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RESILIENCE TO CLUSTERED DISASTER EVENTS AT THE COAST: STORM SURGE

Final Report

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Cover: Drone vision over Lamberts Beach after Cyclone Debbie.
Credit: Michael Kennedy, Chief Operator National Drones Mackay

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EXECUTIVE SUMMARY

What is the problem?

Coastal communities in Australia are particularly exposed to clustered disaster events, due to the impact of cyclones and extra-tropical storms when there can be coincidence of severe wind damage, storm surge, coastal flooding and shoreline erosion. Because the climatic drivers of cyclones and severe storms are stronger during or across specific years (e.g. during La Niña periods), these events often repeatedly impact the coast over periods of weeks to months. The consequences of individual events are therefore exacerbated with little or no opportunity for recovery of natural systems or communities.

The storm events that occurred on the southeast coast of Australia during 1974 are the most significant and recent in memory in terms of coastal impact associated with clustered events. The clustering in that year occurred as a series of at least 10 storms between January and June. Not all of these events led to coastal erosion, but the sequence likely played some role in setting the pre-conditions of the beach that ultimately led to the erosion towards the end of this six month period. The question therefore is to determine the beach response to clustered event sets and the nature of how those events ultimately lead to erosion.

The problem is complex as the response to the forcing will vary – there will be a spectrum from inundation to erosion, and further, there will be varying factors that drive the erosion (e.g. long-shore, cross-shore) that are functions of the location and the event.

Why it is important?

Australia's population is concentrated along the coastline, with over 85% within 50 km of the coastline (Australian Bureau of Statistics 2001). In New South Wales for example, the NSW Government has identified 15 erosional hotspots (Kinsela and Hanslow 2013), along its 2000 km of coastline. Of the approximately 1000 km of erodible sandy beaches (open coast only), 28% is within 220 m of property. In addition to the severe wind and flooding impacts that Tropical Cyclone Debbie imparted in Queensland and New South Wales in March and April 2017, TC Debbie also caused erosion from Mackay to the Gold Coast. Any subsequent storm(s) will potentially worsen the situation at these locations, particularly if they occur before the beaches have had time to rebuild naturally. A coastal engineer at Mooloolaba (Sunshine Coast) indicated that beaches had been protected by the available large volumes of sand as the summer has been absent of the usual consistent storms.

How have we approached the problem?

The study has quantified the risk of these clustered events by determining the nature of the hazard, the elements that are exposed to this hazard and their resultant vulnerability. This risk can then be managed through the coastal and disaster management processes of all stakeholders.

The study has focused on two case studies, Old Bar beach in NSW and the beaches of metropolitan Adelaide. These sites were selected in consultation with the project end-users on the basis that they are actively being managed as erosion 'hotspots'. The physical setting of each site also presents an opportunity to advance our understanding of shoreline processes. The project has adopted the coastal compartment framework as the functional unit for understanding shoreline response at a range of spatial scales, and detailed geomorphological site investigations are being used as input to the beach response modelling.

Together, the risk and coastal compartments framework are powerful in terms of situating the assessment at local, regional and national scales.

END USER STATEMENT

Miriam Middelmann-Fernandes, *Geoscience Australia*

This project has been a collaborative effort between the research partners, Geoscience Australia and the University of Queensland, and end-users in New South Wales, South Australia and Queensland governments. At the end of its fourth and final year, the project has completed the implementation of its utilisation plan. This utilisation plan focused on sharing knowledge of this project to a broader group of stakeholders and ensuring that future users can discover, access and use the data and tools developed through this project. The hub for this knowledge sharing is the ESRI story map which in turn provides the links to the data and tools which are hosted either by Geoscience Australia or github. Critically, the tools are provided with documentation and use-cases so that future users can adapt for their site, anywhere in Australia.

Application of this method at other locations around Australia is likely to have challenges, particularly in relation to data availability and quality. Policy or research driven initiatives at the national scale may be able to address these gaps, but there is currently no concerted activity in this space. The Bushfire and Natural Hazards CRC could potentially advocate this issue to both policy and research groups. The end-users and research partners are well aware of these issues and can contribute to this discussion.

In summary, this project has aligned with the aims of the CRC in delivering a project developed with and for end-users. The project has focused on products that are of use to the end-users and have a life beyond the end of the project. The journal publications may be small in comparison to other projects, however the benefits extend beyond the research value.

PRODUCT USER TESTIMONIALS

End-user: James Guy, Team Leader Coastal Programs, Department of Environment, Water and Natural Resources, South Australia[1].

> *This project has played an important role in building the body of knowledge around shoreline response to clustered storms. The new data, modelling tools and summary information for case study sites, are essential reference materials for coastal managers. This allows agencies like my own to take a more informed approach to future coastal management strategies. For example, as the agency responsible for implementing the South Australian Government's Adelaide's Living Beaches Strategy, DEWNR will use the outcomes of this research to refine our annual beach replenishment program, which is used to maintain adequate storm buffers for the protection of infrastructure along the Adelaide coast".*

End-user: David Hanslow, Senior Team Leader, Coast and Marine Unit, Science Division, Office of Environment and Heritage.

> *This project has developed a probabilistic approach to mapping coastal erosion hazard which incorporates storm clustering. The approach is consistent with the guidance provided in the NSW coastal management manual and compliments existing approaches to hazard assessment. This approach to hazard mapping allows for communication of the likelihood (or probability) of adverse impacts from coastal erosion. It also provides additional information to inform cost benefit analysis of management strategies and thus improves significantly on traditional deterministic approaches to hazard mapping.*
>
> *The open access to data and models is critical for the continual improvement of the underlying science, but also to end users such as councils who can use the data to inform future management of the coast. On the science side, we will be investigating blending the approach adopted in this project with our own models to improve the representation of clustered storms and subsequent beach erosion.*
>
> *The Australian coastal management community is fairly small and is it likely that word will spread to other states which didn't have a case study in this project. We are aware for example that other jurisdictions are incorporating the National Coastal Sediment Compartments framework which is a positive starting point on the journey towards adopting a probabilistic approach to mapping coastal hazards..*

[1] James was an end-user for the bulk of this project. James left SA Government on 25th May 2018.

Public user:

https://twitter.com/coffee_n_coast/status/999544996104626176

INTRODUCTION

The aim of this project was to develop a new methodology to quantify the impact and risk of coincident and clustered disasters on the coast, with an initial focus on storm surge, associated erosion and reshaping of the coastline and the resulting inundation and damage to buildings and infrastructure.

As a basis for risk management at a range of scales suited for use by National, State and Local Government agencies, the objectives of this project were to:

1. Identify coastal landform systems that are vulnerable to erosion and inundation during storms
2. Develop modelled storm surge events to represent clustering at study sites
3. Model shoreline response to storm time series
4. Incorporate information on coastal geology, geomorphology & sediments in assessments of shoreline response modelling
5. Quantify the impact of clustered storm surge events on coastal assets (buildings and infrastructure)

Two case study sites were selected; Old Bar in NSW and Adelaide Metropolitan Beaches in SA. The aim of the project was therefore to develop a methodology that is national in application and demonstrate through the two case study sites.

A review of the progress against the project's objectives as of 30 June 2017 follows.

PROJECT BACKGROUND

The aim of this project was to develop a new methodology to quantify the impact and risk of coincident and clustered disasters on the coast, with an initial focus on storm surge, associated erosion and reshaping of the coastline and the resulting inundation and damage to buildings and infrastructure.

As a basis for risk management at a range of scales suited for use by National, State and Local Government agencies, the objectives of this project are to:

- Examine the physical characteristics of coastal landforms at study sites that are vulnerable to storm surge erosion, as identified by end-users;
- Develop and validate an approach to model the frequency and severity of storm surge events, incorporating clustered events;
- Critically assess available conceptual and numerical models describing and quantifying physical responses of coastal landforms to storm surge;
- Demonstrate the value of an integrated methodology to quantify the impact of clustered storm surge events on coastal assets (buildings and infrastructure);

To meet these objectives, the project will be undertaken through a number of phases:

1. Project planning (completed during 2014/15)
    a. Engage State and Territory end-users to revise and refine the project plan
    b. Select study sites to ensure the utility of outputs for emergency management and land-use planning. Study sites based on the following criteria:
        i. Availability of data, including:
            1. Elevation – access to LiDAR derived elevation surfaces is key, both topographic and bathymetric.
            2. Geomorphology – including datasets such as the NSW Coastal Geomorphology Classification.
            3. Stratigraphy – subsurface studies to help inform estimates of sediment volumes in beach-barrier systems
            4. Access to previous local studies – where available. In particular, any sediment transport or process modelling studies in the region.
        ii. Areas that are of interest to end-users – particularly sites where a better understanding of shoreline response to coastal storms, and impacts on infrastructure is needed for land use planning.
        iii. Representative of a common coastal (beach-barrier) morphotype – this will ensure applicability of developed approach to other locations. Morphotype(s) that are more likely

to experience significant erosion and damage to infrastructure will be selected.

iv. Where storms, and in particular, sequences of storms have occurred and where we have some understanding of the metocean drivers of these events.

v. Political sensitivity/iconic sites – these issues may need to be considered when selecting a site.

2. Model coastal susceptibility/vulnerability to hazards for the Case Studies (completed during 2014/15)
    a. Work with the end-users to establish a lexicon of scientific nomenclature to describe coastal landforms across a predetermined hierarchy of scales, applicable to all coastal regions around Australia;
    b. Describe the study sites in terms of their location in the Primary/Secondary and Tertiary Compartment level and where possible the Sediment Compartment.
    c. Identify landforms on unconsolidated sedimentary coasts in each case study region, and assess their context in terms of the characteristics of the Secondary and Tertiary Compartment level.
    d. Rate the indicative vulnerability/susceptibility of coastal landforms to inundation and erosion hazards.
3. Critical assessment and development of conceptual and numerical shoreline response models (completed during 2016/17)
    a. Identify and critically evaluate conceptual and numerical models used to describe inundation and erosion and their impact on the developed coast;
    b. Develop a set of modelled storm surge ‘events’ that reflects the full range of historical and potential events at the study regions;
    c. Develop and implement a methodology that reflects the impact of clustering on the distribution of severity and frequency of storm events.
    d. Reconstruct historical shoreline responses to storm surge inundation based on existing databases and identify key data gaps;
    e. Fill any essential data gaps using field investigations in collaboration with existing State, Territory and Commonwealth Government, and University programs.
4. Assess the impact and risk of hazards (completed during 2017/18)
    a. Categorise exposure (buildings/infrastructure/coastal defences) on each sedimentary coast morphotype in the study area;
    b. Determine management problems specifically related to coastal infrastructure which were encountered during historical storm passage; relate the historical events to the frequency/severity distribution developed above;

   c. Develop site-specific vulnerability models to inundation based on empirical data and existing vulnerability models;
   d. Resolve the magnitude and rate of shoreline change and determine the impact zone for each event/cluster of events in the modelled event set;
   e. Quantify the risk on coastal communities (including infrastructure and habitats) in terms of probability of (economic) impact and loss.

5. Synthesis (completed during 2017/18)
   a. Apply results to coastal hazard planning at local and regional scales by evaluating the effectiveness of a range of adaptation/mitigation responses. Adaptation/mitigation responses could include e.g. retreat, beach nourishment, zoning, and improved infrastructure, and would be scoped in collaboration with end-users.
   b. In consultation with end-users, develop communication material to include:
      i. Identification how the results from this study can be incorporated into a comprehensive assessment of the resilience of coastal communities and infrastructure to natural hazards.
      ii. Recommendations for a national approach to the acquisition of coastal data and recommend to be considered by COAG to minimise the impacts of coastal risks.

The outcomes of this project include:

- Support for an improved ability of coastal managers and planners to make informed decisions and prioritise resource investment, based on appropriate, quantitative information regarding clustered storm surge events;
- A conceptual framework for integrating coastal studies across a range of spatial scales (local/regional/national);
- A demonstrated methodology for quantifying the impact of clustered events on coastal infrastructure;
- Recommendations for a national approach to the acquisition of coastal data and recommend to be considered by COAG to minimise the impacts of coastal risks;
- The development of a nationally consistent methodology to assess the potential impact of coastal hazards.

RESEARCH APPROACH

The response of a beach to a storm and a storm cluster will depend largely on the physical characteristics of that beach, including sediment type, shoreline orientation and wave climate. It is important that these characteristics and their interactions are understood so strategies to manage erosion, such as beach replenishment and re-vegetation, can be used most effectively.

The research approach adopted in this project is outlined below and is structured according to the key steps required to understand coastal erosion in situations where storm cluster are recognised as a possible driver. The research has not considered beach response to storms under rising sea levels. This would require the incorporation of sea level change scenarios that also factor in changes to future wave climate.

The project has aimed to develop a national method and apply locally at two case-study sites where coastal erosion is an ongoing management issue. This allows others to adapt the approach for other locations, subject to the availability of data.

UNDERSTANDING THE CONTEXT

Without knowledge of the coastal environment, we cannot predict the likely response to future storms. In order to understand the coastal environment, we need to ask;

- where can we find coastal communities that may be susceptible to erosion, and what infrastructure is there? (topography and geography)?
- what is the coastal environment composed of (the geology)?
- what are the physical features of the coast and how does it relate to the geology (the geomorphology)?

As the coast is dynamic and forever changing under the forces of the tide, waves and wind, we need to understand what controls the movement of sediment. A central concept for mapping and understanding sediment movement is the coastal compartment, which describes the physical and process boundaries within which sediment transport occurs. The Australian Sediment Compartments Dataset segments the coastline into primary and secondary compartments. Situating a coastal management study within this compartment framework allows management strategies to more easily consider the regional context of a section of the coast, and the wider processes that affect it. Primary compartments are suitable for large-scale engineering works and long-term strategic plans (50-100 years), whereas secondary compartments are more suited to local to regional planning and site-specific engineering decisions (25-50 years).

Data was collected according to the coastal compartment in which each study location was located. We outline what data was collected and the basis for why that data was collected.

Topography and geography

Digital elevation data describes Australia's landforms and seabed morphology. State and Territory Government departments collect elevation and bathymetric data for a range of purposes relating to disaster management, water security, environmental management, urban planning, and infrastructure design. The project end-users from NSW and SA government provided detailed high resolution digital elevation data for the two case study sites. Geoscience Australia has developed the Elevation Information System[2] (ELVIS) which provides a single point of access to elevation data for the nation.

Exposure refers to the elements at risk from a natural or man-made hazard event. Elements that are at risk in the coastal zone for the two case-study sites include

- Residential buildings (sourced from NEXIS, see below)
- Coastal infrastructure such as stairs, access paths, sewer outflows etc (sourced from imagery (satellite/airborne)

The National Exposure Information System (NEXIS[3]) is a Geoscience Australia capability designed to provide comprehensive and nationally consistent exposure information to enable users to understand what is at risk in a particular area.

The coastal infrastructure data required for this project is local scale and is not available in NEXIS. The project sourced this data from the end-users, digitized features from available imagery and ground-truthed these features as part of field work surveys.

Geology

National and regional scale geology data is used to provide the physical context for each study area, supplemented with local scale data to inform the shoreline response modelling. For each study site, the following data was collected:

- beach profiles (elevation relative to mean sea level) as measured in the field along a line from the dune toe to the low tide water line. This was done at a number of profiles at each study site. In NSW, aerial photography has also been used to generate historical records of beach profile change for a number of locations[4], including Old Bar.
- beach thickness, as measured by Ground Penetrating Radar (GPR) to determine depth to bedrock. This provided an estimate of the volume of beach sediment that could potentially be eroded during storms.
- beach sediment type as determined from samples collected from the lower beach face at each beach profile location. Samples were used to determine gravel, sand and mud content, and mean grain size. The grain size analysis is stored in the MaRS database[5].

[2] http://www.ga.gov.au/elvis
[3] http://www.ga.gov.au/scientific-topics/hazards/risk-and-impact/nexis
[4] http://www.nswbpd.wrl.unsw.edu.au/photogrammetry/nsw/
[5] http://dbforms.ga.gov.au/pls/www/npm.mars.search

Geomorphology

Existing national scale data (the National Coastal Geomorphology Classification (NCGC) and the Smartline data set) were used to identify the nature and location of the coastal landforms at each study site, which is then assessed to determine the landform vulnerabilities.

The main landforms of interest for the Old Bar site are coastal beach and dune systems. The Ground Penetrating Radar (GPR) data highlighted the presence of shallow bedrock in the near-shore and upper beach at several locations adjacent to the eroding sections. The samples taken from Old Bar also showed spatial and temporal variation in the presence of cobble and gravel materials.

The main landforms of interest for the Adelaide Beaches site are also coastal beach and dune systems, with estuarine and lagoonal environments further landward. The GPR investigation did not detect a buried bedrock surface below Adelaide beaches, indicating that there are no bedrock controls to limit potential erosion along that coast. Parts of the coastline that have been subject to erosion in the past have therefore been armoured by the local land managers (installation of hard structures along the shoreline). Sections of the northern Adelaide coast have a history of building out naturally due to sediment transport from the south, and are therefore not armoured.

DRIVERS FOR BEACH EROSION

Beaches undergo natural cycles of build-up and erosion that are linked to periods of fair-weather and storm activity. With a focus on storm clusters, we examined the storm history for our two case study sites. This history can be determined from the observational record (through instruments such as wave buoys) or from models that estimate past wave heights from wind records. These data were then used to model sediment transport within each study site coastal compartment.

The project used a different approach to examine storm history at each case-study site. For Old Bar, observational data was available, whereas for Adelaide hindcast models were used. This contrast also demonstrates that the method developed could be applied regardless of the available storm history data.

This aspect of the project required the development of a synthetic storm event set that has the similar statistical characteristics, e.g. offshore wave height and direction, as the historical record. The definition of a storm was also required, and for this project, we defined a storm as an event where the wave height is greater than that exceeded only 5% of the time at that location. For the Old Bar study site, we take the measured significant wave height at the Crowdy Head Wave Buoy, and with this definition, storm events are defined as time-periods in which the wave height exceed 2.93 m. If two storm events are less than a day apart, then they are combined into a single event, along with any in-between time period of smaller waves. This leads to a collection of storm events that are used for modelling the beach erosion.

Open source software to simulate the synthetic storm events has been developed through the project and can be adapted for other locations. Examples (or use-cases) are provided to guide users https://github.com/GeoscienceAustralia/stormwavecluster .

BEACH RESPONSE

The response of a sandy shoreline to successive storm events was modelled in this study using a numerical model that accounts for cross-shore sand transport from the beach to the nearshore, and longshore sand transport along the beach. The model also factors in changes in wave direction and height that occur as waves enter shallow water. For each study site, the model shows the progressive retreat of the beach face in response to individual storms and storm clusters of varying magnitude.

These are expressed in terms of beach erosion events with annual exceedance probabilities (AEP) of 10%, 5% and 2% (also referred to as return periods (or recurrence intervals) of 10, 20 and 50 years). These AEPs are standard for these kinds of hazard assessments. In the case of the Adelaide metropolitan beaches, for the scenario of no beach replenishment, the 2% AEP beach erosion event resulted in approximately 30 m of shoreline retreat for a section of beach currently fronted by a series of low dunes.

A key product from this beach modelling is a time-series plot that shows repeated cycles of storm erosion and recovery for representative sections of beach. This information is valuable because it provides estimates of the shoreline position and the sand volumes that may be eroded from the beach during individual storms or a storm cluster. For coastal managers, these provide a guide for calculating the volume of sand that may be required to maintain a buffer of sediment on the beach or in the dunes to protect against the largest storms. This enables a more targeted beach replenishment program, as is currently done for the Adelaide Living Beaches Strategy[6].

The modelling of beach volume change has been applied along the full length of the case study beach sites, allowing longshore patterns of beach response to individual storms and storm clusters to be assessed. For Adelaide, this shows that the southern beaches (Seacliff and Kingston Park) experience almost twice the volume of sand loss (~40-60 cubic metres per metre of beach; termed 'storm demand') during a storm than beaches to the north (Semaphore, North Haven). This difference in storm demand is interpreted to be related to smaller waves at the northern end and smaller gradients in longshore sediment transport.

EVALUATING IMPACT

With an understanding of the coastal environment, the physical features of the coast and how the coast may respond to severe individual storms or a storm cluster, the next step is to identify infrastructure assets (buildings, roads, access paths) that may be affected on an eroding coast.

[6] https://www.environment.sa.gov.au/our-places/coasts/Adelaides_Living_Beaches

The project originally planned to use NEXIS for exposure mapping; however, the spatial scale of the modelled impact warranted a different approach. In the case of Old Bar, we identified the infrastructure assets from aerial photography. These features are documented from the imagery by mapping the outline of building roof tops and road edges. This manual approach is labour intensive and would not feasible if the expected exposure is of the order of hundreds of buildings. In those cases, NEXIS would be suitable for exposure mapping.

Utilising geographical information systems we determined the distance between the modelled storm-driven coastal erosion, (i.e. the dune crest for each AEP), and the buildings. These assessments were represented by a series of maps showing various scenarios for potential infrastructure loss. We adopted this approach as a way of communicating susceptibility to erosion and to highlight assets that may be at heightened risk.

KEY MILESTONES

In this section, we highlight the key milestones against the headings used previously and mapping these to the contracted milestones where applicable.

UNDERSTANDING THE CONTEXT

1. Collection of field data to support reporting on context of study sites
    - Field work completed (Milestone 1.4.1) including collection of GPR data and beach sediments
    - Reporting on context of study sites:
        a. GPR processing (GA) and sediment analysis (UQ) resulting in Milestone 1.4.4 report "Application of the National Coastal Geomorphology Classification in a Coastal Sediment Compartment Framework (internal report to the Bushfire and Natural Hazards CRC)"
2. Development and delivery of data products
    - Australian coastal sediment compartments (Milestones 1.4.2 and 2.1.1)
        - Methodology report. (McPherson et al. 2015)
        - Data available as webservices (WMS and WFS), geodatabase, kmz, pdfs, http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_87838
    - Ground penetrating radar data
        - Collected during field work, processed at GA and stored in national database http://www.ga.gov.au/metadata-gateway/metadata/record/100224
    - Sediment analysis
        - Collected during field work, processed at UQ laboratory and stored in national database (Marine Sediments database (MARS) http://dbforms.ga.gov.au/pls/www/npm.mars.search)
    - Exposure data
        - Project specific data developed using consultation with end users (Milestone 2.2.4) resulting in
            - mapping from aerial photography
            - data provided from SA Government (what about NSW – Duncan)?

DRIVERS FOR BEACH EROSION

1. Collection of storm history data with support from end-users (NSW Manly Hydraulics Laboratory for the observational data and CSIRO for the hindcast data)

2. Development of statistical method:
    a. Literature review and publications (Milestone 2.4.1)
    b. Modelling of storm history data to develop event set for beach response modelling (Milestone 2.2.2)
    c. Release of method as open source software through github (Milestone 4.1.1). Method accompanied by user manual and use-cases.

BEACH RESPONSE

1. Collection of aerial photography to understand historic beach response
2. Development of shoreline response method:
    a. Literature review and decision on model approach (Milestone 1.4.3)
    b. Modelling of beach response based on statistical event set and presentation to end-users for peer review (Milestone 3.2.1 and 3.4.1)
    c. Release of method as open source software through github (Milestone 4.2.1). Method accompanied by user manual and use-cases.

EVALUATING IMPACT

1. Development, application and promotion of national method (integrating aspects above):
    - Publication Journal of Coastal Research (Nichol et al. 2016) (Milestone 2.2.3)
    - Presentation to end-users on final impact assessment (Milestone 4.2.2)
    - Story Map (Milestone 4.3.1)

UTILISATION OUTPUTS

The key activities in the utilisation plan were:

- Documentaton of the two software developed through this project (via github), and
- Publication of a general audience communication product, summarizing the data, software, publications and results (ESRI Story Map).

These key activities will be described in the Achievements section below.

This is separate to the unplanned utilisation, i.e. uptake of the National Coastal Sediment Compartments by New South Wales and Victoria as part of their coastal management policies and plans. This is enabled by the open release of this data and methods. Other benefits will accrue over the longer term, for example, the GPR data and sediment analysis form part of national databases and therefore add to the data pool for the nation.

Milestones identified in the utilisation plan were:

- Transfer of modelling techniques,
- Integration of methods into existing approaches used by end-users (planned for NSW), and
- Extension of modelling to additional sites (subject to funding).

ACHIEVEMENTS

Open source software

The project developed software for the statistical event modelling (using R, named stormwavecluster) and adapted the commercial EVO model (product of WBM BMT Ltd) for the shoreline response modelling.

To meet the goals for the project to enable future application of this approach at other locations, the project reached agreement with WBM BMT Ltd to release the EVO model as open source. Following that agreement, the EVO model has been managed in github, with documentation and use-cases prepared. The statistical event modelling code, stormwavecluster, was manged in github from inception. Like the EVO model, this software is also accompanied by a user manual and use-cases.

An introduction to stormwavecluster was provided at the 2017 Coastal Cluster Workshop.

UQ are planning on continuing to use and adapt EVO for post-graduate coastal research projects. GA has utilized the stormwavecluster software for non-storm related research. Part of the code, which fits non-homogeneous Poisson process models with clustering terms, was used by to model earthquake temporal clustering on slow moving crustal faults.

Promotion and engagement

The ESRII Story Map was the method adopted to package and disseminate the data, information and tools (the project's body of knowledge) to ensure discoverability and accessibility into the future. This approach could be then readily promoted to relevant stakeholders using online news story and social media and allows the outputs to be discoverable and accessible online.

The Story Map was promoted initially with a Geoscience Australia online news story http://www.ga.gov.au/news-events/news/latest-news/helping-coastal-managers-plan-better-for-future-storms and associated social media

- Twitter: https://twitter.com/GeoscienceAus/status/988616577724510209 and
- Facebook: https://www.facebook.com/GeoscienceAustralia/posts/1725211744184174 .

A "light" approach was taken, and yet the engagement rate exceeded expectations of Geoscience Australia, and the expectations of an agency of our size. The CRC and University of Queensland also developed their own online news story, with Dredging Today (industry publication, international), PSNews (The Australian Public Sector's leading online news network) and the UNISDR's Prevention Web (the international knowledge platform for disaster risk reduction) also posting their own story (and linking back to the Story Map). The CRC also promoted the story through the Cooperation Research Centres Association newsletter (around 9000 subscribers).

- Dredging Today: https://www.dredgingtoday.com/2018/04/24/new-tool-kit-for-coastal-managers-in-australia/
- UNISDR: https://www.preventionweb.net/news/view/57997
- PSNews: https://psnews.com.au/2018/04/30/coastal-toolkit-to-help-weather-the-storm/
- Cooperative Research Centres Association newsletter https://crca.asn.au/crcanews/ 1 May edition: https://mailchi.mp/crca/news-from-the-crc-association-451245
- University of Queensland https://www.eait.uq.edu.au/news/article/helping-coastal-managers-plan-future-storms
- CRC https://www.bnhcrc.com.au/news/2018/helping-coastal-managers-plan-better-future-storms

Continued promotion of this will rely on in-kind effort from end-users and research partners via their relevant fora, as well as the CRC.

The benefit of social media is demonstrated with this post from a coastal research / consultant:

https://twitter.com/coffee_n_coast/status/999544996104626176 which provided direct feedback on the general communication approach adopted by the project.

Beyond coastal cluster meetings and conferences, the project also promoted the project via:

- Lecture at ANU third year course on Natural Hazards (22 May 2018)
- Development of the coastal erosion component of the UNISDR Words into Action Guidelines on National Disaster Risk Assessment[7] (April 2017)
- Webinar to introduce the coastal erosion component[8] of the Words into Action Guidelines on National Disaster Risk Assessment (November 2017).

[7] https://www.unisdr.org/we/inform/publications/52828
[8] https://www.unisdr.org/files/52828_07coastalerosionhazardandriskassess.pdf

WHERE TO FROM HERE

In the short-term, the following steps can be taken:

- Promote data, tools and methods at relevant forums, social media campaigns as applicable (all parties concerned can support this aspect in their standard role, i.e. GA, University of Queensland, end-users and the BNHCRC), and
- Gather intelligence on usage of data and tools (e.g. website analytics and reviewing feedback from users)

A communication plan could be developed (unfunded) to identify opportunities to promote.

In the medium to longer term, the following steps could be undertaken. These steps are unfunded, however all parties can play a role:

- Develop proposals (if required) to update data and tools, or apply methods in collaboration with users
- Communicate with decision makers on implementation challenges:
    - Gaps and availability in national data sets (e.g. coastal infrastructure, sea-level observations)
    - Uptake of highly technical methods
    - Development of coastal inundation maps
- Identify future research questions in collaboration with users, including
    - sediment transport
    - regional model for statistical storm event modelling
    - quantifying uncertainty
    - inclusion of climate change

GA's role positions it to interact across government, for example,

- climate and disaster risk data and information (e.g. via the subcommittees of ANZEMC),
- spatial data (e.g. via ANZLIC),
- marine and coastal science and infrastructure (e.g. IMOS),
- provision of expert advice, such as the Victorian Coastal Monitoring Program (member of Advisory Board).

which allows GA to provide input on the data and capability gaps that have been identified with this project within the government context. Outside of the government context, GA is collaborating with research groups (e.g. University of Wollongong on a three year ARC Discovery Grant 'Sedimentary processes on sandy coasts in southern Australia') which provides another avenue to potentially steer and guide future research projects in Australia.

Likewise, the BNHCRC interacts across government and research sector and can similarly provide input that could play a role in addressing the gaps in data, capability and research. For example, climate change is considered in the BNHCRC recently published national research priorities.

Further detail on these steps is provided below.

Data

Understanding the context

- Elevation data

National application of the project's methodology requires high resolution bathymetry and elevation which is becoming increasingly available nationally. For example, NSW has recently finalized the acquisition of offshore LiDAR to complement the onshore LiDAR that already exists.

- Exposure

There is a paucity of coastal infrastructure datasets at the jurisdictional level (that is discoverable and accessible) and there is no nationally consistent coastal infrastructure dataset. Each jurisdiction will be at a different state of maturity with regard to their coastal infrastructure asset management and this project has not conducted any investigation to determine the availability of such data. A national agenda would be required to develop such a national dataset and this agenda would likely be driven through either policies dealing with open data or climate change and disaster risk.

The case-studies investigated as part of this project revealed localized impact to infrastructure such as seawalls and access paths and outlined how the project undertook a manual process to derive this data. This approach is simply not appropriate at a national scale.

- Geology and geomorphology

Conducting this kind of modelling showcased in this project is by necessity always going to be site specific, and will require detailed site surveys to contextualise the site within the coastal sediment compartments and geomorphic setting. This type of modelling would typically be conducted by coastal engineers who have experience in model testing and validation.

Driving beach erosion

- Storm history

National application of the project methodology requires wave and sea level observations or model hindcasts. There are currently multi-decadal wave and tidal observations available for NSW and parts of Western Australia and Queensland, however wave observations are lacking in other areas (e.g. St Vincent Gulf near Adelaide). Installing wave observation infrastructure now will be beneficial in the longer term. However, the statistical modelling ideally requires decades or more of observations. NSW invested in this infrastructure in the 1980s following the 1974 series of storms and therefore this project has benefited from its availability. In SA the project has used modelled wave data because observations were unavailable, but in the absence of long-term historical measurements it is difficult to assess the reliability of these modelled inputs, especially in relation to more extreme wave events which are of most significance for projects such as this. Investment in this infrastructure is a matter for the jurisdictions and a function of the risk that they are exposed to. A national forum that determines whether this risk is sufficient to seek national support would be required.

Capacity / Capability

Applying the method defined in the project's publications and using the open source software) requires a high level of statistical modelling knowledge and a willingness to work with sometimes incomplete datasets. To date, the modelling approach has been developed for a local scale model and it would be possible to extend this approach nationally by developing a set of local scale models for each site of interest.

Future research

A key area for taking this research further is to incorporate scenarios of changing wave climate coupled with sea-level rise into the shoreline response modelling. Clearly, any future change in these forcing conditions would lead to a potential for increased exposure to the risks associated with storm clusters, and is a logical extension to this project. This was identified as a topic of interest by end users at the coastal cluster workshop (held on 18 December 2017). While beyond the scope of this current project, factoring in climate change scenarios is technically possible and worthwhile for future risk assessments.

The shoreline response model used in this project has potential for further refinement. In particular, quantification of uncertainties (e.g. with nearshore wave modelling and with beach profile representation) associated with shoreline response to storm clusters would further strengthen the model outputs. With some understanding of these uncertainties, coastal land managers will be even better placed to assess the risks associated with clustered storm events on the coast.

PUBLICATIONS LIST

Understanding the context

McPherson, A., Hazelwood, M., Moore, D., Owen, K., Nichol, S. & Howard, F. 2015. The Australian Coastal Sediment Compartments Project: methodology and product development. Record 2015/25. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2015.025

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Jiang, W., Davies, G., Callaghan, D.P., Baldock, T. and Nichol. S. 2015. Statistical modelling of extreme ocean climate with incorporation of storm clustering. In Weber, T., McPhee, M.J. and Anderssen, R.S. (eds) MODSIM2015, 21st International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2015, pp. 490–496. ISBN: 978-0-9872143-5-5. https://www.mssanz.org.au/modsim2015/G3/jiang.pdf

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Beach response

Gravois, U., Callaghan, D., Baldock, T., Smith, K. & Martin, B. Review of beach profile and shoreline models applicable to the statistical modelling of beach erosion and the impacts of storm clustering. (Bushfire and Natural Hazards CRC, 2016). https://www.bnhcrc.com.au/publications/biblio/bnh-2700

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National Method

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Bushfire and Natural Hazards CRC. Oceans on the Rise. (2016) Issue 16, May 2016, Hazard Note.

Bushfire and Natural Hazards CRC. New Technologies to Better Manage Coastal Erosion. (2017) Issue 31, June 2017, Hazard Note.

TEAM MEMBERS

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