Tidal Lagoon Swansea Bay: Sediment Sources and Depositional Processes in Swansea Bay
Prepared on behalf of Natural Resources Wales

KPAL Report No. 16033

4th November 2014
Tidal Lagoon Swansea Bay: Sediment Sources and Depositional Processes in Swansea Bay

Prepared on behalf of Natural Resources Wales

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1.0 Report scope and purpose

1.1 The purpose of this report is to inform the response by Natural Resources Wales (NRW) to questions relating to Swansea Bay sediments raised by the Examining Authority Panel at an Issue Specific Hearing held on 21st October 2014. The Panel requested that the Applicant (Tidal lagoon Swansea Bay) and NRW provide an information note by Deadline V (4th November 2014) to address four issues:

(i) the sources of sediment that are being added to the bay, in particular from rivers that flow into it
(ii) the quantities of mobile sediments within Swansea Bay
(iii) the quantities of sediment being added to the bay in relation to the figures for annual dredging that have been carried out in past years and that are anticipated as taking place as a result of constructing and operation of the tidal lagoon
(iv) the practicality of mitigating against potential mud accretion within the western bay.

This report provides information to address the first three of these issues.

2.0 The morphology and sedimentary character of Swansea Bay

2.1 Swansea Bay, defined by a line drawn between Mumbles Head and Sker Point (Figure 1), is a relatively shallow marine embayment (depth mostly < -20 m OD). The adjoining part of the northern Bristol Channel is also relatively shallow (< -30 m OD). A ‘rim’ of relatively higher sea bed topography forms an arc between Pwlldu Head and Porthcawl, behind which lies a deeper basin extending southeasterwards from the Mixon Shoal towards a cluster of sand banks to the west of (Porthcawl (Scarweather Sands, Hugo Bank and Kenfig Patches). The ‘rim’ includes the relatively high areas of the White Oyster Ledge and the Scarweather Sands Sand Bank and corresponds with the southerly limit reached by Welsh ice in the Devensian (Last Glacial) period (Bowen, 1970). The ‘rim’ is breached by a relatively deep channel immediate south of the White Oyster Ledge which presents a palaeo-valley cut by the Tawe – Neath river system during times of glacially lowered sea level.

2.2 The line between Mumbles Head and Sker Point is also marked by a number of areas of higher sea bed, including the Green Grounds, Outer Green Grounds and North Kenfig Patches. All of these higher areas represent areas of glacial till, now partially covered by a varying thickness of modern marine sediments, which mark the limits of ice re-advance in the late Last Glacial. The lower areas between the bathymetric highs represent palaeo-valleys of the Tawe, Neath, Afan and Kenfig river systems which became submerged during the Flandrian (Post-glacial) marine transgression.
2.3 Much of the floor of the outer part of Swansea Bay and the northern Bristol Channel consists of relict Pleistocene sediments which are overlain by a patchy distribution of Flandrian deposits (Price & Brooks, 1980; Culver, 1976a,b; Culver & Bull, 1980). The Flandrian deposits include sediments laid down in a number of former lakes and marshy river valleys before marine submergence of the area, and a range of marine sedimentary facies formed during and after the transgression.

2.4 As sea level rose and flooded the Swansea Bay area between about 8500 and 5000 years BP the glacial and terrestrial deposits were partially reworked by marine processes. Large quantities of sand and some gravel were moved landwards to form an extensive coastal barrier system around the margins of the Bay, broken by the outlets of the Rivers Clyne, Tawe, Neath, Afan and Kenfig. Mud and peat accumulated in the back-barrier areas, forming transitional saltmarsh, brackish marsh and freshwater marsh environments. Sea level reached approximately its present level and greatest landward extent around 4000 years BP, since when it has varied by less than 1 m. Sea level fluctuations in the area within the last 2000 years are poorly documented, but evidence from other parts of southwest England and South Wales suggests minor fluctuations of the order of +/- 0.5 m. Limited available evidence from tide gauge records suggests a possible acceleration in the rate of average rate of rise, from c 1.5 to 3.5 mm/yr, in recent decades.

2.5 A fringe of sandy beaches was formed around much of the Bay, with a gravel upper beach in the highest wave energy area between Sker Point and the Kenfig River. Extensive sand dunes developed behind the sandy beaches between Kenfig and Black Pill. However, very little supra-tidal sediment accumulation occurred in the relatively low-energy area of northwest Swansea Bay (between Blackpill and Mumbles Head). This broad pattern of sedimentary environments, established approximately 4000 years ago, largely remains today, although modified locally by the construction of docks and artificial coast defences between Mumbles and Swansea and between Aberavon and Margam.

2.6 The geomorphological evidence suggests that in the past 4000 years the supply of sand to the shoreline around Swansea Bay has been much lower than in the early to mid Flandrian period. The supply of sand to the beaches has not kept pace with the landward movement of sand into the dunes as a result of wind action, resulting in slow ‘roll-back’ of the shore in many places, including the Blackpill area and between Aberavon and Sker Point. Back-barrier peats and silts now lie beneath a thin veneer of predominantly sandy sediments on the foreshore around Blackpill, at Margam and along the southern part of the Kenfig shore. During severe storms, as during the winter of 2013-14, the veneer of sand is sometimes stripped off to reveal the underlying silts and peats.

2.7 Shoreline recession and landward transfer of sand as mobile dunes was especially rapid during the stormiest periods of the Little Ice Age (mid 14th to late 18th century).
However, the shore continues to erode and show slow landward movement in some parts of the Bay which do not have artificial defences (e.g. the southern half of Kenfig and between Norton and West Cross.

2.8 The shoreline of Swansea Bay is almost swash-aligned to the prevailing wave regime (which is dominated by refracted waves from the southwest), and littoral drift of sediment on the beaches is slow. However, morphological and sedimentological evidence (e.g. differential build-up of sediment on either side of groynes, outfalls and other structures, particle size fining trends) indicates there is an overall net west to east movement of upper beach sediments in northwest and northern Swansea Bay (between Mumbles Head and the Neath estuary) and an net northerly movement of upper beach sediments between Sker point and the River Neath. Northeastern Swansea Bay has therefore acted a long-term sink for sediment transported by littoral drift from two directions, and also for sediment brought directly onshore by southwesterly waves.

2.9 Before the construction of the first training walls in the Neath estuary in the 1870s, natural migration of bifurcating low water channels kept the area at the mouth of the Neath estuary relatively open. Construction of the training walls led to a cessation of channel migration and allowed sediment to accumulate rapidly on either side. A succession of sandy dune-capped spits developed in a west to east direction on the Jersey Marine frontage, leading to the formation of Crymlyn Burrows. Similar spit development occurred in a southeast to northwest direction between Aberavon and the Neath estuary, leading to the formation of Baglan Burrows and the enclosure (and eventual reclamation) of Baglan Bay.

2.10 At the mouth of the River Tawe, the creation of a ‘New Cut’ to straighten the river and reclamation for dock development between the early 18th century and the early 20th century led to the obliteration of Fabian Bay and accumulation of sediment on the west side of the western harbour breakwater.

2.11 Much of the existing knowledge about the sedimentary regime of Swansea Bay arises from work undertaken in the 1970s, and relatively limited additional work has been undertaken since that time. A succession of research projects was undertaken by students and staff of the Geology and Oceanography Departments of the University College of Wales Swansea and the Geology Department of University College of Wales, Cardiff. Between 1975 and 1979 a major research project (the Sker Project) was undertaken by the Institute of Oceanographic Sciences (Taunton), funded by the Department of the Environment, driven partly by a need to achieve a better understanding of the effects of sand and gravel extraction on beach erosion along the shore of eastern Swansea Bay (principally Kenfig and Margam). A number of studies were also undertaken around this time by the British Transport Docks Board (BTDB) in relation to the development of the new tidal harbour at Port Talbot and to improve the maintenance dredging regime at both Port Talbot and Swansea docks. The results
of these studies were presented and discussed at a symposium held at University College, Swansea in September 1979 (and subsequently published in Collins et al., 1980). Since that time relatively little new work on the geomorphology and sedimentary regime of Swansea Bay has been published, although some sediment tracer work and sea bed sediment sampling was undertaken in relation to improvements to Port Talbot Harbour and Approach Channel in the later 1990s, and a considerable amount of research has been undertaken on the sand dune systems at Kenfig, Crymlyn and Baglan Burrows, and in northwest Swansea Bay.

2.12 Collins et al. (1979, 1980) provided an interpretation of sediment patterns in Swansea Bay, based partly on the results of sea bed sediment sampling reported by Culver (1976) and Culver & Banner (1978). On the basis of particle size characteristics and other features they recognized ten sediment textural facies which were then grouped into eight spatial provinces (see Figure 2). Although generalised, this map shows a predominance of gravelly sand and gravel in the western part of the entrance to Swansea Bay and extensive area of muddy sand and sandy mud in the central and northeastern part of the Bay, extending towards Port Talbot. To the east of this area the sea bed off Margam and Kenfig is dominated by sands and sandy gravels. Most of the floor of northern Swansea Bay, and the intertidal areas, are shown as being covered by mobile sand.

2.13 Box cores taken within Province 1 in the eastern half of the Bay indicated alternating laminae of sand and mud. Collins et al. (1979 p.69) noted that:

“the sand laminae in the deposit infer the aperiodic or ‘catastrophic’ nature of transport under storm conditions. Sand sized material is transported into the area from the west as part of a larger sediment circulation pattern in the northern Bristol Channel (Ferentinos and Collins, 1978). However, material in transit could become entrapped in the cohesive clay of Province I and be prevented from being transported to the east. The compacted silt layers in the bedding suggest that high concentrations of fine can occur temporarily near the bed resulting in flocculation and rapid mud deposition. Once this material has settled for a short period of time, inter-particle cohesion results in the development of a compacted mud layer which is difficult to re-suspend. Consequently, these high concentrations (related to re-suspension under storm conditions) are likely to be more important in the formation of the deposit than suspended levels in the water column”.

2.14 Banner & Culver (1979) and Culver (1980) concluded that much of the mud and muddy sand present on the floor of eastern Swansea Bay represents re-distributed dredge spoil derived from the Swansea and Port Talbot docks and approach channels. They noted that a layer of fluid mud up to at least 1 m thick periodically forms close to the sea bed and suggested that a significant proportion of this material is moved eastwards and northeastwards, eventually finding its way back into the dredged channels.
2.15 The nature of the sea bed sediment in the eastern part of the Bay was also investigated using geophysical methods, sidescan sonar and box cores during the Sker Project, and the results reported by Blackley (1978). This study confirmed the presence of mainly very fine sands and muds in the area west of Kenfig Patches, extending towards Port Talbot, with predominantly sands and sandy gravels further inshore off Margam and Kenfig. The surface and near-surface muds and muddy fine sands were found to be generally weakly consolidated and potentially mobile. Boulder clay was found to be present very close to the seabed at Kenfig Patches and to the west of Sker Point. The large Scarweather sand bank, and the smaller Hugo Bank and South Kenfig Patches sand bank, sit upon this surface. Analysis of historical charts have shown that the position of the banks has changed since the late mid to late 19th century (Carr and Blackley (1980)), with the result that new areas of the Pleistocene sedimentary substrate have become exposed to localised reworking by waves and currents.

2.16 No recent detailed investigation of sea bed sediment characteristics in Swansea Bay has been undertaken. The sea bed sediment map of the area published by the British geological Survey in 1984 provided a generalised summary of information collected up to the early 1980s (see Figure1). Since that time localised programmes of sediment grab sampling have been undertaken by the Countryside Council for Wales (CCW), NRW and other bodies concerned with habitat monitoring and port activities, but no Bay-wide study has been carried out. Sediments collected from parts of the Bay (mainly the northern part) and analysed as part of the benthic ecology assessment and geotechnical investigations connected with the proposed Swansea Bay tidal lagoon were reported in the Environmental Statement. A further suite of samples from a larger number of stations across the wider bay was collected by TLSB in the spring of 2014 but the samples have reportedly not yet been analysed.

2.17 Similarly, no systematic sediment survey has yet been undertaken to quantify the size distribution and other properties of intertidal sediments around the Bay. Data for beaches on the eastern side of the bay were obtained during the Sker Project, and some data for the Mumbles – Norton area were reported by Moran (1980). However, qualitative records of sediment type, based on visual assessment, are made as part of the strategic beach topographic monitoring surveys undertaken annually by Swansea and Carmarthen Bay Coastal Engineering Group (SCBCEG). Data obtained during the summer 2014 survey have been synthesised and shown in colour-code format in Figures 3, 4, 5 and 6. These diagrams illustrate (a) the variable nature of foreshore between Mumbles and West Cross, (b) the predominantly sandy nature of the foreshore and backshore between Black Pill and the River Tawe (though with areas of foreshore mud behind and adjacent to the mobile reniform sand bar at Lower Sketty), the sandy nature of the beaches between Crymlyn Burrows and Port Talbot, and the existence of predominantly sandy beaches with an upper gravel berm between Margam and Sker Point.
3.0 Sediment sources and sediment transport pathways

3.1 The main potential sources of sediment supplied to Swansea Bay are:

(1) Rivers
(2) Erosion of cliffs and other sedimentary formations around the margins of the Bay
(3) Erosion of Pleistocene and Flandrian sediments exposed on parts of the floor of Swansea Bay
(4) Biogenic production within Swansea Bay
(5) Input of marine sediment from the adjoining Bristol Channel
(6) Sediment derived from capital and maintenance dredging

3.2 The main rivers which supply suspended sediment are the Neath and the Tawe (including its tributary the Nant-y-Fendrod), followed by the Afan. Other inputs of relatively minor importance are provided by the Kenfig River, Clyne River, small streams such as the Black Pill and land drainage outfalls (Chubb et al., 1980).

3.3 Aperiodic monitoring of suspended solids concentrations in the river waters entering Swansea Bay has been undertaken by Welsh Water, Environment Agency Wales and (more recently) Natural Resources Wales, but no systematic long-term data sets exists which would allow an allow and accurate assessment of fluvial inputs to be made. No measurements have been made of bedload transport by rivers into the Bay, although there is general concensus that this is of minor importance.

3.4 Stoner (Welsh National Water Development Authority, cited in Collins et al., 1979 p.69) estimated a fluvial sediment input to Swansea Bay of \(75 \times 10^3\) tonnes / yr, which, based on their estimated mean tidal volume of \(9 \times 10^8\) m\(^3\) would increase the concentration of suspended sediments over the area by approximately 0.25 mg/l (NB estimates of the neap and spring tidal volume in Swansea Bay are provided for comparison in Table 1). Based on limited spot measurements over a 12 month period in 1978-79, Chubb et al. (1980) estimated an average input of 111 tonnes per day (equivalent to \(40.5 \times 10^3\)), but stressed this was based on the arithmetic mean of a relatively small number of samples. No major flood events were captured by the sampling.

3.5 Data held in the NRW database relating to aperiodic monitoring since 1982 shown that suspended solids concentrations in the Neath and Tawe rivers have mostly been recorded to be < 50 mg/l but on occasions following and during floods have been recorded to exceed 1000 mg/l. However, such events are relatively infrequent and short-lived.

3.6 Cliff erosion within Swansea Bay is of very minor importance as a source of sediment. The Carboniferous limestones and shales of the Mumbles area are relatively
resistant and yield little sediment. Unprotected low cliffs composed of glacial till occur along a short length of shore near Norton but the rate of cliff erosion is very low (<0.1 m/yr). Much of the rest of the shore in western Swansea Bay, and between Aberavon and the Kenfig River, is now protected by artificial defences. Intertidal deposits of Flandrian silts and peat on the foreshore at Margam and Kenfig south are subject to periodic erosion during storms but the quantities of sediment released are insignificant.

3.7 There is little doubt that the main natural source of suspended sediment (mud) in the water column of Swansea Bay and the northern Bristol Channel is provided by erosion and reworking of glacial till and Flandrian marine sediments exposed (at least periodically) on the sea bed (Collins et al., 1979, p69). Within Swansea Bay exposed Pleistocene and early Flandian sediments occur at the Inner and Outer Green Grounds, Kenfig Patches and elsewhere. As noted in Section 2 of this report, the large area of weakly consolidated and potentially mobile sandy muds and muddy sands in eastern Swansea Bay provides a very important potential source of suspended sediment which can be activated during storms.

3.8 Biogenic sources of sediment internal to Swansea Bay include both macrofauna (cockles, mussels etc.) and microfauna (e.g. foraminifera). However, while the shells and tests of most of the organisms living in Swansea Bay are calcareous, the carbonate content of the both the sands and muds present in the Bay is relatively low (<3%), indicating this is not a major source.

3.9 Previous studies (summarised in Collins et al., 1979, 1980 and in Collins & Banner, 1979) have provided strong evidence that there is a significant input of non-cohesive sediment (sand and gravel) input into Swansea Bay from the northern Bristol Channel to the south of the Gower Peninsula (see Figure 7). A net easterly movement of such material is indicated both by sea bed drifter experiments and natural tracers (e.g. deep water oyster shells). Transport occurs as a result of wave and wave-induced current actions, and is especially effective during storms and on neap tides (when water depths are smaller and wave - induced forces on the seabed are relatively greater.

3.10 A high proportion of bedload transport occurs not simply by transport of individual grains but through the movement of bedforms on the sea bed. A wide range of bedform types and sizes can exist, depending on local sediment properties and hydrodynamic conditions (especially the interaction of currents and waves). Small-scale bedforms include ripples and megaripples, meso-scale features include dunes, sand waves, bars and sand ribbons, and large-scale features include mega-sand waves and sand banks. Smaller bedforms frequently occur superimposed on the surface of larger bedforms which may show oscillatory or directional movement and changes in size / shape over time. The orientation of bedforms is consistent with net easterly and southwest to northeast movement from the northern Bristol Channel into the outer part of Swansea Bay. Reniform sand bars within the shallow subtidal and intertidal
areas of northwest and northeast Swansea Bay are also important in moving sand shorewards under the influence mainly of refracted southwesterly waves.

3.11 Although Swansea Bay has a very large tidal range, tidal current velocities throughout most of the Bay are too low to transport sediment particles larger than very fine sand. Exceptions are found off Mumbles Head, where ebb tidal flow velocities are enhanced by an anticyclonic gyre, and off Sker Point where flood and ebb flows are also locally accelerated. Collins and banner (1979) have suggested that the accelerated tidal flows around Mumbles Head are sufficiently strong to move sand out of western Swansea Bay, leading to accumulation on the Mixon Shoal. A similar process may have contributed to the formation of the Hugo Bank and South Kenfig Patches bank. Elsewhere, sand (and gravel) transport is entirely dependent on wave action.

3.12 Tidal current are, however, effective in transporting very fine sand and mud (silt and clay sized particles) into, out of, and within Swansea Bay. The average suspended sediment concentration in Swansea Bay is generally less than 50 mg/l, which is considerably lower than the concentrations found in the inner and middle Bristol Channel. However, higher concentrations (up to 270 mg/l) have been recorded under calm weather conditions in the area of higher tidal currents near Mumbles, and occur quite frequently during relatively short periods of high wave activity.

3.13 Field measurements in northwest Swansea Bay and the Tawe approach channel by Davies (1972, 1974) identified two separate current systems within Swansea Bay – a rotary current system located in the northern part of the embayment and a rectilinear current system offshore. The currently velocities and amount of suspended sediment were found to show significant variation with depth through the water column, with flows at different depth sometimes going in different directions. A net (residual) current flow across the Tawe channel from east to west into northwestern Swansea bay was observed. Within the Tawe channel itself, high concentrations of mobile mud were observed to occur within 1 to 2 m of the bed, but it was noted that vessel propellers are effective in dispersing the mud upwards through the water column. Similar high concentrations of fluid mud have been observed in the Port Talbot approach channel and in adjoining areas of the Bay.

3.14 A full mud budget analysis has not yet been undertaken for Swansea Bay, but qualitative assessment of the evidence available from comparison of historical Admiralty charts and Ordnance Survey maps suggests that both the subtidal and intertidal areas of the Bay have acted as a net sink for fine sediment over the past 120 years. Significant accretion of intertidal mud has occurred within the central and eastern subtidal parts of the Bay, and within the intertidal zone adjacent to the Neath estuary.

3.15 Collins & Banner (1979) concluded that the intertidal and shallow subtidal area of northwestern Swansea Bay has experienced relatively minor sediment accumulation
in the past 2000 years because the input of sediment from offshore has been almost balanced by (a) the removal of fine grained sediment by ebb currents past Mumbles headland and (b) the transfer of sandy sediment into the dune behind the shore. The transfer of fine sediment out of this part of the bay occurs when mud is re-suspended by wave action and made available in the water column from transport by tidal currents. Owing to the existence of an anti-cyclonic gyre on the flood tide in this part of the Bay, the length of the ‘ebb’ tidal flow past Mumbles Head is approximately 9 hours. Wave action is of key importance in preventing the initial settling of mud to the bed in this part of the bay, and (b) in controlling its subsequent re-suspension. Any reduction in wave energy, due, for example, to a greater sheltering effect created by a tidal lagoon which would reduce the width of the entrance to northwestern Swansea Bay by approximately one-third, would tend to favour the initial settling of mud and reduce the likelihood of its re-suspension.

3.16 Banner & Collins (1979 p384) noted that:

“In the western sector of the Bay, where a tidal current eddy is developed, mud, thrown into suspension by shoaling waves, is transported in suspension by tidal currents and can be deposited at slackwater, to form flaser-bedding on the foreshore, especially on the shoreward margins of the encroaching littoral sand ridges (Banner and Collins, 1975). The thin (mm to cm) littoral deposits of mud formed on the troughs of sand ripples stabilise those ripples; further cover of sand results in the preservation of the “flaser” mud lenticles within the beach, but the growth of Spartina maritima on the mud itself can enhance mud accumulation to produce stabilised muddy areas in which minor proportions of mobile sand become trapped. The shorewards progression of the wave-built littoral sand ridges also ultimately leads to the muddy accumulations being covered by sand, to create compacted modern mud deposits within the beach. Much mud most also leave the Bay in suspension on the ebb tide, especially when winds blow strongly from the east; air photographs show that the surface water leaving the bay on the ebb is of high turbidity around Mumbles Head, and this is due to muds, reworked from the littoral of the Bay, being transported in suspension into the Bristol Channel at concentrations (surface water at Mumbles) up to 270 mg/l. The fluid mud and static suspensions of mud, found in the lower water column in the estuarine approaches, largely recirculate within the inner parts of the bay, according to the state of the tide, wind drift currents and wave activity. The littoral zone of the eastern side of the bay is kept relatively free from mud deposition, because there is no current gyre (the currents are virtually rectilinear), to concentrate suspensions and deposit them at slack water, and because mud deposition is also re-suspended by the greater wave –induced turbulence caused by the shoaling of virtually un-refracted waves from the west to southwest.”

3.17 In view of the above, there is a significant possibility that any reduction in the effective ebb current speeds off Mumbles, due to disruption of the anticyclonic gyre, and/or a reduction in the effectiveness of wave ‘stirring’ in northwestern Swansea.
Bay, as a consequence of construction of the tidal lagoon, would lead to greater mud deposition and retention within the area. In this connection it is pertinent to note that, during the Second World War, when a causeway was built by the War Office between the Middle and Outer Islands at Mumbles Head (subsequently demolished in the 1950s), there was a reported increase in siltation and dredging requirement within the Tawe approach channel (Langdon, in Collins et al., 1980, p585).

3.18 The present pattern of sea bed sediments within Swansea Bay has unquestioningly been significantly affected by dredging and disposal of dredge spoil. The total amount of capital and maintenance material dredged from Swansea and Port Talbot Docks, and the approach channels to the port of Swansea, Port Talbot and Neath, is unknown. However, Carr & Blackley (1977) reported a total of 6.4 x10⁶ tonnes of maintenance dredging arisings from Swansea, 1.63 x 10⁶ tonnes from Port Talbot Docks, and 10.3 x 10⁶ tonnes from Port Talbot Harbour in the period 1960-76. In addition, these authors reported approximately 11.2 x 10⁶ tonnes of capital dredging arisings from Port Talbot tidal harbour between 1966 and 1969. Prior to the early 1970s, most of the maintenance dredgings were deposited within Swansea Bay, but since 1974 virtually of the dredged material has been deposited at the Swansea Outer disposal ground (see locations on Figure 1). No data are presently available for the period 1977-83, but between 1984 and 2013 a further 72.3 x 10⁶ tonnes of maintenance dredging arisings and 6.7 x 10⁶ tonnes of capital dredging arising was deposited at the Outer disposal site (Figure 8).

3.19 Radioactive trace experiments using small scandium-labelled glass particles were carried out by the Atomic Energy Establishment (Harwell) on behalf of the British Transport Docks Board between May 1973 and January 1974 (Paske, 1974; BTDB, 1974; Jackson & Norman, 1980). The results indicated a dominant west to east and southwest to northeast movement of the labelled material between the inner soil ground, with a considerable proportion of the material ending up in Port Talbot Harbour and approach channel. During this experiment radioactive tracer was also detected after 64 days associated with fine sediment in the Tawe approach channel, indicating that northerly movement of fine sediment and concentration with the inner Tawe approach channel also occurs (Figure 9). The net easterly to northeasterly movement of dredged arisings disposed of at the Outer disposal ground has also been demonstrated by later field surveys (e.g. as summarised in ABPmer, 2010). Monitoring of dredging activities has indicating that during dredging suspended sediment concentrations only occasionally exceed 120 mg/l in the Port Talbot Channel (about twice to three times the typical background levels of 30 to 60 mg/l), while at the Outer disposal ground concentrations during disposal activities rarely exceed 200 mg/l. Much higher concentrations of suspended solids (up to 650 mg/l) have been recorded in the inner Tawe channel (ABP Research & Consultancy Ltd, 1997).
3.20 Following the movement of dredge spoil disposal to the Swansea Bay Outer site (LU130) in 1974, the contribution of dredge disposal to the suspended sediment load of water within Swansea Bay may be expected to have decreased, although no hard data are available to indicate this. As discussed earlier in this report, a large area of potentially mobile muddy sand and sandy muds exists on the seafloor in the east-central part of Swansea Bay, the result at least in part of past dredge disposal activity, and this material continues to be mobilised, leading to mud re-suspension, during severe storms. Figure 8 shows no net declining trend in maintenance dredging requirement at Swansea and Port Talbot since 1984.

3.21 Future dredging requirements at Port Talbot and Swansea are uncertain, but the current three-year disposal licences issued by NRW Marine Licensing Team in 2013 provide for the disposal of up to $3.1 \times 10^6$ tonnes annually from Port Talbot Harbour and Channel and up to 999,999 tonnes annually from Swansea Port Approach Channel (a maximum combined total of approximately $12.3 \times 10^6$ tonnes over the approved three year period).

3.22 The overall impact of dredging on the sediment regime of Swansea Bay has not yet been the subject of a detailed study, but preliminary assessment suggests that, especially prior to 1974, it had a significant effect on suspended sediment concentrations within the Bay. However, natural processes of tidal exchange with the Bristol Channel, and wave-reworking of Pleistocene and Flandrian muddy sediments within the Bay, are alone capable of sustaining average suspended concentrations of up to approximately 40 g/l, and locally higher during storm events. Mud concentrations in the northern part of the Bay are also likely to be enhanced periodically by high flow (flood) events in the Rivers Neath, Tawe and Afan. The fine sediment introduced by the rivers will be partially dispersed as the freshwater plumes enter the Bay, with some from the Tawe being advected into the northwest part of Swansea Bay. Settling of this material can take place at slack water during calm weather conditions and is likely to be enhanced by flocculation processes as the freshwater discharge enters the more saline environment of the Bay. This process may partially explain the relatively high abundance of mobile mud within the inner Tawe approach channel.
4.0 References


Ferentinos, G. & Collins, M.B. (1978) *Sediment Transport through the area to the south of the Eastern Gower, as related to the Sediment Budget of Swansea Bay*. Second Interim Report to the Institute of Oceanographic Sciences, Taunton, by the Department of Oceanography, University College Swansea.


Tables
Table 1. Tidal volumes in Swansea Bay, defined by a line between Mumbles Head and Sker Point, calculated from digitised Admiralty charts surveyed in 1988-1993 and 1883. An absence of intertidal data on the 1883 chart precludes calculation of volumes below the upper tidal levels. Note that the tidal prism has reduced slightly between 1883 and 1988, which equates to an increase in bed levels due to sedimentation and/or dredge spoil dumping.

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<td>Volume below MLWS (-2.9 m OD)</td>
<td>812.0</td>
<td>752.8</td>
</tr>
</tbody>
</table>
Figures
Figure 1. Digital elevation model of Swansea Bay and adjoining area of the northern Bristol Channel, based on Admiralty surveys 1980-1998. Superimposed sea-bed sediment types, taken from a BGS seabed sediment map published in 1984, are shown in blue. Locations of past and present dredge spoil disposal grounds are also shown.
Figure 2. Provinces of bottom sediment distribution in Swansea Bay, based on textural facies (after Collins et al., 1979). Also shown are (a) the Inner spoil ground (maintenance dredgings from Swansea and Port Talbot used until c. 1974, (b) disused (1947) spoil ground, (c) disused (1939) spoil ground, (d) Outer spoil ground used for disposal of Port Talbot capital dredgings (1969-70) and, since 1974, maintenance dredgings from Swansea and Port Talbot.
Figure 3. Surface sediment type in western Swansea Bay recorded by visual observation during the summer 2014 beach topographic survey commissioned by Swansea Bay and Carmarthen Bay Coastal Engineering Group. The base air photograph was flown in July 2013.
Figure 4. Surface sediment type in north-eastern Swansea Bay recorded by visual observation during the summer 2014 beach topographic survey commissioned by Swansea Bay and Carmarthen Bay Coastal Engineering Group. The base air photograph was flown in July 2013.
Figure 5. Surface sediment type along the Baglan to Margam frontage of Swansea Bay recorded by visual observation during the summer 2014 beach topographic survey commissioned by Swansea Bay and Carmarthen Bay Coastal Engineering Group. The base air photograph was flown in July 2013.
Figure 6. Surface sediment type along the Kenfig frontage of Swansea Bay recorded by visual observation during the summer 2014 beach topographic survey commissioned by Swansea Bay and Carmarthen Bay Coastal Engineering Group. The base air photograph was flown in July 2013.
Figure 7. Principal residual ‘net’ bedload sediment transport paths in Swansea Bay and the adjacent Bristol Channel, related to the provincial textures of seabed surface sediments (both mobile and immobile). Dashed line shows the division between east-going and west-going sand streams (easterly indicated by sea-bed drifters, westerly by bedforms). After Collins & Banner, 1979)

Figure 8. Volumes of capital and maintenance dredged material disposed of at the Swansea Bay Outer Ground licenced site between 1984 and 2013 (data supplied by Cefas to NRW Marine Licencing Team)
Figure 9. Distribution of radioactive tracer released from the inner spoil ground, 2, 14 and 64 days after release (reproduced from Jackson & Norman, 1980). NB some areas of the inner Bay were not surveyed.)