West of Wales Shoreline Management Plan 2

Appendix D

Estuaries Assessment

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Haskoning UK Ltd

West Wales SMP2: Estuaries Assessment

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Summary

ABP Marine Environmental Research Ltd (ABPmer) was commissioned by Haskoning UK Ltd to undertake the Appendix F assessment component of the West Wales SMP2 which covers the section of coast between St Anns Head and the Great Orme including the Isle of Anglesey. This assessment was undertaken in accordance with Department for Environment, Food and Rural Affairs (Defra) guidelines (Defra, 2006a). Because of the large number of watercourses within the study area a screening exercise was carried out which identified all significant watercourses within the study area and determined whether these should be carried through to the Appendix F assessment. The screening exercise identified that the following watercourses should be subjected to the full Appendix F assessment:

- Nyfer Estuary;
- Teifi Estuary;
- Dyfi Estuary;
- Dysynni Estuary;
- Mawddach Estuary;
- Artro Estuary;
- Glaslyn/Dwyryd Estuary;
- Cefni Estuary;
- Alaw Estuary;
- Traeth Dulas;
- Menai Strait; and
- Conwy Estuary.

All other watercourses have been defined as having either virtually no interaction with the open coast or an interaction which is likely to be either small and / or localised in nature. For these watercourses an appropriate limit of coastal process interaction has been suggested based on the available data.

The Appendix F assessment for the watercourses listed above found that only Traeth Dulas need not be included within the open coast Shoreline Management Plan (SMP). It was found that the other estuaries need to be included within the SMP and appropriate limits have been determined based on the available evidence.

West Wales SMP2: Estuaries Assessment

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1. Introduction

ABP Marine Environmental Research Ltd (ABPmer) has been commissioned by Haskoning UK Ltd. to undertake the Appendix F assessment for the West Wales SMP2. The extent of the SMP2 is between St Anns Head in the south and the Great Orme in the north and includes the coast of Anglesey.

The main objective of the Appendix F assessment is to assess the need (or otherwise) for the inclusion of estuaries within the Shoreline Management Plan (SMP) process and specifically aims to address the following three key questions relating to the inclusion of an estuary in the SMP process:

- Should the Estuary be included in the SMP process?
- If so, how should the estuary be included?
- How far upstream should the estuary be included?

The conclusions and answers to each of these questions for each estuary inform the overall SMP development process. To address these questions the Department for Environment, Food and Rural Affairs (Defra) 2006 SMP Guidance Volume 1: Aims and Requirements and Volume 2: Procedures (March 2006) is used.

Because of the large number of watercourses within the study area a two staged approach has been undertaken to determine the extent to which the watercourses should be considered within the SMP2:

- The first stage of this approach is a screening exercise which identified all significant watercourses within the study area and based on available data determined which watercourses should be subjected to the full Appendix F assessment. The first phase is documented in Section 2 and Appendix A in this report concluding with a list of estuaries to be carried into the second phase; and
- The Appendix F procedure is outlined in Section 4 and the assessment for each estuary is documented in Sections 4-15, constituting Stage 2 of the process.

1.1 Report Aims

The aims of this report are as follows:

- To identify all significant watercourses within the study area;
- Identify which of these watercourses should be subjected to a full Appendix F assessment; and
- Assess the need (or otherwise) for the inclusion of the identified estuaries in the study area within the SMP process.

1.2 Report Structure

The report is divided into the following sections:

Section 2: Provides an overview and summary of the watercourse screening exercise;

Section 3: Provides an overview of the Department for Environment, Food and Rural Affairs (Defra) Guidance for the production of Shoreline Management Plans (SMPs), with particular reference to the contents and approach outlined in its Appendix F: Integration of Estuaries;

Sections 4-15: Details the Appendix F assessment for each of the 13 estuaries;

Section 16: Provides a summary of the conclusions of the assessment of each estuary.

2. Watercourse Screening (Stage 1)

2.1 Methodology

2.1.1 Data Review

The watercourses were identified using the following data sources; SMP1; Catchment Flood Management Plans (CFMP); the Estuary database; Futurecoast; Google Earth; Ordnance Survey (OS) mapping and internet searches. In using this approach all medium to large watercourses have been identified. Most of the small streams have also been captured although some of the very small watercourses may have been omitted. However these very small watercourses are unlikely to have an impact on coastal processes and consequently all watercourses of relevance to the SMP have been captured using this methodology.

Each watercourse was investigated using aerial imagery from Google Earth, this enabled a broad scale assessment of the form and morphology of the coast thereby identifying potential links between the watercourse and the adjacent open coast. The imagery allowed the identification of the size and shape of the estuary along with evidence of any morphological interactions with the open coast such as spits or deltas.

In addition to the aerial photography, the following data was also sourced to help understand the size and significance of the watercourse.

- Catchment Area (CEH, 2009);
- Mean Freshwater Flow (CEH, 2009 and Defra, 2002); and
- Estuary Area, Intertidal Area and Saltmarsh Area (Defra, 2002 and Davidson et al, 1991).

2.1.2 Boundaries of Other Management Plans

When determining the potential boundaries of the SMP2 it is important to consider boundaries of other management plans. This is to ensure that there are no areas of the coast which fall into a 'gap' between two management plans.

2.1.2.1 Catchment flood management plan

A CFMP gives an overview of flood risk and how this may change over the next 100 years. CFMP's develop policies to manage flooding from rivers, groundwater and surface water but not coastal flooding (flooding directly from the sea), which is addressed through SMPs. CFMP's set out a plan for managing this risk into the future and the three CFMPs of relevance to this study are as follows:

- Conwy and Clywd CFMP: The CFMP for the Conwy and Clywd (EA, 2008a) covers the Conwy and Clywd catchments. The study does not clearly define the downstream boundary of the study with a stated limit of the "estuary mouth" on the Conwy and Figure 1.2 within the CFMP showing the limit at the Conwy suspension bridge. As flood modelling and policies were set for the entire catchment including the part of the estuary seaward of the suspension bridge, it seems that the CFMP considered the entire Conwy catchment as far as the estuary mouth.

- North West Wales CFMP: The North West Wales CFMP covers the river catchments from Anglesey in the north to Borth in the south. The downstream boundaries of the North West Wales CFMP are not clearly defined within the document (EA, 2008b) however the description of the policy areas implies that the CFMP covers all estuaries and rivers as far as the mouths.
- Pembrokeshire and Ceredigion Rivers CFMP: The Pembrokeshire and Ceredigion Rivers CFMP covers the river catchments extending from north of Aberystwyth inland to the Cambrian Mountains, and as far south and east as Tenby. The seaward extent of the CFMP is not explicitly stated within the plan although the policy unit descriptions imply that the CFMP covers all the estuaries and rivers as far as the mouths.

2.1.2.2 River basin management plan

The draft river basin management plan (EA, 2009) focuses on achieving the protection, improvement and sustainable use of the water environment - surface freshwaters (including lakes, streams and rivers), groundwater, some wetlands that depend on groundwater, estuaries and coastal waters out to 1nm (nautical mile) beyond baseline and as such covers the West Wales SMP2 area. The draft river basin management plan has been prepared under the Water Framework Directive, which requires all countries throughout the European Union to manage the water environment to consistently high standards.

2.1.3 Screening

All the above information was collated (Appendix A) to determine whether the watercourse should be subjected to an Appendix F assessment and if not suggest an appropriate limit for the SMP. Due to the high level nature of this document the verdict is not fully prescriptive and instead is largely based on expert judgement of the potential interactions between the watercourse and the coast. *The objective is to scope out any watercourses that are too small to have any significant interactions with the coast and to take those forward which have a potential for interaction.* Overall the conclusions of the screening process were based on judgement of the following criteria:

- Watercourse Size: Watercourses that exchange a large amount of water with the adjacent open coast are more likely to interact in terms of coastal processes through potential changes in tidal prism or flow. The watercourse size has been assessed using the aerial imagery, water flows and intertidal areas.
- Sediment Exchange: The presence of morphological features such as spits, bars, ebb and flood tidal deltas and plumes can be used to infer an exchange of sediment between a watercourse and the open coast. These have been identified from the aerial imagery.

It is important to note that this discussion is based on coastal process interaction only and flood risk is not included within this assessment methodology, all areas of tidal flood risk would however be considered at an appropriate scale by the SMP.

Based on the collated information (Appendix A) it is possible to assign the watercourses to one of the following four categories and forms a key component of the methodology:

Type 1: Watercourse should be subjected to a full Appendix F assessment as the size of the watercourse and sediment exchange with the open coast is potentially significant.

Type 2: Potential for significant interaction between the watercourse and the open coast and therefore should be included in SMP. A full Appendix F assessment is not required as the watercourse is not a full estuary but instead the boundary has been set in this document as part of the screening exercise. The watercourses that fall into this category are typically harbours whereby although it is appropriate to consider them as part of the open coast SMP but an obvious boundary is present at the landward end of the harbour.

Type 3: Watercourse need not be included in the SMP and the estuary boundary can be set at the coast. However, some interaction between the watercourse and the open coast has been identified, this is likely to be localised and limited to the outfall and will not extend significantly further inland.

Type 4: Watercourse need not be included in the SMP as no significant interaction between open coast and the watercourse has been identified.

2.2 Results and Conclusions (Stage 1)

The results of the screening are provided Appendix A and summarised below.

A total of 56 watercourses have been identified as part of this screening exercise. Out of these 56 watercourses the following have been identified as Type 1 watercourses (Figure 1) and should be subjected to the full Appendix F assessment (Sections 3-15 of this document):

- Nyfer Estuary;
- Teifi Estuary;
- Dyfi Estuary;
- Dysynni Estuary;
- Mawddach Estuary;
- Artro Estuary;
- Glaslyn/Dwyryd Estuary;
- Cefni Estuary;
- Alaw Estuary;
- Traeth Dulas;
- Menai Strait; and
- Conwy Estuary.

All other watercourses have been defined as having either virtually no interaction with the open coast or an interaction which is likely to be either small and / or localised in nature. For these watercourses an appropriate limit of coastal process interaction has been suggested based on the available data.

3. Shoreline Management Plans: Integration of Estuaries

The estuary assessment has been produced in accordance with Defra's 2006 Guidance for the Production of SMP's (Defra, 2006). This guidance provides details on what the SMP should include and sets out the best practice methods to help the production of the plans.

"Appendix F: Integration of Estuaries" provides guidance regarding the incorporation of estuarine shores into the SMP process. The guidance enables the scale of water and sediment exchanges between an estuary and adjacent areas of open coast to be considered, along with the scale of management intervention, to feed into the decision as to whether or not an estuary should be included in the SMP process.

3.1 Overview of Guidance

This section provides a brief overview of the guidance contained in Appendix F to provide background and context to the remainder of this report.

3.1.1 Open Coast - Estuary Interactions

The inclusion of an estuaries assessment within the SMP process has arisen in recognition of the importance of understanding physical processes when providing effective flood and coastal management. The interaction of, and exchanges between, the open coast and estuaries mean management policies in one environment have the potential to affect the other.

The interactions between the open coast and estuaries may take a number of forms, as follows (after Defra, 2006):

- Sediment Supply: The open coast may provide a significant supply of sediments to the estuary and the estuary may supply sediment to the coast. Therefore any management policy that acts to alter this supply may have an impact on the estuary;
- Alteration to Longshore Drift: Water flows from estuary can act to block longshore sediment transport across the mouth of the estuary. In addition, high river flows can drive sediment from the longshore transport system offshore;
- Flood and Ebb Tidal Deltas: Sediment within the longshore transport system can be transported into the estuary mouth and stored on flood tide deltas before being transferred to the downdrift coastline. Similarly, ebb tide deltas may store sediments. Ebb tide deltas also serve a natural coastal defence function to the estuary mouth and adjacent stretches of the open coast; and
- Tidal Prism Changes: A change in the tidal prism of the estuary may alter process to the extent that changes also occur to erosion / deposition patterns and / or changes in the dominance of the flood or ebb tide and hence the import or export of sediment. This will have implication for the sediment budget along adjacent coastlines.

3.1.2 Should the Estuary Be Included in the SMP Process?

This is the first stage of the assessment process. The guidance states that this question is to be addressed by considering:

- The type and scale of physical interactions and their significance; and
- Management issues and their significance.

3.1.3 How Should the Estuary Be Included in the SMP Process?

If a decision is made to incorporate the estuary in the SMP, then there are two options for inclusion:

- The estuary could be included in the open coast SMP; and
- The estuary could have its own 'estuary SMP' (eSMP).

3.1.4 How Far Upstream Should the Estuary Be Included?

To completely cover any potential interactions, the estuary should be theoretically incorporated to the tidal limit, however this is not practical in many cases due to the tidal length of an estuary and may overlap with other flood risk management plans (such as Catchment Flood Management Plans). The practical alternative is to determine an upstream limit beyond which no change in shoreline management policy is assumed (Defra, 2006). Defra (2006) provide a number of criteria that could be used to determine the upstream limit of inclusion of an estuary within an SMP. These are:

- Approximate limit of tidal influence;
- Approximate limit of wave influence;
- Approximate limit of non-cohesive sediment exchange;
- Limit of continuity of habitats, development or risk zones;
- Limit of existing CFMP boundaries; and
- Limit as defined by existing Schedule IV Boundary (Defra, 2006).

3.1.5 Estuary Guidance Tables

The guidance does not provide a prescriptive method for assessing estuaries and their inclusion in an SMP. However, a series of Estuary Guidance Tables (EGTs) have been produced that provide consistency in the approach. These EGTs are reproduced in Appendix A of this report for information.

The Procedural Guidance recommends assessments of the 'significance' of water and sediment exchanges between the estuary and open coast and of the management issues within the estuary. In undertaking this assessment, the term 'insignificant' has been difficult to apply since clearly any physical interaction or management issue is significant at some, perhaps very local, scale. Consequently, in undertaking this assessment, the term 'insignificant' has been interpreted as being of no, or low, significance to the regional (i.e. cell-wide) coastal processes. This may mean that some locally important processes or issues do need to be considered, but where these exist they have been highlighted in the following assessments.

3.2 Tidal Locking Assessment

Tidal locking occurs when an exceptionally high tide prevents the discharge of river flows to the sea, this causes the river water to back-up resulting in flooding. If a watercourse is presently susceptible to tidal locking it is likely that the risk will worsen with increased sea levels as tidal levels with the capacity to cause flooding by tidal locking will be reached more often. In addition to the Appendix F assessment process outlined above tidal locking has been identified as an area of concern and as such ABPmer has been asked to comment on the likely future risk of tidal locking within each estuary based on the findings of the CFMP and the morphology of the estuary. This discussion is only a first order approximation of risk and a full assessment can only be made with the use of hydrodynamic modelling and joint probability analysis. The assessment of tidal locking is based on the following parameters:

- Historical records of flooding resulting from tidal locking: These are detailed in the relevant CFMP. It is important to note that a lack of historical records does not necessarily mean that no flooding occurs as records are generally only available for populated areas.
- Modelled current and future risks of flooding form tidal locking: These are also detailed in the relevant CFMP. Again it should be noted that the CFMP only tends to detail flooding in populated areas.
- Fluvial discharge: This data was collected form a number of sources in stage 1 of this study. In general higher flows are more likely to lead to flooding from tidal locking.
- Morphology: If the morphology has been constrained either through a natural hard point, a sluice or reclamation this will present a barrier to fluvial discharge and hence increase the risk of flooding by tidal locking.

4. Nyfer Estuary Assessment

This section represents a conceptual understanding of the Nyfer Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Nyfer is illustrated in Figures 1 and 2.

4.1 Conceptual Understanding

The Nyfer Estuary is situated on the Afon Nyfer at Newport in Pembrokeshire at the southern end of Cardigan Bay. The estuary is orientated along a north-westerly to south-easterly axis with the mouth situated between rocky headlands. The estuary was formed from a flooded river valley which has subsequently infilled with sediment.

At the estuary mouth the main channel runs along the southern bank of the estuary where it flows alongside the rocky foreshore. The main channel is deflected here by Newport Sands at the seaward end of the estuary and Bennet sand spit which is situated a little further up-estuary. The open coast to seaward of Newport Sands is characterised by rocky cliffs with no foreshore indicating little potential for sediment exchange with the adjacent open coast.

On the southern side of the estuary opposite the Bennet sand spit the Parrog juts out into the estuary, the origin of this feature could not be determined although it is now defended with a number of properties constructed on it. The main channel flows across the seaward side of the Parrog and switches to the opposite bank and flows behind the Bennet sand spit and along the northern bank of the estuary. The rocky cliffs outside of the estuary mouth work as a constraint on the estuary along with the Parrog and the road bridge at the top of the estuary. Up-estuary of the road bridge the estuary quickly becomes more fluvial in nature with a limited intertidal area and a meandering course, the road bridge forms the present SMP1 boundary.

Details of the nearshore wave climate in the immediate vicinity of the Nyfer is not available however analysis of the open coast wave climate outside of the Teifi (Posford Duvivier, 2000) has shown that the predominant wave direction is from the west-northwest. The potential for significant amounts of wave energy to propagate into the estuary is low due to the presence of Newport Sands, the Parrog and the Bennet spit and consequently wave energy will be highest along the seaward edge of Newport Sands.

Tidal data is not available for the Nyfer although the Teifi Estuary 12km to the north is macrotidal with a mean spring tidal range of 4.7m at Port Cardigan (UKHO, 2008). Tidal currents in the Nyfer are not known although the estuary is described as strongly flood dominant at the mouth according to the Dronkers parameter (Halcrow, 2002). The river is not gauged and hence flow speeds on the Afon Nyfer are unknown. The flow ratios within the estuary suggest that the Nyfer is partially to well mixed and that plume generation is unlikely (Halcrow, 2002).

The estuary has a small total area amounting to 100ha, 75ha of this is intertidal and 10ha saltmarsh which is distributed along the southern side of the estuary behind the Parrog and immediately up-estuary of the road bridge. No historical analysis or sediment budget has been undertaken to assess the behaviour of the estuary although the large amount of both sand and fine sediment within the Nyfer shows that it has historically been a strong sink for sediment with sand sized sediment probably being sourced from the offshore area and fines from fluvial sources. Although the ratio of intertidal area to total estuary area is high it has been interpreted as being low for its tidal range by Halcrow (2002) and hence there is potential for further sediment accumulation within the estuary.

4.1.1 Response to Sea Level Rise

There is very limited data with which to describe the current and historic processes within the Nyfer Estuary. Based on this limited dataset it is concluded that the estuary is likely to be currently importing small amounts of sediment and hence is a net sink. With a rise in sea level the estuaries capacity will increase and the ability of the estuary to warp-up and maintain its position in the tidal frame is dependant on the availability of sediments. As sediments are currently sourced from potentially large offshore and fluvial supplies it is likely that the estuary will continue to import sediment and accrete into the future.

At the estuary mouth, Newport Sands and the Bennet sand spit exercise an important control on the estuary and protect the inner estuary from wave energy propagating into the estuary from offshore. Historically Newport sands has been stable over the last 100 years (Halcrow, 2002). It is possible that with sea level rise the spit could move landward and possibly break down (Halcrow, 2002) although the break down of the spit is considered unlikely due to the large potential supply.

4.1.2 Assessment of Tidal Locking

The Nyfer Estuary has not been identified as an area at risk of flooding from tidal locking within the CFMP (EA, 2008c), both historically and under future predictions. The Nyfer has an unconstrained natural morphology and a low mean river flow, because of this flooding as a result of tidal locking is not expected either now or into the future.

4.1.3 Summary of Key Processes and Morphology

The degree of exposure within the estuary is controlled by the sand spit (The Bennett) extending across the estuary from north to south and also Newport Sands with the rocky embayment outside of the estuary controlling the overall position of the mouth. The spit and Newport Sands push the main channel up against the Parrog on the south shoreline and reduce the exposure of the estuary to waves. Both the spit and Newport Sands have been stable over the last 100 years and this stability is unlikely to be affected by sea level rise due to the large amount of sediment available offshore.

4.2 Estuaries Assessment

Estuary	Nyfer Estuary
Location	Southern Cardigan Bay, Wales.
Classification	4c - Spit Enclosed Filled Valley
Main characteristics	Macrotidal, small estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Pembrokeshire Shoreline Management Plan (PCC, 2002)
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Nyfer is considered to be small in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a large intertidal zone relative to its total area; a small amount of saltmarsh is present. Channel length: The length of the estuary is considered to be small. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width with a sand spit present on the northern side of the mouth. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: The river is not gauged and hence the magnitude of fluvial flows is unknown. % Area: The estuary has a moderate % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities within the Nyfer are not known. Tidal prism: 3,500,000
	Verdict on significance: The Nyfer has a large tidal range and therefore exchanges a significant amount of water with the coast relative to its size. The flow of water through the estuary mouth will exercise an important control on the spit at the mouth. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The estuary is flood dominant at the mouth according to Dronkers gamma (Halcrow, 2002). Morphological features: The mouth of the estuary is situated in a cliffed bay, Newport sands fronts the estuary with a large sand spit situated behind. The area of intertidal is relatively large compared to the total area and a small amount of saltmarsh is present along the southern shore behind the Parrog and up-estuary of the road bridge. Source sink relationship: Historically the estuary has been a sink for sand sourced sediment from offshore sources and fine sediment from fluvial sources. The proportion of intertidal area suggests that the estuary still has some limited capacity with respect to sediment accumulation and is a weak sink for sediment. Plume generation: The flow ratio suggests that plume generation is unlikely.
	Verdict on significance: The presence of a spit at the estuary mouth and large amounts of sediment within the estuary suggest that the estuary exchanges significant amounts of sediment with the adjacent coast. Beyond the area of Newport sands there is unlikely to be any significant sediment exchange as evidenced by the cliffed and embayed nature of the coastline. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as marginal in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: marginal Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	The estuary is largely natural in character with few management issues. The road bridge at Newport forms a constraint on the upper estuary and the Parrog forms a constraint on the estuary channel at the seaward end of the estuary.
	Verdict on significance: Insignificant, although there are a number of structures within the Nyfer these are unlikely to affect the coast.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as insignificant. *Therefore from Step 5 of EGT5, the Nyfer scores 2 in terms of overall significance and should be included in the SMP process.*

4.3 Discussion

Overall the interactions between the Nyfer and the open coast can be summarised as follows:

1. The Nyfer has a large tidal range and as such exchanges significant volumes of water with the open coast;
2. The Nyfer is a significant sink and along with the morphological features present at the mouth this suggests important sedimentary interactions with the adjacent open coast. This sediment exchange is unlikely to extend beyond Newport Sands; and
3. There is some development within the estuary although these have not been large enough to impact significantly on the adjacent open coast.

Due to the interactions between the Nyfer and the open coast it is considered appropriate to include the estuary within the SMP. Analysis of aerial photography and OS maps shows a clear boundary between the Nyfer Estuary and the Afon Nyfer with a significant decrease in intertidal area upstream of this point and the watercourse adopting a meandering fluvial character. Because of this and also the constraint provided by the bridge it is considered that the SMP boundary should be placed at this point as shown in Figure 2. According to the OS data (Figure 2) this is also the normal tidal limit of the Nyfer Estuary.

5. Teifi Estuary Assessment

This section represents a conceptual understanding of the Teifi Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Teifi is illustrated in Figures 1 and 3.

5.1 Conceptual Understanding

The Teifi estuary is situated on the Afon Teifi in south-west Wales. The estuary is orientated in a north-northwesterly direction and is situated between the rocky headlands of Cemaes Head in the west and Craig y Gwbert in the east. The estuary was formed from a flooded river valley which has subsequently infilled with sediment.

The mouth of the estuary itself features two spits located at Poppit Sands in the west and Pen yr Ergyd in the east which exercise an important control on the morphology of the estuary. The coast to seaward of Poppit Sands is rocky with no little or no intertidal indicating that there is little interaction with open coast in terms of sediment transport. Up-estuary the Teifi narrows significantly between the rock headlands at Old Castle Farm Point (west bank) and St Dogmaels (east bank). It has been reported that the rail bridge at Cardigan represents a restriction to saline penetration (Halcrow, 2002) hence it can be inferred that conditions above the bridge are dominated by fluvial processes. The boundary of the SMP1 is at the Cardigan Bridge.

Analysis of the nearshore wave climate (Posford Duvivier, 2000) has shown that the predominant wave direction is from the west-northwest showing the potential for waves to propagate into the outer estuary although the presence of the spits and Poppit Sands is likely to limit the distance up-estuary to which waves can reach.

The Teifi is macrotidal with a mean spring tidal range of 4.7m at Port Cardigan (UKHO, 2008). Currents within the Teifi are not well defined although flows within the entrance channel in excess of 2m/s have been recorded (Posford Duvivier, 2000). In terms of Dronkers, the tidal asymmetry is flood dominant although flow from the river is significant and there is a definite potential for the flood dominance to be reversed at times of high fluvial discharge (Halcrow, 2002). Net sediment transport is in an easterly direction along Poppit sands.

Historical analysis of the estuary shows that the main channel flowing across Poppit Sands has migrated in an easterly direction since the early 1900s until reaching its present position adjacent to the cliffs at Gwbert (Posford Duvivier, 2000). Historical analysis of the spits (Posford Duvivier, 2000) has shown that since the 1940s the Pen yr Ergyd spit has increased in length at the expense of the Poppit spit which has eroded. This movement of the seaward end of the main channel to the east increased the flow across Pen yr Ergyd causing the spit to extend, deflecting the main channel in the vicinity of the spit and subsequently eroding the Poppit spit. As the Pen yr Ergyd spit became more dominant and further deflected the channel to the west it resulted in the further eastward migration of the channel down estuary subsequently reinforcing the process of change (Posford Duvivier, 2000).

The migration of the seaward end of the main channel to the east has resulted in increased erosion of the cliff frontage and beach at Gwbert, subsequent stabilisation of the cliffs has reduced the supply of material to the Pen yr Ergyd spit. This has resulted in the spit increasing in length whilst also reducing in volume (Posford Duvivier, 2000).

The estuary is relatively small in size with a total area of 200ha, the proportion of intertidal area is large with a total area of 180ha (Halcrow, 2002). Some saltmarsh is present behind Poppit Spit on the west bank and adjacent to Bryn-y-mor on the east bank with a total area of 46ha (Halcrow, 2002). The erosion of the Poppit Spit has caused the saltmarsh situated behind the spit to also erode although throughout the estuary there is a general tendency for accretion of saltmarsh between the 1940s and the 1990s (Posford Duvivier, 2000). The very large proportion of intertidal area shows that the estuary has in the past been a sink for sediment but suggests that the estuary is now approaching, or is at capacity with respect to sediment accumulation. Consequently the Teifi may now be only a very weak sink of sand and fine sized sediment or possibly a weak source of fine sized sediment to the open coast (Halcrow, 2002). A detailed sediment budget and modelling of the hydrodynamic regime would help to confirm the estuaries asymmetry with respect to sediment transport.

The historic sources of sediment are not entirely clear, the embayed and cliffed nature of the coast outside the estuary mouth indicates that little sediment is sourced from the adjacent coast. The river Teifi has a mean flow of 28.89m^3/s (CEH database) showing that the river is capable of transporting a relatively significant amount of fines into the estuary (providing there is an available source) although the presence of large sand flats and the sand spits indicates a probable offshore source of sand sized sediment. Maps of surficial geology offshore show that the seabed outside of the estuary comprises sands and muddy sands indicating a potential source of sand sized material.

5.1.1 Response to Sea Level Rise

The proportion of intertidal area is currently high in the context of other estuaries indicating that the estuary is unlikely to gain further intertidal area and in terms of sediment it is either nearing or at capacity. Historically the estuary has been a net sink for both sands and fines with sediment sourced from offshore (sand) and fluvial / catchment sources (fines).

A rise in sea level would increase the capacity of the estuary to accrete and hence the ability of the estuary to maintain pace with sea level rise will depend on the amount of sediment available to the estuary. As much of the sand seems to be sourced from a large potential source offshore it is likely that there are large amounts of sediment available to the estuary and the estuary will continue to accrete with sea level rise.

If Poppit Spit continues to erode and Pen yr Ergyd spit continues to extend it is possible that the Pen yr Ergyd spit may breach due to a reduction in sediment supply from the now defended Gwbert cliffs. This will lead to the movement of the main channel towards the east.

5.1.2 Assessment of Tidal Locking

There is no record of the Teifi experiencing flooding as a result of tidal locking although the town of Cardigan has been identified as an area at risk (EA, 2008c). The impacts of tidal locking will worsen with sea level rise as the Teifi has a large freshwater flow combined with a macro tidal regime and a relatively constrained morphology up-estuary of Old Castle Farm Point in the vicinity of Cardigan. Down-estuary of this restriction the unconstrained morphology of the open estuary means that it is unlikely that tidal locking will be an issue.

5.1.3 Summary of Key Processes and Morphology

The twin spits and Poppit Sands exercise an important control on the Teifi Estuary narrowing the estuary mouth and hence reducing the exposure of the estuary to waves. The Pen yr Ergyd spit is currently dominant although it is possible that this spit may not hold its position into the future due to cliff stabilisation works which have reduced cliff erosion and hence the supply of sediment to the spit. This would allow the channel to migrate to the east and the subsequent development of the Poppit Spit. Overall it is difficult to predict the future behaviour of the estuary due to the importance and dynamic nature of the spits but their behaviour is a key control on the alignement of channels up-estuary and therefore also the distribution of intertidal area. Further up-estuary the rock outcrop at Dogmaels exercises an important control on the upper part of the estuary marking the point where the watercourse changes orientation and become more fluvial in character.

5.2 Estuaries Assessment

Estuary	Teifi Estuary
Location	Southern Cardigan Bay, Wales.
Classification	4c - Spit Enclosed Filled Valley
Main characteristics	Macrotidal, small estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Cardigan Bay Shoreline Management Plan (Posford Duvivier, 2000)
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Teifi is considered to be small in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a very large intertidal zone relative to its total area; some saltmarsh is present. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width with sand spits present on both sides. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are high compared to the size of the estuary with a mean freshwater flow of 28.89 m/s. Stratification calculations indicate that the estuary partially mixed to highly stratified. % Area: The estuary has a large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities are not known. Tidal prism: 7 790 000 m^3
	Verdict on significance: The Teifi has a large tidal range and freshwater flows are large for an estuary of this size and therefore water exchanges with the adjacent open coast are considered to be significant. The flow of water through the estuary mouth will exercise an important control on the spits at the mouth. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The estuary is flood dominant at the mouth according to Dronkers gamma (Halcrow, 2002) although this does not take into account fluvial flows which are large for an estuary of this size. Morphological features: The estuary is situated between the rocky headlands at Cernaes to the west and Gwbert to the east. The mouth of the estuary is characterised by two spits which exercise important controls on the morphology of the estuary. A further control point is present between the rock headlands at Old Castle Farm Point (west bank) and St Dogmaels (east bank). Between the estuary mouth and Cardigan a large intertidal area is present consisting of sand flat, mudflat and a small proportion of saltmarsh. Source sink relationship: Historically the estuary has been a sink for sand sized sediment from offshore sources and fine sediment from fluvial sources and the eroding saltmarsh behind the Poppit Spit. The large intertidal area suggests that the estuary may have reached capacity with respect to sediment accumulation and could be a weak source of fine sediment to the open coast (Halcrow, 2002). Plume generation: The flow ratio suggests that plume generation is possible during periods of high fluvial flow combined with an ebb tide.
	Verdict on significance: The morphology of the mouth of the Teifi suggests that sediment interactions with the coast are significant, these exchanges are unlikely to extend further than Poppit Sands due to the rocky and embayed nature of the coast further a field. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as marginal in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: marginal Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	The estuary is largely natural in character with few management issues. The rail bridge at Cardigan forms a barrier to saline penetration. Coastal protection works at Gwbert (open coast outside of the estuary) have starved the Pen yr Ergyd spit of sediment. The main channel up-estuary of the spits has migrated to the west resulting in the accretion and silting up of the eastern side of the estuary (Posford Duvivier, 2000).
	Verdict on significance: Significant, the coastal protection works at Gwbert outside of the estuary have had a significant impact on the spit at the estuary mouth and consequently impacts on the estuary regime as a whole.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as significant. *Therefore from Step 5 of EGT5, the Teifi scores 1 in terms of overall significance and should be included in the SMP process.*

5.3 Discussion

Overall the interactions between the Teifi and the open coast can be summarised as follows:

1. The Teifi has a large tidal range and as such exchanges significant volumes of water with the open coast.
2. The Teifi has historically been a significant intertidal sink for both sand and fine sized sediment and is now nearing capacity and consequently is probably a weak source of fine sized sediment to the open coast. The twin spit features present at the mouth suggests important sedimentary interactions with the adjacent open coast. This sediment exchange is unlikely to extend beyond Poppit Sands. Historical analysis has demonstrated that the spits have been highly dynamic in the past and that this has impacted on the estuary as a whole, consequently the future morphology of the estuary will be intrinsically related to the behaviour of the spits.
3. There is some development within the estuary although these have not been large enough to impact significantly on the adjacent open coast. The development outside of the estuary has had a significant impact on the spit at the estuary mouth and therefore has the potential to affect the estuary regime as a whole.

Due to the interactions between the Teifi and the open coast it is considered appropriate to include the estuary within the SMP. Two constraints provide a possible up-estuary SMP limit, firstly the hard rock outcrops at St Dogmaels and secondly the railway Bridge at Cardigan. It is known that the railway bridge at Cardigan provides a barrier to saline water and therefore represents an appropriate limit to coastal processes. Upstream of the bridge although the Teifi is still tidal it becomes more fluvial in character with a limited intertidal and a meandering shape, because of this and the constraint provided by the bridge it is considered that the SMP boundary should be placed at this point as shown in Figure 3. This limit was also used in the SMP1.

6. Dyfi Estuary Assessment

This section represents a conceptual understanding of the Dyfi Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Dyfi is illustrated in Figures 1 and 4.

6.1 Conceptual Understanding

The Dyfi Estuary is situated in central Cardigan Bay on the Afon Dyfi and the estuary is orientated along a west to east axis. The estuary has been formed from a flooded river valley which has subsequently infilled with sediment.

A sand spit is present on the southerly side of the estuary mouth and the open coast on both sides of the mouth is characterised by a long sandy foreshore indicating the potential for significant interaction between the estuary and the open coast. Further up-estuary the Dyfi narrows significantly in the vicinity of the Eglwys Fach and becomes more fluvial in nature with little or no intertidal and a meandering form. There are limited hard points within the estuary to anchor its present formation and the estuary mouth is largely controlled by dynamic forces although some control is provided by the outcrop of rock at Pen y Graig (at Borth) and the presence of some exposed rock on the northern side of the estuary mouth (Posford Duvivier, 2000). The construction of the railway bridge constrains the upper estuary and forms the SMP1 boundary.

The nearshore wave climate outside of the estuary mouth shows that the predominant wave direction is from the west and west-southwest (Posford Duvivier, 2000), this demonstrates the potential for waves to propagate into the estuary although this will be limited by the presence of the Twyni Bach sand spit.

The Dyfi has a macrotidal regime at Aberdovey with a mean spring tidal range of 4.3m (UKHO, 2008). The tidal asymmetry according to Dronkers is flood dominant (Halcrow, 2002), although this parameter does not take into account the impacts of fluvial flows which are relatively large in the Dyfi. Modelled and field data collected by the University of Wales Bangor has investigated the tidal regime of the Dyfi in detail (Brown & Davies, 2007, Brown & Davies, 2009a, Brown and Davies, 2009b, , Davies and Brown, 2007, Robins, 2008a, Robins, 2008b, Robins & Davies, 2009 and Robins, 2009) taking into account the influence of fluvial flow and waves on sediment transport patterns. This showed a complex pattern of sediment transport patterns which can be broadly summarised as follows:

- Ebb dominance to the west of Ynyslas spit and flood dominance to the east (at the mouth of the estuary), this divergence in transport is coincident with a self-maintaining scour hole.
- Further up-estuary, away from the influence of the spit, sediment transport is ebb dominant throughout the lower estuary and flood dominant in the shallower inner estuary.

The flow ratio suggests that there is a potential for sediment plumes to be formed during periods of ebb tide combined with high fluvial flows (Halcrow, 2002). The presence of an ebb tidal delta can be seen in aerial photographs and suggests a complex interaction with the adjacent open coast. Stratification and flow calculations indicate that the estuary is partially to well mixed depending on the magnitude of fluvial flow and the tidal state.

Fluvial flow into the estuary is from three principle watercourses, the Afon Dyfi forms the main part of the estuary and has relatively large flow speeds with an mean flow amounting to some 23 m^3/s at Dyfi Bridge recorded between 1962 and 2006 (CEH archive). Two other watercourses join the estuary along the southern bank, the Leri with a mean discharge of 1.31 m^3/s recorded between 1960 and 2006 (CEH archive) and the smaller Afon Cletwr. Both the Cletwr and the Leri have been canalised during the extensive reclamation undertaken during the construction of the railway line which runs across the embankment adjacent to the southern shore of the estuary. The Leri currently runs 1km inland parallel to the foreshore between Borth and the Twyni Bach sand spit, prior to the 1820s it discharged directly into Cardigan Bay (Gwynedd Council, 1998). The Morfa Borth reclamation resulted in a loss of intertidal area amounting to 2345ha or 56% of the former intertidal area of the Dyfi as a whole (CGP, 2000).

Analysis of historical charts shows that the Twyni Bach has extended in a northerly direction (across the estuary mouth) by about 1km since the 1890s (Halcrow, 2002). To the south of the sand spit sandy foreshore (Borth Sands) stretches some 6km to the town of Borth in the south. The orientation of the spit and sediment transport modelling (Posford Duvivier, 2000) indicates that net longshore sediment transport is orientated in a northerly direction along this section of the open coast.

The estuary is reasonably large in size with a surface area of 1090km^2, of this area 693km^2 is intertidal. Saltmarsh and mudflats are present along the southern shore of the estuary fronting extensive areas of reclaimed land and the railway embankments, the saltmarsh covers an area of 546km^2 (Halcrow, 2002). Sand dunes are present at the estuary mouth to the west of Aberdyfi and landward of Borth Sands and the Twyni Bach sand spit. The main channel within the estuary is very mobile with historical charts showing large changes in its position between 1837 and 1966 (SMP, 1995) and between 1957 and 1984 (Shi *et al*, 1995), these changes to the position of the main channel led to the erosion of the saltmarsh along the southern side of the estuary in 1985 (Shi *et al*, 1995). The reasons for these changes are not understood.

Sediments within the estuary are mostly sand sized with some areas of mud upstream and along the southern bank. The estuary has been accreting since the last glaciation as is evident from the large intertidal areas with sediment probably sourced from the adjacent coast and offshore (sand) and the river (fines). However, analysis has shown that the estuary is currently ebb dominant and therefore a net source of sediment to the open coast. This evidence along with a moderate intertidal area ratio suggests that the estuary has reached capacity with respect to sedimentation and is no longer importing sediment. It is likely that the estuary reached capacity at sometime around the 1960s when it was noted that the estuary had become almost completely infilled (Haynes and Dobson, 1969), tidal measurements at this time showed a tidal pattern similar to that at present implying net ebb dominance since this time (Brown and Davies, 2009b).

Without a detailed historical analysis it is not possible to assess the exact source of his sediment within the estuary, it is likely that sand is sourced from the extensive intertidal area and fines will be sourced from the river. With the estuary flanked by large dune fields on both sides it is also likely that sediment is transferred between the dunes and the intertidal sandflats.

6.1.1 Response to Sea Level Rise

The ratio of intertidal area is moderate to high and the estuary is ebb dominant. As the estuary has been accreting since the last glaciation it can be inferred that this change from a net sediment sink to a net sediment source has occurred as a result of the estuary reaching capacity. With an increase in sea level the ratio of intertidal area would be expected to decrease thereby increasing the estuaries capacity to import more sediment and changing the estuary from a net source of sediment to a net sink for sediment. Given the large potential sources of sediment from the adjacent coastline and offshore it is likely that the estuary would accrete further into the future.

Currently the spit at the mouth of the estuary exercises an important control on the estuary, based on historical evidence the spit has extended over the last 100 years demonstrating a substantial supply of sediment. The flow at the mouth of the estuary will probably prevent further extension of the spit although the feature is likely to remain stable.

6.1.2 Assessment of Tidal Locking

There are no historic records of flooding as a result of tidal locking occurring on the Dyfi (EA, 2008b) although Borth has been identified within the CFMP as an area at risk from flooding as a result of tidal locking. Tidal locking could occur at Borth as a result of high water levels within the Dyfi preventing discharge from the Afon Leri. The Afon Leri is significantly reclaimed and canalised and because of this the Leri will become more susceptible to tidal locking with sea level rise.

6.1.3 Summary of Key Processes and Morphology

The Twyni Bach Spit provides an important control on the estuary mouth, constricting the deep water channel between its tip and the Aberdyfi dunes to the north. The development of the spit has allowed the development of saltmarsh in its lee and forced the deep water channel up against the topographically higher ground on the northern bank. It is likely that the spit has extended significantly (1km) over the last 100 years following the diversion of the Leri which previously flowed out into Cardigan Bay and consequently interrupted the long-shore sediment supply. With sea level rise there is probably enough sediment available to maintain the spit and consequently the sheltered conditions in the lee of the feature. The spit is unlikely to extend any further due to flows through the mouth. The presence of a drift divide (along a east to west orientation) adjacent to the tip of the spit has formed a self-maintaining scour pit in the mouth of the estuary

6.2 Estuaries Assessment

Estuary	Dyfi Estuary
Location	Southern Cardigan Bay – Wales.
Classification	3a – Ria with spits
Main characteristics	Macrotidal, medium estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Cardigan Bay Shoreline Management Plan (Posford Duvivier, 2000), various journal articles detailing tidal asymmetry and sediment transport studies.
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Dyfi is considered to be medium in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a very large intertidal zone relative to its total area; some saltmarsh is present along the southern bank. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width with a sand spit present on the southern side. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Mean freshwater flows are high compared to the size of the estuary with a mean freshwater flow of 23m^3/s. Stratification calculations indicate that the estuary is partially to well mixed. % Area: The estuary has a large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Peak depth averaged water fluxes range between 1 and 5 m^2/s on a spring and a neap tide respectively in the main channel adjacent to Aberdyfi (Brown & Davies, 2009a). Tidal prism: 20 300 000m^3
	Verdict on significance: The estuary has a large intertidal area and a large intertidal range and also relatively high fluvial flows and therefore exchanges significant volumes of water with the adjacent coast. The flow of water through the estuary mouth will exercise an important control on the spit at the mouth. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The estuary is considered to be ebb dominant (Brown & Davies, 2009). Morphological features: The estuary has a large sand spit on the southern side of the estuary. The estuary has large intertidal areas along with significant saltmarsh on the southern bank. Source sink relationship: The estuary is currently a source for sand sized sediment, there is no data with which to assess the source of this sediment, it is likely to be from the extensive intertidal sandflats. Plume generation: The flow ratio suggests that plume generation is possible during periods of high fluvial flow in combination with an ebb tide.
	Verdict on significance: The estuary exchanges large amounts of sediment with the open coast and is currently a source of sand and mud sized sediment to the open coast. The morphology of the open coast on either side of the estuary shows the potential for sedimentary interactions between the estuary and the open coast over a wide scale. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as significant in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: significant Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	Extensive reclamation has been undertaken along the southern side of the estuary where the railway embankment provides flood protection. The rail bridge in the upper estuary provides some constraint to the movement of the estuary. Groynes along the frontage between Borth and the estuary mouth may reduce the amount of sand transported along this frontage.
	Verdict on significance: Marginal, although large amounts of reclamation has been undertaken in the past the estuary appears to have responded and adjusted to these changes in morphology. Groynes along the Borth frontage may impact on the supply of sediment to the southern spit and hence the morphology of this feature.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as Marginal. *Therefore from Step 5 of EGT5, the Dyfi scores 1 in terms of overall significance and should be included in the SMP process.*

6.3 Discussion

Overall the interactions between the Dyfi and the open coast can be summarised as follows:

1. The Dyfi has a large tidal range and a large volume and as such exchanges significant amounts of water with the open coast.
2. The Dyfi has historically been a significant intertidal sink and is now a source of fine and sand sized sediment to the open coast. The spit feature on the southern side of the mouth suggests important sedimentary interactions with the adjacent open coast. This sediment exchange is likely to extend a significant distance along the adjacent coast
3. There is some development within the estuary including significant amounts of intertidal reclamation. Groynes along the open coast to the south of the estuary mouth may impact on the sediment supply to the spit at the mouth of the Dyfi.

Due to the interactions between the Dyfi and the open coast it is considered appropriate to include the estuary within the SMP. Although the Afon Dyfi is tidal for a significant distance inland in terms of coastal processes it is not considered necessary to consider the estuary to this limit. Examination of aerial photographs and OS maps show a distinct barrier between the Dyfi Estuary and the Afon Dyfi in the region of the railway bridge at Dovey Junction. Up-estuary of this point the watercourse has less intertidal area, adopts a meandering form and there is limited evidence of sand sized sediment sourced from the open coast. In addition the watercourse undergoes a significant change in orientation meaning that any waves generated within the estuary will be unable to propagate any further up the estuary. Because of this and the constraint on the estuary form provided by the bridge it is considered that the SMP boundary should be placed at this point as shown in Figure 4.

7. Dysynni Estuary

This section represents a conceptual understanding of the Dysynni Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Dysynni is illustrated in Figures 1 and 5.

7.1 Conceptual Understanding

The Dysynni Estuary is situated in the central part of Cardigan Bay north of Tywyn, the estuary is orientated along a west to east axis. The estuary has formed from an embayment which has become enclosed by a northward trending spit.

The estuary has a very narrow mouth which has become enclosed as a result of a shingle and sand spit extending from the southern side of the estuary indicative of a northerly directed longshore transport along the open coast. It is likely that the estuary mouth is constrained to the north by Sarn-y-Bwch a hard glacial feature extending offshore. Up-estuary of this narrow mouth the estuary opens up into a wider lagoon area called Broadwater, this part of the estuary has areas of intertidal sandflat and saltmarsh. Further up-estuary again, the watercourse is more fluvial in character with a narrow meandering course. The estuary shows evidence of human intervention which has probably contributed in part to its unusual morphology. OS mapping and aerial photos of the spit at the mouth show evidence of a training wall and defences which presumably have been employed to maintain the plan shape of the feature. Within Broadwater the southern side of the estuary shows evidence of reclamation which appears to have been principally for agricultural use.

The nearshore wave climate for the coast at Tywyn (to the south of the Dysynni) shows that the predominant wave direction is from the west-southwest (240-270˚N) and the most common wave height is small ranging between 0.5 and 1.0m (Gwynedd Council, 1998). No wave data is available within the estuary although the narrow mouth will prevent waves generated outside the estuary from propagating into the Dysynni and the small size of the estuary will limit the fetch and hence prevent waves of a significant size from being generated within the estuary.

The tidal regime within the Dysynni cannot be characterised as no data is available although it is known that the tidal range within the estuary is smaller than that outside (Halcrow, 2002). Tidal asymmetry is ebb dominant at the mouth according to Dronkers (Halcrow, 2002), however due to the unusual morphology of the mouth care should be taken in the interpretation of this parameter.

The flow ratio indicates there is potential for a sediment plume to be formed during ebb tide and a high fluvial flow (Halcrow, 2002). The flow ratio also shows that the estuary is partially to well mixed (Halcrow, 2002). Fluvial flow into the estuary is from the Afon Dysynni and flow speeds are moderate in comparison to the estuary size with a mean flow speed of 4.51 m^3/s recorded between 1966 and 2001 (CEH archive).

The estuary has a small area of 117ha of which 69ha is intertidal, this ratio is moderate when the tidal range is taken into account and indicates that the estuary is possibly capable of absorbing more sediment. A small amount of saltmarsh is present in Broadwater amounting to around 22ha (Halcrow, 2002) and sand dunes are situated between the spit and Broadwater, it is possible that some of the sand sized sediment within Broadwater is sourced from or supplied to these dunes. A very large proportion of the estuary has been reclaimed, this is estimated to be in the region of 1844ha (CGP, 2000), amounting to some 94% of the estuaries original area although the methods used to derive this value are unclear. This large amount of reclamation would have reduced the tidal prism greatly, subsequently reducing the speed of flows through the estuary mouth and this could have led to the development of the large spit at the estuary mouth. Further northward-deflection of the estuary mouth would have been prevented by the presence of the sarn and the canalisation of the mouth may have been constructed to keep the estuary mouth open. There is however no evidence to support this theory and no historical details exist to assess the past morphological changes within the Dysynni Estuary although such a study, assuming available data, would likely provide an insight into the development of the current form of the estuary.

The open coast adjacent to the shingle spit has adopted a slight embayed profile between the relative hard-points situated at Sarn-y-Bwch and Tywyn (ABPmer and eftec, 2004). Analysis of the position of Mean High Water (MHW) and Mean Low Water (MLW) along the spit has shown a recession of 1.82m/yr and 2.24m/yr respectively between 1891 and 1992 (ABPmer and eftec, 2004 and SMP, 1995).

7.1.1 Response to Sea Level Rise

Little data is available to assess the present behaviour of the Dysynni and as such it is extremely difficult to predict the possible future response of the estuary to sea level rise.

The spit exerts a significant control on the estuary and although it is defended it is expected that the trend of recession will continue and possibly accelerate with sea level rise as the embayment between Twywn and Sarn-y-Bwch becomes more pronounced. This could lead to beach lowering and the possible breach of the shingle spit thereby opening up the estuary mouth (Halcrow, 2002).

7.1.2 Assessment of Tidal Locking

Although there is no historic evidence, the CFMP has identified Tywyn as an area at risk of flooding from tidal locking in the Dysynni (EA, 2008b). The Dysynni has a very unusual morphology due in part to the extensive reclamation, canalisation and embanking of the estuary. This has resulted in a very narrow mouth and although fluvial flows are generally moderate in magnitude the morphology would hinder the dissipation of fluvial discharge during an exceptionally high tide thereby increasing the risk of tidal locking. Given the constrained nature of the estuary and the present risk of tidal locking, it is likely that the frequency of tidal locking events would increase with a rise in sea level.

7.1.3 Summary of Key Processes and Morphology

The Dysynni has a very distinctive morphology with a very narrow mouth constrained by a spit and dune feature which has extended across the estuary mouth in a northerly direction. This unusual morphology is likely to be due at least in part to anthropogenic intervention which reduced the tidal prism and consequently allowed the development of the spit across its mouth. The Sarn which is situated adjacent to the estuary mouth prevents the mouth from migrating further north. The narrow mouth is heavily constrained and this limits the flux of water in and out of the estuary and in addition provides a high level of protection to the estuary from waves. The estuary has a very small tidal prism as a result of reclamation and it is suggested that the resultant low flows though the estuary mouth may be insufficient to keep the mouth open without the defences present along the spit. Along the open coast a crenulated embayment is forming between the relative hard points of the Sarn (in the north) and the Tywyn defences (to the south) although this is hindered by the coastal railway which runs immediately adjacent to the coast. With sea level rise it is likely that the trend of erosion along the open coast will continue possibly eventually leading to the breakdown of the spit flooding the hinterland and forming a new outlet for the Dysynni.

7.2 Estuaries Assessment

Estuary	Dysynni Estuary
Location	Central Cardigan Bay, Wales.
Classification	4a - Single spit enclosed estuary
Main characteristics	Tidal range unknown although likely to be macrotidal on adjacent open coast, small to medium sized estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). North Cardigan Bay Shoreline Management Plan (Gwynedd Council, 1998).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Dysynni is considered to be small in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a moderate intertidal zone relative to its total area; some saltmarsh is present in Broadwater and immediately upstream on the first meander. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a very small cross-sectional mouth area due to the constriction by the sand spit. Mouth width: The estuary has a small mouth width with a sand spit present on the southern side. Tidal range: The tidal range in the estuary is not available, it is likely to be moderate. Mean freshwater flow: Freshwater flows are moderate compared to the size of the estuary with a mean freshwater flow of 4.51m^3/s. Stratification calculations indicate that the estuary is partially to well mixed. % Area: The estuary has a moderate % area indicating that much of the estuary dries out at low water. Tidal velocities: Unknown. Tidal prism: 4,000,000m^3
	Verdict on significance: The Dysynni is poorly understood although its small volume and constrained morphology indicate that the estuary is unlikely to exchange significant volumes of water with the coast. The Sand spit enclosing the mouth now appears to be heavily defended and trained and consequently the discharge from the mouth will have little impact on this feature. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as marginal with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: With respect to Dronkers the estuary is considered to be ebb dominant, the use of this parameter is problematic in view of the unusual morphology at the estuaries mouth. Morphological features: The estuary has a large sand spit on the southern side of the estuary which has almost closed off the estuaries mouth, the spit is held in place by a training wall and defences. The position of the mouth is likely to be controlled in part by hard glacial feature (Sarn-y-Bwch). Up-estuary the mouth opens out into a lagoon with sandflats, saltmarsh and mudflat. Source sink relationship: It is difficult to conclude if the Dysynni is a net source or sink for sediment and the interpretation of the estuaries behaviour based on geometric relationships is problematic due to the unusual morphology. Overall, the ebb dominance at the mouth along with moderate river flows for an estuary of this size would suggest that although the Dysynni is capable of absorbing more sediment it is probably a weak source of sediment to the open coast. Plume generation: The flow ratio suggests that plume generation is possible during periods of high fluvial flow combined with an ebb tide.
	Verdict on significance: The Dysynni is poorly understood although morphological evidence at the mouth of the estuary indicates that there are little sediment interactions with the open coast. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as insignificant in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: marginal Step 2 – sediment exchange: insignificant Step 3, therefore, from EGT5, process issues are considered to be Grade C

Stage 1 Step 4: significance of management issues (EGT4)	The spit appears to be canalised immediately up-estuary of the mouth and protected at its seaward end by sea defences, these were probably put in place during the construction of the Cambrian Railway in the 1860s. The estuary has been subjected to significant amount of reclamation in the past and it is likely that this has contributed to its unusual morphology.
	Verdict on significance: Significant, although the estuary has been heavily modified in the past it is now largely undeveloped and unmanaged. Failure of the training walls along the spit at the mouth or future changes to the tidal prism through realignment could have the potential to impact on the adjacent coast although no such schemes are known. If the training walls failed the current discharge from the Dysynni may not be strong enough to prevent the mouth from silting up.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade C Step 4 – Management issues assessed as Significant. *Therefore from Step 5 of EGT5, the Dysynni scores 2 in terms of overall significance and does not need to be included in the SMP process.*

7.3 Discussion

Overall the interactions between the Dysynni and the open coast can be summarised as follows:

1. The Dysynni has a large tidal range and a small volume and as such exchanges marginal amounts of water with the open coast. As the spit on the south side of the estuary mouth is heavily defended and trained it is unlikely that flows from the estuary have any impact on the morphology of this feature.
2. The morphology of the adjacent coast does not show any evidence of sediment interactions between the estuary and the open coast.
3. There have been significant amounts of intertidal reclamation within the Dysynni. Any realignment of these reclaimed areas will cause an increase in the tidal prism and a resultant potentially large impact on the estuary mouth although no such reclamations are known. The failure of the training walls and sea defences may cause changes to the alignment and shape of the spit as the current discharge from the estuary may not be sufficient to enable the estuary mouth to stay open.

Due to the important interactions between the Dysynni and the open coast, it is considered necessary to include the estuary within the SMP. It is noted that due to past intervention, the estuary is constrained in places by existing defences (notable upstream of the outfall and immediately upstream of Broadwater) and should these defences fail, the nature of interactions with the open coast may alter. It is especially important to include the spit within the open coast SMP as the evolution and the maintenance of defences along this feature will have important implications for the morphology of the open coast. To adequately consider these issues within the SMP it is considered that the Dysinni should be included to the tidal limit, as shown in Figure 5.

8. Mawddach Estuary Assessment

This section represents a conceptual understanding of the Mawddach Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Mawddach is illustrated in Figures 1 and 6.

8.1 Conceptual Understanding

The Mawddach Estuary is situated towards the northern part of Cardigan Bay at Barmouth, it is orientated along a west to east axis. The estuary has formed from a river valley that has subsequently flooded as a result of sea level rise since the last glaciation.

Sand spits are present on both sides of the estuary mouth indicating that sediment can be transported along the open coast from both the north and the south, although the northern spit has been developed and is now immobile. The shoreline adjacent to the estuary mouth is wide and sandy showing the potential for significant interaction between the estuary and the open coast. Up-estuary, the Mawddach is naturally constrained by hard geology at a number of points and significantly so at two particular points firstly at Fegla Fawr and Coes-Faen and secondly on either side of the estuary at Penrhyn Cregyn. Hard outcrops on either side of the estuary at both of these locations cause the watercourse to narrow at these points.

Anthropogenic intervention has also caused some constraint at both the Barmouth viaduct and the Penmaenpool Bridge. Large amounts of reclamation has been undertaken along the south bank of the estuary for the now dismantled railway and up-estuary of Penmaenpool there has also been some reclamation for agricultural purposes (Gwynedd Council, 1998). The largest land loss occurred during the reclamation of Morfa Fairbourne and with an area estimated at some 360ha, this amounts to a loss of 27% of the former estuary area (CGP, 2000). Barmouth Harbour is situated on the northern side of the estuary near the mouth. OS maps pre 1969 show evidence of a second channel leading into the estuary which was subsequently closed off by the construction of the harbour wall between the breakwater and Barmouth (Gareth White Partnership, 1986), this would have significantly reduced the cross sectional area of the estuary mouth.

The nearshore wave climate for the coast to the north of Barmouth shows that the predominant wave direction is from the south west (210 - 240˚N) and the most common wave height is small with a height of 0/5-1.0m (Gwynedd Council, 1998). No wave data is available within the estuary although the shallow bathymetry of the estuary along with the presence of the spits and the Barmouth viaduct would suggest that little swell is able to penetrate significantly into the estuary.

The tidal regime at Barmouth is macrotidal with a mean spring tidal range of 4.3m (UKHO, 2008). No data could be found detailing tidal flow speeds within the estuary although tidal asymmetry is ebb dominant according to the Dronkers parameter (Halcrow, 2002).

The flow ratio indicates that there is the potential for sediment plume formation at the mouth of the estuary during an ebb tide combined with high river flow (Halcrow, 2002). The aerial photography shows an ebb tidal delta at the estuary mouth indicating the potential for significant interactions with the open coast. The flow ratio also indicates that the estuary is partially mixed.

Fluvial flow into the estuary is via the Afon Mawddach and the Afon Wnion, river flows are generally low relative to the size of the estuary with an average flow of 3.95m^3/s recorded on the upper Mawddach between 1994 and 2006. However, significant flows are possible with the Afon Wnion with peak flow during a 1 in 100 year event approaching 260m^3/s (EA, 2008b).

The estuary is moderate in size with a surface area of 522ha of which 327ha is intertidal, this proportion of intertidal area is low for an estuary of this nature and indicates that there is further capacity for sediment accumulation (Halcrow, 2002). Some 219ha of saltmarsh is present in the estuary with a large amount situated behind the southern spit and also in the relatively wider parts of the estuary between the hard control points.

No historical analysis is available to determine the morphological behaviour of the estuary although the moderate intertidal ratio (only slightly lower than the ebb dominant Dyfi) could indicate that the estuary has potential to accumulate further sediment and therefore is currently a net sink. The mouth width is low relative to the to the channel length indicating that future infilling is likely at the head of the estuary (Halcrow, 2002). This is not in agreement with the tidal asymmetry calculated from Dronkers although the use of these parameters are problematic as they are based on broadscale generalised data (Halcrow, 2002) and consequently only give an indication of the estuaries behaviour. Asymmetry based on detailed flow records or modelling is considered more reliable and the clarification of the Mawddach as either a sediment source or sink would require a detailed sediment budget. Sediment sources are likely to be from offshore as well as the Afon Mawddach and Afon Wnion.

8.1.1 Response to Sea Level Rise

Little data is available with which to assess the past and present behaviour of the Mawddach, consequently it is difficult to predict the potential future evolution of the estuary. Since the intertidal ratio is currently moderate for an estuary of this size and the sediment supply from offshore and the adjacent coast is plentiful it is likely that the estuary will continue to accrete with sea level rise.

The southern spit at the mouth is an important morphological feature which helps prevent the propagation of waves into the estuary and provides considerable shelter to the saltmarsh in the lee. No historical evidence is available to assess the past morphological development of the feature although the flows through the mouth will preclude the further extension of the spit.

8.1.2 Assessment of Tidal Locking

No historic information could be found documenting any flood events in the Mawddach as a result of tidal locking although the CFMP describes Fairbourne as being at risk from this type of flooding. Tidal locking in Fairbourne would occur as a result of the Afon Henddol becoming blocked by high tides within the Mawddach and the river backing up. It is unclear why flooding form tidal locking is a problem within Afon Henddol, it is possible that the surrounding area has a low topography and therefore floods easily. It is likely that the risk of tidal locking will increase with sea level rise.

8.1.3 Summary of Key Processes and Morphology

The southern spit at the estuary mouth along with the reclamation and construction of the viaduct has led to significant accretion in the outer estuary which in turn has reduced the exposure of the inner estuary. Up-estuary a number of natural hard points constrict the estuary and in part contribute the form of the inner estuary. On the northern side of the estuary mouth the spit is now fixed in place by defences. The southern spit will provide an important control on the future behaviour of the estuary. There is no evidence that the spit is currently eroding indicating a sufficient sediment supply from the south. With sea level rise it is likely that there is sufficient sediment to maintain the spit and allow the estuary to continue to infill.

8.2 Estuaries Assessment

Estuary	Mawddach Estuary
Location	Northern Cardigan Bay, Wales.
Classification	3a – Ria with spits.
Main characteristics	Macrotidal, small to medium sized estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). North Cardigan Bay Shoreline Management Plan (Gwynedd Council, 1998).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Mawddach is considered to be small to medium in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a fairly large intertidal zone relative to its total area; some saltmarsh is present behind the southern sand spit and in the wider parts of the estuary. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width with a sand spit present on the southern side. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are low compared to the size of the estuary with a mean freshwater flow of 3.95 m^3/s. Stratification calculations indicate that the estuary is partially mixed. % Area: The estuary has a moderate % area indicating that the estuary nearly dries out at low water. Tidal velocities: Unknown. Tidal prism: 9 190 000m^3
	Verdict on significance: The Mawddach estuary has a relatively large tidal range and volume, because of this it exchanges large amounts of water with the coast, freshwater flow is low so the exchange of freshwater with the open coast will be minimal. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: With respect to Dronkers the estuary is considered to be ebb dominant (Halcrow, 2002). Morphological features: The estuary has a large sand spit on the southern side of the estuary and formally had a spit on the northern side which has subsequently been developed. The estuary has fairly large intertidal areas along with significant saltmarsh in the lee of the spit and throughout the wider parts of the estuary. The area around the estuary consists of topographically steep and high land with a number of rocky hard points which constrain the width of the estuary at a number of points. Source sink relationship: Based on limited data it is concluded that the estuary is currently a sink for sands and fines, there is no data with which to assess the sources of these sediments, it is likely that sands are sourced form the adjacent coast and offshore and fines are from fluvial sources. Plume generation: The flow ratio suggests that plume generation is possible during periods of high fluvial flow combined with an ebb tide.
	Verdict on significance: The morphology of the estuary mouth indicates significant interactions with the open coast over a large spatial scale. The estuary is a large sink for sediment and sources sand sized sediment from the open coast and offshore. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as significant in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: significant Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	Extensive reclamation has been undertaken along the southern side of the estuary where the railway embankment currently provides flood protection. The rail bridge at Barmouth provides some constraint to flows in the estuary with aerial photographs showing evidence of accretion around the base of the structure. A road bridge at Penmaenpool constrains the movement of the river upstream. The construction of the harbour wall at Barmouth closed off a second 'blind' main channel at the estuary mouth and consequently constricted the estuary mouth at high water, this occurred post 1969 (Gareth White Partnership, 1989).
	Verdict on significance: Insignificant, the estuary has undergone significant interference from human activities but none of these are likely to impact on the open coast at present.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as Insignificant. *Therefore from Step 5 of EGT5, the Mawddach scores 2 in terms of overall significance and should be included in the SMP process.*

8.3 Discussion

Overall the interactions between the Mawddach and the open coast can be summarised as follows:

1. The Mawddach has a large tidal range and a large volume and as such exchanges significant amounts of water with the open coast. Freshwater flows are low and therefore the impacts of freshwater on the open coast will be minimal.
2. The Mawddach is probably a sink of sand sized sediment which is sourced from offshore and the adjacent open coast and some fine sediment sourced form the Afon Mawddach and Wnion. The morphology of the adjacent coast shows strong evidence for significant sediment interactions between the estuary and the open coast over a large spatial scale.
3. Although the estuary has been significantly modified through reclamation and construction these impacts are unlikely to extend to the open coast.

Due to the significant interactions identified between the open coast and the estuary it is considered appropriate to include the Mawddach within the open coast SMP. A number of constrictions form barriers to marine processes at the Barmouth Viaduct, Fegla Fawr / Coes-Faen, Penrhyn Cregyn and Penmaenpool Bridge. Of these points Penmaenpool Bridge is considered the most appropriate for the SMP boundary, this is for two reasons. Firstly little sand is deposited up-estuary of this point indicating that the sediment landward of this bridge is sourced from the rivers rather than from the open coast. Secondly, the watercourse becomes more fluvial in nature up-estuary of this point with a meandering morphology and limited intertidal, it is likely that that the bridge constrains the channel at this point resulting in this change in morphology for estuarine to fluvial. Because of this the SMP boundary should be placed as shown in Figure 6.

9. Artro Estuary Assessment

This section represents a conceptual understanding of the Artro Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Artro is illustrated in Figures 1 and 7.

9.1 Conceptual Understanding

The Artro Estuary is situated towards the northern end of Cardigan Bay and is orientated along a west to east axis, the estuary has developed behind Shell (Mochras) Island. The estuary mouth was originally positioned at Mochras Point (to the south of Shell Island) and was diverted to its present position in 1819 resulting in the original mouth silting up as a result of the northerly directed transport along the Morfa Dyffryn frontage (May and Hansom, 2003). Map evidence from the 1830s shows the two channels as still being open (CGP, 2000), the first edition OS map published in 1890 shows that the channel was closed at the seaward end by this time. This shows that the south channel silted up at some point between 1830 and 1890 subsequently joining Shell Island to the mainland. Shingle spits have developed across the estuary mouth from both sides partially blocking the mouth of the estuary. The southerly spit is now developed and protected by rocks. The northerly spit also comprises a breakwater which further constricts the estuary mouth.

Mochas Point is a promontory formed from glacial till and the open coast to the north of the point is characterised by cliffs formed from a discontinuous till ridge fronted by sand and boulder beaches which are drift aligned at 90˚ to the predominant swell direction. The till ridge is probably a continuation of the offshore Sarn Badrig glacial feature To the south of the point the open coast is formed from dunes and sandy beach (Morfa Dyffryn) which are swash aligned to the predominant SW wave direction. Although this coastline is swash aligned to the prevailing wave direction, the former presence of a northerly orientated spit and the subsequent silting up of the original estuary mouth shows a net northerly longshore transport along this frontage (CGP, 2000 and May and Hansom, 2003). Morfa Dyffryn historically has been overall stable suggesting that some sediment is sourced form offshore as the supply from the adjacent coast is likely to be limited (May and Hansom, 2003). Analysis of OS maps has shown some erosion of the low water mark and accretion along the high water mark along this frontage indicating some steepening of the foreshore over the last 100 years (Halcrow, 2002).

The wave climate has been characterised for the stretch of coast to the south of the study area between Ysgethin river and Llanaber. This shows that the predominant wave direction is from the south west (210 - 240˚N) and the most common wave height is small with a height of 0.5-1.0m (Gwynedd Council, 1998). No wave data is available within the estuary although the shallow bathymetry of the estuary along with the narrow mouth orientated away from the prevailing swell direction indicates that it is unlikely that swell from outside the estuary will be able to propagate into the Artro. In addition the small area of the Artro indicates that there is an insufficient fetch to enable significant sized waves to generate within the estuary.

Tidal currents within the mouth of the estuary are strong with flows of up to 2.5m/s this is due to the narrow mouth and the relatively high macrotidal tidal range of around 4m (ABP Research and Consultancy, 2001). The tidal asymmetry is not known. The river Artro is ungauged and consequently no information is available detailing flow speeds.

The estuary has a small intertidal area of 120ha and large proportion (117ha) of this is intertidal (Halcrow, 2002). The mouth width to channel length ratio is average and the high intertidal ratio indicates that the estuary is probably at capacity with respect to sediment accumulation. Only 10ha of saltmarsh is present within the estuary (Halcrow, 2002) this is mainly in the lee of Shell Island. The main entrance channel and the adjacent moorings have historically required dredging to remove sand every 5-10 years and the tidal basin behind Shell Island is dredged to remove silt every 10-15 years (ABP Research and Consultancy, 2001). The fate and quantity of the dredged material is not clear although the application in 2001 was for removal of the spoil from the estuary with deposition of sands on the seaward side of Shell Island and fines on dry land with a relatively small quantity of 9000 tonnes each of the two dredge sites (ABP Research and Consultancy, 2001). Prior to 2001 the sand was deposited within the lagoon forming a small island and it is not known if the dredging frequency has decreased following the deposition of sediment outside of the estuary. The source of this sediment is unknown, it is possible that the sediment is derived from the open coast or is redistributed from elsewhere in the estuary.

The sediments within the estuary are made up of both muds and sands and possible sources include the Afon Artro (fines) and the offshore and adjacent coast (sand). It is also possible that sand is sourced from the extensive Morfa Dyffryn sand dune field to the south. The high intertidal area ratio indicates that the estuary may be at or near capacity with respect to sediment and the mouth width is consistent with the channel length indicating that the estuary is largely in sedimentary balance (Halcrow, 2002). However the dredging requirement within the estuary suggests that the Artro is likely to be a net sink for sediment.

9.1.1 Response to Sea Level Rise

Little is known about the Artro and consequently it is very difficult to predict the future behaviour of the estuary. The lagoon area has a very high intertidal area ratio suggesting that the estuary is at or near capacity with respect to sedimentation and also that there has been a sufficient supply of sediment in the past to enable accretion. If it is assumed that the estuaries response to sea level rise would be to warp-up in-situ and accrete in pace with sea level, it seems likely that there is sufficient sediment available from offshore and fluvial sources to enable this process. Although without a detailed sediment budget it is difficult to confirm.

The Shell Island feature is an important control on the estuary and at present is undergoing a slow rate of erosion along its seaward face, this can be expected to continue into the future although overtopping or breaching of the feature is thought to be unlikely in the near future. The erosion of Shell Island and the adjacent coast supplies sediment to the spits at the mouth of the estuary although the defences along the spits indicate that the features are susceptible to erosion. If both the spits currently require defending it is unlikely that they will be maintained naturally in the future with the increased pressure of sea level rise. If the spits breakdown it will lead to increased exposure of the estuary.

The historical stability of the Morfa Dyffryn feature indicates that the old mouth will not reopen in the near future. Predictions of the future evolution of the dune frontage based on historical analysis of OS maps and expert geomorphological analysis has shown that although some recession of the shoreline and loss of dune volume will occur in the future (Pye and Saye, 2005) this will not be of a great enough magnitude to allow the opening of the former estuary mouth by 2100.

9.1.2 Assessment of Tidal Locking

There is no evidence that the Artro has been or is susceptible to flooding through tidal locking. As freshwater flows are unknown it is difficult to predict how the risk of tidal locking may change in the future but the canalised nature of the river upstream of Pensam Harbour may block freshwater discharge from the Afon Artro during a large tidal event.

9.1.3 Summary of Key Processes and Morphology

The Artro has been heavily modified by humans in the past with its mouth diverted from the south of Mochras Point to its present position. The original mouth is now closed by the Morfa Dyffryn sand dunes and beach and it is unlikely that this will reopen over the next 100 years. The diversion of the estuary mouth has allowed the southern part of the estuary (behind Shell Island) to infill and this area is now is largely intertidal mudflat and saltmarsh. The spits on either side of the present estuary mouth form an important constraint on the estuary by sheltering the inner estuary from waves. The maintenance of the spits into the future will depend on the supply of sediment from the adjacent eroding frontage, the spits are currently heavily defended and probably fixed in place, the defences indicate that the spits could be susceptible to breaching and breakdown in the future exposing the inner estuary to waves. The inner estuary appears to have a sufficient supply of sediment at present to enable accretion and this is likely to continue into the future.

9.2 Estuaries Assessment

Estuary	Artro Estuary
Location	North Cardigan Bay, Wales.
Classification	7a – Symmetrical Tidal Inlet.
Main characteristics	Macrotidal, small estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). North Cardigan Bay Shoreline Management Plan (Gwynedd Council, 1998).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Artro is considered to be small in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a very large intertidal zone relative to its total area; a very small amount of saltmarsh is present. Channel length: The length of the estuary is considered to be small. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width with a sand spit present on the west side and a breakwater on the east side. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are not known. % Area: The estuary has a large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities can reach 2.5m/s (ABP Research and Consultancy, 2001) Tidal prism: 5 150 000m^3
	Verdict on significance: The Artro is a small estuary although the tidal range is large and tidal currents at the mouth can be strong. Freshwater flow is unknown but is thought to be largely insignificant. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as **significant** with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The tidal asymmetry is not known. Morphological features: The estuary is behind Shell Island with the current mouth exiting to the coast to the north of this feature, the mouth is small with sand spits on both sides of the estuary mouth. The estuary has a large intertidal area relative to its size and a very small are of saltmarsh. Source sink relationship: Unknown although based on the available data it can be concluded that the estuary has historically been a sink for sand sourced sediment from offshore sources and fine sediment from fluvial sources. The large intertidal area suggests that the estuary may be approaching capacity with respect to sediment accumulation although the dredging requirement indicates that the estuary is still a net sink. Plume generation: Unknown, there could be a potential for plume generation during high flow events.
	Verdict on significance: The dredging requirement indicates that there is some sediment exchange between the estuary and the open coast and the estuary is a net sink for sand and fine sized sediment. The presence of spits at the estuary mouth and the drift aligned open coast indicates that there is the potential for significant interactions with the open coast. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as **Significant** in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: significant Step 3, therefore, from EGT5, process issues are considered to be Grade A
Stage 1 Step 4: significance of management issues (EGT4)	The mouth of the estuary was diverted in 1819 from a mouth at the south end of Shell Island. The spit on the southern side of the estuary mouth is developed and armoured with rock and the northerly spit is extended with a breakwater. Small periodic dredging campaigns are required to maintain navigable depths within the estuary. A causeway has been built across the estuary to allow access to Shell Island campsite at low tide.

	Verdict on significance: Insignificant, although the estuary is managed to a certain extent none of these practices impact on the interactions between the estuary and the adjacent coast.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as insignificant. *Therefore from Step 5 of EGT5, the Artro scores 2 in terms of overall significance and should be included in the SMP process.*

9.3 Discussion

Overall the interactions between the Artro and the open coast can be summarised as follows:

1. Although the Artro has a small volume, it has a large tidal range and tidal currents are large at the mouth and as such water exchanges with the open coast are significant. Freshwater flows are not known but are likely to be low and therefore the impacts of freshwater on the open coast will be minimal.
2. The dredging requirement within the Artro indicates that the estuary is a net importer of sediment. The morphology of the adjacent coast shows evidence for sediment interactions between the estuary and the open coast with the presence of a spit and a drift aligned coast.
3. Although there have been a number of management practices implemented within the estuary these are not thought to impact on the open coast.

Interactions between the Artro and the open coast are significant and as such the Artro should be included within the SMP. Within the Artro the boundary between the estuary and the Afon Artro and hence the effective limit of marine processes is clearly defined at the railway bridge at Pen Sarn. Up-estuary of this point there is limited intertidal area and the river adopts a meandering fluvial nature. In addition the estuary undergoes a large change in orientation at this point meaning that any limited wave energy that is present within the estuary will not propagate up-estuary of this location. Because of this the SMP boundary should be placed at the bridge as shown in Figure 7.

10. Glaslyn/Dwyryd Estuary

This section represents a conceptual understanding of the Glaslyn/Dwyryd Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Glaslyn/Dwyryd is illustrated in Figures 1 and 8a, bb and 8c.

10.1 Conceptual Understanding

The Glaslyn/Dwyryd Estuary is situated at the northern end of Cardigan Bay immediately to the south of the Llyn Peninsular. The estuary is formed at the conference of the Afon Glaslyn and Dwyryd and is orientated along a southwest to northeast orientation, spits are situated on both sides of the estuary mouth. The estuary is a flooded river valley that has subsequently partially infilled with sediments. Spits are present on both sides of the estuary mouth and the long sandy beaches on the open coast show the potential for significant interactions with the open coast.

The Afon Glaslyn flows along the eastern side of the estuary with Porthmadog Harbour situated on its shore. The estuary on the Afon Glaslyn ends abruptly at the Cob embankment where a tidal sluice marks the up-estuary limit of marine processes, although on spring tides some saltwater is able to seep through the semi-porous barrage enabling the limited development of saltmarsh up-estuary of the Cob (Rhind and Jones, 1994). Upriver of the sluice the Afon Glaslyn meanders across the wide floodplain formed from the former estuary valley.

The Afon Dwyryd flows along the western side of the estuary, the estuary narrows significantly at the Pont Briwet Bridge. This is likely to be due to the hard rock frontages on either side of the estuary. In the region of Abergafren a number of rock promontories act as a control on the main channel and have allowed the development of saltmarsh in the embayments formed by the headlands.

Waves data on the open coast between Ysgethin river and Llanaber to the south of the estuary mouth shows that the predominant wave direction is from the south west (210 - 240˚N) and the most common wave height is small with a height of 0.5-1.0m (Gwynedd Council, 1998). Given the relatively wide estuary mouth and its orientation to the predominant swell, it is likely that waves are able to propagate into the estuary during high tide although the absence of any data precludes the quantification of this.

The tidal range at Porthmadog is not available as the depth of MLW is not known (UKHO, 2008) it is likely that the estuary is macrotidal with a mean spring tidal range of around 4m. The magnitude of tidal flows within the estuary are not known. The Glaslyn is gauged upstream and shows mean flow of 5.76m^3/s between 1961 and 2006 (CEH archive), this speed is small when compared to the large size of the estuary and the impacts of this fluvial flow on the estuary are complicated through the presence of the sluice gate on the Glaslyn. During high tides the sluice gate is closed to prevent saltwater flooding of the reclaimed land behind the Cob, this results in freshwater building up behind the gate which is subsequently released on the low tide. This sudden release of freshwater will likely result in a larger more concentrated flow speed over a smaller time period, it is this process which keeps the main channel open adjacent to Porthmadog and hence probably has the potential to cause a small sediment plume during periods of high river flow in combination with slackwater or an ebb tide. It is known that when a high tide (preventing the opening of the sluice gates) corresponds with large fluvial flows the freshwater backing up behind the Cob can also cause flooding up-estuary (Gwynedd Council, 1998). The Dwyryd is ungauged and hence river flow speeds are unknown. The estuary is ebb dominant at the mouth according to the Dronkers parameter (Halcrow, 2002) although this is based on limited data, based on the overall siltation of the estuary it is likely to be flood dominant except during high river flow events.

The estuary has a large total area amounting to some 1570ha with 1085ha of intertidal (Halcrow, 2002). There is around 348ha of saltmarsh in the estuary this is situated on both the landward and seaward sides of the Cob and also on both banks of the Dwyryd (Halcrow, 2002).

The present shape of the estuary has been significantly influenced by reclamation. The largest reclamation is the Cob, a 1.5km embankment which was constructed in 1811 across the Glaslyn, the construction of the Cob cut off 2045ha (40%) of the upper estuary (CGP, 2000). The Cob also fixed the main channel on the west side of the estuary scouring out a deep water channel and forming the Porthmadog Harbour which was developed between 1821 and 1824 (Gwynedd Council, 1998). This reclamation reduced the tidal prism of the estuary by approximately 60% (Cascade, 2007) this in turn has lead to a reduction in tidal velocities and increases in sedimentation. In addition to the change in tidal prism the large reduction in estuary length has resulted in a dis-equilibrium in the estuary's regime whereby the mouth cross-section is large in comparison to its length. There has also been further reclamation at Morfa Harlech during 1808 on the south bank of the estuary at the mouth where 1484ha has been reclaimed this amounts to some 29% of the total estuary's area (CGP, 2000). In addition there has also been some reclamation at Talsarnau on the upper Dwyryd which occurred at a similar time.

Historical analysis illustrates how the morphology of the estuary has responded to the reduction in estuary area and volume with the intertidal area immediately seaward of the cob showing evidence of significant siltation and saltmarsh accretion between 1951 and 1996 (Cascade, 2007). This is a result of the large reduction in the tidal prism of the upper Glaslyn and the subsequent reduction in tidal velocities over the intertidal areas away from the main channel in the inner estuary. The area up-estuary of the Cob is brackish due to the semi-porous nature of the embankment and this has allowed extensive saltmarsh colonisation within this area since the reclamation (Rhind and Jones, 1994).

Evidence from historical maps and aerial photographs have also shown that the dunes and foreshore on the southern bank of the estuary mouth at Morfa Harlech have accreted into the estuary mouth over the last 150 years (May and Hansom, 2003). Although there is evidence that some accretion predated the construction of the Cob, it is likely that the continued rapid accretion around the estuary mouth is a response to the reduced tidal prism in the estuary causing a corresponding reduction in flows through the estuary mouth. In addition to the changes described above, sandbanks have developed in the approaches to the estuary and the main channel has decreased in depth (Gwynedd council, 1998).

The Admiralty Chart for Porthmadog (1512) notes that the approach channel at the estuary mouth has shown a tendency to shift from one side of the estuary to the other. This change has happened many times in the past and moves in concert with the extension and shortening of the Harlech and Morfa Bychan spits (Gwynedd Council, 1999). Despite this movement of the approach channel the navigation channel remains adjacent to the eastern bank of the estuary further upstream (Gwynedd Council, 1999) constrained by flows from the river and the presence of Cei Ballast.

The sediment within the estuary is mainly sand with some fines, historical evidence indicates that the estuary has been accreting and therefore the estuary is currently a net sink for sediment. The intertidal area ratio is higher than both the Dyfi and the Mawddach indicating that the estuary may be approaching capacity with regards to sediment accumulation. However, both the cross sectional area ratio and the mouth width in relation to the channel length are high indicating that the estuary is still not at equilibrium following the large reclamations that took place in the early 1800s hence there is probably still potential for further sediment deposition within the estuary to balance this dis-equilibrium.

10.1.1 Response to Sea Level Rise

The estuary is still adjusting to the large changes in volume and area that occurred in the early 1800s and consequently is still a net sink for sediment. If it is assumed that the estuaries response to sea level rise would be to warp-up in-situ and accrete in pace with sea level, it seems likely that there is sufficient sediment available from offshore and fluvial sources to enable this process. However, as the extensive reclamation has caused larger changes to the tidal prism when compared to the changes that would be expected from sea level rise it can be concluded that the impacts of the reclamation will be the dominant factor in controlling the estuaries future morphology.

10.1.2 Assessment of Tidal Locking

The Glaslyn Estuary is embanked by the Cob, a large reclamation constructed across the northern part of the estuary, because of this reclamation the Afon Glaslyn flow into the Glaslyn Estuary through tidal sluices. These sluices are closed during high tides to prevent inundation of the reclaimed land to the north, if the high tide is accompanied by large river discharges the freshwater can back up causing flooding (Gwynedd Council, 1998). With an increase in sea level it is likely that the gates will need to remain closed for longer meaning more frequent inundation to the north. This could be a problem during neaps were the tidal level may not get low enough to enable the discharge of river water through the gates.

The Afon Y Cyt flows through Porthmadog and discharges into the Glaslyn Estuary through a narrow outfall. The CFMP has identified this watercourse as being at risk from tidal locking and that the risk will increase in the future (EA, 2008b).

10.1.3 Summary of Key Processes and Morphology

The principal intervention on the Glaslyn/Dwyryd Estuary has been the extensive reclamation of the Glaslyn through the construction of the Cob and the estuary is still responding to this. The mouth of the estuary has no hard constraints and is held in position by sand dunes and a sandy foreshore and is relatively open providing little shelter to the inner estuary from waves propagating into the estuary. The reduction in tidal prism has led to extensive siltation in the upper Glaslyn to seaward of the Cob and a reduction in the width of the estuary mouth through the extension of the Morfa Harlech Feature into the estuary mouth. There are large amounts of sediment available and it is likely that this adjustment will continue into the future.

10.2 Estuaries Assessment

Estuary	Glaslyn/ Dwyryd Estuary
Location	North Cardigan Bay, Wales.
Classification	3a – Ria with spits.
Main characteristics	Macrotidal, large estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). North Cardigan Bay Shoreline Management Plan (Gwynedd Council, 1998). Pen Llyn A'R Sarnau cSAC: Coastal Processes Surveillance and Research Requirements (CGP, 2000). The Cob Reclamation, Environmental Report to Inform Appropriate Assessment (Cascade, 2007).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Glaslyn/Dwyryd is considered to be large in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a large intertidal zone relative to its total area; some saltmarsh is also present. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a large cross-sectional mouth area. Mouth width: The estuary has a large mouth width with sand spits present on either side of the estuary mouth. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are relatively low for an estuary of this size with a mean freshwater flow of 5.76m3/s recorded between 1961 and 2006. These flows are likely to be accentuated as a result of storage behind the sluice. The contribution from the Dwyryd is unknown. % Area: The estuary has a relatively large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities are unknown. Tidal prism: 26 800 000 m^3
	Verdict on significance: The estuary has a large tidal range and a large volume showing that estuary exchanges large volumes of water with the open coast. Freshwater flows are low for an estuary of this size indicating that the exchange of freshwater with the coast will be minimal. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: Based on the morphology and the historic behaviour of the estuary the tidal asymmetry is likely to be flood dominated. Morphological features: The estuary is formed at the confluence of the Afon Glaslyn and Dwyryd; the Glaslyn has been reduced considerably in terms of both area and volume as a result of historical reclamation. The estuary mouth is wide with sand spits on both sides. The intertidal area of the estuary is large with areas of saltmarsh in the vicinity of the Cob in the Glaslyn and along both banks in the Dwyryd. Source sink relationship: Based on historical evidence the estuary is likely to be a sink for fine and sand sized sediment. Fine sediment is probably sourced from the Afon Glaslyn and Dwyryd and sand sized sediment from offshore and the adjacent coast. Plume generation: Unknown for the Dwyryd. There could be a potential for plume generation on the Glaslyn during high flow events and ebb tides.
	Verdict on significance: The estuary is a large sink for sand sized sediment from the open coast and offshore. The morphology of the adjacent coast shows potential for these interactions to exist over a large spatial scale. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as significant in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: significant Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	Very large proportions of the Glaslyn have been reclaimed and also some smaller areas of the Dwyryd, the estuary has still not reached an equilibrium following these changes. A railway bridge in the upper Dwyryd may act to constrain the estuary to some degree.
	Verdict on significance: Marginal, very large areas of estuary have been reclaimed in the past and the Mawddach is still adjusting to this morphological change.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as Marginal. *Therefore from Step 5 of EGT5, the Glaslyn / Dwyryd Estuary scores 1 in terms of overall significance and should be included in the SMP process.*

10.3 Discussion

Overall the interactions between the Glaslyn / Dwyryd Estuary and the open coast can be summarised as follows:

1. The Glaslyn / Dwyryd has a large volume and a large tidal range and as such water exchanges with the open coast are significant. Freshwater flows are low for an estuary of this size and therefore the impacts of freshwater on the open coast will be minimal.
2. The Glaslyn / Dwyryd is a strong sink for sand sized sediment sourced from offshore and the adjacent open coast. The morphology of the adjacent coast shows evidence for significant sediment interactions between the estuary and the open coast over a large spatial scale.
3. Very large areas of reclamation exist in the Glaslyn / Dwyryd and the estuary is still adjusting to these changes in estuary volume.

Interactions between the Glaslyn / Dwyryd and the open coast are significant and as such it is recommended that the Glaslyn / Dwyryd is included within the SMP. Within the Glaslyn the limit of coastal processes is the Cob embankment situated to the north of Porthmadog. Although some saline water does seep through the Cob resulting in the formation of saltmarsh habitat up-estuary, changes to the watercourse down-estuary of the Cob will not impact on the area up-estuary of the Cob and vice-versa.

Within the Dwyryd a geological constraint narrows the estuary significantly at the Dwyryd Bridge. Firstly, this constraint will provide a barrier against significant wave propagation up-estuary of this point. Secondly the estuary becomes more fluvial up-estuary of the bridge with a more meandering morphology and a limited intertidal. In addition aerial photographs and OS data indicate that sediment becomes muddier up-estuary of this point showing that sandy sediments from the adjacent coast are not deposited much further than this point thereby marking the limit of sediment interactions with the open coast.

The proposed SMP boundary should be placed as shown in Figure 8.

11. Cefni Estuary

This section represents a conceptual understanding of the Cefni Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Cefni is illustrated in Figures 1 and 9.

11.1 Conceptual Understanding

The Cefni Estuary (also known as Malltraeth sands) is situated on the southwestern corner of Anglesey, North Wales. It is orientated along a southwest to northeast axis and is fed by the Afon Cefni. The mouth of the estuary (Malltraeth Bay) has a large intertidal sandflat bordered by hard rock outcrops at Ynys Llanddwyn to the southeast and Twyn y parc to the northwest. Twyn y parc separates the estuary from an adjacent series of pocket beaches suggesting that there is little transfer of sediments between the estuary and the open coast to the west of the estuary mouth. The island of Ynys Llanddwyn separates the beaches of Traeth Penrhos (at the estuary mouth) and Traeth Llanddwyn to the east and is connected to the mainland with a sand and rock causeway with a crest level above MHW. Along the sandy foreshore of Traeth Penrhos the coast changes direction with an approximate east to west orientation. The presence of Ynys Llanddwyn and the change in orientation of the coast indicates that sediment transfer between the two beaches is limited. Traeth Penrhos is a sand beach with a relatively uniform slope and Traeth Llanddwyn is a mixed sand and gravel beach with large swash bars (Bristow, 2003)

Along the eastern side of the estuary mouth the intertidal sandflat and Traeth Penrhos is backed by sand dunes and pine forest (Newborough Forest), these sand dunes have accreted into the estuary resulting in a narrowing of the Cefni just upstream of the estuary mouth. Analysis of OS maps show that MHW has progressively prograded into the estuary between 1888 and 2002 (Pye and Saye, 2005). The forest is a relatively recent feature planted in 1948 by the forestry commission to help stabilise the dunes and prevent wind-blown sand from covering roads and crops (CCBC *et al*, 2002). Sand dune development backing Traeth Penrhos was further encouraged with the construction of a fence by the forestry commission in 1951 (Packham and Liddle, 1970) this subsequently encouraged the development of two dune ridges (Bristow, 2003). The trees tend to have a detrimental impact on the dune front by promoting cliffing of the dune face and reducing wind shear resulting in a consequential reduction in sand transport between the dunes and the beach (Bristow, 2003). To remedy this, it has been proposed that the plantations along the dune ridges should be removed to restore natural geomorphological dune-beach interactions and processes.

Further up-estuary the Cefni widens slightly and some saltmarsh is situated in the lee of the duned area. North of the saltmarsh the upper extent of the estuary is marked by the sluice through which the Afon Cefni discharges into the estuary. The main channel flows along the western side of the estuary, the channel was straightened in 1945 in the region below the sluice adjacent to Malltraeth Yard where a meander previously directed the channel towards the eastern side of the estuary. This resulted in sedimentation along the eastern side of the estuary in this area (Packham and Liddle, 1970).

The wave climate is not known for this part of the coast, the estuary is exposed to swells from the southwest although the ability of waves to propagate into the estuary will be hindered by the shallow depths and relatively narrow mouth. Most wave energy will probably dissipate on Traeth Penrhos at the estuary mouth.

Although tidal information is not available for the estuary itself, it is known that the tidal range is macrotidal at Ynys Llanddwyn to the east of the estuary mouth with a mean spring tidal range of 4.4m (UKHO, 2008). No information exists detailing tidal flows in the Cefni Estuary although tidal asymmetry is flood dominant at the mouth according to the Dronkers Parameter (Halcrow, 2002). The Cefni is a small river with a gauged mean flow of $0.40m^3/s$ recorded between 1988 and 2005 at Bodfford in the upper reaches of the river (CEH archive). As maximum flows were not available it is not possible to assess the potential for plume creation although comparison with other rivers in the area suggest that a plume could be possible at maximum river flows on the ebb tide (Halcrow, 2002).

The estuary is large with a total area of 744ha, a very large proportion of this is intertidal which amounts to an area of 614ha (Halcrow, 2002) the estuary is predominantly sandy. The Cefni also has a reasonably large area of saltmarsh with around 111ha (Halcrow, 2002), this is all situated along the eastern side of the estuary in the lee of the sand dunes. The upper estuary underwent significant reclamation between 1806 and 1812 during which the Malltraeth Marshes were reclaimed and the estuary was canalised almost as far as Llangefni (CCBC *et al*, 2002), this reclamation cut off a very large part of the estuary. The cross sectional ratio is on the low line and the mouth width is about average for the channel length suggesting that the estuary has fully adjusted to the reduction in tidal prism and estuary length caused by the reclamation (Halcrow, 2002). The intertidal ratio is high at 0.83, this indicates that the estuary is at or approaching capacity with respect to sediment accumulation (Halcrow, 2002), much of this siltation probably occurred as a response to the reclamation reducing the tidal prism and consequently the flushing capacity of the estuary.

Overall the estuary has historically been a strong sink for sediment as evidenced by the large intertidal area and the accreting dune system on its margin. The source of this sediment is not clear although it is likely that sand is sourced from the large offshore supply (BGS, 1990) and fines from the Afon Cefni.

11.1.1 Response to Sea Level Rise

The estuary has adjusted to the large amounts of reclamation and is now only a very weak sink for sediment which is probably mainly incorporated into the dune system. If it is assumed that the estuaries response to sea level rise would be to warp-up in-situ and accrete in pace with sea level, it seems likely that there is sufficient sediment available from offshore and fluvial sources to enable this process.

The behaviour of the sand dunes exerts a strong control on the estuary, both controlling the width of the mouth and also sheltering the saltmarsh in the estuary and the response of the dunes will depend in turn on the management of the Newborough Forest. A study analysing future changes to the dunes at Newborough as a result of sea level rise concluded that the shoreline would accrete within the estuary and erode slightly along Traeth Penrhos by a period between 2080 to 2100 (Pye & Saye, 2005) under present management practices. This indicates that the shoreline is likely to be broadly stable within the estuary.

11.1.2 Assessment of Tidal Locking

The Cefni has not been identified within the CFMP as a watercourse that is susceptible to flooding from tidal locking either historically or in the future (EA, 2008b). The estuary upstream of Maltraeth is completely reclaimed and canalised, because of this the morphology of the estuary indicates that the Afon Cefni may be susceptible to tidal locking during high tides and large river discharges. However, the available evidence suggests that river flows tend to be low and therefore overall flooding from tidal locking is considered to be unlikely.

11.1.3 Summary of Key Processes and Morphology

The spit extended across the mouth of the Cefni provides an important constraint at the mouth providing shelter to the saltmarsh in its lee. Rock outcrops at Ynys Llanddwyn to the southeast and Twyn y parc to the northwest form an embayment within which the estuary mouth is situated. The estuary has undergone extensive reclamation and the spit has extended across the mouth in response to this reduction in tidal prism. The spit has also been stabilised by the planting of the coniferous forest along the duned areas, it is possible that this plantation could be removed in the future under a proposed new management plan and the response of the dunes will depend in part on this decision. The sand spit and dunes are extensive and are likely to remain in place with future sea level rise even with some slight erosion of the frontage. With the large sediment source available offshore it is likely that the estuary will continue to accrete with sea level rise.

11.2 Estuaries Assessment

Estuary	Cefni Estuary
Location	Southeast Anglesey, North Wales.
Classification	3b – Ria without spits.
Main characteristics	Macrotidal, large estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Ynys Enlli to Great Ormes Head, Llandudno Shoreline Management Plan (CCBC et al, 2002)
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Cefni is considered to be large in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a large intertidal zone relative to its total area; some saltmarsh is also present. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows relatively low for an estuary of this size with a mean freshwater flow of 0.40m3/s recorded between 1988 and 2005. % Area: The estuary has a relatively large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities are unknown. Tidal prism: 31 910 000 m^3
	Verdict on significance: The estuary has a large tidal range and also a large volume showing that the Cefni exchanges large amounts of water with the open coast. Fluvial flow is very low for an estuary of this size and will have little influence on the open coast. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: Based on the morphology, the historic behaviour of the estuary and the Dronkers parameter the tidal asymmetry is likely to be weakly flood dominated although the estuary is nearing capacity. Morphological features: The estuary has historically been subject to significant reclamation and the Cefni currently enters the estuary through a system of sluices. The estuary has extensive areas of intertidal with saltmarsh and sand dunes down the east side. The sand dunes are extensive and have accreted into the estuary causing the Cefni to narrow near the mouth. The estuary mouth flows into Malltraeth Bay which is constrained by two rocky headlands and fronted by a sand beach to the east of the main channel. Source sink relationship: Based on historical evidence the estuary has been a sink for fine and sand sized sediment. Fine sediment is probably sourced from the Afon Cefni and sand sized sediment from offshore. The large intertidal ratio suggests that the estuary is nearing capacity. Plume generation: Unknown.
	Verdict on significance: The estuary is probably a weak sink for sediment which is imported from fluvial sources as well as the adjacent coast and offshore. Sediment interactions with the open coast do not extend over a wide spatial scale will be limited to the area between the promontories of Llanddwyn Island and Twyn-y-parc which mark the limits of significant longshore transport. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as marginal in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: Significant Step 2 – sediment exchange: Marginal Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	Very large proportions of the Cefni have been reclaimed the estuary appears to have reached equilibrium following these changes. The future management of Newborough Forest and Newborough warren will impact on the dune systems in the area.
	Verdict on significance: Significant, although large areas of the estuary have been reclaimed in the past it appears that the estuary has adjusted to these changes. The management of the adjacent dune system by the proposed removal of the coniferous trees will have impacts on the movement of sand and possibly the morphology of the estuary mouth where the dunes constrict the estuary mouth.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as significant. *Therefore from Step 5 of EGT5, the Cefni Estuary scores 1 in terms of overall significance and should be included in the SMP process.*

11.3 Discussion

Overall the interactions between the Cefni Estuary and the open coast can be summarised as follows:

1. The Cefni has a large volume and a large tidal range and therefore water exchanges with the open coast are significant. Freshwater flows are very low for an estuary of this size and significantly modified through the tidal sluice and therefore the impacts of freshwater on the open coast will be minimal.
2. The Cefni is sink for sand sized sediment sourced from offshore and the adjacent open coast and fine sediment sourced from the Afon Cefni. The presence of headlands along the adjacent coast suggests that interactions will be limited to the immediate area.
3. Very large areas of reclamation exist in the Cefni and the estuary has adjusted to these changes in morphology. The management of the dunes will impact on the estuary as the dunes currently constrain the estuary mouth.

Interactions between the Cefni and the open coast are significant and management issues are considered to be important and therefore it is recommended that the Cefni is included within the SMP. A significant constraint is placed on the estuary mouth by the Newborough dune system, although this provides a barrier to wave processes, tidal processes are still important up estuary of this point as evidenced by the significant deposition of intertidal marine sourced sediment. A suitable extent which incorporates the intertidal area of marine sourced sediment is provided by the sluice at the Malltraeth. Up-estuary of this point the river is canalised as a result of reclamation and freshwater flows are low therefore any changes to the watercourse down-estuary of this point will not significantly impact on the area up-estuary and vice versa.

The proposed SMP boundary should be placed at position shown in Figure 9.

12. Alaw Estuary

This section represents a conceptual understanding of the Alaw Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Alaw is illustrated in Figures 1 and 10.

12.1 Conceptual Understanding

The Alaw Estuary forms the watercourse separating Holy Island from Anglesey. The estuary originates as the Afon Alaw which is orientated in a west to east direction although the main part of the estuary is orientated along a north to south axis with a mouth to the north at Holyhead and a mouth to the south at Traeth Cwymyran.

The northern mouth of the estuary is the widest of the two outlets and is enclosed by rocky headlands at Holyhead to the west and Penryhn to the east, the Holyhead breakwater on the west side of the mouth extends nearly halfway across the estuary and provides shelter from north-westerly waves. To the south between the northern mouth and the point at which the Afon Alaw joins the main estuary, the foreshore is characterised by rocky headlands interspersed with sandy pocket beaches and coves with a generally small intertidal area. The west coast is extensively developed with the port of Holyhead and the east coast is fairly undeveloped.

In the region of the Afon Alaw, the estuary narrows due to rocky outcrops on either side of the estuary and the intertidal area increases in size forming Traeth y Griben. The Afon Alaw has spits on either side of its mouth and the intertidal is characterised by a combination of mudflat, sandflat and saltmarshes. Further south the estuary narrows again in the region of the Stanley Embankment and between the Stanley Embankment and the Four Mile Bridge the estuary narrows again to its narrowest point at Four Mile Bridge. The area between the Stanley Embankment and the Four Mile Bridge is known as the Inland Sea which has limited areas of intertidal.

South of the Four Mile Bridge the estuary is constricted at Penrhyn-hwlad, Ty-Gwyn and Cymyran where geological hard points constrict the estuary. This section of the estuary has large areas of intertidal and a narrow main channel with some saltmarsh on the west bank south of the Four Mile Bridge and on the east bank next to Ty-Gwyn. Just up-estuary of the mouth, constriction by rock hardpoints between Tywyn Bryn-y-bar on the west bank and Cymyran on the east bank narrows the estuary significantly; this constriction of the main channel has probably allowed the dunes to develop to the east of Cymyran. The southern mouth is narrow and is flanked Tywyn Bryn-y-Bar to the west and the sandy beach of Traeth Cynyran to the west.

No information could be found detailing the wave climate in the Alaw although the construction of the Holyhead Breakwater between 1848 and 1873 has protected the northern end of the estuary from north-westerly swells. Any northerly swell that does propagate into the estuary mouth will not travel further up-estuary than the Stanley Embankment which completely blocks the estuary apart for a small culvert. The combination of the breakwater at Holyhead, the Stanley Embankment and the Four Mile Bridge means that there is insufficient fetch for swell to generate within the estuary.

The Alaw estuary is macrotidal with a mean spring tidal range of 4.9m at Holyhead (UKHO, 2008). Current speeds from the UKHO Holyhead Harbour chart immediately to the north of the Holyhead breakwater show that current speeds are stronger during the flood during both springs and neaps with peak currents of 0.7 and 0.4 m/s respectively. Peak current speeds during the ebb are 0.6 m/s for spring tides and 0.3 m/s for neap tides. It is likely that these tidal flows measured just outside the estuary mouth will not be representative of the tidal currents within the estuary, the direction of tidal currents at this location show a broad east to west direction whereas estuary tidal flows would be expected to be orientated in a direction broadly parallel to the estuary. The Dronkers parameter infers that the estuary is ebb dominant (Halcrow, 2002) although the use of this parameter is problematic due to presence of two mouths and it has been suggested that the estuary is probably flood dominant overall (Halcrow, 2002). The Afon Alaw is not gauged so it is not possible to assess the significance of the river.

It is likely that the construction of the Stanley Embankment (in 1824) and the Four Mile Bridge have both had a significant impact on the hydrodynamics of the estuary, both bridges have only narrow culverts which funnel tidal flows through forming tidal races and standing waves during high spring tides. Although there is no information detailing the impacts it is noticeable from OS maps and aerial photography that the areas to both the north and south of these structures are characterised by extensive intertidal flats whereas the area between the embankments has very little intertidal area and a large main channel. This indicates that the barriers prevent sediment from entering the Inland Sea during a flood tide and possibly also flush any sediment out during the ebb. The sedimentation to the north of the Stanley Embankment and the south of Four Mile Bridge has probably been encouraged by the embankments reducing tidal flow through the strait.

The total estuary is large with an area of 1085ha and an overall intertidal area of 721ha, only a very small proportion of this is saltmarsh with an area of 63ha. The saltmarsh is situated to the south of Four Mile Bridge and within the mouth of the Afon Alaw. Evaluation of OS data and aerial photographs showed little evidence of reclamation although some of the docks at Holyhead have been built on reclaimed land and there is a cob built across one of the tributaries south of Four Mile Bridge.

Overall the intertidal ratio is moderate indicating that there is potential for the estuary to accumulate more sediment (Halcrow, 2002). However, the intertidal ratio changes significantly throughout the estuary and in general the areas south of Four Mile Bridge and within the Afon Alaw have very high proportions of intertidal when compared to the rest of the estuary. South of Four Mile Bridge this is probably due to the construction of the bridge and to some extent the Stanley Embankment reducing tidal currents through the strait and encouraging deposition of sediment in this area. Consequently it is likely that the Alaw itself and the southern mouth of the estuary through to Four Mile Bridge are largely at capacity with respect to sediment whilst there is scope for further sedimentation throughout the rest of the estuary.

There is no sediment budget and limited historical analysis data available for the estuary although the interpretation of the current morphology allows some tentative conclusions to be drawn. Historically the southern part of the estuary probably sourced sand sized sediment from the extensive coastal and offshore deposits (BGS, 1990). The sediment offshore of the northern mouth of the estuary are more gravelly in nature (BGS, 1990) and the adjacent coast is comprised of pocket beaches and coves indicating minimal longshore transport of sediments into the estuary, this may in part explain the low intertidal ratio in the northern part of the estuary. Cliff erosion to the north of the Stanley Embankment will also contribute a small amount of sediment. There is a high proportion of mud within the Afon Alaw part of the estuary, this is likely to be sourced from the river, the sandy sediments within Afon Alaw are probably sourced from the dunes adjacent to the mouth which is in turn fed by the Traeth y Gribin sandflat. The dunes and spits adjacent to the mouth of the Afon Aluw have historically eroded over the timescale and amount of erosion is not known (Halcrow, 2002).

Because the estuary has a diverse morphology it is helpful to split the Alaw into four distinct zones based the above data.

Zone 1: The area to the north of the Stanley Embankment, exposed to some wave energy with proportional small amounts of intertidal.

Zone 2: The area of Afon Alaw to the west of the sand spits, a small area with proportionally large amounts of intertidal including saltmarsh, the sediments appear to be proportionally more muddy which is derived from the river.

Zone 3: The area between Stanley Embankment and Four Mile Bridge, this area is completely protected form swell and has almost no intertidal area. It is possible that sediment is prevented from entering this area by the embankments or flushed out of this part of the estuary by the high flows through the gaps in the embankments.

Zone 4: The area to the south of Four Mile Bridge forms a relatively narrow estuary with a large proportion of intertidal area. Sediment in this part of the estuary is likely to be sourced from the coast adjacent to the southern mouth or from offshore.

12.1.1 Response to Sea Level Rise

Very little data is available detailing the sedimentary and hydrodynamic regime of the Alaw considering the size and importance of the estuary. It is therefore very difficult to predict the future response of the estuary when little is known about the present and historical behaviour. Firstly, it is likely that the area of estuary to the south of Four Mile Bridge (Zone 4) will continue to source sediment from the adjacent coast and offshore and accrete in line with sea level rise. Secondly it is unlikely that the area north of Four Mile Bridge (Zones 1 and 3) will be able to source enough sand sized sediment for the estuary to warp-up and therefore the intertidal areas will reduce in size. This in turn will lead to an increase in the size of the tidal prism and further erosion of the existing intertidal. Consequently the supply of sand sized sediment to the Afon Alaw part of the estuary system (Zone 3) will decrease leading to a progressive reduction in the size of the dunes and sand spits at the river mouth. The Afon Alaw will continue to supply fine sediment to the river and therefore the mudflats and saltmarsh may continue to accrete within the Afon Alaw, although without quantification of sediment supply form the river it is difficult to confirm this.

12.1.2 Assessment of Tidal Locking

No past or present risk of flooding as a result of tidal locking on the Alaw Estuary is identified within the CFMP (EA, 2008b). The morphology of the estuary, which has both a northern and a southern mouth means that tidal locking is only possible within Zone 2 where the Afon Alaw flows into the main estuary. The available evidence indicates that the morphology of the Afon Aluw is relatively natural and unconstrained, discharge rates are not known but are likely to be low based on the small size of the river. Because of this it is determined that tidal locking is unlikely to be a significant risk at any point within the Alaw.

12.1.3 Summary of Key Processes and Morphology

Due to the large size of this estuary the study area has been split into 4 zones:

Zone 1: This comprises the area to the north of the Stanley Embankment. The morphology of the shoreline in this area is characterisitc of an open coast environment with a series of sandy bays between headlands and some intertidal sandflat. The lack of a contemporary sediment source offshore and the indented character of the coast indicates that little sand sized sediment is supplied to this area and therefore the existing intertidal area could be inundated and probably roll back with sea level rise. Some increased erosion of the cliffs would contribute a small amount of sediment to the foreshore although this would be negligible in quantity. The breakwater provides an important control on the estuary by reducing wave exposure. The area of intertidal sandflat to the north of the Stanley Embankment is probably a result of reduced tidal flow through the strait as a result of the embankments and also the flow being restricted to a central culvert.

Zone 2: This comprises the Afon Alaw itself. The Afon Alaw is muddier than the outer estuary and its mouth is flanked by two sand spits and dune systems. These spits and dunes provide some protection to the inner-estuary where some saltmarsh has developed. The maintenance of these dunes depend on sand supply in zone 1, as the intertidal flats are likely to be inundated (in zone 1) by sea level rise this will correspondingly reduce this sand supply potentially causing the spits and dunes to break down increasing the exposure of the Afon Alaw.

Zone 3: The area between the Stanley Embankment and Four Mile Bridge is impacted greatly by the presence of the two structures which restrict tidal and wave processes. The area is characterised by a very small intertidal area indicating that little sediment is deposited in this area. With sea level rise it is likely that the intertidal area will be reduced further due to the lack of a sediment supply.

Zone 4: The area south of Four Mile Bridge comprises large areas of intertidal. The principal control on the form of this part of the estuary is geological and the estuary is constrained in a number of places by hard points. The Four Mile Bridge probably reduces tidal currents through the strait and therefore has encouraged the siltation of this area and therefore represents an important constraint. There are large amounts of sediment available adjacent to the mouth and therefore it is expected that the estuary will continue to accrete with sea level rise. The mouth is constrained by hard geology and therefore no change is expected with respect to the estuaries exposure.

12.2 Estuaries Assessment

Estuary	Alaw Estuary
Location	Northwest Anglesey, North Wales – separating Anglesey from Holy Island.
Classification	2b – Fjard without spits.
Main characteristics	Macrotidal, large estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Ynys Enlli to Great Ormes Head, Llandudno Shoreline Management Plan (CCBC et al, 2002)
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Alaw is considered to be large in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a moderate to large intertidal zone relative to its total area although this is not spatially consistent over the estuary; a small amount of saltmarsh is also present. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a large cross-sectional mouth area in the north and a small cross-sectional mouth area in the south. Mouth width: The estuary has a large mouth width in the north and a small mouth width in the south. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are unknown. % Area: Overall the estuary has a moderate % area although in the southern part of the estuary this is high indicating that in this area the estuary nearly dries out at LW Tidal velocities: Tidal velocities are unknown. Tidal prism: 45 150 000 m^3
	Verdict on significance: The area, volume and tidal range of the Alaw is large so the estuary exchanges large amounts of water with the adjacent coast. The presence of standing waves under the Stanley Embankment and Four Mile Bridge indicates that tidal currents are large throughout the estuary. The Afon Alaw is not gauged so no flow information is available, inspection of aerial photography and OS surveys indicate that the river is fairly small compared to the total volume of the estuary and hence the impacts of this river are unlikely to extend beyond the intersection of the river with the main estuary. Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: Based on the morphology of the estuary the tidal asymmetry is likely to be flood dominant overall. Morphological features: The Alaw has two mouths and separates Anglesey from Holy Island, the mouth in the north is wide and rocky with little intertidal area and the mouth in the south is narrow with a large proportion of intertidal area. The estuary is large with proportionally the greatest ratio of intertidal area in the estuary south of Four Mile Bridge; the rest of the estuary generally has a very small ratio of intertidal area. Some saltmarsh is present within the Afon Alaw and the southern estuary. The construction of the Stanley Embankment and the Four Mile Bridge has created a mid-section within the estuary that experiences little wave action and limited sediment supply (as evidenced by the limited intertidal area). A number of geological hard points constrict the estuary in places. Source sink relationship: Based on the present morphology it is likely that the estuary south of Four Mile Bridge is a sink for sand sized sediment, with sand sourced from offshore and the adjacent coast. The area north of Four Mile Bridge has a smaller intertidal area, this is likely to be due to the lack of sediment available from offshore at the northern mouth and the morphology of the adjacent coast which hinders longshore transport into the estuary. The Alaw itself also has a large intertidal area much of which is probably sourced from the Afon Alaw (fines) and the adjacent sand flats of Traeth y Gribin (sand). This suggests that the southern estuary and Afon Aluw are at or nearing capacity whereas the northern estuary still has some capacity for sediment accumulation. Plume generation: Unknown but unlikely.
	Verdict on significance: Based on the available evidence the estuary is a strong sink for sand sized sediment south of Four Mile Bridge and a weak sink north of four Mile Bridge, this change is due principally to sediment availability. The morphology of the coast adjacent to both the north and south mouths is embayed showing that sediment interactions with the open coast will be limited in scale to the area local to the estuary mouth. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as marginal in terms of the interaction with the open coast.

Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: marginal Step 3, therefore, from EGT5, process issues are considered to be Grade A
Stage 1 Step 4: significance of management issues (EGT4)	It is likely that the Stanley Embankment and the Four Mile Bridge exert some control on the hydrodynamic and sedimentary regimes and the future management of these structures will impact on the estuary regime. The harbour wall at Holyhead currently provides shelter from NW waves. A small amount of land around Holyhead has been reclaimed.
	Verdict on significance: Marginal, the harbour wall at Holyhead provides significant shelter to offshore waves from the NW and possibly hinders the transport of sediment into and out of the estuary. Although the embankments cause significant impacts on tidal processes and morphology within the estuary it is unlikely that these impacts will extend to the adjacent open coast.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as Marginal. *Therefore from Step 5 of EGT5, the Alaw Estuary scores 1 in terms of overall significance and should be included in the SMP process.*

12.3 Discussion

Overall the interactions between the Alaw Estuary and the open coast can be summarised as follows:

1. The Alaw has a large volume and a large tidal range and as such water exchanges with the open coast are significant. The standing wave at the Stanley Embankment and Four Mile Bridge indicates that tidal currents are strong. Freshwater flows are very low for an estuary of this size and the impacts of freshwater flow are unlikely to extend significantly beyond the intersection of the Afon Alaw with the main body of the estuary.
2. The Alaw is a strong sink for sand sized sediment in the southern part of the estuary and a weak sink in the northern part of the estuary. The presence of headlands along the adjacent coast suggests that interactions will be limited to the open coast area immediate to the northern and southern mouths of the estuary.
3. Although the harbour wall will modify wave propagation into the estuary the morphology of the open coast suggests that longshore transport along the adjacent coast is low and therefore the wall is unlikely to ignorantly impact on sedimentary interactions between the open coast and the estuary. The hydrodynamic and morphological impacts caused by the embankment and bridge within the estuary will not extend to the open coast.

Interactions between the Alaw and the open coast are significant and management issues need to be considered and as such it is recommended that the Alaw is included within the SMP. A significant barrier to wave processes and sediment transport is provided by the Stanley Embankment in the north estuary and the Four Mile Bridge in the south estuary, this is shown by the lack of intertidal deposition within the Inland Sea compared to the areas seaward of these barriers. Because of this it could be argued that these crossings provide a suitable SMP limit. However, because of the nature of the estuary in this section whereby it forms a strait with two mouths it is considered necessary to consider this section throughout its entire length.

Aerial photographs show evidence of sand deposition up-estuary of the intersection between the Afon Alaw and the main estuary. This indicates that sediment interaction with the open coast extends into this part of the estuary and hence it is proposed that this part of the estuary is also included within the SMP to a point just down-estuary of Llanfachraeth.

The proposed SMP boundary should be placed at positions shown in Figure 10.

13. Traeth Dulas

This section represents a conceptual understanding of the Traeth Dulas Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

Traeth Dulas is illustrated in Figures 1 and 11.

13.1 Conceptual Understanding

Traeth Dulas is situated on the east coast of Anglesey and is orientated along a northeast to southwest axis. The mouth of the estuary is constrained by a rock headland on the south and a sand spit extending from a short sandy beach in the north. Upstream of the mouth another spit extends across the estuary from the south, this spit is vegetated by sand dunes and has some saltmarsh in its lee. The open coastline is typified by coves and pocket bays separated by high cliffs, this indicates that interaction between the estuary and the open coast will be restricted to the small beach immediately north of the estuary mouth.

Up-estuary the Traeth Dulas has a large intertidal area which almost completely dries out at low water. The upper part of the estuary is characterised by saltmarsh, a small track and ford crosses this saltmarsh area.

Analysis of the wave climate at Moelfre (to the south of the estuary mouth) shows that the predominant swell direction is from the north-northeast (0-30˚N) (Halcrow, 2002) and wave induced longshore drift along the east coast of Anglesey is in a north to south direction (CCBC *et al*, 2002), this is also indicated by the spit on the northern shore of the estuary. The spit extending from the southern shore could have been formed by tidal currents (CCBC *et al,* 2002). The shallow bathymetry and protection afforded by the spits at the mouth means that waves are unlikely to propagate into the estuary and the estuaries fetch is too small for significant sized waves to generate within the estuary.

The tidal range within the estuary is not known although it is likely to be macrotidal, Moelfre to the south of the estuary has a mean spring tidal range of 6.6m (UKHO, 2008). Tidal flow speeds for the estuary have not been recorded although according to Dronkers parameter the estuary is ebb dominant. The Afon Goch is not gauged and consequently flow speeds are not known, the river looks small on OS maps and aerial photographs and consequently probably does not have a significant flow.

The total estuary area is small amounting to some 103ha and almost all of this is intertidal. The spits at the mouth of the estuary have sheltered the estuary from waves and some saltmarsh (21ha) is situated in the upper reaches of the river and in the lee of the southern spit and rock outcrop. The large intertidal area suggests that there is no scope for further sediment accumulation and suggests that although the estuary has been a sink for sand and silt in the past it is likely to be a very weak source for sediment. The historic sources of sand would largely have been from the large offshore supply adjacent to the coast (BGS, 1990). Fine sediment could also be released from the eroding clay cliffs to the north and transported into the estuary via longshore transport (CCBC *et al*, 2002) and also transported into the estuary from the Afon Goch.

13.1.1 Response to Sea Level Rise

The estuary is poorly understood but the large supply of sediment suggests that the estuary will respond to a rise in sea level by warping up and maintaining its position in the tidal frame.

13.1.2 Assessment of Tidal Locking

The CFMP shows no evidence of flooding from tidal locking within Traeth Dulas (EA, 2008b). The morphology of the estuary is natural and the available evidence indicates that freshwater flows from the Afon Goch are low, because of this it is unlikely that flooding as a result of tidal locking will occur.

13.1.3 Summary of Key Processes and Morphology

The mouth of the estuary is controlled geologically by a headland and two sand spits which reduce the estuaries exposure considerably and provide a principal control on the estuaries morphology. The large supply of sand offshore means that these spits are likely to be maintained into the future with sea level rise. If the spits do breakdown the exposure of the inner estuary will be increased although the headland will still continue to provide some protection in its lee, overall the headland is the primary control on the estuaries form. The estuary is largely natural throughout and heavily infilled with sediment.

13.2 Estuaries Assessment

Estuary	Traeth Dulas
Location	Eastern Anglesey, North Wales.
Classification	3a – Ria with spits.
Main characteristics	Macrotidal, small estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Ynys Enlli to Great Ormes Head, Llandudno Shoreline Management Plan (CCBC et al, 2002)
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: Traeth Dulas is considered to be small in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has very large intertidal zone relative to its total area; a small amount of saltmarsh is also present. Channel length: The length of the estuary is considered to be small. Mouth cross-sectional area: The estuary has a large moderate cross-sectional mouth area. Mouth width: The estuary has a small mouth width. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are unknown. % Area: Overall the estuary has a very large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities are unknown. Tidal prism: 6 590 000m^3
	Verdict on significance: The estuary is small in volume and size and although it has a large tidal range is unlikely to exchange a large amount of water with the adjacent coast. Freshwater flows are not gauged although aerial photographs and OS mapping shows the river to be small and therefore impacts from freshwater flow on the local coast will be small in extent Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as marginal with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: Based on the morphology of the estuary and the Dronkers parameter the estuary is likely to be ebb dominant. Morphological features: Traeth Dulas is a small area which is almost completely infilled at low water. Spits extend from both sides of the estuary mouth and the south side of the estuary is constrained by a rock headland. The spits afford some protection to the estuary allowing saltmarsh to grow in the upper reaches of the estuary and the lee of the southern sand spit. The open coast is characterised by rocky coves and pocket beaches, this indicates that interactions with the open coast do not extend beyond the beach and eroding cliffs immediately to the north of the estuary. Source sink relationship: Based on the current morphology it is likely that the estuary was historically a sink for both sand and fine sized sediment. The sand sized sediment was probably sourced from the seabed offshore and the adjacent beach to the north of the mouth. Fine sediments where probably sourced from the eroding clay cliffs to the north of the estuary mouth and the Afon Goch. The estuary appears to be at capacity with respect to sediment accumulation and therefore it is likely to be a weak source of sediment to the open coast. Plume generation: Unknown but unlikely.
	Verdict on significance: The morphology of the open coast indicates that interactions between the estuary and the adjacent coast do not extend much further than the estuary mouth. The estuary is probably at capacity with respect to sediment accumulation and therefore may export a very small amount of fine sediment to the open coast. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as marginal in terms of the interaction with the open coast.

Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: marginal Step 2 – sediment exchange: marginal Step 3, therefore, from EGT5, process issues are considered to be Grade B
Stage 1 Step 4: significance of management issues (EGT4)	The estuary is largely undeveloped and natural. Some small scale sea defences at Portobello north of the estuary mouth.
	Verdict on significance: Insignificant, the estuary and the adjacent coast are unmanaged. Sea defences to the north of the estuary mouth are unlikely to adversely affect the transport of sediment across this frontage.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade B Step 4 – Management issues assessed as insignificant. *Therefore from Step 5 of EGT5, Traeth Dulas scores 3 in terms of overall significance and does not need to be included in the SMP process.*

13.3 Discussion

Overall the interactions between Traeth Dulas and the open coast can be summarised as follows:

1. Traeth Dulas has a small volume and area and therefore tidal exchanges with the open coast will not be large. Freshwater flows are also unlikely to be important.
2. Traeth Dulas is completely infilled with sediment and therefore there is little capacity for further accumulation. The presence of headlands along the adjacent coast suggests that any interactions will be limited to the open coast immediate to the estuary mouth.
3. The estuary is natural and unmanaged; sea defences to the north of the mouth will not significantly impact sediment transport across this frontage.

Interactions between Traeth Dulas and the open coast are not significant and the estuary has no management issues because of this it is not considered necessary to include the estuary within the SMP. The proposed SMP boundary should be placed across the mouth as shown in Figure 11.

14. Menai Straits

This section represents a conceptual understanding of the Menai Straits, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Menai Straits are illustrated in Figures 1 and 12.

14.1 Conceptual Understanding

The Menai Straits are not a true estuary and separate the Isle of Anglesey from North Wales. The straits are orientated along a southwest to northeast axis.

The narrower of the two mouths is situated in the southwest and is flanked by two spits which act to constrain the mouth. It is likely that the extent of these spits is controlled by the strong tidal currents flowing through the southwestern mouth. In the lee of these spits the intertidal areas of Foryd Bay (on the north bank) and Traeth Melynog (in the south) are situated. The presence of the spits indicates significant interaction with the open coast at the southwestern mouth.

To the west of Caernarfon the shoreline on both sides of the strait comprises a shingle foreshore backed by a gently sloping backshore, to the east of Caernarfon on the south shoreline the backshore is cliffed. Further up-estuary of Y Felinheli the Strait changes character with a more northerly orientation and a narrowing in width meaning that the straits have almost no exposure to wave processes along this stretch. Between Y Felinheli and Menai the estuary remains narrow with rocky outcrops and a limited intertidal. The straits reach their narrowest point at Menai Bridge where the estuary is constrained by rocky outcrops on either side, to the east of Menai Bridge the estuary begins to widen again slightly with intertidal mudflat to the west of Bangor Pier and in the vicinity of Ynys Gaint. The Straits between Y Felinheli and Bangor Pier are formed mainly from outcropping limestone deposits on the Anglesey side of the estuary and clay cliffs on the mainland, the outcropping limestone on the north side of the strait traps fine sediment forming some small pockets of intertidal mudflat in the region of the Menai Bridge.

To the east of Bangor pier the straits open up again to form the wide intertidal northeastern mouth with the extent of the mouth situated approximately between Puffin Island and Llanfaiffechan. The coast between Beaumaris and Puffin Island comprises soft clay cliffs that are eroded by wave action and supply fine sediment to the Straits. The southern coast along this part of the straits is characterised by rock and sand / shingle beaches backed by low lying land and fronted by the large sandy intertidal area of Traeth Lavan. Outside the northeastern mouth the coast to the north is rocky and cliffed indicating little interaction between the coast and the strait. On the south side the coast forms a long intertidal beach with a net westerly sediment transport direction (CCBC *et al*, 2002) indicating that this stretch of coast supplies sand to Traeth Lavan.

The wave climate in the Menai Straits is not available although the orientation and aspect of the Straits indicates that waves will propagate into the estuary mainly at its wide northeastern end.

The presence of spits at the southwestern end of the estuary and the narrow width of the straits between Bangor Pier and Y Felinheli means that wave activity will be limited.

Because of the two mouths and the morphology of the straits, the tidal levels and propagation are very complex. Tidal ranges within the Menai Straits are macrotidal and increase in range towards the northeasterly end. The mean spring tidal range is 4m at For Belan, 4.8m at Y Felinheli, 6.6m at Menai Bridge and 6.8m at Beaumaris (UKHO, 2008). The section of the strait between Belan and the Menai Bridge acts like a hydraulic channel whereby the tidal flow is controlled almost entirely by the tidal levels at each end (George, 2006). This means that when the level is relatively higher at Fort Belan the tidal stream runs northeastward (the flood) and when water levels are relatively higher at Menai Bridge the water runs southwestward (the ebb) (George, 2006). Tides are particularly complex in the area of the straits between the Britannia and Menai Bridges, the area is rocky and narrow with tidal speeds reaching 4.5m/s. The slope of the sea surface is large in this area reaching 0.5m/km and is capable of forming waterfalls and standing waves (George, 2006).

The direction of tidal flows throughout the semi diurnal tidal cycle are complex and well studied. Overall a net residual flow to the southwest has been identified (Harvey, 1968 and Simpson *et al*, 1971) with a tidal excursion on spring tides of 14km. As the Strait is 25km in length this large tidal excursion ensures that the Strait is well flushed with water from the Irish Sea (Kratzer *et al*, 2003).

A number of rivers flow into the Menai Strait these include the Afon Braint at Traeth Melynog, the Afon Carrog and Afon Gywrfai at Foryd Bay, the Afon Seiont at Caernarfon, the Nant y Garth at Y Felinheli, the Afon Cadnant at Menai Bridge, the Afon Cegin at Bangor, the Afon Ogwen at Tal-y-Bont, the Afon Aber at Abergwyngregyn and the Afon Llanfairfechan at Llanfairfechan. Both the Seiont and the Gywrfai are gauged and have small freshwater flows relative to the size of the Menai Straits. The average flow of the Seiont was 4.85m^3/s between 1976 and 2006 and the average flow of the Gywrfai was 2.26 m^3/s between 1970 and 2005 (CEH archive).

The total area and intertidal areas are not available for the entire Menai Straits and assessment of OS maps and aerial photographs indicate that much of the estuary between Menai Bridge and Y Felinheli have little or no intertidal area and instead are characterised by a narrow rocky foreshore. Some intertidal information is available for the following areas that form individual discrete intertidal areas within the Straits:

14.1.1 Foryd Bay

This is a large intertidal area on the south bank of the southwestern mouth of the Menai Strait and is formed behind the spit that extends northwards across the Menai Strait. Foryd Bay has a large intertidal area (285ha) compared to its total area (343ha) and a large proportion of the intertidal is saltmarsh (123ha). The sediment within Foryd Bay is principally sand and the large ratio of intertidal suggests that the area has historically been a sink for sediment and has little capacity to absorb further sediment.

14.1.2 Traeth Melynog

This is similar to Foryd Bay but situated on the opposite bank of the Menai Straits. As for Foryd Bay the intertidal area (314ha) is large compared to the total area (365ha) only a relatively small proportion of the intertidal is saltmarsh (66ha). The sediment within Traeth Melynog is principally sand and the large ratio of intertidal suggests that the area has historically been a sink for sediment and has little capacity to absorb further sediment. Traeth Melynog is backed by the extensive sand dunes of Newborough Warren. The spit has been extending in length since the 1800s as a result of coastal erosion to the northwest.

14.1.3 Traeth Lavan

This large intertidal sand flat area is situated between Bangor and the mouth of the Menai Straits, it has a core area of 3040ha and an intertidal area of 2932ha. Little is known about the processes operating on these sandflats although it is clear that they represent a large sink of sand sized sediment in the Menai Strait.

14.1.4 Summary

Because of the size and diverse morphology of the study area it is helpful to sub-divide the Menai Straits into five distinct zones based on the above data.

Zone 1: The southwestern mouth of the Menai. This area is characterised by two intertidal sandflats (Foryd Bay and Traeth Melynog) protected by the spits that extend across the Menai Straits.

Zone 2: East of Caernarfon to Y Felinheli. This area has relatively strong tidal currents and some intertidal sandflats, the spits at the mouth provide some shelter from significant wave action in this area of the Strait. The intertidal sandflats may source sediment from the adjacent Newborough dune complex. The foreshore generally comprises shingle and scree in the west and mud / clay to the east.

Zone 3: Y Felinheli to Menai Bridge. This area has a small intertidal rocky foreshore with some mud and clay backed by cliffs, the channel is narrow and is dominated by strong tidal currents.

Zone 4: Menai Bridge to Bangor Pier. At this point the Strait widens and some intertidal mudflat is present. The foreshore tends to be backed by cliffs

Zone 5: Traeth Lavan. This area is a large intertidal sandflat at the wide northeastern mouth of the estuary, because of its exposure, wave processes as well as tidal processes are likely to be important in this area. The coast on the northern part of the strait is typically cliffed (except at Beaumaris) and fronted by a combination of mud and clay to the west and sand and shingle in the east. Along the southern part of the strait the coastline has a low aspect fronted by a rocky foreshore with some sand and shingle to the east.

14.1.5 Response to Sea Level Rise

Due to the diverse morphology throughout the Menai Strait and the complicated hydrodynamic processes the response of the area is difficult to predict with certainty. In addition although the hydrodynamics of the estuary are well described there is little information on sediment dynamics.

Firstly it seems likely that the areas of Foryd Bay and Traeth Melynog (Zone 1) will maintain pace with sea level rise as the large intertidal areas suggest that there has historically been sufficient sediment sources to allow significant accretion in these areas. This response will depend greatly on the behaviour of the spits, as large amounts of sand are present offshore (BGS, 1990) it is likely that these features will be maintained into the future and will continue to provide protection to the intertidal areas in their lee. A historical analysis would help confirm the morphological behaviour of these features. The sediment supply for the intertidal sandflats in Zone 2 is probably related to the adjacent Newborough dune complex (although there is no evidence to confirm this) and hence it is suggested that there is sufficient sediment for these features to be maintained into the future. Some erosion of the gravel foreshore has been recorded within Zone 2 (Halcrow, 2002) and this would continue with sea level rise although roll back would be halted by the hinterland possibly leading to coastal squeeze.

The area of the straits between Y Felinheli and Menai Bridge (Zone 3) are dominated by complicated tidal processes and hence changes are difficult to predict. A simple response can be conceptualised whereby the intertidal area decreases as a result of sea level rise. If a rise in sea level causes the hydraulic gradient to increase this may result in greater tidal flows through the estuary and potentially impacting the adjacent areas of the Menai Straits. The south coast has historically experienced localised erosion in places (Halcrow, 2002) and this would continue and possible worsen with sea level rise and the steeper hinterland will prevent the roll back of the intertidal. The northern shore is predominantly hard rock so little change is expected.

It is possible that the fine sediment comprising Bangor flats is sourced from the rivers Ogwen, Cadnant and Cegin although there is no evidence with which to confirm this. It is likely that a proportion of the sediment is also supplied from the eroding soft clay cliffs around Beaumaris. If sediment is from these sources the mudflats can be expected to warp-up in response to sea level rise.

The sediment supply to Traeth Lavan (Zone 5) is not clear although the large area indicates a plentiful historical supply probably from the east. There is some supply available from offshore and the adjacent coast to the east and therefore the intertidal is likely to warp-up in response to sea level rise. A detailed sediment budget of this area would help resolve this with more certainty.

14.1.6 Assessment of Tidal Locking

The CFMP has identified a risk of flooding as a result of tidal locking at both Caernarfon (Afon Seiont and Cadnant) and Bangor (Afon Adda) although the reasons for this are not discussed in detail. With an increase in sea level rise it is possible that tidal locking at these locations will become more frequent. Evidence for flooding due to tidal locking at the other rivers discharging into the Menai Strait could not be found. As the other watercourses tend to be unconstrained with low discharge levels the risk of flooding through tidal locking is considered to not be significant.

14.1.7 Summary of Key Processes and Morphology

Due to the large size of the straits the study area has been split into 5 zones:

Zone1: The southwestern mouth of the straits is principally controlled by the large shingle and sand spits extending from both shorelines across the mouth. In the lee of these spits large intertidal areas are present with areas of saltmarsh. The morphology of this part of the estuary is dependant on the behaviour of the spits, as there are large amounts of potential sediment available on the adjacent coast and offshore it is possible that the spits can be maintained into the future thereby continuing to shelter the intertidal areas in the lee.

Zone 2: Up estuary of the southwestern entrance the strait is relatively wide with a narrow shingle foreshore and gently sloping backshore, up-estuary of Caernarfon the backshore is more cliffed. Some intertidal sandflats are also present offshore. Some localised shoreline erosion has been occurring here and it is likely that this will increase with sea level rise. It is likely that the spits offer some protection from wave activity to this part of the straits.

Zone 3: To the east of Y Felinheli the coastline is more cliffed and therefore the backshore is generally geologically controlled and fixed in place by rocky outcrops, the foreshore is generally narrow and generally comprises mud/clay and rock. The orientation of this part of the Menai Straits means that it is sheltered from wave energy and tidal processes dominate. The south coast has historically experienced some localised erosion which could worsen with sea level rise.

Zone 4: Between Menai Bridge and Bangor Pier the shoreline also has a cliffed backshore (apart from Bangor) and therefore the overall shape of the straits is geologically controlled in this area. A number of large intertidal mudflats are present in this area. The source of this sediment is not known but it is likely to be from Liverpool Bay, the eroding cliffs and the small rivers flowing into the study area, there is likely to be a continued supply of sediment and therefore the intertidal mudflats will accrete in line with sea level rise. This part of the estuary is likely to be more exposed to waves propagating into the study area from Conwy Bay.

Zone 5: The Principal feature in this unit is the large expanse of intertidal sandflat (Traeth Lavan) which is likely to continue to accrete into the future. The coast is open to waves propagating into the study area from Conwy Bay although Lavan Sands provides some protection. The backshore along the south coast is low lying and therefore may be susceptible to inundation with sea level rise.

14.2 Estuaries Assessment

Estuary	Menai Strait
Location	Between Anglesey and North Wales.
Classification	Strait.
Main characteristics	Macrotidal.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Ynys Enlli to Great Ormes Head, Llandudno Shoreline Management Plan (CCBC et al, 2002)
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Menai Straits has a small area compared to its length. Intertidal area: The estuary has a small intertidal zone relative to its total area; a small amount of saltmarsh is also present although its spatial distribution is varied with many parts of the Straits devoid of saltmarsh. Channel length: The length of the strait is considered to be large. Mouth cross-sectional area: The estuaries cross-sectional mouth area is unknown. Mouth width: The estuary has a small mouth width in the southwest and a large mouth width in the northeast Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are low the average flow of the Seiont was 4.85m3/s between 1976 and 2006 and the average flow of the Gywrfai was 2.26 m3/s between 1970 and 2005 (CEH archive). % Area: Overall the estuary has a very low % area although in Zones 1 and 5 (in the vicinity of the 2 mouths) the intertidal ratio is very high indicating that these areas nearly dry out at low water. Tidal velocities: Tidal velocities are large and can reach 4.5m/s. Tidal prism: Unknown.
	Verdict on significance: Tidal velocities are extremely high and therefore the discharge of the Menai Straits is considerable and likely to have a considerable impact on the adjacent coast. There are numerous rivers entering the straits although many of these have a low fluvial flow and therefore the impacts of these rivers are considered to be negligible. Overall in accordance with EGT2, in terms of water exchange, the strait is assessed as significant with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: Due to the nature of the strait it is difficult to assign a net tidal asymmetry. Morphological features: The strait has a diverse morphology which is largely controlled by tidal processes. Both entrances are characterised by large areas of intertidal sandflats and the southwestern entrance is constrained by two sand spits. The central part of the estuary is characterised by a narrow rocky channel with limited intertidal and exceptionally fast tidal currents. Source sink relationship: Based on the current morphology it is likely that the mouths of the strait were historically a sink for both sand and fine sized sediment. The sand sized sediment was probably sourced from the seabed offshore and the adjacent beach outside the mouths of the strait. Fine sediments were probably sourced from the rivers flowing into the strait and some cliff erosion. These intertidal areas estuary appear to be nearing capacity with respect to sediment accumulation and therefore it is likely to be a weak sink for sediment. The status of the central parts of the strait is unclear although rapid tidal currents will keep sediment in suspension and consequently little sediment is likely to be deposited. Plume generation: Unknown but likely due to high tidal currents.
	Verdict on significance: Although the strait has a low intertidal area overall parts of the estuary are significant sinks for sand and to a lesser extent fine sized sediment. This sediment is largely sourced form outside the estuary and therefore shows evidence of potential interactions with the coast. It is possible that the strait also supplies some sand and silt to the open coast through the southwestern entrance. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as significant in terms of the interaction with the open coast.

Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: significant Step 2 – sediment exchange: significant Step 3, therefore, from EGT5, process issues are considered to be Grade A
Stage 1 Step 4: significance of management issues (EGT4)	The estuary is largely undeveloped and natural. Bangor Pier and Port Penrhyn are likely to present a constriction to flow through the northeastern mouth of the estuary.
	Verdict on significance: There are little management issues that are likely to impact on interactions with the open coast and therefore management issues are termed insignificant.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as insignificant. *Therefore from Step 5 of EGT5, the Menai Strait scores 2 in terms of overall significance and should be included in the SMP process.*

14.3 Discussion

As the Menai Strait is not a true estuary it is difficult to apply the Appendix F assessment to the watercourse. Overall the interactions between the Menai Straits and the open coast can be summarised as follows:

1. The Menai Strait has extremely strong tidal currents and a large tidal range and as such exchanges large volumes of water with the open coast at both mouths.
2. The strait has a number of large intertidal sinks and along with the morphological features present at both mouths suggest that large amounts of sediment are exchanged with the adjacent open coast.
3. There are a number of management practices and some development within the estuary although these have not been large enough to impact significantly on the adjacent open coast.

Due to the nature of the strait with mouths at both ends it is considered necessary to include the entire strait within the SMP process. All the rivers flowing into the strait where considered as part of the screening exercise, the Afon Seiont at Caernarfon, the Nant y Garth at Y Felinheli, the Afon Cadnant at Menai Bridge, the Afon Cegin at Bangor, the Afon Ogwen at Tal-y-Bont, the Afon Aber at Abergwyngregyn and the Afon Llanfairfechan at Llanfairfechanwere where all termed to have limited or negligible impact on the open coast and therefore all these rivers do not need to be considered further upstream than there mouths.

The exceptions to this are the Afon Braint at Treath Melynog and the Afon Carrog and Afon Gywrfai at Foryd Bay. As both Foryd Bay and Traeth Melynog are significant sediment sinks that interact with estuaries southwestern mouth it is considered that they should both be included within the SMP. The rivers flowing into these areas are small in extent and it is proposed that the SMP extent should be placed at the point where the rivers become more fluvial in nature as shown in Figure 12.

15. Conwy Estuary

This section represents a conceptual understanding of the Conwy Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Conwy is illustrated in Figures 1 and 13.

15.1 Conceptual Understanding

The Conwy is situated on the north coast of Wales and the estuary is orientated along a north to south axis. The mouth of the estuary is situated between the town of Deganwy (in the east) and the sand dune feature of Morfa Conwy (in the west) which constrain the mouth. The estuary mouth opens out into Conwy Bay with the main deep water channel flowing westwards across the large intertidal area of Conwy sands. The open coast to the west is characterised by intertidal sandflats and beaches, to the east the Great Orme extends out to the north thereby enclosing Conwy Sands and preventing further interaction with the adjacent coast to the east.

Up-estuary the Conwy is constrained at the bridges crossing where an embankment has been built halfway across the estuary and three bridges built over the remaining stretch of water to carry rail, car and pedestrian traffic across the Conwy. The embankment will locally increase flow speeds at this point due to the constraint on the estuaries width. However, as the embankment was constructed on rock outcrops (Knight and West, 1975) the estuary has probably always been constrained to some degree in this area.

Up-estuary of the bridges (in the area adjacent to Glan Conwy) the estuary widens, although this area has been reduced in area through the reclamation of 100ha of the estuary using spoil excavated during the construction of the Conwy tunnel between 1986 and 1993 (CCBC, 2002). The east side of the estuary is also fixed by the Conwy Valley railway line which was constructed in 1879 (CCBC, 2002). To the south of Conwy along the west side of the estuary there is little evidence of human interference with the estuary form although a flood embankment has been constructed to the north of Tal-y-Cafn (CCBC, 2002).

Wave conditions at Kimnel Bay (to the east of the Great Orme) show that the predominant swell direction is from the north-northwest (300-330˚N) (Halcrow, 2002) although the presence of the Great Orme and the narrow estuary mouth will limit the amount of swell that can propagate into the estuary from the Irish Sea.

The Conwy Estuary is macrotidal with a mean spring tidal range of 6.8m at Conwy (UKHO, 2008). Detailed measurements of the tidal regime were made over a typical spring and neap tidal cycle in 1975 and showed that the tidal limit is situated at Llanwrst where HW is reached 1.2hrs after HW at the mouth (Knight and West, 1975). At the estuary mouth the flood and ebb tides during neaps are of a similar magnitude (0.8m/s) and duration. During spring tides a marked asymmetry has been recorded at the estuary mouth showing higher peak velocities during the flood (1.85m/s) when compared to the ebb (1.5m/s) and a longer duration ebb tide (8hrs). At Glan Conwy the east channel has higher maximum velocities during the flood and the west channel has higher maximum velocities during the ebb. Further up-estuary at Tal-y-Cafn a similar pattern is exhibited as at the mouth with the spring flood greater than the ebb (0.6 and 0.4 m/s) and of a shorter duration (3 and 9.5hrs respectively). A deployment at Tal-y-Cafn Bridge over a 9 day survey period during spring tides in February 1996 also showed higher velocities during the flood tide (Simpson *et al*, 2000) The Afon Conwy is a moderately sized river with an average flow rate of 18.86 m^3/s measured between 1964 and 2006 (CEH archive).

The estuary has a moderate area of 764ha and a large proportion of this is intertidal with an area of 628ha (Halcrow, 2002). There is also some saltmarsh within the estuary amounting to 105ha, the saltmarsh is distributed in the lee of the bridge embankment and on the east bank up-estuary of Glan Conwy. The large intertidal area suggests that there is little scope for further sediment deposition and that the estuary has historically been accreting.

The mixture of sand and mud sediment within the estuary indicates a probable historic small sand supply from the open coast and a proportionally significant supply of mud from fluvial sources. Although a detailed description of sediment transport processes within the Conwy is not available the measured tidal currents within the estuary can be used to give an indication of the net sediment transport directions during the tidal velocities recorded at the mouth in 1975. The threshold of motion for a typical sand grain of 250µm can be estimated at around 0.4m/s (Soulsby, 1997) and although the flood tide has a higher peak velocity the ebb tide appears to sustain a longer period of flow at and above this speed at the estuary mouth and therefore there it is likely that the estuary is currently not importing sand sized sediment from the open coast. This is in agreement with tidal asymmetry calculated according to the Dronkers parameter which indicates that the estuary is ebb dominant at the mouth (Halcrow, 2002). To determine the net asymmetry of fine sediment the duration of slackwater is important as it determines the length of time the fine sediment has to fall out of suspension, the determination of the slackwater duration was not possible using the available tidal data.

A more detailed analysis would be required to fully determine the net sediment transport direction although based on the available data it is likely that the estuary is a very weak sink for fluvial derived fines and also possibly a source of fine sediment for the open coast with plume creation possible throughout most of the tidal cycle (Halcrow, 2002).

15.1.1 Response to Sea Level Rise

The large intertidal ratio suggests that the Conwy Estuary is currently only a very weak sink for fine sediment and the analysis of tidal currents indicates that the estuary is not a net importer of sand. With sea level rise the scope for further sedimentation will increase and it is likely that the supply of fines from the Conwy will be able to meet this demand. A detailed sediment budget and study of sediment transport within the Conwy would help to clarify the estuaries response to sea level rise.

The spit at the mouth of the estuary sources sand from a large potential source so it is likely that it will continue to accrete with sea level rise.

15.1.2 Assessment of Tidal Locking

Flooding arising from tidal locking has been identified within the CFMP at Llandudno Junction and Conwy although this process is not described in detail (EA, 2008a) and therefore it is unclear whether this tide locking occurs within the main estuary or the tributaries. Due to the low significance of fluvial flow within the main estuary at this point it is likely that this tidal locking occurs within Afon Gyffin and the drainage channels in the Lllandudno Junction area.

The CFMP notes that the impacts of tidal locking can be detected as far upstream as Trefriw within the Conwy valley although the magnitude of this is not described. The large size of the Conwy along with moderate flow rates indicates that tidal locking is unlikely to be a significant problem in the main estuary and is more likely to impact on the smaller outfalls feeding into the estuary.

It is also noted that most of the low lying main rivers have pumped discharges into the estuaries or the sea meaning that the risk of flooding from tidal locking is not currently a problem in many areas (EA, 2008a). Overall it is likely that an increase in sea level will increase the risk of flooding as a result of tidal locking within the river outfalls at Llandudno Junction and Conwy.

15.1.3 Summary of Key Processes and Morphology

The Conwy Estuary has a narrow constrained mouth both at Morfa Conwy and the Conwy bridge and embankment. This has the effect of reducing the inner estuaries exposure to waves propagating from outside the study area. It is likely that the spit will continue to accrete with sea level rise, this factor along with the constraint at the Conwy Bridge will ensure that the estuary remains sheltered from waves into the future. Up estuary the Conwy is sinuous in plan shape and dominated by tidal processes. Sand is available from a large supply offshore and fines from the relatively large fluvial input, because of this it is likely that the estuary will accrete with sea level rise.

15.2 Estuaries Assessment

Estuary	Conwy Estuary
Location	North Wales.
Classification	3a – Ria with spits.
Main characteristics	Macrotidal, small estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Preliminary Report on Conditions in the Conwy Estuary (Knight and West, 1975).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: Conwy is considered to be moderate in terms of total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a very large intertidal zone relative to its total area; a small amount of saltmarsh is also present. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth width. Tidal range: The tidal range in the estuary is moderate to large. Mean freshwater flow: Freshwater flows are moderate with average speeds of 18.86 m^3/s measured between 1964 and 2006 % Area: Overall the estuary has a very large % area indicating that the estuary nearly dries out at low water. Tidal velocities: Tidal velocities at the mouth reach 1.85m/s during the flood and 1.5m/s during the ebb. Tidal prism: 14 500 000 m^3
	Verdict on significance: The Conwy has a large tidal range, area and volume and therefore exchanges large volumes of water with the adjacent coast. The river has a reasonably strong flow for an estuary of this size so will also be of importance Overall in accordance with EGT2, in terms of water exchange, the estuary is assessed as **significant** with respect to the interaction with the open coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: Based on the morphology of the estuary, measured tidal data and the Dronkers parameter the estuary is likely to be ebb dominant at the mouth. Morphological features: The Conwy has a very large intertidal area with some small amounts of saltmarsh coverage up-estuary of the bridge embankment and adjacent to Glan-Conwy. The mouth of the estuary is constrained by the sand dune feature of Morfa Conwy and the estuary is constrained again at the bridge embankment further up-estuary. Adjacent to the estuary mouth large intertidal sandflats (Conwy Sands) and beaches extend to the north and the west, the Great Orme to the north encloses Conwy Sands and limits sand transport from the coast to the east. Source sink relationship: Based on the current morphology it is likely that the estuary was historically a sink for both sand and fine sized sediment. The sand sized sediment was probably sourced from the seabed offshore and the adjacent beaches to the west of the mouth. Fine sediments were sourced from the Afon Conwy. The estuary appears to be at capacity with respect to sediment accumulation and therefore it is likely to be only a weak sink of fine sediment and possibly also a weak source of fine sediment to the open coast. Plume generation: Likely during all stages of the tide.
	Verdict on significance: Based on the available evidence the Conwy is only a weak source of fine sediment to the open coast which is principally derived from fluvial sources. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as **marginal** in terms of the interaction with the open coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of coastal process issues: Step 1 – water exchange: Significant Step 2 – sediment exchange: Marginal Step 3, therefore, from EGT5, process issues are considered to be Grade A

Stage 1 Step 4: significance of management issues (EGT4)	Some reclamation has occurred within the estuary at Glan Conwy. The construction of the railway embankment has probably further constricted the estuary further in the vicinity of Conwy. The construction of the railway line down the east side of the estuary has fixed the position of this shoreline.
	Verdict on significance: Marginal, some of the estuary has been reclaimed. The embankment at Conwy is likely to be constructed on a former natural constriction although the embankment is likely accentuated this impact on the regime of the estuary; it is likely that this embankment will be maintained as it carries the major rail and road links.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade A Step 4 – Management issues assessed as Marginal. *Therefore from Step 5 of EGT5, the Conwy Estuary scores 1 in terms of overall significance and should be included in the SMP process.*

15.3 Discussion

Overall the interactions between the Conwy and the open coast can be summarised as follows:

1. The Conwy has a large tidal range and a large volume and therefore exchanges large amounts of water with the coast. Fluvial flow is reasonably large and so exchanges of freshwater with the coast will also be of importance.
2. The Conwy is largely at capacity with respect to sediment accumulation and it is likely that the estuary is now only a weak source of fine sediment to the open coast. A large amount of sediment has accumulated around the estuary mouth and is held within Conwy Sands.
3. There are a number of management practices and some development within the Conwy although these have not been large enough to impact significantly on the adjacent open coast.

Interactions between the Conwy and the open coast are significant and as such it is recommended that the Conwy is included within the SMP. The large sandflats and the constrictions formed by the mouth and the railway embankment next to Conwy Castle prevent significant wave energy from propagating into the estuary and therefore the most important processes controlling interactions between the estuary and the open coast are tidal. The tidal limit of the Conwy is situated around 22km inland and as the range decreases up-estuary and becomes proportionally less important it is not considered necessary to consider the estuary to this limit. It is noted that the SMP1 limit is situated at Tal-y-Cafn, based on this coastal process assessment it is not considered necessary to include the Conwy as far as this point up-estuary.

Management issues which have the potential to impact on the tidal prism of the estuary and hence on the interactions with the open coast are the maintenance of the reclamation up-estuary of the Conwy Bridge so it is considered important to include this within the open coast SMP. Because of this the proposed SMP boundary should be placed at positions shown in Figure 13.

16. Conclusions and Recommendations

An assessment has been made of 12 estuaries within the West Wales SMP study area to determine the requirement to include each estuary in the second generation West Wales SMP. This assessment has been undertaken in accordance with Defra's shoreline management plan guidance (Defra, 2006). The estuaries considered within this document were identified following a screening exercise which assessed all major watercourses intersecting with the west Wales coast between St Anns Head and the Great Orme (Section 2 and Appendix A).

The Appendix F assessment carried out for each estuary has determined an appropriate up-estuary limit for the open coast SMP based on coastal processes. The limit for each estuary is summarised in Table 1.

Table 1. Summary of estuary assessment

Estuary Name	Should the Estuary be Included Within the SMP Process?	How Far Upstream Should the Estuary be Included?
Nyfer Estuary	Yes	Immediately upstream of the road bridge (Figure 2)
Teifi Estuary	Yes	Most easterly Cardigan Bridge (Figure 3)
Dyfi Estuary	Yes	Railway Bridge at Dovey Junction (Figure 4b)
Dysynni Estuary	Yes	Normal tidal limit (Figure 5)
Mawddach Estuary	Yes	Penmaenpool Bridge (Figure 6b)
Artro Estuary	Yes	The road bridge (Figure 7)
Glaslyn/Dwyryd Estuary	Yes	The Cob in the Glaslyn and the road/railway bridge across the Dwyryd (Figures8a-8c)
Cefni Estuary	Yes	Malltraeth sluice (Figure 9)
Alaw Estuary	Yes	Seaward of Llanfachraeth (Figures 10a-10c)
Traeth Dulas	No	NA
Menai Strait	Yes	Include entire strait as far as river mouths (Figures 12a-2f)
Conwy Estuary	Yes	Include realignment upstream of Conwy Bridges (Figure 13b)

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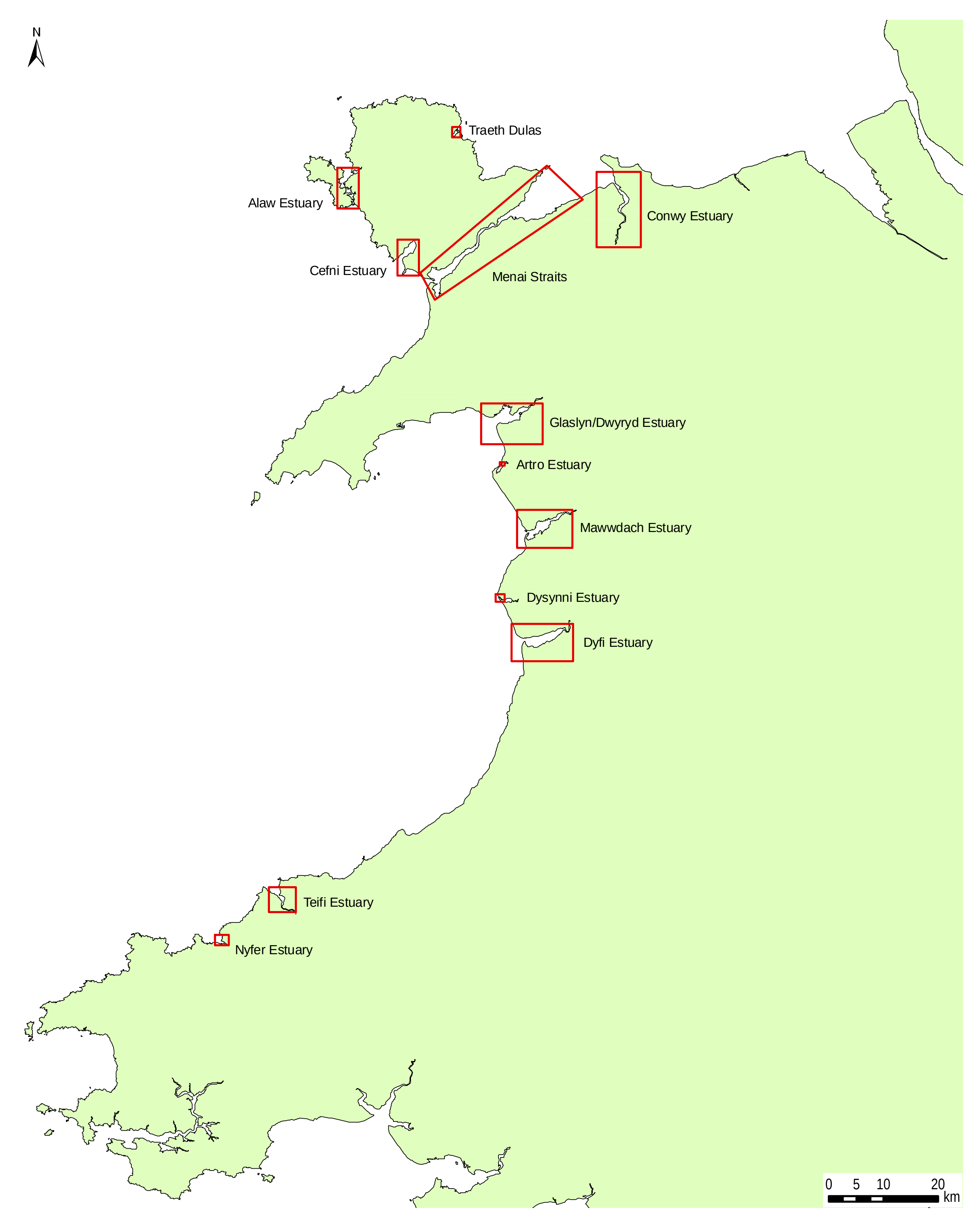
Figures



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Estuaries

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Overview of Study Area

Figure 1

Proposed Extent of SMP

Date	By	Size	Version
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Nyfer Estuary

Figure 2

Proposed Extent of SMP

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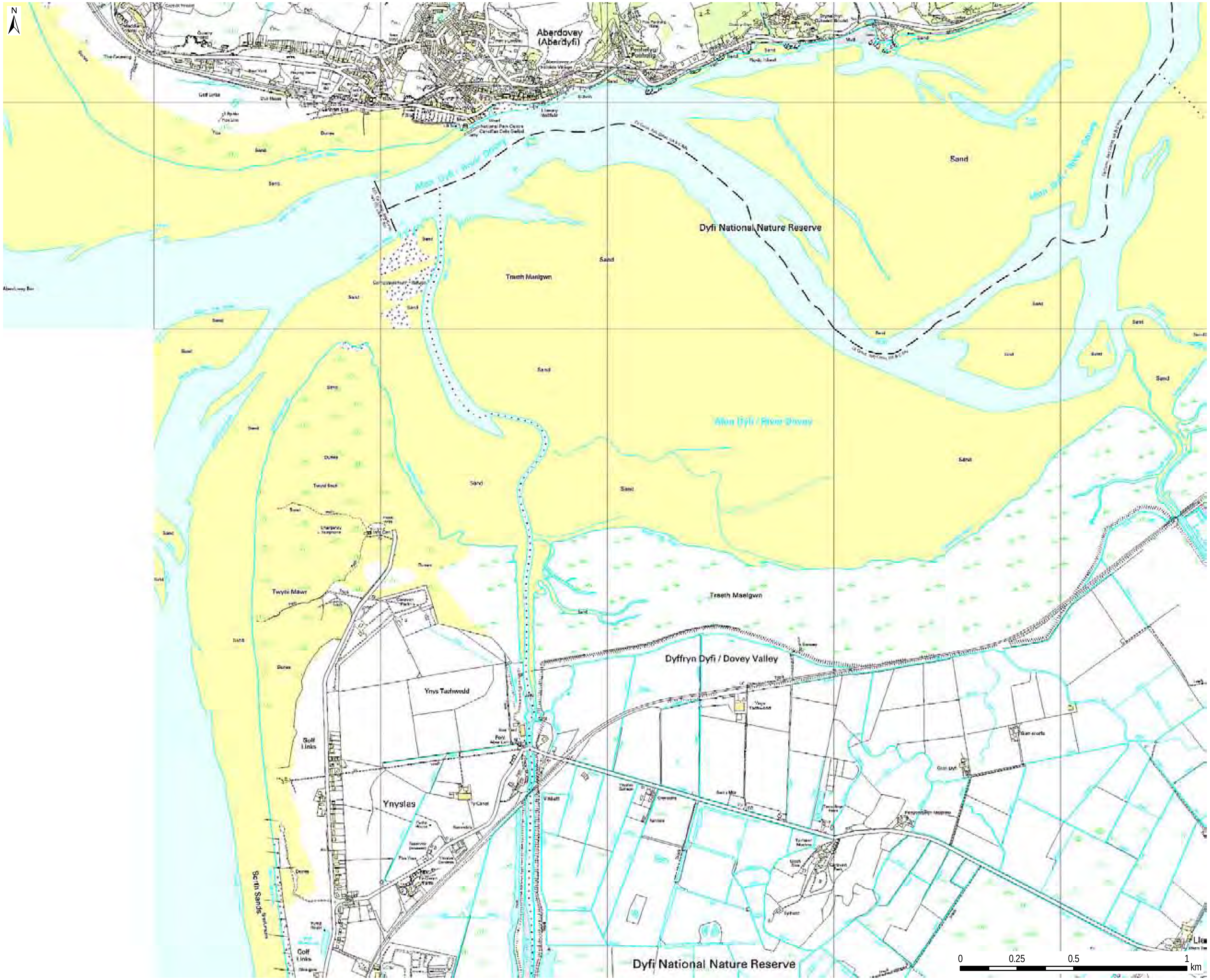
Teifi Estuary

Figure 3



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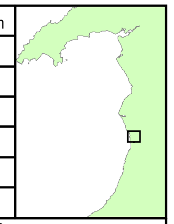

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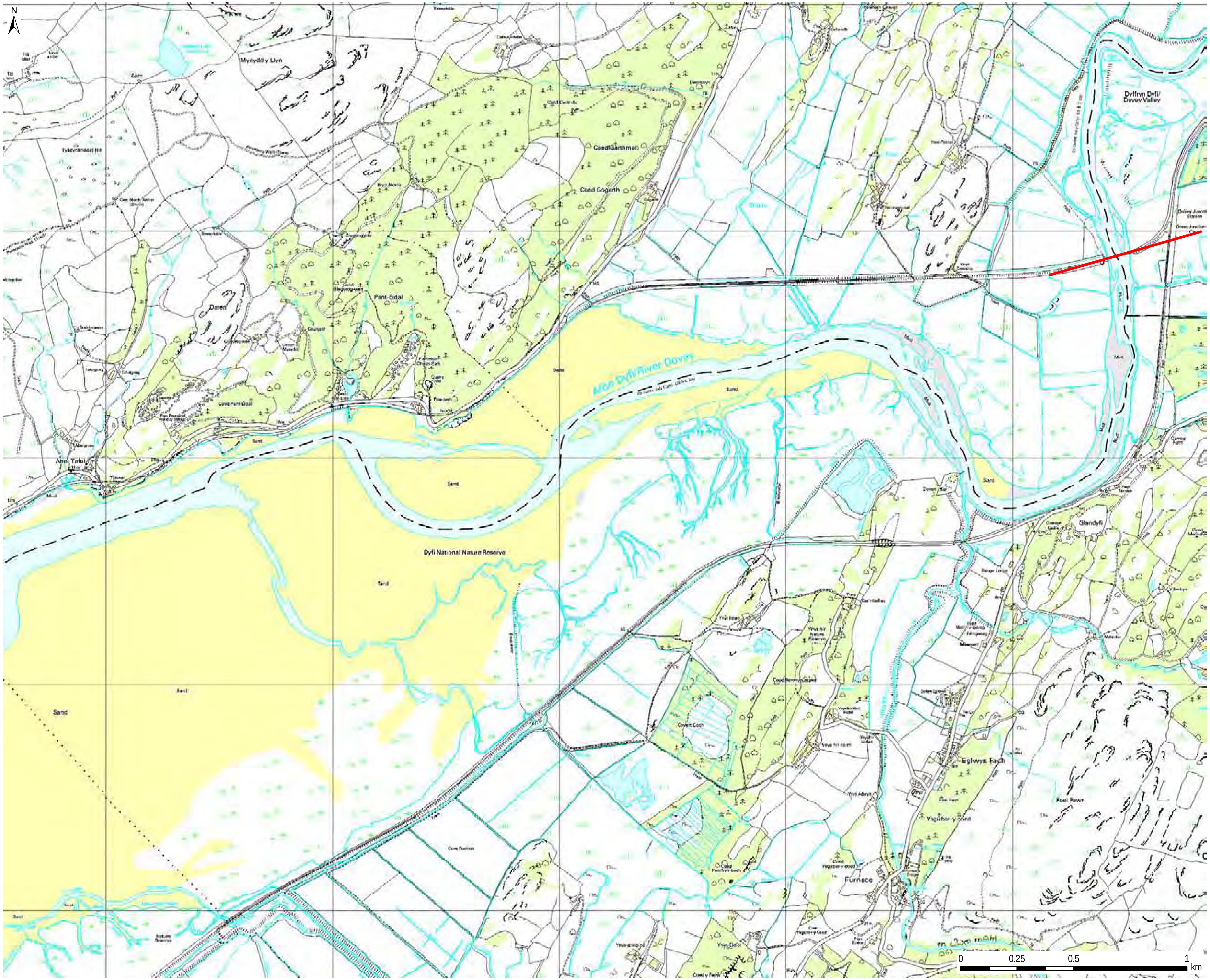
Dyfi Estuary

Figure 4a



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3862 - Fig_Dyfi_4b.mxd			
Produced by ABPmer Ltd			

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Dyfi Estuary

Figure 4b

Proposed extent of SMP

Date	By	Size	Version
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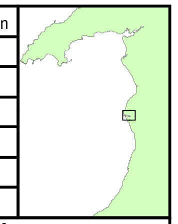
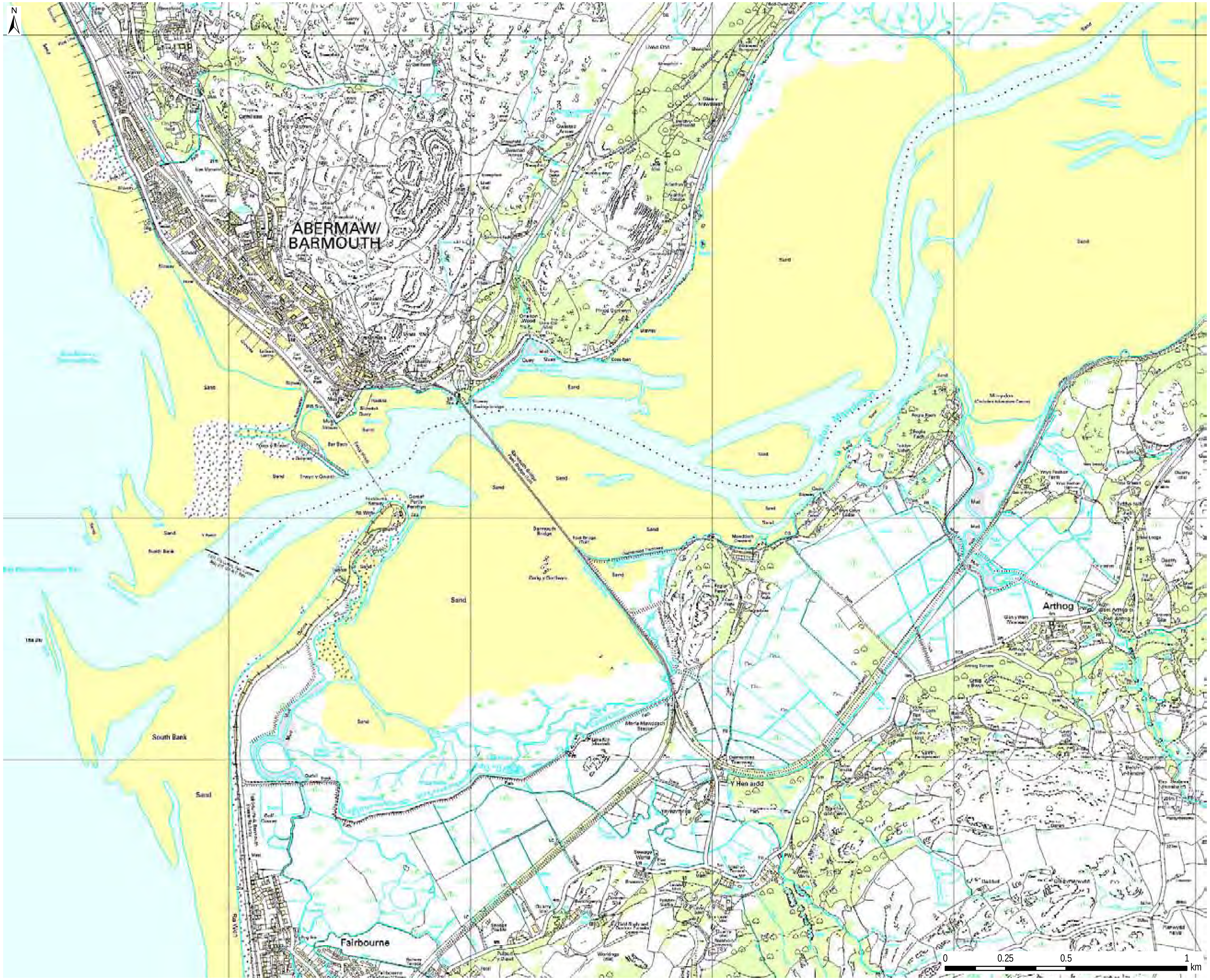


Dysynni Estuary

Figure 5



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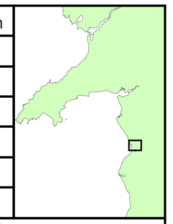
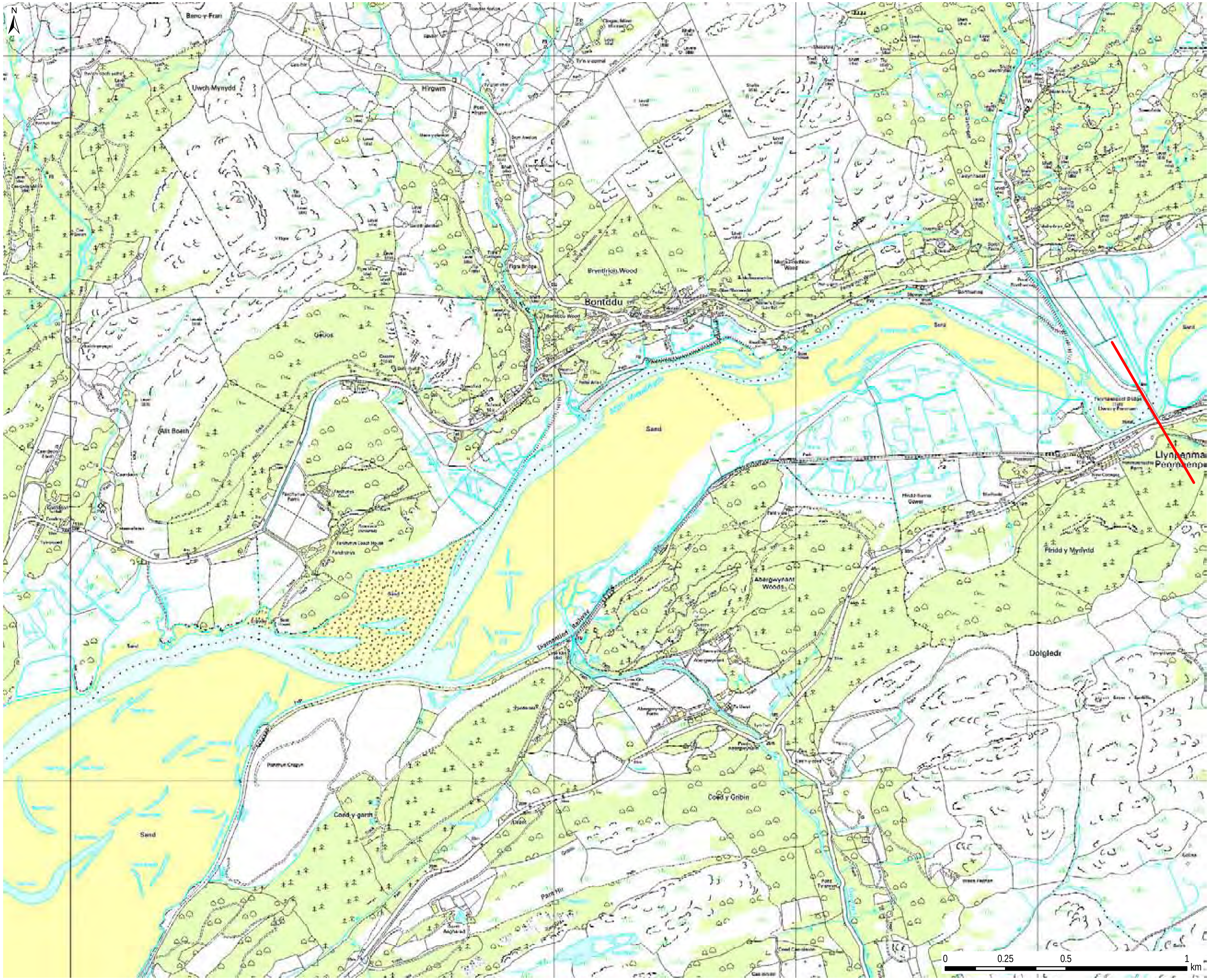


Mawddach Estuary

Figure 6a



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Mawddach Estuary

Figure 6b

Proposed Extent of SMP

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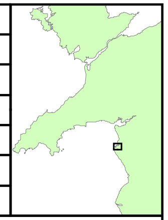

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Artro Estuary

Figure 7

Proposed Extent of SMP

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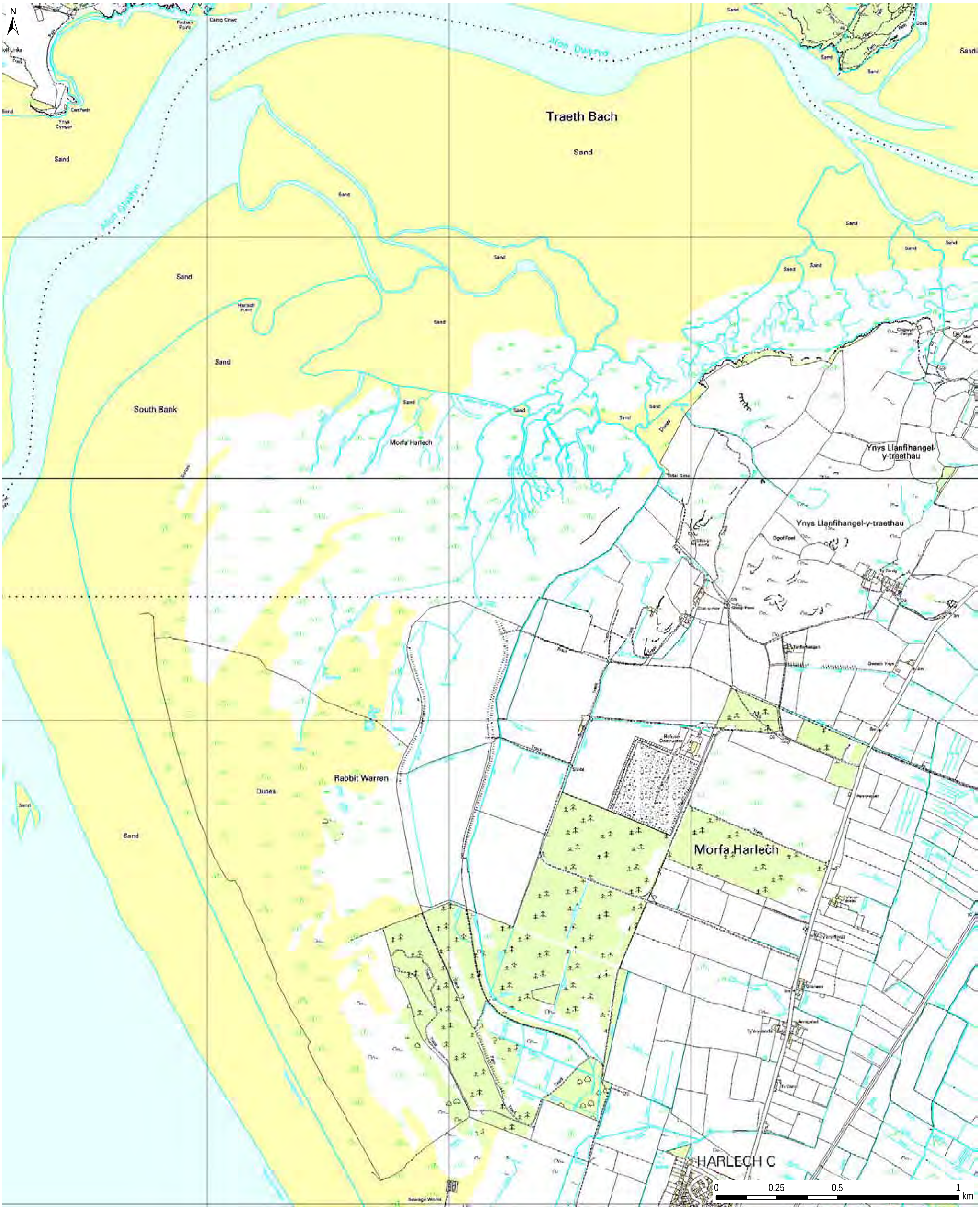
Glaslyn/Dwyryd Estuary

Figure 8a



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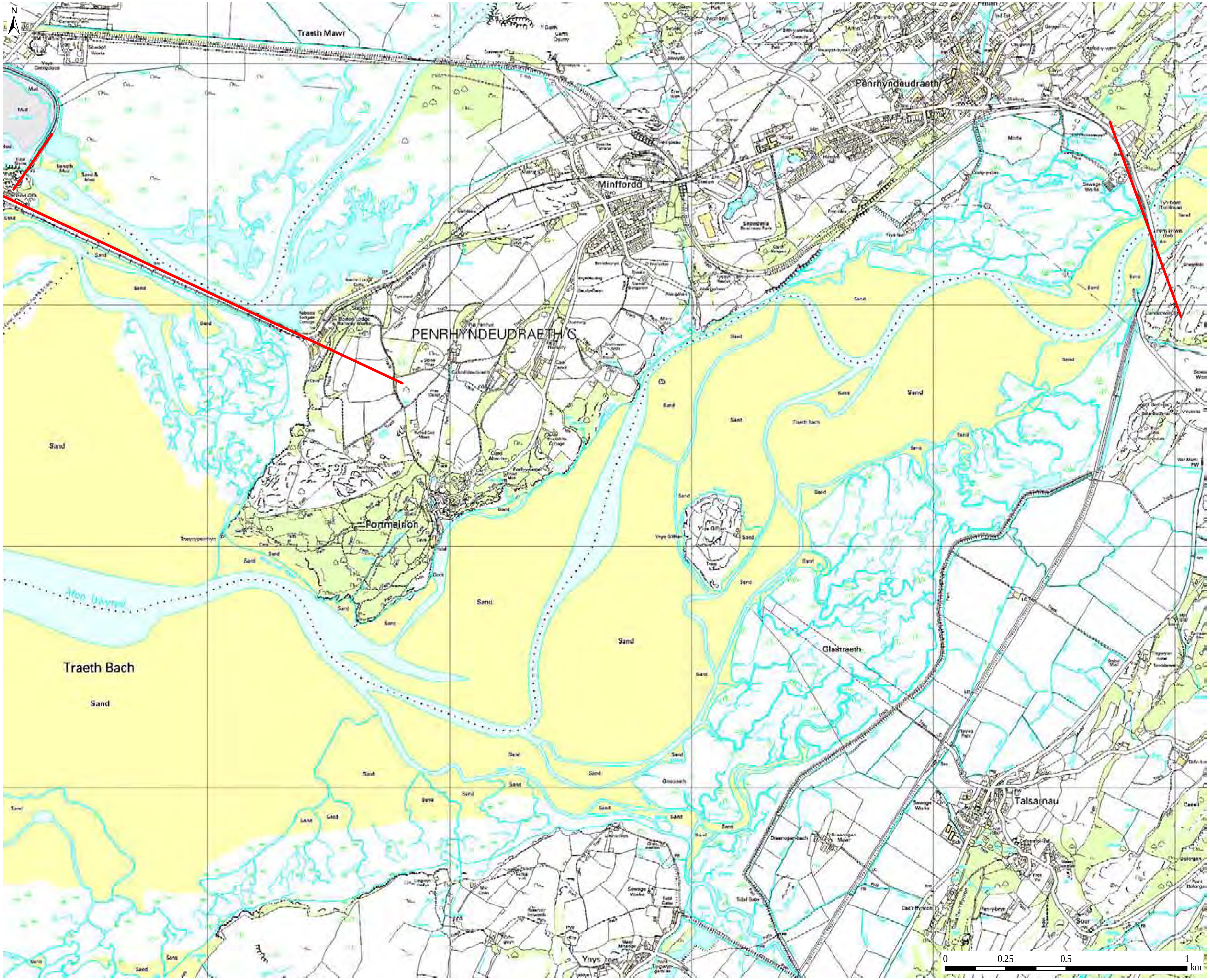
Glaslyn Estuary

Figure 8b



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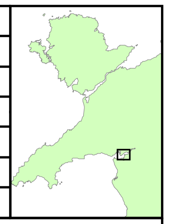

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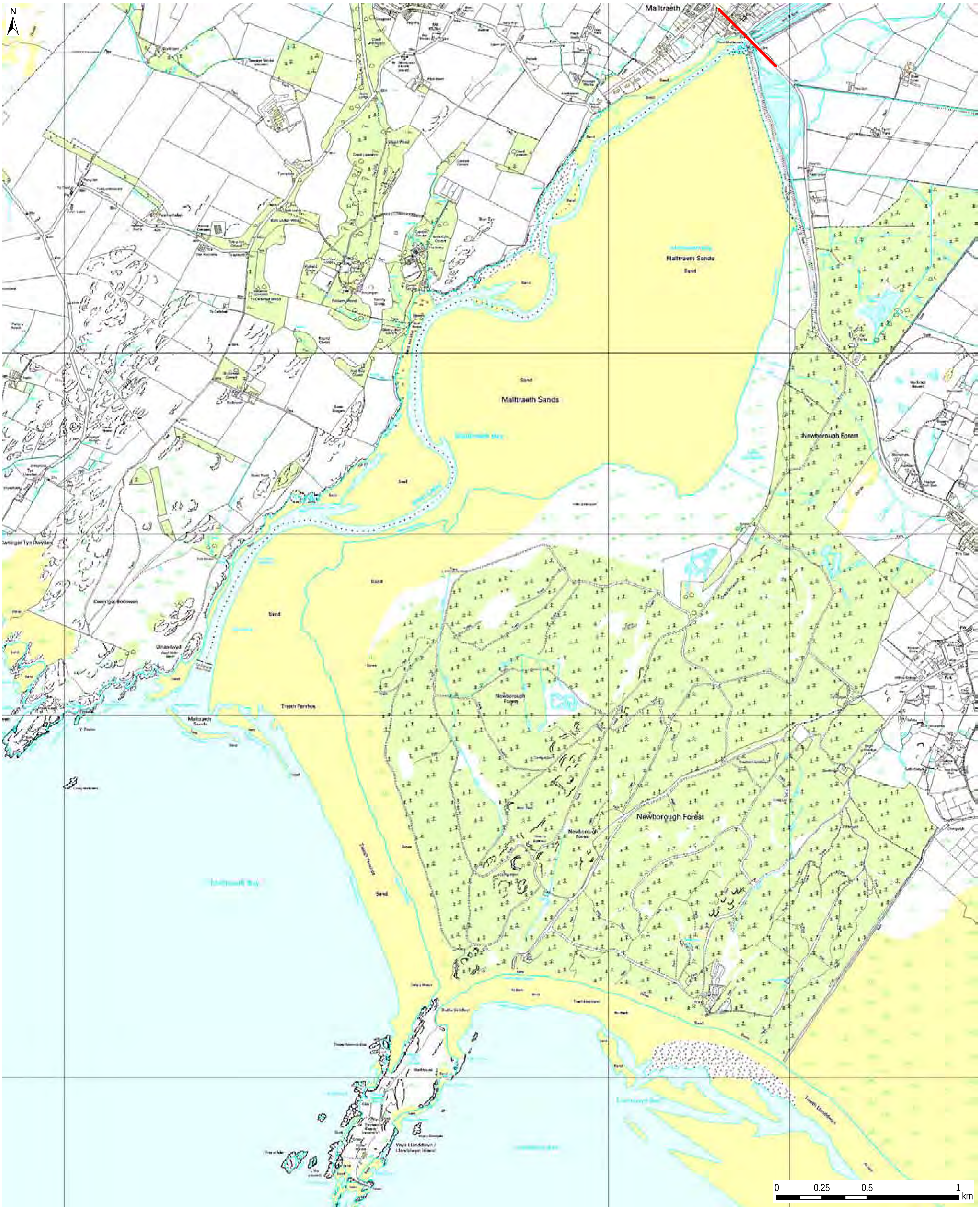
Glaslyn/Dwyryd Estuary

Figure 8c



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Proposed Extent of SMP

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Cefni Estuary

Figure 9

Date	By	Size	Version
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Projection		OSGB 1936	
Scale		1:15,000	
QA		NJG	
3862 - Fig_Alaw_10a.mxd			
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Alaw Estuary

Figure 10a

Proposed Extent of SMP

Date	By	Size	Version
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Projection		OSGB 1936	
Scale		1:15,000	
QA		NJG	
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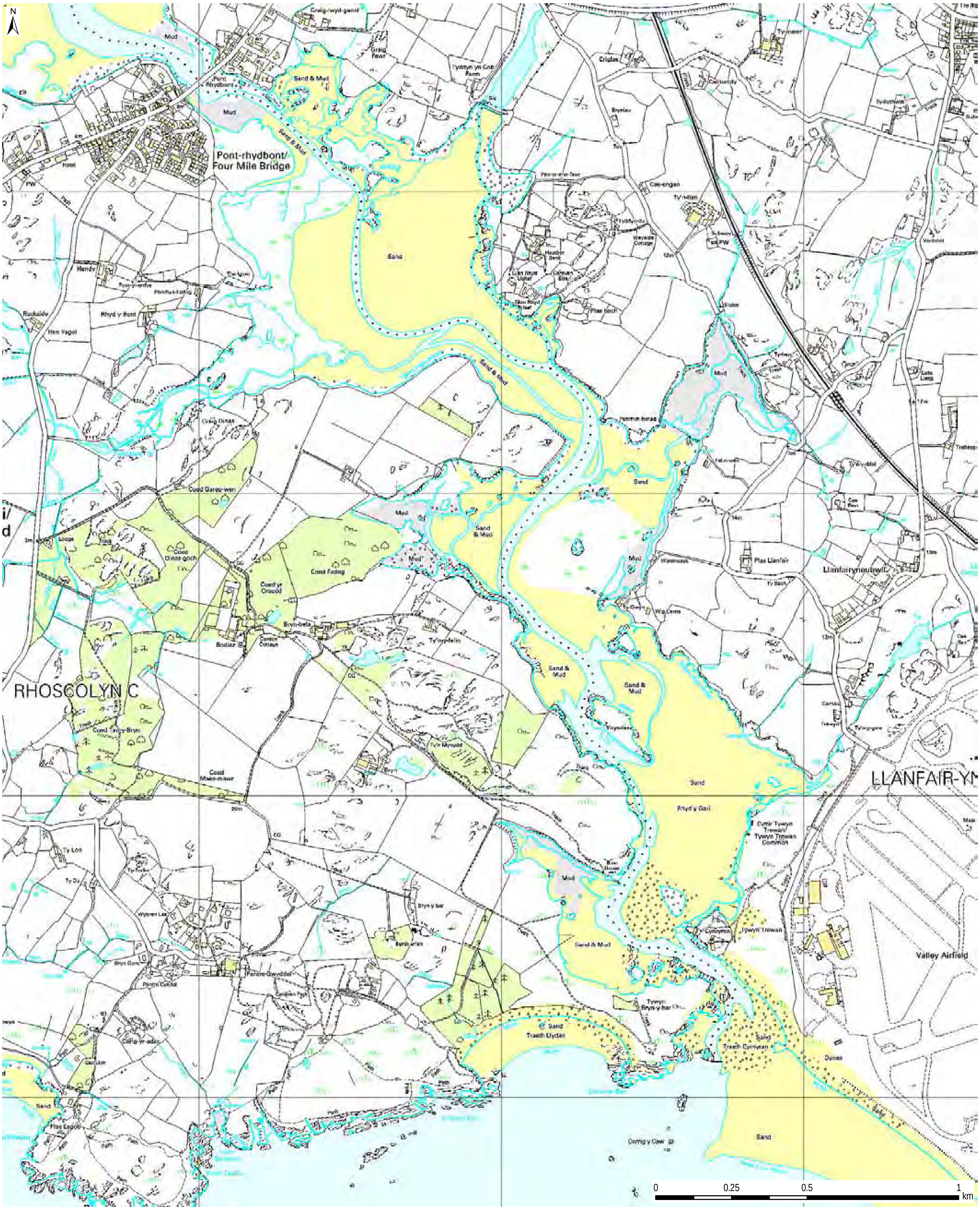
Alaw Estuary

Figure 10b



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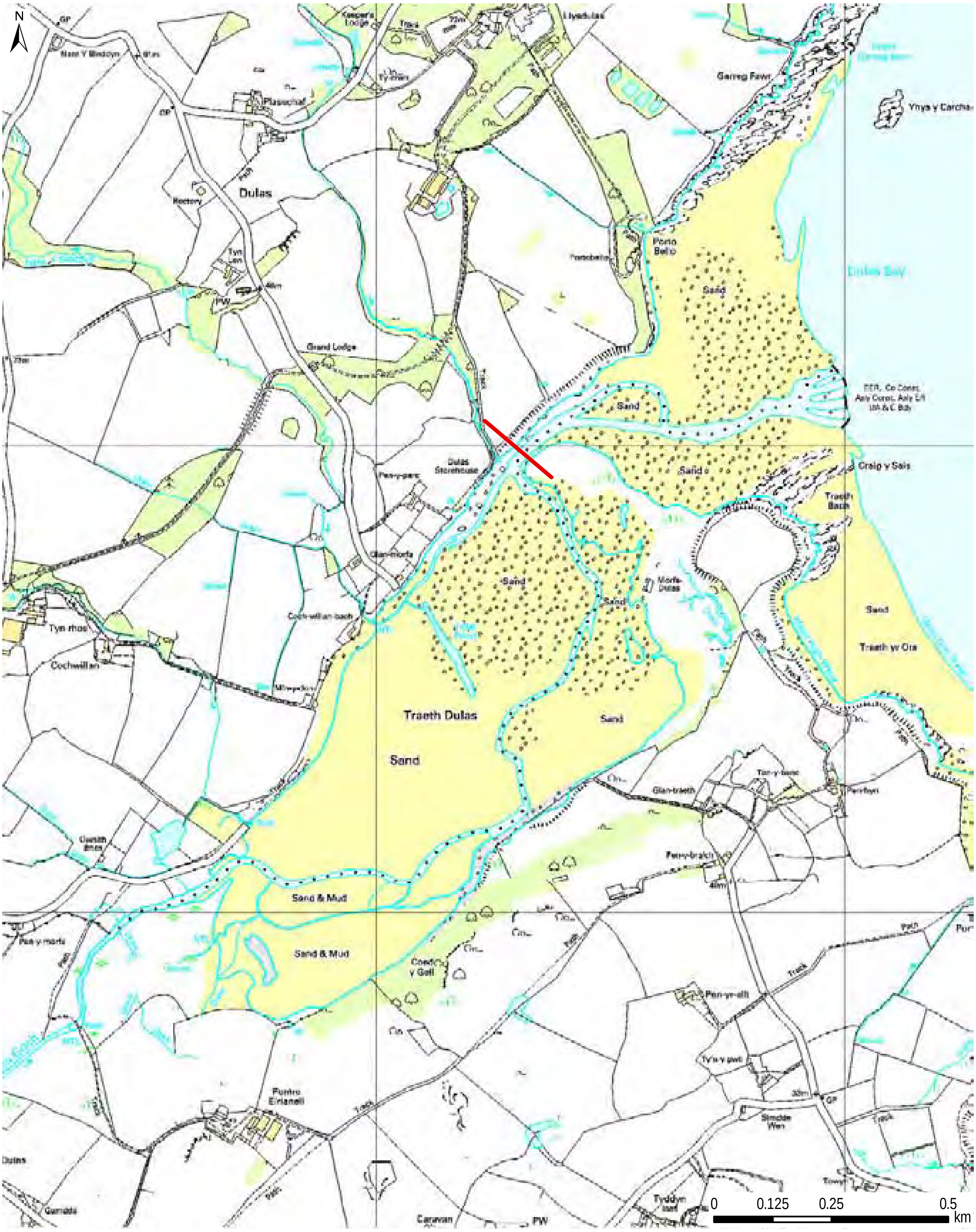
Alaw Estuary

Figure 10c



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3862 - Fig_Traeth_Dulas.mxd			
Produced by ABPmer Ltd			

Proposed Extent of SMP

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Traeth Dulas Estuary

Figure 11

Date	By	Size	Version
Sept 09	NMW	A3	1A
Projection		OSGB 1936	
Scale		1:20,000	
QA		NJG	
3862 - Fig_Menai_12a.mxd			
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Proposed Extent of SMP

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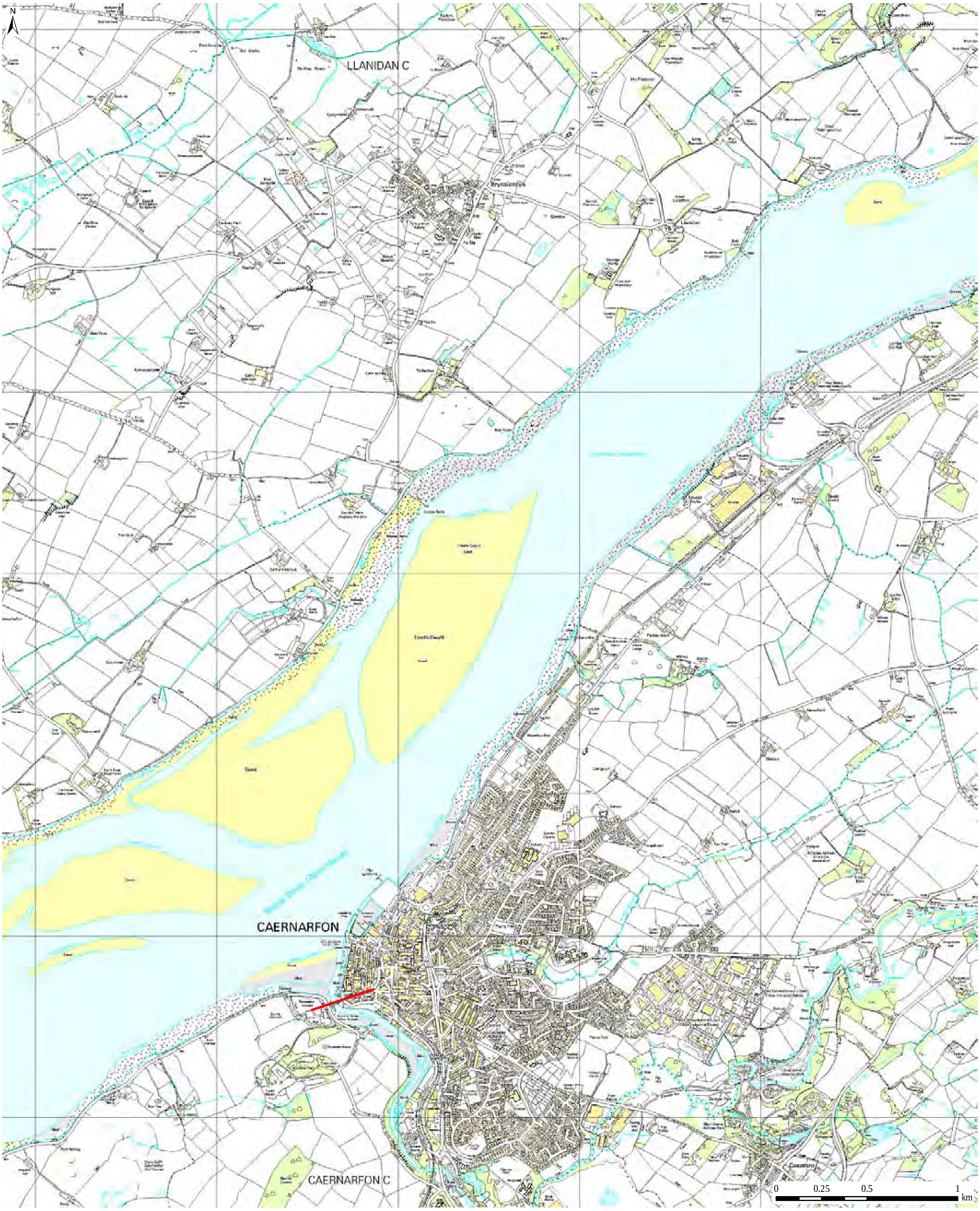
marine environmental research

Menai Estuary

Figure 12a



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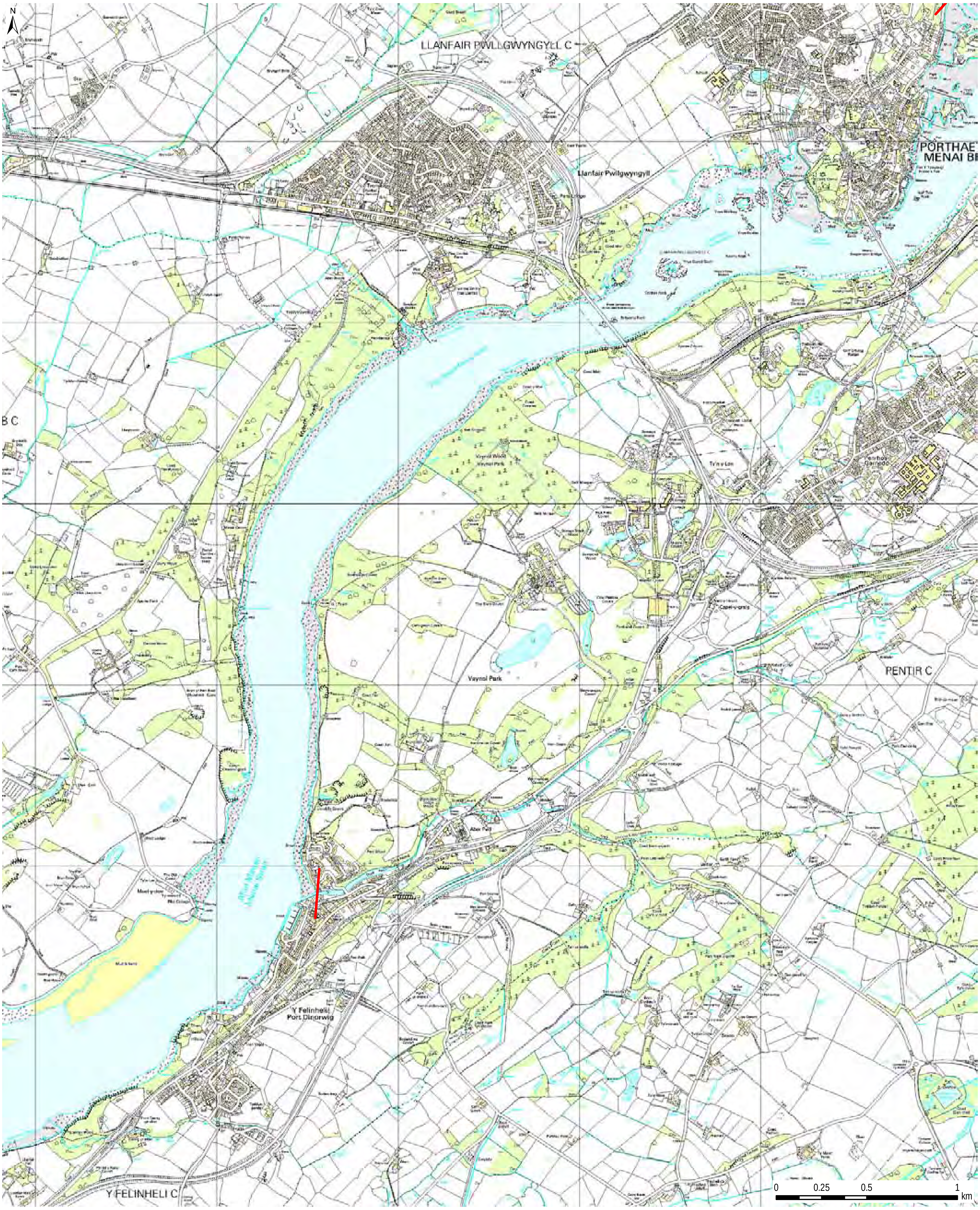
Proposed Extent of SMP

marine environmental research

Menai Estuary

Figure 12b



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Proposed Extent of SMP

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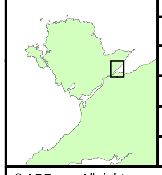
marine environmental research

Menai Estuary

Figure 12c

Proposed Extent of SMP



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Menai Estuary

Figure 12d

Date	By	Size	Version
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Scale		1:20,000	
QA		NJG	
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Produced by ABPmer Ltd			

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Menai Estuary

Figure 12e

Proposed Extent of SMP

Date	By	Size	Version
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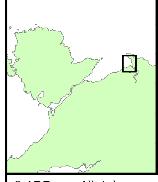
marine environmental research

Menai Estuary

Figure 12f



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Conwy Estuary

Figure 13a

Date	By	Size	Version
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Scale		1:20,000	
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Produced by ABPmer Ltd			

Proposed Extent of SMP

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marine environmental research

Conwy Estuary

Figure 13b

Appendices

Appendix A

Initial Screening of Watercourse

Appendix A. Initial Screening of Watercourse

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Bathesland Water		None	Not known	Not known	Not known	Not known	Internet Search, Google Earth.	This is a small stream flowing out across Newgale beach south of Newgale. Although there is no data to provide any quantification of its importance, assessment of Google images suggest that it is very small watercourse and hence there will be no significant interactions with the open coast. Any interactions will be very limited in extent and magnitude and unlikely to be significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at coast and no Appendix F assessment is necessary.	4
Brandy Brook		None	Not known	Not known	Not known	Not known	Internet Search, Google Earth.	This is a small river flowing out at Newgale, the river flows behind a shingle ridge on the beach. Although there is no quantifiable data with which to assess the significance of the watercourse the presence of a shingle ridge and the size of the river suggest that there is some potential for interactions between the open coast and the watercourse. These interactions will only be locally significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at coast and no Appendix F assessment is necessary.	3
Solfach Harbour (Solva)		None	Not known	Not known	Not known	Not known	CFMP, Google Earth, Internet search.	Solfach is a small ria situated next to the town of Solva with a number of intertidal sandflats towards the top of the estuary and a beach towards the estuary mouth. There is no quantifiable data available to assess the significance of the watercourse although the aerial photographs show that it is estuarine in nature and of a size to be significant in the context of the SMP. Therefore it is concluded that the Solva should be subjected to an Appendix F assessment.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Porthclais (River Alun)		None	Not known	Not known	Not known	Not known	CFMP, Google Earth, Internet search.	Porthclais is a small steep sided tidal inlet with intertidal sandflat and a harbour wall present near the mouth. There is no quantifiable data with which to assess the significance of the watercourse although it is clear from the aerial image that the River Alun is very small in magnitude. Because of the small size of the inlet and the low magnitude of fluvial flow it is considered that Porthclais should be treated as an intertidal sandflat or a small harbour as opposed to a true estuary. Therefore it is concluded that an Appendix F assessment is not necessary and the SMP boundary should be at the head of the tidal inlet.	2
River Gwaun		Cilrhedyn Bridge 22 (SN) 005 349	31.3	1.15	Not known	Not known	CFMP, UK Gauging Station Network, Google Earth, Internet search.	The River Gwaun is a relatively small river with low mean flow speed. The mouth is situated at Fishguard and appears to cut a reasonable deep channel across the wide intertidal within the harbour. The presence of this channel indicates that the watercourse will have some interactions with the open coast although this will be localised and not extend further inland. These interactions will only be locally significant in terms of the SMP Therefore it is concluded that the SMP boundary should be located at the bridge to include the harbour and no Appendix F assessment is necessary.	2
Nyfer Estuary		Not known	Not known	1.11	100	75 (Marsh:10)	Futurecoast, Google Earth, Internet Search.	The Nyfer is a medium sized estuary with its mouth situated at Newport, Pembrokeshire. The river itself has a low flow magnitude in comparison to the estuary size. The estuary has a relatively large intertidal area compared to the total estuarine area and the presence of a wide intertidal sandflat at the mouth of the estuary suggests that interactions with the open coast are likely within the confines of the rocky headlands. These interactions and the size of the watercourse have the potential to be significant in terms of the SMP. It is therefore considered that an Appendix F assessment should be undertaken.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Teifi Estuary		Teifi at Glan Teifi 22 (SN) 244 416	893.6	28.89	200	180 (Marsh: 46)	SMP1, CFMP, UK Gauging Station Network, Google Earth, Internet search.	The Teifi is a medium sized estuary at Cardigan on the Afon Teifi. The estuary has a large intertidal area comprising mudflats, sandflats and small areas of saltmarsh. The river has a relatively large flow magnitude. Sand spits are present at the mouth and suggest the potential for significant interactions with the open coast at least within the confines of the rocky headlands. These interactions and the size both the river and the estuary have the potential to be significant in terms of the SMP. It is therefore considered that an Appendix F assessment should be undertaken.	1
Nant Gilwen Nant Howni		None	Not known	Not known	Not known	Not known	SMP1, Google Earth.	These are small streams that flow to sea at the western end of Traeth Dolwen (Aberporth). Although no quantifiable information is available the aerial images show that Interactions with the open coast are unlikely and therefore the watercourse is not significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Saith		None	Not known	Not known	Not known	Not known	SMP1, Google Earth.	This is a small stream at Tresaith Beach. Although no quantifiable information is available to assess the significance of this watercourse the aerial image shows this is a very small watercourse with no evidence of interactions with the open coast. Hence it is considered that the watercourse is not significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Unknown		None	Not known	Not known	Not known	Not known	SMP 1, Google Earth.	A small stream to the western side of Llangranog Beach. Aerial imagery suggests that the watercourse is small and there is no evidence for interactions with the coast. It is therefore considered that the watercourse is not significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Nant Hawen								Small stream through central part of Llangranog Beach, exiting through a culvert to the sea just west of the shingle bank. Aerial imagery suggests no evidence for interactions with the coast and the watercourse is not considered significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Ffynnon-Ddewi		None	Not known	Not known	Not known	Not known	SMP1, Google Earth.	Small stream flows out to the south west of Cwmtydu Cove, the stream forms a small lagoon behind the beach spit. There is no evidence of interactions with the open coast in the aerial photo and the watercourse is not considered to be significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Halen		None	Not known	Not known	Not known	Not known	SMP1 Google Earth	Small stream cuts a deep valley through the unstable boulder clay cliff along Traeth Gwyn. There is no evidence of interactions with the open coast in the aerial imagery. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Gido								Small stream flows out to sea at Llanina Point. There are some signs of interaction with open coast evident through morphology seen in the aerial imagery; these interactions will only be locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m³/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Afon Cwinten		None	Not known	Not known	Not known	Not known	SMP1 Google Earth	This is a small stream cutting a deep valley in the boulder clay cliff. The aerial photo shows no evidence of interactions with the open coast and is not considered significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Ceri Brook								This is a small stream flowing as a waterfall over hard cliff. The aerial photo shows no evidence of interactions with the open coast and is not considered significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Aeron		None	Not known	Not known	Not known	Not known	SMP1, CFMP, Google Earth, Internet search.	The Aeron River flows through the harbour at Aberaeron. The presence of large harbour arms illustrates the potential for interactions between the open coast and the river. The current SMP boundary is situated at the westernmost road bridge based on the Schedule 4 boundary. It is considered that although no quantifiable information is available the Aeron has the potential to interact significantly with the coast and as such is significant in terms of the SMP. It is concluded that although the Aeron should be included as part of the SMP no Appendix F assessment is required and the boundary should be set at westernmost road bridge to enable inclusion of harbour within SMP.	2
Arth		None	Not known	Not known	Not known	Not known	SMP1, CFMP, Google Earth, Internet search.	The Arth is a medium sized river flowing through Arth village and across the beach through coastal defences. The end defence has been constructed over a former north-west pointing shingle spit. The former presence of a spit and the size of the river suggest that some interaction between the coast and the watercourse is likely. However, these interactions are likely to be limited in magnitude and localised and hence the watercourse is only considered locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Nany Morfa		None	Not known	Not known	Not known	Not known	SMP 1, Google Earth	This is a small stream south of Llanon. No information has been found to quantify the significance of the watercourse although the aerial imagery indicates that it is small with no evidence of any interaction with the coast hence it is considered to not be significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Cledan		None	Not known	Not known	Not known	Not known	SMP1, Google Earth	This is a small stream, flows out to sea south of Llanon; the mouth is blocked by a shingle bank forming a small lagoon. There is no evidence of any interaction with the coast and hence it is considered to not be significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Cwm Peris								A small stream that flows out north of Llansantffraed, holds up drift of shingle on foreshore thereby reducing erosion locally therefore some evidence of interactions with the open coast but will be very limited in extent and magnitude. The watercourse is only considered locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3
Afon Wyre		Wyre at Llanrhystyd 22 (SN) 542 698	40.6	1.01	Not known	Not known	SMP1, CFMP, UK Gauging Station Network, Google Earth, Internet search.	The river has a relatively low average flow magnitude which flows across beach at the northern end of Llanrhystud Bay. There is some evidence of influence on open coast processes with shingle bank and spit developing therefore the watercourse is considered to be locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m³/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Aberystwyth Estuary		Ystwyth at Pont Llolwyn 22 (SN) 591 774	169.6	6.02	Not known	Not known	Futurecoast, SMP1, CFMP, UK Gauging Station Network, Google Earth, Internet search.	The Ystwyth flows behind Tan-y-Bwlch shingle bank before joining the harbour at Aberystwyth. Hence, the behaviour of the shingle bank will be important to the river and the river is considered to be potentially significant in terms of the SMP. No Appendix F assessment is required and the recommended SMP boundary should be at the point at which the river turns inland behind the shingle bank to allow for impacts of the movement of the shingle bank on the river to be considered (same as SMP1).	2
		Rheidol at Llanbadarn Fawr 22 (SN) 601 804	182.1	9.09	Not known	Not known	Futurecoast, SMP1, CFMP, UK Gauging Station Network, Google Earth, Internet search.	The Rheidol Flows through Aberystwyth Harbour and joins with the Ystwyth at the harbour mouth. It is a relatively large river with the presence of harbour walls controlling interactions between watercourse and the coast it is therefore considered significant in terms of the SMP. No Appendix F assessment required. Recommended SMP boundaries at the road bridge at the back of the harbour to ensure that the harbour is considered as part of the SMP (as for SMP1).	2
Clarach		None	Not known	Not known	Not known	Not known	SMP1, CFMP, Google Earth, Internet search.	This is a medium sized river that flows along the southern side of valley before heading north behind the clay and shingle bank backing beach. The size of the river means that it will probably be locally significant in terms of coastal processes and hence only locally significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3
Nant Wallog		None	Not known	Not known	Not known	Not known	SMP1, Google Earth	This is a small stream flowing onto foreshore, the feature in the aerial photo is a Sarn which is believed to be formed largely by glacial processes and therefore does not give an indication of the significance of the watercourse. The aerial image shows no evidence of interactions with the local coast and therefore the watercourse is not considered significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Dyfi Estuary		Leri at Dolybont 22 (SN) 635 882	47.2	1.31	1090	693 (Marsh: 546)	Futurecoast, SMP1, CFMP, UK Gauging Station Network, Google Earth, Internet search.	The Dyfi is a large, wide Estuary with extensive sand and mud flats. Open coast beach is present immediately adjacent to the estuary mouth with a sand spit to the south and shows that significant interactions with the open coast are likely. The Afon Dyfi has a relatively high river flow and is likely to also be significant in the estuary processes. These interactions and both the size of the river and the estuary have the potential to be significant in terms of the SMP. It is therefore considered that an Appendix F assessment should be undertaken.	1
		Dyfi at Dyfi Bridge 23 (SH) 745 019	471.3	23.15					
Dysynni Estuary		Dysynni at Pont-y-Garth 23 (SH) 632 066	75.1	4.51	117	69 (Marsh: 22)	Futurecoast, UK Gauging Station Network, Google Earth, Internet search.	This is a narrow, straight river throughout much of its length with medium magnitude flows. The estuary is relatively small in total area although there are some relatively large areas of intertidal flats in places. The estuary morphology is unusual in that it has a very narrow mouth possibly due either to deflection by natural processes or reclamation. Changes to the morphology of the upper-estuary intertidal could have a significant impact on the mouth at the coast. Because of the unusual morphology of the mouth of the estuary and the relatively large areas of intertidal it is considered that the watercourse could be potentially significant in terms of the SMP. It is therefore considered that an Appendix F assessment should be undertaken.	1
Mawddach Estuary		Afon Mawddach at Tyddyn Gwladys 23 (SH) 735 264	63.1	3.95	522	327 (Marsh: 219)	Futurecoast, UK Gauging Station Network, Google Earth, Internet search.	This is a relatively large estuary with its mouth at Barmouth. Proportionally it has large amounts of intertidal area (sandflats, mudflats and saltmarsh). A spit is present across the mouth (south bank) which is backed by intertidal sandflat. A wooden viaduct in the vicinity of the estuary mouth, aerials show evidence of accretion around base of viaduct indicating that this has a significant control on estuarine processes. A harbour is situated on north side of the estuary mouth protected by a harbour arm. Recorded river flows from the Afon Mawddach are relatively low for an estuary of this size. Based on the size of the estuary and the morphology around the estuary mouth it is likely that there could be significant interactions between the coast and the estuary and therefore it is considered that the Mawddach is significant in terms of the SMP It is therefore considered that an Appendix F assessment should be undertaken.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Afon Ysegethin		None	Not known	Not known	Not known	Not known	Internet search, Google Earth	This is a small to medium sized river with mouth situated at Talybont. The river appears to flow behind shingle bank on beach causing deflection of flow. The size of the river and the morphology of the mouth indicate that interactions with the open coast are likely although they will be localised and limited in extent and magnitude. It is therefore concluded that the river will only be locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3
Arto Estuary		None	Not known	Not known	120	114 (Marsh: 10)	Futurecoast, Internet search, Google Earth	This is a relatively small estuary with its mouth situated to the south of Llandanwg. A large area of intertidal with sandflats, mudflats and saltmarsh is present along with areas of potential reclamation (Shell Island). Sand spits are situated at the mouth from both sides indicating coastal drift from both directions and significant interaction with open coast. A small harbour is present behind the southern spit. The estuary/river boundary ends abruptly, possible evidence of reclamation or presence of sluice. Based on the size of the estuary and the morphology of the mouth there is significant potential for interactions with the open coast and the estuary is likely to be significant in terms of the SMP. It is therefore considered that an Appendix F assessment should be undertaken.	1
Glaslyn Estuary (Traeth Bach)		Glaslyn at Beddgelert 23 (SH) 592 478	68.6	5.76	1570	1085 (Marsh: 348)	Futurecoast, UK Gauging Station Network, Google Earth, Internet search.	This is a relatively large estuary with proportionally large intertidal areas comprising sandflats, mudflats and some saltmarsh. There is a proportionally low river flow magnitude compared to the estuary size. The morphology at the mouth shows evidence for potentially significant interactions with the open coast and it is therefore considered that the estuary is significant in terms of the SMP. It is therefore concluded that an Appendix F assessment should be undertaken.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m³/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Afon Dwyfawr		Dwyfawr at Garndolbenmaen 23 (SH) 500 429	52.4	2.60	Not known	Not known	UK Gauging Station Network, Google Earth, Internet search.	This is a narrow river with small to moderate flow magnitude that flows parallel to the shoreline for 1.3km before flowing across intertidal shingle/sand beach. There is some evidence from aerial photography of interactions between river mouth and the open coast with a large intertidal present in the vicinity of the river mouth. The size of the river and the morphology of the mouth indicate that interactions with the open coast are likely although they will be localised and limited in extent and magnitude. It is therefore concluded that the river will only be locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3
Pwellheli Harbour (Afon Erch and Afon Rhyd-hir)		Erch at Pencaenewydd 23 (SH) 400 404	18.1	0.61	85	60 (Marsh: 3)	Futurecoast, UK Gauging Station Network, Google Earth, Internet search.	Pwellheli is a relatively small estuary situated behind a Crenulate Bay / Training wall (north of mouth) and a sand spit (south of mouth). Some intertidal area and saltmarsh present. The presence of sand spit and a crenulated bay indicates potentially significant interactions between open coast and watercourse although the size of the harbour precludes a full Appendix F assessment. Overall it is therefore concluded that the harbour is significant in terms of the SMP. No Appendix F assessment. SMP boundary situated at road bridge to ensure that the harbour is included within the SMP.	2
Afon Soch		None	Not known	Not known	Not known	Not known	Google Earth, Internet search.	This is a small to medium sized river with the mouth positioned at Abersoch Harbour. River flows across sandflat to the open sea. Due to the size of the river Interactions with the open coast are likely but will be limited in extent and magnitude. Although it is unlikely that the watercourse will be anymore significant than at a local level, in terms of the SMP the harbour should be included. No Appendix F assessment. SMP boundary should be set at the road bridge so that the harbour is considered within the SMP.	2

<table>
<tr><th>Name</th><th>Photo (Source: Google Earth)</th><th>Gauging Station Location</th><th>Catchment Area Upstream of Gauging Station (km²)</th><th>Mean Freshwater Flow (m³/s)</th><th>Estuary Area From (ha)</th><th>Intertidal Area (ha)</th><th>Data Sources</th><th>Discussion</th><th>Type</th></tr>
<tr><td>Afon Daron</td><td rowspan="2"></td><td rowspan="2">None</td><td rowspan="2">Not known</td><td rowspan="2">Not known</td><td rowspan="2">Not known</td><td rowspan="2">Not known</td><td rowspan="2">Google Earth, Internet search.</td><td>This is a small river with its mouth positioned at Aberdaron. The river flows across a sandy beach and aerial photographs show no evidence of significant interaction with coastal processes and therefore the watercourse is not considered significant in the context of the SMP.

Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.</td><td>4</td></tr>
<tr><td>Afon Saint</td><td>This is a small river with its mouth positioned at the west end of Aberdaron beach. The river flows across a sandy beach and aerial photographs show no evidence of significant interaction with coastal processes and therefore the watercourse is not considered significant in the context of the SMP.

Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.</td><td>4</td></tr>
<tr><td>Afon Desach</td><td></td><td>None</td><td>Not known</td><td>Not known</td><td>Not known</td><td>Not known</td><td>Google Earth, Internet search</td><td>This is a small river with mouth situated at Aberdesach. The river flows behind a small shingle bank which deflects flow slightly. The morphology of the mouth indicates that interactions with the open coast are likely although they will be localised and limited in extent and magnitude. It is therefore concluded that the river will only be locally significant in terms of the SMP.

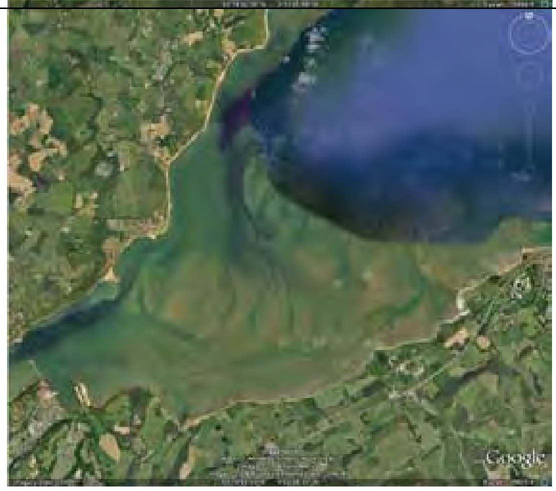
Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.</td><td>3</td></tr>
<tr><td>Afon Liyfni</td><td></td><td>None</td><td>Not known</td><td>Not known</td><td>Not known</td><td>Not known</td><td>Google Earth, Internet search</td><td>This is a small straight river with mouth situated at Pontllyfni. The aerial imagery shows there is some evidence for interactions with the open coast with intertidal deposition around the mouth although these interactions will be limited in extent and magnitude. It is therefore concluded that the river will only be locally significant in terms of the SMP.

Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.</td><td>3</td></tr>
</table>

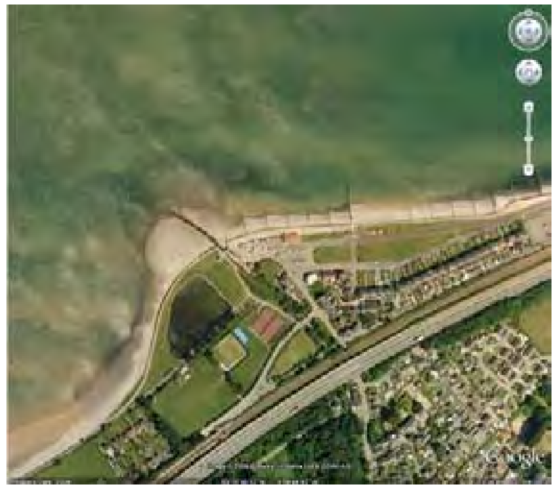
Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m³/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Gwyfai Estuary / Foryd Bay (Afon Gwyrfai)		Gwyrfai at Bontnewydd 23 (SH) 484 599	47.9	2.26	343	285 (Marsh: 123	Futurecoast, UK Gauging Station Network, Google Earth, Internet search.	This is a relatively large estuary with a large intertidal area comprising of sandflats, mudflats and saltmarsh. The estuary mouth is situated on the south bank of the Menai Strait, towards the western end of the strait. River flows are small in magnitude compared to the estuary size. The presence of sand spits and deltas at the estuary mouth indicate the potential for significant interactions with the open coast and therefore the estuary is important in the context of the SMP. It is recommended that an Appendix F assessment is undertaken (include within Menai Straits assessment).	1
Afon Seiont		Seiont at Peblig Mill 23 (SH) 493 623	74.4	4.85	Not known	Not known	UK Gauging Station Network, Google Earth, Internet search.	This is a relatively large river with moderate magnitude of fluvial flow. The mouth is situated at Caernarfon and a small intertidal area is present. The river forms a small harbour at the confluence with the Menai Strait. The size of the river indicates that interactions with the open coast are likely although they will be localised and limited in extent and magnitude. It is therefore concluded that the river will only be locally significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	3
Nant y Garth		None	Not known	Not known	Not known	Not known	Google Earth, OS Maps	This is a small stream that flows out at Y Felinheli on the south bank of the Menai Strait. The river is canalised and flows out into a rocky coast with no evidence from the aerial photos of interactions with the open coast. It is therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m³/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Briant Estuary/ Traeth Melynog/ Traeth Abermenai on OS Map (Afon Braint)		None	Not known	Not known	365	314 (Marsh: 66)	Futurecoast, Google Earth, Internet Search.	This is a relatively large estuary situated on the north bank (Anglesey) of the Menai Strait. The estuary has a large intertidal area and a proportionally small river. The intertidal area is bordered by sand to the south and dunes to the west. Some saltmarsh is present and extensive intertidal sand and mudflats. The mouth of the estuary is characterised by a large sand spit. The size of the estuary and the morphology of the mouth indicate that interactions with the coast are significant hence the estuary is thought to be important in the context of the SMP. Undertake Appendix F assessment, include within Menai Straits assessment.	1
Cadant		None	Not known	Not known	Not known	Not known	Google Earth, Internet Search.	This is a small river with the mouth situated about 1.3km east of the Menai Suspension Bridge. Discharges into the Menai Strait. The aerial image shows no evidence of interactions with the local coast and therefore the watercourse is not considered significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Cefni Estuary		Cefni at Bodffordd 23 (SH) 429 769	22.3	0.40	744	614 (Marsh: 111)	Futurecoast, CFMP, UK Gauging Station Network, Google Earth, Internet search.	This is a relatively large estuary with a wide intertidal sand flat (Malltreath Sands) and some saltmarsh on the southern bank, this wide intertidal area ends abruptly at the road bridge. River flows are very low. The large size of the estuary and the beach at the mouth indicates significant interactions with the open coast and therefore the estuary has the potential to be significant in terms of the SMP. It is recommended that the estuary is subjected to a full Appendix F assessment.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km²)	Mean Freshwater Flow (m³/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Afon fraw		None	Not known	Not known	Not known	Not known	Google Earth, Internet Search.	The Afon Fraw drains the Llyn Coron lake that is situated behind the Aberffraw dune system. The river flows down the westward side of the dunes past Aberffraw before flowing out at the west end of Aberffraw beach. The aerial photos show no evidence of significant interactions with the open coast and the watercourse is not considered significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Crigyll		None	Not known	Not known	Not known	Not known	Google Earth, Internet Search.	The Afon Crigyll is a small river that flows through the sand dunes at Rhosneigr and out across Traeth Crigyll. The aerial photos show no evidence of significant interactions with the open coast and the watercourse is not considered significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Unknown		None	Not known	Not known	Not known	Not known	Google Earth, Internet Search.	This small stream drains Llyn Maelog and flows across Traeth Llydan (Broad Beach) at Rhosneigr. The aerial photos show no evidence of significant interactions with the open coast and the watercourse is not considered significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Alaw Estuary		None	Not known	Not known	1085	721 (63)	Futurecoast, Google Earth, Internet search.	The river flows out into the channel between Holy Island and Anglesey. The mouth joins this channel just north of the main road bridge. The river has a large intertidal area near the mouth (mudflat, sandflat and some saltmarsh). The channel between Holy Island and Anglesey has a mouth to both the north and the south. The northern part is wide with intertidal sandflats, Holyhead Harbour is situated to the west. The southern part (south of four mile bridge and the Inland Sea) is narrow and comprises a very large intertidal area (mudflat, sandflat and some saltmarsh). The mouth is situated to the western end of Cymyran Bay. The scale of this estuary suggests large potential interactions with open coast and hence it is important in terms of the SMP. Undertake Appendix F assessment.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Traeth Dulas		None	Not known	Not known	103	103 (Marsh: 21)	Futurecoast, Google Earth, Internet search.	This is a small to medium sized estuary with large amounts of intertidal sandflat. The mouth appears to be constrained by a rock outcrop to the south and a sand spit is present to the north. The size and morphology of the estuary suggest the potential for significant interactions with the coast and could be significant in terms of the SMP. Undertake Appendix F assessment.	1
Traeth Coch		None	Not known	Not known	583	583	Estuary database	This is a large sand flat with a very small river running across. The fluvial input is likely to be very low and the morphology of the coast indicates that it should be considered as an embayment or a beach rather than an estuary. Because the river is so small it is unlikely to interact with the open coast and therefore it is not considered significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Traeth Lavan		None	Not known	Not known	3040	2932	Estuary Database	This is an embayment situated at the eastern end of the Menai Strait. The Afon Ogwen (see below) flows into the embayment. Very large intertidal area, the flows from the Menai Strait are likely to be large. Because of the size of the estuary it considered that there is the potential for significant interactions with the open coast and therefore Traeth Lavan is significant in terms of the SMP. It is concluded that Traeth Lavan should be included within Appendix F assessment for the Menai Straits.	1

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Afon Cegin		None	Not known	Not known	Not known	Not known	Google Earth, Internet search.	This is a small river that flows through Bangor and out into the Menai Straits at Port Penrhyn on the south bank of the Menai Strait (main land). No evidence of interactions from aerial photographs, because the river is so small it is unlikely to interact with the open coast and therefore it is not considered significant in terms of the SMP. Therefore it is concluded that the SMP boundary should be located at the coast and no Appendix F assessment is necessary.	4
Afon Ogwen		None	Not known	Not known	Not known	Not known	CFMP, Google Earth, Internet search.	Aerial imagery shows a small to medium river flowing out to the east of Bangor with a bridge over the river mouth. The channel of the river appears to be deeply incised into the fronting intertidal indicating possible interactions between he coast and the river. These interactions will only be locally significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at coast and no Appendix F assessment is necessary.	3
Afon Aber		None	Not known	Not known	Not known	Not known	Google Earth, OS maps.	This is a small river that flows out at Abergwyngrgyn on the North Wales coast in the vicinity of the Menai Straits northeastern mouth. Aerial photographs indicate there are possible interactions with the open coast with some evidence of sediment accumulation and saltmarsh colonisation around the river mouth. These interactions will only be locally significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at coast and no Appendix F assessment is necessary.	3

Name	Photo (Source: Google Earth)	Gauging Station Location	Catchment Area Upstream of Gauging Station (km^2)	Mean Freshwater Flow (m^3/s)	Estuary Area From (ha)	Intertidal Area (ha)	Data Sources	Discussion	Type
Afon Llanfairfechan		None	None	None	None	None	CFMP, Google Earth, Internet Search.	This is a small to medium sized river flowing out at Llanfairfechan, it appears to be canalised and flows across intertidal. The aerial photograph shows evidence of accretion on the vicinity of the river mouth and therefore some evidence of interaction with coastal processes. These interactions will only be locally significant in the context of the SMP. Therefore it is concluded that the SMP boundary should be located at coast and no Appendix F assessment is necessary.	3
Conwy Estuary		Conwy at Cwm Llanerch 23 (SH) 802 581	344.5	18.86	764	628 (Marsh: 104)	Futurecoast, CFMP, UK Gauging Station Network, Google Earth, Internet search.	The Conwy is a relatively large estuary with a large intertidal and saltmarsh area. River flows within the Conwy are significant relative to the size of the estuary and hence are likely to be important for estuary processes. The estuary mouth is fronted by a sandy intertidal and shows definite potential for interactions with the open coast. It is therefore considered that the Conwy is significant in the context of the SMP. Therefore it is concluded that the Conwy should be subjected to an Appendix F assessment.	1

Appendix B

Estuary Guidance Tables
(Appendix F of the SMP Guidance)

Appendix B. Estuary Guidance Tables (Appendix F of the SMP Guidance)

Estuary Guidance Table 1 General Decision-Support Framework

The purpose of this Table is to provide the overall context within which decisions will be made concerning the inclusion, or otherwise, of estuaries within the SMP process. EGT1 is supported by further tables EGT2-EGT7.

Key Question	Key Issues for Consideration	Indicators	Reference Tables
Should the estuary be included in the SMP process?	Type, scale and significance* of physical** interactions	▪ Physical size parameters of the estuary ▪ Physical process parameters of the estuary, and degree of sediment supply from river(s) and sediment exchange with the open coast ▪ Presence/absence of morphological features within estuary and/or at estuary mouth ▪ Physical constraints within estuary and/or along adjacent coast (e.g. defences and/or geological controls) ▪ Potential for large-scale changes in alignment of defences within estuary and/or along open coast	EGT2-5
	Nature and complexity of management issues	▪ Presence/absence of control structures at the estuary mouth and/or within the estuary and/or along the open coast ▪ Common sources of risk between the estuary and open coast (e.g. tidal flooding, wave erosion) ▪ Continuity, location and/or scale of receptors at risk close to the estuary /coast interface (e.g. life, development, nature conservation, natural heritage, existing land and water uses) ▪ Limits of other 'strategic' flood and coastal management initiatives (e.g. CFMPs and/or Coastal Habitat Management Plans (CHaMPs))	
How should the estuary be included?	SMP	▪ Physical size (logistics) ▪ Complexity of management issues	EGT6
	eSMP		
How far upstream should the estuary be included?	Consideration of estuarine processes	▪ Balance in fluvial, tidal and coastal processes throughout estuary and extent of interactions (physical and logistical) ▪ Presence of natural or man-made constraints and assessment of cross-sectional morphological form	EGT7
	Selection of shoreline management policy	▪ Presence/absence of morphological features and their interconnectivity between different environments ▪ Location, extent and type of management issues	

* 'Significant' interaction need not necessarily only be confined to 'large', but could relate to other factors key to the development of either the coast or estuary (i.e. complexity of interactions). Assessment of 'significance', therefore, needs to take account of the scale of the interaction relative to other factors (e.g. resistance of geology, availability of sediment).

** Physical interactions principally relate to water and sediment exchanges between the estuary and open coast. Chemical and biological interactions and water quality issues may be incorporated, if appropriate, in consideration of 'management issues'.

Estuary Guidance Table 2 Significance of Water Exchange

This table assists the user in determining the significance of water exchange between the estuary and the open coast in order to inform the decision about whether or not an estuary should be included in the SMP process.

1. Make an informed assessment about the overall **scale** of water exchange between the estuary and the open coast by considering the following estuary parameters from the *Futurecoast* estuaries database and judging whether they fall into the range 'insignificant to low', 'moderate' or 'high to extensive':
   - Total area
   - Inter-tidal area
   - Channel length
   - Mouth area
   - Mouth width
   - Tidal range
   - Mean freshwater flow

2. Supplement the above information with local or specific knowledge about the following estuary parameters:
   - Tidal prism
   - Tidal velocities

3. Use the above understanding to make an informed assessment of the **significance** of the water exchange between the estuary and the open coast. This may be assisted by consideration of the following factors, although there may some anomalies, usually large estuaries or inlets, where the ratios do not apply:
   - Ratio of total area to channel length (large = wide embayment more likely to be subject to wave processes, small = longer, narrower estuary more likely to be dominated by tidal processes)
   - Ratio of tidal range to mean freshwater flow (large = tidal processes dominate, small = river process dominate)
   - Ratio of mouth area to mouth width (large = large average mouth depth and hence large water exchange, small = small average mouth depth)
   - Geology of mouth and adjacent coast (hard = relatively erosion resistant even with high flows associated with high water exchange, soft = erodible even with marginal water exchange)
   - Degree of development of adjacent coast (low = less significant, high = more significant).

Assess significance of water exchange

Significant

Marginal

Insignificant

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Estuary Guidance Table 3 Significance of Sediment Exchange

This table assists the user in determining the significance of sediment exchange between the estuary and the open coast in order to inform the decision about whether or not an estuary should be included in the SMP process.

1. Make an informed assessment about the overall **scale** of sediment exchange between the estuary and the open coast by considering the following estuary parameters from the *Futurecoast* estuaries database or 'estuaries assessment' report (not presented here) and judging whether they fall into the range 'insignificant to low', 'moderate' or 'high to extensive':
   - Tidal asymmetry
   - Presence or absence of morphological features such as banks and deltas
   - Source or sink relationship with open coast (for both cohesive and non-cohesive sediments) – (see 'estuaries assessment' report)
   - Potential for plume generation during river spate (see 'estuaries assessment' report)
2. Supplement the above information with local or specific knowledge about the following issues:
   - Catchment area and existing/planned catchment land uses (influences sediment supply from estuary to coast)
3. Use the above understanding to make an informed assessment of the **significance** of the sediment exchange between the estuary and the open coast, taking into consideration the following factors:
   - Availability of sediment (both cohesive and non-cohesive) to feed transport potential
   - Critical thresholds for erosion, transport and deposition of estuarine and coastal sediments.

Assess significance of sediment exchange

Significant

Marginal

Insignificant

Estuary Guidance Table 4 Significance of Management Issues

This table assists the user in determining the scale of management issues between the estuary and the open coast in order to inform the decision about whether or not an estuary should be included in the SMP process.

1. Take an informed assessment about the scale of management issues by considering the following factors from the Futurecoast estuaries database:
   - Historic reclamation
   - Presence / absence of jetties at the mouth

2. Supplement the above understanding with local or specific knowledge about the following issues:
   - Scope for large-scale anthropogenic intervention (e.g. barrage construction, development proposals)
   - Presence or absence of continuous ‘at risk’ zones between the estuary and coast (e.g. flood risk zones, designated habitat areas, historic environment)
   - Indicative residual life of existing estuarine and coastal defences and scope for widespread changes in shoreline management policy to ‘managed realignment’, ‘hold the line’ (with new defences on eroding cliffs) or ‘advance the line’ (thereby significantly changing existing estuarine tidal prism, or supply of sediment from the coast)
   - Consistency of approach with adjacent SMPs and relevant CHaMPs
   - Relevance of other management issues which can influence the physical interactions between the estuary and coast (e.g. beach replenishment, weirs and sluices, navigation and aggregate dredging, bridges and causeways, training works)

3. Combine the above information to make an informed assessment of the significance of the management issues.

↓

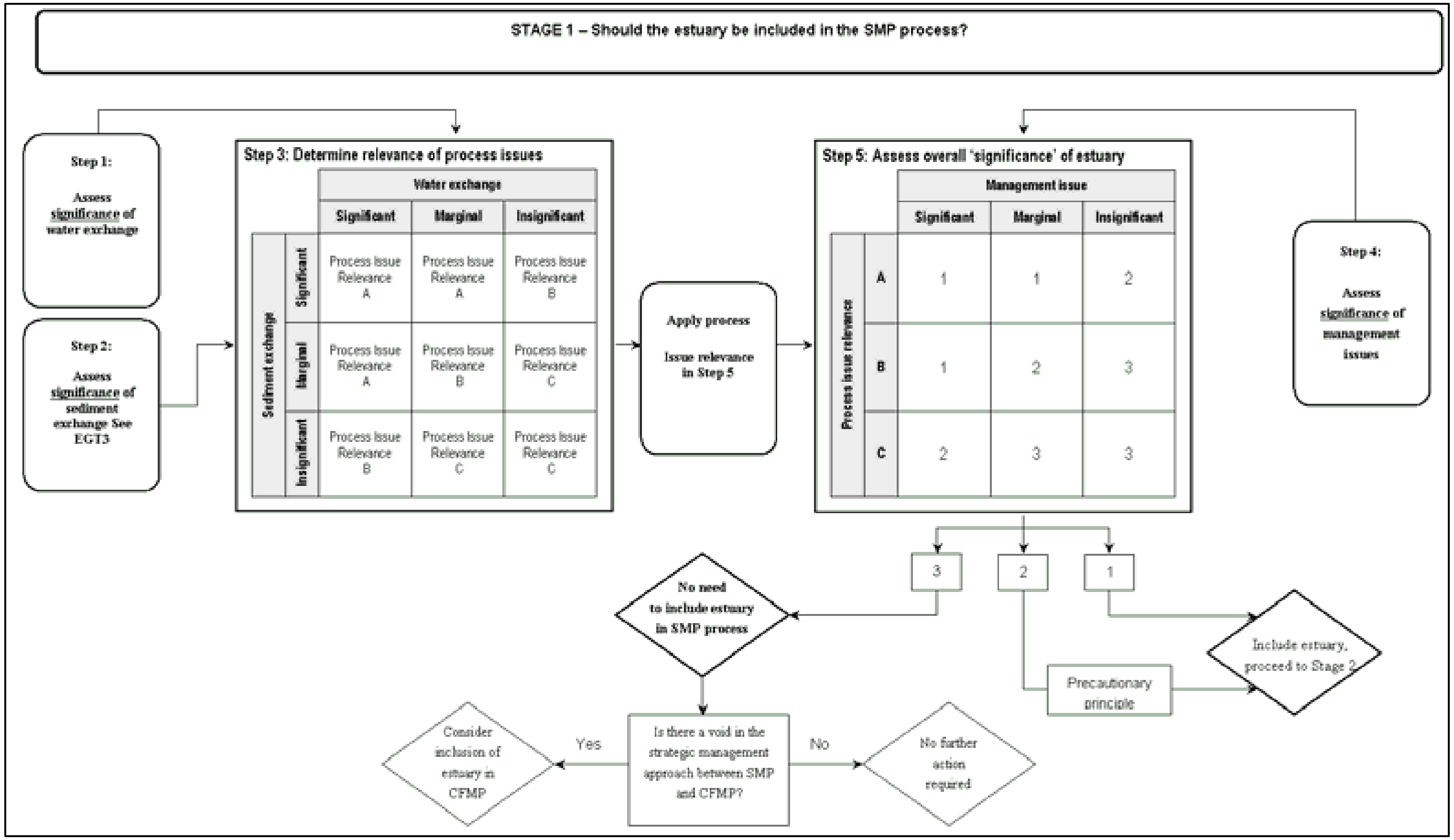
Assess significance of management issues

↓

Significant	Marginal	Insignificant

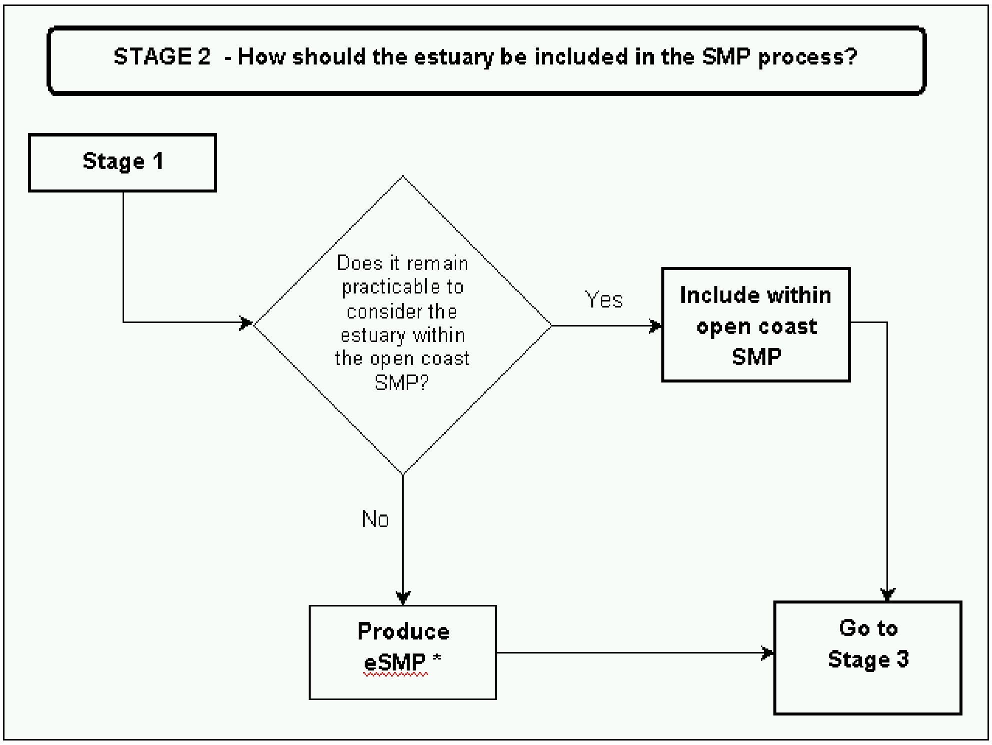
Estuary Guidance Table 5 Assessment of Estuarine Inclusion in SMP Process

The purpose of Estuary Guidance Table 5 is to assist the user in combining findings from EGT2-4 to determine whether or not an estuary should be included in the SMP process. The sensitivity of the decision from this table to changes in the outputs from tables 2, 3 and 4.



Estuary Guidance Table 6 Assessment of Method for Inclusion of Estuaries in SMP Process

This table assists the user in determining how an estuary should be included in the SMP process. It is clearly a qualitative appraisal and should only be undertaken by those familiar with the estuary and its issues.



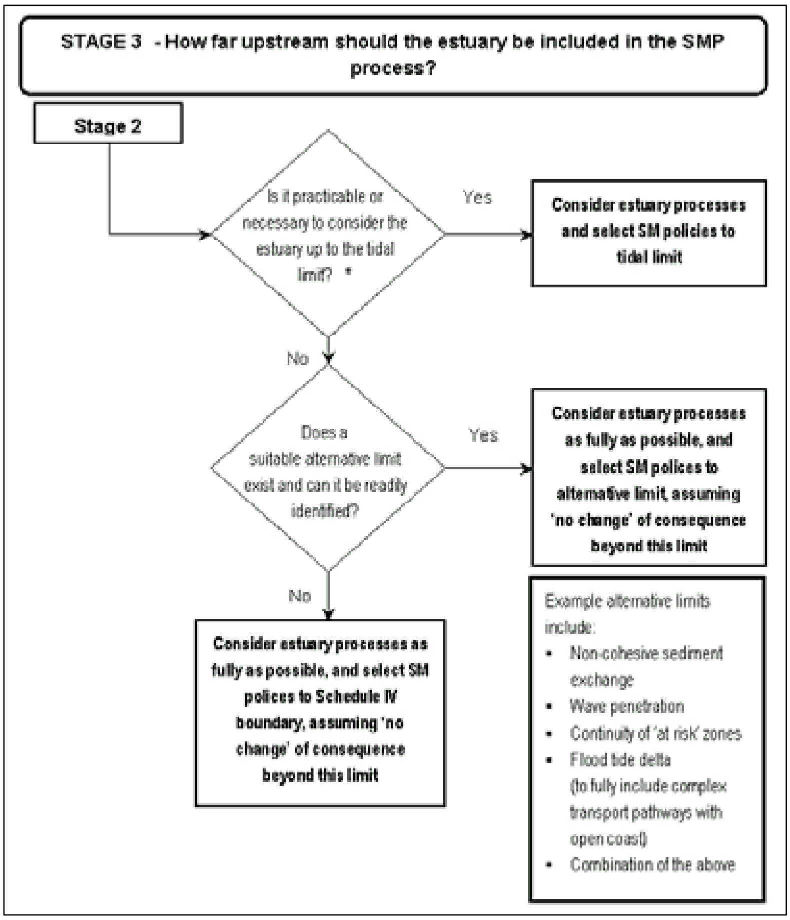
* eSMP must overlap with open coast SMP and those producing each plan must maintain information exchange throughout the plan preparation process

Examples of where it is not practicable to include estuary within open coast SMP are:

- Where the estuary is sufficiently large to necessitate consideration of its process and management policies outside of the open coast SMP.
- Where the estuarine management issues are too complex or diverse to consider within the open coast SMP.

Estuary Guidance Table 7 Assessment of Extent of Estuarine Inclusion in SMP Process

This table assists the user in determining how an estuary should be included in the SMP process.



* It may be necessary to consider an estuary to the tidal limit where there is potential for large-scale change in tidal prism or the estuary is morphologically dynamic (i.e. high natural variability).

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