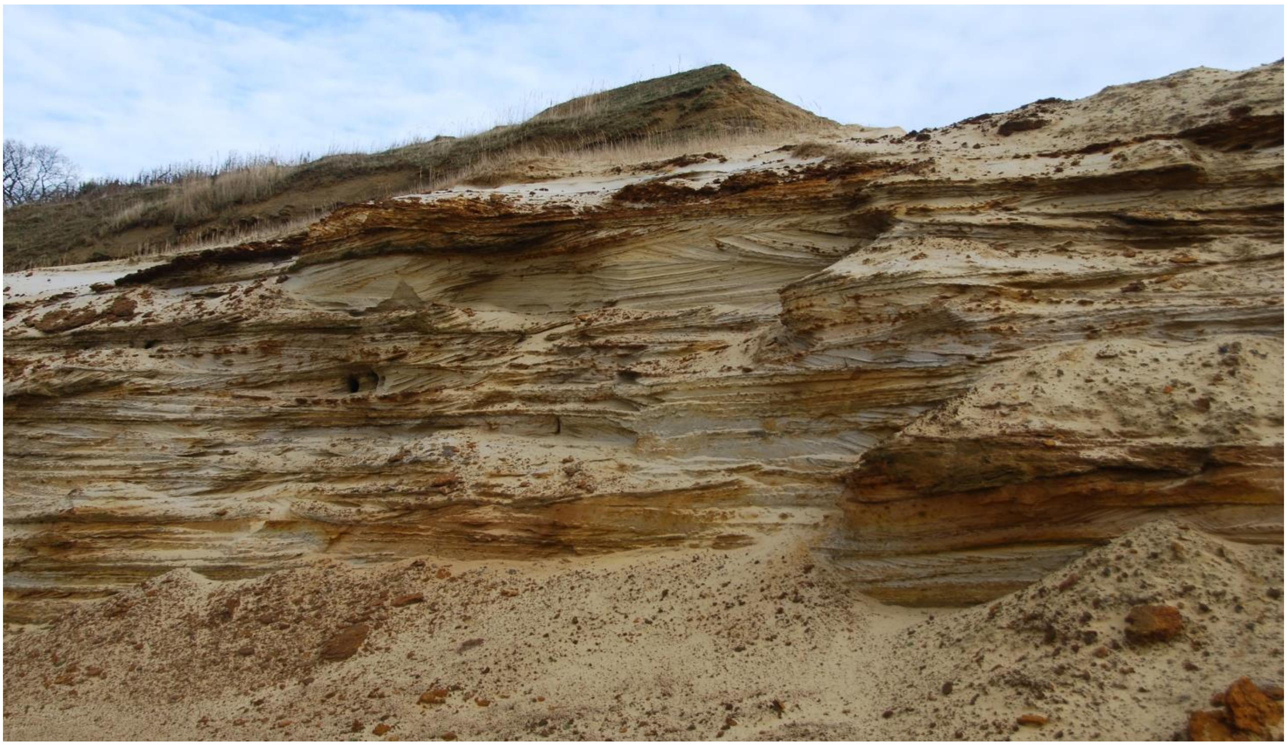
Central
Bedfordshire
Council

Bedfordshire Silica Sand Update, 2017



Cuesta Consulting Limited

October 2017

Contents

1. Introduction & Terms of Reference

1.1 Cuesta Consulting Limited was appointed by Central Bedfordshire Council in December 2016 (Contract Reference 0012016) to provide an update of Cuesta's earlier (2008) study of Silica Sand in Bedfordshire.

1.2 The new study was required to include:

1. An update of the technical information relating to silica sand production in Bedfordshire, and corresponding end-uses;
2. An update on silica sand sales, reserves and operations within the Central Bedfordshire Local Plan area;
3. Technical advice on any silica sand sites and related issues to be considered as part of the Minerals Local Plan Review; and
4. An update on the availability of alternative silica sand production, reserves and resources within areas which are able to compete, effectively, within the markets now being served from sites in Bedfordshire (informed by other recent and ongoing work carried out by Cuesta for other Mineral Planning Authorities).

2. Technical Background

2.1 Silica sand is defined (in the British Geological Survey (BGS) minerals planning factsheet, 2009) as sand which normally has a silica content of more than 95%, usually in the form of quartz sand grains. On account of its high purity and because of the size distribution, strength and shape of its component grains, such sand can be processed for use in a wide range of specialist applications as an industrial mineral, rather than simply being used as a construction material.

Geology – The Silica Sand Resources of Bedfordshire

2.2 In Bedfordshire, silica sand occurs within the Cretaceous Woburn Sand Formation. These deposits date from the middle of the Cretaceous period, around 100 million years ago, and were laid down in a tidal, shallow sea environment. The deposits are predominantly very fine- to coarse-grained, well-rounded quartz sands, with variable (but much smaller) amounts of iron, glauconite, and silt. Since their deposition, and particularly since the sands have become exposed to weathering at or near to the Earth's surface, these 'impurities' have become oxidised such that they impart a range of different colours to the sand: brown to reddish brown where the iron oxide staining is heavy, through various shades of orange and yellow to white (where the purity of the sand is higher and iron staining is minimal or absent). The sands at greater depth, where oxidation has been more limited, may be predominantly grey in colour, irrespective of their mineralogy.

2.3 The Woburn Sands have been worked within Bedfordshire for many decades, both as a source of specialist or 'industrial' sand (particularly around Leighton Buzzard, where the purity Is generally higher) but also - and more extensively - as a source of soft building sand. A previous study for the former Bedfordshire County Council (Cuesta Consulting Ltd., 2006) described the full extent of the Woburn Sand resources and quarries within the County together with the varying end-uses of the material being extracted. A second report (Cuesta, 2008) focused more specifically on the deposits around Leighton Buzzard, from which specialist silica sands have traditionally been produced, and examined details of a number of new sites being proposed at that time for inclusion in the Minerals Local Plan. The present study has a similar geographical focus and provides an update on the 2008 report, following substantial local changes in the number and ownership of the sites being worked.

2.4 The geology of the deposits around Leighton Buzzard is described in detail within the BGS memoir for the area (Shephard-Thorn *et al*, 1994), primarily with reference to the exposures seen within the numerous sand pits available for inspection at that time. The memoir noted that several distinct horizons can be identified within the Formation, but also that these do not form laterally continuous units which can be mapped across the area. Some degree of correlation between the various pits was shown in Figure 14 of that memoir, however. That suggested an upper sequence of high purity medium- to coarse-grained '***silver sands***' (which in practice range from orange to white in colour), overlain in places by '***silty beds***' and/or by medium- to coarse-grained, silty, iron-stained '***red sands***', which cut through and replace the silver sands in the south of the district. These units are underlain by a lower sequence of ferruginous (heavily iron-stained), usually fine- to medium-grained '***brown sands***'. In several of the pits, the upper and lower sequences were found to be separated by a thin marker horizon of sandy, pebbly ferruginous clay. In some areas, the 'brown sands' are predominantly fine-grained and laminated, with thick interbeds of black, silty clay, and are known locally as 'compo', but in other areas they are coarser-grained and less clayey.

2.5 In all areas, the deposits extend beneath the water table, but are usually worked 'dry', with the aid of temporary pumped dewatering in some cases. At one site to the south of Leighton

Buzzard, where most of the sands lie below the water table, they are worked by suction dredging from a lake.

2.6 The differences in grain size, colour and silt/clay content of the various horizons play an important role in determining how the sand is extracted and used. This was examined in detail within the 2006 Cuesta study and is briefly summarised below. More specific consideration, for each of the currently active pits, is given in Chapter 3.

End Uses

2.7 Although silica sand is often associated with glass-making, none of the deposits in Bedfordshire are currently used for that purpose. Instead, the purest 'silver' sands in this area tend to be used as specialist non-staining and neutral sports sands, including golf bunkers, athletics jumping pits and children's play sand.

2.8 The Woburn Sands may also be yellow, orange or brown in colour, however, and these have a different range of specialist end-uses in applications where colour is not of over-riding importance. Relatively coarse-grained varieties can be washed, screened and dried to produce a range of different grades of water filtration sand: a product for which the very rounded grains of the marine sands are particularly well-suited.

2.9 Fine- to medium-grained varieties of coloured silica sand may be suitable, after processing, for use as foundry moulding sands and for a range of horticultural, root-zone, sports and amenity products. For these applications, consistency of product (grading, colour and chemical composition) is more important than specific colour and can be achieved through an understanding of the geological variations within the deposit and the adoption of appropriate extraction, blending and processing techniques.

2.10 Finer-grained silica sands may be used in a range of specialist sports applications, as well as in resins, tile and brick facings and industrial filler applications. The very fine-grained varieties, and those with a higher proportion of silt, are often processed simply by dry screening and/or blending on-site for agricultural and equestrian applications, or for use as general building sand and even low value fill. These need to be distinguished from the other types outlined above, which generally require more complex processing.

2.11 Further details on the various end uses, and their corresponding specification requirements, are set out in Appendix A, which has been updated slightly from similar information presented in Cuesta's previous reports for Bedfordshire (2006, 2008) and for the South Downs National Park (2016).

2.12 Although there is usually some degree of flexibility, and although a number of different end uses may be supplied from a single quarry, there is normally a commercial imperative for each quarry to be worked in such a way that maximises sales to the end uses which are most profitable – usually those for which significant value can be added during processing. This is not always the case, however, and much depends on the commercial priorities of the individual operators. Substantial quantities of Woburn Sand are sold for use as construction aggregates and other relatively low value applications. The low-value sales are largely, but not exclusively, from the least pure (silty and heavily iron-stained) sources of silica sand within the County, particularly those from sites located further away from (to the north east of) Leighton Buzzard. Increasingly, however, even the Leighton Buzzard deposits appear to be being utilised, to a greater extent than previously, for non-specialist purposes. This partly reflects the exhaustion of high quality reserves at some of the quarries and the change in ownership of others, notably the recent (2015) departure from this area of a specialist industrial sand producer (Sibelco, formerly WBB).

3. Detailed Review of Operational Sites

3.1 The following review combines information from previous studies (including Cuesta's 2006 and 2008 reports for Bedfordshire County Council and GWP's 2009 report on the Reach Lane site), with updated information obtained from more recent site visits, planning applications, Minerals Local Plan submissions and discussions with operators. Information is presented for each of the quarries, and proposed extraction sites, from north to south across the Leighton Buzzard area. The sites are illustrated in Figure 3.1, which also shows the extent of the Woburn Sand outcrop and its continuation beneath the Gault Clay formation, to the east.

Bryants Lane / Reach Lane

3.2 Bryants Lane and Reach Lane quarries are conjoined sites located in the Heath & Reach area, to the north of Leighton Buzzard. They are operated as a single unit by L.B. Silica Sand – a small independent operator which now forms part of M. Obrien Plant Hire Ltd. The Reach Lane part of the site is currently subject to a Section 106 legal agreement which restricts mineral extraction operations within the site. However, at the time of preparing this report, a new consolidating planning application was understood to be in preparation.

3.3 The geological succession at Bryants Lane / Reach Lane comprises an upper unit of fine-grained silty /clayey sands, underlain by less clayey, whitish-yellow fine-grained sands, and by a lower sequence of more heavily iron-stained, steeply cross-bedded, medium-grained sands, passing downwards into lighter-coloured fine- to medium-grained sands with orange and brown staining, and with extensive 'carstone' (ironstone) reefs, especially towards the base. The first two of these units correspond to the 'silty beds' and 'silver sand' sequence as identified by the BGS, although the latter is largely finer-grained than seen elsewhere in the district. The lowest two units correspond to the BGS 'brown sands' sequence, though again these are quite different to the descriptions given in the BGS memoir, being more variable and generally coarser-grained. They are quite unlike the stratigraphically equivalent 'compo' sands found in several other quarries in this area (see below). The 'silver sand' unit at Bryants Lane includes an upper 2m-thick horizon of almost pure white sand, underlain by less pure 'off-white' sand. Similar deposits existed at Reach Lane but have been worked out.

3.4 All of these units are worked separately by selective dry digging, with dewatering from a small sump at the base of the excavation to enable the lowest units to be worked in dry conditions. Processing of the extracted sand is described in detail in the GWP (2009) report and remains largely unchanged. The significant difference is that ironstone – which was formerly discarded or sold only as occasional blocks – is now crushed and sold more extensively as construction aggregate (for use in foundations, sub-base etc.). As a consequence, there is now little material discarded, other than overburden and silt from the washing plant.

3.5 The combined Bryants Lane / Reach Lane operation has averaged a total annual output of 121,000 tonnes over the four-year period 2013 to 2016 (slightly higher than the pre-recession figure of 111,000 tpa, reported in 2003). Additional sales of crushed ironstone are expected to amount to around 20,000 tonnes in 2017, bringing the total output to around 140,000 tpa.

3.6 Excluding the ironstone, some 65% of recent output has been used in the construction sector (primarily as building sand and for use in 'heritage' lime mortars) with the remaining 35% being used as specialist silica sand. The GWP (2009) report on Reach Lane described the various markets being supplied at that time, and how the various outputs from the processing plant are matched to the different specialist uses. The report noted that even the 'brown sands' from Reach Lane have a high silica content (between 98% and 99%, after washing) and are thereby suitable for a wide range of products.

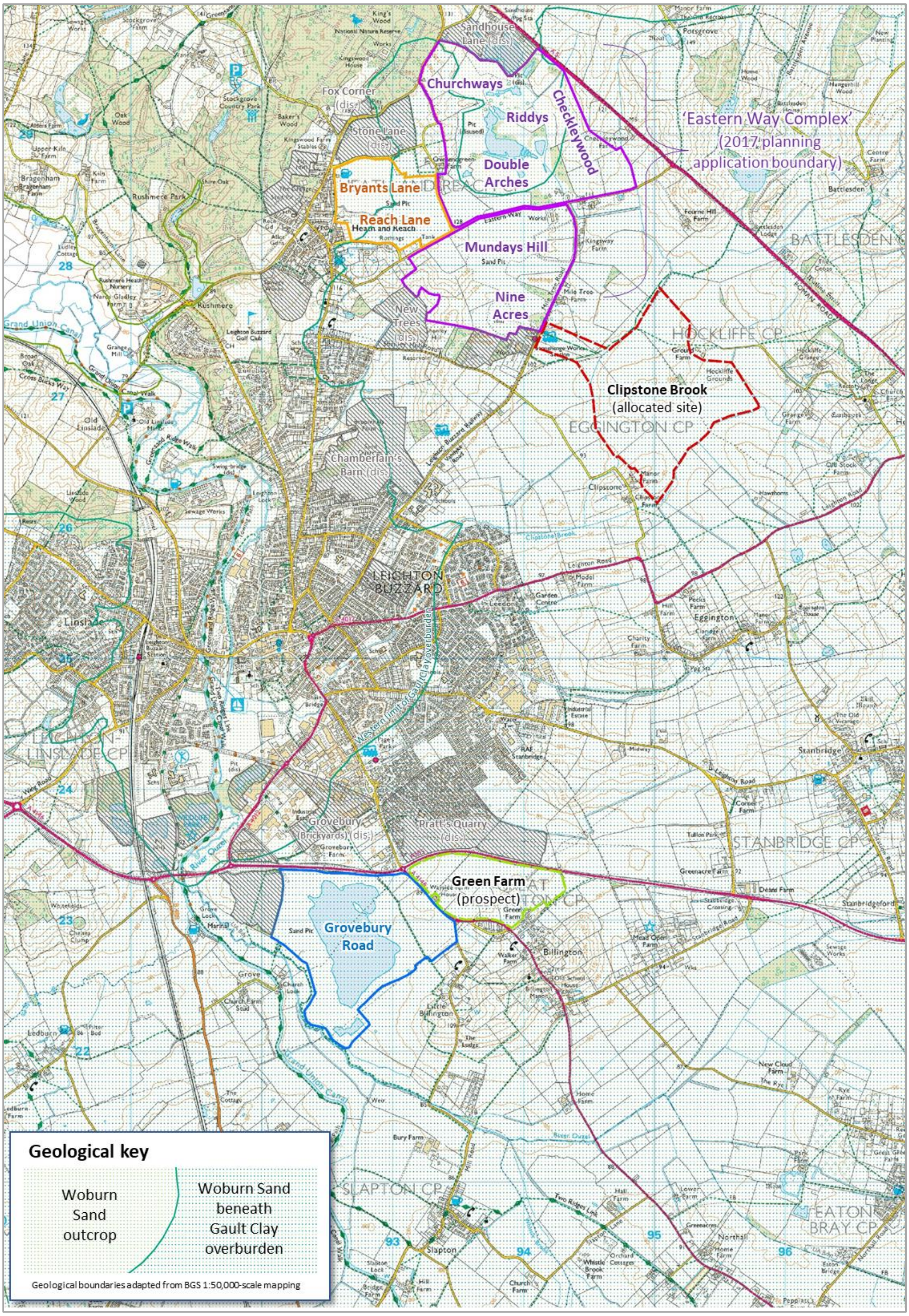


Figure 3.1: Existing and former silica sand quarries and proposed sites, within the Leighton Buzzard area.

3.7 The main specialist markets for this unit in recent years have been golf courses, (bunker sand and top dressing), natural turf sports pitches, synthetic sports pitches, equestrian applications, athletic landing pits, play sand, agriculture and foundry sand. The company is actively developing new markets and opportunities for the specialist sand, and additional uses (as noted on the company website) include tile adhesive grout, non-slip floorings, brick-facing / moulds and paint manufacturing. The website also mentions ceramic and glass manufacture, though it is not thought that any of the output is currently used for such purposes. The GWP (2009) report on Reach Lane confirms that although glass sand has been produced from this area in the past, the remaining reserves of relatively high purity 'white sand', do not meet today's tight quality specifications.

3.8 Detailed assessment of the reserve/resource figures at the combined Bryants Lane/Reach Lane site is currently in progress, supported by ongoing site investigations (Autumn 2017). Subject to the findings of those investigations, the company estimates that the total sand remaining within the site is around 2.22mt, of which approximately 224,000 tonnes is thought likely to be relatively high purity white and off-white sand from Bryants Lane. This may be increased if a steeper stable slope configuration can be established to enable the excavation to be widened (this being subject to ongoing geotechnical analysis). The current estimate for brown sand within the Reach Lane boundary, as advised by the company in September 2017, is 690,000 tonnes. Most of this lies beneath the plant area, however, and currently there are restrictions on any further extraction. Much of this could therefore only be extracted and processed (subject to a successful future planning application) using relatively simple mobile plant.

3.9 Based on an estimated total reserve of 2.22mt, and a future annual output of 140,000tpa, the reserves would have an expected lifetime of up to 16 years.

Eastern Way Complex

3.10 This group of adjoining quarries – Mundays Hill, Double Arches, Churchways, Checkleywood and Riddys – is currently operated by Garside Sands – the specialist sands division of Aggregate Industries. Access to the Double Arches processing plant was secured by the company in 2015 following the withdrawal of the previous operator (Sibelco, formerly WBB) from the Leighton Buzzard area. Both the Double Arches site and Nine Acres Quarry (directly adjacent to Mundays Hill, and also previously worked by Sibelco) are understood to have no remaining permitted reserves, but remain in the ownership of Arnold White Estates Limited.

3.11 Permitted reserves totalling 3.85 million tonnes still remain within Churchways and Checkleywood quarries, with a further 0.64mt at Mundays Hill[1], where a consolidating application, submitted for the Eastern Way Complex in 2016 included a proposal for a small westerly extension to release 0.45mt of additional reserves.

3.12 The combined output of the Eastern Way complex is understood to be in the order of 350,000tpa, and current plans (as detailed within the recent consolidating application) are for extraction to continue until about 2032.

3.13 Approximately 98% of the total output from the Eastern Way quarries is sold for specialist silica sand applications, with the remaining 2% being sold either as concreting sand or directly to local customers with no defined end-use (see Table 3.1 below).

[1] The original consolidating planning application indicated reserves of 1.32 Mt at Mundays Hill. However, there was a further request for information under Reg 22 of the EIA Regulations, and the operator clarified that the existing reserves are 0.64 Mt.

Product Type	End Use	% of sales (2013-2016)
Concrete Products	Ready-mixed concrete Concrete roofing tiles Concrete blocks	1
Plastering / Mortar Sand		0
Asphalt Sand		0
Specialist Sands (fully processed – washed, screened and dried)	Sports applications Water filtration sands Pet care Traction sand Industrial uses Brick facings	36
Specialist Sands (screened only)	Horticulture Brick facings (wet blasting) Sports applications	62
Merchanting	No defined end uses	1
TOTAL		**100**

Table 3.1: 'Typical' breakdown of output from Eastern Way quarries 2013 to 2016
(note, this excludes material processed at Eastern Way but sourced from Grovebury Quarry)

SOURCE: Garside Sands, September 2017

3.14 Further details are given below for each of the component quarries within the Eastern Way complex.

3.15 **Mundays Hill** quarry works two distinct horizons within the Woburn Sand Formation. The upper unit is comprised of fine- to medium-grained 'silver sand' which is almost pure white in some areas and tinged with yellow and orange in others, with abundant fossil wood and lignite fragments and with hard, ferruginous 'carstone' reefs developed in places near the top of the succession. The lower unit is made up of much finer-grained, silty brown 'compo' sand, which contains thin interbeds of dark silty clay.

3.16 The upper unit is worked dry, entirely for the production of specialist industrial sands which are selectively extracted and processed (washed, graded, dried and stored) on site for a range of specialist end uses. The white sands are worked separately for use in applications where the highest levels of purity are required, whilst the various shades of yellow and orange are blended at the face to achieve a consistency of colour and grading for other applications. The annual production of these industrial sands from Mundays Hill quarry hitherto has represented a higher proportion of total output than can be maintained from the remaining reserves (largely because the working faces in this unit are already more advanced than those in the bench below).

3.17 The lower horizon of finer, brown sand is also worked dry, and is subject only to simple processing to meet specification requirements for construction applications (building sand only) and for some additional types of specialist sand that do not require full processing.

3.18 For the reasons noted above, the remaining reserves at this site (approximately 0.64 million tonnes in total) are not in the same proportion as current or historical output. The proposed western extension would release an additional 0.45mt.

3.19 **The Nine Acres** pit, which is now disused, formerly worked a single geological horizon of 'compo' sand – the overlying upper sequence of silver sands being absent at this location.

The workable reserves were minimal at the time of Cuesta's previous (2008) study and are believed to have been exhausted shortly after that work, but are described here because of their potential relevance to other nearby resources, including the strategic site allocation of the land at Clipstone Brook (see below).

3.20 When inspected by Cuesta in 2005, the deposits here were found to be significantly finer-grained than those seen in any of the other Woburn Sand quarries in the Leighton Buzzard area – this being consistent with the descriptions given by the BGS, as summarised in para. 2.4, above. The sequence revealed at that time comprised thin beds of white to grey fine-grained silty sand with thin laminations of clay and silt together with local concentrations of iron staining and lignite particles along sub-horizontal bedding planes. The site was being worked only intermittently, with all of its output being processed through the Double Arches plant site (wet screening to remove both fines (clay & silt) and small quantities of coarser sand, followed by drying and grading). The resultant products were used entirely as specialist sands for a range of sports and equestrian applications, as well as in resins, adhesives, industrial filler applications, tile and brick facings, sands for wet blasting, agricultural applications (fertilisers), and mortar sands.

3.21 The Nine Acres sand was found to be particularly well suited to these applications because of its very fine grain size, its high silica content (which gives good chemical resistance, insulation properties and strength) and because of its high adhesion and water resistance. The very low clay content in the finished product was also of importance in terms of volume stability and suitability for use in resin binding systems. The sand was not suitable for use in normal building /construction situations as it was too fine, too single sized and too clean to work. For similar reasons, it was not used for any of the more specialist end uses supplied from other sites in the area.

3.22 **Double Arches** quarry was previously thought to have workable reserves beneath the existing plant site, but these have not been inspected and it is understood that there are no longer any plans for them to be worked. The processing facilities continue to be fully operational.

3.23 **Churchways, Checkleywood** and **Riddys** are long-established adjoining quarries which have been operated as a single unit for many years. At the time of our previous studies (Cuesta 2006, 2008) the sites were producing only small quantities of building sand, but were expected to increase their output in future years to cover a wider range of products, including dry-screened specialist sands as well as building sands and a smaller proportion of low value fill material, but no concreting sand. Following the demise of several other quarries as reserves at those sites have been exhausted, and the withdrawal of Sibelco from this area, that expectation seems likely to have been fulfilled. Although Garside Sands were unable to confirm figures for individual quarries, it is thought likely that a substantial proportion of the 350,000tpa for the Eastern Way complex as a whole will have been from these sites. At the end of 2016, the remaining permitted reserves at the Churchways complex were stated by Garside Sands (in their consolidating planning application) to be 3.85 million tonnes (2.84mt at Checkleywood and 1.01mt at Churchways).

Land at Clipstone Brook

3.24 This area, located directly to the east of the Mundays Hill site (see Figure 3.1), is allocated as a Strategic Mineral Site within the adopted Minerals and Waste Local Plan, having been put forward by WBB Minerals in conjunction with the land owners, in December 2007. Although WBB (now Sibelco), no longer have an interest in the site, it is now being investigated further by another operator, who are reviewing the data obtained by WBB and are planning to carry out further drilling and testing of the site.

3.25 In a letter to BCC dated 13th December 2007, WBB Minerals had indicated that the sands here 'could provide a replacement for sands currently produced at our operations at both Pratts and Nine Acres Quarries when these permitted reserves become worked out'. Supporting information was provided to Cuesta by WBB in 2007 in the form of average grading data for two distinctly different parts of the deposit: The uppermost unit was a relatively coarse sand, with very similar grading characteristics to the 'red sands' and 'silver sands' that were formerly worked at WBB's Chamberlain's Barn site, and to the coarser upper sands ('red sands') unit at their former Pratts Quarry. These were shown to be underlain by a finer sand, which has very similar grading characteristics to the 'compo' – type brown sand deposits at Nine Acres (see Cuesta 2008, Appendix A, for comparisons). WBB's geologist advised that the Clipstone Brook deposit is less obviously characterised by agglomerated (iron-cemented) particles than the sands at Chamberlain's Barn and should therefore be less likely to suffer from the same drawbacks as that material in terms of its suitability for the high-grade end-uses supplied from Pratts Quarry.

3.26 From the figures supplied by WBB to Bedfordshire County Council, the Clipstone site is understood to contain approximately 2.5 million tonnes of proven reserves, though it is not clear at this stage how this breaks down into the two main types of sand described above. Given the very different rates of consumption of the finer sands (e.g. from Nine Acres quarry) and the coarser sands (e.g. from Pratts) it is therefore impossible to calculate, at this stage, how many years' supply are contained within the proposed working area.

3.27 In March 2017, based on a preliminary assessment of the 'inherited' drilling and testing data from WBB, the geologist now investigating the site suggested that it may contain up to 2 million tonnes of relatively coarse-grained high purity (~98% silica) 'silver sand' and noted that this *might* have the potential to be considered as a source of sand for glass-making. These observations, however, are subject to more detailed review of the WBB data, and to the findings of further drilling and testing. Whether or not the site is economically viable will depend, in particular, on the thickness of Gault Clay overburden and on the height of the water table.

Grovebury Quarry

3.28 Grovebury Quarry (formerly known as 'Grovebury Road') is located directly to the south of Leighton Buzzard (see Fig 3.1). It is operated by Garside Sand's parent company – Aggregate Industries – one of the UK's largest producers of construction materials. Most of the succession at Grovebury Road falls below the natural water table and, for this reason, it has not been possible to observe the deposits in-situ. From descriptions provided by the company's geological manager in 2017, the deposits comprise an upper layer of well-graded sand with grits and occasional iron-cemented sands (believed by AI to be part of the BGS 'brown sand' sequence) and a lower unit of dark brown / grey glauconitic sands containing silty beds and hard phosphorous-rich bands. It is only the uppermost unit that has been worked.

3.29 The relative height of the water table at this site also dictates the method of working, with the sand being extracted by suction dredging rather than by dewatering and conventional dry digging. This option helps to avoid the costs (including impact mitigation costs) that can be associated with dewatering.

3.30 Within the upper sands there are variations in colour, grain size and other properties but, whereas these could be selectively extracted by dry digging methods, as is done at other sites, the suction dredging process does not allow this. Instead, screening is used to separate the dredged material out into various size classes which are then used for different purposes: most are used in concreting applications, but some of the coarser grades are used in water filtration, whilst the finer-grained sands are used primarily for various sports applications (see below for further details).

3.31 Although the Grovebury Quarry sand, on its own, is incapable of making a satisfactory concrete, it is successfully blended with sharper sand and coarse aggregate from Quaternary sand & gravel sites elsewhere. Additional construction uses, following processing, include building sand (plastering & mortar) and asphalt sand. The overall proportion of total output used for construction purposes over the period 2013 to 2016 was around 47%. This compares with an average of 69% for the years 2003-2006 (see Table 3.2, below).

3.32 As shown in Table 3.2, the remainder of the sand extracted from Grovebury Quarry is split between fully processed specialist sands (transferred to Garside Sand's nearby Eastern Way plant for washing, processing, drying and storage); other specialist applications including various sports sands, processed primarily by screening the wet, dredged sands on site; and sales to local building merchants etc., for which the final end use cannot be determined.

Product Type	**End Use**	**% of sales**	
		2003-2006	**2013-2016**
Concrete Products	Ready-mixed concrete Concrete roofing tiles Concrete blocks	59	30
Plastering / Mortar Sand		9	14
Asphalt Sand		1	3
Specialist Sands (fully processed – washed, screened and dried)	Sports applications (Astro-turf) Water filtration sands Pet care Traction sand (rail transport) Industrial uses (fluidised bed boilers / foundry sand) Brick facings (dried sand)	16	23
Specialist Sands (screened only)	Horticulture (Forestry commission, garden centres etc) Brick facings (wet blasting) Sports applications (golf bunkers, top dressing, equestrian)	13	25
Merchanting	No defined end uses	2	5
TOTAL		**100**	**100**

Table 3.2: 'Typical' breakdown of output from Grovebury Quarry, 2003 to 2006 and 2013 to 2016

SOURCE: Aggregate Industries, February 2007, and September 2017

3.33 It is worthwhile noting that, in respect of the specialist sand output from Grovebury Quarry Aggregate Industries once supplied a much higher proportion of its output as specialist water filtration products. This, however, required the selective screening of only the coarser grades of sand, and left a large proportion of fine-grained sands for which no high value end-uses could be found, at that time. By contrast, the ability to sell a high proportion of the output into concrete applications was a more attractive economic proposition. Over the last decade or so, the finer grained sands have found new, high value applications in the sports sector, notably in connection with synthetic sports pitches.

3.34 Aggregate Industries were unable to provide current output figures for Grovebury Quarry but, based on previous knowledge of the site, and the company's previously stated intentions to increase output to compensate for the closure of the adjoining Grovebury Farm

(‘Brickyards’) quarry (Cuesta, 2008), and allowing for recovery from the recent recession, it is estimated that recent output from Grovebury will have been in the order of 320,000 tonnes per annum. This compares with an average output of around 280,000tpa between 2003 and 2006.

3.35 There are now only limited permitted reserves left at the margins of the quarry, although the company is currently exploring the possibility of extracting additional coarse sand from the lake floor (within the existing permission boundary). Together, these reserves are said by the company to be sufficient to maintain supplies for approximately five to eight years. At the estimated current rate of output this would imply something like 1.6 to 2.5mt of remaining reserves. The current planning permission at Grovebury extends only to 2021, and a time extension may therefore be needed to complete the extraction.

Land at Green Farm, Billington

3.36 This area, located directly to the east of Grovebury Road Quarry, and to the south of the former Pratts Quarry, was also proposed for inclusion within the Minerals Local Plan (site MD13) but was not taken forward. It is now being investigated by another operator with further drilling and testing to be undertaken following the investigations at Clipstone Brook. Pending revision to take account of the findings of that investigation, the following observations are taken from Cuesta’s earlier (2006, 2008) reports.

3.37 The deposits at Green Farm would be expected to be very similar to those in the former Pratts quarry which, when inspected by Cuesta in 2005, were found to comprise an upper sequence of coarse- and medium-grained, iron-stained reddish-brown sands (part of the ‘red sand’ sequence, as described in the BGS memoir), underlain by a lower sequence of finer-grained yellow sands (presumed to be part of the lower ‘brown sand’ sequence) with sporadic concentrations of heavier iron-staining and localised concretions of hard ferruginous sandstone, extending beneath the water table. This overall similarity is understood to have been confirmed by the former WBB’s drilling and testing. Although the detailed results of that investigation have not been seen, WBB’s geologist advised, in 2007, that the sand within the MD13 proposed site was “identical” to the upper sequence of coarse- to medium-grained red-brown sands seen in Pratt’s quarry, and would be capable of producing the same range of products.

3.38 The lower unit of finer grained sands was not encountered in the investigation of the proposed new site, implying that those deposits are either not present or to be found only at greater depth below the water table. This is consistent with expectations given the south-easterly dip of the strata in this area.

3.39 WBB advised that the increased depth of the lower sands, if present within this site, would make them impractical to extract. That would be comparable with the situation at Grovebury Road Quarry, directly to the west, where (as previously noted) wet working is used, but only for the uppermost unit of relatively coarse sand. This contrasts with the situation at Pratts Quarry, where dewatering is utilised to enable selective dry digging of the (relatively shallow) lower deposits.

3.40 The upper sands within Pratt’s Quarry were found in Cuesta’s 2006 study to display the coarsest grain size distribution of any of the quarries within the area and were understood to be used, primarily, to produce a range of specialist industrial gradings for the water filtration market, along with sports sands and horticultural sands. Together, those end uses were stated by WBB at the time to account for around 63% of production from that site.

3.41 Other industrial uses for the upper sands, accounting approximately for a further 12% of production, were understood from WBB to have included filler applications, chemical industry applications, adhesives, ceramic body production, foundry applications, polymers and plastic coatings, resins, acid-resistant roofing tiles, flooring compound sand, specialist brick facings, architectural masonry, and fluid-bed boiler sands, bringing the total proportion of processed specialist sands at this site to around 75% of total production.

3.42 The remaining 25% of production from Pratt's Quarry, in 2005, was almost exclusively derived from the lower seam and was used only for constructional end uses such as mortar and concreting sands.

3.43 From the figures supplied by WBB to Bedfordshire County Council, the MD13 proposal contained in excess of 3 million tonnes of proven reserves. This, however, is subject to more detailed analysis, including the findings of further site investigations currently being planned.

3.44 If the site were subsequently to be developed (subject to planning), it is not known whether the balance of specialist sand / construction sand would be similar to that for Grovebury Quarry (i.e. with a high proportion of construction sand) or more comparable to the output from the former Pratts Quarry (with a higher proportion of specialist sand).

Summary of Silica Sand Output and Reserves in Bedfordshire

3.45 Bringing together the information presented above, the current position regarding output, reserves and resources of silica sand from the Leighton Buzzard area can be summarised as follows:

Annual Output

3.46 The combined annual output of sand from the Leighton Buzzard silica sand quarries (i.e. Bryants Lane/Reach Lane, the Eastern Way Complex and Grovebury Quarry) over the period 2013 to 2016 (including consultant's estimates in the case of Grovebury) has been in the order of 0.79mtpa. This compares with a slightly higher total of around 0.88mtpa a decade earlier (Cuesta 2008), though that was from a much larger number of sites, several of which have since closed.

3.47 Within those figures, the quantities of specialist silica sand output currently amount to approximately 0.54mtpa, very slightly less than the corresponding figure of 0.55mt in 2007. Specialist sands now account for around 68% of the total output from these quarries, compared with around 62.5% in 2007. This increase is despite the loss of several specialist sand quarries due to the exhaustion of reserves since 2007, and reflects the substantially increased output from the Eastern Way complex.

Permitted Reserves

3.48 The combined permitted reserves of sand at the Leighton Buzzard quarries, as of September 2017, is considered to be between 8.3 and 9.2 million tonnes. If permitted, the proposed western extension at Mundays Hill would take these estimates to a maximum of 9.66mt. This compares with a figure of 22.93mt at the end of 2007 (Cuesta 2008, Table 4.1).

3.49 The current maximum estimate of reserves (excluding the proposed extension) would equate to a landbank of approximately 11.6 years - a reduction of more than 14 years compared with the equivalent calculation ten years earlier (i.e. approximately 26 years at the end of 2007). This reduction is despite the fact that additional permitted reserves were granted for the extension of Grovebury Quarry during that time, and implies either that output has been significantly higher than the figure for 2007 during the intervening period, or (more probably, given that the period included a major recession), that there has been a more recent reassessment of reserves by one or both of the companies involved.

Future Resources

3.50 As evidenced by the recent and planned investigations at both Clipstone Brook and Green Farm, Billington, additional resources of silica stand still remain within the Leighton Buzzard area. These occur primarily to the east and south of the areas which have previously been worked.

3.51 Unlike the older quarries, which were all initiated (at least) in areas where the Woburn Sands crop out at the surface, most of the unworked resources occur beneath an increasingly thick overburden of Gault Clay.

3.52 The sands achieve a thickness of around 60m just to the east of Leighton Buzzard, but thin rapidly at outcrop towards the west (as noted by Shephard-Thorne et al, 1994. In that western area, the deposits have largely been either worked out or sterilised by other land use / development. Further east, the BGS memoir is unable to provide information regarding thickness, and further consideration of the viability of extraction in these areas will need to be informed by the findings of further drilling at Clipstone Brook and Green Farm Billington, which are currently being planned.

3.53 Quarrying beneath thick overburden deposits substantially increases the costs and difficulties of extraction. It also requires increasingly large surface areas in which to work, because of the need for moving and storing the overburden material. Nevertheless, such extraction can still be economically feasible for relatively high value minerals such as silica sand (as has been demonstrated for the site allocation at Clipstone Brook).

3.54 Additional complications arise where substantial proportions of the mineral lie beneath the water table, necessitating either wet working (as seen at Grovebury Quarry) or pumped dewatering to allow dry excavation. The latter offers far greater potential in terms of the ability for separating different types of sand at the quarry face (and thereby being able to produce a wider range of specialist sands), but it brings with it additional potential impacts on the water environment which can be very costly to mitigate. In very general terms, these difficulties are likely to be experienced most in areas of lower ground and with increasing distance towards the south and east – because of the gentle south-easterly dip of the strata.

3.55 It will be for the industry to assess where the limits of feasibility lie in terms of developing future resources within these areas but the potential clearly exists and this needs to be borne in mind in terms of safeguarding the resources for future use.

4. Bedfordshire's Role in the Future Supply of Silica Sand

Introduction

4.1 Given that the permitted reserves of high quality silica sand in Bedfordshire have reduced substantially over the last decade, and that future resources within the area are likely to become increasingly difficult to work, it is useful to examine the range of alternative supply sources within the UK, and Bedfordshire's role in the overall pattern of supply.

Alternative Sources of Silica Sand in England

4.2 Information on UK sources of silica sand was recently compiled by Cuesta in connection with work for the South Downs National Park Authority and West Sussex County Council (Cuesta, 2016, Table 6.1). Subsequently, as part of the duty to co-operate initiative between the SDNPA, Central Bedfordshire and all other mineral planning authorities with involvement in silica sand production, that table has been updated with quantities of permitted and planned (allocated) reserves in each area – most recently in connection with the Examination in Public of the West Sussex/South Downs joint Minerals Local Plan, in September 2017.

4.3 Table 4.1, below presents an updated version of Cuesta's original table, with the latest available tonnages, as agreed at that Examination or, in the case of Bedfordshire, as assessed in this report. It is important to note that output rates, where shown in this table, correspond to the total sales of sand from the quarries concerned, rather than just sales to specialist end-uses. In most cases they therefore include a proportion of sales to construction-related end-uses, including concrete, mortar, plaster and asphalt. This provides a more realistic indication of the overall rate of consumption of the reserves.

4.4 The number of years represented by the remaining reserves is based either on a calculation from the total rate of output, where this is known, or by subtracting one year from the durations shown in Cuesta's 2016 report for the SDNPA, where current rates of output are not known.

4.5 The table should be regarded as a work in progress, and more detailed information will hopefully come to light in due course through the ongoing collaborative work by the mineral planning authorities. Such work will also be able to track the progress of releasing additional reserves from sites which are currently identified within live planning applications (such as Rudheath Lodge in Cheshire East) and planned allocations (notably within Surrey and Norfolk).

4.6 Table 4.1 excludes production and reserves from sites in Scotland. As noted in Cuesta's 2016 report for the South Downs, the output from Scottish sites has an important bearing on the market for glass sand, where the high commodity value justifies much longer transport distances, but those sites are not considered relevant to the lower value and more local markets supplied from Bedfordshire.

Table 4.1: Sources of Silica Sand Production in England, as at September 2017

MPA, Geological Formation	Active Quarries	Foundry Sand	Glass Sand[1]	Other Industrial Sand	Other specialist sand[2]	Stock of permitted reserves[3]		Annual Output[4]
						mt	Years	mtpa
Bedfordshire (Woburn Sand)	Bryants Lane/Reach Lane Eastern Way Grovebury	(✓)	✗	✓	✓	9.0 – 10.0	13	0.79
Cheshire E. (Chelford Sand)	Dingle Bank	✗	✓	✓	✓	10.3	23	0.442
Cheshire E. (Gawsworth Sd.)		✗	✗	✓	✓			
Cheshire East (Congleton Sand)	Eaton Hall	✓	✗	✓	✓			
	Bent Farm	✓	✗	✓	✓			
	Arclid	✓	✗	✓	✓			
Dorset (Poole Formation)	Warmwell	✗	✗	✓	✗	?	1	?
	Henbury	✗	✗	✗	✓	?	9	?
Essex (Kesgrave Sands)	Martell's	✗	✗	✓	✓	?	12	?
Hampshire (Folkestone Formation)	Kingsley	✗	✗	✗	✓	?	5	?
	Frith End	✗	✗	✗	✓	?	2	?
Kent (Folkestone Fm)	Addington	✓	✗	✓	✓	0.98	>10	?
North Lincolnshire (Quaternary)	Messingham	✓	✓	✓	✓	?	<10	?
Norfolk (Leziate Beds)	Leziate sites	✗	✓	✓	✓	2.20	3	0.785
Norfolk (Mintlyn Beds)		✗	✗	✓	✓			
North Yorkshire (Osgodby Fm)	Burythorpe	✓	✗	✗	✓	0.5	>10	?
Nottinghamshire (Nottingham Castle Fm)	Two Oaks Farm[5]	✗	✗	✓	✓	12.0	38	0.32
Staffordshire (Rough Rock)	Hurst	✗	✗	✗	✓	?	?	?
Surrey (Folkestone Fm)	North Park & Pendell Farm	✓	✓	✓	✓	2.4	12	0.200

Notes: 1: includes both clear glass and coloured glass
2: includes ceramics, resins, grout, paint, fillers, water filtration and (potentially) frac sand
3: includes horticulture, sports and leisure applications
4: includes all output from silica sand quarries, including construction uses, to indicate the rate of consumption of the reserves.
5: Two Oaks Farm works a deposit with a lower silica content, but nevertheless supplies into the 'industrial' and 'specialist' sand markets.

Transportation Distances

4.7 Cuesta's South Downs report considered the likely market radii for relatively low-grade silica sand deposits. Whilst it was found that a wide range of transport distances may be encountered – often depending on specific product types and customer relationships – distances of up to 40 miles were common, and up to 80 miles was feasible, even for sand used in sports, leisure and horticultural end-uses. For sands with greater added value from processing (e.g. for industrial processes, water filtration and high-end sports applications, such as synthetic turf), one operator noted that travel distances would often be up to around 100 miles one way but also that it is not uncommon for such sand products to travel up to 200 miles one way, particularly where supply sources for particular products are limited. A notional average 100-mile radius was assumed, in that study, for silica sands other than those for glass or sodium silicate production.

4.8 If a similar radius were applied to the output from Bedfordshire, the same customers could potentially be served from sites within all of the areas listed in Table 4.1. In most cases, the alternative sources fall within a 100-mile radius of Leighton Buzzard. In others (e.g. Cheshire East, Dorset and North Lincolnshire), they lie just outside that limit but would nevertheless be capable of serving at least some of Bedfordshire's customers. Only Burythorpe in North Yorkshire lies a significant distance beyond the 100-mile radius, but that is a very small operation with limited reserves and would probably not be capable of supplying anything but its existing customers.

The Importance of Maintaining Future Supplies from Bedfordshire

4.9 The foregoing analysis would suggest that there are a number of viable alternatives to Bedfordshire, in terms of maintaining an ongoing supply of silica sand. It must be remembered, however, that all of those areas already supply to a range of existing customers and may or may not be able to increase future output to compensate for any future decline in production from Bedfordshire.

4.10 More significantly, some of the areas – particularly Norfolk, Surrey, parts of Cheshire East, North Lincolnshire (and potentially the South Downs National Park, if ever developed) – have a major role to play in supplying high quality sand for the glass industry. Whilst each of those areas could theoretically divert a greater proportion of their output into lower-specification markets, they are unlikely to do so, and it would not be in the interests of resource efficiency to anticipate this.

4.11 It is therefore considered essential that Bedfordshire should continue to play its traditional role in maintaining future supplies of silica sand. It should do so by allocating suitable sites for future extraction, as and when they are proposed by industry; by recognising the strategic need for ongoing supplies when determining future applications, and by considering the option of identifying Areas of Search to encourage further prospecting by industry in areas that are likely to have workable resources and limited environmental impact. Consideration should also be given to extending the Mineral Safeguarding Area for silica sand further east into areas where the mineral is concealed beneath Gault Clay.

5. Conclusions

5.1 In accordance with the study brief, this report has provided an update of the technical information relating to silica sand production in Bedfordshire, and corresponding end-uses together with updated information on silica sand sales, reserves and operations within the Central Bedfordshire Local Plan area. This has focused on the Leighton Buzzard area - the only part of the county from which specialist / industrial sands are produced. It has included observations relating to one allocation within the Minerals Local Plan, and one additional prospective site being investigated by industry.

5.2 The study has found that the combined annual output of sand from the Leighton Buzzard silica sand quarries over the period 2013 to 2016 has been in the order of 0.79mtpa. This compares with a slightly higher total of around 0.88mtpa a decade earlier. Within those totals, the quantities of specialist silica sand output have been maintained at very similar levels to those seen in 2007 (currently around 0.54mtpa). Specialist sands now account for around 68% of the total output from these quarries, compared with around 62.5% in 2007. This increase is despite the loss of several specialist sand quarries due to the exhaustion of reserves since 2007.

5.3 The combined permitted reserves of sand at the Leighton Buzzard quarries, as of September 2017, is considered to be between 8.3 and 9.2 million tonnes. This compares with a figure of 22.93mt at the end of 2007 and represents a current landbank of around 11.6 years.

5.4 The report has also provided an update on the availability of alternative areas of silica sand production which would theoretically be capable of competing within the markets now being served from sites in Bedfordshire. This is very much a work in progress, which will be developed further through the ongoing collaborative work between the various silica sand producing mineral planning authorities.

5.5 Whilst alternative sources of supply do exist, each of them has its existing range of customers to supply and some of the major sources are primarily focused on producing high specification sands for glass-making and/or sodium silicate production. It is therefore considered essential that Central Bedfordshire should continue to play its traditional role in maintaining future supplies of silica sand. It is recommended that this should include:

1. allocating sites for future extraction, as and when suitable sites are proposed by industry;
2. recognising the strategic need for ongoing supplies when determining future applications for silica sand extraction; and
3. considering the option of identifying Areas of Search to encourage further prospecting by industry in areas that are likely to have workable resources and limited environmental impact.

5.6 It is also recommended that consideration should also be given to extending the Mineral Safeguarding Area for silica sand further east into areas where the mineral is concealed beneath Gault Clay.

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APPENDIX A: Markets and End Use Requirements

A1. As indicated within this report, there is a wide range of specific end uses for which silica sand from the Leighton Buzzard area of Bedfordshire is used. This section provides updated information about the main markets for silica sand in the UK, both at a national scale and more locally, together with a review of available information regarding the physical and chemical quality requirements within each market sector, where this is known.

Markets

A2. In the UK, existing and potential markets for silica sand range from industrial glass production and foundry casting / moulding sand (traditionally the primary markets for such materials) to emerging and potentially highly significant markets such as hydraulic fracturing ('frac' sands). In between, there has been a steadily expanding range of markets for which specialist (silica) sand is the preferred or only suitable material. These range from water filtration and industrial product manufacturing (paints and plastics, polymer compounds, rubber, sealants, resins, adhesives and ceramic products) to various sports and leisure uses (golf courses, sports pitches, rootzone products, top-dressing materials, bunker sand, equestrian sand, jumping pit sand and play pit sand) and to a number of horticultural and agricultural applications.

A3. Except at a very broad scale (such as that reported in the Office of National Statistics Business Monitor PA1007: Mineral Extraction in Great Britain, and in the United Kingdom Minerals Yearbook published by the BGS - which uses the same information), very little quantitative data is available on either levels of demand from (or sales to) any of these specialist markets. ONS data on silica sand production in Great Britain from 1970 to 2014, (but with broad subdivisions by market sector only since 1999[2]) is shown in Table A1, below.

A4. Drawing largely on the same source of data, and on a 2007 survey by the Silica and Moulding Sand Association, the BGS factsheet on silica sand (2009 version) notes that, historically, foundry casting was an important market for silica sand but that, with the progressive decline in UK heavy manufacturing industries, there has been a steady reduction in demand within that sector. From the data shown in Table A1, that trend seems to have continued through to the present day. Glass manufacturing became the largest consumer of silica sand in the UK in the mid-1980s[3] . Demand within that sector appears to have peaked in about 2006, however, and has since declined slightly. Over the same period there has been a substantial increase in the 'other' markets for silica sand which, together, now exceed the total sales to glass manufacturing, and have done since at least 2006. Since 2003, sales to agricultural, horticultural and leisure uses have been recorded separately from 'other industrial sands' and, by 2013, this sector had become comparable in scale, in terms of tonnage, to the current market for glass sand (although still a long way short of the 2006 peak for glass sand, which needs to be borne in mind as the economy recovers from the recent prolonged recession).

[2] PA1007 data is available online from 1999 onwards. Earlier data - for Great Britain as a whole - is given in the former Minerals Planning Guidance Note 15, and is included in Table A1. More detailed subdivisions of that data is given only in printed editions of the PA1007 reports, which are commercially available but have not been accessed for the purposes of this study.

[3] See Figure 2 of the BGS mineral planning factsheet on silica sand

Table A1: Silica Sand Production in Great Britain, 1970 to 2014 (Source: Business Monitor PA1007)

Year	Total Silica Sand Production in Great Britain (mt)	Foundry Sand (mt)	Glass Sand (mt)	Other Industrial Sand (mt)	Agriculture, Horticulture and Leisure (mt)
1970	**5.782**				
1971	**5.645**				
1972	**5.478**				
1973	**6.775**			Detailed breakdown not readily available before 1999 (see footnotes on previous page)	
1974	**5.990**				
1975	**6.139**				
1976	**5.901**				
1977	**6.283**	Foundry sand dominant			
1978	**6.224**				
1979	**5.829**				
1980	**5.708**				
1981	**4.451**				
1982	**4.123**				
1983	**4.026**				
1984	**4.328**				
1985	**4.178**				
1986	**4.108**				
1987	**4.029**				
1988	**4.340**			'Other' sands growing	
1989	**4.380**				
1990	**4.132**		Glass sand dominant		
1991	**4.201**				
1992	**3.615**				
1993	**3.587**				
1994	**4.038**				
1995	**?**				
1996	**?**				
1997	**4.704**				
1998	**4.662**				
1999	**4.092**	1.043	1.593	1.456	
2000	**4.095**	0.987	1.755	1.353	
2001	**3.848**	0.880	1.853	1.115	
2002	**3.833**	Confidential	1.940	1.331	
2003	**4.073**	Confidential	1.896	1.645	
2004	**5.011**	Confidential	2.663	Confidential (>0.886)	0.838
2005	**4.146**	Confidential	2.120	0.954	Confidential (> 0.553)
2006	**5.174**	Confidential	2.206	1.306	Confidential (> 1.086)
2007	**4.909**	0.527	1.930	1.178	1.274
2008	**4.777**	0.443	1.932	1.186	1.216
2009	**3.755**	Confidential	Confidential	1.096	0.988
2010	**4.070**	0.353	1.582	0.913	1.222
2011	**3.969**	0.382	1.528	0.956	1.104
2012	**3.888**	0.340	1.489	0.782	1.277
2013	**3.961**	Confidential	Confidential	0.837	1.448
2014	**3.948**	Confidential	Confidential	0.982	1.394

A5. This progressive shift in market demand, from heavy manufacturing prior to the mid-1980s to the far more diverse markets seen today has had very important implications for the types of sand required. This is brought into sharp focus by comparing the current situation with that prevailing when the former Minerals Planning Guidance note 15 was published, in 1996. That document reported a growing market requirement for higher quality processed sands which was tending to focus attention, at that time, on fewer sites with high quality raw materials and more sophisticated processing plant. It noted that, because of this, the suitability of some of the permitted reserves for industrial applications may be neither economically nor practically viable in the future. The more recent diversification of the market has significantly changed this outlook. Whilst there is still a requirement for high quality sands and sophisticated processing (as discussed in more detail below), there is also now a much broader range of applications and a correspondingly wide range of requirements for different types of sand.

A6. Potentially, the market could change again in the near future, with the emerging requirement for 'frac' sands. If hydraulic fracturing of onshore deposits becomes an established method of 'unconventional' oil and gas production in the UK, this will introduce an additional, high specification sector to the market for silica sand, and potentially could greatly increase the overall level of demand. Whether or not this would have any impact on the study area, however, will depend not only on the fate of this industry but also on the suitability of the resources for this particular end use. This is considered later in this report.

A7. Monitoring the availability of sands to meet the increasingly diverse range of requirements is a further complication. Separate landbanks are required (by the NPPF) to be maintained for silica sand and for other forms of sand & gravel. This is carried out in all MPAs where silica sand is produced, but is often a difficult exercise, particularly where silica sand and construction sand are produced from the same deposits (as is the case in several areas including Bedfordshire, Hampshire, Surrey, Kent, Cheshire and Essex, as well as the South Downs and West Sussex). In such cases, unless it is possible to sub-divide the resource outcrops into distinctly separate geological units (which does not seem to be the case in the South Downs area), the available permitted reserves can only be apportioned between the separate landbanks on the basis of recent sales information, as supplied by the operators. Whilst this is done, where necessary, in other MPAs, in practice it is difficult. This is because the split between different markets supplied from individual quarries may vary over time depending on the success or otherwise of individual operators in marketing their products for specific end-uses.

End Use Specification Requirements

A8. Previous research in Bedfordshire (Cuesta 2006 and 2008) and in Surrey/Kent (GWP 2009b & 2010) found that there were limited published specifications or industry-wide standards for most of the specialist end-uses noted above (with the exception of frac sands) and instead, individual product specifications are developed. For some end-uses, particularly for glass sand and foundry sand, manufacturers and customers develop their own specifications and associated products. Partnerships are established between particular suppliers and customers, and parameters and testing methods are agreed to establish a suitable product fit. In other cases, particularly for sports, leisure and horticultural sand, the operating companies tend to develop their own 'bespoke' products and then aim to encourage brand loyalty among their particular customers through demonstrable quality and skilful marketing.

A9. This section of the report initially outlines the relative importance of the different physical properties and the chemical composition of the sand for different end-use applications. Each of the main end-use types are then reviewed in turn, noting details of either generic or more specific requirements (or at least end-user preferences), where these are known.

Properties of Silica Sand and their Relevance in End Use Applications

A10. Several properties of silica sand are commonly evaluated to determine end-use suitability. As described in Chapter 2, the most common properties assessed are: Particle Size Distribution or PSD (the range of sand grain sizes present), colour, sand grain shape (sphericity and roundness) and chemical composition (particularly the total silica content and percentage presence of impurities). However, the relative significance of these properties and the values or specifications required varies according to end-use. In some applications, particularly for ‘frac-sands’, additional physical properties, such as the strength of the sand grains, are also important.

A11. The range of sand grain sizes present is important in all end-use applications. Most applications require ‘tightly graded’ or ‘well sorted’ sand – one that contains a limited range of sand grain sizes. Some applications, such as water filtration sand, some ‘frac-sands’ and horticultural sands require material that is relatively coarse. Other applications tend to require a medium-grained or fine-grained sand. In all of these applications there are limits to the quantity of ‘fines’ (the clay and silt content, less than 63 microns) and the gravel-sized content (greater than 2mm), both of which need to be controlled by screening before any further processing takes place (or as part of that process where screening is all that is needed).

A12. Colour is used intuitively by operators as an indicator of end-use suitability. A white sand is generally regarded as being ‘clean’ – having low or negligible silt, clay and organic matter content – and is more likely to have a higher silica content and lower iron oxide content. So, for example, a layer or lens of white sand in a building sand quarry may be extracted and marketed separately - say as cattle bedding material - without any additional processing. The intrinsic higher grade physical properties are understood simply by the colour of the sand.

A13. Whilst a more detailed analysis of chemical composition is required in industrial applications (see para. A15 below), it would appear that colour is used more widely in sports, leisure and horticultural applications to indicate end-use suitability. For example, a play-sand, golf bunker sand and equestrian sand should be ‘off-white’ in colour and non-staining.

A14. Sand grain shape has little or no importance in glass making, where the grains are melted at high temperatures, or in applications using ‘silica flour’, where the grains are crushed down to a powder. However, it is of importance in all other end-use applications. The shape of sand grain required varies widely depending on the end-use. So, for example, a filter sand should generally be more rounded and of higher sphericity to improve permeability, and for ‘frac sands’ these properties are essential to enable the particles to be emplaced within minute fractures; whereas a golf bunker sand should generally be more angular to improve compaction.

A15. The chemical composition of the sand is most important in true industrial manufacturing applications, since the chemistry of a material can have a significant impact on the final product in a process involving heat and/or pressure. Therefore, end-use chemistry specifications are most important in glass-manufacture, in the use of foundry sand, in the production of sodium silicate, in the manufacture of fillers, and in the production of ceramic glazes and clay-based white ceramics.

A16. The more detailed specifications (or at least widely-agreed preferences) for each end use application are discussed in more detail in the following sections.

Industrial Manufacturing Applications

Glass

A17. Although glass making is not currently one of the end-uses supplied from silica sand sites in Bedfordshire, some of the higher purity 'silver sands' are potentially suitable for this purpose and have occasionally been used in the past. Given that glass making sands are becoming increasingly rare in the UK, it is therefore useful to understand the requirements which need to be met, even if this is only to confirm that the Bedfordshire deposits may need to be ruled out.

A18. The most common type of glass is soda-lime-silica glass, found in such everyday objects as glass bottles and jars (glass containers), and mirrors and windows (flat glass). Glass containers may be made from clear glass (known in the glass manufacturing industry as 'flint glass') or from coloured glass. Glass fibre for insulation and reinforcement, glass bulbs and fluorescent tubes are also produced in the UK.

A19. Soda-lime-silica glass contains between 70% and 74% silica (from silica sand or recycled glass 'cullet') and other constituents including limestone, dolomite, feldspar and salt. Silica sand therefore forms a large percentage of the raw materials entering the batch and must itself be of very high silica content (at least 97% - see below). Moreover, the consistency of the chemical composition is of paramount importance and uniformity of feedstock must therefore be maintained. Glass making is a continuous process, with furnaces being run continually for many years at a time, and it is imperative for them to be provided with an equally continuous supply of consistent, high quality sand. Variations in the chemistry of the sand could lead to variations in melting characteristics and thus in the quality of the finished glass.

A20. The former standard used in glass manufacture was: *BS2975:1988 Methods for sampling and analysis of glass-making sands*. This included specifications for the various types of glass described above. The revised *BS2975-1:2004 Sampling and analysis of glass-making sands, Methods for sampling and physical testing of glass-making sands* and *BS2975-2:2008 Sampling and analysis of glass-making sands, Methods for chemical analysis* omit these specifications. There is now greater flexibility and product specifications are developed instead by individual glass-manufacturers. However, the former standard specifications are still used as guidance between suppliers and manufacturers.

A21. The quality of the sand demanded by glass manufacturers depends on the type of glass made. For clear container glass, the sand must have very high silica content (99% or more) and be essentially almost free of coating, staining or detrital heavy minerals. For coloured glass, a silica content of 97% may be tolerated.

A22. Very small amounts of certain impurities, particularly iron oxide, in the sand will lead to tinted or opaque glass. This is critical for clear container glass but for flat glass and coloured container glass, slightly higher proportions of iron content are allowed. The BGS factsheet gives the following broad chemical specification: *'Glass sand for colourless glass containers generally has an iron content of <0.035% Fe_2O_3, for flat glass in the range 0.06% to 0.1% Fe_2O_3, and for coloured containers 0.2%-0.3% Fe_2O_3'*. This is consistent with the specifications given in the former B2975:1988. Titanium Dioxide (TiO_2) should generally be below 0.03% in clear glass and Chromium (Cr_20_3) below 0.002%, as these compounds may also impart colour to the glass. Higher levels of both are tolerated in coloured glass.

A23. Alumina (Al_2O_3) can be considered an impurity in glass sand as it increases the viscosity of the glass, making it difficult to work and, as with iron oxide, can lead to decreasing glass transparency. However, alumina can also be added to some glass batches as it gives greater chemical durability, a lower coefficient of expansion and greater resistance to devitrification (crystallization of glass). For flint glass, Al_2O_3 can be around 0.5%, and for some types of coloured glass, up to about 4% may be tolerated.

A24. Glass sands must also have a very low content of grains which do not melt easily (highly refractory minerals), such as chromium, kyanite and andalusite, otherwise unmelted grains in the glass will form unsightly 'stones' and points of weakness. The levels of aluminium, magnesium, calcium and the alkalis (sodium and potassium) affect the melting properties and therefore need to be kept at consistent levels.

A25. The range of sand particle sizes present in the silica sand is also important in glass manufacture. Excessive fines in the sand are undesirable because they tend to carry impurities, cause dusting and lead to blisters in the glass. Coarse grains are also undesirable as they can survive in the melt and cause scum in the batch or 'stones' in the finished product. Coarse sand is also more difficult to fuse and tends to increase the cost and time taken to finish a batch. A narrow size distribution is preferred, usually in the range 125 to 300 microns with typically no more than 0.2% greater than 500 microns and no more than 1% less than 125 microns. There should be no fraction greater than 710 microns or less than 63 microns.

Foundry Casting.

A26. Silica has a higher melting point than the pouring temperature of iron, steel, copper and aluminium. This enables castings, which form the basis of the heavy engineering and manufacturing industries, to be produced by pouring molten metal into moulds made out of silica sand. In the past, naturally-bonding sands were used containing enough clay to give the mould strength without adding an additional bonding agent. However, as noted in the BGS factsheet, the requirements for foundry sand are now of higher quality, due to the greater precision required for the aerospace, military and automotive parts now being produced. It is therefore currently far more common for clay-free washed sands with a high silica content to be used. A binding agent such as bentonite clay or a chemical, such as resin, is added to the sand as a bonding agent. These synthetically bonded sands can be controlled to offer moulding properties that are dependably uniform with a superior surface finish and greater dimensional accuracy.

A27. First published in 1946 by the American Foundrymen's Society, The Foseco Ferrous Foundryman's Handbook (Brown, 2000), now in its Eleventh Edition, would appear to still be the common comprehensive reference guide used by the Foundry Industry. Suitable specifications for various castings are described.

A28. A foundry mould must be able to withstand the high temperature of molten metal, be strong enough to withstand the pressure of the molten metal without yielding, yet be permeable enough to allow the steam on contact and the gases in the metal to dissipate through the sand. The PSD, particle shape and chemistry of the sand are all important in satisfying these requirements, although some compromise must be made in order to best meet them all.

A29. The chemical composition of the foundry sand is most important as an indication of its refractoriness – its ability to withstand strength at high temperatures. The chemical composition of the sand also can affect the acid demand value which has an important effect on the catalyst requirements of cold-setting acid catalysed binders. The Foundryman's Handbook gives a guide on the appropriate limits for the chemical composition of silica sand for foundry use as follows:

- SiO_2 95-96% min the higher the silica, the more refractory the sand

- LOI 0.5% (Loss on Ignition) - limits on organic content
- Fe_2O3 0.3% max Reduces refractoriness
- CaO 0.2 max Raises the acid demand value
- K_2O, Na_20 0.5% max Reduces refractoriness
- Acid demand value to pH4 - 6ml max as a high acid demand adversely affects acid catalysed binders.

A30. Whilst in the past values such as the average grain size and AFS (American Foundry Society) Grain Fineness Number (GFN) were used, the latest edition of the handbook states that the choice of sand should now more typically be based on PSD. The smaller or finer the grains, the smoother the metalwork produced. However, if the sand grains are too small, the venting of gases and steam becomes poor. Therefore, the selection of a moulding sand is a balance using the finest grain size possible that still allows safe venting of the moulds. Foundry sands usually fall into the range 150–400 microns, with 220–250 microns being the most commonly used. No more than 2% should be less than 200 microns and no more than 0.5% less than 63 microns.

A31. The best permeability of moulding sands is achieved where the grains are both rounded and uniform. Angular-grained sand tends to pack and if the grains are not uniform, small grains may pack between larger ones. However, despite the fact that the highest permeability can be obtained by using a uniform-sized sand, in practice a range of 5 or 6 sieve sizes of sand is used to prevent all the grains from reaching a critical temperature and change in volume at the same time (for silica this is 573°C), which would cause 'scabbing' in the product. High sphericity of grains is also ideal in foundry sand as the surface area of grains decreases with increasing sphericity minimising the amount of binder needed. The Foundryman's Handbook states that 'the best foundry sands have grains which are rounded with medium to high sphericity giving good permeability and high strength at low binder additions. More angular and lower sphericity sands require higher binder additions, have lower packing density and poorer flowability'. In practice, a range of grain shapes may be used depending on the end result required.

Sodium Silicate Manufacture

A32. Sodium silicate is another high specification silica product, for which very few deposits in the UK have proved to be suitable. As with glass making, it is useful to consider the requirements, if only as a means of discounting the Bedfordshire sands as a potential source.

A33. Sodium silicates form a range of soluble compounds, produced from soda ash and silica sand and marketed as glassy clear or powdered solids or as a liquid. They are used in the production of soaps, detergents, adhesives, zeolites, glaze and enamels and within passive fire protection. Silica gel is a highly pure, porous solid made by acidifying sodium silicates and is used for its desiccant and absorption properties in the preservation of food, in the cosmetic industry and in cat litter.

A34. No particular commonly used end-use specifications were identified. However, a typical product data sheet for a sand that is used in the manufacture of sodium silicates was provided by a commercial operator. This indicates that high purity silica sands with a silica content greater than 99% may be required. As the final product is white, limits on iron oxides (Fe2O3) are important and were given at 0.05% with an alumina (Al_2O_3 content) of less than 0.1%. Limits were also given for other metals and alkalis. Of particular note is the alumina content which, if too high, forms insoluble aluminium silicates causing operational problems with the filtration systems used in sodium silicate production. The PSD was given as: no portion > 1mm, at least 90% between 125um and 500um with a maximum of 7% less than 125um. The grain shape used was of medium sphericity and sub-angular grains.

Paints and Plastics, Polymer Compounds, Rubber, Sealants, Resins and Adhesives.

A35. Crystalline silica, when ground into very fine flour is used as a reinforcing filler in a wide range of manufactured products. It is used to improve the appearance and durability of architectural and industrial paint and coatings. High purity silica contributes critical performance properties such as brightness and reflectance, colour consistency, and oil absorption. In architectural paints, silica fillers improve tint retention, durability, and resistance to dirt, mildew, cracking and weathering. Low oil absorption allows increased pigment loading for improved finish colour. In heavy-duty offshore or marine paints and self-cleaning exterior wall coatings, the durability of silica imparts excellent abrasion and corrosion resistance. Silica flour is also used in plastics for encapsulating electronic components and as a filler in a wide range of specialist epoxy resins, sealants adhesives and flooring compounds.

A36. No particular commonly used end-use specifications were identified although information from a range of product sheets marketed by Garside Sands would indicate that there is some flexibility in chemical composition, with total silica content of around 96-97% acceptable and relatively high levels of iron oxides (Fe_2O_3) at around 2%.

Ceramics.

A37. Ground silica is an essential component of the glaze (converted by heat to Cristobalite) and body formulations of all types of ceramic products, including tableware, sanitary ware, ornaments and floor and wall tiles. In the ceramic body, silica is the skeletal structure upon which clays and flux components attach. The silica is used to modify thermal expansion, to regulate drying and shrinkage, and to improve both structural integrity and appearance.

A38. No particular commonly-used end-use specifications have been identified, although the GWP report states in section 4.6 that, for this end-use, sand should typically have a silica content above 97.5%, less than 0.55% alumina (Al_2O_3) and less than 0.2% iron oxide (Fe_2O_3).

Hydraulic Fracturing Sands

A39. Hydraulic fracturing (commonly referred to as 'fracking') is the process of pumping a fluid into wells at high pressure to fracture the host rock to stimulate oil or gas flow in low permeability host rocks. These fractures allow the oil and gas to escape from the host rock into the well to be pumped to the surface. One of the components of the fluid is typically water, the other is a proppant which remains packed tightly in the fractures to keep (or 'prop') them open. The proppant also acts as a permeable medium within the fractures that allows the oil and gas to flow out of the host rock.

A40. Approximately 70% of the proppants used in hydraulic fracturing are naturally occurring silica sand ('frac sand'). Other less cost-effective types of proppants include resin-coated silica sand, and ceramic proppants such as calcined alumina and calcined bauxite. Whilst frac sands for use in low permeability strata are not yet exploited as an end-use in the UK, if onshore hydraulic fracturing becomes established in the UK in future, then this could potentially become a very important new market for suitable types of silica sand.

A41. There are two standards that are widely used in determining the suitability of silica sand as a frac sand. These are: American Petroleum Institute (API) Recommended Practice (RP) 19C: 2006 Measurement of Proppants used in Hydraulic Fracturing and Gravel-Packing Operations (replaced RP56:1995) and BS EN ISO 13503-2:2006 and A1:2009. Petroleum and Natural Gas

Industries. Completion Fluids and Materials. Measurement of Properties of Proppants used in Hydraulic Fracturing and Gravel-Packing Operations.

A42. Frac sand must also be capable of withstanding the high pressures found at depths of several thousand metres below the surface. A very high grade silica content of greater than 99% is required as other deleterious materials may crush under the high pressures reducing permeability. In addition, a laboratory test should show that the sand produces no more than 10% fines at 4000 - 6000 psi (28 - 42 MPa).

A43. If the proppant sand contains carbonate, it could have a tendency to 'cement' inside the fracture which will reduce permeability. Acid solubility can be an indication of carbonate content and other impurities and this test is used for frac sands. Less than 2% weight loss in acid solution is appropriate for frac sand falling between UK sieve mesh sizes 30 (600 microns) and 50 (300 microns).

A44. The PSD impacts the permeability and strength of the frac sand and a narrow size distribution is preferred to retain a high permeability. If a wide range of grain sizes were used, the smaller grains would fall between the larger grains when tightly packed together as a proppant. Proppant sizes are generally defined and marketed as falling between two standard US sieve mesh sizes: 90% of the sand should fall between these sieve sizes. As a general rule coarser sands are used for oil production and finer sands for gas production. The most commonly used size designation is 20/40 (850/425 microns). Others include 12/20 (1700/850 microns) and 40/70 (425/212 microns). Most frac sand is between 850 and 212 microns.

A45. In addition, there are limits on the silt (2 microns to 63 microns) and clay content (<2 microns). Finer clays and silts could be carried back into the host rock blocking off paths for the oil or natural gas and slowing harvest rates. The presence of clays on the surface of frac sand could also create additional friction slowing harvest rates by reducing conductivity. A turbidity test (the degree to which transparency of the fluid is lost) is used to measure the amount of fines – the maximum turbidity should be 250 FTU (Formazin Turbidity Unit).

A46. Frac sands must be as spherical and round as possible to flow into fractured shale and then provide good porosity, permeability and compressive strength once in place. Angular grains and fragments tend to pack together at high pressures, which will decrease porosity and permeability. Average sphericity and roundness values of more than 0.6 are required for frac sands.

Water Filtration

A47. Silica sand is widely used by the water industry in the filtration of solids from drinking water, in the treatment of wastewater and in the production of water from wells. It is also used for water filtration in the food & drink industry, for effluent treatment in other manufacturing industries and in swimming pools. Silica sand (and silica gravel) is used in many types of filter including rapid gravity filters, slow sand filters and continuous sand filters.

A48. For sand used as a filter in drinking water, the following standard applies: BS EN 12904:2005 Products used for treatment of water intended for human consumption. Silica sand and silica gravel. Limits on chemical composition are given.

A49. Important characteristics of the sands that are used for these purposes include:

- high silica content (an intrinsic property: silica is chemically inert, so will not degrade, dissolve or react when it comes into contact with acids, contaminants, volatile organics or solvents) – a figure of more than 96% is given on many sand filter product sheets and a Type 1 sand used as a filter in drinking water must have a silica content greater than 96%;

- uniform sub-angular to rounded grain shapes (another intrinsic property of the sand grains: some degree of angularity allows for better retention of solids, whereas greater roundness improves porosity and rate of through-flow);
- closely-graded size distributions - by comparison with most other specialist grades of silica sand, the particle sizes required for water filtration grades are relatively coarse, usually in excess of 500 microns and are supplied in several very narrow, overlapping grading categories (e.g. 1180 to 600 microns; 1700 to 850 microns; 2.00 to 1.00mm and so on, continuing up into gravel size fractions). There is a limit on the oversize and undersize portion of 10%;
- cleanliness, i.e. containing minimal impurities and minimal silt/clay content (the first is an intrinsic characteristic of the sand, whereas the second can be improved by washing and screening).

Sports & Leisure Applications

A50. An increasingly important market for silica sand, which is now becoming dominant, in terms of quantity supplied, is in various sports and leisure applications, particularly in golf courses, natural (turf) sports pitches, synthetic sports pitches, equestrian surfaces, athletics (jumping pits) and children's play sand. For the most part, these end-uses cannot be supplied from the more common sources of construction sand, because of the requirements for grain roundness, strength, colour and other properties. However, sand with a silica content of less than 95% (and therefore not strictly 'silica sand' as defined by the BGS) has proved suitable for use in some of these applications – notably in the case of sand for use on sports pitches, supplied from Triassic sandstones in Nottinghamshire (Rees, 2016). The requirements in each case and the reasons for those requirements vary slightly between different applications, as described below.

A51. Guidance produced by the Sports Turf Research Institute (STRI) is widely used in sports turf construction and maintenance in both golf courses and sports pitches. The most recent guidance is: Baker (2006) *Rootzones, Sands and Top-Dressing Materials for Sports Turf which refers to the United States Golf Association (USGA): 2004 Revision Recommendations for a Method of Putting Green Construction*.

A52. In turf applications, total lime content is the most influential chemical component. A greater lime content within a sand strongly influences the alkalinity of the turf, raising the pH which in turn increases the competitiveness of weeds and meadow-grass. For most applications on sports turf areas, the lime content of any sand, root-zone or top dressing should be below 0.5%. On winter games pitches with fairly acid soil, top dressing sands with a lime content up to 2% might be acceptable. pH should be reasonably neutral, between 4.5 and 9.3.

A53. Sand selection is a balance between the needs of good drainage and aeration, reasonable moisture retention and stability. The range of sand grains present is important in consideration of all these requirements. Therefore, PSD is probably the most important property of the sand for sports and leisure applications. With the exception of bunker sand, a narrow grain size distribution within the medium and smaller coarse-grained sand sizes is required. A number of PSD grading envelopes are given in the STRI guide for different end-uses, with upper and lower limits being defined for what is 'acceptable' and what is recommended (the latter comprising more restrictive (narrower) grading envelopes). It is reasonable to assume that, for any sand which falls within these limits in its natural state, it should be possible to comply with the more stringent recommended limits by means of simple processing (dry screening or, if necessary, wet screening to remove any excess fine material).

A54. For most turf construction and maintenance purposes, it is considered by the STRI that the effect of grain shape is relatively small compared to PSD. Nevertheless, recommendations for particle shape are given for different applications. Particle shape has been shown to influence the stability of the sand and angular grains are generally avoided (except in bunker sand). Rounded to sub-angular grains are considered to be the most suitable shape, promoting good drainage without excessive compaction.

A55. Total silica content is not generally specified for any sports and leisure applications, although non-staining white sands (implying high-purity silica sand) are required in some applications. However, high silica content does make the sand resistant to further weathering and helps it retain its original particle size and shape, thereby ensuring that the required drainage and air-filled porosity characteristics of the materials are maintained. In addition, sand deposits conforming to the relatively narrow grain size specifications required are typically found within sands composed predominantly of silica, thereby limiting the washing and screening required.

Golf Courses

A56. Golf courses require large quantities of sand, both in construction and in annual maintenance. An 18-hole course will require at least 3,500 tonnes of an 80% sand (or sometimes 100% sand) rootzone mixture for the construction of the greens and tees, up to 1,000 tonnes of bunker sand and would typically use at least 100 tonnes p.a. of an 80% sand mixture for top dressing.

A57. Sands that are used in the UK for golf course construction generally have to comply with the recommendations of the Sports Turf Research Institute (SRTI). Silica sand is recommended and widely preferred. The characteristics of the sand which make it particularly suitable vary slightly between the various different applications, particularly in colour and grading requirements, but the fundamental, intrinsic characteristics of silica sand which are important in all cases are:

- High silica content (which makes the sand resistant to further weathering and helps it retain its original particle size and shape, thereby ensuring that the required drainage and air-filled porosity characteristics of the materials are maintained);
- uniform sub-angular to sub-rounded particle shape (which helps to achieve good drainage without excessive compaction);
- size distributions mainly within the "medium" and "coarse" ranges, i.e. with particle sizes ranging from 0.25 to 1.00mm, but with a proportion of finer sands for root-zone mixtures. (*again, these requirements are achieved by washing and screening but efficiency is higher if the source sand is predominantly within this range, with minimal silt and clay*); and
- neutral pH (calcareous sands, by contrast, depending on the severity of the pH, may be detrimental to the turf and may limit the availability of micronutrients).

A58. Sands which do not have any or all of these characteristics would still be capable of being used, but would require higher levels of maintenance to overcome the resulting problems. Moreover, the status and reputation of a golf course is judged to a large extent on the quality and appearance of its greens and bunkers. Materials and treatments which can enhance these qualities are therefore extremely important and have become increasingly sophisticated over the last 30 years. Whereas green-keepers would have made do, in the past, with locally available sands and soils, the commercial production and marketing of specialist sands and top-dressing mixtures has raised the standards significantly and virtually all golf clubs now source top dressings and bunker sands from specialist suppliers.

A59. **Root-zone sand** should be free of gravel (to avoid damage to mower blades and bed knives) and, to conform to a USGA mix should contain 60 percent or more between 250 microns and

1mm, the medium range with no more than 10 percent coarser than 1.00mm. The sand may also contain up to 20 percent of particles in the fine (125 to 250 micron) range with an additional 5 percent or less in the very fine (75 to 125 micron) range. The use of excessively fine sand, or material that includes more than ten percent of very fine sand, silt and clay, results in rootzones that are slow to drain and poorly aerated. Particles with a sub-angular or sub-rounded shape are preferred, since highly angular sands tend to pack tightly and may injure turf roots, while highly rounded sands may be loose and unstable during turf establishment. Colour is generally of little importance for a rootzone sand, since it is mixed with dark organic material and is quickly covered by the turf.

A60. **Top-dressing sands** help to keep established turf in good condition by promoting a good balance of water retention and drainage. They should have a particle size distribution that is similar to (and therefore compatible with) that of the original rootzone material and previous top dressings, in order to maintain the existing characteristics and playing quality. Coarser-grained sand laid over finer-grained material, for example, may result in a green surface that is deficient in nutrients and has a low water retention, whereas fine over coarse may result in a surface which retains water with very little air-filled porosity.

A61. **Bunker sand** needs to be cleaner than root-zone sands. Higher proportions of silt and clay may cause the sand to crust over frequently, requiring repeated maintained to keep it in playable condition. Other than this, the particle size distribution should be similar to that used in the greens themselves (since the sand is often blasted out of the bunkers and onto the greens). The preferred particle shape for bunker sand is angular, since this helps the sand to resist movement under impact from a golf ball, thus resulting in fewer buried balls. Sports Turf Research Institute (STRI) guidance suggests a limit of 'no more than 60% of the particles in the rounded and well-rounded shape categories'.

A62. The colour of bunker sand is important, since it is exposed to view and adds aesthetic appeal. Light-coloured sands are generally preferred, usually white, light brown, yellowish brown or light grey. While some clubs use a pure white sand to provide dramatic contrast in colours, tans or light browns are more natural, easier to maintain and are easier to play from because they reflect and glare less. Except where white or very light-coloured sand is demanded, there is actually no necessity to use silica sand for bunkers. In fact, provided that it is suitably graded, as detailed above, a sharp sand (e.g. from a river terrace deposit) may provide a better source of material than a soft sand, which will generally be much less angular.

Natural (turf) sports pitches

A63. The demand for top quality winter sports pitches (football, rugby and hockey) at all levels from Premier League down to school pitches has increased significantly in recent years placing a premium on high quality turf surfaces in which good drainage, increased carrying capacity and high standards of maintenance are required. In a typical top-class football pitch such as the new Wembley Stadium the 200mm lower rootzone will comprise 100% sand with the 100mm upper rootzone 80% sand plus 20% soil. Such constructions will require 3-4,000 tonnes of sand depending on the size of the pitch.

A64. With regard to the selection of suitable sand for these pitches, most of the basic principles outlined above for the construction and maintenance of greens on golf courses are equally relevant. Sub-rounded to sub-angular silica sands are again preferred for the same basic reasons, both in root-zone construction and in top dressing. However, as noted above, sand with a silica content of less than 95% can sometimes be used for these purposes, provided that it has these characteristics. Consistency of colour and texture are important for aesthetic reasons, although the actual colour is generally not significant.

Synthetic sports pitches

A65. Synthetic (e.g. Astroturf) sports pitches represent an important and growing market for silica sand, which is used both in the supporting layers, beneath the synthetic material, and as an infilling within the 'carpet' itself, to support the individual fibres of the material. The sand has to be resilient and stable, so that it achieves and maintains good drainage characteristics without excessive compaction, as well as achieving the desired levels of energy dispersement and ball bounce. The characteristics of silica sand that make it a preferred material for golf courses and natural turf pitches are therefore once again important (see above). Sub-rounded to sub-angular particle shape is especially important, since more angular grains would damage the fibres of the carpet and would also lead to more compaction and poorer drainage, whilst excessively rounded grains would not allow a firm enough surface to be developed.

Equestrian Applications

A66. Silica sand is used in a growing number of equestrian applications, from riding arenas to training gallops. Different surfaces require different types of construction and different materials, but the fundamental principles are, once again, to achieve the right balance between good drainage, water retention, surface resilience and the need to minimise maintenance. Silica sand is again preferred because of its ability to achieve these requirements, particularly when 'single sized' (or at least, closely graded) sands are used: these tend to drain extremely quickly, passing water straight through to drainage layers beneath, yet will maintain a certain degree of moisture (dependent on grain size).

A67. The combination of fast drainage and moisture retention creates a riding surface that mimics that of a beach foreshore. The surface stays firm enough to prevent the hoof sinking in, yet yielding enough to avoid jarring the hoof on impact with the ground. The requirement is for a material that will not furrow, but will compact sufficiently to give a surface upon which horses and ponies will gain the necessary exercise, yet will not be placed under any undue strain.

A68. As well as having size and shape characteristics that will achieve these requirements, the individual sand grains need to be hard and durable, so that the overall characteristics of the surface do not degrade over time. In many cases the sands are also required to be non-staining (i.e. virtually free of impurities such as iron and of silt/clay particles).

A69. Untreated sand needs to be watered to keep fines down. However, the sand can be mixed with wood chips, fibres or rubber to reduce the need to water. Fines (particles less than 63 microns) should be negligible.

Jumping pits and play sand

A70. Long jump, high jump and triple jump landing pits demand high purity, non-staining durable silica sands that will provide and maintain a soft-landing surface with good drainage (i.e. rounded to sub-rounded grains).

A71. Sands which are supplied for play pits are also required to be soft (i.e. with rounded to sub-rounded grains) and to be non-staining and usually white or pale in colour.

A72. Play Sand should conform to *BS EN 71-1:2014 Safety of Toys*. Mechanical and physical properties for Play Sand and, if used beneath play equipment, it must also comply with: *BS EN 1177:2008 Impact attenuating playground surfacing, Determination of critical fall height*. Play Sand must be laid to depth of 300mm. There is no equivalent standard for jump sand.

A73. Play Sand and Jump Sand are generally double-washed to remove greater quantities of fines and impurities. H65 (from North Park quarry in Surrey) marketed by Bourne Amenity has a PSD of 30.6% between 250 and 500 microns, 63.9% between 250 and 125 microns and 5.1% between 125 and 50 microns.

Horticultural and Farming Applications

<u>Horticulture</u>

A74. Silica sand is used in horticulture, market gardening and forestry as a soil conditioner and as component of specialist compost and lawn dressing mixtures. As with the top-dressing mixtures described above, the clean, inert, durable and neutral pH characteristics of the silica grains are important in these applications.

A75. There are very limited specifications for horticultural end-uses. A wider range of sand sizes can be used, including the coarser fraction. Horticultural sands are usually marketed according to the ratio of sand to organic soil material. An 80:20 mix for example would comprise 80% sand and 20% soil. Particularly brands are also promoted, such as a 'Kingsley mix' by Tarmac which uses indigenous topsoil blended with the silica sand from Kingsley Quarry in Hampshire.

<u>Agriculture</u>

A76. In farming, silica sand is used as a carrier for fertiliser and animal feed additives where, in addition to the characteristics listed above, sub-rounded to rounded particle shapes help to ensure free-flowing characteristics and to minimise compaction of the products.

A77. Off-white high purity silica sand is preferred as a bedding material for cattle due to its 'cleanliness' and lack of impurities. This restricts the growth of bacteria and other micro-organisms.

Other Specialist Applications

A78. Other, specialist uses for silica sand (excluding the construction market) range from traction sand used in the rail industry (which need to be strong, durable and free-flowing), to aquariums (which need washed, graded lime-free sands of any kind, but 'silver sands' are commonly used), and the construction of Japanese ornamental 'Zen' gardens (which use washed medium to coarse quartz sand).

Summary

A79. There are a wide range of specialist and industrial end-uses for silica sand but the relative importance of the different markets has varied significantly over time. The need for foundry sand has progressively declined since the 1970s, whilst the demand for sports, leisure and horticultural sands has steadily increased, particularly within the last decade. These latter applications (taken as a group) are now beginning to dominate the market, in terms of overall tonnage supplied, overtaking the demand from the glass industry which, itself, has declined in recent years, though it still remains important. In future, the requirement for 'frac sands' may change the markets again, potentially adding greatly to the overall level of demand if the unconventional oil and gas industry becomes established in the UK.

A80. Each of the growing number of end-uses has its own particular requirements in terms of grading (particle size distribution), grain shape, silica content and maximum levels of impurities. Very high purity silica sands (typically greater than 98% or even 99%) are required in glass making and sodium silicate production, where both the level of impurities and consistency of chemical composition are crucial. Other industrial and specialist applications can utilise lower purity sands, but still require material with a silica content of around 96% or more. Whilst many of the required properties can be modified to some extent by processing, there are limits to what can be achieved, both practically and economically, and it is therefore of major importance to utilise sands which have intrinsic qualities which are as close as possible to those which are needed.