Institution: Birkbeck, University of London

Unit of Assessment: 14

Title of case study: Transforming shoreline management policy and practice

Period when the underpinning research was undertaken: 2010-2020

Period when the claimed impact occurred: 2016-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

The Environment Agency has used Brooks' digitised cliff analysis methodology (REF1) and her position on one of their Technical Assurance Groups to provide quality-assured guidance issued to coastal authorities in England and Wales in order to effectively manage shoreline retreat.

Brooks' research was used in the Marine Climate Change Impacts Partnership 2020 Report Card. These reports are acted upon by decision makers within the government and are part of the evidence base to inform the next UK Climate Change Risk Assessment and National Adaptation Plans.

Brooks' input on the £20m (GBP20,000,000) Bacton Sandscaping project has raised awareness of the need to protect East Anglia's coastal communities, tourism interests, habitats of rare species, multiple local businesses, and numerous commercial and intellectual stakeholders in addition to protecting the Bacton Gas Terminal itself, part of the UK's critical national infrastructure supplying a third of the UK's gas annually.

2. Underpinning research (indicative maximum 500 words)

Storms create serious problems for coastal managers because they inflict damage on infrastructure and communities and are unpredictable. Brooks' research aims to understand the consequences of storm impacts and whether shorelines can recover naturally. Cliff retreat is one crucial aspect because a) cliffs cannot recover once removed; and b) cliff retreat delivers thousands of tonnes of sediment into the nearshore zone, particularly in response to climate change-related sea level rise, a key area of focus for Brooks' research. Brooks won a prestigious Leverhulme Fellowship in 2014 (between October 2015 and August 2016), and generated publications on surge impacts (eg: REF3), including correspondence in Nature.

Early underpinning research in the 1990s was in collaboration with Professor Malcolm Anderson at the University of Bristol, and Professor Mike Crozier at the University of Wellington, New Zealand which began a new way of thinking about how and why hillslopes fail, transforming the way that both academics and practitioners understand and work with the natural behaviour of slopes.

Current research delves into the complexity of shoreline change through cliff erosion, being driven by the combination of still water levels and wave activity, both of which increase during storms (REF4). It also tackles the critical issue of sea level rise in setting the baseline conditions for storm impacts, showing how storm impacts will increase in future. For coastal managers to respond effectively to erosion the research findings of current and future storm impacts have proven invaluable, especially for East Anglian coastal managers where erosion is a serious threat. To provide the highest possible value to stakeholders, the underpinning research has followed two main avenues.

Following a grant of £9,000 (GBP9,000) from the Crown Estate (2009) for her project on cliff recession, sediment supply and bathymetric change on the Suffolk coast, Brooks developed, calibrated and applied a shoreline response model to rapidly retreating cliffs (REF5), retreating up to 7 metres per year (REF6). The model can generate future shoreline locations under different future emissions scenarios (UK Climate Impacts Programme; UKCiP09). It couples the Digital Shoreline Analysis System (DSAS) of the United States Geological Survey (Thieler et al., 2017) to a shoreline response module, which can plot future shorelines in real space. It includes different sea level rise expectations for future planning epochs (eg: Environment Agency use 2025, 2055 and 2105). These shoreline predictions are used to establish land loss in internationally important habitats such as the National Nature Reserves of Suffolk (that have been designated as RAMSAR sites for special protection under European legislation, as well as being Areas of Outstanding Natural Beauty and Sites of Special Scientific Interest, as national designations). Used with terrestrial and airborne laser scanning, the predictions also enable quantification of sediment release from retreating cliffs.

A second aspect is Brooks' work on complex barrier coasts such as North Norfolk, which uses a contemporary and historic big data approach to investigate large-scale shoreline change (REF1) in sites extremely vulnerable to sea flooding during storms and surges (REF3). The back-barrier area is populated and infrastructure is at risk. Brooks has developed a methodology combining cross-shore transects (since 1992), aerial photographs, DSAS, field-based Real Time Kinematic (RTK) survey and aerial Light Detection And Ranging (LiDAR) resources (REF1). This research has identified high-magnitude storms since 2006, demonstrated their shoreline impacts, and shown the co-variance with forcing conditions using temporal data sets on wave heights and water levels. The 5 December 2013 surge (the largest event for 60 years) spawned a research approach that focuses on the alongshore variation in storm impacts and subsequent recovery showing sections of coast that recover easily and contrasting them with those that don't (REF2). This data-rich methodological approach is currently being used to study cliff and beach impacts from the 2018 "Beast from the East", driven by a Sudden Stratospheric Warming (SSW) which generated the largest onshore waves since 2009 (when wave records began on the UK East coast). This research is quantifying beach lowering and cliff retreat in front of the Bacton Gas Terminal, an installation of major national strategic importance.

Both areas of research have had instrumental and capacity building impacts through development of new methodological approaches which allow evaluation of shoreline morphological change (through Digital Elevation Models (DEMs) of Difference) together with storm forcing data (winds, waves, water levels). Insights have benefitted coastal planners, policy makers, communities, national infrastructure and habitats in coastal areas, through early warning and evacuation planning for floods, and shoreline protection strategies for erosion.

3. References to the research (indicative maximum of six references)

REF1) Pollard, J.A., Brooks, S.M. and Spencer, T. (2019) 'Harmonising topographic and remotely sensed datasets, a reference dataset for shoreline and beach change analysis'. *Scientific Data* 6(1). https://doi.org/10.1038/s4158-019-0044-3.

REF2) Brooks, S.M., Spencer, T. and Christie, E.E. (2017) 'Storm impacts and shoreline recovery: mechanisms in the Southern North Sea'. *Geomorphology*. http://www.sciencedirect.com/science/article/pii/S0169555X16306110.

REF3) Spencer, T., Brooks, S.M., Moeller, I., Evans, B. and Tempest, J. (2015) 'Southern North Sea storm surge event of 5 December 2013: Water levels, waves and coastal impacts' *Earth Science Reviews* 146, 120-145. DOI: 10.1016/jearscirev.2015.04.002

REF4) Brooks, S.M., Spencer, T., and Boreham, S. (2012) 'Mechanisms for cliff retreat in rapidly receding soft-rock cliffs: marine and terrestrial influences, Suffolk coast, U.K'. *Geomorphology*, 153 – 154, 48 – 60. DOI: 10.0106/jgeomorph.2012.02.007.

REF5) Brooks, S.M. and Spencer, T. (2012) 'Shoreline retreat and sediment release in response to accelerating sea level rise: measuring and modelling cliffline dynamics on the Suffolk Coast, UK'. *Global and Planetary Change* 80 - 81, 165 – 179. DOI: 10.1016/j.gloplacha.2011.10.008.

REF6) Brooks, S.M. and Spencer, T. (2010) 'Temporal and spatial variations in recession rates and sediment release from soft rock cliffs, Suffolk Coast, UK'. *Geomorphology* 14, 26-41. DOI:10.1016/j.geomorph.2010.08.005.

REF7) Masselink, G., Russell, P., Rennie, A., Brooks, S. and Spencer, T. (2020) 'Impacts of climate change on coastal geomorphology and coastal erosion relevant to the coastal and marine environment around the UK'. *MCCIP Science Review 2020*, 158–189. DOI: 10.14465/2020.arc08.cgm

4. Details of the impact

Brooks' new methodological approaches allow coastal planners and policy makers (including the UK National Government) to evaluate shoreline morphological change. They have directly informed both planning for early warning and evacuation and flood-related issues, and protection strategies for shoreline erosion. Meanwhile, Brooks' work on managing cliff recession is helping to build a picture of how the Bacton Sandscaping project is progressing and its role in nationally strategic shoreline protection.

The Environment Agency

One of the Environment Agency's (EA) key functions is to provide evidence and advice to inform government policy and support others to develop risk management skills and capacity. It is the leading authority for managing the UK shorelines and, in its capacity as expert advisor, provides

advice to all local planning authorities in the UK on planning applications, local plans and environmental assessments.

A 2017 Environment Agency report on cliff recession on the Anglian coastal monitoring area (1) cites Brooks' research when it notes the rising concern of risk to the public due to coastal erosion. Brooks has shown an average cliff retreat rate of up to 7 metres per year at Covehithe and 12-15 metres for individual storms. The report demonstrates the risk of erosion on this stretch of coastline, while underlining Brooks' contribution to strategies to combat it. Additionally, rising sea levels are threatening coastal habitats, putting internationally important species at risk. The habitats are natural sea defences, nurse fish stocks and have recreational value, while East Anglia's cliffs are some of Europe's fastest eroding. This information is making a difference to the new generation of Shoreline Management Plans (SMPs) for the area, where managed realignment is now preferred over hold the line or no active intervention (as stated in the SMP 7, Section 8: Plan updates).

The 2017 report drew heavily on Brooks' data and analysis of cliff retreat, noting that Brooks is one of the few researchers drawing attention to the issue, despite its national importance. The report recommends that employing a similar methodology to the digitised cliff top position method developed by Brooks in 2010 would provide a more thorough overview of recession changes (1). Moreover, Brooks provides "additional insight into the trends and patterns of movement over time, in particular the observation that erosion rates have increased in recent years" (1). Following its publication, the report was used to communicate risk to local communities and as evidence of the differences between the observed erosion rates and those quoted in various SMPs. The latter point is especially important because SMPs are the primary method by which local authorities manage coastal erosion.

Following publication of the 2017 report, in September 2019 Brooks was invited to join one of the Environment Agency's Technical Assurance groups as part of their remit in providing quality advice. The main goal is to map and model the sensitivity of coastal cliff erosion to future relative sea level rise around Wales and England, over the next hundred years. Major users of the Environment Agency's technical assurance include all Local Authorities with unprotected cliffs, landowners with large estates on the coast, and organisations such as the National Trust. The National Trust in particular is being kept informed by the Technical Assurance group: an example of a partner with hundreds of miles of coastline under their stewardship (2).

The Bacton Sandscaping Project

Brooks' research has particular relevance to the ongoing management of the easily-erodible shorelines of East Anglia, as shown in her involvement in monitoring sand movement following 'sandscaping' of the coast near Bacton. The East Anglian coastline is of strategic importance to the UK because it houses the Bacton Gas Terminal (as well as the Sizewell nuclear power plant, currently planning for expansion), which supplies a third of the UK's gas annually. It is also relevant as a popular tourist destination, boasting sandy beaches, rare wildlife, and attracting around 140,000,000 day trippers annually, bringing in £10bn (GBP10,000,000,000) and supporting 240,000 jobs per year: https://www.visiteastofengland.com/business-tradeGrowing_tourism_directly_employs_around_240000_people (4). Moreover, her research has been essential to communicating the importance of the Bacton project to the public and to ensuring that it achieves its aims; e.g. a *Conversation* article reporting on the project used Brooks' research on southern North Sea storm surges (REF4) (3) – later picked up by *Yahoo! News* and *Phys.org* - to contextualise the need for the project. In July 2019, the BBC interviewed Brooks about the project (4), on the recommendation of Royal Haskoning DHV – the company that designed the scheme.

The 2012 Kelling to Lowestoft Ness Shoreline Management Plan covering the Bacton area (5) previously advocated a "Hold the Line" approach to coastal defence in the Bacton area using fixed groynes and to hold the beach in place. However, Brooks' research has consistently provided evidence that "Hold the Line" is not necessarily the best approach for rapidly eroding soft sediment coastlines. The new mobile sandscaping scheme chosen for future protection of the Bacton Gas Terminal is directly in line with what Brooks research recommends.

Historically, the Bacton Gas Terminal was defended by timber groynes but these provide only

limited defence and are prone to damage and wear, as well as providing only 10% Annual Exceedance Probability protection against storms (6). These factors led to a rapid increase in erosion in the area in recent years. Bacton Gas Terminal was more than 100m from the cliff edge when it was built in the 1960s. However, some parts of the complex are now only 10m away. A solution needed to be found in order to protect the gas terminal and to prevent the 2,000 people who lived in neighbouring villages from losing their homes to erosion. However, continued coastal defence of the local community, which form(s) an integral element of the community and socio-economic structure of northeast Norfolk, was only economically viable in the short term under current UK treasury rules, while hard solutions involving coastal rock armour against wave overtopping were discounted. A permanent, economically viable solution was needed and was identified in the form of sandscaping, which uses natural processes to manage defence against storms by placing sand at strategic points along the coast (6).

The Bacton Sandscaping Project, first proposed in 2016 and launched in summer 2019, has seen 1,800,000m^3 of sand placed along the beaches at Bacton. This forms a natural barrier and cost-effective solution against coastal erosion and will potentially not need to be replaced for another 15 to 20 years. It will also benefit coastal communities located downdrift through maintenance of protective beaches. The £20m (GBP20,000,000) project was carried out by a public-private partnership led by Team Van Oord, a multi-partner team incorporating Dutch companies Royal Haskoning DHV, Van Oord, Kier Group and Mackley, which have a combined turnover of £5bn (GBP5,000,000,000). The project also involves Coastal Partnership East – a partnership between Great Yarmouth Borough Council, North Norfolk District Council, and East Suffolk Council, the Environment Agency, the Water Management Alliance, and others to manage the coast - Norwich-based independent oil and gas company Perenco, consulting engineers' firm St La Haye, the Environment Agency, Shell – who operate the terminal – and North Norfolk District Council, who recruited and contracted Team Van Oord. Its work will secure long-term environmental, economic, and cultural stability and sustainability for the local area and, due to the importance of Bacton Gas Terminal, for the UK as a whole.

Brooks has also been working collaboratively with the ongoing monitoring at Bacton, attending meetings with Technical Directors at Royal Haskoning and the Sandscaping Research Network. As part of this, Brooks worked with computer scientists at Birkbeck, Bournemouth and the British Geological Survey to develop low-power wireless sensors that connect to the internet, have an embedded GPS (for positional information) and can be placed in rugged coastal locations to monitor continuous changes to the sediment volumes. The sensors were due to be tested in 2020 but have been delayed by the Covid-19 crisis. It is hoped that work on testing the sensors will resume in 2021.

Wider impacts on policy makers

Brooks' research findings on sediment release from retreating cliffs (Brooks et al., 2012; Brooks and Spencer, 2012) were included in a 2016 report (7) by Waveney District Council (now East Suffolk Council), due to concerns over Southwold beach lowering. This is important because sediments are instrumental in protecting the coast; Brooks' research quantifies retreat but explicitly links it to sediment volumes being released from updrift cliffs that supply sediment to the beaches at Southwold. The report states "Importantly, this modelled cliff recession and sediment release shows an increasing proportion of the overall sediment being provided by the Easton Cliffs – 24% to 2050 and 33% to 2095. Sea level rise is likely to lead to increased cliff recession, but subsequently there may be more material within the system for the beaches at Southwold". This work has led to Brooks collaborating with the Marine Knowledge Exchange Network (MKEN). MKEN is a diverse networking group with representatives from East Anglian Councils, Natural England, Environment Agency, Water Management Alliance, National Trust, Norfolk Wildlife Trust and Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Brooks' collaborative work has continued with her role as a Principal Investigator on a £3.4m (GBP3,400,000) NERC-funded project "BLUE coast: 'Physical and biological dynamic coastal processes and their role in coastal recovery'". She serves on the Executive Committee and the Scientific Advisory Board of BLUEcoast, which aims to enhance the evidence base of Shoreline Management Plans. This project is running between 2016 and 2022 (NE/N015878/1). Research on this project has yielded 10 Scientific papers, numerous conference presentations (including

Coastal Sediments 2019 and the Institute of Civil Engineers, 2019), and regular knowledge exchange meetings with the British Geological Survey and the Environment Agency. Brooks was invited to advise on the project "Dynamic Dunescapes". This project includes partners from the National Trust, Natural England, other Wildlife Trusts and Natural Resources Wales and was set up to restore sand dunes across England and Wales (https://dynamicdunescapes.co.uk/the-project/).

Furthermore, Brooks' collaboration with major partners is affecting national policy. In the face of the climate crisis, Brooks' invited co-authored review paper on coastal geomorphology (REF7) was used to develop the Marine Climate Change Impacts Partnership (MCCIP)'s *2020 Report Card on Marine Climate Change Impacts* (8). Some of the key headlines arising from the report card include "the latest UK sea-level rise projections imply increased coastal-flood risk", and "coastal assets will be subjected to enhanced rates of erosion, inundation and weathering or decay due to the effects of climate change". The report cards provide "short, comprehensive, quality assured, high level assimilation of knowledge set out in a visually impacting way" that can be quickly used by policy makers such as ministers, Parliament and the devolved administrations. Moreover, the reports form part of the evidence base to inform the next UK Climate Change Risk Assessment (CCRA) and National Adaptation Plans (8).

5. Sources to corroborate the impact (indicative maximum of 10 references)

1) Stanley, R., Staley, P., *Cliff Recession in the Anglian Coastal Monitoring Area – Report*, Environment Agency (August 2017)
2) Environment Agency Testimonial
3) Brown, S., 'Giant 'sandscaping' plan to save Norfolk coast will only put off the inevitable' (5 August 2019) https://theconversation.com/giant-sandscaping-plan-to-save-norfolk-coast-will-only-put-off-the-inevitable-121346
4) Morelle, R., 'Vast sand scheme to protect Norfolk coast' *BBC News* (18 July 2019) https://www.bbc.co.uk/news/science-environment-48965715
5) Shoreline Management Plans: 6 Kelling Hard to Lowestoft Ness (Lead: North Norfolk District Council); 7 Lowestoft Ness to Felixstowe Languard) Lead: Suffolk Coastal District Council)
6) Johnson, M., Goodliffe, R.J.W., Doygun, G., Flikweert, J., Spaan, G., *From Idea to Reality: The UK's First Sandscaping Project*, International Association of Dredging Companies (Spring 2020)
7) *Southwold Beach Analysis Report*, Waveney District Council (21 October 2016)
8) *Marine Climate Change Impacts Report Card 2020*, Marine Impacts Climate Change Partnership (2020) http://www.mccip.org.uk/media/2011/08_coastal_geomorphology_2020.pdf