Cynulliad Cenedlaethol Cymru
The National Assembly for Wales

# The Sand and Gravel Resources of North West Wales

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In association with:

ENVIROS

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## Summary

This report was commissioned by the National Assembly for Wales to evaluate the location and volume of potentially workable resources of land-based, fine-grained mineral aggregate in the area of the Mineral Planning Authorities of Anglesey County Council, Conwy Borough Council, Gwynedd Council and the Snowdonia National Park Authority; to examine the commercial potential of the resources; to identify the environmental constraints on future exploitation and to make recommendations on the most appropriate means of safeguarding the resources.

From a review of existing data, ten areas considered likely to yield potential mineral were identified. Each of these was geomorphologically mapped and 89 potential mineral bearing blocks identified. Each block was subject to a technical appraisal, based on an analysis of pre-existing data and a geological mapping and limited borehole programme, in order to determine the quantity and quality of potential mineral. Altogether, some 530 million tonnes of potential mineral were identified, divided into 270 million tonnes of sand and 260 millions tonnes of gravel. At the county level 92 % of potential mineral occurs in Gwynedd, with Conwy and Anglesey together providing less than 8 % and the National Park area virtually none. At the local level the greatest concentration of reserves, more than 75 % between them, occur in only three areas: Cors Geirch north of Pwllhelli; south of Nefyn and Penygroes, all in Gwynedd. All other areas provided less than 25%. In the Cors Geirch and Nefyn areas sand makes up approximately 75 % of the potential mineral; in the Penygroes area the proportions are reversed. In general terms the distribution of potential resources bears little relationship to areas of demand and the Caernarfon, Bangor and Conwy-Llandudno-Colwyn Bay areas all have disappointingly low volumes of potential mineral resource.

Some 60% of the potential resource blocks identified in the region are affected by one or more major planning constraints or environmental designations. Whilst many of these do not preclude the possibility of future exploitation they nonetheless highlight the potential conflicts that are likely to occur if the resources ever need to be exploited. As part of this study all the planning and environmental constraints affecting each block have been identified and a simplified scoring system applied in order to provide some rational basis for determining the overall level of constraint affecting any individual resource block.

Unless there is major change caused by environmental, political or economic concerns it has been assumed that the existing supply scenario in North West Wales, largely land-won with a contribution from marine-dredged supply, is likely to continue for the foreseeable future. Consequently, the report makes a number of recommendations, the chief of which are that Gwynedd should continue to provide the majority of sand and gravel in the region through continuation of extraction in the Penygroes area; that Conwy should continue to meet demand by import or crushed rock; that Anglesey should protect areas around Pentraeth to supply island demand; and that, elsewhere, a number of Mineral Presumption Areas should be identified to cover blocks of particular quality or potential commercial value. Because of the volume and quality of sand identified in Cors Geirch and Nefyn these areas should also be protected from sterilization. It is also recommended that further research should be conducted into a planning policy framework for the development of sustainable aggregate supply through a network of small local quarries providing local supplies in the National Park and other rural areas in the region.

# 1 INTRODUCTION

## 1.1 The objectives of the study

This project was commissioned by the National Assembly for Wales in conjunction with the Mineral Planning Authorities of Anglesey County Council, Conwy Borough Council, Gwynedd Council and the Snowdonia National Park Authority. The objectives of the study were:

- To evaluate the location and volume of potentially workable resources of land-based, fine-grained aggregates (sand) in the area of the four Mineral Planning Authorities.
- To consider the economic and commercial exploitation of the resources in relation to their commercial potential, accessibility to current and future areas of market demand and alternative sources of supply.
- To identify and assess the environmental constraints on future exploitation of the resources.
- To recommend the most acceptable means of satisfying the demand for fine aggregates through an assessment of the constraints on all potential resources
- To make recommendations on the most appropriate means of safeguarding the resources from sterilisation through further research, future Government guidance and advice to the North Wales Regional Aggregates Working Party and Mineral Planning Authorities

## 1.2 The organisation of the report

This report is in two parts. This part includes a review of the origin of the sand and gravel deposits in North West Wales, an account of the methods used to identify potential mineral resources, a summary of the resources identified on a resource block by resource block basis, an outline of the planning, economic and environmental constraints that may affect exploitation and a set of conclusions and recommendations regarding the future provision of aggregate supply.

The second part comprises a set of technical appendices, including:

Appendix A: GIS maps of resource areas

Appendix B: Bibliography of the geology of North West Wales

Appendix C: Summary set of tables showing technical parameters, mineral volume and environmental constraints for all identified resource blocks

Appendix D: Summary compilation of all pre-existing boreholes in the region

Appendix E: Laboratory test results

Appendix F Borehole logs

Appendix G: Definitions of environmental designations

Appendix H Geographical Information System showing maps of the geomorphology, the resource blocks, borehole locations and planning and environmental constraints

Appendix A is bound in with the report. All the other appendices are provided as disk files and are supplied to the National Assembly for Wales, the local Mineral Planning Authorities, the Snowdonia National Park Authority and other statutory bodies as part of the final report. With exception of Appendices D, F and G, for which copyright applies, copies of the remaining appendices are available to the public on CD at cost from the contractor.

## 2 THE ORIGIN, DISTRIBUTION AND CHARACTER OF POTENTIAL AGGREGATE RESOURCES IN NORTH WEST WALES

### *Definitions*

Aggregates are bulk minerals used primarily in the construction and civil engineering industries. They may be divided into two classes:

- *Crushed rock* is obtained by the quarrying of exposed hard rock, usually by blasting, and its size reduction by mechanical crushing. It is used in a wide range of mainly civil engineering applications. Because different types of rock have properties suitable for particular specialised purposes crushed rock is often exported well beyond the region in which it is quarried.
- *Sand and Gravel* is obtained either by the digging of soft, usually unconsolidated sediments and its size reduction by mechanical grading or by marine dredging. It is used primarily in the construction industry for building sand, for concreting and for foundation fill. Most sand and gravel is used within the region in which it is quarried as transport costs rise significantly with greater distance.

This report is primarily concerned with the potential land-based sand and gravel aggregate resources and, in particular, sand which is deficient in the region. In order to sustain the building and civil engineering industries in the region, sufficient sand and gravel needs to be locally available for sale at an economic cost each year to satisfy the industry demand. Sand and gravel may be obtained from local sand and gravel quarries, from offshore marine dredging or by import from neighbouring areas. Of these sources, local sand and gravel quarries are the cheapest, though not necessarily either the most environmentally friendly or sustainable.

### Current aggregate production

Production of sand and gravel in the region over recent years has been restricted to a small number of large, active quarries, and the landing of marine dredged sand, in areas administered by Gwynedd Council. The other local authorities either have no sand and gravel extraction or limited, local and often part-time or temporary workings for specific period or projects. Table 1 lists the current statistics of volume of production and use together with currently permitted reserves and landbank status. It is the responsibility of the local planning authority, though its Mineral Planning Authority, to monitor the demand for sand and gravel, identify the areas in which sand and gravel reserves occur, allocate areas in their Unitary Development Plans in which extraction of sand and gravel may be permitted and to consider any planning applications that may arise. As areas of current extraction become worked out over the years it is necessary to establish a land-bank of permissions or indications in order to provide a sustainable supply.

**Table 1: Sand and Gravel Statistics Gwynedd 2001-2002**

| Use | Tonnes | Permitted Reserves (tonnes) | Landbank (Years) |
|---|---|---|---|
| Soft Sand | 48,529 | | |
| Sharp Sand | 49,001 | | |
| Concrete | 44,873 | | |
| Unknown | 70,561 | | |
| Total | 212,964 [1] | 3,000,000 | 15 |

[1] *Includes 47,750 tonnes of marine sand landed at Port Penrhyn, Bangor.*

## The origin, distribution and character of potential aggregate resources

Most of the sands and gravels suitable for use in the construction industry, including those dredged from offshore, were laid down as glacial sediments [1] during the Quaternary period. This period began some 1.6 million years ago and continues to the present. During the Quaternary the Earth was subject to repeated oscillations of climate between cold and warm stages. During the cold stages large glaciers developed in upland areas in Britain and extended into lowland areas to form extensive ice-sheets. As these ice-sheets advanced they eroded large volumes of rock debris, transported it through the base of the ice and deposited it either beneath the ice-sheet as subglacial *diamict* [2] or at and immediately beyond the ice margin as *outwash* [3]. Diamict is unsuitable for use as mineral aggregate due to its high proportion of included silt and clay but outwash, deposited by proglacial meltwater stream systems, is naturally sorted into sands and gravels and is often ideal.


Most of the glacial sediments in North West Wales were deposited during the last cold climate oscillation, the Devensian Glacial Stage, between approximately 25 and 11 thousand years ago. During this period a large ice-sheet developed over Scotland, expanded to occupy the northern Irish Sea basin, abutted against the mountain front of Snowdonia to a height of at least 200 m, overran much of Anglesey and the Llŷn peninsula and extended south through Cardigan Bay towards the Celtic Sea (Figure 1). At the same time a smaller ice-sheet, the Welsh Ice-Sheet, developed over the Welsh Mountains, particularly Snowdonia. This fed valley glaciers that radiated outwards down pre-existing river valleys to the north, via the Conwy valley, Nant Francon and Nant-y-Betws; to the west via the Nantlle valley; to the southwest via the Vale of Ffestiniog, the Mawddach and the Dyfi valleys; and to the east or north-east via the Dee, the Clwyd and the Vyrnwy.

*Figure 1. The maximum limits of the Devensian Glaciation in Britain showing main ice dispersal areas, flow directions and retreat stage positions.*

At the maximum of the glaciation, about 22,000 years ago, the two ice-sheets became confluent on a line running along the North Wales coast southwest through the Llŷn peninsula (Figure 2 A). On retreat the two ice-sheets separated and at each stage of retreat a variety of landforms and deposits were generated at and immediately in front of the ice-margin (Figure 2 B-D).

[1] Glacial sediments include all sediments deposited directly or indirectly by glaciers.

[2] Diamict, or boulder-clay or till, is a product of subglacial deposition and consists of a heterogeneous mix of grain sizes from boulder to clay making it unsuitable for aggregate.

[3] Outwash is a product of deposition at, under or in front of the ice-margin by meltwater streams exiting the glacier. It consists of a wide range of usually well-sorted gravels, sands and silts. The size range of any particular outwash deposit is a function of water flow velocity and the size of sediment delivered to the glacier front. It is the primary source of good quality land-based aggregate.

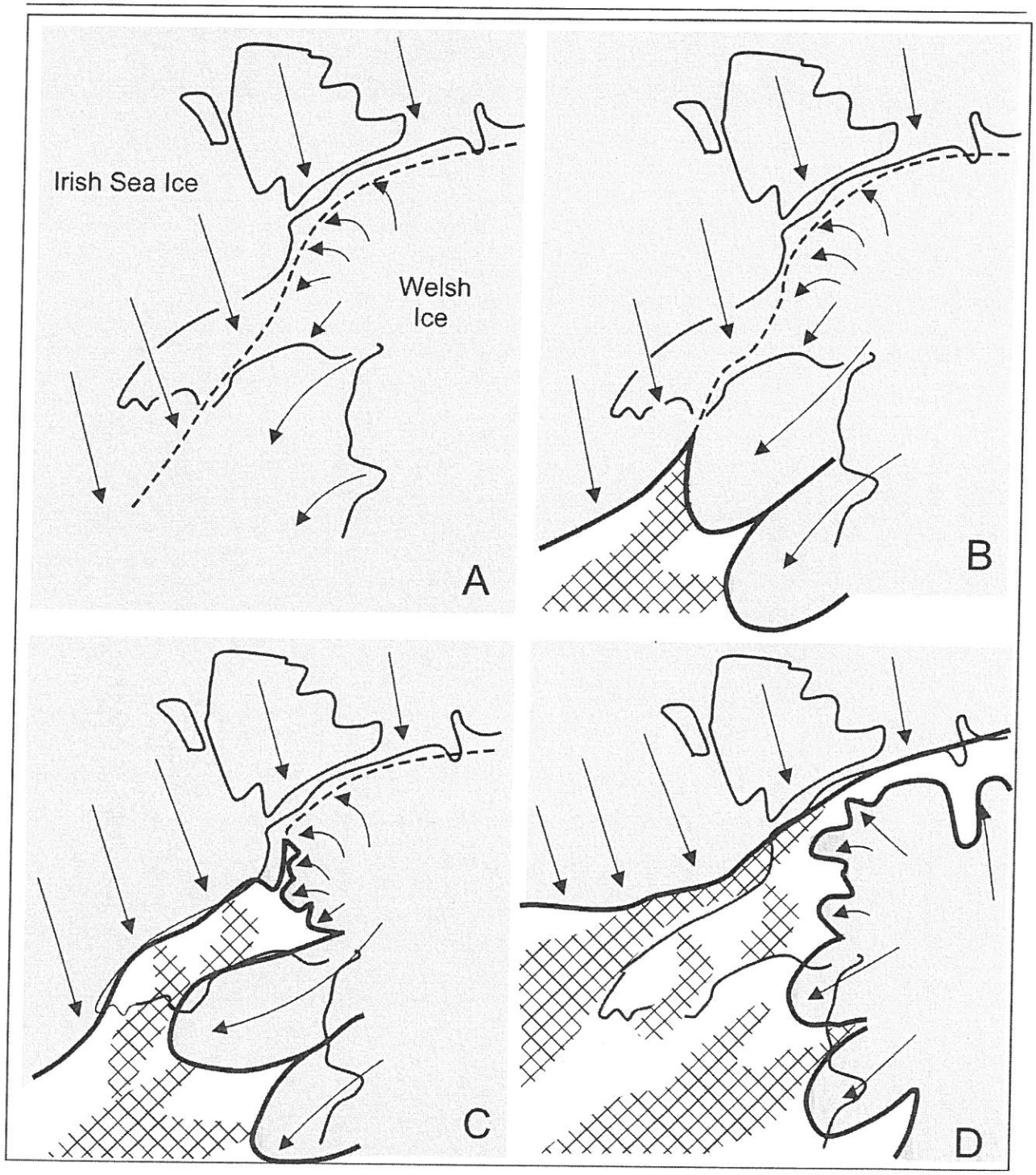


*Figure 2 The relationship between Irish Sea Ice and Welsh ice during the advance and retreat of the Devensian glaciation. A Maximum expansion at c. 22,000 years ago. At this time the Irish Sea Ice Sheet ran south as far as the Celtic Sea and its eastern margin was confluent with Welsh ice moving west and south-west. B. At c. 17, 000 years the Irish Sea Ice Sheet had retreated and was uncoupling from the Welsh Ice Sheet through north west Wales. C & D. Stages in uncoupling around 15-16,000 years.*

In general terms the Welsh Ice-sheet left behind relatively little depositional evidence of its retreat. This is because upland ice-sheets are principally erosional, as demonstrated by the rugged scenery of much of the Snowdonia National Park area, and any glacial deposits generated were transported out beyond the mountain belt into Tremadoc and Cardigan Bays on

the west. The valley glaciers draining north coalesced with the Irish Sea ice-sheet and any sediment carried by them was reworked. Moreover, most Snowdonian valleys are deep and narrow and much of the glacial sediment deposited in them during retreat was subsequently removed by erosion in post-glacial times. Consequently, most of the area of the National Park has little residual glacial deposit. What exists is either diamict, and thus unsuitable for mineral extraction, or restricted to small, thin and discontinuous areas of outwash. As there is a basic relationship between distance of glacial transport and the size of rock fragments carried by a glacier, the glacial deposits that do occur are predominantly very coarse. Outwash deposits containing significant quantities of cobble or boulder gravel are unsuitable for extraction because of the amount of waste generated during processing. In the more open valleys in the east, especially the Dee beyond Bala, however, significant areas of outwash occur on the flanks of the modern river.

Lowland ice-sheets are principally depositional so the Irish Sea ice-sheet, in contrast to the Welsh ice-sheet, left behind very large quantities of glacial sediment as it retreated across the Llŷn Peninsula and away from the Snowdonian mountain front. Much of the debris in these deposits, derived from long-distance sources in Western Scotland and the Southern Uplands is, as a consequence of the relationship between distance of transport and size of rock fragment, predominantly fine. This is accentuated by debris derived from the floor of the northern Irish Sea which is composed either of earlier glacial deposits or relatively weak Carboniferous or Permo-Triassic bedrock that breaks rapidly into sand and fine gravel under glacial transport. This pattern, however, is complicated by the passage of Irish Sea ice across areas of Welsh bedrock fringing the current coast. and its incorporation into glacial deposits. As the Welsh bedrock is close to its source it is coarser and it diminishes the otherwise finer grain of the Irish Sea ice-sheet glacial deposits. Thus, in much of northern Llŷn, where the Irish Sea ice-sheet extended only a little way south over Welsh rocks at any particular stage of retreat, the glacial deposits are predominantly fine. In the coastal strip of the Arfon lowlands, however, Irish Sea ice penetrated some distance inland and the glacial deposits have a significant component of Welsh rocks and are consequently coarser. This is compounded by the incorporation into the Irish Sea ice of large quantities of very coarse Welsh glacial deposits delivered by Welsh glaciers draining north and coalescing with the Irish Sea ice. Similar conditions pertain along the narrow coastal strip between Conwy and Abergele and is compounded by extensive sterilization by urban development.

Following the end of the last glaciation (c. 11,0000 years ago) the climate ameliorated and glacial deposits were dissected by down-cutting rivers and redistributed at lower elevations as river terraces and river flood plains. The progressive reworking of these older deposits has washed out much of the fine-grained silt and clay into offshore or estuarine areas, leaving behind relatively well sorted sands and gravels often as low terraces bordering the modern course of rivers. With the exception of the Conwy, Dee and Dyfi, all of which display extensive terraces across their valley floors, most of the other north Wales rivers are relatively short and steep and exhibit only discontinuous terraces. Consequently, over much of the area they do not provide large volumes of potential mineral resource.

Extensive alluvial floodplain deposits occur in many of the major valleys in North Wales, particularly the Conwy, the Dyfi, the lower parts of the Glaslyn and the Dysynni, to the rear of Tywyn. Most of the remaining valleys, however, especially in Snowdonia, have only narrow and intermittent alluvial strips across their floors. Deposits also occurs in coastal areas, particularly east of Abergele, where much is sterilised by urban development. Older alluvial deposits, mostly covered by peat, occur around Pwllhelli and in a wide strip running northeast from Newborough in Anglesey. Alluvial deposits are predominantly fine-grained though at depth they are often underlain by sands and gravels. This upward change is due to a major change in river regime over the postglacial period with higher energy braided river systems being progressively replaced by lower energy meandering systems as rivers adjusted to the change from a cold to a temperate climate. The meandering component are primarily composed of silts and clays formed by slow vertical accretion during successive flood events and are not suitable for mineral extraction. River

flood plains are naturally located at or just above the water table and this provides considerable economic and environmental problems for extraction.

During the glacial period the sea-level was low, as a function of the amount of water locked up on the land surface as ice. On deglaciation sea-level rose and many of the lower portions of the former glacial valleys were flooded out and became progressively filled with fine-grained estuarine sediment. This is particularly marked at the mouths of the Glaslyn, Mawddach and Dyfi estuaries and in the lower part of the Vale of Clwyd, particularly west of Rhyl. In the inactive parts of these estuaries most of the sediment is fine-grained and unsuitable as mineral. In the active portions, well-sorted, mobile sand is plentiful but uneconomic to extract. Environmental issues, particularly the interference with natural systems, often with unknown consequences, precludes possible extraction. The outer, marine edges of many of the estuaries have developed extensive sand-dunes; at Morfa Dyffryn, near Llanbedr, at Morfa Harlech, around Pwllheli, on the west coast of Anglesey around Valley, Aberffraw, Malltraeth and Newborough and in discontinuous strips along the coast between Towyn and Kinmel Bay. Although the quality of dune sand for aggregate use is high and some small extraction takes place at Valley in Anglesey, almost all the areas are heavily constrained by environmental designations and it seems unlikely that such prominently placed resources would be developed.

## 3 EXISTING INFORMATION ON POTENTIAL SAND AND GRAVEL RESOURCES

The identification of potentially workable sand and gravel resources requires information on the distribution, thickness and character of glacial and other related deposits. This information may be derived from geological maps, academic publications, previous mineral aggregate resource investigations, site investigation reports, borehole records and current and former sand and gravel workings.

Although most of North West Wales has been geologically mapped some areas, notably the northern Llŷn peninsula and parts of southeast Gwynedd, have not. Other significant areas, such as that around Bangor, have only been partially drift mapped. Moreover, many older maps do not conform to modern classifications of glacial deposits, have insufficient detail to allow prospects for mineral potential to be identified, or are of questionably accuracy. Thus, the British Geological Survey map of the Quaternary Geology of the UK [1] shows extensive sand and gravel deposits in the coastal area between Tywyn and Fairbourne, based on original field mapping undertaken in the mid 19th century. A revised 1:50,000 map of the area [2], published in 1995, however, reclassifies most of these deposits as diamict. The same UK Quaternary map shows no sand and gravel in eastern Llŷn yet this area has supported a number of active quarries for many years and the University of Liverpool [3] assessment of the area identified significant mineral resources.

Taking these limitations into account a review of all the geological maps suggests that potential sand and gravel resources in North West Wales are relatively sparse but occur in the following areas:

- in a large area running from Pwllhelli northwestwards towards Nefyn in Llŷn
- in a narrow strip running northeast from Llanrug, through Pentir towards Talybont in the Arfon lowlands
- in small areas around Pentraeth in Anglesey
- in a small area around Sarnau, northeast of Bala
- in a narrow but mostly developed strip behind Colwyn Bay and Penrhyn Bay
- in the Conwy valley, and
- in a small area north of Tywyn

[1] British Geological Survey. 1977. Geology of the UK(Quaternary Geology): North Sheet. 1:625,000.
[2] British Geological Survey. 1995. Cadair Idris, Sheet 149. Solid and Drift geology. 1:50,000.
[3] Crimes, T.P. et al. (1988) Assessment of Sand and Gravel Resources in the eastern Llŷn peninsula, North Wales. Report to the Welsh Office.

Academic publications have provided much information on the pattern of glaciation in the region together with geomorphological maps and detail of the stratigraphy and sedimentology of potential mineral resource, especially in the Llŷn peninsula and parts of Anglesey and the Conwy Valley [1]. Liverpool University conducted an assessment of the sand and gravel resources of an area of 165 km$^2$ in the eastern Llŷn in 1988 and identified five major resource blocks in the area between Penygroes and Bryncir with a total of 150 million tonnes of potential mineral. Roberts [2] examined the whole of Gwynedd, excluding the National Park and the area examined by Liverpool University, and identified 101 potential deposits totaling 430 million tonnes of potential mineral. No detailed examination of the mineral potential of Anglesey has been undertaken but consideration of the glacial geology suggests it is small. Similarly, no detailed examination of the Conwy valley or the coastal strip between Llandudno and Rhyl has been undertaken and most parts of the latter area where mineral is reported are heavily constrained by urban development.

Site investigation reports, largely concerned with infrastructure schemes such as new or improved highways, electric transmission lines, water and gas pipelines and other civil engineering projects, contain detail of drift deposits though most are located in or in the immediate periphery of urban areas. Borehole records, derived from the archives of the British Geological Survey, drilling contractors, civil engineering companies, statutory authorities and local planning authorities, provide over 5,200 records. Most were not drilled for the purpose of determining mineral resources and do not penetrate the full depth of drift deposits. Nonetheless, many boreholes assist in identifying the presence or absence of potential mineral resource. The geographical spread of boreholes is very patchy and, invariably, the great majority (over 4,500) are located in or near urban areas or along the line of major highway improvement schemes, such as the recently completed A55 through North Wales. A significant number are, for commercial reasons, confidential. Very few occur in the areas identified from existing geological mapping as containing mineral. A list of the location of boreholes for the region are given in Appendix D and is derived from the borehole database of the British Geological Survey.

The only existing full-time workings of sand and gravel in the region are at Cefn Grainiog and Bryncir, in eastern Llŷn, and Sarnau north of Bala, all in Gwynedd. Small, part-time working of dune sand occurs at Valley in Anglesey. Former workings of recent date, but now abandoned or restored, occur at Pentraeth in Anglesey; west of Penygroes, west of Y Ffor in Llŷn, and at Pentir near Bangor. Numerous, often very small workings pre-date the planning process throughout the region, are generally not exposed and are frequently unrecognizable.

Based on these sources the total mineral resources within the three mineral planning areas of Gwynedd, Anglesey and Conwy, together with the National Park, are estimated to be of the order of some 650 million tonnes. Little of this is proven, however, and even less is potentially workable.

## 4 SEDIMENT-LANDFORM ASSEMBLAGE ZONES

Investigations into how glacial systems behave in terms of transport and deposition of debris have resulted in the generation of models of glacial sedimentation which can be used to identify potential mineral aggregate resources. The basis of these models is the recognition that particular types of glacial landforms are associated with particular types of glacial sediment as the landform reflects the depositional process that created it. This leads to the concept of the *sediment-landform assemblage* which is defined as an area in which relatively homogeneous geomorphological, stratigraphic and lithological characteristics occur. The identification of sediment-landform assemblages therefore provides a first approximation for potential mineral resources. Three major glacial sediment-landform assemblages zones can be recognized and their distribution through North West Wales is shown in Figure 3.

[1] A full list of relevant academic papers is provided in Appendix B.
[2] Roberts, W. 1996. A report on Sand and Gravel Deposits in Gwynedd. Gwynedd County Council.

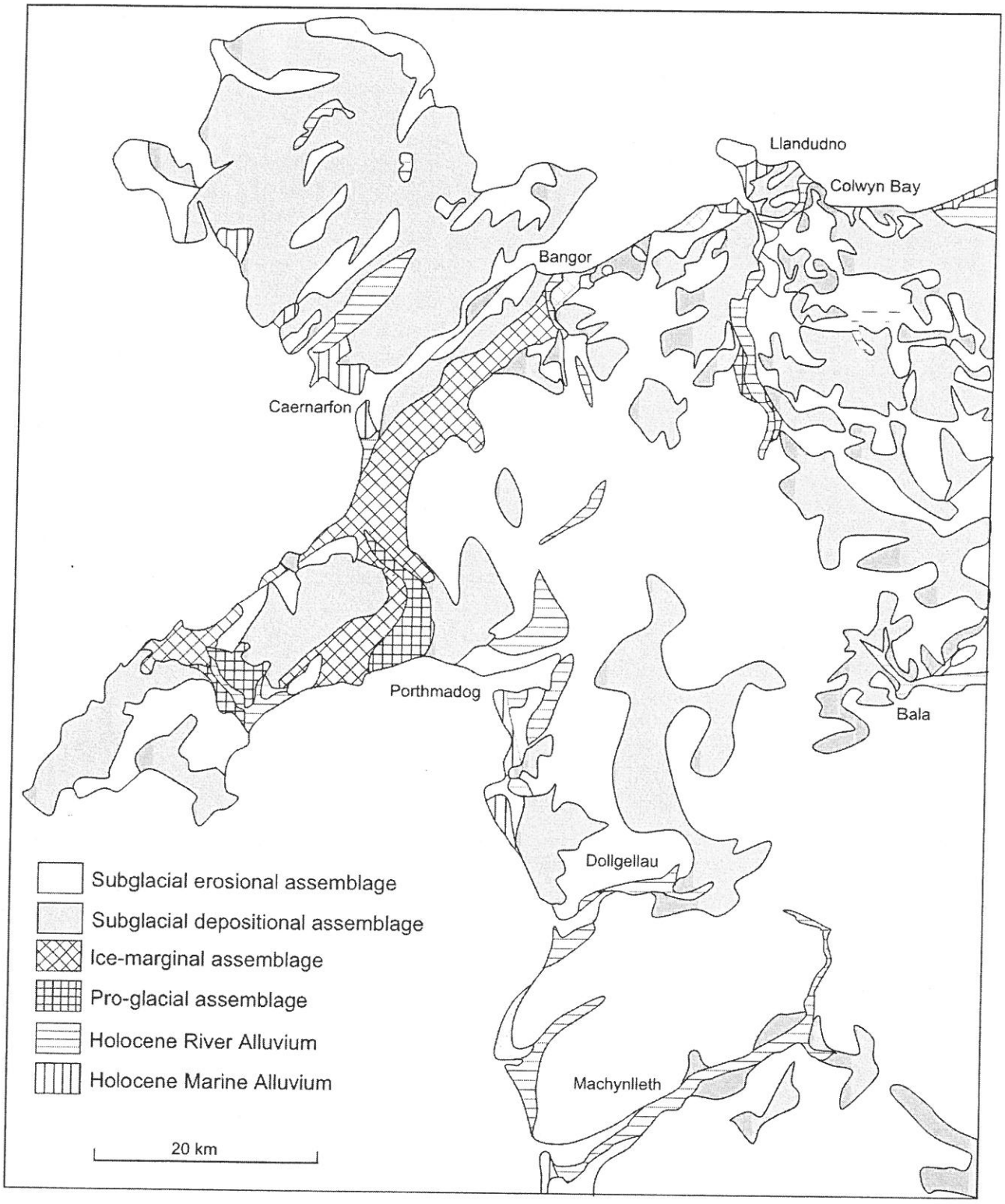


*Figure 3 Map of distribution of sediment-landform assemblages in North West Wales.*

*Subglacial assemblage* This includes all the landforms and sediments generated by the erosion, transportation and deposition of debris at the base of a glacier and can be divided into two sub-assemblages. A subglacial erosional assemblage, normally associated with upland glaciation, is dominated by erosion over deposition and is characterised by the extensive occurrence of glacial erosional landforms at a wide range of scales from large cirque basins to small ice-moulded rock

landforms. This assemblage covers almost all the mountainous areas of North West Wales which are, as a consequence, relatively free of glacial deposits. Where glacial deposits occur they are predominantly composed of diamict deposited in thin, irregular, often impersistent sheets. Sand and gravel occasionally occurs within diamict as a response to deposition by subglacial streams but is often thin and discontinuous. Consequently this assemblage has very limited aggregate potential and what occurs is frequently of low volume, is very coarse and difficult to identify. A subglacial depositional assemblage, in contrast, is normally associated with lowland glaciation in which eroded bedrock is transported through the ice and frequently re-deposited further down the flow direction. This process often leads to very thick accumulations of subglacial diamict and the generation of a characteristic set of ice-moulded depositional landforms, including drumlins. Although some small areas of sand and gravel occur in isolated esker systems formed in tunnels at the base of the ice, the predominance of diamict ranks the aggregate potential of this assemblage very low.

*Ice-marginal assemblage* This includes all the landforms and sediments deposited at the margin of a glacier system. By definition, the velocity of a glacier reduces to zero at the snout and all the debris contained within and beneath it is, as a consequence, rapidly released, often in very significant volume in what is termed an ice-contact environment. Because of the rapidity of snout changes, a wide variety of depositional environments are generated including ice-front alluvial fans, ice-marginal sandur [1] and temporary lake basins. Much of the associated deposition takes place over ice which, on melt, collapses causing complex ice-disintegration topography to be created. At the same time moraine ridges are generated either by accumulation of debris at the margin or by bulldozing by movement in the ice. Together these processes create a very distinctive suite of landforms associated with complex sequences of diamict, gravel sand and mud. Consequently, they form potentially good sources of aggregate, easily identified but often difficult to extract due to their inherent coarse grain and complex interdigitation with diamict and mud. A long, narrow zone of ice-marginal sediment-landform assemblage runs from west of Nefyn northwestwards through Tefor and Caernarfon towards Bangor and marks one major retreat position during the withdrawal of the Irish Sea ice-sheet.

*Pro-glacial assemblage* This includes all landforms and sediments deposited beyond the margin of a glacier. At the snout all the water derived from melt of the glacier is discharged from exit tunnels into very large meltwater streams that carry exceptionally high loads of sediment. As these streams widen their flow away from the glacier the velocity diminishes and the sediment load is deposited in large, low-angled fans or sandur. Internally, sandur exhibit grading from coarse gravel near the glacier snout to fine sand or silt way beyond it. Consequently, they have high, good quality aggregate potential. In many pro-glacial environments large lake systems develop, dammed by ice margins or moraines or impounded in over-deepened rock basins. These act as major sediment sinks as meltwater streams immediately drop their sediment load on entry into lake deltas. Consequently they can provide high, good quality aggregate potential. Most pro-glacial lakes are small but a large example occurs northwest of Pwllheli, fed by the margin of the Irish sea ice-sheet to the north and dammed by the northern margin of a Welsh ice-lobe occupying Tremadoc Bay.

## 5 IDENTIFICATION OF TARGET AREAS

From consideration of the distribution, origin and character of glacial and related deposits in North West Wales, detail provided by the archive of existing geological information and the identification of sediment-landform assemblage zones likely to yield significant quantities of sand and gravel the following general conclusions regarding potential areas of search may be drawn:

- The upland areas, including the majority of the National Park, are predominantly erosional and glacial deposits are limited in extent and thickness, highly localized, mostly thin and

[1] Sandur is an Icelandic term used to describe areas of outwash in front of a glacier.

discontinuous and predominantly composed of diamict or coarse-grained gravel, largely unsuitable for mineral extraction.

- Large parts of Anglesey are underlain either by drumlins composed of thick diamict or by ice-moulded bedrock and are largely devoid of potential mineral. Small areas of subglacial fluviatile sedimentation, in the form of subglacial esker systems, have yielded mineral around Pentraeth. Other small areas, sufficient to provide local sources may occur but are likely to be coarse-grained, difficult to identify and of relatively low volume.
- The Arfon lowlands running from Trefor north-eastwards towards Bangor, together with the narrow coastal strip between Conwy and Abergele, are characterized by ice-marginal sediments but due to contamination with coarse-grained sediment derived from Snowdonia are likely to yield complex, locally very variable sequences of diamict and outwash in which good quality mineral is probably of small volume, hard to locate, difficult to work and associated with significant thicknesses of overburden and waste.
- The area around Nefyn is characterised by ice-marginal sediments of almost exclusive Irish Sea origin and is likely to yield significant fine-grained mineral.
- Parts of the Llŷn peninsula northwest of Pwllheli are likely to yield significant quantities of well-sorted sands due to their origin in deltas feeding ice-dammed lake systems derived from fine-grained Irish Sea ice sources to the immediate north.
- Areas peripheral to the National Park, especially along the major valleys of the Dee, the Conwy and the Dyfi are likely to contain significant volumes of potential mineral both from former valley sandur systems and from Holocene river terraces but this will be predominantly coarse-grained.
- Floodplain deposits along the floor of major valleys are predominantly composed of silt and clay, becoming coarser with depth. Most of the sand component is found at depth, below the water-table, and is therefore not likely to provide major aggregate resources.
- Coastal sands, including dune and beach sand, though forming a potentially good mineral resource are unlikely to be exploited on a large scale for environmental reasons.

Arising from these conclusions, the following areas were identified as the most promising for further investigation and are shown in Figure 4. It should be emphasised that these areas have been identified almost entirely on geological criteria. Local environmental and planning constraints occurring in each of the areas are considered in a subsequent part of this report.

Area 1 Cors Geirch, Pwllheli

Area 2 Nefyn, Gwynedd

Area 3 Trefor to Pontlynffi, Gwynedd

Area 4 Glynllifon to Bontnewydd

Area 5 Llanrug, Gwynedd

Area 6 Glascoed to Talybont, Gwynedd.

Area 7 Northeast of Bala, Gwynedd.

Area 8 Pentraeth, Anglesey.

Area 9 Conwy Valley, Conwy.

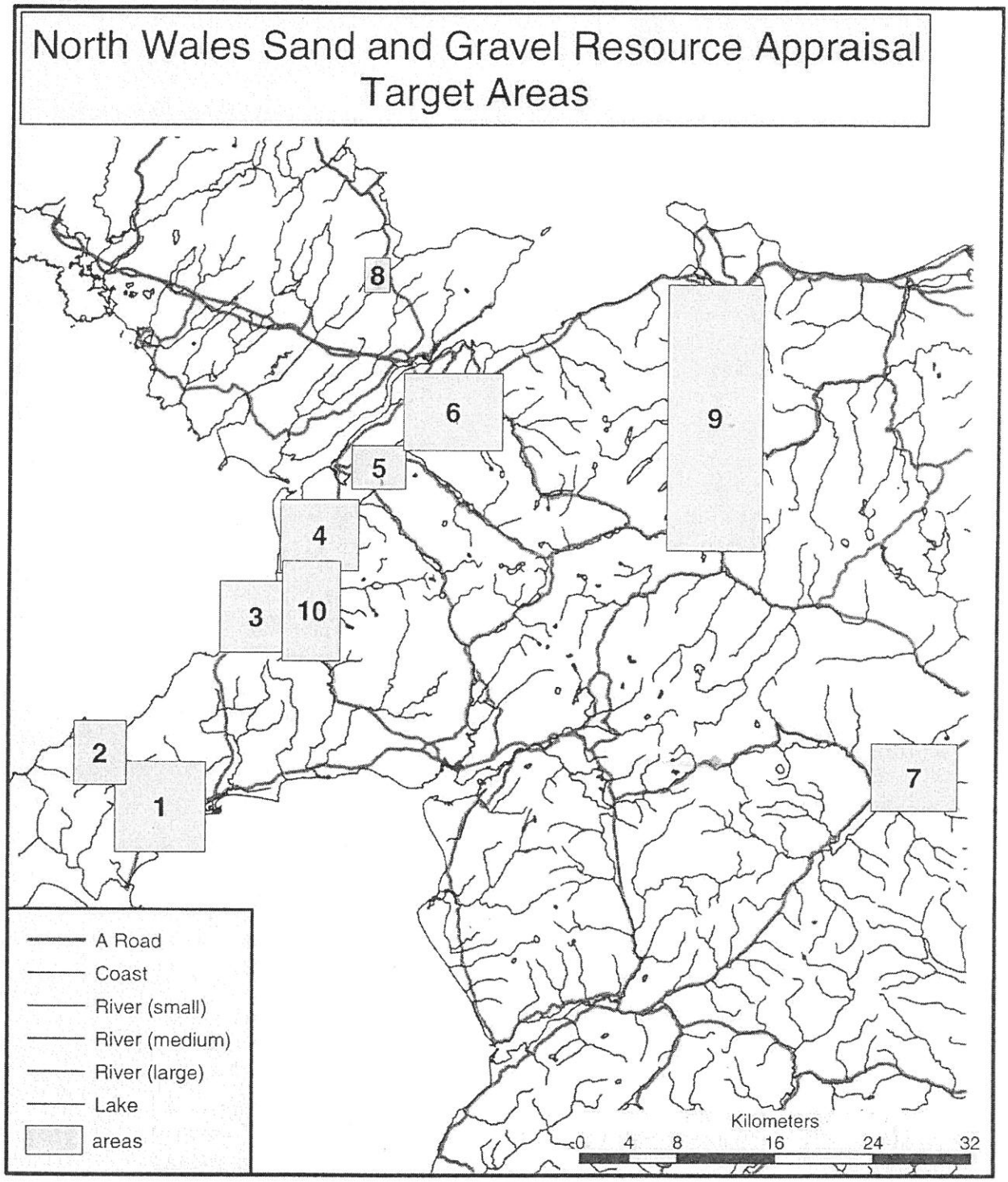


Figure 4. Location of target areas

The following areas were also examined as potential target areas but were rejected for the reasons given.

- *The Dyfi valley* This area contains very significant volumes of sand and gravel in valley sandur and Holocene river terraces [1] but is far from any significant market and only a small part is within the administrative boundaries of the assessment area. It might, however, be suitable for small-scale extraction serving local markets.
- *North of Tywyn* This area is far from major markets and contains only small areas of predominantly very coarse mineral. It might be suitable for small-scale, local extraction but quality is likely to be poor.
- *The coastal area between Llandudno and Rhyl* Small deposits of sand and gravel of Irish sea origin have been identified and are likely to contain fine grained mineral. All potential deposits, however, are heavily constrained or sterilised by urban development.
- *The coastal area between Talybont and Llanfairfechan* Although originally considered to be of some potential given the close proximity to Bangor, morphological mapping revealed significant diamict at the surface and cliff sections at Aber Ogwen and Glan-y-Mor Isaf [2] show a complex sediment sequence dominated by diamict with limited sand and gravel. The narrow coastal plain is also constrained by both the A55 and the Chester-Holyhead railway, limiting potential exploitation to very small, environmentally visible blocks with difficult access..
- *The Elwy Valley* Running east towards the Vale of Clwyd, the Elwy valley is flanked for much of its length by a narrow valley sandur composed, in part, of thick successions of sand brought in by Irish sea ice penetration into the area. Potential resource blocks, however, are small, some considerable distance from the main coastal market and poorly serviced by main roads. The area may provide resources suitable for small scale local use.
- *The area south of Trawsfynydd* Some of the linear ridges south of Lyn Trawsfynydd have been previously identified as eskers but further investigations confirms them as drumlins, composed of diamict, unsuitable for mineral extraction.

## 6 SEARCH CRITERIA

Following selection of search areas it was necessary to identify a set of search criteria that define the type of mineral aggregate that is sought. The search criteria applied within the target areas are listed below but it should be emphasised that these may vary depending upon local circumstances. A policy of developing local resources for local needs or the exploitation of particular quality minerals for particular applications, for example, may reduce the normal minimum volume required for commercial exploitation of general purpose, regional scale reserves.

*Lithology* The primary contractual requirement was to find reserves of fine-grained aggregate, or sand (< 2 mm in diameter), as the region is generally deficient in this class of aggregate.

*Mixed Sand and Gravel* It was agreed at the first Steering Group meeting that the search would include not only deposits of homogeneous sand but also deposits of mixed sand and gravel from which sand may be derived. Obviously, the higher the proportion of gravel in a mixed sand and gravel deposit the lower the proportion of sand and hence the greater degree of processing required to remove it. Thus a mixed deposit of sand and gravel containing 20 % sand would yield 80 % gravel. If the market demand for gravel is low much of the gravel has to be stock-piled to

[1] Thomas, G.S.P., Summers, A.J. & Dackombe, R.V. 1982 The Late-Pleistocene deposits of the middle Dyfi, Wales, Geological Journal, 17, 297-309.

[2] Edge, M.J, Hart, J. and Pointon, K. 'The sequence at Aber Ogwen and Glan-y-Mor Isaf', In: Addison, K., Edge, M.J. and Watkins, R. (Eds) The Quaternary of North Wales: Field Guide, Quaternary Research Association, Coventry.

await possible future sale. As the industry does not normally use gravel greater than pebble size, except as a source of crushed aggregate, any significant proportion of cobble or boulder gravel (> 64 mm in diameter) has to be stored and subsequently back-filled or transported elsewhere. To reflect these problems only gravel likely to yield more than 40 % of sand was included in the search criteria and mixed sand and gravel with a proportion of cobble or boulder gravel of more than 5% was excluded.

*Proportion of Fines* In order to minimize processing, potential resources need to be relatively free of silt and clay. In their regional mineral assessment reports the British Geological Survey have traditionally used a maximum proportion of 40 % fines (<0.0624 mm) to differentiate between mineral and non-mineral. Consultation with the industry, however, suggests that this figure is too high and a figure of 15 % is more appropriate.

*Minimum thickness* The British Geological Survey use an average minimum thickness of 1 m to define an economically viable mineral resource. This is felt to be much too low and consultation with the industry suggests an average minimum thickness of 3 m is more appropriate.

*Minimum ratio of overburden* 'Overburden' is defined as the ratio of non-mineral overlying mineral in any potential resource. This ratio is important as higher ratios increase the cost of extraction. The British Geological Survey use a ratio of not more than 3:1 but consultation with the industry suggest that a ratio of 1:1 is more appropriate.

*Waste* 'Waste' is defined as the ratio of mineral to non-mineral within any potential resource. This is important because many types of glacial deposit, especially those deposited in ice-marginal environments, contain rapidly varying, often discontinuous sequences of sediment, usually diamict or laminated or massive mud, which serve to contaminate the potential mineral and increase the cost of extraction. Consultation with the industry suggests that minimum ratio of waste to mineral of 1:1, or 50 % of a potential resource volume..

*Minimum quantity* Consultation with the industry suggests that the minimum quantity of extractable mineral in any potential resource likely to be used for regional scale supply should not be less than 0.5 million tonnes. Smaller quantities may apply to resource blocks likely to be used to meet local demand or for special purposes.

*Depth* In the industry the normal maximum depth of extraction, below which technical difficulties and hence costs increase, is 20 m. Potential resources located below this depth are therefore excluded.

*Working conditions* In general, resources located above the water-table are significantly cheaper to extract than those below the water-table. Extraction below the water-table may also cause significant environmental problems due to contamination of ground-water, alteration of the ground-water circulation system, leakage of water used in processing into river systems and disposal of water saturated with mud washed from the mineral removed. Resources located below the water-table were therefore excluded.

*Deleterious materials* Deleterious materials are naturally occurring rocks, sediments or minerals such as coal, shell beds, peat and alkali-silica reactive minerals that reduce the quality of mineral aggregate or make them unsuitable for use by reducing their load-bearing or shear strength or causing chemical reaction when mixed with cement in concrete production. The bedrock types in North West Wales from which glacial deposits are derived, including those sourced from Irish Sea ice, are generally free of deleterious material.

From the above discussion, 'mineral' is defined for the purposes of this study as a deposit which meets the requirements listed below. Deposits not meeting these requirements are defined as 'non-mineral'.

- the deposit should contain no less than 40 % sand grade
- the deposit should contain no more than 15 % silt and clay grade
- the deposit should contain no more than 5% cobble and boulder grade
- the minimum deposit thickness should be not less than 3 m

- the maximum ratio of overburden to mineral should be no more than 1:1 or not more than 50% of the mineral volume
- the maximum ratio of waste to mineral should be no more than 1:1 or not more than 50% of the mineral volume
- the minimum quantity of extractable mineral should be 0.5 million tonnes, except for local needs
- the deposit must lie within 20 m of the surface
- the deposit should occur above the water-table
- the deposit should not contain significant quantities of deleterious materials

Since the aim of the project was to identify the commercial potential of sand and gravel aggregate resources, it is important to consider other, practical constraints which might inhibit the working of any prospect when identifying potential resources. These include the proximity to current and future market centres, the proximity to existing or planned developments, the proximity to or inclusion within environmentally sensitive areas and the potential traffic problems that might be generated by development, including site access and the use of substandard minor roads. These are dealt with on a resource block by resource block basis in section 10 below.

## 7 METHODS FOR IDENTIFYING POTENTIAL RESOURCES

The primary method of identifying areas of potential mineral resource within a target area was the construction of a geomorphological map. Geomorphological mapping involves the field identification, recording and interpretation of individual landforms, normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with a particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. The most common landform types are described below, along with their potential for aggregate extraction. It should be emphasised that geomorphological mapping is not an exact science and the descriptions that follow define the 'ideal' type. In practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

*Proglacial sediment-landform assemblage landforms*

Sandur act as major proglacial sediment sinks and are formed by the lateral and vertical accretion of sediment deposited by meltwater stream systems emerging from a glacier and fanning outwards into the proglacial area. Reflecting the decline in stream power they decrease in surface gradient down-stream and progressively deposit finer-grained sediment: the upper part deposits coarse gravels, the central part finer gravel and sand and the lower part fine sand and silt. As a potential mineral resource they contain clean, well-sorted gravels, sands and silts, in ordered succession, often very thick but are commonly located close to the modern water-table making exploitation difficult. One major sandur system runs in a widening fan from a series of ice-marginal moraines arcing across the wide col lying south of Penygroes south towards Criccieth and its upper part supports a number of active quarries. Other examples occur in the Conwy valley.

Deltas form when sandur stream systems enter lake basins or the sea. Due to reduction in velocity on entering the water, sediment is rapidly deposited. Most deltas show a three-fold internal structure. Topsets are deposited across the delta surface by progradation of the sandur system and are composed of gravel; foresets are deposited by avalanche down the delta slope immediately beyond the water-line and are usually composed of sand; bottomsets are deposited across the floor of the lake by suspension from the fine-grained sediment in the input water and are usually composed of silt and clay. Delta sediments are frequently dissected by fluvial action when the lake drains out to form series of incised terraces. The topset and foreset components of delta sediments represent a significant, well sorted aggregate resources but the bottomset are usually too fine for use. Most pro-glacial lakes are small but a large example, now much

dissected, occurs northwest of Pwllheli, fed by the margin of the Irish sea ice-sheet to the north and dammed by the northern margin of a Welsh ice-lobe occupying Tremadoc Bay.

*Ice-marginal sediment-landform assemblage landforms*

Ice-front alluvial fans accumulate at the immediate ice-margin, often on the ice itself, from meltwater stream exit tunnels. They are characteristically steep and very coarse-grained, reflecting the high velocity of flow in the feeding tunnels, and are often intercalated with sheets of diamict formed by slumping from the immediate ice-margin. Their aggregate potential is consequently low due to the high proportion of waste and cobble and boulder content.

Marginal sandur form when meltwater draining the ice-margin is obstructed by older moraine in the immediate proglacial area and flow is directed parallel to the ice-margin rather than directly away from it in relatively narrow, flat-floored troughs. Deposition within them is invariably coarse and often mixed with diamict formed from slumping off the adjacent ice-margin. Consequently their mineral potential is relatively low, yielding large volumes of unusable coarse gravel and waste. A large number of marginal sandur occur in the area between Caernarfon and Bangor.

Kames terraces are areas of mounded topography that occur in irregular bands or linear sets of isolated mounds. They form at the edges of glaciers which abut against steep rock slopes either along the flanks of valley glaciers or the edge of lowland ice-sheets. Meltwater sedimentation is channeled between the ice-margin and the rock slope and deposition takes place in a linear trough on or against the ice. In some cases the trough grades down-ice into marginal sandur. When the ice beneath the trough melts out the sediment above collapses to form irregular 'kame mounds' and water-filled basins, or 'kettle holes'. When the ice-margin retreats the inner margin of the trough of sediment accumulation collapses to form an irregular terrace edge. Mineral potential is relatively low because of the generally coarse nature of the trough fill and the occurrence of much diamict. Major example of kame terraces occur around Groeslon, south of Caernarfon, and south of Llanrug.

Moraines [1] are linear or arcuate ridges up to 50-60 m high formed at the margin of glaciers. They often occur as successive parallel ridges where each ridges represents either a temporary still-stand during retreat or a subsequent readvance limit. A number of different moraine types can be distinguished, based primarily on their internal structure and composition and only partly on their form:

- *Ablation moraines* These form at the margin of the glacier by supra-glacial debris sliding off the surface of the ice-margin, or melted-out from within the ice itself and accumulating as a wedge of sediment against the snout. They are almost invariably composed of diamict and their aggregate value is minimal.
- *Push moraines* These form by the bulldozing of debris lying in the immediate proglacial zone by the forward movement of the glacier during readvance or minor snout oscillation. They are commonly highly deformed internally and their lithological composition depends upon the type of sediment incorporated from the proglacial zone. If this includes sand and gravel then the aggregate potential of the push moraine ridge may be high; if it includes diamict it will be low. The prominent ridge at Dinas Dinlle, south of Caernarfon, is a type example of a push moraine and is composed of highly deformed sheets of sand, gravel and diamict
- *Kame moraines* are similar to kame terraces but are usually larger and more complex. They form at the snout of a stagnating glacier by the accumulation of both diamict and outwash on top of buried ice. As the ice melts a complex area of ice-disintegration topography is generated consisting of small-scale ridges, mounds and basins, often in wide linear belts. The mineral potential depends upon the sediment of which they are composed. A good example of a kame moraine occurs south of Nefyn.

[1] The term 'moraine' is used in the literature to describe both a landform and a deposit. To avoid confusion the term is used here to identify a landform only.

In the absence of exposure it is often difficult to correctly classify moraines on geomorphological criteria alone as their form is often similar. This presents some problems in identifying potential aggregate resource blocks in areas of complex ice-marginal sedimentation such as that extending along the north west coast of Gwynedd as very few of the moraines are exposed.

*Subglacial sediment landform assemblage landforms*

Diamict plains are areas of relatively low amplitude, subdued topography underlain almost entirely by diamict. Their aggregate potential is consequently negligible. Where the diamict is very thick the surface is often flat and featureless and often poorly drained. An example is the wide embayment to the rear of Porth Neigwl beneath which the diamict is at least 50 in thickness. Anglesey is also largely underlain by thick diamict plains as are parts of the adjacent mainland coast.

Drumlins are elongate, smooth ridges on a scale of up to a kilometre in length, 50 m high and a few hundreds metres wide. They occur in fields, commonly called 'basket of eggs' topography', with a common orientation running parallel with the former ice-flow direction. They are formed under fast-flowing, thick ice during episodes of major subglacial flooding; the drumlin form being a type of bedform.. They are almost wholly composed of diamict and their aggregate potential is negligible. Much of Anglesey displays extensive drumlin fields as do parts of the adjacent mainland between Caernarfon and Bangor and both flanks of the Conwy valley.

Eskers are long, narrow, sharp-crested, often sinuous ridges up to 20 m in height composed of sand and gravel. They represent the former position of subglacial tunnels draining the base of the ice and preserved as a 'cast' of the tunnel form, complete with its sedimentary fill. This provides good aggregate potential as the ridge form is easily exploited but reflecting the high velocity of flow in subglacial tunnels sediment is very coarse. The direction of eskers reflects the flow direction of the ice. In large ice-sheets this is usually at right angles to the ice-margin direction but between Caernarfon and Bangor the flow direction and ice-margin direction coincide. As a consequence a number of the linear ridges occurring in that area are difficult to classify as they may either be eskers draining marginal meltwater or ice-marginal moraine ridges.

*Non-glacial landforms*

Amongst non-glacial landforms a number of other landform types are useful for identifying aggregate resources. These include:

River terraces and valley alluvium Following ice retreat fluvial processes became dominant and stream systems attempted to adjust their courses through the cover of glacial deposits. As sea-level was low at this time the glacial deposits were rapidly dissected by down-cutting streams and much sediment was removed leading to deposition of river terraces further down-stream. As much of the finer sediment was washed out into the sea these terraces were formed of relatively clean, well sorted sands and gravels, forming good potential mineral resources. As the rivers of North Wales are relatively short, however, few extensive areas of river terrace occur except along the Dyfi, the upper part of the Dee and the lower Conwy. Moreover, many of these river terraces are only a few metres above modern river level and would be difficult to work as excavation would extend below the water table.

Alluvial fans Following glaciation many tributaries to main rivers valleys were left 'hanging' as a consequence of glacial overdeepening of the main valley. During the Late Glacial and Early Holocene much of the debris lying on valley slopes was flushed out to form alluvial fans at tributary junctions. These can provide an aggregate resource, especially in isolated areas, but are often contaminated by fines resulting from mud flows.

The following table summarises the relationship between sediment-landform assemblages, landform type and mineral potential. The abbreviations for landform type are used in tables of resource block volumes in a later part of this report.

***Table 2: Mineral Potential of Glacial Landform Types***

| Proglacial Assemblage | | | Ice-Marginal Assemblage | | | Sub-glacial Assemblage | | | Non-glacial | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landform | Mineral Potential | | Landform | Mineral Potential | | Landform | Mineral Potential | | Landform | Mineral Potential |
| S | Sandur | H | AF | Ice-front alluvial fans | M | D | Drumlins | L | RT | River Terraces | H |
| DT | Delta | H | MS | Marginal Sandur | M | DP | Diamict Plains | L | A | Alluvial Fans | L |
| | | | KT | Kame Terrace | H | E | Eskers | M-H | | | |
| | | | AB | Ablation Moraines | L | | | | | | |
| | | | PM | Push Moraines | L | | | | | | |
| | | | KM | Kame Moraines | H | | | | | | |
| | | | M | Moraine (Undifferentiated) | L | | | | | | |

L = low M = medium H = high

## 8 METHODS OF IDENTIFYING INDIVIDUAL RESOURCE BLOCKS

From the geomorphological map of each target area a filtering process was used to identify potential resource blocks. The first level of filtering was the type of geomorphological feature. Thus, features identified as sandur, marginal sandur, ice-front alluvial fans, deltas, kames, kame terraces, eskers and river terraces were all included as, reflecting their depositional environments, they are likely to contain potential mineral. Features identified as diamict plains, drumlins, lake floors, push-moraines and ablation-moraines were excluded as they are unlikely to contain potential mineral.

All moraines of unknown origin were included in the filtering process, for two reasons. First a significant number of moraines are likely to be kame-moraines even though they cannot be identified as such by their morphology alone and lack sufficient exposure to confirm their origin. Second, moraines form the dominant landform in a number of target areas, particularly areas 4, 5 and 6 in the Arfon lowlands and their exclusion from further investigation would substantially reduce the number of potential prospects in these area, particularly as they mostly lie in reasonable proximity to the major market demand areas. Including all moraines, however, also runs the risk of wasting resources in investigating a significant number of resource blocks that, subsequently, prove to yield little or no mineral.

The second level of filtering was done on the basis of pre-existing borehole information and section detail reported in the literature. Thus, if a pre-existing borehole though a moraine of otherwise unknown origin yielded thick diamict it was excluded; if it yielded significant sand and gravel either alone or as part of a mixed diamict and sand and gravel sequence, it was included.

Each resource block identified normally equates to an individual geomorphological feature though in some cases a number of adjacent features of similar type are combined together. In a limited number of cases where resource blocks are very large they have been divided into two contiguous blocks, usually along a convenient feature such as a road.

## 9 METHODS OF ASSESSING RESOURCE BLOCK VOLUME AND QUALITY

*Criteria for selecting borehole locations*

In order to prove the occurrence of mineral and provide a reasonably accurate estimate of its volume and quality each resource block identified as potentially mineral bearing in the geomorphological survey should, ideally, have one or more boreholes drilled through it. In reality this is impractical as boreholes forms a significant proportion of budget costs in a sand and gravel appraisal survey. In this survey some 80 potential resource blocks were identified within the nine target areas and funds for a maximum of 20 boreholes were available. Some optimization of borehole locations was therefore necessary and the following priorities were established:

1. At least one borehole, but preferably more, should be drilled in all resource blocks regarded as meeting the primary search criteria – the identification of significant reserves of sand.
2. Boreholes should be drilled in representative resource blocks likely to yield at least 40 % sand in a mixed sand and gravel resource block in areas closest to the main market centres.

*Method of Assessing resource block volume and quality*

The ideal method of assessing the volume and quality of a potential resource block is via a set of closely-spaced boreholes as glacial sediments, by the nature of their depositional process, vary considerable both vertically and laterally over short distance. Using this method, the stratigraphy of the block is reconstructed from the borehole data and resource volume calculated by constructing a contour map of the thickness of each unit identified as potential mineral from accurate survey of the geometry of the resource block. The quality of a resource block is determined by comparing the grain-size distribution of each unit identified as potential mineral with the primary search criteria; in this case homogenous sand or mixed sand and gravel containing more than 40 % sand. In reality, especially for broad scale preliminary assessments such as this study, there is generally insufficient information for this method to be used. Consequently, resource volume has been estimated by one of three other methods:

Method 1 Where one or more boreholes have been drilled in the block volume is estimated by averaging the thickness of mineral in the boreholes that meets the primary search criteria and multiplying by the surface area of the resource block. This leads to some overestimate of volume as most blocks are irregular in form and rarely flat. Block quality is determined by laboratory grain-size analysis of samples of sediment taken at regular, usually one metre, intervals down the boreholes. Details of the method of grain-size analysis used are given in Appendix D, together with test results. Averaging the results of these grain-size analyses gives an average percentage distribution of all grain sizes in the block. The total proportion of sand, including coarse, medium and fine grades, and the total proportion of pebble gravel are then multiplied by the area of the block to give the volume in each of the two principal grain-size categories.

Method 2 Where no boreholes are available but exposure occurs in the block an estimate of the minimum thickness is made on the basis of the exposure record and the surrounding geology and the volume calculated by multiplication by the surface area of the resource block. Block quality is determined as in method 1 by laboratory analysis of the grain-size distribution of samples obtained from exposed section.

Method 3 Where no boreholes are available and no exposure occurs in the block an estimate of the thickness is made by inference from similar types of block and the volume calculated by multiplication by the surface area of the resource block. The block quality, in terms of an estimated percentage ratio of likely sand and gravel yield, is also inferred from similar types of block.

*Reliability of volume and quality estimates*

Resource blocks have been classed into three categories of reliability to reflect the sources of information available about each block and the method used for estimating volume and quality. These categories generally equate with the method of assessing resource block volume and quality used but also take into account uncertainties in landform identification, variations in the thickness of overburden and waste and difficulties experienced in drilling. The categories are:

*High* Used where borehole and sample information is available and is consistent in terms of thickness, grain-size, thickness of overburden and amount of included waste. Some reliance may be placed on these estimates in the immediate vicinity of borehole locations but should not be extrapolated to adjacent areas where boreholes have not been drilled as glacial deposits vary considerably over short distance.

*Medium* Used where there is no boreholes information but some sample information is available from exposed section. These estimates have a moderate margin of error but should be used with caution. A detailed drilling and sample testing programme should be undertaken before exploitation of blocks classed as of medium reliability is considered.

*Low* Used where no borehole, sample or exposure information is available. Volume and grain-size distribution estimates are based on comparison with other blocks of similar geomorphological character and the general geological conditions in the area. These estimates have a wide margin of error and should therefore be used with very considerable caution. A detailed drilling and sample testing programme should be undertaken before exploitation of blocks classed as of low reliability is considered.

*Commercial Potential*

Resource blocks have been classified into three categories of commercial potential: *high, medium* and *low.* These categories are a qualitative judgment that takes into account one or more of the following technical factors: the volume of the deposit, the quality of the deposit, the amount of overburden and waste, the ease of extraction and any specific difficulty that may be encountered in working the block. It also takes into account an assessment of existing or planned development directly affecting the block, highway access, proximity to market, local environmental designations and planning zonation. It should be noted that the significance of some of these latter factors varies over time due to changes in planning policy or commercial conditions. Thus, a block which may, at this time, be considered too far from market to be commercially viable may, at some future date, be considered environmentally advantageous in encouraging local sources for local markets. Equally, a particularly high quality resource considered to be uneconomic through distance to market now may become economic when similar reserves nearer to market are depleted. Similarly, environmental constraints are rarely absolute and policy towards them often changes in the light of changed economic conditions. Consequently, an assessment of any particular resource block as of high commercial potential should not be taken as a recommendation. It has been assumed that with the exception of National Parks, SAC's, SPA's and RAMSAR sites, all other environmental designations or planning constraints do not, necessarily, preclude the possibility of mineral extraction.

The method of assessment used (1, 2 or 3) in estimating the volume and quality of a resource block, the reliability of the estimate (high, medium and low) and the possible commercial potential (high, medium and low) are reported in all following tables of tables of resource block volumes. As the industry works by weight of aggregate, all volumes have been converted from cubic metres, derived from area times thickness calculations, into metric tonnes using a value of 1.6 tonnes per cubic metre as the average in-situ bulk density. In some consolidated deposits this figure may be higher (up to 2.0 tonnes per cubic metre) but is unlikely to be much lower. Tonnages quoted are therefore minimum estimates

# 10 POTENTIAL SAND AND GRAVEL RESOURCES

This section of the report provides an overview of the geological characteristics and potential mineral resources of each of the selected target areas. It briefly describes the geomorphology of each of the areas, the origin of the landforms, identifies the individual resource blocks and the environmental and other constraints affecting them, outlines the mineral assessment strategy used to identify the best potential resources in the area, provides a statistical summary of identified resource volume and quality and a set of summary conclusions about the potential of the area. For definitions of environmental designations see Appendix E.

## 10.1 Area 1 Cors Geirch

*Description* This is an area of some twenty square kilometres bordering both sides of Cors Geirch and adjacent parts of the valley of the Afon Rhyd-hir, northwest of Pwllhelli. The area is bounded on the south by the A499, on the east by the A497, on the north by a cross-valley ridge at Maesoglan and on the west by the flanks of the prominent rock ridge between Carneddol and Carn Fadryn. Included within it are the small villages of Rhyd-y-clafdy, Efailnewydd and Penrhos together with many farms and rural dwellings. Recent 1:50,000 geological maps cover the southern part of the area but the northern part has not been mapped. No published geomorphological map exists, it has limited natural exposure, no history of previous working and very limited borehole information. The area was identified in the University of Liverpool 1988 assessment of the sand and gravel resources of eastern Llŷn as a likely source area of fine-grained aggregate and it is for this reason that it was selected as a target area.

*Geomorphology* The geomorphology of the area is shown in Appendix A Figure 1 and consists of a set of three prominent terraces bordering the floor of Cors Geirch and the lower reaches of the Afon Rhyd-hir. A *high terrace*, at a level of 70 m OD in the north around Hendre declining to 50 m OD in the south around Rhyd-y-clafdy, occupies an irregular linear tract between Cors Geirch and Afon Rhyd-hir and a linear strip on the western side of Cors Geirch. A *middle terrace*, at heights between 28 and 35 m OD is fragmentary but occupies small patches of ground along the flanks of the high terrace. A *lower terrace*, at between 10 and 12 m above OD, occupies a narrow strip running from east of Llanbedrog northwards along the western flank of Cors Geirch past Rhyd-y-clafdy. It is matched by a very narrow strip of equivalent terrace on the eastern flank of Cors Geirch. Further extensive terrace at this height occupies ground south of the Polish Home and eastwards through Penrhos village. Much of the eastern flank of the Afon Rhyd-hir around Efailnewydd is occupied by the same terrace which extends northwards towards and beyond Bodvel Hall. The upper terrace surface was formed by deltaic sedimentation into a large ice-dammed lake, whose surface stood at approximately 55-60 m OD, fed from a declining Irish Sea ice-margin lying across the northern end of the Cors Geirch valley and dammed up by the northern margin of a large lobe of Welsh ice occupying Tremadoc Bay. The delta was supplied from two sources, the large col at Maesoglan and the narrow rock channel at Nant y Gledrydd. The middle and lower terraces were probably cut by incision into the delta surface by meltwater streams draining from the Irish Sea ice-margin after the lake had drained.

*Resource Blocks and Designations* Eleven resource blocks have been identified in the area and are illustrated in Appendix A Figure 2 together with environmental designations. A small portion of Block 1J forms part of an AONB and is bordered by an SSSI and an SAC. Otherwise, none of the blocks are directly constrained but the whole area is bordered to the southwest and northwest by an AONB. Blocks 1B, 1C, 1G, 1I and 1K are bordered by an SAC and NNR on the floor of Cors Gierch. Block 1A, at Polish House is partly occupied by a large residential establishment, a caravan park, a golf driving range and a sewage works and a planning application has been submitted for a nine hole golf course over much of the remaining area. Block 1H is partly occupied by the village of Efailnewydd and block 1K by the village of Rhyd-y-Clafdy. Otherwise the area of the blocks is mainly agricultural with isolated farms and residential building.

*Assessment strategy* Existing information indicated that this area is probably the best potential source of good quality sand in the region and a significant proportion of the drilling programme

was consequently allocated to investigation of the area. Six blocks were investigated by assessment method 1 using boreholes and samples obtained from them; two blocks by method 2 using natural exposure for obtaining samples; and the remaining three by method 3, geological inference.

*Block 1A (Polish House)* This block covers an area of 0.82 square kilometres and is located on the eastern side of Cors Geirch immediately north of the A499 Pwllheli to Abersoch road. It consists of a flat terrace at around 20m rising to the north and is fronted by a marked bluff on the south and eastern side overlooking the lower end of Cors Geirch. It is bordered on the north by Polish House, a large residential establishment and is occupied by a large caravan park a golf driving range and a sewage works. A planning application has been submitted for a nine hole golf course over much of the remaining area. Because of these constraints no boreholes were drilled in the block and no previous boreholes exist. Sections in the block show up to 5m of sand and gravely sand and the block is estimated to be a minimum of 10 m thick with minimum waste and negligible overburden. On the basis of two exposure samples the block is estimated to contain 11.6 million tonnes of sand, 0.87 million tonnes of gravel and 0.66 million tonnes of waste, with a sand to gravel ratio (excluding fines) of 93:7. In the absence of borehole data this estimate is rated as of only moderate reliability and must be viewed with caution. Although it is clear that the block contains significant fine-grained mineral it is rated as of low commercial potential because of the degree of current or planned development.

*Block 1B (Pen-y-Bryn)* This block occupies an area of 0.34 square kilometres and forms the southern part of the upper delta terrace. It takes the form of a long, narrow, partly flat and partly undulating surface at an elevation of 50 m running south from the B4415, and flanked on both sides by steep slopes (Appendix A, Plate 1). No settlement occurs on the surface of the block but it overlooks the village of Rhyd-y-clafdy and a number of adjacent houses on the western side. A planning application for exploiting sand and gravel on the western side of the block was submitted in 1994 but was rejected on appeal. The assessment of the block was made on the basis of two boreholes (UL01 and UL01A) yielding 15 samples of mineral, two small exposures on the western margin and three pre-existing boreholes associated with the planning application. The locations of the these boreholes is unknown and sample data is not available. The thickness of mineral in the five boreholes was 17.5 m, 10 m, 25 m, 25 m and 25 m with minimal overburden and the block is estimated to have a average minimum thickness of 21 m. The water-table was not encountered in any of the boreholes. The block is estimated to contain 10.49 million tonnes of sand, 0.91 million tonnes of gravel and 0.23 million tonnes of waste with a percentage sand to gravel ratio (excluding fines) of 92:8. No gravel larger than small pebble was encountered. This estimate is rated as of high reliability. Normally, extrapolation beyond the immediate location of boreholes is not advisable due to inherent variability over short distance in glacial deposits but in this case the ordered nature of deltaic sedimentation and the high density of boreholes gives some confidence that the remainder of the block contains similar sediments to those obtained in the boreholes, except towards the northern end where diamict rises within 10 m of the surface and to the south where interbedded bottomset lacustrine sediment is likely to increase in thickness. The block is rated as of high commercial potential due to the quality of the mineral and good access to the B4415 on its northern edge.

*Block 1C (Bryn Bodvel)* This block covers an area of 0.85 square kilometres and is an extension of Block 1A to the north across the B4415. It forms a flat delta surface at a uniform height of 51 m bordered by steep slopes on all sides. It is occupied by one farm and a number of dwellings and is crosses by two minor roads. The assessment was made on the basis of three boreholes (UL05, UL06 and UL08) yielding 19 samples of mineral, including exposure samples taken from a small, abandoned sand pit on the northern margin and a major section showing at least 10 m of sand exposed to the rear of Cefn Mine (Appendix A, Plate 7). The thickness of mineral in the three boreholes was 17.0 m, 14.5 m and 12.5 m with minimum overburden and water was not encountered. The thickness of minerals in the boreholes appears to be an underestimate and the average thickness has been recalculated on the basis of available section to be nearer 18 m. The block is estimated to contain 22.0 million tonnes of sand, 1.41 million tonnes of gravel and 1.23 million tonnes of waste with a sand to gravel ratio (excluding fines) of 94:6. No gravel larger than

small pebble was encountered. The estimate is rated as of high reliability and extrapolation may be possible across the area of the block due to the consistency in the sedimentary record in the boreholes and their high density. The block is rated as of high commercial potential due to the quality of the mineral. Road access is good on the southern and eastern portion of the block but the remainder is served only by narrow minor roads.

*Block 1D (Coed Cae-Rhos)* This block covers an area of 0.73 square kilometres in a narrow strip of high terrace at a height of 45-47 m on the western side of Gors Geirch. It is contiguous with block 1E to the north and is unoccupied. The assessment is based on one borehole (UL02) drilled through the centre of the block and two samples. The mineral was not exposed. The borehole recorded 4.5 m of mineral before passing into thick diamict. The block is estimated to contain 3.74 million tonnes of sand, 0.71 million tonnes of gravel and 0.23 million tonnes of waste, with a sand to gravel ratio (excluding fines) of 87:13. The estimate is regarded as of high reliability and likely to reflect the remainder of the block. Because of the limited thickness and volume, however, the block is rated of low commercial potential. The block also has poor road access.

*Block 1E (Ty-isaf)* This block covers an area of 0.70 square kilometres in a narrow strip of high terrace at a height of 52 metres to the west of Rhyd-y-clafdy and is contiguous with blocks 1F to the north and 1D to the south (Appendix A, Plate 2). The assessment is based on one borehole drilled through the centre of the block and two samples. The mineral was not exposed. The borehole recorded 4.6 m of mineral before passing into laminated mud and thick diamict. The block is estimated to contain 2.72 million tonnes of sand, 1.60 million tonnes of gravel with a sand to gravel ratio (excluding fines) of 64:35. The estimate is regarded as of high reliability and likely to reflect the remainder of the block. Because of the limited thickness and volume, however, the block is rated of low commercial potential. The block also has poor road access

*Block 1F (Bodgadle)* This block occupies an area of 0.7 square kilometres and forms a narrow strip of flat delta terrace, bounded by a steep front, at a height of 52 m west of Rhyd-y-clafdy (Appendix A, Plate 2). It is bordered to the west by a steep rise to the rock slope of Moel Caerau and is contiguous with Block 1E (Ty-isaf) to the south and separated from it by a small valley. The block is occupied by two farms with others on the immediate margin and is bisected by the B4415. The assessment was made on the basis of one borehole (UL04) located in the centre of the block and two samples. The thickness of mineral was 2.5 m, with minimal overburden, and the borehole terminated in thick bottomset laminated clay and diamict. Water was not encountered. Compared to the thick sand reported by the local farmer as occurring in an old pit, now unexposed, located on the edge of the terrace margin 800 m to the southeast, the borehole record was unexpected but indicates that much of the delta surface in the marginal areas is underlain by rising diamict and bedrock. Thickness of mineral may be expected to increase towards the delta terrace margin. The block is estimated to contain 3.94 million tonnes of sand, 0.49 million tonnes of gravel and 0.23 million tonnes of waste, with a sand to gravel ratio (excluding fines) of 87:13. The estimate is rated as of high reliability but because of the obvious lateral variation should not be extrapolated away from the borehole. The block is rated as of low commercial potential due to the poor thickness recorded in the borehole. The potential might improve towards the eastern edge of the block but would have to be proven by a program of detailed site investigation.

*Block G (Mathan Uchaf)* This block occupies a large area of 1.43 square kilometres running south from the junction of the A497 and the B4354 for some 2 kilometres. Its surface is complex. At the south it is forms part of the upper delta surface at around 48 m but rises north of Mathan Uchaf into a series of prominent mounds up to 78 m high. The northern part forms a subdued terrace at around 85 m sloping to the south. The block is occupied by a number of farms and dwellings and is bisected by a number of narrow minor roads. No exposure occurs within the area except for small surface scrapings. The assessment was made on the basis of two boreholes (UL07 and UL09) yielding 12 samples of mineral. The thickness of mineral in the three boreholes was 11.4 m and 10.2 m with minimum overburden. Water was not encountered. The thickness of minerals in the boreholes appears to be an underestimate, due to the irregular topography in the central part and the overall average thickness estimate has been increased to 15 m. The block is estimated to

contain 31.08 million tonnes of sand, 1.64 million tonnes of gravel and 1.72 million tonnes of waste with a sand to gravel ratio (excluding fines) of 95:5. No gravel larger than small pebble was encountered. The estimate is rated as high reliability but extrapolation from the boreholes should not be undertaken as the borehole density is low, the area is very large and lithological variation is likely to be considerable. The block is rated as of high commercial potential due to the quality and volume of mineral. Road access is good on the eastern margin but the remainder is served only by narrow minor roads.

*Blocks 1H (Efailnewydd), 1I (Llwyn Beuno), 1J (Crugan) and 1K (Rhyd-y-Clafdy)* These blocks are treated together as they have similar geological conditions. They all form part of the lower terrace at elevations between 10 and 12 m, and occupy a narrow strip west of Rhyd-y-clafdy (Block 1K), a fan-shaped block running to the coast east of Llanbedrog (Block 1J) and in two areas bordering Afon Rhyd-hir, west of Efailnewydd. (Blocks 1H and 1I). The terrace was formed by fluvial incision into the delta surface after the lake occupying the area had drained and is therefore likely to be composed of coarser-grained sediment. No boreholes were drilled through the blocks but section detail is available to the east of Cefn y Bont in Block 1H and on the coast east of Llanbedrog (Block 1J). The blocks were estimated to be an average of 5 m thick above the water table although exposure in Block 1H west of Efailnewydd suggests thickness to 8 or 10 m. On this basis the blocks are estimated to contain a combined total of 9.68 million tonnes of sand, 19.65 million tonnes of gravel and 7.33 million tonnes of waste with a sand to gravel ratio of 40:60. Because of the absence of boreholes these estimates have low reliability. All the blocks are ranked low in commercial potential due to their coarse grain, relatively high proportion of fines, limited thickness and proximity to the water-table.

*Mineral Summary* A summary of the potential mineral in the area is shown in Table 2. The eleven blocks contain an estimated 122 million tonnes of mineral including 95 million tonnes of Sand (75 % of total mineral), 27 million tonnes of gravel (20%) and 12 million tonnes of overburden and waste (10%) and occupy a total area of some 10 square kilometres with an average thickness of between 10 and 20 metres. Some two thirds of the sand occurs in blocks identified as having high commercial potential.

***Table 3: Area 1 Cors Geirch - Summary of Resource Blocks and Volumes***

| *Block* | *Landform Type* | *Basis of Assessment* | *Reliability* | *Commercial Potential* | *Area Sq Km* | *Block Volume (Millions of tonnes)* | *Sand (Millions of tonnes)* | *Gravel (Millions of tonnes)* | *Waste (Millions of tonnes)* |
|---|---|---|---|---|---|---|---|---|---|
| 1A Polish House | RT | 2 | M | L | 0.82 | 13.13 | 11.60 | 0.87 | 0.66 |
| !B Pen-y-bryn | DT | 1 | H | H | 0.35 | 11.64 | 10.49 | 0.91 | 0.23 |
| 1C Bryn Bodvel | DT | 1 | H | H | 0.86 | 24.65 | 22.01 | 1.41 | 1.23 |
| 1D Coed Cae-Rhos | DT | 1 | M | L | 0.73 | 4.68 | 3.74 | 0.71 | 0.23 |
| 1E Ty-isaf | DT | 1 | L | L | 0.70 | 4.45 | 2.72 | 1.60 | 0.13 |
| 1F Bodgadle | DT | 1 | H | M | 0.70 | 5.63 | 3.94 | 0.49 | 0.23 |
| 1G Mathan Uchaf | KM | 1 | H | H | 1.43 | 34.43 | 31.08 | 1.64 | 1.72 |
| 1H Efailnewydd | RT | 2 | M | L | 1.98 | 15.88 | 4.19 | 8.51 | 3.18 |
| 1I Llwyn Beuno | RT | 3 | L | L | 0.48 | 3.88 | 1.02 | 2.08 | 0.78 |
| 1J Crugan | RT | 3 | M | L | 1.15 | 9.23 | 2.44 | 4.95 | 1.85 |
| 1K Rhyd-y-Clafdy | RT | 3 | L | L | 0.96 | 7.68 | 2.03 | 4.12 | 1.54 |
| **Total for Area** | | | | | **10.17** | **135.28** | **95.26** | **27.28** | **11.77** |

The mean grading of the resources in the area, based on sixty samples taken from 8 blocks, is shown in Table 3 and the envelope of grading curves in Figure 5. The median grain size is medium sand (0.25-0.50 in diameter), averaging 32% of total mineral. Almost all the sands are well sorted. The proportion of fines is in all cases below the search criteria limit of more than 15 %. Only one block, Block 1H (Efailnewydd) had more than the search criteria maximum limit of more than 5% cobble gravel.

**Table 4: Area 1 Cors Geirch - Block Mean Grading Percentage**

| | | Size Distribution (%) | | | | | | Fines:Sand:Gravel Ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Block* | *Samples* | *Cobble Gravel* | *Pebble Gravel* | *Coarse Sand* | *Medium Sand* | *Fine Sand* | *Fines* | *% Fines* | *% Sand* | *% Gravel* |
| 1A Polish House | 3 | 0.00 | 6.22 | 13.84 | 55.34 | 19.56 | 5.04 | 5.04 | 88.74 | 6.22 |
| 1B Pen y Bryn | 15 | 0.00 | 7.22 | 16.37 | 56.31 | 16.35 | 3.79 | 3.79 | 89.03 | 7.22 |
| 1C Bryn Bodvel | 19 | 0.00 | 4.88 | 4.71 | 17.45 | 59.16 | 13.80 | 13.80 | 81.31 | 4.88 |
| 1D Coed Cae-rhos | 4 | 0.00 | 11.80 | 41.72 | 35.12 | 8.37 | 3.00 | 3.00 | 85.21 | 11.80 |
| 1E Ty-Isaf | 3 | 0.00 | 34.66 | 30.65 | 22.07 | 9.69 | 2.93 | 2.93 | 62.41 | 34.66 |
| 1F Bodgadle | 2 | 0.00 | 12.50 | 42.20 | 31.70 | 10.00 | 3.60 | 3.60 | 83.90 | 12.50 |
| 1G Mathan Uchaf | 12 | 0.00 | 4.16 | 5.57 | 33.34 | 47.49 | 9.44 | 9.44 | 86.40 | 4.16 |
| 1H Efailnewydd | 2 | 6.20 | 47.23 | 13.03 | 12.39 | 8.85 | 12.32 | 12.32 | 34.27 | 53.43 |
| 1I Lwyn Beuno | * | | | | | | | | | |
| 1J Crugan | * | | | | | | | | | |
| 1K Rhyd-y-Clafdy | * | | | | | | | | | |
| **Average for Area** | | **0.78** | **16.08** | **21.01** | **32.96** | **22.43** | **6.74** | **6.74** | **76.41** | **16.86** |

* Not sampled.

*Summary Conclusions:*

- Area 1 has very significant volumes of easily worked, high quality sand amounting to some 95 million tonnes, together with 27 million tonnes of gravel
- Few of the resource blocks identified are directly constrained by environmental designations
- Resource blocks located on the high delta terrace generally provide the best resources
- Blocks 1B (Pen-y-Bryn), 1C (Bryn Bodvel), and 1G (Mathan Uchaf) are of relatively high commercial potential
- Block 1A (Polish House) has significant volume of good quality sand but is largely sterilised by current and planned future development and is consequently rated as low commercial potential.
- Blocks 1D (Coed Cae-Rhos), 1E (Ty-isaf) and 1F (Bodgadle), though located on the high terrace, are of low volume and limited thickness and are rated as of low commercial potential
- Blocks 1H (Efailnewydd), 1H (Llwyn Beuno), 1J (Crugan) and 1K (Rhyd-y-clafdy), all occurring on the lower terrace of the area are dominantly coarse, relatively thin, have high proportions of waste and are probably affected by high water tables. They are rated as low commercial potential.

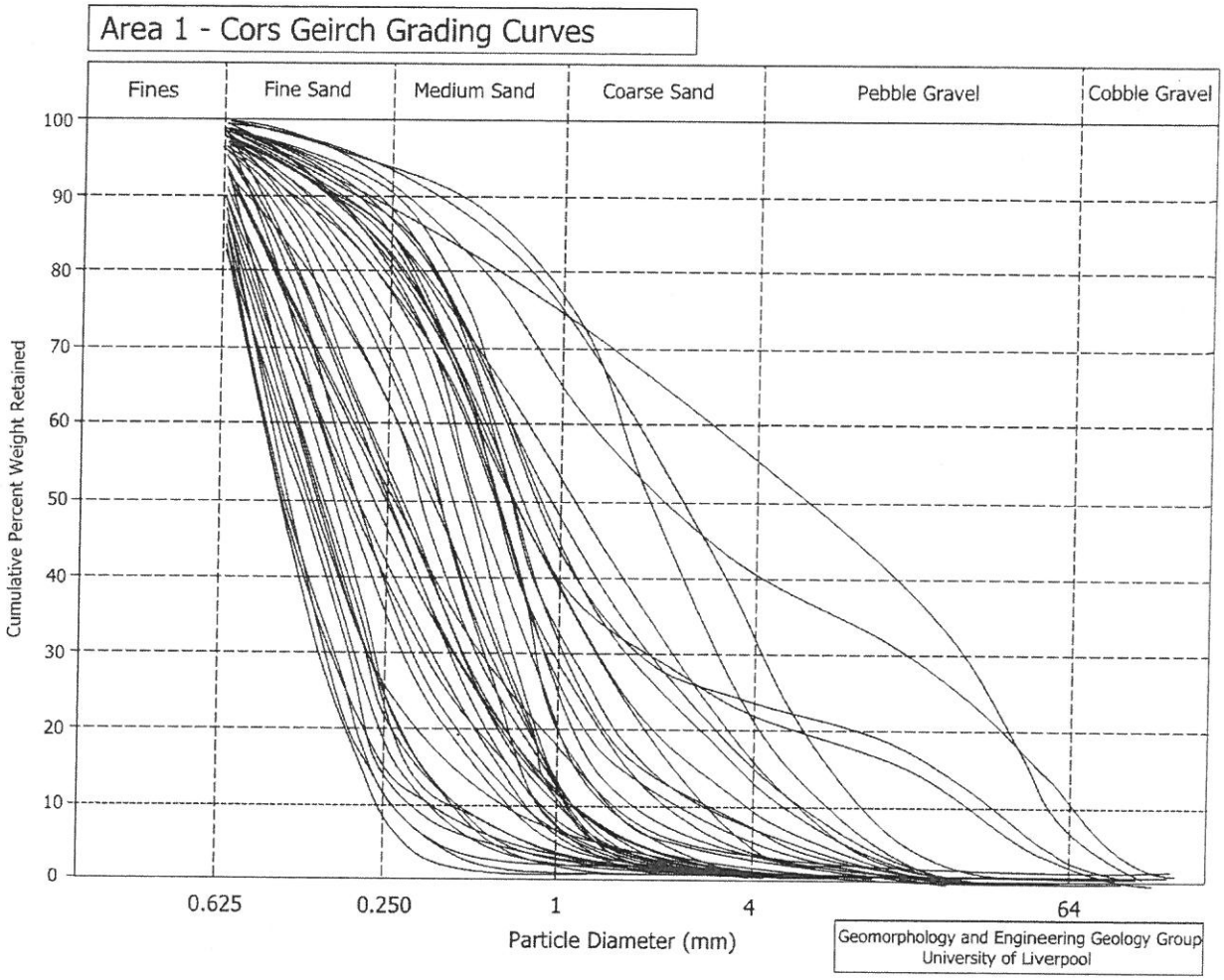


*Figure 5 Grain-size distribution curves for Area 1 – Cors Geirch.*

## 10.2 Area 2 Nefyn

*Description* This area lies to the south and west of Nefyn and forms the eastern part of a low coastal plain running southwest towards Tudweiliog. It covers some twenty five square kilometres and is bounded on its northern and western side by the sea and on its southern and eastern side by the hill masses of Carn Fadryn, Garn Boduan and Gwylwyr. The line of the hills is broken between Carn Fadwyn and Garn Boduan by a wide col on the floor of which is a deeply incised channel running southeast into the head of Cors Geirch where it is contiguous with Area 1. Included within the area is the town of Nefyn, the villages of Morfa Nefyn, Edern and Tudweiliog together with some sixty farms and rural dwellings. There is no 1:50,000 geological map cover and very few pre-existing boreholes. One former sand and gravel quarry, now restored, is located at Maesoglan. Unpublished geomorphological maps and geological sections, together with geological reports on the recent landslide at Porth Nefyn, provide considerable stratigraphic detail of the extensive coastal exposure between Porth Dinllaen and Penrhyn Bodeilas. Contrary to the British Geological Survey 1:625,0000 map, which shows the subdued ridges running between Edern towards Tudweiliog as sand and gravel, most appears to be composed of diamict and the target area was consequently drawn to include only prominent mounds, each between 20 and 40 m in height, occurring around Maesoglan, south of Porth Dinllaen and around Fron Oleu, immediately south of Nefyn. The area was selected as a target because of the proven outcrops of sand and gravel along the adjacent coast and the former extraction from the Maesoglan quarry.

*Geomorphology* The geomorphology of the area is shown in Appendix A, Figure 3 and consists of a series of large, irregular ridges, up to 50 m in height, orientated NNW to SSE and separated by

deeply entrenched channels that lead into the head of the Cors Geirch to the south-east. The main ridges are complex and consist of a set of irregular subsidiary ridges, mounds and basins, many water filled. The series of ridges are all probably kame moraines, formed at the margin of the Irish Sea ice-sheet when it lay against the slope of the coastal hill masses during a major still-stand episode in its retreat. The irregular form of the ridges and the evidence of collapse into small basins, suggests that most were created by ice stagnation rather than push and are therefore likely to be composed of sand and gravel rather than diamict.

*Resource Blocks and Designations* Three potential resource blocks have been identified in the area and are shown in Appendix A, Figure 4 together with environmental designations. Block 2A (Maesoglen) is unconstrained but abuts against an AONB on its southern margin, a SSSI on its northern and eastern boundaries and is adjacent to a NNR to the southeast. Block 2B (Porth Dinllaen) is almost entirely within an AONB, except for a small portion along its southern boundary, and is bounded on its northern side by a SSSI and a SAC and is constrained by a large golf course. The coastline forming the northern margin of the block is a Heritage Coast. Block 2C (Fron Oleu) is bounded on its east by an AONB and on its south by an SSSI.

*Assessment strategy* Two blocks, 2A (Maesoglan) and 2C (Fron Oleu), were investigated by assessment method 1 using boreholes and samples obtained from them, together with section detail from an abandoned quarry in the Maesoglan block. Block 2B (Porth Dinllaen) was not drilled as excellent sections through the block were available in coastal cliff section cutting through it.

*Block 2A (Maeslogen)* This block occupies a large area of 3.2 square kilometres south of the junction between the A497 and the B4412, south of Nefyn. It forms a prominent, elongated ridge, up to 35 m above surrounding ground, running broadly east to west (Appendix A, Plate 3). The surface is complex with numerous minor ridges, mounds and channels and a distinctive area of kettle basins on its southern margin where the ridge abuts against the rock towards Mochras. The block is occupied by a small number of farms and rural dwellings and abuts against an AONB on its southern margin and a SSSI on its eastern margin. Limited exposure occurs in the former sand and gravel quarry and waste disposal site at Maeslogen (Figure 6), now partly landscapes, and has been figured by Edge[1]. Numerous small exposures occur on the sides of minor road cuts and almost all show sand with some subordinate gravel.

[1] Edge, M.J. 1990. 'Cors Geirch and Maesoglan' In: Addison, K., Edge, M.J. and Watkins, R. (Eds) The Quaternary of North Wales: Field Guide, Quaternary Research Association, Coventry.

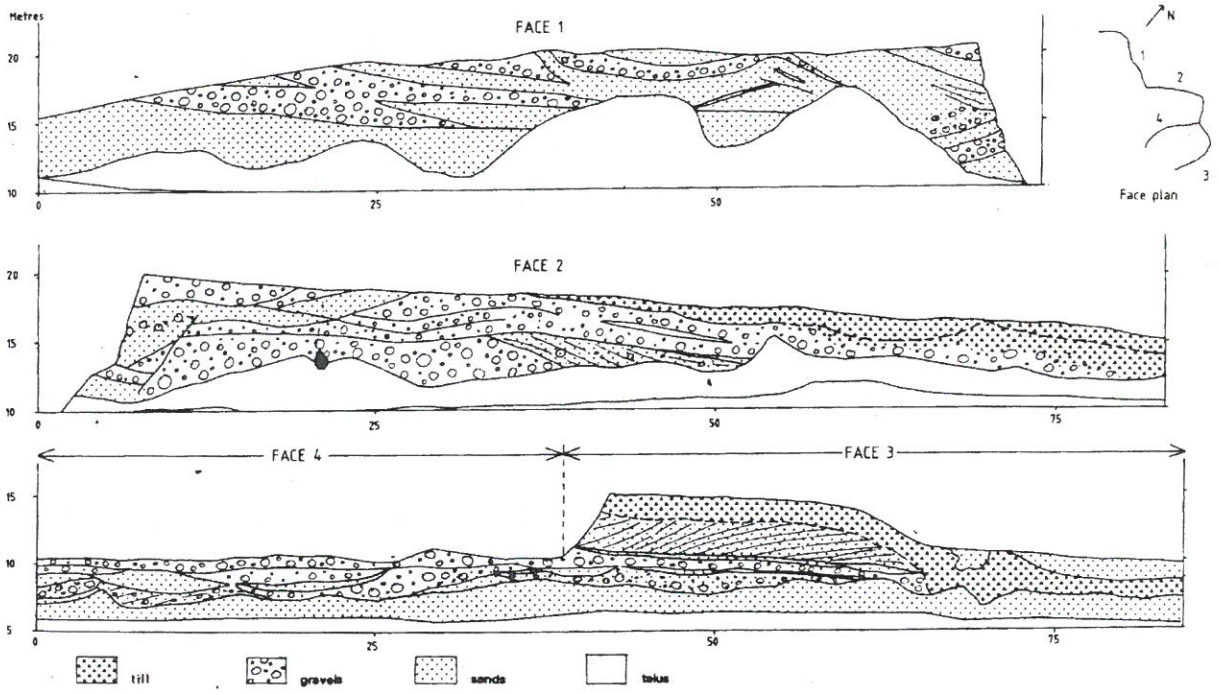


*Figure 6 Sections in the former Maeslogen Quarry (From Edge, 1990).*

The ridge is identified as a large kame-moraine complex formed at the margin of the stagnating Irish Sea Ice margin when it blocked the col between Garn Boduan and Carn Fadryn and passed meltwater drainage south into the prograding deltas filling the lake at Cors Geirch. Sedimentary sequences confirm this and are characteristic of distal sandur, lake delta foresets and shallow-water lake floor. The assessment was made on the basis of one borehole (UL10) located in the centre of the ridge north of Groesffordd and test samples taken from the borehole, the former workings at Maeslogen and road cuts. The borehole reached 18 m depth with 15 m metres of was mineral recorded with 3 m of intercalated waste. Water was not encountered. The block is estimated to contain 42 million tonnes of sand, 18 million tonnes of gravel and 7 million tonnes of waste. No gravel larger than small pebble was encountered. The estimate is rated as of high reliability but extrapolation from the boreholes should not be undertaken as the borehole density is low, the area is very large and lithological variation is likely to be considerable. The block is rated as of high commercial potential due to the quality and volume of mineral. Road access is good.

*Block 2B (Porth Dinllaen)* This block occupies a low, subdued, poorly defined ridge of approximately 0.77 square kilometers located to the west of Morfa Nefyn and south of Porth Dinllaen. The eastern margin abuts against residential property in Morfa Nefyn and much of the remainder of the area is occupied by a golf course. The block lies wholly within an AONB, is bounded to the north by a Heritage Coast and a SAC and to the west by a SSSI. The block is very well exposed in coastal cliff sections to the north and south of Porth Dinllaen and the block is identified as a kame moraine formed at the margin of the Irish Sea Ice when it had retreated from Maeslogan towards the coast. The assessment was made from coastal sections exposed around Porth Dinllaen. These show extensive sequences of well sorted fine to medium sand and subordinate gravel and mud (Figures 7, 8 and 9); all characteristic of a distal sandur environment draining from an Irish sea ice margin to the north. The block is estimated to contain 9 million tonnes of sand and 4 million tonnes of gravel. No gravel larger than small pebble was encountered. The block is rated as of low commercial because due to the high level of environmental constraint.

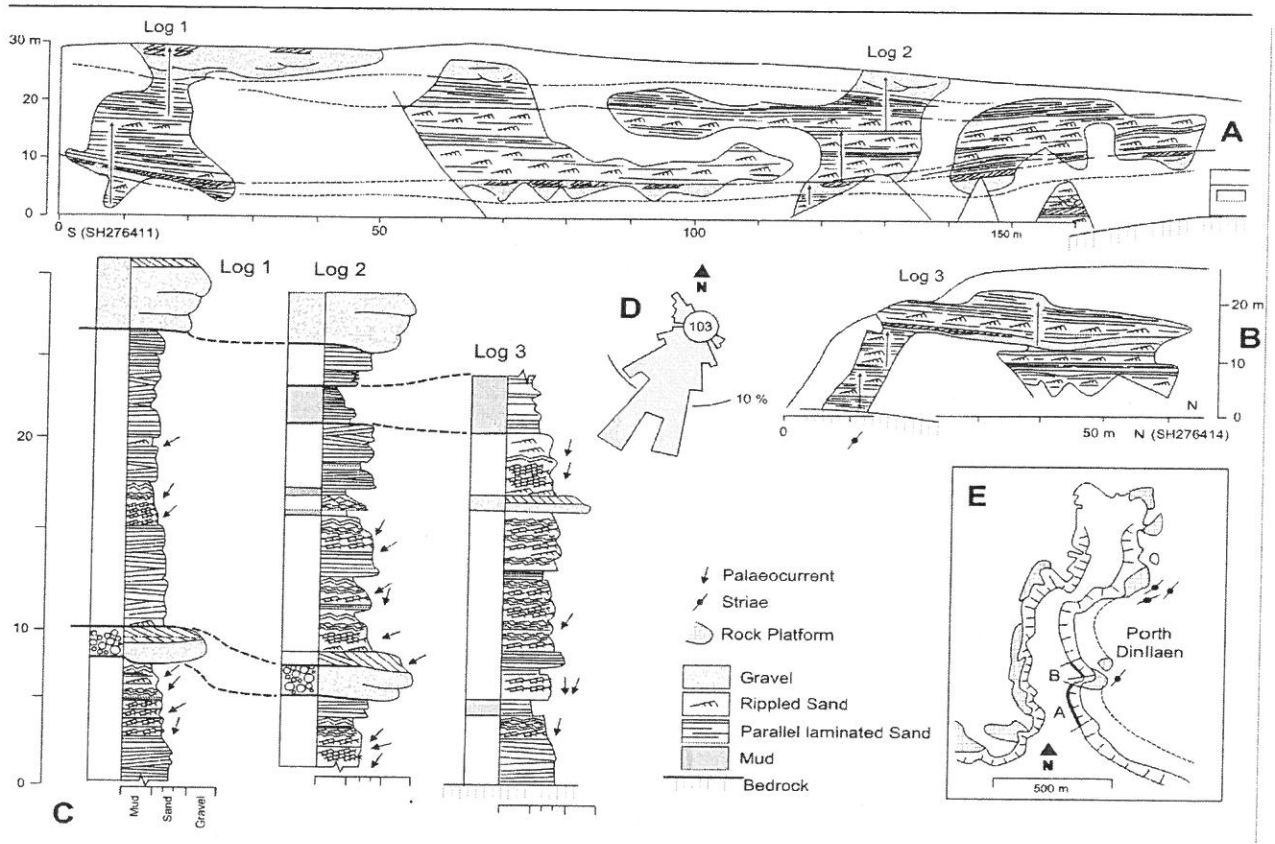


*Figure 7 Coastal sections in glacial deposits around Porth Dinllaen. A and B: Sections south of Porth Dinllaen. C: Vertical log profiles showing vertical variation in amount of sand and gravel. D. Palaeocurrent indicators. These show the direction of former glacial stream flow. E: Location of sections.*

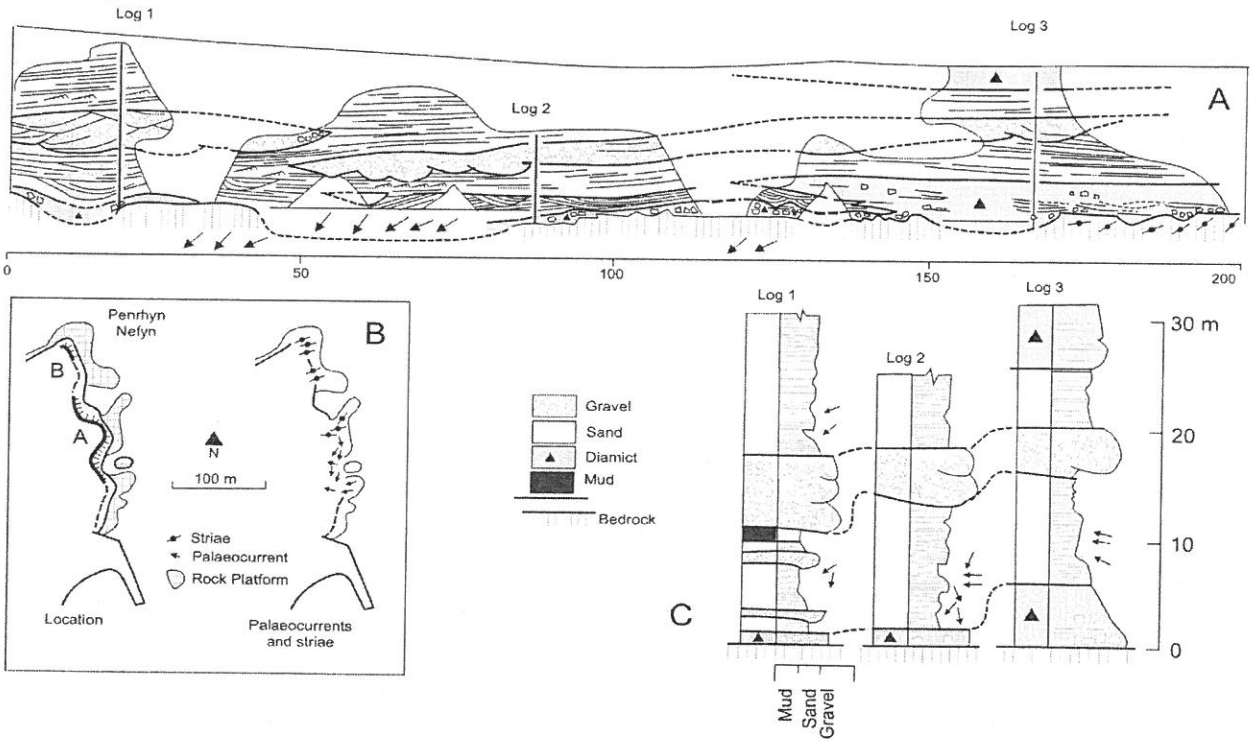


*Figure 8. Coastal sections in glacial deposits around Penrhyn Nefyn. A: Cliff sections. B: Location of sections.. C: Vertical log profiles showing vertical variation in amount of sand and gravel.*

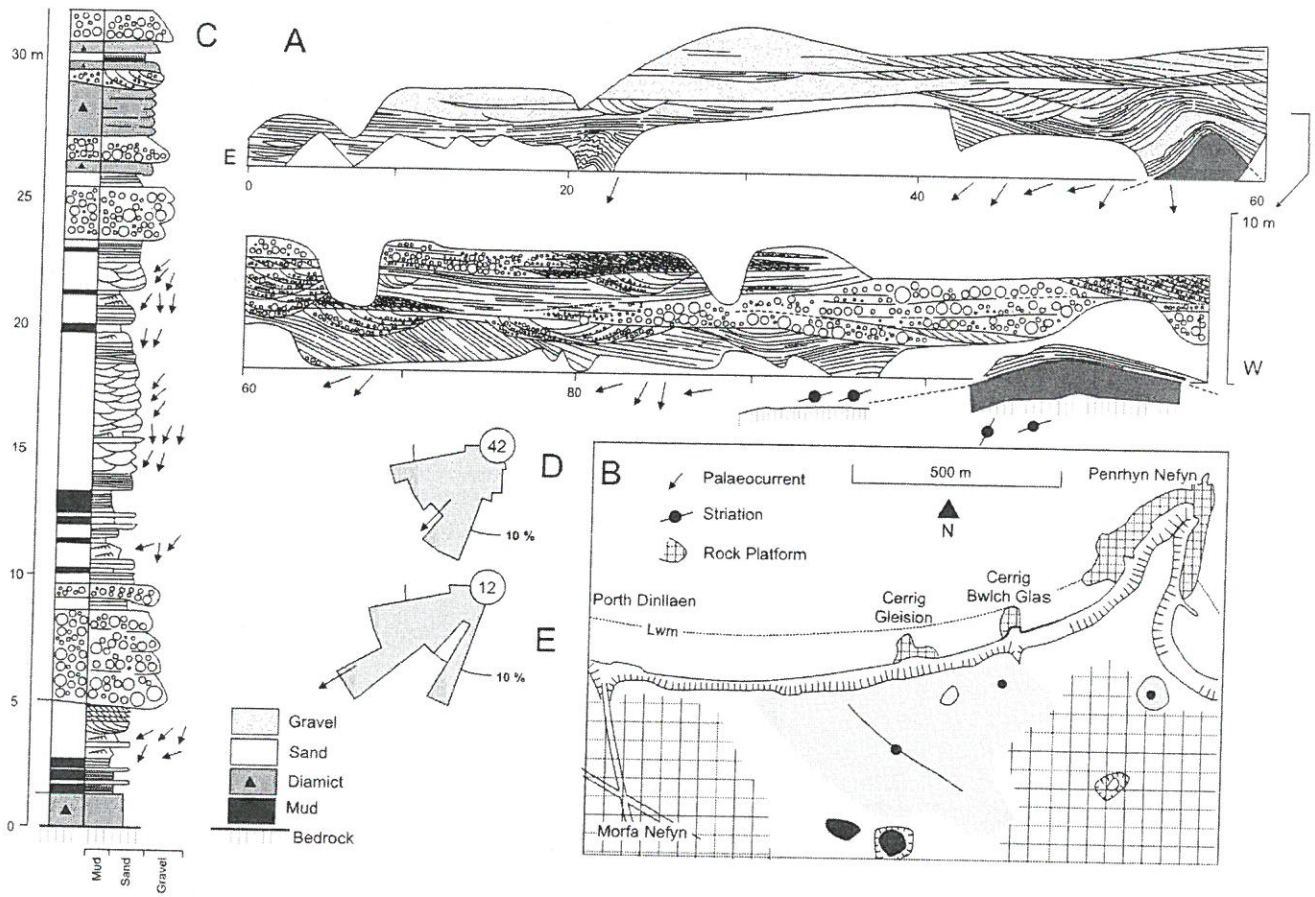


*Figure 9 Coastal sections around Morfa Nefyn. A: Section in cliff between Cerrig Bwlch Glas and Cerrig Gleision. B: Geomorphological map of area. C: Generalised vertical log profile. Serial section. D Palaeocurrents. E: Striations.*

*Block 2C (Fron Oleu)* This block occupies a low, flat-topped terrace of approximately 0.8 square kilometers, sloping gently south from Nefyn towards the junction of the A497 and the B4412. It is bounded on its east by an AONB and on its south by an SSSI. The block is unexposed and the assessment was made using one borehole (UL11) which recorded 7 m of mineral before encountering an obstruction. Water was not encountered. The block is estimated to contain 6.4 million tonnes of sand, 2.76 million tonnes of gravel and 1.02 million tonnes of waste. No gravel larger than small pebble was encountered. The estimate is rated as of high reliability but extrapolation from the boreholes should not be undertaken as the borehole density is low. Commercial potential is moderate.

*Mineral Summary* The three blocks occupy an overall area of some 5 square kilometres with an average thickness of 10 m. A summary of the potential mineral is shown in Table 4 and the mean grading for the area, based on 17 samples taken from the three blocks, is shown in Table 5. The proportion of fines in the drill hole from block 2A (Maesoglen) is very high and compared to the samples from former quarry workings appear to be unrepresentative of the mineral block as a whole. Similar consideration apply to block 2C (Fron Oleu). Consequently, the proportion of fines in these two blocks has been reduced to 10% in Table 4 and the proportion of sand and gravel proportionately increased in order to reflect this. On this basis the three blocks contain an estimated total of 83 million tonnes of potential mineral including 58 million tonnes of sand (63%) and 25 million tonnes of gravel (27%). The mean grading for the area, based on 17 samples taken from the three blocks, is shown in Table 5 and the envelope of grading curves in Figure 10. The median grain size is fine sand in all blocks but with significant variation within and between blocks. Cobble gravel does not occur.

**Table 5: Area 2 Nefyn - Summary of Resource Blocks and Volumes**

| Block | Landform Type | Basis of Assessment | Reliability | Commercial Potential | Area Sq Km | Block Volume (Millions of tonnes) | Sand (Millions of tonnes) | Gravel (Millions of tonnes) | Waste (Millions of tonnes) |
|---|---|---|---|---|---|---|---|---|---|
| 2A Maesoglen | KM | 1 | M | H | 3.22 | 66.93 | 42.17 | 18.07 | 6.69 |
| 2B Porth Dinllaen | KM | 2 | M | L | 0.77 | 14.73 | 9.28 | 3.98 | 1.47 |
| 2C Fron Oleu | KM | 1 | M | M | 0.80 | 10.21 | 6.44 | 2.76 | 1.02 |
| **Total for Area** | | | | | **4.78** | **91.87** | **57.89** | **24.81** | **9.18** |

**Table 6: Area 2 Nefyn – Mean Block Grading Percentage**

| | | Size Distribution (%) | | | | | | Fines:Sand:Gravel Ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Block | Samples | Cobble Gravel | Pebble Gravel | Coarse Sand | Medium Sand | Fine Sand | Fines | % Fines | % Sand | % Gravel |
| 2A Maesoglen | 7 | 0.00 | 1.89 | 5.26 | 12.88 | 50.22 | 29.80 | 29.80 | 68.36 | 1.89 |
| 2B Porth Dinllaen | 6 | 0.00 | 5.12 | 19.75 | 33.76 | 29.73 | 11.64 | 11.64 | 83.24 | 5.12 |
| 2C Fron Oleu | 4 | 0.00 | 4.88 | 4.71 | 17.45 | 59.16 | 13.80 | 13.80 | 81.31 | 4.88 |
| **Average for Area** | | **0.00** | **3.97** | **9.91** | **21.36** | **46.37** | **18.41** | **18.41** | **77.64** | **3.97** |

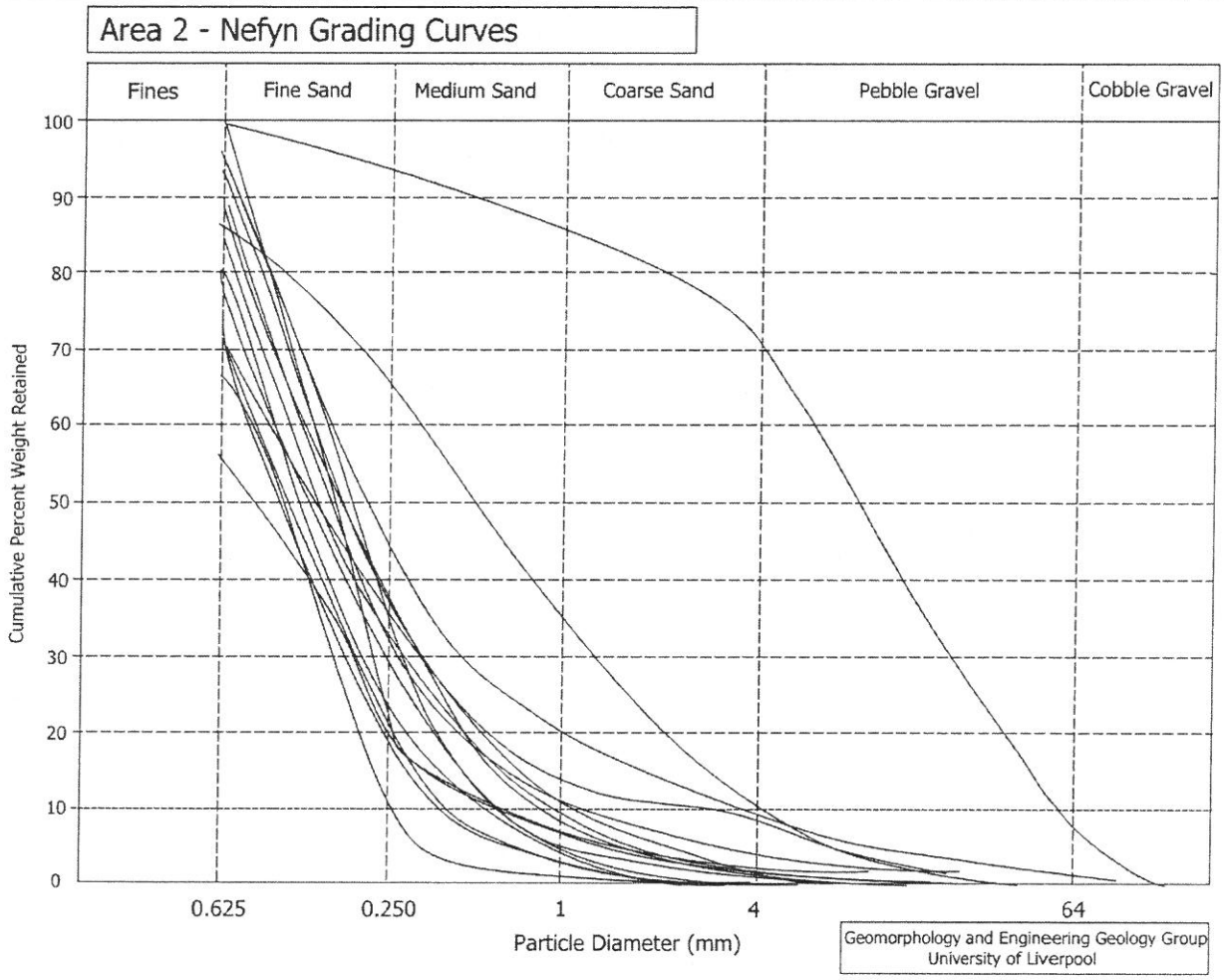


*Figure 10 Grain-size distribution curves for Area 2 - Nefyn.*

*Summary Conclusions:*

- Area 2 has significant volumes of easily worked, high quality sand and gravel amounting to 58 million tonnes of sand and 25 million tonnes of gravel.
- The estimate for Block 2A (Maesoglen) is regarded as only of moderate reliability as the one borehole appears to be unrepresentative. The kame moraine origin of the block suggests considerable local variation in mineral quality and further investigation would be needed to ensure a low proportion of fines in the mineral. On the basis of the proportion of sand and gravel, however, the block is rated as of high commercial potential.
- The estimate for Block 2B (Fron Oleu) is also regarded as of only moderate reliability, for the same reasons as above. In addition, the one borehole terminated at only 8m due to obstruction in cobble gravel, giving some uncertainty about the total thickness of mineral. As a consequence this block is rated as of medium commercial potential.
- Although Block 2C (Porth Dinllaen) has significant volume of mineral it is highly constrained by environmental designations as well as development and is ranked as of low commercial potential.

## 10.3 Area 3 Trefor - Pontllyfni

*Description* This area forms a narrow strip between the coast and the steep rock massif of Bwlch Mawr, between Trefor and Pontllyfni on the shore of Caernarfon Bay and occupies an area of some 5 square kilometres. Included within the area is the village of Clynog and some forty or fifty farms and dwellings. There is no former geological or geomorphological map cover but extensive exposure occurs in coastal cliffs. There is no history of mineral working and the area is devoid of borehole information. The area was selected as a target area principally because of the proven outcrops of sand and gravel along the adjacent coastal sections.

*Geomorphology* The geomorphology of the area is shown in Appendix A, Figure 5 and consists of a simple series of sub-parallel, low amplitude linear ridges up to 20 m high and up to a kilometer long running southwest, oblique to the coast, and separated by narrow, flat-floored channels. The sub-parallel form of the ridges identify them as ice-marginal moraines, each marking a stage in the retreat of the Irish sea ice-margin. Coastal exposure through them, however, demonstrates that they vary in origin. Some are entirely composed of undeformed diamict and are probably ablation moraines while others are composed of alternating thrust slices of diamict and deformed outwash, indicating that they are push moraines. The intervening troughs are composed of sand and gravel and represent marginal sandur systems draining parallel to the ice–margin to the southwest.

*Resource Blocks and Designations* Ten potential resource blocks were identified in the area and are shown in Appendix A, Figure 6 together with environmental designations. The whole of the coast is part of a Heritage Coast and all but two blocks in the north of the area fall entirely within an AONB. Block 3J (Aberafon), at the southern end of the area is fronted by a SSSSI along the foreshore. Only the two northern blocks, Blocks 3A (Pontllynfi) and 3B (Cai Morfa), are entirely unconstrained. The blocks in this area can be divided into two types, Type 1 and Type 2, based on their primary geological characteristics, and their differences have significant implication for aggregate resources both in this area and those to the north.

*Type 1 blocks* These include Blocks 3B, 3D, 3F, 3H and 3J. They form a series of narrow, sub-parallel, flat-floored channels running southwest off the rock slope, obliquely towards the coast. Block 3J (Aberafon), at the southern end, is well exposed in cliff section and Block 3B (Cai Morfa) has limited section in a river cut to the east of Pont Aberdesarch. Blocks 3D (Ty'n-y-Coed), 3F (Bach Wen) and 3H (Clynnog) are unexposed but it is likely that they are composed of similar sedimentary sequences. Sections in Block 3J (Aberafon) are illustrated in Figures 11 and Appendix A, Plate 6 and show complex lateral transitions between sand and gravel. To the north, however, the sands and gravels are overlain by a diamict sheet that thins and passes out of the sections to the south. Beneath the diamicts the sands and gravels are deformed. The sequence is consistent with the filling of a large ice-marginal channel system subsequently partially overridden by minor advance of the ice. Consequently, the Type 1 Blocks represent a response to progressive retreat of an ice margin and the creation and then abandonment of marginal sandur systems in front of it. Each of these blocks therefore represents a potential sand and gravel resource as it is dominated by proglacial fluvial processes rather than sub-glacial or ice-marginal processes.

*Type 2 Blocks* These include Blocks 3A, 3C, 3E, 3G and 3I. They form the counterpart to the marginal sandur channels of Blocks 3B, D, F, H and J described above in that they each occurs separating one Type 1 block from the next. Thus a Type 1 block is followed by a Type 2 which in turn is followed by a further Type 1 block in ordered sequence northwards up the coast. Type 2 blocks consist of narrow ridges, up to 25 m high, orientated north-east to south-west and predominantly composed of diamict or alternating diamict and coarse-grained gravel. Thus, Block 3G (Ffynnon Beuno) is almost completely composed of diamict (Figure 12), is deformed and is probably a push-moraine[1]; Block 3A (Pontlynffi) is composed of thick diamict underlying coarse gravel (Figure 13); Block 3I (Tyddyn Hen) is composed of thick diamict overlying coarse gravel

[1] See section 7 for a discussion of the various types of moraine ridges, their internal composition and aggregate potential.

(Figure 14); and Block 3C (Pen-y-Bryn Mawr) is composed of a rapidly varying sequence of intercalated diamicts and gravels (Figure 15). These sequences are consistent with deposition at or immediately to the rear of an ice margin either by ablation of debris from within the ice or flow of surface debris off the ice-margin, resulting in thick accumulation of diamict. In all cases the aggregate resource potential of this type of block is very low.

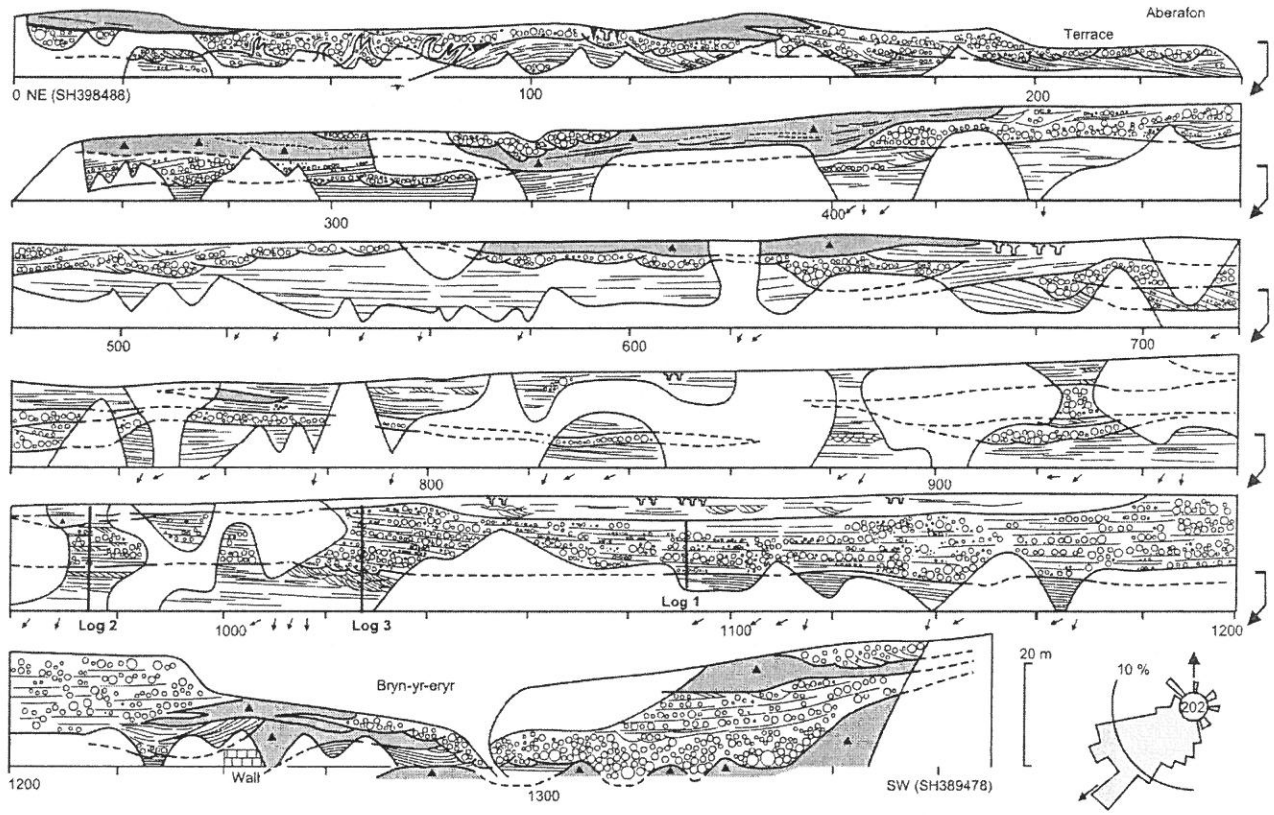


*Figure 11 Sections through a Type 1 Block: the ice-marginal channel forming Block 3J at Aberafon. Note that the sections are largely composed of sand and gravel overlain by diamict to the north,*

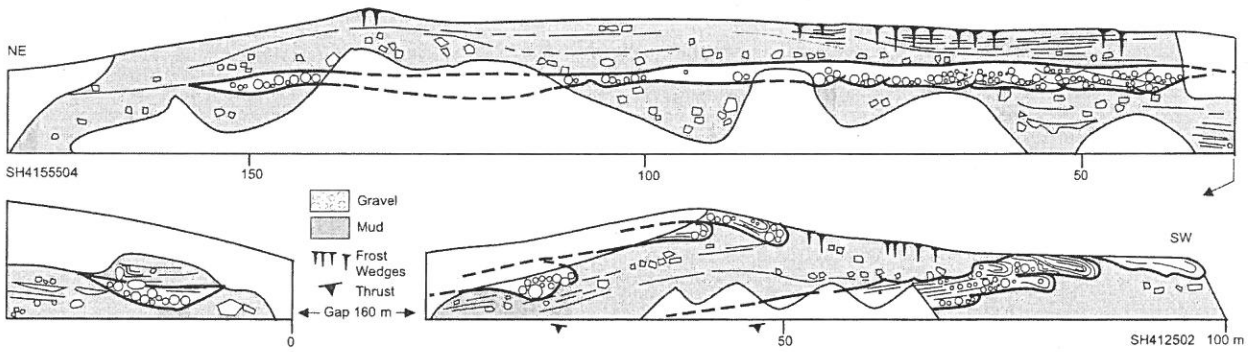


*Figure 12 Sections through a Type 2 Block: the moraine ridge forming Block 3G at Ffynnon Beuno. Note that the ridge is composed almost wholly of diamict. Note the overfolds at bottom right. The moraine is a push moraine, formed by successive override of the glacier margin.*

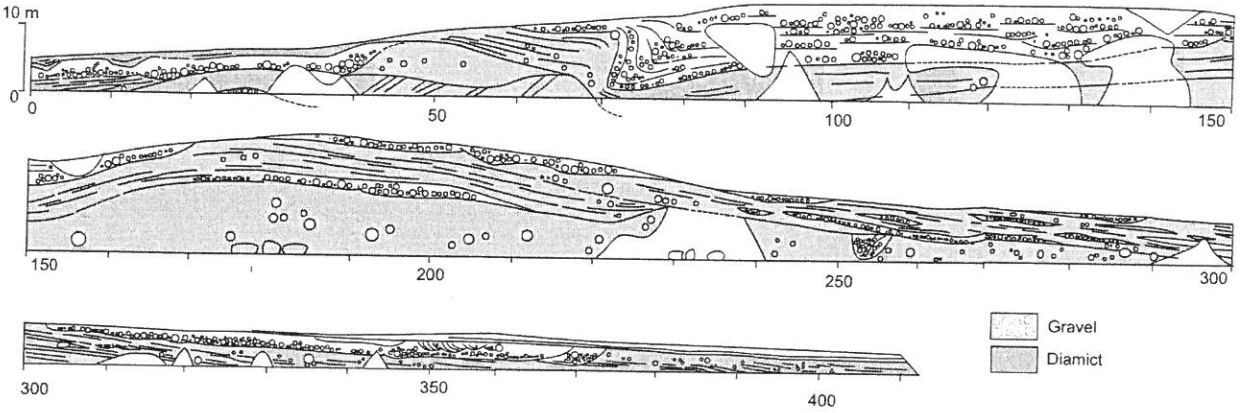


*Figure 13 Sections through a Type 2 Block: the moraine ridge forming Block 3A at Pontllynfi. The sections are largely composed of diamict underlying gravels. Note the large deformation structures at around 70-80 m. The moraine is part an ablation moraine and part a push-moraine.*

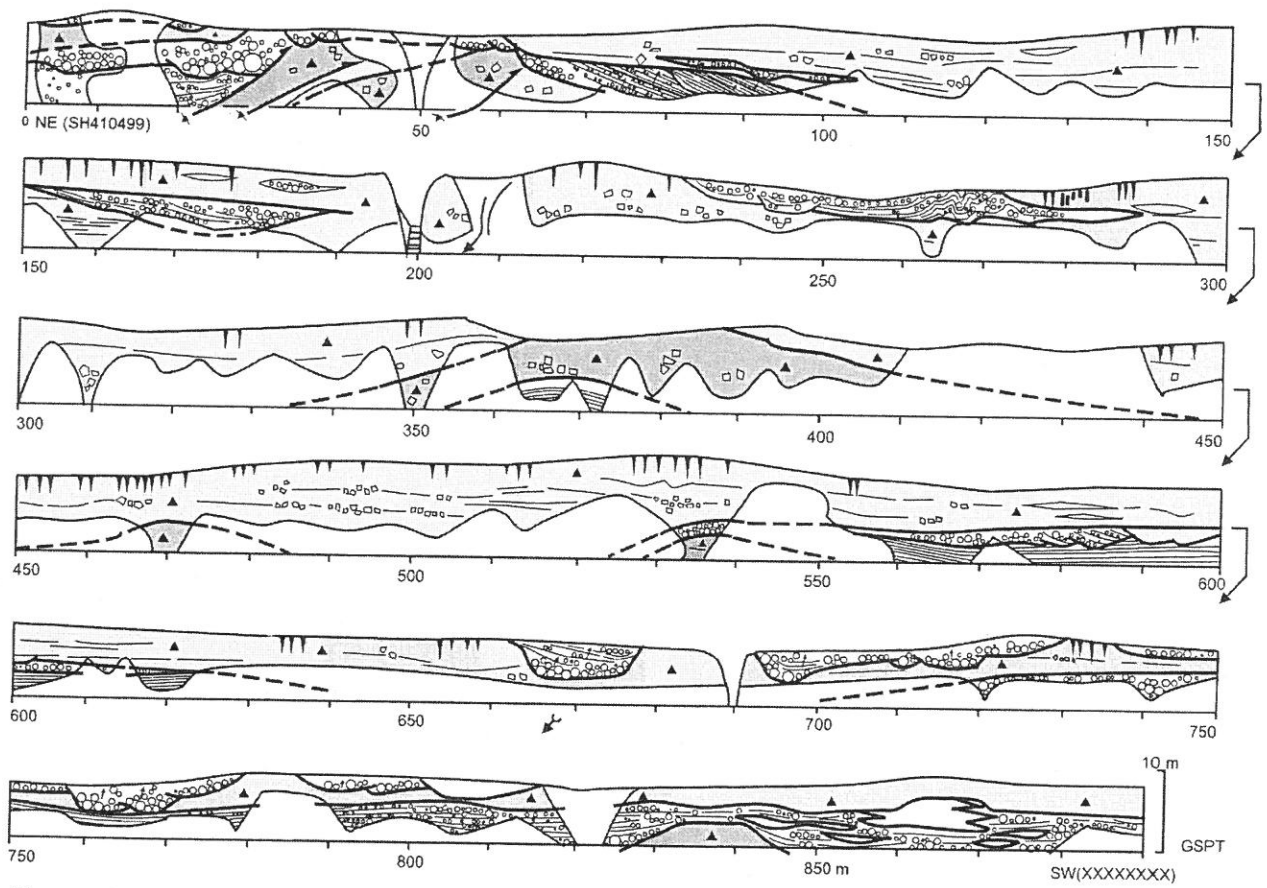


*Figure 14 Sections through a Type 2 Block: the moraine ridge forming Block 3I at Tyddyn Hen. The sections are largely composed of diamict overlying gravels. Note thrusting between 1-50 m. The moraine was probably formed by successive override of the ice margin and consequent deposition of diamict.*

*Assessment strategy* No boreholes were drilled in the area and reliance was placed on the extensive coastal exposure to determine internal composition. Consequently, a different method of calculating volumes was used. Total volume of potential mineral was calculated by multiplying the area of the block by the estimated average thickness of mineral in the block. A percentage proportion of mineral and waste was then estimated from stratigraphic detail in coastal exposure. Thus, if 25 % was mineral and 75% non-mineral, usually diamict, the volume for each was allocated accordingly. The volume of mineral obtained was then allocated to sand or gravel by estimating the proportion of each from logs taken through the sections, taking into account the proportion of sand contained in mixed sand and gravel units and the proportion of gravel exceeding pebble size

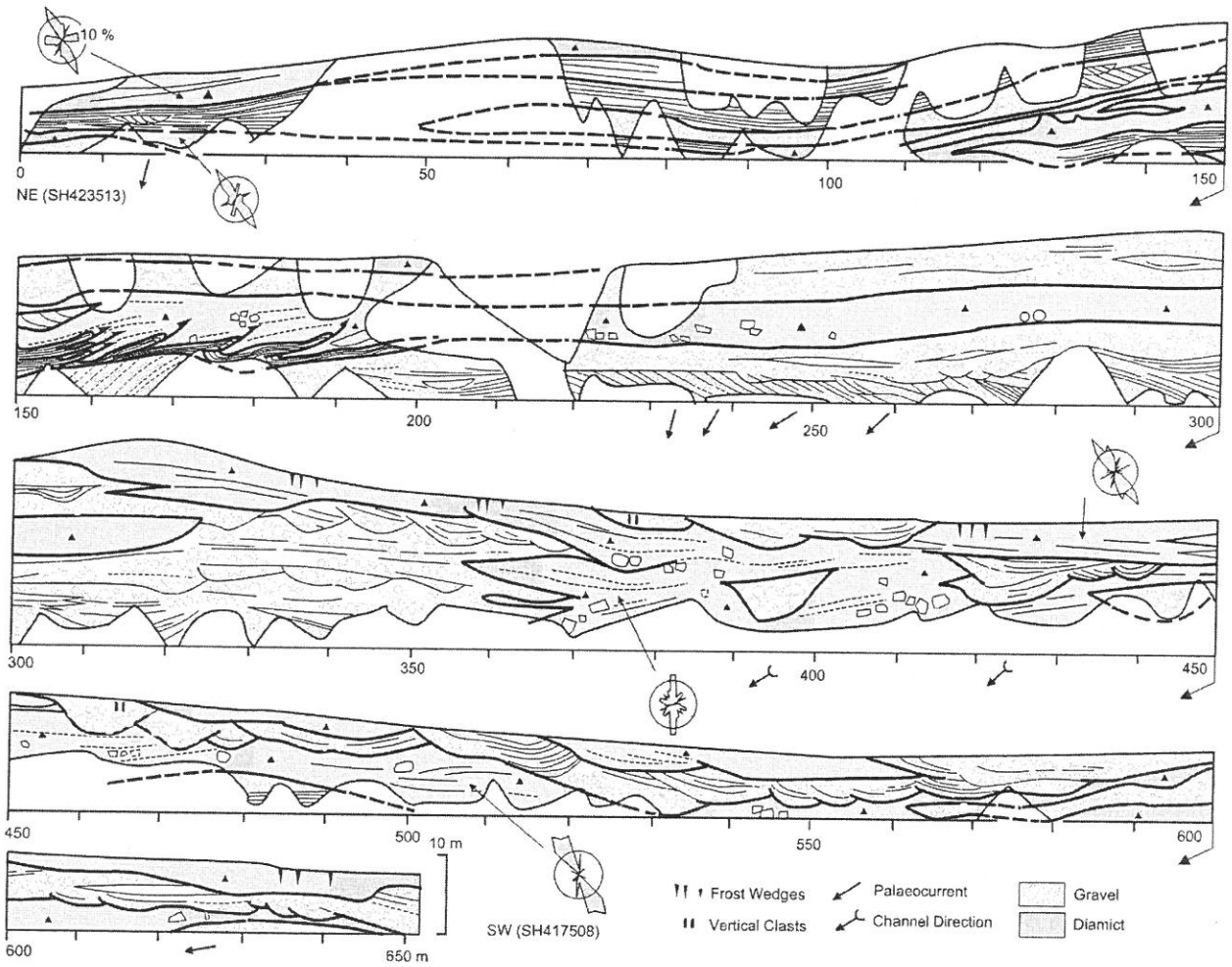


*Figure 15 Sections through a Type 2 Block: the moraine ridge forming Block 3C at Pen-y-Bryn Mawr. Note the complex interdigitation between diamict and coarse gravel and the low-angled thrusts between 150-200 m. The moraine was probably formed during a prolonged period of ice-marginal oscillation.*

*Mineral Summary* The ten blocks occupy an area of some 3 square kilometres with an average thickness of 8.5 m. A summary of the potential mineral is shown in Table 6. Overall, the blocks are estimated to contain some 23 million tonnes of mineral made up of 9 million tonnes of sand and 13 million tonnes of gravel, plus 23 million tonnes of waste. Reflecting their different origins, the blocks vary significantly in the volume of mineral contained within them and many fall outside the search criteria either because the ratio of waste to mineral exceeds 50%, the calculated minimum mineral volume is less than 0.5 million tonnes or the percentage of gravel larger than cobble exceeds 5% or, in some cases, all three. Thus, all the blocks defined as Type 2, push or ablation moraines, have low volumes of mineral and high volumes of waste. Blocks defined as

Type 1, marginal sandur, in contrast, have a high proportion of sand and gravel and low volumes of waste.

**Table 7: Area 3 Trefor - Pontlynffi - Summary of Resource Blocks and Volumes**

| Location | Block Type | Landform Type | Basis of Assessment | Reliability | Commercial Potential | Area Sq Km | % Mineral in Block | % Waste in Block | % Sand in Mineral | % Gravel n Mineral | Block Volume (Millions of tonnes) | Sand (Millions of tonnes) | Gravel (Millions of tonnes) | Waste (Millions of tonnes) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3A Pontllynfi [1] | 2 | PM | 2 | M | L | 0.43 | 20 | 80 | 30 | 70 | 6.83 | 0.41 | 0.96 | 5.47 |
| 3B Cai Morfa | 1 | MS | 3 | L | L | 0.44 | 70 | 30 | 40 | 60 | 3.51 | 0.98 | 1.48 | 1.05 |
| 3C Pen-y-Bryn Mawr [1] | 2 | PM | 2 | M | L | 0.32 | 50 | 50 | 20 | 80 | 7.70 | 0.77 | 3.08 | 3.85 |
| 3D Ty'n-y-Coed | 1 | MS | 3 | L | L | 0.52 | 70 | 30 | 30 | 70 | 4.15 | 0.87 | 2.03 | 1.24 |
| 3E Cefngwreichion [1 2] | 2 | PM | 2 | M | L | 0.21 | 10 | 90 | 20 | 80 | 3.40 | 0.07 | 0.27 | 3.06 |
| 3F Bach Wen | 1 | MS | 2 | L | L | 0.14 | 80 | 20 | 30 | 70 | 1.10 | 0.27 | 0.62 | 0.22 |
| 3G Ffynnon Beuno [1] | 2 | PM | 2 | M | L | 0.21 | 20 | 80 | 30 | 70 | 3.32 | 0.20 | 0.47 | 2.66 |
| 3H Clynnog | 1 | MS | 3 | L | L | 0.42 | 70 | 30 | 30 | 70 | 3.39 | 0.71 | 1.66 | 1.02 |
| 3I Tyddyn Hen [1] | 2 | PM | 2 | M | L | 0.41 | 30 | 70 | 30 | 700 | 6.58 | 2.30 | 0.99 | 3.29 |
| 3J Aberafon | 1 | MS | 2 | M | M | 0.35 | 80 | 20 | 60 | 40 | 5.54 | 2.66 | 1.77 | 1.11 |
| **Total:** | | | | | | **3.02** | | | | | **45.55** | **9.24** | **13.32** | **22.98** |

[1] Block has 50% or more as waste
[2] Block has less than 0.5 million tonnes of mineral

*Summary Conclusions:*

- Although the area contains a significant total volume of mineral most occurs in small blocks of limited volume and thickness, with high proportions of waste, and mostly constrained by significant environmental designations
- Three blocks: 3A (Pontlynff), 3E (Cefngwreichion) and 3G (Ffynon Beuno) have more than 50 % waste.
- Only two blocks: 3C (Pen-y-Bryn Mawr) and 3J (Aberafon) have significant volumes of sand relative to gravel; all the remainder are very coarse.
- Only two blocks: 3I (Tyddyn Hen) and 3J (Aberafon), have been ranked as of medium commercial potential; all the others are ranked low.
- Overall, the area is a generally poor prospect compared to other areas and would require very detailed site investigation to prove commercially viable mineral.

## 10.4 Area 4 Glynllifon - Bontnewydd

*Description* This area is a northeast extension of Area 3 and partially overlaps with and forms a northerly extension to the area investigated for sand and gravel resources around Penygroes by the University of Liverpool in 1988. It covers an area of some 14 square kilometers, is bordered on the west by a strip of marine alluvium between Pontllyfni and Morfa Dinlle, on the east by the foothills of Snowdonia and on the north by Afon Gwyrfai. The isolated ridge at Dinas Dinlle has been excluded from the target area as it is almost wholly occupied by a hill-fort and unlikely to be developed. The area is relatively heavily populated and includes the villages of Llanwrog, Groeslon and Llanwnda as well as numerous hamlets, farms and single dwellings. It also

includes the large area of the Glynllifon Country Park and estate. The area contains virtually no exposure or history of mineral working. Except for very closely spaced boreholes on the line of the recent A487 improvement between Llanwnda and Penygroes the area is otherwise devoid of boreholes. The area was selected as a target area because of its geological resemblance to Area 3 and its lateral connection to proven sand and gravel bearing ground to the south around Penygroes.

*Geomorphology* The geomorphology of the area is illustrated in Appendix A, Figure 7 and comprises a set of low amplitude, sub-parallel linear ridges averaging a kilometre long by 2-300 m wide and up 20 m high, striking to the northeast. The ridges are separated either by narrow entrenched channels or flat-floored troughs but wider areas of elevated terrace occur to the west of Llanwnda and a prominent kame terrace flanks the rear of the village of Groeslon. The ridges and troughs are very similar in form to the ridges and troughs of Area 3 and are consequently likely to be of similar origin and provide similar aggregate prospects. For the ridges (Type 2 Blocks) the only local comparator is the well-exposed ridge at Dinas Dinlle which is a large, intensely deformed push-moraine composed of rapidly varying sequences of gravel, sand and diamict (Figure 16). Most of the other ridges of the area are probably similar and consequently likely to contain little workable aggregate. No well exposed comparator exists for the intervening troughs (Type 1 Blocks) but stream-cut sections and field excavation suggest that they are composed largely of coarse-grained gravel together with significant quantities of diamict. Based on the geomorphology the area does not present a good aggregate prospect, being dominated by ice-marginal sediment.

*Resource Blocks and Designations* Sixteen potential resource blocks were identified in the area and are shown in Appendix A, Figure 8 together with environmental designations. Blocks 4E (Rhiwfallen), 4F (Plasmawr) and 4P (Groeslon) are, respectively, equivalent to the Blocks A6, A7 and A9 of the 1988 survey. The 1988 survey did not, however, undertake any drilling or sediment sampling in these blocks but simply provided an estimate of aggregate volume, undifferentiated between volume of sand and volume of gravel. We have added to this data by estimating the separate volume of sand and gravel based on limited section detail.

Only two Type 1 Blocks, 4L (Glan-rhyd) and 4M (Caer Moel), were identified as potential resource blocks and the majority were identified as Type 2 Blocks, mostly push moraines. An exception is the large area occupied by block 4P (Groeslon) which was identified as a kame-terrace. It sits above the village of Groeslon as a steep-fronted terrace and is well exposed in a number of stream sections. Composition, however, is predominantly coarse with a significant component of cobble gravel and other waste.

In terms of designations, parts of block 4C (Glynllifon) are occupied by an SAC and a large number of listed building, including one Grade I. Blocks 4E (Rhiwfallen) and 4F (Plasmawr) are both bordered by an SAC and block 4H (Rhedynog) is occupied by a number of Scheduled Ancient Monuments. All other blocks have no designations but frequently border settlements with listed building status. Block 4C (Glynllifon) is bisected by the A499 road and a number of other blocks, including 4G (Mount Hazel) and 4H (Rhedynog), have a degree of ribbon development along the length of minor roads that traverse them.

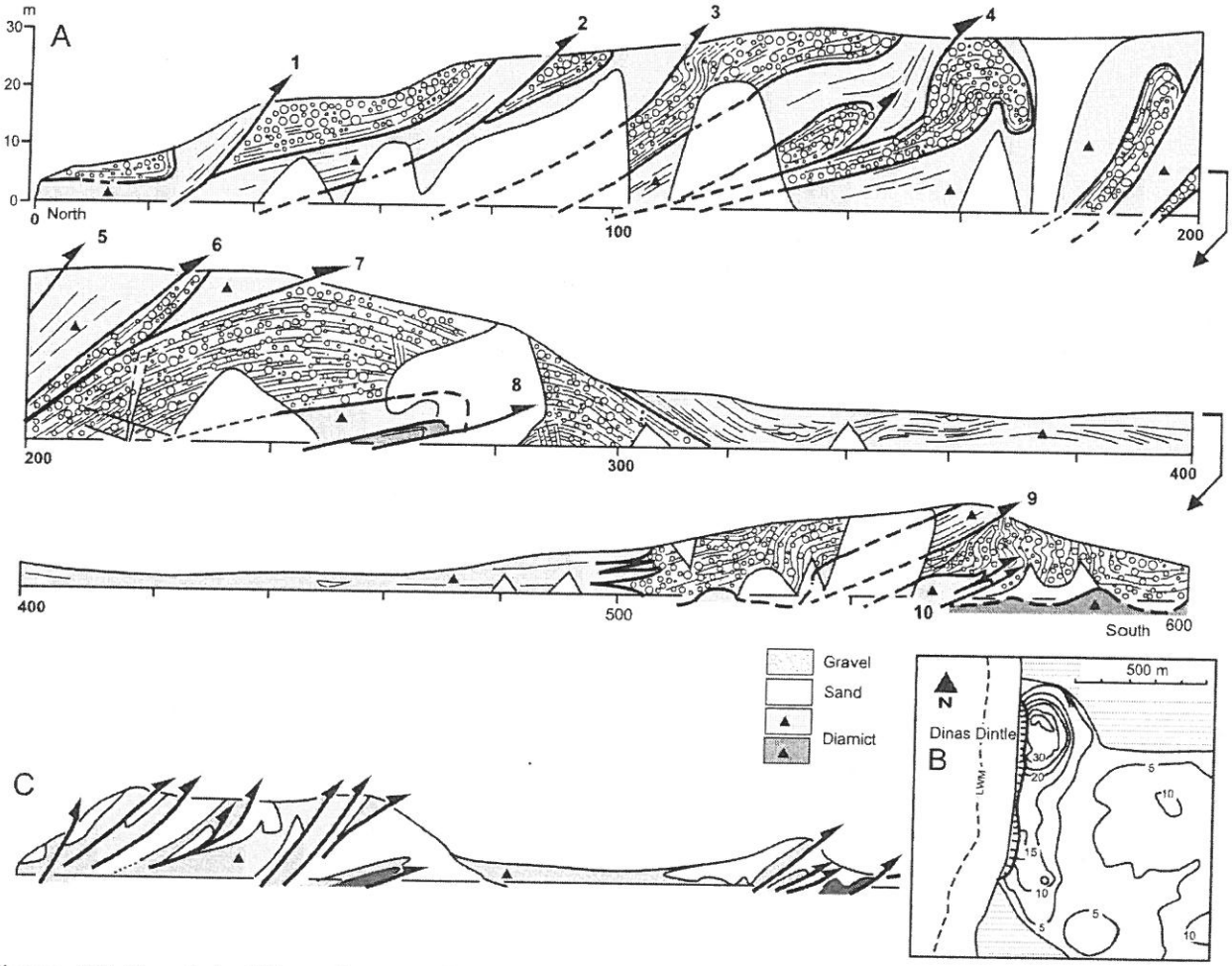


*Figure 16 Coastal cliff sections at Dinas Dinlle. A. Serial section running north-south through sections showing distribution of thrusts and folds. B. Location Map. C: Summary of structure.*

*Assessment strategy* As the geomorphology suggested that the overall prospect for the area was poor no boreholes were drilled through blocks in the area. In the absence of large scale exposure reliance was placed on field sections, auger holes and geological inference from the type of blocks defined in area 3. A similar methodology to that adopted in Area 3 was used for calculating volume of waste and proportional volume of sand and gravel, but with little assistance from section detail. Consequently reliability is low.

*Mineral Summary* The sixteen blocks occupy an area of some 6 square kilometres with an estimated average thickness of 8.5 m. A summary of the potential mineral is shown in Table 10-6 below. The blocks are estimated to contain some 40 million tonnes of mineral made up of 10 million tonnes of sand and 29 million tonnes of gravel, plus 37 million tonnes of waste. Reflecting their different origins, the blocks vary significantly in the volume of mineral contained within them and many fall outside the search criteria either because the ratio of waste to mineral exceeds 50%, the calculated minimum mineral volume is less than 0.5 million tonnes or the percentage of gravel larger than cobble exceeds 5%. None of the blocks has a higher proportion of sand than gravel.

**Table 8: Area 4 Glynllifon-Bontnewydd - Summary of Resource Blocks and Volumes**

| Block | Landform Type | Basis of Assessment | Reliability | Commercial Potential | Area Sq Km | % Mineral in Block | % Waste in Block | % Sand in Mineral | % Gravel n Mineral | Block Volume (Millions of tonnes) | Sand (Millions of tonnes) | Gravel (Millions of tonnes) | Waste (Millions of tonnes) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4A Pen-y-Bythod [1] | PM | 3 | L | L | 0.15 | 50 | 50 | 30 | 70 | 1.66 | 0.25 | 0.58 | 0.83 |
| 4B Bodfan [1] | PM | 3 | L | L | 0.22 | 50 | 50 | 30 | 70 | 3.53 | 0.53 | 1.24 | 1.76 |
| 4C Glynllifon [1] | KM | 3 | L | L | 0.78 | 50 | 50 | 30 | 70 | 7.51 | 1.13 | 2.63 | 3.75 |
| 4D Tai Elen Glyn [1] | PM | 3 | L | L | 0.24 | 50 | 50 | 30 | 70 | 3.02 | 0.45 | 1.06 | 1.51 |
| 4E Rhiwfallen [1 3] | KM | 3 | L | L | 0.51 | 50 | 50 | 30 | 70 | 8.15 | 1.22 | 2.85 | 4.07 |
| 4F Plasmawr [1 4] | PM | 2 | L | L | 0.42 | 50 | 50 | 30 | 70 | 6.65 | 1.00 | 2.33 | 3.33 |
| 4G Mount Hazel [1] | PM | 3 | L | L | 0.35 | 80 | 20 | 30 | 70 | 4.42 | 1.06 | 2.47 | 0.88 |
| 4H Rhedystog [1] | PM | 3 | L | L | 0.51 | 20 | 80 | 20 | 80 | 8.14 | 0.33 | 1.30 | 6.51 |
| 4I Bethesda [1 2] | PM | 3 | L | L | 0.15 | 20 | 80 | 20 | 80 | 1.94 | 0.08 | 0.31 | 1.55 |
| 4J Ty-hen [1 2] | PM | 3 | L | L | 0.05 | 40 | 60 | 30 | 70 | 0.52 | 0.06 | 0.14 | 0.31 |
| 4K Gadlys [1] | RM | 2 | M | L | 0.59 | 30 | 70 | 20 | 80 | 5.70 | 0.34 | 1.37 | 3.99 |
| 4L Glan-rhyd | MS | 3 | L | L | 0.47 | 70 | 30 | 30 | 70 | 3.80 | 0.80 | 1.86 | 0.76 |
| 4M Caer Moel | MS | 3 | L | L | 0.16 | 60 | 40 | 30 | 70 | 1.32 | 0.24 | 0.55 | 0.13 |
| 4N Cae'r – helygen [1 2] | PM | 3 | L | L | 0.09 | 30 | 70 | 30 | 70 | 0.72 | 0.06 | 0.15 | 0.14 |
| 4O Bryn Beddau [1 2] | PM | 3 | L | L | 0.15 | 30 | 70 | 30 | 70 | 1.23 | 0.11 | 0.26 | 0.25 |
| 4P Groeslon [5] | KT | 2 | M | L | 1.16 | 70 | 30 | 20 | 80 | 18.50 | 2.59 | 10.36 | 7.40 |
| **Total for Area:** | | | | | **6.00** | | | | | **76.78** | **10.24** | **29.46** | **37.18** |

[1] Block has 50 % or more as waste
[2] Block has less than 0.5 million tonnes of mineral
[3] Partly equivalent to Block A6 in the 1988 survey
[4] Equivalent to Block A7 in the 1988 survey
[5] Equivalent to Block A9 in the 1988 survey

*Summary Conclusions:*

- Although the area contains a significant total volume of mineral most occurs in small blocks of limited volume and thickness, with high proportions of waste and with little sand.
- Twelve of the 16 blocks have 50 % or more as waste.
- No block has significant volumes of sand relative to gravel.
- Based on existing borehole evidence the gravel in many blocks, especially 4F (Plasmawr), 4I (Bethesda) and 4K (Gadlys) is likely to be very coarse.
- Block 4P (Groeslon) has the largest reserves but has a low ratio of sand to gravel and the gravel is very coarse with significant cobbles and boulders.

- All of the blocks have been ranked as of low commercial potential.
- Overall, the area is a poor prospect compared to other areas and would require very detailed site investigation to prove commercially viable mineral in any reasonable volume.

## 10.5 Area 5 Llanrug

*Description* This area is a north-eastward extension of Area 4 towards Llanrug. It covers an area of approximately 10 square kilometres and is bordered to the northwest and east by the entrenched valley of the Afon Seiont and to the southeast by the rise of slope into Snowdonia. The area includes the small town of Llanrug on its eastern margin, the village of Caeathro at its western margin and a moderate number of farms, isolated dwellings and a few small country estates. The area has been geologically mapped at 1:25,000 scale [1] and this identified most of the ridges, and the complex morphological area around Pant Afon, as composed of sand and gravel. The area has also been partly geomorphologically mapped [2]. The area has no current mineral working but a number of locations show evidence of earlier extraction, especially in the Pant Afon area. The area is devoid of boreholes and has very limited exposure. Large sections in the Seiont Brick Works, immediately east of the area, however, reveal a complex stratigraphy of Welsh and Irish Sea diamicts and coarse gravels. The area was selected as a target area because of its geomorphological resemblance to Areas 3 and 4, the extent of sand and gravel identified on the geological map and the proximity of the area to the main market areas of Caernarfon and Bangor.

*Geomorphology* The geomorphology of the area is shown in Appendix A, Figure 9 and comprises a set of small, low amplitude, sub-parallel linear ridges (Appendix A, Plate 5) and occasional mounds, separated by narrow, incised channels striking northeast on the southeast flank of the Afon Seiont. At the southwestern ends the ridges break up and are separated by a large flat terrace or sandur surface running towards Caernarfon. Further to the southeast the ridges pass into subdued areas underlain by extensive diamict cut by occasional channel systems. Further to the southeast, around Pant Afon, is an extensive area of irregular hummocky topography with a number of subsidiary ridges and small water-filled basins. This is bound on the east and north by flat areas of diamict that pass into gravel in the area underlying Llanrug. The ridges and troughs are very similar to the ridges and troughs of Area 3 and 4 and are probably push moraine ridges and accompanying ice-marginal sandur troughs and incised channels, each marking a stage in retreat of the Irish Sea ice margin. They are consequently likely to be composed of a similar variety of sediment dominated by diamict and with only small volumes of mineral. The area around Pantafon, in contrast, is similar to the kame-moraine ridge at Maesoglen near Nefyn, though more subdued. It is likely therefore to be a potential source of good quality aggregate.

*Resource Blocks and Designations* Thirteen potential resource blocks were identified in the area and are shown in Appendix A, Figure 10. All blocks are free of designations except for a number of listed buildings located on blocks 5A7 (Bryn llan) and 5B (Pant Afon).

*Assessment strategy* As the area is very similar to Areas 3 and 4 the overall prospects was regarded as poor so boreholes were concentrated in the kame-moraine area around Pant Afon on the expectation that this would yield mineral similar to that in other large kame-moraines in the region. Two boreholes (UL13 and UL14), however, both terminated rapidly in thick diamict and yielded only minimal, coarse-grained mineral. Consequently, no detailed assessment could be made. The other twelve blocks were assessed using the same methodology adopted in Area 4 and volume of waste and proportional volume of sand and gravel, were estimated. The reliability of the volume estimates is consequently low.

*Mineral Summary* The thirteen blocks in the area occupy an area of some 2 square kilometres with an estimated average thickness of 5 m. A summary of the potential mineral is shown in

[1] British Geological Survey 1:25,000 Sheet SH55 and SH56 Lyn Padarn, 1988.
[2] Embleton, C. 1964. The deglaciation of Arfon and southern Anglesey and the origin of the Menai Straits. Proceedings of the Geologists' Association 75, 407-430.

Table 9. The blocks are estimated to contain some 4.8 million tonnes of mineral made up of one million tonnes of sand and 3.8 million tonnes of gravel plus 8.3 million tonnes of waste. All but two of the blocks show levels of waste of 50 % or more and none, except for Pant Afon, exceeded the minimum criteria of 0.5 million tonnes of usable mineral.

***Table 9: Area 5 Llanrug - Summary of Resource Blocks and Volumes***

| *Location* | *Landform Type* | *Basis of Assessment* | *Reliability* | *Commercial Potential* | *Area Sq Km* | *% Mineral in Block* | *% Waste in Block* | *% Sand in Mineral* | *% Gravel n Mineral* | *Block Volume (Millions of tonnes)* | *Sand ( Millions of tonnes)* | *Gravel ( Millions of tonnes)* | *Waste ( Millions of tonnes)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5A1 Tyddyn Cae [1 2] | P M | 3 | L | L | 0.10 | 30 | 70 | 20 | 80 | 1.25 | 0.08 | 0.30 | 0.88 |
| 5A2 Pont-rug [1 2] | P M | 3 | L | L | 0.07 | 20 | 80 | 30 | 70 | 0.58 | 0.03 | 0.08 | 0.46 |
| 5A3 Dolgynfydd Uchaf [1 2] | P M | 3 | L | L | 0.06 | 25 | 75 | 20 | 80 | 0.50 | 0.02 | 0.10 | 0.37 |
| 5A4 Tai Llan [1 2] | P M | 3 | L | L | 0.05 | 40 | 60 | 20 | 80 | 0.36 | 0.03 | 0.12 | 0.22 |
| 5A5 Glynifon [1 2] | P M | 3 | L | L | 0.04 | 50 | 50 | 30 | 70 | 0.32 | 0.05 | 0.11 | 0.16 |
| 5A6 Ty'n-y-Coed [2] | P M | 3 | L | L | 0.06 | 80 | 20 | 20 | 80 | 0.36 | 0.06 | 0.23 | 0.07 |
| 5A7 Bryn llan [1 2] | P M | 3 | L | L | 0.04 | 50 | 50 | 20 | 80 | 0.29 | 0.03 | 0.12 | 0.15 |
| 5A8 Llwyn-y-brain [1 2] | P M | 3 | L | L | 0.03 | 50 | 50 | 30 | 70 | 0.34 | 0.05 | 0.12 | 0.17 |
| 5A9 Glan Seiont [1 2] | P M | 3 | L | L | 0.06 | 50 | 50 | 30 | 70 | 0.47 | 0.07 | 0.16 | 0.23 |
| 5A10 Bryn Afon [1 2] | P M | 3 | L | L | 0.11 | 50 | 50 | 20 | 80 | 0.90 | 0.09 | 0.36 | 0.45 |
| 5A11 Tyddyn Mawr [1 2] | P M | 3 | L | L | 0.09 | 50 | 50 | 20 | 80 | 1.01 | 0.10 | 0.41 | 0.51 |
| 5A12 Erw Hywell [1 2] | P M | 3 | L | L | 0.02 | 50 | 50 | 30 | 70 | 0.17 | 0.03 | 0.06 | 0.09 |
| 5B Pant Afon | K M | 1 | M | M | 1.34 | 30 | 70 | 20 | 80 | 6.45 | 0.39 | 1.55 | 4.52 |
| **Total for Area:** | | | | | **2.08** | | | | | **13.02** | **1.02** | **3.72** | **8.28** |

[1] Block has 50% or more of waste
[2] Block has less than 0.5 million tonnes of mineral

*Summary Conclusions:*

- Despite its initial promise the area revealed no significant volumes of mineral and that found occurred in small, uneconomic blocks that included large proportions of waste.
- Although the boreholes in the Pant Afon area revealed no significant mineral, evidence from old workings in the area suggests that mineral may exist in workable quantities. Some considerable effort would be needed to find it, however, as the internal structure of the block is probably very complex and, from the limited information derived from the boreholes, predominantly thin and coarse.
- All blocks except 5B (Pant Afon), which was ranked medium, have been ranked as of low commercial potential.

## 10.6 Area 6 Glasgoed - Talybont

*Description* This area is a north-eastward extension of Area 5 through Pentir towards Talybont, east of Bangor, covering an area of approximately 20 square kilometres. It consists of a narrow strip of irregular topography flanked largely by bedrock ridges towards Bangor on the northwest and the rise of the rock slope into Snowdonia on the southeast The area includes the village of Pentir, the small town of Talybont and many farms and dwellings. It is bisected by the A4366 and crossed by the A5 in the north, giving good access to all areas. Except around Glasgoed [1] the area has not been geologically mapped but part has been geomorphologically mapped [2]. The area has no current mineral working but former workings occur around Pentir. No boreholes occur within the area and there is limited exposure. The area was selected because of its similarity to Area 5, evidence of previous working and proximity to the main market area of Bangor.

*Geomorphology* The geomorphology of the area is shown in Appendix A, Figure 11 and comprises a linear strip of somewhat isolated narrow ridges and mounds set within a large flat sandur that is bordered on both sides by extensive area of subdued diamict or low bedrock cored ridges. At the south-western end of the area, around Glasgoed Hall, is a large, complex set of multiple, generally subdued sub-parallel ridges running southwest. To the northeast a series of subdued mounds or linear ridges cross the B4547 and are surrounded by extensive flat sandur surfaces. Further northeast, running parallel with the A4366 from its junction with the B4547 through Pentir towards the A5, are a series of very prominent linear ridges regarded by some as esker ridges. The main sandur crosses the A5 a little east of its junction with the A55 and forms a distinct set of terraces on the right bank of the Afon Ogwen before Talybont.

*Origin.* The ridges are very similar to the ridges of Area 5 and are probably of the same origin as ice-marginal push moraine ridges and accompanying ice-marginal sandur troughs, each marking a stage in retreat of the Irish Sea ice margin. They are consequently likely to be composed of a similar variety of sediment dominated by diamict and with only small volumes of mineral. Alternatively, some of the sharp-crested ridges around Pentir may be esker ridges taking subglacial drainage to the southwest, parallel to the ice margin. In this case they should be composed of well-sorted gravel.

*Resource Blocks and Designations* Twelve potential resource blocks were identified in the area and are shown in Appendix A, Figure 12. Most blocks are free of designations, except for block 6A (Glasgoed Hall), 6B (Rhydau) and 6H (Llyn Cororion) which have Scheduled Ancient Monuments located on them.

*Assessment strategy* As the area is very similar to Areas 5 the overall prospects were regarded as poor so boreholes were concentrated in blocks adjacent to areas previously exploited around Pentir. The other blocks were assessed using the same methodology adopted in Area 4. with volume of waste and proportional volume of sand and gravel estimated by inference. The reliability of the estimates is consequently low.

*Block 6A (Glasgoed Hall)* This block, occupying an area of 0.48 square kilometres, is identified on the BGS map as composed of sand and gravel and was also identified as a large potential resource in the 1996 survey by Roberts [3]. Detailed mapping of the block, however, revealed that drift was generally very thin with much bedrock obtruding through it. Moreover, much of the western side of the block exposed extremely coarse gravel, up to boulder size, or very coarse diamict rendering it unsuitable for mineral extraction. The block is estimated to contain 0.92 million tonnes of gravel, much of its very coarse, less than 0.1 million tonnes of sand and over 2 million tonnes of waste. It was consequently ranked as of low commercial potential.

[1] British Geological Survey 1:25,000 Sheet SH55 and SH56 Lyn Padarn, 1988.

[2] Embleton, C. 1964. The deglaciation of Arfon and southern Anglesey and the origin of the Menai Straits. Proceedings of the Geologists' Association 75, 407-430.

[3] Roberts, W. 1996. A report on Sand and Gravel Deposits in Gwynedd. Gwynedd County Council.

*Block 6B (Rhydau), Block 6D (Hendre) and Block 6G (Meolycl)* These blocks are grouped together by their probable origin as eskers. Block 6B (Rhydau) is a small, subdued ridge, 700 m long, orientated approximately east-west, that crosses the B4547 at the small hamlet of Rhydau. It is partly constrained by a minor road running along its crest and a number of dwellings and is unexposed. It is estimated to contain 0.4, 0.6 and 0.67 million tonnes of sand, gravel and waste respectively.

*Block 6D (Hendre)* is a narrow, sharp crested ridge about 600 m long running east-west to the west of Pentir. It is exposed at its western end and displays well-bedded pebble gravel and sand. It is estimated to contain 0.20, 0.29 and 0.21 million tonnes of sand, gravel and waste respectively and is probably too small for other than local use.

*Block 6G (Moelycl)* is a narrow, sharp crested, slightly sinuous ridge, 1200 m long and up to 25 m high, bordered on each side by flat marginal sandur channels, to the east of Pentir. It is well exposed but predominantly composed throughout of very coarse boulder gravel, making it unsuitable for extraction. It is estimated to contain 0.19, 1.67 and 0.46 million tonnes of sand, gravel and waste respectively. All three blocks are ranked of low commercial potential because of their low volume and coarse grain.

*Block 6C1 (Groeslon) and 6C2 (Glan Rhyd)* These blocks are small, isolated mounds, probably of kame-moraine origin set in a large area of flat sandur. Block 6C1 (Groeslon) has a previous history of working but is no longer exposed and is partially constrained by development. Both have very small calculated volumes of mineral, each below 0.5 million tonnes and are unlikely to be exploited other than for local supplies. They are ranked as of low commercial potential.

*Block 6F (Pen-y-Bryn)* This block are relatively large, occupying 0.33 square kilometres, and forms a linear ridges running approximately north-east to south-west through Pentir. It is probably of kame-moraine origin. It has previous mineral history with at least two former quarries worked in it but no current exposure. It is estimated to contain some 1.8 million tonnes of sand and 2.70 million tonnes of gravel and has been ranked as of moderate commercial potential on the basis of its previous history.

*Block 6E (Niwbwrch)* is immediately north of Block 6F and similar in form. It occupies 0.55 square kilometres and poor roadside exposure in a small, former quarry at its western end confirm pebble gravel and sand. Consequently a borehole (UL15) was located on the crest of the ridge but terminated at shallow depth in thick diamict and yielded no mineral. It is likely, however, that this ridge, though variable in composition, does contain mineral and an estimate predicts relatively low volumes of 0.31 million tonnes of sand and 0.73 million tonnes of gravel. The block is ranked as of low commercial potential because of its low volume and the need for considerable site investigation to find appropriate mineral.

*Block 6K (Pentir) and 6H (Llyn Cororion)* Both blocks comprise extensive flat areas either flanked by diamict ridges or kame moraines. They are consequently interpreted as marginal sandur of likely mineral potential. Block 6K (Pentir) is exposed in a river-cut section and showed pebble gravel and sand. Consequently a borehole (UL16) was located on the surface of the sandur adjacent to the section. . Somewhat surprisingly this revealed a limited thickness of gravel before penetrating thick underlying diamict. The block is estimated to contain 0.31 million tonnes of sand and 0.73 million tonnes of gravel, based on the proportion of sand to gravel found in section. The block is ranked of low commercial potential because of the uncertainty over its composition.

*Block 6H (Llyn Cororion),* located immediately south of the junction of the A5 and the A55, forms a flat floored trough between two partly rock cored moraine ridges to the north and south. The surface is diversified by minor terracing and pitted kettle holes, including the large Llyn Cororion. Sections in small stream cuts identify pebble gravel and sand and on this basis the block is estimated to contain 0.62 million tonnes of sand and 1.44 million tonnes of gravel. The block is also ranked of low commercial potential because of its low volume and a potentially high water-table.

*Block 6I (Tai'n-y-Coed) and 6J (Felin Cochwillan)* These two blocks form adjacent terrace fragments on the east side of Afon Ogwen, south of Talybont. They are very poorly exposed but

appear to be composed of pebble gravel of predominantly local origin set in a sand matrix. They are probably part of a sandur system that drained from Welsh ice retreating up the Ogwen valley but subsequently incised through in the Holocene. Together, they are estimated to comprise 0.75 million tonnes of sand and 1.54 million tonnes of gravel. They are unlikely to be exploited, however, due to their small volume and isolation from suitable highway access and have consequently been ranked of low commercial potential.

*Mineral Summary* The twelve potential blocks in the area occupy an area of some 3 square kilometres with an estimated average thickness of 6 m. A summary of the potential mineral is shown in Table X. The blocks are estimated to contain some 15 million tonnes of mineral made up of 4.6 million tonnes of sand and 10.5 million tonnes of gravel plus 14.2 million tonnes of waste. Blocks 6A (Glascoed Hall), 6E (Niwbwrch) and 6K (Pentir) show 50% or more waste and Blocks 6C1 (Groeslon), 6C2 (Glan Rhyd) and 6D (Hendre) have less than 0.5 million tonnes of usable mineral.

*Summary Conclusions:*

- Despite some promise derived from small previous workings in the area no significantly large resources have been identified. Most blocks are too small to be economic, except for local use.
- The area is unlikely to provide adequate resources to satisfy the adjacent market in Bangor.
- All blocks except 6F (Pen-y-Bryn) have been ranked as of low commercial potential.
    - Although the borehole in the Pentir area revealed no significant mineral, evidence suggests that mineral may exist in workable quantities in blocks within or adjacent to previous workings, especially Block 6F (Pen-y-Bryn), which has an estimated yield of 4.5 million tonnes.

***Table 10: Area 6 Glasgoed-Talybont - Summary of Resource Blocks and Volumes***

| *Block* | *Landform Type* | *Basis of Assessment* | *Reliability* | *Commercial Potential* | *Area Sq Km* | *% Mineral in Block* | *% Waste in Block* | *% Sand in Mineral* | *% Gravel n Mineral* | *Block Volume (Millions of tonnes)* | *Sand (Millions of tonnes)* | *Gravel (Millions of tonnes)* | *Waste ( Millions of tonnes)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6A Glasgoed Hall [1] | PM | 3 | L | L | 0.48 | 30 | 70 | 10 | 90 | 3.06 | 0.09 | 0.83 | 2.14 |
| 6B Rhydau | E | 3 | L | L | 0.17 | 60 | 40 | 40 | 60 | 1.67 | 0.40 | 0.60 | 0.67 |
| 6C1 Groeslon [2] | KM | 2 | L | L | 0.08 | 60 | 40 | 40 | 60 | 0.40 | 0.10 | 0.14 | 0.16 |
| 6C2 Glan Rhyd [2] | KM | 3 | M | L | 0.09 | 60 | 40 | 40 | 60 | 0.55 | 0.13 | 0.20 | 0.22 |
| 6D Hendre [2] | E | 2 | M | L | 0.05 | 70 | 30 | 40 | 60 | 0.70 | 0.20 | 0.29 | 0.21 |
| 6E Niwbwrch [1] | KM | 1 | M | L | 0.33 | 20 | 80 | 30 | 70 | 5.24 | 0.31 | 0.73 | 4.19 |
| 6F Pen-y-Bryn | KM | 2 | M | M | 0.50 | 70 | 30 | 40 | 60 | 6.42 | 1.80 | 2.70 | 1.93 |
| 6G Meolycl | E | 2 | M | L | 0.21 | 80 | 20 | 10 | 90 | 2.31 | 0.19 | 1.67 | 0.46 |
| 6H Llyn Cororion | MS | 3 | L | L | 0.31 | 70 | 30 | 30 | 70 | 2.93 | 0.62 | 1.44 | 0.88 |
| 6I Tai'n-y-Coed | S | 2 | M | L | 0.10 | 70 | 30 | 30 | 70 | 0.83 | 0.17 | 0.41 | 0.25 |
| 6J Felin Cochwillan | S | 3 | L | L | 0.34 | 60 | 40 | 30 | 70 | 2.69 | 0.48 | 1.13 | 1.08 |
| 6K Pentir [1] | MS | 1 | M | L | 0.31 | 20 | 80 | 30 | 70 | 2.51 | 0.15 | 0.35 | 2.01 |
| **Total for Area:** | | | | | **2.97** | | | | | **29.33** | **4.64** | **10.49** | **14.20** |

[1] Block has 50% or more waste
[2] Block has less than 0.5 million tonnes of mineral

## 10.7 Area 7 Bala

*Description* This area covers approximately 25 square kilometers to the north, northeast and east of Bala and includes both flanks of the Dee as far as the Gwynedd border with Denbighshire, to the east of Llanderfel. The area is relatively thinly populated but includes the town of Bala, the village of Llanderfel and a number of small hamlets, farms and rural dwellings. Geological map cover at a scale of 1:50,000 exists [1], but no geomorphological map, and natural exposure is limited to river bank cuts on the flanks of the Dee. One small quarry is located at Sarnau and exploits a specialist market for grey sand used in restoration of buildings in conservation areas. The quarry also imports soft sand from North-east Wales for general building work. The quarry is currently inactive though planning permission has recently been granted for an extension of the site to the north. The area was selected as a target area principally because of the existing mineral extraction history in a part of Gwynedd otherwise deficient in potential mineral resources.

*Geomorphology* A geomorphological map of the area is shown in Appendix A, Figure 13. The Afon Tryweryn flows south to Bala and is bordered by a narrow strip of recent alluvium flanked by small, irregular river terraces and extensive diamict, some in drumlinoid form. At Bala the Afon Tryweryn joins the outlet of Llyn Tegid to flow as the Afon Dyfrdwy (River Dee) eastwards across a wide flood plain. This is flanked on its northern side by a series of terraces, up to 8m above river level, and a series of small alluvial fans on the southern side. To the east, where the river narrows as it cuts through a prominent rock ridge running across its course, a set of moraines, partly arcing across the valley, are preserved on the south bank to the west of Pale Hall. The moraines include a number of irregular mounds and basins developed in relatively thin sand and gravel deposits overlying bedrock (Appendix A, Plate 4). To the north and south of the Afon Dyfrdwy bedrock outcrops extensively and drift deposits are limited to valley floor infill of diamict, partly drumlinised. At Sarnau, a small ridge, composed of sand and gravel, runs northeast and is flanked by a series of large mounds and an adjacent area of peat and alluvium. Further northeast, at Bethel, a small moraine, composed of coarse gravel and diamict, arcs across the head of Nant Ffrauar.

*Origin* During the last glaciation in this part of Wales ice moved northeast from ice source areas in the Arenigs and the Cader Idris range. During retreat the ice margin paused during various still-stand episodes and generated small moraines at the margin, in front of which sandur sediments accumulated. Most of these sandur are now much eroded and occur as a residual series of terraces flanking the Afon Dyfrdwy. The arcuate ridge at Bethel identifies another still-stand episode and the elongated ridge at Sarnau, orientated in the direction of ice flow is probably a small esker system draining from the snout of the glacier into a small dammed-up lake.

*Resource Blocks and Designations* The sandur terraces flanking the Afon Dyfrdwy, the small cross-valley moraine ridges at Bethel and west of Pale Hall, together with the small esker ridge at Sarnau all provide potential sand and gravel deposits. Geomorphological mapping, however, demonstrated that all the moraine ridges were unsuitable for mineral extraction due to their very limited extent, steep slope, admixture with diamict or irregular bed-rock surface. Small mounds and ridges to the east of Sarnau, though first thought to be similar in origin to the esker ridge at Sarnau, proved to be composed of diamict. Consequently, three potential resource blocks were identified and are shown in Appendix A, Figure 14; two occur in former sandur terraces and the third occupies the esker ridge at Sarnau. The whole of the area south and west of Bala, including the town itself, is within the area of the Snowdonia National Park and part of Block 7B at Llanfor abuts against its boundary. The esker Block 7A at Sarnau is adjacent to a SSSI. Otherwise the area is unconstrained.

*Assessment strategy* One borehole was drilled in an area north of the small quarry in Block 7A and Blocks 7B and 7C were assessed using natural exposure.

*Block 7A (Sarnau)* This block occupies an area of 0.17 square kilometers and forms a linear ridge trending north-east immediately west of the A 494 south of Sarnau. The quarry is developed on the south-west part of the ridge but is poorly exposed. Previous work in the quarry [2] showed a

[1] British Geological Survey 1:50, 000 Sheet 120 Bala. 1996.
[2] G.S.P.Thomas, unpublished notes and sections 1988..

characteristic esker-delta facies sequence composed of fining upwards sets of cross-bedded pebble gravel to coarse to medium sand, dipping north-east. These were probably deposited at the exit of an ice-tunnel into a small delta feeding an ice-marginal lake to the north-east. The unexploited parts of the ridge to the north-east should, therefore, be composed of similar sediment and this has been confirmed by trial pit investigations undertaken by the quarry operator. Consequently, a borehole (UL17) was located in this area but, surprisingly, penetrated some 2.5 m of diamict before termination and no sand or gravel was encountered. This suggests considerable lithological variation and contamination with diamict in the down-ice direction. On the basis of test samples the block is estimated to contain 1.0 million tonnes of sand and 1.0 tonnes of gravel though further detailed investigation would be needed to prove this.

*Block 7B (Llanfor)* This block consists of a suite of flat sandur terraces occupying an area of 0.62 square kilometers on the northern margin of the floor of Afon Dyfrdwy at Llanfor, east of Bala.. Exposure is very limited and composition was estimated on the basis of comparative exposure in similar terrace sequences down-valley. The block is estimated to contain 2.15 million tonnes of sand and 3.22 tonnes of gravel though further detailed investigation would be needed to prove this. The outermost terraces, close to the river, are very low and likely to be at or below the water-table, making exploitation difficult.

*Block 7C (Bryn Banon)* This block consists of a prominent sandur terrace, up to 15 m above the river, on the north side of the Afon Dyfrdwy and extending in a narrow strip both east and west of Bryn Banon. It occupies approximately 0.17 square kilometers. Exposure is limited but sections show pebble gravel in a sand matrix in typical stacked sandur bar structures. The block is estimated to contain 0.6 million tonnes of sand and 0.9 tonnes of gravel.

*Mineral Summary* The three potential resource blocks occupy an area of less than a square kilometer and have an estimated average thickness of 6.7 m. A summary of the potential mineral is shown in Table X. The blocks are estimated to contain some 9 million tonnes of mineral made up of 3.76 million tonnes of sand and 5.13 million tonnes of gravel plus 1 million tonnes of waste.

***Table 11: Area 7 Bala - Summary of Resource Blocks and Volumes***

| *Block* | *Landform Type* | *Basis of Assessment* | *Reliability* | *Commercial Potential* | *Area Sq Km* | *% Mineral in Block* | *% Waste in Block* | *% Sand in Mineral* | *% Gravel n Mineral* | *Block Volume (Millions of tonnes)* | *Mineral (Millions of tonnes)* | *Sand (Millions of tonnes)* | *Gravel (Millions of tonnes)* | *Waste (Millions of tonnes)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7A Sarnau | E | 1 | M | H | 0.17 | 90 | 10 | 50 | 50 | 2.23 | 2.01 | 1.01 | 1.00 | 0.22 |
| 7B Llanfor | S | 2 | M | M | 0.62 | 90 | 10 | 40 | 60 | 5.97 | 5.37 | 2.15 | 3.22 | 0.60 |
| 7C Bryn Banon | S | 2 | M | M | 0.17 | 90 | 10 | 40 | 60 | 1.67 | 1.51 | 0.60 | 0.90 | 0.17 |
| **Total for Area:** | | | | | **0.97** | | | | | **9.87** | **8.89** | **3.76** | **5.13** | **0.99** |

*Summary Conclusions:*

- All the blocks are small in volume but sufficient in any one case to meet local demand though further detailed investigation is necessary before reliable estimates of reserves and commercial potential can be established.
- Block 7A (Sarnau) has been rated as of high commercial potential, despite the failure of boreholes to prove reserves, due to the history of previous working, the size of reserves relative to local demand, the nature of the aggregate and the excellent road access. The remaining blocks are rated of medium commercial potential.

## 10.8 Area 8 Pentraeth, Anglesey

*Description* Anglesey is largely dominated by subglacial environments and most of its area is either covered by thick diamict, often moulded into drumlins, or large areas of scoured bedrock. Potential for significant mineral reserves, even to meet local demand, is therefore low. Some small areas, however, show evidence of subglacial fluvial deposition, especially around Pentraeth and possibly around Llangoed where some gravels and sands are exposed on the coast at Leiniog. Both these areas were geomorphologically mapped but the gravels around Lleiniog could not be traced inland with any certainty and outcrop on the coast was unsuitable for aggregate being partly lithified by carbonate percolation and mixed with diamict. This potential prospect was therefore rejected. The area around Pentraeth, however, has a mineral history and a small, but now abandoned, quarry that previously served mainly local markets, occurs southwest of the town at Hendre Farm. The area identified covers some 7 square kilometers, mainly to the north of the quarry. Geological map cover exists and small outcrops of sand and gravel are identified. There are no borehole records and outcrop is limited.

*Geomorphology* A geomorphological map of the area is shown in Appendix A, Figure 15 and Figure 18 and comprises a series of small ridges, generally orientated NE to SW, parallel with other ice flow indicators, and small, irregularly distributed mounds. Bedrock outcrops occur across much of the area and are an indication of an irregular bedrock topography and a probable thin and very variable cover of glacial sediment. Sand and gravel ridges orientated in the direction of ice flow in areas otherwise underlain by diamict usually suggest an origin as subglacial esker systems. These occur when water flow in tunnels beneath the ice stops due to changes in the dynamics of the ice and sediment in transit is suddenly deposited. When the ice melts the deposited tunnel fill is left as an often long, narrow and usually sinuous esker ridge. Eskers can yield significant quantities of well sorted sand and gravel, often coarse, but easily worked as they occur in ridge form.

*Resource Blocks and Designations* Five potential resource blocks were identified in the area, all to the west or south-west of Pentraeth, and are shown in Appendix A, Figure 16. None of the blocks are directly constrained but Block 8E (Plas y brain) is adjacent to an SSSI and an SAC and Block 8C (Rhos Farm) is adjacent to an SSSI, SAC and an AONB.

*Assessment strategy* No boreholes were put down in the area as permission was refused for the most likely prospect. Assessment was consequently made on the basis of the logging and sampling of natural exposure and samples obtained from former quarry section.

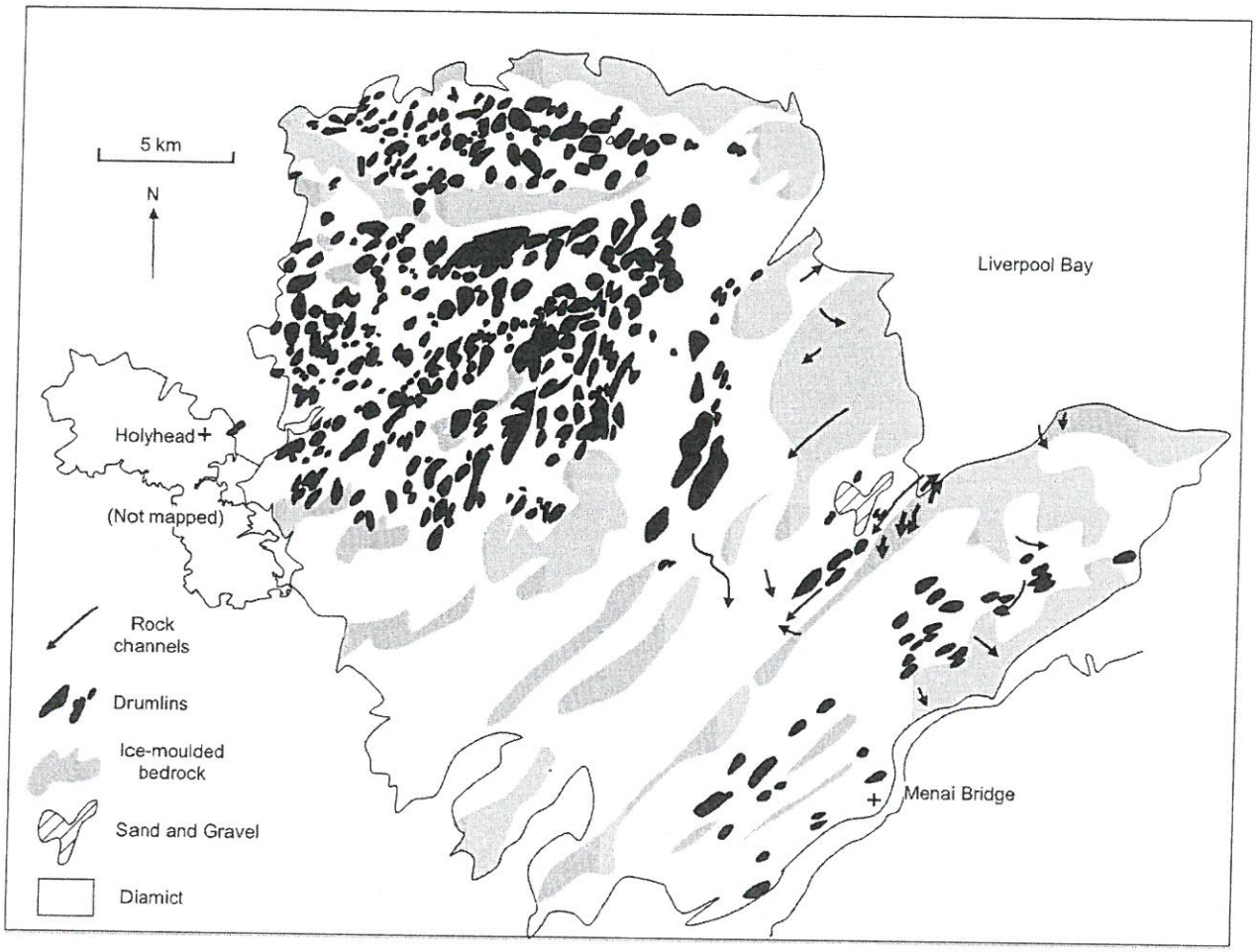


*Figure 18. Outline map of the glacial geology of Anglesey showing distribution of diamict, ice-moulded bedrock and drumlins. Note the very limited areas occupied by outwash deposits.*

*Block 8A (Hendre)* This block forms a small mound about 500 m in diameter and approximately 10 to 15 m high. Its north-eastern end has an abandoned quarry occupying about one half of the block. This is mostly landscaped but with some sections visible. These show alternating sequences of sand and gravel of Irish Sea origin, together with significant intercalated diamict, but insufficient is exposed to determine precise environments of deposition. Although no boreholes were drilled in the block it seems likely that the remainder of the block has similar sedimentary characteristics to the quarried area. Consequently, the block is estimated to contain approximately 0.48 million tonnes of sand and 1.11 tonnes of gravel, with a significant proportion (30 %) of waste.

*Block 8C (*Rhos Farm*)* This block occupies an area of 0.42 square kilometers and consists of set or irregular ridges orientated north-east to south-west. Unfortunately, site access and permission to put down a borehole in the centre of the ridge was denied by the landowner. Field section occurs on the western margin around Rhos-y-Gad, however, shows significant gravel with a sand matrix and estimates based on laboratory testing indicate that the block contains approximately 0.61 million tonnes of sand and 1.42 million tonnes of gravel.

*Blocks 8B (Ty'n-Pwll), 8D (Rhos-y-Gad) and 8E (Plas y brain)* These blocks are treated together as they have similar geological conditions. Each comprises a small, irregular ridge or mound broadly orientated north-east to south-west. Exposure is extremely limited and little reliable assumption can be made on mineral quality or quantity. The field evidence also suggests that each mound may, in part, be rock cored or underlain by an uneven bedrock surface.

*Mineral Summary* The five potential resource blocks in the area occupy an area of less than a square kilometer and have an estimated average thickness of 7m. A summary of the potential mineral is shown in Table 10-11 .The blocks are together estimated to contain some 5.6 million tonnes of mineral made up of 1.69 million tonnes of sand and 3.93 million tonnes of gravel plus 3.37 million tonnes of waste.

**Table 12: Area 8 Anglesey - Summary of Resource Blocks and Volumes**

| Block | Landform Type | Basis of Assessment | Reliability | Commercial Potential | Area Sq Km | % Mineral in Block | % Waste in Block | % Sand in Mineral | % Gravel n Mineral | Block Volume (Millions of tonnes) | Mineral (Millions of tonnes) | Sand (Millions of tonnes) | Gravel (Millions of tonnes) | Waste (Millions of tonnes) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8A Hendre | E | 2 | M | M | 0.18 | 70 | 30 | 30 | 70 | 2.27 | 1.59 | 0.48 | 1.11 | 0.68 |
| 8B Ty'n-Pwll | ? | 3 | L | L | 0.16 | 60 | 40 | 30 | 70 | 1.28 | 0.77 | 0.23 | 0.54 | 0.51 |
| 8C Rhos Farm | E | 3 | M | M | 0.42 | 60 | 40 | 30 | 70 | 3.37 | 2.02 | 0.61 | 1.42 | 1.35 |
| 8D Rhos-y-Gad | E | 3 | L | L | 0.06 | 60 | 40 | 30 | 70 | 0.81 | 0.49 | 0.15 | 0.34 | 0.32 |
| 8E Plas y brain | E | 3 | L | L | 0.08 | 60 | 40 | 30 | 70 | 1.26 | 0.76 | 0.23 | 0.53 | 0.50 |
| **Total for Area:** | | | | | **0.90** | | | | | **8.99** | **5.62** | **1.69** | **3.93** | **3.37** |

*Summary Conclusions:*

- All the blocks are small in volume but sufficient in any one case to meet local demand.
- All blocks have been ranked as of low commercial potential with the exception of Block 8A Hendre which is ranked as medium as this has proven mineral and a significant amount of unexploited reserve.
- In the case of Hendre and all the other blocks further detailed site investigation would be necessary before mineral can be proven.

## 10.9 Area 9 Conwy Valley

*Description* This area covers the length of the Conwy valley and its adjacent margin, from south of Llanrwst to a little short of Conwy, an area of approximately 40 square kilometres. The area is relatively thinly populated but includes the small towns of Llanrwst and Trefriw and the villages of Tal-y-Bont and Ty'n-y groes, together with a number of small hamlets, farms and rural dwellings. Geological map cover at a scale of 1:50,000 exists [1], but no geomorphological map, and natural exposure is limited to river exposure on the flanks of the Afon Conwy . There are no active quarries in the area, little evidence of former working and very few borehole records. The area was selected as a target area principally because of its proximity to the major market areas of Llandudno and Colwyn Bay.

*Geomorphology* A geomorphological map of the area is shown in Appendix A, Figure 17. Recent alluvium covers most of the flat floor of the valley and is flanked by steep rock slopes carrying little drift cover, much fretted with an extensive network of rock-cut drainage channels [2]. A number of major alluvial fans drain from steep, left-bank tributary valleys opposite Llanrwst, and

[1] British Geological Survey 1:50,000 Sheet 106 Bala. 1996.

[2] Embleton, C. 1961 'The geomorphology of the Vale of Conwy, North Wales, with particular reference to deglaciation', *Transactions of the Institute of British Geographers*, 29, 47-70.

at Trefriw, Dolgarrog and Tal-y-Bont. Some small drumlins, orientated northwards, occur between Dolgarrog and Talybont and also in the area around Ty'n-y groes. In the south the town of Llanrwst is located on a large sandur terrace at approximately 10 m above the river flood plain level. Further small terrace remnants at the same height occur on the river bank opposite Llanrwst. In the north, a major spread of sandur terrace, also some 10 to 15 m above the flood plain, runs on the western side of the valley from the confluence of the Conwy with the Roe towards the river bridge at Tal-y cafn. To the rear it is flanked by an undulating diamict surface, part moulded into drumlins.

During the last glaciation the Conwy valley acted as a major northward distributary of Welsh ice from source areas to the southwest in Snowdonia. At Conwy this ice stream met and coalesced with the Irish Sea ice, which penetrated only a little way south into what is now the inner Conwy estuary. On retreat, the overdeepened floor of the Conwy valley was rapidly filled with outwash deposits to form an extensive valley sandur. In Holocene times, much of this was removed by fluvial incision, leaving isolated remnants along the valley margin as flat terraces. Further sandur sediment is likely to occur beneath the Holocene river alluvium but will be below the water-table.

*Resource Blocks and Designations* Two potential resource blocks were identified in the area and are shown in Appendix A, Figure 18. Block 9A (Llanrwst) is bordered to the south by the National Park and approximately three-quarters of its area is developed. Block 9B (Tal-y-cafn-uchaf) is fronted for much of its length by a SSSI and its area includes two Scheduled Ancient Monuments and a number of listed buildings.

*Assessment strategy* No borehole were drilled in the area and assessment was made using the same methodology adopted in Area 4. with volume of waste and proportional volume of sand and gravel estimated by inference from naturally exposed section. The reliability of estimates is consequently low.

*Block 9A (Llanrwst)* This block occupies an area of 1.56 square kilometres of which more than three-quarters is sterilised, especially on the northern side, by urban development in Lanrwst. It forms a flat terrace some 10-15 m above the adjacent river flood plain. The block is poorly exposed and no usable boreholes occur. Consequently, little reliable assumption can be made on mineral quality and estimates are derived from a limited number of test samples and inference. The block is estimated to contain 7.21 million tonnes of sand, 10.81 million tonnes of gravel and 2.00 million tonnes of waste, less than 25 % of which, however, is potentially accessible.

*Block 9B (Tal-y-cafn-uchaf)* This block occupies an area of 1.84 square kilometres and takes the form of a prominent terrace, or set of terraces flanking the west bank of the Afon Conwy south of the Tal-y cafn river bridge. Exposure is generally poor but some excellent local section occurs at Tal-y cafn (Appendix A, Plate 8) and appears characteristic of the block, consisting predominantly of pebble gravel set in a sand-silt matrix. Based on samples it is estimated that the block contains 8.48, 12.71 and 2.35 million tonnes of sand, gravel and waste, respectively.

*Mineral Summary* The two potential resource occupy a total area of 3.4 kilometres and have an estimated average less than a square kilometer and have an estimated average thickness of 8m, though this may extend up to 10 or 15 m in favourable areas. A summary of the potential mineral is shown in Table X. The blocks are together estimated to contain some 39.2 million tonnes of mineral, made up of 15.68 million tonnes of sand, 23.53 million tonnes of gravel and 4.65 million tonnes of waste.

| Table 13: Area 9 Conwy Valley - Summary of Resource Blocks and Volumes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Block* | *Landform Type* | *Basis of Assessment* | *Reliability* | *Commercial Potential* | *Area Sq Km* | *% Mineral in Block* | *% Waste in Block* | *% Sand in Mineral* | *% Gravel n Mineral* | *Block Volume (Millions of tonnes)* | *Mineral Volume (Millions of tonnes)* | *Sand Millions of tonnes)* | *Grave (Millions of tonnes)* | *Waste (Millions of tonnes)* |
| 9A Llanrwst | S | 2 | L | L | 1.56 | 90 | 10 | 40 | 60 | 20.02 | 18.02 | 7.21 | 10.81 | 2.00 |
| 9B Tal-y-cafn-uchaf | S | 2 | L | L | 1.84 | 90 | 10 | 40 | 60 | 23.55 | 21.19 | 8.48 | 12.71 | 2.35 |
| **Total for Area:** | | | | | **3.40** | | | | | **43.57** | **39.21** | **15.68** | **23.53** | **4.36** |

*Summary Conclusions:*

- Although both blocks are large, Block 9A (Llanrwst) is severely limited by existing development and effective reserves are less than a quarter of the total calculated.
- Both blocks have been ranked as of low commercial potential due to lack of boreholes, limited exposure and consequent uncertainties in estimating the reserves.

## 10.10 Area 10 Penygroes

The area between Penygroes and Bryncir, in Gwynedd, provides the principal source of sand and gravel for North West Wales and currently supplies most of the land-derived mineral production in the region. The area was investigated in detail by The University of Liverpool in 1987 as part of a wider investigation into the sand and gravel resources of eastern Lŷn. It used a similar methodology to that adopted in this report and utilized 1:25,000 scale geomorphological mapping to identify potential resource blocks and an extensive programme of drilling, trial pitting and associated laboratory analysis to determine mineral volume and quality. The report identified 14 major resource blocks, all located in an approximately linear strip either side of the A487 between Penygroes and Bryncir. Because of the regional scale of the present investigation we have not resurveyed the area or drilled any further boreholes.

For compatibility between this and the 1988 report we have retained the original block labeling but have recalculated the 1988 figures to express volume in tonnes rather than cubic metres. The original report calculated only bulk mineral volume and did not distinguish the proportion of sand to gravel. To provide further compatibility with this report we have calculated these proportions using the grading characteristics supplied with the 1988 report. Because of the significance of this area we summarise the main characteristics of each block below.

*Description of area* The area covers approximately 45 square kilometers in a strip approximately four kilometres wide running from a little north of Penygroes to south of Bryncir. To the north it is contiguous with Area 4 (Glynllifon to Bontnewydd) and to the northern part of Area 3 (Trefor to Pontlynffi) to the west. Penygroes is the major settlement; smaller settlements occur around Bryncir but elsewhere settlement is sparse. The recently realigned A487 road runs north-south through the centre of the area. Quarries currently operate at Bryncir and Graianog and former workings occur west of Penygroes and west of Graianog. Planning permission exists for sand and gravel extraction at Henbant Bach, west of Graianog and at Cae Efa Lwyd, west of Penygroes, but are dormant.

*Geomorphology* The geomorphology of the area is illustrated in Figure 19. To the west and north of Penygroes a series of sub-parallel moraine ridges and narrow intervening sandur are contiguous with similar moraine ridges and sandur channels to the north and west in areas 3 and 4 of this report. In this respect they are geologically similar and consist of a very variable suite of predominantly coarse gravels and associated diamicts deposited in ice-marginal conditions during retreat of the Irish Sea ice-sheet north from the area. To the south of Penygroes the moraines bulge south to pass as a series of arcuate cross-valley moraines occupying the low double col that separates the prominent hill massifs of Bwlch Mawr, Foel and Mynydd Craig Goch. Beyond an area of lake floor sediment fronting the moraine ridge at Graianog, the outermost arcuate moraine ridge, at Bryncir, swings southwestwards to form a series of earlier moraines running towards Pwllheli. Beyond it, to the south, is a widening fan surface, the Rhoslan Sandur, running south. This took much of the meltwater drainage from the ice margin when it stood in the col.

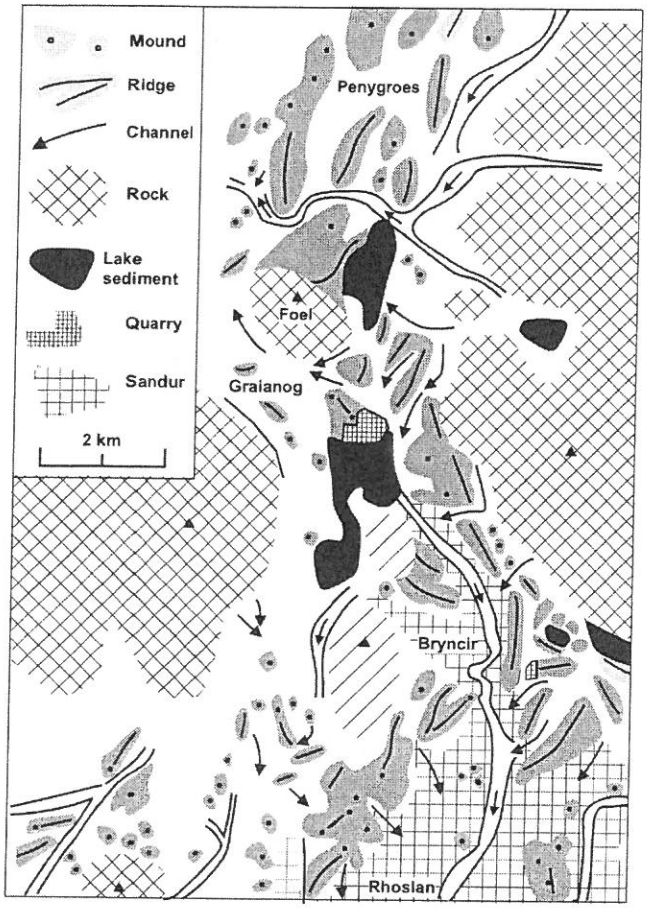


*Figure 19 Geomorphological map of the area around Graianog.*

The moraine ridges were formed during successive retreat stages of the Irish Sea ice sheet as it wasted away northwards and a palaeogeographical reconstruction of the area during a number of these stages is given in Figure 41. In the earliest stage (Stage A, Figure 41) the Irish Sea ice-margin abutted against the rock slope rising to Snowdonia on the east, lay against the rear of the moraine ridge at Bryncir and ran southwestwards across the lowland area of Southeast Lŷn. At this time large quantities of outwash sediment exited from the ice margin at various points and accumulated in the Rhoslan sandur. On its southern margin this sediment abutted against the margin of local Welsh ice retreating eastwards into southern Snowdonia. As the ice-sheet continued to retreat it progressively uncovered the hill masses of northern Llŷn (Stages B and C, Figure 20) and built further moraines north of Bryncir. One of these was the complicated moraine at Graianog, part of which abutted directly into a small moraine dammed lake fronting the ice-margin (Stage D, Figure 20). As the ice-sheet retreated further into the Arfon lowlands the meltwater exits in the area became inactive and the Rhoslan sandur system was abandoned.

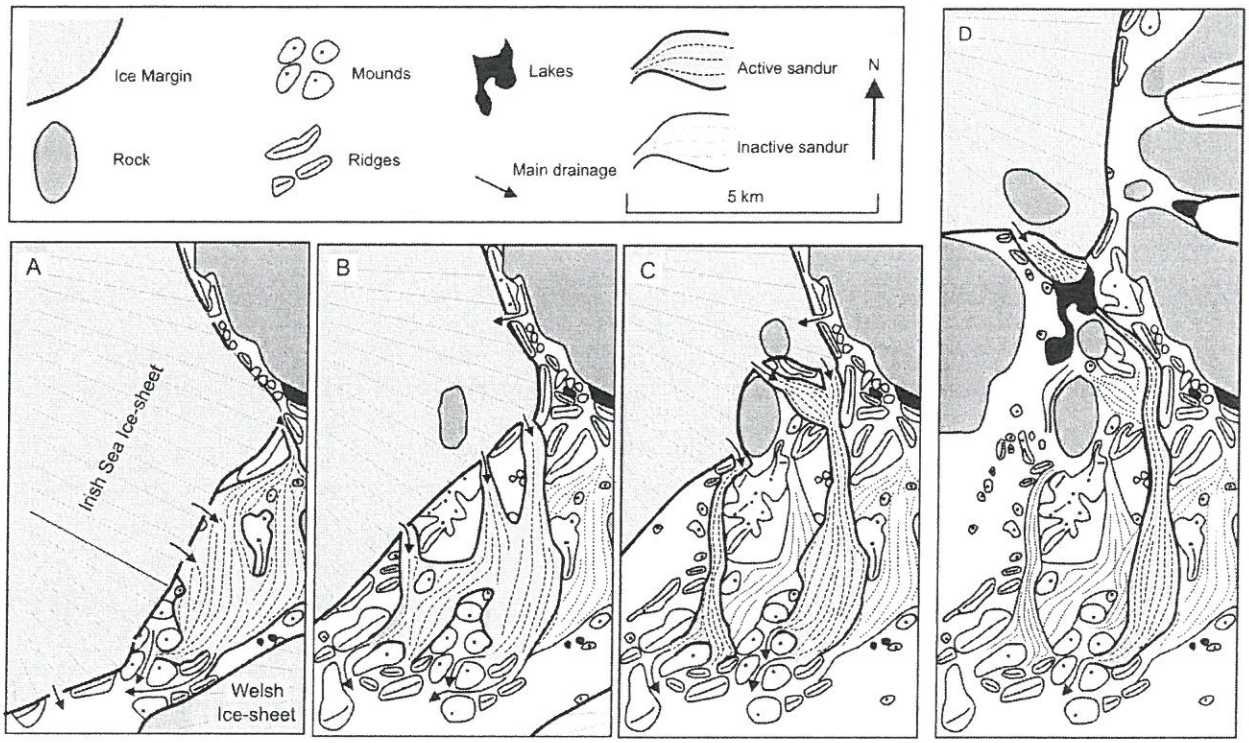


*Figure 20 A palaeogeographical reconstruction of stages in retreat of the Irish Sea ice sheet from the area around Graianog.*

*Resource blocks and designations* Five major resource blocks were identified in the 1988 survey, each divided into one or more sub-blocks. These are shown in Appendix A, Figure 19, together with environmental designations. For continuity, the original block numbers have been retained in this survey but with the addition of an area prefix. Thus, Block 10A4 refers to Block A4 in the 1988 survey. Two additional blocks have been defined to cover blocks not given numbers in the 1988 survey. These are Block 10F at Llecheiddior Uchaf and Block 10G at Hendy. Full details of all these blocks can be found in the 1988 report.

Environmental designations in the block are complex: the northwest part of Block 10A1 and the northeast part of Block 10A4 border a SSSI; Block 10B is bordered by an AONB; Block 10C4 is bisected by an AONB and bordered by a SSSI and a Special Area of Conservation; and Blocks 10C1 and 10D are bordered by the National Park. In addition Blocks 10A5, 10C3, 10C1 and 10D have Scheduled Ancient Monuments on their surface.

A summary of the principal characteristics of the resource blocks is listed below and full details of estimated volumes are given in Table 13..

*Block 10A1 (Garth Dorwen)* This is a small kame terrace located immediately north of Penygroes and has an area of 0.23 square km. It has no evidence of previous working but contains an estimated 1.18 million tonnes of sand and 1.44 million tonnes of gravel. It has low commercial potential as much of the deposit lies close to Penygroes and is unlikely to be exploited.

*Block 10A2 (Cae Efa Lwyd)* This is another small kame terrace or kame moraine located immediately west of Penygroes with an area of 0.16 square kilometres. It has two small disused pits on its northern and southern margins and a current planning permission. It has an estimated 0.91 million tonnes of sand and 1.11 million tonnes of gravel. Commercial potential is high, though of small volume, given its previous working and access.

*Block 10A3 (Tan-y-bryn)* This is a moderate sized kame moraine covering an area of 0.33 square kilometres southwest of Penygroes. It has a significant previous history of working with disused sand and gravel pits on the north, south and eastern sides. It contains an estimated 2.13 million

tonnes of sand and 4.52 million tonnes of gravel and is regarded as a of high commercial potential.

*Block 10A4 (Minfford)* This is a moderate to large sized kame moraine covering an area of 0.52 square kilometres lying west of Penygroes. It has no history of previous working and test samples indicate a predominance of gravel and a significant component of cobbles. This is reflected in its estimated 0.40 million tonnes of sand and 3.56 million tonnes of gravel. The block is regarded as having medium to low commercial potential due to the high proportion of coarse gravel and uncertainty in the estimates.

*Block 10A5 (Plas Newydd)* This is a large block, probably a push moraine, of over 1.63 square kilometres lying two kilometres west of Penygroes and bordering on Areas 3 and 4. The block was originally described as having little topographic expression and ill-defined boundaries and resurvey confirms this. The block contains one disused quarry. The block is adjacent to Area 4 and test samples indicate that it has similar composition to comparable blocks in this area with high gravel content, a significant proportion of cobble and boulder gravel and a relatively high proportion of waste caused by intercalated diamict. The block was consequently regarded as of low commercial potential. The block is estimated to contain 3.02 million tonnes of sand and 9.05 million tonnes of gravel.

*Block 10B (Ffridd-bach)* This large, prominent block, of 1.55 square kilometres, lies west of Llanlynfi and extends northeastwards off the north slope of the hill mass of Foel (Figure 21). It consists of a series of parallel ridges separated by flat areas that probably represent ice-front alluvial fans or sandur. The deposits are consequently likely to contain significant quantities of mineral, but possibly contaminated in part with units of diamict. On the basis of four boreholes the block was estimated to contain 9.42 million tonnes of sand and 14.13 million tonnes of gravel and was regarded as comparable to blocks currently containing working quarries in the area and thus of high commercial potential.

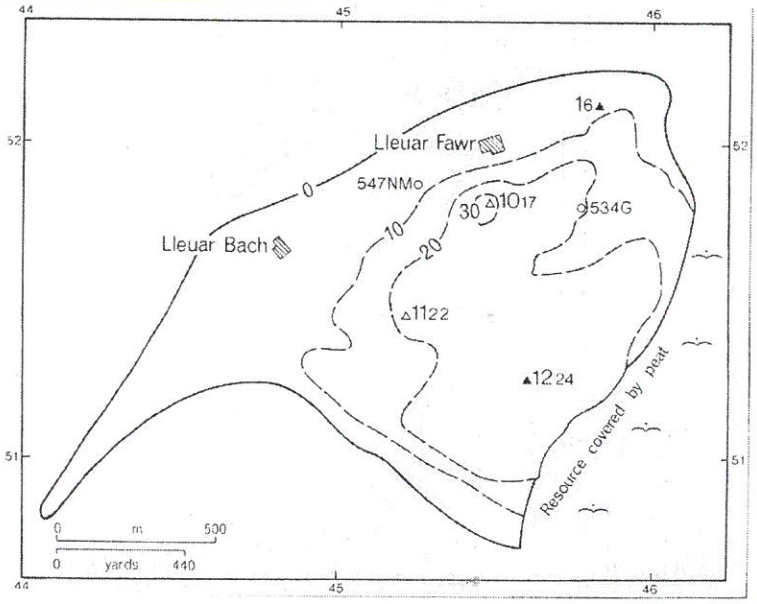


*Figure 21 Map showing lines of equal thickness of sand and gravel resources in Block 10 B at Fridd-bach.*

*Block 10C1 (Cwmbran)* This block lies northeast of Pant Glas and covers an area of 0.96 square kilometres with the eastern portion within the boundary of the National Park. The block is part of an arcuate kame moraine complex banked against the rock slope rising towards Snowdonia on the eastern side of the Afon Dwyfach valley. No boreholes were drilled through this block and estimates are based on comparisons with adjacent and similar Block 10C2 (Bodychain). Consequently, the reliability is low. Estimates record 6.52 million tonnes of sand and 12.10 million tonnes of gravel but as the proportion of waste in this block is unknown this should probably be reduced by at least 25%. Without detailed investigation the block was ranked as of low commercial potential.

*Block 10C2 (Bodychain)* This block lies to the north of Block 10C1 in a similar location banked against the eastern side of the Afon Dwyfach valley and is also part of an arcuate kame moraine complex (Figure 22). It covers an area of 1.62 square kilometres and includes three disused quarries. It records some of the thickest sequences of sand and gravel in the area, up to 22 m.

On the basis of four boreholes the block is estimated to hold 11.15 million tonnes of sand and 20.71 million tonnes of gravel. Numerous boreholes drilled through the block as part of the construction of the re-aligned A 487 confirm both the thickness and quality of the mineral in the block and it is regarded as a significant resource with high commercial potential. Most of the northern and eastern portion of the block, however, is covered by a high density local road network and is largely sterilised. The southern portion, east of the new A487, is unconstrained and provides the best prospect.,

*Block 10C3 (Graianog)* This block lies on the western side of the Afon Dwyfach valley and has the form of a cross-valley kame moraine ridge arcing southeast off the margin of the hill mass of Foel (Figure 22). It has an area of 1.18 square kilometres and contains the major working quarry of Cefn Graianog together with a number of older workings. The sedimentology of the quarry has been investigated by Thomas *et al.*[1] and part of it consists of a coarse-grained, ice-marginal delta system feeding into a small, moraine dammed lake occupying the now boggy ground to the immediate south of the quarry. A cross section through the delta is shown in Figure 23. On the basis of ten boreholes the block is estimated to comprise some 11.15 million tonnes of sand and 20.71 million tonnes of gravel. Much of the block has already been exploited and the area to the north is likely to become increasingly coarse, due to its close proximity to the former ice-margin, and may exacerbate the current problem in the quarry of an increasing volume of cobble and boulder gravel.

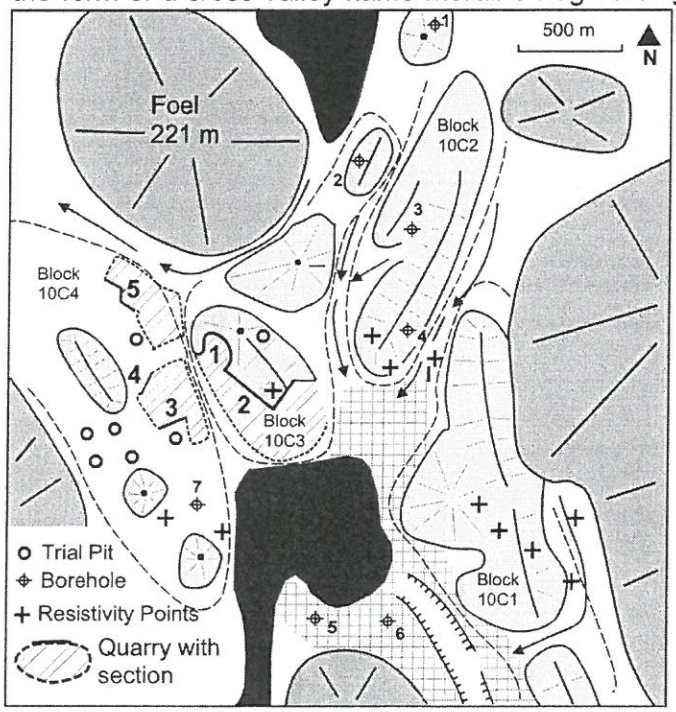


*Figure 22. Map of the area around Graianog Quarry showing distribution of resource blocks, boreholes and current or former quarries.*

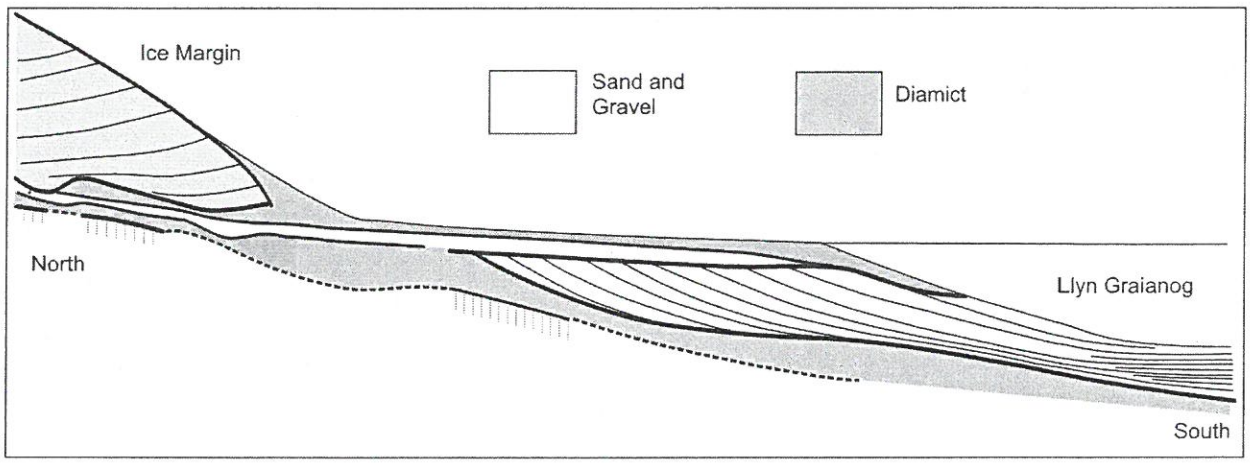


*Figure 23. Cross section through Graianog Quarry showing palaeogeographic reconstruction of the ice-marginal delta system.*

[1] Thomas, G.S.P. Chester, D.K. and Crimes P. 1998 The Late Devensian glaciation of the eastern Llyn peninsula, North Wales: evidence for terrestrial depositional environments. Journal of Quaternary Science, 13(3), 255-270.

*Block 10C4 (Ty-Glas)* This block lies to the immediate west of Block 10C3 and occupies an area of 2.75 square kilometres in the low col between the hill masses of Foel to the north and Bwlch Mawr to the west. Planning permission exists for mineral extraction at Henbant Bach at the northern end of the block. Although much disturbed by former quarrying, the morphology suggests that the block is part of an arcuate cross-valley kame moraine that probably links with a similar moraine occupying Block 10C1 on the eastern side of the Afon Dwyfach valley. The block contains at least two major disused quarries, together with other smaller abandoned workings. An overall assessment based on 20 boreholes suggested block reserves of 10.58 million tonnes of sand and 12.94 million tonnes of gravel. Much of the sand, however, is very fine and unsuitable for aggregate and the proportion of mud and other waste is locally high. Thomas *et al.* demonstrated that much of the northwest area of the block, previously regarded as a possible future area of exploitation, is composed of diamict unsuitable for aggregate. The area to the south, however, bordering the former lake margin, is likely to contain good quality mineral. Overall, the block is rated as of only moderate commercial potential as much of the more easily exploited mineral has already been removed, the sedimentology is locally very complex and detailed investigation would be required in order to prove commercially exploitable resources.

*Block 10D (Bryncir)* This large block lies on the eastern side of the Afon Dwyfach and extends from the southern end of Block 10C1 at Pant Glas to Bryncir. It covers an area of 2.54 square kilometres and is part of a cross-valley moraine system older than that identified around Graianog. The morphology within the block consists of a series of closely spaced, sub-parallel moraine ridges together with small areas of sandur and ice-disintegration topography. It also includes areas, however, where the drift cover is thin and bedrock protrudes through or is close to the surface, particularly along its eastern limit. Overall, the feature is a kame moraine but some ridges show deformation as small-scale push moraines (Figure 24). The block includes two active quarries, together with some other abandoned workings. More than half of the northern and eastern parts of the block fall within the boundary of the National Park. On the basis of four boreholes the block was estimated to contain 8.12 million tonnes of sand and 12.19 million tonnes of gravel and to have high commercial potential. Because of the scale of the block, however, and the evident variation in both landform and exposed section, detailed investigations would be necessary to prove appropriate mineral quality in any specific area within the block.

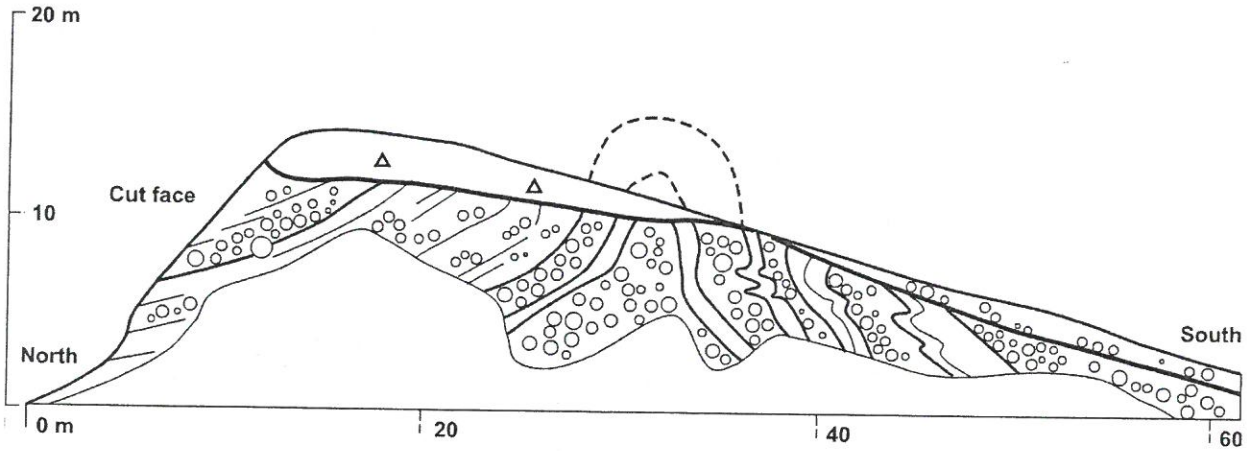


*Figure 24. Section through part of the Bryncir moraine showing folding caused by ice-push.*

*Block 10E (Derwyn fawr)* This moderate to large sized block covers an area of 1.75 square kilometres on the western side of the Afon Dwyfach between the hill mass of Y Foel to its north and Mynydd Cennin to its west. It forms a set of arcuate kame moraine ridges running from northwest to southeast that match up with similar ridges at the northern end of Block 10D on the eastern side of Afon Dwyfach. It is fronted by a sloping sandur surface or ice-front alluvial fan leading into the head of the Rhoslan sandur to the south. The block has no history of exploitation and no exposure. Boreholes, however, show mineral up to 20 m thick (Figure 25) with an even

distribution of grain sizes and an estimated volume of 8.18 million tonnes of both sand and gravel. The block was regarded as of high commercial potential probably able to produce aggregate of similar quality to existing quarries in the area but with a superior grain size distribution.

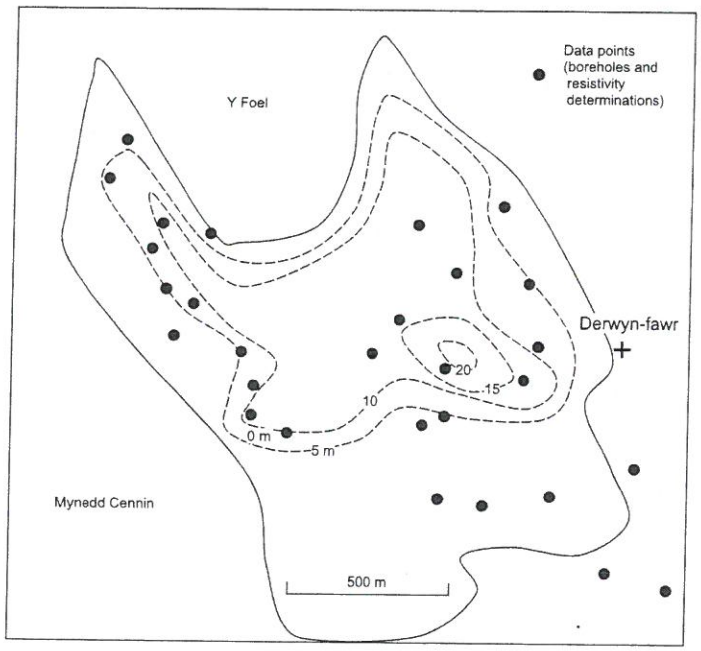


*Figure 25 Map showing lines of equal thickness of sand and gravel in Block 10E at Derwyn fawr*

*Block 10F (Llecheiddior Uchaf)* This small block, not formally identified in the 1988 survey by number, occupies an area of approximately 0.50 square kilometres to the west of Bryncir. It forms a double or triple-ridged kame moraine showing a steep northern, or up-ice slope, probably marking the contact with the ice-margin, and a shallow southern, down-ice slope, probably part of an ice-front alluvial fan. The block shows evidence of considerable former quarrying operations but no current exposure. It was estimated to contain 1.14 million tonnes of sand and an equivalent volume of gravel and was rated as of moderate commercial potential because of its low overall volume and relatively high proportion of fine sand and silt. Because of limited investigation the estimates are of low reliability.

*Block 10G (Hendy)* This small block, also not formally identified in the 1988 survey by number, occurs south of the moraine ridges at Llecheiddior and correlates with the outer part of the Bryncir moraines on the eastern side of Afon Dwyfach. The block consists of a narrow, linear ridge that extends southwest discontinuously towards Pwllheli. It occupies an area of approximately 0.50 square kilometres. The block contains a number of former, now restored quarries. On the basis of three boreholes the block was calculated to contain approximately 1.25 million tonnes of sand and 2.50 million tonnes of gravel. The block was regarded as of medium to low commercial potential, mainly because much of the narrow ridge is effectively sterilised by three farms and a minor road running partly along its crest.

*Mineral Summary* A summary of the potential mineral in the area is shown in Table 13. The fourteen blocks cover a total area of 15.29 square kilometres and contain an estimated total of 72.87 tonnes of sand (38 % of total mineral) and 118.69 million tonnes of gravel (62 % of mineral). The largest volume of potential mineral, at over 30 million tonnes, occurs in the currently unexploited Block 10C2 at Bodychain. A further four blocks contain mineral reserves of over 20 million tonnes, including Graianog and Bryncir which, between them, include all the active quarries in the area. Three blocks contain between 10 and 20 million tonnes; one between 5 and 10 and three with less than 5 million tonnes.

**Table 13: Area 14 Penygroes - Summary of Resource Blocks and Volumes**

| Block | Landform Type | Basis of Assessment | Reliability | Commercial Potential | Area sq Km | % Sand in Mineral | % Gravel n Mineral | Sand (Millions of tonnes) | Gravel (Millions of tonnes) | Total Sand and Gravel (Millions of tonnes) | Waste (Millions of tonnes) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10A1 Garth Dorwen | KT | 1 | H | L | 0.23 | 45 | 55 | 1.18 | 1.44 | 2.62 | 0.52 |
| 10A2 Cae Efa Lwyd | KM | 1 | H | H | 0.16 | 45 | 55 | 0.91 | 1.11 | 2.02 | 0.05 |
| 10A3 Tan-y-bryn | KM | 1 | H | H | 0.33 | 32 | 68 | 2.13 | 4.52 | 6.64 | 0.12 |
| 10A4 Minfford | KM | 1 | H | L | 0.52 | 10 | 90 | 0.40 | 3.56 | 3.96 | 0.16 |
| 10A5 Plas Newydd | PM | 1 | H | L | 1.63 | 25 | 75 | 3.02 | 9.05 | 12.07 | 0.96 |
| 10B Ffridd-bach | S | 1 | H | H | 1.55 | 40 | 60 | 9.42 | 14.13 | 23.55 | 7.06 |
| 10C1 Cwmbran [2] | KM | 1 | H | L | 0.96 | 35 | 65 | 6.52 | 12.10 | 18.62 | 0.00 |
| 10C2 Bodychain | S | 1 | H | H | 1.62 | 35 | 65 | 11.15 | 20.71 | 31.86 | 0.70 |
| 10C3 Graianog | DT | 1 | H | H | 1.18 | 37 | 63 | 8.88 | 15.12 | 24.00 | 0.00 |
| 10C4 Ty-glas | KM | 1 | H | M | 2.06 | 45 | 55 | 10.58 | 12.94 | 23.52 | 3.86 |
| 10D Bryncir | KM | 1 | H | H | 2.54 | 40 | 60 | 8.12 | 12.19 | 20.31 | 1.02 |
| 10E Derwen Fawr | KM | 1 | H | H | 1.76 | 50 | 50 | 8.18 | 8.18 | 16.35 | 0.89 |
| 10F Llecheiddior Uchaf | KM | 1 | H | M | 0.29 | 50 | 50 | 1.14 | 1.14 | 2.28 | 0.00 |
| 10G Hendy | KM | 1 | H | M | 0.47 | 33 | 66 | 1.25 | 2.50 | 3.75 | 0.12 |
| **Total for Area:** | | | | | **15.29** | | | **72.87** | **118.69** | **191.56** | **15.46** |

[1] Table derived from University of Liverpool report (1988) recalculated in tonnes. Percent sand and gravel calculated from sample records in the 1988 report. Blocks A6, A7 and A9 are equivalent to Blocks 4E, 4F and 4P in Area 4 and are not listed here. Block A8 was not identified in this report.

[2] Volume of waste for Block 10C1 (Cwmbran) not available.

### The future of existing extraction sites in Area 10

Area 10 contains the two principal sand and gravel quarries in North West Wales. Both quarries have opened since publication of the 1988 report, though in adjacent areas. Cefn Graianog Quarry in Block 10C3 exports 85 % of the aggregate extracted to the North Wales region, comprising 2 % building sand; 34 % concreting or sharp sand, 30% gravel for concrete aggregate and 31 % gravel for other purposes. Bryncir Quarry in Block 10D exports all the material extracted to the North Wales region, comprising 37 % building sand, 57 % gravel for concrete aggregate and 6% used for fill.

The operators of Cefn Graianog quarry have experienced some difficulty working the deposit, largely because of the relatively high proportion of oversize material encountered. This problem is likely to be exacerbated if extraction moves further north towards the predicted location of the ice margin responsible for creating the ridge. Should this problem serve to make the operation of the quarry uneconomic two possible alternatives solutions arise for maintaining security of supply from the area.

The first alternative is to abandon working at Cefn Graianog and apply for planning permission to exploit one or other of the resource blocks in Area 10 identified as having significant reserves of commercial quality and moving the processing plant to it if successful. These blocks include:

- Block 10B at Fridd-bach. This block, otherwise unconstrained, has very difficult minor road access, compounded by the lack of a junction with the A487 which would require site traffic to pass through Llanlynfi.
- Block 10C2 at Bodychain. The south western side of this block is unconstrained and has direct access to the adjacent A487.
- Block 10C4 at Ty-glas. Although much worked in the past, and with one area in the northeast part at benefiting from planning permission, it is our view that this block has had much of the more easily exploited mineral removed and, with the exception of an area in the south, has difficulty with the proportion of waste.
- Block 10E at Derwen Fawr. This block, otherwise unconstrained, also has very difficult road access which could only be resolved by bridging the Afon Dwyfach, which borders the eastern side of the block, to gain access the A487.

The second alternative is to abandon working at Cefn Graianog, apply for planning permission for Block 10C at Bodychain, keep the processing plant on site at Cefn Graianog and connect with the new quarry by conveyor. A major constraint, however, is that the conveyor would have to cross the recently completed cycle route connecting Bryncir with Caernarfon.

In any of these cases it would be essential that very detailed site investigation was undertaken, at a higher density than currently available, to ensure that the inherent variability seen in the deposits of this area was clearly established.

The future of extraction at Bryncir appears from the evidence available to be reasonably well assured, particularly in sets of mounds to the east and south of the current workings. Elsewhere in the block, especially along its eastern margin there are some reservations regarding lateral continuity and the irregular occurrence of bedrock at shallow depth.

Summary conclusions:

- Area 10 contains the largest volume of potential mineral in North west Wales, amounting to approximately 192 million tonnes, split between sand, with 73 million tonnes, and gravel with 119 million tonnes.
- Of the 14 identified resource blocks only two are currently exploited: Blocks 10C3 at Graianog and 10D at Bryncir.
- Of the blocks currently not exploited five have high commercial potential, of which the largest is Block 10C2 at Bodychain.
- Although most blocks are relatively sand-poor, some large volume blocks contain higher than average proportions of sand. These include Blocks 10D at Bryncir and 10E at Derwen Fawr and. Some low volume blocks also contain significant volumes of sand. These include Block 10A2 Cae Efa Lwyd and 10F at Llecheiddior Uchaf.
- Any radical resolution of the problems experienced at Cefn Graianog should be preceded by very detailed site investigation.

## 10.11 The Mineral Resources of North west Wales

Table 14 and Figure 26 provides a summary of the gross potential mineral resources of North West Wales based on the work reported here. Overall, some 530 million tonnes of potential mineral have been identified, broken down into 270 million tonnes of sand and 260 million tonnes of gravel. Of the total approximately one half has been ranked as of high commercial potential. The distribution is not spread evenly. At the county level the great majority of resources occur in Gwynedd (92 %), with Conwy and Anglesey together providing less than 8% and the Snowdonia Park Authority area zero. At the regional level the distribution is also not spread evenly. Thus, the greatest concentration of reserves (together totaling nearly 75 %) occurs in the Cors Geirch, Nefyn and Penygroes areas and all the other areas combined provide less than 25 %. The table also indicates that the resources bear little relationship to areas of demand for mineral. Thus all the potential resource areas along the west and north coasts that are in close proximity to the major demand areas of Caernarfon, Bangor and the Conwy-Llandudno-Colwyn Bay areas have disappointingly low volumes of potential reserves and none contain any resource blocks ranked as of high commercial potential. This carries two implications. First, is that any effort to find resources very close to market is likely to be difficult and expensive. Second is that if sand and gravel supply from land-based resources is to be maintained relative to marine-won resources or import from other areas of Wales, then the Penygroes area, the nearest large resource block area to the main centres of demand, is likely to remain the major source area of supply.

Of the 205 million tonnes of mineral in the Cors Geirch and Nefyn areas, 75 % is sand. Of the 190 million tonnes of mineral in the Penygroes area, 62 % is gravel. This implies that if the current difficulties in obtaining a supply of sand from the Penygroes area are maintained, due to the need to grade large quantities of gravel and stockpile the residue, then the Cors Geirch and Nefyn area may, in the future, be a better prospect for supplying sand.

***Table 15: Gross Potential Mineral Resource in North West Wales***

| *Area* | *Sand Millions of tonnes* | *Gravel Millions of tonnes* | *Total Mineral Millions of tonnes* | *Total Mineral ranked as of High Commercial Potential* | *Area Rank by Gross Potential Mineral Resource* |
|---|---|---|---|---|---|
| 1 Cors Geirch | 95.26 | 27.28 | 122.53 | 67.54 | 2 |
| 2 Nefyn | 57.88 | 24.81 | 82.69 | 60.24 | 3 |
| 3 Trefor-Pontllyfni | 7.53 | 13.72 | 21.25 | 0.00 | 6 |
| 4 Glynllifon-Bontnewydd | 10.24 | 29.46 | 39.70 | 0.00 | 4 |
| 5 Llanrug | 1.02 | 3.72 | 4.74 | 0.00 | 10 |
| 6 Glasgoed-Talybont | 4.64 | 10.49 | 15.13 | 0.00 | 7 |
| 7 Bala | 3.76 | 5.13 | 8.89 | 2.01 | 8 |
| 8 Pentraeth | 1.69 | 3.93 | 5.62 | 0.00 | 9 |
| 9 Conwy Valley | 15.68 | 23.53 | 39.21 | 0.00 | 5 |
| 10 Penygroes | 72.87 | 118.48 | 191.35 | 124.74 | 1 |
| **Totals:** | **270.58** | **260.54** | **531.11** | **254.53** | |

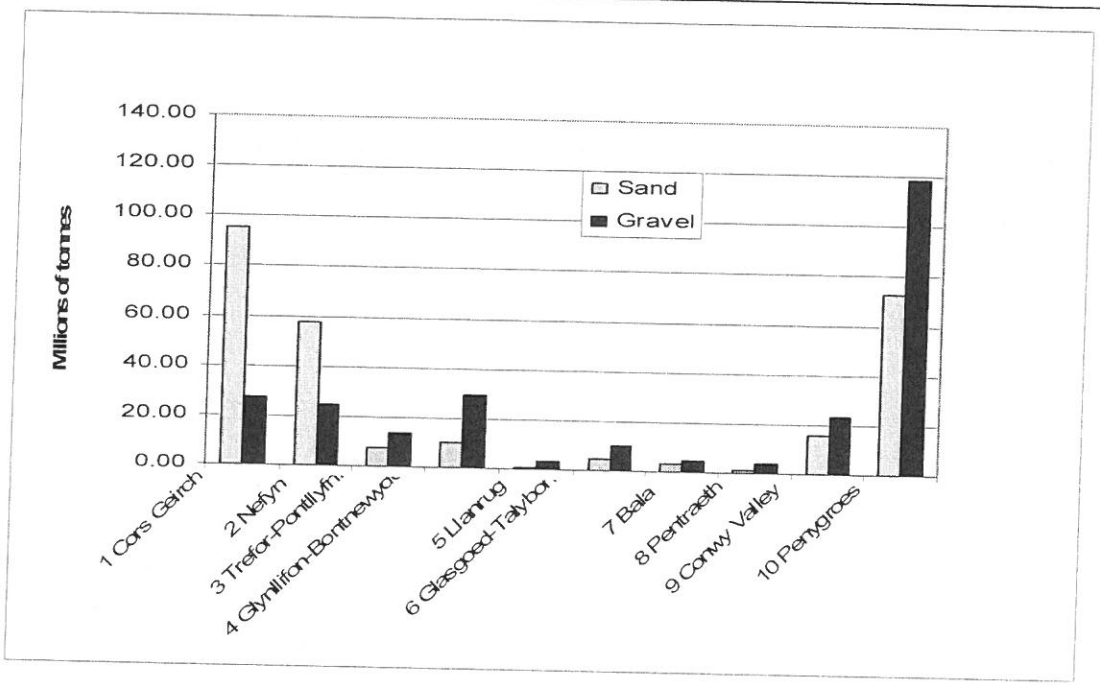


*Figure 26. Distribution of Gross potential mineral resources in North West Wales by area.*

# 11 ENVIRONMENTAL, ECONOMIC AND PLANNING ISSUES

## Introduction

The principal source of sand and gravel in North West Wales is centered on resources within the Gwynedd Council area. That area supplies sand and gravel to the adjacent areas of Anglesey, Conwy and the Snowdonia National Park. The quality of the landscape is one of Gwynedd's principal assets, and there is therefore concern about the environmental capacity of this sensitive area to absorb additional mineral working.

The Welsh Assembly Government recognises the importance of the supply of aggregates to the economic well-being of the country and the results of this study will help to ensure that sources of aggregates are available for all regions, and that these can be exploited in a way that is both sustainable and environmentally responsible.

The maintenance of future supplies of sand and gravel from resources in Gwynedd is therefore seen to be a matter of sub regional, rather than local importance. This study has established the location and nature of sand and gravel resources in North West Wales. The information can be used to assist the development of UDP policies and/or make site specific land use allocations to maintain future regional supply in a way that meets sustainable development objectives.

## Study methodology

Enviros Consulting Limited has assisted the University of Liverpool in its assessment of identified sand and gravel resources in North West Wales. Enviros carried out a review of national and local mineral planning policy and the supply and demand of sand and aggregates in the study area. Interviews were carried out to supplement a desk study of the current position. Each of the resource blocks identified by field studies were assessed to understand constraints on their future exploitation and the results were used to advise on the implications for mineral planning in the study area.

## Planning policy and sustainable development

'Planning Policy Wales' was published in 2002 [1]. The document sets the context for sustainable land use planning policy for the preparation of Unitary Development Plans and development control decisions. However, because of the differences between mineral working and other forms of development the Assembly' Government's land use planning policies for minerals development are contained in separate mineral planning documents (see below).

The Assembly Government intends to mainstream the principles of sustainable development into the way it operates. This means taking social, economic, and environmental issues into account in everything it does. 'Planning Policy Wales' is a key strategy which underpins the principle of sustainable development. In terms of resource use, Welsh planning policy supports the UK vision for sustainable development, which includes prudent use of natural resources. One of the Assembly Government's principals underpinning its approach to sustainable development is respect for environmental limits through the sustainable use of natural resources.

The Assembly Government's 2003 Sustainable Development Report and Action Plan describes the commitment to pursue the vision of a sustainable Wales and reports on progress in relation to its 12 sustainable development indicators:

- Percentage of people of working age in work.
- Percentage of people at 19 with at least an NVQ level 2 qualification or equivalent.
- Crime rates per 100,000 population for theft from a vehicle, burglary in a dwelling, violent crime.
- Percentage of unfit dwellings.
- Emissions of greenhouse gases.

[1] Planning Policy Wales, Welsh Assembly Government, March 2002.

- Days per year when air pollution is moderate or higher in Cardiff, Swansea, Port Talbot, Aston Hill, Narberth.
- Percentage of river lengths of good or fair chemical and biological quality
- Population of wild birds
- Household waste and amount recycled or composted (kg per person per year).
- Percentage of people who are Welsh speakers.
- Percentage of electricity produced in Wales generated from renewable sources.
- Wales global ecological footprint in area units per person

The Assembly Government now takes sustainable development into account in all decisions and has developed, and started to use, a sustainability appraisal methodology, or 'integration tool' for use in designing policies. At a minerals planning level, the Assembly Government is considering use of a methodology which assesses the capacity of Welsh land to accommodate future aggregate extraction (EMAADS, see below).

Minerals Planning Policy for Wales was published in 2000 [1], prior to publication of national planning policy and a specific, but draft, Technical Advice Note (TAN) on Aggregates (both published in 2002). The 2000 minerals planning document sets out land use planning policy guidance of the Assembly Government in relation to mineral extraction and related development in Wales. Mineral Planning Authorities are required to take the guidance into account in the preparation of Unitary Development Plans and it may be a material consideration when making development control decisions.

A key difference between mineral extraction and other forms of development is that extraction can only take place where the mineral is found to occur. The guidance requires development plan policies and decisions to take into account all costs and benefits associated with mineral working in accordance with the Assembly's Sustainable Development Scheme [2]. In essence this means mineral planning should have regard to social progress which recognises the needs of everyone, effective protection of the environment, prudent use of natural resources and the maintenance of high and stable levels of economic growth.

Key objectives of sustainable mineral development are:

- Meet society's needs for minerals,
- Protect areas of natural or built heritage,
- Limit the environmental impact of extraction,
- Encourage high standards of restoration, and
- Encourage efficient use of minerals.

The outputs from this study will help local authorities to meet the objectives of national planning policy. Local authorities in the study area will have a greater understanding of where sand and gravel resources are located, the constraints and opportunities for exploitation of those resources and the extent to which they should contribute to the supply of aggregates to meet the needs of society.

Paragraph 11 of the guidance expects local authorities to make a contribution to meeting local, regional and UK minerals needs through their Unitary Development Plan. This should be done through the aegis of the Regional Aggregates Working Parties. Paragraph 12 of the guidance expects authorities to agree the contribution each should make to meet regional needs. The guidance suggests that *" policies which seek to meet only local needs or which rule out all forms of mineral working within an area will only rarely be acceptable".*

Guidance specific to aggregates is covered under paragraphs 67 to 70 of the document and the key points are:

[1] Minerals Planning Policy Wales, The National Assembly for Wales, December 2000.
[2] Sustainable development Scheme, The National Assembly for Wales, November 2000.

- It is essential for the economic health of the country that the construction industry is provided with an adequate supply of the minerals it needs,
- More detailed guidance on the technical aspects of the provision of aggregates will be provided in a Technical Advice Note (TAN), and
- Significant resources of high specification aggregates occur in Wales and this type of aggregate is important to the UK as a whole.

A consultation draft TAN covering aggregates was issued in 2002.[1] and at the time of publishing this study report, the draft is still at the consultation stage. The draft TAN sets out more detailed advice on the mechanisms for delivering the policy for aggregates extraction by mineral planning authorities and the aggregates industry. The TAN will supersede Mineral Planning Guidance Note 6.

The TAN sets out the objective in planning for aggregates provision: *"to ensure supply is managed in a sustainable way so that the best balance between environmental, economic and social considerations is struck, while making sure that the environmental and amenity impacts of any necessary extraction are kept to a level that is acceptable to the determining authority".*

Aggregate production data for informing the TAN is based on periodic survey work undertaken by the Regional Aggregate Working Parties (RAWP). In relation to the study area this is the North Wales RAWP. Their latest report is summarised later, below.

Econometric forecasts have been used to project aggregate demand to inform planning decisions about future levels of supply. There is evidence that recent projections were significantly higher than actual land won production. There is also a view that the provision of supply (extraction facilities) to meet exaggerated demand forecasts can lead to a higher level of supply of primary resources and deter the need to use alternative materials. The National Assembly for Wales has decided that this approach to planning for the supply of aggregates does not tie in closely enough with the principles of sustainable development.

It is intended that monitoring of aggregated demand will be undertaken by RAWPs using ideas relating to environmental capacity and environmental capital and that future supply of aggregates will reflect current notions of sustainability by:

- A careful assessment of existing resources;
- Only allowing additional extraction to take place in the most environmentally acceptable locations and recognising that in some local authority areas resources may not be available, or that it may be inappropriate or unacceptable for them to contribute to regional supply;
- Reducing the proportion of primary aggregates used; and
- Minimising transport of aggregates by road, seeking self-sufficiency within regions and re-assessing the environmental issues associated with exporting aggregates to areas outside Wales.

**EMAADS**

The draft TAN represents a shift in the emphasis of planning policy in its approach to both demand and supply of aggregates in Wales. Consultants were appointed in May 2002 to establish a new methodology for estimating demand and supply of aggregates based on sustainable aims.

With regard to supply, an environmental capacity methodology is proposed for use in assessment of the capacity of different areas in Wales to accommodate future aggregate extraction. The methodology is known by the acronym EMAADS [2]. The methodology applies 1 km grid squares to identified resource blocks and a capacity analysis is undertaken, assessing the square's performance against 12 indicators which attempt to address the environmental capacity-related

[1] Consultation Draft Minerals Technical Advice Note (Wales) – Aggregates, The National Assembly for Wales, February 2002.
[2] Establishing a Methodology for Assessing Aggregates Demand and Supply, Final Report, Arup, April 2003.

impacts of quarrying. The results are displayed graphically in a wedge diagram showing each indicator value. The results can then be amalgamated into a regional capacity map. The methodology is not intended for use in UDP site selection or as a basis for development control decisions. However, the capacity map can form the basis for policy discussions at the RAWP level or identify 'preferred areas' worthy of further investigation.

Environmental capacity can be considered in terms of 'physical', 'ecological/environmental' and 'perceptual'. The methodology examines a number of indicators which cover the different capacity elements as follows:

| *Indicator* | *Physical* | *Ecological/ environmental* | *Perceptual* |
|---|---|---|---|
| Settlements in local area | | | |
| Watercourses at risk | | | |
| Standard of road network | | | |
| Agricultural land use class | | | |
| Nature conservation sites | | | |
| Historic sites | | | |
| Rights of way | | | |
| Proximity to National Park/AONB | | | |
| Proximity to SLA/heritage coast | | | |
| Impacts from existing working | | | |
| Buffer zones | | | |
| Disused workings in areas | | | |

This current study does not apply the EMAADS methodology to the identified resource blocks. This is because the methodology requires a number of qualitative judgments to be made which are more correctly applied at RAWP level. However, a comparative assessment is provided, based on a simplified version of the above indicators. This should enable the Assembly and the RAWP to draw some initial conclusions about the development constraints of the resource blocks.

**Mineral planning background in the study area**

Prior to the reorganisation of administrative areas in 1996, mineral planning in the study area was primarily the responsibility of Gwynedd and Clwyd County Councils. Mineral planning is now administered by the new unitary authorities which, in the study area, are Gwynedd Council, Isle of Anglesey County Council, Conwy County Borough Council and the Snowdonia National Park Authority.

The Gwynedd County Structure Plan was adopted in 1993 by the former county council. It contains the following policies relevant to sand and gravel extraction and this study:

Policy DD2

*There will be a presumption in favour of granting planning permission for mineral extraction and evaluation, where such activities do not conflict with policies designed to conserve the natural environment or the amenity of local residents.*

Policy DD4

*Areas in which potential mineral resources have been identified will be considered for designation as mineral consultation areas within which there will be a presumption against development prejudicial to subsequent exploitation of the identified resource. The recognition of these areas*

*will not in itself give rise to any presumption in favour of the granting of planning permission for the exploitation of such minerals.*

Policy DD6

*Proposals for the winning and working of minerals will be assessed against the following criteria:*

i. *The impact on the National Park, AONB's, Heritage Coast and Landscape Conservation Areas*
ii. *The effect on features of archaeological, architectural and historic interest*
iii. *The effects on nearby towns, villages, communities and residents*
iv. *The traffic generated and its impact on the local highway network*
v. *The demand for the proposed product and the location of other sources of supply*
vi. *The effect on local and county-wide employment*
vii. *The effects on farming activities*
viii. *The suitability of the site for restoration and an acceptable after use*
ix. *The agricultural quality of the land concerned*
x. *The potential effect on water resources*
xi. *The impact on areas of nature conservation interest*

Policy DD8

*In considering proposals for the development of aggregate mineral workings the county council will have regard to the need to maintain an adequate landbank of permitted reserves calculated in accordance with national and regional guidance.*

Policy DD10

*The county council will encourage the use of local secondary aggregates, where appropriate, as alternatives to naturally occurring aggregates or other minerals.*

Policy DD11

*The county council will encourage the supply of marine dredged aggregates as an alternative to land based aggregates where the use of coastal landing sites does no cause significant problems in terms of marine ecology, coastal protection, landscape conservation, preservation of amenity, or the transport of aggregates.*

The County Structure Plan is a material planning consideration but the level of its importance diminishes as each replacement Unitary Development Plan proceeds through the statutory procedure towards its adoption.

Supplementary Planning Guidance (SPG) for Minerals (in Gwynedd County Council area) was published by the county council in March 1996 just prior to its abolition. The SPG is still a material planning consideration for the consideration of mineral development in most of the study area (part of Conwy County Borough Council area lies within the former Clwyd County Council area. The guidance consists of a written statement of detailed policies for the winning and working of minerals within the area of the county of Gwynedd and its successor authorities. The guidance covers the period 1996 to 2006 and it was always intended that the guidance would be reviewed as part of the Unitary Development Plan process. The policies of the SPG are in general conformity with the Gwynedd Structure Plan.

The SPG defines Primary and Secondary Aggregates for the purposes of mineral planning in the area. Primary aggregates are those which have been won and worked from the ground directly. In the study area, they consist of crushed granite, limestone and, to a lesser extent, quartzite. Secondary aggregates are not derived directly from the ground but from materials which have been discarded as part of the extraction process, for example, slate and granite quarry waste, disused railway line ballast, recycled concrete, road planings and other industrial materials. A

further source of secondary aggregates is recycled construction waste but that material is beyond the scope of this study.

This study is principally concerned with evaluating the location and volume of 'fine aggregates' in North West Wales. In 1996 the SPG considered that *"the area benefits from substantial deposits of glacial and fluvial-glacial sand and gravel".*

The SPG had a number of objectives and, to some extent, it can now be regarded as dated. However, other than 'Minerals Planning for Wales', current guidance is either in draft or in unadopted form. In essence, the SPG sought to ensure an adequate and sustainable supply of minerals to meet an identified need. In pursuit of this, the SPG set demand forecasts, which are now superseded. It also set a number of general policies which continue to be planning considerations for the purposes of development control.

In summary, SPG policies relevant to this study are:

- GP1 – Sustainable use of resources – to encourage the sustainable use of mineral resources.
- GP2 – Landscape designations – protect designated areas.
- GP3 – Nature conservation and biodiversity – safeguard designated sites.
- GP4 – Landbanks – maintain a landbank of sand and gravel reserves in accordance with regional and national guidelines.
- GP8 – Planning criteria – criteria to be satisfied before planning permission granted.
- GP9 – Protection of mineral resources – safeguard identified resources from sterilisation by other development.
- SG1 – Further permissions – presumption in favour of new permissions in a defined area to meet forecast need for sand and gravel.

**Gwynedd Council**

The council area lies within part of the former Gwynedd County area and contains all the principal sand and gravel workings in the region. The following sand and gravel extraction sites are relevant:

| | | |
|---|---|---|
| Graianog Farm, Llanllyfni | SH 460 495 | (Active) |
| Bryncir Quarry, Dolbenmaen | SH 486 455 | (Active) |
| Sarnau, Bala | SH 968 390 | (Inactive) |
| Henbant Bach, Clynnog | SH 446 495 | (Inactive) |
| Cae Efa Lwyd, Penygroes | SH 464 529 | (Dormant) |
| Tan y Bryn, Penygroes | SH 466 521 | (Dormant) |

Together, these sites provided for a reserve in the order of 3,000,000 tonnes as at 31 December 2002 [1]. The main quarry operators are Tarmac Quarry Products Limited and RMC Aggregates (North Western) Limited.

A consultation draft Unitary Development Plan was published in July 2002 and responses are currently being considered. It is the intention of the council to review the mineral policies later this year to take into account more recent guidance and information, including the results of this study. The following current policies are relevant to this study:

- Policy C6 – Proposals for mineral working – proposals for new mineral workings will be refused unless there is demonstrable need, the economic benefits are clearly stated and certain other criteria are met.

[1] Source: Letter from Development Control Manager, Gwynedd Council, 29 July 2003.

- Policy C7 – Impact of proposed mineral workings – proposals will be approved provided they do not have any unacceptable impact on certain criteria including designated areas.
- Policy C8 – Safeguarding mineral resources – proposals which impede the future availability of identified mineral resources [on the proposals map] will be refused.
- Policy C11 – Removal of secondary and recycled aggregates – proposals to remove material from a mineral working deposit will be granted providing certain are met.

**Isle of Anglesey County Council**

The council area lies within part of the former Gwynedd County area. There are no conventional sand and gravel extraction sites but a small site produces sand, clinker and ash from a deposit of spent railway fuel and dune sand has been extracted from other small sites. None of these sites make any significant contribution to Anglesey's sand and gravel requirements.

A deposit Unitary Development Plan was published in November 2001 and proposed changes were published in October 2002. The following current policies are relevant to this study:

- Policy MP1 – Aggregate landbank – a landbank of permitted reserves for aggregate will be maintained.
- Policy MP3 – Need for minerals – regard will be had to certain criteria including national, regional or local or requirements.
- Policy MP8 – Sterilisation – mineral resources will be protected from sterilisation.

**Conwy County Borough Council**

The council area lies partly within of the former Gwynedd County area and partly within the former Clywd County area. There are currently no sand and gravel resources being worked. Aggregate is produced from hard rock quarries located along the coast. There are no permitted reserves of fine aggregates/sand.

Currently, the mineral development plan framework in the County Borough is provided by the Gwynedd Structure Plan and the Clwyd Structure Plan. A draft Unitary Development Plan was published in April 2001. The policies are currently being reviewed and it is intended to put the plan on deposit in April 2004. The following current policies are relevant to this study:

- Policy M1 – Proposals for the winning and working of minerals will be assessed against certain criteria, including the contribution it makes to meeting local, regional and national requirements.
- Policy M10 – land designated on the proposals map for winning and working of minerals will be safeguarded from inappropriate development.

**Snowdonia National Park Authority**

The National Park lies within of the former Gwynedd County area. The Eryri Local Plan incorporating minerals and waste 1993 – 2003 was adopted in 1999. There are currently no sand and gravel resources being worked and the park authority does not anticipate any proposals for extraction of sand and gravel will be forthcoming because exploitable resources are considered to be of negligible extent. The following current policies are relevant to this study:

- Policy MW1 – the NPA will not allocate any new land for extraction or quarrying of aggregates.
- Policy MW3 – proposals for new workings will be considered in relation to the NPA's statutory duty to enhance and protect the environment of the National Park and assessed against certain criteria including the availability of sources outside the National Park.

A deposit draft Unitary Development Plan is expected to be published in 2003. Similar policies to the Local Plan are currently proposed.

**Review of North Wales Aggregates Survey information**

The North Wales Regional Aggregates Working Party Annual Report 2001 represents the most up to date published information on the sales of aggregates, amount of reserves and the size of the landbank within the study area. The report is based on the results of an aggregate monitoring survey for the calendar year 2001.

Anglesey, Snowdonia and Conwy made no contribution to North West Wales sub-regional sand and gravel sales between the period 1996 to 2001. Gwynedd continues to be the sub-regional supplier, but the survey shows a continued decline in sales. For example, from 371,000 tonnes in 2000 to 216,000 tonnes in 2001[1].

The sand and gravel landbank for North West Wales is currently 15 years with reserves at 3,070,000 tonnes. If production continues at a rate of 200,000 tonnes per annum for the next five years, the level of reserves in 2007 will be 2,070,000 with a landbank of 10 years. If exploitation of reserves at Henbant bach is not commercially viable then the level of reserves at 2007 would be 870,000 tonnes with a landbank of only 4.35 years.

Future aggregate demand predictions from the 1995 North Wales RAWP report have been shown to be optimistic. Sales of sand and gravel in the whole of North Wales were predicted to be 2.18 M tonnes but were actually 1.39 M tonnes. Based on recorded trends since 1992, further increase in sales over and above 2001 levels is now considered to be unlikely. Recycled construction and demolition waste, and secondary aggregates supplies (for example from slate waste) will play an increasing role as a substitute to primary won materials. There is little difference in end use of sand and gravel between 1997 and 2001 - the survey showing a greater use in soft sand and less use for fill.

No major development proposals or highway schemes are planned in the study area in the foreseeable future and the overall conclusion is one of a declining supply to meet a declining demand - itself influenced by more sustainable use of construction materials and substitute materials.

There are few options for alternative to fine aggregates. Research findings on the use of slate waste and recycled construction/demolition waste are both current. Further increases in the use of marine dredge sand is beyond the scope of this study but it should be noted that this source has its own environmental constraints including sea-bed/coastal impacts, wharfage issues and transport costs. Crushed rock fines from hard rock quarries in Conwy represent a further alternative source of fine aggregates, particularly in concrete manufacture.

**The economics of sand and gravel supply and demand**

Other than the workable sand and gravel permitted reserves in Gwynedd, some marine dredged sand and some other negligible supplies of fine aggregates from active sites in the study area, future prospects must be tested against an emerging policy which aims to ensure that sustainability and protection of the environment lie at the very heart of planning for minerals extraction.

Future demand for primary won sand and gravel will depend on its local availability, the suitability of alternative sources of material and the cost of transporting material to the user. Unless values are enhanced by conversion to a construction product at source (for example concrete products), sand and gravel has a low value relative to transport costs. Constraints on future supplies due to environmental capacity considerations may result in transport of supplies over increased distances, with the cost increase passed to the purchaser.

Gwynedd is currently able to supply most of the fine aggregate demand in North West Wales with a contribution from marine dredged supplies. If future supplies from Gwynedd are constrained, supplies may have to be sourced from beyond the sub region. The ability of the construction industry to absorb the inevitable increase in cost is dependent on the availability of alternative supplies and whether there are opportunities to change the way the material is used. If greater

[1] This includes marine dredged sand landed at Bangor

environmental protection measures are called for, to mitigate against additional extraction in environmentally sensitive locations, the extraction industry will base their future plans on whether the market can accommodate the greater costs. If it cannot then the industry is likely to reduce or terminate production,

**Prospects**

The study has identified a number of potential resource blocks (or 'prospects') and a technical assessment has been applied in relation to reliability and commercial potential. An environmental assessment has also been applied using a simplified form of the EMAADS indictors. The simplified indicators are:

- proximity of prospect to designated areas,
- proximity of prospect to built up/development areas, and
- location of prospect in relation to road systems.

A simple numerical grading system has been applied to represent low, moderate or high levels of significance for each indicator. 'Not applicable' is used where the significance is not considered relevant to the indicator.

Each level of significance is defined as follows:

| | 1 | 2 | 3 |
|---|---|---|---|
| **Designated areas** | Lies more than one kilometres from a designated area | Lies within one kilometre of a designated area | Lies on, partly on or abuts a designated area |
| **Built-up** | Lies more than two kilometres of a built up area | Lies within one kilometre of a built up area | Lies on, partly on or abuts a built up area or areas planned for development |
| **Transport** | Lies within one kilometre from primary road network and relatively close to main user concentrations | Lies within one kilometre from a primary road network and some distance from main user concentrations | Lies more than one kilometre from primary road network and some distance from main user concentrations |

High scores for environmental indicators would indicate strong constraints against development of the prospects. This is likely to be reflected in a resistance to planning permission being granted based on the Assembly's approach to considering environmental capacity. The local authorities, through the RAWP, would need to consider the environmental impacts before including these prospects as a resource which could contribute to meeting future demand.

Appendix B (Sheet 3) presents the results of this initial assessment. It is not intended to be an accurate method of determining sand and gravel resources which could be relied upon to meet future demand. However, the approach does give some indication of the likely scale of environmental constraints which must be considered and the trade-off which may have to be made to apply the future aim with regard to supply: *"to ensure that future supply of aggregates is obtained from the most acceptable locations, taking into account the geological availability of different types of aggregates and the environmental capacity of areas in Wales to supply aggregates".*

**Resource conclusions:**

The following conclusions can be drawn from the environmental assessment applied to each identified prospect in the study area.

***None of the prospects achieve a low score in all three environmental indicators.***

For example, low significance scoring against designated area and built up area constraints may still leave a moderate or higher significance against transport constraints. These issues may become clearer if the EMAADS methodology is applied but we suspect that individual sites will still require judgemental considerations with respect to their environmental suitability and merits.

***Prospect which score relatively well against environmental constraints may still score badly against technical and commercial constraints.*** It is apparent that prospects which show relatively good scores against environmental constraints are often furthest from the main user areas or score poorly against other technical criteria. These prospects sites may be considered as a future exploitable resource but with suitable mitigation and/or further individual prospect investigation.

**Implications for minerals planning in North West Wales**

Discussions with each of the mineral planning authorities has indicated a need for a common approach. There is much to be gained by applying a joint approach through joint supplementary planning guidance (SPG) which takes into account the resources identified in this study and the sustainable mineral development policy promoted by the Assembly. SPG can be produced within the existing development plan review timeframe.

Gwynedd must continue to provide the majority of sand and gravel supplies to the area. There is the potential for smaller prospects outside of Gwynedd and these should be exploited in a way which meets local needs.

Prospects should be shown on a resource map prepared by the RAWP using either EMAADS or a similar assessment methodology.

It may be necessary to grade mineral areas on the prospect map to show those prospect with lower environmental constraints and those prospects which also require further technical consideration. A criteria-led policy approach will therefore continue to remain important.

Development plans should include complimentary policies supporting the objectives of better use of the available resources in North West Wales, secondary aggregate supply, and alternatives to aggregate supply (recycling, use of alternative materials, etc).

It may be difficult to apply the draft TAN sustainable mineral policy in practice – especially in the short term (next 5 to 10 years) without making trade-offs.

**Local supply for local need**

In the main, the structure of the aggregate industry in Britain is dominated by large national, and increasingly, multinational companies that, in order to benefit from economies of scale and reduced capital costs of plant, seek to develop large, high volume quarries. This structure is most suited to the supply of aggregates to large areas of adjacent urban population where demand is high. It is less attractive in areas of moderate or low population density as demand is low and utilization of fixed-cost plant, measured either in volume of aggregate processed through it, or in days worked, is low. It is also less attractive for the customer as average distance from quarry to customer in such areas will invariably be higher and will be reflected in the cost.

An alternative framework for the aggregate industry in predominantly rural areas may be to place less reliance for meeting demand on large quarries and instead seek to develop small, sustainable quarry operations that supply only a local market. Some countries with large areas of predominantly low population density already operate such a model. Norway, for example, is a large country the great majority of which is of very low population density. Scattered throughout, is a hierarchy of small urban settlements ranging upwards from populations of a few hundred to a few thousand people and separated from one another by often long distances of a hundred kilometres or more. Around the periphery of the capital, Oslo, conventional sand and gravel

quarries operate to provide demand for the building and civil engineering industries. Elsewhere, however, very small quarries operate to serve an essentially local demand as the large distance between settlements prohibits large scale regional quarries because of the high cost of transport. The great majority of these quarries are operated part-time by local people using relatively unsophisticated and low-cost mobile plant, on an as-and-when basic, often in conjunction with other occupations such as agriculture. The siting of quarries is determined by the availability of appropriate mineral resources and its location is the responsibility of the Norges geologiske undersøkelse (Norwegian Geological Survey) who provide data to the local flyke (or county), who act as the equivalent of a Mineral Planning Authority. Like Wales, the greater proportion of aggregate is obtained by exploitation of glacial deposits.

Although Wales is not comparable to Norway in either size or population density the principle of local supply may nonetheless apply as the crucial parameter is not the absolute distance between market centres, and hence quarries, but a critical distance limit, approximately 25 km in the UK, beyond which the cost of transporting a low cost product such as aggregate escalates rapidly. Little information is available on the market costs of relatively small quantities of aggregate in small towns in Wales that fall outside this distance limit but hearsay evidence suggests that within the Snowdonia National Park, for example, much of the aggregate demand is supplied by purchase from national chain builders merchants, at significantly high cost.

Local supply has a number of significant advantages compared to large-scale operations:

- Small quarries with low-volume production will have much lower scenic impact than traditional workings and may be acceptable even in sensitive areas if carefully sited.
- Small quarries have the capacity for lower operating and production costs due to the development of cheap mobile plant, leading to a lower price to the local market.
- Low-volume, small quarries can provide flexibility in production schedules, including part-time or seasonal working and opening and closing on demand.
- Small quarries would generate a lower volume of site traffic and have less effect on local roads.
- Small quarries should be much easier to landscape and restore.
- Small quarries, suitably screened, could be used as reserve sites, to be used as and when necessary

This report has demonstrated that in all the areas examined, sufficient small scale resources exist to supply local markets amounting to no more than perhaps a few thousand tonnes of aggregate production per year compared with the normal minimum of a few hundred thousand tonnes per year for conventional extraction methods. As the report was principally concerned with establishing regional resources, many areas adjacent to small towns, especially within the boundary of the National Park, were not mapped in any detail but it seems likely that adequate resources could be found if sufficient geological research was undertaken in these areas to locate them.

As a policy of sustainable local quarry working is applicable to a significant proportion of Wales, and not just the area covered in this report, we would recommend that research be conducted on a national basis, under the auspices of the National Assembly, to devise a possible planning policy and framework for its implementation. This research should examine existing policy and practice in foreign countries, the inherent problems of identifying small local mineral resources and address issues such as the effect of replacing large quarries with a number of smaller operations and the planning controls required to prevent permissions granted for specific small quarries being used as a precedent for larger developments.

**Continued supply of marine dredged sand**

Marine dredged sand currently contributes approximately 20 to 25 % of total aggregate sales in Gwynedd. Although there is no clear breakdown between sand and gravel this probably represents about half of total sand sales. In recent years, especially in South Wales which is almost wholly dependent upon marine dredged sand for aggregate supply, public concern about the environmental impact of offshore dredging on marine life and beach depletion has risen

markedly. It may be therefore be judicious to examine the implications of a relatively rapid change in public policy towards marine dredging, its effects on supply and on local planning policy. Cession of marine supply would require the replacement of about 45,000 tonnes of sand with land-won supplies. In the short-term this would place an immediate strain on existing quarries and supplies would probably have to be supplemented to some considerable degree by import from other areas, at significant extra cost. In the longer term the quarries could probably be geared up to produce the extra volume as sand forms a relatively high, though variable, proportion of the resource. It may, however, be more economic for the supply from Cefn Graianog to be replaced with sand resources from elsewhere in the region. Consequently, it may be prudent to safeguard in advance known blocks of high quality sand in the Cors Geirch or Nefyn areas.

## 12 CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

This principal conclusions of the study are:

- North West Wales contains some 530 m tonnes of potential aggregate reserves, of which 260 million tonnes are sand and 270 million tonnes are gravel.
- Approximately one half of the potential aggregate reserves (265 million tonnes) have possible commercial value.
- Over 90% of potential aggregate reserves occur in Gwynedd.
- 75% of all potential reserves occur in three areas: Cors Geirch, Nefyn and Penygroes, all in Gwynedd.
- Less than 10% of potential reserves occur in Anglesey and Conwy.
- Potential reserves of possible commercial value occur at Pentraeth in Anglesey, sufficient for local needs.
- Potential reserves of possible commercial value occur in Bala, sufficient for local needs.
- Conwy is deficient in potential reserves of possible commercial value.
- No potential reserves of any significance, other than for small-scale local use, occur within the Snowdonia National Park Authority area.
- The Arfon lowlands, in which the main demand areas are located, is of low mineral potential.
- Extensive volumes of good quality sand have been identified in Cors Geirch (65 million tonnes) and around Nefyn (42 million tonnes).

### Recommendations

1. Gwynedd should continue to provide the bulk of sand and gravel resources for the North West Wales region.
2. Conwy should continue to meet demand by import from outside the authority area or from crushed rock, as appropriate
3. Anglesey should safeguard all identified resource blocks in the Pentraeth area for potential local use.
4. Gwynedd should safeguard the following resource blocks in order to provide adequate long-term mineral reserves:

   Block 6K (Pentir) in the Glasgoed-Talybont area

   Block 7A (Sarnau) in the Bala area

   Block 5B (Pont Afon) in the Llanrug area

   Blocks 10B ( Fridd-bach), 10C2 (Bodychain), 10C3 (Graianog), 10C4 (Ty-glas), 10D (Bryncir), 10E (Derwen Fawr), 10F and (Llecheiddior Uchaf) in the Penygroes area

5. Gwynedd should recognise the potential long-term strategic value of the sand-rich resource blocks in Cors Geirch and Nefyn by safeguarding the following:

   Blocks 1B (Pen-y-bryn), 1C (Bryn Bodvel) and 1G (Mathan Uchaf) in Cors Geirch

   Blocks 2 A (Maesoglen) and 2C (Fron Oleu) in Nefyn

6. The North Wales Regional Aggregates Working Party should be invited to take the findings of this report as a starting point for confirming areas for safeguarding and that it should initiate steps towards reaching a consensus agreement amongst the Mineral Planning Authorities regarding the areas to be protected.

7. A regional application of EMADDS or a similar methodology, perhaps based on the data presented in this report, should be used to evaluate resource blocks

8. A research program should be established, preferably under the auspices of the National Assembly, to investigate and devise a planning framework for the adoption of a policy of sustainable local quarry working for local aggregate needs.

**List of Appendices:**

Appendix A Plates and Geographical Information System maps of resource areas
*(Bound in the rear of the report)*

Appendix B Bibliography of the geology of North West Wales
*(PDF file: Appendix B Bibliography of the Geology of North Wales.pdf)*

Appendix C Summary of technical parameters, mineral volumes and environmental designations
*(PDF file: Summary of resource blocks.pdf)*

Appendix D Summary of pre-existing boreholes
*(PDF file: Borehole summary.pdf)*

Appendix E Laboratory test results
*(PDF file: Lab data.pdf)*

Appendix F Borehole logs
*(PDF file: Borehole logs.pdf)*

Appendix G Definitions of Environmental Designations
*(PDF file: Definitions of Environmental Designations.pdf)*

Appendix H ARCVIEW GIS database
*(These files are supplied only to Ordnance Survey license holders)*

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 1
## Area 1 Cors Geirch Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

**Geomorphology**

- Sandur
- 1st sandur terrace
- 2nd sandur terrace
- 3rd sandur terrace
- Diamict
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes



Kilometers
0 0.25 0.5 1 1.5 2

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 2
## Location of Resource Blocks

This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging , pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

- Scheduled Ancient Monuments (CADW)
- Resource Blocks

**Listed Buildings (CADW)**

- A
- B
- C
- I
- II
- II*
- Country Parks (CCW)
- Heritage Coastline
- Biosphere Reserve (UNESCO)
- Biogenetic Reserves (Bern Convention 1981)
- Special Protection Areas (EC Birds Directive)
- Special Areas of Conservation (EC Habitats Directive)
- Marine Nature Reserves
- National Nature Reserves (CCW)
- Local Nature Reserves (CCW)
- Sites of Special Scientific Interest
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty
- Snowdonia National Park
- Boreholes



Kilometers
0 0.4 0.8 1.2

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 3
## Area 2 Nefyn Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

**Geomorphology**

- Sandur
- 1st sandur terrace
- 2nd sandur terrace
- 3rd sandur terrace
- Diamict
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 4
## Area 2 Nefyn Location of Resource Blocks

This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

- Scheduled Ancient Monuments (CADW)
- Resource Blocks

**Listed Buildings (CADW)**

- A
- B
- C
- I
- II
- II*

- Country Parks (CCW)
- Heritage Coastline
- Biosphere Reserve (UNESCO)
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- National Nature Reserves (CCW)
- Local Nature Reserves (CCW)
- Sites of Special Scientific Interest (SSSI)
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty (AONB)
- Snowdonia National Park
- Boreholes

Kilometers
0 0.4 0.8 1.2

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 5
## Area 3 Trefor-Pontlynfi Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

**Geomorphology**

- Sandur
- 1st sandur terrace
- 2nd sandur terrace
- 3rd sandur terrace
- Diamict
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes



Kilometers
0 0.2 0.4 0.8 1.2 1.6

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 6
## Area 3 Trefor-Pontlynfi Location of Resource Blocks

This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

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- Resource Blocks

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- Snowdonia National Park
- Boreholes

Kilometers
0 0.3 0.6 0.9

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 7
## Area 4 Glynllifon-Bontnewydd Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

**Geomorphology**

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- 3rd sandur terrace
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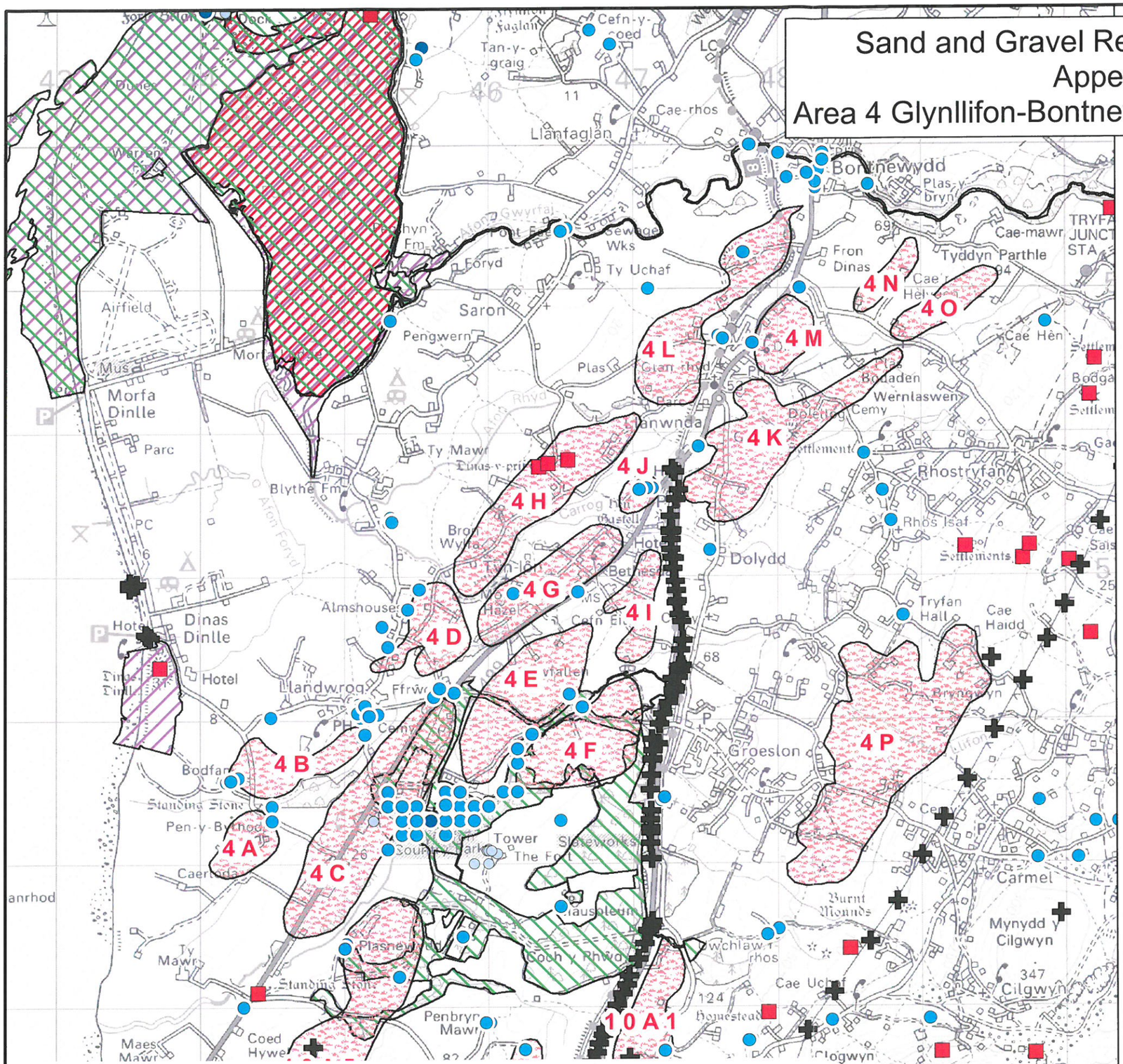
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes



Kilometers
0 0.2 0.4 0.8 1.2 1.6

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 8
## Area 4 Glynllifon-Bontnewydd Location of Resource Blocks




This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

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- Local Nature Reserves (CCW)
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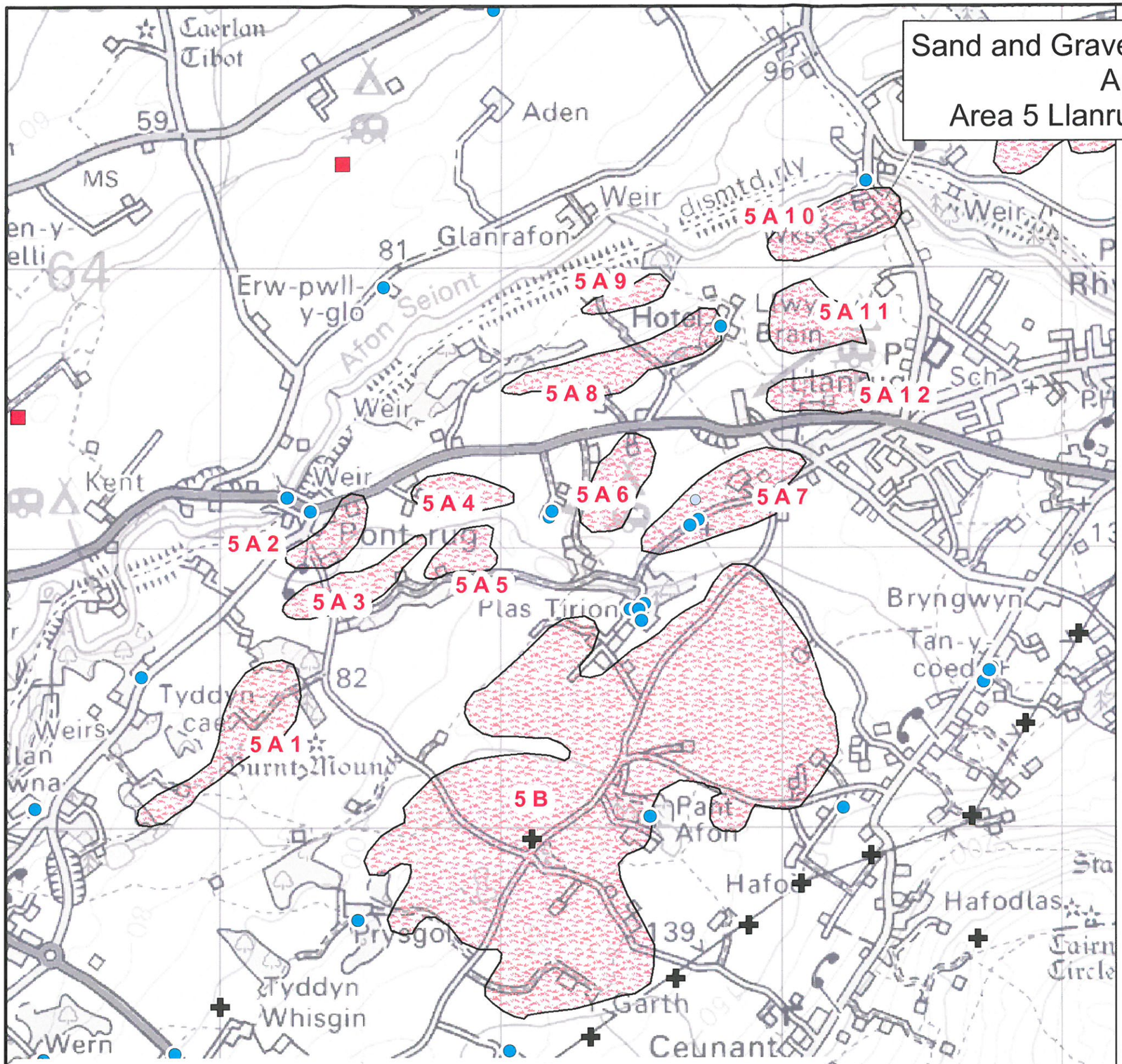
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty (AONB)
- Snowdonia National Park
- Boreholes

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 10
## Area 5 Llanrug Location of Resource Blocks




This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

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- Boreholes

Kilometers
0 0.2 0.4 0.6

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 11
## Area 6 Glasgoed-Talybont Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

**Geomorphology**

- Sandur
- 1st sandur terrace
- 2nd sandur terrace
- 3rd sandur terrace
- Diamict
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes

Kilometers
0 0.3 0.6 1.2 1.8 2.4

# Sand and Gravel Resources of North West Wales
# Appendix A Figure 12
# Area 6 Glasgoed-Talybont Location of Resource Blocks

This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

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- Resource Blocks

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- Areas of Outstanding Natural Beauty (AONB)
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- Boreholes

Kilometers
0 0.4 0.8 1.2

# Sand and Gravel Resources of North West Wales
# Appendix A Figure 13
# Area 7 Bala Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

**Geomorphology**

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- 2nd sandur terrace
- 3rd sandur terrace
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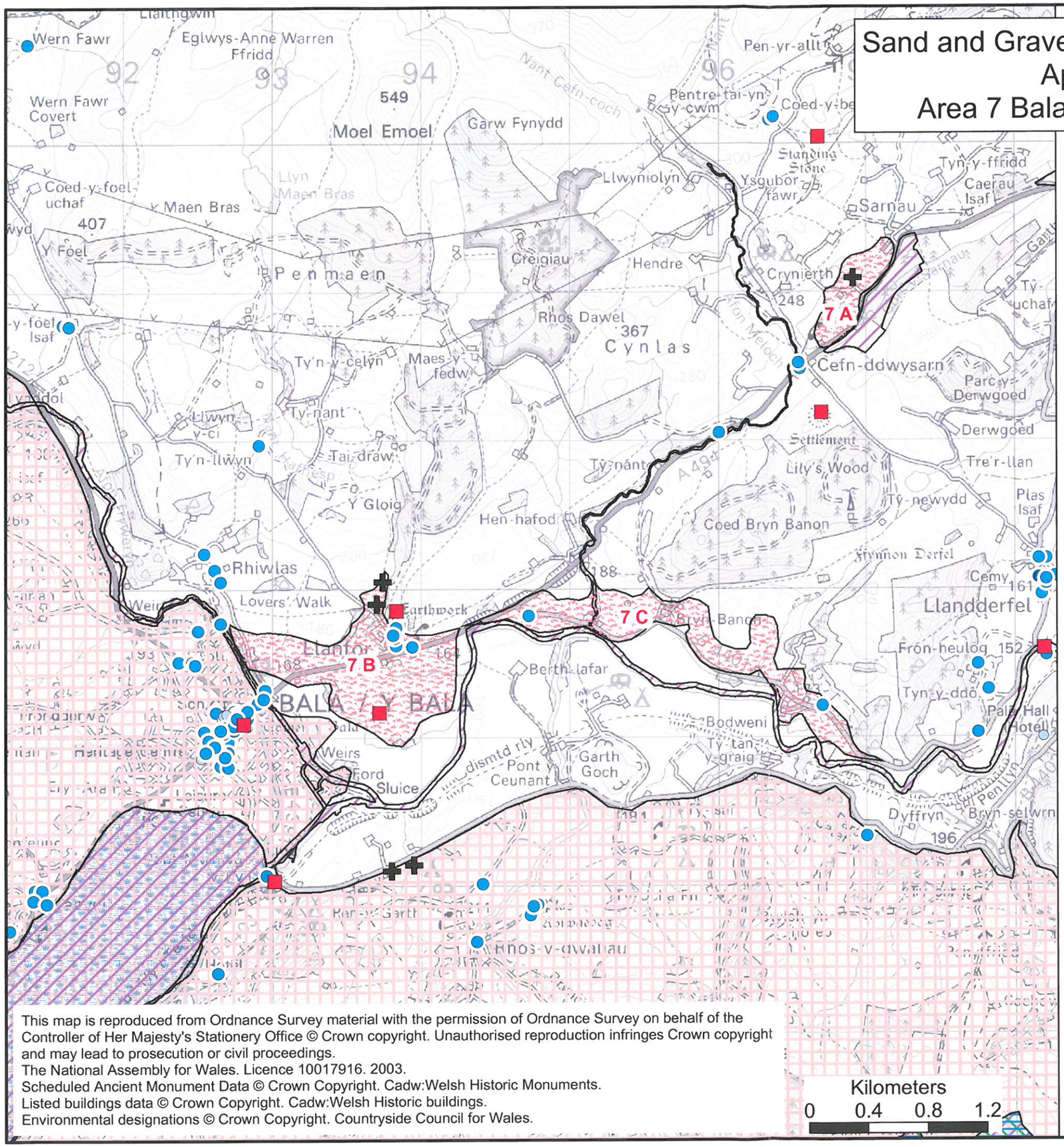
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes



Kilometers
0 0.5 1 1.5 2

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 14
## Area 7 Bala Location of Resource Blocks




This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

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- Resource Blocks

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- Marine Nature Reserves (MNR)
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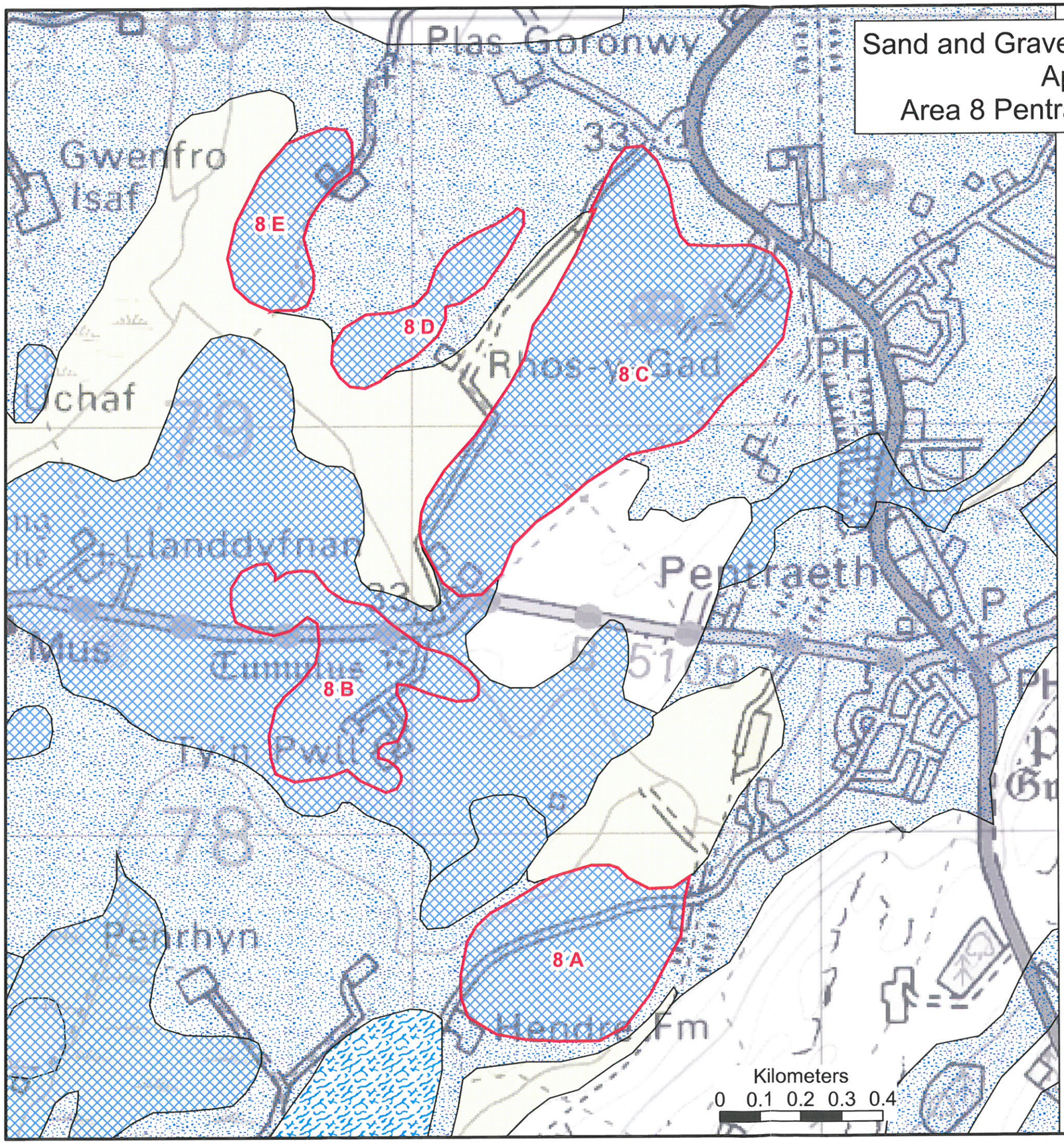
- Local Nature Reserves (CCW)
- Sites of Special Scientific Interest (SSSI)
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty (AONB)
- Snowdonia National Park
- Boreholes

Kilometers
0 0.4 0.8 1.2

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 15
## Area 8 Pentraeth Anglesey Geomorphology



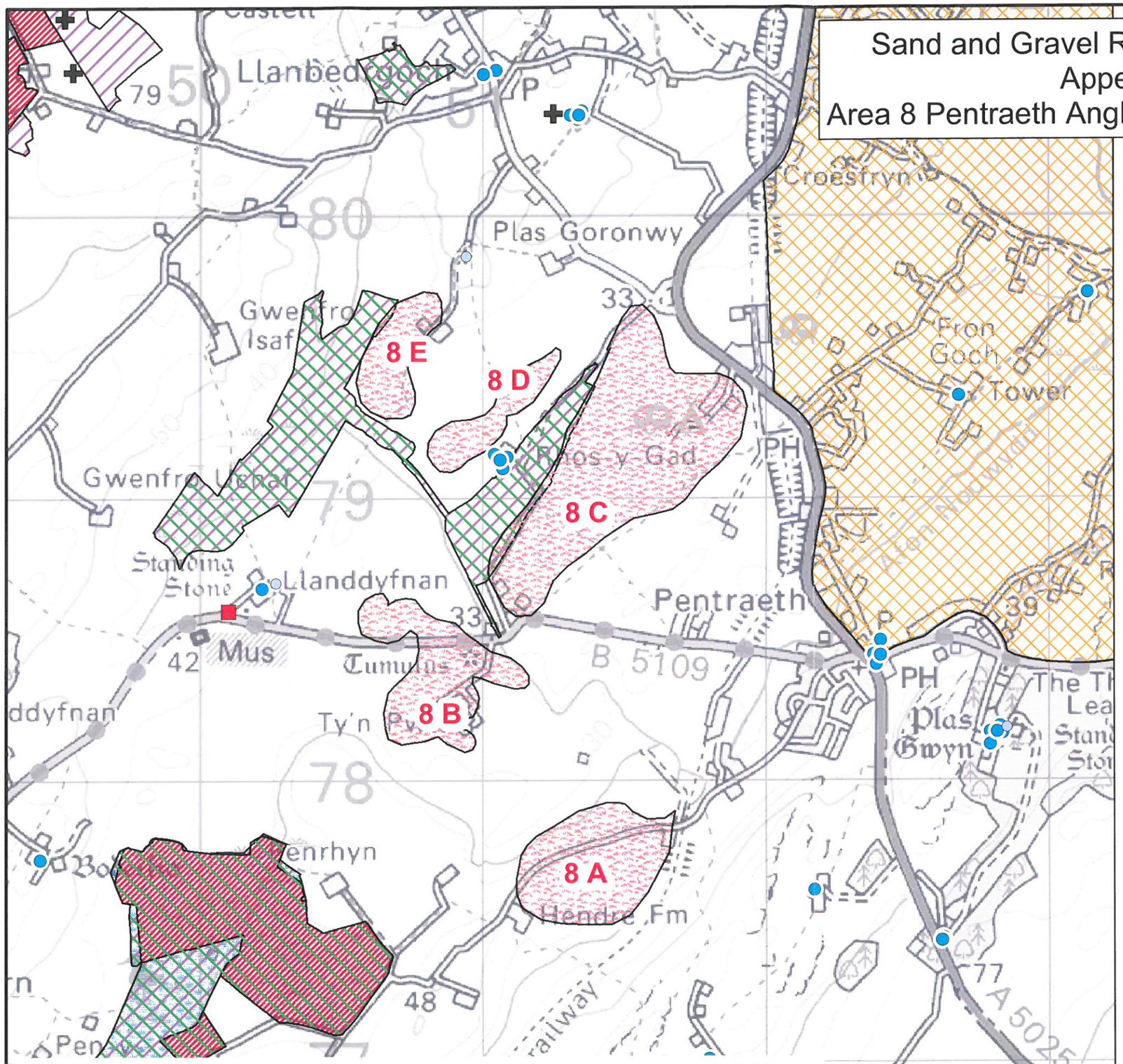

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

- Resource Blocks

**Geomorphology**

- Sandur
- 1st sandur terrace
- 2nd sandur terrace
- 3rd sandur terrace
- Diamict
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes

# Sand and Gravel Resources of North West Wales
## Appendix A Figure 16
## Area 8 Pentraeth Anglesey Location of Resource Blocks




This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

- Scheduled Ancient Monuments (CADW)
- Resource Blocks

**Listed Buildings (CADW)**

- A
- B
- C
- I
- II
- II*
- Country Parks (CCW)
- Heritage Coastline
- Biosphere Reserve (UNESCO)
- Biogenetic Reserves (Bern Convention 1981)
- Special Protection Areas (EC Birds Directive)
- Special Areas of Conservation (EC Habitats Directive)
- Marine Nature Reserves (MNR)
- National Nature Reserves (CCW)
- Local Nature Reserves (CCW)
- Sites of Special Scientific Interest (SSSI)
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty (AONB)
- Snowdonia National Park
- Boreholes

Kilometers
0 0.2 0.4 0.6

# Sand and Gravel Resources of North West Wales
# Appendix A Figure 17
# Area 9 Conwy Valley Geomorphology

This map shows the geomorporphology within each Sand and Gravel Resource Area and is the primary source for the identification of potential mineral resource within each target area. The field mapping involved the identification, recording and interpretation of individual landforms. Field mapping was normally on a mapping scale of 1:10,000. Different sediment-landform assemblages generate different landform types and each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

Resource Blocks

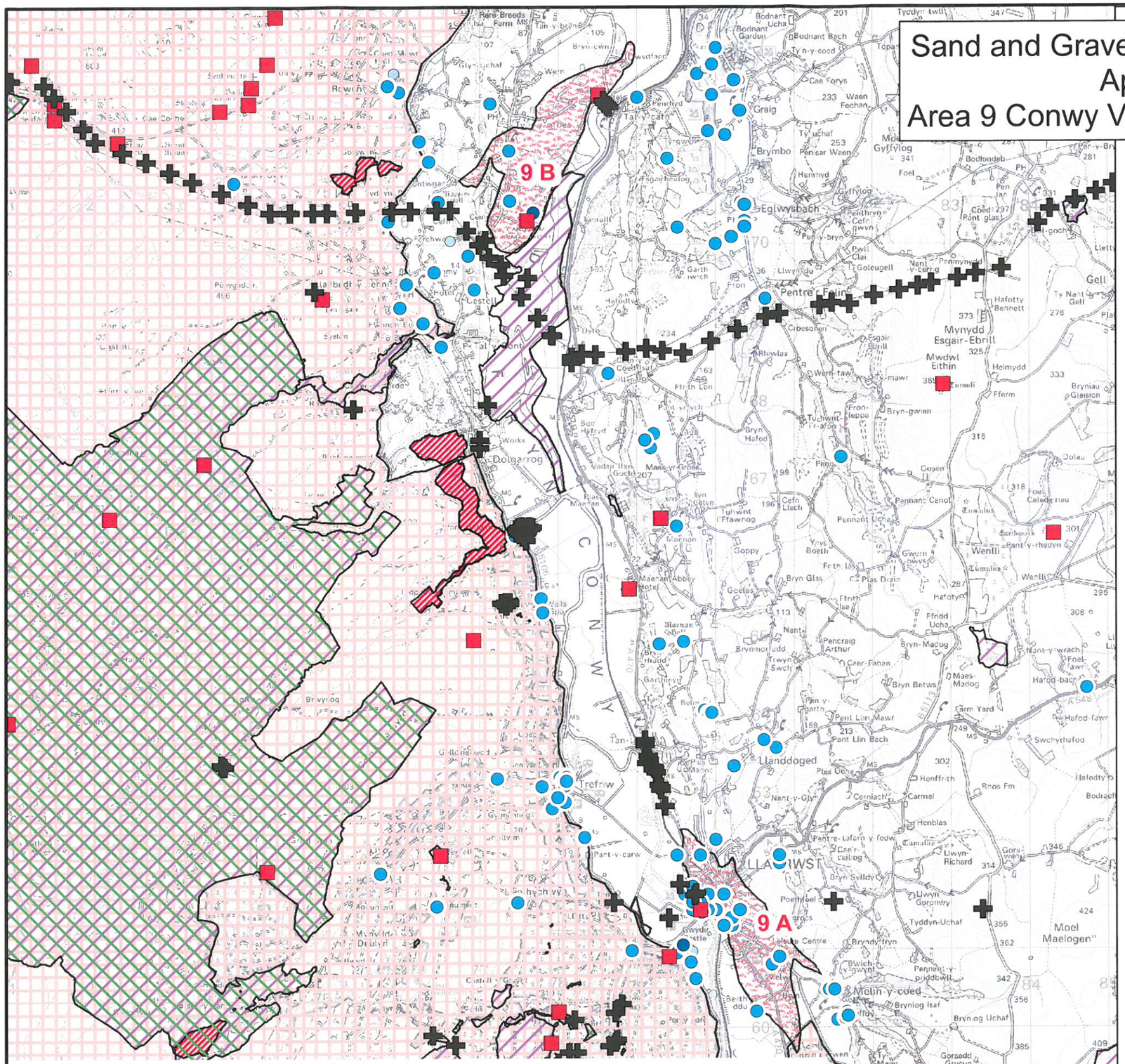
**Geomorphology**

- Sandur
- 1st sandur terrace
- 2nd sandur terrace
- 3rd sandur terrace
- Diamict
- Moraine ridge
- Drumlin
- Esker
- Kame / Moraine
- Kame terrace
- Alluvial fan
- Alluvium (terrace)
- Alluvium
- Peat
- Boreholes



Kilometers
0 0.45 0.9 1.8 2.7 3.6

# Sand and Gravel Resources of North West Wales
# Appendix A Figure 18
# Area 9 Conwy Valley Location of Resource Blocks




This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging, pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

- Scheduled Ancient Monuments (CADW)
- Resource Blocks

**Listed Buildings (CADW)**

- A
- B
- C
- I
- II
- II*
- Country Parks (CCW)
- Heritage Coastline
- Biosphere Reserve (UNESCO)
- Biogenetic Reserves (Bern Convention 1981)
- Special Protection Areas (EC Birds Directive)
- Special Areas of Conservation (EC Habitats Directive)
- Marine Nature Reserves (MNR)
- National Nature Reserves (CCW)
- Local Nature Reserves (CCW)
- Sites of Special Scientific Interest (SSSI)
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty (AONB)
- Snowdonia National Park
- Boreholes

# Sand and Gravel Resources of North West Wales
# Appendix A Figure 19
# Area 10 Penygroes Location of Resource Blocks

This map shows the distribution of potential resource blocks. It is based on field geomorphological mapping, section logging , pre-existing data and a limited borehole programme. Resource blocks are identified on the basis of observed or inferred geological factors that would influence the viability of mineral extraction, including thickness, sedimentology, volume, quality and proportion of waste. Quality and volume of mineral will vary considerable within individual resource blocks and further investigation would be needed to prove the commercial viability of any block. Consequently, the map does not represent the distribution of workable mineral resources. each landform type is associated with particular suite of sediments as the landform reflects the depositional process that created it. Thus, if a landform can be correctly identified it can be used to identify the sedimentary composition and hence its potential as an aggregate resource. It should be emphasised, however, that geomorphological mapping is not an exact science, and in practice many real landforms are composites of one or more different types and are consequently difficult to classify and interpret.

- Scheduled Ancient Monuments (CADW)
- Resource Blocks
- Boreholes

**Listed Buildings (CADW)**

- A
- B
- C
- I
- II
- II*

- Country Parks (CCW)
- Heritage Coastline
- Biosphere Reserve (UNESCO)
- Biogenetic Reserves (Bern Convention 1981)
- Special Protection Areas (EC Birds Directive)
- Special Areas of Conservation (EC Habitats Directive)
- Marine Nature Reserves
- National Nature Reserves (CCW)
- Local Nature Reserves (CCW)
- Sites of Special Scientific Interest
- Wetlands of International Importance (RAMSAR sites)
- Areas of Outstanding Natural Beauty
- Snowdonia National Park

Kilometers
0 0.7 1.4 2.1