LINCOLNSHIRE BIODIVERSITY PARTNERSHIP

LOCAL GEODIVERSITY ACTION PLAN

for the Historic County of Lincolnshire
(Lincolnshire, North Lincolnshire
& North East Lincolnshire)

LINCOLNSHIRE GEODIVERSITY GROUP
(A Working Group of Lincolnshire Biodiversity Partnership)

Published by Lincolnshire Biodiversity Partnership
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In August 2009, the Geodiversity Group of the Lincolnshire Biodiversity Partnership were successful in achieving funding by Natural England through Defra's Aggregates Levy Sustainability Fund (ALSF) for a Lincolnshire Geodiversity Action Plan and Geodiversity Audit for Aggregates Sites.

The aims of the project were:-
1) To resurvey existing Regionally Important Geological/Geomorphological Sites (RIGS) linked to aggregate extraction
2) To identify and survey new sites linked to aggregate extraction
3) To produce a Geodiversity Action Plan and Geodiversity Audit for aggregates sites in the historic county of Lincolnshire

A decision by the ALSF Working Group was taken to produce a full GAP for Lincolnshire to ensure that a comprehensive document could be established and that the action plan tables would take account of all of the issues relating to geodiversity, not just aggregates. It is envisaged that the document will be reviewed and added to as geodiversity issues and areas of interest are expanded on by the publication of this document, and no later than 5 years from its publication.

The Geodiversity Audit will be published separately so it can be expanded from the initial aggregates sections as and when resources allow.

Members of the ALSF Working Group were:-
- Lincolnshire Biodiversity Partnership (LBP) – Margaret Haggerty & Katie Milburn
- Lincolnshire County Council (LCC) – Jon Watson
- Lincolnshire Wolds Countryside Service (LWCS) – Helen Gamble
- Consultant Geologist and Surveyor – Tim Langdale-Smith
- Consultant Geologist and Surveyor – John Aram

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Responses to the consultation draft document were received from the following:-

Keith Ambrose – British Geological Survey
Helen Blenkharn – City of Lincoln Council
Ian Brooks – Engineering Archaeological Services Ltd.
Alan Gardner – Witham First and Third District Internal Drainage Boards
Stephen Jack – Lincolnshire Wolds Countryside Service
Moira Jenkins – Hereford and Worcestershire Earth Heritage Trust
Alan Jones – Humber Inca
Dan Jones – Humber Inca
Alan Kidd – North Yorkshire Geodiversity Partnership
Jonathan Larwood – Natural England
Helen McCluskie – Doncaster Council
Thomas Richards – Hereford and Worcestershire Earth Heritage Trust
Phil Smith – Environment Agency
Don Wright – Lincolnshire Wildlife Trust

PART 1 - Introduction

Geodiversity underlies and determines the character of our landscape

1. What is Geodiversity

Geodiversity is the variety of rocks, minerals, fossils, soils and landscapes, together with the natural processes which form them. It provides the key link between geology, landscape, biodiversity and people - from the time of our ancestors' first settlements through to the present day. We still rely on this important resource today and it is essential that it is protected for future generations.

2. Vision

The historic county of Lincolnshire should be a place where people understand and care about geodiversity, where geodiversity is recognised as part of healthy functioning ecosystems and where geodiversity is a natural consideration in policies and decision making for the benefit and well-being of our communities.

3. Aim

To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

4. Objectives

- To develop and maintain an audit of the geodiversity resource in Lincolnshire
- To conserve and develop the geodiversity of Lincolnshire
- To have geodiversity included in relevant plans and policies of all local and regional authorities and relevant organisations by 2015
- To raise awareness of geodiversity among local authorities, professional partners, landowners and managers, across all levels of education and the general public
- To create a positive feedback system enabling effective reporting, monitoring and review of the LGAP to partners and other interested parties
- To create a sustaining LGAP that will actively pursue funding to enable it to achieve its aim

5. Context

The emerging UK Geodiversity Action Plan (UKGAP) will set out a framework for geodiversity action across the UK, providing common aims, objectives and targets which will link national, regional and local activities. The UKGAP will be a mechanism for encouraging partnership and influencing decisions by policy makers and funding bodies, as well as promoting best practice across the country. The UKGAP will establish a shared understanding of what is happening and what further steps are needed to promote and conserve geodiversity, creating an effective process for measuring and reporting on progress and, importantly, celebrating success.

Local Geodiversity Action Plans (LGAPs) are developed by local partnerships. They identify and describe the local geodiversity resource, local priorities and actions needed to maintain and ensure a future for local geodiversity whilst promoting its effective management. Any action taken will contribute to the achievement of local, regional and national targets for geodiversity conservation.

The geodiversity of Lincolnshire is, by its definition, county wide. However, the Geological Conservation Review (GCR) undertaken between 1977 and 1990 selected and designated GCR sites which are of stratigraphic significance in the record of British geological history. The GCR helped guide the designation of Sites of Special Scientific Interest (SSSI) which form a representative suite of particularly important sites that receive statutory protection for their national geological, geomorphological and/or physiographical value and interest. Now that such sites are relatively well protected from damaging activities through improving legal safeguards and increasing public awareness and support, it is time to turn attention to sites of more local significance and wider geodiversity interest.

Each local planning authority in Lincolnshire holds a list of selected sites of geodiversity interest. These are known as Regionally Important Geological and Geomorphological Sites (RIGS) and were selected and designated on the basis of local knowledge and geodiversity interest, along with information from the GCR. The Government's publication of Planning Policy Statement 9 (PPS9) *Biodiversity and Geological Conservation* in August 2005 introduced the term *Local Site* (of importance for wildlife and/or geology) and guidance was issued the year after on how to proceed at a local level in identifying and protecting Local Sites especially through the new Local Development Frameworks that planning authorities are now required to produce. Geological locations of importance are now being called Local Geological Sites (LGSs) and the term RIGS is being phased out. Sites of biodiversity importance are now known as Local Wildlife Sites.

Survey work on previously identified RIGS and potential geological sites of interest is currently on-going with the introduction of rigorous criteria for selecting LGSs as recommended by Defra (see *Local Geological Sites: Guidelines for their Identification and Selection Guidelines in the Historic County of Lincolnshire (Lincolnshire, North Lincolnshire and North East Lincolnshire),* 1st Edition. Lincolnshire Biodiversity Partnership). Although LGS will not have the same statutory protection as SSSIs, their incorporation by local planning authorities into their Local Development Frameworks will enable decisions on development to be made in the full knowledge of the geodiversity value of the site.

6. Working group and administration

Through funding from Natural England's Aggregates Levy Sustainability Fund (ALSF) Grant Scheme, the Lincolnshire Geodiversity Group have produced this document and action plan tables that take account of all issues relating to geodiversity, not just aggregates. It is envisaged that the document will be reviewed and added to as geodiversity issues and areas of interest are expanded on by the publication of this document, and no later than 5 years from its publication.

The Lincolnshire Geodiversity Group is a working group of the Lincolnshire Biodiversity Partnership, which brings together local authorities, statutory agencies, voluntary and not-for-profit organisations with a responsibility for and interest in geodiversity and biodiversity in the historic county of Lincolnshire. It coordinates action, information and protection, and provides services for partner organisations. The Partnership is independent of any of its constituent organisations.

7. Coverage

The area covered by the Lincolnshire Geodiversity Action Plan is the historic county of Lincolnshire, subsequently referred to as 'Lincolnshire'. This is in line with the geographical coverage of the Lincolnshire Biodiversity Partnership, i.e. the administrative areas of Lincolnshire, North Lincolnshire and North East Lincolnshire.

Of course, geodiversity does not necessarily recognise administrative boundaries and active and effective liaison with adjacent county geodiversity groups will allow sharing of best practice across landscape character areas. As the historic county of Lincolnshire falls across two administrative regions, work will continue with the established regional geodiversity groups of the East Midlands Geodiversity Partnership and the Yorkshire and Humber Regional Geodiversity Forum.

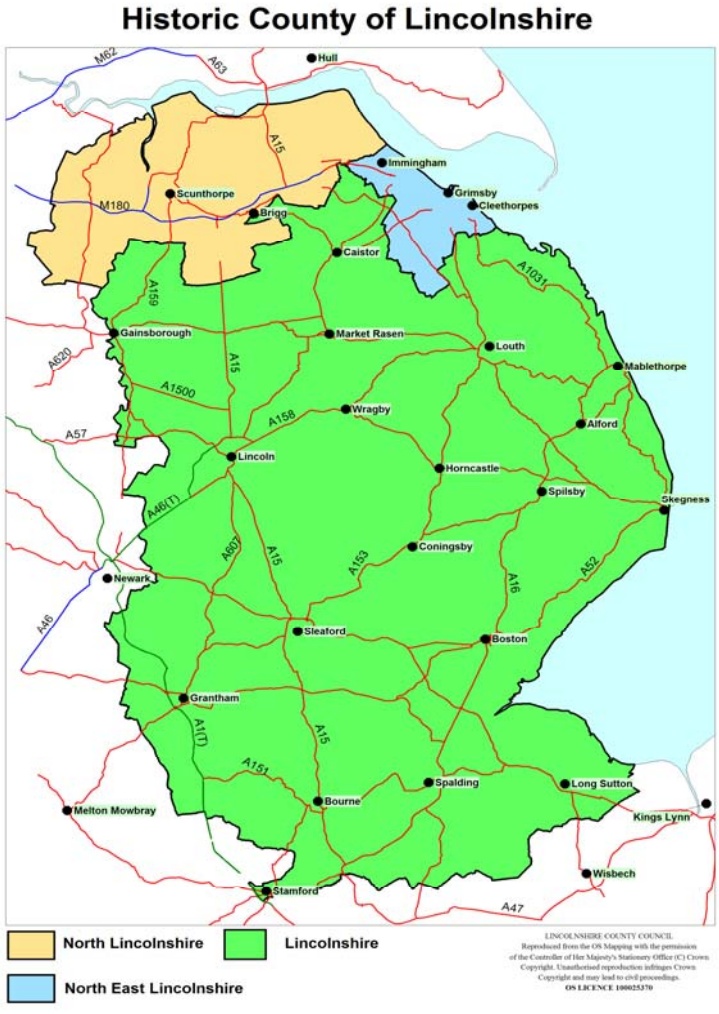


Figure 1 –
Map of historic Lincolnshire showing boundaries of the three main planning authorities.

8. Geodiversity of Lincolnshire

8.1 Bedrock Geology

Lincolnshire's bedrocks form a simple pattern of north-south stripes at the surface, with the older Triassic rocks in the west, overlain progressively by marine Jurassic rocks and the younger Cretaceous rocks in the east. Originally deposited nearly horizontally they all became uplifted above sea-level and then tilted down to the east by a few degrees around 60 million years ago. Since then at the surface they have been subjected to weathering and erosion under a range of climates including glacial and periglacial during the last 2 million years.

The oldest rocks were deposited in a hot, arid, desert environment around 245 million years ago, in what is now the north-western part of the county. In adjacent parts of Nottinghamshire and underlying the Isle of Axholme, pebbly cross-bedded sands of the Sherwood Sandstone Group were deposited by a large river system flowing across the desert from what is now northern France. Subsequently a fine red-brown dust was deposited across this low-lying, flat land, as the Mercia Mudstone Group, formerly known as the Keuper Marl. Violent desert thunderstorms and flash-floods intermittently deposited layers of greenish silts and fine sands across the area, with temporary playa lakes forming in the lowest hollows. Evaporite minerals including Halite (rock-salt) and Gypsum formed in the hypersaline waters in the lakes and in the surface sediments where evaporation was rapid. The Triassic period was terminated about 208 million years ago by a major series of marine incursions that progressively flooded much of England, forming the mudstones and thin limestones of the Penarth Group now found near Gainsborough.

Lincolnshire then remained beneath the sea, or just emerged along coastlines as reefs, marshes, or small islands throughout the Jurassic period. Lias Group mudstones and limestones with ironstones dominate the Lower Jurassic rocks, occurring along the western side of the county from the Humber as far south as Grantham. The Charmouth and Whitby Mudstone Formations formed in deeper waters than the shallow, oxygenated waters of the Frodingham Ironstone Formation and the Marlstone Rock Formation, with their higher proportion of bottom-dwelling life preserved as fossils. Free-swimming and floating life including ammonites and belemnites, with rare plesiosaurs and ichthyosaurs dominates the fossil record in the mudstones. In contrast *Gryphea* (Devil's toe-nails) and bivalves, with rare star-fish and brittle-stars, dominate the ironstones' fossil records.

By the Middle Jurassic more extensive areas of shallow, sub-tropical seas across the county supported a rich variety of life that also extended into the brackish and occasional fresh-water environments. The Inferior Oolite Group, including the Lincolnshire Limestone, forms the narrow ridge of increasingly higher ground extending south from the Humber as far as Lincoln, where it is breached by the River Witham. South of Lincoln it forms an increasingly higher and wider ridge of limestone breached just north of Grantham by the Ancaster Gap, before widening into the Kesteven Plateau that dips gently eastwards beneath the Fens. The lowest beds, the Northampton Sand Formation (previously called the Northampton Ironstone) and the Grantham Formation (previously called the Lower Estuarine Series) are both quite variable in thickness and tend to occur along the upper scarp slope immediately beneath the capping of Lincolnshire Limestone. Varying in thickness from less than 20 metres near the Humber to more than 40 metres south of Grantham, it also shows a range of textures and structures related to differing water depths and energies. The rock frequently

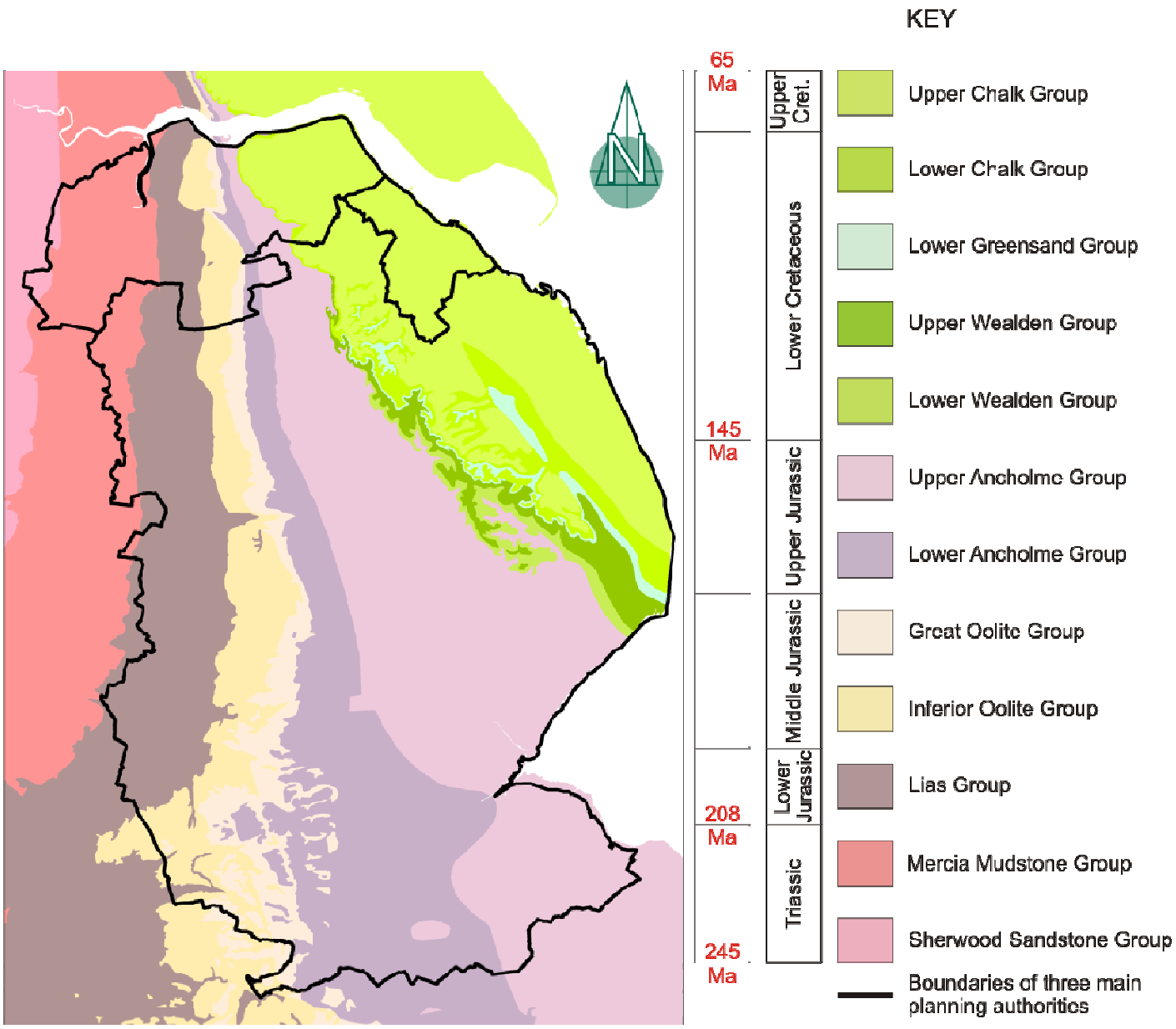
includes small grains of sand or broken shell rolled by currents in calcium carbonate muds to form pellet-like ooids up to 2 mm. in diameter that may be so abundant as to create an oolitic limestone. Under conditions with greater energy broken shell fragments may collect to form bioclastic limestones, whilst less energetic sea-bed conditions inside a lagoon allow precipitation of lime muds as micritic limestones. Distinctive Jurassic limestones gained local names; 'Cathedral Stone' being quarried and used in the building of Lincoln Cathedral, whilst 'Ancaster Stone' was used in building many stately homes including Belton House near Grantham, as well as many smaller private dwellings and in dry-stone walls between fields. The most common fossils found include many burrowing and sea-bed dwelling shellfish as well as patches of corals and very occasionally sharks' teeth.

The Great Oolite Group marked a change in environment to shallow coastal marshes with some partial vegetation cover, where thin beds of brightly coloured clays and silts form the Rutland Formation (previously called the Upper Estuarine Series). Initially a deepening, then shallowing and another deepening of the sea-water deposited the thin Blisworth Limestone, Blisworth Clay and Cornbrash Formations that thin and become progressively over-stepped toward the north of the county. A deepening of the sea marks the start of the Upper Jurassic, where mudstones dominate after a brief fine sand rich bed in the Kellaways Formation. The following Oxford Clay, Ampthill Clay and Kimmeridge Clay Formations indicate a return to deeper water conditions with ammonites and belemnites the most common fossils, and some rare predators including ichthyosaurs and plesiosaurs.

At the final stages of the Jurassic a return to shallow seas began locally, with the deposition of the sands that now form the lower beds of the Spilsby Sandstone Formation, with the evidence of its fossils in its upper beds showing they are of Cretaceous age. A relatively hard, but porous rock with glauconite grains it occurs extensively in the southern part of the Lincolnshire Wolds, but thins northwards as it becomes over-stepped by a sequence of thin younger beds. These include the Claxby Ironstone Formation, ooidal ironstone; the Tealby Formation, predominantly mudstones with a thin Tealby Limestone Member; the Roach Formation, a mixture of limestone and sandstone with ironstone; and the Carstone, an ooidal ferruginous sandstone. Whilst the Claxby Ironstone has a rich fossil record, including very large bivalves, otherwise fossils are rare, with sea-urchins and marine bivalves in the limestones suggesting normal, shallow marine conditions.

The youngest bedrock is the very thick Upper Cretaceous Chalk Group, formed from the remains of microscopic organisms including coccoliths and algae, they also contain scattered larger fossils including echinoids, bivalves and large ammonites. Flints found both within the chalk and in glacially derived sediments had great value as tools for prehistoric man, leading to early settlement of the Lincolnshire Wolds. Normally a white or cream colour, the lowest chalk bed is an unusual dark red colour with pink bands a few centimetres thick occurring in the lower few metres of the main chalk rock. The Hunstanton Formation (Red Chalk), of Lower Cretaceous age, is clearly seen on the coast near Hunstanton (Norfolk) and in cliffs just north of Flamborough Head (Yorks.) In the Lincolnshire Wolds it occurs clearly in the road cutting at Red Hill near Goulceby, as well as in the bottom of many of the larger north Lincolnshire chalk quarries including South Ferriby and Mansgate. A distinctive red coloured strip of soils can often be seen in ploughed fields on valley sides at the base of the white chalk in the Wolds.

Figure 2 – Bedrock geology map of Lincolnshire. Not to scale.



8.2 Superficial Geology

Over half of the present land surface of the county is blanketed with a covering of Quaternary superficial deposits that formed during the last 2 million years, when climates fluctuated between cold glacial and warm inter-glacials, including some warmer than the present day. Consequently the Quaternary includes glacial and fluvioglacial deposits along with younger Flandrian silts, peat, sands and alluvium that cover the Fenlands, the coastal plains east of the Wolds, much of the Humber coast and the Isle of Axholme.

The majority of deposits produced by Pleistocene glaciers were previously known as 'boulder clay', but are now referred to as till. Associated with the till deposited directly by glacial ice were wide spreads of sands and gravel derived and transported from the till by glacial melt-water streams. Where local ponding of melt-waters occurred lakes formed and finely layered glacio-lacustrine sediments were formed as different grain sizes of sediments seasonally settled through the water from the suspension load of the feeding streams.

Ice-sheets from the north stripped bare the different rocks over which they passed; soft mudstones formed clay-rich tills, whilst sandstones, limestones and flint added larger stones and boulders to the till mixture. Exotic erratic rocks transported from distant places along the ice routes were also incorporated into the more local till mixture. At the maximum of the Anglian glacial advance, about 440,000 years ago, the ice-sheets reached North London with several hundred metres of ice covering all Lincolnshire. Less extensive subsequent glaciations re-worked part of the earlier till and their fluvioglacial sediments, along with sediments formed during the interglacial time. During the Devensian last ice advance between 30,000 and 15,000 years ago, the ice-sheets only reached northern and eastern Lincolnshire, blocking the mouth of the Humber and The Wash, with a moraine that reached from West Keal, through Boston to the North Norfolk coast near Hunstanton.

During interglacial periods the climate was warmer at times than the present day, with rivers, soils and vegetation that supported a variety of life. Meltwater-fed braided streams deposited large areas of sand and gravel well beyond the ice limits into river systems that had different sizes and courses from the modern day drainage pattern. Many rivers flowed through broad floodplains with the gravel bedload forming terraces related to changes in sea-level and river discharge. Incised channels found below several modern day rivers and the Humber estuary relate to lower sea-levels after the Anglian glaciations, whilst up to four higher level terraces along rivers may be related to isostatic compensation from depression caused by glacial loading. Changes in the courses of many of the regions rivers were due to periods when glacial ice blocked their mouths, causing the River Trent to flow through Lincoln for a time, whilst the River Witham flowed through Sleaford. The last glacial advance also caused the formation of a wide shallow lake in the Humber Heads and Isle of Axholme area, and a similar one in the Fenlands. When tundra conditions prevailed with only sparse vegetation, fine sand was picked up by strong winds and blown eastwards. When their route was blocked by ridges of higher ground, sands were deposited at the foot of west-facing scarps as coversands, often masking a sharp break in slope at the change in bedrock geology.

During the retreat of the Devensian ice sheet around 14,500 years ago permafrost conditions were widespread across the county, with waterlogged ground and unstable conditions on slopes. Ice-wedge casts and cryoturbation features occur widely in sand and gravel deposits from this time, whilst soliflucted materials on steeper slopes moved downslope to accumulate at the foot of slopes and in the floor of valleys. The steep scarp slopes of the more resistant beds, especially where they were underlain by impermeable beds, were particularly susceptible to both cambering and solifluction.

During the last 19,000 years as sea-level rose it submerged the land and the forests that now form part of the bed of the North Sea. At several point along the modern coast this landscape of submerged forests can be seen as tree stumps and roots in a thin soil developed on the Devensian till. Drainage work in the peat Fenlands and the Witham valley also unearth ‘bog oaks’, the remains of hardwood trees, as well as silver birch and pine tree trunks killed by water-logging of the soil as sea-level rose. These inundations flooded The Wash and Fenland areas where many metres of complex marine, brackish and freshwater deposits originated from rivers and marine transported sediments, filling in irregularities eroded by the Devensian ice as it pushed inland between the Wolds and North Norfolk. A similar combination of estuarine and fluvial deposits can be found in the Humber Heads area and their extension into parts of the Isle of Axholme. Along the courses of the larger modern rivers alluvium, a mixture of clay and silt, covers the floodplains. With the raising of banks and the straightening of river courses fresh supplies of these sediment are increasingly rare, except in the very lowest parts of their courses where sluice gates and pumping systems modify the natural processes.

8.3 Geomorphology

During the second half of the Twentieth Century the study of geomorphology, developed from the landform classification system by physical geographers, recognised that changes in climate over long time-scales were a major factor in landform change. Scientific measurement combined with mathematical analysis and computer based predictive modelling were developed to meet the needs of engineers and planners. Coastal defence schemes, flood-plain developments, slope stability problems and landscape planning all benefited from the predictive modelling approaches that were being developed.

In Lincolnshire, differences in the bedrock's resistance to weathering and erosion control the large scale landscape features of flat, well-watered lowlands and dry uplands. Changes in the slope of the land often occur where there are changes in the underlying bedrock geology, although this may be masked by superficial deposits including coversands and soliflucted materials. Where impermeable mudstones are overlain by permeable rocks, prominent scarps and dip slopes form, with the Lincolnshire Limestone, Spilsby Sandstone and Chalk scarps giving spectacular views from their western edges. Along the higher and steeper scarps springs often occur, with slumping and rotational landslides that further modifying the scarp face. Lesser scarps related to the Marlstone, thin limestones and sandstones within the Lower Jurassic mudstones also form steps in the landscape in the Trent and Witham lowlands where they provided better drained sites suitable for small settlements. The bedrock's influence is much reduced over extensive areas in the Fenlands and other low-lying areas that are blanketed by a thick covering of superficial deposits, whilst an impermeable glacial till mantles extensive areas of the Lincolnshire Limestone in the southern half of the county.

During the Ice Ages the drainage pattern of the region was modified many times by changing sea-levels and by glacial ice blocking river outlets to the sea. At different times the Rivers Trent and Witham flowed to the North Sea through the Lincoln and Ancaster Gaps, not via the Humber. At many places near Louth and Caistor there are smaller examples of glacial diversions of rivers and gorges cut by overflowing lakes. Today's rivers have evolved from these multi-channel braided courses where they originated in response to dramatic changes in water flow and in sediment supply at the end of the Ice Ages, into meandering rivers within extensive flood-plains that have most recently been modified by man. In the final stages of the Ice-ages, permafrost retained water frozen deep in the ground for long periods of time, with only the top metre or so thawing out seasonally. The resulting high water-table caused rapid run-off of melting ice, snow and rain focussing into depressions and excavating steep sided valleys that cut down as the permafrost progressively thawed, leaving a dry-valley pattern on the dip slopes of the chalk and limestone uplands.

During cold periods characterised by tundra climate, the lack of vegetation allowed the prevailing westerly winds to pick up and transport fine sand and silts eastwards, banking them as inland dunes against the foot of even small westward facing scarps, where they often still mask sharp breaks in slope. Aeolian processes at the present time are most obvious along the coast where fine sand, from the dry surface of wide inter-tidal beaches, are blown inland by on-shore winds, building dunes many metres high. Inland 'soil blow' may be a particular problem during dry spring months in the Fenlands, whilst fine sand may also be blown from fields on light sandy soils over the Spilsby Sandstone in the Wolds. With changing climate, the drying and contraction of mudstones beneath buildings is likely to be a recurring issue for builders and planners.

8.4 Coastal Geomorphology and Processes

The long coastline of the county currently includes a wide range of physical features and different processes operating. A progressive rise in sea-level of over 100 metres during the last 19,000 years means that the North Sea has changed its position and boundary with the land considerably. Stumps of trees that grew less than 4,000 years ago can be seen at very low tides along the modern coast in ‘submerged forests’ between Skegness and Mablethorpe. During an earlier inter-glacial the coastline lay along the eastern side of the Wolds, where chalk cliffs and a wave-cut platform lie concealed beneath Devensian glacial till.

The current coastal balance includes a net gain of land as sediments eroded from the coast north of the Humber, combined with sediments re-worked from the floor of the North Sea, have built out a massive spit at Gibraltar Point, south of Skegness. Ridge and runnel beaches between Cleethorpes and Skegness show the long-shore drift of sands southwards, whilst sand dunes behind the beaches have been built up by marram grass trapping sand blown from the beaches by on-shore winds.

In the more sheltered waters of The Wash, embayment salt marsh vegetation also traps fine sand and silt during the few hours around each high tide. In this slack water period mud also settles out of suspension from the very shallow water between the creeks, providing a binding cover for the sediments beneath. For centuries the salt-marshes were used to extract salt from sea-water, then the vegetation covered salt-marshes were ‘reclaimed’ into agriculture by the building of new sea-walls. In the Humber Estuary, the mixing of fresh river water with salt water carried upstream by tides resulted in clay minerals settling out of suspension, forming mud banks within the river and clay marshes along the shores.

8.5 Soils

Soils, formed by the interaction between the geosphere, biosphere and atmosphere, form an important interface with agriculture and man. Lincolnshire soils vary in thickness from a few centimetres to over a metre in response to the underlying geology, location in the landscape and agricultural practices. The thinnest soils tend to occur over chalk and limestone escarpments and on valley sides, with the deepest soils in the Fenlands.

Generally insufficient time has passed since Lincolnshire was last glaciated for the soils to have become fully synchronised with the present climate, hence they are still closely related to the underlying bedrock or superficial geology. In the earliest stages of soil formation the nature of these geological materials controls the soil’s characteristics. The grain size of the parent material controls the soil texture, stone content and its permeability, whilst its chemical composition determines the acidity (pH) and the amount of free calcium carbonate. These in turn influence the amount of microscopic organisms that contribute to the soil forming processes, the fertility of the soil and the vegetation it can support. Not surprisingly, the cultural landscapes of the county vary with the soils, as did their attractiveness to early settlers. The survival of archaeological artefacts is largely dependent on the preservation potential of the soil.

9. Issues and Priorities

The below are only some of the issues that relate to the geodiversity of Lincolnshire and further potential issues such as oil and gas exploration, carbon capture and storage are being viewed along with other areas of interest, such as economics, the historic environment, biodiversity and climate change.

Some key issues:-

- Local Character stone

To ensure the sympathetic restoration and maintenance of key historic buildings, such as Lincoln Cathedral, the local stone that buildings were originally constructed of should be used wherever possible. It is also vitally important that wherever possible, new developments reflect the traditional, vernacular style of the local area.

- Continued/renewed quarrying and minerals extraction

Extraction can destroy areas of interest as well as exposing fresh ones. It is envisaged that where sites are currently dormant they may become active once again as the economic climate changes, with fewer resources available for exploitation. The recycling of crushed aggregates, such as hardcore, concrete and tarmac is becoming more widespread and safeguarding resources is a current and future key issue.

- Secondary development pressures on disused sites

The use of disused sites for wildlife or recreational purposes, housing or industrial use, landfill or recycling areas can impact on the available geodiversity such as key rock exposures or fossil sites. Unauthorised use by vehicles can damage sites and encourage fly-tipping, and where public or educational access is available can prevent or deter people from exploring and enjoying the geodiversity features.

- Coastal processes

The Lincolnshire coastline has altered many times over geological timescales, however it is the current and future threats, including climate change, to the industries and human populations that live, work and holiday along or near the coastline that predominates local, regional and national planning issues. Coastal sea defences alter the natural marine processes that have and are shaping the current Lincolnshire coastline and have an impact on the wider east coastline.

- Local and Regional Strategies

Local Authorities are now required to produce Local Development Frameworks (LDF) and inclusion of geodiversity issues, such as landscape characterisation issues and mineral safeguarding, provides an indication of the importance these factors now hold. All authorities are currently required by central government to monitor progress towards achieving positive conservation management of all Local Sites, both geological and wildlife, and inclusion of such sites within the LDF enables decisions on development to be made in the full knowledge of the geodiversity value of the site.

PART 2 – Action Plan Tables
2010-2015

10. Delivery

For the Lincolnshire Geodiversity Action Plan (GAP) to be an effective tool in delivering its aim, a wide range of partnerships must be engaged in developing and delivering the actions, as outlined in the following tables. The following partners and organisations have been initially highlighted as being involved but this list is not exhaustive and as the GAP continues to develop it is envisaged that new partners will be involved in its delivery:-

BBC – Boston Borough Council
BGS – British Geological Survey
CLA – Country Land and Business Association
CLC – City of Lincoln Council
ELDC – East Lindsey District Council
EMGP – East Midlands Geodiversity Partnership
ESTA – Earth Science Teachers Association
FWAG – Farming and Wildlife Advisor Group
HGS – Hull Geological Society
LCC – Lincolnshire County Council
LBP – Lincolnshire Biodiversity Partnership
LERC – Lincolnshire Environmental Records Centre
LGG – Lincolnshire Geodiversity Group
LNU – Lincolnshire Naturalist Union
LWCS – Lincolnshire Wolds Countryside Service
LWT – Lincolnshire Wildlife Trust
NE – Natural England
NELC – North East Lincolnshire Council
NFU – National farmers Union
NLC – North Lincolnshire Council
NKDC – North Kesteven District Council
SGS – Stamford Geological Society
SKDC – South Kesteven District Council
SHDC – South Holland District Council
WLDC – West Lindsey District Council
YHRGF – Yorkshire and Humber Regional Geodiversity Forum

To progress the Lincolnshire Geodiversity Action Plan (GAP) and deliver many of the actions outlined in the following tables, achieving funding for a Geodiversity Officer (see action 6.2.1) is crucial. Without a funded full-time Geodiversity Officer, the Lincolnshire Geodiversity Group will have difficulties in delivery of the GAP which will struggle to achieve its aim or become a sustainable delivery mechanism for the protection and enhancement of the Geodiversity resource within Lincolnshire.

11. Action Plan Tables

Aim - To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

Objective 1	Target	Action	Partners (lead in bold)	Timescale
1. To develop and maintain an audit of the geodiversity resource in Lincolnshire	1.1 To survey known sites of interest	1.1.1 Survey all RIGS sites and assess against LGS criteria as adopted by the LBP Steering Group	**Local Authorities** LGG	By 2013
		1.1.2 Utilise existing knowledge and survey other known sites of interest and assess against LGS criteria	**Local Authorities** LGG, LBP	By 2015
	1.2 To audit existing geodiversity information	1.2.1 Undertake a desktop study of all available information – such as existing plans, policies, publications, scientific and academic research, mineral plans and landscape characterisation assessments	**LGG, LBP** Local Authorities, BGS	By 2013
		1.2.2 Audit of Museums and other Collections	**LCC, NELC, NLC,** LGG, LBP, LNU, Louth Museum, HGS, SGS, BGS	Initially by 2013 then ongoing
	1.3 To audit skills and resources from existing and potential partners of the LGAP	1.3.1 Produce a list of existing and potential partners with an interest in the LGAP	**LGG** LBP	By 2011
		1.3.2 Contact existing and potential partners for audit of skills and resources	**LGG** LBP	By 2012

Action Plan Tables

Aim - To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

Objective 2	Target	Action	Partners (lead in bold)	Timescale
2. To conserve and develop the geodiversity of Lincolnshire	2.1 To ensure no loss of important geodiversity sites	2.1.1 Produce a database of geological, geomorphological and/or physiographical SSSIs, indicating latest known condition.	**Natural England** LGG	2011 and then in line with NE reporting
		2.1.2 Identify SSSIs that require direct management to bring sites/features into favourable condition.	**Natural England** LGG	2012
		2.1.3 Work with landowners to bring SSSIs sites/features into favourable condition	**Natural England** LGG	2015
	2.2 To identify where features and access can be improved on LGSs and undertake work	2.2.1 Utilise LGS condition monitoring forms to produce a database where work is needed to bring the site into favourable condition (connects with 1.1.1 & 1.1.2)	**LGG,** LBP Local Authorities	Within 12 months of sites being surveyed
		2.2.2 Liaise with site owners and managers to secure improvement works and access on existing LGSs via potential grant schemes (connects with 1.1.1 & 1.1.2)	**LGG,** LBP Local Authorities, Natural England Site operators (ownership and managers must be identified)	Within 24 months of sites being surveyed
	2.3 To further opportunities on new sites for protection of geodiversity, access and education	2.3.1 Work with quarry operators and industry representatives to establish open lines of communication with regard to protection of geodiversity, access and education in closed and working quarries (connects with 3.3)	**LGG, LCC, NELC, NLC,** Site operators (ownership and managers must be identified)	Ongoing By 2015
		2.3.2 Work with planners to ensure restoration plans take account of, and where appropriate include, protection of geodiversity, access and education (connects with 3.3)	**LGG**, LCC, NELC, NLC,	Ongoing and as notified

Action Plan Tables

Aim - To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

Objective 3	Target	Action	Partners (lead in bold)	Timescale
3. To have geodiversity included in relevant plans and policies of all local and regional authorities and relevant organisations by 2015	3.1 Review existing policy documents from local authorities and partnerships to determine whether appropriate policies exist to safeguard geodiversity	3.1.1 Undertake desktop survey of relevant documents and produce database of all relevant policies	**LGG, LBP,** Local Authorities	2012 & Ongoing as policies become available or change
	3.2 Provide support and advice to enable policy changes to safeguard geodiversity	3.2.1 Produce model policies and circulate to all relevant partners	**LGG**, **LBP,** LCC, NELC, NLC	2012 and modify as required
		3.2.2 Geodiversity Officer to meet with representatives to engage interest and provide specialist input into policy changes	**LGG, LBP**	2013
	3.3 To provide specialist, site specific advice to planners in relation to individual planning applications that raise issues in relation to geodiversity conservation.	3.3.1 Produce a series of factsheets to distribute to planners and policy makers	**LGG, LBP,** Local Authorities	2014
		3.3.2 Geodiversity Officer available to provide specialist advice via consultation and site visits	**LGG, LBP,**	2014
	3.4 Monitor success of geodiversity awareness in policies	3.4.1 Develop a monitoring system database and policy effectiveness	**LGG, LERC**,LBP Local Authorities	2015 & Ongoing as new plans and strategies published

Action Plan Tables

Aim - To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

Objective 4	Target	Action	Partners (lead in bold)	Timescale
4. To raise awareness of geodiversity among local authorities, professional partners, landowners and managers, across all levels of education and to the general public	4.1 To raise awareness among local authorities and professional partners	4.1.1 Contact local authorities, new and existing partners and industry representatives highlighting the LGAP and LGS process, directing them to the website, literature and specialists advice available	**LGG**, LBP, Local Authorities	2010 and ongoing
		4.1.2 Work with regional Geodiversity forums to promote the local, regional and national importance of Lincolnshire's geodiversity	**LGG, LBP,** HGS, SGH Local Authorities EMGP, YHRGF	2010 and ongoing
		4.1.3 Promotion of specialist advice available via Geodiversity Officer (connects with 6.2.1)	**LGG, LBP,** Local Authorities	2011 then ongoing
	4.2 To raise awareness of the links between geodiversity, landscape, biodiversity and archaeology	4.2.1 Liaise with all existing and seek new, closer working relationships with new partners to ensure linkages between geodiversity, landscape, biodiversity and archaeology at all levels.	**LGG, LBP,** Local Authorities, Museums, LNU, Natural England, EMGP, YHRGF	2010 then ongoing
	4.3 To raise awareness with landowners and managers	4.3.1 Develop factsheets of the special qualities of key geodiversity features and tie in with agri-environment practices and grant schemes.	**LGG, LBP, Natural England,** LCC, NELC, NLC, CLA, NFU, FWAG	2014
		4.3.2 Utilise site meetings and key farmer events to promote factsheets and encourage site visits.	**LGG**, LBP, Natural England LCC, NELC, NLC, CLA, NFU, FWAG	As required
	4.4 To raise awareness across all levels of education	4.4.1 Provide teacher training days and literature on the geodiversity of Lincolnshire	**LGG**, LWT, LNU, LWCS, HGS, SGS Louth Museum	2014
		4.4.2 Provide information on sites where educational groups are welcome	**LGG**, LWT, LNU, LWCS, HGS, SGS, Louth Museum	2014
	4.5 To raise awareness to the general public	4.5.1 Develop, expand and promote the Geodiversity section on the LBP website, with associated printed literature, utilising links with existing and potential partner websites and newsletters	**LGG, LBP** BGS, EMGP, YHGF	Ongoing completed by 2015
		4.5.2 Undertake events and open days to promote the geodiversity of Lincolnshire	**LGG**, LWT, LNU, LWCS, HGS, SGS Louth Museum	3 per year
		4.5.3 Provide and promote geodiversity exhibitions in museums and wider venues	**LGG**, LBP, HGS, SGS, LWCS, Local Authorities	3 per year

Action Plan Tables

Aim - To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

Objective 5	Target	Action	Partners (lead in bold)	Timescale
5. To create a positive feedback system enabling effective reporting, monitoring and review of the LGAP to partners and other interested parties	5.1 To enable all partners and interested organisation to feedback on the LGAP process and actions	5.1.1 Create an e-mail list/forms on the website to ensure all partners are able to feedback on the process and actions	**LGG, LBP**	2011
		5.1.2 Undertake group visits and consultations to allow interested parties/groups to become informed and involved as volunteers	**LGG**, LBP	2010 and ongoing
	5.2 To create an effective reporting system	5.2.1 Create a database for easy reporting	**LGG, LERC,** LBP	2010
		5.2.2 Input data on a regular basis to ensure up-to-date reporting and make available via the website	**LGG, LBP,** LERC	2011
	5.3 To enable an effective monitoring and review system of the LGAP	5.3.1 Create a database for monitoring	**LGG, LERC,** LBP	2011
		5.3.2 Ensure monitoring is undertaken regularly and that any actions not started or remain uncompleted are followed up to determine why and facilitate any future actions	**LGG, LBP**	Ongoing - Annual monitoring
		5.3.3 Undertake regular reviews of the LGAP to assess the effectiveness of the actions undertaken and develop new actions to aid delivery of the objectives	**LGG, LBP**	Ongoing - Annual review

Action Plan Tables

Aim - To enhance understanding and action to conserve and develop the geodiversity of Lincolnshire, whilst promoting and managing its sustainable use.

Objective 6	Target	Action	Partners (lead in bold)	Timescale
6. To create a sustaining LGAP that will actively pursue funding to enable it to achieve its aim	6.1 To have all partner organisations signed up to deliver and assist in delivering the LGAP	6.1.1 Maintain the continued support of LBP partner organisations for the Lincolnshire GAP – and encourage attendance and representation at relevant meetings	**LGG,** LBP	2011
	6.2 Secure sustainable funding for the work of the Geodiversity group of the Lincolnshire Biodiversity Partnership	6.2.1 Investigate sources and apply for funding for a Geodiversity Officer for Lincolnshire	**LGG, LBP**, Local Authorities	2011 and ongoing for continued funding
		6.2.1 Investigate sources and apply for resources to undertake delivery of actions within and related to the LGAP	**LGG, LBP**, Local Authorities	2011 and ongoing for continued funding
		6.2.3 Identify gaps in knowledge and target resources towards survey of a comprehensive suite of geodiversity sites throughout Lincolnshire (connects with 1.1.1, 1.1.2, 1.2.1 & 1.2.3)	**LGG, LBP,** LERC	Ongoing
	6.3 Provide a co-ordinated range of advisory services to guide planners, operators and land managers with maintenance and development of geodiversity features on their land	6.3.1 Maintain close liaison with statutory undertakers and other bodies whose developments and actions are not subject to planning controls, in order to prevent or minimise any conflict with biodiversity interests	**LGG, LBP**, LWT, LWCS, HGS, SGS, Local Authorities, CLA, NFU, FWAG	2013
		6.3.2 Improve the availability and quality of information and advice on grant schemes that would assist in delivering improvements in the geodiversity resource for Lincolnshire	**LGG, LBP**, Local Authorities, CLA, NFU, FWAG	Ongoing as sources and applicants become known
		Also see 4.1.1, 4.1.2, 4.1.3, 4.2.1 & 4.2.2		

GLOSSARY & TECHNICAL TERMS

Aeolian
The action of the wind relating to processes of erosion, transport and deposition of materials.

Alluvium
Detrital deposits made by rivers or streams composed of gravels, sands, silt and clay, often containing organic matter.

Anglian Ice Advance
The glacial stage in Britain, from 500,000 to approximately 300,000 years ago, when the ice advance covered all of Lincolnshire, extending as far south as London and Cardiff.

Ammonites
A group of marine molluscs, usually with tightly spiralled shells and internal gas-filled chambers that became extinct at the end of the Cretaceous. Ammonites, a group of the cephalpods, are important index fossils, due to their ability to evolve rapidly and their wide distribution throughout shallow seas.

Belemnites
An order of the cephalopods, these marine molluscs were closely related to the modern squid and octopus before becoming extinct in the early Tertiary. The bullet-shaped solid calcite guard is the only part usually preserved, earning it the nickname of 'Devil's Thunderbolt'.

Bioclastic
A biochemical sedimentary rock consisting of fragments of organisms, such as limestone composed of shell fragments.

Biodiversity
The variety of life on Earth.

Biodiversity Action Plan (BAP)
National, local and sector-specific plans established under the UK Biodiversity Action Plan, with the intention of securing the conservation and sustainable use of biodiversity.

Biosphere
The organic world where living organisms are found.

Bog Oak
The term given to native timber that has been preserved in wetlands and by rising sea level. Also see **Submerged forest**.

Boulder clay or Till
Generally non-stratified material deposited directly by glacial ice, either at the base of the glacier or at the front, where meltwater causes flowing and slumping within the material which often contains material transport along the path of the glacier.

Brachiopods
Marine invertebrates with an external shell consisting of two symmetrical valves of unequal size, usually attached to the sea floor by a stalk.

Coversands
Wind blown deposits of fine, light, acidic sand sometimes with inland dune systems present – in Lincolnshire it supports heathland and woodland vegetation.

Cretaceous
The latest of the three periods of the Mesozoic Era, which ran from 145 – 65 million years ago.

Cryoturbation
Frost churning and mixing of materials from various horizons, from the soil down to the bedrock, due to freezing and thawing.

Devensian Ice Advance
The last glacial stage in Britain, from 115,000 to approximately 10,000 years ago, when the ice advance reached north and east of Lincolnshire.

Erratics
Rocks transported by glacier or iceberg which occur embedded in the till, in reworked gravels or on the ground surface once the ice has retreated. In Lincolnshire, the origins of erratics can be traced from Norway, Scotland and the North of England.

Evaporite
A sediment deposited from a saline solution as a result of extensive or total evaporation of the water.

Ferruginous
A rock cemented by iron oxide, or the red or rust-colour staining from iron oxide.

Fluvioglacial
Meltwater streams from glacier and the material deposits made by such streams

Geodiversity
The variety of rocks, minerals, fossils, soils and landscapes, together with the natural processes which form them.

Geodiversity Action Plan (GAP)
National, local and company-specific plans established under the UK Geodiversity Action Plan, with the intention of promoting and managing the sustainable use of geodiversity resources.

Geology
The scientific study of the Earth, its materials, structures, processes and history.

Geomorphology
The science concerned with understanding landforms and the processes by which they are shaped, both at the present day as well as in the past.

Geosphere
The inorganic world which includes the lithosphere, hydrosphere, cryosphere and atmosphere.

Glaciolacustrine
A lake adjacent to a glacier and the material deposited into such lakes.

Glauconite
A green mineral which weathers to a dull khaki colour and found in abundance in the Spilsby Sandstone, earning it the local name of 'Greenstone'.

Gryhaea
The calcite shell of this now extinct oyster is thick and survives well after weathering and erosion of the mudstones in which it mostly occurs. Particularly common in the Lower Jurassic rocks, it is sufficiently resilient to have endured transportation by rivers and glaciers, with its thick gnarled shell earning it the nickname of 'Devil's Toenails'.

Hypersaline
Greater than normal salinity of seawater – in excess of 40 parts of dissolved solids per thousand by weight.

Inter-glacial
A period of warmer climate that separates two colder glacial periods during an ice age.

Isostatic compensation
The adjustment of the lithosphere, especially the raising of topography when areas that were previously loaded, such as by glaciers.

Jurassic
The middle of the three periods of the Mesozoic Era, which ran from 208 – 145 million years ago.

Lincolnshire Biodiversity Action Plan (Lincolnshire BAP)
The local BAP covering the historic county of Lincolnshire, i.e. the areas administered by Lincolnshire County Council, North Lincolnshire Council and North East Lincolnshire Council. The first edition was published in 2000 and the second, revised edition was published in 2006. This is available on the web site: www.lincsbiodiversity.org.uk

Lincolnshire Biodiversity Partnership (LBP)
The Lincolnshire Biodiversity Partnership brings together local authorities, statutory agencies, voluntary and not-for-profit organisations with a responsibility for and interest in biodiversity in the historic county of Lincolnshire. It coordinates action, information and protection, and provides services for partner organisations. The Partnership is independent of any of its constituent organisations. Partners are listed on the website www.lincsbiodiversity.org.uk

Lincolnshire Environmental Records Centre (LERC)
This centre collects, collates, manages and disseminates information relating to the wildlife, sites and habitats of Lincolnshire, under the auspices of the Lincolnshire Biodiversity Partnership.

Lincolnshire Geodiversity Action Plan (Lincolnshire GAP)
The local GAP that covers the historic county of Lincolnshire, i.e. the areas administered by Lincolnshire County Council, North Lincolnshire Council and North East Lincolnshire Council.

Local Development Framework (LDF)
Local Development Frameworks deliver the spatial planning strategy for the local planning authority's area. They are replacing statutory Local Plans.

Local Geological Site (LGS)
Local Geological Sites (LGSs), along with geological, geomorphological and physiographical Sites of Special Scientific Interest (SSSIs) are the most important places for geodiversity and their function is to protect such interest and, where possible, provide educational opportunities.

Local Site
Local Sites are sites of substantive nature conservation value. Local Sites encompass both biodiversity and geodiversity, with sites known as Local Wildlife Sites and Local Geological Sites respectively. Local Wildlife/Geological Sites are also possible where interests coincide. Although they do not have any statutory status, many are equal in quality to the representative sample of sites that make up statutory Sites of Special Scientific Interest (SSSIs).

Local Wildlife Site (LWS)
Local Wildlife Sites (LWSs), along with biological Sites of Special Scientific Interest (SSSIs), some of which are of international importance, are the most important places for wildlife in the county. They have substantive nature conservation value and their continued presence makes a significant contribution to maintenance of biodiversity. They may also have an important role in contributing to public enjoyment and understanding of nature.

Marls
A friable calcareous clay composed of micrite and clay minerals.

Micrite
A limestone composed of a fine (< 5 microns) microcrystalline carbonate sediment.

National Indicator 197 (NI197)
A National Indicator for the performance of Local Authorities. Improved Local Biodiversity – the proportion of Local Sites where positive conservation management has been or is being implemented.

Ooids
Mostly calcareous precipitated concentric layers of calcium carbonate formed round a nucleus as it is rolled about the sea floor by currents, with a diameter of typically 1mm or less.

Periglacial
An area that is located and that has conditions, processes and topographical features that are adjacent to a glacier, such as low temperatures and strong winds.

Permafrost
The soil or subsoil that remains permanently frozen throughout the year as the mean annual temperature of the soil remains below freezing.

Planning Policy Statement (PPS)
A statement published by the Office of the Deputy Prime Minister (ODPM), replacing Planning Policy Guidance.

Regionally Important Geological and Geomorphological Sites (RIGS)
Established in 1990 by the Nature Conservancy Council (NCC), Regionally Important Geological and Geomorphological Sites (RIGS) are the most important non-statutory geoconservation sites. RIGS were designated based on local knowledge and so highlight local geological diversity and heritage and are important as an educational, historical and recreational resource. Lincolnshire RIGS are currently being re-surveyed in line with Local Geological Sites (LGS) guidelines and assessed against agreed criteria. Once passed, LGSs may be adopted by Local Authorities and included within Local Development Plans as the term RIGS is being phased out.

Ridge and runnel
Alternations of sand ridges and depressions parallel to the shoreline on beaches of shallow slope.

Saturated debris
Generally formed when unconsolidated material becomes saturated and unstable, with flows accelerated by gravity and tending to follow steep channels. Deposits are poorly sorted with no internal structure.

Site of Special Scientific Interest (SSSI)
An area of land designated by Natural England and that has statutory protection for its special interest at a national level due to its geological, geomorphological and/or physiographical features or its flora and fauna interest.

Solifluction
The slow downward movement of water-logged soils, characteristic of permafrost terrain, generally where there is very little vegetation to hold the ground together and where water released by the spring thaw cannot percolate downwards. The slumping usually occurs in the form of lobes which form distinctive patterns.

Submerged forest
The remnants of forest, woodland or trees that became inundated and preserved by a rise in water level, either by sinking of the land or rising sea level.

Triassic
The earliest of the three periods of the Mesozoic Era, which ran from 245 – 208 million years ago.

Tundra
Undulating treeless region where vegetation is limited to mosses, grasses and lichens and where the subsoil is permanently frozen.

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