**DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS** **CSG 15**

Research and Development

# Final Project Report

(Not to be used for LINK projects)

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| Project title | Understanding and predicting beach morphological change processes associated with the erosion of cohesive foreshores |
| DEFRA project code | **FD1915** |
| Contractor organisation and location | Posford Haskoning Ltd<br>Rightwell House<br>Bretton, Peterborough, PE3 8DW |
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## Executive summary (maximum 2 sides A4)


There are significant stretches of cohesive shore platform in the United Kingdom where variable amounts of sand and gravel overlie cohesive clay materials (such as Holocene mud, glacial till and London Clay). Many stretches lie along the most rapidly eroding shorelines in the country (Holderness, Essex and north Kent) and pose significant problems for management. The process of downcutting of the shore platform and the interaction between the cohesive and non-cohesive components is not well understood.

The coastal community needs to be better able to manage cohesive platforms because of their value as habitats and their importance in controlling the functioning of the wider coastal system, including beach form and sediment budgets. This importance is not limited to areas in which platforms are normally visible; in other locations they may rarely be revealed but still have a significant geomorphological role, particularly in regulating recession rates. In 2001, the Defra Coastal Concerted Action recommended this scoping study to assist coastal authorities in the management of cohesive shorelines.

The objectives of this study were four-fold:

- Identify some of the user-defined problems and issues relevant to the erosion of cohesive foreshores and their potential relationship to beach morphology, through consultation with relevant stakeholders
- Undertake a scoping study (to current best practice) of the processes associated with the erosion of cohesive shore platforms and interactions with the sediment budget in order to identify the research and development needs
- Define a research project that will address the gaps in our understanding and provide detailed guidance to best practice regarding the management of these coastlines (provided separately as a CSG7)
- Provide preliminary advice regarding the management of these coastlines.

The targeted consultation exercise provided the end-user perception of the importance of the erosion processes from a management perspective. The low return of completed questionnaires suggests that awareness of the subject is poor and that improved understanding and dissemination is required.

The scoping report provides a detailed appraisal of previous research in the field of cohesive shore platform weathering and erosion. It examines how these processes may affect the sustainability of the adjoining beaches, the evolution of any backing cliffs, and their influence on sediment budgets. The investigation of processes has not been restricted to the foreshore alone (as the project title suggests), but has also covered the subtidal zone (shoreface). This is because processes operational across the whole of the littoral zone make a significant contribution to the changing geomorphology of the shore platform, either directly or indirectly.

The scoping study shows that although the processes that weather and erode cohesive platforms have been identified, the rates at which they operate have not. The CSG7 research proposal recommended that further research needs to be targeted at providing a better understanding of the fundamental underlying principles that control the rate of cohesive shore platform erosion, providing a baseline starting point for better strategic management. The research will need to examine and improve the technical understanding of the roles of the different parameters and processes that contribute to the downcutting of cohesive shore platforms. Four main research areas are recommended for further investigation:

- the specifics of the weathering and erosion processes, particularly the effect on downcutting rates of abrasion related to sediment size and thickness of surface sediments (beach) and the importance of biological processes
- the relationship between platform and beach geomorphology and the platform weathering and erosion processes in a range of space and time scales
- the relative influence of material strength in the rate at which weathering and erosion processes proceed
- the need to test models of platform development at different sites.

The ultimate aim of the advanced research would be to provide guidance on best practice management of cohesive shorelines, in line with Defra/Environment Agency objectives. However, the present scientific understanding of cohesive shore platforms is insufficient to provide detailed guidance at this scoping stage and so preliminary management advice was given. Advice was provided on do nothing scenarios, reducing platform downcutting by beach recharge, designing better structures and managed realignment.

# Scientific report (maximum 20 sides A4)

**Deliverable 1: Consultation**

As part of the scoping study, a targeted consultation exercise was undertaken. The overall aim of the exercise was to identify and define some of the key user-defined problems and issues related to the erosion of cohesive shore platforms and their relationship to beach morphology. A list of consultees was compiled to represent those who are potentially affected by the erosion of cohesive shore platforms and therefore who would:

- have an interest in the research and
- have knowledge and previous experience of the subject.

A list was produced based on knowledge of the locations of eroding cohesive shore platforms, from a meeting with the Project Officer and through the experience of the project team. Individuals were selected from the following areas

- Local Authorities
- Environment Agency
- Defra
- English Nature
- EPSRC Beach Processes Network
- Academia

A consultation questionnaire was sent to 9 consultees, and completed questionnaires were received back from 3 consultees. This low response is taken as an indication of the lack of awareness of the subject of erosion of cohesive shore platforms and the associated issues, from both a science and a management perspective. However, a number of conclusions were drawn from the consultation exercise.

- The topic of cohesive platform lowering has not been the subject of a great deal of research in the past and management practice has generally not given much consideration to the process. It is the role of research to provide the understanding and tools for the management practices to incorporate

- Some important points were raised by consultees regarding how we place the process of an eroding platform, and coastline, into a management framework. Again, this decision-making process is one in which future research of the subject should feed into

- Some useful technical issues for investigation in a research project were raised, such as the role of abrasion and the rates of lowering of platforms.

**Deliverable 2: Scoping Report**

The focus of the scoping report was to provide a literature review of the processes of weathering and erosion of cohesive platforms. These processes were then placed in the context of the wider coastal system, by examining their relationship to change in beach form and how this may affect the stability of any backing cliffs. The report provided an assessment of previous research on these types of shore, with studies described from both the United Kingdom and worldwide, to provide an exhaustive review of the current state-of-the-art. Using this research as a guide, the scoping re-evaluates where there is a need for further work and establishes the critical areas where knowledge is insufficient.

The scoping report was divided into six main sections:

1. Processes of weathering and erosion
2. The platform-beach-cliff system
3. Measurement techniques
4. Case examples
5. Preliminary management advice
6. Research needs and recommendations

Section 1 discussed the erodibility of cohesive sediments and the power of the assailing forces to erode. It then highlighted the main weathering and erosion processes which act to downcut cohesive shore platforms. These include abrasion by mobile, non-cohesive surface sediment; mechanical wave erosion; biological processes; softening of the fabric due to pressure fluctuations induced by waves; desiccation and wetting; physico-chemical effects; freeze-thaw (frost). The section concluded that presently, there is no definitive description of cohesive platform weathering and erosion because the roles of the different processes have not been exhaustively studied. The roles of subaerial and marine processes are not fully understood and it has not been clearly demonstrated that either process is principally the cause of platform downcutting. The main difficulty lies in separating the effects of each process.

Section 2 introduced the concept that cohesive platforms are generally associated with beaches and cliffs, and downcutting is best understood in the context of a broader geomorphological system that includes all three. The section discusses the relationships between the platform, cliff and beach, and the potential impact of sea-level rise and increased storminess. It is generally agreed that the primary control on the long-term rate of cliff toe erosion is the rate of vertical lowering of the platform and the beach. While subaerial weathering processes may dictate when and where a slope failure will occur, the frequency of failures over the long term is strongly determined by the rate at which the platform profile and beach are eroded.

Section 3 provided a review of the different techniques that have been employed to understand different aspects of cohesive platform erosion and beach change. They were divided into techniques that are used to measure platform downcutting, those used to analyse beaches (or cliff recession) that have a bearing on broad-scale platform evolution and those used to measure material properties, particularly *in situ*. The techniques to measure platform downcutting include the micro-erosion meter, underwater abrasion table and micro-scale laser mapping. Broad-scale changes can be measured by macro-scale laser mapping, GPS surveys and beach profiling, and *in-situ* material properties using various types of flumes.

Section 4 outlined examples of cohesive shore platform erosion from the United Kingdom and worldwide. In the United Kingdom, cohesive shore platforms occur along many stretches of the east and south coasts. Examples include the Pleistocene till shores of Holderness, north-east Norfolk and Northern Ireland, the Tertiary shores of Essex/north Kent (London Clay Formation) and West Sussex/Hampshire/Isle of Wight (Bracklesham and Barton Groups), and the Holocene exposures of the East Anglian, Lincolnshire and Lancashire coasts and the Thames Estuary. They are also recognised along other mid-latitude (e.g. southern Baltic Sea) and high latitude (e.g. southern Beaufort Sea) shores. They form a large part of the perimeters of the Great Lakes, comprising over 40% of the shoreline of the lower lakes (Lake Ontario, Lake Erie, southern Lake Huron and southern Lake Michigan).

Section 5 provided preliminary management advice which is discussed later in this report as the 4th deliverable.

Section 6 highlighted the main areas where further research is required before detailed guidance documentation can be produced.

- There remain gaps in our understanding of the main processes that control the rate at which cohesive platforms weather and erode. Little is known about the effectiveness of each individual process as a weathering or erosive agent and previous platform studies have suffered generally from a lack of rigorous quantitative investigation. Previous research has also failed to explore the relationships and interactions between the individual processes, which rarely operate in isolation. Estimations of the relative rates at which individual processes act (they could be as high as tens of centimetres over a tide) are still in their infancy. It has also been difficult to distinguish between processes, which may be very different, but have the same effect on platform morphology.

- The cases of abrasion by non-cohesive sediments and bioerosion highlight these deficiencies. Most studies acknowledge the importance of abrasion by the movement of coarser sediment across the surface of the cohesive material, but they have not provided a definitive means of predicting this. Little is known about the relationship between the thickness of the surface layer and the degree of protection provided, nor is there much information on the typical thickness and mobility of sediment on actual cohesive shorelines. The influence of organisms on the erosion dynamics of cohesive platforms has also received little attention. Research is required to understand the contribution of biological erosion relative to marine and subaerial processes, and the relative importance of the erosive and protective effects of the organisms themselves.

- Cohesive shore recession rate relates to the constant adjustment of the platform form through a broad range of processes. However, clear relationships between platform morphology and the process environment have yet to be established. Short to medium-term rates of development requires further investigation to help resolve the problems of prediction over the long term.

- There is little available information on what measure of strength can be used to predict resistance to erosion by wave-induced forces, abrasion by surficial sediments, and the effects of softening or weathering of the cohesive sediment. Critical to understanding the strength and geotechnical properties of materials is their measurement *in situ* and presently, there is a dearth of such measurements. Advanced research is needed to determine the form of the relationships between critical shear stress for erosion and shear strength, clay content (particle size distribution), water content, and other geotechnical and chemical properties.

- New modelling tools are needed to represent the development of cohesive foreshores. These should be process-based so that they can represent foreshore response to changed wave climates and rate of sea level rise. They should be suitable for investigating shore response to management scenarios, so should be capable of representing the installation of structures, and their removal from currently protected areas. Since decisions regarding the management of cohesive shores will, in many cases, affect neighbouring sections of coast the modelling tool should be capable of functioning at a reasonably large scale, to capture such interaction. In addition the tools should be capable of representing uncertainty in processes, parameters and future loading conditions.

Based on these recommendations an innovative R&D project to meet the research needs in this field was completed as a Defra CSG7 (discussed later in this report as the 3rd deliverable).

**Deliverable 3: Proposed Research Project (CSG7)**

The scoping study demonstrates that little research has been undertaken, specifically addressing the issues of cohesive shore platform erosion, and its implication for coastal management. A lack of data and a clear understanding of the erosion processes have also handicapped numerical model development. The purpose of the proposed research is to build upon the conclusions of the scoping study to investigate the following scientific problems:

1. the specifics of the weathering and erosion processes, particularly biological and wave processes
2. the relationship between geology, material strength, weathering/erosion processes and platform morphology
3. the prediction of cohesive platform evolution in the light of future climate change and human factors.

The main purpose of the proposed research will be to provide a scientific grounding in cohesive shore platform erosion and to translate these into detailed design guidance to help decision makers implement effective management strategies along these types of shoreline. The study is envisaged to:

- design and implement field programmes at two contrasting platform-beach sites along the United Kingdom coast to collect samples and gather *in situ* data on geology and biology
- test the platform and beach samples in the laboratory for geotechnical, biological and textural parameters
- interpret and integrate the field data and the results of the sample tests into an overall assessment of platform weathering and erosion, and their relationships with platform and beach morphology
- collect current and historical data of the sites and neighbouring shorelines to describe their local geomorphological interactions and their role in larger coastal systems
- use the data, geomorphological descriptions and interpreted results to produce models of the sites
- produce a final report on the scientific results of the project and translate these into preliminary best practice guidelines regarding management of these shorelines
- draw conclusions relevant to practical shoreline management arising from the project, through cross-Theme exchange of results and a series of end user workshops

**Deliverable 4: Preliminary Management Advice**

The scoping report argues that the dynamic and morphological responses of a beach system to changes in the adjacent cohesive platform is important for resolving management issues. Indeed, many estimates of sediment yield from shoreline erosion ignore the important contribution made by the platform. The erosion of the platform proceeds at a rate dependent upon the erosion processes and will produce fine and coarse sediment into the coastal system. The coarser sediment moves along the shoreline by wave and tidal action influencing other areas as they pass and finer sediment is removed offshore in suspension. Changes to erosion and transport processes will impact on the sediment budgets, which in turn will have long term impacts on the areas where sediment is usually deposited. In addition to being an important influence on the beach, the platform also acts as a regulator of cliff erosion. Over time, in a natural state, the rates of downcutting of the platform and retreat of the cliff tend to reach a state of equilibrium as the platform regulates the wave energy impinging on the cliff toe. The downcutting of the platform can also be an important consideration in the long-term performance of coastal defence structures, especially as these structures have their foundations in the same formations. The water depth in front of structures such as sea walls can increase significantly over their design life, affecting the overtopping performance and standard of protection as well as increasing the risk of undermining and failure.

The preliminary options for management outlined in the scoping report included:

- Do Nothing - One potential management view is that no attempts should be made to prevent cohesive platform erosion. The likelihood of this option being adopted is increased by its minimal initial cost. “Do nothing” may be the preferred option in areas that are currently unprotected. However, it should be noted that, due to climate change, future rates of cliff retreat might be higher than they have been in the past. The consequences of do nothing may, therefore, be an increase in shore retreat rate.

- Reduce platform downcutting by beach recharge - The failure of many coastal structures may result from undermining through continuing erosion of the cohesive platform seaward of the structures. In order to reduce cohesive shoreline recession it may be necessary to prevent downcutting across the whole profile. One of the main methods of reducing erosion of a cohesive profile is to artificially create a substantial beach. A healthy beach is probably the most effective form of coastal defence since it has the ability to adapt its shape naturally to changing wave and tidal conditions and dissipates wave energy. However, it must be noted that this technique often has limited or no effect on erosion of the subtidal shoreface.

- Design better structures - The rapid erosion of cohesive platforms increases the difficulty of establishing a purely structural solution. For example, structures built in areas subject to high storm activity and scarcity of beach sediments may lead to rapid erosion. Beaches may be narrow and the effectiveness of groynes in building a protective beach would probably be restricted. The highly erodible nature of cohesive materials also makes it difficult to provide stable foundations. Thus, one of the most common failures of sea walls is inadequate toe protection leading to scour and collapse. Failure of groynes usually occurred through scour at their bases, especially on their downdrift sides.

- Managed realignment - Even when a cliff toe is protected with structures, vertical erosion of the platform will continue leading to a steepening of the profile, allowing increased wave energy to reach the beach or protective structure. As shore platforms at protected sites continue to lower, water depth increases and the protective structures are undermined and become more expensive to maintain, and managed realignment will increasingly be considered as a possible management option.