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Mineral Resource Information in Support of National, Regional and Local Planning:

Cheshire (comprising Cheshire, Boroughs of Halton and Warrington)

Commissioned Report CR/05/090N

BRITISH GEOLOGICAL SURVEY

COMMISSIONED REPORT CR/05/090N

Mineral Resource Information in Support of National, Regional and Local Planning

Cheshire (comprising Cheshire, Boroughs of Halton and Warrington)

G E Norton, A J Bloodworth, D G Cameron, D J Evans, G K Lott, S F Hobbs, N A Spencer and D E Highley

This report accompanies the 1:100,000 scale map: This report accompanies the 1:100,000 scale map: Cheshire (comprising Cheshire, Boroughs of Halton and Warrington).

Key words

Mineral resources, mineral planning, Cheshire.

Front cover

Brine wellhead at Holford Brinefield, Cheshire. Photo by David Highley © BGS NERC 2006.

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1 Introduction

This report is one of a series prepared by the British Geological Survey for various administrative areas in England for the Office of the Deputy Prime Minister's research project *Mineral Resource Information in Support of National, Regional and Local Planning.*

The accompanying map relates to the county of Cheshire (comprising Cheshire, Boroughs of Halton and Warrington), and delineates the mineral resources of current, or potential, economic interest in the area and the sites where minerals are or have been worked. It also relates these to national planning designations, which may represent constraints on the extraction of minerals.

Three major elements of information are presented:

- the geological distribution and importance of mineral resources;
- the extent of mineral planning permissions and the location of current mineral workings; and
- the extent of selected, nationally-designated planning constraints.

This wide range of information, much of which is scattered and not always available in a consistent and convenient form, is presented on a digitally-generated summary map on the scale of 1:100 000. This scale is convenient for the overall display of the data and allows for a legible topographic base on which to depict the information. However, all the data are held digitally at larger scales using a Geographical Information System (GIS), which allows easy revision, updating and customisation of the information together with its possible integration with other datasets. The information will form part of a *Summary of the Mineral Resources of the North West Region.*

The purpose of the work is to assist all interested parties involved in the preparation and review of development plans, both in relation to the extraction of minerals and the protection of mineral resources from sterilisation. It provides a knowledge base, in a consistent format, on the nature and extent of mineral resources and the environmental constraints, which may affect their extraction. An important objective is to provide baseline data for the long term. The results may also provide a starting point for discussion on specific planning proposals for minerals extraction or on proposals, which may sterilise resources.

It is anticipated that the map and report will also provide valuable background data for a much wider audience, including the different sectors of the minerals industry, other agencies and authorities (e.g. The Planning Inspectorate Agency, the Environment Agency, The Countryside Agency and English Nature), environmental interests and the general public.

Basic mineral resource information is essential to support mineral exploration and development activities, for resource management and land-use planning, and to establish baseline data for environmental impact studies and environmental guidelines. It also enables a more sustainable pattern and standard of development to be achieved by valuing mineral resources as national assets.

The mineral resources covered are sand and gravel, crushed rock aggregate, silica sand, salt, brick clay, building stones, peat, coal, hydrocarbons and metalliferous mineralisation.

1.1 RESOURCES AND RESERVES

Mineral resources are natural concentrations of minerals or bodies of rock that are, or may become, of potential economic interest as a basis for the extraction of a commodity. They will exhibit physical and/or chemical properties that make them suitable for specific uses and be present in sufficient quantity to be of intrinsic economic interest. Areas that are of potential economic interest as resources of minerals change with time as new uses are developed, product specifications change, recovery technology is improved or more competitive sources become available.

That part of a mineral resource, which has been fully evaluated and is commercially viable, to work is called a mineral reserve. In the context of land-use planning, the term mineral reserve should strictly be further limited to those minerals for which a valid planning permission for extraction exists (i.e. permitted reserves). Without a valid planning consent, no mineral working can take place and consequently the inherent economic value of the mineral resource cannot be released and resulting wealth created, the ultimate fate of mineral reserves is to be either physically worked out or to be made non-viable by changing economic circumstances.

Mineral resources defined on the map delineate areas within which potentially workable mineral may occur. These areas are not of uniform potential and also take no account of planning constraints that may limit their working. The economic potential of individual sites can only be proved by a detailed evaluation programme. Such an investigation is an essential precursor to submitting a planning application for mineral working. Extensive areas are shown as having no mineral resource potential, but some isolated mineral workings may occur in these areas. The presence of these operations generally reflects local or specific situations.

1.2 ENVIRONMENTAL DESIGNATIONS

The map shows the extent of selected, nationally-designated planning constraints as defined for the purposes of this study. These are defined on a common national basis and therefore represent a consistent degree of constraint across the country. No interpretation should be made from the map with regard to the relative importance of the constraints, either in relation to mineral development proposals or in relation to each other. Users should consult policy guidelines issued by the relevant Government department, statutory agency or local authority.

The constraints shown on the map are:

- Part of the Peak District National Park;
- National nature conservation designations – National Nature Reserves (NNR) and Sites of Special Scientific Interest (SSSI);
- International nature designations – Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Ramsar sites; and
- Scheduled Monuments

Mineral development may also be constrained by many other factors not shown on the map, including local landscape designations, considerations relating to the protection of other resources, such as groundwater, and local amenity or environmental concerns, such as noise, traffic and visual impact. These have been excluded because the constraint is not defined on a national basis or the information is not generally available. The extent or degree of relevance of such constraints can be ascertained from the relevant statutory agency or the appropriate Mineral Planning Authority.

2 Sand and gravel

Sand and gravel are defined on the basis of particle size rather than composition. In current commercial practice, following the introduction of new European standards from 1st January 2004, the term ‘gravel’ (or more correctly coarse aggregate) is used for general and concrete applications to define particles between 4 and 80 mm, and the term ‘sand’ for material that is finer than 4 mm, but coarser than 0.063 mm. For use in asphalt 2 mm is now the break point between coarse and fine aggregate. Most sand and gravel is composed of particles that are rich in silica (quartz, quartzite and flint), but other rock types may occur locally.

The principal uses of sand are as fine aggregate in concrete, mortar and asphalt. The main use of gravel is as coarse aggregate in concrete. Substantial quantities of sand and gravel may also be used for construction fill.

Cheshire produced 1.935 million tonnes of sand and gravel in 2004, almost all of which was construction sand, principally concreting sand and building sand. Estimated permitted reserves were 19.7 million tonnes at the end of 2003 (source: NW Regional Aggregates Working Party). Recent production figures are shown in Figure 1.

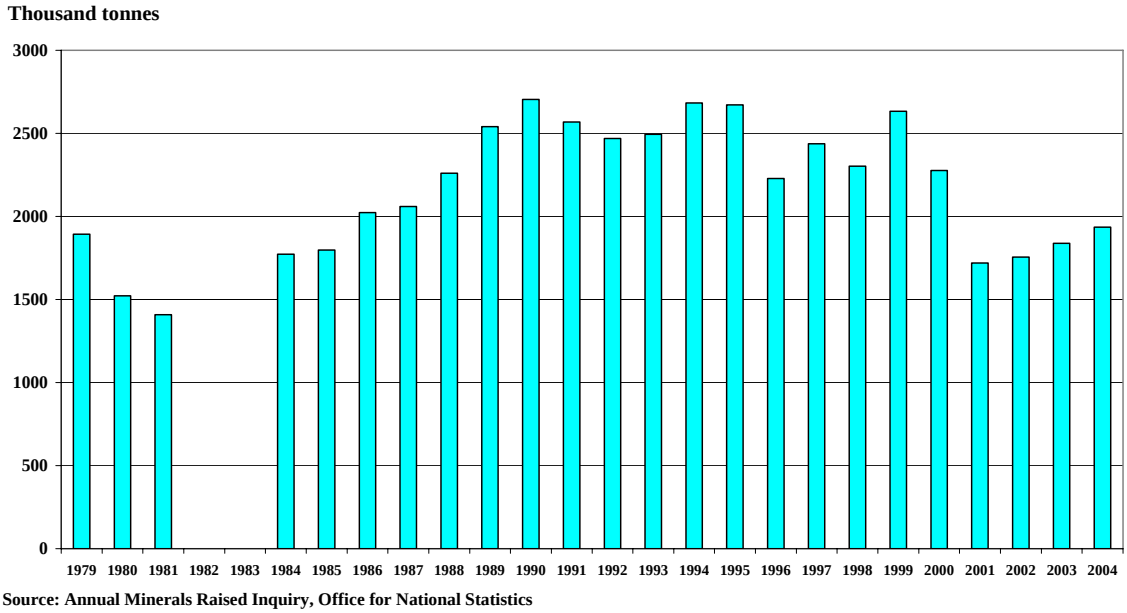

Figure 1. Production of sand and gravel in Cheshire, 1979-2004

Sand and gravel resources occur in a variety of geological environments. In Cheshire, these resources are mostly associated with outwash deposits from glaciated areas during the last ice age (less than 100,000 years ago). Cheshire was subjected to the last glacial maximum in the late Devensian period, and thus deposits in the county are largely of this age or younger. Deposits from earlier glaciations are either obscured by later deposits or were removed during the passage of ice over the county. The sand and gravel deposits were formed in a variety of environments including glaciofluvial rivers formed from melting ice and river terraces formed after the main ice had retreated away from Cheshire. Glaciofluvial deposits are thus generally older and more extensive than the river terrace deposits. They also tend to have a lower proportion of a fine-grained component, which renders them more economically viable. In some areas, this leads to high silica sands, which are dealt with in a later section since they represent an important national resource for industrial uses such as glassmaking. The other glaciofluvial deposits in Cheshire tend to be of variable quality and are often covered in large thicknesses of overburden (commonly boulder clay), and so are not easily worked. In areas where the overburden is relatively thin, the deposits constitute a valuable resource, such as in the Vale Royal to the

southwest of Northwich. The glaciofluvial deposits are composed predominantly of sand with little gravel.

These deposits are all considered as superficial deposits and were assessed in the south of Cheshire by BGS in the 1980s. Resources identified in this area are identified separately on the map, and the possible extent of sand and gravel concealed beneath overburden is shown. These concealed resources were defined by overburden to mineral ratios (overburden to mineral less than 3:1).

Outside these areas, available data are more limited. Generally, only exposed sand and gravel are defined, although sub-alluvial resources of sand and gravel occurring beneath modern river floodplains may be extensive in some areas, and are marked on the map. However, narrow (< 200 m width) spreads of sub-alluvial deposits are mainly excluded from the map. Their limited width is likely to preclude economic working of any sand and gravel present.

2.1 RIVER TERRACE DEPOSITS

These deposits occur in both raised river terrace sequences and as flood plain terraces associated with and underlying present day alluvium. They are of late Devensian age. River terraces occur at several levels in most of the major valleys in the county flanking the present flood plain, particularly associated with the River Dee, River Weaver, River Dane and the major tributaries thereof. The older terraces are higher above the present course of the river and are generally dry in their upper parts. Younger terraces can be saturated at their bases. The deposits comprise sequences of sands and gravels with sheet-like morphology, sub-horizontal upper surfaces, and thicknesses of up to a few metres. The younger deposits are more laterally continuous since they have been less downcut by subsequent river erosion.

River terrace deposits are not currently worked in Cheshire except in association with more extensive glaciofluvial sand and gravel deposits.

2.2 GLACIOFLUVIAL DEPOSITS

In Cheshire there are several areas where fast-moving, high-volume rivers derived from glacial meltwater laid down gravelly deposits in middle Devensian times. These deposits are here named “glaciofluvial deposits”, and are described below. This category also includes some areas of sand and gravel originally mapped as glacial deposits. It is likely that areas of glaciofluvial sand and gravel underlie much of the county although, in most places, they are covered by till. This is suggested by the occurrence of low ridges and hummocks; these features often have been proved to contain glaciofluvial sands through small excavations or where current river courses cut through the glacial topography.

The glaciofluvial deposits marked on the map belong to the previously designated Middle Sands and Gravels and Upper Sands and Gravels. In some places, they are separated by a substantial thickness of boulder clay. The Middle Sands tend to be better sorted and with fewer fine grained (clay and silt) horizons than the Upper Sands, and thus generally constitute a more valuable resource, even though overburden thickness may be greater. The Middle Sands contain the high silica sands described in a later section, and were probably formed by deposition of sands derived wholly from aeolian Permian sandstones.

In general, the glaciofluvial deposits thicken locally to more than 30 m where they infill hollows or valleys. They are frequently graded and cross-bedded, and may contain many individual beds of varying grain sizes. The sands are mostly red in colour, due to being derived mainly from the Permo-Triassic succession, although in the east, they tend to be orange to grey due to the inclusion of material from the Carboniferous rocks in that area. There may be layers or pods of clay or silt within the succession, which can prove problematic during extraction.

The area to the southwest of Northwich is very important for the extraction of sand and gravel for construction purposes. This area contains the Delamere and Over sands – continuous beds of sands and gravels over large areas. The Delamere Sands are found in a triangular body of outwash sands and gravels reaching up to 9 m thick in exposures in quarries, although borehole data suggests that locally the thickness of sand and gravel may each be up to 29 m. In many places it is covered by significant thicknesses of till, which make working the sand and gravel uneconomic. The Over Sands are found in a long narrow deposit of sand and gravel that locally may be over 30 m thick.

In the east and south-east of Cheshire, glaciofluvial sands and gravels, other than the high silica sands, are quarried for construction sand at several other sites such as White Moss near Crewe, and Mere Farm near Macclesfield.

3 Silica sand

Silica (industrial) sands contain a high proportion of silica (SiO_2) in the form of quartz and are used for purposes other than as construction aggregates. They are essential raw materials for the glass and foundry castings industries, but also have a wide range of other industrial applications, including in ceramics and chemicals manufacture, for water filtration media and in sports and horticultural applications. They are produced from both loosely consolidated sand deposits and by crushing weakly cemented sandstones. Unlike construction sands, which are used for their physical properties alone, silica sands are valued for a combination of chemical and physical properties. These include a high silica content in the form of quartz and, more importantly, low levels of impurities, particularly clay, iron oxides and refractory minerals such as chromite. Silica sands typically have a narrow grain size distribution, generally in the range 0.5 mm to 0.1 mm, although coarser grades are required for some applications. For most applications, silica sands have to conform to very closely defined specifications and consistency in quality is of critical importance. Particular uses often require different combinations of properties. Consequently, different qualities of silica sand are usually not interchangeable in use. Silica sands command a higher price than construction sands. This allows them to serve a wider geographical market, including exports.

Silica sand processing is of varying degrees of complexity and depends on the nature of the raw materials and the end use of the sand. It typically requires a high capital investment in plant. Processing is aimed at modifying both the physical and chemical properties of the sand to meet user specifications. The ease with which contaminants (such as iron-bearing impurities and clay) can be removed, together with the level of losses incurred in removing oversize and undersize fractions from a sand, has a major bearing on its potential use. Within the UK, deposits of silica sand occur in only limited areas and quantities, and the special characteristics of silica sand extraction, in particular the cost of processing, means that the industry has a restricted distribution.

Cheshire is the most important source of silica sand in Britain accounting for about 25% of total production with an output of over 1 Mt/y. The silica sand is used principally in the manufacture of float (flat) glass at St Helens, for foundry use and a wide range of other industrial and horticultural applications. The deposits being worked on the eastern side of the Cheshire Plain are in an area broadly bounded by Congleton, Sandbach, Holmes Chapel and Chelford.

Production is based on the Congleton Sand and Chelford Sand, which are fluvial sands of Pleistocene age deposited during an inter-glacial period. They are believed to be the same horizon and occur as an irregular sheet up to 30 m or more in thickness, in places infilling hollows and valleys in the underlying Triassic mudstones or till. The deposits thin towards the west. The sands are themselves cut into by overlying till and glaciofluvial sands (Gawsworth Sand) and consequently their thickness can vary significantly over relatively short distances.

They may be worked beneath substantial thicknesses of overburden. The Gawsworth Sand is unsuitable for use as silica sand but is used for construction applications, including concreting sand. The Chelford Sand is purer and slightly coarser than the Congleton Sand but both consist of well-rounded quartz grains with a uniform particle size and are largely free of impurities. Pebbles are rare. They have a high silica content (96-98% SiO_2) and the white sand within the Chelford Sand has an iron content of about 0.1% Fe_2O_3 and is suitable for the manufacture of flat glass. Extraction is by both dry working after dewatering to lower the water, which allows selective extraction of different qualities, and by wet working using suction dredging. Processing involves washing, attrition scrubbing and size-classification to remove coarse and very fine fractions and to produce a clean sand with the desired particle-size distribution. Coarse chromite, even in small amounts, is a serious impurity in flat glass manufacture and is removed during size classification. Most foundry sands are supplied dry. Selected grades are also coated with resin binders for foundry casting, producing a high value-added product.

Resources of silica sand are difficult to define without detailed drilling and an evaluation of their properties, including the ease with which they can be processed to marketable quality. The silica sand deposits are mainly concealed beneath an overburden of glaciofluvial sand and/or till. The resource area has been broadly defined by the area bounded by Chelford, Congleton and Sandbach. Remaining resources of the low iron (white) Chelford Sand are believed to be limited.

4 Crushed rock aggregate

A variety of hard rocks, when crushed, are suitable for use as aggregates. Their technical suitability for different applications depends on their physical characteristics, such as crushing strength and resistance to impact and abrasion. Higher quality aggregates are required for coating with bitumen for road surfacing, or mixing with cement to produce concrete. For applications such as constructional fill and drainage media, with less demanding specifications, lower quality materials are acceptable.

Cheshire has very limited resources of crushed rock aggregate and production is small (20,000 tonnes in 2003). Permitted reserves of crushed rock aggregate were 5.6 million tonnes at the end of 2003 (source: NW Regional Aggregates Working Party). In Cheshire, the main rock type used for crushed rock aggregates is sandstone, which occurs in the western margins of the Pennine Hills. Here, various Carboniferous sandstones of the Craven Group, Millstone Grit Group and Pennine Coal Measures Group have previously been used for crushed rock, although there are currently only working quarries in the Milnrow Sandstone in the Pennine Lower Coal Measures, the Chatsworth Grit in the Millstone Grit Group, and in sandstones in the Bowland Shale Formation, all near Macclesfield. Near Warrington, the Chester Pebble Beds Formation has also been quarried for crushed rock sand and gravel. Although this formation is widespread across the county, it is not shown on the map face, since exploitation is only currently occurring at Southworth in the north of the county.

5 Building stones

Historically the area has been a prolific source of Carboniferous and Permo-Triassic sandstones for local building purposes.

The oldest rocks of the area, once quarried extensively for building stone, are the Carboniferous sandstones of the Millstone Grit Group that lie along its eastern margin from Macclesfield to Congleton Edge, with former important quarries at Tegg’s Nose (Roaches Grit and Chatsworth Grit), Billinge (Rough Rock), Hawkshead (Minn Sandstones), The Cloud and Rainow Hill

(Chatsworth Grit) and Mow Cop (Chatsworth Grit and Rough Rock). The steeply dipping nature of the beds in the quarries was the principal cause of their eventual decline. The overlying sandstones of the Pennine Coal Measures Group were also extensively quarried for building stone, notably at Kerridge Hill (Milnrow Sandstone).

The basal pebble bed succession of the overlying Permo-Triassic Sherwood Sandstone Group has been widely used in the past for building purposes, most notably from quarries in Chester, for the cathedral fabric, and at Eccleston, Christleton, Waverton, Saighton, Handley, Tattenhall, Tarvin, Holt and Neston.

The predominantly red-brown (occasionally white) sandstones of the Helsby Sandstone Formation were also once extensively quarried (at Runcorn, Frodsham, Lymm, Helsby, Manley, Simmond's Hill, Delamere, Kelsall, Peckforton and Kidnall), and can be seen in numerous buildings across their outcrop in the west of the area. The quarries at Runcorn were, in the 19th century, the largest in Europe and supplied stone to the cities of Liverpool and Manchester as well as for export.

The Tarporley Siltstone Formation was once an important source of flaggy stone used for hearth stones and window sills and was quarried at Kelsall, Utkinton and Tarporley.

There are currently five active building sandstone quarries in the area all within the Milnrow Sandstone of the Carboniferous succession.

6 Salt

Salt (sodium chloride, NaCl) occurs in nature in the solid form as rock salt (halite) or in solution as brine. Rock salt occurs in beds, commonly associated with mudstone, ranging from a few centimetres up to several hundred metres in thickness. The purity of individual salt beds depends on the extent of mudstone interbedding. Salt-bearing strata may underlie extensive areas, but does not crop out at the surface in the UK because of dissolution by groundwater. The boundary at which salt dissolution is taking place is called the 'wet-rockhead.' Where salt-bearing strata are too deep to be affected by groundwater, the normal contact between the salt and overlying rock is known as 'dry-rockhead.' Brine occurs naturally at the wet-rockhead but may also be produced artificially by injecting water into the salt bed and pumping out the resultant salt solution. This may contain up to 25% NaCl when fully saturated.

Rock salt is extracted by underground mining for use principally in de-icing roads and by controlled brine pumping for use as a chemical feedstock and in the manufacture of white salt. Natural or 'wild' brine pumping has, in the past, resulted in accelerated subsidence over wide areas. Modern, controlled methods of brine extraction do not cause subsidence.

Salt-bearing strata of Permian and Triassic age underlie extensive areas of England. Resources of Triassic age in the Cheshire Basin are economically the most important accounting for about 85% (about 5 million tonnes) of total UK production. In England rock salt of Permian age is also mined at the Boulby Potash Mine in the North York Moors National Park.

There are huge resources of salt in the Cheshire Basin which occur within the Triassic Mercia Mudstone Group. There are two salt-bearing formations, a lower Northwich Halite Formation and an upper Wilkesley Halite Formation. Production is entirely confined to the former. The maximum known thickness of the Northwich Halite Formation is some 280 m and the salt occurs in beds that are virtually pure halite and in others where there are varying amounts of mudstone and siltstone. It has been estimated that some 25% of the formation consists of mudstone. The Wilkesley Halite Formation is even thicker and has a known thickness of some 405 m. The upper half of the Wilkesley Halite Formation is somewhat purer than the Northwich Halite. The inset map shows the outcrop or wet-rockhead of the Northwich and Wilkesley Halite formations, and

the concealed, sub-surface extent of salt-bearing strata. The Cheshire Basin extends southwards into Shropshire.

Salt extraction in Cheshire is by rock salt mining at the Winsford Mine, which has a mine capacity of 2.25 Mt/y although production averages about 0.9 Mt/y. Extraction is by room and pillar mining and is currently from the Bottom Bed of the Northwich Halite at a depth of about 140 m. The rock salt, which contains about 92% NaCl, is principally used for de-icing roads. The mine, with some 26 million m^3 of space, has a constant temperature and humidity and is dry and gas-free. The mine is currently being used as secure document storage. Part of the mine is also being used for the permanent storage of hazardous wastes. Strict criteria will be used for the type of material stored, which will be dry waste that is non-flammable, non-biodegradable and non-radioactive.

Most salt in Cheshire (85%) is extracted by solution mining and almost all is by controlled brine pumping. A very small quantity of natural, or 'wild,' brine is produced at Wincham. Controlled brine pumping involves the creation of stable cavities up to 145 m in diameter and up to 200 m in height in suitable salt strata by introducing water under carefully controlled conditions and pumping up the resultant brine. The size and shape of the cavities are designed to maintain stability of the overlying strata. Brine wells are laid out on a regular grid about 200 m apart and the process recovers about 25% of the total salt reserve. Controlled brine pumping takes place at the Holford and Warmingham brinefields in Cheshire from the Northwich Halite Formation at depths of over 250 m.

Completed solution cavities are left full of saturated brine although some are used for both waste disposal and storage purposes. Salt-bearing strata are ideally suited for the creation of storage cavities for natural gas, compressed air and fluids. In particular there is increasing interest in the creation of smaller cavities for natural gas storage. This is taking place at the Warmingham Brinefield and at the Holford Brinefield.

7 Hydrocarbons

7.1 CONVENTIONAL OIL AND GAS

The county covers much of the area of the important Cheshire Basin, a major sedimentary basin linked to the offshore East Irish Sea Basin (EISB), within which hydrocarbons (mainly gas), have been discovered in the Morecambe, Lennox, Millom, Hamilton (including East and North), Bains, Calder, Dalton, Ormond South and Crossans fields. Oil has also been produced from the Douglas and Lennox fields. Given that similar geological conditions exist in the Cheshire Basin there has, since the early 1970's, been much exploration activity directed at finding hydrocarbons onshore.

Urban development dominates areas of the county, with large conurbations around Chester, Crewe and Northwich. Despite this, hydrocarbon exploration activity across the entire county has been high, with many kilometres of seismic reflection data having been acquired and 10 hydrocarbon exploration wells drilled (Table 1). However, despite the presence of suitable source (Carboniferous – Silesian) and reservoir (Permo-Triassic) rocks beneath the county, somewhat surprisingly no oil or gas has been discovered to date. All exploration wells have been plugged and abandoned as dry holes with only one (Blacon East), in the extreme west of the county, having had small oil shows. Just to the west of Blacon East, in Flintshire, lies the Sealand No.1 coalbed methane (CBM) well that proved gas.

In early 2005 areas of the county covered by hydrocarbon exploration licences were small, some the result of licences overlapping from adjacent counties. All were associated with CBM or mine gas (methane) development, and reflecting the fact that conventional hydrocarbon prospectivity

in the county is not presently perceived as great. Following several phases of hydrocarbon exploration, it is now known that following their deposition, the Carboniferous source rocks were exposed and eroded in the central areas of the Cheshire Basin prior to deposition of the potential Permo-Triassic reservoir rocks. There is thus limited prospectivity in the central parts of the basin, which includes the present county. Perhaps the most prospective areas are to be found in the northwest or western areas of the county, more immediately adjacent to the producing East Irish Sea Basin and where potential Carboniferous source rocks exist both at crop and in the subsurface. If suitable remaining source rocks and trapping configurations can be found, then some potential may still exist in the southeast of the county and deeper parts of the basin. Ironically, the area of the Blacon East hydrocarbon exploration well now appears to be covered by a licence covering CBM development/production.

To the west in Flintshire, bituminous oil shales associated with the Westphalian Ruabon Yard Coal were worked from the 18th century to the 1930's when production ceased. Uses included paraffin and gas production. However, if present beneath the county, they are unlikely to be of economic importance.

Table 1. Hydrocarbon exploration and CBM wells drilled in Cheshire.

Exploration wells	*Drilling date*	*Original operator*	*Current license area and operator*	*Status*
Blacon East	1981	Shell UK Exploration & Production	PEDL 147 Greenpark	P & A, slight oil shows
Blakenhall	1992	Hamilton Oil Company Ltd	Open acreage	P&A Dry
Boots Green	1996	Brabant Petroleum Ltd	Open acreage	P & A Dry
Bosley	1986	BP Petroleum Development Ltd	Open acreage	P & A Dry
Burford #1	1987	Shell UK Exploration & Production	Open acreage	P & A Dry
Elworth #1	1988	Mobil North Sea Ltd	Open acreage	P & A Dry
Ince/Kemira	?1994-2001	Evergreen Resources (UK) Ltd	Open acreage	Series of Coal Bed Methane wells
Knutsford #1	1974	British Gas	Open acreage	P & A Dry
Milton Green	1965	Esso Petroleum Company Ltd	Open acreage	P & A Dry
Winsford	1997	Brabant Petroleum Ltd	Open acreage	P & A Dry

7.2 ABANDONED MINE GAS DRAINAGE (AMM), COAL MINE METHANE (CMM) AND COAL BED METHANE (CBM) POTENTIAL

The county of Cheshire is flanked by coalfields close to or outcropping on almost all sides. Results of hydrocarbon exploration suggest that similar Westphalian (Coal Measures) deposits extend beneath much of the Cheshire Basin and the county, but at depths greater than 1200 m.

The North Wales (Flintshire) coalfield includes generally easterly dipping, but structurally complex, Pennine Lower-Middle Coal Measures. These sequences contain mainly medium volatile coking coal, with an average gas seam content of 8.4 m^3 CH_4t^{-1}. The coalfield, exposed parts of which has been worked in Wales, extends eastwards and shows rapid deepening on the western margins of the Cheshire Basin, where it becomes concealed in the west of the county. Former underground workings do not extend far eastwards and do not extend beneath the county.

The South Lancashire Coalfield lies concealed beneath northern areas of the county. It contains Pennine Lower-Middle Coal Measures of high to medium volatile rank bituminous coals with an average gas content of 9 m^3 CH_4t^{-1}. The coalfield has been heavily worked to the north of the county, but unmined areas exist in the southern concealed parts. These two coalfield areas extend beneath the county and though heavily mined in the past outwith the county area, have no working collieries. They thus offer no CMM potential. Prospects for AMM are good if mines are not flooded and worked areas extend beneath the county, probably limiting potential to the northern and northwestern extremes of the county.

To the southeast of the county the North Staffordshire coalfield crops out. It contains Pennine Lower-Middle Coal Measures with coal bearing strata of high to low volatile rank bituminous and an average gas content of 8.0 m^3 CH_4t^{-1}. The coalfield has exposed and concealed areas that have been extensively worked, but much coal remains. Distant and to the south lies the Shropshire coalfield, with Upper-Lower Coal Measures containing high volatile rank bituminous coals that have been heavily work but have an unknown average gas content.

In the USA, most CBM production is from coals containing 7 or more m^3 CH_4t^{-1}. The gas content of the coals of the adjacent North Wales (8.4 m^3 CH_4t^{-1}) and South Lancashire (9.5 m^3 CH_4t^{-1}) are thus high and above the economic threshold as defined in America.

CBM potential from virgin coal seams in the concealed parts of the North Wales and South Lancashire coalfields beneath the county might, therefore, be perceived as good. However, prospects may be limited by the rapid deepening of coal bearing-strata that might lie at too great a depth for methane extraction. This is probably reflected in the location of the Kemira/Ince CBM exploration well(s) drilled just south of the River Mersey estuary in the north and northwest of the county (Table 1) and current exploration licences held by Alkane (PEDL 038), Greenpark (EXL 273), Biogas (EXL 276), Island (PEDL 145) and Eastern/Pegasus (EXL 253) in the north and north west of the county. Greenpark also operate PEDL 147 in the west of the county, which covers the area of the Blacon East and West (oil and gas) and Sealand (CBM) exploration wells. The company is again interested in methane development/production hereabouts. It is noteworthy that two CEGB wells drilled around 1984 for other purposes a few kilometres WSW of the Kemira/Ince CBM well, had methane associated with them.

Between 1994 and mid 2003 Evergreen Resources UK held exploration licences covering much of the north and northwest of the county from around Warrington to south of the Mersey and down to near Wrexham. A series of pilot well schemes were drilled to evaluate the CBM potential in these areas, most notably to the west of Chester and around Warrington. These licences have now been relinquished or ownership transferred to Greenpark (PEDL 147), Biogas (EXL 276) and Island (PEDL 145), whilst evaluation of CBM potential is presumably still ongoing in these areas.

In the southeast of the county, PEDL 077, operated by Stratagas, overlaps the county boundary with Staffordshire and is related to methane development/production from the North Staffordshire Coalfield.

7.3 UNDERGROUND COAL GASIFICATION (UCG)

UCG is a technology that is being assessed in the UK. It involves the *in situ* conversion of coal in seam into a combustible gas by reacting it with air (or oxygen) pumped from the surface and the removal of the product gas via another borehole. The gas may be used, for example, in electricity generation. The resource criteria for UCG includes seams that are thicker than 2 m at depths of between 600 m and 1200 m. There also needs to be standoffs from operational and abandoned mine workings, urban areas, dense faulting and major aquifers. Areas of good UCG potential occur in the western and northwestern parts of the county.

8 Peat

Peat is an unconsolidated deposit of compressed plant remains in a water-saturated environment such as a bog or fen. Bogs occur in areas where water inputs, almost exclusively from precipitation, have a low nutrient content and where the rainfall is sufficient to maintain the ground surface in a waterlogged condition. Bog vegetation is characterised by acid-tolerant plant communities of which the moss genus *Sphagnum* is dominant. The two main types of bog are (i) raised bogs, characteristic of flat underlying topography and found on plains and broad valley floors and (ii) blanket bogs, which occur mainly in upland areas where conditions are suitably cool and wet. Many lowland raised bogs have been designated as sites of international and national conservation areas. Peat is dug in England mainly from raised lowland bogs, almost entirely (98%) for horticultural use, either as growing media or as a soil improver. Areas of upland blanket peat are not worked and therefore are not shown on the map.

There are several areas of peat accumulation, which have formed in hollows in the superficial deposits. In places, the thickness of the peat is sufficient to be exploited. Although there are many patches of peat across Cheshire, they are not all marked on the map face, since extraction only occurs in three small areas: east of Warrington, near Wilmslow and east of Crewe.

9 Brick clay

Various formations in Cheshire have been exploited for brick clay, however, only one small area to the east of Warrington is currently being quarried for this purpose. Here, both boulder clay and Triassic Mercia Mudstone Group mudstones are being used. A landfill site near Crewe (Maw Green) also has permission to extract boulder clay. These lithologies have extensive outcrops across Cheshire, but since they are only worked in these two locations, and otherwise are of variable quality and thickness, the total extent of outcrop is not shown on the map face.

10 Metalliferous mineralisation

On the margins of the sedimentary sequence associated with the Permo-Triassic Basin, there are areas of barite and copper mineralization, with minor occurrences of lead and other base and precious metals. These have been worked since Roman times, but were a particularly important resource in the 18th, 19th and early 20th centuries and were extensively mined in this period. The main area of mineralization occurs on Alderley Edge, where Sherwood Sandstone Group rocks are the host lithologies and mineralization occurs along fault zones. At Bulkeley – Bickerton near Nantwich, the mineralization is found in a similar setting on the western margin of the basin, and is characterised mainly by barite occurrences in the Wilmslow Sandstone Formation.

BGS has investigated the potential for economic mineralization in the Cheshire Basin as part of a major interdisciplinary project. It was concluded that there might be more base metal mineralization at other locations in the Cheshire Basin (Plant et al., 1999; The Cheshire Basin: Basin evolution, fluid movement and mineral resources in a Permo-Triassic rift setting).

11 Aims and limitations

The purpose of the maps in this series is to show the broad distribution of those mineral resources that may be of current or potential economic interest, and to relate these to selected nationally-recognised planning designations. The maps are intended to assist in the consideration and preparation of development plan policies in respect of mineral extraction and the protection of important mineral resources against sterilisation. They bring together a wide range of information, much of which is scattered and not always available in a convenient form.

The maps have been produced by collation and interpretation of mineral resource data principally held by the British Geological Survey. Information on the extent of mineral planning permissions has been obtained from the relevant Mineral Planning Authority (MPA). Some of these permissions may have lapsed or expired. The status of individual areas can be ascertained from the appropriate MPA. Location information on national planning designations has been obtained from the appropriate statutory body (Countryside Agency, English Nature and English Heritage). For further information the relevant body should be contacted.

The mineral resource data presented are based on the best available information, but are not comprehensive and their quality is variable. The inferred boundaries shown are, therefore, approximate. Mineral resources defined on the map delineate areas within which potentially workable minerals may occur. These areas are not of uniform potential and also take no account of planning constraints that may limit their working. The economic potential of specific sites can only be proved by a detailed evaluation programme. Such an investigation is an essential precursor to submitting a planning application for mineral working. Extensive areas are shown as having no mineral resource potential, but some isolated mineral workings may occur in these areas. The presence of these operations generally reflects very local or specific situations.

The maps are intended for general consideration of mineral issued and not as a source of detailed information on specific sites. The maps should not be used to determine individual planning applications or in taking other decisions on the acquisition or use of a particular piece of land, although they may give useful background information which sets a specific proposal within context.

12 Planning permissions for the extraction of minerals

The extent of all known extant and non-extant planning permissions for the extraction of minerals is shown on the map, irrespective of their current planning or operational status. The polygons were digitised by BGS from Plotting Sheets and other documents supplied by Cheshire County Council, and any queries regarding the sites shown should be directed to these authorities at the address shown below. The polygons cover active, former and restored mineral workings and, occasionally, unworked deposits.

Planning Permissions represent areas where a commercial decision to work mineral has been made, a successful application has been dealt with through the provisions of the Town and Country Planning legislation, and the permitted preserve will have been depleted to a greater or lesser extent. The current planning status is not qualified on the map, but is available in the underlying database.

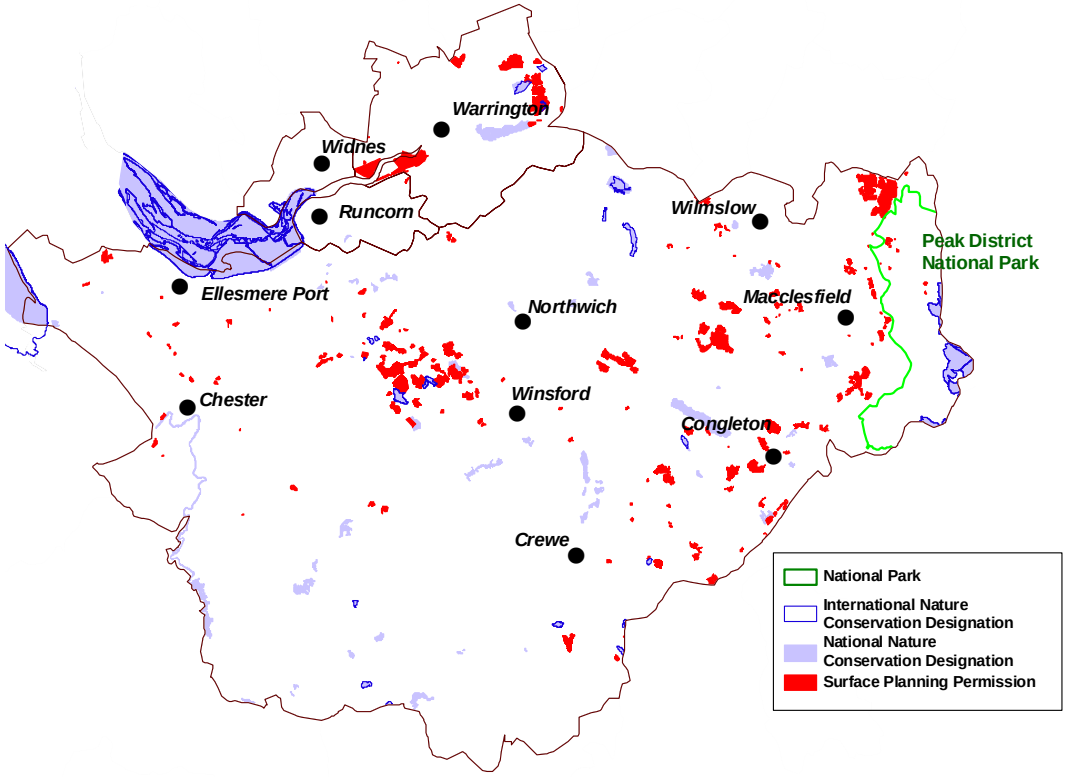

Figure 2. Main environmental designations and planning permissions in Cheshire.

Contact addresses:

Cheshire County Council, Environmental Planning Services, Backford Hall, Backford, Chester CH1 6PZ. Tel: 01244 603102, Fax: 01244 603033, Web: www.cheshire.gov.uk

Halton Borough Council, Environmental Services Department, Grosvenor House, Halton Lea, Runcorn WA7 2GW. Tel: 0151 424 2061, Fax: 0151 471 7304, Web: www.halton-borough.gov.uk

Warrington Borough Council, Minerals and Waste Planning, Community Services Department, New Town House, Buttermarket Street, Warrington WA1 2NH. Tel: 01925 444400, Fax: 01925 442759, Web: www.warrington.gov.uk

Appendix

TOPOGRAPHIC BASE

CONSTRAINT INFORMATION

Constraint information published on the accompanying map has been provided from the various agencies listed below; any enquiries on this information should be addressed to the relevant agency.

English Nature

Digital SSSI, SAC, SPA, RAMSAR and NNR boundaries © English Nature 2004

Contact address: English Nature, Northminster House, Northminster, Peterborough PE1 1UA. Tel: 01733 455000. Fax: 01733 455103. Web page: www.english-nature.org.uk

English Heritage

Positions of scheduled monuments at 25th September 2003.

The majority of monuments are plotted using a centred NGR symbol. Consequently the actual area and/or length of a monument protected by the legal constraints of scheduling cannot be represented here. Monuments scheduled since that date are not accounted for. © Copyright English Heritage.

Contact address: English Heritage, 23 Savile Row, London W1S 2ET. Tel: 0207 973 3132. Web page: www.english-heritage.org.uk

Countryside Agency

Digital AONB boundaries © Countryside Commission 1986 (now Countryside Agency)

Contact address: Countryside Agency, John Dower House, Crescent Place, Cheltenham, Gloucestershire GL50 3RA. Tel: 01242 521381. Fax: 01242 584270. Web page: www.countryside.gov.uk

The Coal Authority

Coal License Areas © The Coal Authority, 2004

Contact Address: The Coal Authority, 200 Lichfield Lane, Mansfield, Nottinghamshire, NG18 4RG. Tel: 01623 427162, Fax: 01623 638338

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CHESHIRE

(comprising Cheshire, Boroughs of Halton and Warrington)

British Geological Survey — Natural Environment Research Council

Office of the Deputy Prime Minister — Creating sustainable communities

Mineral Resource Information in Support of National, Regional and Local Planning

Mineral Resources

Scale 1:100 000

Compiled by G.E.Norton, A.J. Bloodworth, D.G. Cameron, D.J. Evans, G.K. Lott, S.F. Hobbs and D.E. Highley.
Project Leader: D.E. Highley.
Digital cartography by N.A. Spencer, British Geological Survey.
Published 2006.

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For more information see www.mineralsUK.com

BIBLIOGRAPHIC REFERENCE

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SAND & GRAVEL

Superficial deposits

- Sub-alluvial: Inferred resources
- Sub-alluvial: Indicated resources (only in areas assessed by BGS)
- River Terrace deposits
- Glaciofluvial deposits
- Glaciofluvial deposits: Concealed (only in areas assessed by BGS)
- Boundary of area assessed for sand and gravel at the indicated resource level
- Approximate extent of area worked for silica sand

PEAT

SANDSTONE

- Crushed rock and Building stone (Milnrow Sandstone, Chatsworth Grit and sandstones in Bowland Shale Formation) — Carboniferous

MINERAL PLANNING PERMISSION (as at 01.09.05)

Source: Mineral Planning Authorities

- Surface planning permission (valid and expired)
- Underground planning permission other than coal (valid and expired)

MINERAL WORKINGS

- Chelford — Active site
- *Acton Grange* — Inactive (including yet to be worked), worked-out and/or restored site

Mineral commodity

CBM	Coalbed Methane	Oil	Oil	SiS	Silica Sand
Cl	Clay & Shale	Peat	Peat	SiR	Silica Rock
Fr	Fireclay	Sg	Sand and Gravel	Sst	Sandstone
Gas	Natural Gas	Salt	Salt	Sec	Secondary Aggregate
Min	Mineral, unspecified	San	Sand		

- Active coal-fired power station
- Active underground mine
- Active Brinefield

ENVIRONMENTAL DESIGNATIONS (as at 01.01.06)

- National nature conservation designations (SSSIs and NNRs)
- International nature conservation designations (SACs, SPAs and Ramsar sites)
- National Park: Peak District (part)
- + Scheduled Monument

ADMINISTRATIVE AREAS

- Mineral Planning Authority
- District

Aims and Limitations

The purpose of the maps in this series is to show the broad distribution of those mineral resources which may be of current or potential economic interest and to relate these to selected nationally-recognised planning designations. The maps are intended to assist in the consideration and preparation of development plan policies in respect of mineral extraction and the protection of important mineral resources against sterilisation. They bring together a wide range of information, much of which is scattered and not always available in a convenient form.

The maps have been produced by the collation and interpretation of mineral resource data principally held by the British Geological Survey. Information on the extent of mineral planning permissions has been obtained from the relevant Mineral Planning Authority (MPA). Some of these permissions may have lapsed or expired. The status of individual areas can be ascertained from the appropriate MPA. Location information on national planning designations has been obtained from the appropriate statutory body (Countryside Agency, English Nature and English Heritage). For further information the relevant body should be contacted.

The mineral resource data presented are based on the best available information, but are not comprehensive and their quality is variable. The inferred boundaries shown are, therefore, approximate. Mineral resources defined on the map delineate areas within which potentially workable minerals may occur. These areas are not of uniform potential and also take no account of planning constraints that may limit their working. The economic potential of specific sites can only be proved by a detailed evaluation programme. Such an investigation is an essential precursor to submitting a planning application for mineral working. Extensive areas are shown as having no mineral resource potential, but some isolated mineral workings may occur in these areas. The presence of these operations generally reflect very local or specific situations.

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BUILDING STONES

Historically the area has been a prolific source of Carboniferous and Permo-Triassic sandstones for local building purposes.

The oldest rocks of the area, once quarried extensively for building stone, are the Carboniferous sandstones of the Millstone Grit Group. These lie along its eastern margin from Macclesfield to Congleton Edge, with important quarries at Tegg's Nose (Roaches Grit and Chatsworth Grit), Billinge (Rough Rock), Hawkshead (Minn Sandstones), The Cloud and Rainow Hill (Chatsworth Grit) and Mow Cop (Chatsworth Grit and Rough Rock). The steeply dipping nature of the beds in the quarries were the principal cause of their eventual decline. The overlying sandstones of the Pennine Coal Measures Group were also extensively quarried for building stone, notably at Kerridge Hill (Milnrow Sandstone).

The basal pebble bed succession of the overlying Permo-Triassic Sherwood Sandstone Group has been widely used in the past for building purposes, most notably from quarries in Chester, for the cathedral fabric, and at Eccleston, Christleton, Waverton, Saighton, Handley, Tattenhall, Tarvin, Holt and Neston.

The predominantly red-brown (occasionally white) sandstones of the Helsby Sandstone Formation were also once extensively quarried, at Runcorn, Frodsham, Lymm, Helsby, Manley, Simmond's Hill, Delamere, Kelsall, Peckforton and Kidnall, and can be seen in numerous buildings across their outcrop in the west of the area. The quarries at Runcorn were, in the 19th century, the largest in Europe and supplied stone to the cities of Liverpool and Manchester as well as for export.

The Tarporley Siltstone Formation was once an important source of flaggy stone used for hearth stones and window sills and was quarried at Kelsall, Utkinton and Tarporley.

There are currently 6 active building sandstone quarries in the area all within the Milnrow Sandstone of the Carboniferous succession, in the Kerridge Hill, Macclesfield area.

PLANNING PERMISSIONS FOR MINERAL EXTRACTION

The extent of all known extant and former planning permissions for mineral working is shown on the map, irrespective of their current planning or operational status. The polygons were supplied as digital files by Cheshire County Council, and also were digitised by BGS from Plotting Sheets and other documents supplied by Warrington Borough Council. In addition, planning permission information was digitally acquired from Ministry of Housing and Local Government maps for the area and incorporated in the data. This data has been checked and amended by the local Authorities shown below. Any queries regarding the sites shown should be directed to these authorities at the addresses shown below. The polygons cover active, former and restored mineral workings and, occasionally, unworked deposits.

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METALLIFEROUS MINERALISATION

On the margins of the sedimentary sequence associated with the Permo-Triassic Basin, there are areas of barite and copper mineralization, with minor occurrences of lead and other base and precious metals. These have been worked since Roman times, but were a particularly important resource in the 18th, 19th and early 20th centuries and were extensively mined in this period. The main area of mineralization occurs on Alderley Edge, where Sherwood Sandstone Group rocks are the host lithologies and mineralization occurs along fault zones. At Bulkeley - Bickerton near Nantwich, the mineralization is found in a similar setting on the western margin of the basin, and is characterised mainly by barite occurrences in the Wilmslow Sandstone Formation.

BGS has investigated the potential for economic mineralization in the Cheshire Basin as part of a major interdisciplinary project. It was concluded that there might be more base metal mineralization at other locations at depth in the Cheshire Basin (Plant et al., 1999; The Cheshire Basin: Basin evolution, fluid movement and mineral resources in a Permo-Triassic rift setting).

CRUSHED ROCK AGGREGATE

A variety of hard rocks, when crushed, are suitable for use as aggregates. This technical suitability for different applications depends on their physical characteristics, such as crushing strength and resistance to impact and abrasion. Higher quality aggregates are required for coating with bitumen for road surfacing, or mixing with cement to produce concrete. For applications such as constructional fill and drainage media, with less demanding specifications, lower quality materials are acceptable.

Cheshire has very limited resources of crushed rock aggregate and production is small (20,000 tonnes in 2003). Permitted reserves of crushed rock aggregate were 5.6 million tonnes at the end of 2003 (source: NW Regional Aggregates Working Party). In Cheshire, the only rock type used for crushed rock aggregates is sandstone, which occurs in the western margins of the Pennines. Here, various Carboniferous sandstones of the Craven Group, Millstone Grit Group and Pennine Coal Measures Group have previously been used for crushed rock, although there are currently working quarries only in the Milnrow Sandstone of the Pennine Lower Coal Measures, the Chatsworth Grit in the Millstone Grit Group, and in sandstones in the Bowland Shale Formation, all near Macclesfield. Near Warrington, the Triassic Chester Pebble Beds Formation has also been quarried for crushed rock and sand and gravel. Although this formation is widespread across the county, it is not shown on the map face, since exploitation is only currently occurring at Southworth in Warrington.

PEAT

Peat is an unconsolidated deposit of compressed plant remains in a water-saturated environment such as a bog or fen. Bogs occur in areas where inputs of water (almost exclusively from precipitation) have a low nutrient content and where the rainfall is sufficient to maintain the ground surface in a waterlogged condition. The vegetation is characterised by acid-tolerant plant communities in which the moss genus *Sphagnum* is dominant. The two main types of bog are (i) raised bogs, characteristic of flat underlying topography and found on plains and broad valley floors and (ii) blanket bogs, which occur mainly in upland areas where conditions are suitably cool and wet. Many lowland raised bogs have been designated as sites of international and national conservation areas. Peat is dug in England mainly from raised lowland bogs, almost entirely (98 per cent) for horticultural use, either as growing media or as a soil improver. Areas of upland blanket peat are not worked and therefore not shown.

There are several areas of peat accumulation which have formed in hollows in the superficial deposits and, in places, the thickness of the peat is sufficient to be exploited. Although there are many patches of peat across Cheshire, they are not all marked on the map face, since extraction only occurs in three small areas: east of Warrington, near Wilmslow and east of Crewe.

SILICA SAND

Silica (industrial) sands contain a high proportion of silica (SiO_2) in the form of quartz, and are used for purposes other than as construction aggregates. They are essential raw materials for the glass and foundry castings industries, but also have a wide range of other industrial applications, including in ceramics and chemicals manufacture, for water filtration media and in sports and horticultural applications. They are produced from both loosely consolidated sand deposits and by crushing weakly cemented sandstones. Unlike construction sands, which are used for physical properties alone, silica sands are valued for a combination of chemical and physical properties. These include a high silica content in the form of quartz and, more importantly, low kevels of impurities, particularly clay, iron oxides and refractory minerals such as chromite. Silica sands typically have a narrow grain size distribution, generally in the range 0.5 mm to 0.1 mm, although coarser grades are required for some applications. For most applications, silica sands have to conform to very closely defined specifications and consistency in quality is of critical importance. Particular uses often require different combinations of properties. Consequently, different qualities of silica sand are usually not interchangeable in use. Silica sands command a higher price than construction sands. This allows them to serve a wider geographical market, including exports.

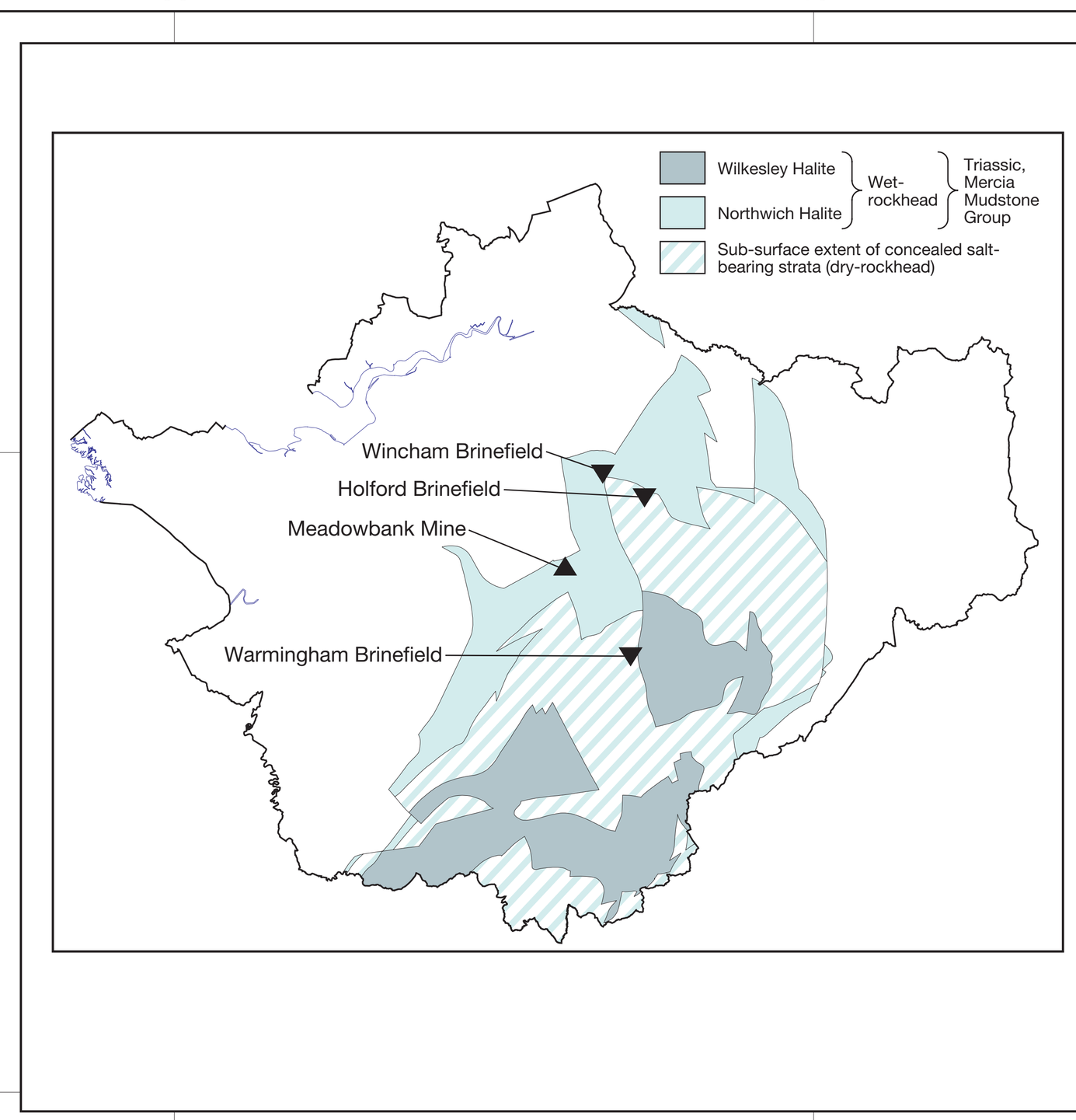
Silica sand processing is of varying degrees of complexity and depends on the nature of the raw material and end use of the sand. It typically requires a high capital investment in plant. Processing is aimed at modifying both the physical and chemical properties of the sand to meet user specifications. The ease with which contaminants (such as iron-bearing impurities and clay) can be removed, together with the level of losses incurred in removing oversize and undersize fractions from a sand, has a major bearing on its potential use. Within the UK, deposits of silica sand occur in only limited areas and quantities, and the special characteristics of silica sand extraction, in particular the cost of processing, means that the industry has a restricted distribution.

Cheshire is the most important source of silica sand in Britain accounting for about 25 per cent of total production with an output of over 1 million tones per year. The silica sand is used principally in the manufacture of float (flat) glass at St Helens, for foundry use and a wide range of other industrial and horticultural applications. The deposits being worked on the eastern side of the Cheshire Plain are in an area broadly bounded by Congleton, Sandbach, Holmes Chapel and Chelford.

Production is based on the Congleton Sand and Chelford Sand, which are fluvial sands of Pleistocene age deposited during an inter-glacial period. They are believed to be the same horizon and occur as an irregular sheet up to 30 m or more in thickness, in places infilling hollows and valleys in the underlying Triassic mudstones or till. The deposits thin towards the west. The sands are themselves cut into by overlying till and glaciofluvial sands (Gawsworth Sand) and consequently their thickness can vary significantly over relatively short distances. They may be worked beneath substantial thicknesses of overburden. The Gawsworth Sand is unsuitable for use as silica sand but is used for construction applications, including concreting sand. The Chelford Sand is purer and slightly coarser than the Congleton Sand but both consist of well-rounded quartz grains with a uniform particle size and are largely free of impurities (pebbles are rare). They both have a high silica content (96-98 per cent SiO_2), and the white sand within the Chelford Sand has an iron content of about 0.1 per cent Fe_2O_3 and is suitable for manufacture of flat glass. Extraction is by both dry working after dewatering to lower the water, which allows selective extraction of different qualities, and by wet working using suction dredging. Processing involves washing, attrition scrubbing and size-classification to remove coarse and very fine fractions and to produce a clean sand with the desired particle-size distribution. Coarse chromite, even in small amounts, is a serious impurity in flat glass manufacture and is removed during size classification.

Most foundry sands are supplied dry and selected grades are also coated with resin binders for foundry casting, producing a high value-added product.

Resources of silica sand are difficult to define without detailed exploration surveys and an evaluation of their properties, including the ease with which they can be processed to marketable quality. The silica sand deposits are mainly concealed beneath an overburden of glaciofluvial sand and/or till. The resource area has been broadly defined by the area bounded by Chelford, Congleton and Sandbach. Remaining resources of the low iron (white) Chelford Sand are believed to be limited.



SALT

Salt (sodium chloride, NaCl) occurs in nature in the solid form as rock salt (halite) or in solution as brine. Rock salt occurs in beds, commonly associated with mudstone, ranging from a few centimetres up to several hundred metres in thickness. The purity of individual salt beds depends on the extent of mudstone interbedding. Salt-bearing strata may underlie extensive areas, but does not crop out at the surface in the UK because of dissolution by groundwater. The boundary at which salt dissolution is taking place is called the 'wet-rockhead.' Where salt-bearing strata are too deep to be affected by groundwater, the normal contact between the salt and overlying rock is known a 'dry-rockhead.' Brine occurs naturally at the wet-rockhead but may also be produced artificially by injecting water into the salt bed and pumping out the resultant salt solution. This may contain up to 25 per cent NaCl when fully saturated.

Rock salt is extracted by underground mining for use principally in de-icing roads and by controlled brine pumping for use as a chemical feedstock and in the manufacture of white salt. Pumping of natural or 'wild' brine has, in the past, resulted in accelerated subsidence over wide areas. Modern, controlled methods of brine extraction do not cause subsidence.

Salt-bearing strata of Permian and Triassic age underlie extensive areas of England. Resources of Triassic age in the Cheshire Basin are economically the most important accounting for about 85 per cent (about 5 million tonnes) of total UK production. In England, rock salt of Permian age is also mined at the Boulby Mine in the North York Moors National Park.

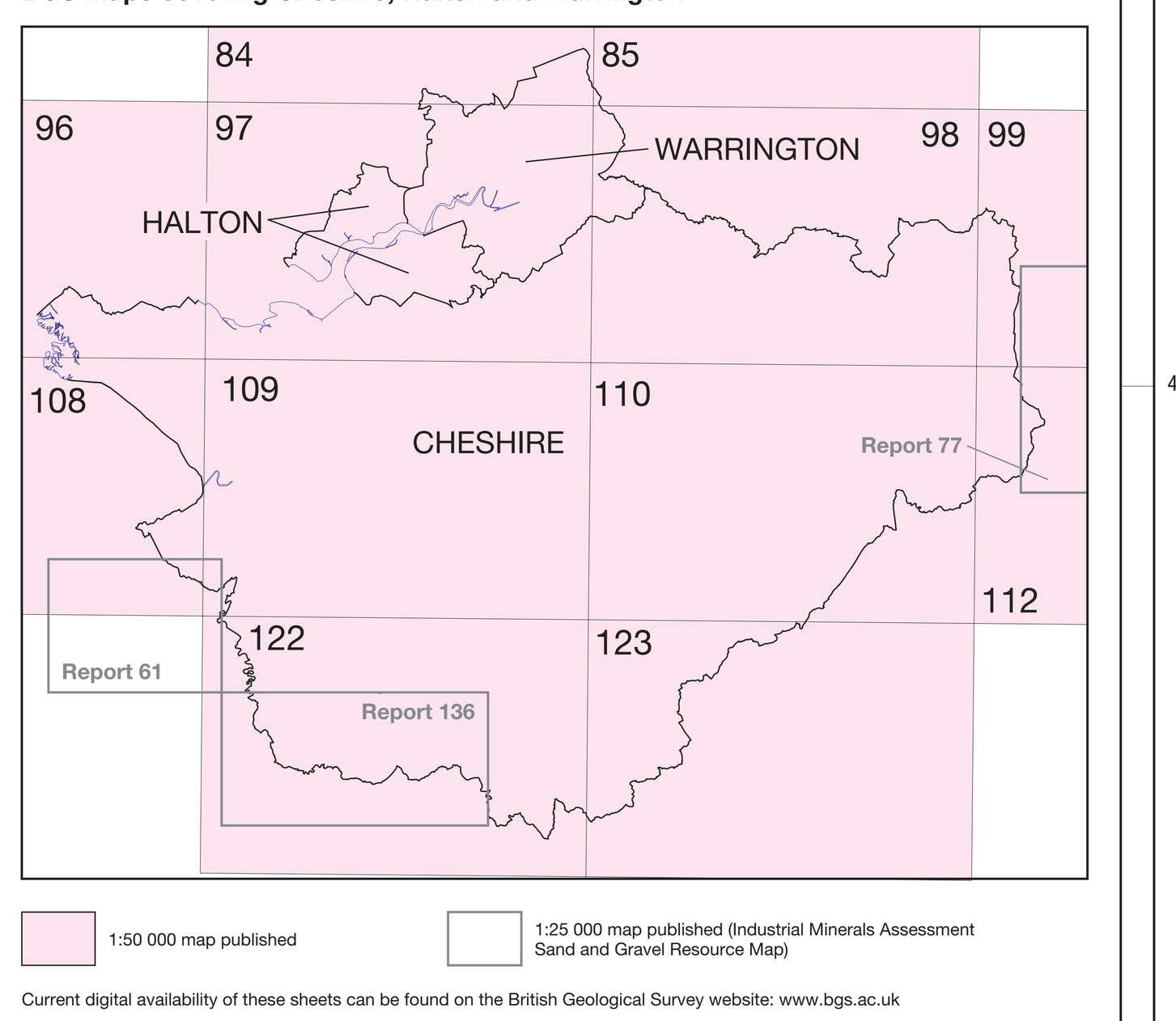
There are huge resources of salt in the Cheshire Basin which occur within the Triassic Mercia Mudstone Group. There are two salt-bearing formations, a lower Northwich Halite Formation and an upper Wilkesley Halite Formation. Production is entirely confined to the former. The maximum known thickness of the Northwich Halite Formation is some 280 m and the salt occurs both in beds that are virtually pure halite and in others where there are varying amounts of mudstone and siltstone. It has been estimated that some 25 per cent of the formation consists of mudstone. The Wilkesley Halite Formation is even thicker and has a known thickness of some 405 m. The upper half of the Wilkesley Halite Formation is somewhat purer than the Northwich Halite. The map shows the outcrop or wet-rockhead of the Northwich and Wilkesley Halite formations, and the concealed, sub-surface extent of salt-bearing strata. The Cheshire Basin extends southwards into Shropshire.

Rock salt is extracted by mining at the Winsford Mine, which has a mine capacity of 2.25 Mt/y although production averages about 0.9 Mt/y. Extraction is by room and pillar mining, and is currently from the Bottom Bed of the Northwich Halite at a depth of about 140 m. The rock salt, which contains about 92 per cent NaCl, is principally used for de-icing roads. The mine, with some 26 million m^3 of space, has a constant temperature and humidity and is dry and gas-free. The mine is currently being used as secure document storage. Part of the mine is also being used for the permanent storage of hazardous wastes. Strict criteria will be used for the type of material stored, which will be dry waste that is non-flammable, non-biodegradeable and non-radioactive.

Most salt in Cheshire (85 per cent) is extracted by solution mining and almost all is by controlled brine pumping. A very small quantity of natural, or 'wild' brine is produced at Wincham. Controlled brine pumping involves the creation of stable cavities up to 145 m in diameter and up to 200 m in height in suitable salt strata by introducing water under carefully controlled conditions and pumping out the resultant brine. The size and shape of the cavities are designed to maintain stability of the overlying strata. Brine wells are laid out on a regular grid about 200 m apart and the process recovers about 25% of the total salt reserve. Controlled brine pumping takes place at the Holford and Warmingham brinefields, from the Northwich Halite Formation, at depths of over 250 m.

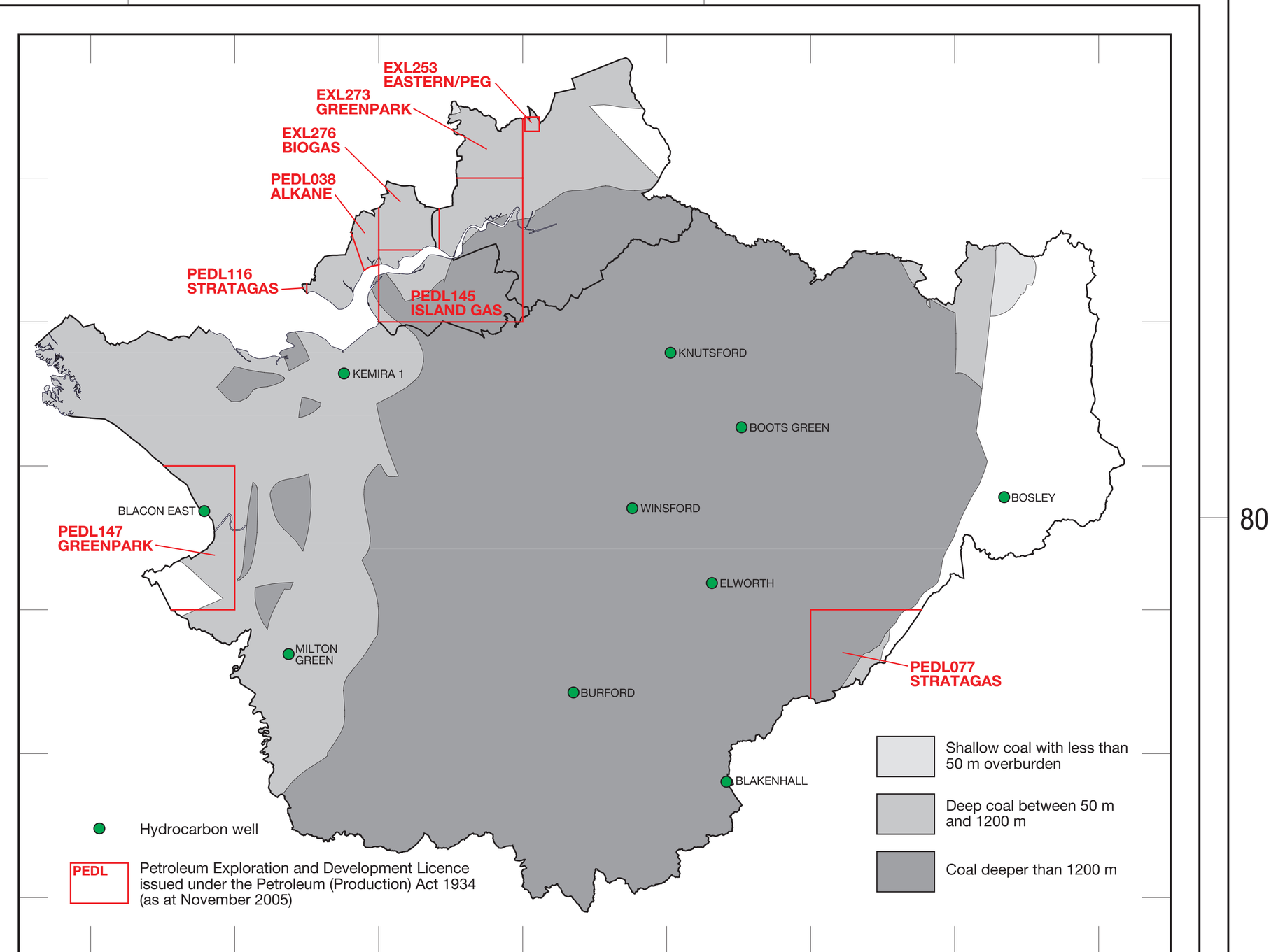
Completed solution cavities are left full of saturated brine although some are used for both waste disposal and storage purposes. Salt-bearing strata are ideally suited for the creation of storage cavities for natural gas, compressed air and fluids. In particular, there is increasing interest in the creation of smaller cavities for natural gas storage and this is taking place at the Warmingham Brinefield and the Holford Brinefield.

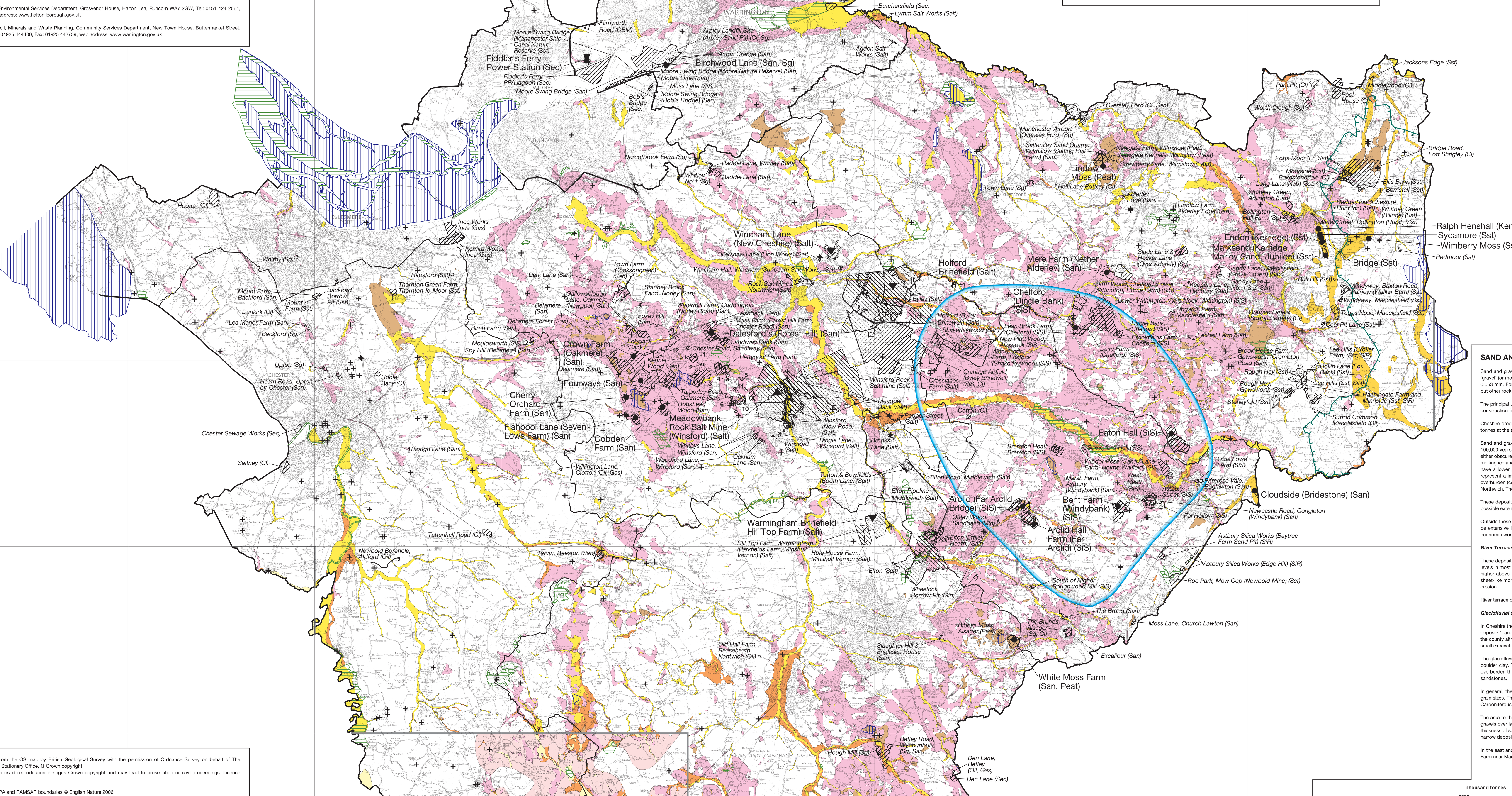
BGS maps covering Cheshire, Halton and Warrington



BRICK CLAY

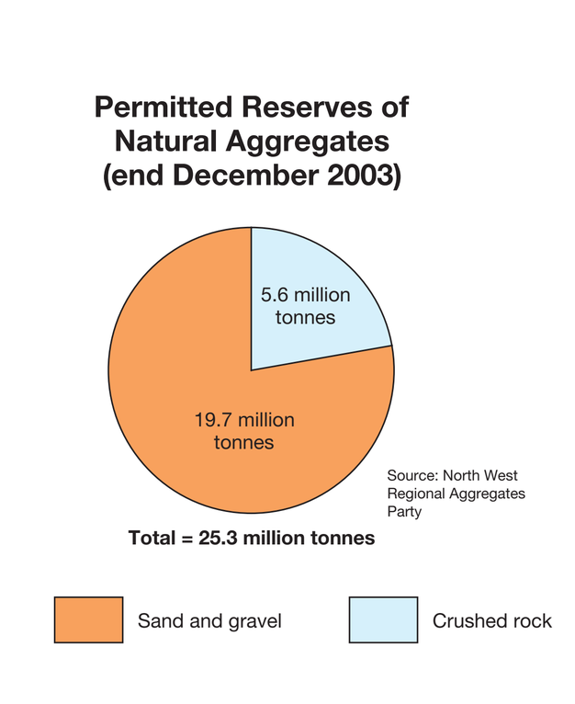
Various formations in Cheshire have been exploited for brick clay, however, only one small area to the east of Warrington is currently being quarried for this purpose. Here, both boulder clay and Triassic, Mercia Mudstone Group mudstones are being used. These lithologies have extensive outcrops across Cheshire, but since they are only worked in these two locations, and otherwise are of variable quality and thickness, the total extent of outcrop is not shown on the map face.

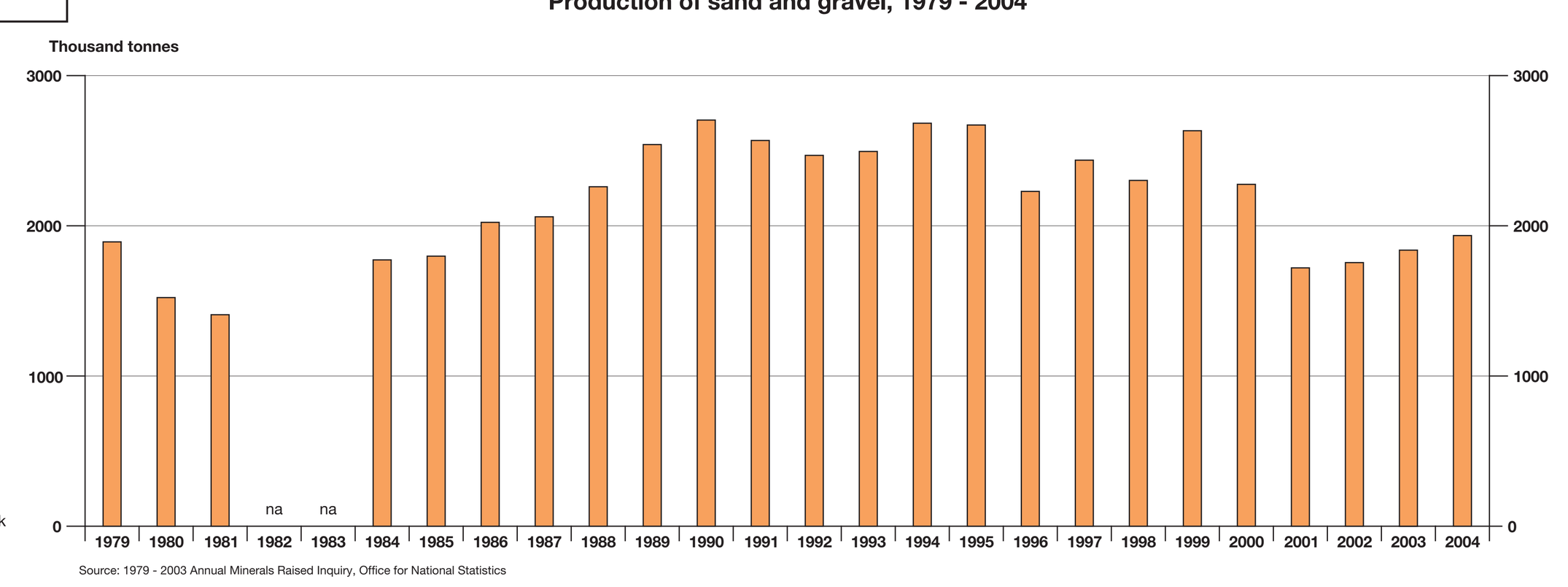




PLANNING PERMISSIONS ON MAP FACE

1. *Sandiway Quarry (Dalesford's Lane) (San)*
2. *Dalefords Lane (San)*
3. *Sandiway (Marton Sands, Newchurch Common, Whitegates) (San)*
4. *Cookstool Farm (San)*
5. *Red House Farm (San)*
6. *Whitegate Road (Marton Hill) (San)*
7. *Springbank Farm (Hill Top Farm, Whitegate Road) (San)*
8. *Hill Top Farm (San)*
9. *Springbank Farm, Marton (Hill Top Farm) (San)*
10. *Gale Green, Marton (Springbank Farm, Marton) (San)*
11. *Brook House Farm (San)*
12. *Crabtree Farm, Oakmere (San)*





Production of sand and gravel, 1979 - 2004