A. and Holt, R. D. (2005) 'Trophic cascades across ecosystems', Nature, 437, 880-883.

Renberg, I, (1990) A procedure for preparing large sets of diatom slides from sediment cores. Journal of Paleolimnology, 4, 87–90.

Renberg (1991) The HON-Kajak sediment corer. Journal of Paleolimnology 6, 167–170.

Ryves, D.B., Anderson, N.J., Flower, R.J. & Rippey, B. (2013) Diatom taphonomy and silica cycling in two freshwater lakes and their implications for inferring past lake productivity, Journal of Paleolimnology, 49, 411-430.

Stanton, T., Johnson, M., Nathanail, P., MacNaughtan, W & Gomes, R.L. (2019) Freshwater and airborne textile fibre populations are dominated by 'natural', not microplastic, fibres, Science of The Total Environment, 666, 377-389.

Stanton, T., Johnson, M., Nathanail, P., MacNaughtan, W & Gomes, R.L. (2020a) Freshwater microplastic concentrations vary through both space and time, Environmental Pollution, 263, 114481.

Stanton, T., Kay, P., Johnson, M., Chan, F.K.S., Gomes, R.L., Hughes, J., Meredith, W., Orr, H.G., Snape, C.E., Taylor, M., Weeks, J., Wood, H. & Xu , Y.(2020b) It's the product, not the ploymer: rethinking plastic pollutuon, WIREs Water, 8, e1490: https://doi.org/10.1002/wat2.1490

Turner, S., Horton, A.A., Rose, N.L. & Hall, C. (2019) A temporal sediment record of microplastics in an urban lake, London, UK. Journal of Paleolimnology, 61, 449–462.

Williams, P., Whitfield, M., Biggs, J., Bray, S., Fox, G., Nicolet, P. and Sear, D. (2003) 'Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England', Biological Conservation, 115: 329–341.

Williams, P., Biggs, J. and Nicolet, P. (2010) 'New clean-water ponds: A way to protect freshwater biodiversity', British Wildlife, 22: 77-85.

THE QUARRY LIFE AWARD

HEIDELBERGCEMENT

To be kept and filled in at the end of your report

Project tags (select all appropriate):

This will be use to classify your project in the project archive (that is also available online)

Project focus:

- ☐Beyond quarry borders
- ☒Biodiversity management
- ☐Cooperation programmes
- ☐Connecting with local communities
- ☐Education and Raising awareness
- ☐Invasive species
- ☒Landscape management
- ☐Pollination
- ☒Rehabilitation & habitat research
- ☒Scientific research
- ☐Soil management
- ☒Species research
- ☐Student class project
- ☐Urban ecology
- ☒Water management

Flora:

- ☐Trees & shrubs
- ☐Ferns
- ☐Flowering plants
- ☐Fungi
- ☐Mosses and liverworts

Fauna:

- ☐Amphibians
- ☐Birds
- ☐Insects
- ☐Fish
- ☐Mammals
- ☐Reptiles
- ☐Other invertebrates
- ☐Other insects
- ☒Other species

Habitat:

- ☒Artificial / cultivated land
- ☐Cave
- ☐Coastal
- ☐Grassland
- ☐Human settlement
- ☐Open areas of rocky grounds
- ☒Recreational areas
- ☐Sandy and rocky habitat
- ☐Screes
- ☐Shrub & groves
- ☐Soil
- ☐Wander biotopes
- ☒Water bodies (flowing, standing)
- ☒Wetland
- ☐Woodland

Stakeholders:

- ☒Authorities
- ☒Local community
- ☒NGOs
- ☒Schools
- ☒Universities

Table 1. Species list of diatoms encountered in the Lake C sediment core.

Achnanthes lanceolata	*Gyrosigma acuminatum*
Achnanthes minutissima	*Gyrosigma spencerii*
Amphora libyca	*Navicula cryptocephala*
Amphora pediculus	*Navicula gregaria*
Amphora pediculus	*Navicula rhynocephala*
Antinocyclus normanii	*Navicula trivialis*
Asterionella formosa	*Navicula veneta*
Aulacoseira ambigua	*Navicula sp 1*
Aulacoseira distans	*Nitzschia amphibian*
Aulacoseira granulate	*Nitzschia dissipata*
Aulacoseira moniliformis	*Nitzschia frustulum*
Cocconeis pediculus	*Nitzschia gracilis*
Cocconeis placentula	*Nitzschia linearis*
Craticula cuspidate	*Nitzschia palea*
Ctenophora pulchella	*Nitzschia recta*
Cyclotella atomus	*Rhoicosphenia abbreviata*
Cyclostephanos dubius	*Rhoicosphenia curvata*
Cyclostephanos invisitatus	*Staurosirella pinnata*
Cyclotella meneghiniana	*Stephanodiscus hantzschii*
Cyclotella pseudostelligera	*Stephanodiscus medius*
Cyclostephanos tholiformis	*Stephanodiscus parvus*
Cymatopleura solea	*Surirella bifrons*
Cymbella minuta	*Surirella brebissonii*
Cymbella ventricosa	*Surirella linearis*
Diatoma tenius	*Tabellaria ulna*
Diatoma vulgaris	*Gomphonema olivaceum*
Fragilaria capucina	*Gomphonema parvulum*
Fragilaria fasciculata	*Gomphonema parvulum*
Fragilaria parisitica	