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Note For the Record			NFR/3400737/PROJ/00001A
Topic area	**Site Optimisation and Closure Engineering Planning Application**		
Subject	**Evolution of the Drigg Coast SAC and SSSI in relation to the LLWR site**		
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Related records	LLWR/ESC/Mem(13)224		

Objective

This note is to summarise available relevant information that may be useful in relation to the evolution of the Drigg Coast Special Area of Conservation (SAC) and site of Special Scientific Interest (SSSI).

[This note extracts information directly from LLWR/ESC/Mem(13)224]

1 Summary

We consider that no definitive projection can be made for the future development of the spit or the evolution of the coastal dunes and the impact of the development of the LLWR, bearing in mind:

- the potential impact of current and future policy decisions on climate change and sea level rise;
- the high level of uncertainty regarding the timing, rate and degree of sea-level rise and coastal erosion and the associated detailed development of the spit and the potential recession of the dunes;
- the transient nature of dune formations;
- the successional nature of the colonisation of new dunes as they are formed; and,
- the particular features of the current mature dune formation that constitute the features of primary interest in designating the Drigg dunes as a SAC/SSSI.

Possible future evolution of the area includes:

- roll back of spit gravel into the estuary / floodplain basin, or simple overriding immersion of the gravel spit, is most likely – in either case leading to formation of a ‘Ravenglass Bay’ and destruction of the bulk of present day dunes on their current site;
- avulsion of the River Irt with potential sudden cutting off of some part of the spit;

- some northern part of the dunes (over the till-based part of the spit) may recede and re-establish further NE as the coast recedes.

Even for those cases where the dunes are reformed, at the point when erosion of the disposal area begins the present-day SAC/SSSI area has already been eroded. If the area remains a 'closed system' with no significant input of fresh sand-sized sediment, dunes may move landwards as the coastline recedes but will occupy a smaller area. Furthermore, juvenile dunes will be characterised by lower biodiversity than the mature dunes currently present. The continuation of a mature dune system is not ruled out but will depend on the rate of coastal erosion. Based on evidence for the formation of the current dunes, a period of some thousands of years may be required to establish mature dunes.

The presence of the LLWR, offering greater resistance to erosion than the adjacent land, may provide an area around which sand may accumulate and thus afford some enhanced prospect of dune formation. However, this is considered to be highly speculative and unlikely to be influenced by the future development of LLWR.

2 Physical and geomorphological evolution of the coast and estuary

The dune system exists at present primarily on the Drigg Spit (to the south of the shore road) together with juvenile dunes in Carl Crag Bay (as noted above).

The dunes that front the LLWR and which form the northern part of the Drigg promontory rest on top of till deposits that constrain the rate of coastal recession. The dunes of the southern part of the Drigg promontory rest on gravels that may erode, but the presence of the dunes would have little impact on future rate of coastal recession.

Reference [1] considered the development of the Cumbrian coastline in the vicinity of the LLWR, extending some thousands of years into the future. The report was stated to be a "synthesis of desk and field studies undertaken over a period of more than ten years, complemented by mathematical modelling using statistically and physically based approaches" (p.112 of reference [1]) and provides an historical and evolutionary context, as well as a model-based projection. The focus for that work was to consider site disruption in the context of the dispersal of, and the potential for environmental impacts from, the long-lived radionuclides present in the disposed wastes. Habitat evolution was not addressed specifically, nonetheless, sediment budgets and dune morphology, moisture content and vegetation distribution (in order to inform estimates of their resilience to climate change and sea-level rise) were considered.

Despite the level of work invested in that project, considerable uncertainty remains in the nature and timescale of future coastal evolution. This relates mainly to rates of global sea-level rise, which are uncertain due to uncertainty in the response of the Greenland and Antarctic ice sheets to changing temperatures and ice margin sea-levels, see below.

The dunes have a limited significance in the evolution of the coastline over the timescale of a few hundred to a thousand years covered by the ESC. It is concluded in reference [1] that the site will be eroded in around 1,500 to 2,000 years as a result of coastal erosion and sea-level rise. This estimate is subject to significant uncertainty from a number of sources, which is difficult to quantify, and it is worth quoting verbatim the concluding paragraph from reference [1] (p.117).

> "*It must be appreciated that forecasting the development of the Cumbrian coastline in the vicinity of the LLWR involves a wide variety of uncertainties.*

Important uncertainties include the local sediment availability and the inter-related issue of beach volume increase or decrease with its attendant implications for the degree of protection afforded by the beach at the cliff toe. However, the largest uncertainty is related to the future pattern of climate and sea-level change (both in terms of cumulative sea-level elevation and rate of sea-level rise) for which there is continuing debate and research. Because the actual pattern of sea-level change that will occur depends both on policy decisions and on currently unquantified modelling uncertainties, it is not appropriate to assign probabilities to individual cases of climate and sea-level change."

It is worth emphasising that climate change and sea-level rise are uncertain as a result of both policy decisions and modelling uncertainties.

The entire frontage of the LLWR and the northern part of the Drigg promontory are underlain by a till ridge. Therefore, the erosion assessments are based on cliff recession modelling that does not consider the response of dunes to direct wave attack. Under future conditions of potentially rapid rising sea level and limited supply of sand-sized sediment, existing sand dunes will be eroded.

The evidence for past avulsion[*] of the course River Irt is equivocal, but even if an avulsion were to occur in the future, it would not be expected to affect timing of erosion of the disposal area, which is determined by erosion of the coastal frontage.

Reference [1] considers that the Drigg dunes started to form around 6000 years before present (BP), at a time of very high availability of sediment from erosion of glacial sediments and falling sea levels (see p.31 of reference [1] and Section 4 of reference [2]), and the dunes are based on till on the northern part of the spit and gravel to the south. However, Fish [2] states that conditions of high availability of sand-sized sediment are not likely to occur in the future as sea levels rise, as the soft sediments are now largely eroded and exhausted, and along much of the St Bees to Ravenglass coastline the pre-glacial cliffs cut in hard Permo-Triassic sandstone are close to the current shoreline. Over the last 1000 years, vegetation growth has largely stabilised the existing dunes (e.g. p.31 of reference [1]) and evidence from historical maps suggests that dune accretion had effectively ceased some 200 years ago ([2] subject, of course, to short term variations). This is consistent with characterising the dunes as 'mature', with diverse floral colonisation.

3 Dune formation

Sand dunes generally develop behind large sandy beaches that dry out at low tide allowing sand grains to be blown landward. For dunes to develop and be maintained there must be a sufficient supply of sand of the size 0.2 to 2 mm. Sand dune vegetation varies depending upon the time elapsed since sand was deposited, sand stability and local hydrological conditions. Embryonic and mobile dunes occur mainly on the seaward side of a dune system where sand deposition is occurring; these areas are often dominated by marram grass *Ammophila arenaria*. Fixed dunes form where sand has stabilised and where a rudimentary soil has had a chance to develop. These areas

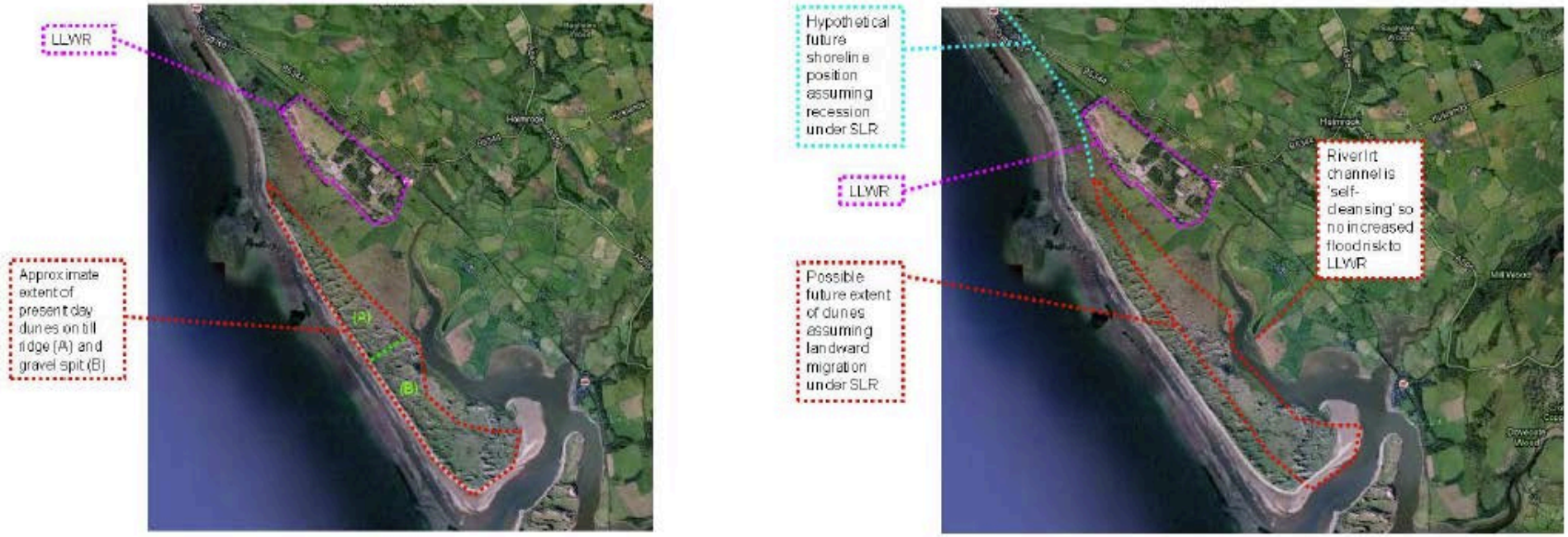
[*] Avulsion refers to a sudden change of a water bed or the course of a river or stream leading to an immediate and noticeable transfer of land or soil, or a sudden cutting off of land. Soil transfer from avulsion differs from accretion or alluvion, where there is a gradual and imperceptible build-up of land by the continuous activity of the sea, a river, or other natural causes; similarly the cutting off of land due to avulsion differs from the more gradual process of erosion leading to loss of land.

usually have lime-rich soils and are particularly rich in plant species. On older dunes, calcium may be leached from the soils leading to the development of acid dune grassland or dune heath. In wet depressions between dune ridges, dune slacks may develop. These are often characterised by the presence of creeping willow *Salix repens* and a number of moss species.

Reference [2] suggests that the present-day coastal system surrounding the LLWR is a closed system, and this "implies there will be no significant input of sediment to the system in the future and that coastal evolution will be characterised by reworking of existing sediment stores (in the dunes and till cliffs)." Under future conditions of rising sea level and limited supply of sand-sized sediment, there is little opportunity for expansion of the existing dune system or formation of new dune systems. Nonetheless, there is an adequate existing supply of sand for the dunes to move landwards, whilst the overall sediment volume stays the same or decreases. Moreover, although sediment budgets have been accounted for in the coastal modelling undertaken, the contribution of sand-sized material to the beach sediment budget from the erosion of gravels on the southern part of Drigg Spit (see Section 3) may add to the local source materials for dune formation as the coastline recedes.

For slow/moderate sea-level rise, gravel and sand will roll back, albeit constrained by the Irt channel and there may come a time when the Irt breaks through the spit, leaving the southern part of the spit as an isolated gravel based dune feature (at some distance form LLWR). However, under conditions of rapidly rising sea level with the dune system being subject to direct wave attack, combined with a limited supply of sand-sized sediment, the spit is likely to be overridden and reference [2] suggests that the existing sand dunes will be eroded.

Reference [2] presents a hypothetical coastal arrangement around Drigg in the future (Figure 1). This is not a specific time-based projection, but is representative of conditions that may prevail at some time immediately before erosion of the LLWR commences. This projects the sand dunes migrating inland and moving towards the southern end of the LLWR site.



From [2]; note SLR = sea-level rise.

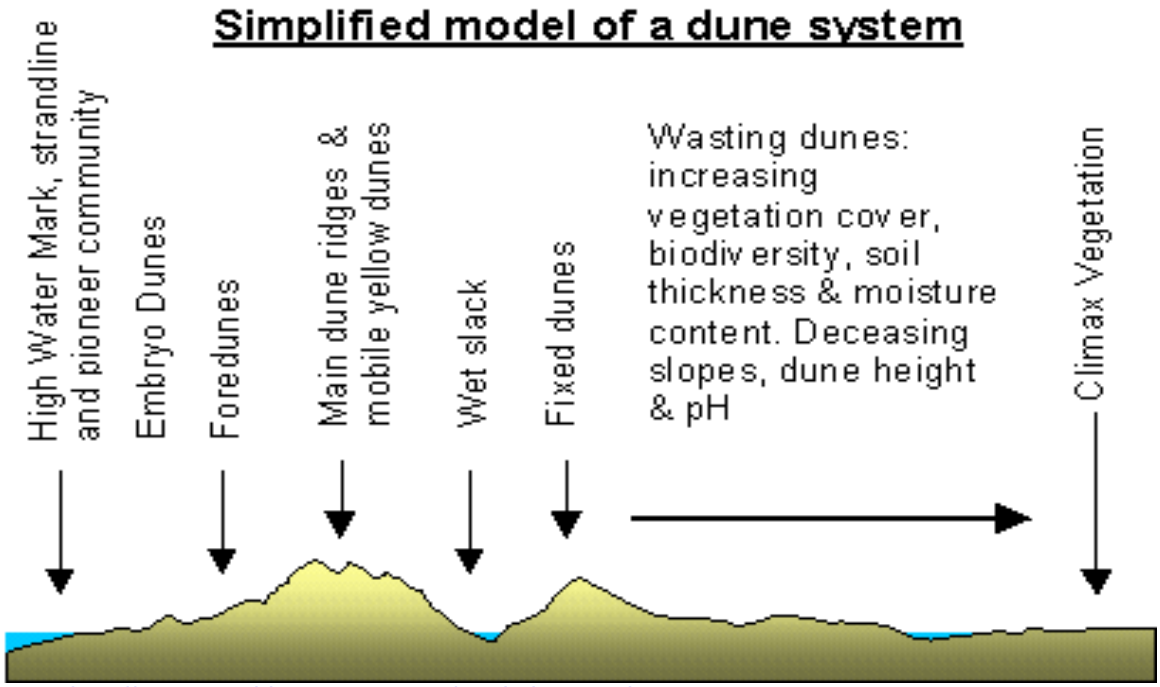
Figure 1: Present-day and hypothetical future arrangement of coastal landscape of adjacent and to the south of the LLWR site

4 Colonisation of dune systems

The Joint Nature Conservation Council (JNCC) characterise the Drigg dunes as Atlantic decalcified fixed dunes (*Calluno-Ulicetea*). There are substantial areas of the habitat type, showing a wide range of ecological variation. Some areas are dominated by heather *Calluna vulgaris* and bell heather *Erica cinerea*. Within the dry dune heath are wetter areas in which cross-leaved heath *Erica tetralix* is prominent. There are large areas of acidic dune grassland with a prominent lichen component and also areas where sand sedge *Carex arenaria* grows in carpets of the moss *Racomitrium canescens*.*

It is clear that sediment availability as sea levels rise, erosion of the existing dunes and potential impacts of climate change on maritime flora will all contribute to the persistence, or otherwise, of the dune system. In addition, changing system maturity (as new dunes form) will influence the dune habitat.

A simplified model of the development of coastal sand dunes (Figure 2) indicates the complexity and fragility of a mature dune system, and the mat of vegetation covering a dune is vital to reducing erosion. Hence the colonisation by pioneer species such as marram grass (*Ammophila arenaria*), sea rocket (*Cakile maritima*) and sand couch grass (*Elytrigia juncea*) are key to the stabilisation of the dunes, leading to later colonisation by the more diverse flora typical of the mature dune complex.



From: http://www.sanddunes.20m.com/Evolution%20.htm

Figure 2: Simplified model of a mature coastal sand dune system

If the rate of change is slow enough, and the equivalent environments emerge or persist then the equivalent flora/fauna is likely to establish (although competition from other flora/fauna cannot be ruled out). In turn, this prompts the observation that even if sand dunes continue to be present along the evolving coastline, the nature of the habitat

* http://jncc.defra.gov.uk/ProtectedSites/SACselection/SAC.asp?EUCode=UK0013031

supported may alter considerably, i.e. with more juvenile dune formation characterised by the presence of pioneer species and less mature dune persistence with loss of the species diversity characteristic of such systems.

5 Likely evolution of the dune system and the physical impact of LLWR

Dunes tend to form around obstacles offering resistance to sand being blown across the foreshore, such as rocks or even driftwood or decaying vegetation. If the higher ground in front of the disposal area (whether the area up to Vault 9 or the areas represented by Vaults 10 to 14 or Vaults 15 to 20) is more resistive to erosion than the lower ground to the south, then the area to south of the site (and later the south site area itself) may provide a location for dune accumulation. Although not as extensive as the current dunes, they could be complemented by other dunes in a future Irt/Mite floodplain bay.

The actual outcome of dune stability and migration depends on many factors: the rate of sea-level rise; storminess; precipitation; temperature, etc. Forward projections are thus highly speculative, but the ability to manage the LLWR site in sympathy to the neighbouring natural environment can only be positive.

Ensuring the continued active management of the LLWR site, for example by passing its care after the period of authorisation to Natural England or its successor bodies or similar wildlife conservation bodies, offers the potential to incorporate the area of the LLWR site into a future SSSI or equivalent protected area

Development of the LLWR site should not be considered in isolation as many other man made features may also influence future evolution of the Drigg Spit. Notably, future management of the current rail line embankment (see Figure 3) and the potential expansion of Drigg village could both offer much greater physical challenges to dune migration than the LLWR.

Figure 3: Relative areas of the Drigg Spit and LLWR disposal area and the present-day railway line and embankment

6 Future Site Management

None of the prognoses for the future development of the spit or the evolution of the coastal dunes can in any way be changed by alternative disposal area developments. In particular, the disposal area is small compared with the present day SAC/SSSI dune system and should not be considered in isolation from other man made features in the area (such as the railway and embankment).

We consider that continued disposals at the site as required to support the NDA waste strategy, with landscaping, planting and management to reflect natural vegetation offers the optimum potential for habitat preservation. Sympathetic end-management of the site after the Period of Authorisation, for example by or in consultation with Natural England, its successor bodies or other conservation body, may offer further potential to actively incorporate the site into a future SAC/SSSI.

7 References

1 Fish P, Thorne M, Moore R, Penfold J, Richards L, Lee M and Pethick J., *LLWR Environmental Safety Case: Forecasting the Development of the Cumbrian Coastline in the Vicinity of the LLWR Site*, Quintessa Report QRS-1443X-1 to LLWR, Version 1, July 2010.

2 Fish P, *LLWR ESC Technical Queries, Significance of the dune system at Drigg*, Halcrow Technical Memo ESC-TQ-SUE-022 to LLWR, 11 December 2012.