



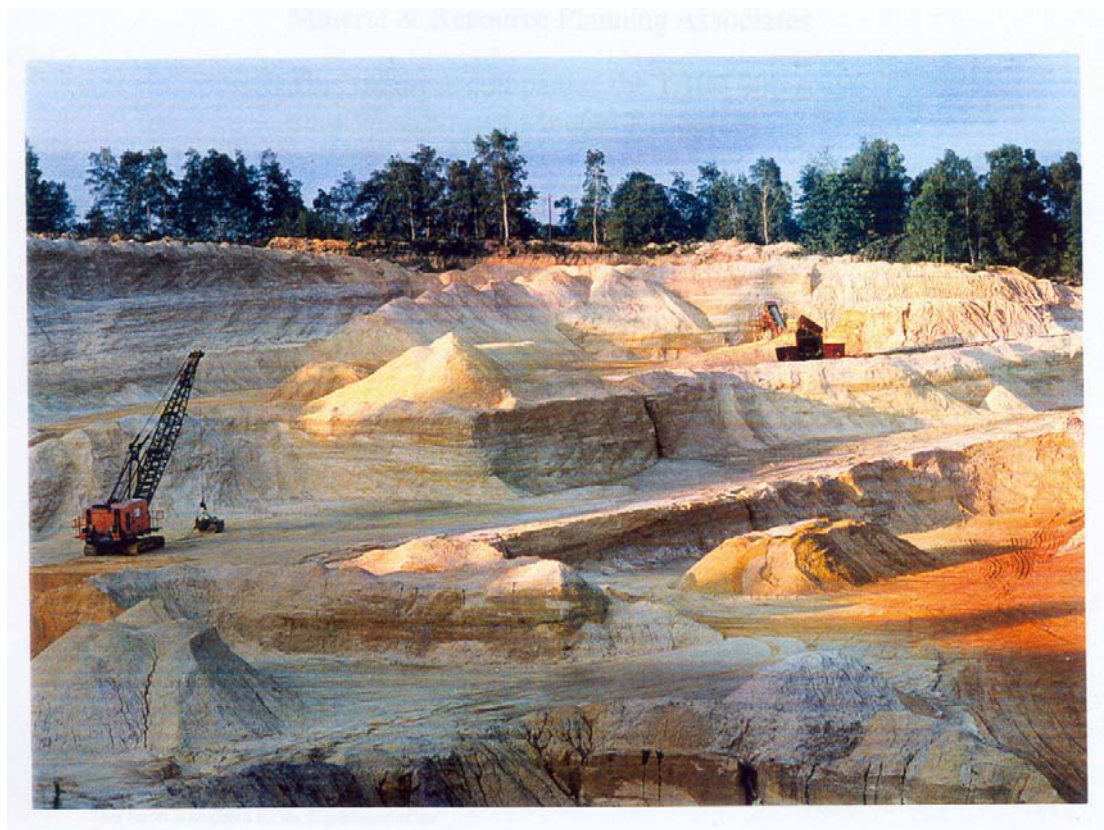
British  
Geological  
Survey



*Department of the Environment,  
Transport and the Regions*

## Mineral Resource Information for Development Plans

### West Sussex: **Resources and Constraints**





BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WF/98/5

Mineral Resources Series

**Mineral Resource Information for Development Plans:  
Phase One  
West Sussex: Resources and constraints**

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This report accompanies the 1:100 000 scale map: West  
Sussex Mineral Resources

*Cover photograph*  
Working face in Folkestone Formation  
sands at Pendean pit, near Midhurst

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## SUMMARY

This report is one of a series prepared by the British Geological Survey for various administrative areas in England and Wales for Phase One of the Department of the Environment, Transport and the Regions Research Project *Mineral Resource Information for Development Plans*.

The report and accompanying map relate to the area of the West Sussex Mineral Planning Authority. The report and map delineate and describe the mineral resources of current, or potential, economic interest in the area and relate these to national planning designations which may represent constraints on the extraction of minerals. Three major elements of information are presented and described:

- the geological distribution and importance of mineral resources
- the extent of mineral planning permissions and the location of current mineral workings
- the extent of selected planning constraints (national statutory designations)

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. The map is produced at 1:100 000 scale, which is convenient for overall display and allows for a legible topographic base on which to depict the information. In addition, as the data are held digitally using a Geographical Information System (GIS), easy revision, updating and customisation are possible, including presentation of subsets of the data at larger scales.

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 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, by providing a knowledge base on the nature and extent of mineral resources and the environmental constraints which may affect their extraction. However, it is anticipated that the maps and report will also provide valuable data for a much wider audience, including the minerals industry, the Planning Inspectorate, the Environment Agency, the Countryside Commission, other agencies and government bodies, environmental interests and the general public.

The mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. The methodology for the collection and display of the data is described and a range of sources of information and further contacts is presented. The mineral resources covered are sand and gravel, crushed-rock aggregate, brick clay, chalk, oil and gas, building stone, fuller's earth and secondary aggregates.



## INTRODUCTION

*'..... it will become increasingly important to have reliable information about the nature, quantity and location of mineral resources as workable reserves in environmentally acceptable areas become scarcer.'*

Sustainable Development: The UK Strategy.  
The UK Government's response to the Rio Earth Summit.

This report is one of a series that has been prepared by the British Geological Survey for various administrative areas in England and Wales in relation to the Department of the Environment, Transport and the Regions research project *Mineral Resource Information for Development Plans*.

The report relates to the administrative area of West Sussex and should be used in conjunction with the mineral resources map of the county which accompanies this report. The report and its associated map delineate and describe the mineral resources of current or potential economic interest in West Sussex and relate these to national planning designations which may represent constraints on the extraction of minerals. 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, by providing 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 discussions on specific planning proposals for mineral extraction or on proposals which may sterilise resources.

All the data are held in digital form which can be readily revised on a regular basis. This also provides scope for producing customised maps of selected information, including the display of part of an administrative area in greater detail or a grouping of administrative areas to provide a broader picture. The county mineral resource map is at 1:100 000 which is a convenient scale for overall display and to show the information on a legible topographic base. The report and map represents the situation at 1st January 1998.

Mineral resources are valuable national assets and their extraction and use makes a major contribution to wealth creation, the infrastructure of our society and quality of life of individuals. However, minerals can only be worked where they occur and their extraction, particularly in the densely populated landmass of Britain, causes conflicts with other desirable aims of society, either by loss or change to valued landscapes, habitats or features of historical and archaeological interest, or due to amenity impact.

Basic mineral resource information is essential to support mineral exploration and development activities. In the wider context of sustainable development, mineral resource data are required for resource management and land-use planning. These data also contribute to the baseline data needed for environmental impact studies and environmental guidelines. Moreover, knowledge of the extent and quality of mineral resources, and their rate of extraction, can help value them as national assets. This ensures that the capital they represent is managed properly and rates of depletion monitored.

## **MINERALS PLANNING**

It is the function of the planning system through the development plan and individual decisions to achieve a balance between competing objectives. Achieving that balance requires adequate data on the relevant competing objectives, including the extent and details of mineral resources. As the development of workable resources in environmentally acceptable areas is becoming more difficult, it will become increasingly important in the policy development process to have comparative and reliable data on the distribution and quality of such resources.

The 'development plan' includes structure plans, which contain strategic planning policies, and local plans, containing detailed policies and proposals, or unitary development plans, which combine both functions. In addition, relevant authorities must produce local plans on minerals and/or waste. Development plans set out the main considerations on which planning applications are determined and form the essential framework of the planning system. The importance of the development plan system in planning decisions is emphasised by Section 54A of the Town and Country Planning Act 1990, which requires that planning applications and appeals be determined in accordance with the development plan, unless material considerations indicate otherwise. The planning system is, therefore, a plan-led system. Development plans are produced through an extensive process of consultation with prospective developers and the general public. Development plan preparation must take account of Government guidance. This is primarily set out in Planning Policy Guidance notes (PPGs), Mineral Planning Guidance notes (MPGs) and Regional Planning Guidance notes (RPGs). These provide advice on a range of general and specific issues.

The Planning and Compensation Act 1991 introduced a mandatory requirement that all Mineral Planning Authorities (MPAs) in England and Wales prepare either a local plan or a unitary development plan which set out the policies and proposals against which planning applications and appeals are determined. Mineral local plans are intended to provide a clear guide to mineral operators

and the public where mineral extraction is likely in principle to be acceptable, and where not. They cover a period of at least 10 years and are reviewed periodically to take account of new information and changing circumstances. MPAs are, therefore, required to undertake regular assessments of the existing resources in their areas and of the reserves for which planning permissions have been granted.

The key elements of a minerals local plan or of the mineral policies of a unitary development plan are:

- to balance through its policies the essential need for minerals against protection of the environment and local amenity
- to make an appropriate provision for the supply of minerals and provide an effective framework within which the minerals industry may make planning applications
- to identify areas of possible future mineral working
- to prevent unnecessary sterilisation of resources by the use of safeguarding policies, including defining mineral consultation areas

It follows from the above that information on the extent, quality and, if possible, quantity of mineral resources is an essential prerequisite for the production of mineral local plans, both in the context of identifying areas of future mineral working and the longer term objective of the protection of important mineral resources against sterilisation. Such data should be available to all parties to assist them in their contribution to the development plan process, both to protect mineral resources from sterilisation and to provide for sufficient resources to meet the needs of society. This work is intended to assist that process.

Three major elements of information are presented and described:

- the geological distribution and importance of mineral resources
- the extent of mineral planning permissions and the location of current mineral workings
- the extent of selected planning constraints (national statutory designations)

The map brings together a wide range of information, much of which is scattered and not always available in a consistent and convenient form. The data are held digitally using a Geographical Information System (GIS), which allows for easy revision, updating and customisation, including presentation of subsets of the data at larger scales. 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 Commission and English Nature), environmental interests and the general public.

## **MINERAL RESOURCE CLASSIFICATION**

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 and be present in sufficient quantity to be of intrinsic economic interest. Mineral resources are thus economic as well as physical entities.

The identification and delineation of mineral resources is inevitably somewhat imprecise as it is limited not only by the quantity and quality of data currently available but also involves predicting what might, or might not, become economic to work in the future. The assessment of mineral resources is, therefore, a dynamic process which must take into account a range of factors. These include geological reinterpretation as additional data becomes available, as well as the continually evolving demand for minerals, or specific qualities of minerals, due to changing economic, technical and environmental factors. Consequently areas that are of potential economic interest as sources of minerals may change with time. Criteria used to define resources, for example in terms of mineral to waste ratios, also change with location and time. Thus a mineral deposit with a high proportion of waste may be viable if located in close proximity to a major market, but uneconomic if located further away. The criteria used to delineate mineral resources are outlined in the relevant commodity section of the report. These criteria vary depending on the quality of the information available.

The map of West Sussex shows the extent of **inferred mineral resources**, that is those mineral resources that can be defined from available geological information. They have neither been evaluated by drilling or other sampling methods, nor had their technical properties characterised, on any systematic basis. Mineral resources defined on the map delineate areas within which potentially workable minerals may occur. These areas are not of uniform potential, nor do they take account of planning constraints which 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. The individual merits of the site must then be judged against other land-use planning issues.

That part of a **mineral resource** which has been fully evaluated and is commercially viable to work is called a **reserve** or **mineral reserve**. The relationship between **measured, indicated** and **inferred resources** and evaluated commercial deposits (**reserves**) is

described in more detail in Appendix 3. In the context of land-use planning, however, 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 maps have been produced by the collation and interpretation of data principally held by the British Geological Survey. The geological lines are taken, with some generalisations, from available BGS 1:25 000, 1:50 000 scale and 1:63 630 scale maps. These published maps are based on 1:10 560 or 1:10 000 scale surveys, which cover most of the county. In general, the more recent the survey the more detailed it is likely to be.

Where sand and gravel assessment studies have been undertaken by the British Geological Survey, sufficient information may be available to define mineral resources at the **indicated resource level**. The sand and gravel resources of the coastal plain fall into this category. The linework here is based on the 1:25 000 scale mineral assessment map.

## **MINERAL WORKINGS AND PLANNING PERMISSIONS**

The location and name of mineral workings that are currently active or temporarily inactive, together with the main mineral commodities produced, are shown on the map and in Appendix 1.

The extent of mineral planning permissions is shown on the Mineral Resources Map. They include all permissions granted since 1st July 1948 and all IDO (Interim Development Orders - planning permissions granted between 1943 and 1948) permissions, whatever their subsequent status in relation to legislation relating to the Planning and Compensation Act 1991 and the Environment Act 1995. Planning permissions cover active mineral workings, former mineral workings and, occasionally, unworked deposits. They represent areas where a commercial decision to work minerals has been taken in the past and where the mineral reserve may have been depleted to a greater or lesser extent. Within the overall site there may be a number of planning permissions at various stages of development and restoration. The planning permissions data were obtained from West Sussex County Council.

The present physical and legal status of individual permissions is not qualified on the map or in the report. The areas shown may, therefore, include inactive sites, where the permission has expired due to the terms of the permission, i.e. a time limit, and inactive (dormant) sites where the permission is still valid. Sites which have been restored have not been separately identified. A planning

permission may extend beyond the mapped resource as it may make provision for operational land, including plant, overburden tips and landscaping, or it may extend to an easily identified or ownership boundary. Information on the precise status and extent of individual planning permissions should be sought from the Mineral Planning Authority (Appendix 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:

- Areas of Outstanding Natural Beauty (AONB)
- National Nature Reserves (NNR)
- Sites of Special Scientific Interest (SSSI)
- Scheduled Monuments

Mineral development may also be constrained by 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 Mineral Planning Authority (Appendix 2).

AONBs have been digitised from maps obtained from the Countryside Commission and English Nature provided digital data on SSSIs and NNRs. Information on the location of Scheduled Monuments has been obtained in digital form from English Heritage. The areas shown as NNRs and SSSIs may also be subject to international designations reflecting their wider ecological importance. They may include Ramsar sites (wetlands of international importance as listed in accordance with the Ramsar Convention), or proposed Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) as identified in accordance with EC Directives on wild birds and natural habitats, respectively.

## **MINERAL RESOURCES**

### **OVERVIEW**

The mineral resources of West Sussex occur in sedimentary rocks ranging from Jurassic to Quaternary age. Historically, the majority of the sedimentary units within the county have been worked for specific minerals including ironstone, brick and tile clays, cement raw materials, agricultural lime, building stone and aggregate. A geological sketch map and generalised vertical section showing the succession in West Sussex and resources derived from the rocks is given in Figure 1.

West Sussex has had a long history of mineral working. Gravel working at Boxgrove, east of Chichester has uncovered 500 000 year-old hominid remains ('Boxgrove Man'). These remains are amongst the oldest found outside Africa. Boxgrove Man was fashioning flint hand axes from material taken from the chalk cliffs behind a beach (Upper Raised Beach) which was subsequently buried by Head Gravel. This site is of international archaeological importance.

The Weald played a major part in the development of the British iron industry. Iron ore smelting began in pre-Roman times but achieved a peak in the 16th and 17th centuries, when it was a major industry. However, the industry declined from the mid-18th century, when coke was first used successfully as a reductant and the iron industry became largely based on the coalfields. An attempt to revive the industry in 1857 and 1858 was unsuccessful. The ironstone most widely used was that occurring at the base of the Wadhurst Clay, where it typically occurs as sideritic mudstones in thin beds or nodules. It was also worked from the Ashdown Beds, the Grinstead Clay, the Upper Tunbridge Wells Sand and the Weald Clay. Iron content of the ores varied between 31 and 38 percent  $\text{Fe}_2\text{O}_3$ . The ironstone was smelted using charcoal obtained from the local woodlands. These ironstones have no economic significance today.

As in many other areas of England, the building stone industry was far more widespread in West Sussex in the past than it is today. A wide variety of Lower Cretaceous sandstones and limestones were formerly worked as building stones supplying very localised markets. With changes in building methods and fashions, this industry has contracted to a few small working quarries supplying a specialised market.

Major extractive industries surviving in the county include aggregates won from the Quaternary Head and Fan Gravels of the Sussex Coastal Plain around Chichester. These gravels constitute an extensively exploited and locally-important source of aggregates.

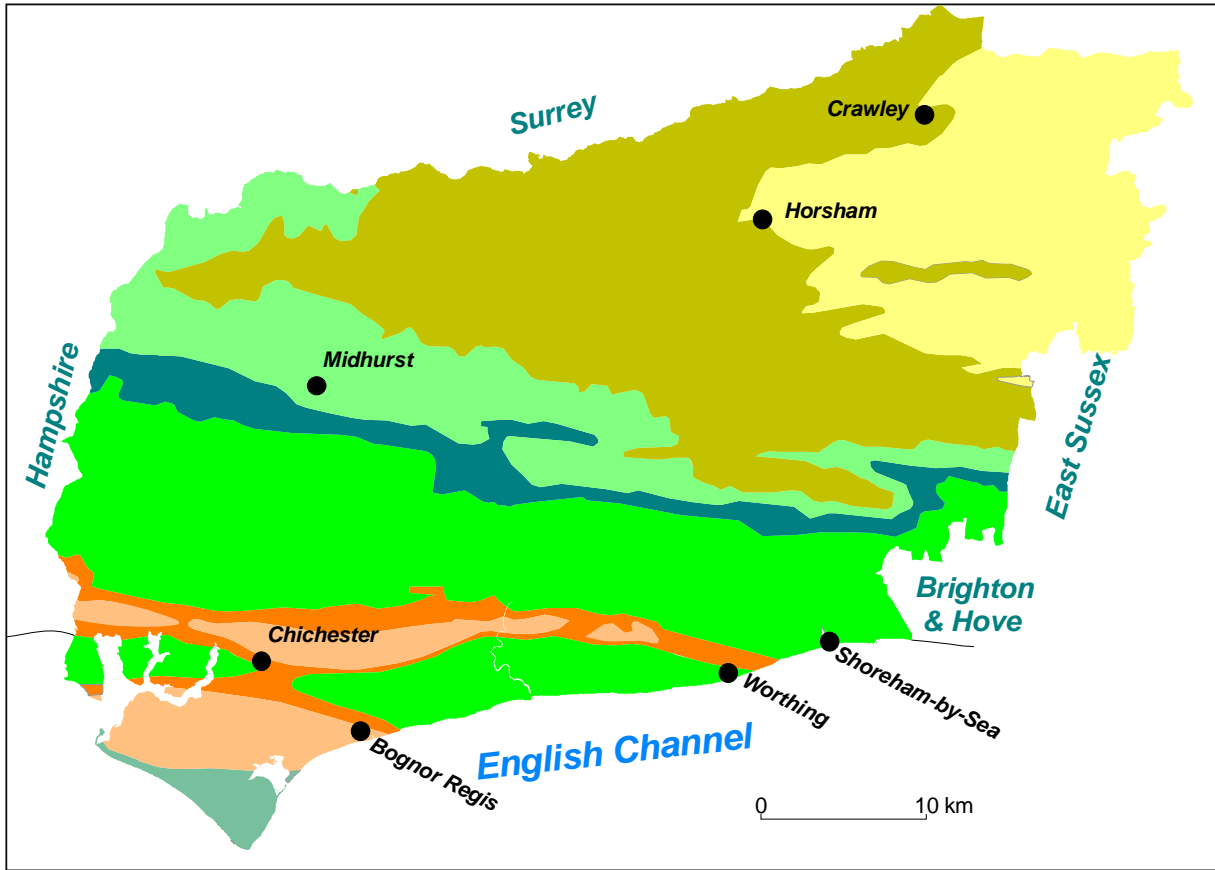


Figure 1. Sketch map of the solid geology of West Sussex.



West Sussex Mineral Resources and Constraints

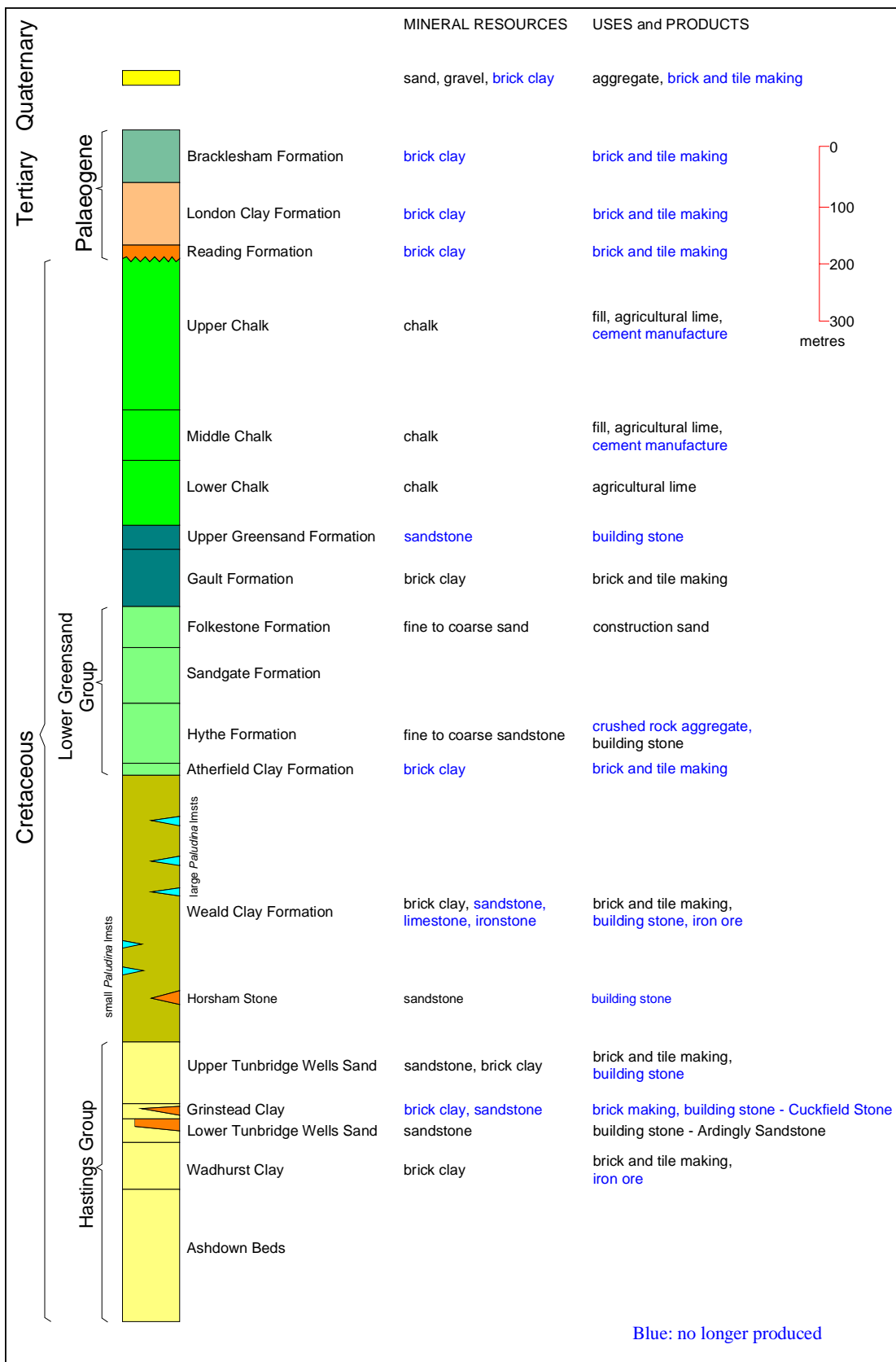


Figure 1 (continued). Generalised vertical section for the rocks of West Sussex and their uses.

Sand extracted from bedded deposits in the Lower Cretaceous in the central part of the county supplies the whole of Sussex and south-eastern Hampshire with building and concreting sand. The Hastings Group clays and Weald Clay in the northern portion of West Sussex form the basis for an industry manufacturing bricks and tiles used in large volumes across south-east England. Chalk is worked on a relatively small-scale for agricultural lime and fill. Until recently it was worked as a raw material for cement. Cement is no longer manufactured in the county.

West Sussex is prospective for both oil and gas. A number of exploration holes have been drilled, resulting in the discovery of one producing field at Singleton. It is highly likely that further wells will be drilled, with more discoveries possible.

Extraction of aggregates, particularly from the limited remaining gravel resources of the coastal plain, and from the Folkestone Formation, is likely to be the prominent issue in the mineral planning process in West Sussex in the future.

## **SAND AND GRAVEL**

The sand and gravel resources of West Sussex may be divided into two broad categories:

- Superficial or ‘drift’ deposits of Quaternary age and consisting of sand and gravel resources, and related deposits, of the West Sussex coastal plain
- Bedrock or ‘solid’ sand deposits comprising the Cretaceous, Folkestone Formation.

The two deposits are very different in character, in terms of both composition and particle-size distribution. The Quaternary deposits consist essentially of flint gravel in a fine matrix, with a relatively small sand fraction. In contrast, the clean quartz sands of the Folkestone Formation have relatively little fine-grained material and also tend not to contain gravel.

Sand and gravel production data for West Sussex are summarised in Figure 2. The overall trend shows a decline in output, although a strong cyclical variation is superimposed on this. The cyclical variations in output are clearly related to economic activity in the construction sector.

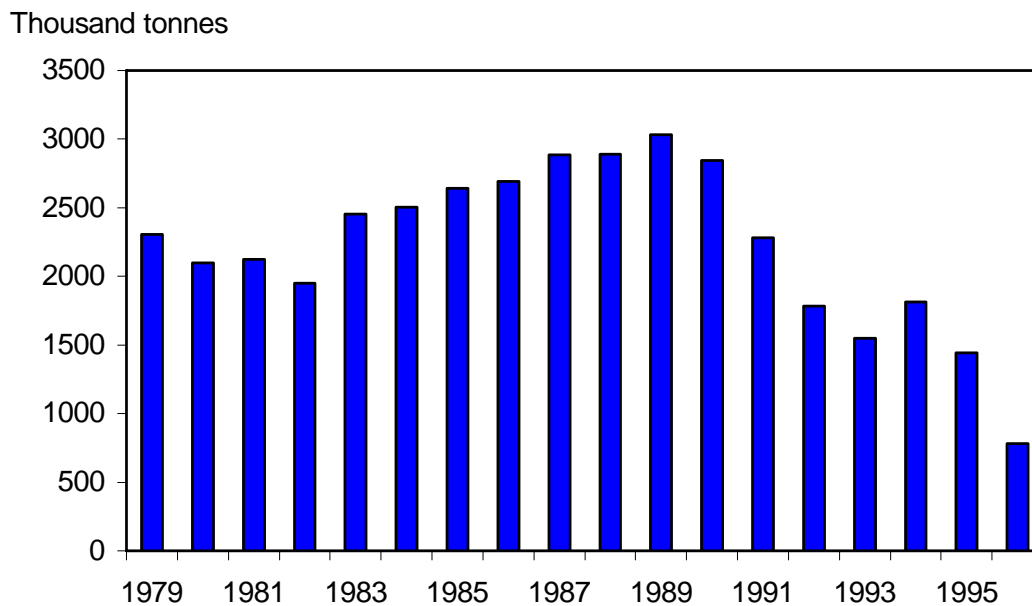
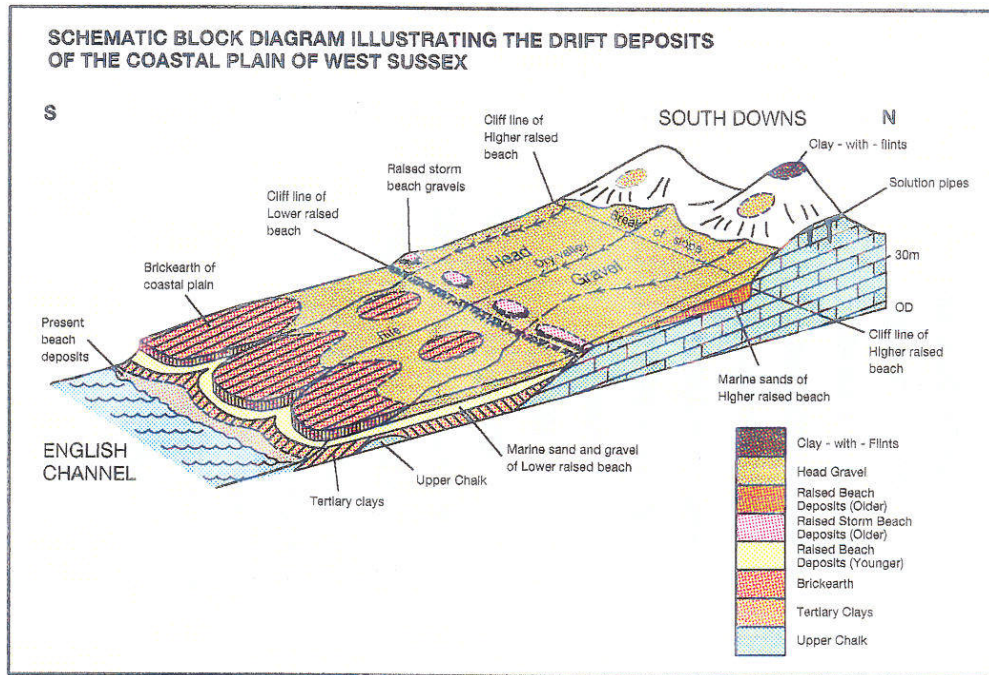


Figure 2. Sand and gravel production in West Sussex (Source: Office for National Statistics). na: data not available.

### Gravel

The gravel resources of West Sussex shown on the Mineral Resources Map are defined as those deposits on the coastal plain containing appreciable quantities of >4 mm material. There are seven pits currently being worked for gravel in the Chichester area. Gravel resources are identified within the deposits mapped as Head Gravel, Fan Gravel and Storm Beach Deposits. The relationships between the Quaternary sediments of the Sussex coastal plain are shown in Figure 3. The Upper (Older) and Lower (Younger) Raised Beach Deposits have been excluded because they consist principally of fine (<0.25 mm) sand, which is unsuitable for most construction applications. Although predominantly siliceous (flint), the gravel within these latter deposits also contains appreciable amounts of chalk and other deleterious material. The Upper Raised Beach Deposits tend to be of limited extent and are generally concealed beneath Head Gravel Deposits.

All the deposits are 'clayey' (10 to 20 percent silt and clay) or 'very clayey' (20 to 40 percent silt and clay) and are, therefore, generally more expensive to process compared to cleaner materials. Their value as aggregate is determined principally by their being the only local supply of gravel-grade material.



**Figure 3. Schematic diagram showing relationships between the Quaternary sediments of the Sussex coastal plain.**

### **Head Gravel**

The Head Gravel is the most extensive deposit and consists of a sheet of angular flint gravel set in a dominantly clayey matrix. Head Gravel is a complex periglacial mass-movement deposit containing materials derived from the dip slope of the South Downs, the local Palaeogene and Raised Beach Deposits (Shephard-Thorn *et al.*, 1982). It overlies deposits of the Upper and Lower Raised Beach along the West Sussex coastal plain. Where it overlies the Lower Raised Beach, the Head Gravel is generally thinner and covered by a later Brickearth. In an unprocessed state the material can be used as 'hoggin' (a gravel and clay mixture used for fill and for surfacing rough tracks). Where the content of fines is below 30 per cent, the Head Gravels can be processed to produce coarse aggregates for use in concrete or for re-combination with other materials for local sub-base. Processing entails both washing and crushing, although the quality of the final product depends on the nature and ease with which fines can be removed, both from the gravel as a whole and from individual flints.

Two successive layers of clayey gravel, separated by a thin silt bed are recognised above Upper Raised Beach Deposits at Boxgrove. A thinner and less continuous layer of Head Gravel spreads over the Lower Raised Beach Deposits. In general form the deposit is wedge-shaped in section, thinning southwards from a maximum of about 7 metres in the north.

The Head Gravel can be considered as two separate deposits, a higher level deposit associated with the Upper Raised Beach, and a lower level deposit overlying part of the Lower Raised Beach. Overall particle size characteristics for these two separate deposits show a significant difference (Table 1). The topographically lower (and presumably younger) Head Gravel has a somewhat lower gravel content. This lower deposit is also less consistently developed, thinner overall and frequently buried beneath Brickearth. Consequently the lower deposit is a less valuable resource.

Head Gravel	>64mm	64-16mm	16-4mm	4-1mm	1-0.25mm	0.25-0.063mm	<0.063mm
Upper	2	31	26	9	4	4	24
Lower	1	23	23	12	6	6	29

**Table 1. Mean grading data for the Upper and Lower Head Gravels. Recalculated from data in Lovell & Nancarrow (1982).**

### **Fan Gravel**

The Fan Gravel is considered to be a fluvial (river) deposit emanating from the confines of the Lavant valley and an unnamed stream west of Chichester. The Lavant valley deposit broadens into a fan to the south-east of Chichester. It is younger than the Lower Raised Beach Deposits. Boreholes indicate that it is overlain by a brickearth in places and disappears beneath younger fluvial and marine/estuarine deposits in the 'rifes' draining the Lower Raised Beach area.

The Fan Gravel has been extensively worked to the south-east of Chichester where up to about 10 m was identified in open pits during the time of the geological survey (early 1980s). It is generally less 'clayey' than the Head Gravel and is composed principally of angular with some well-rounded flint. Mean grading data for the deposit is given in Table 2. Remaining resources are limited.

Fan Gravel	>64mm	64-16mm	16-4mm	4-1mm	1-0.25mm	0.25-0.063mm	<0.063mm
	trace	29	28	12	6	6	18

**Table 2. Mean grading data for the Fan Gravel. Recalculated from data in Lovell & Nancarrow (1982).**



Figure 4. Workings in Fan Gravel at Portfield quarry (courtesy of West Sussex County Council).

### ***Raised Storm Beach Deposits***

There are limited outcrops of Raised Storm Beach Deposits occurring as a line of low mounds to the east of Chichester. They are thought to be the remnants of an offshore bar associated with the Upper Raised Beach Deposits, although information on these gravels is very limited. Available data shows the deposit to be a 'clayey' sandy gravel principally composed of angular and well-rounded flint.

The Lower Raised Beach area east of the River Arun in the urban area of Worthing is excluded from the map because of its poor quality. There was no Upper Raised Beach platform specifically identified during the mapping of the Worthing urban area, although a considerable area of Head on the lower dip slopes of the Chalk around the 30 metre contour line might well be similar in lithology to the Head Gravel further west. No information exists on the quality of this material and as such it has been excluded from the map.

## **Sand**

### ***Folkestone Formation***

The Folkestone Formation provides a sub-regionally-important source of sand and is worked in a number of locations in West Sussex. The Folkestone Formation consists mainly of large-scale, cross-bedded sands and weakly cemented sandrock of variable particle-size distribution. The sands tend to become finer toward the

eastern and western extremes of the county and to coarsen upwards. They are generally finer than 1.0 mm and typically show a size distribution with 90 percent less than 0.5 mm and some 10-15 percent passing 150 µm prior to washing. The sands are commonly pale fawn or yellow in colour; patchy red staining by iron oxides is common, along with white bleaching under acidic heathland soils.

The thickness of the deposit varies considerably, but general thinning of the sequence down to 10-20 m is evident to both east and west. The thickest beds are between Midhurst and Washington where 40-70 m are present.

Within the county area, ten sites are worked within the Folkestone Formation for building and concreting sand and constructional fill. Most comprise dry workings where sand is dry screened to remove coarse ironstone fragments and lumps of clay prior to use as building sand. In places, the coarser sand is washed to produce concreting sand and for the manufacture of concrete tiles. Some pits are wet and are worked by dredging. This sand is hydrocycloned to remove undersize material.

### ***Sandgate Formation***

The Pulborough Sandrock (part of the Sandgate Formation) is a well-sorted, uniformly fine-grained, buff-coloured to yellow sand which is 8 to 10 m thick. Since it is too fine-grained for most construction applications, it is not shown on the map. However, until recently it was worked on small-scale at Limbourne near Fittleworth for use as a surface facing on clay bricks.

## **CRUSHED-ROCK AGGREGATE**

There are no sources of high-quality crushed-rock aggregate in West Sussex. However, sandstones within the Hythe Formation are quarried at the Bognor Common quarry near Fittleworth for use as hardcore and constructional fill.

## **CLAY**

Clay is used mainly in the manufacture of structural clay products, such as facing and engineering bricks, pavers, clay tiles and vitrified clay pipes. Brick manufacture is the largest tonnage use. Clays may also be used as a source of constructional fill and for lining and sealing landfill sites. The suitability of a clay for the manufacture of structural clay products depends principally on its behaviour during shaping, drying and, most importantly, firing. This behaviour will dictate the final properties of the fired brick, including its strength, porosity (water absorption) and aesthetic qualities.

A wide range of clays have been used for brick manufacture in the past. However, modern brick making technology is highly capital

intensive. This technology is increasingly dependent on clay raw materials with predictable and consistent forming and firing characteristics to achieve high yields of saleable products.

Production data for clay produced in West Sussex are summarised in Figure 5. Despite an overall decline, production of brick clay is strongly cyclical and is bound closely to economic activity in the construction sector.

### Wadhurst Clay

The Wadhurst Clay crops out between East Grinstead and Horsted Keynes and consists of mudstones and silty mudstones with thin clay-ironstones. It reaches a maximum thickness of about 70 m, but thins to the north beneath younger rocks of the Hastings Group. The Wadhurst Clay is worked for the manufacture of bricks at West Hoathly and at Freshfield Lane, both in the north east of the county. At Freshfield Lane, Upper Tunbridge Wells Sand is mixed with Wadhurst Clay for brick manufacture.

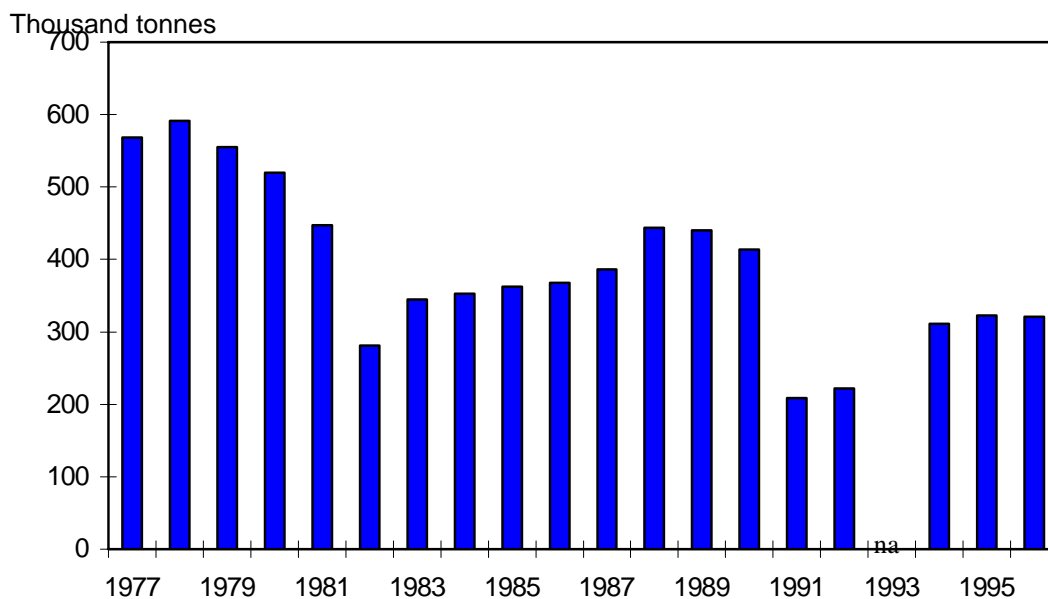


Figure 5. Clay production in West Sussex (Source: Office for National Statistics). na: data not available.

### Weald Clay

The Weald Clay of south-eastern England is a regionally-important brickmaking raw material. It is worked at several sites in West Sussex for the production of facing bricks and tiles. The clay mineral assemblage in this mudstone sequence is dominated by kaolinite and illite, although variation in clay and non-clay mineralogy within the sequence allows manufacture of a wide variety of brick products. The Weald Clay occupies a large area of low-lying ground in the north and central part of the county. It



consists of up to 450 m of mudstones and silty mudstones, as well as thin beds of sandstones, shelly limestones and clay-ironstone. Distribution of working and disused pits indicates that usable clays are, or have been, quarried from all levels within the Weald Clay. The map, therefore, shows the full extent of this formation in the county. Quarrying operations generally avoid horizons rich in pyrite (sometimes weathered to gypsum), siderite, calcite and those with abundant ostracod shelly fossils. When present in significant quantities in the brick clay, one or more of these components can cause serious problems either in the manufacture or in-service performance of the bricks.

### **Gault**

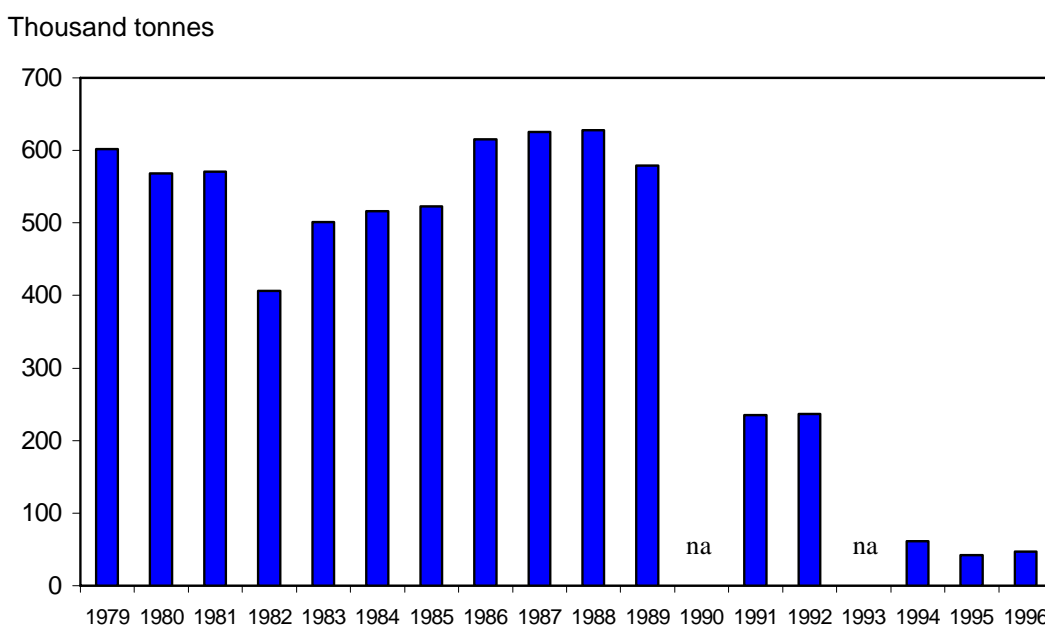
The Gault Formation consists of mudstones and silty mudstones which become progressively more silty toward the top of the sequence. In West Sussex, the Gault is 90-100 m thick. Historically, the Gault clay has been worked at several localities in the county. Poor forming properties caused by high shrinkage on drying renders this material unsuitable for most modern brick manufacturing processes. Only one working pit now remains at Pitsham, producing raw materials for the manufacture of handmade bricks. Gault clay is worked at another pit (Small Dole) as a landfill sealant. In the past, the Gault was also worked at this site as a cement raw material.

### **CHALK**

Chalk is a relatively soft, fine-grained, white limestone, mostly consisting of the debris from planktonic algae. The Chalk is of Upper Cretaceous age and occurs extensively in eastern and southern England where it forms an important source of 'limestone' raw materials. In West Sussex, the Chalk forms the prominent natural feature of the South Downs. The Downs are characterised by undulating downland scenery, dissected by coombs and steep sided dry valleys. Chalk is currently extracted from four quarries in the County, mostly for agricultural use, but also for constructional fill. With the closure of the Shoreham Cement Works in 1991, there is now no extraction for cement production. A further three quarries are inactive at present. Production of chalk in West Sussex has declined dramatically over the past decade (Figure 6). In excess of 600 000 tonnes was produced in the county in 1986, compared with just over 60 000 tonnes in 1996. This fall is primarily due to the closure of the cement works at Shoreham.

The Chalk comprises a uniform sequence of porous limestones and marly chalks which are up to 400 m thick in West Sussex. It is characterised by the presence of flints which mostly follow bedding planes. The flint occurs as nodular courses and tabular beds and is particularly common in upper parts of the sequence. Flint is readily removed from the chalk during quarry processing.

Although the Chalk has a uniform appearance, a wide variety of different lithologies is present. There are three main subdivisions; Lower, Middle and Upper Chalk.



**Figure 6. Production of chalk in West Sussex (Source: Office for National Statistics). na: data not available.**

The Lower Chalk contains a considerable amount of clayey chalk and marl and pyrite nodules are common. This part of the sequence is generally of low chemical purity (<93.5 percent CaCO<sub>3</sub>), although some beds, especially near the top of the deposit, can contain much higher percentages of CaCO<sub>3</sub>.

The Middle Chalk contains fewer marl seams and for the most part comprises a sequence of soft, blocky, white chalk. Flint bands are numerous in the uppermost few metres. The Middle Chalk deposits are mainly of medium- to high-purity (93.5 - 98.5 percent CaCO<sub>3</sub>).

The Upper Chalk contains numerous flint bands. It is mostly of high- or very high-purity (97.0 to >98.5 percent CaCO<sub>3</sub>), if the flint content is excluded.

The Chalk outcrop is largely free of superficial deposits apart from alluvial deposits in the main river valleys and various drift deposits on the lower slopes of the Downs flanking the coastal plain. Chalk is the most important aquifer in south-east England and is the principal source of water supply in West Sussex.

## **OIL AND GAS**

Hydrocarbon exploration in Sussex started in the late 19th century, when the railway station at Heathfield in East Sussex was lit by natural gas which came from a borehole drilled into Wealden strata. Despite this early indication of hydrocarbon potential, prior to 1980 only 4 exploration wells had been drilled in West Sussex. These were Worth Forest in 1932, Henfield 1 in 1936/7, Bolney 1 in 1963 and Middleton 1 in 1971, all without significant success. However, following the discovery of the Humbly Grove oilfield in Hampshire in April 1980, it became apparent that West Sussex had potential for both oil and natural gas. Since then, the whole of West Sussex has been systematically explored by seismic surveys and 18 wildcat exploration wells have been drilled. Of these, five are still confidential.

The most important discovery is the Singleton oilfield which was found in 1989. It is estimated to have recoverable reserves of 0.36 million tonnes (approximately 2.7 million barrels) of oil. Production started in 1991 and up until the end of 1997 some 287 000 barrels had been produced. Other oil discoveries were made at Baxter's Copse in 1983, Storrington in 1985/86 and Lidsey in 1987. These discoveries remain undeveloped. Basic details of all released wells are given on the Mineral Resources Map.

The oil and gas found in West Sussex is considered to have been generated largely, if not entirely, from Lower Jurassic (Lias) mudstones. In West Sussex, oil reservoirs discovered to date have been in the Great Oolite limestones, the same reservoir as in the nearby Horndean and Humbly Grove oilfields in Hampshire. All the fields are structural traps.

There appears to be some potential for further discoveries throughout the county. However, given the extent and coverage of exploration wells already drilled, it is unlikely that any further discoveries will be larger than those already made. Exploration and development licences, shown on the accompanying map, indicate that approximately half the county is currently licensed for exploration. Production licences exist for the Storrington and Lidsey discoveries, as well as the Singleton oilfield.

## **BUILDING STONE**

Building stone has been produced from a number of horizons within the Lower Cretaceous rocks in the northern half of the county. Working of building stone was widespread in the past. Present quarrying activities are restricted to seven sites within the county. A continuing supply of building stone for new building and for restoration is necessary to maintain local vernacular architecture.

The upper 15 to 18 m of the Lower Tunbridge Wells Sand comprises a massive thickly-bedded, fine- and medium-grained quartzose sandstone known as the Ardingly Sandstone. The Ardingly Sandstone is currently quarried from three localities in the High Weald. These are generally where unweathered stone occurs beneath a cover of Grinstead Clay.

Beds of fine-grained micaceous sandstone in the upper part of the Upper Tunbridge Wells Sand have been exploited in the past as building stone. Well-bedded material produced even-thickness slabs of fine-grained durable sandstone from this unit, which crops out between Horsham and Haywards Heath. Some material is produced at the Freshfield Lane brickworks.

The Weald Clay contains thin beds of sandstone, shelly limestone and clay ironstone. A number of the sandstone and limestone units within the Weald Clay have been extensively worked for building stone, the most important of which is the Horsham Stone. This unit (in the lower part of the Weald Clay) was worked in the area to the south and west of Horsham. The stone is a hard, fine-grained calcareous sandstone and is found in layers between 0.1 and 0.6 m thick. It has been valued traditionally as a source of building stone and high-quality paving and roofing stone. There is one active quarry at Slinfold near Horsham which is working the Horsham Stone.

The Hythe Formation provides sources of sandstone building stone within the Lower Greensand. Two quarries are currently active working the Hythe Formation near Midhurst and Petworth (Bognor Common). The latter is principally a source of aggregate, but is also used for building and rockery stone.

## **SILICA SAND**

Silica (industrial) sands contain a high proportion of silica in the form quartz and are valued for their chemical purity and physical properties, principally narrow particle-size distribution, on which their industrial applications are based. The clean, well-sorted sands of the Folkestone Formation of the northern Weald are an important source of silica sand for use in glass manufacture, foundry applications and various other industrial uses. In contrast, the Folkestone Formation of the southern Weald has been little worked as a source of silica sand, although this may partly reflect distance to major markets.

The distinction made between silica sands and construction sands is based principally on their end-use applications and market specifications, rather than a fundamental difference in the two raw materials in the ground. Nevertheless, since most industrial uses of silica sand demand a product of high purity and narrow size distribution, preferred sands are those that are clean, free of

impurities and are well-sorted. Depending on end-use application processing of silica sands is of varying degrees of complexity and often requires a high capital investment in plant. The ease with which impurities, such as iron-bearing contaminants and clay, together with the level of losses incurred in removing oversize and undersize fractions from a sand has a major bearing on its possible use as a silica sand.

Resources of silica sand are difficult to define without a detailed evaluation of their properties and, most importantly, the ease with which they can be processed to an acceptable quality. However, locally the sands of the Folkestone Formation may have some potential.

### **FULLER'S EARTH**

A wide range of clays have been referred to as 'fuller's earth' in the past, the term being derived from their former use for cleansing or 'fulling' woollen cloth. In Britain the term is now used to describe clays composed essentially of the clay mineral Ca-smectite, which has a unique combination of properties on which the clay's industrial applications are based.

Fuller's earth is a rare clay and has a very restricted distribution in Britain. Lenticular deposits within the Lower Greensand are currently worked in Bedfordshire and Oxfordshire and, until recently, Surrey. There have been a number of historical references to the occurrence and former extraction of fuller's earth in the Tillington area of West Sussex. These reports stimulated investigations by the British Geological Survey in the mid-1970s to characterise the occurrences, in terms of location, size and quality. The investigations involved mapping, deep augering, trenching and the drilling of five boreholes. The trenching programme proved a bed of fuller's earth with a thickness of over 4 m at two localities adjacent to the A272 west of Petworth, suggesting that a large deposit of fuller's earth might be present within the Lower Greensand (Hythe Formation) of the Lodsworth-Tillington area. However, none of the subsequent boreholes encountered any significant beds of fuller's earth, suggesting that the thick beds at outcrop are highly lenticular and of limited areal extent. These results were confirmed by a drilling programme in the Tillington area conducted in the mid-1980s by a commercial producer.

Numerous other occurrences of fuller's earth have been found elsewhere in West Sussex, but none are of size to be of commercial interest. The Tillington fuller's earth is the largest known occurrence in the southern Weald and the only locality where the mineral is reported to have been extracted in the past.

## **SECONDARY AGGREGATES**

The term ‘secondary aggregates’ is used to describe a range of materials which may be used for aggregate purposes (subject to conditions of quality and contamination), but which arise as wastes from a variety of activities. They may be considered under three main headings:

- Naturally-occurring materials arising from mineral extraction and processing operations, such as quarry/ processing waste
- Materials arising from manufacturing processes, such as slags and ash, which may be of variable composition
- Construction and demolition wastes which may be in a natural or manufactured state. These include road sub-base, road planings, concrete rubble and masonry. These materials are only given brief consideration in this study as arisings are highly variable in location, type and duration.

Utilising the aggregate potential of such materials may have the advantage of both reducing the demand for primary aggregates and the problems of waste disposal. In general, however, secondary aggregates are only suitable for less demanding applications, and their production may not always be environmentally or economically desirable.

Scope for production of secondary aggregates in West Sussex from mineral or manufacturing waste is extremely limited. There are no working mineral operations generating large volumes of waste material and there are no redundant operations with large spoil tips within the county. Heavy manufacturing facilities and power generators likely to produce waste usable as secondary aggregate are absent from the county. The principal source of secondary aggregates generated within the county will therefore be construction and demolition waste and road planings.

## **MINERAL RESOURCES AND PLANNING CONSTRAINTS**

The landscape character of West Sussex reflects the nature and structure of the underlying rocks, the erosive forces to which they have been subjected and the soil and vegetation that they support. This character is constantly changing due to economic and social pressures in the short-term and to geomorphological processes in the long-term. Mineral extraction can cause irrevocable, but not necessarily harmful, change to a locality over a relatively short timescale. In order to ensure that such changes are sustainable and do not harm the environment the most valuable landscapes and habitats (National Parks, AONB, SSSI's etc.) are given a greater degree of protection from mineral working. The need for mineral workings in such areas has to be justified by a most rigorous examination of the merits of the proposal. This examination considers the wider public interest in the development of the resource and the social and economic issues as well as the need to protect the environment.

Mineral extraction in areas designated as SPA's or SAC's may be acceptable if there are no alternatives and if there are imperative reasons of overriding public interest which support the development. For certain priority SAC's, development can only be considered to be acceptable if there are overriding reasons of public health or safety or due to beneficial environmental consequences. Whilst the requirement to assess the acceptability of mineral working in such designated areas is therefore stringent, there is no total prohibition on working minerals in such areas.

The resolution of conflicts between mineral resource development and other considerations is undertaken through the development plan framework and the development control system with a balanced appraisal of the issues raised. The Mineral Resource Map of West Sussex provides a syntheses of available information which can be revised and updated as additional data becomes available. Additional constraint information can be incorporated as required. It is hoped that this map and the associated report will assist local and national government, the minerals industry and other interests in the consideration and production of policies in development plans.

A considerable part of West Sussex is subject to national planning designations. Of major significance in relation to mineral resources is the extent of two AONBs (the Sussex Downs and the High Weald). The Sussex Downs designation covers almost the whole of the Chalk outcrop (except for urban areas), almost half of the Folkestone Formation and part of the sand and gravel resource north of Chichester. The High Weald designated area includes all the outcrop of the Wadhurst Clay.

There is a significant relationship between the location and numbers of scheduled monuments and mineral resources. This is particularly notable on the outcrop of the Folkestone Formation and the northern scarp of the Chalk, with the intervening Gault clay (not defined as a resource on the map) mainly barren of such monuments.

A similar pattern of distribution is seen in relation to the designated nature conservation areas (NNRs and SSSIs) which, with the exception of coastal/ lagoon areas, are mainly concentrated on the Folkestone Formation and the Chalk (particularly the northern scarp) where areas of heath and limestone grassland are found.



## SELECTED BIBLIOGRAPHY

For further information on national planning policy, users should consult the following:

- Planning Policy Guidance
- Mineral Planning Guidance Notes
- Regional Planning Guidance Notes

published by the HMSO for the Department of the Environment, Transport and the Regions.

Information from the following documents and maps was used in the compilation of the map.

### a) British Geological Survey 1:50 000 or 1:63 360 (\*) geological map sheets

Sheet	Name	Edition	Published
286	Reigate	S+D	1978
300	Alresford	S+D	1975
301	Haslemere	S+D	1981
302*	Horsham	S+D	1972
303*	Tunbridge Wells	S+D	1971
316	Fareham	S+D	1998
317/332	Chichester & Bognor	S+D	1996
318/333	Brighton & Worthing	S+D	1984
331	Portsmouth	S+D	1994
S Solid edition			
D Drift edition			
S+D Solid and Drift editions combined			

### b) British Geological Survey Sheet Memoirs

GALLOIS, R W and WORSSAM, B C.1993. Geology of the country around Horsham. *Memoirs of the British Geological Survey*, Sheet 302. (England and Wales).

THURRELL, R G, WORSSAM, B C and EDMONDS, E A. 1968. Geology of the country around Haslemere. *Memoirs of the British Geological Survey.*, Sheet 301. (England and Wales).

YOUNG, B and LAKE, R D. 1988. Geology of the country around Brighton and Worthing. *Memoirs of the British Geological Survey*, Sheets 318 and 333. (England and Wales).

### c) British Geological Survey Reports and other publications

HARRIS, P M 1995. The United Kingdom Minerals Industry. (Keyworth, Nottingham: British Geological Survey).

CAMERON, D G, HIGHLEY, D E, HILLIER, J A, JOHNSTON, T P, LINLEY, K A, MILLS, A J, SMITH, C G and WHITE, R. 1998. Directory of Mines and Quarries 1998. 5th Edition. (Keyworth, Nottingham: British Geological Survey.)

LOVELL, J H & NANCARROW, P H A (1983) The sand and gravel resources of the country around Chichester and north of Bognor Regis, Sussex. *British Geological Survey Mineral Assessment Report 138*.

MOORLOCK, B S P AND HIGHLEY, D E. 1991. An appraisal of fuller's earth resources in England and Wales. *British Geological Survey Technical Report WA/91/75*.

SHEPHARD-THORN, E R, BERRY, F G & WYATT, R J (1982) Geological notes and local details for 1:10 000 sheets SU 80 NW, NE, SW, NE, SU 90 NW, NE, SW, SE, TQ 00 NW, SW (West Sussex coastal plain between Chichester and Littlehampton). *British Geological Survey Technical Report WA/VG/82/02*.

YOUNG, B, HIGHLEY, D E AND MORGAN, D J. 1979. Calcium montmorillonite (fuller's earth) deposits in the Lower Greensand of the Tillington area, West Sussex. *Open-file report No. 1979/1, Institute of Geological Sciences*. 11pp.

#### **d) Others**

ANON, 1994. Sustainable Development: The UK Strategy. (London: HMSO).

DEPARTMENT OF THE ENVIRONMENT. 1996. Survey of Land for Mineral Working in England, 1994. 2 Volumes. *London: HMSO*.

DEPARTMENT OF THE ENVIRONMENT. 1996. Minerals Planning Guidance: General Considerations and the Development Plan System. MPG1. *London: HMSO*.

DEPARTMENT OF THE ENVIRONMENT. 1994. Minerals Planning Guidance: Guidelines for Aggregates Provision in England. MPG6. *London: HMSO*.

DEPARTMENT OF TRADE AND INDUSTRY, 1997. The Energy Report: Oil and Gas Resources of the United Kingdom. Volume 2. *The Stationery Office*.

WEST SUSSEX COUNTY COUNCIL. 1997. West Sussex Minerals Local Plan. Deposit Draft. January 1997.

WORSSAM, B C. 1972. Iron ore workings near Horsham, Sussex, and the sedimentology of Wealden clay ironstones. *Proceedings of the Geologists Association*, Vol. 83, pp. 37-55.

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This study has greatly benefited from the co-operation of many organisations and individuals who provided information and advice, and their assistance is gratefully acknowledged.

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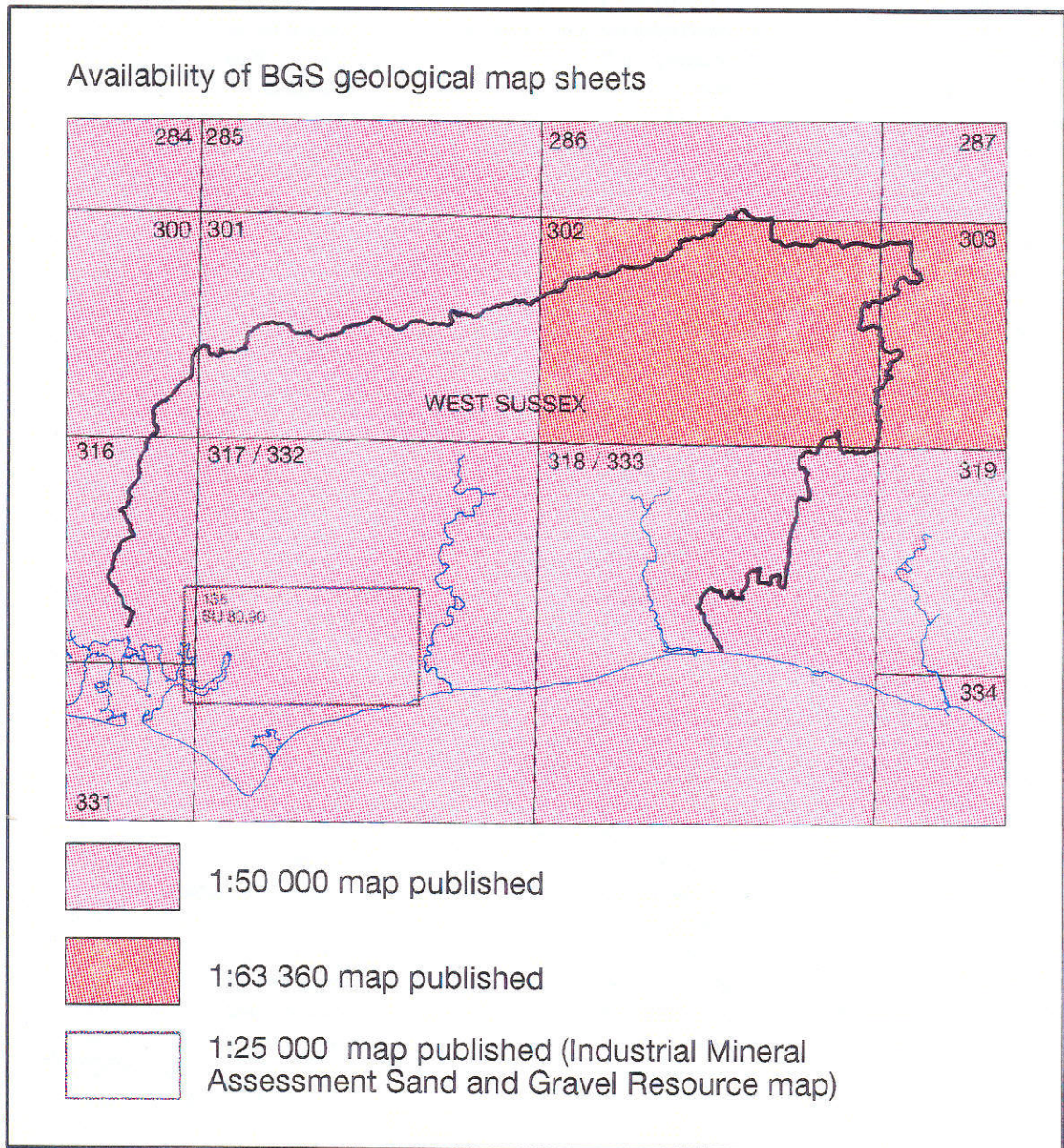


Figure 7. Availability of BGS geological map sheets

## APPENDIX 1: MINERAL WORKINGS IN WEST SUSSEX

<i>Operator</i>	<i>location</i>	<i>commodity</i>
Ambion Brick Co Ltd	Langhurstwood	Common Clay & Shale
ARC - Southern	Hampers Lane (Storrington)	Sand & Gravel
ARC - Southern	Little Hambrook Farm (Hambrook)	Sand & Gravel
ARC - Southern	Minsted Sandpit	Sand & Gravel
BJN Roofing Ltd	Stone	Sandstone
SOCO UK Onshore Ltd	Singleton Oilfield	Oil
SOCO UK Onshore Ltd	Storrington Oilfield	Oil
RH & RW Clutton	Paddockhurst Stone	Sandstone
The Cranleigh Brick & Tile Co	Ashpark Brickyard	Common Clay & Shale
Steve Dudman Plant Ltd	Chantry Lane Sandpit	Sand & Gravel
Steve Dudman Plant Ltd	Cocking	Chalk
Steve Dudman Plant Ltd	Valdoe Wood Gravelpit	Sand & Gravel
Steve Dudman Plant Ltd	Washington	Chalk
Duncton Quarrying Co Ltd	Duncton Chalk Quarry	Chalk
Freshfield Lane Brickworks Ltd	Freshfield Lane Brickworks	Common Clay & Shale
Freshfield Lane Brickworks Ltd	Freshfield Lane Brickworks	Sandstone
Goodwood Estate Co Ltd	Goodwood Estate Gravelpit	Sand & Gravel
C J Hurst Esq	Graffham Sandpit	Sand & Gravel
Ibstock Building Products Ltd	Laybrook	Common Clay & Shale
Ibstock Building Products Ltd	West Hoathly	Common Clay & Shale
J & W (Aggregates) Ltd	Jubilee Wood Sandpit	Sand & Gravel
Keymer Tile Co Ltd	Keymer Tile Works	Common Clay & Shale
W T Lamb & Son Ltd	Pitsham	Sand & Gravel
W T Lamb & Son Ltd	Pitsham Brickworks	Common Clay & Shale
Local Stone Co Ltd	Bognor Common Stone Quarry	Sandstone
Philpots Quarry Ltd	Hook	Sandstone
Philpots Quarry Ltd	Philpots	Sandstone
RMC - Hall Aggregates (South Coast)	Pendean	Sand & Gravel
RMC - Hall Aggregates (South Coast)	Sandgate Park Sandpit	Sand & Gravel
RMC - Hall Aggregates (South Coast)	West Heath Common Sandpit	Sand & Gravel
Robins of Herstmonceux	Newtimber	Chalk
Rudgwick Brickworks Co Ltd	Rudgwick Brickworks	Common Clay & Shale
Shropshire Stone & Granite co	James	Sandstone
Tarmac Quarry Products Southern	Heath End Sandpit	Sand & Gravel
Tarmac Quarry Products Southern	Portfield gravelpit	Sand & Gravel
Tarmac Quarry Products Southern	Rock Common Sandpit	Sand & Gravel
Taylor Plant & Haulage Ltd	Slindon Bottom	Sand & Gravel

**APPENDIX 2: CONTACT ADDRESSES FOR FURTHER ENQUIRIES**

<p>West Sussex County Council                  Planning Department                  County Hall                  Chichester PO19 1RL                  Tel: 01243 777609                  Fax: 01243 777232</p>	<p>Adur District Council                  Civic Centre                  Ham Road                  Shoreham-by-Sea                  West Sussex BN43 6PR                  Tel: 01273 455566                  Fax: 01273 454847</p>
<p>Arun District Council                  Council Offices                  Littlehampton                  West Sussex BN17 5LF                  Tel: 01903 716133                  Fax: 01903 730442</p>	<p>Chichester District Council                  East Pallant                  Chichester                  West Sussex PO19 1TY                  Tel: 01243 785166                  Fax: 01243 776766</p>
<p>Crawley Borough Council                  Town Hall                  Crawley                  West Sussex RH10 1UZ                  Tel: 01293 528744                  Fax: 01293 511803</p>	<p>Horsham District Council                  Park House                  North Street                  Horsham                  West Sussex RH12 1RL                  Tel: 01403 215100                  Fax: 01403 262985</p>
<p>Mid Sussex District Council                  Oaklands                  Oaklands Road                  Haywards Heath                  West Sussex RH16 1SS                  Tel: 01444 458166                  Fax: 01444 454665</p>	<p>Worthing Borough Council                  Town Hall                  Chapel Road                  Worthing                  West Sussex BN11 1HA                  Tel: 01903 239999                  Fax: 01903 207365</p>
<p>Countryside Commission                  John Dower House                  Crescent Place                  Cheltenham                  Gloucestershire GL50 3RA                  Tel: 01242 521381                  Fax: 01242 584270</p>	<p>English Nature                  Northminster House                  Northminster                  Peterborough PE1 1UA                  Tel: 01733 340345                  Fax: 01733 68845</p>
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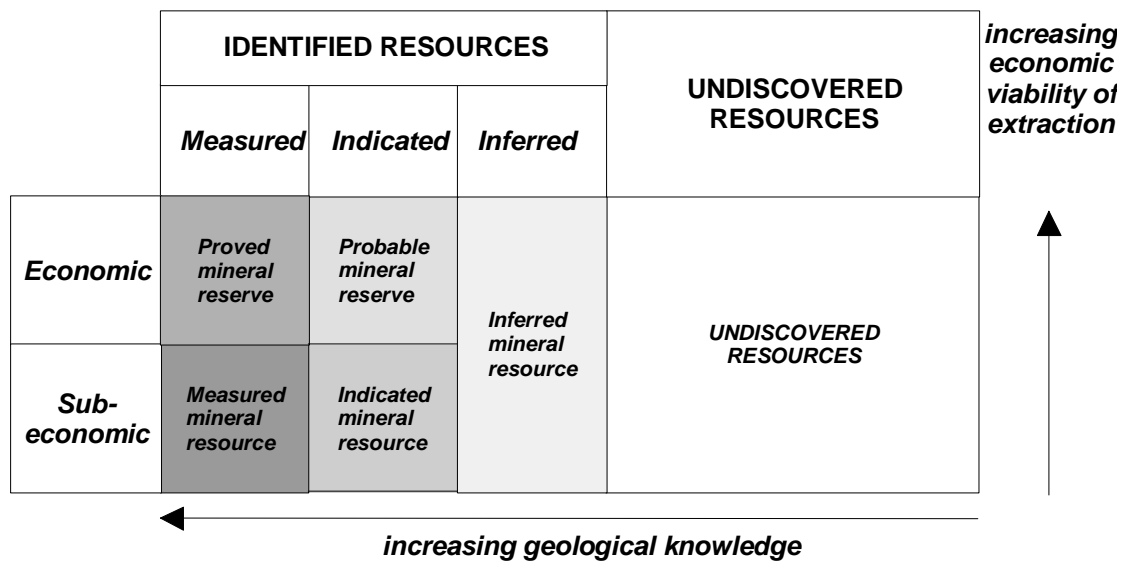
### **APPENDIX 3: METHODOLOGY**

The British Geological Survey (BGS) was commissioned in 1993 by the Department of the Environment to prepare, on a trial basis, a set of concise statements mainly in map form, to show the broad distribution of mineral resources in selected counties and to relate these to selected, nationally-designated planning constraints. The trial study developed a methodology for the collection and display of data in a consistent and comparable format for four Mineral Planning Authority (MPA) areas - Bedfordshire, Derbyshire, Staffordshire and the Peak District National Park. The concept developed by the BGS for the trial study is now being extended to some twenty mineral planning authorities in England and Wales through a further phase of the project which started in 1996.

The main element of the trial study was the production of maps, with accompanying interpretative reports, for each MPA area. All mineral resource and planning constraint information has been collated digitally on a PC-based system using Intergraph Microstation to produce a cartographic database. Data has been captured as a series of files, structured on separate levels so that they can be viewed either independently or in various combinations, as required. Most of the information has been taken digitally from hard copy maps, mainly with scales between 1:50 000 and 1:10 000. Other material was obtained in a variety of digital formats which have had to be converted for use by the Intergraph Microstation System. The structure of the information will allow the data to be transferred in digital form to the BGS MINGOL (MINerals GIS On-Line) system. MINGOL is being developed to provide a decision-support system for the rapid solution of minerals-related problems to aid corporate and public resource management. It applies a state-of-the art GIS to relate the nature and distribution of mineral resources to other information such as planning and environmental constraints, and mineral exploration, borehole and commodity statistics datasets.

As the data are held digitally, map output can be on any scale but 1:100 000 has been found to be a convenient size to summarise the information for individual MPAs. This provides a legible topographic base which enables both the broad implications of the information, and sufficiently accurate detail, to be shown. The particular advantage of holding all the information in digital form is that it is comparatively easy to update and revise as additional information becomes available, and also provides scope for producing customised maps of selected information or areas on request.

**Figure 1** Classification of resources and reserves



*Based on McKelvey, 1972*

**Classification of resources and reserves**

The diagram, Figure 1, is a representation of a conventional method for classifying mineral reserves and resources, based on a system introduced the US Bureau of Mines and the US Geological Survey and adapted by the British Geological Survey. In this conceptual diagram the vertical dimension of the diagram represents the economic viability of the resource and consists simply of two categories, **economic** and **sub-economic**, depending on whether or not the mineral deposit is commercially viable under prevailing economic circumstances. As demand, mineral prices and costs of extraction may change with time, so mineral resources may become reserves and vice versa.

The horizontal dimension represents degrees of geological knowledge about the resource, from mere speculation about its existence (right-hand side) to thorough assessment and sampling on a systematic basis (left-hand side).

In the present study the mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. Since the mineral resource data presented are not comprehensive and the quality is variable, the boundaries shown are approximate. Most of the mineral resource information presented is, therefore, in the **inferred resource** category (Figure 1), that is to say, those resources that can be defined from available geological information and which may have some economic potential. They have neither been evaluated by drilling, or other sampling methods, nor had their technical properties characterised on any systematic basis. Inferred resources may be converted into indicated and measured resources with increasing degrees of investigation and assessment.



A mineral resource is not confirmed as economic until it is proved by a relatively expensive evaluation programme. This usually involves a detailed measurement of the material available for extraction together with an evaluation of the quality of the material, its market suitability, the revenues generated by its sale and, ultimately, the viability of the deposit. This activity is an essential precursor to submitting a planning application for mineral extraction. That part of a resource that is both ‘measured’ and ‘economic’, i.e. that has been fully evaluated and is commercially viable to work, is called a **reserve** or **mineral reserve**. It is customary to distinguish **proved** and **probable reserves**, which correspond to the economic parts of measured and indicated resources respectively (Figure 1).

It is invariably the case that there is a significant reduction in area or volume estimates as resources are further investigated to prove reserves. The reasons for this is that it is impossible to apply initially all the various constraints that working procedures and environmental issues may impose. This is particularly the case with extensive deposits like sand and gravel where physical constraints imposed by roads, railways and urban development may drastically reduce the potential area available for extraction, even before factors such as quality and mineral thickness are taken into consideration.

In the context of land-use planning, however, the term **reserve** should strictly be further limited to those minerals for which a valid planning permission for extraction exists, i.e. **permitted reserves**. The extent of mineral planning permissions (other than coal) is shown on the Mineral Resources Map. These cover both active mineral workings and inactive mineral workings. Some mineral planning permissions may have remained unworked, and others may have become uneconomic prior to being worked out. In many cases the areas involved are likely to have been worked to some extent in the past, and may now be restored. In addition, parts of the resource areas may have been fully evaluated by the minerals industry, but either have not been subject to a planning application or have been refused permission for extraction. These areas are not depicted on the map.

A **landbank** is a stock of planning permissions and is commonly quoted for aggregates. It is composed of the sum of all **permitted reserves** at active and inactive sites at a given point of time, and for a given area, with the following provisos:

- it includes the estimated quantity of reserves with valid planning permission at dormant or currently non-working sites;
- it includes all reserves with valid planning permission irrespective of the size of the reserves and production capacity of particular sites;
- it does not include estimated quantities of material allocated in development plans but not having the benefit of planning permission; and
- it does not include any estimate for the contribution that could be made by marine dredged, imported or secondary materials.

**It is important to recognise, however, that some of the permitted reserves contained within landbanks have not been fully evaluated with the degree of precision normally associated with the strict use of the term reserves, indeed some may not have been evaluated at all.**

### **Mineral workings and planning permissions**

The locations and names of mineral workings in West Sussex are shown on the maps. The information is derived from the British Geological Survey's Mines and Quarries Database, updated as appropriate from West Sussex County Council's records. Letters (e.g. Sg = sand and gravel) are used to show the main mineral commodity produced.

The extent of the planning permissions shown on the Mineral Resources Map cover active mineral workings, former mineral workings and, occasionally, unworked deposits. The present physical and legal status of the planning permissions is not qualified on the map. The areas shown may, therefore, include inactive sites, where the permission has expired due to the terms of the permission, i.e. a time limit, and inactive (dormant) sites where the permission still exists. Sites which have been restored are not separately identified. Under the provisions of the 1995 Environment Act, after 1 November 1997, sites that are classified as dormant may no longer be worked until full modern planning conditions have been approved by the Mineral Planning Authority. A 'dormant site' is defined as a site where no mineral development has taken place to any substantial extent in the period 23 February 1982 and ending 6 June 1995. Information on the precise status and extent of individual planning permissions should be sought from West Sussex County Council.

Most planning permissions appear on a mapped mineral resource area and thus the underlying resource colour identifies the mineral type. Planning permissions may fall outside resource areas for the following reasons:

- permissions shown partly off resource areas may extend to ownership, or other easily defined boundaries, or to include ground for ancillary facilities such as processing plants, roads and overburden tipping
- isolated workings occurring outside defined resource areas may reflect very local or specific situations not applicable to the full extent of the underlying rock type: brick clay working in Gault clay at Pitsham is an example, as is the Bognor Common quarry in the Hythe Formation.

The latest data available for the total areas of planning permissions in West Sussex, collected for the Department of Environment Minerals Survey of 1994, is shown in Table 1. This information is updated at intervals.

**Table 1 Areas of planning permissions for mineral workings in West Sussex (as at 1.4.94)**

	<b>Commodity</b>	<b>Total permitted area (ha)</b>	<b>No. of sites</b>	<b>%</b>
Surface workings	Chalk	77	9	7.92
	Clay/shale	235	11	24.18
	Oil/gas (exploration/appraisal)	7	4	0.72
	Oil/gas (production)	2	1	0.2
	Sand and gravel (construction)	613	28	63.07
	Sandstone	38	6	3.91
	<b>Total</b>	<b>972</b>	<b>59</b>	<b>100</b>

Source: *Department of the Environment, 1996, Survey of Land for Mineral Workings in England, 1994.*