

## EXTRACTING MARINE AGGREGATE RESOURCES FROM THE PLEISTOCENE SOLENT RIVER, EAST OF THE ISLE OF WIGHT

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### ABSTRACT

Sands and gravels infilling the former Solent River valley are locally over 30 m thick, east of the Isle of Wight. Mapping from seismic data shows that the river took a pronounced turn to the south as it left the valley now submerged beneath the Solent seaway and spread in a broad floodplain over the low relief inner-continental shelf east of the Isle of Wight. The long cut and fill history, reconstructed from a substantial amount of high resolution aggregate industry data, shows that the river occupied several courses in this region within two major bedrock bounded channel features. Several separate gravel deposits occur within the valley infill and are likely to be the product of periglacial gravel bed river sedimentation during successive sea level low stands in the Pleistocene. These gravels are separated, and in places covered by thick sequences of finer-grained sediments deposited in temperate fluvial, estuarine and ultimately marine interglacial environments.

Marine aggregates are extracted from several localities in the valley infill. They consist of clean, poorly sorted dark grey to light brown, flint rich, sandy gravel and gravel with a low shell fragment content. Gravels are typically rounded with common cobbles. Dredging targets either channel margin terrace deposits up to 15 m thick or more extensive channel infills, over 20 m thick. Dredging takes place either at anchor or by trailing slowly over carefully defined loading zones to manage cargo quality and comply with extraction licence conditions. The submerged floodplain of the Solent River preserves a complex record of Pleistocene environmental changes as well as providing large tonnages of locally sourced aggregates for southern England.

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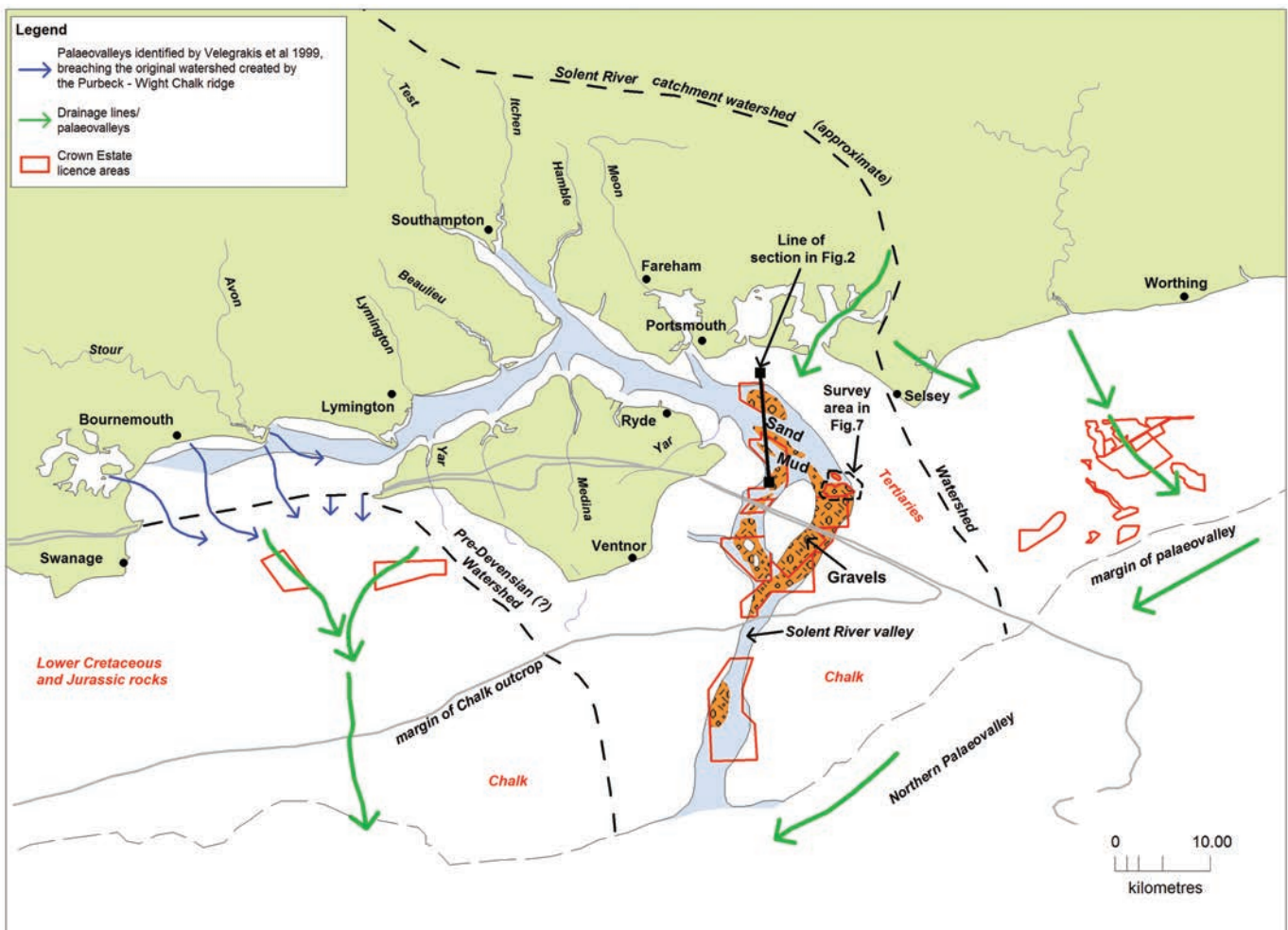
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### INTRODUCTION

The Solent River existed during episodes of lower than present sea level during the Pleistocene when the present Solent seaway separating the Isle of Wight from the mainland was exposed as land. Falling sea levels during cold stages of the Pleistocene caused rivers to extend on to the newly exposed continental shelf. As a consequence, several rivers draining present day Dorset, Hampshire and the Isle of Wight, such as the Frome, Stour, Avon, Test, Itchen, Meon and Medina converged to form a trunk stream which drained east and then southwards over the low relief inner continental shelf east of the Isle of Wight (Figure 1).

The Solent River was itself a principal northern tributary of the English Channel River examined by Gibbard (1988). Remnant deposits of the Solent River's tributaries exist on land (Allen and Gibbard, 1993) but the most substantial sedimentary record of the river's history lies submerged off the Isle of Wight. Seismic surveys of the river valley reveal a feature several kilometres across comprising a mixed sediment infill locally over 30m thick, commonly masking any contemporary bathymetric expression of the valley or the river's course. Early surveys (Dyer 1975) revealed clearly the valley's course and hinted at the complex nature of

the infill but produced relatively low resolution data. Velegrakis *et al* (1999) acquired extensive seismic data on the area between Poole Bay and the Needles on the Isle of Wight, seeking to investigate changes to the submerged river's catchment and course west of the Isle of Wight. Further surveys, almost all for the marine aggregate industry, have focussed on specific sections of the valley infill east of the Isle of Wight to define extractable sand and gravel deposits with seismic line spacing of typically 200m on a grid pattern. Taken together, these studies give an extensive and detailed coverage of the valley west and east of the Isle of Wight. Sands and gravels have been extracted from the valley infill for construction aggregate for about 40 years. Production agreements permitting this activity are issued by the Crown Estate (as mineral owner) following receipt of a Marine Licence from the Government's regulatory authority, the Marine Management Organisation. The statutory marine licensing procedure requires that dredging companies undertake an environmental impact assessment and consult widely on their proposals. A sound knowledge of the geological origins and extent of the sand and gravel deposits is needed for a licence application to proceed successfully, along with an understanding of the past and present processes acting on the deposits. This paper examines the geological



**Figure 1.** The course of the lower reaches of the Solent River and its tributaries during Pleistocene sea level low stands, showing underlying geology, adjacent river valleys and aggregate extraction licence areas.

aspects of the economically important Solent River gravel east of the Isle of Wight and explains how the gravels have been investigated and extracted by the marine aggregate industry in recent years.

**EXTENT OF THE SUBMERGED SOLENT RIVER VALLEY EAST OF THE ISLE OF WIGHT**

The submerged valley is over 4 km wide and its western margin is located over 3 km to the east of the Isle of Wight (Figure 1). The valley cuts deeply through the Tertiary strata of the Hampshire – Dieppe Basin, through folded Chalk and Lower Cretaceous Greensand and Clay. The course of the valley takes a prominent turn south in the outer-eastern approaches to the Solent seaway. There does not appear to be any clear bedrock control on this change of direction although subtle variations in bedrock elevation in the folded Tertiary strata may be a factor. Using aggregate industry survey data, the valley is understood to be eroded to a level about 50 m below the sea surface (measured from Chart Datum (CD), or lowest astronomical tide), similar to the figure of at least 46m below Ordnance Datum quoted by Dyer (1975). The valley has a low relief base distinguished by a locally prominent reflector on seismic profiles. The valley is truncated at the seabed by a marine planation surface and is commonly completely infilled so that the valley margin is level with the seabed. A bedrock “island”

separates two portions of the valley south-east of the Isle of Wight (Figure 1) and these converge downstream of a narrow chalk outcrop which is the offshore continuation of the Isle of Wight monocline. An impressive high resolution bathymetric image of the English Channel seabed in this region is presented in James *et al* (2010) and parts of the Solent River valley are visible in this image where the valley is only partly infilled. The valley trends north to south to a base level at 60 m below CD at the confluence with the Northern Palaeovalley. This palaeovalley took major regional drainage during episodes of low sea level when the entire English Channel was subaerially exposed. Although the Solent River formed only part of the drainage off southern Britain, it represented the largest river draining from the southern English landmass into the Northern Palaeovalley.

**THE VALLEY INFILL: ENVIRONMENTS OF DEPOSITION**

*Overview of seismic data*

Seismic data interpretation indicates that the valley infill is composed of sandy gravel and separate bodies of finer grained sand and mud. The gravelly deposits are commonly separated by erosional surfaces from the finer sediments, which onlap the margins of the gravel units, as interpreted from seismic profiles. In cross section (Figure 2), there is a general alternation of fine and coarse-grained units. At least seven major cut and fill

events are identified, the youngest culminating in the infill of the Nab Channel (the main shipping route into the Solent seaway). Each cut and fill cycle represents fluvial erosion followed by deposition of either coarse or fine-grained sediment.

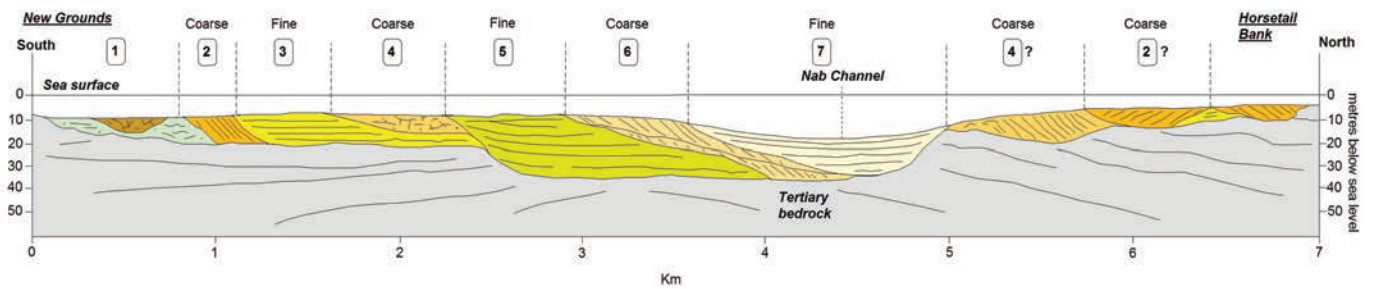
The alternation of contrasting sediment units suggests major contrasts in depositional environments over time. The deposits are oldest in the west and south-west and young to the east and north-east, suggesting channel migration as the valley was reoccupied by the river during successive lowstands. The lack of any sedimentation in the area during the present high stand is assumed to be representative of previous high stands and therefore depositional environments relate to periods of lower than present sea level when either gravel or fines were deposited by the river.

**Gravels**

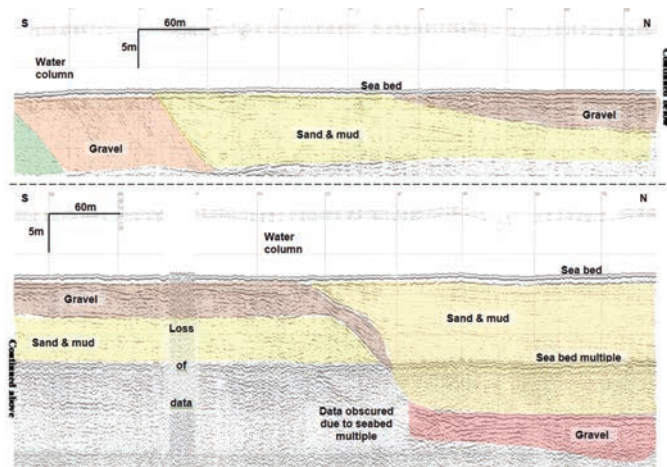
The gravels consist predominantly of poorly sorted subrounded or subangular flints ranging from granule to cobble size; and the sands are quartz rich showing variations in grain size and colour across the valley. Shell fragments are largely absent from the deposits. Gravel units were formed during cold stages in a periglacial environment as part of a gravel bed river, analogous for example to rivers draining the Canadian arctic at the

present time. Uniformly dipping reflectors on seismic profiles commonly correspond to gravelly deposits. This seismic response is interpreted to indicate cross bedding caused by the lateral accretion of bar surfaces as the river migrated over the low relief floodplain (Figure 3). High amplitude irregular discontinuous reflectors also correspond to gravel deposits and suggest aggradation of coarse-grained sediment in a braided river environment. Certain gravel units display a lens or sheet-like geometry in cross-section and sediment thicknesses vary from 3 m to over 15 m. Later erosion has left these units as terraces adjacent to deeper channels (Figure 3). Other gravel deposits form channel fills which either infill the main channel or are left as terraces above the main channel (Figure 4).

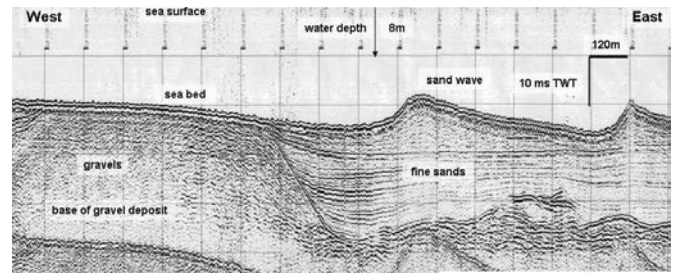
These terrestrial gravel deposits were derived from erosion of the Chalk uplands of the catchment, including the Hampshire, Dorset and Isle of Wight downland. The flint remaining represents the durable component of the Chalk succession, removed during successive cold stages of the Pleistocene, whilst the sands are likely derived mainly from the Lower Tertiaries and Greensands of the region. Variations seen in the colour (reddish brown – grey), gravel content (30 – 90%) and sand grain-size (fine – medium) of the gravel units suggest changes in derivation and post depositional processes as the river catchment evolved during the Pleistocene.



**Figure 2.** Cross section south-north across the submerged Solent River deposits in the approach to the Solent seaway, derived from interpretation of high resolution seismic data. 1- 7 are major seismic units which represent fine-grained sediment units with near horizontal bedding and coarse-grained gravelly units with dipping or irregular bedding structures in a cut and fill sequence. The location of the section is shown in Figure 1.



**Figure 3.** Interpreted seismic profile from south-north across the infill of the Solent River east of the Isle of Wight. The sediment units reduce in age from south to north (across the profile) and exist as terraces above the deep infilled channel on the far right (north) of the profile.



**Figure 4.** Interpreted seismic profile from west-east across the infill of the Solent River in its eastern section, east of the Isle of Wight, showing seismic responses interpreted as representing gravels and fine-grained sands.

**Fines**

The internal structure of the fine-grained successions (interpreted from seismic data) consists of low angle or flat bedding units within a homogeneous valley infill, onlapping either the gravel units or bedrock at the valley margins (Figures 3 and 4). Low energy sedimentation is

inferred and the thickness and extent of these units (over 10 m and commonly over 20 m, over several kilometres east of the Isle of Wight) suggests a change to estuarine or intertidal sedimentation as the valley gradually became a marine inlet during transgression. Truncation of the fine grained successions by erosion surfaces and younger gravel units indicates a return to cold conditions in a succeeding cold stage (Figure 3) as the river's base level fell with a lowering sea level.

It is therefore suggested that the complex alternation of sediment units within the infill east of the Isle of Wight owes its origin to climatic and associated sea-level changes during several stages of the Pleistocene, forming a large-scale cut and fill sequence. In the absence of any age estimates derived from the infill, an absolute stratigraphy is not possible to establish, but based on the number of seismic/sedimentary unit alternations resolved, the entire sequence is likely to originate over several glacial/interglacial or interstadial cycles. The most recent infill, within the Nab Channel, is fine-grained and is likely to be Holocene in age with the youngest gravel unit of likely late Devensian age.

**Marine events**

The river valley has undoubtedly been completely submerged by sea-level rise during more than one interglacial but evidence for wholly marine shelf conditions is not apparent within the deposits. The top of the infill (the present seabed) is truncated by an erosion surface cross-cutting all underlying units (Figure 3), interpreted as an early Holocene ravinement surface. Reworking of sand and gravel during this transgression is evidenced by widespread sea bed gravelly veneers and bedforms over parts of the infill (Figure 4). It is likely

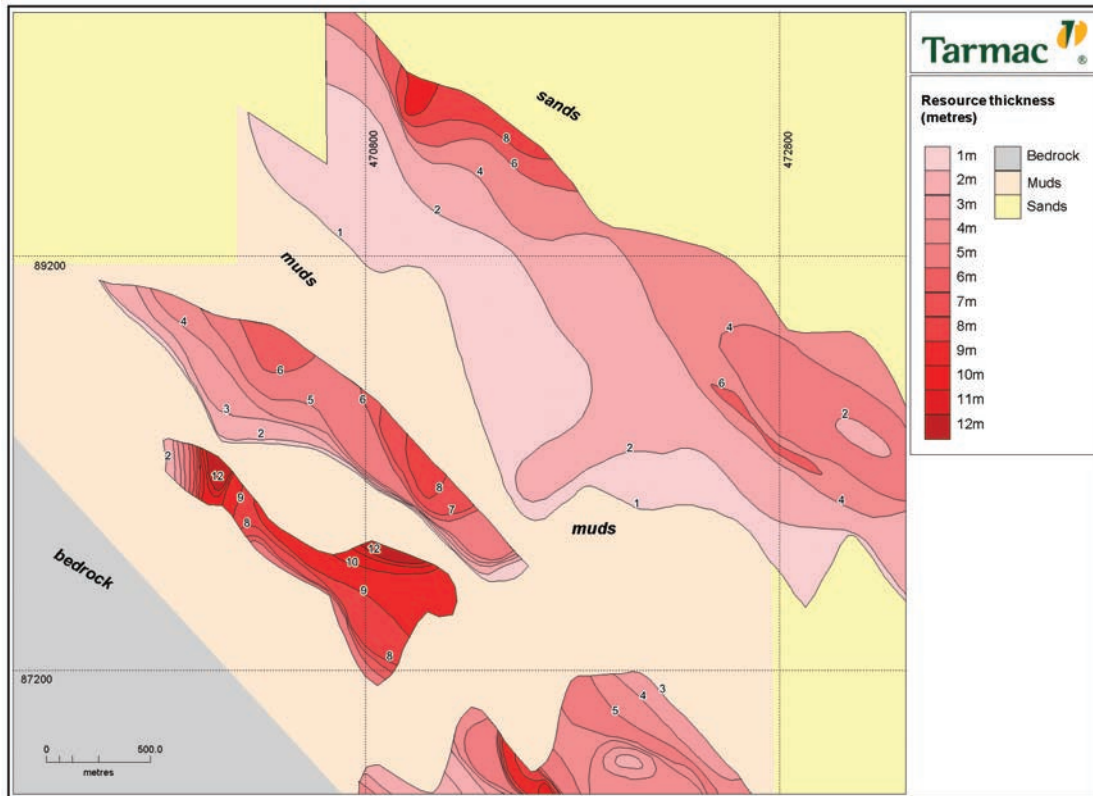
that this erosion surface also dates back to earlier interglacials as the low stand – high stand cycle was repeated throughout stadial/interstadial and glacial/interglacial stages in the Quaternary.

**LOCATING AND ASSESSING DEPOSITS FOR DREDGING**

*Data collection*

High resolution 2D seismic surveys by the aggregate industry have over the past 20 years or so built up a thorough coverage of the valley infill. These correspond to gravel prospecting and dredging licence areas in the region, which are granted by the Crown Estate and Marine Management Organisation to several marine aggregate dredging companies (Figure 1). Accurate satellite guided navigation and ever improving geophysical processing technology have allowed the definition of viable aggregate resources within the infill and the exclusion of fine sands and muds from the dredging plans of each company.

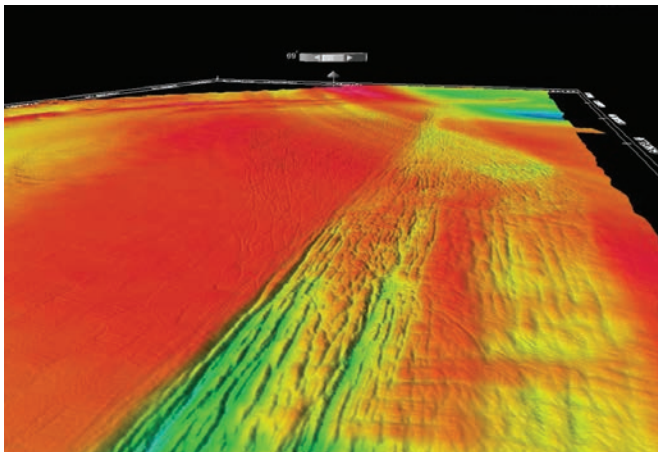
Isopachyte charts are compiled showing the extent and thickness of resources and reserves (Figure 5) with core samples assisting interpretation of seismic data and demonstrating aggregate quality. Ground modelling techniques provide reserve and resource volumes which are converted to tonnages with modifying factors such as dredgability, water depth constraints and extraction licence conditions taken into account. Dredgability is influenced by the extent of the gravel deposit, its orientation with the tide and the water depth. Deposits with overburdens of fines are not viable for dredging because the fine sediment would contaminate the quality of the gravel cargo, even if the overlying cover was thin.



**Figure 5.** Example of isopachytes of gravel deposits in the Solent River, as used for aggregates resource assessment and the planning of dredging operations.

**Extraction**

Dredging techniques comprise trail dredging and anchor dredging. In the former, a dredger steams parallel to the tide at about 1 - 2 knots (0.5 - 1 m/s), trailing its pipe along the seabed pumping a mixture of sea water and sediment into its hopper. Anchor dredging involves the ship becoming almost static while loading with the anchor deployed and the ship set against the running tide. This technique is suited to highly localised deposits (say less than 300 m across) which will not be extractable by trail dredging. Anchor dredging is only possible where the deposit is relatively thick, typically at least over 6 m, as otherwise the dredge pipe will excavate a depression and potentially reach unwanted clay bedrock or underlying fines if the gravels are too thin. Specific loading areas are provided to the dredgers by the company geologists to manage extraction and cargo quality in relation to licence conditions (Figure 6). The navigational accuracy, pump power and sophistication of vessel propulsion and steering systems on modern dredgers, together with the skill of their crews, ensures extraction is as efficient and consistent as possible. Extraction is possible in all but the most severe weather conditions provided the over board pipework and cabling is unaffected by the movement of the ship in rough seas.

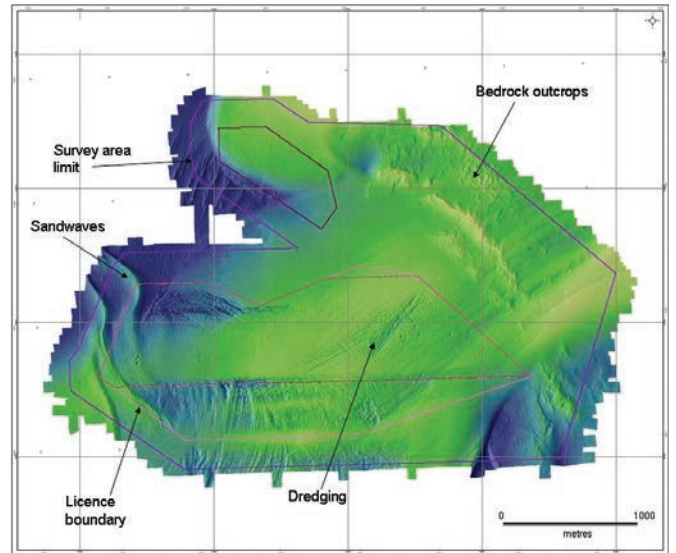


**Figure 6.** Oblique view of the seabed of an extraction site east of the Isle of Wight taken from full coverage high resolution multibeam bathymetric data, looking east. The view measures approximately 1.5 km from left to right and the irregular seabed is the result of several years of dredging activity, the smooth seabed being currently undredged. Water depths range from 15 m in red to 20 m in green.

**Monitoring**

Extraction is monitored in all dredging areas on a regular basis. Multibeam bathymetric data collection gives 100% seabed coverage with millions of data points and a resolution of the seabed to less than 1 m if required. Figure 7 shows an extraction site in the eastern part of the infill, with resolution of bedrock outcrops immediately beyond the valley margin, the smooth seabed of the infill and the various individual dredge marks created during loading. Dredge depths and remaining reserves are monitored by comparing such data to pre-dredge bathymetric and resource thickness information.

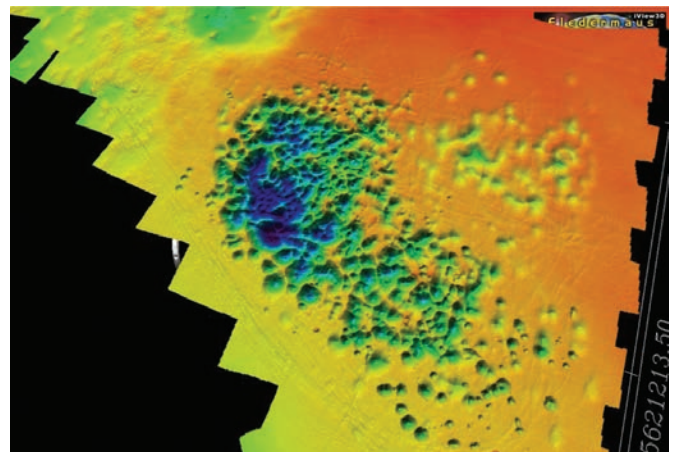
Anchor dredging over time produces coalescing conical depressions in the seabed, for example in Figure



**Figure 7.** Multibeam bathymetric data from an extraction licence in the eastern part of the Solent River infill (see Figure 1 for location). Greens represent water depths of 12 – 22 m CD and blues represent depths of 22 – 30 m CD.

8, where extraction over several years has taken place on a north bank terrace deposit of the river, 4 km south of Hayling Island. This survey data can vertically exaggerate the slope gradients and a true scale representation of a similar anchor dredge patch is shown in Figure 9.

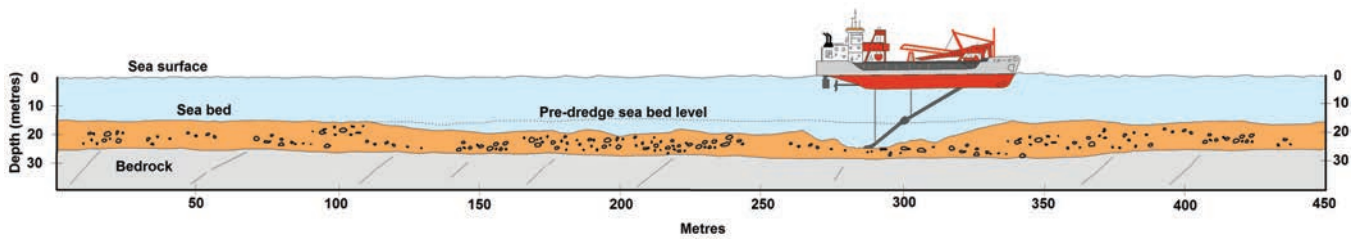
Monitoring demonstrates that both anchor and trail dredge areas do not infill with sediment and are stable over time, which is expected given the immobility of the relict coarse sediments and the lack of any recent Holocene sedimentation in this region.



**Figure 8.** Multibeam bathymetric data from an extraction licence north-east of the Isle of Wight showing dredge depressions caused by anchor dredging. The image is approximately 500 m across and water depths range from 10 m in red and yellow to over 20 m in blue at the base of the dredged depressions.

**ECONOMIC CONTRIBUTION AND CONCLUSION**

The submerged Solent River valley east of the Isle of Wight contains hundreds of millions of tonnes of sand and gravel. Not all of this is extractable or permitted for extraction at present, but nevertheless the river's deposits have provided much of the construction sand and gravel



**Figure 9.** Cross section from resource and bathymetric data at true scale over an anchor dredged area in 10 m thick Solent River gravels showing subdued seabed gradients and a dredger at work.

for the local region since the 1960's and should continue to do so for many decades to come. Landings of marine aggregate from licence areas off the south coast from west of the Isle of Wight to Shoreham total between 3.5 and 5.5 million tonnes per year and at least 50% of this comes from the Solent River alone. Most of the aggregate is used in the region between Poole and Newhaven where it is landed and processed at purpose built wharves for distribution into the region's construction industry. A varying but significant amount is used for beach replenishment and coastal defence, with beaches at Bournemouth, Hayling Island and further east benefiting from Solent River sand and gravel.

The location of the Solent River deposits and the dependency of the marine aggregate industry on the tide, means two cargoes can be dredged per day, at each low water, with the cargo landed at high water. Taking advantage of each tide maximises production and the closeness of the resources minimises the steaming distance between wharf and loading area (Figure 10). The Solent River is one of the most productive natural aggregate sources in the UK and the cluster of licence areas over its submerged downstream course illustrates the extent to which the industry has prospected and developed this major but still poorly understood record of Pleistocene environmental change.



**Figure 10.** Tarmac Marine Dredging Ltd's dredger "City of Chichester" returning to Southampton wharf having dredged a cargo of sand and gravel. Built in 1997, the purpose built vessel has a cargo capacity of over 2200 tonnes and can dredge in water depths of up to 35 m.

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