Proposed approach

Project:	Prediction of stream bank erosion in the Great Barrier Reef catchments
Client:	Department of Environment and Science (DES)
Date	July 2019

1 Challenge solution overview

This proposal responds to Challenge Statement 4: Improve modelling of processes impacting on water quality.

Challenge 4 seeks an innovative solution to improve modelling of the major drivers of water quality (e.g. sediment, nutrients) to inform future management in Queensland. The aim of this challenge is to develop a modelling approach which delivers improved representation of the key drivers of water quality impacts, due to agricultural practices and/or landscape processes, which would inform targeting of mitigating strategies to improve water quality management. The innovative approach would be included in the updated modelling toolkit used in the Paddock to Reef program; with the overall objective of identifying priority management actions to improve water quality in the Great Barrier Reef.

The Paddock to Reef program currently estimates stream bank erosion within the Source Modelling framework using the Dynamic SedNet model. The model, and the data inputs currently utilised, is a reasonable tool for estimating the relative contribution of bank erosion at large whole of catchment scales. However, its applicability at smaller spatial scales (i.e. reach or sub-catchment) to estimate erosion rates and undertake prioritisation is limited due to the coarse datasets used, size of the model links and sub-catchment areas and modelling assumptions.

The limitation of the Dynamic SedNet model have been outlined in the *Stream bank management in the Great Barrier Reef catchments: a handbook* (Bartley et al, 2015). Some of these issues include:

- The bank erosion equation in the SedNet model was based on the empirical relationships presented in Walker and Rutherfurd (1999) and Rutherfurd (2000) that used meander migration rate as a surrogate for bank erosion. Many rivers in Queensland have a macro channel configuration which are confined by resistant floodplain/terrace material which limits lateral adjustment. Most of the channel erosion occurs on inset benches and floodplains within the macrochannel. The modelling currently cannot account for the differing erodibility of benches, inset floodplains and terraces.
- There is the potential for large systematic errors without sufficient model calibration (De Rose et al., 2005). Furthermore, calibration of end of catchment loads which is typically done in the GBR catchments can result in significant under/over prediction of sediment sources within the catchments including stream bank erosion rates (Brooks, et. al. 2013).
- The models provide a reach averaged estimate which doesn't consider the explicit erosion process (e.g. incision/widening vs meander migration) that can often vary within a reach, and even vary on different banks within the same reach. As a result, there could be large zone of concentrated sediment loss within a broader reach (Links can be 10s of km in length).

There is an opportunity to investigate alternative modelling approaches for assessing stream bank erosion rates and risk within the Great Barrier Reef catchments. We propose investigating the feasibility of a widely used approach in USA to the GBR catchments.

The proposed solution

Stream bank and gully erosion have been identified as the dominant sources of sediment in Queensland catchments (Olley et al., 2013). These erosion processes provide a pathway for sediments and nutrients, such as nitrogen and phosphorous, to enter waterways. Stream bank erosion has been identified as a major threat to Great Barrier Reef.

We propose to investigate the practicality of using (or modifying) alternative bank erosion models within the coastal catchments of the GBR. One of the approaches investigated will be the Bank Assessment of Non-point Source Consequence of Sediment (BANCS). BANCS is widely used in the USA as a method to assess bank erosion risk. Reef Catchments have recently captured high resolution LiDAR data across four of their largest rivers and most active river systems: The O'Connell River, Cattle Creek, Murray Creek and St Helens Creek. LiDAR data of these river systems was also captured in 2009. These two datasets provide a unique opportunity to assess the applicability of the BANCS modelling approach. The proposal is aligned with a key objective of the EOI to 'develop specifications and/or supporting standards that facilitate better model management, use, validation and access'.

BANCS is an empirical, process integrated model used to predict the rate and volume of stream bank erosion. The model integrates two erodibility tools: the Bank Erosion Hazard Index (BEHI) and the Near Bank Stress (NBS) rating (Bigham et al., 2018). The BEHI allocates an overall score with respect to a bank's erodibility, or shear strength, based on stream condition. In contrast, the NBS rating describes the relative level of shear stress acting upon the eroded stream bank due to in-stream hydraulic conditions. The empirical relationship between BEHI and NBS indices are then used to create BEHI/NBS curves which enable the prediction of streambank erosion rates and annual sediment yields in the region of model development. The BANCS method has shown high correlation with observed erosion rates in numerous studies (largely in North America).

BANCS is used widely in the northern hemisphere and has been approved by several key bodies in the international stream restoration community including the U.S. Environmental Protection Agency and the U.S. Forest Service. However, stream bank erosion rate prediction curves produced via the BANCS methodology are limited to the physiographic region of model development (Rosgen, 2015). Although BANCS is regarded as the gold standard of stream bank erosion modelling in North America and elsewhere, it cannot currently be used in Queensland as an empirical relationship between hydraulic and geotechnical processes that influence stream bank erosion has never been developed for the region. However, the empirical nature of the model, where key variables are calculated through location-specific observed data, is likely to result in a more accurate performance when compared with the current modelling approaches.

The 2009 and 2019 LiDAR and aerial imagery data of the streams within the Mackay Whitsundays region provide an opportunity to develop and validate stream bank erosion rate prediction curves for the region. These curves could then be applied and tested on other streams within the Great Barrier Reef catchments. For example, recently acquired LiDAR data capture within the Fitzroy River catchment by the Fitzroy Basin Association provides an opportunity to test the approach in drier inland catchments.

Although the model has proven accurate in North America, a drawback of implementing BANCS has been the requirement for collecting significant field-based data, which is costly in terms of both time and resources. Several observed or measured stream bank characteristics are used to calculate the BEHI including bank height, bank angle, material composition, surface protection, root depth and density, and stratification of material within banks (Bigham et al., 2018). Similarly, determination of the NBS typically relied on field measurements (Rosgen, 2009).

Recent advancement in the quality and accessibility of high-resolution aerial imagery and LiDAR topographical data could offer an alternative approach. Importantly, the use of such data could lead to efficiency improvements through estimating of BEHI and NBS parameters remotely. We propose to develop and test desktop approaches to determine BEHI and NBS indices to inform the development of a stream bank erosion prediction curve for application in the Mackay Whitsundays region. This novel approach will facilitate rapid assessment of stream bank erosion rates in the region and which may help update current modelling approaches.

The development of alternative, desktop approaches to inform the BANCS model is likely to result in greater uptake of the model throughout Queensland, as the accessibility will be enhanced. It would no longer be necessary for the costly gathering of field-based data. Furthermore, the development of such approaches represents an innovative enhancement of the BANCS model itself.

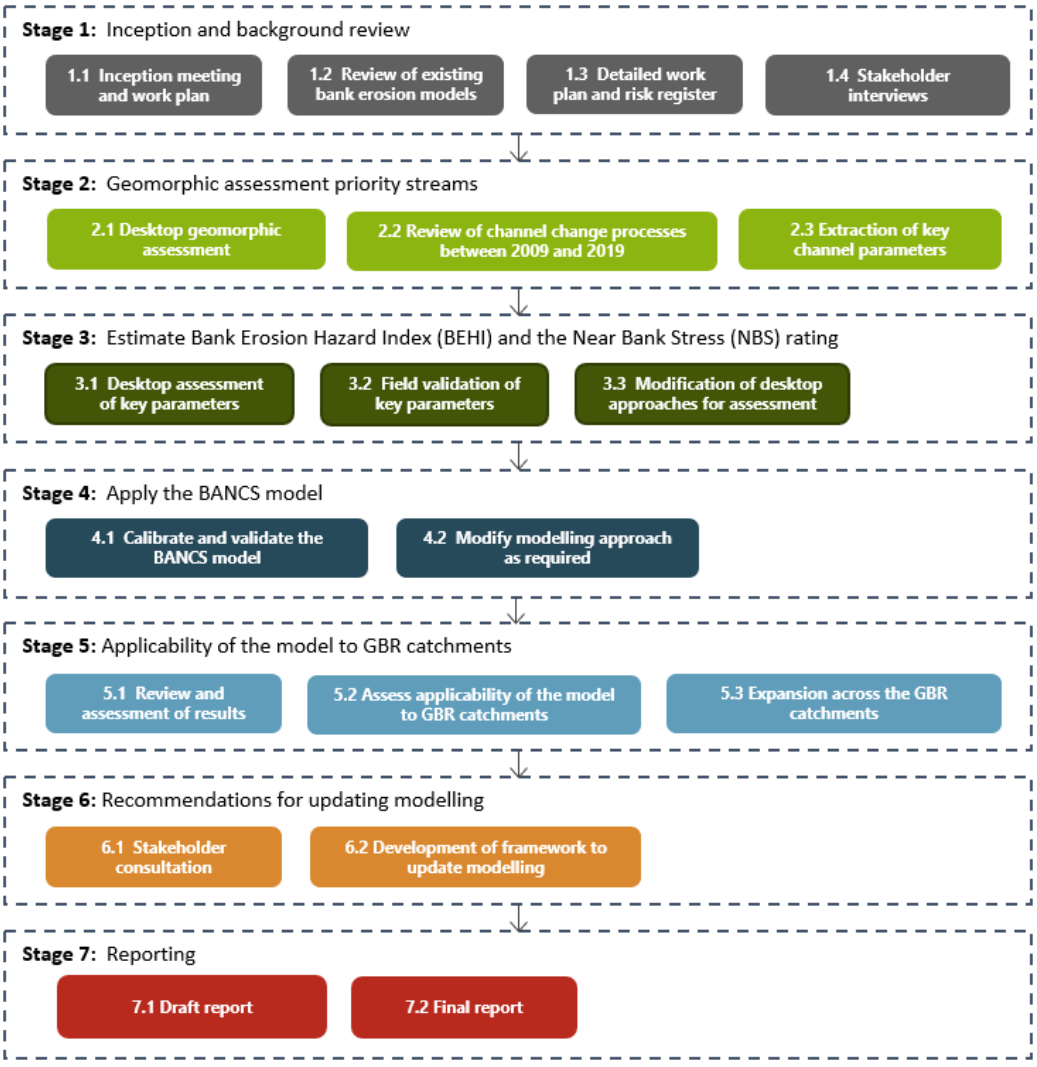
The impact of the proposed solution

Overall, the development of a regional BANCS model for Mackay Whitsundays area is likely to significantly improve stream bank erosion modelling, one of the key drivers of water quality decline in the GBR. The BANCS method is capable of predicting erosion rates for a range of stream types and streambank erosion process (i.e. subaerial, mass failure, and fluvial entrapment) (McQueen, 2011). One of the major criticisms of the current stream bank modelling approach within the Paddock to Reef program is it applies the same empirical relationship to all stream types. However, this relationship has been shown to poorly represent many stream types in Queensland.

The development of a BANCS approach for the prediction of stream bank erosion in the Mackay Whitsundays region is likely to deliver improved representation of a major driver of poor water quality in the Great Barrier Reef. As such, the model could inform long-term water quality management and erosion mitigation strategies.

1.1 Method

We propose to undertake this project in seven stages:



The following describes each of the tasks in our seven stages in detail.

Stage 1. Inception and background review

Objective/s	Agree on the project objectives and work plan for delivery and discuss any contractual matters
Outputs	Agreed work plan Inception meeting minutes
Inputs	Request for Quote Statement of Work Alluvium Offer of services

Task 1.1 Inception meeting and work plan
We will initiate the project by meeting with DES to discuss the project in detail, specifically:

- our method, work plan and the key outputs and communication touch points
- key stakeholders and engagement strategy
- the extent of the study area
- dates for workshops and other meetings as required

An important part of this task will be discussing our proposed approach, timeframes and structure of the project, to discuss and agree on any changes.

We will undertake the inception meeting at the DES offices.

Task 1.2 Stakeholder interviews
We will attend meetings with key stakeholders to discuss the project. Key stakeholders are likely to include Paddock to Reef Modellers, QWMN Fellow and other leading experts in Queensland. The purpose of the interviews will be to seek feedback on our approach, current modelling practices and any other strategic considerations which may benefit the project. We will also determine what existing information and literature is available for bank erosion model prediction with Queensland.

Based on these interviews we will determine criteria to assess bank erosion models in Task 1.3.

Task 1.3 Review of existing bank erosion models and options report
We will undertake a detailed review of bank and channel erosion models. We will undertake a SWOT analysis (strengths, weaknesses, opportunities and threats) of the various models and their applicability the GBR catchments. Based on the SWOT analysis and assessment against the criteria identified in Task 1.2 we will develop an options report which will identify the models/approaches that are most appropriate for modelling stream bank erosion within the GBR catchments.

Based on previous reviews we believe the BANCS model is likely to be the most appropriate model/approach to investigate. We have developed this proposal based on this assumption.

However, if our review identifies any major flaws in the BANCS approach or an alternative modelling approach which is more appropriate, we will update our work plan approach in Task 1.4.

Task 1.4 Detailed work plan and risk register
A detailed work plan based on the outline provided in this proposal will be developed incorporating any feedback provided. In particular, timelines will be adjusted to account for the project kick off date. In terms of risk registers, we commonly prepare these across all of our projects and have suitable templates and major risks identified (e.g. timeliness, access to data, stakeholder engagement, political sensitivity, staff changes, client satisfaction). We propose to develop the register collaboratively with DES and agree on rectification actions.

If a modelling approach other than BANCS is identified in Task 1.3 we will update the technical details of our work plan.

Stage 2. Geomorphic assessment priority streams

Objective/s	Understand the active channel erosion processes within the priority streams
Outputs	A summary of channel erosion processes and sediment loss estimates
Inputs	LiDAR data and aerial imagery stream in the Fitzroy River catchment and Mackay Whitsundays region

Task 2.1 Desktop geomorphic assessment
We will undertake a desktop assessment of the following streams:

- O'Connell River (Mackay – Whitsundays region)
- Murray Creek (Mackay – Whitsundays region)
- Fitzroy River (Fitzroy Basin)
- Raglan Creek (Fitzroy Basin)

The purpose of this assessment is to understand the geomorphic properties of these reaches including degree of confinement, presence of terraces, vegetation condition, and sediment transport and storage processes.

Task 2.2 Review of channel change processes between 2009 and 2019
Following on from Task 2.1 we will review multi-temporal LiDAR and aerial imagery analysis between 2009 and 2019. The purpose of this review will be to classify the type, rate and direction of channel change processes. This will include the quantification of bank erosion rates. This will assist the calibration of bank erosion models in Stage 4 and Stage 5.

Task 2.3 Extraction of key channel parameters
We will extract key channel parameters from the LiDAR data for each stream to be utilised within the BANCS model (or an alternative approach). These parameters are likely to include width, depth, sinuosity, bank height, bank slope and vegetation condition.

Stage 3. Estimate Bank Erosion Hazard Index (BEHI) and the Near Bank Stress (NBS) rating

Objective/s	Develop desktop approaches for assessing key indices used in the bank erosion model
Outputs	Guidelines for desktop procedures for assessing key indices used in the bank erosion model
Inputs	LiDAR data, aerial imagery, channel parameters

Task 3.1 Desktop assessment of key parameters
We will use the key channel parameters identified in Task 2.3 and other desktop approaches to assess the key indices required in the bank erosion model. For the BANCS approach this will involve extracting the following parameters for the Bank Erosion Hazard Index (BEHI) and the Near Bank Stress (NBS) rating :

- **BEHI**: bank height, bankfull height, bank angle, surface protection, root depth and density, material composition and stratification of material within banks (Bigham,et al., 2018)
- **NBS**: Geomorphic assessment (presence of transverse/central bars or channel pattern changes), radius of curvature, bankfull width, applied shear stress, hydraulic radius, reach slope (Bigham,et al., 2018)

We believe desktop approaches can be used to assess most of these parameters. For parameters relating the vegetation condition and bank material composition we will utilise LiDAR canopy height layers, regional

ecosystem data and soil mapping. This will involve developing a framework to determine estimates of root depth, vegetation composition and bank material composition based on available data.

Task 3.2 Field validation of key parameters
We will work with Reef Catchments and the Fitzroy Basin Association to develop a targeted field program. The purpose of the field program will be to verify our desktop assessments undertaken in Stage2 and Task 3.1. A priority will be to assess the effectiveness of our desktop approaches for assessing vegetation condition and bank material composition.

Task 3.3 Modification of desktop approaches for assessment
Based on the findings from our field assessments we will modify our desktop assessment method if applicable. This will include incorporating key findings/learnings into the frameworks developed in Task 3.1.

Stage 4. Apply the BANCS model

Objective/s	Apply the BANCS approach to the study streams
Outputs	Bank erosion predictions using the BANCS approach
Inputs	The BEHI and NBS

Task 4.1 Calibrate and Validate the BANCS model.
To calibrate the BANCS approach we will use the estimations of BEHI and NBS ratings from the 2009 LiDAR and erosion rates between 2009 and 2019 determined in Task 2.2. This will assist in developing Annual Streambank Erosion Rate curves for different BEHI and NBS ratings.

A section of each reach will not be used in the calibration data. This section will then be used to validate to modelling approach.

Task 4.2 Modify modelling approaches as required
Based on the validation outcomes we will modify our modelling approaches as required to provide an improved calibration. This may involve modifying or trialling alternative frameworks to those developed in Stage 3.

Stage 5. Applicability of the model to GBR catchments

Objective/s	Determine the applicability of the model to the broader GBR catchments
Outputs	Recommended approach to expanding across GBR catchments
Inputs	Outcomes of Stage 4 Understanding of bank erosion processes across the GBR

Task 5.1 Review and assessment of results
We will use the outcomes of the validation processes undertaken in Stage 3 to assess the accuracy of the BANCS modelling approach. This will include assessing the results of both the systems within the wetter Mackay Whitsundays region and those in the drier Fitzroy River system.

Task 5.2 Assess applicability of the model to GBR catchments
We will assess the applicability of model to the broader GBR catchments. This will involve categorising the GBR catchments into hydrophysiographic regions and assessing the applicability of the model to each region based on the outcomes of Task 5.1.

Task 5.3 Expansion across the GBR catchments
We will outline key recommendations to assist in the calibration and validation of the modelling approach to other hydrophysiographic regions within the GBR. This will include recommendations relating to data collection, field verification and modelling approaches.

Stage 6. Recommendations for updating modelling

Objective/s	Recommend an approach to update bank erosion modelling
Outputs	Program to facilitate modelling update
Inputs	Annual Streambank Erosion Rate curves

Task 6.1 Stakeholder consultation
We will undertake a series of stakeholder meetings to present the outcomes of Stage 4 and Stage 5. We will consult with the Paddock to Reef Modellers to understand current modelling limitations and opportunities to update approaches.

Task 6.2 Development of framework to update modelling
We will develop a framework to update existing Paddock to Reef Source models based on the Annual Streambank Erosion Rate curves developed in Stage 4. This will include recommended approaches to fit the curves into the existing Source model reach links.

Stage 7. Reporting

Objective/s	Document project outcomes and recommendations
Outputs	A final report on project outcomes and recommendations
Inputs	Outcomes from Stage 2 to Stage 6.

Task 7.1 Draft report
We will document the project outcomes in the report. The report will include an overview of the:

- Literature review on bank erosion models and their applicability to the GBR catchments
- Assessment of study streams including geomorphic assessments, channel change processes and parameter extraction
- Application, calibration and validation of the BANCS model
- Assessment of the applicability of the model to streams in the GBR catchments and recommendations to further develop the approach
- Recommendations relating to updating streambank modelling within the Source modelling framework

We will produce a complete draft report for DES to review. Alluvium requests that one set of consolidated comments is provided on behalf of DES and any other stakeholders. We assume that these will be provided within approximately 2 weeks of submission of the draft report. Alluvium will discuss with DES the preferred report format and the intended audience to ensure that the language and level of technical detail meets DES expectations.

Task 7.2 Final report
A final report will be prepared incorporating comments provided by DES and other stakeholders.