HM Government
Department of Energy and Climate Change

South West RDA

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

SEVERN TIDAL POWER

Supply Chain Survey Report

JULY 2010

Contents

EXECUTIVE SUMMARY

Alongside the various studies being carried out as part of the Government's Severn tidal power feasibility study, the assessment of the possible constraints in terms of supply chain is also an important consideration in any decision on whether the Government could support any option.

The implementation of a tidal scheme in the Severn estuary, especially a large one (or a combination of smaller schemes), would require not only a great amount of materials and equipment but also large scale innovative construction design and installation processes (numerous caissons, long embankments, sluices, locks etc). Although most of the technologies and construction design are proven and mature, the magnitude of the largest schemes would require a multi-national joint venture.

In order to make sure the regional, national and international market will be able to meet the project's likely level of demand, a supply chain survey has been undertaken. This survey is based on the responses to a specific questionnaire sent to Trade Associations, Manufacturers, Contractors, Ports and other bodies, and also on existing reports.

The survey is mainly focused on the following topics which have been considered as the most sensitive in terms of supply chain and which could stall the project and/or increase the costs and lead-time:

- Vessels for dredging, caisson installation, embankment construction…
- Aggregates for concrete, ballast and embankment fill (sand and gravel, crushed rock and armour stone)
- Concrete for caissons and other civil works (cement, rebar…)
- Caisson construction yards
- Turbines and generators
- Availability of skilled labour

As for the other construction materials and mechanical or electrical equipment (e.g. sluice-gates, cranes, transformers, cables, switch gear…), even for the larger schemes, the magnitude of the demand is not considered as a major concern on the international market. Provided the procurement process is adequately managed, securing these materials and equipments should not be a particular problem either on the UK market or on the international one.

However, at this stage of the study some questions remain due to the lack of detailed information and data. In particular, the report does not provide relevant information on the impact on road and rail transport during the construction phase. This impact depends heavily on the location of the construction and manufacturing sites (caisson, precast facility etc), and of the quarries and ports where materials and equipment will be landed. Sea and rail transport are likely to be preferred so as to meet sustainability objectives.

Vessels

As vessels will play a major role in the preparation works (dredging) and in the installation or construction of the various structures, their availability on the international market is a key factor.

The current demand for marine equipment remains critical, due to a steady demand from the oil and gas industry and an increasing demand for offshore wind deployment, in particular in Europe. Nevertheless, a Severn scheme would require mainly dredgers, tugs and crane-barges for the installation of caissons and equipments and these types of vessels are unlikely to compete with the demand for vessels for offshore wind deployment (e.g. Jack-Up barges…).

Most of the vessels required for a Severn scheme are available on the UK and European market but orders would have to be placed well in advance (from 1 to 2 years) to ensure availability at the required time and to secure the appropriate or specific vessels. Due to the harsh conditions in the Estuary (currents, waves…) or to the specific requirements (e.g. deep dredging), some existing vessels would have to be adapted or modified.

The Dutch Eastern Scheldt storm surge barrier, commissioned in 1986, is a good example of innovative construction technologies which lead to the development of various purpose-built vessels. The building of a Severn tidal scheme would also rely on innovation and new dedicated vessels could be envisaged so as to be independent from the current market.

Aggregates

Aggregates (sand and gravel or crushed rock) are by far the largest quantities of construction material required for the Severn schemes, in particular for the Cardiff-Weston barrage but also for the lagoons (embankment).

As the demand for aggregates for construction fill (embankment) and ballast is very high, the use of suitable dredged materials from foundation and navigation channels works could significantly relieve the pressure on the market. Mainly dredged sand and gravel could be considered as a substitution of ballast and construction fill for the barrage schemes (for the Cardiff-Weston barrage, these dredged materials could replace all the sand and gravel required). On the other hand, for the lagoon schemes, the volume of suitable dredged materials is too low (or even non-existent for the Bridgwater Bay lagoon) and it is unlikely that the remaining aggregates for construction fill and ballast could be sourced from the UK market. In order to meet this demand, several possibilities could be envisaged: significant increase in the current extraction capacity or additional imports from overseas quarries. New licenses for dredging could also be considered, in particular in the Bristol Channel.

The demand for armour stone (which cannot be sourced in large quantities in the UK) is far beyond the current imports from Northern Europe, apart from the Beachley barrage. For the other schemes, only a significant increase in the delivery rate of existing rock quarries (e.g. Glensanda) and in overseas imports (e.g. Norway) could meet this demand.

Secondary and recycled aggregates could also make an important contribution to the supply of construction aggregates, in particular for ballast. China clay and slate waste could be used for a STP project, as the main quarries are respectively located in Devon and Cornwall or in North Wales.

Concrete

Aggregates for concrete could all be sourced from the national market, and for the smaller barrages (Shoots and Beachley) as well as for the Welsh Grounds lagoon, the regional markets could provide most of these materials.

The other concrete components (cement, rebar…) can be easily sourced from the UK market and for steel from the national and international market. Various concrete batch plants would have to be installed on each construction site, in particular for the caissons construction, but this is standard practice for any large construction project.

Caisson construction yards

The location of the caisson construction yards is critical and should take into account various parameters such as: environmental impacts, consent process, caisson transport cost, site characteristics (e.g. water depth, transport network for material and equipment delivery) and carbon footprint. At this stage, it is difficult to confirm that the potential identified sites (existing ports or shipyards and coastal sites) are suitable.

For the smaller schemes, potential sites could be envisaged along the Bristol Channel, but for the Cardiff-Weston barrage several sites would be required either around the UK coast or elsewhere in Europe (e.g. Netherlands or Northern Spain).

Turbines and generators

Only three European turbine manufacturers have the expertise and capacity to deliver specific tidal range turbines (bulb turbine or Straflo turbine) as well as their generators. The major Chinese turbine manufacturers also might be able to deliver a % of bulb turbines, provided they work under the supervision of one of the European turbine leaders.

The ongoing experience of a consortium of these 3 manufactures for the Brazilian Madeira hydro project (delivery of 72 bulb turbines) would provide interesting feedback and would confirm soon that procuring about 100 turbines is feasible for the smaller schemes.

As for the Cardiff-Weston barrage, delivering such a large number of turbines (more than 200) is considered as very challenging by the manufacturers using only existing facilities. A consortium between them is not the only key to success. So as to increase the delivery rate and the manufacturing capacity, a development and procurement strategy is likely to be set up by these manufacturers and investment in a new plant or in an assembly facility could be envisaged.

Skilled labour

The report also addresses labour and skills issues and provides additional information from existing surveys. According to the various respondents, it is confirmed that shortage of workforce in marine and civil engineering, mechanical and electrical installation, as well as in site supervision, are likely to occur. The various energy projects scheduled/proposed in the UK in the period to 2030 (nuclear plants, wind farms…) would all be competing for similarly skilled people.

The current economic downturn brings about many skill transfers within the industry and construction sectors and a significant shortage of labour and skill might be expected when the economy recovers. However, locating the caisson construction yards in various sites in the UK (or in Europe) would minimise labour shortages and international joint-ventures set up on purpose for the construction may well mitigate the remaining labour problems.

****

I - INTRODUCTION

STP Feasibility study

The feasibility study of tidal range power development in the Severn Estuary is being managed by a cross-government group led by the Severn Tidal Power (STP) team from the Department of Energy & Climate Change (DECC). The Terms of Reference of this study are as follows:

- assess in broad terms the costs, benefits and impact of a project to generate power from the tidal range of the Severn Estuary, including environmental, social, regional, economic, and energy market impacts;
- identify a single preferred tidal range project (which may be a single technology/location or a combination of these) from the number of options that have been proposed
- consider what measures the Government could put in place to bring forward a project that fulfils regulatory requirements, and the steps that are necessary to achieve this
- decide, in the context of the Government's energy and climate change goals and the alternative options for achieving these, and after public consultation, whether the Government could support a tidal power project in the Severn Estuary and on what terms

Public Consultation

In Phase 1 of the study, 10 potential development options (the long-list) have been considered (including barrages, lagoons, a tidal reef and tidal fence) and the Government carried out the first public consultation (January-April 2009), on the following:

- a recommended shortlist of 5 schemes for more detailed analysis this year
- the scope of the Strategic Environmental Assessment (SEA) that is being carried out within the feasibility study
- the issues the feasibility study is considering and how these are being approached

Over 730 responses were received from this 1st Public Consultation and most of them agreed with the scope of the SEA work proposed. Some detailed changes have been suggested and made to the SEA objectives, including to the Resources and Waste topic which is closely linked to the supply chain issues:

- to promote sustainable use of resources particularly with respect to aggregate
- to reduce waste generation and disposal, increase re-use and recycling and achieve the sustainable management of waste

Additional points most frequently raised in consultation responses will be also assessed by the feasibility study:

- the impact of any scheme would have on the local infrastructure and on local communities, including on roads and services, navigation, the Severn Bore, and construction effects
- compliance with the environmental and other legislation that applies to the Estuary and related areas
- where and how raw materials and skills needed to build a scheme would be sourced
- the overall CO2 balance of a scheme including emissions associated with construction, and knock-effects on infrastructure and services
- the impact on the environment , including the geomorphology of the Estuary and how sedimentation might affect scheme feasibility

Supply Chain Study

The implementation of a tidal scheme in the Severn estuary, especially a large one, would create considerable demand across the entire supply chain. The project would generate supply chain issues, including securing:

- sufficient basic materials (steel, concrete, aggregates…)
- suitable marine and land equipment
- caisson fabrication capacity and yards
- timely supply of mechanical equipment, in particular turbines
- timely supply of electrical equipment, in particular generators, transformers…
- suitable logistics and installation plant

- skilled and experienced contractors and sub-contractors
- access to skilled and experienced labour forces, scientific advisors and project supervisors

Moreover, the location of the construction sites (including caisson yards), quarries and manufacturing plants may also impact the existing regional and even national transport network (road & rail).

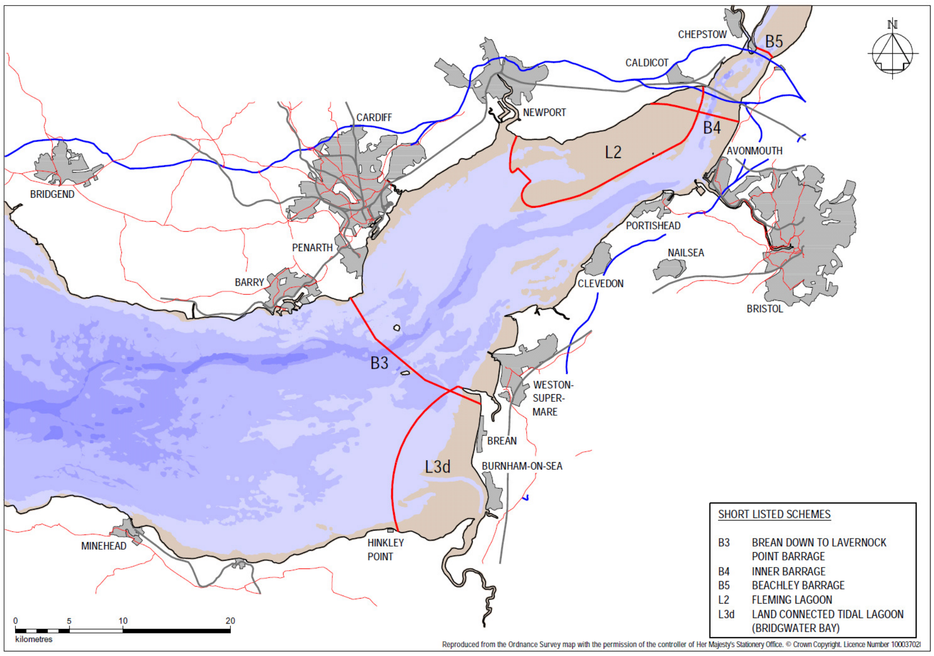
The availability of materials could impact upon overall project costs through both direct cost increases and time overruns. A lack of materials would stall the project and could also add a premium onto material prices. This is especially true for the larger schemes due to the vast quantities of materials required.

Difficulties in procuring marine plant equipment and turbines could also occur due to resource competition from other projects in European countries (and elsewhere) which all have to meet similar renewable energy targets. Competition for plant could increase costs through the creation of a price premium as well as delay project completion.

We propose to test the market's capability to meet the potential demand for a range of Severn tidal power schemes - this would also give manufacturers and suppliers advance notice of possible future demand, thus allowing them time to gear up their production capacity (provided a scheme is decided and planning permission obtained). This is why the STP Team decided to launch an overall study on supply chain issues in addition to the work being done by the Parsons Brinckerhoff-led consortium under the SEA contract.

The conclusions of this report should help inform the choice of the preferred scheme so as to mitigate the risks of delay and cost increases. The report is mainly focused on the 5 proposed short-listed schemes (base case); the interim results of the ongoing optimisation study of the schemes have been taken into account in this survey, particularly the embankment design (tonnage of materials) and number of turbines:

- **Cardiff-Weston Barrage:** A barrage crossing the Severn estuary from Brean Down, near Weston super Mare, to Lavernock Point, near Cardiff. It could generate 8.6GW –nearly 5% of UK electricity and twice the capacity of the UK's largest fossil fuel plant.
- **Shoots Barrage:** Further upstream to the Cardiff-Weston scheme. It could generate 1.05GW, equivalent to around the size of a large fossil fuel plant.
- **Beachley Barrage:** The smallest barrage on the proposed shortlist, just above the Wye River. It could generate 625MW, equivalent to around the size of medium fossil fuel plant.
- **Bridgwater Bay Lagoon:** Lagoons are new concepts which impound a section of the estuary without damming it. This scheme is sited on the English shore between east of Hinkley Point and Weston super Mare. It could generate 1.36GW (base case)
- **Welsh Grounds Lagoon:** An impoundment on the Welsh shore of the estuary between Newport and the Severn road crossings. It too could generate 1.36GW (base case)



Map of the 5 short-listed schemes

According to the size of the schemes and also to their design, the report tackles the supply chain issues for the 2 categories of schemes (a lagoon has a longer length of impoundment construction than a barrage relative to the impounded area):

- Barrage: Cardiff-Weston, Shoots and Beachley
- Lagoon: Bridgwater Bay and Welsh Grounds

During the preliminary optimisation analysis of the feasibility study, the design of each scheme has been improved (alignment, number and size of turbines…). For lagoons, cost and resource estimates have been based on conventional rockfill embankment construction. Although other forms of construction, e.g. the Fleming Group's tied wall proposal and geosynthetic reinforced embankments, have been considered, conventional rockfill has the greatest certainty of technical feasibility and represents a worst case form of construction in terms of material and labour resources. A better estimate of the quantities of construction materials has been made available for all shortlisted schemes and this report is based on this updated assessment.

The report is focused mainly on the following critical supply chain topics:

- Vessels
- Main civil works
  - concrete (cement + aggregates + rebar)
  - materials for embankments (aggregates & armour stone)
- Main mechanical equipment
  - turbines
  - other steelworks: gates, cranes and sluices
- Main electrical equipment
  - generators, transformers, switchgear…
- Labour and skills

In order to identify the major constraints in terms of supply chain and resources, a questionnaire was prepared for the above list of topics (see Appendix 1). The questionnaire also tackles labour and skills issues and specific questions are asked, including comments on the DTZ survey undertaken in Phase 1 of the STP feasibility study, so as to update some data.

This questionnaire was split into 2 parts:

- a short presentation of each scheme, including an estimation of the quantities of materials required for the construction as well as the main characteristics of the various equipment to be manufactured (base case).
- a list of questions for each topic

This questionnaire was sent in June 2009 to various Manufacturers, Contractors, Trade Associations, Ports and other bodies (see list – Appendix 2); about 100 questionnaires were emailed.

About 25% of recipients sent a detailed and comprehensive response in relationg to their core activity. It is interesting to note that very few responses came from Electrical and Mechanical (excluding Turbines) bodies, mainly because the delivery of such equipment is not considered as a concern. Regarding Labour & Skills issues, very few responses were sent due to the difficulty at this level of study to estimate the real skill needs and to assess skill shortages. Phone calls, meetings and additional emails with the respondents provided further information.

Additional information was also found from various documents (books, brochures, websites…) and published reports and surveys (see Appendix 3 "Sources of Information").

For each question, a summary of the most relevant responses is set out in the report as well as some recommendations or proposals suggested by some respondents.

The level of supply chain constraints is assessed and summarised for each short-listed scheme according to the following scale within the regional, national and international markets:

☺ : no particular concern – available according to scheduled timescale
😐 : medium concern – high demand but enough resources or suppliers/manufacturers
☹ : major concern – very high demand and/or lack of resources or suppliers/manufacturers – high risk of delay (lead time)
💣 : critical concern – no resource or shortage of supplier/manufacturer – serious risk of delay (lead time)

☺ : no particular concern – available according to scheduled timescale
😐 : medium concern – high demand but enough resources or suppliers/manufacturers
☹ : major concern – very high demand and/or lack of resources or suppliers/manufacturers – high risk of delay (lead time)
💣 : critical concern – no resource or shortage of suppliers/manufacturers – serious risk of delay (lead time)

Severn Tidal Power - Supply Chain Issues
Cardiff-Weston Barrage Scheme - Summary

Major Components	Main Constraints	Alternative Solutions	Availability in the Market												Overall Supply Chain Level			
			Regional				National				International							
			☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣
Vessels					X			X			X					X		
Dredgers	Suitable for deep water dredging				X				X		X					X		
Tugs					X			X			X				X			
Barges (ballast, rock…)					X			X			X				X			
Heavy barge cranes…	High demand, very few vessels					X			X			X				X		
Jack up	High demand, very few vessels					X			X			X				X		
Civil Works																		
Caisson construction yards	Very few sites, far from Severn estuary				X			X				X				X		
Concrete																		
- cement					X		X				X				X			
- aggregates					X			X			X					X		
- rebar	High demand	Worldwide imports			X			X			X					X		
Aggregates (embankment & ballast)	Shortage of sand in the UK	Use of dredged materials from foundation preparation		X				X			X					X		
Armourstone (embankment)	Shortage in the UK	Imports from Europe				X				X		X				X		
Main Mechanical Equipments																		
Turbines (+ Generators)	Only 3 manufacturers. Delivery rate	Construction of a new facility				X				X			X				X	
Dam/Turbine gates	International market					X			X			X				X		
Lock gates	International market					X			X			X				X		
Bascule bridges	International market					X			X			X				X		
Gantry/Goliath cranes	International market				X				X			X				X		
Main Electrical Components																		
Transformers	Very few suppliers					X			X				X				X	
Generator breakers	High demand				X			X				X				X		
Cables	High demand				X				X				X				X	

Aggregates supply takes into account available dredged materials

☺ : no particular concern – available according to scheduled timescale
😐 : medium concern – high demand but enough resources or suppliers/manufacturers
☹ : major concern – very high demand and/or lack of resources or suppliers/manufacturers – high risk of delay (lead time)
💣 : critical concern – no resource or shortage of suppliers/manufacturers – serious risk of delay (lead time)

Severn Tidal Power - Supply Chain Issues
Shoots Barrage Scheme - Summary

Major Components	Main Constraints	Alternative Solutions	Availability in the Market												Overall Supply Chain Level			
			Regional				National				International							
			☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣
Vessels																		
Dredgers	Suitable for deep water dredging				X				X		X					X		
Tugs					X			X			X				X			
Barges (ballast, rock…)					X			X			X				X			
Heavy barge cranes…	High demand, very few vessels					X			X			X				X		
Jack up	High demand, very few vessels					X			X			X				X		
Civil Works																		
Caisson construction yards	Very few sites, far from Severn estuary				X			X				X				X		
Concrete																		
- cement				X			X				X				X			
- aggregates				X			X				X				X			
- rebar	High demand	Worldwide imports			X			X			X					X		
Aggregates (embankment & ballast)	Shortage of sand in the UK	Additional dredging in the Bristol Channel or use of dredged materials from foundation preparation			X			X			X						X	
Armourstone (embankment)	Shortage in the UK	Imports from Europe				X			X		X					X		
Main Mechanical Equipments																		
Turbines (+ Generators)	Only 3 manufacturers. Delivery rate	Construction of a new facility				X			X		X				X			
Dam/Turbine gates	International market					X			X		X				X			
Lock gates	International market					X			X		X				X			
Bascule bridges	International market					X			X		X				X			
Gantry/Goliath cranes	International market				X				X		X				X			
Main Electrical Components																		
Transformers	Very few suppliers					X			X		X				X			
Generator breakers	High demand				X			X			X				X			
Cables	High demand				X				X				X				X	

Aggregates supply takes into account available dredged materials

☺ : no particular concern – available according to scheduled timescale
😐 : medium concern – high demand but enough resources or suppliers/manufacturers
☹ : major concern – very high demand and/or lack of resources or suppliers/manufacturers – high risk of delay (lead time)
💣 : critical concern – no resource or shortage of suppliers/manufacturers – serious risk of delay (lead time)

Severn Tidal Power - Supply Chain Issues
Beachley Barrage - Summary

Major Components	Main Constraints	Alternative Solutions	Availability in the Market																Overall Supply Chain Level			
			Regional				National				International							
			☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣
Vessels																		
Dredgers	Suitable for deep water dredging				X			X			X					X		
Tugs					X			X			X				X			
Barges (ballast, rock…)					X			X			X				X			
Heavy barge cranes…	High demand, very few vessels					X			X			X				X		
Jack up	High demand, very few vessels					X			X			X				X		
Civil Works																		
Caisson construction yards	Very few sites, far from Severn estuary	Constraints due to the Severn crossings				X		X				X					X	
Concrete																		
- cement				X			X				X				X			
- aggregates				X			X				X				X			
- rebar	High demand	Worldwide imports		X			X				X				X			
Aggregates (embankment & ballast)	Shortage of sand in the UK	Use of dredged materials from foundation preparation		X			X				X				X			
Armourstone (embankment)	Shortage in the UK	Imports from Europe				X		X			X				X			
Main Mechanical Equipments																		
Turbines (+ Generators)	Only 3 manufacturers. Delivery rate	Construction of a new facility				X			X			X				X		
Dam/Turbine gates	International market					X			X		X				X			
Lock gates	International market					X			X		X				X			
Bascule bridges	International market					X			X		X				X			
Gantry/Goliath cranes	International market				X				X		X				X			
Main Electrical Components																		
Transformers	Very few suppliers					X			X			X			X			
Generator breakers	High demand				X			X			X				X			
Cables	High demand				X				X				X				X	

Aggregates supply takes into account available dredged materials

☺ : no particular concern – available according to scheduled timescale
😐 : medium concern – high demand but enough resources or suppliers/manufacturers
☹ : major concern – very high demand and/or lack of resources or suppliers/manufacturers – high risk of delay (lead time)
💣 : critical concern – no resource or shortage of suppliers/manufacturers – serious risk of delay (lead time)

Severn Tidal Power - Supply Chain Issues
Welsh Grounds Lagoon - Summary

Major Components	Main Constraints	Alternative Solutions	Availability in the Market												Overall Supply Chain Level			
			Regional				National				International							
			☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣
Vessels																		
Dredgers	Suitable for deep water dredging				X				X		X					X		
Tugs					X			X			X				X			
Barges (ballast, rock…)					X			X			X				X			
Heavy barge cranes…	High demand, very few vessels					X			X			X				X		
Jack up	High demand, very few vessels					X			X			X				X		
Civil Works																		
Caisson construction yards	Very few sites, far from Severn estuary				X			X			X					X		
Concrete																		
- cement				X			X				X				X			
- aggregates				X			X				X				X			
- rebar	High demand	Worldwide imports		X			X				X				X			
Aggregates (embankment & ballast)	Shortage of sand in the UK	Additional dredging in the Bristol Channel				X			X			X					X	
Armourstone (embankment)	Shortage in the UK	Imports from Europe				X			X			X				X		
Main Mechanical Equipments																		
Turbines (+ Generators)	Only 3 manufacturers. Delivery rate	Construction of a new facility				X			X		X				X			
Dam/Turbine gates	International market					X			X		X				X			
Lock gates	International market					X			X		X				X			
Bascule bridges	International market					X			X		X				X			
Gantry/Goliath cranes	International market				X				X		X				X			
Main Electrical Components																		
Transformers	Very few suppliers					X			X			X			X			
Generator breakers	High demand				X			X			X				X			
Cables	High demand				X				X				X				X	

Aggregates supply takes into account available dredged materials

☺ : no particular concern – available according to scheduled timescale
😐 : medium concern – high demand but enough resources or suppliers/manufacturers
☹ : major concern – very high demand and/or lack of resources or suppliers/manufacturers – high risk of delay (lead time)
💣 : critical concern – no resource or shortage of suppliers/manufacturers – serious risk of delay (lead time)

Severn Tidal Power - Supply Chain Issues
Bridgwater Bay Lagoon - Summary

Major Components	Main Constraints	Alternative Solutions	Availability in the Market												Overall Supply Chain Level			
			Regional				National				International							
			☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣	☺	😐	☹	💣
Vessels																		
Dredgers	Suitable for deep water dredging				X				X		X					X		
Tugs					X			X			X				X			
Barges (ballast, rock…)					X			X			X				X			
Heavy barge cranes…	High demand, very few vessels					X			X			X				X		
Jack up	High demand, very few vessels					X			X			X				X		
Civil Works																		
Caisson construction yards	Very few sites, far from Severn estuary				X			X				X				X		
Concrete																		
- cement				X				X			X				X			
- aggregates					X			X			X					X		
- rebar	High demand	Worldwide imports			X			X			X					X		
Aggregates (embankment & ballast)	Shortage of sand in the UK	Additional dredging in the Bristol Channel. No suitable dredged materials from foundation preparation				X			X			X					X	
Armourstone (embankment)	Shortage in the UK	Imports from Europe				X			X			X				X		
Main Mechanical Equipments																		
Turbines (+ Generators)	Only 3 manufacturers. Delivery rate	Construction of a new facility				X				X			X				X	
Dam/Turbine gates	International market					X			X		X				X			
Lock gates	International market					X			X		X				X			
Bascule bridges	International market					X			X		X				X			
Gantry/Goliath cranes	International market				X				X		X				X			
Main Electrical Components																		
Transformers	Very few suppliers					X			X			X			X			
Generator breakers	High demand				X			X			X				X			
Cables	High demand				X				X				X				X	

Aggregates supply takes into account available dredged materials

II - VESSELS

Introduction

For the construction of each scheme, various vessels should be required for the following tasks:

- dredgers for foundation preparation, caissons installation (in particular for turbine caissons so as to provide sufficient submergence for the turbines), navigation channels (also caisson towing channels from construction yards): trailer suction hopper dredgers, large cutter suction dredgers, grab dredgers (clamshell), dragline, ladder or continuous flight bucket dredgers…,
- jack-up construction crane barges (e.g. for rock dredging pre-treatment by drilling and blasting),
- towboats, tugs (e.g. for caissons towing),
- vessels for caissons ballast filling,
- floating cranes or cranes barges for light equipment installation, bulkheads removal…(fully rotating crane)
- heavy load crane barges or heavy lift crane vessels (e.g. heavy derrick barge, sheer-legs cranes) for turbines, transformers, gates installation,
- bottom-dump or side-dump barges/split hopper barges for embankment construction and placement of underwater fills
- rock transport (pontoons, barges…) for embankments and armouring construction,
- supply, services, safety and crew boats

Due to the specificity of these tidal schemes located in a harsh sea environment (high tidal velocity at spring tides, waves…), all the marine vessels will play an essential role in the project development. The construction method, sea-bed preparation and transportation of materials and equipments will rely on the availability of these vessels and also on their performance and ability to achieve specific tasks.

Since sea embankments and breakwaters are being constructed in ever more severe environments, their designs are becoming increasingly sophisticated as a result of advanced understanding of hydrodynamics of wave interaction with the structure and the sloping bottom. Experience has been accumulated worldwide and translated into these improved and complex designs. For the constructor, this means the positioning and placement are very demanding. Large crane barges with high stability and greater reach are required; mooring systems are used with increased holding capacity for taut-line moorings.

Availability of these types of vessels in the national and international market

According to the Marine Contractors responses, it is difficult to give precise figures at this stage if the exact requirements of the vessels are not yet defined. The duration of the project, the scope of work and the requirements of warranty surveyors would be vital for the definition of the requirements, also of importance are e.g. sailing distances, water depth, lifting heights and weights, crew requirements (with regards to nationality or Health and Safety requirements).

The availability of large and specialised marine equipment (trailer suction hopper dredgers, large cutter suction dredgers, heavy load crane barges…) is under pressure in the international market. Only small equipments such as small dredgers, tugs, barges, pontoons, cranes can be easily sourced within the national market.

Vessels of the types and sizes required for a Severn Tidal Power scheme operate on an international scale. Very few of the above listed vessels are available inside the UK national market at present but most of major European Dredging and Marine contractors (mainly from Belgium and the Netherlands) have a representation in UK (e.g. Boskalis, BAM, Van Oord, DEME…) and all are capable of undertaking these works and would have the appropriate equipments given sufficient lead in times. A worldwide mobilisation could be also possible, in particular from the Middle and Far East market where new suppliers have been created. Consortia or Joint Ventures could be envisaged between European Dredging and Marine Contractors.

For large projects, contracts are generally placed well in advance (from 0.5 year up to 2 years) so as to ensure availability at the required time and to secure the appropriate or specific vessels. Key to success is proper advance sourcing, contracting and planning hand in hand with the suppliers. Marine Contractors are unable to predict for future periods further away than 2-3 years and spot markets such as "Salvage projects" which are unpredictable but may have some duration, may also disrupt their forecast. Moreover, ongoing international long term contracts might pose a problem in terms of availability: some vessels can operate several years in the same country for different projects in order to make cost-effective their transportation and deployment.

Here are some examples of advance booking requirements:

- Vessels requiring from 18 to 24 months advanced booking:
  - Jack-ups are limited in availability (very small fleets) and generally booked well in advance (> 1.5 to 2 years)
  - Sheer-legs cranes with high capacity (e.g. >1000T) are limited and should be booked > 1.5 year in advance
  - Dredgers, in particular for deep water, are also limited in availability (very few suitable vessels) and generally booked well in advance (> 1.5 year)
- Vessels requiring at least 6 months advanced booking:
  - Tugs are a commodity, availability is generally not a problem.
  - Lifting barges (flattop with crawler crane)
  - Barges, workboats …etc.

Nowadays, there is limited availability of dredging equipment within the world (particularly grab dredger; the only UK based seagoing commercial grab dredger is operated by UK Dredging, in Cardiff) due to large developments in the Middle East and Africa currently employing much of the available plant (marina and ports projects); India and China are also future large dredging markets but the existing fleets and planned vessel construction in the Far East would meet this new demand but not add to the European resource. Nevertheless, the current collapse in the worldwide property market could slow development in the Gulf (e.g. Dubai projects) and in parts of South East Asia, which might release dredgers for use in the Bristol Channel if the economic recession remains long-term.

Moreover, those dredging vessels capable of working in the Severn Estuary environment, and with the ability to address the deep dredged depth, are critical. Some existing dredgers could be modified so as to meet these technical requirements: e.g. cutter suction dredgers may need to be re-fitted for the Cardiff-Weston barrage to reach the maximum depths required.

Case study - The large rock cutter section dredger "D'Artagnan"
Example of a large dredger


D'Artagnan dredger - © IHC Holland

A large rock cutter suction dredger ("D'Artagnan") has been commissioned, built (2003-2005) and is in operation by the French subsidiary (Société de Dragage International - SDI) of the Belgium Marine Contractor DEME (Dredging, Environmental & Marine Contractor). This dredger is one of the largest in the world and it can dredge to a depth of 35m, and is equipped with two inboard dredge pumps and one submerged dredge pump on the cutter ladder. The dredged material can be pumped ashore through a 1,000mm discharge pipe (at a distance of up to 10km). The ship is equipped with a modern barge loading system which can load barges moored alongside the dredger. It includes among other things a buffer system which enables dredging for a longer period under unfavourable weather conditions. The dredger is equipped with two propellers (3,700kW each) that can generate a speed of nearly 12.5 knots.

Nevertheless, the specification requirements of a STP project in respect of rock dredging and cutter deployment should be studied so as to make sure this vessel is appropriate.

The rock barges and rock transportation ships which are very specific vessels would generally be chartered on the international market, or be provided by the rock suppliers. As the sources of large size rocks are not in the UK but mainly in northern Europe (Norway…), these barges and vessels are in great demand, mainly for port construction or refurbishment (breakwater dykes…). The long distance rock transportation vessels might have to be supplemented by additional vessels, chartered in, modified or built from new. Rock barges are routinely repaired and re-fitted most seasons, and this work can be done around UK shores.

Jack-up vessels are certainly the most critical due to the small number of existing vessels in Europe and the steady demand for offshore wind farm installation. But installation processes (in particular for caissons) are unlikely to rely on Jack-up vessels, maybe with the exception of final placement.

The caissons will be floated into position, and will mainly require tugs. Tugs are relatively easy to source, and are not routinely used for wind farms.

Work barges, inshore craft and safety vessels are available in the UK, but may be in increasingly short supply as the offshore wind market ramps up.

Need for specific built or retro-fitted vessels

It is normal practice on a large project for construction equipment, including vessels, to be modified or adapted to suit the particular requirements of the project, e.g. the harsh marine conditions of the Severn estuary. Yards in UK such as A&P Tyne and North European shipyards have capability to undertake such works. Modifications or re-fits vary widely, but could typically take from six months to a year to procure, and execute.

As with the Dutch Delta Scheme (e.g. Eastern Scheldt storm surge barrier), it is also possible that purpose-built vessels will be required for sea bed preparation and for caisson placing. These new vessels are likely to be built in the following places, China, South Korea or Latvia or Poland. New vessels typically take from two to three years to procure. It was common place to buy Build Slots in recent years but this is now not the case because the vessel construction market is now weakening after seeing several years of extremely high activity.

Compatibility of the harsh site conditions with vessels

The unique environment of the Severn Estuary with high current velocities at spring tides, the extreme tidal range and the sediment load are bound to present several significant challenges to the designers and constructors for station keeping, manoeuvring and operations (e.g. high bollard pull vessels engaged to tow caissons do not normally have to cope with such conditions). Accurate positioning and placement of caissons is likely to be a challenge (mooring and winching robust systems). The particularly high volume of suspended material within the estuary would be a significant challenge in relation to a number of issues and would be a considerable factor influencing how the caissons are placed. The installation methods outlined by STPG in their 1989 report addressed these issues in some detail and showed how existing technology and vessel types could be used (modified / fitted out for the purpose).

Most existing jack-ups can only move at wave heights of 1.5 m and below. In the Bristol Channel these conditions are much shorter in duration than most other near shore locations around the UK. The wind speeds encountered would also limit operating hours and also the number and lengths of time when movement of the barges is possible. It is possible to design Jack-Ups to move in wave heights up to 2.5 metres, and this is increasingly the standard for offshore wind farm vessels.

The bigger challenge would however be the preparation of the surfaces onto which the caissons will have to be landed. These will have to be accurately levelled, to tight tolerances, and these graded surfaces will be very vulnerable until such time as the caissons have been sunk onto them during neap tides. It is very possible that this levelling work will have to be performed more than once on many caissons, because it will often be the case that a week to ten days may pass when it is not possible to sink a caisson due to bad weather condition. During the time between weather windows, the tidal currents are likely to move large amounts of sand and silt along the seabed into any excavations.

Therefore innovative solutions for the foundation preparation could be envisaged like those used for the Eastern Scheldt storm surge barrier in the 1980s (see below case study; prefabricated mattress consisting of reinforced geotextile fabrics and graded stone layers laid out by a specific vessel - Cardium).

The offshore wind and offshore oil and gas industries have already developed construction capabilities in harsh marine environments which could be helpful for the Severn estuary.

Although the conditions will reflect the equipment choice, it will be more of a factor on the installation methods and constraints rather than on the equipment itself.

Ports

Further study of the available vessels, their dimensions and requirements, will determine the ability of the existing ports to accommodate them. Port operators will seek to continue all existing cargo movements and will thus seek to accommodate new opportunities on other berths (this will also depend on the international trade situation). Most of the Severn estuary ports are able to provide facilities for a wide range of vessels of varying sizes (Port Talbot, Bristol, Cardiff…). A number of alongside facilities exist at these ports but depending on requirements, some bespoke facilities may need to be developed to meet the project requirements. Upgrade and improvement might be required at any of the Severn estuary ports to accommodate large and numerous vessels (e.g. dredgers) or to deal with heavy loads (e.g. turbines) as it is unlikely that the existing infrastructure and cargo facilities will be adequate for them. Development land at these ports is also available to support the vessels requirements.

Case study - The Eastern Scheldt storm surge barrier (Oosterschelde – Delta Works)
Example of construction innovation

The Eastern Scheldt storm surge barrier (completed in 1986), was the most ambitious part of the Delta project. The original plan was to build a 9km dam in the mouth of the Eastern Scheldt (20 to 40m depth; 3m tidal range). Preparatory works started in 1967 with the construction of 3 islands: Roggenplaat, Neeltje Jans and Noordland. In 1973, 5km of dam had been built but, under pressure from scientists, the fishing industry and environmental associations, parliament decided to launch further studies so as to protect this unique natural habitat. In 1975, the government decided that a storm surge barrier with sliding gates should replace the initial dam. This scheme would protect against flooding while conserving the ecosystem: the barrier would remain open when conditions were normal (3/4 of the original tidal movement is therefore maintained) and would be closed when sea water levels were high. The technology needed to construct this huge barrier had yet to be invented and the experience gained building the other Delta dams was not suitable. The idea was to place 65 prefabricated concrete piers in a very firm stone foundation and to insert 62 large steel sluice-gates between them. The final project consisted in constructing 3 barriers implemented in the 3 remaining channels: the Hammen, the Schaar van Roggenplaat and the Roompot (total length: 3km). Parliament approved this plan in 1979.

The Eastern Scheldt storm surge barrier was such an exceptional project that a new approach had to be taken to every part of its construction. A consortium of Dutch contractors was formed (Dosbouw) and cutting-edge methods and materials were used. Most of the prefabricated and construction works (piers, foundation mattress, storage of armour stone…) were carried out in the Neeltje Jans and a temporary bridge was built to connect the island to shore.

First, at the construction site, large diameter dolphin and anchor piles (steel cylinder piles) were driven to serve as moorings for the extensive floating construction operations to come. The loose sands in the top 10-20m of the foundation under the barrier were then compacted by vibratory means. A special floating rig, the **Mytilus**, jetted and vibrated 4 large diameter vibrating needles (2.1m diameter – 18m length) down to a depth up to 50m below sea level. The entire compression process took place under water and continued 24h per day. The ship consists of five pontoons: a main pontoon of 18.9m long and four auxiliary pontoons with a total length of 32.9m. On the ship were lifting cranes 55m high. The lifting winches which were fixed to them had a pulling power of 120t. The construction cost of the Mytilus was €15.9m in 1986 (about £29m in 2009).

As bed protection, improvement and depth compaction were not enough to ensure that the piers could be placed safely, a foundation had to be constructed to prevent scouring. Polypropylene mattresses filled with graded layers of gravels were used (36cm thick, 42m wide and 200m long). They were made at a factory specially built for their production in the Neetltje Jans island. The mattresses were winched up on a huge floating reel and then placed on the specially-designed vessel, the **Cardium** which laid them at a rate of 10m per hour during slack water period. This vessel was also able to dredge the upper sands of the seabed before laying the protection mattress. An additional gravel ballast mattress was finally laid over the seams to prevent erosion so as to protect the mattresses against wear, which could be developed through the opening and closure of the gates. The construction cost of the Cardium was €49.9m in 1986 (about £96m in 2009); the actual cost was eighty percent higher than expected.

The 65 concrete piers were constructed inside 3 large construction docks 15m deep which were excavated, diked off and dewatered using 320 underwater pumps. The piers are colossal structures made of prestressed concrete: 30 to 40m high and their dry weight was up to 18,000t. A purpose-built factory produced 450,000m^3 of concrete over 4 years. The piers were hollow and were filled with sand when they were in position. As all the piers had to be completed in only 4 years, they were produced in staggered batches with work beginning on a new pier every 2 weeks. At the peak of the activity 30 piers were being constructed simultaneously.

When all the piers in a construction dock were completed, the dock was flooded and the encircling dike was opened so that they could be towed to one of the channels in the mouth of the Eastern Scheldt. A giant catamaran crane barge, the **Ostrea** vessel was designed and built to lift the piers in the construction dock, transport them to the channels and then place them with great precision on the foundation mattress (margin error of a few cm). The Ostrea was the flagship of the Delta fleet. With its length of eighty-seven metres, the typical U-shape and a capability of 8,000 horsepower, it was a most impressive ship. With the open side of the 'U', the ship manoeuvred around the pier. The ship could steer easily, thanks to its four screw propellers. On both sides there were two giant goliath cranes 50m high. The piers were fixed to these cranes. As the cranes could not lift more than 12,000t whereas the piers weighed 18,000 tonnes, the piers were only half-lifted and transported to their final location. It took 1 year to place all the 65 piers. The construction cost of the Ostrea was €34m in 1986 (about £65m in 2009).

The **Macoma** vessel was specially built to moor the Ostrea while it was placing the piers and to clean the site immediately beforehand. The piers were positioned with a pin-point accuracy at slack water using very sophisticated measuring equipments. It took a year to place them all. This pontoon was situated exactly in front of the place where a pier would be placed. When the Ostrea had taken a pier, it moored against the Macoma. To offer the Ostrea some stability, the pontoon had a coupling mechanism with a power of 600 tonnes. The Macoma also had a second function: an enormous vacuum cleaner was used to ensure there was no sand between the pier and the bottom. This was an extremely difficult task, because the tidal movements moved large amounts of sand each day. The construction cost of the Macoma was €20.4m in 1986 (about £38m in 2009).

For even greater stability and protection from the powerful tidal currents, the piers were embedded in sills made up of armourstone (up to 10t each). A specific vessel, the Trias was designed specially to lay the top layer so as to avoid any damage to the piers. This vessel was equipped with a long, extendable arm that could place the heaviest stones accurately. 5m tonnes of stones were needed and since they were not available in the Netherlands, they were shipped over a 4 year period from Germany, Finland, Sweden and Belgium. The construction cost of the Trias was €11.3m in 1986 (about £20m in 2009).

At the final stage, the service ducts, pier capping units, sluice-gates, sill beam and upper beam had to be put in place. The hollow service ducts, which would later be covered by a road, were laid on top of the piers. The ducts contain the operating and control equipment for the gates. The steel gates (from 6 to 12m high) were suspended between piers. The biggest sluice-gate weighs 480t. A specific barge-crane, the Taklift 4 was used for the installation of the gates.

Many other specific vessels were used for this project: Portulus, control vessel with underwater vehicle for controlling proper mattress installation, 2 self positioning stone dumpers (2,000t load), Johan V geotechnical reconnaissance pontoon, Jan Heijmans vessel which helped the Cardium place the mattress, the Sepia and Donax I vessels which worked with the Macoma during the placement of gravel ballast on the mattresses…

The total construction cost of the scheme was €2.7bn in 1986 (about £5bn in 2009) and the cost of all the purpose-built vessels accounted for about 6% of budget. The maximum workforce was 1,600 people for the construction.

The barrier had a revolutionary design. Many techniques had not been used before and if they had, it was not during such a large-scale project as this one. There were no ships suitable for the construction of the storm surge barrier. For the building of the dam, several vessels were designed, which were individual tours de force. The ships were all "state-of-the-art". Most of the ships were provided with a system which could automatically and very precisely determine the location of the ship. The bearing techniques for orientation were quite new. In addition, new techniques were used to identify the surface and the structure of the sea bottom. Equipment such as gyroscopes and accelerometers would have been indispensable. To process the data flows provided by the equipment, large computers were necessary.

The main purpose-built vessels like the Cardium, Ostrea and Macoma, have never been used on other projects because of their specific design. Nevertheless, this Delta project has proved that challenging works can be overcome thanks to innovative construction solutions and also to specific tools and dedicated vessels.

Competition from other offshore construction projects

The increasing focus on offshore wind, wave, tidal stream and European Super Grids is likely to increase the pressure on the existing vessel resource. However, firm commitment to these programmes will make sure that new investment is brought in to alleviate the current scarcity of supply. As offshore wind turbines are increasing in size (to 5 or 6 MW and even 8 MW, in particular floating wind turbines which are currently being developed in Norway), new cost effective and fast installation methods are likely to be developed in the short term. So as to take advantage of the short weather windows and to optimise the duration of the mast and nacelle installation, Marine Contractors envisage now to build specific vessels able to lift and transport a pre-assembled wind turbine (mast + nacelle + blades) and to fix it to the foundation structure or to anchor it. Therefore, very few of the existing installation vessels would be adequate for installing turbines or foundations in the years after 2020 (or maybe earlier). This may actually release some of the existing vessels back onto the market, as they become redundant, through lack of sufficient lifting capacity at the hub heights that will be required for 6 MW and above turbines. Nevertheless, these vessels might also then move to the Far

East to service countries like India and the Philippines that are looking to install large scale wind farms off their coasts using smaller wind turbines; but this scenario is not confirmed. Therefore, the availability of heavy lift barges or transportation vessels for a STP scheme could be better than expected.

Competition from concurrent large construction projects may increase costs as demand for the resources of plant, labour and materials surpasses supply. Early involvement of the contractor(s) and suppliers would contribute to the project's success by engaging those parties in the development process and providing, at the relevant stage, certainty by securing resources.

It is relevant to note that if the London Gateway Project is resumed (initially scheduled in 2009-2013 but postponed), the demand for Marine equipment might be slightly put under strain (30 million m^3 dredging, 1,300 m quay construction…).

Conclusion

Availability of dredging and marine equipment changes to satisfy global demand and the major vessels likely to be required for the STP scheme would need to be assessed in more detail now so as to provide an input to the overall scheme selection process. The particular environment of the Severn Estuary is likely to influence the type of vessels and their fittings. Forward planning and early engagement with suppliers would address the vessel availability, modifications to suit the demands of the environment and the timeframes.

The demand for specialised marine equipment is likely to remain steady (in particular due to planned offshore wind energy projects but also due to forthcoming wave and tidal developments), the long lead-in times of a STP project should provide an opportunity to address potential equipment capacity gaps. Anticipated changes are more likely to occur in the geographical location of the equipment rather than due to change of workload.

Also, the construction method must be optimised or even innovated so as not to be too dependent on the international vessels market (e.g. many moles or similar rock walls in the past have been serviced by rail mounted Goliath cranes installed on the crest of the structure; it is possible that a similar approach could be used on the barrages or lagoons to supplement crane vessels).

The Eastern Scheldt case study has proved that innovation can bring efficient responses to technical challenges and purpose-built vessels can also be envisaged for specific tasks.

III - MAIN CIVIL WORKS

Introduction

During the preliminary optimisation analysis of the feasibility study, the design of embankments and breakwaters for navigation locks were modified and based on conventional embankment fill and rubble mound. All the figures have been updated and the results come from the best variant of each short-listed scheme. The volume and tonnage of materials, in particular for the embankments, has been re-assessed according to the most suitable alignment, taking into account the sea-bed quality (volume of dredged materials required) and the water depth. Further studies on alternative solutions for embankment design (e.g. Fleming wall proposal for the Welsh Grounds lagoon) are being undertaken as potential alternative forms but conventional embankment fill and rubble mound is the worst case scenario in terms of labour and material resources and provides greater technical certainty.

The summary of the main construction materials required for each scheme is set out as follows:

Barrage schemes - Embankment and breakwater (lock) construction

	Barrages					
	Cardiff-Weston		Shoots		Beachley	
Embankments						
Overall crest length (km)	3.8		5.46		0.57	
Foundation preparation	million m^3	million ton	million m^3	million ton	million m^3	million ton
Sand bed (on dredged surface)	0.479	0.814	0.271	0.461	0.043	0.073
Embankment Structure	million m^3	million ton	million m^3	million ton	million m^3	million ton
Control structure rockfill (0.1 - 1t; 70% crushed rock - 30% armour stone)	1.598	3.516	0.401	0.882	0.103	0.227
Containment mounds (tonne quarry-run rock; crushed rock)	1.385	3.047	1.806	3.973	0.144	0.317
Filter Type 1 (0.6 - 35mm; gravel)	0.789	1.499	0.843	1.602	0.085	0.162
Filter Type 2 (50 - 250mm; gravel)	0.191	0.363	0.237	0.450	0.022	0.042
Sand core	6.359	10.810	3.337	5.673	0.364	0.619
Armour stone (0.3 - 1t)	0.038	0.084	0.346	0.761	0.036	0.079
Armour stone (1 - 3t)	0.600	1.320	0.525	1.155	0.044	0.097
Breakwater for locks (rubble mound)	million m^3	million ton				
Sand core and bed	0.096	0.163				
Derrick stone (<1t; 70% crushed rock – 30% armour stone)	0.115	0.253				
Armour stone (0.3 - 1t)	0.021	0.046				
Armour stone (1 - 3t)	2.839	6.246				
Rock armour (3 - 6t)	0.424	0.933				
Total materials for embankments	million m^3	million ton	million m^3	million ton	million m^3	million ton
Total sand	6.934	11.788	3.608	6.134	0.407	0.692
Total gravel	0.980	1.862	1.080	2.052	0.107	0.203
Total sand & gravel	7.914	13.650	4.688	8.186	0.514	0.895
Total crushed rock	2.584	5.685	2.087	4.591	0.216	0.475
Total sand & gravel & crushed rock	10.498	19.335	6.775	12.776	0.730	1.371
Total armour stone	4.436	9.759	0.991	2.181	0.111	0.244
Filling materials (landing area for locks)	3	5.7	3	5.7	0	0

Sources: Parsons Brinckerhoff & DECC

In order to compare the demand for construction aggregates with the regional and national output capacity statistics (breakdown: sand & gravel – crushed rock – armour stone), each category of materials required has been classified according to this breakdown. It has been assessed that control structure rockfill and derrick stone are made of 70%

crushed rock and 30% armour stone; filter type 1 (0.6 – 35mm) are supposed to be gravels in the survey but they could also be small crushed rocks.

As for landing areas for the navigation lock (estimate: 3 million m^3), dredged materials from foundation preparation are likely to be suitable.

Barrage schemes - Concrete structures (caissons...) and pre-cast armour units construction

	Barrages					
	Cardiff-Weston		Shoots		Beachley	
Precast armour units (Dolosse)						
Number of 5t units Dolosse	60,501		0		0	
Concrete for Dolosse (4m^3/unit)	0.242	0.605				
Rebar		0.05				
Cement for Dolosse units (320kg/m^3)		0.077				
Concrete structures						
Form surfaces (incl. Caisson lock)	million m^2	14.749	million m^2	1.843	million m^2	1.166
Crest works	million m^3	million ton	million m^3	million ton	million m^3	million ton
Reinforced concrete (Wave wall)	0.097	0.243	0.089	0.223	0.009	0.023
Cement (350kg/m^3)		0.034		0.031		0.003
Rebar		0.020		0.019		0.002
Caissons						
Caissons (turbines & gates)	129 caissons		46 caissons		31 caissons	
Structural concrete	6.332	15.830	0.673	1.683	0.338	0.845
Cement (350kg/m^3)		2.216		0.236		0.118
Rebar		1.299		0.134		0.065
Sand ballast	8.062	12.093	0.825	1.2375	0.392	0.588
Concrete ballast	0.746	1.641	0.111	0.244	0.049	0.108
Cement for ballast (315kg/m^3)		0.235		0.035		0.015
Caissons (lock & breakwater)	35 caissons		6 caissons		6 caissons	
Structural concrete	0.898	2.245	0.073	0.183	0.073	0.183
Cement (350kg/m^3)		0.314		0.026		0.026
Rebar		0.184		0.015		0.016
Sand ballast	1.271	1.907	0.158	0.237	0.158	0.237
Concrete ballast	0.328	0.722	0	0	0	0
Cement for ballast (315kg/m^3)		0.103	0	0	0	0
Total materials for concrete structures	million m^3	million ton	million m^3	million ton	million m^3	million ton
Total sand ballast	9.333	14.000	0.983	1.475	0.550	0.825
Total concrete	8.401	20.680	0.946	2.332	0.469	1.159
Total concrete aggregates (sand & gravel & crushed rock)		11.374		1.283		0.637
Total cement		2.903		0.327		0.163
Total rebar		1.503		0.168		0.083

Sources: Parsons Brinckerhoff & DECC

The total tonnage of construction aggregates (concrete aggregates, aggregates for embankment fill, sand ballast, sand bed…) and armour stone is as follows:

	Barrages		
	Cardiff-Weston	Shoots	Beachley
	million tonnes	million tonnes	million tonnes
Total aggregates for construction fill (embankment fill/sand ballast/sand bed)	33.334	14.251	2.196
Sand & gravel	27.649	9.660	1.721
Crushed rock	5.685	4.591	0.475
Total aggregates for concrete (structures & precast armouring)	11.707	1.283	0.637
Total armour stone	9.759	2.181	0.244

Barrage schemes – Tonnage of construction materials

Sources: Parsons Brinckerhoff & DECC

Lagoon schemes - Embankment and breakwater (lock) construction

	Lagoons			
	Welsh Grounds		Bridgwater Bay	
Embankments				
Overall crest length (km)	25.85		14.94	
Foundation preparation	million m^3	million ton	million m^3	million ton
Sand bed (on dredged surface)	1.089	1.851	2.125	3.613
Embankment Structure				
Control structure rockfill (0.25 – 2.5t; 70% crushed rock - 30% armour stone)	0.400	0.880	1.405	3.091
Containment mounds (tonne quarry-run rock; crushed rock)	9.107	20.035	8.561	18.834
Filter Type 1 (0.6 - 35mm; gravel)	4.484	8.520	3.661	6.956
Filter Type 2 (50 - 250mm; gravel)	1.243	2.362	0.957	1.818
Sand core	13.977	23.761	22.378	38.043
Armour stone (0.3 - 1t)	1.759	3.870	1.458	3.208
Armour stone (1 - 3t)	3.252	7.154	1.454	3.199
Total materials for embankments	million m^3	million ton	million m^3	million ton
Total sand	15.066	25.612	24.503	41.655
Total gravel	5.727	10.881	4.618	8.774
Total sand & gravel	20.793	36.494	29.121	50.429
Total crushed rock	9.387	20.651	9.545	20.998
Total sand & gravel & crushed rock	30.180	57.145	38.666	71.427
Total armour stone	5.131	11.288	3.334	7.334

Sources: Parsons Brinckerhoff & DECC

Lagoon schemes - Concrete structures (caissons...) and pre-cast armour units construction

	Lagoons			
	Welsh Grounds		Bridgwater Bay	
Precast armour units (Dolosse)				
Number of 5t units Dolosse	0		468,667	
Concrete for Dolosse (4m^3/unit)			1.875	4.687
Rebar for Dolosse				0.389
Cement for Dolosse units (320kg/m^3)				0.600
Concrete structures				
Form surfaces (incl. Caisson lock)	million m^2	2.886	million m^2	4.735
Embankment crest works	million m^3	million ton	million m^3	million ton
Reinforced concrete (Wave wall)	0.294	0.735	0.213	0.533
Cement (350kg/m^3)		0.103		0.075
Rebar		0.061		0.045
Caissons				
Caissons (turbines & gates)	32 caissons		42 caissons	
Structural concrete	1.057	2.643	2.027	5.068
Cement (350kg/m^3)		0.370		0.709
Rebar		0.216		0.416
Sand ballast	1.991	2.986	3.094	4.641
Concrete ballast	0.049	0.108	0.247	0.543
Cement for ballast (315kg/m^3)		0.015		0.078
Caissons (lock & breakwater)	6 caissons		6 caissons	
Structural concrete	0.076	0.190	0.077	0.193
Cement (350kg/m^3)		0.027		0.027
Rebar		0.016		0.016
Sand ballast	0.154	0.232	0.161	0.241
Total materials for concrete structures	million m^3	million ton	million m^3	million ton
Total sand ballast	2.145	3.218	3.255	4.882
Total concrete	1.476	3.675	2.564	6.337
Total concrete aggregates (sand & gravel & crushed rock)		2.021		3.485
Total cement		0.515		0.889
Total rebar		0.293		0.477

Sources: Parsons Brinckerhoff & DECC

The total tonnage of construction aggregates (concrete aggregates, aggregates for embankment fill, sand ballast, sand bed…) and armour stone is as follows:

	Lagoons	
	Welsh Grounds	Bridgwater bay
	million tonnes	million tonnes
Total aggregates for construction fill (embankment fill/sand ballast/sand bed)	60.363	76.309
Sand & gravel	39.712	55.311
Crushed rock	20.651	20.998
Total aggregates for concrete (structures & precast armouring)	2.021	6.063
Total armour stone	11.288	7.334

Lagoon schemes – Tonnage of construction materials
Sources: Parsons Brinckerhoff & DECC

A – Aggregates and armour stone

Introduction

In this report, the word “aggregates” refers to the following materials for civil works:

- aggregates for concrete (sand & gravel; crushed rock)
- materials used as fill for embankments (sand core, crushed rock), caissons (sand ballast) and sand bed on dredged surface

Armour stone (and rock armour) are large stones (> 1t) used for embankment and breakwater slope protection.

The supply of aggregates for construction (concrete aggregates, ballast, embankment fill, armour stone…) is one of the major issues for each STP scheme due to the very large volume of materials required.

There are two main streams of aggregates supply: “primary” aggregates (sand, gravel and crushed rock), extracted from the ground (quarry or gravel pit) or dredged from the seabed (marine aggregates), and “recycled and secondary” aggregates.

Primary aggregates are produced from naturally occurring mineral deposits, extracted specifically. Most construction aggregates come from hard, strong rock formations by crushing to produce crushed rock aggregate or from naturally occurring particulate deposits such as sand and gravel (either land-won or marine dredged). The most important sources of crushed rock in Britain are limestone (including dolomite), igneous rock and sandstone.

Recycled aggregates generally arise as a result of reusing materials, such as concrete and brick, from demolished buildings, roads and hard-standings. **Secondary aggregates** are the by-products of other processes, either minerals-related, such as waste material from slate and china clay extraction, or from electricity generation and manufacturing, such as ash from coal-fired power stations and slag from iron and steelmaking.

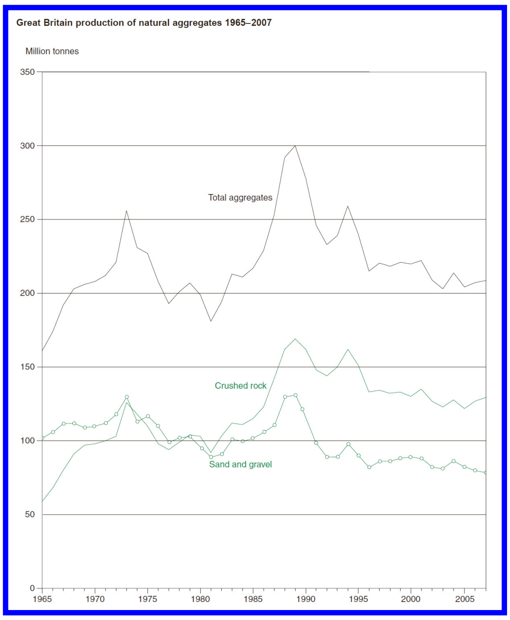
Data for 2005 has been used throughout this report because this is the year for which most complete information is available. Updated data from 2007 or even 2008 (when available) are also mentioned.

A-1 Primary aggregates

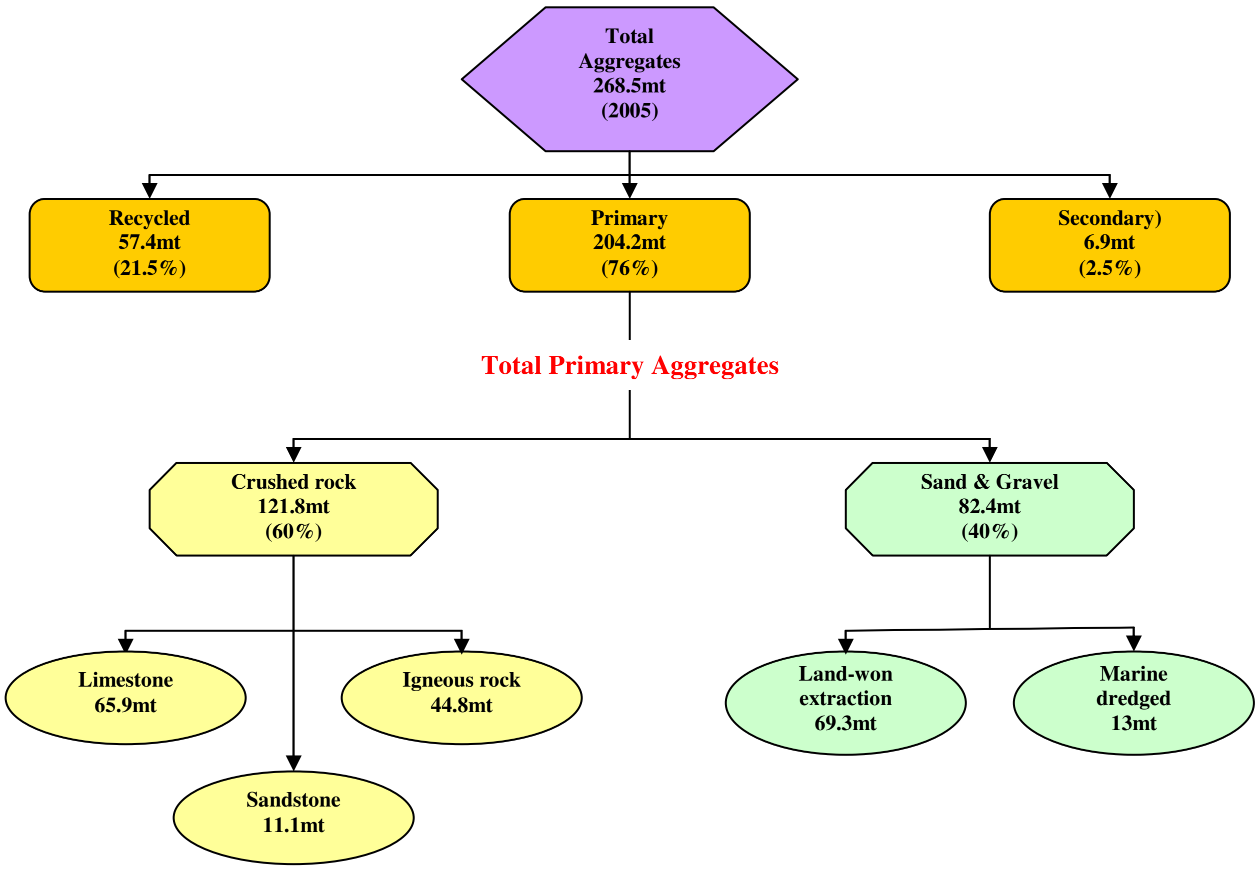
Primary aggregates production in the UK - Background

Sales of primary aggregates peaked at 300mt in 1989 but have since declined considerably. In 2007 about 208mt of primary aggregates were extracted for sale in Great Britain, comprising 62% of crushed rock, 31% of land-won sand and gravel and 7% of marine dredged sand and gravel. In 2005 the data were as follows: 204mt of primary aggregates, including 60% of crushed rock and 40% of sand and gravel (including marine dredged); see “GB - aggregates supply chain” figure below.

In England and Wales, the principal source of crushed rock is limestone, accounting for about 67% of supply, whereas in Scotland igneous rock is the dominant source of crushed rock (93%). No marine dredged sand and gravel is landed in Scotland, whilst in England and Wales marine sources accounted for 17% and 40% of total sales of sand and gravel, respectively. Northern Ireland produces sand and gravel only from land-won and also crushed rock (average output of 20mt; 27.1mt in 2007).



Great Britain – Production of primary aggregates 1965-2007
Source: British Geological Survey – UK Mineral Yearbook 2008



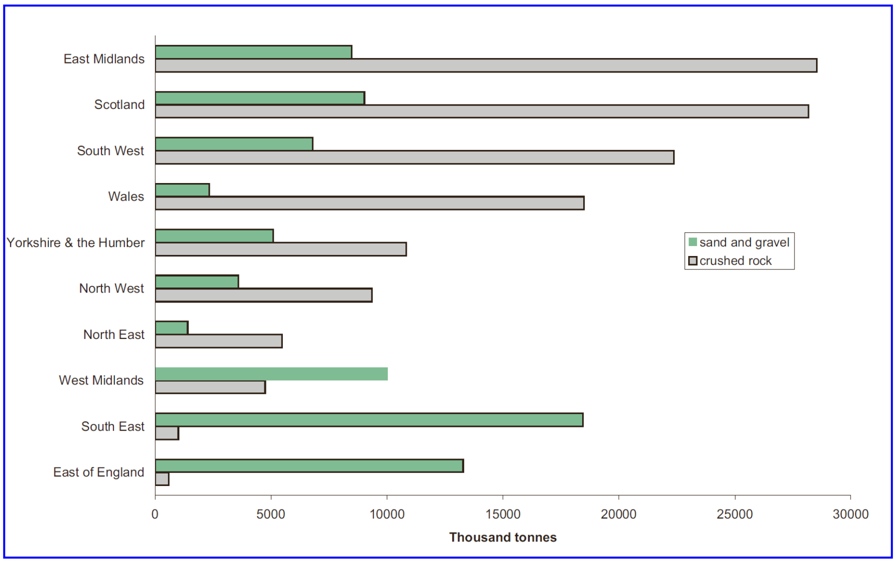
Great Britain: Aggregates supply chain (excluding imports - 2005)
Sources: Annual Minerals Raised Inquiry 2005, ONS

The various sources of primary aggregates in the UK are set out in the following table (2005 data):

	Land-won Sand & Gravel	Marine Sand & Gravel	Total Sand & Gravel	Crushed Rock	Total primary Aggregates
	Million Tonnes				
North East	1.15	0.43	1.58	5.33	6.91
North West	3.41	0.26	3.67	7.99	11.66
Yorks & the Humber	5.1	0.15	5.25	10.87	16.12
East Midlands	9.23	0	9.23	27.47	36.70
West Midlands	9.25	0	9.25	4.42	13.67
East of England	13.23	2.33	15.56	0.24	15.80
South East	7.24	8.11	15.35	1.09	16.44
London			4.01	0	4.01
South West	*6.31*	*0.62*	*6.93*	*23.18*	*30.11*
England	58.93	11.90	70.84	80.59	151.43
Wales	*1.63*	*1.11*	*2.74*	*16.53*	*19.28*
Scotland	8.08	0	8.08	24.73	33.54
Great Britain	69.37	13.02	82.39	121.86	204.25
Northern Ireland	5.80	0	5.80	19.78	25.58
UK	75.17	13.02	88.19	141.64	229.83

UK: sales of primary aggregates by Region and Country – 2005
Sources: Annual Minerals Raised Inquiry 2005, ONS for GB. Department of Enterprise, Trade and Investment for Northern Ireland

The latest available data in 2007 are set out in the following chart:



Great Britain – Production of primary aggregates (sand and gravel – crushed rock) by Region – 2007
Source: British Geological Survey – UK Mineral Yearbook 2008

The relatively stable sales of recent years ended abruptly towards the end of 2008 with the global economic decline causing a significant fall in the demand for aggregates. The Mineral Products Association estimate that sales of crushed rock aggregates fell by 12% in 2008 as a whole, while sand and gravel sales fell by 15% compared to 2007. The outlook for 2009 is not good with demand predicted to be at its lowest level since 1997. The economic crisis and the downturn in aggregate sales have had a significant impact on many operators with sharp falls in profit, plant closures and job losses being announced by most companies.

As the development of a Severn Tidal Scheme (if decided in 2010) could not start before 2015 (or even later), this gives us hope of a construction market recovery and an improvement of the aggregates production in the UK.

Primary aggregates consumption in the UK

The UK has large resources of material suitable for use as aggregates. Historically, the UK has been self sufficient in the supply of primary aggregates and imports have not been necessary (excluding armourstone). The average total consumption of primary aggregates in the UK is about 220mt per year (production plus imports less exports; about 208mt in Great Britain). The total consumption of primary aggregates in Great Britain is set out in the following table:

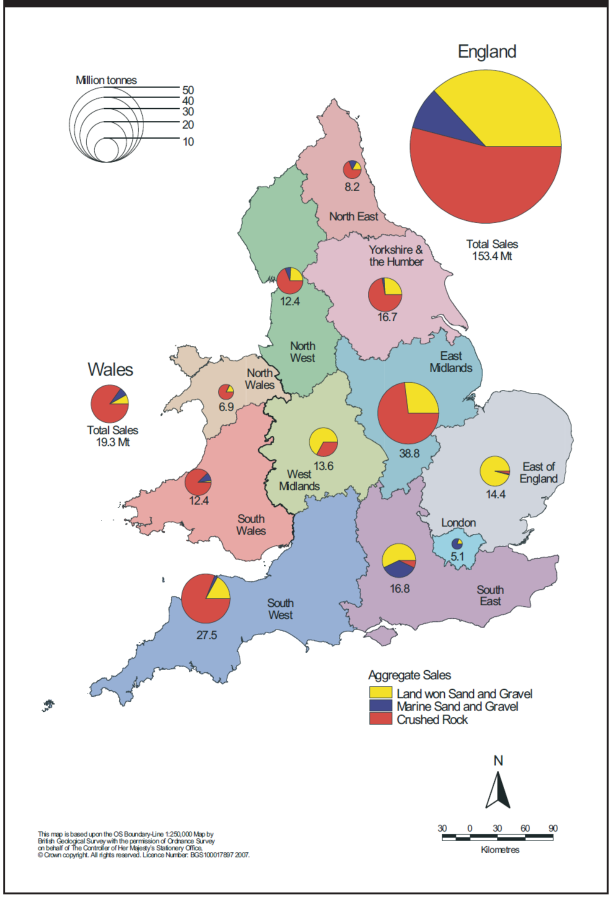
Year	Crushed rock (mt)				Sand and gravel (mt)			Total Aggregates (mt)
	Limestone	Igneous rock	Sandstone	Total	Sand	Gravel	Total	
2005	66	46	11	123	43	39	82	205
2006	70	46	11	127	42	38	80	207
2007	67	51	12	130	42	36	79	208

Consumption of primary aggregates in Great Britain – 2005 - 2007
Sources: British Geological Survey and ONS

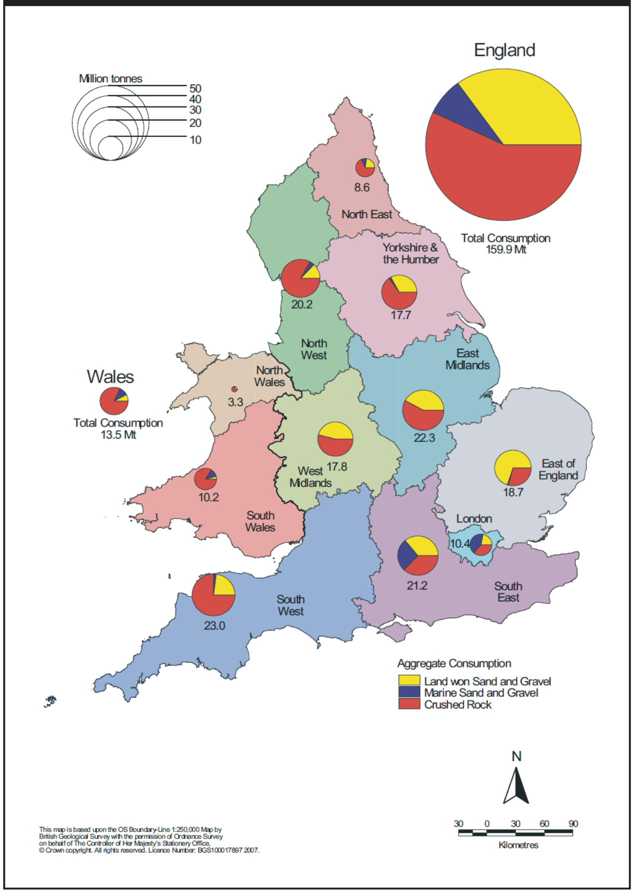
In 2005, 205mt of primary aggregates were consumed in Great Britain, including 160mt in England and 13.5mt in Wales.

The following maps summarizes the sales and consumption of primary aggregates in England and Wales:

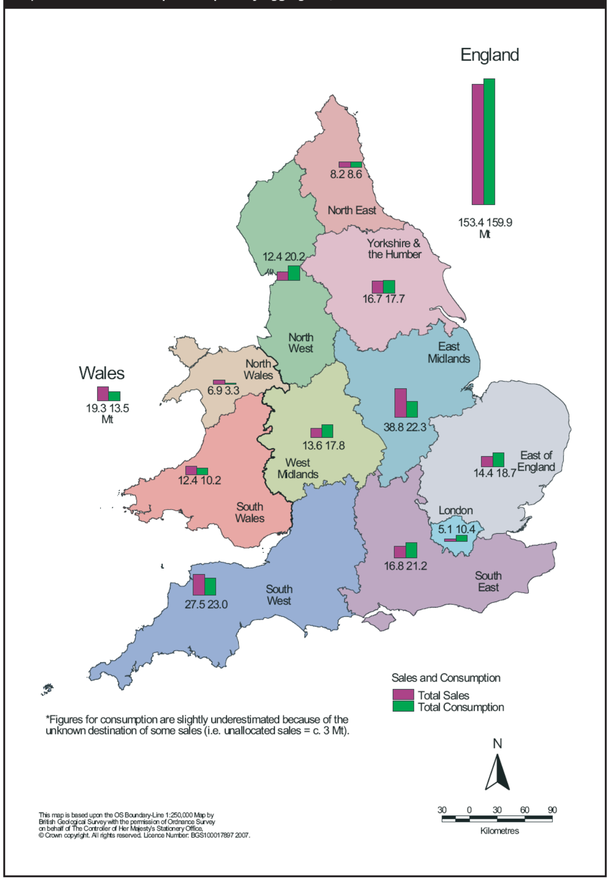
Map 4: Sales of sand and gravel and crushed rock for aggregates, 2005



Map 5: Consumption of sand and gravel and crushed rock for aggregates, 2005



Map 9: Sales and consumption of primary aggregates, 2005

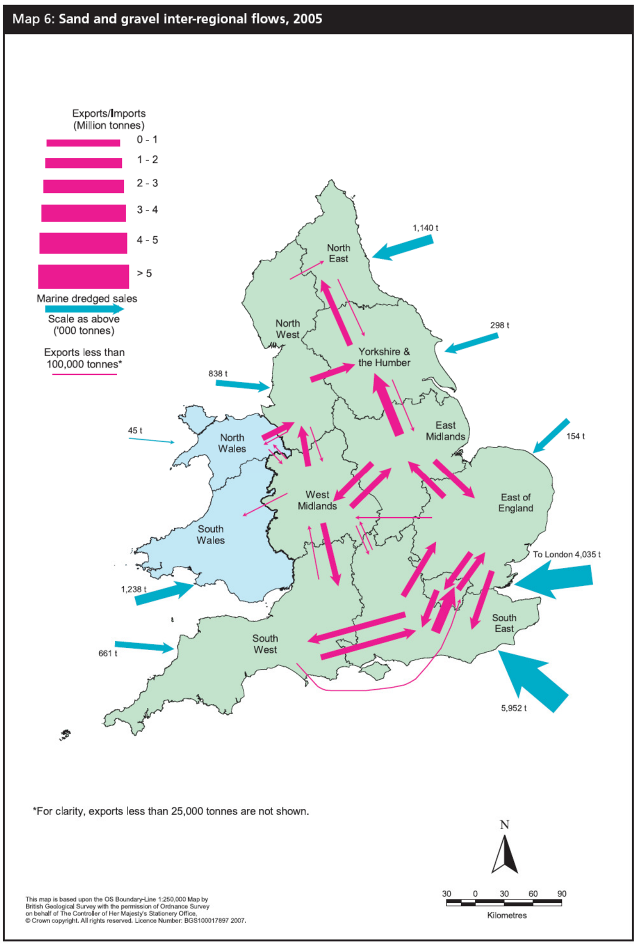


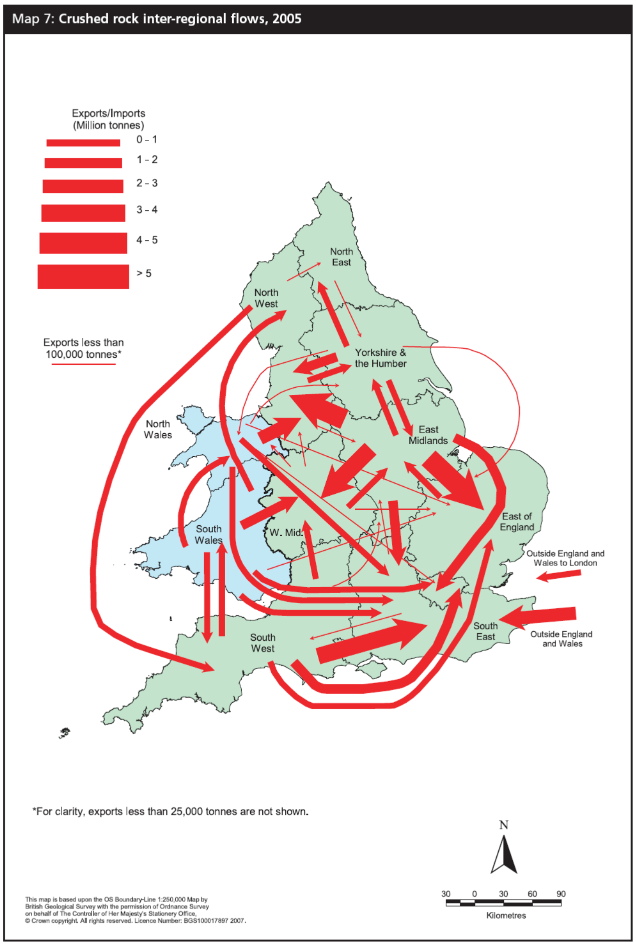
Sales and consumption of primary aggregates - 2005

Source: Collation of the results of the 2005 Aggregate Mineral Survey for England and Wales
British Geological Survey - May 2007

Inter-regional flows of primary aggregates

However, the distribution of these primary aggregates resources is uneven. In particular, there is an almost total absence of hard rock suitable for crushed rock aggregates in Southern and Eastern England, where demand is high. Consequently, there is substantial and increasing movement of aggregates within the UK and especially to these areas by rail and road. To a more limited extent, there is also shipment from Scotland and, on a lesser scale, from Wales and Northern Ireland.





Primary aggregates inter-regional flows - 2005
Source: Collation of the results of the 2005 Aggregate Mineral Survey for England and Wales
British Geological Survey - May 2007

There are over 1,600 aggregates quarries in the UK, roughly split 40:60 between sand and gravel sites and crushed rock (1,300 quarries in Great Britain and a fleet of 28 marine aggregate dredgers). Wales and South West England together have 124 quarries and 22 wharves for marine dredged aggregates. There are also a large number of aggregates producers, which range from single quarry owners to multi-national companies operating many sites throughout the country. Five multi-national companies (Tarmac Group, Hanson Aggregates, Aggregates Industry, CEMEX and Lafarge Aggregates) currently account for more than 70% of total aggregates production in the UK.

The principal modes of transport employed for the distribution of aggregates sales from quarries and wharves are as follows: 90% road, 9% rail and 1% shipment by water. Crushed rock is very often transported by sea from coastal quarries in the UK (Scotland – Glensanda, Wales and Northern Ireland) to destinations principally in England (average of 3mt/year; 90% of the crushed rock is from outside England). For crushed rock the proportion of rail deliveries increased to about 15%.

End-use of aggregates

Generally, primary aggregates are used for the following purposes:

- Concrete aggregates
- Asphalt and roadstone
- Construction and fill (e.g. embankment, dyke…)
- Rail ballast

- Mortar…

The breakdown of primary aggregates production (including marine aggregates) by end-use in Great Britain, Wales and in the South West is set out in the following table (based on 2007 data):

Region/Country	Production of primary aggregates by end-use (mt & %) - 2007			
	Concrete aggregates	Construction uses &fill	Other uses (roadstone, railway ballast…)	Total (mt)
South West	*9.5 (32.5%)*	*9.3 (31.9%)*	*10.4 (35.6%)*	*29.2*
Wales	4.6 (22.1%)	8.5 (40.9%)	7.7 (37%)	20.8
England	63.3 (42.2%)	40.6 (27.1%)	46.1 (30.7%)	150
Scotland	10.4 (28.1%)	12.4 (33.4%)	14.3 (38.5%)	37.1
Great Britain	**78.3 (37.6%)**	**61.5 (29.6%)**	**68.3 (32.8%)**	**208.1**

Production of primary aggregates (sand, gravel & crushed rock) by end-use (2007)
Source: UK Mineral Yearbook 2008 - British Geological Survey

The specific breakdown of sand and gravel production (land-won and marine dredged) by end-use in Great Britain, Wales and in the South West is set out in the following table (based on 2007 data):

Region/Country	Production of sand & gravel by end-use (mt and %) - 2007					
	Sand		Gravel		Sand & Gravel for construction fill	Total sand & gravel (mt)
	Building Sand (mortar…)	Concreting Sand	Other uses (binder…)	Concreting Gravel		
South West	*1.1 (16.2%)*	*2.9 (42.6%)*	*0.1 (1.5%)*	*1.2 (17.6%)*	*1.5 (22%)*	*6.8*
Wales	0.7 (30.4%)	0.9 (39.1%)	0.1 (4.3%)	0.4 (17.4%)	0.2 (8.7%)	2.3
England	10 (14.9%)	25.9 (38.6%)	0.2 (0.3%)	21.2 (31.6%)	9.8 (14.6%)	67.1
Scotland	1.6 (17.8%)	3.4 (37.8%)	0.1 (1.1%)	1.9 (21.1%)	2 (22.2%)	9
Great Britain	**12.3 (15.7%)**	**30.2 (38.5%)**	**0.4 (0.5%)**	**23.5 (30%)**	**12 (15.3%)**	**78.5***

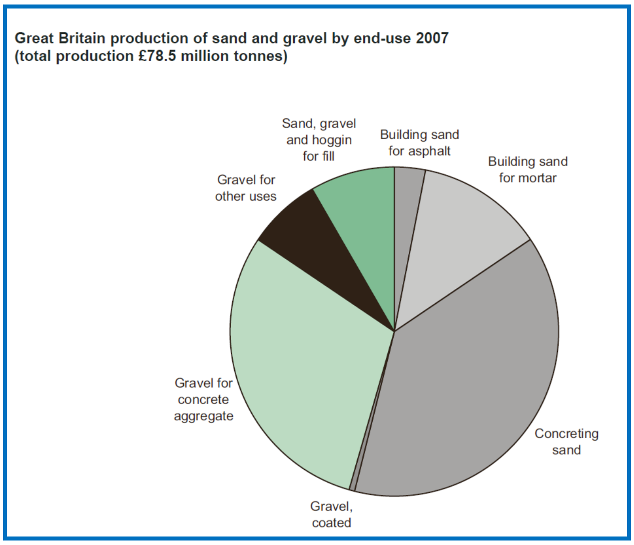
Production of sand and gravel by end-use (2007)
Source: UK Mineral Yearbook 2008 - British Geological Survey
***78.5mt: land-won 64.7mt; marine 13.8mt**

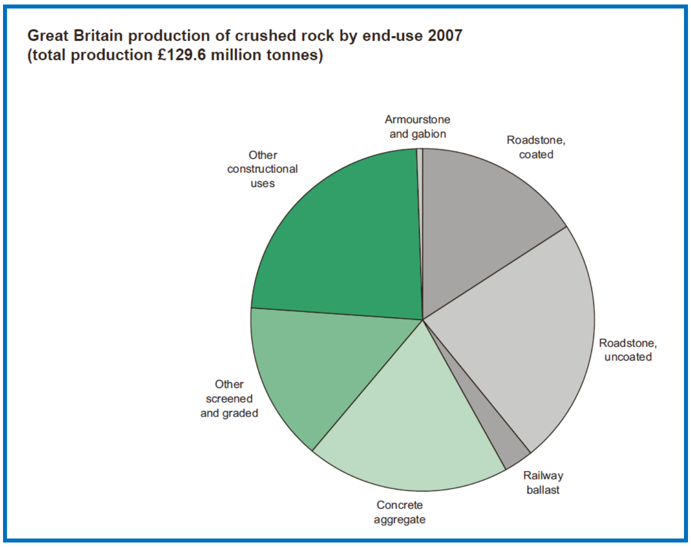
Finally, the specific breakdown of crushed rock production by end-use in Great Britain, Wales and in the South West is set out in the following table (based on 2007 data):

Region/Country	Production of crushed rock by end-use (mt and %) - 2007					
	Roadstone	Railway ballast	Construction uses & fill	Concrete aggregate	Armourstone & gabion	Total crushed stone (mt)
South West	*8.8 (39.3%)*	…	*7.8 (34.8%)*	*5.4 (24.1%)*	*0.06 (0.3%)*	*22.4*
Wales	6.4 (34.6%)	0.3 (1.6%)	8.3 (44.9%)	3.3 (17.8%)	0.07 (0.4%)	18.5
England	33.1 (39.9%)	2.3 (2.8%)	30.8 (37.1%)	16.2 (19.5%)	0.45 (0.5%)	82.9
Scotland	11 (39.1%)	1.3 (4.6%)	10.4 (37%)	5.1 (18.1%)	0.26 (0.9%)	28.1
Great Britain	**50.5 (39%)**	**3.9 (3%)**	**49.5 (38.2%)**	**24.6 (19%)**	**0.78 (0.6%)**	**129.6**

Production of crushed rock by end-use (2007)
Source: UK Mineral Yearbook 2008 - British Geological Survey

These tonnages and breakdowns of end-use will be used to assess the impact of the aggregates demand (aggregates for concrete, ballast and aggregates for embankment fill) for the shortlisted STP schemes on the regional and national market, assuming the breakdown in % remains the same. As an increase in the production capacity is likely to occur due to a better economic situation (higher demand expected), these 2007 figures will be increased by a few % so as to get a more relevant and realistic assessment.





Breakdown of sand-gravel and crushed rock production in Great Britain - 2007
Source: UK Mineral Yearbook 2008 - British Geological Survey

Exports of aggregates

The UK is, in fact, a net exporter of aggregates. This is primarily due to export of sand and gravel dredged on the UK Continental Shelf but landed at foreign ports, principally in the Netherlands, Belgium and France (amounting to about 6mt/year). There are also exports of crushed rock from Glensanda, Britain's only coastal superquarry located on Loch Linnhe in western Scotland (Morvern Peninsular). The average exports of primary aggregates from the UK are 12mt/year (8mt of sand and gravel, including 6mt of marine dredged; 4mt of crushed rock).

United Kingdom summary 2003–2007

Commodity		2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
		Tonnes					£ thousand				
Aggregates											
Production											
Sand & gravel (a)		91 211 000	97 333 000	94 666 000	92 107 000	93 236 000					
Crushed rock (b)		122 885 000	127 674 000	121 860 000	126 895 000	129 577 000					
	Total	214 096 000	225 007 000	216 526 000	219 002 000	222 813 000					
Imports											
Natural aggregates–											
Crushed rock (c)		632 792	619 076	1 516 919	2 270 355	1 909 733	10 064	10 661	19 037	27 202	27 501
Sand and gravel (d)		861 439	924 304	643 594	634 844	896 715	11 406	14 481	14 117	17 583	18 260
	Total	1 494 230	1 543 380	2 160 513	2 905 198	2 806 448	21 470	25 142	33 154	44 785	45 761
Exports											
Natural aggregates–											
Crushed rock		3 188 232	4 528 231	4 850 971	5 322 099	5 959 212	13 275	22 865	25 141	25 773	33 637
Sand and gravel (d)		8 419 845	8 174 262	8 453 949	9 308 961	8 089 175	36 708	36 414	40 493	45 498	46 624
	Total	11 608 077	12 702 493	13 304 920	14 631 060	14 048 387	49 983	59 279	65 634	71 271	80 261

(a) Including production from marine dredging.
(b) Great Britain only.
(c) For a number of years, a significant amount of armourstone imports are believed to be wrongly classified as 'granite, crude'. In 2007, this figure was 326 446 tonnes, and this has reduced from 1 331 520 tonnes in 2005, suggesting this issue is being addressed.
(d) Principally marine-dredged sand and gravel. Source: HM Revenue and Customs. However, the Crown Estate Commissioners give the following figures for marine-dredged sand and gravel landed at foreign ports (tonnes): 2003: 6 095 640; 2004: 6 191 867; 2005: 6 471 453; 2006: 6 714 659; 2007: 6 649 041.

UK – Imports and exports of primary aggregates (2003 – 2007)
Source: UK Mineral Yearbook 2008 - British Geological Survey

Imports of aggregates

The average imports of primary aggregates to the UK are 3mt/year (0.9mt of sand and gravel, 0.6mt of crushed rock and 1.5mt of armour stone).

Norway is by far the leading rock supplier for the UK and around 1.8mt of aggregates was imported from Norway in 2005: 0.2mt of sand and gravel, 0.3mt of armour stone and the remainder was crushed rock aggregates for railway ballast, concreting aggregates, asphalt aggregates and material for road sub base. Norway exports an average of 10 - 12mt of crushed rock aggregates (including armour stone) to Europe from 20 coastal hard rock quarries and exports also 0.2mt of gravel from 3 sand and gravel producers. There are currently 8 main quarries in Norway (Larvik, Jelsa, Tau, Askoy, Dirdal…) exporting crushed rock and armour stone to the UK and they have in excess of 2,000mt of reserves (igneous and metamorphic rocks).

Norwegian hard rock quarries have annual outputs in the range 1 to 2.5mt/year, with the largest quarry Jelsa (operated by Norsk Stein A/S) having annual production of about 3.5 to 5mt/year (350mt reserves). Norway has deep-water anchorage, low tidal range and a well developed infrastructure to allow for harbour facilities for medium to large bulk carriers.

The other overseas aggregates providers for the UK are Ireland (0.4mt in 2003), Denmark (0.3mt in 2003) and France (0.5mt in 2003).

The major constraint on the ability of overseas sources to export more rock aggregates to England or Wales is not the ability to supply but more the capacity of the receiving wharves to unload and distribute the aggregates (the cost of bulk aggregates is very sensitive to transport logistics). With the cost of a new large bulk carrier barge (97,000t) being around £50 million and smaller 30,000t ship £15 million, the industry requires a guaranteed long term market to justify such investments. Ships with a capacity in excess of 15,000t are required to be economical to import crushed rock aggregates or rock armour. There are not many wharves that have deep enough water to take these vessels. Moreover, a viable minimum of suitable land area to stockpile rocks is around 1.5 hectares so as to hold around 125,000t of single size crushed rock aggregate or 70,000t of mixed grades. In England, stockpiles areas at wharves vary in size from 0.4 to 12 hectares.

There are currently 30 wharves where crushed rock aggregate is landed in England. The average amount of crushed rock imported through each of the medium to large crushed rock wharves in England ranges from 50,000 to 600,000t per year. Currently 62% of all crushed rock aggregates landed at wharves is distributed by road. The largest wharf unloading crushed rock aggregates is the Isle of Grain (North Kent) which is able to handle over 2mt/year; the majority of aggregates imported from the Glensanda quarry are landed at this wharf.

With current infrastructure and number of wharves and concerns over maintaining aggregates quality, the maximum additional amount of crushed rock aggregates that could be landed in England is estimated at an additional 2 to 3mt/year. If more rock aggregate is to be imported, then there will be a need for existing wharf capacity to increase. Several locations have been identified as additional wharves with potential to land crushed rock aggregates: 6 in the North West, one in the Bristol Channel (Barnstaple, Devon) and the bulk of the remainder in the South East. Issues to be considered in locating future wharf sites include:

- Access to adequate deep water
- Enough space to stockpile aggregates
- Access to suitable roads and rail with capacity to transport aggregates
- Neighbourhood issues

Another constraint to be considered will be the weather windows when this rock can sail from the main West and North European quarries, and more especially, be landed. Generally for rock supply to the UK East coast, vessels wait for a suitable weather window, before making a rapid crossing to the landing site. Special measures are taken to very rapidly unload the barges in as short a time as possible, to refloat them before the next weather system comes in. These short sea crossings will not be possible for the Severn estuary which is located too far, and it is likely that the rock will need re-handling from deep sea to shallow draft vessels.

It may prove necessary to modify some existing vessels in order to adapt them for rock handling. Rock is a very demanding cargo, and hulls and holds need considerable amounts of sacrificial steel plating to protect the structure of the vessel from damage from rock impact on loading and unloading.

Armour stone

The armour stone market is very variable, with possibly large tonnages imported in one year at one port and almost none in another. It is difficult to produce the large blocks of rock required from UK quarries because the rock is often fractured and, in most cases, it is not possible to load directly into ships or onto barges. Therefore, very little of the rock armouring used around the UK comes from Britain. The Scottish quarry Glensanda has a huge reserve of granite rock and large capacity of sea transport (and good rail connection to other mainland quarries); therefore, it could also be envisaged to extract more rock armouring from this site. Glensanda is Europe's largest granite quarry.

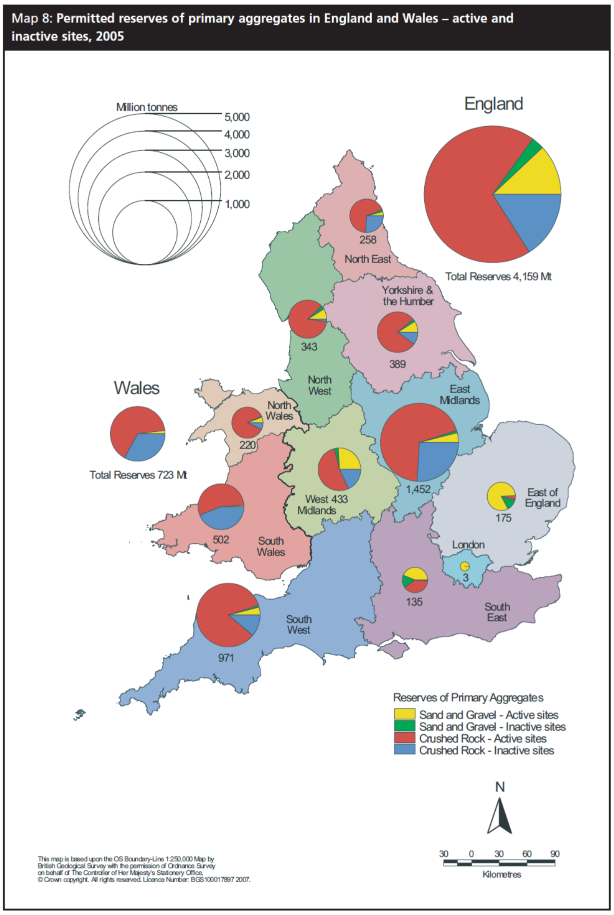
Due to the requirement for a dense and highly durable rock for this particular application, it is highly likely that the rock for these embankments or breakwaters would come from Norway or Northern Europe (Sweden…) and Western Europe (France, Spain; coastal quarries), where much of the existing rock armouring is currently sourced. Rock will be required in different sizes: the most critical will be the large armour rock. The development and blasting plans for the quarry have to ensure that an adequate quantity of each size can be obtained. These plans must include temporary roads so that the hauling to the sorting and stockpiling areas can be carried out efficiently. But most quarries are not prepared to drill and blast specifically for armour stone as it disrupts normal production.

Reserves of aggregates in the UK

Total permitted reserves for aggregate use in active and inactive sites in England and Wales (including sites that have not yet been opened at the end of 2005) were 4,882mt (4,159mt for England and 723mt for Wales).

In England, crushed rock accounted for 85% (3,556mt); sand and gravel the remaining 15% (603mt) whereas in Wales, crushed rock accounted for 97% (704mt); sand and gravel the remaining 3% (18mt). In Scotland, the reserves estimates were 1,491mt in 2005: crushed rock accounted for 92% (1,368mt) ; sand and gravel the remaining 8% (123mt).

Many of the UK quarries producing the highest quantities of aggregates have some, albeit limited, capacity to increase their supplies in the short term with the need for only minimal investment. This potentially could be in the order of 10 to 12mt/year. However, increasing the rate of extraction would also increase the depletion rates of the permitted reserves for these quarries. This is likely to result in an increase in applications for planning permission to release extra reserves in order that the individual companies could ensure long term viability.



Reserves of primary aggregates in England and Wales - 2005
Source: Collation of the results of the 2005 Aggregate Mineral Survey for England and Wales British Geological Survey - May 2007

Aggregates production in England and Policy

In England there is a well established mineral planning system which includes the principle that the construction industry should receive the aggregates required, consistent with the principles of sustainable development (Department for Communities and Local Government – DCLG – Mineral Policy Statement 1: Planning and Minerals - 2006). A National and Regional Guidelines for Aggregates Provision in England is regularly published and revised and these guidelines indicate how provision for the supply of aggregates should be made to meet anticipated future need. The DCLG is committed to keeping these guidelines under review. The last National and Regional Guidelines for Aggregates Provision in England (2005-2020) recommend generally lower levels of provision than the previous set issued in 2003 due to an overall fall in national demand for aggregates and an increase in use of alternatives to primary aggregates, notably construction and demolition waste.

Nine Regional Aggregates Working Parties provide technical advice (e.g. assessment of the resources and demands) to the DCLG and to the Government Offices and Regional Assemblies.

Million tonnes per annum

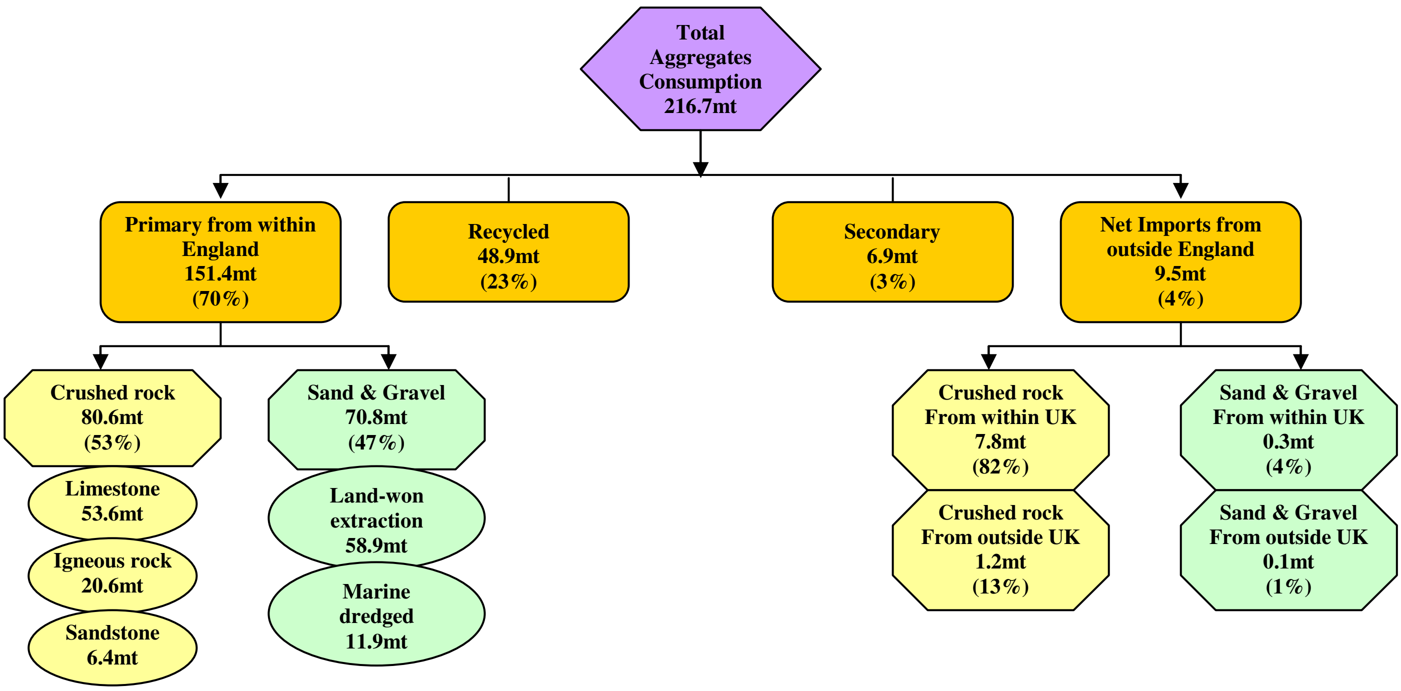
	Element of supply	2003 guidelines	New guidelines	% difference	
Guidelines	Land won sand and gravel	67	64	- 4	- 7
	Crushed rock	101	93	- 8	
Assumptions	Marine sand and gravel	14	16	+14	
	Net imports to England	11	9	- 18	
	Alternative materials	57	62	+ 9	
Total		250	244	- 2.4	

Changes between the 2003 guidelines for England and the 2005 one (expressed as average amounts per annum)
Source: National and regional guidelines for aggregates provision in England 2005-2020

New Regions	Guidelines for land-won production		Assumptions		
	Land–won Sand & Gravel	Land-won Crushed Rock	Marine Sand & Gravel	Alterna-tive Materials	Net Imports to England
South East England	195	25	121	130	31
London	18	0	72	95	12
East of England	236	8	14	117	7
East Midlands	174	500	0	110	0
West Midlands	165	82	0	100	23
South West	85	412	12	142	5
North West	52	154	15	117	55
Yorkshire & the Humber	78	212	5	133	3
North East	24	99	20	50	0
England	**1028**	**1412**	**259**	**993**	**136**

National & Regional guidelines for aggregates provision in England 2005-2020 (Million tonnes)
Source: National and regional guidelines for aggregates provision in England 2005-2020

The aggregates supply chain in England is shown in the above figure:



England: Aggregates supply chain (2005)
Sources: Mineral Extraction in GB 2005, Collation of the results of the 2005 Aggregates Minerals Survey for England and Wales and Survey of arising and use of alternatives to primary aggregates in England 2005

Total imports into England in 2005 were 9.5mt (4% of its primary aggregates needs), of which 95% was crushed rock. The primary source for these imports is Wales (6.2mt: 5.6mt crushed rock and 0.5mt sand). Other sources include Norway (1.6mt), Scotland (1.5mt, mainly from the Glensanda quarry), Northern Ireland (1mt) and France (0.2mt).

Aggregates production in Wales and Policy

In Wales a new mineral planning system is under development which will seek to reconcile the demands for aggregates with sustainability issues. Mineral Planning Policy Wales (2000) sets out the land-use planning policy guidance of the Welsh Assembly Government in relation to minerals, extraction and development in Wales (it includes all minerals, except marine aggregates). Minerals Technical Advice Note 1 (MTAN1): Aggregates (2004) sets out detailed advice on the mechanisms for delivering policy for land-based aggregates extraction by Mineral Planning Authorities and the aggregate industry. The Welsh Assembly Interim Marine Aggregates Dredging Policy (2004) seeks to ensure sustainable, objective and transparent decision-making to meet society's needs for aggregates dredged from the Bristol Channel, Severn Estuary and River Severn. Primary aggregates production in Wales is about 19mt/year (2005) and is dominated by crushed rock. Policy contained within MTAN1 suggests the following recommendations:

- Aggregates should be worked in as close a proximity as possible to the market
- Rail and water modes are favoured over road transport
- The total level of production in Wales should not exceed 27mt/year before 2010

Primary aggregates production in Wales is dominated by crushed rock which represents about 86%. Crushed rock is made up of limestone and dolomite (73%), sandstone only in South Wales (15%) and igneous rock (12%). Land based sand and gravel extraction is far more developed in North Wales than in South Wales where marine dredging provides most of this material thanks to large deposits in the Severn Estuary and Bristol Channel.

There are also large quantities of mineral waste (slate, colliery spoil…) which can be used. Around 6mt of recycled aggregates are available and about 30% of them can be re-used for construction aggregates.

Aggregates production in Scotland and Policy

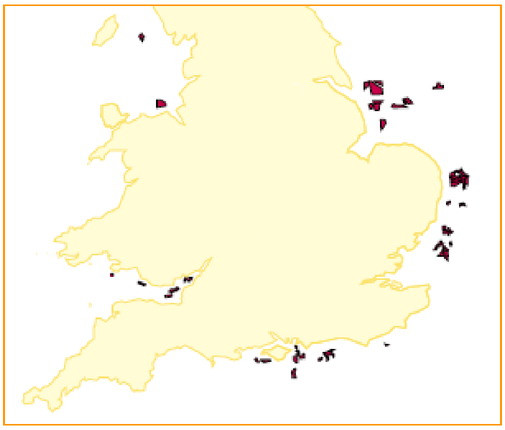
In Scotland, the National Planning Framework sets out the strategy for long term spatial development. Scottish Planning Policy (SPP) 4 – Planning for Minerals (Scottish Executive 2006) sets out planning policies that are intended to ensure that a steady supply of material is maintained to meet the demand and the economy in an acceptable and sustainable manner. Production levels are around 30-35mt/year; in 2005 the production output was 29.5mt (crushed rock: 22mt; sand and gravel: 7.5mt) and 5.5mt were exported, mainly from the large Glensanda coastal quarry (including 1.5mt to England). The overall contribution from recycled and secondary aggregates is around 18%.

Glensanda quarry, formerly owned by Foster Yeoman Ltd is now part of Aggregates Industries Ltd. Output from the Glensanda quarry is around 6 to 7mt/year (granite aggregate), of which 1.5mt is exported to England and the bulk of the remainder (about 70%) to other countries in Europe through ports in the Netherlands, Belgium, France, Denmark and Sweden and in depots in Germany and Poland. The quarry has permission to produce a maximum of 15mt/year (800mt reserves). This quarry serves the market both in the UK and beyond, with crushed rock aggregate being transported via the world's largest self loading transport ships (two 97,000t carrying capacity ships and one 37,000t ship owned by Yeoman Glensanda). Aggregate from Glensanda is used primarily for rail ballast and concreting aggregates (80%), with the remaining 20% being used for road sub base. Aggregates for the South East England market are discharged at a major terminal on the Isle of Grain in Kent (capable of handling over 2mt/year); material is then transhipped onto barges for transfer to Gibbs Wharf on the Thames in Essex, as well as other ports in southern and eastern England. Rock can also be landed directly at Robins Wharf on the Thames at Northfleet; other terminals include Liverpool, Greenock, Southampton and Great Yarmouth.

Other locations in Scotland have been identified as suitable for large quarries exporting aggregates. However, such developments raise substantial environmental concerns and the attempt to develop a major coastal quarry on Harris in the 1990s was unsuccessful.

A-2 Marine aggregates

The Crown Estate owns most of the mineral rights to the seabed and issues commercial licences to explore and extract sand and gravel in English and Welsh waters. The Crown Estate owns the territorial seabed (out to 12 nautical miles) and the rights to explore and utilise the non-energy mineral resources of the continental shelf (out to 200 nautical miles). An extraction licence is only issued if permission to dredge is given by the Marine and Fisheries Agency in England (shortly to become the new Marine Management Organisation - MMO - following the introduction of the Marine Bill) or the Welsh Assembly Government according to a Dredging Permission process. Any new licences to dredge would typically be subject to tendering and in places there are permitting constraints mainly arising from environmental concerns and conservation designations. Although licences are commonly acquired through tender rounds, it is also possible for a developer of a major project to apply for their own specific licence to The Crown Estate, particularly if existing licences are not capable of supplying required volumes and/or qualities. The developer would then obtain permission to dredge the sea bed, possibly linked with the Infrastructure Planning Commission (IPC) decision. Alternatively under "normal" circumstances it is estimated that it would take 3-4 years to get a permission to dredge under the new MMO-administered scheme.


licensed areas

The existing policy structure in the Welsh portion of the Bristol Channel is determined by the Interim Marine Aggregate Dredging Policy, published by the Welsh Assembly Government in 2004. This sets a cap on the marine extraction tonnage that is permitted in Welsh waters, and also sets a policy requirement for extraction to progressively move further offshore. There is no equivalent in English waters and the marine aggregates supply depends mainly on the market demand and is not constrained by ratio.

There are currently 80 Crown Estate licensed areas in the UK (50% on the East Coast) producing approximately 23mt of marine aggregates per year (21.54mt in 2008; 23mt in 2007 and 24,16mt in 2006). In 2008, 13.1mt was landed in England and Wales and of this total, 1.486mt landed in the Bristol Channel.

The potential supply of marine aggregates is not as constrained as this might suggested. In the Bristol Channel and Severn Estuary, the permissions are not resource-limited. Whilst permissions are typically issued for a maximum extraction from an area which is based on pro-rata across the term, it will often be possible to vary an existing permission to allow a more rapid extraction rate. There is also the possibility that additional tonnage may be approved with an updated environmental statement. Nevertheless, there are areas of environmental sensitivity, particularly in the upstream part of the Severn Estuary which may restrict dredging activities but these are likely to be mitigated.

Marine aggregates (sea-dredged sand and gravel) have made an important contribution to aggregates supply in the UK. In addition to landings at wharves for construction use (55 wharves throughout England and 13 in Wales), marine aggregates are also landed at numerous coastal locations for beach nourishment and contract fill or exported to Europe. In 2006, the amount of marine aggregates dredged along the UK coast was about 24.16mt/year and the main end-use was as follows:

- About 13.4mt (55%) for aggregates construction (concrete…) for the English and Welsh market
- About 6.7mt (28%) for exports to Europe
- About 4.2mt (17%) for beach nourishment and contract fill in the UK

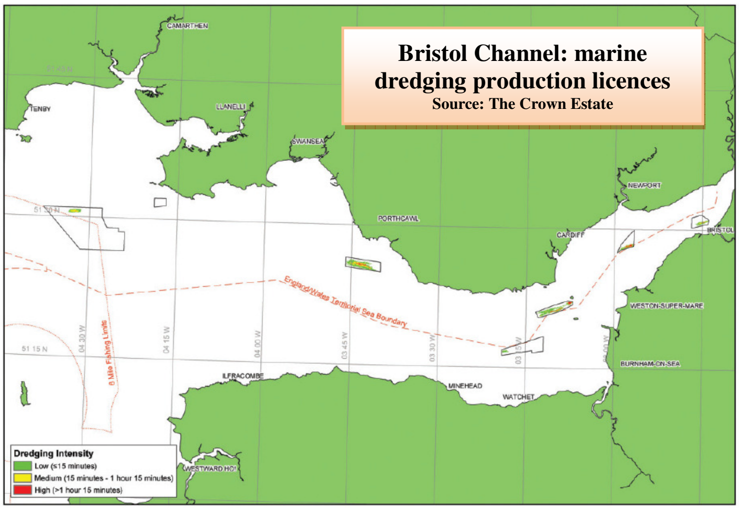
There are substantial reserves of sand (no significant reserves of gravel) mainly in the Severn Estuary and the Bristol Channel suitable for construction aggregates and civil engineering purposes. The locations of sand reserves are well understood and concentrated in two areas:

- Upstream in the Severn Estuary (westward to the Holms) and
- Significant resources farther offshore, lying in the central Bristol Channel, south of Carmarthen Bay

According to the Crown Estate, the national primary marine aggregates reserve (50:50 Sand/Gravel) is 120mt and the national primary marine sand reserve (less 20% gravel) is 83mt. These estimates (2008 survey) represent reserves available on consented production licence areas. The area of the seabed licensed for marine aggregates dredging in 2007 totalled 1,344km^2 (0.12% of the UK seabed) and only 137.6km^2 (11.7%) has been already dredged. The declared reserves significantly under-report the volumes of sand lying in the Bristol Channel as only permitted reserves are presented. With additional permitting, enough marine aggregate resources are likely to be available to comfortably satisfy any of the development options.

Nevertheless, marine aggregates reserves are not directly comparable with terrestrial figures as these reserves are constrained by the relatively short term of environmental permissions, rather than the availability of the resource. In this region, the potential resource of marine aggregates (particularly sand) is substantial.

Around 21% of the sand and gravel used in England and Wales is now supplied by the marine aggregates industry. In the Bristol Channel, 11 production licences, operated by British Dredging Ltd, Hanson Aggregates Marine Ltd, Llanelli Sand Dredging Ltd and United marine Dredging Ltd extract about 1.5mt/year (1.77mt in 2007) from a permitted licensed tonnage of 2.62mt. In 2007, 1.05mt were landed at Welsh wharves and 0.72mt at English wharves. South Wales is uniquely dependent on marine dredged sand which accounts for more than 90% of its supply.



Bristol Channel: marine dredging production licences
Source: The Crown Estate

In the UK, the dredging fleet is operating today at capacity (28 purpose built dredgers with a total hopper capacity of 112,000t). Investment is required to maintain the dredging fleet in the near future. The age profile of this fleet shows that 81% are more than 15 years old and 26% of vessels are older than the generally accepted working life of 25 years. The cost of building a new vessel is in a range £25 to 40 million. Typically a 5,000t capacity vessel is able to dredge up to 1.2 million tonnes of aggregate a year, more than the largest sand and gravel quarries on land.

After landing at the wharf, transport by road is the main distribution method (93% of total landings) and this distribution is limited to, on average, 50km. Therefore, whilst the marine aggregates industry does have the ability to increase their proportion of aggregates supply, it is currently broadly limited to the geographical areas it already supplies. For a project of the magnitude of a STP scheme, as the demand for marine aggregates is high, changes in the transportation and/or landing points (wharves) would be required so as to ease the delivery of these materials to the construction sites. The Bristol Channel wharves are often in smaller ports (e.g. Newport), although aggregates are also delivered into Avonmouth.

As with many dredging projects, extraction rates may be accelerated by the relocation of vessels to the point of demand. On short turnarounds, associated with shorter transit times a single 5000t dredger would be able to produce significantly >2 million tonnes per annum of dry discharged sand or significantly more using wet discharge.

A-3 Secondary and recycled aggregates

Introduction

Secondary and recycled aggregates make an important contribution to the supply of aggregates and help reduce the rate at which primary aggregates resources are depleted. Maximising their use is a key objective of Government policy and supply from these sources has increased significantly in the last decade (e.g. 26% of total aggregates supply in England in 2005).

National and Regional policies seek to promote the use of secondary and recycled aggregates and are compatible with recycled aggregate demand. These materials are available in the UK, and transportation by sea from Cornwall to the Severn should be within economic reach. The amount of potentially available secondary and recycled aggregates being used is, however, felt to be reaching its maximum; additional material that could be supplied in the future is estimated to be around 7mt/year, based on 2005 sales rates (56mt in England: 48.9mt of recycled aggregates and 6.9mt of secondary aggregates; 67mt in the UK). The current market share of around 26% in England is expected to grow to 30% by 2011.

The % of secondary or recycled aggregate used for concrete construction is likely to remain low because the exposure conditions, environment and quality of concrete required for marine structures with a design life of 120 years plus may preclude the use of these materials. On the other hand, ballast for caissons could rely significantly on these materials.

China clay waste

China clay resources in Britain are confined to the granites of South West of England (Devon and Cornwall). There is, however, a significant volume of waste materials arising from china clay extraction available in the South West with the potential to be used in such projects.

China clay sales were 1.35mt in 2008 compared with 1.67mt in 2007 (peak output of 3.28mt in 1988). Today production is confined to the St Austell Granite (85% of sales), the south-western margin of the Dartmoor granite, and on the adjacent but separate Crownhill Down Granite. The UK is a major exporter of china clay and in 2008 1.19mt (88%) of sales were destined for export, including 0.75mt to Europe.

The extraction and processing of china clay involves the production of very large quantities of waste (22mt of waste material is generated for the extraction of 2.5mt of china clay) and about 90% is suitable for the recovery of secondary aggregates (sand and coarse aggregates), the remaining being a micaceous residue which is disposed of. China clay waste is exempt from the Aggregates Levy and sales for aggregates use have increased from 2.1mt in 2001 to 2.6mt in 2005. It is also estimated that 450-600mt of china clay waste are currently stockpiled in spoil pits, and the quantity is increasing year on year as more is tipped (about 15-20mt/year); an estimated 45-100mt is potentially useable.

Without any further investment, china clay waste could contribute at least 2-2.5mt/year to replace primary aggregates in a wide range of applications. Sales of china clay waste are mainly in the South West but small quantities are also shipped to London and the South East. Most of the china clay is transported by road and a marginal sea transportation (due to the rising cost of sea freight and fuel and the lack of available vessels) is done from ports facilities like the Port of Fowey (rail connected + deepwater, which has the capacity to load vessels with up to 6,000 tonnes of secondary aggregates) or Pomphlett docks (Plymouth). A higher contribution of china clay aggregates in a STP scheme would require investment so as optimise the transportation (rail and sea).

PFA and GGBFS

PFA (Pulverised Fuel Ash from coal fired power stations) and GGBFS (Ground Granulated Blast Furnace Slag) are both likely to be considered as cement replacement. Availability to meet the construction programme would need to be investigated for the larger schemes and might not be adequate from UK sources. UK sources of slag for use as a cement replacement material were being fully utilised before the current recession. In recent years about 20% of the UK cement market has been met from slag and PFA sources (about 3mt/year). Nevertheless, there may be a shortage of PFA when a STP scheme construction is launched.

There are still significant stockpiles of fly-ash at UK coal-fired power stations and, aside from transport costs, there are unlikely to be any constraints in their supply in the medium term. GGBS is no longer produced in high quantities in the UK and importation from Europe is required now. If the supply is not sufficient, then sources outside the UK would be investigated (Many of the major suppliers are international companies and therefore able to secure these supplies from abroad) and alternative concrete mixes might be used for some of the concrete to provide the required durability in sea water. There are also possible new products which should be available in substantial quantities by the time construction of an STP scheme is likely to start.

Slate waste

In South West England, only four active slate quarries remain in Cornwall. From the average 2mt/year of slate waste arisings from these quarries, approximately 0.2mt per year are available for use as aggregates but mainly for low grade applications (bulk fill, pipe bedding…) because they are considered as weak materials. This is why these materials are generally used within short distance (20 miles) from the quarries; the exemption from the Aggregate Levy would now enable these materials to be transported further.

In North Wales, slate waste has a better quality and can be used in higher value application, such as sub-base, concrete… Nowadays only two quarries, Penrhyn and Oakeley, remain in operation. Permitted reserves of slate in North Wales were estimated at 42.5mt in 2005.

The process of slate quarrying generates vast amounts of waste rock. There are estimated to be 700-900mt of slate waste in North Wales (Gwynedd), and over half is constrained by a range of environmental designations or by distance from any possible bulk transport options. However, the remaining 270-370mt in the Bethesda and Blaenau Ffestiniog districts are suitable for use as aggregates. Current extraction is increasing this amount by 6mt a year. Slate waste could, theoretically, supply some 50% of UK crushed rock sales. This amounts to a market size of some 59mt/year. It is widely used in North Wales for general fill and road building and these applications represent the major future use of slate waste. Penrhyn quarry has recently started to send slate waste by sea from Port Penrhyn to Liverpool and Manchester and it is anticipated that up to 200,000t per year could be sent to each destination. It is also planned to establish a rail terminal at Blaenau Ffestiniog from where slate waste from Oakeley quarry will be sent to English markets.

Recycled & Secondary aggregates - England	Million tonnes / year	% supply of secondary and recycled aggregates	% total aggregates supply (207.2mt)
Recycled aggregates	**48.9**	**88**	**23**
Construction & demolition waste	*42*	*75*	*20*
Spent rail ballast	*1.2*	*2*	*1*
Asphalt planings	*5.6*	*10*	*3*
Secondary aggregates	**6.9**	**12**	**3**
Power station ash	*1.8*	*3*	*1*
Iron and steelworks slag	*0.75*	*1*	*0.4*
China clay waste	*2.6*	*5*	*1*
Slate waste	*0.15*	*0.2*	*0.07*
Glass waste	*0.15*	*0.2*	*0.07*
Colliery spoil	*1*	*2*	*0.5*
Others	*0.45*	*0.8*	*0.2*
Total recycled and secondary aggregates	**55.8**	**100**	**26**

England summary of recycled and secondary aggregates sales – 2005
Source: National and regional guidelines for aggregates provision in England 2005-2020

A-4 Dredged materials for a STP scheme (preparation works)

Dredged aggregates from preparation works

Extensive dredging would be required along the alignment of the barrage or the lagoon to provide not only a level foundation on sound rock but also a sufficient submergence for the turbines; dredging would be required as well for navigation channels (to provide access to and from the new navigation lock) or for caisson towing channels from construction yards.

The materials dredged should comprise mainly sand, gravel, soft rock (mudstone) and hard rock (limestone); mud and soft clay should also be dredged and disposed of as they would not be suitable for construction works. Due to their grading and potential contaminants (silt, clay…), these dredged materials in the Severn estuary would not meet the necessary high quality specifications for concrete aggregates; this is why they are not taken into account as a source of concreting aggregates for the STP schemes.

The sand and gravel marine aggregates would be the main materials suitable for embankment construction and caisson ballast. We assume in this survey that 80% of sand and gravel dredged for the preparation works could be used for embankment fill and ballast.

All the soft and hard rock dredged are likely to be weak materials which would break down and soften when worked as concrete aggregates. They could be used as fill materials for the landing areas for locks (Cardiff-Weston and Shoots barrage) or for the construction of compensatory habitat areas in the estuary.

According to the geology data and the optimisation of each alignment, the following tables set out the estimates of volume (and tonnage) of dredged materials as well as their category:

Dredging - Barrages	Cardiff-Weston		Shoots		Beachley	
Navigation channels	*million m^3*	*million ton*	*million m^3*	*million ton*	*million m^3*	*million ton*
Mud and soft clay	0	0	0	0	0.043	0.073
Sand and gravel	22.340	33.510	3.600	5.400	1.200	1.800
Rock - soft (mudstones)	12.170	26.774	4.400	9.680	0.800	1.760
Rock - hard (limestones)	0.620	1.178	0	0	1.940	3.686
Caissons (incl. Lock) & embankments	*million m^3*	*million ton*	*million m^3*	*million ton*	*million m^3*	*million ton*
Mud and soft clay	2.140	3.210	0	0	0.014	0.021
Sand and gravel	4.740	8.058	0.479	0.814	0.073	0.124
Rock - soft (mudstones)	9.968	21.930	1.710	3.762	0.600	1.320
Rock - hard (limestones)	0.065	0.143	0	0	0.482	1.060
Sub-totals	*million m^3*	*million ton*	*million m^3*	*million ton*	*million m^3*	*million ton*
Mud and soft clay	2.140	3.210	0	0	0.014	0.021
Sand and gravel	27.080	41.568	4.079	6.214	1.273	1.924
Rock - soft (mudstones)	22.138	48.704	6.276	13,. 07	1.400	3.080
Rock - hard (limestones)	0.685	1.321	0	0	2.422	4.746
Total dredging	**52.043**	**94.803**	**10.189**	**19.656**	**5.109**	**9.772**
Total dredged materials likely to be used (ballast, land fill…)	***49.903***	***91.593***	***10.189***	***19.656***	***5.095***	***9.751***

Dredging - Lagoons	Welsh Grounds		Bridgwater Bay	
Navigation channels	*million m^3*	*million tonnes*	*million m^3*	*million tonnes*
Mud and soft clay	1.000	1.500	1.000	1.500
Sand and gravel	0	0	0	0
Rock - soft (mudstones)	0	0	0	0
Rock - hard (limestones)	0	0	0	0
Caissons (incl. lock) & embankments	*million m^3*	*million tonnes*	*million m^3*	*million tonnes*
Mud and soft clay	2.070	3.105	5.151	7.727
Sand and gravel	2.935	4.990	0	0
Rock - soft (mudstones)	2.171	4.776	1.811	3.984
Rock - hard (limestones)	0	0	0	0
Sub-totals	*million m^3*	*million tonnes*	*million m^3*	*million tonnes*
Mud and soft clay	3.070	4.605	6.151	9.227
Sand and gravel	2.935	4.990	0	0
Rock - soft (mudstones)	2.171	4.776	1.811	3.984
Rock - hard (limestones)	0	0	0	0
Total dredging	***8.176***	***14.371***	***7.962***	***13.211***
Total dredged materials likely to be used (ballast, land fill…)	**5.106**	**9.766**	**1.811**	**3.984**

Source: Parsons Brinckerhoff & DECC

These tables show that for Cardiff-Weston barrage and Beachley barrage, dredged sand and gravel could relieve significantly the demand for construction aggregates or ballast on the market (provided their quality meets the requirements). For the other schemes, dredged sand and gravel would not be considered as a major substitution of construction aggregates and for Bridgwater Bay lagoon, these dredged materials are purely and simply not available.

Main constraints for marine dredging in the Severn Estuary

Dredging and disposal licenses are highly regulated under a full range of policy and legislation. The main policy and guidance documents are: Welsh Assembly Interim Aggregates Dredging Policy; Marine Minerals Guidance Note 1: Guidance on the Extraction by Dredging of Sand, Gravel and Other Minerals from the English Seabed; Marine Minerals Guidance Note 2: The control of Marine Minerals Dredging from the British Seabed. The legislative control for marine aggregate is the Marine Mineral Dredging regulation 2007, for which there are separate pieces of legislation in England & Wales.

Capital dredging requires consent under Coastal Protection Act (CPA – 1985) and disposal of dredged materials are currently regulated together under the Food and Environmental Protection Act (FEPA – 1985). These consents are subject to the satisfactory completion of an Environmental Impact Assessment (EIA), stakeholder consultations etc.

However, this system is in the process of being rationalised into a new marine licensing regime under the Marine and Coastal Access Bill which is scheduled to be adopted in winter 2009. The proposed Marine Bill will introduce a new system of marine spatial planning that is considered essential for sustainable use of the sea and to deliver an effective and coherent approach to the management of the marine environment. Therefore the construction dredging and disposal operations for a Severn Tidal Power scheme would require a Marine Licence from the new Marine Management Organisation (which will be 2 separate bodies, one in England and one in Wales; new licensing regime is expected to be in place in Q.1 2011).

The main constraints with respect to marine aggregate extraction, capital dredging and disposal operations for the construction of the schemes, particularly for the Cardiff-Weston Barrage, are as follows:

- Finding and licensing new dredging areas mainly in the Severn Estuary (or the Bristol Channel) in order to supply additional marine aggregates for embankment construction (see chapter A-5).
- Finding and licensing suitable sites for the disposal of any dredged material that cannot be used within the construction works. The scale of the constraint would depend on the volume and nature (including type and quality) of the dredged material and the location and characteristics of the disposal site.
- Finding cost-effective beneficial uses for soft rocks (particularly mudstone): compensatory habitats works?
- Impacts of dredging and disposal on conservation features of the Severn Estuary SAC, SPA and Ramsar would need to be assessed, mitigated and compensated under the Habitats Regulations, for example loss/damage of sandbank resource, intertidal habitat and impact on *Sabellaria* reefs. Conservation agencies, generally, have a preference in the Severn Estuary for surficial (fine) sediments to be kept within the estuary system in order to maintain intertidal habitats
- Dredging operations in the vicinity of the main navigation channels would need to be carefully managed to ensure safety of navigation.
- Other constraints include impacts on coastal processes and sediment transport, ecology, water and sediment quality, marine archaeology, aggregate dredging, fisheries …etc.

Main constraints for spoil or temporary disposal in the estuary

Limited options are available for disposing surplus spoil in the estuary or at sea. The best option would be to create a reclamation area within the vicinity of the works to be used as a lay down or processing area for the works. The reclamation area would require a marine facility for the import of materials.

The condition of untreated dredged material presents various problems for storage, principally the saturated nature of the material that requires suitable time and areas of land to enable dewatering to take place (which would vary depending on the type and amount of material). Direct transfer from excavation to final position is a preferable option, although may have implications on the construction programme. Storage would have to be carefully considered for any of the schemes at any location. Storage, and possibly treatment, of material on land would require licensing and consents, including by the Environment Agency under the Waste Management Regulations/Land Drainage Act.

Finding a suitable disposal site would depend on the type and quantity of dredged material. The key constraint would be in finding a suitably deep area of the Severn Estuary/Bristol Channel relatively close to the construction works; with a capacity to hold the required quantity of material to be disposed of; and without presenting a risk to navigation or the designated conservation features in the Estuary. In addition other constraints which would need to be given full consideration include impacts on coastal processes (sediment transport and budgets), ecology, water and sediment quality, marine archaeology, aggregate dredging, fisheries etc.

There are a number of licensed disposal sites in the Severn Estuary for the placement of maintenance dredged materials from the entrances and immediate approaches to ports. These disposal sites are licensed specifically for the disposal of relatively small quantities of maintenance dredged material (predominantly silts, some sands). It is unlikely that these sites would be suitable for the disposal of large quantities of capital dredged materials. There is a (now disused) disposal site that was used during the construction of the Cardiff Barrage. There is also a proposed disposal site in the outer estuary (Holm Deep) for the disposal of capital dredged material during the construction of the Bristol Deep Sea Container Terminal, which may possibly have capacity following the construction of the terminal. Detailed assessment would need to be undertaken in order to determine whether or not these sites would be suitable for the disposal of dredged material from the construction of the Cardiff-Weston Barrage.

We should be aware that baseline conditions in the Severn Estuary against which to consider disposal operations and the dispersal of material from existing disposal sites would change during and following the construction of the Cardiff-Weston Barrage, and to a lesser extent the other schemes. Careful consideration would need to be given as to whether dredged material is disposed upstream of the barrage within the Severn Estuary or downstream of the barrage in the Bristol Channel. The Conservation Agencies and CEFAS (Centre for Environment, Fisheries and Aquaculture Science) would be among the key advisors in making this decision.

As for the temporary disposal of dredged materials used for construction works, solutions exist to avoid large storage areas. Sand fill would not need to be landed onshore, techniques are available for placing the material directly into the works after being dredged; nevertheless it would require an efficient synchronisation between the dredging works and the embankment construction. Retaining bunds of rockfill construction with a central sealing zone can be formed initially to contain the dredge arisings.

Re-handling materials should be minimised as it would significantly increase the overall project cost. “Just in time” logistics should be adopted to ensure that materials are optimally used throughout the project.

A-5 Aggregates and armour stone for a STP scheme:

Introduction

At this stage, it is difficult to estimate the ratio of primary aggregates that would be sourced either from quarries or from dredging (including dredged materials from foundation preparation and navigation channels). Further work is necessary to consider the suitability of the aggregate sources and the associated transport links.

The local authorities which help regulate the industry and are responsible for approving (or not) applications for aggregates extraction have to operate in accordance with national policies and policy guidelines. These guidelines (in England) include assumptions about future aggregates demand so that the local authorities plans can make sufficient provision for future aggregates supply.

According to the Mineral Products Association (MPA), existing plans should have sufficient capacity to meet the aggregates needs of all the options – with the possible exception of the lagoon schemes. Given the scale of potential demand for concrete aggregates, crushed rock and fill materials there would need to be further analysis to determine if existing Government plans included sufficient supply capacity to meet the demand of this option. The Government’s policy guidance is regularly reviewed and there is the opportunity to revise forecasts of future aggregates demand to reflect the Severn Tidal Power scheme requirements. Moreover, very large schemes would have to be considered separately in terms of aggregates supply and exemption clauses for such projects could be applied.

The choice of the best quarries will depend also on the location of the caisson construction yards. For saving and for environmental reasons, these quarries should have a marine access for waterborne transport or even a good rail or road connection. Glensanda in Scotland, but also other smaller quarries in Great Britain, has access to marine wharves. Raynes quarry in North Wales supplies some crushed rock limestone into the South East and igneous rock from coastal quarries in Cornwall also supply small amounts to the South East. Nevertheless, the local ports may not have the infrastructure to assist in the movement of the bulk material and some upgrading works would be needed.

The demand for construction aggregates for each STP scheme has been compared to the future (2015-2020) regional and national annual output capacity based on the 2007 data slightly increased. This demand will be split during the construction timescale and at this stage of the study, it has been assessed that the average annual demand is equal to the total demand divided by the number of years required for civil engineering construction (this assumption is optimistic because at the beginning of the works a peak demand is likely to occur). This comparison only gives an idea of the impact on the current market.

For each type of aggregates (concrete aggregates, aggregates for embankment fill or for ballast), the demand has been compared to the regional and national breakdown capacity by end-use (assumption: the breakdown of primary aggregates production by end-use remains the same – see 2007 figures from table p29).

Due to the lack of available detailed data on aggregates production and end-use breakdown in Northern Ireland, the demand for materials of each STP scheme has been compared only to the Great Britain market and not the UK's.

Aggregates for concrete

In 2007, Great Britain produced 78.5mt of aggregates for concrete (72.7mt in 2005), including: 24.7mt of crushed rock and 53.8mt of sand and gravel (including marine dredged materials landed at British ports). By the time a STP scheme would be constructed (around 2015-2020), the production of concrete aggregates is estimated as: 5mt/year in Wales, 10mt/year in South West and 80mt/year in Great Britain.

The impact of the overall annual demand for concrete aggregates (caissons, crest wall, ballast, precast armour units…) of each STP scheme is as follows:

Demand for aggregates for concrete (structures, ballast & precast armour units)	Total demand for aggregates for concrete	Duration of civil engineering construction	Annual demand for aggregates for concrete	% of annual average production of concreting aggregates (forecast - 2020)		
				Wales Total average production	South West Total average production	GB Total average production
Scheme	mt	Year	mt/year	5mt/y	10mt/y	80mt/y
Cardiff-Weston barrage	11.71	6	1.95	39.0%	19.5%	2.4%
Shoots barrage	1.28	4	0.32	6.4%	3.2%	0.4%
Beachley barrage	0.64	4	0.16	3.2%	1.6%	0.2%
Welsh Grounds lagoon	2.02	5	0.40	8.1%	4.0%	0.5%
Bridgwater Bay lagoon	6.06	5	1.21	24.3%	12.1%	1.5%

Impact of the demand for aggregates for concrete (structures, ballast and precast armouring) on the national and regional market
Source: Parsons Brinckerhoff & DECC

If aggregates for precast armour units are not taken into account (i.e. these precast armour units could be directly imported from overseas facilities), the impact becomes:

Demand for aggregates for concrete (structures & ballast)	Total demand for aggregates for concrete	Duration of civil engineering construction	Annual demand for aggregates for concrete	% of annual average production of concreting aggregates (forecast - 2020)		
				Wales Total average production	South West Total average production	GB Total average production
Scheme	mt	Year	mt/year	5mt/y	10mt/y	80mt/y
Cardiff-Weston barrage	11.37	6	1.90	37.9%	19.0%	2.4%
Shoots barrage	1.28	4	0.32	6.4%	3.2%	0.4%
Beachley barrage	0.64	4	0.16	3.2%	1.6%	0.2%
Welsh Grounds lagoon	2.02	5	0.40	8.1%	4.0%	0.5%
Bridgwater Bay lagoon	3.49	5	0.70	13.9%	7.0%	0.9%

Impact of the demand for aggregates for concrete (structures, ballast) on the national and regional market
Source: Parsons Brinckerhoff & DECC

In both cases, these tables show that the demand for concrete aggregates for Cardiff-Weston barrage (and to a lesser extent for Bridgwater Bay lagoon) has a significant impact on the Welsh and South West production. On the other hand, the demand on the Great Britain market is much less.

The demand for concreting aggregates for the other schemes can be easily sourced in Great Britain and to a certain extent in Wales and in the South West.

As the current production of aggregates for concrete represents around 30-35% of the overall production of primary aggregates in Great Britain (total 229.8mt in 2005 and 204.2mt in 2007), this percentage could be slightly increased by shifting the end-use of aggregates extracted so as to better adapt the production to the demand (in particular for Cardiff-Weston barrage).

At this stage of the study, the % of sand and gravel for concrete sourced from marine aggregates cannot be easily assessed; nevertheless, as the tonnage required remains within the current dredging capacity, it is unlikely that additional dredging licences would be needed for concrete aggregates (unless marine dredging close to caissons construction yards would be more cost effective than transporting aggregates from distant quarries).

Nevertheless, the choice of these sources (quarry or marine dredging) will depend heavily on the location of the caisson construction yards. At this stage of the study, it is difficult to identify the exact regional or even national sources.

Primary aggregates for embankment/breakwater fill and sand ballast (caisson)

For each STP scheme, the impact of the overall demand for primary aggregates for embankments and breakwaters fill (excluding armour stone), ballast and seabed sand to the forecast (2015-2020) regional and national annual output capacity of all construction and fill aggregates is set out in the following table:

Demand for primary aggregates for embankment & breakwater fill, sand ballast & seabed (sand, gravel & crushed rock)	Total demand for aggregates	Duration of civil engineering construction	Annual demand for aggregates	% of annual average production of aggregates for construction fill (forecast - 2020)		
				Wales Total average production	South West Total average production	GB Total average production
Scheme	mt	Year	mt/year	9mt/y	10mt/y	63mt/y
Cardiff-Weston barrage	33.33	6	5.56	61.7%	55.6%	8.8%
Shoots barrage	14.25	4	3.56	39.6%	35.6%	5.7%
Beachley barrage	2.20	4	0.55	6.1%	5.5%	0.9%
Welsh Grounds lagoon	60.36	5	12.07	134%	121%	19.2%
Bridgwater Bay lagoon	76.31	5	15.26	170%	153%	24.2%

Impact of the demand for primary aggregates for embankment & breakwater fill, sand ballast & seabed on the national and regional market
Source: Parsons Brinckerhoff & DECC

This table shows that only the Beachley barrage has a small impact on the regional production of aggregates for construction and fill. For the other schemes, aggregates for construction and fill cannot be sourced on the regional markets and for the lagoon schemes, the impact on the national market is also very high.

We should also bear in mind that the classification “aggregates for construction fill” in the current surveys and statistics does not only encompass materials for embankment fill or ballast; therefore this comparison is likely to be pessimistic because the breakdown of end-use of all the aggregates produced in the regional and national market could change by the time a STP scheme is scheduled. Nevertheless, this comparison provides a relevant approach to the problem of aggregates supply.

The impact of the overall demand for sand and gravel for construction fill (ballast, embankment and breakwater core, seabed) is as follows:

Demand for sand & gravel for ballast, embankment core and seabed Scheme	Total demand for sand & gravel for construction fill mt	Duration of civil engineering construction Year	Annual demand for sand & gravel for construction fill mt/year	% of annual average production of sand and gravel for construction fill (forecast - 2020) Wales Total average production 0.3mt/y	South West Total average production 2mt/y	GB Total average production 13mt/y
Cardiff-Weston barrage	27.65	6	4.61	1536%	230%	35.4%
Shoots barrage	9.66	4	2.42	805%	121%	18.6%
Beachley barrage	1.72	4	0.43	143%	21.5%	3.3%
Welsh Grounds lagoon	39.71	5	7.94	2647%	397%	61.1%
Bridgwater Bay lagoon	55.31	5	11.06	3688%	553%	85.1%

Impact of the demand for sand & gravel for embankment & breakwater fill, sand ballast & seabed on the national and regional market

Source: Parsons Brinckerhoff & DECC

And the impact of the overall demand for crushed rock for construction fill (embankment and breakwater fill) is as follows:

Demand for crushed rock for embankment and breakwater fill Scheme	Total demand for crushed rock for construction fill mt	Duration of civil engineering construction Year	Annual demand for crushed rock for construction fill mt/year	% of annual average production of crushed rock for construction fill (forecast - 2020) Wales Total average production 9mt/y	South West Total average production 8mt/y	GB Total average production 50mt/y
Cardiff-Weston barrage	5.69	6	0.95	10.5%	11.8%	1.9%
Shoots barrage	4.59	4	1.15	12.8%	14.3%	2.3%
Beachley barrage	0.48	4	0.12	1.3%	1.5%	0.2%
Welsh Grounds lagoon	20.65	5	4.13	45.9%	51.6%	8.3%
Bridgwater Bay lagoon	21.00	5	4.20	46.7%	52.5%	8.4%

Impact of the demand for crushed rock for embankment & breakwater fill on the national and regional market

Source: Parsons Brinckerhoff & DECC

These tables highlight the very high impact of the demand for sand and gravel not only on the regional markets but also on the national one. Only sand and gravel required for the Beachley barrage for construction and fill could be easily sourced on the national market (mainly from dredging).

As for crushed rock, the demand for the lagoon schemes has a significant impact on the regional markets and to a lesser extent on the national one. Beachley barrage has less impact on the regional and national markets; for the other barrages, the demand for crushed rock could be easily met on the national market. The demand for crushed rock for the lagoon schemes could also rely either on an increase in the output capacity of existing quarries (e.g. Glensanda) or on additional imports from European quarries (e.g. Norway).

The use of dredged materials for the foundation preparation works and the navigation channels could relieve this high demand. As already mentioned, mainly sand and gravel dredged are likely to be suitable for construction aggregates.

Assuming that 80% of sand and gravel dredged for the preparation works could be used for embankment fill and ballast or seabed, the net demand for sand and gravel for construction and fill is as follows:

Demand for sand & gravel for ballast, embankment core and foundation preparation	Total demand for sand & gravel for construction fill	Dredged materials for foundation preparation used (80% sand & gravel)	Net demand for sand & gravel for construction fill	Duration of civil engineering construction	Net annual demand for sand & gravel for construction fill	% of annual average production of sand & gravel for construction fill (forecast - 2020)		
						Wales Total average production	South West Total average production	GB Total average production
Scheme	mt	mt	mt	Year	mt/year	0.3mt/y	2mt/y	13mt/y
Cardiff-Weston barrage	27.65	33.25	0	6	0	0%	0%	0%
Shoots barrage	9.66	4.97	4.69	4	1.17	391%	58.6%	9.0%
Beachley barrage	1.72	1.54	0.18	4	0.045	15.1%	2.3%	0.3%
Welsh Grounds lagoon	39.71	3.99	35.72	5	7.14	2381%	357%	55.0%
Bridgwater Bay lagoon	55.31	0	55.31	5	11.06	3688%	553%	85.1%

Impact of the demand for sand & gravel for embankment & breakwater fill, sand ballast & seabed on the national and regional market after deducting 80% sand and gravel dredged

Source: Parsons Brinckerhoff & DECC

When 80% of sand and gravel dredged for preparation works are used as aggregates for construction and fill, this table indicates that these dredged materials can relieve significantly the demand for sand and gravel for the barrage schemes. For the Cardiff-Weston barrage they can substitute for 100% of them.

As for the lagoons, due to the lack of sand and gravel on the seabed (particularly for the Bridgwater lagoon), the use of dredged materials has little or even no impact on the demand. Therefore, in order to meet this high demand, the alternative solutions are as follows:

- increase in the output capacity of existing sources of sand and gravel including marine dredging (within the current licensing framework)
- intensive use of secondary and recycled aggregates, in particular for ballast and seabed (e.g; china clay waste or slate waste)
- more imports from overseas sources
- additional dredging licenses, in particular in the Bristol Channel, so as to avoid transportation costs

Armour stone for embankment and breakwater

The second main concern for embankments and breakwaters in terms of materials is the availability of armour stone: rip rap or rock armouring (Class A or B rock). The annual demand for the largest STP schemes is between 1.4 and 2.3mt whereas the average imports of armour stone in Great Britain is about 1.5mt/year.

If we assume that by the time a STP scheme would be built about 2mt of armour stone can be produced and imported per yearin Great Britain, the impact of this demand on the national market is set out in the following table:

Demand for armour stone for embankment & breakwater	Total demand for armour stone	Duration of civil engineering construction	Annual demand for armour stone	% of annual average production & imports of armour stone in GB (forecast - 2020)
Scheme	mt	Year	mt/year	2mt/y
Cardiff-Weston barrage	9.76	6	1.63	81.3%
Shoots barrage	2.18	4	0.55	27.3%
Beachley barrage	0.24	4	0.06	3.1%
Welsh Grounds lagoon	11.29	5	2.26	113%
Bridgwater Bay lagoon	7.33	5	1.47	73.3%

Impact of the demand for armour stone on the national and regional market

Source: Parsons Brinckerhoff & DECC

This table shows that for the Cardiff-Weston barrage and the lagoon schemes, the demand for armour stone is very high and would require additional sources or significant increases in extraction capacity.

Most of the rock armouring materials would be sourced from Scotland (Glensanda), provided the current size of extracted rock would be increased, and also from overseas quarries already specialized in rock armouring supply (Norway…). The total amount required cannot be extracted from the existing specific quarries without significant increase in delivery rates; the current volume of imported armour stone (1.5mt/year) would also be increased by a maximum of 50% (based on 3-year consumption of armour stone).

In order to cope with the shortage of rock in Great Britain, it would be worth comparing the use of precast armour units (fabrication, transport and placing cost) to the extraction and transportation of rock armouring from overseas.

Conclusion – Aggregates & armour stone

In order to meet the demand for aggregates for concrete, embankment fill and sand fill (caisson ballast) the existing UK sources (marine dredging and quarries) would have to take part in the delivery chain, provided their location is compatible with the construction sites. A more detailed study needs to be undertaken so as to identify the various sources in Great Britain and even in Europe, taking into account transportation (sea and land), materials quality and technical characteristics, as well as availability of permitted resources – on land and offshore.

In Great Britain, these aggregates could be extracted from existing quarries in South Wales and the Mendip Hills or even from coastal quarries in Southern Ireland (Arklow) and West coast of Scotland (mainly from the Glensanda coastal quarry). The large volume of aggregates needed would require a significant increase in the current UK delivery rate which could be reached either by stepping up the extraction output or by importing more aggregates from European quarries.

The location of the caisson construction yards would also determine the most suitable sources for concreting aggregates so as to optimise transportation.

The proportion of dredged materials from preparation works which could be used for construction aggregates has to be confirmed in particular for the Cardiff-Weston barrage and the lagoons.

Nevertheless, these global results do not highlight in detail the disparities of the impact of each type of aggregates (sand, gravel or crushed rock) on the regional and national market according to the current end-use of these materials. At this stage of the study, the volume of concreting aggregates cannot be assessed for each component (sand, gravel or crushed rock) and the official records of production of aggregates for construction and fill do not distinguish sand from gravel.

If we assume that the breakdown of end-use of aggregates extracted in the regions and in Great Britain cannot be significantly modified therefore, the impact of the demand of each type of aggregates can be summarized as follows:

- Concreting aggregates: the Welsh and South West market could provide these materials for the smaller barrage schemes and to a certain extent for the Welsh Grounds lagoon. For Cardiff-Weston barrage and Bridgwater bay lagoon, these materials would be sourced from the Great Britain market (quarries and land-won or marine dredging).
- Crushed rock for embankment and breakwater fill: only the demand for the Beachley barrage could be met on the regional market; for the other schemes, the Great Britain market could provide enough materials and additional imports from overseas could be envisaged for the two lagoons (or an increase in the output capacity of existing UK quarries).
- Sand and gravel for embankment and breakwater fill and for ballast or seabed: dredged materials for preparation works would relieve significantly the demand for the barrages and the Great Britain market would provide enough materials. As for the lagoons, additional sources would be required, including overseas imports (provided sea transport remains cost effective) or new dredging licenses (provided this way of supply is easier to set up and cost effective). The use of significant volumes of secondary and recycled aggregates would also be part of the possible solutions, in particular for ballast (e.g. china clay or slate waste).
- Armour stone for embankment and breakwater: only the demand for Beachley barrage can be met on the Great Britain market; for the other schemes, an increase in the capacity and delivery rate of existing quarries (e.g. Glensanda) would not be sufficient and a significant rise in imports from European rock quarries is likely to be the only solution.

B – Caisson construction yards

Introduction

The number of caissons for each scheme is as follows (Phase 2 estimates):

Number of Caisson Scheme	Turbine, sluice and plain caisson	Navigation lock caisson	Breakwater caisson	Total caisson
Cardiff-Weston barrage	129 (54/46/29)	18	17	164
Shoots barrage	46 (15/25/6)	4	2	52
Beachley barrage	31 (13/9/9)	4	2	37
Welsh Grounds lagoon	32 (10/14/8)	4	2	38
Bridgwater Bay lagoon	42 (36/0/6)	4	2	48

Number of caisson
Source: Parsons Brinckerhoff

The caissons would be constructed in dry dock, towed and floated out to their location on the barrage, lowered onto the pre-prepared foundations and ballasted with sand and/or concrete for stability. It might also be necessary to make provision for bringing the caissons to the site by sea tows, or semi submersible barges. The caissons might then be sunk at a nearby location, for re-floating and rapid deployment to their final locations during suitable weather windows.

The caissons can be built year-round in the yards and their shipment and installation on the site would mainly depend on the tides. Installation methods would be designed to allow placement throughout the year when the tides are suitable, subject to favourable weather. The caissons would be suitable for open sea tow.

For the Cardiff-Weston scheme, caisson manufacture would require coastal sites close to deep water and if possible, with good road and rail links so as to ease material and equipment delivery (to a certain extent, improvement of transportation network could be envisaged). Caisson floating draughts (which would vary from 10m for the shallowest plain caissons to 21m for the turbine caissons) would limit the choice of sites.

A typical site would contain 3 basins each large enough to accommodate 4 caissons and would have a total area of 140 hectares (dry and wet docks). STPG report mentioned 4 sites in the vicinity of the barrage and others in Scotland or England (see map).

Such caisson yards should be located in areas where key components could be easily sourced so as to reduce transport costs (e.g. sources of construction aggregates).

For the Shoots barrage, due to the proximity of Second Severn Crossing, and in order to avoid any collision of towed caissons on the bridge piers, the caisson yard should be located downstream of this bridge. Part of the English Stones embankment could be used as one side of the dry dock for caisson construction.

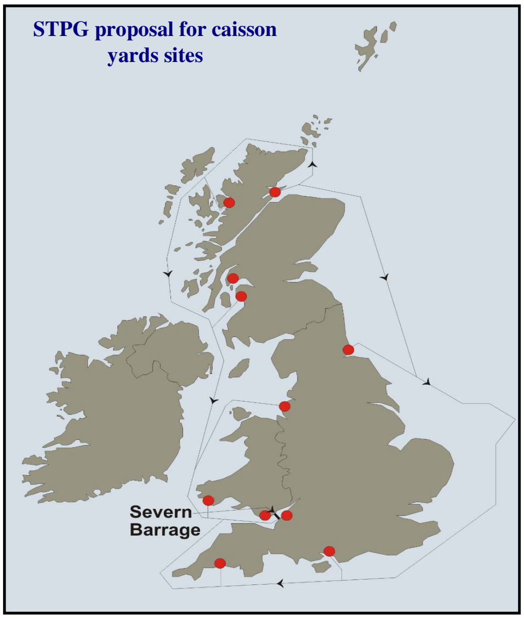
As for the Beachley barrage, for the same reasons (M48 bridge located downstream), the caisson yard should be implemented upstream of the barrage.

It is interesting to note that the Belgium Marine Consultant DEME (Dredging, Environmental & Marine Engineering) mentioned in its response a solution for the caisson construction yard. The solution would consist of building a very large casting yard within a cofferdam (like the one used for the construction of the Cardiff Bay Barrage). This casting yard would be implemented within the footprint of the future locks, where deep dredging would be required. In a final stage, the locks could then be built in a dry enclosure. However, the impact of this solution on navigation routes during the construction would need to be considered.

Potential coastal sites in UK/Europe suitable for the construction of caisson yards facilities

The feasibility of the caisson design depends heavily on the possibility of construction yards along the UK coast or even in Western Europe. It is certainly one of the major constraints for each scheme.

According to the responses, a detailed assessment is required to consider available draught, land and equipment and the associated supporting infrastructure. There would be issues to be addressed in relation to the environment and the cost, carbon footprint… associated with moving the caissons from the production facility to the site. The consent and permit process might lead to delay in the construction programme and therefore, the choice of the most suitable caisson yards sites must be studied and confirmed well in advance.



The 1989 STPG study found 11 caisson yard sites available around the UK (able to accommodate 12 caissons per site), but only 4 sites are located within the South West and Wales. Some respondents estimate that only about 35-40% of the caisson construction works could be done within Wales and South West region in the case of Cardiff-Weston Barrage, and smaller barrages or lagoons would need up to 3 and 4 caisson yards which may potentially keep all caisson yards within the South West and Wales area. However, this will largely depend on the economic conditions impacting the availability of such sites and therefore there still can be a leakage to the rest of the UK.

Several of the coastal sites identified in the STPG report still exist (but some of them are located on the east coast):

- Arnish, Isle of Raasay - Highland
- Campbeltown - Argyll
- Methil, Firth of Forth
- Nigg, Cromarty Firth
- Mostyn, Dee
- Swan Hunter - Middlesbrough

Suitability of existing port (in the UK or in Europe) for the implementation of a caisson yard facility

A further study would be required to consider the contemporary situation at candidate ports. Market demands at ports regularly change land-use patterns and it seems likely that once potential sites for a caisson yard facility (or facilities) have been identified it may be necessary to secure the site with a financial commitment. The availability of land and equipment to serve a caisson yard facility may exist at the time of a recession but would quickly disappear when trade increases and there is further demand for port facilities to move and store cargo. Access to Ports is restricted in relation to the draught, beam and length of the vessels that they can accommodate and these issues would limit the location of existing ports able to deal with the production and movement of caissons. The size of existing dry docks for caisson construction is also a constraint.

The DECC study on UK ports for the Offshore Wind Industry (2009) mentions some ports which might be suitable for the construction or the storage of caissons (further investigation is required so as to check water depth, locks, available space, sea conditions…):

- Hunterston Terminal (Firth of Clyde): former oil rig site, one of the deepest sea entrances in Northern Europe (water depth at LAT: 20m); available for redevelopment; maybe suitable for large caissons construction (operational dry dock)
- Swansea and Port Talbot: located in the vicinity of the project; as depth is limited, maybe suitable for smaller caissons construction
- Nigg Yard (Cromarty Firth): offshore platform yard, floating caisson opening; maybe suitable for large caissons construction (water depth at LAT: 9.14m)
- Harland & Wolff in Belfast: could be suitable for smaller caissons in the dry dock (water depth at LAT: 8.6m)
- Milford Haven (Wales); one of the deepest port.

Nevertheless, these ports would probably not have sufficiently large areas for the caissons to be mass produced in. The need for large working space, might mean that the only viable casting yards would be the sites of former oil field fabrication yards.

The suitability of European ports (e.g. Cherbourg, Le Havre, Rotterdam…) depends on transport conditions and possibilities of towing the caissons through the Channel. East European ports on the Baltic may not be suitable as water depths are very limited.

Former yards used for oil and gas platform construction are still existing and could be re-used:

- Ardyne Point at the mouth of the Clyde (owned by Sir Robert McAlpine): 3 docks used for constructing North Sea oil platform in the 1970s, each big enough for the largest caissons. Investments for upgrading and refurbishment should be required so as to re-use it (provision of docks gates…)
- Kishhorn Yard (West coast of Scotland): also developed for oil platform construction in the 1970s

Also, sites in Western Europe could be considered, in particular some which have been used for offshore structures in Norway, Holland, France and Spain.

Conclusion – Caisson construction yards

The possibility of implementing caisson construction yards (location, consent…) is considered as a major issue for each STP scheme and more particularly for the Cardiff-Weston one which would require several sites.

More detailed studies have to be undertaken later in order to confirm the availability of the potential sites, taking into account environmental impacts, consent process, caisson transport (tug) cost, sites characteristics (e.g. water depth, transport network for material and equipment delivery…) and carbon footprint.

Innovation in caisson construction and transport could also be envisaged so as to optimise the size and number of yards. More yards could reduce construction risk (by reducing the effect of a delay at one yard) and would also result in lower total yard costs, provided more existing yards could be used without much modification.

C – Concrete

Introduction

Concrete is also a major concern due to the large volume required and their impact on the UK market. Each component of the concrete must be taken into account so as to anticipate any bottleneck in the supply chain. For large projects, materials required for concrete fabrication and works (rebar, formwork, cement…) are procured through national and international markets (rather than regional markets). It is difficult to predict availability in 5 to 10 years time, however pre-ordering well in advance would be the key to availability.

Aggregates for concrete

See section A-5 "Aggregates & armour stone for a STP scheme".

Cement

Finished cement production in Great Britain was 10mt in 2008 (11.9mt in 2007). This is a notable drop as cement production has remained above 11mt for the last 5 years. Increasing competition in overseas markets has led to a decline in cement exports in recent years, with UK exports of cement falling to 487,000t in 2007, compared with 613,000t in 2006 and 826,000t in 2000. The UK has become a net importer of cement due to insufficient domestic production capacity, importing more than 2,370,000t of cement in 2007.

Year	Cement clinker		Portland cement	
Thousand Tonnes	Exports	Imports	Exports	Imports
2000	256	351	570	1,420
2001	169	387	327	1,182
2002	161	290	306	1,143
2003	61	506	216	1,715
2004	83	377	214	2,034
2005	135	406	321	1,645
2006	91	517	522	1,397
2007	28	836	459	1,534

UK imports and exports of cement clinker and Portland cement
Source: HR Revenue & Customs

The 5 largest cement manufacturers in the UK are Hanson (Heidelberg Cement Group; 3 plants), CEMEX UK Cement (3 plants), Lafarge Cement UK (7 plants), Tarmac Buxton Lime and Cement (1 plant) and Quinn Group (1 plant) operating 15 cement plants. Due to high energy prices and deteriorating market conditions, Lafarge has suspended operations at its Westbury cement production facility (Wiltshire) and CEMEX has closed Barrington plant (Cambridgeshire).

Cement plants have cement capacity of between 0.3mt/year to 1.4mt/year. Cement is transported mainly by road and sometimes by rail.

Company	Cement Plant	Cement capacity (thousand tonnes/year)	Transport
Lafarge Cement UK	1. Dunbar	1000	Road/Rail
	2. Hope	1300	Road/Rail
	3. Cauldon	1000	Road
	4. Aberthaw	500	Road
	5. Westbury	700	Road/Rail
	6. Northfleet	1000	Road
	7. Cookstown	500	Road
CEMEX UK	8. South Ferriby	800	Road
	9. Rugby	1250	Road
	10. Barrington	300	Road
Hanson Cement	11. Ketton	1400	Road/Rail
	12. Padeswood	800	Road
	13. Ribblesdale	1400	Road
Tarmac Buxton Lime & Cement	14. Tunstead	800	Road/Rail

Location of the main cement plants

Assuming that 13mt/year of cement could be produced in the UK by the time a STP scheme is likely to be constructed, the impact of the total demand for cement (civil structures, concrete ballast and precast armouring) on the national market is as follows:

Demand for cement (structures, ballast & precast armour units) Scheme	Total demand for cement mt	Duration of civil engineering construction Year	Annual demand for cement mt/year	% of annual average production & imports of cement in the UK (forecast - 2020) 13mt/y
Cardiff-Weston barrage	2.98	6	0.50	3.8%
Shoots barrage	0.33	4	0.08	0.6%
Beachley barrage	0.16	4	0.04	0.3%
Welsh Grounds lagoon	0.51	5	0.10	0.8%
Bridgwater Bay lagoon	1.49	5	0.30	2.3%

Impact of the total demand for cement on the national market
Source: Parsons Brinckerhoff & DECC

If only civil structures (caissons, crest walls…) and concrete ballast are taken into account, the impact becomes:

Demand for cement (structures & ballast) Scheme	Total demand for cement mt	Duration of civil engineering construction Year	Annual demand for cement mt/year	% of annual average production & imports of cement in the UK (forecast - 2020) 13mt/y
Cardiff-Weston barrage	2.90	6	0.48	3.7%
Shoots barrage	0.33	4	0.08	0.6%
Beachley barrage	0.16	4	0.04	0.3%
Welsh Grounds lagoon	0.51	5	0.10	0.8%
Bridgwater Bay lagoon	0.89	5	0.18	1.4%

Impact of the demand for cement (structures & ballast) on the national market
Source: Parsons Brinckerhoff & DECC

Only the Cardiff-Weston barrage would have a relative impact on the UK demand for cement production. There are two Lafarge cement plants in the vicinity of the Severn Estuary: Aberthaw (0.5mt/year) and Westbury (0.7mt/year; provided this facility would be re-opened after the economic recession), and the other plants located in the UK are likely to be able to meet this demand.

In case of shortage of cement supply in the UK, cement importation from overseas plants (Europe) might be envisaged from cement plants located close to European ports so as to optimize transportation. Pre-ordering well in advance would be the key to availability.

Concrete production

The average UK production of ready-mixed concrete is about 11mt per year. The location and limited capacity of existing concrete plants is unsuitable for the largest STP schemes (from 3mt/year to 2.2mt/year).The existing UK cement plants typically supply less than 300m^3 each per day; there are about 1,300 ready-mixed concrete plants in the UK (a number of concrete production plants closed during 2008).

Moreover, there will be insufficient plants within range of the construction yards to be able to supply these sites. The quantities of concrete required will justify the setting up of concrete batching plants at most of the caisson construction sites. This is a normal practice for projects requiring large quantities of concrete. These will probably have a quay besides the plant to accept cement, sand and aggregates brought in by sea directly to the site. This would greatly cut the burden on the local transport infrastructure, and would enable bulk deliveries by water which would be cheaper than by rail or road.

The overall impact of concrete demand for civil structures, ballast and precast armouring on the UK market is as follows (assuming that in the future, 12mt/year of concrete could be produced):

Total demand for concrete (structures, ballast & precast armour units) Scheme	Demand for concrete			Total demand for concrete mt	Duration of civil engineering construction Year	Annual demand for concrete mt/year	% of annual average production of concrete in the UK (forecast - 2020) 12mt/y
	Structures mt	Ballast mt	Precast armour units mt				
Cardiff-Weston barrage	18.32	2.36	0.61	21.29	6	3.55	29.6%
Shoots barrage	2.09	0.24	0	2.33	4	0.58	4.9%
Beachley barrage	1.05	0.11	0	1.16	4	0.29	2.4%
Welsh Grounds lagoon	3.57	0.11	0	3.68	5	0.74	6.1%
Bridgwater Bay lagoon	5.79	0.54	4.69	11.03	5	2.21	18.4%

Impact of the demand for concrete (structure, ballast & precast armouring) on the national market
Source: Parsons Brinckerhoff & DECC

Without taking into account the concrete for precast armour units, the result is as follows:

Demand for concrete (structures & ballast) Scheme	Total demand for concrete mt	Duration of civil engineering construction Year	Annual demand for concrete mt/year	% of annual average production of concrete in the UK (forecast - 2020) 12mt/y
Cardiff-Weston barrage	20.68	6	3.45	28.7%
Shoots barrage	2.33	4	0.58	4.9%
Beachley barrage	1.16	4	0.29	2.4%
Welsh Grounds lagoon	3.68	5	0.74	6.1%
Bridgwater Bay lagoon	6.34	5	1.27	10.6%

Impact of the demand for concrete (structures & ballast) on the national market
Source: Parsons Brinckerhoff & DECC

Mainly the largest schemes (Cardiff-Weston barrage and Bridgwater Bay lagoon) would have a significant impact on the national concrete production.

Steel reinforcing bars

Most of the manufactured steel reinforcing bars are currently made from recycled scrap metal. In 2007, the production of rods and bars for reinforcement in the UK was 0.785mt for home delivery + 0.327mt for exports (total output capacity: 1.112mt); 0.575mt were imported.

The overall impact of rebar demand for civil structures and precast armouring on the UK market is as follows (assuming that in the future, 1.5mt/year of rebar could be manufactured):

Demand for rebar (structures & precast armour units) Scheme	Total demand for rebar mt	Duration of civil engineering construction Year	Annual demand for rebar mt/year	% of annual average production & imports of rebar in the UK (forecast - 2020) 1.5mt/y
Cardiff-Weston barrage	1.55	6	0.26	17.3%
Shoots barrage	0.17	4	0.04	2.8%
Beachley barrage	0.08	4	0.02	1.4%
Welsh Grounds lagoon	0.29	5	0.06	3.9%
Bridgwater Bay lagoon	0.87	5	0.17	11.5%

Impact of the demand for rebar (structures & precast armouring) on the national market
Source: Parsons Brinckerhoff & DECC

The UK steel making facilities (in particular Celsa Steel Ltd in Cardiff which produces about 0.89mt/year of reinforcing and wire rod products and recycles 1.3mt of the 3.3mt of steel scrap used by UK steelworks) are likely to be able to meet all the demand for rebar for the smaller schemes (annual demand: 0.02 to 0.06mt).

As for the Cardiff-Weston barrage (total demand: 1.55mt) and the Bridgwater Bay lagoon (total demand: 0.87mt), overseas importations could be required; this is a classical practice for large construction projects.

Precast concrete units manufacturing

The main demand of precast concrete (PC) units includes PC protection armour units for embankment or breakwater (Dolosse for the base case). The UK precast concrete industry has a capacity of around 40mt/year.

The organisations that hold the patents for precast armour units such as Accropodes or Dolosse fulfil a design function but do not manufacture the units. They allow the units to be produced under license for given projects. The fabrication of moulds and the production of the units are the responsibility of the project.

Existing precast concrete facilities are generally capable of satisfying usual demand and have the capacity to deal with small fluctuations but they are almost all located inland. The need for a substantial increase in production can be addressed in a number of ways and these can be managed with sufficient time and resource. Production alternatives might include: the use of various existing plants in Europe (or further afield) and transport by sea to the site; expansion of existing plants (and associated transport links); or the provision of a new dedicated but temporary facility to produce the units specifically for the STP scheme.

It is likely that the preferred solution would be the construction of purpose built casting yards set up at a coastal location in the Severn Estuary for manufacture of precast concrete armour units or wall, both because of the quantities required and for ease of transport to the embankment. The construction of these precast armouring units could also be envisaged within existing port facilities (e.g. Port Talbot or Avonmouth), using sea or rail transportation.

Precast concrete armour units are only proposed for the Cardiff-Weston and Bridgwater bay schemes, based on 5t Dolosse units. The impact on the UK precast units manufacturing market is rather low.

Demand for precast armour units (Dolosse – 5t/unit) Scheme	Total number of units (Dolosse)	Total weight mt	Duration of civil engineering construction year	Annual demand for Precast armour units mt/year	% of annual average production of precast units in the UK (forecast - 2020) 40mt/y
Cardiff-Weston barrage	60,501	0.303	**6**	0.040	0.13%
Bridgwater Bay lagoon	468,667	2.343	5	0.468	1.17%

Impact of the demand for precast armouring on the national market
Source: Parsons Brinckerhoff & DECC

There is limited equipment to handle precast units but the construction industry should respond to new demands and thus adequate fore-warning of the needs for plant would enable new requirements to be addressed. Trucks and cranes to move and handle such units are widely used in the construction industry and would not be a problem.

Conclusion - Concrete

The main constraint for concrete supply is the availability of aggregates already mentioned in chapter A. The other concrete components (cement, steel…) can be sourced from the national market or even from overseas and the key to success is anticipation.

Like other large projects, on-site concrete batching plants have to be installed.

D – General points

Competition from other concurrent large construction projects in the UK or in Europe

Competition from concurrent large construction projects would increase costs as demand for the resources of plant, labour and materials surpasses supply. Nevertheless the global resources required to meet the project objectives do exist. Major civil engineering projects comparable with a STP scheme (e.g. Channel Tunnel) have been successfully constructed despite other opportunities being available for the labour plant and materials required. Early involvement of the contractors and suppliers would contribute to the project's success by engaging those parties in the development process and providing, at the relevant stage, certainty.

In terms of aggregates and concrete supply, the possibility of other major projects is not a significant constraint on supply to Severn Tidal Power schemes. The UK markets would take a number of years (from 5 to 10 according to the MPA) to recover from the current recession and individual projects such as Crossrail and Nuclear power stations account for only small proportions of total demand (for example the Olympics project is accounting for no more than 1% per year of national aggregates and concrete demand).

Nevertheless, aggregates, cement, and ready-mixed concrete volumes fell sharply during the second quarter of 2009 as the construction recession intensified, according to the latest quarterly survey of construction material trends by the Mineral Products Association (MPA). Compared with the same period of 2008, sales volume of crushed rock and sand and gravel aggregates fell by 29% and 27% respectively, cement and ready-mixed concrete by 32% and 37% respectively, and asphalt by 24%. The MPA says these rates of decline are broadly similar to the first quarter, and are likely to moderate slightly in the second half of the year, as industry demand dropped dramatically in the third and fourth quarter of 2008, so the comparative base is reduced. By the time a STP is scheduled to be constructed, the economic situation is likely to more favourable for construction projects.

Impact on existing transport infrastructure

The location of all the five STP proposals that are currently under consideration would require improvements to the local transport infrastructure to link the proposed works with the existing network. The demands on the road network could be reduced by maximising the potential use of rail and sea delivery of materials. For the larger schemes the improvements would be more substantial and extensive and have a significant, albeit possibly temporary, impact upon the environment. Given the limitations on the existing road network it is inevitable that some upgrading and strengthening work would be required. The location of the sites for preparatory works would be a key issue and the opportunity to use seaborne transport would have a significant impact upon the extent of landside infrastructure that needs to be provided and improved. The location of the quarries for aggregates supply, far from the construction sites, could lead to transport constraints as well as the location of precast facilities or other materials suppliers.

In any case, the closeness to the sea offers a far better solution to moving most materials than would be possible by land; it makes more sense to install temporary quays, and jetties and to take the transport burden off the existing infrastructure. Within the responses, it is also mentioned that the creation of a new or the enhancement of an existing port in the Severn estuary that would be used as a base for sea-borne transport, would be a suitable solution to minimize long-haul road transport.

Moreover, rail transportation would be prioritized when possible. For example, when the second Severn crossing was built most of the aggregates and fill material requirements for the embankments and approach roads were sourced from large quarries in Somerset and delivered by rail to the project.

E - Conclusion

The proposed civil engineering works for all the selected STP projects are not particularly innovative and would generally involve proven techniques (e.g. port and marina construction or extension, storm surge barrier construction…). Only the scale of the largest schemes is considered a technical challenge. The civil engineering issues that might delay completion are all predictable and, subject to appropriate management and assessment, can be accommodated.

The main issues would be the location of caissons construction yards, the supply chain for sand and gravel and armour stone and… the weather. Innovative design and construction process could be one of the keys to success.

IV - MAIN MECHANICAL AND ELECTRICAL EQUIPMENTS

A – Turbines and Generators

Introduction - Background

Turbine units are the main mechanical concern; only two existing horizontal axis turbine designs are suitable for a tidal power plant: bulb turbine (the name "bulb" comes from the shape of the upstream casing which contains a generator located on a horizontal axis) and Straflo turbine ("Straight Flow"; the concept is based upon a rim driven generator of the former Escher Wyss company – now Andritz Hydro; the patent has already expired). The turbines envisaged for each shortlisted STP scheme are set out as follows (base case from Phase 2 Optimisation study):

Barrage: Turbines + Generators	Units	Cardiff-Weston	Shoots	Beachley
Bulb-Turbines rated 40MW (base case)	No	216		
Straflo-Turbines rated 35MW (base case) *or variant Bulb-Turbines*	No		30	
Straflo-Turbines rated 12.5MW (base case)	No			50

Lagoon: Turbines + Generators	Units	Welsh Grounds	Bridgwater Bay
Bulb-Turbines rated 25MW (new base case)	No	40	144
Bulb-Turbines rated 12.5MW (previous base case)	No	108	108

Bulb turbines for tidal barrages were developed specifically in the 1960s for the La Rance barrage built and operated by EDF (24 units rated 10MW; 5.3m diameter; 93 rpm). Bulb turbines are able to generate electricity in two directions of flow and can also be used as pumps. Bulb turbines have been installed in many low head hydro power plants worldwide but after La Rance, only in smaller tidal power plants: Jiangxia (China - 5 bulb units rated 0.5, 0.6 and 0.7MW - total 3.2MW - 1980) and Kislaya Guba (Russia - 1 bulb unit rated 0.4MW - 1968). The Sihwa barrage in South Korea is the latest large tidal barrage project in the world and the 10 bulb turbines rated 25.6MW are scheduled to be commissioned in mid-2010.

Bulb units are manufactured by the following main turbine manufacturers:

- Alstom Hydro (France)
- Voith Hydro (Germany)
- Andritz Hydro (Austria/Germany)
- Hitachi (Japan)
- Dongfang Electrical Machinery Company Ltd (Dongfang Electric Corporation - DEC - China)
- Harbin Electric Machinery Company Ltd (Harbin Electric Inc. - HEC - China)
- Bharat Heavy Electrical Ltd (India)

Only Alstom, Andritz and Voith have the expertise and know-how to handle large projects, are able to meet the technical requirements for a STP scheme (size, output capacity…) and can deliver large numbers of units. For the other turbine manufacturers, bulb units are not considered as their core activity.

The main bulb and Straflo turbines manufactured by the 3 major turbine suppliers are set out in the following tables:

Country	Scheme	Power (MW)	Head (m)	Runner Diameter (m)	Number of Units	Year of completion	Manufacturer
USA	Vidalia	25	5	8.2	8	1987	Markham UK & Hunger Hydraulic UK
China	Chang Zhou	42.9	9.5	7.5	3	2007	Alstom Hydro
China	Qiao Gong	48.5	13.8	7.45	4	2007	Alstom Hydro
China	Tong Wan	46.2	11	7.1	4	2007	Alstom Hydro
China	Wu Jin Xia	36.1	9.2	7	4	2007	Alstom Hydro
USA	Greenup	25	9	6.1	3	1982	Alstom Hydro
USA	Rock Island	58	12	7.4	8	1978	Alstom Hydro
France	Saut Brenaz	23	8	6.25	2	1986	Alstom Hydro
France	Chautagne/Belley	46	14.7	6.4	4	1980	Alstom Hydro
Portugal	Crestuma	43	11.3	6.8	3	1987	Alstom Hydro
USA	Racine	24.6	7	7.7	2	1983	Andritz Hydro
Austria	Melk	21.7	8.2	6.3	9	1985	Andritz Hydro
Austria	Greifenstein	35	10.9	6.5	6	1985	Andritz Hydro
Austria	Freudenau	30.3	10.8	7.5	6	1998	Andritz Hydro
Austria	Ybbs Persenbeug	48.5	12.1	7.5	1	1993	Andritz Hydro
Thailand	Pak Mun	35.4	13.5	6	4	1994	Andritz Hydro
USA	Belleville	25.9	5.5	7.5	2	1999	Andritz Hydro
USA	Arkansas 2	35	12.6	7	3	1999	Andritz Hydro
China	Da Yuan Du	31.3	11.2	7.5	4	1999	Andritz Hydro
China	Fei Lai Xia	39	14	7	4	1997	Andritz Hydro
Turkey	Karkamis*	34.8	?	7.5	6	2000	Andritz Hydro
South Korea	***Sihwa (tidal)***	***25.4***	***5.8***	***7.5***	***10***	***2009***	***Andritz Hydro***
Ontario-Canada	St Mary	18	?	7.1	?	1978	Voith Hydro
China	Ma Ji Tang	18	?	6.3	?	1978	Voith Hydro
China	Jing Nan	35.4	11.0	6.3	2	1992	Voith Hydro
China	Bailongtan	33	18.0	6.4	6	1994	Voith Hydro
Austria	Melk	22.3	8.2	6.3	3	1979	Voith Hydro
Austria	Greifenstein	34.7	10.9	6.5	3	1981	Voith Hydro
Austria	Oberaudorf - Ebbs	30.9	11.6	6.1	2	1988	Voith Hydro
Austria	Freudenau	30.3	6.8	7.5	2	1992	Voith Hydro
Austria	Ybbs Persenbeug	48.5	12.1	7.5	1	1993	Voith Hydro
Pakistan	Chashma	23.7	13.8	6.3	8	1994	Voith Hydro
USA	New Martinsville	20	6.4	7.3	2	1986	Voith Hydro
USA	Cannelton	29.6	6.1	7.7	3	2008	Voith Hydro
USA	Smithland	25.7	5.5	7.7	3	2008	Voith Hydro
USA	Willow Island	21.3	4.9	7.7	2	2008	Voith Hydro
USA	Meldahl	37.2	7.6	7.7	3	2009	Voith Hydro
Germany	Rheinfelden	21.3	4.8	7.7	2	2006	Voith Hydro
Brazil	San Antonio	71.0	13.9	7.5	10	2008	Voith Hydro
Brazil	Jirau	76.6	15.2	7.5	10	2009	Voith Hydro
Turkey	Karkamis*	35.5	14.5	6.3	6	1999	Voith Hydro

Main large bulb-turbines (diameter > 6m) installed in the world

*Karkamis: consortium led by Andritz hydro with Voith Hydro

Straflo turbines were designed mainly for low head run of river hydro plant and around 100 units have been installed in the world. Only one Straflo turbine (Rated 20MW – 7.6m diameter – 50 rpm) was installed in 1984 for the Annapolis demonstration tidal power plant (Nova Scotia – Canada). To date, due to the previous patent, the Straflo turbines were only manufactured by Andritz Hydro. As the patent has expired, other turbine manufacturers can now use this technology but they are likely to be reluctant to manufacture Straflo turbines for fear of encountering higher costs and technical shortcomings.

Country	Scheme	Power (MW)	Head (m)	Runner Diameter (m)	Number of Units	Year of completion	Manufacturer
Switzerland	Augst-Whylen	6	7	3.8	13	1994	Andritz Hydro
Switzerland	Laufenburg	11.6	10	4.25	10	1993	Andritz Hydro
Manitoba-Canada	Pointe du Bois	8.5	14	?	1	1999	Andritz Hydro
Nova Scotia-Canada	***Annapolis (tidal)***	***20***	***7***	***7.6***	***1***	***1984***	***Andritz Hydro***

Examples of Straflo turbines installed in the world

It is important to bear in mind that Alstom, Andritz and Voith are also able to design and manufacture generators, governors, protection system, excitation, control and monitoring system as well as gates, stoplogs and valves (Alstom and Andritz).

In the following presentations of the 3 major turbine manufacturers, a summary of the technical discussions on the Severn project and recommendations are also set out (meetings held in DECC office and also in their headquarters offices).

Alstom Hydro

Alstom Hydro (5500 staff in 19 countries) is a 50/50 joint venture (set up in 2006) between Alstom (Alstom Power and Alstom Transport) and the Bouygues Group (2 main sectors: construction and media/telecoms). Alstom Hydro is now one of the major suppliers of hydroelectric equipments and services, having installed turbines and generators capable of providing more than 400GW of electricity (25% of global hydroelectric generating capacity; 310 GVA generators and 155GW turbines). Alstom Hydro operates in more than 70 countries worldwide.

With more than 250 bulb turbines (runner diameter varies from 3m to 7.5m) installed worldwide (total output: 5,000MW; including more than 35 large units commissioned in China alone during the last ten years), Alstom Hydro has gained wide knowledge and experience in design, manufacturing, installation, commissioning and management of complex bulb projects, whatever the environmental conditions. The former Neyrpic and Alsthom companies (now Alstom Hydro) were involved in the design of La Rance bulb turbines and they supplied 12 units (the other units were manufactured by Jeumont-Schneider and the Société des Forges et Ateliers du Creusot). Alstom Hydro (former GEC Alsthom Turbine Generators Ltd), as a member of the STPG consortium, was also involved in the Severn studies carried out in the 1980s. Therefore, Alstom Hydro has perhaps the best expertise in bulb turbine design for tidal barrages.

Alstom Hydro is committed to developing a more “fish-friendly” turbine (fewer but longer blades for Kaplan and Bulb turbines so as to reduce fish mortality + spherical design of the hub) and to mitigate environmental impacts (e.g. oil-free operation thanks to runner bearings lubricated by water for Kaplan turbine).

Alstom Hydro has 2 development and test facilities:

- Turbine Technology Centre in Grenoble (France – 140 staff) including 7 test rigs for all type of turbines (Francis, Kaplan, Bulb…). Modelling (Computational Flow Dynamics - CFD) is used to improve turbine efficiency and performance as well as model tests. Two recent test rigs, one of which has been in operation since 2003, are used for bulb turbines.
- Generator technology Centre in Birr (Switzerland)

Alstom Hydro has several turbine/generator manufacturing facilities in the world: Taubaté (Brazil), Tracy (Canada), Tianjin (China), Baroda (India) and Grenoble (France). Large turbines are mainly manufactured in China, India and Brazil; bulb turbines and Kaplan are currently built in the Taubaté, Tianjin and Tracy facilities. Other generator manufacturing facilities are: Bilbao (Spain), Birr (Switzerland).

Alstom Hydro estimates that 65,000 hours are reported to be needed to produce a large bulb turbine (>50MW) and around 35,000 hours for smaller units. For instance, in the Taubaté facility where bulb turbines are manufactured for the San Antonio and Jirau hydro power plant in Brazil (see below), the annual working hour capacity is 1.25 million (780 staff); currently 2 bulb turbines per month are delivered in this facility. It would be possible to increase the bulb turbine delivery rate by a further 2 units per month provided there is no higher demand in Brazil and South America for other types of turbine. Nevertheless, there are point constraints in the manufacturing cycles, particularly the use of limited boring machines, blade sourcing and manufacturing. A delivery rate of 44 turbines per year, as proposed in the original STPG studies, could not be achieved without an improvement in the existing international facilities (expansion of existing facilities or even a possible construction of a dedicated facility in the UK so as to meet not only the Severn demand but also the other future tidal schemes in the North West Region). For example, for the Three Gorges scheme, runners were constructed at site due to their large size and transport issues.

According to Alstom, the main constraints from the turbine supplier point of view is the pace of civil work and the final client processes on design/drawings approval, that have to be in line with what will be requested as the pace for manufacturing and engineering. As a precondition, Alstom Hydro recommends a very early kick-off meeting clearly defining interfaces and critical path of components with payment events and deliverables in a logical sequence to avoid non added value work being done in different phases of the project. In its experience, issues on time schedules are mostly due to interfaces and decision-making processes.

Alstom Hydro has developed a Plant Integrator™ concept so as to provide complete and optimised power solutions to customers. Improvements in manufacturing process have been achieved and up to 25% lead time savings are possible.

All the key components of a turbine unit are designed and manufactured by Alstom itself so as to control the quality and manufacturing process. Alstom uses a Primareva planning tool which can take into account existing orders plus 3-year workload and 5-year marketing forecast.

In terms of size of the bulb turbines, nowadays an 8m runner diameter is considered as the upper limit due to existing machine size (in particular boring machine). A 9m diameter bulb turbine could be envisaged but it would be a technical challenge and it would require further investments for the machine tools. Alstom Hydro is also constrained by lack of large boring machines and machining centres where turbines are made.

Alstom Hydro also points out possible constraints in terms of steel and nickel supply. Steel availability depends on the world-wide steel consumption, among other thing, in competing projects. The situation in a few years depends on the economic situation, local and global policies, and can vary considerably in terms of costs and delay for material procurement.

Alstom Hydro optimizes the material procurement process depending on the market situation, taking into account all suitable materials for turbine construction. The Alstom global supplier panel, based on framework agreements for key commodities such as carbon and stainless steel plates, castings, forgings, copper and silicon steel plates among others, forecast through a very strong load analysis process, makes it possible to anticipate its load and also the load of its suppliers through a very close scanning process undertaken by its Key Commodity Managers for each strategic commodity.

In Alstom's experience of working on projects such as Rio Madeira and large Chinese projects, they have never been in a situation of material shortage. This is largely due to having in place a strong material procurement process and ensuring that material specifications are in line with supplier capacities and technology needs.

Andritz Hydro

Andritz Hydro (formerly VA Tech Hydro) has been part of the Andritz Group (Pulp & Paper, Hydro, Metals, Environment & Process and Feed and Biofuel) since 2006.

Andritz Hydro is a leading global supplier of turnkey electromechanical systems and services to hydropower plants and offers new hydroelectric power stations as well as services, rehabilitation and upgrading of existing plants.

Thanks to several acquisitions of European turbine manufacturers (Escher Wyss, ELIN, Vevey, Bouvier, Charmilles…) and recently General Electric Hydro (2008), Andritz Hydro has more than 160 years of expertise in hydropower.

Before the acquisition of GE Hydro, VA Tech (4,500 staff) had large turbine manufacturing workshops in Ravensburg (Germany), Linz (Austria), Kriens (Switzerland), Schio (Italy), Madrid (Spain), Morelia (Mexico) and Faridabad (India). Three large generator and electrical manufacturing workshops are located in Weiz and Vienna (Austria) and in Bhopal (India). Three R&D laboratories are located in Linz (Austria) and Vevey and Zurich (Switzerland). There are several sales and services offices in the world (25 countries).

The acquisition of GE Hydro (400 staff, 9 very large facilities in Canada, China, Brazil, Sweden, three Hydraulic laboratories in Brazil, Canada and Finland) is a key milestone in Andritz Hydro development and this company is becoming one of the key global hydro turbine manufacturers. There are now several Andritz hydro facilities all around the world and in particular in countries where the hydro demand is high (China, South America, India…).

VA Tech Hydro has installed around 26,000 turbines (245GW) and 51GVA generators; GE Hydro has installed a total of 152GW turbines and 107GVA generators.

More than 300 bulb units have been supplied by Andritz Hydro for heads up to 27m, a maximum runner diameter of 8.2m and outputs up to 55 MW (77MW for the current Rio Madeira project). The total installed capacity amounts to 4,500 MW approximately. Andritz Hydro is one of the leaders in Bulb turbine/Generator units with more than 50% market share in the last decade.

Andritz Hydro has been involved in 2 tidal schemes:

- Annapolis (Nova Scotia-Canada): 1 Straflo turbine (Sulzer Escher-Wyss; 7.6m runner diameter) rated 20MW (1984)

- Sihwa (South Korea): 10 Bulb turbines (7.5 runner diameter) rated 25.4MW (order in 2005 – completion originally due by the end of 2009 but power plant commissioning delayed to mid-2010)

Andritz Hydro has no specific experience of reversible bulb turbines as proposed as a variant for Cardiff-Weston barrage or the lagoon schemes which may require some development work.

For the Sihwa project, the owner Korean Water Resource Corporation (K-Water) selected Daewoo Engineering and Construction Co. as a prime contractor. Andritz Hydro was a Daewoo subcontractor and the scope of work comprised: detailed design of the bulb turbines/generators and their ancillaries, supply of all major electromechanical equipments (turbine runners, turbine shaft seals and bearings, oil heads, guide vanes, governors, stator cores and windings, rotor poles and combined bearings). Key components (e.g. turbine runners, bearings, generators) were manufactured mainly in Germany and Austria at Andritz workshops and shipped to site, while the bulk of steelwork and Balance of Plant were made in Korea. Due to the scheme configuration, the turbines operate only on flood generation mode, and during ebb they operate on sluicing mode. Andritz Hydro carried out many hydraulic studies so as to optimise the efficiency of these bulb turbines and to adapt them to the unusual context for a tidal scheme (flood generation). As a matter of fact the available basin volume has to be filled within a given time so as to assure maximal energy production and therefore the start of the turbines has to be well estimated for each cycle. Thanks to this project, Andritz Hydro has acquired updated expertise in tidal generation and bulb turbine design.

Andritz Hydro can manufacture bulb turbines of around 7.5 to 8m diameter, but above that size, they say they are not economic to produce nor very stable in operation. As for Straflo turbines, they can also manufacture large fixed blades machines; despite this they do not have many orders. For large hydro projects it can take 12 months to do the design and model testing of a single turbine, a further 22 months to manufacture and then 10 months to ship, install and commission, i.e. a total of 40 months. However, it is possible to shorten this time with a large order, and of course a number of turbines can be processed in parallel.

Shipping and transporting the turbines to the construction sites is also considered as a challenge. For example, from the Ravensburg manufacturing facility, Andritz Hydro transports the turbines on specified heavy load/width roads to the Neckar river, where they are transported by barge to the coastal ports on the Baltic.

Andritz Hydro offers a warranty of 2 years with their hydro turbines, and they have a design lifetime of 40 years with a recommended major overhaul after 20 years. For tidal turbines they thought these periods would be considerably longer as they are not in such continuous use. They do not offer any ongoing maintenance contract but offer to train the engineers of the operating company to handle any normal faults. If anything more serious goes wrong they would agree a separate contract for that.

In conclusion, Andritz Hydro thought they would be able to supply turbines for the lagoon and smaller barrage options, provided they were given an order a couple of years ahead, and they would probably do it as part of a European consortium in order to spread the risk and make the delivery time more acceptable. They did not think the turbines for a Cardiff –Weston barrage could be delivered on the expected timetable without a major expansion in manufacturing capacity, and they would need some confidence that the project would go ahead before taking this investment risk.

Voith Hydro

Voith Hydro (formerly Voith Siemens Hydro Power Generation – joint venture with Siemens in 2000) is a division of the Voith Group (Voith Paper, Voith Hydro, Voith Turbo and Voith Industrial Services). Voith Hydro core activity is turbine and generator manufacturing; they have design capabilities but are less involved in the manufacturing of other mechanical equipment (e.g. gates...) but they work closely with other mechanical manufacturers in hydro mechanical equipment.

Voith Hydro has installed about 40,000 turbines and generators in the world (total capacity around 300GW) and has more than 135 years of hydro expertise.

Voith Hydro (4000 staff) has 5 main facilities (there are also worldwide service and sales offices):

- Heidenheim (Germany): headquarters, R&D laboratory and facility mainly devoted to turbines rehabilitation
- York (USA): North America headquarters and large engineering, manufacturing and servicing facility and also R&D laboratory for mechanical equipment

- Sao Paulo (Brazil): manufacturing facility, capable of handling the largest turbine runners in the world (crane capacity of up to 300t); R&D laboratory for generators and electrical equipments
- Shanghai (China): manufacturing facility focusing on high-performance turbines and generators (China and East Asia market)
- Kawasaki (Japan): facility dedicated for new and modernization projects (turbines, generators, auxiliaries, control & automation equipment, transformers and high-voltage switchgear)

Since 1955, Voith Hydro has installed over 180 bulb turbines in the world with outputs to nearly 50MW and diameters up to 8m.

Voith Hydro has no experience in tidal turbines but its know-how in bulb design would allow the company to undertake design studies and to manufacture such turbines. Voith Hydro is also used to working closely with Andritz Hydro (they share a facility in Ravensburg) and Alstom.

Voith Hydro can currently deliver 6-15 bulb turbines per year with a maximum delivery rate of 1 unit/month. The average manufacturing lead time for one large bulb unit (from manufacturing to site delivery) would be 19 – 20 months (without preliminary design study and modelling test); it would be 15-16 months for smaller bulb units.

Voith Hydro have a long experience of handling supply chain constraints; they are used to manufacturing the bulb components in various places in the world (China, Brazil...) with the right manufacturers and then they assemble them in one place, sometimes in a new purpose-built facility close to the construction site. For instance, a new assembly facility has been built in China (Shangai) for a large hydro scheme (Francis turbines) where welding, heat treatment and final assembly are undertaken by local workforce. The facility and equipment cost €10m. Voith Hydro suggests that for the Severn, a new specific assembly facility could be built (instead of a full manufacturing facility)

A 9m bulb diameter is not considered as a technical challenge; Voith has already manufactured 8.5m bulb for the USA.

Voith Hydro also confirms that delivering between 100 and 220 turbines is a challenge which can be overcome thanks to a consortium set up between the 3 major European suppliers; the Madeira experience shows that such cooperation works well. A delivery rate of up to 3-4 bulb/month could be achievable for the larger Severn schemes.

Voith Hydro seems to be reluctant to work with Chinese turbine manufacturers (subcontractors) for bulb turbines because of the lack of Chinese experience in bulb and also due to problems of quality.

Voith Hydro suggests that as soon as the decision of the Severn scheme is taken, a pre-design contract would be set up between the 3 turbine leaders so as to start the design study of the turbines (3-6 month preliminary studies); an independent hydro consultancy could be asked to supervise the design study, particularly for the interface with civil-works (e.g. Coyne & Bellier, Lahmeyer International, Stucky...)

Case study: the Brazilian Madeira Hydro project.
Example of a turbine manufacturers consortium

In Brazil, 2 large run of river hydro dam projects on the Madeira river were launched in 2008. In order to meet the demand for the numerous bulb turbines & manufacture), a consortium between Alstom Hydro (leader), Andritz Hydro and Voith Hydro was set up.

- San Antonio (3,200MW): 20 bulb-units rated 71MW and 24 bulb-units rated 75.5MW - 7.5 runner diameter (to be commissioned in 2012)
    - Alstom will provide 19 bulb turbines + 22 generators + 50% of the project's hydro-mechanical and lifting equipments
    - Andritz will provide 12 bulb turbines + 12 generators + 24 voltage regulating systems
    - Voith will provide 13 bulb turbines + 10 generators
- Jirau (3,300MW): 28 bulb-units rated 75MW - 7.5 runner diameter (to be commissioned in 2015)
    - Alstom will provide 10 bulb turbines + 17 generators + 28 speed governors, monitoring systems, bus bars and surge/neutral devices
    - Andritz will provide 8 bulb turbines + 8 generators + 28 voltage regulating systems
    - Voith will provide 10 bulb turbines + 3 generators
    - The remaining 16 bulb turbines are not included in this contract and they will be manufactured by DEC (China)

The magnitude of these projects and the turbine manufacturer consortium will provide an interesting example for the STP schemes.

The Alstom-led consortium has set up a manufacturing process as follows:

- Study, design and delivering of the first bulb unit: around 32 months
- Total timescale for the supply of the turbines for each scheme: 88 months after main order to proceed
- San Antonio will be the first scheme to be constructed; construction of the Jirau scheme will be launched 36 months later (52 months of common works on both schemes)
- Average delivery rate: Alstom 1.5 turbine/month; Andritz and Voith: 1 turbine/month

The design of the bulb units is based on shared design, in particular combined hydraulics and mechanical design for the turbine and shared generator design. San Antonio is to use 4 to 5 bladed turbines and Jirau will use 4 bladed turbines.

Chinese turbine manufacturers

Harbin Electric Machinery Company Ltd - HEC, established in 1951, manufactures generating equipment for hydro and thermal power plants. HEC has manufactured more than 500 turbines units for about 200 hydropower plants in China (40% of large hydropower units in China have been supplied by HEC), in particular 700MW turbines for the Three-Gorges scheme. To date, HEC has already exported 138 turbines (total capacity: 12GW; 138 units) to 24 foreign countries (USA, Canada, Pakistan, India, Brazil, Iran…).

Dongfang Electrical Machinery Company Ltd - DEC, established in 1984, is involved in nuclear, thermal and hydropower. DEC is the 2nd hydro turbines supplier in China (40% of the national market, including also 14 x 700MW turbines for the Three-Gorges left bank power plant) and the company has already manufactured 60 large and medium generating units in China and abroad (USA, Peru, Philippines, Turkey, Indonesia, Canada, Pakistan, Iran…). DEC will also deliver the remaining 16 bulb turbines (75MW) for the Jirau hydropower scheme.

These two Chinese turbine suppliers only manufacture Francis and Kaplan turbines but they are already involved in large bulb units projects (7.5m diameter) in China. They are likely to have the necessary manufacturing capacity to deliver large bulb turbines for tidal schemes. Under the supervision of one of the 3 major European turbine manufacturers (consortium or subcontractor), in particular to improve the quality of their products which remains an issue, they could offer additional manufacturing capacity for bulb turbines (mainly non reversible units). HEC have far larger machining centres available in China (up to 16m diameter boring machines, compares to 8m limit at Alstom for example). HEC has also 2 coastal manufacturing bases for large size manufacturing and assembling.

Main issues

Due to the high and steady worldwide demand for hydro turbines (average 50GW/year), most of the turbine manufacturers have a reasonably full order book with around two years of firm production and are running at near capacity. Moreover, the size of the turbines is growing (>700MW; 1000MW turbine projects in China) and requires further investment, in particular for machine tools. The bulb-turbine market is also soaring because run of river schemes seem to be easier to build.

Tidal turbines for barrages are still considered as a niche market and turbine manufacturers are waiting for further projects before modifying their organisation. Due to the economic recession, even the large tidal projects in South Korea were delayed in 2009 by the owners and investors (Garolim…). But the situation has already evolved due to the country’s commitments to developing renewable energy and South Korea has just confirmed the launching of the 1.32GW Incheon tidal barrage which is scheduled to be completed in June 2017. In the UK, the development of tidal projects like the Mersey or the Solway, scheduled to be commissioned by 2020, would also change the turbine manufacturers’ strategy.

It is difficult for the three main turbine manufacturers to provide relevant information on their ability to meet the demand for hundreds of bulb turbines… It is likely that a consortium would need to be set up in order to share the financial and technical risks and to be able to deliver in time the high number of units for a Cardiff-Weston scheme, and even for the smaller schemes.

The overall turbine unit delivery rate for these three turbine manufacturers could reach between 3 and 6 units/month but this increase in capacity would also depend on the short and long term demand for conventional hydro turbines. If

China (and also another country like India or Brazil) confirms its commitment to building more very large hydro schemes, the market will be very strained and all the turbine manufacturers will have to make strategic choices.

It is too early at this stage to compare the two following manufacturing strategies:

- Using existing worldwide facilities and transporting the bulb units by sea to the construction site
- Developing a new facility (or more) in the vicinity of the construction site so as to mitigate cost of transportation and to meet the delivery rate

Shipping the turbines from the facilities to the construction site is also challenging due to the size and weight (a 7.5m turbine weighs around 200t) and requires vessels or barges, and perhaps heavy load/width roads. A specific study could be undertaken so as to compare the transportation solutions.

The decision to invest in one or maybe two new manufacturing facilities in the Severn area would require a high degree of certainty for the turbine manufacturers (probably signed contract for the number of turbines required). Some possible locations would be possible either close to the future caisson construction yards or within existing ports facilities (e.g. Port Talbot or Avonmouth).

The Madeira Hydro project highlights the fact that the STPG assessment for the Cardiff-Weston turbines delivery rate (44 turbines/year – 5 years) is very challenging; the current situation among the 3 major turbine manufacturers (delivery rate: 2-3 turbines/month) means that it would take between 6 and 9 years to supply the 216 Cardiff-Weston turbines. Therefore, additional facilities for manufacturing or assembling are essential for the improvement of the delivery rate.

Turbines and caissons

The use of caissons for river and sea civil works construction is now a standard practice (barrier, embankment, bridge, marina, port, lock…). During the Delta Plan projects in the Netherlands, many embankments and dams were built with caissons (e.g. Volkerak dam, Veerse Gat dam, Zandkreek dam…) and construction and installation processes were improved. The replacement of the Braddock Dam (Pennsylvania – USA) in 2002 by a new gated dam (4 radial gates) was a technical breakthrough (largest float-in navigation structure built in the USA): the 190m long dam was divided into 2 caissons built in a construction yard (27 miles downstream from the dam site) and towed to the site after foundation preparation.

There are very few examples of caissons used for hydro power plant housing turbines. Generally turbines and generators are assembled when the caissons are on site and perfectly positioned. The first example of turbines and generators assembled in the construction yard and floated into position was the 400kW experimental Kislaya Guba tidal power plant in the early 1960s. Later, Alsthom Atlantique and Neyrpic built three 25MW bulb turbines and installed them in two steel caissons which were transported across the Atlantic in a submersible load-carrying ship, off-loaded and towed up to the Mississipi and Ohio rivers into an existing dam (Greenup project). Then the caissons were sunk in their final position within a temporary cofferdam which was dewatered and the caissons were concreted in. In 1980, Boving & Co. were awarded a contract for a single steel caisson housing height 8.2m diameter bulb turbines (Vidalia scheme – USA).

The STPG report mentioned that the turbines should not be installed in their caisson in the construction yard so as not to delay the installation rate of caissons on the site. During the discussion with the turbine manufacturers, the suppliers did not made many suggestions on the turbine installation process, and conventional methods on the final site had been assumed.

The installation of the turbines inside the turbine-caissons is also considered to be a very delicate task using heavy-lift crane barges and previous experiences (in particular installation of large sluice-gates for storm surge barriers) has shown that a good installation and management process is the key to success.

Conclusion - Turbines

The turbine delivery for the smaller schemes can be achieved by the three leading turbine manufacturers using a consortium so as to mitigate risk and to tackle manufacturing issues. Lessons learnt from the Madeira project should provide interesting feedback. Only the 30 turbines for the Shoots barrage scheme and to a certain extent the 40 bulb turbines for the Welsh Grounds lagoon could be sourced from only one turbine manufacturer in the timescale envisaged.

As for the Cardiff-Weston barrage (and to a certain extent for the Bridgwater Bay lagoon), delivering such a large number of turbines is considered as very challenging by the manufacturers, if they were to use only the existing manufacturing facilities. A consortium between them is not the only key to success. In order to increase the delivery rate and the manufacturing capacity, a development and procurement strategy is likely to be set up by these manufacturers and investment in a new plant could be envisaged, provided contracts can be signed in advance.

B – Gates-Cranes-Bascule bridge

The overall demand (in thousand tonnes of steel) for steelwork for sluice gates, lock gates, stoplogs, gantry cranes, stoplog handling cranes and temporary bulkheads is as follows:

Scheme	Total demand for fabricated steelwork Thousand tonnes
Cardiff-Weston barrage	200
Shoots barrage	65
Beachley barrage	47
Welsh Grounds lagoon	45
Bridgwater Bay lagoon	50

Demand for fabricated steelwork
Source: Parsons Brinckerhoff

It is very unlikely that these items of mechanical equipment will be supplied from the UK, but the UK could provide a significant amount of steel components manufactured in its facilities (e.g. Corus). The specialist nature of the design, manufacture and installation of gates, bascule bridges and similar equipment limits the number of providers. Such equipment is often sourced from suppliers based in the Netherlands who have the experience and capacity to produce and install these facilities.

Regarding the gates, they could be provided either by turbine manufacturers or by international suppliers (in particular from the Far East). Cranes can be sourced from worldwide manufacturers, in particular in Asia. Bascule bridges are more specific equipment and the demand is low.

Sufficient time should exist to identify suppliers, procure the materials and design, manufacture and install all the equipment. These should not be critical path items.

Transportation of these pieces of equipment would be the main issue due to their size. The installation process would have to be optimised so as to avoid too large land area for stockpiling these equipments (which means ports infrastructure availability) and to install them directly on the construction site.

In terms of raw material, as all this equipment is made of steel, variation in prices on the market is likely to be one of the major issues.

C – Other technical equipment

With the possible exception of the large transformers and switch gear equipments (and cables to a certain extent), there are few other electrical items that would cause undue concern. With a project of this nature with long lead-in times, securing the necessary equipment should not be a particular problem, provided the process is adequately managed.

Some electrical components can also be provided by turbine manufacturers (e.g. control systems…).

Given the current and ongoing need to overhaul the UK's electricity grid network, and parts of the associated infrastructure, to meet increased demand and changes in connection requirements (wind energy, biofuel power stations, etc) there are many competing schemes for suppliers and contractors. There is a similar requirement in parts of Europe. These demands are likely to increase costs.

Aside from the competing schemes, other concerns are the availability of sufficient suppliers to provide the electrical equipment, a sufficient work force of skilled designers and contractors and the dependency upon the supply chain from the designers to the provision of base materials to the installation. Given the extent of the demand for electrical equipment, international resources would be required to address the supply requirement. Appropriate management of the supply chain would be necessary to ensure sufficient time for design, manufacture and installation of the equipment.

D – General points

Competition from other concurrent large construction projects in the UK or in Europe

Competition from concurrent large construction projects may increase costs as demand for the resources of plant, labour and materials surpasses supply. Nevertheless the global resources required to meet the project objectives do exist. Major engineering projects comparable with the STP have been successfully constructed despite other opportunities being available for the labour plant and materials required. Early involvement of the contractor(s) and suppliers would contribute to the project's success by engaging those parties in the development process and providing certainty at the relevant stage.

For the mechanical equipment, the main competition is the demand for large hydro schemes (mainly turbines + generators, gates…) and for the electrical components, the ambitious European target on renewables could result in possible bottlenecks in the delivery rate of suppliers.

Impact on existing transport infrastructure

The abnormal load routes on the national and local road network are of limited extent and it is likely that each of the five STP options under consideration would require some upgrading and/or strengthening to accommodate heavy loads and dense road traffic.

The opportunity to transport equipment by sea directly to the point of installation would reduce the need for road improvements and as most of the heavy equipments (transformer, bulb-unit…) are likely to be sourced outside the UK, sea transportation is likely to be the preferred solution. For example, for the future Hinkley Point nuclear station, EDF Energy favours sea transportation so as to mitigate the impact on the road and bridge network.

The need to deal with maintenance and replacement of heavy and large components (e.g. generator or transformer) needs to be considered in overall project/life costs.

E – Conclusion

The magnitude of a STP Scheme would pose constraints in terms of the supply chain for mechanical and electrical equipment, especially a Cardiff-Weston barrage and to a lesser extent Bridgwater Bay lagoon due to the number of turbines and electromechanical equipment associated.

There are a number of concerns that could delay the completion of a scheme. These are the availability of sufficient suppliers to provide all the mechanical and electrical equipments required and the dependency upon the supply chain from the designers, to the suppliers of base materials to the final installation.

Therefore early involvement of potential suppliers is essential to determine a feasible construction programme for these pieces of equipment.

Most of the supply chain issues could be addressed via a procurement strategy and firm orders.

V – LABOUR AND SKILLS

A Severn Tidal Scheme will support temporary employment in the industry during the development and construction period. The core phases of development for each scheme require a range of skill sets and construction tasks, in particular for the following areas:

- site investigation, design, supervision and site overheads…
- marine engineering: dredging, marine heavy lifting operation…
- civil engineering and construction: caissons, embankments, navigation lock, surface building…
- mechanical engineering and manufacturing: turbines, gates, cranes…
- electrical engineering and manufacturing: generators, transformer, control system…

During the operational phase, various skills will be required, in particular for the maintenance.

Previous estimates have been made of employment creation and skills required to construct a Severn scheme (STPG 1989 report). The DTZ Regional Economic Impact Study also provides some estimates based on engineering data generated during the first phase of the STP feasibility study and was used as the basis for the questionnaire (http://severntidalpowerconsultation.decc.gov.uk/supporting_documents). However, it should be noted that updated data on construction cost and labour requirements have been provided by Parsons Brinckerhoff during Phase 2. These are provided below.

Many respondents found questions posed relating to labour and skills difficult to answer given the strategic nature of the study. However some respondents usefully provided additional information from existing surveys from various Sector Skills Councils (e.g. Sector Skills Council for Science, Engineering and Manufacturing Technologies and the Engineering Construction Industry Training Board).

The following information is a summary of responses received and data from existing reports and surveys (see Appendix 3 – Sources of Information).

Parsons Brinckerhoff updated data on construction employment estimate (Phase 2)

During its optimisation study (Phase 2), Parsons Brinckerhoff (PB) has updated the construction cost of each scheme (results provided after the questionnaire responses). DTZ estimated that the value earned per employee ranged between £139,000 and £144,000. Using this as a basis, the overall construction employment estimates are given in the table below. It should be noted that these figures may change as scheme costs are further refined and methodologies are reviewed.

As operating and maintaining a Severn Tidal Scheme will require various specific skills, a first assessment of local labour share and capacity to deliver these future jobs has also been made.. The composition of operating employees by discipline is as follows (Parsons Brinckerhoff assessment):

- 10% manager
- 35%-45% skilled technicians
- the remainder would consist variably of unskilled workers, trainees and administrators.

Schemes	Total Cost (incl. Contingency excl. compensatory habitat) £bn	Overall no FTE jobs
Cardiff-Weston Barrage	20.832	140,000 to 150,000
Shoots Barrage	3.931	25,000 to 30,000
Beachley Barrage	2.659	Around 20,000
Welsh Grounds Lagoon	5.501	35,000 to 40,000
Bridgwater Bay Lagoon	10.643	70,000 to 80,000

STP schemes – Total cost and overall number of FTE jobs
Source: Parsons Brinckerhoff (phase 2)

How many of the above jobs would be realised in South West England and Wales, or even the UK, will be dependent on a number of factors previously discussed by DTZ. The full range of assumptions underpinning regional employment estimates are under review at the time of writing but phase 2 studies by PB suggest that the following should be considered:

Assumptions:

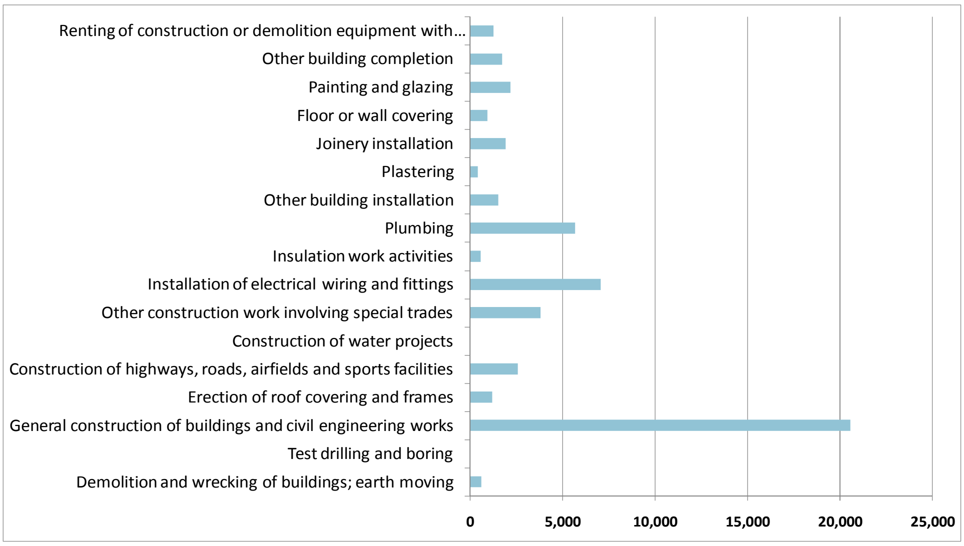
- Cardiff-Weston barrage caisson yard employment in the region would represent one third of total UK caisson yard employment.
- For Shoots and Beachley barrage and for the lagoons, all caissons could be built in the region, with concrete aggregates sourced within the region.
- For Shoots and Beachley barrage and for the lagoons, labour employment in material manufacture is assumed to be related only to transmission equipment and cranes, not turbines equipment and gates
- For Shoots barrage, civils employment should be split 50:50 between shores; 90% of M&E employment assumed on English shore.
- For Shoots and Beachley barrage and for the lagoons, the regional employment required for material supply is assumed to be the same as Cardiff-Weston barrage. There is considerable uncertainty over this estimate due to uncertainty in material sources.

These assumptions in addition to the points raised below and those made in the peer review of the DTZ study will be fed in to work to revise the regional employment estimates.

Local Area and Regional construction labour capacity

The NOMIS employment data for 2006 suggests that Construction Broad Sector (SIC F) employed 51,300 people in the Local Area as defined by DTZ in 2006, and 52,200 in 2007. However 2008 and 2009 data are expected to show decreases in new entrants to the Construction industry due to the economic recession.

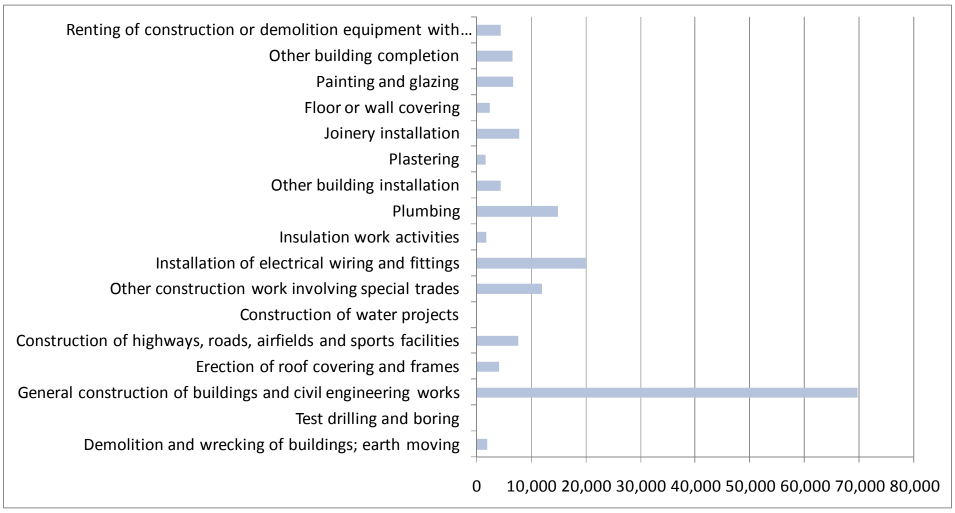
The profile of construction workforce in the Local Area is shown below in the following Figure. As shown in this Figure, not all of the 52,200 employees in Construction in the Local Area will be available or will have skills to work at both Hinkley Point Nuclear Plant and Severn Tidal Project sites.



Total employment in Construction (SIC 45) and Architectural and Engineering and Related Activities (SIC 74.2) by Occupation type in the Local Area in 2007

In fact, between 25,000 and 36,000 employees will have relevant sector skills for the majority of works excluding those in occupations related to residential construction and repair works.

Within the South West and Wales there have been 167,113 employees in the construction industry in 2007. The breakdown by occupation types is shown in the Figure below.



Total employment in Construction (SIC 45) and Architectural and Engineering and Related Activities (SIC 74.2) by Occupation type in the South West and Wales in 2007

In a similar way as analysed for the Local Area, we can assume that the number of employees with relevant sector skills in the South West and Wales was between 118,000 and 134,000. This is a large pool of construction workforce; however it reflects the current level of demand from construction projects and doesn't take into account future requirements. Obviously lesser number of employees will be available from outside the Local Area the longer it takes to travel to the construction site.

The current recession has seen major redundancies in many sectors of the economy including the Construction sector. The South West has the second lowest unemployment rate among all UK territories at 5.7% in 2009, whereas unemployment has reached 7.7% in Wales – higher than England, GB, and UK averages. The number of jobs in the construction industry in the South West has decreased by 1.4%, and in Wales by 0.8% by December 2008 compared to 2007. These figures will increase as the situation has worsened in 2009. Whilst the pool of unemployed may be good news for current construction projects as this drives the cost of labour down and means that skills are easier to find, the situation will be changing in the medium to long-term as these unemployed workers will be absorbed into other industries and their skills will not be up-to-date anymore.

The Construction Skills Network (CSN) reports acknowledge that Major Infrastructure Projects (MIP) led and financed/part-financed by the government will serve as a cushion in the difficult times for the industry.

The CSN outlook (2009-2013) for construction in Wales and in the South West Region is summarized as follows:

Wales
Total employment and annual recruitment requirement (ARR) by occupation: 2009-2013

	Employment		ARR
	2009	2013	2009-2013
Senior, executive, and business process managers	3,450	3,730	<50
Construction managers	7,250	7,940	170
Non-construction professional, technical, IT, and other office-based staff	9,840	10,500	160
Wood trades and interior fit-out	14,060	14,540	390
Bricklayers	2,860	2,890	<50
Building envelope specialists	4,660	4,960	<50
Painters and decorators	5,770	5,870	140
Plasterers and dry liners	3,320	3,550	170
Roofers	900	880	<50
Floorers	1,220	1,260	60
Glaziers	2,610	2,680	120
Specialist building operatives nec*	4,110	4,260	110
Scaffolders	1,490	1,540	<50
Plant operatives	3,180	3,160	120
Plant mechanics/fitters	950	1,010	<50
Steel erectors/structural	2,330	2,460	50
Labourers nec*	6,950	7,710	220
Electrical trades and installation	5,310	5,350	50
Plumbing and HVAC Trades	6,300	6,580	130
Logistics	1,650	1,730	<50
Civil engineering operatives nec*	4,080	4,100	<50
Non–construction operatives	5,150	5,390	
Total (SIC 45)	**97,440**	**102,090**	**2,120**
Civil engineers	2,420	2,330	<50
Other construction professionals and technical staff	4,960	5,060	130
Architects	580	560	<50
Surveyors	2,520	2,820	<50
Total (SIC 45 and 74.2)	**107,920**	**112,860**	**2,330**

South West
Total employment and annual recruitment requirement (ARR) by occupation: 2009-2013

	Employment		ARR
	2009	2013	2009-2013
Senior, executive, and business process managers	6,360	6,740	<50
Construction managers	16,650	17,820	<50
Non-construction professional, technical, IT, and other office-based staff	24,080	23,930	100
Wood trades and interior fit-out	24,190	23,750	80
Bricklayers	9,330	9,700	50
Building envelope specialists	11,100	11,000	<50
Painters and decorators	13,830	13,110	<50
Plasterers and dry liners	2,960	3,190	<50
Roofers	4,570	4,470	100
Floorers	3,460	3,510	<50
Glaziers	3,950	3,930	<50
Specialist building operatives nec*	6,190	6,230	50
Scaffolders	1,680	1,790	<50
Plant operatives	4,440	4,080	<50
Plant mechanics/fitters	1,860	1,840	90
Steel erectors/structural	1,810	1,870	100
Labourers nec*	13,480	14,110	90
Electrical trades and installation	11,060	10,820	160
Plumbing and HVAC Trades	15,530	15,160	<50
Logistics	1,860	1,860	<50
Civil engineering operatives nec*	4,790	4,470	<50
Non–construction operatives	13,180	12,930	
Total (SIC 45)	**196,360**	**196,310**	**1,130**
Civil engineers	4,710	4,490	100
Other construction professionals and technical staff	12,330	12,370	170
Architects	3,750	3,650	<50
Surveyors	4,680	4,990	<50
Total (SIC 45 and 74.2)	**221,830**	**221,810**	**1,450**

Source: Construction Skills Network (CSN) outlook (2009-2013)

* nec - not elsewhere classified

In Wales, during the period 2009-2013, total new infrastructure construction output is forecast to grow at an annual average rate of 5.2%, driven in particular by transport and energy projects (£84m Port Talbot Peripherical Distributor Road, £320m Private Finance Initiative scheme to expand the M4 and a new bridge across the Menai Strait, £400m wood-chip fuelled electricity station at Port Talbot…). Total construction employment of 113,510 in 2007 is forecast to fall to 107,920 by 2009, and then rise by 4.6% to 112,860 in 2013. In order to meet this demand, and after taking into account those entering the construction industry other than from training and those leaving, 2,330 new workers will be required to join the construction field each year.

In the South West, during the period 2009-2013, the prospects for growth in new infrastructure construction are poor. Total construction employment is projected to remain static between 2009 (221,830), and 2013 (221,810), after falls between 2007 and 2009. After taking into account those entering the construction industry other than from training and those leaving, 1,450 new workers will be required to join the construction field each year.

It is interesting to note that the Severn tidal scheme is only mentioned in the CSN Wales report. The possible Hinkley Point Nuclear Plant is not mentioned in the South West report.

If approved, construction of a new nuclear power plant at Hinkley Point will start, according to the current plans sometime in 2013-2014. nPower has been acquiring rights for sites, which are suitable for nuclear power stations in Wales, and plans to build at around the same time as planned by EDF Energy for Hinkley Point. The new Oldbury nuclear plant could also be launched by E.ON later.

The 2005 Wales and South West Workforce Mobility reports by IFF Research (*Workforce Mobility and Skills in the UK Construction Sector prepared for Construction Skills, DTI and ECITB)* found that only 41% of Construction industry workers in Wales worked on projects in more than two types of Construction sub-sectors (out of five total). In the South West 65% of workers worked on projects in more than two types of sub-sectors. However this does not represent great changes in skills or qualifications. The report further shows that 65% of workers in the Construction sector in the South West had always worked in the same occupational area as their current job. Overall, just over a third (35%) had ever switched roles – this would amount to 48,000 workers in the South West region in 2007 across all occupations. In Wales only 25% of workers in the Construction sector had ever switched roles, which would represent 18,000 of workers across all occupations in the country in 2007. Propensity to gain new skills and qualifications required to switch roles is therefore quite low in Wales.

	Where currently working…											
Where from originally…	London %	South East %	East %	NE %	NW %	Y&H %	East Mids %	West Mids %	**SW %**	Wales %	Scot. %	N. Ire %
London & South East	40	66	16	2	1	*	4	3	**10**	2	*	-
East	7	3	55	1	*	1	1	*	**1**	1	*	-
North East	5	2	3	91	2	3	1	1	**1**	1	1	*
North West	5	2	4	1	75	3	2	4	**3**	3	1	1
Yorkshire & Humberside	1	2	2	2	9	81	8	2	**1**	2	1	-
East Midlands	3	3	5	*	*	5	65	5	**1**	1	-	-
West Midlands	2	2	2	1	3	*	8	76	**3**	3	-	*
South West	1	4	*	1	*	1	1	*	**67**	3	*	*
Wales	3	1	1	-	2	*	1	1	**5**	81	1	-
Scotland	4	2	*	1	2	1	2	1	**2**	1	91	2
Northern Ireland	-	*	1	1	1	*	*	*	**1**	-	1	90
Outside the UK	30	12	11	*	5	5	7	7	**5**	2	4	7

Construction workers mobility (IFF Research)

The above table shows that 67% of construction workers in the South West are originally from that region whereas the ratio is 81% in Wales. A relatively high proportion of the South West construction workforce comes from other region.

The South West and Wales are likely to be unprepared to supply labour for a nuclear power station and a Severn Tidal scheme (especially the largest barrage option) together because the industry will be adjusting after the economic recession in the years leading to the start of the construction work of the new nuclear plant (Hinkley Point?) and the Severn Estuary.

Labour supply in the UK

Since July 2008, 128,000 people were made redundant in the Construction sector across the UK according to ONS. The number of redundancies in the 1st quarter of 2009 increased by 195% compared to the 1st quarter in 2007 and even in 2008. At the same time the number of vacancies nationally has been steadily decreasing since March-May 2008.

United Kingdom
Total employment and annual recruitment requirement (ARR) by occupation: 2009-2013

	Employment		ARR
	2009	2013	2009-2013
Senior, executive, and business process managers	98,010	105,160	1,600
Construction managers	219,080	235,520	3,550
Non-construction professional, technical, IT, and other office-based staff	282,340	292,630	1,460
Wood trades and interior fit-out	281,150	285,750	4,370
Bricklayers	88,160	90,920	2,420
Building envelope specialists	92,590	95,870	1,050
Painters and decorators	135,660	133,090	2,820
Plasterers and dry liners	48,300	51,930	1,460
Roofers	46,520	46,740	480
Floorers	38,050	38,900	570
Glaziers	41,740	43,300	1,220
Specialist building operatives nec*	56,170	57,780	950
Scaffolders	24,260	25,780	880
Plant operatives	46,750	45,400	1,300
Plant mechanics/fitters	27,060	27,820	880
Steel erectors/structural	28,330	29,070	900
Labourers nec*	116,590	125,070	1,950
Electrical trades and installation	177,880	181,100	2,740
Plumbing and HVAC Trades	176,920	180,110	1,290
Logistics	32,280	34,300	660
Civil engineering operatives nec*	59,660	58,150	710
Non–construction operatives	123,930	125,540	
Total (SIC 45)	**2,241,430**	**2,309,930**	**33,260**
Civil engineers	52,300	52,620	1,170
Other construction professionals and technical staff	143,930	144,820	1,670
Architects	40,550	40,490	400
Surveyors	57,280	61,700	530
Total (SIC 45 and 74.2)	**2,535,490**	**2,609,560**	**37,030**

Source: Construction Skills Network (CSN) outlook (2009-2013)

The Construction Skills Network (CSN) report predicts that the workforce expansion in construction industry in the UK will re-start in 2011 (in 2.5-3 years from now), and that the employment will increase by about 74,000 starting from 2010, which will see 18,500 employees a year on average. The annual recruitment requirement for this level of growth is about 37,000 excluding new entrant trainees in the UK. Overall 37,000 people have entered into construction employment in 2007. A slowdown was felt in Wales and Scotland and the total expansion of the workforce in Great Britain stood at 32,800 employees. CSN and other Sector Skills Councils recognise the difficulty of training and delivering new recruits and upgrading the skills of the current workforce.

The economic recession will have a profound impact on the availability of labour for projects starting after 2011. In the short-term, i.e. for any projects starting in 2009-2010, the construction workforce will be available and cheaper due to redundancies. In the long-term this outflow of workers will mean losses of skills and experience and the actual losses of labour, which will transfer into other industries. At present skills shortages are some of the highest in the Construction Industry according to the Learning and Skills Council (LSC). The workforce made redundant from the industry will be harder to reach for any training programmes run by LSC and Skills Councils, which will exacerbate the problem.

The Severn Tidal Project is one of the many new plants required to both replace the ageing energy infrastructure in the UK and meet the renewable energy targets. Some 30-40GW of generating capacity in the UK has to be replaced by 2030, of which around 15GW is needed by 2016 and much of the transmission and distribution network will need to be renewed or upgraded.

The UK has committed to sourcing 15% of its energy from renewable sources by 2020 which means delivering around 30% renewable electricity (5.5% today) so as to reach a total output of 38.5GW.

The Government's ambition is to deploy 25GW of offshore wind on top of the already planned 8GW. However a BERR paper on supply chain constraints (*BERR Supply Chain Constraints on the Deployment of Renewable Electricity Technology – Douglas Westwood 2008*) analyses only 18GW planned capacity as, given the timescales, it is a more realistic target. Offshore wind farms are considered as the most viable option due to several factors including planning constraints. However, they are facing some of the supply chain obstacles: for example, increasing skills shortages due to “experience and desire to work offshore becoming increasingly scarce”.

The BERR report also found that if the 2020 target of 35.8GW for all types of renewable energy projects is met, this is expected to require 122-133,000 jobs from current levels of 16-26,000 to manufacture, construct, and operate. The report further indicates that construction of biomass power stations is experiencing “growing lead-times due to levels of power plant construction both inside and outside the UK”.

Other infrastructure projects include Crossrail, which requires 8,700 FTE jobs during construction phase. Crossrail services will start in 2017 as currently planned, and therefore this project will also compete for resources with other construction projects nationally during the next decade.

Across the UK there are 11 sites (3 of them in the South West and Wales), which have been proposed for possible nuclear power station development. It is anticipated that only one nuclear station will be built before 2020. Even if a nuclear power station is built outside the South West and Wales it will still have an impact on the availability of construction and civil engineering workforce for the Severn Tidal Power Project.

Among competing barrage schemes equivalent to a small STP scheme, two tidal barrages over the Solway Firth and the Mersey are currently being studied, and are initially planned to be completed within similar time scales (The Mersey Tidal Power scheme is scheduled to be commissioned in 2020 and construction should start in 2014). If these projects are confirmed and launched, they could add supply chain constraints, in particular for the turbines delivery (unless, turbine manufacturers take the opportunity to invest in a shared facility for all these schemes).

The BPC therefore concludes that the UK capacity for MIP construction will be under high pressure from 2013 and onwards, which will definitely have major implications for labour availability and cost. This may cause delays, and not only for Severn Tidal Project but for other MIPs.

International labour capacity

Internationally, many countries are facing similar problems in terms of depleting energy production facilities, and many have significant plans to build more power stations and renewable energy generating projects.

Nuclear power plants require a lengthy construction process due to complexities of technology and safety requirements that need to be met. The latest average construction time for nuclear plants is 6-7 years according to International Atomic Energy Agency (IAEA) statistics for projects initiated between 2001 and 2007 (based on 25 reactors). During 1996-2000 the average construction time was 12 years (based on 23 reactors).

Therefore, if construction of the first new nuclear power plant will start in 2-3 years, it will run through 2011/2012 to 2017/2018. However many commentators consider the start of a project/s in 2-3 years as being overly optimistic and many others point to new case studies of nuclear power plant construction available from France and Finland where Areva supplied plants are currently being built (EPR). Both construction projects have suffered delays: Finnish power plant in Olkiluoto is three years behind the schedule to be completed in 2012; and EDF French plant in Flamanville in Normandy has been reported to be nine months behind schedule.

The main competition for international skills is coming from neighbouring EU countries where more than 29 nuclear projects are planned to be completed before 2020. Not only does this put high pressure on the availability of engineering, mechanical, and electrical components of nuclear projects but also on the availability of experienced international experts in nuclear engineering, as well as in construction of major projects.

Internationally there are skills to build large scale projects but the world has embarked upon a simultaneous nuclear power build programme, which will put the strain on both supply chain and human resources available and thus will put even more strain on availability of project management and skilled construction labour for the UK MIPs. Tidal engineering skills are also in a nascent stage in terms of availability as they are being built up by a handful of companies across the world through the ongoing research and demonstration projects.

Possibility of transferable skills from other industries

Project management skills are available outside the construction and engineering industry and potentially many consulting companies have people with project/programme management skills, who could be re-trained for construction and engineering projects to be able to deal with technical issues. They would however, lack relevant experience and will need specific support. Re-training may potentially be less than one year. Very often consulting firms suffer skills shortages themselves, and therefore availability of the workforce willing to transfer to another industry may be limited.

Manufacturing is experiencing overall decline in the UK and is likely to continue to do so in the future. This may provide a good source of labour especially for lower and medium skilled jobs. Retraining may take up to 1-2 years depending on qualifications.

In particular, it is likely that industries such as mining and shipbuilding could provide a labour force with both transferable skills and the potential to be re-trained. The main areas for re-training are: caisson construction, marine heavy lift operation and turbine manufacture. The re-training periods could range from 3-18 months, depending upon the level of skill in the initial workforce and the required level of competence (i.e. a training in a skill combined with experience of applying that skill).

Assessment of the % of works which could be directly done within Wales and South West region (% of construction cost)

The questionnaire asked respondents to fill in a table setting out the main construction cost for each scheme (based on Phase 1 construction cost data) and to estimate the % of works directly done in the two Regions, in the UK and abroad. The Bristol Port Company (BPC) and the Severn Tidal Power Group (STPG) both carried out this assessment (see the tables below). As the construction cost data have been revised in Phase 2 study, these tables only give a first assessment of possible workforce breakdown. They should be interpreted and applied to the updated scheme cost and employment estimates.

Construction stage	Cardiff-Weston Barrage	% of work done in the Regions or in UK or Abroad				Shoots Barrage	% of work done in the Regions or in UK or Abroad				Beachley Barrage	% of work done in the Regions or in UK or Abroad				Welsh Grounds Lagoon	% of work done in the Regions or in UK or Abroad				Bridgwater Bay Lagoon	% of work done in the Regions or in UK or Abroad			
		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad
Pre-construction	209					30					21					41					38				
Preliminaries and site overheads	*1,035*	*15*	*15*	*30+*	*40-*	*129*	*25*	*25*	*50-*	*0-5+*	*104*	*25*	*25*	*50-*	*0-5+*	*161*	*25*	*25*	*50-*	*0-5+*	*161*	*25*	*25*	*50-*	*0-5+*
Embankments	*505*	*25*	*25*	*40*	*10*	*159*	*35*	*35*	*25*	*5*	*19*	*40*	*40*	*20*		*795*	*25*	*25*	*40*	*10*	*637*	*25*	*25*	*40*	*10*
Navigation Locks	*1,001*	*15*	*15*	*15*	*55*	*52*	*25*	*25*	*5-*	*55*	*52*	*25*	*25*	*5-*	*55*						*20*	*25*	*25*	*5-*	*55*
Surface Buildings	*83*	*25*	*25*	*50*		*42*	*25*	*25*	*50*		*25*	*25*	*25*	*50*		*42*	*25*	*25*	*50*		*42*	*25*	*25*	*50*	
Caissons	*5,314*	*18-*	*18-*	*54-*	*15+*	*608*	*50-*	*50-*	*10+*		*600*	*36-*	*73-*	*10+*		*319*	*25-*	*25-*	*50-*		*377*	*25-*	*25-*	*50-*	
Total general civils	**7,938**					**990**					**800**					**1,317**					**1,237**				
Generating plant	*5,841*	*2.5-*	*2.5-*	*5-*	*90+*	*642*	*5-*	*5-*	*10-*	*80+*	*382*	*5-*	*5-*	*10-*	*80+*	*919*	*5-*	*5-*	*10-*	*80+*	*919*	*5-*	*5-*	*10-*	*80+*
Grid connection	*500*	*5*	*5*	*90-*	*5+*	*96*	*5*	*5*	*90-*	*5+*	*47*	*5*	*5*	*90-*	*5+*	*113*	*5*	*5*	*90-*	*5+*	*90*	*5*	*5*	*90-*	*5+*
Gates	*1,160*	*15*	*15*	*15*	*55*	*356*	*25*	*25*	*5-*	*55*	*242*	*25*	*25*	*5-*	*55*	*315*	*25*	*25*	*5-*	*55*	*321*	*25*	*25*	*5-*	*55*
Total Mechanical and Electrical	**7,501**					**1,094**					**671**					**1,347**					**1,330**				
Design and Supervision	271	17	17	50	16	38	25	25	50-	10+	31	25	25	50-	10+	42	25	25	50-	10+	41	25	25	50-	10+
Site Investigation	4	25	25	50-	10	0.6	25	25	50-	10	0.2	25	25	50-	10	2	25	25	50-	10	1.7	25	25	50-	10
Ancillary Works	300	25	25	50		100	25	25	50		80	25	25	50		10	25	25	50		50	25	25	50	
Contingencies	1,209					182					141					220					209				
Contractors on costs and profits	746					112					87					136					129				
Total construction costs	**17,969**					**2,546**					**1,831**					**3,115**					**3,035**				

% of work done in the Regions or in the UK or abroad for each scheme – The Bristol Port Company assessment (Phase 1 data)

Construction stage	Cardiff-Weston Barrage	% people employed, by location of normal residence				Shoots Barrage	% people employed, by location of normal residence				Beachley Barrage	% people employed, by location of normal residence				Welsh Grounds Lagoon	% people employed, by location of normal residence				Bridgwater Bay Lagoon	% people employed, by location of normal residence			
		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad		South West	Wales	UK	Abroad
Pre-construction	209	5	10	85		30	5	10	85		21	5	10	85		41	0	15	85		38	15	0	85	
Preliminaries and site overheads	*1,035*	*11*	*22*	*67*		*129*	*11*	*22*	*67*		*104*	*11*	*22*	*67*		*161*	*0*	*33*	*67*		*161*	*33*	*0*	*67*	
Embankments	*505*	*11*	*22*	*67*		*159*	*11*	*22*	*67*		*19*	*11*	*22*	*67*		*795*	*11*	*22*	*67*		*637*	*11*	*22*	*67*	
Navigation Locks	*1,001*	*8*	*17*	*50*	*25*	*52*	*8*	*17*	*50*	*25*	*52*	*8*	*17*	*50*	*25*					*25*	*20*	*25*	*0*	*50*	*25*
Surface Buildings	*83*	*13*	*12*	*75*		*42*	*13*	*12*	*75*		*25*	*13*	*12*	*75*		*42*	*25*	*0*	*75*		*42*	*25*	*0*	*75*	
Caissons	*5,314*	*13*	*12*	*75*		*608*	*13*	*12*	*75*		*600*	*13*	*12*	*75*		*319*	*25*	*0*	*75*		*377*	*25*	*0*	*75*	
Total general civils	**7,938**					**990**					**800**					**1,317**					**1,237**				
Generating plant	*5,841*	*5*	*5*	*50*	*40*	*642*	*5*	*5*	*50*	*40*	*382*	*5*	*5*	*50*	*40*	*919*	*0*	*10*	*50*	*40*	*919*	*10*	*0*	*50*	*40*
Grid connection	*500*	*5*	*5*	*80*	*10*	*96*	*5*	*5*	*80*	*10*	*47*	*5*	*5*	*80*	*10*	*113*	*0*	*10*	*80*	*10*	*90*	*10*	*0*	*80*	*10*
Gates	*1,160*	*5*	*5*	*70*	*20*	*356*	*5*	*5*	*70*	*20*	*242*	*5*	*5*	*70*	*20*	*315*	*0*	*10*	*70*	*20*	*321*	*10*	*0*	*70*	*20*
Total Mechanical and Electrical	**7,501**					**1,094**					**671**					**1,347**					**1,330**				
Design and Supervision	271	10	10	70	10	38	10	10	70	10	31	10	10	70	10	42	0	20	70	10	41	20	0	70	10
Site Investigation	4	10	10	80		0.6	10	10	80		0.2	10	10	80		2	0	20	80		1.7	20	0	80	
Ancillary Works	300	5	5	90		100	5	5	90		80	5	5	90		10	0	10	90		50	10	0	90	
Contingencies	1,209					182					141					220					209				
Contractors oncosts and profits	746					112					87					136					129				
Total construction costs	**17,969**					**2,546**					**1,831**					**3,115**					**3,035**				

% of work done in the Regions or in the UK or abroad for each scheme – The STPG assessment (Phase 1 data)

Possible skills shortages

STPG has identified three primary areas of skills shortage for the construction stage activities. They do not believe that there will be a significant shortage of skills in the design/development stage activities, principally due to the globalisation of the design supply chain. The three construction stage activities with skills shortages are:

- Caisson construction, whether this is undertaken in a dry dock or in-situ, slip-formed or otherwise, there is very little local capacity. Probably the nearest and most recent slip-forming works were at the LNG storage facility, constructed by Taylor Woodrow, for CB & I, at Milford Haven., these were on-shore, fixed facilities.
- Marine heavy lifting operations – most marine heavy lifting operations in the UK are undertaken using suppliers from mainland Europe. Developments in off-shore wind farms could result in an increase in the capacity of this market within Europe.
- Turbine manufacture due to the reduced number of companies able to supply these specific turbines

The consequences of other concurrent works will largely be determined by their location. STPG does not believe that projects such as Crossrail will have an adverse impact on any of the schemes in this study, as it is too far away geographically, and the skill sets are somewhat different (Crossrail is almost all below ground construction and tunnelling).

However, if the proposed new nuclear power stations at Hinkley Point and Oldbury run concurrently with any of these schemes they could generate significant risks to:

- Locally available labour
- Accommodation for the migrant workforce
- Availability of high quality concrete
- Availability of raw materials

The scale of the risk will vary, depending on the scheme, but even the smallest scheme, Beachley Barrage, if under construction at the same time as a nuclear power station at Oldbury, could effectively double the demand for local labour and accommodation.

Off-shore wind projects may limit the availability of marine heavy lifting resources (people and plant).

Skilled labour for operation and maintenance

During the operational phase, according to respondents, the key skills required in a tidal power plant are as follows:

- Management skills:
    - HR and people management
    - Leadership, team management, coaching and mentoring
    - Project and Contract management (e.g. maintenance works)
    - Quality management
    - Risk management
    - Collaboration and operating across businesses

- Engineering skills: a wide range of technical skills at varying levels from semi-skilled, through craft and technician, to skilled engineer
    - Electrical and electronic engineering
    - Mechanical engineering
    - Control and instrumentation engineering
    - Telecommunications engineering
    - Civil engineering
    - Software/Systems engineering

- Commercial skills:
    - Budgeting
    - Customer care and service

- Trading awareness

These skills are applied across key engineering activities such as:

- Plant operation
- Plant maintenance
- Specialist areas such as power system protection

However, the Electricity Industry is experiencing significant recruitment difficulties and skills gaps in the workforce (in particular in technical and craft jobs). The main reasons of recruitment difficulties identified as being the most important by Electricity Industry employers are:

- Shortage of appropriately skilled/qualified people in the marketplace
- Competition for skills from other employers
- The poor image of engineering industries
- Low number of applicants

Conclusion

Based on the analysis of research published by different Sector Skills Councils (Construction Skills, ECITB, SEMTA) and the BPC and STPG responses, some skills shortages are likely to occur in engineering (design, construction and supervision), in particularly in civil, marine and electrical engineering.

Nevertheless, most of the supply data mentioned in this survey do not take account of students coming out of college or university or transfers of workforce from other industries. Therefore, the net requirement is likely to be lower than shown in the figures.

The various scheduled MIPs schemes (nuclear plant, infrastructure works, wind farm…) will all be competing for similarly skilled employees, however, with the general down turn in work in the construction sector, and the impact of the Credit Crunch, it is likely that several of these schemes will be shelved or delayed, so that the peaks in resource demands predicted a year or so ahead may be much less severe than might have otherwise have been the case. However, demand may peak again in 5-10 years.

For the barrage schemes, most of the labour demand will be used for the construction of the caissons. If this work was done at existing shipyard or port sites there is unlikely to be a shortage of suitable labour. On the other hand, if the construction was located in a purpose built caisson yard, the amount of labour required and available would be an important factor in the choice of location of the yard.

For the lagoon schemes, not only will there be a need for caissons but there will also be a greater labour demand for the embankment, including marine expertise to handle the construction vessels (barges…). Such operations will use relatively little labour, and companies tend to use their own carry teams of specialists who travel from project to project. They would act as a cadre to which locally trained labour could be added.

There will be a further discussion of employment issues in the revised regional economic impacts study, the options definition report and the SEA Communities topic paper.

VI – POSSIBLE FURTHER STUDIES

The report highlights the need for further study or analysis in the following main areas (for each scheme):

Vessels

- Need for purpose-built vessels due to innovative construction or installation process.
- Assessment of the various vessels required (number, size, type…) and location of ports able to accommodate them (including possible improvement and refurbishment).

Aggregates

- Location of potential additional dredged areas required for marine aggregates supply (lagoon schemes): Bristol channel or other UK coast.
- Assessment of the volume of recycled and/or secondary aggregates required and location of the corresponding sources.
- Analysis of Government plans for aggregates extraction forecast and proposal for changes.

Concrete

- According to the demand of cement, location of the cement plants, including overseas imports (the result is also linked to the choice of the caisson construction yards).
- Precise assessment of the volume/tonnage of concrete aggregates required for each component: sand, gravel and crushed rock. These figures would enable choice of the most suitable quarries (delivery, location, transport…) including overseas imports (the result is also linked to the choice of the caisson construction yards).
- Accurate volume of precast concrete units (protection armour…) required and location of the plant including imports.

Caisson construction yards

- Confirmation of the availability of the sites mentioned, including existing ports according to the technical requirements.
- For each scheme, optimization of the location of the caisson construction yards.

As for the other mechanical and electrical equipments, at this stage it is too difficult to know where these components could be sourced because most of them are likely to be delivered from overseas manufacturers. However, the impact on existing transport infrastructure will be better assessed by these additional studies on civil works which represent the largest potential transport burden.

The scope of further studies would also address the potential environmental impacts of each technical choice in terms of location of sources of materials and equipment, transportation, temporary storage, disposal of materials (e.g. dredged materials unsuitable for construction use), road/bridge improvement, harbour upgrading…

APPENDIX 1

SEVERN TIDAL POWER
QUESTIONNAIRE

A - VESSELS

For the construction of each scheme, various vessels should be required for the following tasks:

- dredgers (trailer suction hopper dredgers, large cuter suction dredgers, grab dredgers…),
- jack-up barges (for rock dredging pre-treatment by drilling and blasting),
- tugs (for caissons towing),
- vessels for caissons ballast filling,
- floating cranes (equipments installation, bulkheads removal…)
- heavy load crane barges (e.g. heavy derrick barge) for turbine, transformer, gates installation,
- side dumping barges/split hopper barges for embankments construction,
- rock transport (pontoons, barges…) for embankments and armouring construction,
- …

Q1: what is the availability of these types of vessels in the national and international market? What are the most critical type of vessels in terms of availability

Q2: how do you envisage this availability changing over the next ten years?

Q3: where can these vessels be sourced (country, main owner-charterer…)?

Q4: will some additional specific vessels have to be built or retro-fitted? If yes, where (country…) and what are the likely timeframes for doing so?

Q5: what are the consequences of competition from other concurrent large offshore construction projects in UK or in EU (e.g. offshore wind farms…) in terms of vessels availability?

Q6: could the harsh site conditions (tidal stream velocity, waves) be incompatible with conventional vessels, in particular for the caissons installation?

Q7: is the capacity of the existing port facilities in the Severn estuary appropriate for these vessels? Do these ports need to be upgraded so as to accept these vessels (berth size, crane capacity, mooring…)?

SEVERN TIDAL POWER
QUESTIONNAIRE

B – CIVIL WORKS

Dredging
Q1: according to the existing policies and legislation on marine dredging in the Severn Estuary, what are the main constraints?

Q2: what are the main constraints for getting additional licences for dredging in the estuary?

Q3: where can the dredged materials be stored before being re-used for civil works (ballast, construction…)?

Q4: what are the main constraints for getting licences for spoil disposal in the estuary? Are there already areas suitable for this spoil disposal?

Caissons yards
Q5: what is the up to date list of potential coastal sites in UK/EU suitable for the construction of caisson yards facilities?

Q6: is there any existing port (in UK or EU) suitable for the implementation of a caisson yard facility?

Q7: what are the main constraints for manufacturing, building and installing equipments/assembly facilities required for each caisson yard (cranes, quays…)?

Concrete
Q8: are the existing national and regional policies that prescribe volume and location of aggregate extraction compatible with the aggregates demand (gravel, sand…)?

Q9: are the existing national and regional policies that identify, or have the secondary outcome of production of, suitable secondary aggregates (e.g. bottom ash from waste incinerators) compatible with the recycled aggregates demand?

Q10: what is the availability in the regional, national or international market of:
- steel bar reinforcement
- cement (Portland)
- additive compounds (fly ash…)
- formwork/shuttering?

Q11: pozzolanic cements and cements using more than 60% of slag as aggregate are more resistant to sea water. If these were used instead of pure Portland cement, are there likely to be significant constraint in their supply?

Q12: are the existing UK concrete plants suitable and appropriate?

Q13: what is the availability of dumper trucks, cranes for precast concrete armour units installation…?

Q14: what is the compatibility of precast concrete armour units manufactoring (0.78 million tonnes for Cardiff-Weston scheme) with existing precast production and facilities in UK or EU?

Materials for embankments & breakwaters
Q15: are the existing national and regional policies that prescribe volume and location of aggregate extraction compatible with the materials demand for embankments/locks breakwaters (rock, sand…)?

Q16: what are the main constraints in terms of sources of rocks in UK and EU?

Q17: where are the most suitable sites for materials sourcing (quarries…)?

Q18: how to cope with the shortage of rock sources?

General points

Q19: in civil works, what is the major concern which could delay the completion of the scheme?

Q20: what are the consequences of competition from other concurrent large construction projects in UK or in EU (e.g. nuclear plant, Crossrail…) in terms of civil engineering and works?

Q21: what is your assessment on the capability of existing transport infrastructure to cope with increased construction traffic? Does the transportation of materials from regional and national sources require upgrading or strengthening the existing roads or bridges?

SEVERN TIDAL POWER
QUESTIONNAIRE

C – MAIN MECHANICAL EQUIPMENTS

Total weight of fabricated steel components: about 200,000 tonnes for Cardiff-Weston scheme.

Turbines
The following questions are also appropriate to the supply of generating equipment.

Q1: what are the main constraints in terms of manufacturing/design? Can the demand of large number of units be easily met within the timeframe available?

Q2: in particular, for Straflo turbines, as there is only one European manufacturer (due to patents), what are the main specific constraints (ability to provide the number of turbines, risks of time delays to completion…)?

Q3: what are the best locations for turbine assembly facilities? New facility built close to the turbine caissons yard or existing facility?

Q4: is the installation solution suggested in the STPG report still appropriate?

Q5: is there a risk of shortage of specific materials (e.g. stainless steel…) required for the construction of the turbines? If yes, are there any alternative solutions?

Q6: what are the main constraints in terms of turbines supply?

Gates (dam, turbines and locks) and bascule bridges
Q7: can the regional or national manufacturers meet the demand of gates and bascule-bridges supply?

Q8: what are the main constraints in terms of gates/bridges supply?

General points
Q9: in mechanical engineering, what is the major concern which could delay the completion of the scheme?

Q10: what are the consequences of competition from other concurrent large construction projects in UK or in EU (e.g. nuclear plant, Crossrail, hydro power plants…) in terms of mechanical engineering and procurement?

Q11: what is your assessment on the capability of existing transport infrastructure to cope with increased construction traffic? Does the transportation of heavy or large components from regional or national facilities require upgrading or strengthening the existing roads or bridges?

SEVERN TIDAL POWER
QUESTIONNAIRE

D – MAIN ELECTRICAL EQUIPMENTS

Electrical equipments
Q1: what are the key electrical components whose supply could be challenging?

Q2: can the regional or national suppliers meet this electrical equipment demand?

General points
Q3: in electrical engineering, what is the major concern which could delay the completion of the scheme?

Q4: what are the consequences of competition from other concurrent large construction projects in UK or in EU (e.g. nuclear plant, Crossrail, hydro power plants, wind farms…) in terms of electrical engineering and procurement?

Q5: what is your assessment on the capability of existing transport infrastructure to cope with increased construction traffic? Does the transportation of heavy or large components from regional or national facilities require upgrading or strengthening the existing roads or bridges?

SEVERN TIDAL POWER
QUESTIONNAIRE

E – LABOUR & SKILLS (MARINE, CIVIL WORKS, MECHANICAL AND ELECTRICAL)

Q1: indication of the number of jobs (for each field) that might be directly created in Wales and South West region during the construction works.

Q2: in case of regional (Wales and South West) job creation, assessment of the % of resident and new resident labour force (level of employment displaced in the region).

Q3: assessment of the particular skills required for the studies (site investigation, design studies…) and the construction works in each field. In what study and construction fields is there a risk of shortage of skills and/or workforce?

Q4: given the likely work force demands outlined in Part 1, to what extent do you think there is likely to be spare capacity in the following markets to meet this labour demand:

- Regional (South West and Wales)
- National
- International

Q5: in case of shortage of particular labour supply, are you aware of industries with transferable skills that may be able to fill these gaps? If so, give estimates of likely period to re-train.

Q6: assessment of the % of works which could be directly done within Wales and South West region (% of construction cost).

Q7: what are the consequences of competition from other concurrent large construction projects in UK or in EU (e.g. nuclear plant, Crossrail, hydro power plants, wind farms…) in terms of labour and skills?

Q8: indication of the number of jobs (for each field) that might be directly created in Wales and South West region for the operation and maintenance of each scheme.

Q9: in what operation and maintenance fields is there a risk of shortage of skills and/or workforce?

Q10: do you have any comment on DTZ data and figures presented in Part 1?

APPENDIX 2

LIST OF CONTACTS (QUESTIONNAIRE)

In italics, response received.

Civil Works

- *Institution of Civil Engineers (ICE)*
- Civil Engineering Contractors Association

Aggregates

- *MPA Mineral Products Association (MPA)*
- Aggregates Industry UK Ltd
- Institute of Quarrying
- British Aggregates Association:
- *British Marine Aggregate Producers Association (BMAPA)*
- South West Region Aggregates Working Party

Vessels - Ports :

- *Association of British Ports*
- British Ports Association:
- UK Major Ports Group
- *Bristol Port*
- United Kingdon Harbour Masters Association
- Bristol Docks
- Cardiff Harbour Authority
- Newport Harbour Commissioner
- Porthcawl Harbour
- Burry Port
- Penarth Harbour
- *Milford Haven Port Authority* (response from *Ledwood Mechanical Eng)*
- Tenby Harbour
- *Bridgewater Harbour*

- Society for Underwater Technology
- Marine and Coastal Construction Services

- *International Marine Contractors Association*
  - ACERGY (UK)
  - Technip (F)
  - Heerema Group (NL)
  - HELIX Energy Solution Group (USA)
  - SAIPEM (IT)
  - *Van Oord (NL)*
  - Tideway (NL)
  - Royal Boskalis Westminster (NL)
  - *SMIT (UK)*
  - Global Marine Systems
  - Bourbon (F)

Dredging

- Central Dredging Association
- *UK Dredging* (response with ABP)
- *Dredging, Environmental & Marine Engineering (DEME – B)*

- Land and Water

Reinforced Concrete
- British Cement Association
- British Association of Reinforcement

Formwork…
- National Access Scaffolding Confederation

Precast concrete
- National Precast Concrete Association:

Service road + surface buildings
- Chartered Institute of Building (CIOB)
- Chartered Institution of Building Services Engineers

Mechanical & Electrical

- Electrical Contractors Association
- Institution of Engineering and Technology
- Institution of Mechanical Engineers
- *British Construction Steelwork Association*
- UK Steel
- Association of Electrical and Mechanical Trades (AEMT)
- British Electrotechnical & Allied Manufacturers Association (BEAMA)
- Forwarded to Electrical Companies: *Areva T&D Ltd* response

Manufacturers - Contractors

Civil contractors
- Eiffage TP (F)
- Bouygues Construction (F)
- *Vinci Construction (UK)*
- Bam Nuttall
- Dean & Dyball
- *Morgan East*
- Volker Wessels
- Volker Stevin
- C Spencer
- Raymond Brown
- Balfour Beatty
- Murphy Group
- Galliford Try
- DCT Civil Engineering
- Gerwick (USA)

Marine contractors
- Delta Marine Consultants (NL)
- *Deltares (NL)*
- Land & Marine Ltd
- Briggs Marine
- *Dredging, Environmental & Marine Engineering (DEME – B)*

Turbines

- *Alstom Hydro (F)*
- *Andritz Hydro (AU)*
- *Voith Hydro (G)*
- Hitachi (J)

Mechanical

- *Sheffield Forgemasters Engineering Ltd*
- Cleveland Bridge
- Severfield Reeve Structures (Watson Steel)
- William Hare

Electrical

- ABB
- Pauwels (Be)
- *Siemens UK*
- Clemessy (F)
- Wilson Power Solutions
- Balfour Kilpatrick
- Hitachi-Power (D)

Cranes

- Demag cranes
- *Kone cranes*
- Alatas
- Pegasus Mechanical Lifting

STPG

- *Sir Robert McAlpine*

Miscellaneous

- *Crown Estate*
- Hydro - Dam
- British Dam Society
- British Wind Energy Association (BWEA)
- Rijkswaterstaat (RWS; NL)
- International Business Wales
- Confederation of Business Industry
- UK Contractors Group
- Engineering Construction Industry Association (ECIA)
- HMG Government
- Department for Business Enterprise & Regulatory Reform (BERR)/ Department for Innovation, Universities & Skills (DIUS): review of productivity and skills in the engineering construction sector
- Department for Energy & Climate Change (DECC) - Trade promotion from UK Renewables
- Department for Energy & Climate Change (DECC) - Renewable Energy & Innovation Unit (REIU)
- *Department for Business, Innovation & Skills (BIS)*
- Department for Business Enterprise & Regulatory Reform (BERR) - Office of Nuclear Development
- *Members of the STP Regional Workstream (South West Regional Development Agency, Environment Agency, Welsh Assembly Government…)*

APPENDIX 3

SOURCES OF INFORMATION

Previous studies

- Department of Energy – Severn Barrage Project (STPG) – Detailed Reports 1989 (Volumes I – V)
- Department of Trade and Industry – The Severn Barrage (STPG) – Definition Study for a New Appraisal of the Project – Final report 2002

Vessels/Ports

- Construction of Marine and Offshore Structure by Ben C. Gerwick Jr (CRC Press – 2007)
- Eastern Schield storm surge barrier: Delta project brochures
- UK Ports for the Offshore Wind Industry: Time to Act (DECC – BVG associates – 2009)

Turbines

- Bulb/pit/S-turbines and generators – Voith Siemens brochure
- Bulb turbines and generators – VA Tech Hydro brochure
- Bulb Units – The complete solution for low head – Alstom Hydro brochure

Aggregates

- The role of imports to UK aggregates supply (British Geological Survey – 2005)
- Aggregates supply in England – Issues for planning (British Geological Survey – 2008)
- Collation of the results of the 2005 Aggregates Minerals survey for England and Wales (British Geological Survey – 2007)
- National and regional guidelines for aggregates provision in England 2005-2020 (Communities and Local Government)
- Construction aggregates – Mineral Planning Factsheet (British Geological Survey – Communities and Local Government – 2007)
- Managing aggregates supply in England – A review of the current system and future options (British Geological Survey – 2008)
- Primary Aggregate Reserves in England 1990-2004 (British Geological Survey – Communities and Local Government – 2006)
- The need for indigenous aggregates production in England (British Geological Survey – 2008)
- Aggregates resource alternatives: options for future aggregate minerals supply in England (British Geological Survey – 2008)
- Wales: Minerals Planning Policy-Minerals Technical Advice Note – 1: Aggregates (2004)
- Scottish Aggregates Survey (One Scotland – Scottish Government – 2007)
- Technical and Strategic Assessment of Aggregate Supply Options in the South West Region (South West Regional Assembly – Capita Symonds Ltd – 2005)
- South West Regional Aggregates Working Party – Annual Report 2006
- Marine Aggregate Dredging – The Area Involved – 10th Annual Report (BMAPA – The Crown Estate – 2007)
- Aggregates from the sea (BMAPA brochure)
- UK Minerals Yearbook – 2008 (British Geological Survey)

Concrete

- Cement – Mineral Planning Factsheet (British Geological Survey – Communities and Local Government – 2008)
- UK Steel - Key Statistics 2008 – EEF (*data for rods and bars for reinforcement*)

Labour & Skills

- Construction Skills Network: Labour Market Intelligence 2009-2013
  - Wales
  - South West
  - UK
- Energy Skills – Opportunity and Challenge. A report to Government by the Sector Skills Organisations responsible for Energy. A response to the Energy White Paper 2007 (2008)
- Sector Skills Council for Science, Engineering and Manufacturing Technologies (SEMTA): Engineering Skills Balance Sheet – An analysis of Supply and Demand issues (2008)
  - England
  - Wales
  - South West
- Skills Shortages in the UK Construction industry (Chartered Institute of Building – 2008)
- Today's investment – tomorrows asset: skills and employment in the Wind, Wave and Tidal sectors (SQWenergy - report to the BWEA – 2008)
- Energy & Utility Skills – Sector Skills Agreement – Stage 1 and 2 – Report on the electricity industry (2006)
- Energy & Utility Skills – Employment and Skills Study of the UK Electricity Industry (2004)

Miscellaneous

- Supply Chain Constraints on the Deployment of Renewable Electricity Technologies (BERR – Douglas-Westwood – 2008)
- 2016 Future Supply Chain – Cap Gemini – The Global Commerce Initiative (May 2008)