FINAL REPORT

Indigenous priorities in spatially enabled planning of the Indigenous estate

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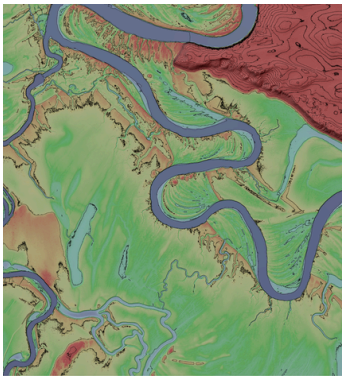

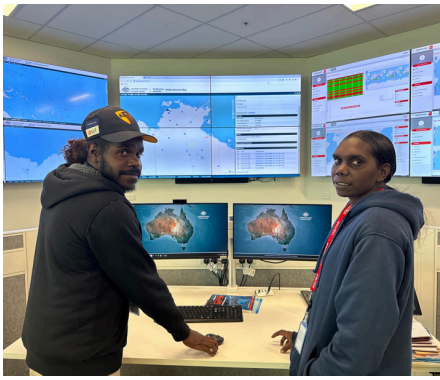







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Acronyms

AHP: Analytical hierarchical process

AIATSIS: Australian Institute for Aboriginal and Torres Strait Islander Studies

ALC: Anindilyakwa Land Council

ANU: Australian National University

BOM: Bureau of Meteorology

CARE: Collective benefit, Authority to control, Responsibility, and Ethics

CMS: Church Missionary Society

COAG: Council of Australian Governments

CRCNA: Cooperative Research Centre for Northern Australia

CSIRO: Commonwealth Scientific and Industrial Research Organisation

DEA: Digital Earth Australia

ESRI: Environmental systems research institute

GA: Geosciences Australia

GEMCO: Groote Eylandt Mining Corporation

GHAC: Groote Holdings Aboriginal Corporation

GIS: Geographic Information Systems

IDG: Indigenous Data Governance

IDS: Indigenous Data Sovereignty

IPA: Indigenous Protected Area

IPBES: International Platform on Biodiversity and Ecosystem Services

IPCC: International Panel on Climate Change

MaNP: Mapping a New Path

MCRA: Multi-criteria risk analysis

MMP: Makarda Management Plan

PBC Prescribed Body Corporates

SDG: Sustainable development goals

SES: Social-ecological systems

SLR: Sea level rise

TEK/WEK: Traditional ecological Knowledge / Western ecological Knowledge

TO: Traditional Owner

UN: United Nations

UNDRIP: United Nations Declaration on the Rights of Indigenous Peoples

Project Participants

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Executive Summary

Remote Indigenous organisations need reliable and spatially enabled data to plan for their Country, culture, infrastructure and future economic development. Yet many mapping tools and commercial datasets are designed for western planning systems and mainstream organisations. They do not always reflect Traditional Owner priorities, cultural restrictions, local knowledge or Indigenous data sovereignty. For the remote community-controlled organisations, there is limited research and practice into how you may effectively partner with academia, government and private industry to assist in generating data for decision making while keeping local people, Country and cultural governance at the centre.

Modern-day natural resource managers frequently rely upon Geographic Information Systems (GIS) to manage resources and identify opportunities for the economic activation of their assets. However, remote Indigenous community-controlled businesses are at a distinct disadvantage when attempting to access GIS technologies as compared to their non-remote and non-Indigenous counterparts. A key issue for Indigenous land managers is the difficulty in representing Indigenous cultural concerns and priorities in GIS tools which were developed for western land management and planning. The Anindilyakwa Land Council (ALC) have embarked upon implementing a GIS program to assist in activating their Indigenous estate for an ambitious economic and social development program.

The project has generated datasets, geospatial models and associated story maps which are integrated into a GIS, providing a platform for community voices in Country planning. This data can be utilised as a layer of ‘baseline’ information as critical data to unlock the potential of future community-led development projects and to assist the board in their preparations for mine closure.

The establishment of an embedded data unit by the ALC has been central to the success of this project. The data unit has administered the GIS and coordinated activities between partners and Anindilyakwa Traditional Owners to ensure that data creation and research is conducted according to Indigenous Data Sovereignty (IDS) and Indigenous Data Governance (IDG) principles to deliver genuine benefit to community. This has provided a unique opportunity for the ALC to collaborate with industry (Aerometrex), government (Geoscience Australia) and a university (ANU) to document this collaborative process and provide a blueprint for other remote communities to access the benefits of a culturally informed, community-led GIS initiative.

Chapter 1: The ALC data unit and spatial enablement

1.1 Introduction

Remote Indigenous organisations need reliable and spatially enabled data to plan for their Country, culture, infrastructure and future economic development. Yet many mapping tools and commercial datasets are designed for western planning systems and mainstream organisations. They do not always reflect Traditional Owner priorities, cultural restrictions, local knowledge or Indigenous data sovereignty. For the remote community-controlled organisations, there is limited research and practice into how you may effectively partner with academia, government and private industry to assist in generating data for decision making while keeping local people, Country and cultural governance at the centre.

As Groote Eylandt prepares for a future beyond mining royalty income, the Anindilyakwa Land Council is investing in data, mapping and spatial technologies to support Anindilyakwa-led planning for land, sea, culture and economic development. This report documents a CRCNA-funded partnership aimed at improving the ALC's ability to integrate core baseline GIS data into decision making processes. It shows how Indigenous-owned GIS can support practical planning needs while also protecting cultural knowledge, strengthening decision-making authority and advancing a broader model of Indigenous spatial enablement across northern Australia.

This introduction first situates the project within the broader challenge of spatially enabling Indigenous organisations in ways that are culturally appropriate, locally useful and governed by Indigenous priorities. It then outlines the CRCNA project's research questions, partnership model and key success factors, before providing background on Anindilyakwa people, Country and the post-mining transition that shapes the ALC's long-term planning context.

Natural resource managers increasingly rely on Geographic Information Systems (GIS) to manage resources, inform planning and identify opportunities for economic development. However, remote Indigenous community-controlled organisations often face significant barriers to accessing and applying GIS technologies when compared with non-remote and non-Indigenous organisations. Prior academic research has noted that the broader benefits of spatial enablement in Australia have been slow to extend to Indigenous organisations (Taylor et al. 2012). A key issue for Indigenous land managers is that many GIS tools were developed within Western land management and planning contexts, making it difficult to represent Indigenous cultural concerns, priorities and relationships to Country. The ALC

recognises that geospatial data can support economic and community development while also contributing to its core function of preserving Anindilyakwa land, language and culture.

The ALC and its Data Unit are in an early phase of investing in geospatial technology, providing an important opportunity to develop a model for integrating community cultural priorities and concerns into Indigenous-owned GIS systems. Funding received through the CRCNA project *Integrating Indigenous Priorities in Spatially Enabled Planning of the Indigenous Estate (AT.4.2223009)* has been used to address the following key research questions:

- How can cultural layers of spatial data relating to community concerns and priorities be appropriately included in Indigenous-owned GIS systems?
- How can private-industry spatial data providers adapt their products appropriately to remote Indigenous cultural and geographical contexts?
- How can government stakeholders add value to community-controlled spatial data projects?
- How can specialised spatial data tools such as LiDAR, photogrammetry and high-resolution imagery support community mapping priorities?
- How can Indigenous Data Sovereignty underpin key principles in a bottom-up GIS project?
- How can an Indigenous Land Council incorporate social and demographic data in a geodatabase?

Indigenous Data Sovereignty (IDS) and Indigenous Data Governance (IDG) have emerged as important frameworks for shifting power dynamics by repositioning data within settler colonial structures. The attempted elimination of Indigenous peoples, cultures, languages, stories, laws and Country began in Australia with settler colonisation in the late 18th century and continues through the structures of the settler colonial project (Wolfe, 1999; 2006; Veracini 2018). Its consequences have been violent, extensive and spatially uneven across Australia (Moran 2002). In response, Indigenous peoples continue to assert their cultures, lifeways and sovereign rights. These frameworks are being used by Indigenous peoples to reclaim, protect and preserve their knowledges and narratives (Carroll et al. 2020; Lovett et al. 2019; Wilks et al. 2018; Rainie et al. 2017; Kukutai & Taylor 2016). This project aims to operationalise IDS and IDG principles through the Indigenous-led creation and use of geospatial data for cultural preservation, planning and decision-making.

1.2 Key research objectives

The Anindilyakwa people are the Traditional Owners of the remote Groote Eylandt archipelago, a collection of islands, land and seascapes that form Anindilyakwa Country. The Anindilyakwa Land Council (ALC), under the direction of the 14 clans of the archipelago and through the powers of the *Aboriginal Land Rights (Northern Territory) Act 1976*, exists to capitalise on the opportunities and technologies of the 21st century while preserving Anindilyakwa land, language and culture (ALC 2024a). The ALC's vision for Groote Eylandt is a 'viable, culturally rich and sustainable two stream (diversified) economy, not dependent on mining royalty income, which is controlled by Anindilyakwa people' (ALC 2024a, p. 25). The Groote Eylandt Mining Company has operated one of the world's largest manganese mines continuously since 1965. The mine is forecast to close in 2033 and, with it, royalty payments to the ALC will end. The ALC aims to achieve complete financial safety by the end of the mine closure process. Community leaders have expressed the view that the current island economy, which is fully dependent on royalty income, 'would not and should not last forever' (ALC 2024a, p. 25; Groote Holdings Aboriginal Corporation 2022, p. 1). Elders want to see a future for their children that is not dependent on royalty or welfare, and community members have 'clearly expressed their desire to determine what their future will be like and to lay the foundations for it' (Groote Holdings Aboriginal Corporation 2022, p. 1).

In 2021, at the request of the ALC, the Australian National University (ANU) First Nations Portfolio produced a report that provided a comprehensive community profile and updated demographic, social and economic indicators (Taylor et al. 2022). The report also supported the ALC to establish its own Data Unit, which employs Anindilyakwa people to 'collect and analyse data on an ongoing basis' and 'provide its own decision makers with data and information to support evidence-based decision making' (Taylor et al. 2022). The report supports the vision and principles for post-mine-closure Groote Eylandt and is intended to assist the ALC in realising Indigenous-led economic and community development. Established in early 2022, the Data Unit now owns, collects, commissions, houses and analyses data relating to Anindilyakwa people and Country, contributing to a robust and sovereign Indigenous data infrastructure. As part of this process, the ALC has begun implementing a GIS program to assist in activating the Indigenous estate for an ambitious economic and social development agenda.

1.3 Anindilyakwa people and their Country

The creation story of Groote Eylandt is represented in the ALC emblem, depicting the Morning Star, the Sawfish, and the Hammerhead Shark (Figure 1).

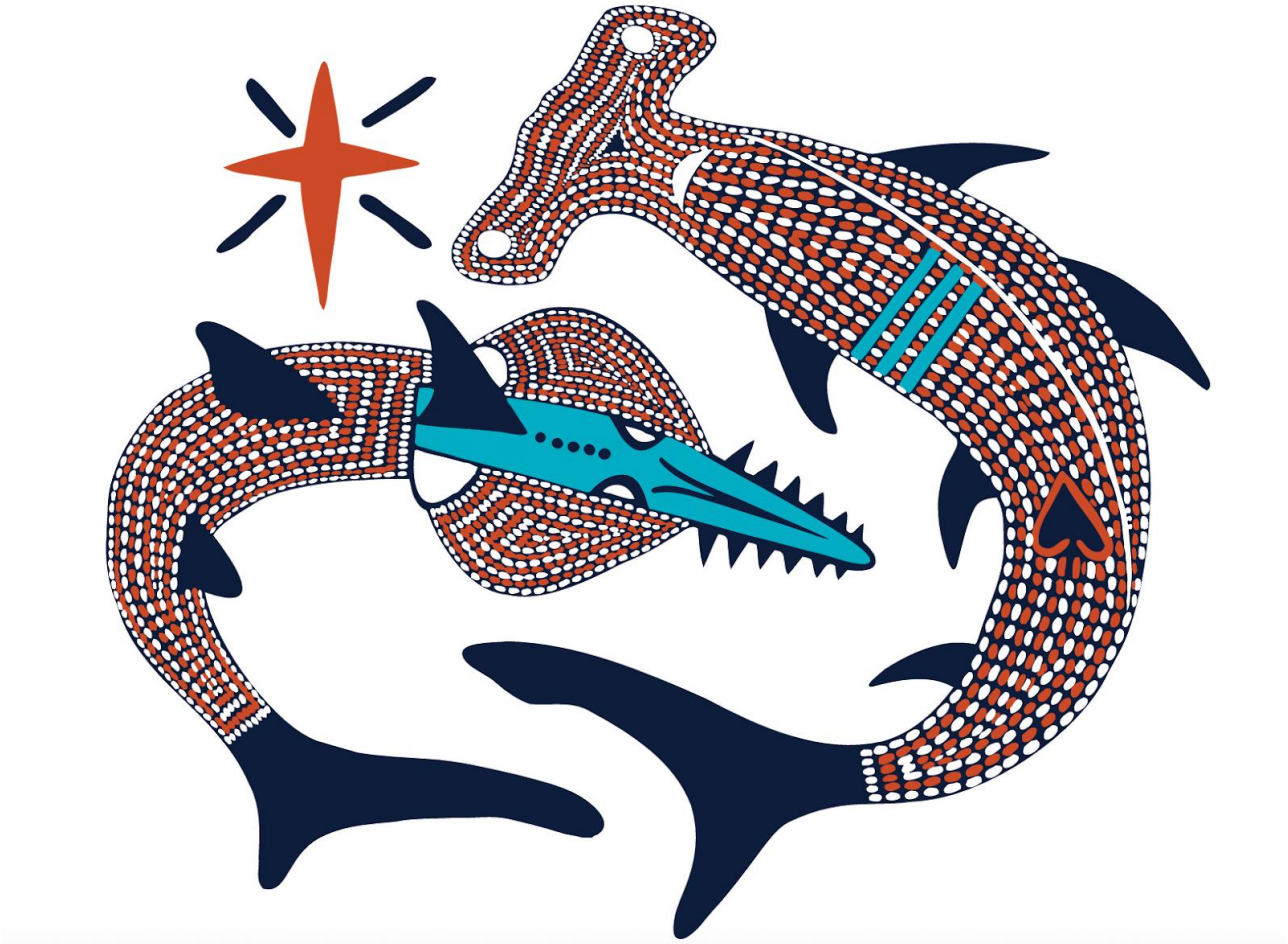

Figure 1: Morning Star, Sawfish and Hammerhead Shark. Credit ALC

‘In the beginning the island was dark. Barnimbirra (Morning Star) brought daylight to the island and ever since then there has been day and night. In creation times, Yumaduwaya (Stingray), Mangwarra (Hammer Head Shark) and Yugwurrirrindangwa (Sawfish), began their journey from the eastern coast of Arnhem Land. On their way to Groote Eylandt they stopped at Bickerton Island, transforming themselves from human beings to sea creatures. Then they journeyed on to Groote Eylandt. On the way, they agreed to go on to the centre of the island and decided to enter from the north, but Sawfish said, “I’ll take a short cut”. After the Stingray had left him, Sawfish set off with a crowd of many different stingrays, all travelling together, following on after him. Sawfish led the way, probably because he was the biggest. Meanwhile Lirreba, the Tide, was growing big. Sawfish reached Groote Eylandt, came out of the sea, and started to cut his way through the land, using his teeth and nose as he went. So he made the Angurugu River, cutting out the land and throwing the earth aside,

> opening a way for him and travelled towards Centre Lake. As the water came in, the dirt was stirred up, and Lirreba, the Tide, grew bigger and bigger, following close behind Sawfish. Then came all the stingrays, still following behind Sawfish as he led the way. Then he went to the centre of the island where he created Central Hill (Yandarrnga.)(ALC 2023, pp. 14-15)

Groote Eylandt is approximately 640 km east of Darwin, the Northern Territory state capital; just over 1000 km from Cairns, a key Far North Queensland city; and around 50 km off the Arnhem Land coast (ALC 2023). The name 'Groote Eylandt' itself is the four-hundred-year-old legacy of the Dutch explorer Abel Tasman, who ostensibly re-named the island on his 1644 expedition in the Gulf of Carpentaria (ALC 2023). The island, situated in the remote waters of the Arafura Sea in the Gulf of Carpentaria (Figure 2), is accessible only via limited commercial flights from Darwin, a charter flight operated by the Groote Eylandt Mining Company (GEMCO), or by boat. Bickerton Island, on the western side of the archipelago, is less than 10 km from the Arnhem Land coast. The region is classified as a Very Remote Area according to the Australian Bureau of Statistics Indigenous Structure (ABS 2021). Community profiles and demographic data collected at the local scale, such as Taylor et al's (2022), tend to be more representative than the large-scale census.



Figure 2: Groote Eylandt in relation to Australia

The word Anindilyakwa refers to the language spoken by the Indigenous peoples who inhabit the islands of the Groote Archipelago, comprising the Warnindilyakwa people and more recently, the Nunggubuyu people who emigrated from the mainland. Commonly, and in this thesis, Anindilyakwa is also used as the name of the people, culture, and language of the Groote Archipelago region (ALC 2024b). I will use “Groote Eylandt” or “the island” to refer to the region from here onwards, as this reflects the terminology used by those who live there. Anindilyakwa people were brought to the island over 8,000 years ago on a series of songlines, which created the entirety of the land and seascape, gave names to places, and provided law for kinship, marriage, and ceremony (ALC 2024b). Anindilyakwa people are connected through a complex kinship web which includes two moieties, each comprising seven clans. All 14 clans have respective responsibility for tracts of Country across the archipelago. The intricacies of clan and moiety structure not only dictate marriage law but form a web through which dissemination of knowledge and responsibility for cultural stories held within and about the landscape occurs. Anindilyakwa people have close contact with nearby Indigenous groups including those living across the sea. Songlines which are intimately connected to Anindilyakwa reincarnationist beliefs “crisscross the sea” between the island and the mainland, and the markarda (Sea Country) harbours sacred sites (ALC 2024b; Lalara et al. 2019).

With the passing of the Aboriginal Land Rights (NT) Act in 1976, Anindilyakwa people were among the first Indigenous peoples in Australia to be recognised as having inalienable freehold title over their land – a position stronger than having Native Title rights (ALC 2024b; see Appendix 1 for map; Altman 1995, 2011: 4). Sacred sites exist across the island and the landscape is inseparable from, and constitutive of, cultural knowledge and social relation. The Anindilyakwa Indigenous Protected Area (IPA), established in 2006 and expanded in 2012, covers around 10,000 km^2 of land and sea Country (Taylor and ALC 2016; ALC 2023; see Appendix 2 for IPA boundary map). The markarda is protected from all forms of seabed mining under the Northern Territory Minerals Title Act (ALC 2024b).

The largest town on the island is Alyangula, where much of the service and mining population live. Angurugu and Umbakumba are the two largest Indigenous communities on the island, and Milyakburra on Bickerton Island is the third (Figure 2). There are several small outstations and satellite communities across the archipelago. In 2021, the region recorded a population of around 2,500 people (ABS 2021). Groote Eylandt is home to around 1,500 Indigenous people, most of whom are Anindilyakwa, and which has remained stable over the last decade (Taylor et al. 2022). When accounting for the Indigenous

population base as well as the collective of Indigenous individuals who create a demand for services in the region, there is a wider diaspora population of around 2,000 people (Taylor et al. 2022). A majority of the approximate one thousand non-Indigenous people living on the island are either employed in the provision of services for Anindilyakwa people, or through the GEMCO mine (Taylor et al. 2022).

1.4 Report Structure

The report is structured as follows:

Chapter 1 provides an introduction to the project and key objectives; a description of the ALC and an outline of the role of the ALC data unit followed by an overview of Anindilyakwa people and their country. (Lead author: ALC; ANU)

Chapter 2 describes the collaborative geospatial data capture undertaken by Aerometrex on Anindilyakwa Country, including data collection protocols, high-quality products and access arrangements. (Lead author: Aerometrex)

Chapter 3 details the development of an in-situ Anindilyakwa Story Map and presents a methodological model for adaptation across remote communities in northern Australia. (Lead author: ANU; ALC)

Chapter 4 details the development of community-driven spatial modelling of climate change impacts and presents the methodology as a model for broader adoption. (Lead author: ANU; ALC)

Chapter 5 reflects on the project's key findings, considers geospatial knowledge exchange between Indigenous organisations, and outlines strategic avenues for capitalising on the benefits of spatial enablement. (Lead author: ANU)

Chapter 2: Collaborative geospatial data capture – establishing protocols, high quality products and enabling access

2.1 Introduction

As lead representatives of industry within the 'Integrating Indigenous priorities in spatially enabled planning of the Indigenous Estate' project, Aerometrex had two key objectives:

1. Understand/Discover new use cases for Airborne LiDAR and Aerial Imagery within Indigenous groups by supporting the ALC to achieve its community-led initiatives and goals.
2. Develop a framework for Aerial Survey and Remote Sensing operations to be undertaken in accordance with Indigenous Data Sovereignty & Governance principles by documenting key collaborations between Aerometrex & the ALC Data Unit.

These two objectives are interlinked, as Aerometrex would only be able to successfully and effectively support the ALC within the scope of the project by supplying data in a way that maintains their Data Sovereignty and is wholly governed by the community's cultural priorities.

There are few documented case studies of collaborations of this nature and scale between Traditional Owner Groups, Land Councils or remote Indigenous communities and commercial providers of aerial survey data. Most case studies are either centred on more accessible, small-scale technologies such as drones (Macdonald et al. 2021; Provost et al. 2025), include aerial data acquisition undertaken via a collaboration with Government or University (rather than direct procurement by Traditional Owners) (Armstrong et al. 2026; Rachcoff et al. 2025) or do not include the provision of data for sole ownership, access and control by Traditional Owners (Nearmap 2024). As such, this project represents a novel opportunity to explore how commercial Aerial Survey data suppliers can collaborate directly with Traditional Owners and deliver data wholly in line with their cultural priorities and community-led initiatives.

2.1.1 *Objective One – Discover new use cases for Airborne LiDAR and Aerial Imagery for Indigenous groups*

Airborne LiDAR and Aerial Imagery data has been integrated into geospatial management and decision-making frameworks for decades across many of Australia's key industry sectors, including Government (Local, State and Federal), Mining and Exploration, Forestry and Agriculture. Operational dependencies on aerial survey data within these industries has given rise to a mature procurement and specifications standard for Airborne LiDAR and Concurrent Aerial Imagery overseen by the Intergovernmental Committee on Surveying and Mapping (ICSM). The ICSM Airborne LiDAR (and Concurrent Aerial Imagery) Acquisition Specification "aims to provide advice to federal, state, and local government entities and government-owned corporations who seek to understand, plan, and acquire airborne LiDAR data." (Intergovernmental Committee on Surveying and Mapping: Elevation, Depth, and Imagery Working Group 2025). Although it is primarily designed for government procurement, it has been nearly universally adopted by any non-government industries across Australia regularly procuring Airborne LiDAR and Aerial Imagery.

The ICSM standards play a critical role in making aerial survey data more accessible, allowing for Contracting Authorities of any nature to approach the market with confidence to obtain data that is fit for purpose. However, a key limitation exists in that the standardised data specifications, i.e. quality levels, accuracy benchmarks and common deliverables, as they are all based on technical requirements related to well established commercial use cases. Due to this limitation use of these standards, although still beneficial, can be challenging for non-specialist users from industry sectors not yet commonly using LiDAR and Aerial Imagery. These challenges do not arise due to perceived lack of expertise by prospective users but is linked to the disconnect between novel use cases and well-established standards. This is particularly relevant to Traditional Owner groups and Indigenous Communities, given the ICSM procurement framework is built on standardisation and fostering common access to data as opposed to tailoring data to bespoke community-led requirements and maintaining Data Sovereignty.

Objective One is designed to ensure that the ALC is provided aerial survey data that is fit for purpose while exploring the suitability of standard Aerial Surveying scoping and procurement processes to direct collaborations between industry and Traditional Owner Groups. By establishing a detailed understanding of the proposed and potential use cases for Airborne LiDAR, Aerial Imagery and derived datasets across the ALC, as industry representatives Aerometrex hopes to document key considerations that can form the foundation for

procurement and project scoping methods that are community-led and aligned closer to the CARE principles (Carroll et al 2020) than current methodologies.

Objective Two – Develop a framework for Aerial Survey and Remote Sensing operations to be undertaken in accordance with Indigenous Data Sovereignty & Governance principles

The definition of 'Indigenous Data' within established concepts such as Indigenous Data Sovereignty and Indigenous Data Governance can vary slightly in terminology when applied within Australia and the world. Williamson, Provost & Price (2022) use a definition of Indigenous Data that "refers to the information or knowledge, in any format or medium, which is about and may affect Indigenous peoples both collectively and individually." Other sources define Indigenous Data to include 'data about Indigenous communities, peoples, lands, and resources' (Rainie et al. 2019) and 'data about their peoples, territories, lifeways and natural resources' (Lovett et al. 2018) within the Indigenous Data Sovereignty frameworks. Although these variations do not fundamentally alter the core concepts of Indigenous Data Sovereignty and Governance, the varying degree to which notions such as 'land', 'territories' and 'natural resources' are specifically mentioned is of particular interest when examining the principles of IDS and IDG through the lens of Aerial Surveying and Earth Observation.

Aerometrex is one of Australia's largest suppliers of Aerial Survey data (Airborne LiDAR and Aerial Imagery) and has captured, at minimum, approximately 6.5 million square kilometres of Aerial Survey data across continental Australia since 2001. This data consists of high-resolution Aerial Imagery (5-10cm resolution) and medium to high density Airborne LiDAR (4-30 pts.m^{-2}). The data has been acquired on behalf of Government and Private sector clients, with access permissions ranging from private, subscription to open source. Beyond Aerial Survey data, the global commercial satellite imagery market has grown to over $7 Billion in 2025 (Claight 2026), with numerous suppliers now offering continental coverages across Australia, at a resolution of 15-30cm and refreshed multiple times a year. The amount of Aerial Survey data and Earth Observation data being collected and made commercially and/or freely available demonstrates the proliferation of the use of this type of data within a wide range of industries, not only in Australia but across the world – data that could be viewed as describing and measuring Indigenous 'land', 'territories' or 'natural resources'.

Since the commercial imagery industry, both Aerial and Satellite, has become so mature and large scale it is unlikely that Indigenous groups will be afforded the opportunity to govern the collection, ownership, and application of existing or new data. This same data is being

increasingly commonly used by commercial groups that wish to utilise land for industrial activities that have the potential to threaten Indigenous stewardship of the land (Kennedy et al. 2023). Therefore, there is an opportunity for commercial data providers to become active participants and collaborate with Traditional Owners and Indigenous community groups to make existing data more accessible.

As part of Objective Two Aerometrex hopes to explore and document the key considerations that are relevant for commercial Aerial Survey providers to ensure that work is undertaken in line with the core concepts of Indigenous Data Sovereignty. Building upon the outcomes of Objective One, following the identification of use cases unique to remote Indigenous cultural and geographical contexts, Aerometrex hopes to explore how commercial providers can better align with the FAIR and CARE data principles to make Aerial Survey data more accessible to Traditional Owners when collected across their lands.

2.2 Geospatial Datasets

2.2.1 Airborne LiDAR & Aerial Imagery

As part of the project Aerometrex carried out a simultaneous Airborne LiDAR and Concurrent Aerial Imagery survey designed to supply the Data Unit and ALC with key foundational geospatial datasets across the Groote Archipelago. Aerometrex utilised a RIEGL VQ-780II LiDAR scanner dual mounted with a Phase One IXU-1000 RS medium format R:G:B camera within a Vulcanair P68 aircraft to capture simultaneous LiDAR and Imagery data across 3,375 km^2 of the Groote Archipelago. **Table 1** summarises the aerial survey parameters utilised for data acquisition.

Table 1: Aerial survey parameters utilised for data acquisition

Survey Parameter	
Survey Altitude (metres above ground)	1000 m
Target Ground Speed (kn)	135 kn
Image Forward Overlap	70%
Swath Side Overlap	30%
Scanner Field of View (FOV)	60 °
Scan Frequency (lines per second)	280 lps
Minimum Point Density	12 $pts.m^{-2}$

Average Point Density	14 pts.m^{-2}
Imagery Resolution (GSD)	10 cm
Maximum returns per pulse	4 returns
Laser Pulse Frequency	1800 kHz

Data acquisition took place between 16 May 2023 and 23 July 2023 under ICSM standard environmental conditions (Figure 3), including:

- Atmospheric conditions free of cloud, fog, heavy smoke and haze between the aircraft and ground during all collection operations.
- Ground conditions must be free of snow and not subject to flooding or fire.

A suite of twenty Ground Control Survey Points (GCPs) was collected across both Groote Island and Bickerton Island, allowing for z-axis adjustment of the LiDAR data within those regions. Data across all other regions remained unadjusted. As a result, the LiDAR and Aerial Imagery Data had the following accuracies (Table 2):

Table 2: Accuracy specifications for the Airborne LiDAR and Aerial Imagery survey data

LiDAR Accuracy – Groote & Bickerton Islands	
Absolute Accuracy	
Vertical Accuracy[1]	±10 cm at 95% CI
Horizontal Accuracy	±30 cm at 95% CI
Relative Accuracy	
Vertical Accuracy	±5 cm at 95% CI

[1]Absolute vertical accuracy applies to all derived elevation datasets in these regions

LiDAR Accuracy – All Other Island	
Absolute Accuracy	
Vertical Accuracy[2]	±20 cm at 95% CI
Horizontal Accuracy	±30 cm at 95% CI
Relative Accuracy	
Vertical Accuracy	±5 cm at 95% CI

[2]Absolute vertical accuracy applies to all derived elevation datasets in these regions

Absolute Accuracy	
Horizontal Accuracy	±3 pixels at 68% CI



Figure 3: Image showing the full extent of the Aerial Imagery survey undertaken by Aerometrex on behalf of the ALC. The Airborne LiDAR survey also covered the same area. The dataset shown is 10 cm resolution RGB Aerial Imagery. The red area highlights imagery excluded for cultural reasons. Inset images shoes points of detail from Across Groote and Bickerton Islands

The LiDAR Point Cloud was classified in accordance with ICSM quality standards (Table 3), in line with Aerometrex's Type 1 and Type 2 classification levels (Figure 4 - 6). Groote Island and Bickerton Island were classified to Type 2; all other Islands were classified to Type 1.

Table 3: Point Cloud Classification scheme and quality level.

Point Cloud Classification			
Class	Description	Type 1 (ICSM Level)	Type 2 (ICSM Level)
0	Unclassified*	N/A	N/A
1	Default Infrastructure	N/A	Level 2
2	Ground	Level 3	Level 3
3	Low Vegetation (0-0.3m)	Level 1	Level 1
4	Medium Vegetation (0.3-2.0m)	Level 1	Level 1
5	High Vegetation (2.0m+)	Level 1	Level 3
6	Building	Level 1	Level 3
7	Noise (High & Low)	Level 2	Level 3
8	Model Key Point**	Level 3	Level 3
9	Water	Level 3	Level 3
10	Bridge	Level 3	Level 3



Figure 4: Classified Airborne LiDAR Point Cloud, Alyangula, Groote Island. Ground l shown in brown, Buildings in red, vegetation in green, water in blue and other infrastructure in grey. Inset A shows the ALD office building

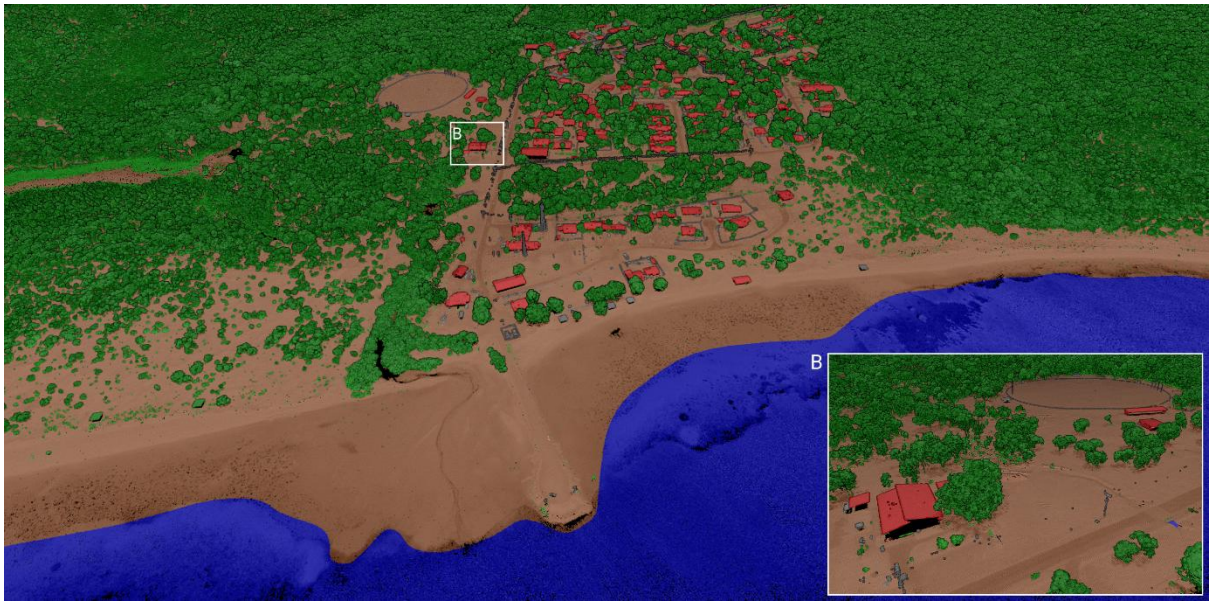

Figure 5: Classified Airborne LiDAR Point Cloud, Umbakumba, Groote Island. Ground l shown in brown, Buildings in red, vegetation in green, water in blue and other infrastructure in grey. Inset B shows the Umbakumba Cultural Centre

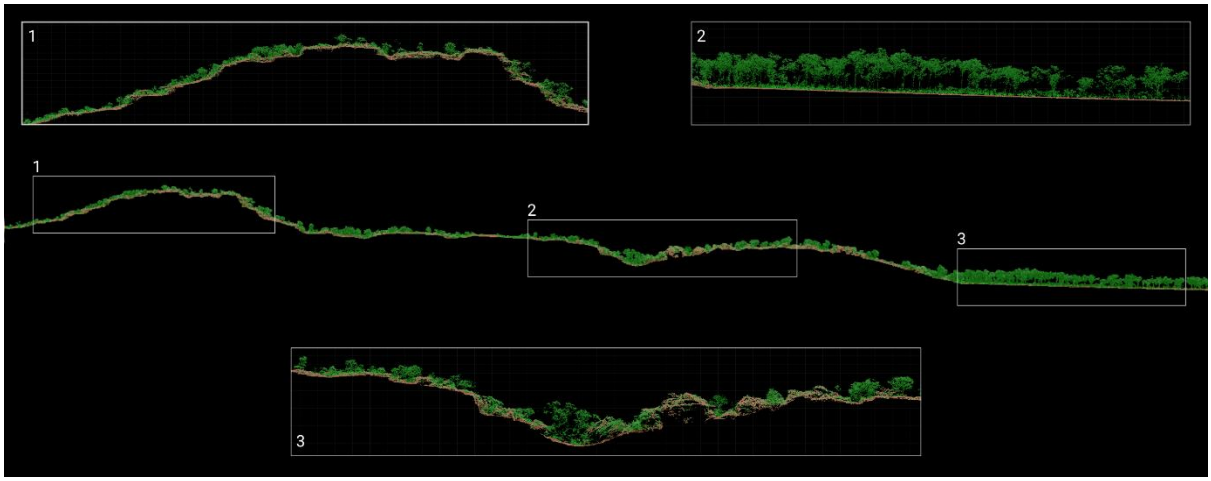

Figure 6: Profiles showing the Classified LiDAR Point Cloud from central Groote. Ground is shown in brown, Vegetation in green

2.2.2 Derived Datasets

The ALC were also supplied with several derived datasets / project deliverables (all derived from the foundation Airborne LiDAR and Aerial Imagery data) aligned with the immediate project needs to the Data Unit.

A Digital Terrain Model (DTM) with a spatial resolution of 50 cm was derived from ground classified points within the LiDAR point cloud (Figure 7), providing a clear representation of the ground-surface topography across the entire project area (Figure 8). The DTM was generated using industry standard methodologies whereby a Triangulated Irregular Network was generated from all ground classified points, then converted into a continuous cellular raster. As well as the DTM, the Airborne LiDAR Point Cloud and Aerial Imagery frames were combined to generate a hybrid LiDAR & Photogrammetric 3D Mesh Model of specific areas of Groote Island, selected by the ALC in consultation with the broader community (Figure 9). The 3D Mesh Models provide a fully three-dimensional representation of the landscape and can be rendered in game engines to generate high fidelity images and videos.

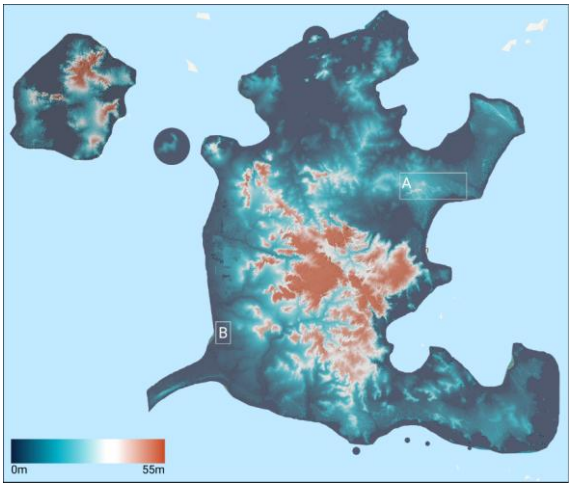

Figure 7: Digital Terrain Model (DTM) of Groote and Bickerton Islands. Elevation is shown as blue low, orange high. Boxes A and B show the extent of frames shown in Figure 6

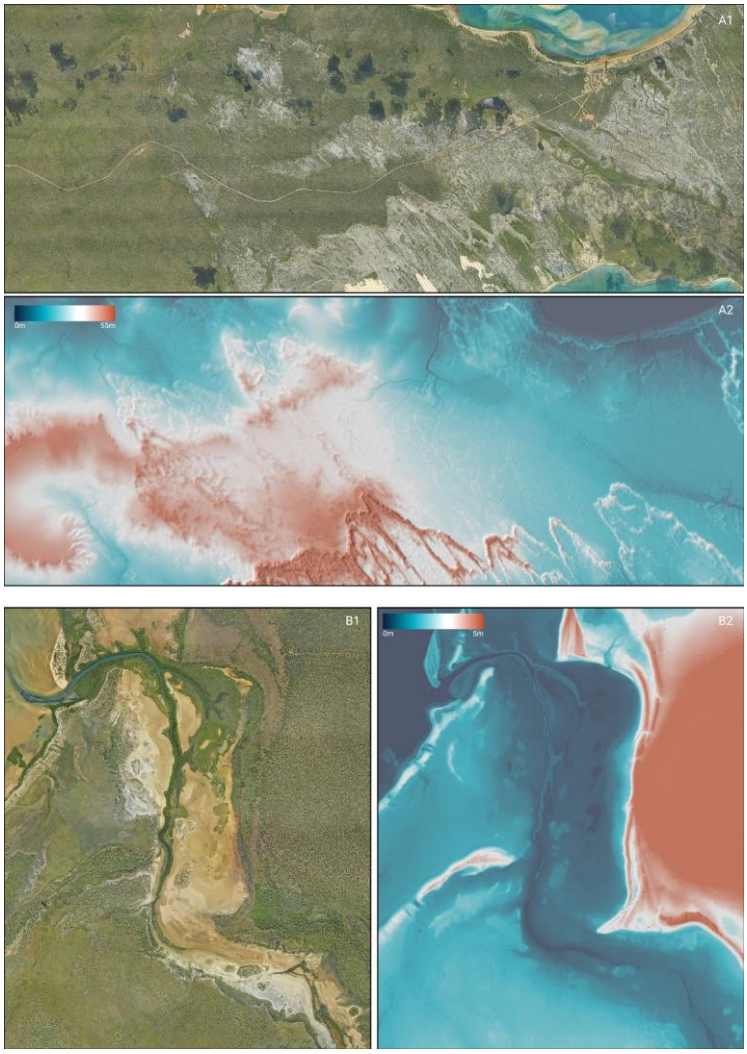

Figure 8: Aerial Imagery and Digital Terrain Models from Groote Island. A1-2 and B1-2 both show the data from the same location



Figure 9: Areas of Groote Island, selected by the ALC in consultation with the broader community

2.2.3 Collaborative Survey Design

The overall suite of geospatial datasets delivered was designed to meet the ALC's project budget, as well as immediate priorities linked to the community initiatives within the proposed project. Wherever possible the specifications of the aerial survey were balanced to 'future-proof' the data against evolving priorities and as yet unknown projects. An example of this is the Type 2 classification across Groote Island and Bickerton Island. The immediate use of the data will primarily be based on the Aerial Imagery and terrain data (i.e. Sketch Mapping and sea level rise risk analysis), which requires only a high-quality classification of the ground surface (i.e. Type 1). However, it was possible to classify the Point Cloud within the project budget to Type 2 to enable

future projects to include analysis of built infrastructure such as buildings and/or above ground vegetation. The result is a suite of datasets that are designed specifically for the immediate requirements within this project but also represent a highly valuable complete coverage of Anindilyakwa Country for use into the future.

2.3 Collaborative Geospatial Data Planning, Acquisition, Processing & Delivery

Close collaboration between Aerometrex and the ALC was critical in order to achieve Objective One and establish a foundation for Objective Two. Effective collaboration throughout the planning, acquisition, processing and delivery stages is essential to ensure that the data was fit for purpose, aligned with community priorities, as well as acquired and delivered in a 'culturally safe' manner to maximise benefit across the community. This collaboration took place between a wide range of functions across the Aerometrex team, including Flight Operations, Product Management, Production and Project Management, working closely with the ALC Data Unit who facilitated input from the broader community when required. Outlined in this section are key examples of collaboration between Aerometrex (Industry) and the ALC throughout the project life cycle, which resulted in the delivery of a community-led Aerial Survey.

2.3.1 Learning About Culture, Community and Use Cases

A key part of any project, of any scale, is developing an understanding of why we are collecting the data and how it is going to be used by the end client. This exploration goes beyond simply establishing the required specifications (i.e. resolution or point density) to also develop an understanding of the operational and/or commercial drivers that are motivating the procurement of the data. Full knowledge of the required specifications as well as the proposed uses of the data and the outcomes clients hope to achieve using the data provides the foundation to design the Aerial Survey fully in line with a client's immediate priorities as well as potential future initiatives. The same framework is equally applicable when collaborating with Traditional Owner groups and remote Indigenous communities, however the benefit stems from understanding cultural and community-based motivations for undertaking the projects (as opposed to pure commercial outcomes). The result is a project that is aligned community-led priorities from beginning to end.

Throughout the early stages of the "Integrating Indigenous priorities in spatially enabled planning of the Indigenous Estate" project, Aerometrex representatives were able to meet with members of the ALC Data Unit as well as members of the broader Anindilyakwa community, on Anindilyakwa

country (Figure 10). The purpose of these visits was to learn about the Anindilyakwa culture, primarily through the lens of proposed use cases for the data that will be captured. During the visit to Groote Island, Aerometrex representatives were able to:

- Spend time with members of the Anindilyakwa Men's and Women's Art Groups to learn about their native materials, such as pandanus, and the geographical and seasonal dependencies on their collection.
- Listen to oral histories about culturally significant local points of interest such as Qantas Bay and Red Sands.
-
- Learn about significant local fauna including the Hopping Mouse and Ghost Bat which are the basis of targeted ecological management initiatives by Rangers.



Figure 10: Project stakeholders visiting the Anindilyakwa community on country, at the Men's Art Centre

These visits were facilitated by the ALC Data Unit and provided members of Aerometrex with invaluable exposure to the Anindilyakwa culture, including Anindilyakwa music, people and art, in the very early stages of project planning. This provided the foundational understanding for the cultural and community-based motivations for the data acquisition, within the context of the broader project, and allowed for the Aerometrex and Data Unit teams to develop stronger working relationships which would prove critical to the execution of subsequent planning stages. Overall, the visits and workshops completed as part of this project demonstrate the effectiveness of taking a collaborative approach, as opposed to a consultative approach, to successfully implement community-led data acquisition. The beneficial outcome of understanding the cultural and community-based motivations for the survey mean that immediate priority use cases, potential future use cases and project budget can all be balanced to deliver a fit for purpose and future-proofed Aerial Survey.

2.3.2 *Facilitation of Community Guidance in the Survey Planning Stage*

It is commonplace within the Aerial Survey industry to have to navigate air space access restrictions to gain permission to execute a survey, as well as needing to time the survey around other local operations such as commercial flights, aerial mustering or mine site blasting to maintain safe operations. It is a common necessity to alter or tailor survey parameters multiple times throughout a project to either gain permission to access airspace or conduct the survey in a safe manner, this may include flying at a certain altitude, changing AOI extents, increasing swath overlap or altering laser power levels.

The Groote Archipelago represents relatively ‘simple’ airspace to operate Aerial Surveys in compared to other regions in Australia, i.e. it does not include any busy commercial airports, busy flight paths or strict government (e.g. defence) airspace restrictions. The only standard considerations that were identified in the initial stages of planning by the Aerometrex Flight Operations team was the need to establish contact with mining active operations on the island to ensure no blasting was occurring during the time of the survey. However, during initial visits to Groote Island and after submission of initial proposed flight plans to the Data Unit, the Flight Operations team were made aware of some culturally sensitive and/or significant areas that would require alteration of the proposed plan.

One example was a culturally significant mountain, Central Hill, in the central region of Groote Island. There were no cultural sensitivities that prohibited Aerometrex from imaging Central Hill, however stories shared by the community indicated flying directly over the mountain would disturb the mountain locally within landscape. In this scenario it was Aerometrex’s objective to collaborate with the ALC such that the entire region could be captured but done so in a way that would not disturb the landscape around Central Hill. This would provide the ALC with full coverage of the archipelago and a continuous basemap for use across the island. To achieve this, Aerometrex Project Management and Flight Operations representatives collaborated with the ALC Data Unit to redesign the survey flight plans such that the aircraft did not fly directly over the mountain (Figure 11). The ~60° FOV of Aerometrex’s sensors could be utilised in this case to Central Hill from an oblique angle, providing full coverage in a way that respected the cultural significance of the region. This is one specific example of the continual communication between Aerometrex and the ALC Data Unit, underpinned by the ALC Data Unit continually liaising with the wider community, to

ensure that the extent of the survey and the manner in which it was conducted was culturally appropriate.

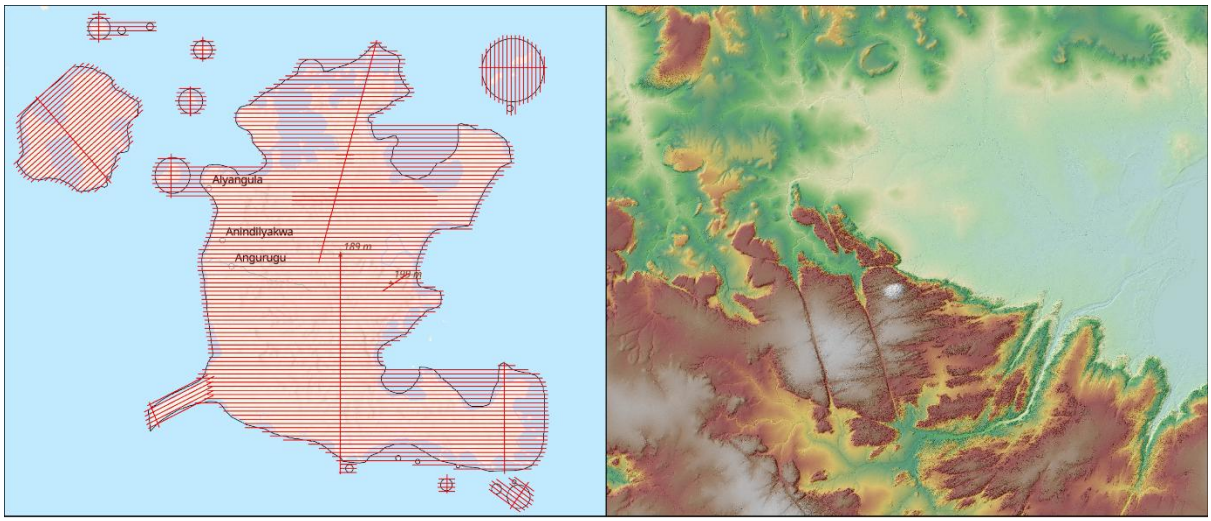

Figure 11: Left, Preliminary flight plans for the Aerial Survey of Groote Island (prior to community collaboration and planning). Right, Continuous Digital Terrain Model of [Insert Mountain Name] made possible be redesigning proposed flight plans to ensure a cult

The case of Central Hill serves as a powerful example that when collaborating directly with Traditional Owners, Aerial Surveyors need to consider not just the usual access requirements but also their place within the environment and any associated cultural considerations. It is on the part of industry to be open to learning the relevance of cultural aspects in relation to flight planning, survey design and execution, noting that these cultural aspects may be localised and vary within community groups. Communication in the planning stages should be detailed enough that cultural aspects can be respectfully accounted for operationally, utilising the same set of tools employed to navigate highly complex regulatory restrictions in other jurisdictions or locations.

2.3.3 Achieving Comprehensive Data Coverage, Delivered in 'Culturally Safe' Way

In the early stages of project planning the ALC identified the value of acquiring Aerial Survey data across the entire Groote Archipelago to serve as a continuous benchmark dataset. This presented a unique data delivery challenge for the ALC Data Unit and Aerometrex, as the ALC wanted to obtain a seamless imagery mosaic of the entire island, but some regions of the island are not culturally appropriate for all community members to view. The solution was for the ALC Data Unit to provide Aerometrex with digitised extents of any region that should have restricted viewing access for any group for any reason. These polygons were then used to generate a universally

appropriate mosaic, with any sensitive regions removed, that could be shared and viewed by anyone within the community with confidence. The extent of the full imagery mosaic versus the culturally appropriate imagery mosaic is shown in Figure 3. Having a culturally appropriate layer meant that the ALC could leverage modern data hosting and streaming web services such as Metro Map with the confidence no community member would be exposed to data that was inappropriate. The complete version of the mosaic, inclusive of culturally sensitive areas, was delivered directly to the ALC to be managed within their digital data systems as per their standard governance framework.

The ALC opted for strict Data Governance practices to protect data covering culturally sensitive areas, as opposed to excluding those areas altogether, ensuring that if a specific critical use arises for the data, it will be available for all areas of country. When we compare this to projects in industry (where data is not being procured by Traditional Owners), when culturally sensitive areas are identified they are sometimes excluded from the survey or clipped out and deleted in post-processing, ensuring any potential community benefit of that data is lost. The ALC's endeavour to ensure all areas are surveyed to maximise potential benefit highlights an important role that industry and data providers can play, by shifting away from excluding culturally significant areas by default and ensuring that they collaborate with Traditional Owners to move towards asking 'how can we facilitate delivering this data in a culturally safe manner to Traditional Owners so they can derive benefit from its acquisition'.

2.4 Discussion

2.4.1 New Use Cases for Airborne LiDAR and Aerial Imagery Within Remote Indigenous Communities

Chapters 3 and 4 of this report outline in detail two of the key use cases identified for the Aerial Survey data that were identified in the very early stages of the project:

- High resolution basemaps to support community sketch mapping.
- Enhanced data visualisation for developing cultural story maps.
- Extensive elevation datasets to assess the risk associated with sea level rise to culture and community across Groote Island.

As the project evolved and the initial datasets (Aerial Imagery and LiDAR) were delivered to the ALC they were integrated into daily operations and new use cases were identified as well. An

example is desktop environmental monitoring of remote areas, demonstrated through the identification of vegetation die back on North East Island within the imagery hosted in Metro Map, prompting field investigations. Although all highly beneficial, these initial use cases are not new or novel, simply executions of existing, well established use cases of this type of data within the context of remote indigenous communities (i.e. high-fidelity basemaps, flood/inundation modelling and environmental management).

As the project evolved, a key new and novel use case for this type of data was identified: establishing a 'Digital Twin of Country'[1]. There is no consensus on a single definition for a Spatial Digital Twin, but they are often described as a virtual geospatial replica of the environment, with the real-world linked to its digital, high-fidelity representation by geospatial information and data describing its dynamic processes (Xue et al. 2026). The key benefit of a Digital Twin is supporting analysis, communication and simulation to drive informed planning and management decisions (Stoter et al. 2021). During this project, the notion of a 'Digital Twin of Country' within the context of Indigenous communities came to represent a holistic geospatial data foundation (Digital Twin) that can be shared in culturally appropriate ways, both in community / on country and externally, that is fully controlled and governed by the community.

The evolution of Digital Twin of Country use case is best demonstrated through the addition of the Hybrid LiDAR and Photogrammetric 3D mesh Models to the project deliverables supplied by Aerometrex. The mesh models are designed to be high-fidelity three-dimensional representations of significant regions of Groote Island. The addition of the Mesh Models was motivated by use cases centred on communication and visualisation. This was highlighted by Anindilyakwa community members utilising game-engine video renders of the 3D models as backdrops to knowledge sharing and yarning sessions at the National Indigenous Mapping Workshop in Perth in 2024 (Figure 12). Plans are in place to extend the coverage of the 3D mesh models by an additional 550 km^2, integrate the results from projects outlined in Chapters 3 & 4 and utilise streaming services and video rendering to make the data readily available (where appropriate) across the community and externally via web-map services.

[1] *Term first shared with project team members by Andrew Dowding, Ngarluma Traditional Owner, Co-Founder and Managing Director, Winyama*

The novel development of the extensive Anindilyakwa foundational geospatial data layers as part of this project, with the movement towards establishing a Digital Twin of Anindilyakwa Country, highlights novel new use for this type of data in indigenous communities: establishing Digital Twins of Country to provide benefit across wide range of disciplines, support both immediate and future community-led priorities, integrate other data layers from across the community and develop innovative storytelling and communication tools – all while maintaining Indigenous Data Sovereignty and Governance.



Figure 12: Images of ALC Data Unit representatives utilising Hybrid LiDAR & Photogrammetric Mesh Models as visualisation tools in a yarning session and the National Indigenous Mapping Workshop in Boorloo/Perth, 2024

Implications for Aerial Survey and Remote Sensing (EO) Industry Regarding Indigenous Data Sovereignty

As outlined in Section 2.1.2, the proliferation of commercial Aerial Imagery, Airborne LiDAR and Satellite Earth Observation highlight the extent to which data representing Indigenous lands, territories and natural resources is being procured and utilised by industry but not necessarily being made accessible to Traditional Owners. The evolution of the commercial imagery industry over the last decade, both Satellite and Aerial Imagery, has meant that there is little opportunity for indigenous groups to claim ownership or control over this data (where they wish to do so) in line with the principles of Indigenous Data Sovereignty. Furthermore, the lack of access to this type of data to Traditional Owners, and the regularity at which it is being collected by industry, means that in the geospatial sector there is a clear risk of commercial entities and third parties who wish to access or exert influence over indigenous lands may have more extensive, better access to modern remote sensing data than the Traditional Owner groups.

The collaborations between Aerometrex and the ALC has demonstrated that minimal considerations and alterations to standard practices are required to execute a project of this nature in a way that is community-led and aligned with Indigenous Data Sovereignty and Governance Principles. Key considerations include:

- Being open to learning about and understanding the cultural and community-based motivations for the data acquisition to inform holistic survey design.
- Extending survey planning to include not just access, but the surveys place within environment to account for potential cultural sensitivities – and being willing to accommodate these sensitivities for mutually beneficial outcomes.
- Collaborate closely with community members to ensure that the survey is informed by community-led priorities and delivered in a culturally safe manner, while supporting the community to maximise its benefit (i.e. maximum coverage combined with culturally appropriate delivery).

Although these are all easily implemented, they become more difficult to achieve when the project is not being undertaken directly between the Traditional Owners and the Data Provider, which is often the case. Without the direct working relationship between the ALC Data Unit and Aerometrex, the information required to implement the project in this way would likely be much harder to obtain, or at the very least, take much longer to ascertain via standard consultation approaches (as opposed to direct ongoing collaboration).

When undertaking projects with industry or government clients, data providers should look to advocate where possible for collecting data and providing it in culturally safe ways to Traditional Owner groups rather than defaulting to not collecting the data at all or deleting it in post-processing. This default approach is often the simplest avenue to execute the project but ensures that there is no opportunity for Indigenous communities to access and benefit from data captured on their country by third parties. Commercial data providers have the ability to, wherever possible, support spatial enablement programs and be active participants in fostering and promoting informed access to data that has been, or will be captured, across Indigenous communities or lands.

Even though the nature of the commercial imagery industry, both Aerial and Satellite, means that it is challenging for Indigenous groups to exert their right to Data Sovereignty and Governance over

this type of data (if they wish to do so), a change in approach by data providers can at least establish a framework closer aligned to the FAIR and/or CARE data principles.

2.5 Key Project Takeaways

A key objective for all stakeholders within the “Integrating Indigenous priorities in spatially enabled planning of the Indigenous Estate” project was to identify key lessons/outcomes that can be scaled up and applied to other projects across the NT and Australia. From the perspective of Aerometrex as industry representatives in the project, there were two key outcomes that have broad applicability to other projects involving collaborations between Aerial Survey Data providers and Traditional Owner Groups.

2.5.1 The Critical Role & Benefit of the ALC Data Unit

Throughout Aerometrex’s involvement in the project the data unit has been instrumental by acting as a key facilitator – linking community-led initiatives with our technical capabilities. Many of the insights that led to the effective planning and execution of the project in a culturally safe manner (in line with the ALC’s Indigenous Data Sovereignty and Governance objectives) were made possible by the effective ability of the Data Unit to liaise with the broader community and provide rapid, authoritative feedback. Furthermore, having geospatially trained community members within the Data Unit meant that they could effectively combine technical and cultural elements to derive mutually beneficial outcomes throughout the project. Not only did the Data Unit act as effective conduits between external project stakeholders and community, but when external stakeholders collaborated, i.e. Aerometrex and ANU, it was always facilitated by the ALC Data Unit representatives to ensure all project work was aligned to community priorities and the Anindilyakwa community were not excluded from project planning, development and execution at any stage (Figure 13).

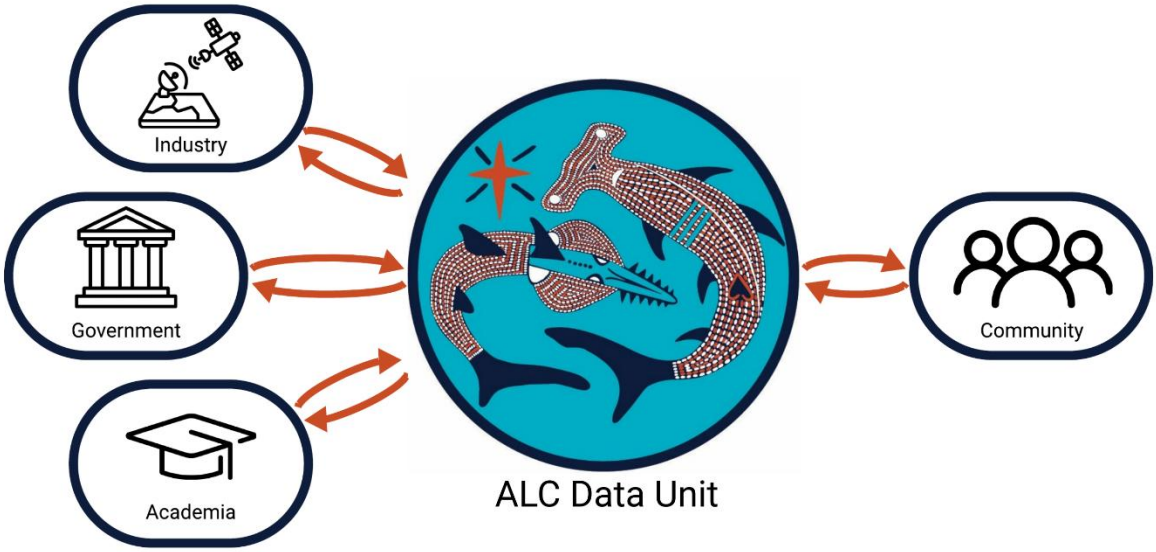

Figure 13: Schematicv showing the critical roles that the ALC Data Unit played within the scope of the project, 1) Key conduit between all project stakeholders and the Anindilyakwa Community, 2) Facilitator of collaborations between project stakeholders to ensure

The clear contribution to the success of the project that the Data Unit played, especially related to the acquisition and delivery of the geospatial data layers, highlights the importance of geospatial enablement and training of community members within Traditional Owner Groups. It may not be possible to have a function as mature as the ALC Data Unit in all communities or organisations, but this project highlights the potential benefit of even having individual community members provided with Geospatial and Data Acquisition training in order to act as facilitators when collaborating with industry in order to ensure data is delivered in accordance with community priorities and Indigenous Data Sovereignty principles.

2.5.2 Implications of Indigenous Data Sovereignty & Governance Principles Relating to Aerial Surveying and Remote Sensing Industries.

The successful execution of the ALC Airborne LiDAR and Aerial Imagery survey demonstrates that projects can be undertaken that maintain Indigenous Data Sovereignty and Governance with very little deviation from standard practices. Throughout the project Aerometrex tailored our operations to ensure that the ALC maintained ownership and governance over the data and operations were fully aligned with community priorities. The required operational alterations to accommodate this deviated very little from accommodations made for commercial entities as part of our business-as-usual operations. What was critical for success was establishing a working relationship and collaborative framework to establish the necessary cultural context and community priorities to

guide the operations, as compared to understanding a client's commercial and operational requirements. This demonstrates that achieving work of this nature is a matter of industry education, not industry capability.

This CRCNA project is somewhat unique compared to other projects that include the acquisition of data across Indigenous communities and lands, whereby industry was able to collaborate directly with Traditional Owners, as opposed to a) third parties (e.g. Academia, Government or Industry) undertaking community consultation on behalf of data providers, or b) providing data to private end-users separate to Traditional Owner groups whose lands are being surveyed. In some ways this makes the broader application Indigenous Data Sovereignty and Governance principles more complex in standard data acquisition projects. However, understanding the relevance of these principles should not be viewed as a risk to operations, but rather an opportunity for industry to be an active participant and ensure not just clients benefit from the data we collect, but also the traditional owners whose lands are being surveyed.

The Aerial Surveying, Remote Sensing and Earth Observation Industries (and other commercial imagery and data providers) should in theory be able to be active participants in advocating for Indigenous Data Sovereignty & Governance Principles within the industry – enabling greater access to data for Traditional Owners.

Chapter 3: Keeping Culture Strong: The development of an in-situ Anindilyakwa Story Map

3.1 Introduction

Key findings from an ANU Honours thesis by Alice Gill are presented in this chapter. The thesis is entitled *Keeping Culture Strong: Co-Creating a Story Map using sovereign Anindilyakwa data* and was published in 2024 (full version available in Gill 2024). It outlines the development of an in-situ Anindilyakwa Story Map created in collaboration by researchers at the Australian National University (ANU) and the ALC Data Unit, specifically with two young Anindilyakwa researchers, Joshua (Josh) Mamarika and Danelle (Del) Bara. The first-person tense of the thesis has been preserved to retain writing style of the original work.

> 'Young people need to know this story for the future…to keep the culture strong!'
> (Constantine Mamarika, cited in Gill 2024, p 48)

The project explored the following question: How can the ALC enact Indigenous data sovereignty (IDS) and Indigenous data governance (IDG) to use its sovereign geospatial data to preserve Anindilyakwa culture, in the context of settler colonialism? This investigation was also guided by two sub-questions:

1. Are Story Maps appropriate and useful mediums by which to utilise geospatial data and preserve culture and cultural knowledge?
2. How and why is true co-creation of a Story Map important? What is the role of an external, non-Indigenous researcher in this process?

These questions relate to two of the core interrogations underpinning the overarching Integrating Indigenous Priorities in Spatially Enabled Planning of the Indigenous Estate project, that is:

- How can Indigenous Data Sovereignty underline key principles in a bottom-up GIS project?
- How can cultural layers of spatial data relating to community concerns and priorities be appropriately included in Indigenous-owned GIS systems?

The thesis showed that, in spite of the limitations detailed later in this chapter, Story Maps are an appropriate and useful medium to operationalise sovereign geospatial data held by the ALC. The process of working with the Data Unit (Mamarika and Bara) to co-create the Story Map has contributed to level power dynamics that have been established and perpetuated through the settler colonial project by following a methodology which integrates Anindilyakwa and Western ways of knowing and doing.

The research offers a rich and original first-person account of what genuinely collaborative, decolonising, community-led research looks like in practice. The project described here is itself an example of Indigenous Data Sovereignty and Indigenous Data Governance principles. It is a decolonising act that resists eliminative narratives and practices perpetuated through the settler colonial institutions by making Indigenous knowledge visible. As such, the chapter documents and examines the transformative possibilities and challenges associated with the co-creation of Story Maps that respect Anindilyakwa Data Sovereignty and Data Governance, with all data and the Story Map itself are wholly owned by the ALC.

This is one of the first Story Maps created by, or at the request of an Indigenous group, using fully Indigenous-owned and housed data, created exclusively within that group's software licensing, for the express purpose of preserving culture and cultural knowledge.

The chapter is structured around the key contributions emerging from the thesis. It presents the conceptual anchors that shaped her research: settler colonialism, Indigenous Data Sovereignty and Governance, and community GIS; her methodological innovations, the ethics and governance structure of the project, the fieldwork itself, and finally the co-created Story Map that emerged and the community response to it. The chapter concludes with a reflection on what this project reveals about best practice in collaborative Indigenous research, with specific relevance to the CRCNA's objectives in northern Australia.

3.2 Literature Review

3.2.1 The exclusion of Indigenous peoples from data collection, analysis, and ownership

In the top-down Indigenous policy space, there is a readily accepted and often unexamined assumption that numbers, in the form of data, statistics, and quantitative assertions, express truth (Fogarty et al. 2018; Morphy 2016; Fforde et al. 2013). The creation and application of relevant data by governments and other institutions is said to be a 'vital precondition for devising adequate

policy responses" and '[monitoring] the effectiveness' of said policy measures (Davis 2016, p. 25). There appears to be an inherent trust in quantitative analyses and a trust that the information surmised from data will be applied by governments and institutions to overcome inequity and the impacts of 'historical' discrimination (Davis 2016; Kukutai & Taylor 2016; Lovett 2016). Many Indigenous statistics serve settler colonial states like Australia by justifying actions and interventions in Indigenous lifeways which are touted as evidence-based and supported by statistics, but which in practice cause harm and a continuation of settler colonial damage (Jelfs 2016; Lovett 2016; Walter & Anderson 2013).

The significance of numbers and data is suffused through the settler colonial project, in policymaking and in public communication, as well as in more subtle ways. Consider for example Section 127 of the Australian Constitution, which stated (from 1901-67) that 'in reckoning the numbers of the people of the Commonwealth…aboriginal natives shall not be counted' (as cited in Taylor 2016: 206). The phrasing of Section 127 and its inclusion in the Constitution - Australia's document of nationhood and democracy - evinces the importance of being counted or discounted in the settler state, especially given that the census is a central tool of government for the allocation of resources (Snipp 2016). While Section 127 was repealed following the 1967 referendum, its existence speaks to the narrative of elimination that the settler colony asserts against Indigenous peoples.

This kind of aggressive and obvious discounting is not necessarily present today. However, data and numbers tend to document a prevalent discourse of difference, deficit, and dysfunction in Indigenous peoples and communities, known as the deficit model (Walter & Suina 2019; Fogarty et al. 2018; Morphy 2016; Fforde et al. 2013; Walter & Anderson 2013; Fforde et al. 2013). The deficit model describes how the explanation for persistent socio-economic differences between cultural groups in a population (such as Indigenous and non-Indigenous Australians) is posited to be a result of the 'values, behaviours, attitudes, and capacities' of the poorly performing group (Walter & Anderson 2013, p. 35). Fogarty et al. (2018, p. xi) assert that 'it particularly occurs when discussions about disadvantage become so mired in reductionist narratives of failure that [Indigenous] people themselves are seen as the problem'.

Deficit discourse has the effect of perpetuating race-based, pejorative, and patronising discourse and policy (Fogarty et Al. 2018). Statistics form a pillar of the deficit discourse, in that statistics are gathered which measure poor performance against education, health, social, and economic indicators (Hogarth 2017).

Yet what is not explicit is that the statistics being gathered seek to 'bring up' Indigenous people to a baseline acceptable standard which it is implicitly indicated that non-Indigenous people already function at (Pholi et al. 2009). The entire 'Close the Gap' campaign, as a flagship policy implemented expressly to improve outcomes for Indigenous Australians, is demonstrative of this, where 'success' is measured against predetermined and non-Indigenous ideals (Fogarty et al. 2018, p. ix; Fforde et al. 2013, p. 165; Pholi et al. 2009, pp. 9-10). Furthermore, data collected under the deficit model enhances stereotypes by quantifying ways in which Indigenous populations differ to non-Indigenous populations (for example, incarceration statistics being disproportionally higher). Reductionist narratives, quantifying stereotypes, and measuring success against non-Indigenous ideals provide circular explanations of inequality which conveniently exclude any other historical, political, cultural or social explanation - such as, for example, settler colonialism (Hogarth 2017; Walter 2016). In this way, data has immense power, because it helps to shape and uphold the narratives that are told about Indigenous peoples existing in settler colonial states.

The deficit model forms one sibling of what Kukutai & Taylor (2016, p. xxi) describe as a 'twin problem': a lack of reliable data (as aforementioned), and misuse of traditional knowledge. This second sibling, the misuse of traditional knowledge, contains dual elements: one being the extraction and exploitation of Indigenous knowledge, though, for example, biopiracy, wherein profitable pharmaceutical breakthroughs are achieved through pirating traditional and Indigenous knowledge of the medicinal properties of plants (Cottrell 2022; Klenk et al. 2017; Nordin et al. 2012). The other element, which I focus on in this thesis, speaks to methodology, wherein traditional knowledge and Indigenous methodologies are excluded from research and management processes (Lovett et al. 2020; Neale et al. 2019; Smith 2012).

The way data is assigned meaning is both representative and constitutive of power relations (Lovett 2016). Who decides the questions we seek to answer? Who decides and controls the ways in which we answer those questions? Who is advantaged and who is disadvantaged by these decisions? I ask these questions to draw attention to the way that power relations are inherent in statistical enquiry, particularly enquiry which follows standard scientific method. It is in this way that data has power: data collected in settler colonial states by non-Indigenous researchers is predominantly collected through settler colonial methodologies and interpreted and applied to uphold settler colonial power relations and governance structures (Walter & Suina 2019). The result is data which unreliably suggests Indigenous peoples are performing poorly, and ensuing policy which seeks to address gaps in performance, in a self-enforcing cycle (Hogarth 2017; Fforde et al. 2013; Pholi et al. 2009). The reason why policy which is informed by unreliable and deficit

data will never close the perceived statistical education, health, social, and economic 'gaps' is because the settler colonial project so violently disrupted Indigenous lifeways that the persisting structural impacts will never be amended under settler colonial logic or intervention (Lea 2020). The disruption that the settler colonial project brought to Indigenous Australia is rarely acknowledged in data collected, processed, and acted on by governments and institutions, and is strongly demonstrative of the invisible eliminative narrative that underpins settler colonial states, which I discuss below (Lea 2020; Wolfe 1999).

3.2.2 Settler colonialism and the narrative of elimination

Settler colonialism offers a distinct paradigmatic position from which to interpret and analyse relations between people and land (Veracini 2011; Freeman 2010; Barker 2009; Wolfe, 1999;). Wolfe was and Veracini is a seminal Australian writer in the settler colonial literature, and while their conceptualisations of settler colonialism have some differences, both writers present settler colonialism as distinct from other forms of colonialism and as providing an appropriate vocabulary with which to express the structural and ongoing impacts of colonisation in Australia. Colonialism refers to the act and structure of extracting value from Indigenous labour, whereas settler colonialism refers to the disentitlement and displacement of Indigenous peoples from their land then the co-opting and replacement of that land for settlers' own economic purposes (Veracini 2011; Barker 2009; Wolfe 1999). Australia is in this sense a settler colony, whereas, for example, British occupation of India was colonial. Not only is settler colonialism conceptually useful because it is distinct and more relevant to this thesis than the concept of colonialism, but it also has the scope to explain the ongoing, systemic, intergenerational impacts of invasion and subjugation under settlers on Indigenous peoples in Australia (Veracini 2011; Barker 2009; Elkins and Pedersen 2005; Wolfe 1999).

Settler colonialism establishes and embeds structural land- and place-based disadvantages and power dynamics, because the power of settler colonial states is expressed by controlling the relationship between land and populations of that land (Wolfe 1999). The displacement of Indigenous peoples from lands, which has occurred and is occurring across the world, is an active and targeted fracturing of Indigenous lifeways (Simpson 2017; Wildcat 2010). So, there is a genuine practical imperative to employ the settler colonial framework and understand its implications to promote better outcomes for people, for land (for Country), and for culture, because it is under this regime that relationships between people, Country, and culture have been ruptured. Eminent authors in the broader field this thesis is situated in and literature on which this thesis

directly builds on have employed the settler colonial lens (Williamson et al. 2023; Lafferty 2021; Potter 2020; Sandgren 2017; Russell-Mundine 2012; Foley 2003).

A key characteristic of settler colonialism is that invasion is a structure, not an event (Wolfe 1999). Settler colonialism cannot be understood as a singular event that occurred when the first European ships berthed on Australian shores, because this would place colonisation in the past, at a defined point on the timeline, and set it apart as something historical (Freeman 2010). It is true that, in Australia, settler colonialism began at a point in the past, but it persists into the present. The evidence lies in the continued acts of violence against Indigenous lifeways, those outright and those more concealed, in order to effect dispossession of land (Baker 2009). This leads to a second key characteristic of settler colonialism: the cunning part of its structure which veils its own existence and enables its operation in invisibility (Tuck & Ree 2013; Barker 2012; Povinelli 2002). Invisibility enables the settler colonial state to continue operating its mission to co-opt land and erase evidence of any prior existence within that land blamelessly and without explicit identification, for example, terra nullius (Barker 2012). This builds directly on such historical principles as the 'Doctrine of Discovery', which was used by European powers in early colonial times to justify limitations on Indigenous sovereignties across the world, yet which persists in contemporary law, policy, history, and consciousness (Miller 2019).

Settler colonialism is at its strongest when it is invisible and possesses a 'recurrent need to disavow' settler colonial acts, which works to conceal the 'actual operation' of settler colonial practices (Veracini 2011, p. 14). An example tying these two characteristics together is when colonial acts of violence, such as massacres of Indigenous peoples or the Stolen Generation, are in the past, and conceptualised as part of Australia's history. The rhetoric of such events being a 'chapter in our nation's history' (Rudd 2008) suggests that settler colonisation is over and that as a nation we move linearly forward and away from colonisation. What is never acknowledged is that colonial acts of violence are still perpetuated today, both visibly and invisibly, and the violence extends from physical through to epistemic (Baker 2009).

A way to frame and characterise said violence is through the logic of elimination (Veracini 2018; Blagg 2008 as cited in Anthony 2013; Banivanua Mar 2012; Wolfe 2006; Wolfe 1999). The logic or narrative of elimination is the key conceptual extract from the settler colonial literature I am applying to this thesis. It refers to the attempted total eradication of Indigenous people from their land and the replacement of Indigenous lifeways with (in the case of Australia) European lifeways, to enable colonial possession of Indigenous land (Wolfe 2006). Elimination is achieved through

“the breaking down of native title into alienable individual freeholds, native citizenship, child abduction, religious conversion, resocialisation in total institutions such as missions or boarding schools, frontier homicide” (Wolfe 2006, p. 388). While writing the previous sentence I began to create a mental checklist for Australia – each elimination strategy was ‘ticked off’. Then, to complete elimination, the settler colonial state attempts to replace eliminated peoples and landscapes with its own dominant memories, cultural stories, and histories. In this way, it seeks to replace Indigenous memory (Tuck & Ree 2013).

The narrative of elimination is told in a multitude of ways, an example already touched on being the first twin problem: the use of data and statistics to ‘bring up’ Indigenous people to an unacknowledged baseline standard - which is, of course, a European baseline standard. For example, health policy which aligns Indigenous people to a non-Indigenous standard assumes understandings of illness that accounts only for a definition of health which considers the body as a discrete physical entity (Heil 2003). However, in the embodiment of many Indigenous worldviews, health is constituted through sociality and connectedness (Heil 2003). Data and statistics in the health space can represent only discrete indicators, not sociality and connection, and hence, Indigenous markers of health and wellbeing are eliminated from representation in health policy. Other examples of elimination include the renaming of Indigenous places with western or anglicised words, evident in places on Groote Eylandt.

The reproduction and transmission of Indigenous knowledge over generations threatens the settler colonial project because such processes uphold the autonomy and integrity of Indigenous peoples and cultures, making Indigenous knowledge visible and therefore powerful. Hence, violence which fractures Indigenous knowledge transmission has a privileged position in hegemonic regimes like settler colonialism (Pérez 2019; Spivak 2015). The impacts of epistemic violence include the silencing of voices, gaps in ways to express oppressed-oppressive relationships, and the separation of knowledges and cultures (Anthony 2013). It is a violence which can bring the loss of spirit, self and the soul (Atkinson & Woods 2008). An example of epistemic violence in Australia is the attempt to eradicate Indigenous languages via missions during earlier colonial times, which took place to some extent on Groote Eylandt (Rademaker 2018). Epistemic violence is strongly related to the second twin problem described earlier, that of the misuse and purposeful disregard of Indigenous epistemologies and methodologies.

Groote Eylandt presents an unusual setting in the colonial history of Australia in that the first European people did not settle on the land until 1921, it was one of the first jurisdictions granted

land rights under the Aboriginal Land Rights Act (NT) 1976, and it is also still strongly influenced by state and federal structures, policies, and funding arrangements that perpetuate the settler colonial project (Altman & Markham 2015; Altman 1995, 2011). Similarly, the royalty dependency dynamic with the extractive manganese mining operation on the island and what the future of Groote Eylandt looks like once the mine closes is another operational arm of the settler colonial project. The settler colonial analytic assists in understanding distinct and spatially distinct impacts on Groote Eylandt and Anindilyakwa people by providing explanatory power through such concepts as the narrative of elimination. Settler colonial theory provides the vocabulary needed to explain the impacts of the disruption of culture and the replacement of tangible and intangible Indigenous lifeways with European lifeways.

3.2.3 Indigenous Data Sovereignty and Indigenous Data Governance

One decolonising act is to reposition data within settler colonial power structures. Rather than being the subjects of data which upholds the deficit model or having their knowledge extracted to be applied out of context, Indigenous peoples should own their data and effectively participate in data gathering and research. Williamson et al. (2023, p. 284) define Indigenous data as 'information or knowledge, in any format or medium, which is about and may affect Indigenous peoples both collectively and individually'. Barlo et al. (2021, p. 44) define Indigenous data in a complementary way as 'people's stories and life experiences and knowledges'. IDS and IDG have emerged over the past two decades in response to the unequal positioning of data within settler colonies. They operate in a 'recognition space' which positions Indigenous peoples as stewards and owners of their data rather than as subjects and emphasises relational over hierarchical methodologies (Wilks et al. 2018, p. 11). The goal of IDS is not to equate Indigenous data with non-Indigenous data but rather to develop and apply a framework for the management of data that aligns with Indigenous epistemologies (Rainie et al. 2017).

IDS refers to 'the right of Indigenous peoples to exercise ownership over Indigenous Data' (Williamson et al. 2023). IDS emerged as big data, open data, open science, and data reuse became embedded more firmly into research and institutional practices in the 1990s (Carroll et al. 2020). These approaches to data management increased the risk that Indigenous data could be mishandled and misappropriated, and it became clear that Indigenous data needed to be defined, collected, used, and stored in a way which aligns with and supports Indigenous lifeways (Carroll et al. 2020; Lovett et al. 2019; Rainie et al. 2017; Kukutai & Taylor 2016). IDS was codified through the 2007 United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) which

stipulates rights and interests in relation to data about Indigenous peoples, territories, and lifeways (Carroll et al. 2020).

Realising IDS means adopting IDS principles into data governance structures. IDG refers to 'the right of Indigenous peoples to autonomously decide what, how, and why Indigenous data are collected, accessed, and used' (Williamson et al. 2023, p. 284; Carroll et al. 2019; Rodriguez-Lonebear 2016). The CARE principles, developed by Carroll et al. (2020), prioritise value-based, relational data approaches as developed in IDS literature, within actual data governance structures. Enacting these principles leads to equitable outcomes by promoting equitable participation in data and research processes and expands Indigenous jurisdiction to 'non-geographically bound relational contexts, including digital environments' (Jennings et al. 2023, p. 1547; Williamson et al. 2023).

Collective benefit recognises that benefits accrue when "data ecosystems are designed and function to support (1) Indigenous nation and community use and reuse of data; (2) use of data for policy decisions and evaluation of services; and (3) creation and use of data that reflect community values" (Carroll et al. 2020, p. 6). Collective benefit seeks inclusivity to realise equitable outcomes.

Authority to control refers to the right of Indigenous peoples to determine governance protocols, to have access to data that supports self-determination, and to be actively involved in decision making around Indigenous data held by other entities.

Responsibility encapsulates the idea that researchers and data collectors have a responsibility to create and nurture respectful, and ideally reciprocal, relationships with the Indigenous peoples whom the data originate and may characterise.

Ethics asserts that Indigenous peoples' rights, safety, and wellbeing should be the focus across the data lifecycle to minimise harm, maximise benefits, promote justice, and allow for future use.

Further, principles should be determined by Indigenous peoples and based on community values, or at the very least, determined in collaboration between Indigenous peoples and researchers. The CARE principles emerge from and are couched within the related Indigenous methodologies field, which at the most general level, are 'alternative ways of thinking about research processes' (Louis 2007, p. 133). The principles of Indigenous methodologies, which are as varied as

Indigenous peoples and groups worldwide, retain commonality through four principles: relational accountability, respectful representation, reciprocal appropriation, and rights and regulation (Table 4).

Table 4: Integrating CARE principles and Indigenous methodology principles

IDS/IDG principle (Carroll et al. 2020)	Indigenous methodology principle (Louis 2007)	Similarities/linking themes
Collective benefit	Reciprocal appropriation	Reciprocal appropriation refers to the point that 'all research is appropriation' (Rundstrom & Deur 1999, p. 239) and stipulates adequate benefits for Indigenous people and the researcher, in the same way that collective benefit seeks inclusivity to realise equitable outcomes.
Authority to control	Rights and regulation	Rights and regulation 'refers to research that is driven by Indigenous protocols, contains explicitly outlined goals, and considers the impacts of the proposed research' (Louis 2007, p. 133), as the authority to control refers to the right of Indigenous peoples to determine governance protocols and be actively involved in decision making.
Responsibility	Relational accountability	Relational accountability means that researchers are responsible to the relationships they form during a research process, from beginning to 'end'.
Ethics	Respectful representation	To maximise benefits and minimise harm, researchers must practise 'humility, generosity, and patience' (Louis 2007, p. 133), and be sensitive to the purpose or intended audience of Indigenous knowledge.

There have been some early adopters of IDS, IDG, and the CARE principles, but this is an emerging field, especially in the applied space (see Lafferty 2021; Sandgren 2017; Taylor & Doran 2017; Potter 2016 for examples on which this thesis directly builds). Conceptually, the development of IDS and IDG is robust, especially when considered in tandem with the Indigenous methodologies, literature, which has been developing steadily over the last two decades. Given the gap between theory and application there is a need to operationalise IDS and IDG, gather and reflect on the insights generated, and take tangible action toward addressing the challenges of producing data to reflect the needs of Indigenous peoples. Carroll et al. (2020) emphasise the need for further research to explore the application of the principles.

Walter (2016) posits the idea of a ‘recognition space’ which allows Indigenous peoples to “speak back to the state” in a language of data and statistics that both parties understand and culturally respect (Wilks et al. 2018, p. 11). In the context of IDS and IDG, such a recognition space provides Indigenous people with an opportunity to engage with government processes and commercial avenues through being the stewards of their data (Wilks et Al. 2018). The geospatial space holds much potential in this area, in that there is a tragedy of the commons-like effect in Australia: Australian and state governments have undertaken spatial enablement programs in a top-down, centrally organised manner (also referred to as the Australian Spatial Data Infrastructure) (ANZLIC Committee on Surveying and Mapping 2024; Nairn et Al. 1999). The benefits of spatial enablement programs are rarely extended to Indigenous organisations, which tend to be small and under-resourced. Hence, Traditional Owners cannot benefit from geospatial data and analysis to the same extent that governments and other organisations can. However, there is increased uptake of geospatial data and GIS amongst Indigenous organisations, and a demonstrated desire that data reflects a relational rather than hierarchical or top-down approach (Wilks et al. 2018). The recognition space is growing, and spatial data is a key avenue of growth.

3.2.4 Geographic Information Systems and community GIS

Geographic Information Systems (GIS) are computerised systems used for querying, manipulating, analysing, and displaying geospatial data (Chang, 2019). More broadly, GIS can be conceptualised as a tool and field that is ‘both an expression and a part of a political process’ (Harris & Weiner 1998, p. 69). Those who use GIS manipulate data to create information that advances knowledge and informs decision making in a variety of academic and other contexts (Chang 2019). However, GIS is not and should not be seen through an only applied or a purely technical or objective lens (Harris & Weiner 1998). In fact, GIS can map narratives from the personal to the cosmological, and those who wield GIS as a tool are active in mapping such narratives (Howitt 2002).

The capacity for GIS to incorporate qualitative data and ontologically diverse forms of ‘data’ emerges because of the way GIS represents space. Many GIS models rely on interpretations of space and are inherently subjective (McHarg 1969). Subjectivity has been at the core of GIS since its inception in McHarg’s seminal 1969 work Design with Nature, which describes early GIS using light table overlays to create subjective but explicit rankings of input factors based on expert knowledge (McHarg 1969). Hence, in cultural applications of GIS, there lies an intersection between ‘data’, western scientific methodologies, and subjective interpretation at individual and

community levels, which is the space in which GIS can be utilised in Indigenous contexts. It is in this intersection that social and participatory GIS emerged and continues to develop. There are a number of names for this subfield in GIS: participatory (Moylan et al. 2009), bottom-up (Talen 2000), qualitative (Boschmann et al. 2014), and community-integrated (Harris & Weiner 1998). I use the term community GIS in this research as it aligns with terminology used on Groote Eylandt.

Community GIS can portray the unique spatial data that emerges from experience to represent cartographies of individual and group spatial narratives (Boschmann & Cubbon 2014). Community GIS is strongly influenced by qualitative research techniques, including approaches from feminist and decolonising literature, which recognise (1) that knowledge is situated and contingent, and (2) that appreciating differences in the experiences of individuals and groups provides opportunity for empowering and empowered research (Boschmann & Cubbon 2014), especially when qualitative processes are led by those voices which are being researched. The strength of community GIS lies in the process of 'revealing how perceptions and behaviour are grounded in space from research participants' standpoints' (Prener 2021, p. 269).

Community GIS processes allow representations of multiple ways of understanding relationships with space and are epistemologically distinct to top-down and quantitatively heavy data and GIS approaches (Prener 2021). Community GIS allows people to convey the character of a place or space and provides for spatial complexity and interconnections between the articulations of subjective viewpoints to be expressed and mapped (Potter 2016; Talen 2000). Howitt (2011, p. 133) calls for research 'that is situated, engaged, and based on the relationships and processes that occur in the lived experience of places', and the capacity of GIS to represent space qualitatively is one important way that such research may be carried out (Potter 2016). Community GIS is not a novel method, and the literature and applications have been developing since 1969. The way qualitative data can be incorporated into GIS is becoming more refined, especially in the Indigenous space, as demonstrated in the following section.

3.2.5 Operationalising IDS and IDG through GIS

The development of community-based, Indigenous GIS over the last two decades has proven valuable in the actualisation of IDS and IDG principles, and in considering Indigenous peoples and groups as legitimate end-users of data for Indigenous-led decision-making and development (Williamson et al. 2023). Indigenous GIS is a way of transmitting knowledge that arises from and is embedded in physical and cultural landscapes (Brown & Nicholas 2012). Indigenous GIS can

support cultural resource use and management, be used as assertions of rights and interests over Country and produce important stories about relationships to landscapes (Williamson et al. 2023; Moylan et al. 2009;). The reason GIS is suited to these purposes is because of its capacity to integrate with Indigenous knowledge systems that operate on oral and visual bases, and to display information in layered or tiered approaches (Corcoran & Baker, 2017). A tiered representation of landscape, as tends to be developed in GIS (Chang 2019; McHarg 1969), aligns with Indigenous epistemologies, which also tend to be revealed through hierarchical, gendered, or experiential layers (Williamson et al. 2023).

There are critiques within the literature to the integration of Indigenous knowledges and GIS, which arise from the understanding of how there are power imbalances present when data and technical processes are applied to Indigenous knowledge. Rundstrom (1995), for example, notes that maps reflect and reinforce the cultural values of those who make them. This means that the position of the map maker needs to be taken carefully into account, and contextualised. Map-makers have supported settler colonial dispossession of land globally through maps, so as a mapmaker myself through this thesis, I need to reflexively consider how I make and co-create maps, for what purpose, whose interests are represented, and the kind of institutional power I represent as a researcher (Russell-Mundine 2012; Crampton 2001;). Similarly, a map being multi-layered or visually representative does not in itself mean it is aligned with or reflective of Indigenous lifeways and there are limitations to representing subjective experiences (Hart & Homsy 2020; Brown & Nicholas 2012). Methodological and creative design choices therefore matter. When Indigenous GIS is undertaken poorly by or with non-Indigenous researchers, there is a risk that the output will simply be another attempt at assimilating Indigenous knowledge (through Indigenous data) to western positions or be extractive (Williamson et al. 2023; Hart & Homsy 2020; Syme 2020; Rundstrom 1995). However, these critiques are not insurmountable. It is imperative to ensure that (1) mapping outputs reflect and reinforce cultural values in a context-driven manner, and (2) the GIS or spatial representations created are meaningful and not a perpetuation of settler colonial activity (Potter 2016). In doing so, it must be ensured that Indigenous GIS projects are handled with care, and with CARE (Williamson et al. 2023; Carroll et al. 2020).

Indigenous GIS projects which promote equitable participation and value-based relationships are being conducted in Australia. The space is emerging but there are notable examples, such as how Yawuru people in Broome developed GIS as assertions of rights over land and as ways of managing cultural heritage (Potter et al. 2016; NBY 2014). The development of a cultural values model on Arakwal Country and a spatial database is another significant example of the

operationalisation of IDS and IDG (Lafferty 2021). Dja Dja Warrung include improving GIS capability in their 20-year management plan to inform decision-making and store traditional knowledge (DBW 2014). The following section presents a meta-analysis of the literature in this emergent niche, to demonstrate how this project is uniquely positioned at the forefront of operationalising IDS and IDG in the GIS space by exploring a novel way in which Indigenous peoples can be stewards of their data.

3.2.6 Story Maps and meta-analysis of Indigenous spatial data projects

Story Maps are unique in the GIS space because they combine maps and the process of mapping, which have the power to make visible things which may be hidden, with storytelling, a process whereby people convey experience, knowledge, and intangible meanings and values (Hart & Homsy 2020). Collaboratively integrating narratives and landscapes within Story Maps constitutes a form of digital storytelling and allows for stories to be told in layered and spatialised ways which often support community building (Hart & Homsy 2020; Davis 2011). Digital stories that are created with a humanistic approach (such as story mapping) can mediate between individual experience and collective memory, while situating knowledge within spatial and temporal contexts (Marshall et al. 2022; Kwan & Ding 2008). In this way, Story Maps are uniquely situated to offer significant potential for use in Indigenous contexts, where landscapes may be read as libraries which harbour not only collective memory but collective knowledge (Colloff 2020). The ability to spatially represent collective knowledge, as told by an individual with the responsibility of holding that knowledge, with the support of multimodal non-spatial elements is deeply aligned with the relational, visual, and oral nature of Indigenous worldviews and knowledge-sharing (Syme 2020). Indeed, this is why the ALC was interested in developing and testing a Story Map with community.

The Table 5 below is a representative summary of recent studies of Indigenous spatial data projects that generated a map-based digital storytelling product.

Table 5: Meta-analysis of Indigenous spatial data storytelling projects

Project	Researchers	Indigenous participants	Method of sharing data with participants	Was the geospatial data returned/ handed to participants after project completion?	Was the geospatial owned and housed by community?
Indigenous Virginia Digital	University of Virginia	Monocan Indigenous	Informative consultation about	Yes. Participants retain their story	No

Storytelling Projects (Kasey & Roach 2021)	researchers and students	community members	university archival material and oral stories	and access to Story Map	
Social Sciences and Humanities Research Council (RSLMA n.d.; Pyne et al. 2022)	Social Sciences and Humanities Research Council and Shingwauk Residential Schools Centre	Indigenous peoples as represented by five different organisations	Engagement during creation	Yes. Stories were handed back once created.	No
Mapping Indigenous LA (UCLA 2024)	University of California researchers	Indigenous youth, community leaders, and Elders in LA	Informative consultation about university archival material and oral stories, engagement during creation	Yes. Stories are handed back once created (and are publicly accessible)	No
Visualizing the Cherokee Homeland through Indigenous Historical GIS (Kirk 2013)	University of Kansas Masters student	Cherokee Nation community members	Engagement during creation	Yes. Once completed it became property of the Eastern Band of Cherokee Indians	Yes (post completion of researcher's project)
Indigenous Pennsylvania: Past, Present, and Future (Gilsoul 2022)	Gettysburg College Honours student	N/A	Engagement during creation	Yes. Story Map is publicly available	No
Cherokee Landscapes (Townsend et al. 2020)	Illinois State University	Eastern Band of Cherokee Indians	Collaboration through creation	Yes. Product is publicly accessible	No
Aboriginal Tasmania Story Map (Anderson 2018)	University of Tasmania researchers	Four major Aboriginal community groups	Informative consultation about university archival material and oral stories, engagement during creation	Yes. Story Map is publicly accessible	No
Dyarubbin: Mapping Aboriginal history, culture and stories of the Hawkesbury River, New South Wales	University of New South Wales researchers	Members of the Darug Custodian Aboriginal Corporation and Darug community members	Collaboration through creation	Yes. Story Map is publicly accessible	No

(Karskens et al. 2022)					
Sarayaku: in defense of territory	CEJIL and the Amazon Conservation team	Sarayaku community	Engagement during creation	Yes. Story Map is publicly accessible	No

Many of these projects shared the data used by providing hard copy maps, or access to digital databases or living websites, to the Indigenous participants. However, there were no instances where, of their own accord, an Indigenous community or organisation undertook to generate Indigenous data through research partnerships, and the data produced was fully owned and housed by said community. This research and the Story Map we co-created has its genesis within an Indigenous organisation (the ALC); all the data created and used in the product is owned and housed by the ALC; and the creation of the Story Map itself was done through the ALC's GIS software licensing. Therefore, this research and the Story Map product are situated at the forefront of operationalising IDS, and I found no other project with a similar grounding in the literature.

3.3 Methodology and Research Design

3.3.1 Decolonising and Indigenous methodologies

Power dynamics are embedded in the research process, and there is no research free from bias (Evans et al. 2014; Sheehan 2011; Lavallee 2009). Much traditional, Western research undertaken and the knowledge generated from said research reflects dominant colonial systems and is often used to uphold and perpetuate these systems (Kukutai & Taylor 2016; Bainbridge et al. 2015; Smith 2012). Decolonising and Indigenous methodologies, which are different but closely entwined, are paradigmatically distinct research praxis approaches and active ways to respond to colonization (Chalmers 2017; Country et al. 2016; Evans et al. 2014; Smith 2012; Howitt 2011).

Decolonising and Indigenous methodologies are as complex and layered as Indigenous lifeways themselves (Evans et al. 2014). The immutable commonality between the two praxis approaches is that both centre and revitalise Indigenous ways of knowing, being, and doing in an explicit way, and alternative to Western positivist scientific methodologies (Evans et al. 2014; Smith 2012). The location of knowledge within and emergent from the networks of relationships that comprise the world and the self is inherent within these methodologies. Knowledge is relational and context-based, rather than separate, universalised, and objective as it is in colonial systems (Kwaymullina 2016).

Centring Indigenous lifeways and knowledge in the research process is a decolonial act because the process itself insists on addressing power relations (Barlo et al. 2021; Evans et al. 2014; Leeuw et al. 2012). Undertaking research using a decolonising methodology allows space within academia for recognising ways of producing and holding knowledge that are uniquely Indigenous, such as through traditional relationships, local practices, and storytelling (Botha 2011; Lavallée 2009; Belanger 2001). Purposefully constructing projects which are bound by and centre Indigenous knowledge, but also operate within mainstream research spaces, works at equalising power relations between dominant Western ways of doing and Indigenous ways of doing (Botha 2011). The equalisation occurs as a result of the respectful relationship which is built between the researcher, the 'researched', and the data (Barlo et al. 2021; Evans et al. 2014; Sheehan 2011).

In fact, the building of respectful relationships during an Indigenous research process is the "only way" to engage with cultural knowledge, and speaks to the emergent, relational nature of Indigenous epistemologies (Barlo et al. 2021, p. 43). This is how bias emerges in research, because these relationships include a researcher's understanding of and relationship with the power structures, they may be embedded in, and by which they may be influenced. Engaging in Indigenous research means taking accountability as a researcher, and interrogating the deep ways in which bias may impact the ways you can create a safe space for knowledge to be shared (Barlo et al. 2021; Bourke 2014; Moreton- Robinson 2013). There is vulnerability to developing a relationship. And yet, from this vulnerability comes strength, the development of trust, and the emergence of knowledge and a research process - distinctly apart from traditional scientific methodologies - that can empower and change individuals, communities, and institutions alike. As Dei (2000, p. 128) states, 'small acts' are cumulative and significant for social change. The collaborative production of the first Anindilyakwa Story Map and how that process provided the story for this thesis is a 'small act' and is based upon key principles of decolonising research including reciprocal appropriation, relational accountability, and respectful representation (Louis 2007).

3.3.2 Ethical research

Undertaking ethical research is a tangible element to the imperative of addressing power imbalances between Indigenous peoples and researchers (AIATSIS 2020; Kwaymullina 2016). Hence, an important part of the research design process was gaining ethical approval. Formal ethical review and clearance for this thesis was sought through the Australian Institute for Aboriginal and Torres Strait Islander Studies (AIATSIS), as a variation to an existing approval for

the ANU Grand Challenge project entitled Mapping a New Path (MaNP). The AIATSIS approval reference is EO226-20200000 and the corresponding ANU Human Research Ethics Committee reference is 2020/498. MaNP is designed to facilitate the need for communities to exchange ideas and skills and operates on the proven basis that mapping is an effective and inclusive way for Traditional Owners to share their knowledge about physical and spiritual landscapes to identify community goals, opportunities, and areas of collaboration (Doran 2024). An executed Research Collaboration Agreement also exists between the CRCNA, the ANU, and the ALC.

A major administrative delay in the AIATSIS ethics approval process, beyond the control of my supervisor and I, meant that clearance was not received until 1 May 2024, twenty-three days prior to the original submission due date of this thesis. The first two field trips I took to Groote Eylandt were therefore consultative in nature and I did not collect primary data, instead focusing on building my relationship with the Data Unit in alignment with the responsibility and ethics CARE principles (Carroll et al. 2020). I was able to collect primary data and undertake interviews with community members on the third and final field trip, delayed until the first week of June. Timeline of meetings, field trips, and ethics approval process is presented in Figure 14.

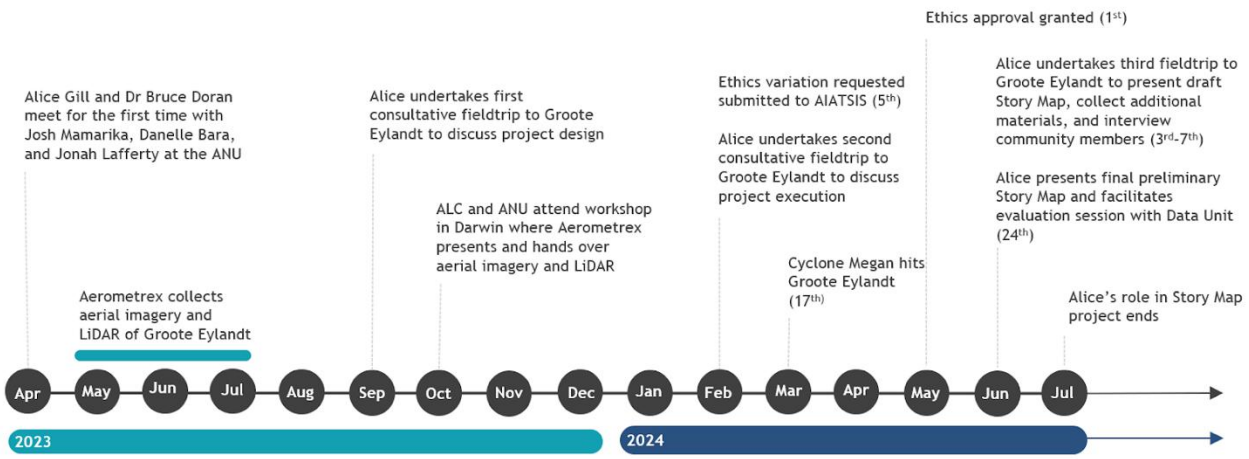

Figure 14: Timeline of meetings, field trips, and ethics approval process

3.3.3 The Mebina Framework

This research adapts Absolon's's Petal Flower model of Indigenous methodologies, as a framework by which to guide and describe the research design and process. The Petal Flower is a metaphor encapsulating the diverse methodologies and journeys which occur in Indigenous research processes, without being prescriptive or formulaic (Absolon 2008). Chiefly, the Petal Flower is significant and mimics Indigenous worldviews because: its components are interrelated

and interdependent; it is ‘earth-centred’ and holistic; it is cyclical and changes with the seasons; and finally, it has spirit and life, as it is of Country (Absolon 2008, p. 96).

The non-prescriptive yet encapsulating metaphor which the Petal Flower provides resonates with the Indigenous and decolonising methodologies that inform this thesis and provided a way to operationalise the CARE principles (Carroll et al. 2020). However, I wanted the framework to be more reflective of specific Anindilyakwa context and represent more strongly the non-linear process that emerged during the Story map co-creation process. The notion of retaining a core idea, which is continually circled back to and revisited over time and with maturity to eventually bring new insights, describes well the process that we undertook. I have therefore adapted the Petal Flower Framework, becoming the Mebina Framework, to better inform my approach by:

1. Combining the centre and petal elements into one;
2. Reordering some of the elements and their descriptions to better suit the context on Groote Eylandt and more closely resemble the research process we undertook; and
3. Changing the flower to a wattle, which is native to and emblematic of Australia.

Mebina (Anindilyakwa for wattle), pictured in Figure 15, flowers in the *akilarrkamarika*/dry season (Groote Eylandt Linguistics 2010). *Mebina* does not have a centre surrounded by petals, as the North American flowers that Absolon takes her inspiration from do, but one combined central flower, which aligns exactly with the adaptations I made to the original Petal Flower. I chose to use it to represent the adapted framework and have labelled it accordingly in Figure 15.

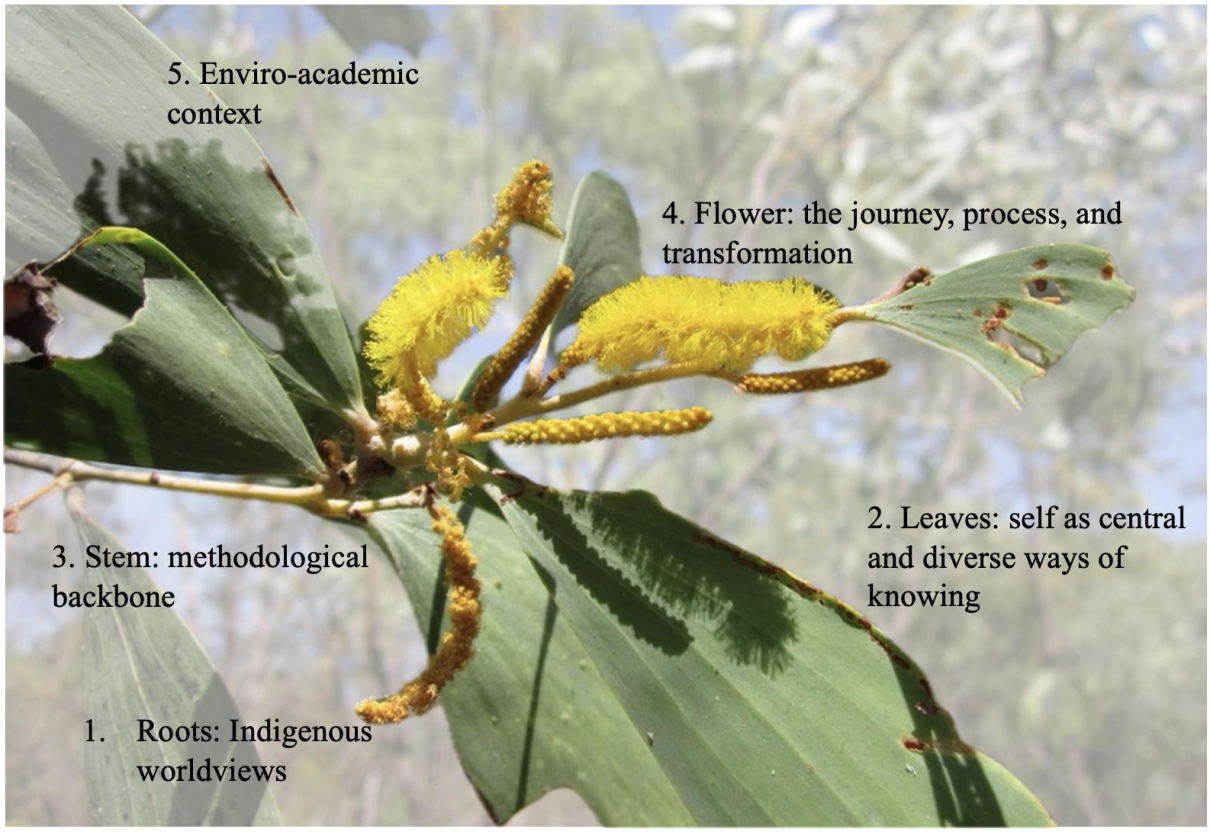

Figure 15: Mebina Framework, picturing Acacia difficilis on Groote Eylandt. Credit: Samuel Brown (iNaturalist)

The Table 6 below demonstrates the original elements and their description, how I have adapted them, and the justification and contextualisation for doing so.

Table 6: Meta-analysis of Indigenous spatial data storytelling projects

Petal Framework element and description from Absolon (2008: 98-100)	Adapted Mebina Framework element	Contextualisation of the adapted Mebina Framework in regards to this thesis
1. Roots: Indigenous worldviews "Indigenous research is a search for congruency with one's own worldview"	1. Roots: Indigenous worldviews	The process of creation of the Story Map, as well as the Story Map itself, are congruent with Anindilyakwa worldviews because they both were designed in collaboration with Anindilyakwa people. The decision-making of how to represent Country was led by Anindilyakwa people and Traditional Owners of Country.
2. Centre flower: self as central to research "Self is central to Indigenous research methodologies as Indigenous researchers recalled memories, motives, personal responsibility"	2. Leaves: self as central and diverse ways of knowing	The importance of the self emerged in the Story Map creation process as Elders who shared stories would bookend their storytelling by describing how it was (for example) their grandmother's story. There was no knowledge decontextualised from kinship, culture, law, story, or Country.

3. Leaves: the journey, process, transformation "The journey of the self through the research process"	3. Stem: methodological backbone and supports	This is why Chapters 2 and 4, which include analysis and critique of settler colonialism and its impact, are central to my argument and why my thesis has been structured in the way it has. This 'backbone' also provides and houses the IDS, IDG, and methodological principles underpinning this research.
4. Stem: methodological backbone and supports "The backbone of Indigenous research comprises a critique of colonialism, imperialism and of euro western research on Aboriginal peoples"	4. Central flower: the journey, process, and transformation	The way we designed and created the Story Map was through a series of circular processes. Each of the three trips I took to the island, we undertook essentially the same activity: sat down in a room, looked at a large map, shared stories, made tea, and talked. But each time this process was repeated there was greater trust and understanding, so by the third repetition of this cycle, the relationship was strong enough that we were able to communally execute our intentions with relative ease.
5. Petals: diverse ways of searching for knowledge "The significance of Indigenous language, culture, and traditions"	5. Enviro-academic context	Due to (1) the way in which this project was initiated by the ALC, who defined my role clearly as a 'technical consultant', and (2) progress within my research school and the ANU, thanks to work of many Indigenous and non-Indigenous people working in the space, that has opened up avenues where Indigenous research is supported and encouraged, the enviro-academic context for this thesis was holistically supportive.
6. Enviro-academic context "In many cases, the environment can be intolerant, harsh, chilly and antagonistic toward Indigenous research and methodologies"		

Ceding control

It should be noted that Absolon's Petal Flower is intended to 'connect Indigenous researchers, Indigenous research, and Indigenous methodologies' (Absolon 2008, p. 96). While I am not Indigenous, I have prioritised the use of Indigenous methodologies to conduct research; the Story Map product brief was created by the ALC; and Anindilyakwa community members and employees of the ALC have led decision-making on the objectives, scoping, design, data collection, and output of this research. I drew on a concept from Sheehan (2011, p. 77) on Respectful Design that describes how respectful research design 'authentically cedes ownership of methods in the interest of good human science'. A significant majority of research is defined by authoritative control, which is exercised by the researcher or institution in which that researcher operates (Absolon 2008; Louis 2007;). Opposingly, the creation of the Story Map was defined by me relinquishing my control of the project objectives, scoping, design, data collection, and output. This allowed the voice of Anindilyakwa people to remain centred as decision-makers and authorities of knowledge. The idea of ceding control also appeared in Absolon (2008), wherein she writes that community-driven and owned processes require researchers to relinquish power and control and display a degree of

humility, given that they are de-centring themselves from research. Neither Absolon nor Sheehan's papers reference the other, but my degree of confidence in this concept was significant after seeing that both were communicating the same idea in the same context of Indigenous research methodology.

Sheehan (2011, p. 77) further emphasises that 'best evidence arises from the researched when they maintain possession and control of their information, formulate and apply their own language for description and analysis, and engage authentically in ways that provide opportunities for new self-conceptions'. Through layers of decision-making and discussion over time about how and why a Story Map would work to tell stories, Anindilyakwa people engaged authentically in the creation process. This thesis in its whole was process-based as opposed to outcome-based, however, a process guided by respect and intention will tend to produce an output reflective of that process (Howitt 2011; Sheehan 2011). Process-based research which retains specific goals but leaves open-ended (and hence, unclear) pathways towards said goals can make researchers anxious, as it can resemble a loss of control (Absolon 2008). But control is not lost, it is relinquished, and in this thesis it was relinquished to Anindilyakwa people.

Fieldwork and the Story Map

Fieldwork was essential to the creation of the Story Map and was integral to realising all five aspects of the Mebina Framework. Funding for my travel was provided through a CRCNA grant via the ALC (AT.4.2223009 - Integrating Indigenous Priorities in Spatially Enabled Planning of the Indigenous Estate). All community members involved in the creation of the Story Map, who were not already employed through the Data Unit or Language Centre, were reimbursed for their time. The following section describes the meetings, workshops, and field trips, and the methods used to create the Story Map and collect the data needed for this thesis. The methods presented here under the title of 'Fieldwork' were co-designed, and both emerged from and responded to the ways that Anindilyakwa people think and work, and hence, were innately bound to place and people. Thus, the process we undertook to create the Story Map is representative of the relational and contextual ways that Indigenous lifeways are connected, whilst being grounded and bounded by the research principles and frameworks that I drew from the literature. Any Indigenous research guided by methodology not co-designed and situated in place does not align with IDS, IDG, and decolonising and Indigenous research (Evans et al. 2014; Smith 2012; Botha 2011; Belanger 2001; Lavallée 2009). Further, the data gathering methods described in this chapter are not

qualitative, they are Indigenous, which is paradigmatically distinct and is a decolonising act because it resists categorisation under western concepts (Lavallee 2009)

The creation of a Story Map, in our case, required collaboration between community storytellers, the story-mapmakers, and the social and physical elements of landscape. The stories which formed the Story Map emerged iteratively and with circularity through viewing, discussing, and storytelling, in formal and informal conversation settings. I describe the meetings we had off-island, then describe the trips on-island and semi-structured interviews, and finally how the Story Map was assembled.

Meetings and workshops off-island

My supervisor and I met with the ALC Data Unit initially and relatively informally in April 2023, when Jonah Lafferty (Data Unit coordinator), Joshua (Josh) Mamarika, and Danelle (Del) Bara (both Anindilyakwa) visited the ANU (Figure 16). This provided us the opportunity to meet each other and establish our relationship and was the first time we talked about story mapping together. There was one other instance where I spent time with the Data Unit off-island: in October 2023, when the ALC invited myself and an ANU postdoctoral fellow also working in this space, Dr Rachael Gross, to attend a two-day data workshop with Aerometrex in Darwin. The aerial imagery and LiDAR data collected by Aerometrex in July 2023 had been processed and was officially handed over to the Data Unit. Dr Sam Holt, the lead analyst from Aerometrex, suggested that the imagery captured is the best in the world of Groote Eylandt and is some of their highest quality data to date (S. Holt, pers. comm., 24 October 2023). In terms of this thesis the workshop in Darwin progressed the Story Map planning significantly as, led by Josh and Del, we were able to explore the +/- 3 pixel, 6 cm resolution imagery of the island, including locating turtles and crocodiles. Josh and Del finalised six locations on Mamarika Country (the eastern side of the island) to represent as stories within the Story Map through this imagery (Figure 19 - Figure **18**). Both meetings, each undertaken collaboratively and, where appropriate, led by Josh and Del as representatives of the Data Unit and Anindilyakwa people, were critical to building a shared conceptual understanding of the Story Map. Furthermore, they both provided opportunities for Josh, Del and I to develop our relationship in both formal and informal settings, directly aligning with best practice Indigenous and decolonising methodologies as well as IDS principles of relational accountability, respect, and responsibility (Barlo et al. 2021; Carroll et al. 2020; Evans et al. 2014; Sheehan 2011; Louis 2007). See Table 7 below for illustration of how this occurred.

Table 7: Examples of developing relationships in formal and informal settings

Setting	Analysis
Formal	During the Aerometrex workshop, an agenda item was present specifically for brainstorming locations on the island to include in the Story Map. This was led by the Data Unit, and as the researcher and Story Map technician, the results of the brainstorming session were directed towards me. We hence worked collaboratively to decide where these locations were and how we might represent them in the Story Map, with discussions occurring within the formalised context of the workshop agenda.
Informal	In the evenings, after the workshop had finished, I spent time walking around Darwin CBD with the Data Unit, having casual conversations, eating ice cream, and learning some Anindilyakwa slang words. While not immediately or obviously relevant to the creation of the Story Map, these kinds of occasions were in fact crucial, because they increased the levels of trust between (in particular) Josh and Del and me. In less formal terms, it was an opportunity for us to become more friendly with each other.



Figure 16: Alice Gill, Jonah Lafferty, Danelle Bara, Dr Bruce Doran, and Joshua Mamarika at the ANU, April 2023. Credit: Danelle Bara

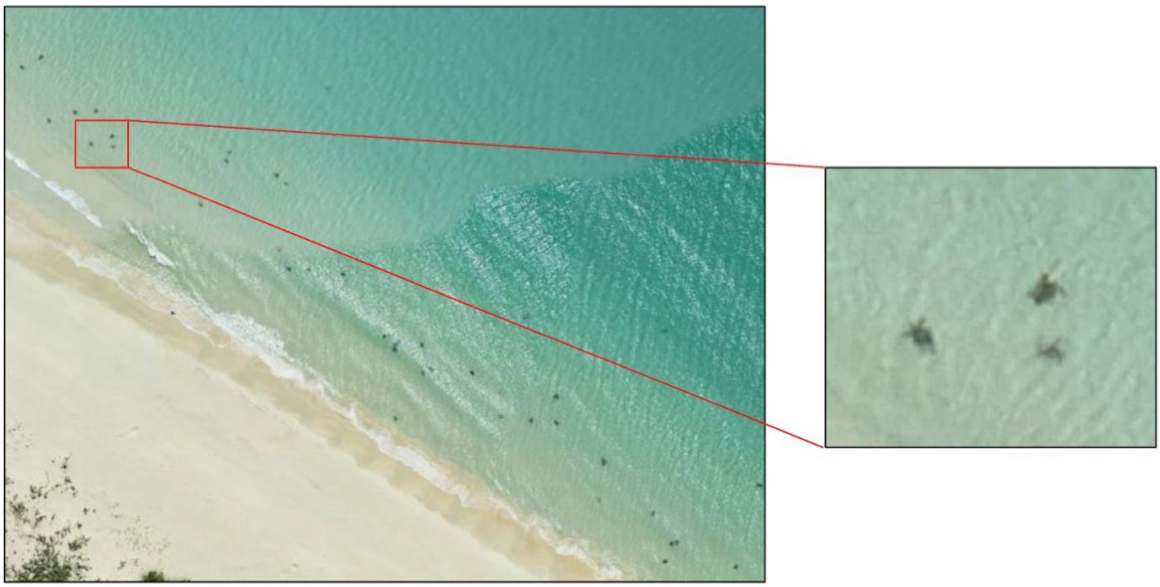

Figure 17: Aerial imagery of Groote Eylandt showing turtles/emenda which are approximately 50 cm wide



Figure 18: Aerial imagery of Groote Eylandt showing a crocodile/dingyarrbiya which is approximately 3 m long

Fieldwork on Groote Eylandt

While the meeting and workshop off-island were important, the most productive and important

moments in the development of the Story Map occurred when I was on-island. I travelled thrice to Groote: in September 2023, February 2024, and June 2024. The first two trips were consultative in nature as I had not yet received ethics approval. The third and final trip was postponed several times due to significant and unavoidable delays, including Cyclone Megan striking the island in mid-March (Perera and Morgan 2024) and the delay in ethics approval, but nevertheless proved to be pivotal and a true culmination of all the work which preceded it. I spent 4-5 days on the island each time, with the timing of each trip based on the availability of the Data Unit and including consideration of any cultural events to ensure my presence would not be an inconvenience.

The tangible elements of how each field trip unfolded remained relatively unchanged on each of the three occasions and generally followed an agenda equivalent to what is described in **Error! Reference source not found.** below. The intangible elements were the primary things which changed and progressed with each trip, which I realised when I reflected on the time spent co-creating the Story Map. In particular, the third trip truly demonstrated the Mebina Framework.

- Drive to Umbakumba (2 hours), where Josh and Del live and the Data Unit's office is located.
- Bring up the Aerometrex imagery of the island on the large television screen in the office.
- Move around the map to different parts of the island, focussing on the six locations identified by Josh and Del, and speak about them. The way the landscape was continually interacted with via the large screen formed the way that we collaborated *with* the landscape: it guided our conversation, was continually returned to, and remained the central point of connection. Whilst physically being on Country is important, the accessibility that the imagery afforded meant we were able to access conversations about place without necessarily being in-place.
- Invite any community members to join us. Visitors (and story-tellers) included a number of Elder women employed at the ALC Language Centre (also located at the Umbakumba office), respectfully and kindly known as the 'Old Ladies', relatives of Josh and Del, and key community members who are knowledge-holders, Traditional Owners, or *Jungai* (of their mother's Country) of a particular place and therefore authoritative.
- Show an example of a completed Story Map.
- Facilitation of any discussion which should arise organically: for example, Indigenous Data Sovereignty (which emerged through questions from community such as, who will have access to the Story Map?) and what my role is in the creation process (which I communicated as providing technical and coordination skills).
- Discuss action items and the plan for getting the Story Map created, which involved delegating tasks between the Data Unit and I. For example, after my second trip, it was the responsibility of Josh and Del to collect and write down a story about one of the six locations (see Figure 24).

The large screen in the Data Unit office was integral to our process because of the opportunities it provided for engagement over images, which was most often the aerial imagery of the island.

Visual stimuli position people to view, understand, and relate together (Sheehan 2011). The photos below are intended to help visualise the collaborative process of how the Story Map was developed conceptually but are also important for illustrating how the research methodology and Story Map co-creation process occurred (Figure 19 - Figure **24**).



Figure 19: Josh and Del navigating the aerial imagery during the Darwin Workshop. Credit: Alice Gill

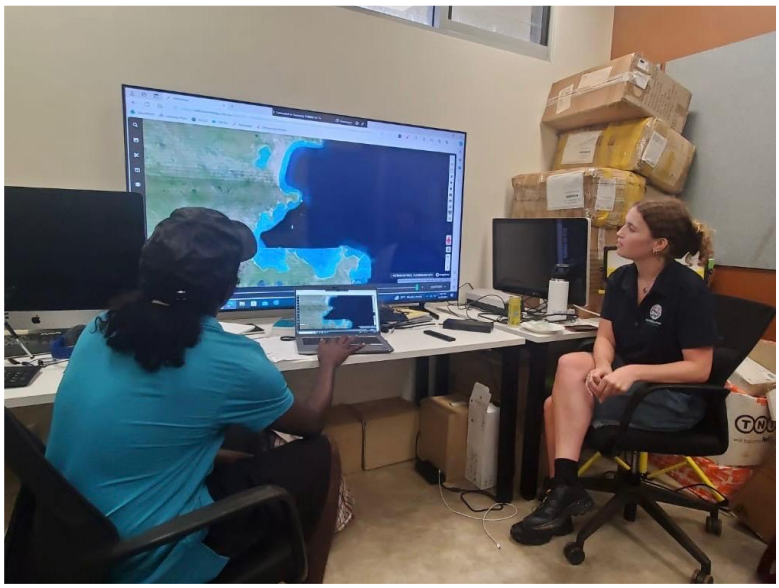

Figure 20: Josh Mamarika and Alice Gill looking at imagery in the Data Unit office. Credit: Gwendolyn Withrow



Figure 21: Showing an example Story Map. Credit: Thales Belasco



Figure 22: Showing Constantine Mamarika a 3D model while he shows photos from his helicopter flight to the same place. Credit: Jonah Lafferty



Figure 23: Josh talking with Millie and Colleen Mamarika about the Story Map locations. Credit: Jonah Lafferty

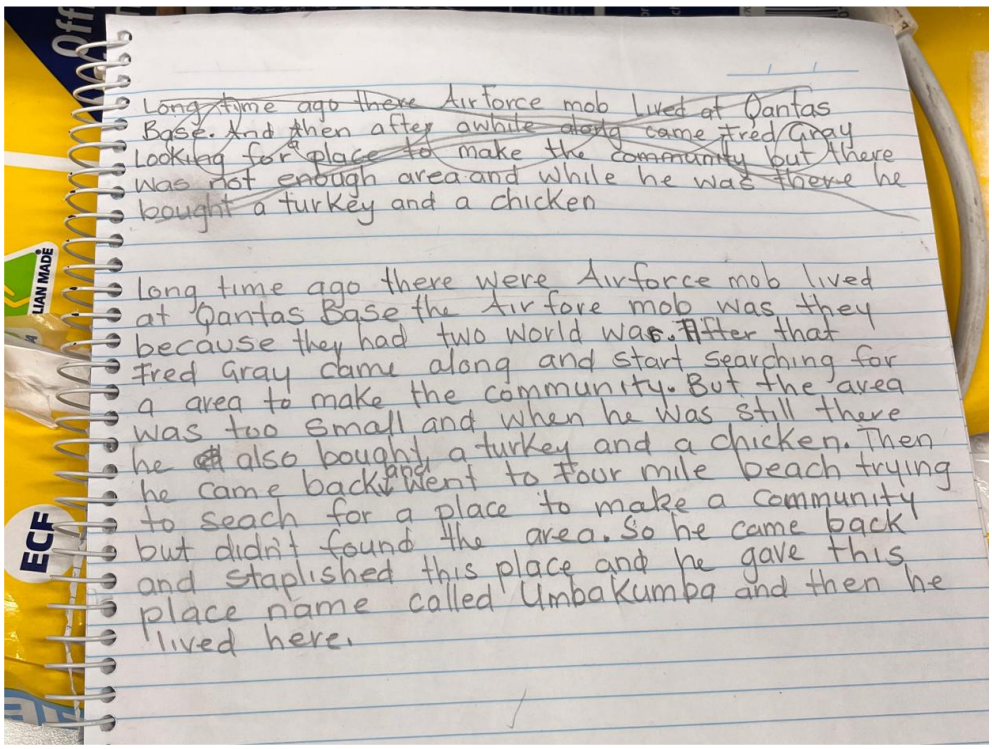

Figure 24: Josh talking with Millie and Colleen Mamarika about the Story Map locations. Credit: Jonah Lafferty

Primary data collection: semi-structured interviews

Important to assisting me in answering my research questions, I undertook semi-structured interviews with several Anindilyakwa community members who had contributed to the Story Map creation process. Semi-structured interviews were an appropriate choice of method as they are flexible, can respond easily to emergent themes, and are often integrated with cultural values mapping exercises (Potter et al. 2016; Partington 2001). While I had intended to undertake these interviews on the third field trip (after receiving ethics approval), it was clear that they would have occurred whether I initiated them or not. One senior community member, Constantine Mamarika, who provided two stories, initiated his own evaluation of the usefulness of the Story Map unprompted by me. I took advantage of the organic nature of our conversation and sought verbal consent from him to record his answers. He was immediately affirmative, and we had a conversation analysing how and why the Story Map is useful and some of its limitations.

Assembling the Story Map and examples of the ALC's geospatial data

There are 4 elements or 'ingredients' to the Story Map we created which I have listed in Table 8, along with descriptions of how they were used in our process. Combining them together resulted in the final Story Map.

Table 8: The 'ingredients' of the Story Map and how they were used

Story Map Ingredient	Comments and limitations
Maps, including aerial imagery and 3D data models of the six selected locations	It should be noted that the aerial imagery takes some computer processing power and a good internet connection to load fully in the Story Map. One issue arose: the 3D models utilise GDA2020 georeferencing and the Story Map software uses WGS84. This meant that, to have the 3D data included in the Story Map with a basemap, the 3D models would need to be transformed. This requires a level of skill in GIS and processing power within computers and should be noted as a limitation in operationalising the datasets.
Narrative text	Lavallee (2009: 28) describes how "the gathering of stories explores lived experience and can be defined as existential phenomenological inquiry", which justifies how stories were gathered in this Story Map to support cultural preservation. Narrative text was collected on-Country. The contributing story tellers spoke the stories out loud while I recorded and transcribed the words verbatim. Permission was sought each time I transcribed a story. The text was then copied into the Story Map and formatted for readability.
Multimedia, including photos, videos, and audio	The ALC Language Centre provided several historical images of the Umbakumba and Qantas Bay areas. Additionally, Josh, Del, and other collaborators were keen to document the work both on and off the island, which was made easier through smartphones.

Intuitive and appropriate design	I made several conscious design choices based on how Anindilyakwa would use the Story Map, the main being using the 'self-guided map tour' function. This choice was justified over the 'guided map tour' and linear 'sidecar' options, which allow for greater media incorporation but provide less accessibility, choice, and freedom in exploring the map. I felt that the intended Story Map users would benefit most from a non-linear and self-guided explorative journey even though the trade-off was reduced media capability.

To create the Story Map, Josh and Del were responsible for collecting the narrative text (the six stories) and multimedia elements, while I was responsible for the integration of the maps and 3D models into the Story Map software and the functional design. A few days into the final field trip, I was able to present to Josh and Del a draft of the final product. Del and I edited the map in-situ, for example by changing the formatting of the sentences to make it easier for Anindilyakwa people to read, and Josh was persistent in collecting multimedia elements (including an Anindilyakwa song) and gaining the respective cultural approvals needed to include them. By the end of this field trip, the three of us had a clear understanding of how the final model would look and I had a clear brief to work to, to finalise the Story Map in its preliminary form in the weeks following this trip. The following two figures are screenshots of the aerial imagery of Groote Eylandt which was used as a key visual stimulus and focus point during meetings with community members.

The following six figures are screenshots of a small area from each of the six locations that were made into a 3D model by Aerometrex for representation through the Story Map (Figure 25 - Figure **30**). Users can engage with the model by zooming in and out and panning around to explore the high-resolution representations of Country. The 3D models were created from the LiDAR data with vertical accuracy +/-30 cm and horizontal accuracy +/-30 cm.



Figure 25: 3D model of Umbakumba



Figure 26: 3D model of Yabangumanja / Alyimberrma / Qantas Bay showing the old jetty



Figure 27: 3D model of Dingala / Red Sands



Figure 28: 3D model of the place originally identified as Marungkala



Figure 29: 3D model of Angwurrburna / Emeda / The Lakes



Figure 30: 3D model of Madurrungkwamanja / Dalumba Bay / Turtle Beach

The following three screenshots are of the Story Map itself, reproduced with permission (Figure 31 - Figure **33**). Currently the Story Map is published internally to the ALC only and not accessible to the public. These screenshots do not show the functionality of the Story Map and are intended to be representative only. The timeframe of the Honours year did not allow for presentation and analysis of the Story Map to the wider community.

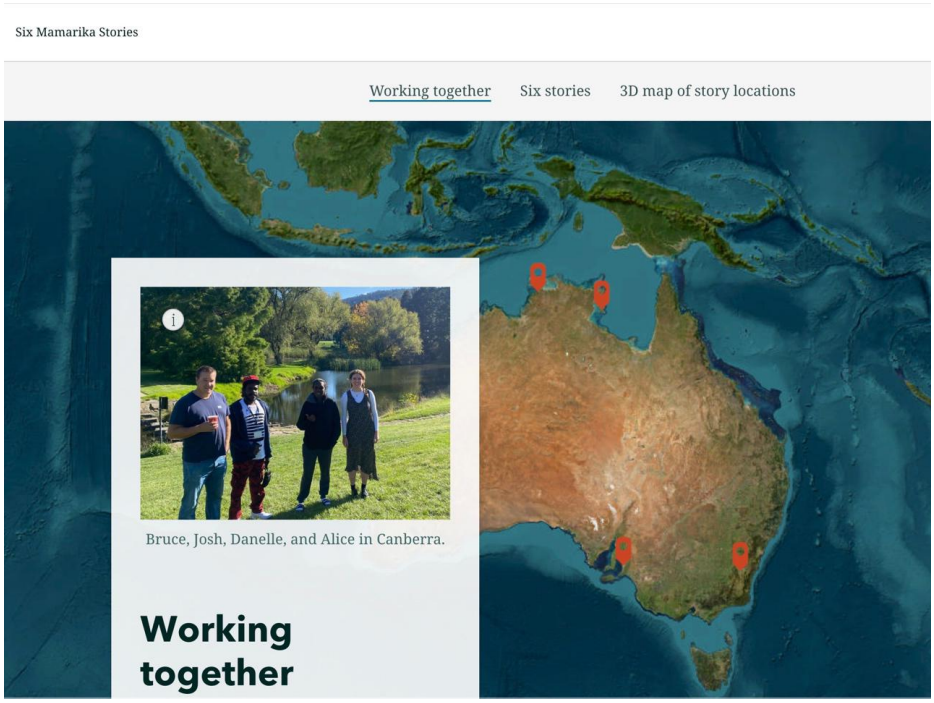

Figure 31: Screenshot of the introductory section

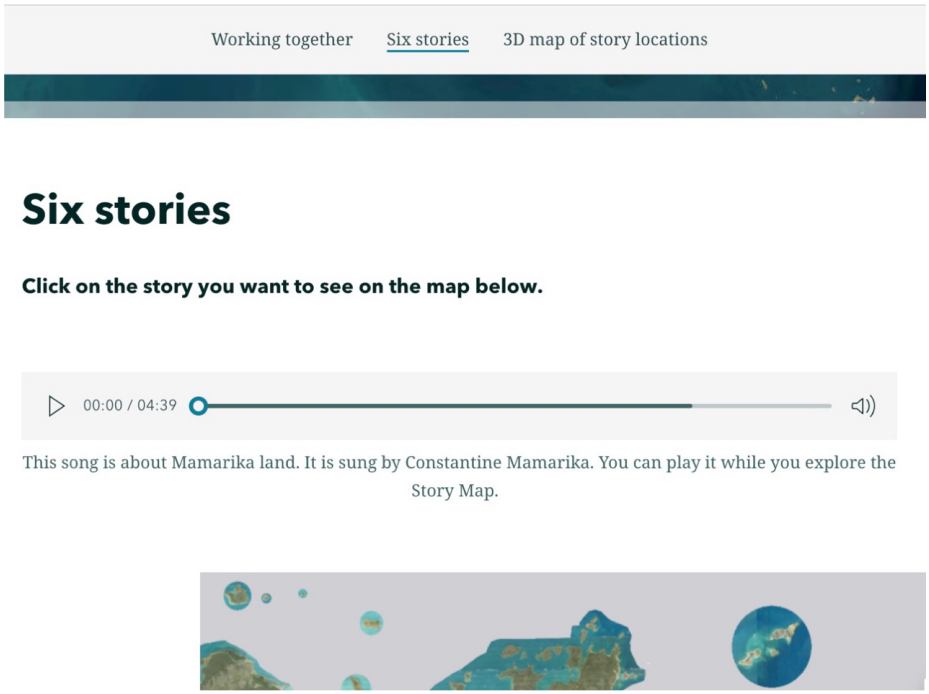

Figure 32: How the main Anindilyakwa music file has been implemented

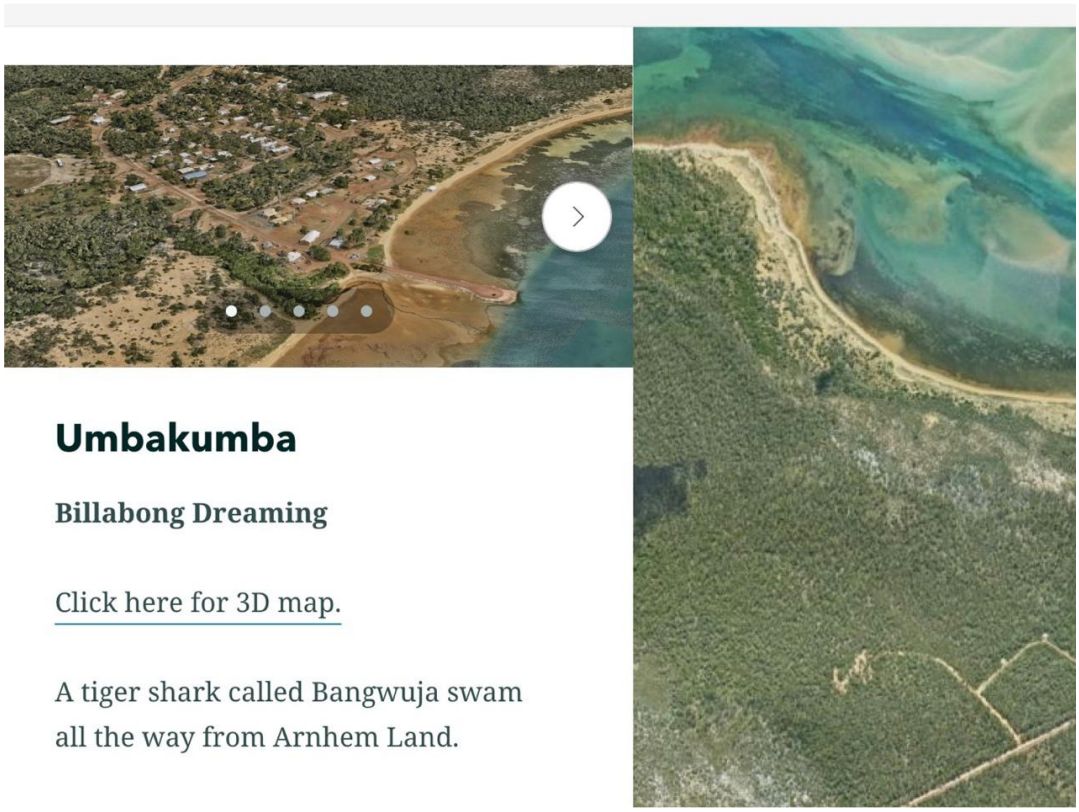

Figure 33: One of the six stories. Users scroll down to read the text on the left, while the map is on the right. There are five images against each location. Users navigate to the 3D model by clicking the hyperlink

3.4 Discussion

> ‘Young people need to know this story for the future…to keep the culture strong!’ (Constantine Mamarika)

This chapter addresses my research questions by analysing how the ALC has used its sovereign geospatial data to preserve and transmit cultural knowledge through creating a Story Map. In the first section I argue that Story Maps are useful and culturally appropriate media by which to place and share cultural knowledge. In the second section I reflect on the Story Map creation process to assert that, when there is time and funding available, it is possible for Indigenous groups to work with researchers in ways that produce genuine benefits to both parties and are decolonising acts. I conclude this chapter by assessing the limitations of our research process and avenues for future research. This thesis has explored a novel way in which to work with Indigenous groups through the co-creation of a Story Map in a manner that may not have been done previously in a research setting. I use boxes which relate the core aspects of the Mebina Framework to the co-creation process, which demonstrate how the Framework (1) accurately and contextually describes the research process and (2) can be used to evaluate the outcomes of the research (Figure 34).

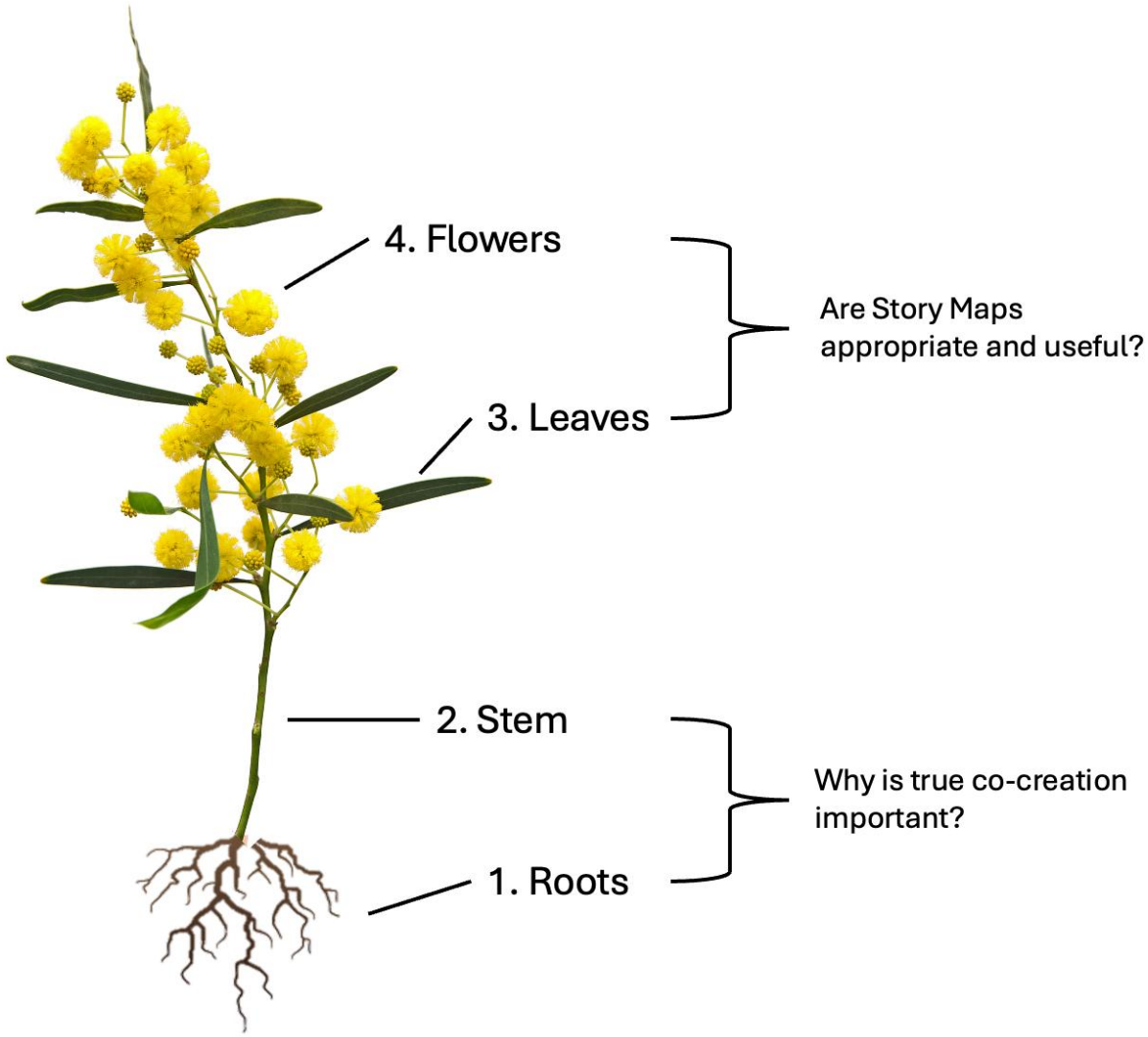

Figure 34: Integrating the Mebina Framework and the research questions

3.4.1 Are Story Maps appropriate and useful?

The roots: Indigenous worldviews

This element of the Framework underscores how Indigenous research must be congruent with Indigenous worldviews (Smith 2012; Absolon 2008). The co-creation process of the Story Map was by necessity congruent with Anindilyakwa worldviews in the following way: the kinship structure present in Anindilyakwa culture relates all people with each other, and with non-human elements of and within the landscape. This structure represents a relational web which connects all and provides specific roles and responsibilities that individual people hold (Bawaka Country 2016). In isolation, no one individual, animal, plant, or place holds the full scope of Anindilyakwa knowledge. However the relational kinship structure creates a collective responsibility of knowledge amongst

community, and this knowledge is gained often through familial, gendered, and experiential layers (etc.) (Williamson et al. 2023; Bawaka Country 2016).

Josh and Del did not know the stories of the six places chosen for inclusion in the Story Map, but they knew who did have those stories. The relational web was put into action when Josh, Del, and I followed up with the people they identified as having the appropriate knowledge. To illustrate the collective responsibility of knowledge, on the first day of the final field trip we spent several hours with Colleen and Millie Mamarika recording four of the six stories. Colleen and Millie said the final two stories were not theirs but were Constantine Mamarika's stories, and based on this advice, the following day we spoke with Constantine. He generously and happily provided the stories for which he retained responsibility. Hence, there was no way for the Story Map to be created except in such a way that was congruent with Anindilyakwa ways of knowing because of the collective responsibility for cultural knowledge, thus aligning exactly with the roots of the Mebina Framework.

The stem: methodological backbone

This element of the Framework asserts that the backbone of Indigenous research comprises a critique of colonialism (Absolon 2008). As established in the literature review, the core theoretical and methodological pillars of this thesis lie in operationalising IDS and IDG, which I assert are responses to the settler colonial project because they reposition power structures. These are powerful concepts, but in the geospatial space and especially in Australia, have not been richly tested. In response to the Social Indicators Report (Taylor et al. 2022), the ALC have undertaken to significantly increase their demographic and geospatial data capabilities. The aerial imagery and 3D data that Aerometrex produced at the request of the ALC demonstrates that the organisation, on behalf of Anindilyakwa people, has access to technologies that they are actively using to become spatially enabled. Not only was the collection of the data informed by cultural concerns but it is also the highest quality spatial data of Groote Eylandt in the world (S. Holt, personal communication, 24 October 2023), and it is completely owned and housed by the ALC. The ALC, therefore, is exercising sovereignty over its data, which is the definition of IDS.

Furthermore, IDG is defined by Indigenous people deciding 'what, how and why' Indigenous data is used, and was operationalised through the Story Map creation process. I was provided an ALC log-in for their GIS software licence, meaning that no ALC data ever left their systems during my involvement. The Story Map was created entirely in-house. All instances of ALC data appearing in

this thesis, which is an ANU-owned research output, were permitted by the Data Unit. Hence, Anindilyakwa people decided how their data was used through the entirety of this process.

In reference to the meta-analysis table in the literature review above, the Story Map was created using data owned and housed by the ALC, in response to a specific brief from the ALC, thus elevating this thesis more in line with IDS and IDG principles more than any project identified in the table.

Usefulness is an important metric to measure the Story Map by, because a product that is not useful has no purpose. Those best positioned to assess the usefulness of the Story Map are Anindilyakwa people themselves, hence I centre their words here. We decided early on that the target audience would be children so the Story Map could be used in school and Learning on Country programs.

> 'We got kids coming up, getting education, they need to know the history of what's in our island' (Constantine Mamarika).

There is anecdotal and statistical evidence that children on the island and across remote communities in the NT are not attending school at the same rates as older generations, which is leading to a decline in literacy and numeracy rates (Guenther et al. 2022; Taylor et al. 2022). Similarly, several Anindilyakwa Elders expressed to me with considerable emotion that children these days do not know histories and stories of culture as strongly. Josh told me, in reference to the Story Map, '*that's why we need the map*'.

> 'We need stories to remember our history and so we know for the next generation… So they know, the generation growing up, so when they go to the library or art centre, they can see the story in the walls' (Constantine Mamarika).

When asked if he thought the Story Map was a good way to tell stories, Josh said:

> 'Yes…because we put all the stories [together], I was getting information from the Ladies and the owners of that Country, and it is alright for the kids to hear and listen' (Josh Mamarika).

The Story Map may then be a useful template for transmission of cultural knowledge as not only does it align with Anindilyakwa ways of knowing, but it can also be adapted to suit the specific needs of the moment. It is not a static product and can be adapted and replicated in future. The ALC has inhouse data and technology capabilities through the Data Unit and in-house translation capabilities through the Language Centre, both of whom were involved in the co-creation of the Story Map and who have significant capacity to continue using such a product in future. But a strength of Story Maps is that they can involve the whole community, from concept to fruition: in the quotation above, Josh describes his own involvement as an emerging young member of community; the involvement of the Old Ladies; jungai (owners of specific parts of Country); and finally, children, demonstrating how expansively community can be involved. A further strength of the Story Map is that it provides the ability to visualise Country, within which knowledge is stored.

> 'The map is good so we can show which area, so we can mark the area, so they know which area we are talking about' (Constantine Mamarika).

Not only can the area be marked on the map, but it can also be engaged with via the 3D model, so Country may both visualised and experienced. The timing of the Honours year did not accommodate a community-wide evaluation session. However, I asked Josh if he thought community would like the map, to which he replied:

> 'They like it because I was doing this map and stories, and the ladies are pretty proud of the map. Constantine Mamarika, an Elder, was helping us putting all the names and stories. And yeah!' (Josh Mamarika).

In response to being asked what his favourite part of creating the Story Map was, Josh replied 'Sharing the knowledge'. This sentiment was demonstrated repeatedly throughout the entirety of the process from community, with insistence and passion. Josh's response (below) to the question 'Do you like the idea of a Story Map? Why do you like it?' again underscored this point: that the Story Map is a tool for preserving and transmitting Anindilyakwa culture.

> 'It is important for - that's why we're making this map - to live for the new generation, for the kids' (Josh Mamarika).

3.4.2 What does true co-creation look like, and what is the role of a researcher?

I will use the following two elements of the Mebina Framework to reflect on the co-creation process, its strengths, and my role as a researcher within it: the leaves, representing self and diverse ways of knowing; and the central flower, which represents journey and transformation.

The leaves: self and diverse ways of knowing

This component represents how the self is central to Indigenous research, as well as how there are diverse ways of knowing. How I interpreted this in the context of Anindilyakwa ways of knowing is that the Indigenous self is an autonomous and important representative of knowledge, which is reflected through definitions of Indigenous data as 'people's stories and life experiences and knowledges' (Barlo 2021, p. 44). But the location of knowledge within the self is never decontextualised from relational kinship structures, culture, story, law, or Country (Bawaka Country 2016). So, the relational framework provides authority to individuals as holders of knowledge, but that authority only makes sense when contextualised in relation to other holders of knowledge. There are hence as many diverse yet connected ways of knowing as there are individuals. This strongly links to the root's element of the Mebina Framework.

I also have interpreted the leaves element in relation to how I have situated myself in this process (Absolon 2008). I found my position as a technician helpful throughout the process: it provided the boundaries of my engagement and defined my role – I was not there to help, or uncover new truths, but to co-create the Story Map. The concept of ceding control emerged with poignancy midway through my Honours year as I considered how best to apply the tools of GIS in a cultural context, which, as a sub-discipline, has been critiqued as having the potential to continue the process of assimilating and eliminating Indigenous knowledge when mishandled or the position of the map-maker is not considered (Hart & Homsy 2020; Sheehan 2011; Rundstrom 1995). I implemented the principles of ceding control of the methods required to create the Story Map as a research design choice, which had two main overlapping advantages:

1. Led by Josh and Del, Anindilyakwa community were fully responsible for choosing which areas of the island they were to share stories of, how those stories were told and recorded for inclusion in the map, and what other multimedia elements would be included to support the storytelling
2. This, in turn, meant that my role was limited to an operational, technical, and facilitative capacity within the Story Map making process

The reason I was able to relinquish control, in a methodological choice distinct from much traditional western scientific research, again links back to the collective responsibility for knowledge which is upheld through relationality. People either knew, or knew people who would know, what we needed in the Story Map, and it was my job to take that information and literally put it into the Story Map. To relinquish control researchers are required to demonstrate a degree of humility (Carroll et al. 2020; Absolon 2008; Louis 2007), which manifested for me as exercising patience and trust in a culturally complex process which was not always clear to me. Doing so allowed for the organic emergence of Josh and Del as strong guiding forces in the creation process. My individual knowledge of how to operate computers and the Story Map software was an important part of the process of its creation, but not in isolation: it was authorised and contextualised through the relationship that Josh, Del, and I developed over the course of my Honours year. This was how our co-creation methodology emerged and operated. Had I not ceded control of the methodology, the content of the Story Map would have been greatly informed by my own knowledge and decision-making which would be decontextualised and inappropriate, given I was working to a brief the ALC provided me.

A distinct point of difference to this thesis is the ample funding available through the CRCNA grant which enabled me to spend a significant amount of time on, and to be flexible with scheduling visits to, Groote Eylandt over the course of the Honours year. The time I spent on-island and in-situ meant I was not rushed to seek results, and could dedicate time and energy to developing a shared conceptual basis with the Data Unit and in particular Josh and Del. What this looked like in practice was formal and informal situations repeated over the months from April 2023 to June 2024 where our relationship developed. Over time, I became known, trusted, and with the ceding of control, demonstrated repeatedly I was here to support the wishes of community without imposing my own agenda. Respectful Indigenous research is a relationship building process, and developing non-extractive relationships is part of decolonising geographic practice (Leeuw et al. 2012; Sheehan 2011). This is a point of difference to the long history of western researchers being extractive in their practices and benefiting from Indigenous knowledge without allowing any benefits to flow back to community (Wilks et al. 2018; Nakamura 2010; Lavallee 2009; Louis 2007; Chambers 2006). Each time I was on the island were essentially unchanged, with the passing of time, revisitation, and the building of trust in our relationship, the intangible and relational elements emerged. Our relationship became stronger, and we developed a greater understanding of what the final Story Map product would look like, aligning with a respectful research design principle

which Sheehan (2011, p. 71) describes as cycles of revisitation to a visual stimulus (in our case, the imagery of the island) which 'culturally connect the visual, cognitive, social, and pedagogic systems'.

The central flower: the journey, process, and transformation

This component represents how Indigenous research encompasses multiple journeys which can be transformative and sometimes difficult, and that the stories of research journeys are integral to their methodology (Absolon 2008, p. 98, 151). This thesis is structured in such a way which tells the story of the thesis journey whilst being inseparable from the methodology. There is a literal element to this too: journeys tend to involve travelling, of which the Data Unit and myself did a considerable amount during the Honours year. Travelling and being on-Country was integral to producing the Story Map, and I will tell the story of the third and final field trip to demonstrate why.

After the second trip to Groote Eylandt in February 2024, I felt confident that we had an action-oriented pathway laid out to get the Story Map created: the six locations were identified; we had 3D data on the way; and Josh and Del had defined the task of speaking to the respective story-holders to collect the stories, write them down, and send them to me to put into the Story Map. But in the three months that followed, there was limited progress. By the end of May the Data Unit had sent me one of six stories. However, in June 2024, by the end of the first two days of the final field trip, we had collected all six stories and I had put them into a draft Story Map. We made more progress in those two days than we had in the three months preceding. Reflecting on this, both the Data Unit coordinator and I had noticed how confident and effective Josh and Del were in engaging with senior members of community to collect the stories.

The Data Unit coordinator mentioned that my presence seemed to encourage Josh and Del in taking ownership of the Story Map amongst community. I realised on reflection that a reciprocal, relational process had occurred wherein my presence as the Story Map technician gave Josh and Del confidence to engage with senior knowledge-holders, whilst simultaneously, Josh and Del's presence gave me the confidence to guide our process where operational or coordination matters arose (for example, defining the length of the story). We had emerged, were 'becoming', together (Bawaka Country 2016). After those two days of extreme productivity, it became evident that we had done things the right way, and in fact it could not have happened any other way - this was why such limited progress had been made while I was in Canberra, removed from Anindilyakwa context. The Data Unit Coordinator was particularly struck by how confident Josh was in facilitating the telling of the stories, and I had noticed how both Josh and Del's English skills and overall

confidence had improved over the course of the Honours year. Similarly, my confidence in working with Anindilyakwa people had increased the more time I spent on Groote Eylandt.

A key moment of culmination occurred on the third day of this field trip, in which Josh, Del, and I were in the office at Umbakumba editing the Story Map together. We spent around an hour problem-solving a way of getting an audio file from Josh's phone into my laptop so it could be put into the Story Map, and when we eventually figured out the problem and played the song from the Story Map, there was an atmosphere of celebration in the room. We exchanged high-fives and were uplifted. Contextualising this academically, I understood that this moment was the result of the relationship we had developed over the course of the year, and directly aligned with best-practice Indigenous research principles which stipulate that building respectful relationships during research processes is the only way to engage with cultural knowledge, and there was no hierarchy to any of our positions: my 'western' ways of doing, and Josh and Del's Anindilyakwa ways of doing, were equal (Barlo et al. 2021; Evans et al. 2014; Botha 2011; Sheehan 2011;). Botha (2011, p. 323) writes that the legacy of colonialism will cease when the knowledge that is traded across the self-other boundary is done so by equals. I do not claim to have 'ceased' any form of colonialism on Groote Eylandt, but as Dei (2000) writes, small acts are cumulatively significant for social change. Getting the song file into the Story Map was an empowering moment for the three of us and is perhaps the most defining moment I recall when I reflect on the entire Honours year.

The evaluation above has demonstrated that true co-creation is possible through Indigenous research that is open-ended and process-based, and in which the researcher relinquishes the control of methods to Indigenous people or groups themselves. This aligns directly with best practice Indigenous geography research methodologies which need to be collaborative, relational and process-based (Leeuw 2012, p. 132; Howitt 2011). The importance of spending unhurried and repeated time in place cannot be understated, as this is how relationships emerge and are strengthened, and respectful relationships which flow two-ways are integral to robust Indigenous and decolonising research methodologies. The ability to do this was possible only through ample funding: time and money were integral. Indigenous research practice which allows for mutual benefit inherently addresses power imbalances because the history of Indigenous research is that only the researcher benefits (Leeuw 2012). I have used the leaves and the stem of the Mebina Framework to demonstrate how the Story-Map co-creation process is a mutually beneficial and best-practice methodology. Furthermore, processes which make Indigenous knowledge visible and therefore powerful by upholding the autonomy and integrity of Indigenous

peoples and cultures threaten the settler colonial project by rewriting the narrative of elimination (Pérez 2019; Spivak 2015; Wolfe 1999)

3.4.3 Limitations and pathways for future research directions

Story Map considerations

Story Maps have proven to be a useful and appropriate way for the ALC to use its sovereign geospatial data to preserve and transmit cultural knowledge. That being said, they are not a perfect solution for every land council and Indigenous organisation across Australia. The ALC is unique in that it is well funded through mining royalties, and hence its capabilities to commission the collection of such high-quality geospatial data is rare amongst Indigenous organisations. During my field trips, we viewed the Aerometrex imagery through Metro Map, which enabled seamless navigation and zoom functions with no load time, meaning that deep contextual evaluations were not hindered by technological issues. Google Earth, for example, would have been a limiting software to use as it has far less resolution and it is difficult to access metadata. Additionally, organisational GIS software licences are expensive to maintain unless the organisation is registered as a charity – a professional subscription to Esri is $11,693 per annum per desktop, whereas a nonprofit subscription is $2000 per annum per desktop (Esri, n.d.a; Esri, n.d.b). Free GIS programs such as QGIS do not currently have Story Map capabilities. Organisations without the financial or technical capability to own and use geospatial data cannot become spatially enabled. Another point of difference is the existence of the Data Unit itself, which enacts Indigenous data governance and supports local decision-making within the ALC in response to the ANU's First Nations Portfolio report. The Data Unit is recognised as a core function of the ALC under Section 64.1 of the Aboriginal Land Rights (NT) Act 1976, meaning they are funded regardless of royalty income, and without the close engagement and strong individual relationships between the Data Unit and I, the Story Map co-creation process would not have happened as it did.

Furthermore, there are data and software limitations encountered within Story Map creation. In assembling the Story Map I found technological issues to do with prohibitive file sizes and georeferencing issues requiring complex transformations that were unable to be resolved prior to completion of this thesis. Neither of these issues are insurmountable, and the close relationship that the ALC has fostered with Aerometrex means that they can be resolved in future. What must be considered is how difficult the issues are to resolve, as this will impact the usability and accessibility of the geospatial data if the resolutions are beyond the capabilities of the Data Unit.

Additionally, the ArcGIS StoryMaps tool is continually evolving (Evans, 2024), requiring end users to update existing material.

In the context of this thesis, it is likely that the ALC and Data Unit will eventually need to transition the Story Map to a new or updated platform in future. If this does occur, all the 'ingredients' used in the Story Map we created will remain with the ALC. The integrative capacities of the Story Map were significant and useful, but it was the process of documenting the stories, in-situ, and demonstrating how the ALC's data could be used, which emerged as the focal point. This was reflected by Constantine, who said that:

> 'It's best to tell the stories about the place on Country' (Constantine Mamarika)

The expertise and autonomy will remain with the Data Unit regardless of whether Story Maps continue to be supported as a product in future, and further, the Data Unit will remain a core function of the ALC regardless of any structural changes resulting from royalty payment changes. Our process showed that the collection of stories as 'ingredients' - which can then be implemented in myriad ways including on-Country - was the strength.

Time limits and reflections on ethics approval

The timeframe of an Honours year does not translate well to working with Indigenous groups, for two main reasons in my context. Firstly, the administration and timing involved in receiving ethics approval was limiting, and the associated bureaucratic delays were incongruent with the methodology we had developed on Country. It was an impediment to our workflow, given that within two months of beginning my Honours year I had met the key people with whom I was to be working, undertaken due diligence by reading necessary research agreements, had cultural approval from the ALC, had visited Groote Eylandt, and collaborated with the Data Unit and Anindilyakwa community members. A research head agreement between the ANU and ALC had also been established under the broader CRCNA project. Despite this, I was not permitted to collect primary data myself until the final 6 weeks of the Honours year. Ethics committees were initially established to ensure no physical harm was done to research participants in university settings, but over time their role has expanded to include the protection of marginalised communities from exploitative research (Connor et al. 2018; Boyd et al. 2008). While in theory this could be a decolonising position, the model is not suited to research where that marginalised community is positioned as a co-researcher and collaborative entity (Connor et al. 2018). Ironically,

non-Indigenous members of a university ethics committee, very removed from the research setting, may place caveats on a project after the researcher has gained community approval and support. Thus, the process of gaining ethics approval may actually contribute to the elimination of Indigenous voices in research and within the academy, as it recognises institutional protocols as having more weight than cultural protocols and context-based partnerships.

Secondly, the time limits of the Honours year did not easily accommodate unavoidable events such as Cyclone Megan (Perera & Morgan 2024). Due to human error wherein a shipping boat was left at the port during the cyclone event, the main jetty on Groote Eylandt was severely damaged meaning shipping and supply boats could not berth at the jetty (Perera & Morgan 2024). Supplies for the island, including petrol, were dramatically reduced. Whilst delaying my final field trip, the more significant outcome from the cyclone event was how dramatically the ceasing of mining operations and hence the ceasing of royalty payments impacted the ALC. The financial impact of ceased royalty payments shrunk the ALC's operations rapidly and brought to prominence the importance of robust planning and decision-making in preparation for the mine closure in 2033. I noted how what was prioritised after the cyclone was economic and community development and health, which are important and the ALC is legally responsible for. However, maintaining strong culture did not appear as a priority, and I suggest that perhaps the bureaucracy and institutional structure of the ALC does not easily allow for the prioritisation of cultural preservation.

Future options to extend story mapping by the ALC

This was the first foray of the Story Map tool, and it was successful. There are logical avenues for extending Story Map usage internally to the ALC as their functionality means they can be leveraged for other stories, sites, and purposes – for example, representing men's and women's business, other Dreaming stories, or modern histories. The Story Map we co-created can be updated and additional material readily included (e.g. other story sites). Entirely new Story Maps could be created, for example to represent the history of contact between Anindilyakwa and Macassans, which is a current ALC project in early stages (H. Moody, pers. comm., 12 February 2024). Permissions and cultural authorisations are easily implemented as a way of protecting sensitive information. An important future extension which could happen in the near term is for the Data Unit to share the Story Map with the wider community across the island.

The ALC could also utilise Story Maps as a vehicle for cultural education aimed externally to the organisation, for example as a module which new researchers, mine workers, or service workers

must engage with before beginning their work on-island. Engagement with such an interactive yet simple tool as a Story Map could improve cultural awareness and knowledge about Anindilyakwa lifeways. This extension would also operationalise the Story Map within the 'recognition space' (Wilks et al. 2018): using Story Maps in such a way would position Anindilyakwa people as stewards and owners of their data for a relational purpose. The benefit of Story Maps for the purposes outlined above is that they are easily adaptable, with many functions which have advantages for different purposes – for example, 'spyglass' tools which are an interactive way to view historical and current images, or guided map tours which take the user on a specific journey.

Extensions of story mapping to other contexts

This thesis has explored the use of Story Maps by the ALC as a tool for presenting geospatial information in a way that operationalises IDS and IDG principles and aligns more strongly with Indigenous ontologies than traditional GIS outputs. Story Maps have a distinct advantage over traditional geospatial tools like static maps because of the way that they integrate narratives and landscapes and incorporate multimedia elements (Hart & Homsy 2020; Davis 2011). This way of digitally telling stories in layered and spatialised ways can situate individual and collective knowledge, therefore aligning with Indigenous knowledge-sharing systems (Syme 2020). Story Maps could represent living cultural landscapes appropriately (NBY 2016; UNESCO, n.d.). Story Maps, amongst other geospatial data undertakings, may therefore be an important part of ensuring that the benefits of spatially enabled governments and commercial enterprises are extended to Indigenous organisations.

The literature review identified (1) that most Story Mapping projects originate in the US or Canada and (2) no project was initiated by or the data owned and housed by the relevant Indigenous organisation, it could be strongly argued that Story Maps are an underutilised technology in Australia and should be applied to more contexts. The results of this thesis could support the implementation of a broader, nation-wide program which assists Indigenous communities in developing Story Maps specific to their Country. The telling of stories through this tool was an inherently and overwhelmingly positive experience for the Data Unit and I, and I suggest it is something that can and should be replicated at a broader scale as it is likely to be the case that other Indigenous communities would also have a positive and empowering experience.

Story Maps may not be a singular 'solution' to spatial enablement or data sovereignty. They require good quality geospatial data as evidenced by the commission and use of the data collected

by Aerometrex. The ALC, through royalty payments and the CRCNA grant, has a strong platform from which to negotiate for such data. Not all Indigenous organisations have such financial capability. Notwithstanding, Story Maps retain significant advantages which should not be underestimated.

3.5 Conclusion

The aim of this research was to explore how the ALC can use its sovereign geospatial data to preserve and transmit culture by co-creating a Story Map. This aim was met through the collaboration between the researcher (i.e. me) and the Data Unit to produce the ALC's first Story Map, and through being the first to use the ALC's high-quality geospatial data for cultural preservation purposes. In this thesis I have reflected on and analysed the process used to co-design and co-create the Story Map, to tell the story of how culturally informed, place-based research processes can produce important cultural products and be transformative for the people involved. In the context of the research presented in this thesis, Story Maps were found to be an appropriate and powerful tool for the ALC to operationalise IDS and IDG principles to the highest degree. They are also aligned with Anindilyakwa ways of knowing and present a medium by which to communicate cultural knowledge, which is an important and integral part of resisting settler colonial eliminative practices.

The literature in this space is rich with conceptual suggestions for the implementation of decolonising acts, but real-world demonstrations that model how IDS, IDG, and Indigenous methodologies can be realised through geospatial data are relatively rare at the current time. The Story Map we co-created, and the way we did so, has not been done before. This thesis has therefore produced an important and usable product for the ALC in response to their brief, whilst also progressing the literature and field. I would like to conclude this thesis by asserting that the relationships which developed over the course of the Honours year, emerging as displays of trust, care, and vulnerability, not only held me deeply accountable (Leeuw et al. 2012) as a non-Indigenous researcher but also fostered a contextualised, reciprocal, and equal process of growth that was a decolonising and transformative act.

Chapter 4: Coastal climate change on Anindilyakwa Sea Country: GIS mapping and modelling for internal capacity

4.1 Introduction

Key findings from an ANU Master's thesis by Gwendolyn Withrow are presented in this chapter. The thesis is entitled *Coastal climate change on Anindilyakwa Sea Country: GIS mapping and modelling for internal capacity* and was published in 2024 (full version available in Withrow 2024).

Principles for better Indigenous research and policies are increasingly recognised and adopted; however, there are significant gaps and limitations which perpetuate colonial legacies. On the international scale, the United Nations (UN) has codified several principles for Indigenous rights including the recognition of sovereignty. However, these are not enforced on the nation-state level, and where sovereignty remains unrecognised, it is often accompanied by flawed Indigenous policies, as is the case in Australia. A similar trend exists in Commonwealth climate policy, where global ideals of climate justice and disaster mitigation are acknowledged but not consistently implemented. The research topic on modelling the impacts of sea level rise (SLR) and coastal erosion in relation to cultural values and concerns on Anindilyakwa Country, was developed collaboratively with ALC representatives.

The goal of the thesis was to create an effective working knowledge utilising Geospatial Information Systems (GIS) appropriately and rigorously situated within the Indigenous context. Spatially explicit and locally derived datasets are particularly useful for internal local decision-making and can be designed to encapsulate appropriate risk levels, physical hazard modelling, and cultural values. Co-design and community-oriented publication ensured that the modelling outputs are available, applicable, and appropriate for the primary grant partners, the ALC. This research was co-developed with the ALC to produce useful GIS outputs that support their capacity and capability to make informed decisions about their estate (CRCNA 2024). The thesis sought to answer the following questions:

1. How will climate change affect Anindilyakwa Saltwater Country, and can knowledge of these impacts support future management and planning?
2. What is an effective way to model and communicate coastal climate change impacts for a remote, Indigenous community, such as the Traditional Owners of Anindilyakwa Land and Sea Country?

4.2 Literature Review

4.2.1 Global climate change and oceanic response

The ocean's impact on, and response to, global climate is immense, and the complexities therein have inherent uncertainties. Sea level has increased faster since 1900 than it has in the previous 3000 years and warmed faster than it has in the past 11,000 years, which could result in 1.0 to 1.2 m of global mean sea level rise by the end of the century relative to 1990 (Masson-Delmotte et al. 2018; Church et al. 2013; DCC 2009;). Sea level rise is typically modelled out to 2100, which has high variability due to the range of possible carbon mitigation responses (Slangen et al. 2023; Pörtner et al. 2019; Church et al. 2013). Due to higher thermal inertia in hydrologic systems and delayed feedbacks, oceanic responses to climate change occur at a slower rate (Slangen et al. 2023; Pörtner et al. 2019). Because of the multiple contributing drivers, the higher thermal inertia of water as compared to air, and the relatively slow circulation of oceanic systems, sea level rise will continue well-after atmospheric carbon dioxide concentrations stabilise, potentially for many millennia (possibly at an average rate of 1m/century) (Pörtner et al. 2019; Church et al. 2016). These same factors inhibit accurate decadal and centennial predictions of sea level rise, where sudden ice sheet collapse and thermodynamic feedback shifts within atmosphere, biosphere, and hydrosphere systems will alter net oceanic expansion throughout the remainder of the century and beyond (Slangen et al. 2023; Collins 2019).

Beyond the limitations of modelling the ocean's net volumetric response, regional and coastal responses add another layer of complexity. Climate change also affects ocean acidity, water temperature, and currents, leading to species migration and extinction and the possibility of irreversible ecological shifts (Poloczanska et al. 2018; Hoegh-Guldberg & Bruno 2010). Regional and local sea levels vary on scales ranging from seconds to decades, depending on factors spanning waves, storm surges, tides, erosion, tectonic plate movement, currents, climate modes, and global ocean volume (Church et al. 2016). The impacts of human induced global warming are particularly difficult to model in coastal systems, where atmospheric, hydrologic, and terrestrial forces converge (Arias et al. 2021). Local and regional sea level rise is determined by the mean sea level, tidal forcings, wave set-up, air pressure, near shore winds, and terrestrial hydrological flows (DCC, 2009; Slangen et al. 2023). Storm surges and the compounding impacts of riverine flooding, low atmospheric pressure, rainfall volume, and potential tidal amplification can lead to extreme flooding and then erosion risk and saline intrusion (DCC 2009). These acute, intense weather events then compound with longer-term geomorphic changes (e.g. beach erosion) in coastal environments; moreover, extreme weather events are likely to increase in intensity and

severity under climate change (Poloczanska et al. 2018; Church et al. 2016). Global mean sea level combined with extreme sea level events and regional sea level biophysical dynamics leads to deep uncertainty with potential for high impact, especially for vulnerable populations (Slangen et al. 2023; Masson-Delmotte et al. 2018).

Coastal regions are notably vulnerable to climate change due to the intersection of terrestrial, marine, and atmospheric forcings; they are also sites of interconnected and sensitive biophysical systems. Socio-ecological systems (SES) represent the interdependence of human and ecological resources, stocks, flows, and wellbeing, are particularly vulnerable to sudden, subtle, or irreversible shifts in a changing climate (Noble et al. 2021; Cote & Nightingale 2012). The IPCC defines resiliency as “the ability to absorb the impacts of climate change while maintaining the same structure and functions of the environment and includes the ability to learn from the disturbance" (Pörtner & Alegría 2022). Increasingly, ecosystems are perturbed beyond their thresholds and their regimes shift into new, potentially less desirable states (quantified by biodiversity, natural resources, stability, aesthetic, etc.) (Cote & Nightingale 2012). Climate change will exacerbate existing coastal pressures which span the complex SES of estuaries, coral reefs, tidal flats, salt marshes, sandy beaches, and the populations therein (Berrouet et al. 2018; Murphy 2015). Modelling is limited and responses will vary across regional, local, and ecological scales, due to uncertainties including ice sheet melt, erosion processes, weather patterning, and responses within ecosystems, particularly in low-lying coastal (Slangen et al. 2023; Masson-Delmotte et al. 2018; Church et al. 2016).

4.2.2 Australia’s monsoonal north and remote Indigenous communities

The trajectory uncertainties, SES interdependencies, and spatiotemporal variabilities of coastal climate change have heightened significance when implications are integrated on a specific locale. Sea level rise affects industry, ecologies, tourism, infrastructure, and those who rely heavily on coastal resources are more vulnerable to sudden or irreversible changes (Birkmann et al. 2022; Tigchelaar et al. 2021; DCC 2009). Indigenous Peoples have been internationally recognised as highly vulnerable to climate change, due to their exposure to climate hazards and higher reliance on natural resources (Green et al. 2009). Coastal Indigenous communities are likely to be among the first to experience impacts (Fischer et al. 2022). Coastal climate change impacts have serious and difficult to measure implications for cultural heritage on Indigenous lands (Crowley 2016; Green 2006):

- Waterways have special significance, and their ecologies and biophysical dynamics will change, particularly fresh to saline intersections;
- Species of totemic or material significance;
- Coastal, intertidal, and marine sacred sites;
- Mosquito-borne and infectious enteric diseases may become more prevalent due to increased temperatures, humidity, and rainfall;
- Intensification due to the overlap with other stressors such as commercial fishing, weeds, marine debris, and local development;
- Physical capacity to engage in outdoor activities during inclement and dangerous weather (both economic and cultural).

The likelihood and manifestation of these risks is dependent on the specific spatiotemporal predictions of the region. Rates of sea level rise in north and western Australia are nearly double the planetary average (likely due to climate mode variability and warming waters) (Church et al. 2016; DCC 2009). Sea levels across northern Australia rose 6-9 mm between January 1993 and September 2011 and up to 12 mm in the Gulf of Carpentaria (Bird et al. 2013). Northern Australia is generally predicted to experience increased heavy rainfall events and flooding and a decrease in cyclone frequency but an increase in intensity, as well as overall higher temperatures and increased number of hot days (Arias et al. 2021; Moise 2015). Northern Australia is defined by muddy shorelines that are subject to high tides and the eroding and destructive forces of cyclones (DCC 2009). Monsoonal wet season, including regional flooding, cyclones, and storm surges damage to habitats, erode beaches, and enact biophysical changes to benthic environments. (Bird et al. 2013; DCC 2009). Cyclones in Australia are already highly variable (both tracks and frequency) due to the complex intersection of planetary circulation and climate drivers such as El Niño and La Niña; notably, both modes will also increase in volatility as climate change intensifies (Chand et al. 2019). Global sea surface temperature has increased significantly, and the trend is slightly diminished within the Gulf of Carpentaria; ocean acidity and salinity have also followed global trends, with increasing uncertainty on regional, local, and ecosystem levels (Moise 2015). Shifting oceanic conditions further strain SES and their resilience to withstand intense weather events (Tigchelaar et al. 2021; Murphy 2015).

Coastal biophysical responses will be driven by the above climate trends, but the SES, human, and Country dimensions are more difficult to predict and compounded by the legacy of colonialism. Poor morbidity and mortality rates are exacerbated by extreme temperature and weather events,

increased infectious diseases, and Country degradation (DHAC 2023; Lansbury et al. 2023). Often, food security and enjoyment of place are cited as the main insecurities for Indigenous communities; however, the Indigenous synchronicity and interdependency of human and ecological wellness means the impacts are far wider reaching (Fischer et al. 2022). The following risks to health, wellbeing, and health systems will be increasingly threatened under climate change (DHAC 2023):

- Mental health;
- Infectious disease;
- Chronic and non-communicable disease exacerbations;
- Injury and fatalities;
- Malnutrition and food-related disease;
- Heat-related illness;
- Increased demand for health services;
- Disrupted health service delivery;
- Damage to health care infrastructure;
- Overwhelmed health services.

Put succinctly, sick Country leads to sick Peoples (DHAC 2023; Lansbury et al. 2023). Further, Aboriginal and Torres Strait Islander Peoples have drawn parallels between colonial and climate change impacts, including degradation of Country, limited power to address disasters, decreased resource access, and eventually the risk of forced migration (Lansbury et al. 2023; Fischer et al. 2022). Globally, Indigenous communities exhibit common characteristics that enhance their SES resiliency as well, including social cohesion, collective land stewardship, and strong belief in problems solvability which enables effective management and multi-benefit responses (Ford et al. 2020). The Australia State of the Environment Report 2021 (which included an unprecedented Indigenous chapter) recognises that the condition of Country and Indigenous Peoples' connection therein is "very poor" (Cresswell et al. 2021).

SES are integral to the lived experience of remote Indigenous communities, and the sensitive stressors of climate change are typified within coastal, low-lying communities. Risk assessment requires locale-specific methodologies that encompass awareness of global climate uncertainties and possible trajectories. As climate change accelerates past the Paris Agreement target, biophysical responses across planetary systems and coastal locales also intensify. Indigenous, remote, coastal communities are among the most vulnerable to climate change and should be

sufficiently informed and adequately supported to adapt and manage their Country for a climate sustainable future.

Coastal climate change adaptation and preparedness is often implemented on the local level, with mixed results reflective of socio-economic disparities. Remote Indigenous communities have a lower capacity due to a number of factors, including prevalence of chronic health issues, poorer quality state-funded facilities and services, decreased access to higher quality support institutions, and other systemic disadvantages (DHAC 2023; Crowley 2016; Petheram et al. 2010; Green 2006;). Furthermore, Indigenous Peoples are often relegated to a simplified victim-hero binary that praises their valuable knowledge and laments their vulnerability while omitting prevailing colonial contexts and their internal forward-planning capacity (Campion et al. 2024b; Lansbury et al. 2023: Ford et al. 2016). Indigenous land and sea management is informed by tens of thousands of years of custodianship and the deep, nuanced Knowledges developed therein (DHAC 2023; Lansbury et al. 2023). Indigenous Knowledges exceed the bounds of resource management and documenting changes on Country; they include ethics, wellbeing, and complex systems analysis (Romm 2024; Fischer et al. 2022). Numerous Indigenous communities have enacted culturally relevant management plans, however, their capacity to extend the jurisdiction to outside groups and adjacent territories is limited (Fischer et al. 2022). Effective climate change strategies require Indigenous wisdom and leadership, supported by collaboration with relevant experts and power brokers, such as the expertise offered within this research (DHAC 2023). This thesis supports the Indigenous capacity toward better IPA management and coastal development through robust, applicable modelling of climate change predictions (Fischer et al. 2022). Indigenous estate planners need internal capacity to respond to the intensifying risks to lives, property, infrastructure, and environment; however, this is limited by funding, the scope of Commonwealth structures, and lack of cohesive policy into local actions.

Because Commonwealth standards for climate response do not clearly extend to remote Indigenous communities, the question arises of how best to enable local climate solutions. In the absence of codified national and state recognition of sovereignty, local agency supported by robust data and analysis can enable best outcomes for climate forward decision-making (Lansbury et al. 2022; Nursey-Bray et al. 2019). From the review of international ideals, relevant policy, and academic literature, the following principles were derived: free prior informed consent, respectful sharing of TEK/WEK, community-based management, and enabling sovereignty of land and sea rights and decision-making. In the following section, these principles are synthesised into the goal of creating a useful climate change model within the remote Indigenous context.

4.3 Research Design

4.3.1 Ethical and effective working knowledge outputs for Indigenous estate planning

A working knowledge output is defined by the goal of utility for the target community that is ensured through co-design and transdisciplinary research (Barnett et al. 2023; Barber et al. 2014). Ethical and effective implementation is achieved by the core project principles, the Our Knowledge Our Way report, and previous literature analysis (Woodward et al. 2020). A summary of these principles follows: co-design, self-determination, respectful inclusion of Traditional and Western knowledges, community-based management and appropriate governance, free prior informed consent, and sovereignty of land and sea rights and decision-making.

These principles for better engagement in Indigenous research are implemented through careful research design. Free prior informed consent is explicit and enforced through the Anindilyakwa-led CRCNA grant and the comprehensive Indigenous data sovereignty within the ALC Data Unit (CRCNA 2024; Taylor 2022). These institutions also enable the principles of self-determination, community-based management and governance, and sovereignty. Which, in turn, are supported by the partnerships herein, primarily the IPA and Ranger programs, which are the primary bodies for land and sea management on ASC (ALC 2024b). Despite the aforementioned concerns regarding the Westernised structures imposed on Indigenous land management, these bodies currently wield the highest capacity and closest alignment with Indigenous interests (Taylor, 2016). Indigenous Peoples' connection to Country exceeds the designation of stakeholder or manager, in that their history, well-being, and culture are inextricable from Country; as such, collaboration and co-design are preferred (Reed et al. 2021; Ogar et al. 2020). Co-design and blending of TEK/WEK are both highly prioritised and inherently complicated by the incompatibility of extractive and holistic worldviews (Campion et al. 2024a; Fischer et al. 2022). Methodologies and methods were chosen to promote a knowledge translation rather than extraction or prescription (Brinckley et al. 2024; Williamson et al. 2023).

This framework facilitates a more ethical implementation of GIS, which then actualises the goal of an effective working knowledge. The spatially explicit datasets are accessible, relevant and span quantitative and qualitative analysis of cultural values and physical risks. To best address climate change concerns, the following aims were named: i) community communication, ii) leverage in policy and negotiations, iii) disaster resiliency, and iv) ongoing monitoring and evaluation (Figure). Community communication answers the requirements of self-determination, internal agency, and

Indigenous-led solutions. Rigorous and explicit data is a useful tool for Indigenous rights leverage in its capacity to translate risks and values in an accurate and recognised format (Potter 2020; Xu et al. 2020; Young & Gilmore 2017). Risk assessment on the appropriate spatiotemporal level is essential for effective disaster resiliency and climate-forward development (Palutikof et al. 2019; COAG 2011). Similarly, monitoring and evaluation is best conducted locally with culturally appropriate techniques (Lansbury et al. 2023; McElwee et al. 2020). By naming these aims and integrating them into the research design, the outputs address the systemic concerns within the remote Indigenous context and better address the CRCNA grant objectives.



Figure 35: Working knowledge framework for Indigenous climate-forward capacity

4.3.2 Indigenous-forward method selection: research by conversation and identifying useful modelling outputs

The highly uncertain projections, SES dynamics, and locale-specific concerns of coastal climate change are well-suited to GIS analysis. GIS design and methods were carefully selected under the goal of producing a working knowledge and following principles for better Indigenous research engagement. Understanding of coastal dynamics and pattern changes requires biophysical data, such as elevation, geomorphology, and atmospheric and hydrologic climate projections (Palutikof et al. 2019; Mummery 2016). Social, economic, and ecological factors are essential for identifying the consequences of these changes and assessing risk (Akash et al. 2023; Kumar et al. 2022; Mummery 2016). The increasing uncertainty and complexity of coastal climate change can be

offset by longer-term datasets and in-situ monitoring to better understand trends and interactions (Mummery 2016; Walsh et al. 2016). Due to the lack thereof, particularly in the context of Australian cyclones and their impacts, a human-centric risk assessment with appropriate thresholds is warranted (Sutton 2019; Walsh et al. 2016). Efficacy of community vulnerability awareness is enabled by locale specific data that encompasses physical terrain, development scale and type, and hazard awareness (both gradual and acute) (Pörtner et al. 2022a; NCCARF 2017; Mummery 2016; Bird et al. 2013; COAG 2011; DCC 2009). Thus, the three useful models selected include a quantitative SLR, an erosion risk model, and a qualitative and participatory values model.

ASC is a low-lying remote coastal region with compounding future concerns under climate change and colonialism. A principled, transdisciplinary, co-designed approach was employed to increase the usefulness of the resulting models (see 1.3) (Van Kerkhoff 2014). This approach is also advised when addressing complex, uncertain, and interdependent SES which may exhibit surprise reactions (Cockburn et al. 2018). Three domains were synthesised: refined quantitative technical expertise, participatorily developed values and concerns, and the ethics of Indigenous data sovereignty and cultural awareness (Figure 35). Each discipline was supported by relevant partners (co-supervisor, the Rangers, the ALC), and each was iteratively informed by each other toward three explicit publications of working knowledge. The inherent uncertainty in co-design and iterative development led to notable changes in the final process. The three final model concepts include projected future SLR, coastal erosion risk, and cultural values and concerns on Country. These constituted three separate maps, to be integrated into a story map format for ease of access and applicable use by relevant parties.

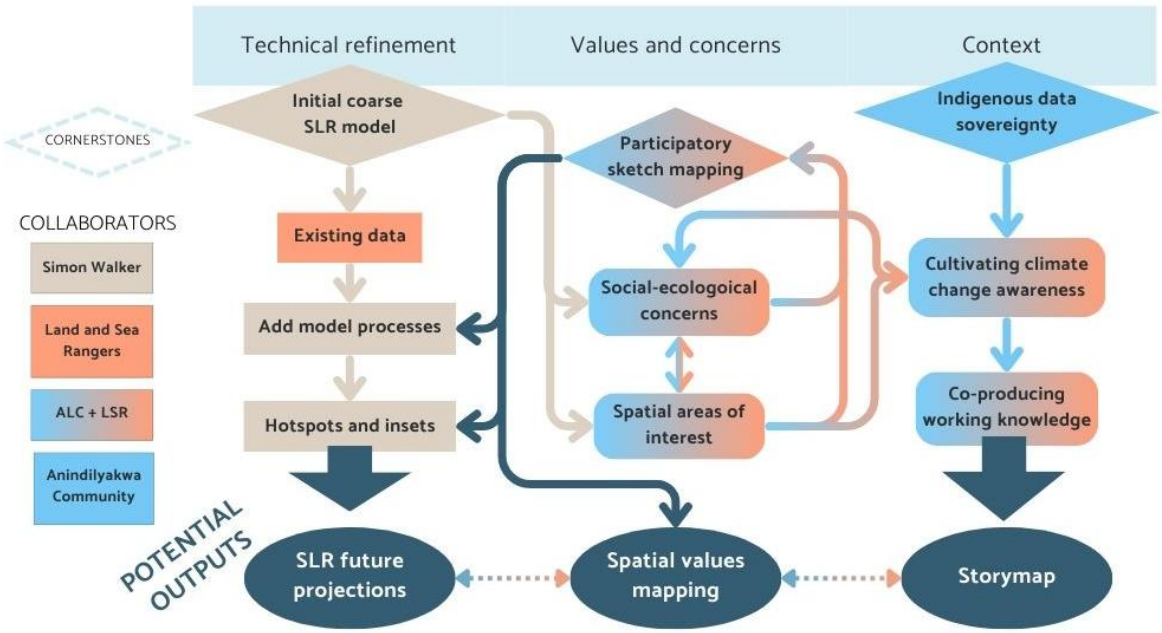

Figure 35: Flowchart for building a useful model of climate change impacts on Anindilyakwa Country

Often, the selection of methods and outputs is metered by Western scientific concepts that omit an Indigenous perspective (Fischer et al. 2022). Decolonial research often engages the method of yarning, which reflects an Indigenous preference for and expertise in extended conversations as a method for knowledge exchange (Linder 2024; Fischer et al. 2022) (Bessarab & Ng'Andu 2010). Oration is preferred for knowledge dissemination as it prevents misunderstanding and reinforces context, as opposed to the Western preference for statistical numbers or written word (Lansbury et al. 2023; Fischer et al. 2022). Trusted Indigenous People can reach knowledge holders within their network and facilitate culture-appropriate knowledge exchange, moreover, prioritising knowledge through relationship ensures engagement with pertinent concerns (Lansbury et al. 2023). Additional knowledge translation methods of varying efficacy (as identified by Brinckley et al. 2024) employed in this research include field visits, knowledge mapping, work with community champions, information packages, workshops, meetings, infographics, online content, presentations, reports, and photo/voice recordings (loosely ranked from best to better). Synthesis of knowledge is hindered by the incompatibility of extractive (Western) versus holistic (Indigenous) worldviews (Campion et al. 2024b; Fischer et al. 2022) (Klenk et al. 2017). To ensure equitable, effective knowledge exchange, research design encompasses yarning, participatory qualitative mapping, and rigorous quantitative modelling, all delivered in an accessible and appropriate format for the user audience.

Congruent with Indigenous knowledge practices, the scope of this research is dictated by conversations and consultations led by Anindilyakwa people (Bessarab and Ng'Andu, 2010; Brinckley et al. 2024) (Castleden et al. 2012). The inception of the sea level rise model concept occurred during a lunchtime chat; a coarse model displayed to a room of Elders in Umbakumba generated interest and anecdotal storytelling; and the work culminated during a conversational workshop and mapping session at the Ranger headquarters. These yarns revealed that climate change was witnessed and felt, although the mechanics and trajectories were not fully understood, which is reflective of Aboriginal and Torres Strait Islander self-reporting (Lansbury et al. 2023). Due to the brief timeline of a Masters' thesis and the pragmatic interruptions that limited the scope of fieldwork, extended yarning with the Anindilyakwa community was less developed than intended.

4.3.3 Data Sovereignty

For successful development, delivery, and longevity of the working knowledge outputs, they must be appropriately implemented, integrated, and maintained. This is accomplished by employing strong data sovereignty principles, both inherent within the ALC structure and informed by outside literature. UNDRIP's Article 31 states: 'Indigenous Peoples have the right to govern the collection, management, access, interpretation, dissemination, and reuse of data regarding themselves or their concerns' (UNGA 2007). However, current Commonwealth legal protections for Indigenous Knowledge and intellectual property are currently inadequate, creating risks such as appropriation, misuse, and potential harm (FNP 2024; Williams 2021). The CARE Principles for Indigenous data governance seek to fill the gaps in policy by integrating four principles: collective benefit, authority to control, responsibility, and ethics (Carroll et al. 2020). These more robust approaches were used throughout this thesis.

Hosting and maintaining the final GIS models and story map within the ALC Data Unit ensures quality, accessibility, and ease of access for future projects, promoting continuity and longevity (ALC 2024a; Taylor 2022; Vollstedt et al. 2021). Because the data and analytical outputs are fully owned and stored within the ALC, they can be used for negotiations, decision-making, rights advocacy, and funding research without the need to consult the researcher (Taylor 2022). The prevalence of GIS projects within Indigenous spaces has led to an increase in support and resources, such that the ALC and Rangers have numerous avenues for future projects, troubleshooting, or technical refinement (Holcombe 2023).

4.4 Research Methods

4.4.1 GIS implementations and justifications

There were several considerations when selecting model types and methods, foremost the directives of the CRCNA grant, the Aerometrex GIS data, and the aim to increase internal capacity for estate management and decision-making (CRCNA 2024). Higher-resolution data, (i.e. <1 m spatial grid resolution) such as the Aerometrex datasets, is commonly cited as a paramount component of effective risk assessment and locally applicable modelling (Fereshtehpour & Karamouz 2018; NOAA 2017; DCC 2009). Remote sensing, GIS, and indices are particularly useful for regions without detailed, precise, or longevity of quality data, as well as difficult to access locations with delicate ecosystems (Lin & Pussella 2017; Mani Murali et al. 2013). ArcGIS was chosen over its open-source counterpart QGIS, as the ALC Data Unit is fully integrated with ArcGIS (Gill 2024; Taylor 2022). Natural phenomena are inherently difficult to model with precision, so model design focused on appropriate risk analysis, inclusion of most relevant variables, and ease of use by target audience (Oubennaceur et al. 2021; Narra et al. 2017; Le Cozannet et al. 2013; Malpica et al. 2007). Modelling outputs were chosen through co-design with the Rangers to ensure relevancy and suitability (Vollstedt et al. 2021; Nguyen et al. 2020; Potter 2020). The versatility of GIS enables interlinkages of datasets and facilitates ease of comparative analyses (Chang 2018). The final three outputs included the SLR bathtub model, the MCRA erosion risk model, and the participatory map of values and concerns. Through consultation and co-design, the SLR model emerged as the first model, which enabled the conversations around values and concerns on Country, and then the selection of erosion as the defining risk index (Figure 36).

Each model was developed utilising the Aerometrex LiDAR DEM (0.5 m) and Aerial Imagery (0.1m) as a basemap. A visual inspection of shoreline extent demonstrates the benefits of the higher-resolution Aerometrex DEM as compared to the GA shoreline (30 m), particularly in comparison to the detailed aerial photography (Figure 37). The accuracy and refinement of both topography and visual data provides a better representation of ASC realities on the ground, which leads to more useful modelling of sites and dynamics.

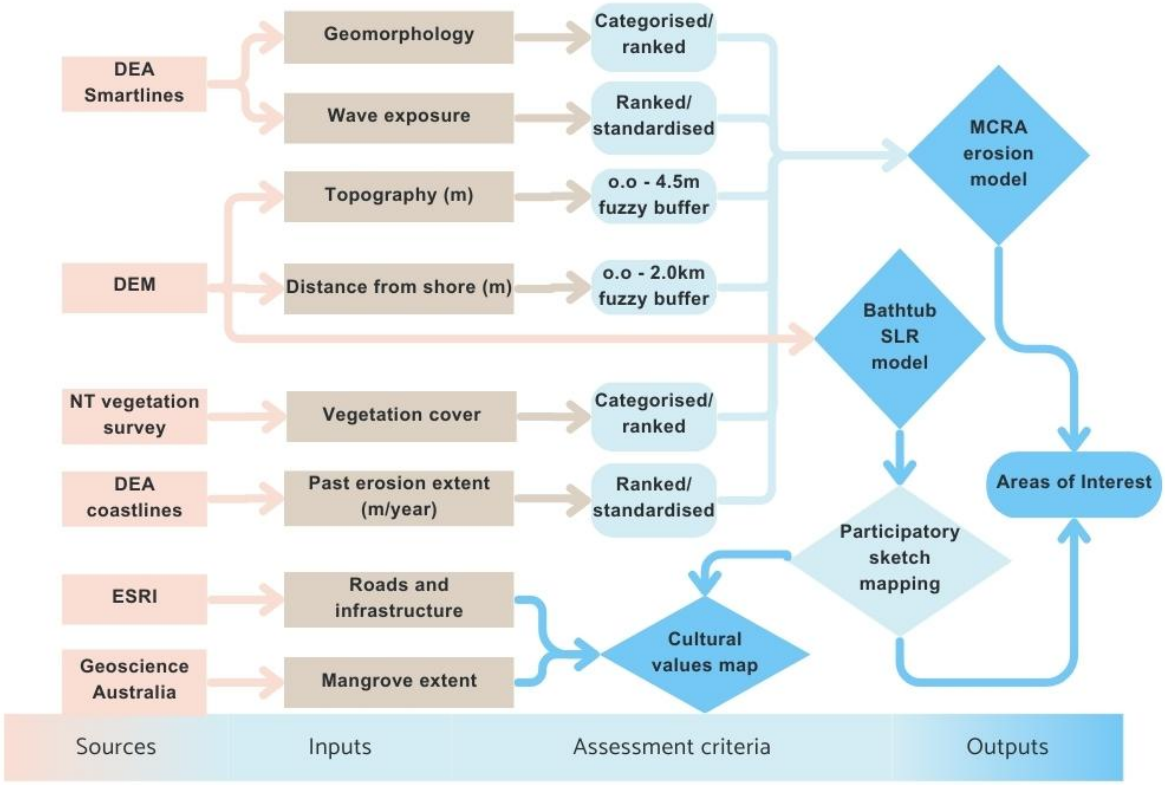

Figure 36: GIS components and outputs for the SLR, erosion and cultural values mapping

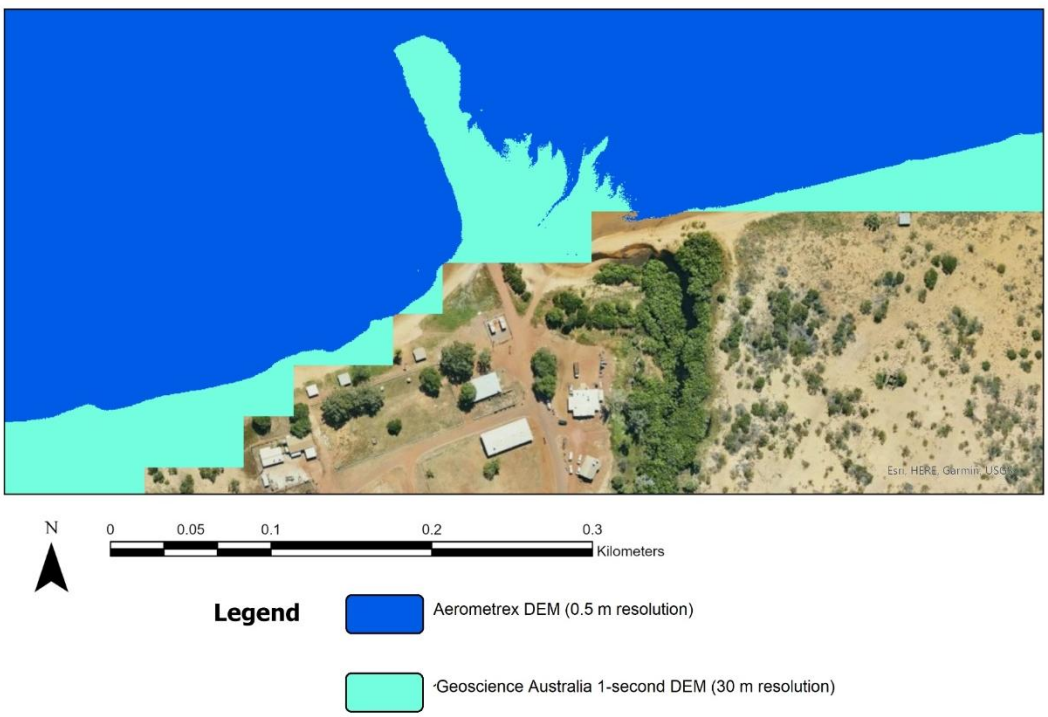

Figure 37: Resolution comparison of Aerometrex and Geoscience Australia data

4.4.2 Sea level rise bathtub model

Sea level rise (SLR) is an inevitable and accelerating hazard that will continue to escalate due to global warming, and the impacts for socio-economically vulnerable communities are complex and potentially highly disruptive. Despite this, SLR modelling capacity is limited, particularly at the regional and local scale, due to uncertainties around ice sheet melt, erosion processes, weather patterning, and responses within ecosystems (Bishop-Taylor et al. 2021; Palutikof et al. 2019; DCC 2009). Existing sea level rise models of the Gulf of Carpentaria are either absent or coarse, and those in existence were not readily accessible to decision-makers. The CoastAdapt website provides a standardised risk assessment for Australian coastal climate change, but only provides inundation mapping for highly populated areas (East Arnhem is excluded) (Palutikof et al. 2019; CoastAdapt 2017;). The Coastal Risk Australia website uses CSIRO's Canute 3.0 SLR estimation, GA's DEM and the Google Earth Engine to model future SLR, however, it also does not encompass Groote Eylandt (Figure 39) (CRA 2024). Thus, a simple but effective bathtub SLR model was selected as the foremost output for this research.



Figure 38: The Coastal Risk Australia sea level rise inundation map lacks coverage for remote, low population regions (CRA 2024)

A bathtub inundation model combines globally accepted future SLR projections and local variability estimates with a DEM to estimate the future height of sea level. As per the metaphoric name, a bathtub or 'bucket fill' model assumes static topography and does not integrate coastal erosion into its computations (DCC 2009; NOAA 2017). The physical forcings that drive coastal erosion are numerous, interdependent, complex, and difficult to model on a spatiotemporally accurate scale (Déguénon et al. 2024; Narra et al. 2017). Despite this simplification, a bathtub model is a well-accepted tool for SLR projections and highly applicable on ASC, where existing coverage is either coarse or absent and the majority of the islands are low-lying.

Risk assessment must be proportional to the objectives (i.e. human prosperity, health of Country, sustainability of ecosystems), address the probabilistic range of impacts, incorporate best available data, and be explicit about valuations (Sutton 2019). Changes in topography and bathymetry due to erosion, currents, and storm patterns are all likely to intensify under climate change and will impact the net sea level change in specific locations (Konlechner et al. 2020; Lin and Pussella, 2017; Church et al. 2016). These complex dynamics are cited as additional arguments for a higher risk assessment threshold (Church et al. 2016; DCC 2009). 2100 is the metric year used by Department of Climate Change, and higher climate change risk thresholds are increasingly recommended, particularly when vulnerable SESs are involved (Church et al. 2016; DCC 2009; Lee et al. 2023; Sutton 2019). As understanding of planetary feedbacks has progressed and mitigation of greenhouse gases has stalled, higher risk estimates have become increasingly significant and have been advised in national policy (Lee et al. 2023; Slangen et al. 2023; DCC 2009). In summation, decision-makers are advised to use worst-case scenarios to inform adaptation and planning strategies, particularly in sites of high uncertainty and vulnerability. Accuracy in resolution and accuracy of sea level estimation are two critical components for an effective bathtub SLR model. Freely available DEMs in Australia have a vertical error range of 2.5m due to targeting the uppermost surface rather than bare earth (Kulp and Strauss, 2019). This error range has led to an underestimation of SLR risks, particularly as modelling typically occurs at an elevation of 1 m or less. The efficacy of the bathtub model is dependent on the quality of the informing DEM (Coveney and Fotheringham, 2011; Fereshtehpour & Karamouz 2018; NOAA 2017). Because the DEM is high resolution (0.5 m) and locally specific to ASC, the data has much lower error statistics that often occur when downscaling from larger data sets (Coveney & Fotheringham 2011).

4.4.3 *Participatory sketch mapping*

To complete the risk assessment, sites and types of values must be identified in a locally and culturally appropriate and relevant manner. Risk and vulnerability are defined as the intersection of hazards and their capacity to impact a system, site, or entity of value (Pörtner et al. 2022a; UNEP, 2021). Participatory and transdisciplinary research tends to better represent the dynamics and concerns of changing SES within the local context with local knowledges (Cockburn et al. 2018). Since the 1990s, participatory mapping has been used to capture social, cultural, and ecological phenomena, and is especially useful for land use planning, resource management, resolving conflicts, and conservation (Hoverman et al. 2010).

Cognitive mapping is a form of visual data collection which enables representation of abstract ideas, processes, and mental maps (Hoverman et al. 2010). Moreover, it has been found to be compatible with Indigenous epistemologies where ground maps can resemble Dreaming tracks and sites, and thus are more readily understood (Mooney & Tan 2010). Participatory sketch mapping is most effective when the process is transparent and respectful, when both Western and Traditional knowledges are acknowledged, and the resulting map is shared in a useful manner for all parties (Robinson et al. 2016). To produce the maps, individuals are asked to draw, loosely and often interpretively, over a standardised map of a region (Rambaldi et al. 2006). When properly georeferenced and formatted, these sketches can be digitised and rendered in ArcGIS software and translated into raster format (Noble et al. 2020; Potter 2020). The results from sketch mapping workshops have been positively received by Indigenous participants as both respectful and useful knowledge (Holcombe 2023; Hoverman et al. 2010; Robinson et al. 2016). Participatory sketch mapping has been shown to be particularly applicable to sharing knowledges between Western and Traditional spheres (Noble et al. 2020; Robinson et al. 2016; RNTBC 2014). Successful participatory sketch mapping requires that the shared knowledge is appropriately handled and accessible to the appropriate audience in a suitable format, which is ensured by the final consultations and story map publication (Hoverman et al. 2010).

MCRA erosion model

Erosion arose as a considerable concern, particularly due to the geomorphological constraints of the bathtub model (Palutikof et al. 2019; Siebentritt 2016; DCC 2009). Coastal erosion also impacts and compounds risks to ecological and cultural values on Country (see 5.4) with potential complex system feedbacks (i.e. turtle nesting sites, sacred locations, mangrove extent and health, and access to Country). Addressing the gap between the SLR model's scope and risks to coastal

values further advances the goal of providing support for medium to long-term decision-making, monitoring, and strategizing (CRCNA 2024; Bishop-Taylor et al. 2021;).

Coastal erosion is driven by numerous biophysical feedback processes with significant shifts during extreme weather events (Lin & Pussella 2017). In modelling these, the Universal Soil Loss Equation fails to model sediment fate and the European Soil Erosion Model cannot model the response to a singular erosion event (Vieira et al., 2021). Sediment budgets can be affected by human activities, including development driven erosion, mining activities, adaptation strategies, and river run-off, which are not considered in this model (Konlechner et al., 2020; Le Cozannet et al., 2013). Similar to the effects of terrestrial sediment, bathymetry and intertidal landforms and their shifts have a significant impact on erosive patterns (Hoque et al., 2019; Konlechner et al., 2020). Rather than create an intensive (and likely still uncertain) physical forcings model, an index of risk likelihood with in-built uncertainty was deemed preferable.

This model made significant use of the Smartline coastline dataset, which was pioneered in Australia, and features summary data of geomorphology, wave exposure, and other variables within a vector dataset (Sharples et al., 2009). GA Smartlines at a scale of 1:25,000 with numerous variables summarised and standardised as attributes along a coastline, is an innovative and useful resource for erosion risk assessment (Nanson et al., 2022; Sharples et al., 2009).

To best resolve the limitations of biophysical predictive models, an analytical hierarchy process (AHP) was chosen to represent the likelihood that a particular coastal extent may erode under intensifying climate change (Lin and Pussella, 2017; Özyurt* and Ergin, 2010). This led to a multi-criteria risk assessment (MCRA) erosion model that augments the Smartline dataset by adding inland dimensional aspects and incorporating vegetation cover. An MCRA is further advantageous over a process model as it encapsulates a range of erosion hazards, including cyclones, human activity, gradual regime shifts under climate change, and spans both aqueous and atmospheric erosion forces (Hadipour et al., 2020; Hoque et al., 2019; Lin and Pussella, 2017).

Effective mapping of coastal vulnerabilities requires logically combining heterogenous characteristics into a readable output, with appropriate expertise and acknowledgement of uncertainty, to which GIS is well-suited (Figure 13) (Le Cozannet et al., 2013; Lin and Pussella, 2017; Narra et al., 2017). This can be accomplished with an AHP, which consists of the following steps (Saaty, 1980):

1. Define the problem and its hierarchical context: the "point" of the pyramid is the goal of the decision, expanded into broad objectives, then the selective criteria, and finally a set of alternatives;
2. Evaluate the relative importance across the hierarchy using pairwise matrices;
3. Synthesise the pairwise matrices into weighted scores and combine criterion as per the hierarchy tree.

The pairwise comparisons enable qualitative characteristics to be standardised into numerical indices, as determined by expert analysis (Le Cozannet et al., 2013; Nguyen et al., 2020; Saaty, 1990). The resulting matrices' eigenvectors and eigenvalues are integrated as criteria weights using the hierarchy tree, which ensures logically sound layering and calculation of raster outputs (Behera et al., 2019a; Le Cozannet et al., 2013). The GIS layers for their respective criteria are combined following the McHargian overlay principles to produce a single, legible indexed map representing the primary goal (McHarg, 2006). As closely as possible, this MCRA erosion model adhered to Le Cozannet et al.'s procedures (2013).

Story maps for knowledge sharing

Story maps offer a visually driven medium for conveying scientific information and spatially referenced data to either a public or restricted audience (dependent on ESRI publishing settings) (Vollstedt et al. 2021; Cope et al. 2018). Educators and researchers use story maps because they combine text, figures, and multimedia, alongside ArcGIS maps and models (Gill 2024; Cope et al. 2018). This versatility and accessibility make story maps an effective hazard awareness tool (Oubennaceur et al. 2021; Vollstedt et al. 2021). Often omitted, sharing of Western science is an integral part of successful, respectful knowledge exchanges with Indigenous Peoples (Brinckley et al. 2024; Woodward et al. 2020). A locally oriented approach designed for public awareness and relevant decision-makers is both novel and necessary and is exemplified by the final story map publication to an Anindilyakwa audience (Vollstedt et al. 2021).

4.5 Fieldwork and results

Because of the collaborative and iterative nature of this research, fieldwork and outputs occurred concurrently throughout its duration. All outputs were co-designed, and some early outputs then informed subsequent consultations (Figure 39). The three modelling components are a bathtub SLR model, a values map created with the Anindilyakwa Rangers and Community, and a MCRA

erosion model. These models will be supplemented with additional relevant datasets and published in a story map that will accompany the Ranger's forthcoming MMP. Co-design resulted in a research timeline that deviated from the typical thesis structure - as such, methods, consultations, and results overlapped throughout. Consultations were organised by the ALC Data Unit, and their relationships on Country yielded higher response rates of higher calibre; an oft cited dynamic where established trust facilitates better knowledge exchanges on Country (Campion et al. 2024b; Woodward et al. 2020; Castleden et al. 2012). The results presented below are organised chronologically, indicating the order that processes occurred, which demonstrates the iterative and reflexive process of each step.

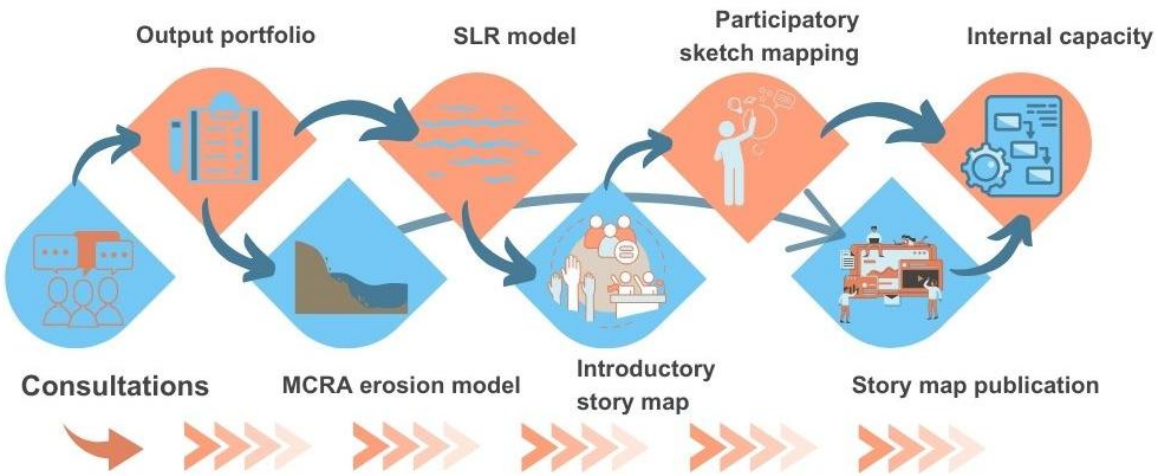

Figure 39: Flowchart of fieldwork and results

4.5.1 First field visit: initial scoping

During the initial consult visit in February, the concept of a sea level rise model was broached and a yarn about coastal climate change concerns commenced, within an appropriate two-way dimension (Brinckley et al. 2024). A coarse preliminary sea level rise model was shown on a large display screen in a room of Elders at the language centre in Umbakumba to demonstrate the researcher's intent. Yarning revealed that climate change was witnessed and felt, although the mechanics and trajectories were not fully understood, which aligned with Aboriginal and Torres Strait Islander self-reporting across Australia (Barnett et al. 2023; Lansbury et al. 2023; Petheram et al. 2010). The socially secure setting and visual aid facilitated an easy knowledge sharing despite linguistic barriers (Lansbury et al. 2023; Clarke 2002). On the following day, a scoping meeting with the Rangers revealed an alignment of aims and goals with their forthcoming MMP.

This synergy became a foundational element for this research collaboration and the working knowledge outputs.

4.5.2 Remote consultation: the output portfolio and story map

Because of the substantial alignment with the MMP scope, the Rangers became the primary collaborative entity, which was maintained through frequent emails, video calls, and documentation. Through this process, an output portfolio was delivered as a comprehensive guide for the intent, scope, and potential model development. The framing and risk analysis within the output portfolio drew heavily from Commonwealth literature so as to reflect national standards and regional concerns (Cresswell et al. 2021; Palutikof et al. 2019; NCCARF 2017; Church et al. 2016; Crowley 2016; Capon 2014; AS 2013; Bird et al. 2013; COAG 2011; DCC 2009). The output portfolio enabled exchange of tangible and conceptual information, the former as an itemised list of concerns and risks and the latter by encouraging reflective conversations about climate change on Country. Again, visual aids were invaluable, particularly the thorough summaries of coastal risk within by the GA Smartlines, which enhanced conversations about hazard risks (Nanson et al. 2022; Sharples et al. 2009).

A summary of concerns on ASC was derived over the course of the collaboration (Box 1). The first iteration of climate change concerns was summarised within the output portfolio, which was reviewed and discussed with the Ranger team. In preparation for the second field visit, an introductory story map was produced with a summary of the discussed coastal concerns, climate change background information, and an overview of the planned workshop activities. The story map was informed by the same resources as the output portfolio, as well as the conversations that occurred after its delivery. Delivery and presentation of the story map is discussed below, and its ongoing availability has supported numerous subsequent meetings and consultations. This introductory story map was shared among key knowledge holders for review and feedback prior to arrival for the second field visit.

- Unexpected, significant dieback area on Northeast Island
- Mangrove extent and health
- Beach erosion, both acute from storms and more gradual geomorphological changes
- Saline intrusion, especially mangroves and wetlands
- Ecological shifts and aspirations for carbon sequestration
- Biodiversity changes and impacts for key species (i.e. turtle nesting sites)
- Smell of the water changes (more like freshwater) and the fish have moved
- Cyclones moving slower and staying longer
- Algae blooms and coral bleaching, as well as water quality and ocean acidification
- South Point area -- access, potential road development, erosion and flood risk
- Sites: Dreaming, art (cave paintings), camping, fishing, spawning, burials
- Umbakumba flooding stories, where Elders went during cyclones, past flood extents -- potential for change with Qantas Bay topology in the future and the significant sandbar
- Access to Country, which will influence funding, some areas are already only accessible half of the year due to weather

Box 1: Emerging concerns and changes on Anindilyakwa Country

Sea level rise model

The bathtub SLR model parameters were selected to encompass appropriate assessment for a high-risk scenario, as is befitting the increasing risk, modelling uncertainty, and sensitivity of local systems. The average prediction for Groote Eylandt SLR in the year 2100 was 1 m. This is in relative agreement with the Commonwealth's primary coastal climate change risk assessment tool, which approximates 0.70 m in East Arnhem in the year 2090 (CoastAdapt 2017). For further accuracy, the Canute 3.0 sea level rise modelling tool was consulted, each point surrounding Groote Eylandt was logged, and the planners should allow for values were summed and averaged (Jakob et al. 2023). Parameters were set for a base year of 2023 (as per the Aerometrex data collection date), a high-risk scenario and modelled out to the year 2100. The model results for each point around ASC were recorded and averaged (mean value: 1.0044 m, range: 0.35 m). Due to computational constraints, inherent limitations of precise modelling, and the risk awareness directive for the model's use, the averaged sum was deemed a sufficient measure rather than matching each point to its value around the island (Hague 2022; Hunter 2012; DCC 2009).

A coarse-level model using a 30 m resolution DEM from GA was created to ensure the suitability of procedures, produce an estimate of expected results, and serve for final comparison of model suitability (Figure 40). Once the DEM is imported, all values below the desired elevation (in this instance, 1 m) are masked off and formatted to an appropriate colour. To complete the model, the Aerometrex DEM was imported into ArcGIS Pro 3.3.2, organised into sub-groups of mosaic rasters for ease of handling, and then masked. The same process was used to create a layer of current sea level, for ease of visual comparison.

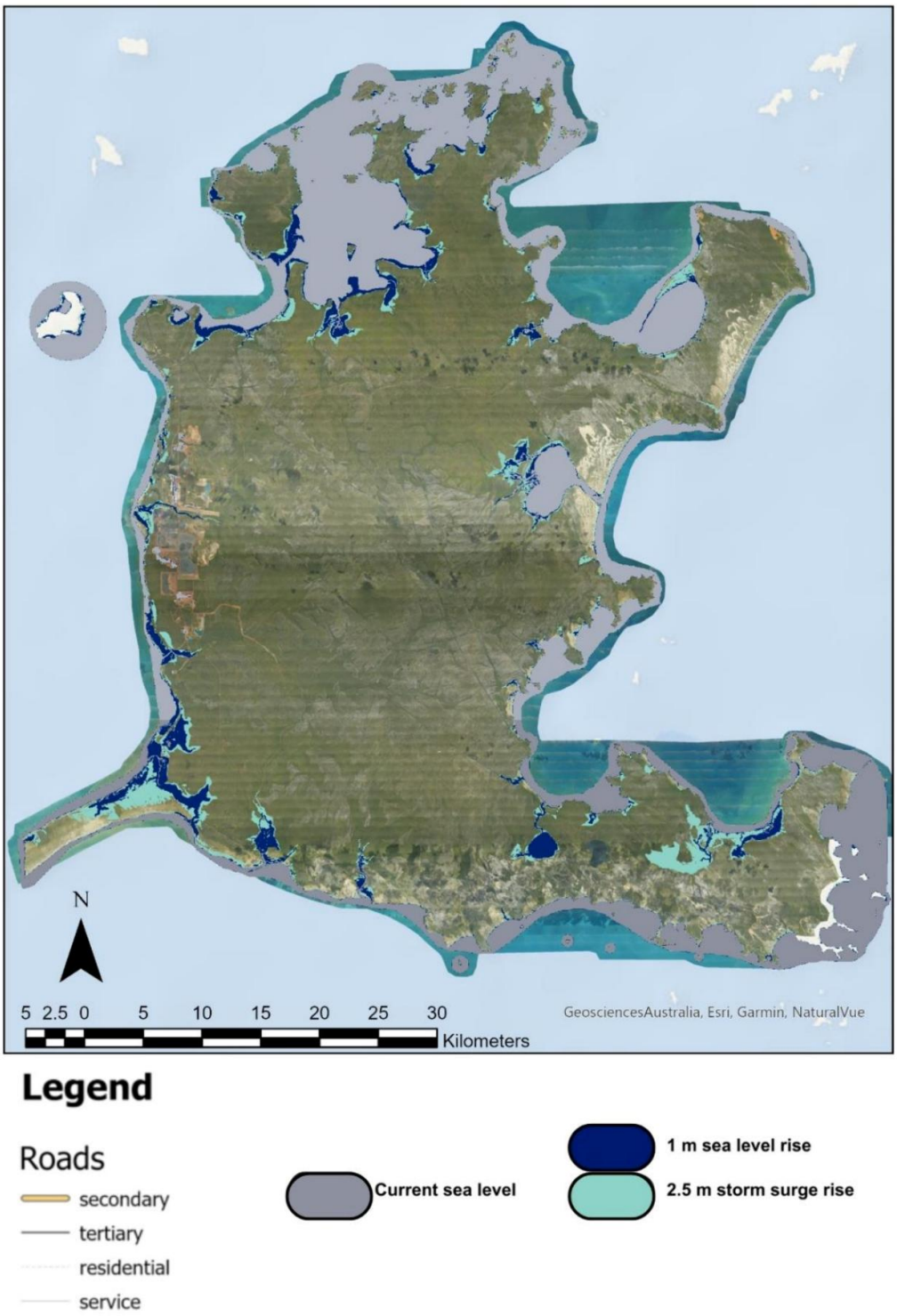

Figure 40: Groote Eylandt sea level rise bathtub model with current sea level, 1 m of sea level rise, and 2.5 m of sea level rise

MCRA erosion model

The MCRA erosion model was designed using an AHP, which synthesises six physical characteristics into a singular index representing the likelihood of future erosion at a spatially explicit extent (see Withrow 2024 for full technical details of the MCRA modelling process).

An AHP method was chosen because calculating precise changes to shorelines by physical forcings is uncertain and computationally intensive, due to complex biophysical feedbacks (including ecological regime shifts and potential anthropological adaptations) as well as the unpredictability of extreme weather events (Vieira et al. 2021; Özyurt* & Ergin 2010). GIS-derived coastal vulnerability indices using AHP are increasingly prevalent across a range of scales, geographies, and concerns, which provides numerous case-studies and robust expert insights (Hadipour et al. 2020; Nguyen et al. 2020; Narra et al. 2019; Le Cozannet et al. 2013; Mani Murali et al. 2013). Many coastal risk models create two indices (physical and social) that are then combined into a net coastal vulnerability index (Bera & Maiti 2021; El-Shahat et al. 2021; Behera et al. 2019a; Narra et al. 2019; Özyurt* & Ergin 2010). For this research, SES values, human environs, and infrastructure were not aggregated into the final index model for a variety of reasons (Hoque et al. 2019; Lin & Pussella 2017). Foremost, the users of the models are familiar with the location of communities and dwellings and explicit imagery is more beneficial than implicit indices for management decisions. Secondly, ASC is largely undeveloped, and analysis of built-environ and biophysical interactions would be better suited for site-specific analysis (which could be a valuable consideration for future research). Due to these considerations as well as feedback from community consultations, the scope of the MCRA erosion model only encompasses physical hazard vulnerability.

Criteria selection was informed by expert consultation (Dr Simon Walker, CSIRO), case-studies, availability and quality of datasets, and relevancy to ASC concerns. The selected risk criteria are wave exposure, geomorphology, proximity to shoreline, topography, vegetation cover, and past erosion extent. For each criterion, their characteristic attribute was ranked according to the likelihood it would contribute to future erosion, from 1 (lowest risk) to 5 (highest risk) and represented as a georeferenced map of the study site (Behera et al. 2019a; Narra et al. 2017). Attribute thresholds and relative rankings were determined using cross-tabulation of references, examination of datasets and their context, and site appropriate scaling (Nguyen et al. 2020; Behera et al. 2019a; Hoque et al. 2019; Le Cozannet et al. 2013).

- *Geomorphology* is defined as landforms, substrates, and their processes and histories, and as this encompasses both composition and structure, it is highly pertinent to past and future erosion trends (Hoque et al. 2019; Mani Murali et al. 2013). Ranking of alternate geomorphology classes was completed using cross-tabulation and referencing Smartlines literature (Nanson et al. 2022; Hoque et al. 2019; Lin & Pussella 2017; Narra et al. 2017; Le Cozannet et al. 2013; Sharples et al. 2009).
- *Proximity* to the coastline (shortest linear distance from any given terrestrial point) is a dominant parameter due to the nearness of ocean and wave energy forcings (El-Shahat et al. 2021; Behera et al. 2019a; Narra et al. 2017; Hughes 2016). The Distance Accumulation tool was utilised to construct a continuous, linear, fuzzy gradient extending from the coast (rank 5) to 2 km inland (rank 0), based off of visual estimation of pertinent scope for a decadal timeframe extending to 2100 (Narra et al. 2017). The accuracy and efficacy of the proximity measurement is enhanced by the 0.5 m resolution of the Aerometrex DEM (Narra et al. 2017; Coveney & Fotheringham 2011).
- *Topography* is the average elevation above sea level, as determined by the Aerometrex DEM; higher elevations are more protected from both ongoing inundation and acute erosion due to extreme events (Hoque et al. 2019; Mani Murali et al. 2013; Coveney & Fotheringham, 2011). Attribute rankings began at 5 for elevations less than 0.5 m above sea level and reduced across a continuous, linear, fuzzy gradient to 0 for elevations above 4.5 m. These parameters were chosen for a medium- to long-term predictive scope across the predominantly low-lying coastal regions of ASC. The higher resolution and site-specific DEM from Aerometrex exceeds most standards for effective modelling and enables best quality risk assessment for erosion, especially at high-risk sites (Coveney & Fotheringham 2011).
- *Vegetation cover* is an increasingly recognised variable in shoreline stabilisation, alongside greater understanding of the complex vulnerability and resilience feedbacks of the ecosystems therein (Bera & Maiti 2021; Vieira et al. 2021). The vegetation cover layer is locale-specific as it is derived from the Groote Eylandt vegetation survey dataset from 2018 with a resolution of 1:50 000, using Sentinel-2 satellite image data (Cuff 2018). Classification for rankings was accomplished with cross-tabulation and confirmation by Dr Rachael Gross (co-supervisor), where denser, long-established, significant vegetation was ranked 0 and bare, cleared, or semi-aqueous land classifications were ranked 5 (Narra et al. 2017; Vieira et al. 2021).
- *Shorelines* are the average location where ocean and coast meet, and changes occur due to a range of gradual and abrupt biophysical processes (Nanson et al. 2022; Hoque et al. 2019).

The DEA Coastline dataset spans 1988-2019 and estimates shoreline change by combining tidal gauges and models with satellite imagery with an accuracy to 7.3 m (Bishop-Taylor et al, 2021; Nanson et al. 2022).

- *Wave exposure* indicates extents that currently experience higher intensity wave activity, which will likely continue and progress as climate change intensifies (Lin & Pussella 2017). The knock-on effects on coastal processes (waves, water levels, bathymetry, etc.) are interdependent and difficult to predict with regional accuracy (Hughes 2016). The wave exposure criteria are embedded within the GA Smartlines data and were extrapolated and formatted for this model.

In ArcGIS Pro 3.3.2, datasets for the six selected criteria were uploaded, examined, and their attributes ranked such that each spatial geographic entity is identified by a single ranking for each criterion (Figure 41). Geomorphology, waves, and erosion were extrapolated from the GA Smartlines dataset and extrapolated inland using Distance Accumulation tool to create a three-dimensional footprint (Narra et al. 2017).

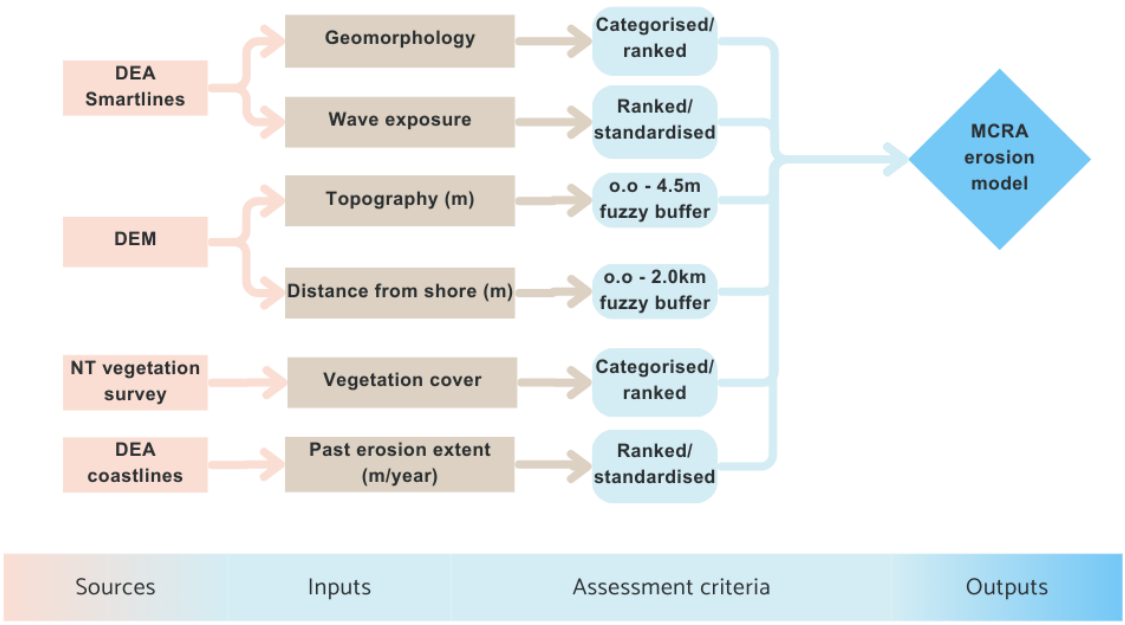

Figure 41: MCRA erosion model GIS components

After the criteria were defined, examined, and ranked, the criteria were compared to each other first by cross-tabulation and then formally using a pairwise matrix (Nguyen et al. 2020; Behera et

al. 2019a; Hoque et al. 2019; Le Cozannet et al. 2013). This analysis revealed the following valuations: topography, geomorphology, and proximity are regarded as dominant criteria (El-Shahat et al. 2021; Narra et al. 2017); vegetation is considered complex due to system feedback (El-Shahat et al. 2021; Vieira et al. 2021); and wave exposure and past erosion extent are identified as less significant criteria for the pairwise ranking (Lin & Pussella 2017). The equation was applied through the Raster Calculator function below by modifying each criterion by its weight and then summing into a singular index. The final MCRA erosion model for Groote Eylandt (Figure 42).

$$Erosion\ index = 0.07 * past_shorelines\ + 0.17 * geomorphology\ + 0.03 * wave_exposure\ + 0.3 * proximity\ + 0.16 * vegetation_cover\ + 0.24 * topography$$

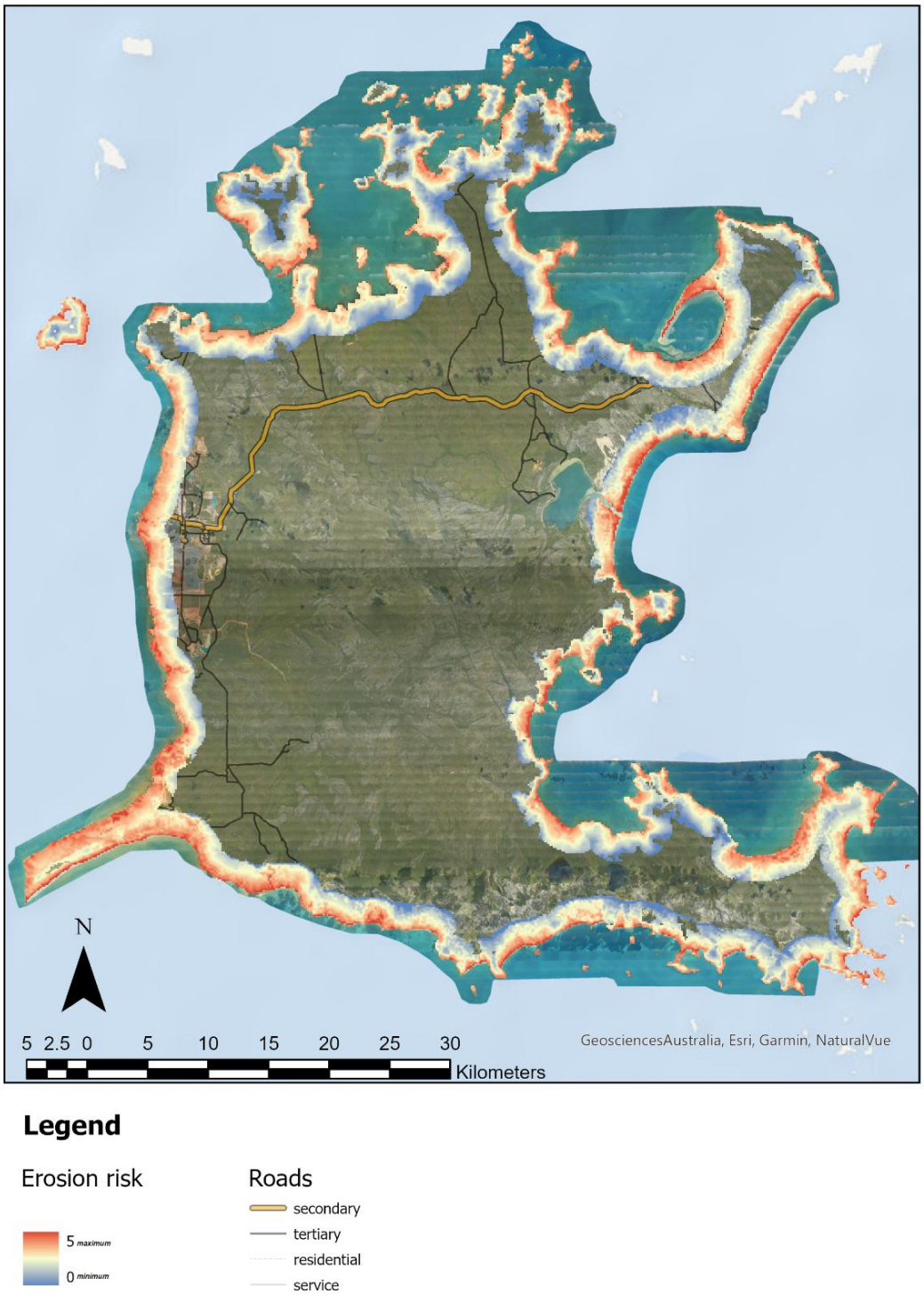

Figure 42: MCRA erosion model of Groote Eylandt

Participatory sketch mapping of cultural values and the use of story maps to convey knowledge

To identify cultural values on ASC, participatory sketch mapping involved a workshop with relevant knowledge holders that was digitised and refined through consultations into a relevant form. Participatory sketch mapping ensured that the values and concerns of the Anindilyakwa community were effectively, accurately, and ethically represented (Holcombe 2023; Noble et al. 2020; Potter 2020). The Ranger workshop included 18 participants consisting of senior and junior staff, local community members, as well as additional ALC staff and community members. Participant selection and invitation followed the Indigenous-forward methods of using community contacts to invite relevant knowledge holders to the conversation (Lansbury et al. 2023). Community members not on the Ranger payroll were compensated for their time, and catering was provided by the ALC Data Unit, as requisite for respectful engagement (Lansbury et al. 2023; Potter 2020). The workshop shared the Western understanding of climate change via the story map and integrated Traditional Knowledges through the participatory sketch mapping. This knowledge sharing in a culturally appropriate, accessible setting encouraged yarning, as per Indigenous preferred methods (Brinckley et al. 2024; Ryder et al. 2020; Hoverman et al. 2010).

The sketch mapping workshop was held at the Ranger headquarters in Alyangula with consensual audio recording. Seven base maps with the Aerometrex aerial imagery were prepared in advance of the workshop: one with the SLR model, two with each half of the island (north/south), and four of each quadrant. The maps were printed on A3 paper, placed in transparent sleeves, clipped and marked for reference to ensure accuracy when transposed. The workshop commenced with an open conversation about climate change, including queries to the participants and a presentation of the story map (Figure 43). Then, the base maps and permanent markers were distributed, and participants were encouraged to mark areas of high value and high concern (Potter 2020; Sandgren 2017; Rambaldi et al. 2006). The process encouraged unstructured conversation about climate change, changes on Country, and planning and management techniques (Lansbury et al. 2023; Hoverman et al. 2010). Yarns and the quotations therein informed and justified the processes for developing final model outputs.



Figure 43: Photos of the sketch mapping workshop (photograph: Dan Keynes)

Digitising and use of sketch mapping data

As prescribed within the output portfolio, values mapping could have been visualised as a singular combinatory metric or as discrete categorical polygons. Through the workshop process, the latter emerged as the preferred medium. Ranking the multiplicity of values on Country into a singular index is antithetical to the Aboriginal concept of Country interdependence (Fischer et al. 2022), so qualitative categorical representation was deemed more appropriate. The process of digitising followed these steps (Potter 2020; Sandgren 2017):

1. Digitise spatial data from participatory sketch mapping;
2. Thematically categorise responses, values, and concerns;
3. Supplement and synthesise with pertinent datasets;
4. Compare, refine, and publish for access by relevant parties.

The participatory sketch maps were photographed and georeferenced in ArcGIS Pro 3.3.2. Areas of interest were traced as polygons or lines, colour-coded, and categorised (see Table 9 below). Interests that could be readily and accurately represented by existing datasets were imported into the values map.

Table 9: Values on Country and their representation in ArcGIS

Values	Representation
Burial sites	Polygons
Art (cave paintings)	Polygons
Dreaming	Polygons and tracks
Songlines	Existing dataset within Ranger's system
Fishing	Existing recreation dataset in IPA plan
Camping	Existing recreation dataset in IPA plan
Recreation	Existing recreation dataset in IPA plan
Mangroves	DEA mangroves (Landsat)
Turtle nesting	Polygons
Oysters	Polygons
Mud mussels	Polygons
Access to Country	Roads

Concerns and values within existing, non-sensitive datasets were identified to be integrated into the final story map publication. Because the final story map publication is dynamic and not static, publication does not require a visually streamlined map with a singular metric. Layers can be selected and deselected depending on the user's preference. Furthermore, the story map end-

users are ASC residents and staff, so greater detail and less summation is preferable. During research design consultations ArcGIS story maps were identified an ideal format for disseminating the results of GIS models, data delivery and as a communication tool for workshop preparation. As a visually driven, accessible medium, story maps enable a cohesive narrative presentation of complex scientific concepts with integration of the spatially relevant datasets on ASC (Vollstedt et al. 2021; Cope et al. 2018). The first iteration of the story map was developed in preparation for the second field visit. It focused on climate change communication, outlining the processes and expectations for the sketch mapping workshop, and showcased the modelling work thus far. The bathtub SLR model was a prominent feature of this introductory story map, which prompted yarning about concerns on Country. The story map and adjoining workshop fulfilled the Indigenous request for '…increased familiarity and use of the IPCC and its reports for Indigenous Australians with a community and/or professional role of relevance to climate change' (Lansbury et al. 2023). The story map development and delivery process has facilitated the sharing of Western knowledges and ensured a more equal knowledge exchange rather than extraction (Brinckley et al. 2024; Woodward et al. 2020) (Figure 44).



Figure 44: Output portfolio presentation, second field visit (photograph: Dan Keynes)

4.6 Discussion

Remote Indigenous communities require locally contextualised, robust data to support climate-forward decision-making, such as the GIS models produced herein. The MMP and the CRCNA

defined the scope of the outcomes; the goal of a *working knowledge* framed research design; the literature review and consultation processes revealed principles for better Indigenous engagement. These principles include participatory design and processes, ethical and respectful knowledge sharing, and a transdisciplinary approach. The scope and context of this research position the *working knowledge* outputs in an Indigenous management context without prescribing Indigenous solutions; as a non-Indigenous researcher in a Western epistemology, there is a risk of miscommunication, omissions, and assumptions. Thus, the scope was limited to developing and delivering data and increasing internal management capacity, as aligned with the ALC's strategies (Figure 45).

Because these outputs have been co-designed for integration with the MMP, there is intrinsic capacity for community communication, relevancy in policy, disaster strategizing, and tracking changes on Country. Model efficacy was strengthened by synthesis of planetary scale trajectories and thresholds, methods that are appropriately matched to biophysical uncertainties, and high-resolution, locally contextualised data. Deliberate choices in methodology, research design, and engagement supported the relational partnerships as well as ensuring the relevancy of outputs for the ALC.



Figure 45: ALC capability development strategies (source: ALC, 2024d)

As a knowledge sharing technology, GIS can integrate a variety of perspectives, scenarios, and concerns and synthesis of internal and external dataset. There is a growing trend in the uptake of internal GIS resourcing for Indigenous land management and cultural preservation, as well as increasing support for trainings, data sovereignty, and research design (Holcombe 2023; RNTBC 2014). The development of models for and within the ALC is highly advantageous for advancing internal capacity; numerous publicly available datasets were not recognised or implemented within current management strategies, due to their inaccessibility or lack of internal expertise. This thesis and its outcomes support the management of the Anindilyakwa estate by making cultural values and physical risks known and accessible in a spatially explicit dataset.

4.6.1 Model applicability to address emerging concerns

Effective land and sea management requires internal capacity and data to support SES problem-solving and climate-forward decision-making. Because systems thinking is integral to Indigenous ontologies, conceptualisations of wellness, and estate planning, it is logical to use SES analysis as

the foundation for model design (Romm 2024). While the static hazard risk models do not encapsulate the feedback and dynamics within (Déguénon et al. 2024); they can provide a strong foundation for future analyses using stock and flow, feedback, or causal loop diagrams (Dyball & Newell 2014). The quality of the Aerometrex data, the efficacy of the co-design process, and the practices of Indigenous data sovereignty supports these future modelling developments.

The models approach risk assessment by spatially exploring the intersection of physical hazards and cultural values. The two physical hazard models address the leading coastal climate change concerns on ASC, sea level rise and coastal erosion. The participatory sketch mapping process identified specific categories of values, increased internal agency, and enhanced climate change awareness. The accompanying story maps (both introductory and published iterations) provide conceptual background that is relevant and reviewed by participants. The community-oriented development and ALC ownership of these outputs enable internal future utilisation and expansion of these models.

During consultations, emerging concerns included access to Country, mangrove extent and health, and the forthcoming mine closure alongside future developments. These three queries are examined using the SLR, erosion, and values extents to evaluate model potential and efficacy. Notably, the presentation, layering, and scaling (zoom) of the maps and models are accessible to ALC users via internally held story maps.

4.6.2 Mangrove extent and health

Mangroves arose as a significant site of value during the participatory sketch mapping workshop, and the significance and vulnerability of the Gulf of Carpentaria mangroves is previously established (Hammer et al. 2023; Duke et al. 2021). Mangroves are generally sites of high biodiversity value and shoreline protection, erosion defence, and carbon sequestration (Vieira et al. 2021). A pre-existing DEA dataset of mangrove extent was imported and the SLR rise models were overlain for visual comparison. On the closest view (left), an instance of storm surge potential is identified in the upper left. This section correlates with a gap in mangrove extent. This could be indicative of a surface flow drainage pattern or a lower elevation that is susceptible to saline intrusion. Sites of pattern interruption such as these (as compared to most of the neighbouring coastal extent, centre image) may merit in-situ examination to determine causation or ongoing monitoring (Figure 46).

Because mangroves are interphase ecosystems between terrestrial and marine environs, they highly susceptible to biological, geological, chemical, and physical shifts (Vieira et al. 2021). These boundary dynamics also make them both highly susceptible to coastal erosion and key species for mitigation erosion and storm surge risk (Nanson et al. 2022; DCC 2009). Because of these compound and complex systems dynamics and high cultural and ecological, mangroves and their systems often merit increased study, which the SLR and erosion (not shown) models provide.

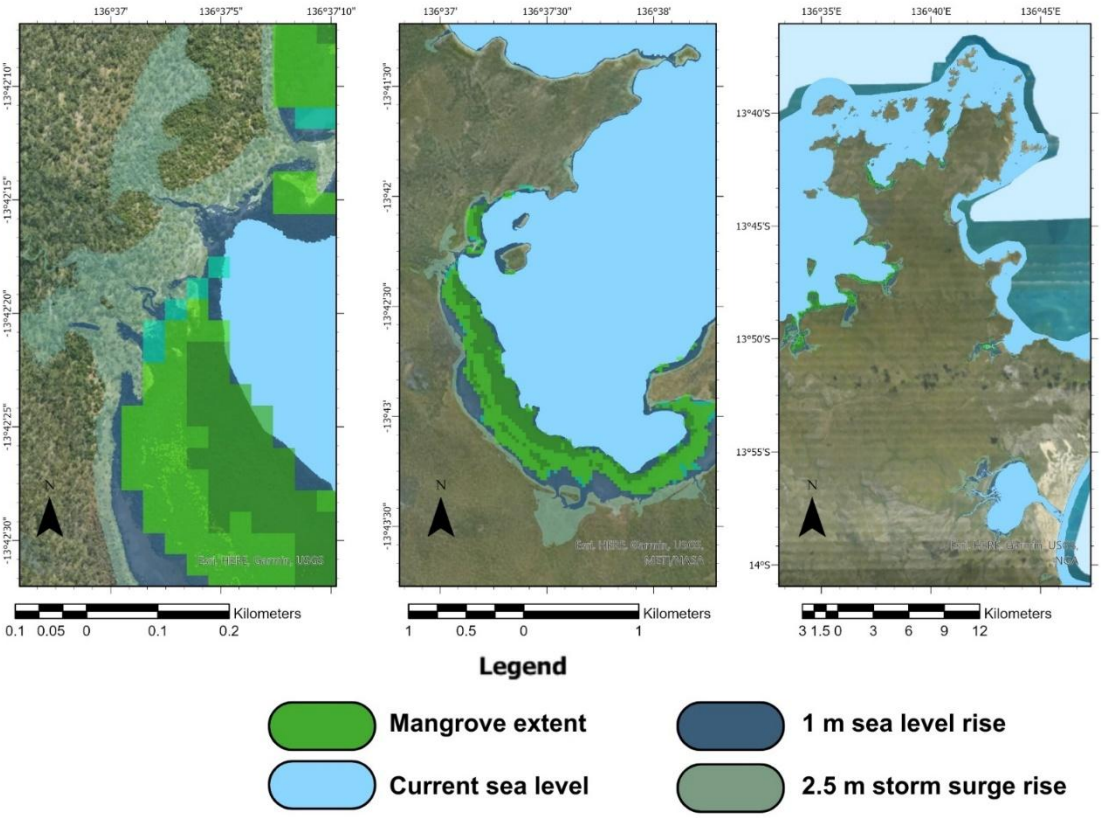

Figure 46: Mangrove extent and sea level rise models for visual comparison

4.6.3 Maintaining access to Country

Access to Country is a critical aspect of Indigenous rights, sovereignty, and continued sense of wellness (Bock et al. 2021; Woodward et al. 2020; Duane 2013; Green 2006). Track maintenance constitutes a significant portion of Ranger resources and time allocation (K. Eden, personal communication, August 14, 2024). After Cyclone Megan, fuel lines were interrupted for upwards of four months, which disrupted activities on Country, including track maintenance and cyclone recovery (Fitzgerald & Brann 2024). The repercussions demonstrated both the acute disruptions in the form of inaccessible roads, a destroyed pier, loss of the ferry to Bickerton Island (Figure 47), as

well as the compounding issues of an under-resourced community that suffered a protracted recovery.

The southeastern peninsula on Groote Eylandt is a site of recreation and fishing and there are discussions about current accessibility (D. Keynes, personal communication, 13 August 2024). During the story map presentation and yarning, the near total inundation on the peninsula was a site of high concern. The compound impacts of future SLR and current erosion risk on roads is shown below in (Figure 47). A suggestion that arose during yarns in the Ranger headquarters was whether to pivot funding toward sea or air access instead of relying on roads to some high-value areas with difficult track access.

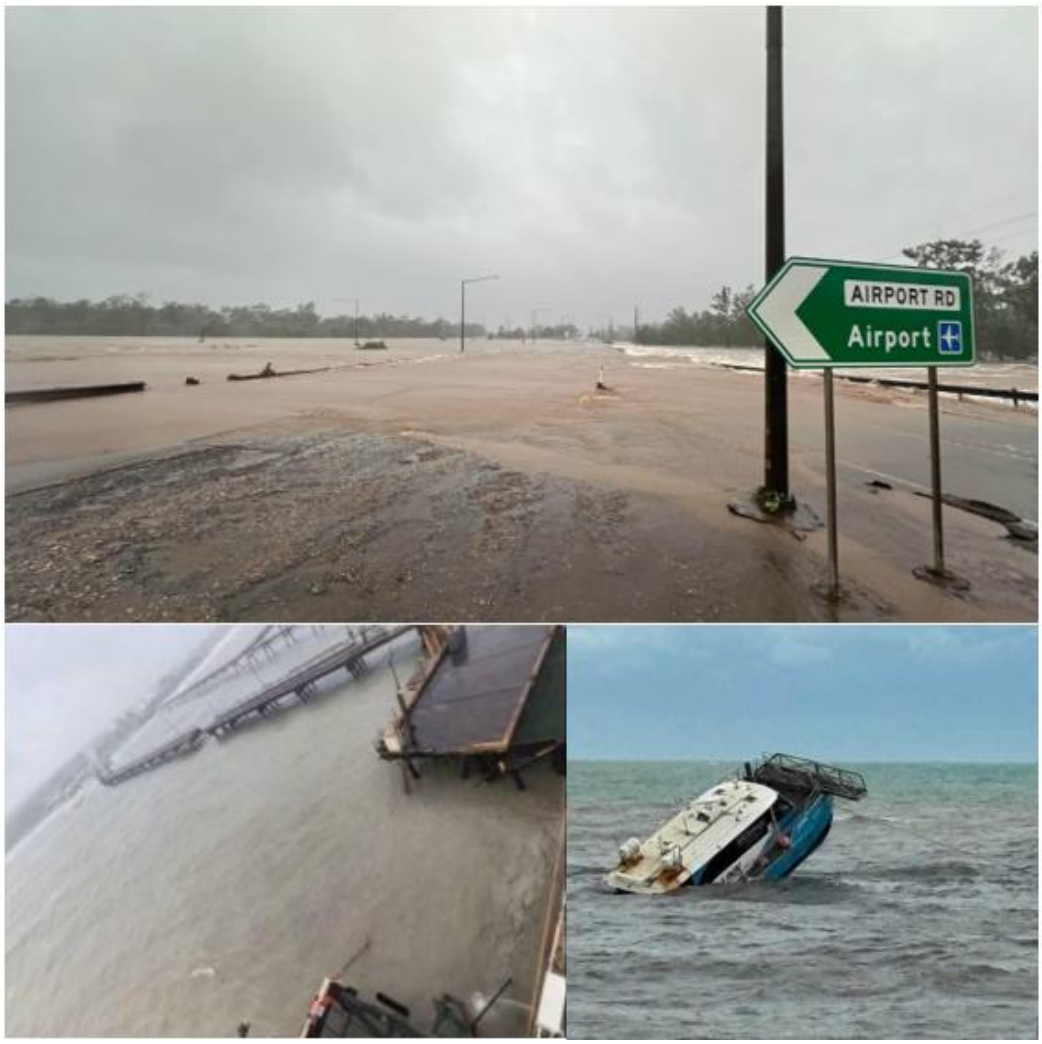

Figure 47: Photos after Cyclone Megan in March 2024 (source: Thales Belasco)

The choices of how to ensure continued access to Country are varied, and the management strategies must encompass land use planning, coastal protection, infrastructure, and environmental services (Rosendo et al. 2018). These overlapping and intersecting interests can all be supported by spatially explicit and relevant models (Figure 48).

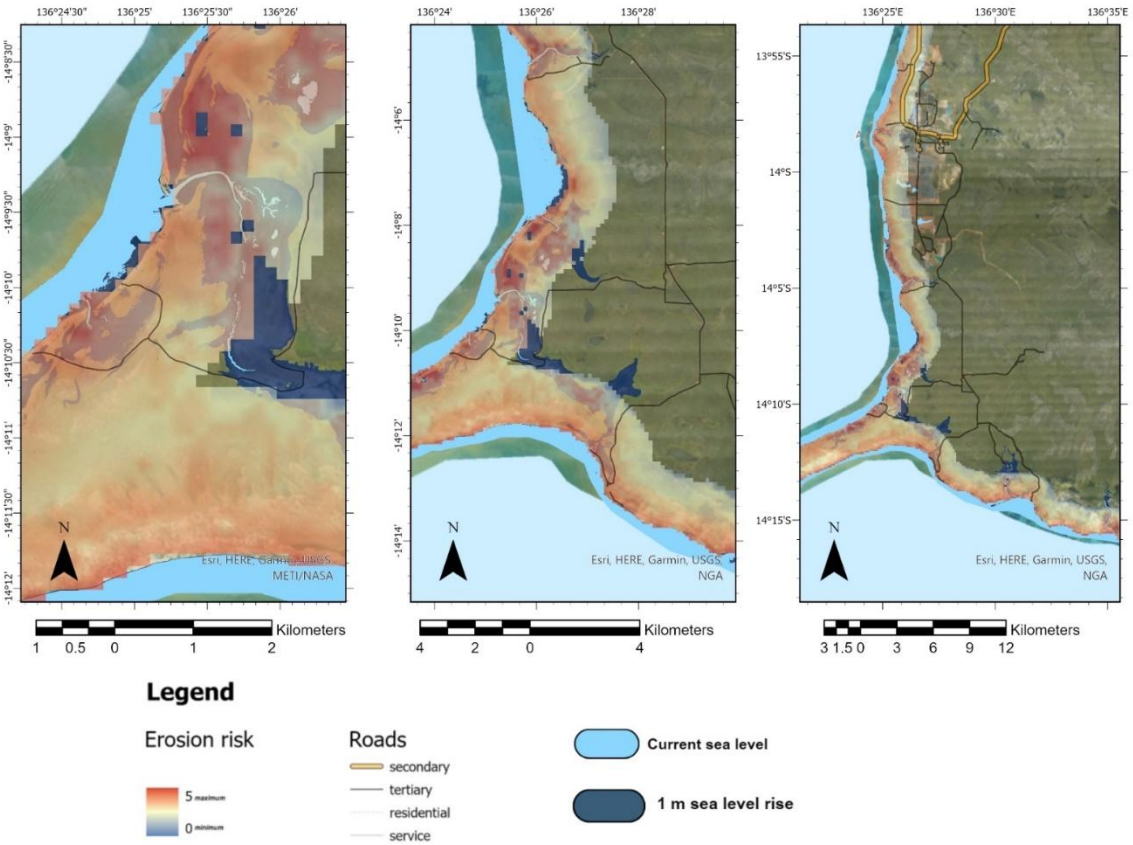

Figure 48: Access to Anindilyakwa Sea Country via road infrastructure, multi-criteria erosion risk model, and 1 m of sea level rise model

4.6.4 Economic development transitions

A sustainable, ethical, Anindilyakwa-forward economic transition is a key goal as the current mining lease reaches its expiration. The Little Paradise development area (Figure 49) is intended to provide infrastructure support for the smaller mining project, a luxury resort, aquaculture, and solar farming. The coastal survey report for development preparation defined their long-term scope as ‘greater than five years’ (Smith & Referral 2022). Additional scoping for longer-term sustainability into future decades may be warranted. Further systems analysis of ecological values and potential impacts could enhance the combined goals of sustainable economic development and preservation of cultural values.

Figure 49 and Figure **50** below are maps with various overlays on the region of interest. There is significant mangrove growth and a low-lying region within the bay (top, bottom). This area may become more vulnerable as SLR accelerates, and the nearby developments may facilitate ease of monitoring and evaluation, if properly managed. Notably, this resolution of erosion model is less suited for site-specific development analysis, due to the broad index summary and non-specific soil and sediment identification (top). However, it does indicate extent of potential risk, which seems to be in agreement with the development choices (Figure 50), where the location of the resort is further west than the high erosion risk sand bar. The components of the erosion model can be selected and analysed individually, as evidenced by the topography model (middle).

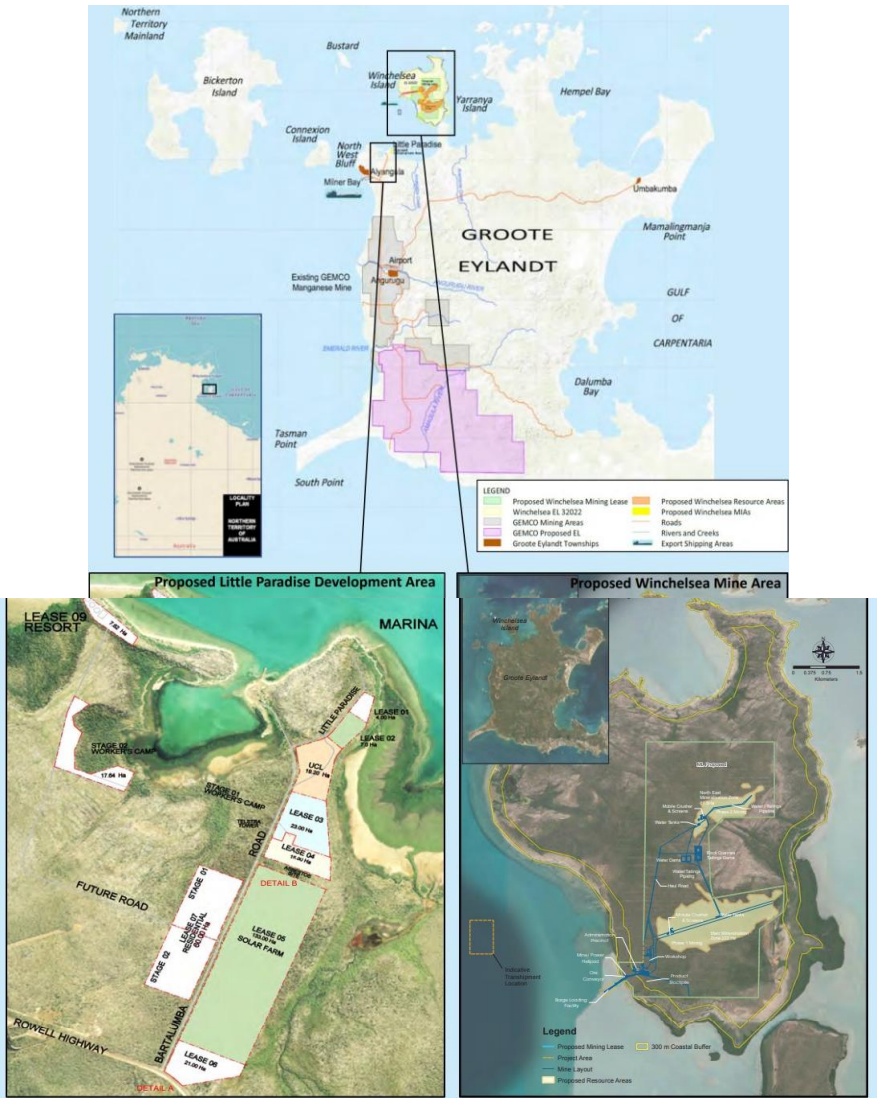

Figure 49: Development plans for Little Paradise and Winchelsea Mine (source: GHAC 2022)

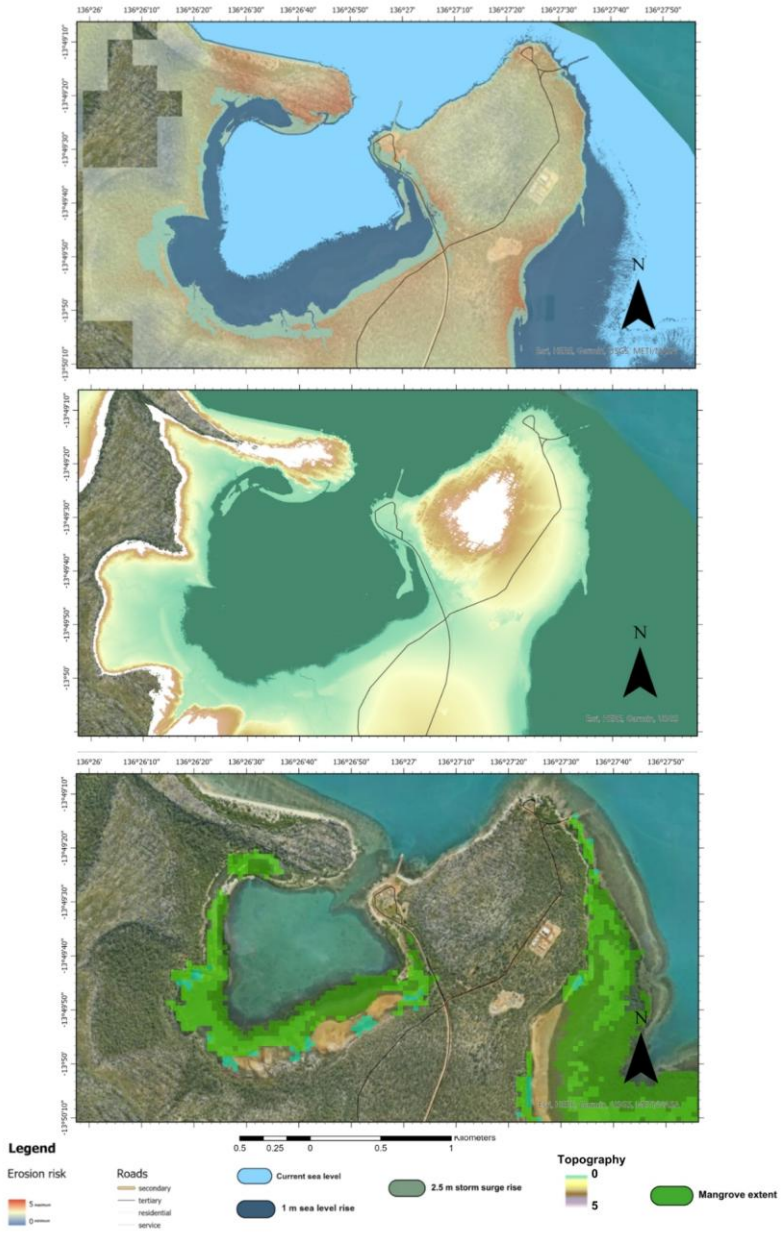

Figure 50: Development site considerations for Little Paradise, Groote Eylandt

Application of working knowledge outputs

Working knowledge is the founding goal of this thesis, defined through the aims of community communication, leverage in policy and industry, disaster resilience and planning, and monitoring and evaluation (Barnett et al. 2023; Barber et al. 2014). The inclusion in the MMP ensures utility and accessibility, and the three emerging concerns from the previous section demonstrate applicability. Community communication is enacted through the MMP, the story map publication, and the continued availability of these outputs within the ALC Data Unit, enhanced by decolonial

and culturally informed methodologies. Monitoring and evaluation are demonstrated above in the inspection of the mining closure and future development sites and can be further explored by tracking changes in high-risk, high-value ecosystem sites, such as mangroves. Disaster resilience and leverage are typified by the importance of and support to maintain access to Country, for both infrastructure planning and funding allocation. Further capacity for each of these four aims is explored in detail below, which further demonstrates alignment with the overarching CRCNA grant objectives and Anindilyakwa's current Strategy Plan (ALC 2024d).

Community communication

The value and importance of visual communication was apparent throughout the entirety of the consultation and co-design process. This community-driven communications approach is reflective of prevailing national-level advice for better risk awareness, which suggests culturally sensitive, linguistically appropriate, and accessible engagement (DHAC 2023). The outputs of this thesis were designed for their target audience, as exemplified by the story map for the participatory workshop (Palutikof et al. 2019; Vollstedt et al. 2021). The MMP engages a novel approach to communication and education, where publications include a standard report document, posters, bilingual classroom materials, and web hosted materials (D. Keynes, personal communication, 13 August 2024). The publication of these outputs into these formats is indicative of broader goal of community awareness.

Indigenous data sovereignty and the ALC Data Unit ensures that the datasets and models are available, irrespective of researcher availability or longevity of partnerships. The knowledge is the property of the community that it pertains to, and it remains accessible for reference and development. These protocols are the designation of the CRCNA grant and ALC priorities. Future community-directed outputs are feasible under the grant's provisions, including the potential for 3D photogrammetry, 3D printing, and model augmentation (Gill 2024; Morris 2023).

Leverage and negotiations across sectors

Authoritative, locally relevant analysis can be a powerful tool in negotiations across sectors, including policy and industry (Potter 2020; Young & Gilmore 2017). The lack of research about climate change impacts on remote Indigenous communities results in a lack of policy awareness and action (Lansbury et al. 2022). Climate change litigation has already occurred in Australian councils and state governments when low-lying coastal land was not properly assessed for risk (Lansbury et al. 2022; Mummery 2016). Expert groups on local and national levels utilise multi-

criteria models for adaptation policy and strategies, and the MCRA erosion is similar to those utilised in both regulatory policy and local decision-making (Le Cozannet et al. 2013). Similarly, SLR bathtub models are an institutionally accepted risk assessment tool (Fereshtehpour & Karamouz 2018; NOAA 2017; DCC 2009). Applications include funding for the disaster resiliency strategies and better funding allocation, such as modes of transport for access to Country. Cultural landscape mapping and ecosystem service analysis can improve decision-making and conflict resolution by explicitly naming interests and concerns, particularly when developed participatorily (Xu et al. 2020). Further, there are already examples of formal Indigenous state and international grievances, such as litigation for negligence on the Commonwealth level (Schuijers 2023), and human rights violations submitted to the UN (Strang 2023).

Tenure and sovereignty are ongoing issues, where the IPA program does not provide comprehensive management authority (D. Keynes, personal communication, 13 August 2024). Within the Northern Territory, there is increased recognition of the necessity of Aboriginal Sea Country rights and political momentum toward more effective sovereignty (NTG 2024) (Hoskins 2024). Economic opportunity, knowledge management, infrastructure investment, and self-determination of cultural priorities are named in Territory and ALC strategies (ALC 2024d; NTG 2024). Knowledge management, spatially explicit data, and internal access and awareness enable the actualisation of these goals.

IPBES and other UN bodies have developed numerous accounting strategies to quantify SES and cultural values, and emergent research seeks to better align these metrics with Indigenous ontologies (Normyle et al. 2022). There is significant merit in translating cultural values into an explicit framework that is accessible, inclusive, and comprehensive for policy and management spheres (Normyle et al. 2022; UN, 2021; Woinarski & Baker 2002). This is far beyond the scope of the values mapping herein, but similar projects have led to ecosystem accounting on a globally recognised scale (Normyle et al. 2024).

Coastal management and potential disaster resiliency

Governments support local entities with guidelines, information, and resources for community disaster planning and response (COAG 2011). If these supports are not adequately accessible for the community in question, what then? Management issues often include fragmented governance and unclear local responsibilities, which can be overcome with capacity building and knowledge exchange (Rosendo et al. 2018). High-quality data and expert assessments can reduce the cost

and interruption of maintenance and disaster losses (Mummery 2016; Stevens & Collins 2011). GIS methodologies can support policy, including disaster management, forecasting and warning capacity, analysis of adaptation and development options, and enhancement of natural resource management and land use planning (Nguyen et al. 2020) (Stevens & Collins 2011). Visually explicit identification of risk enables preadaptation and monitoring of high-risk hotspots under accelerating and compounding coastal climate change risks (El-Shahat et al. 2021). Data that are contextualised by local and Traditional Knowledges support better land management and increased resiliency (Burgos-Ayala et al. 2020; Hadlos et al. 2022).

Effective coastal management requires integration with disaster resilience and climate adaptation strategies and support for local governance from the national level (Rosendo et al. 2018). The models herein can be utilised for a variety of management purposes (Box 3).

- Risk assessments are undertaken for priority hazards and widely shared among at-risk communities;
- Consider risks, vulnerabilities, and capabilities across the social, economic, built, and natural environments;
- Information on lessons learned is accessible and available for governments, organisations, and communities;
- Maps and information are routinely shared among relevant parties;
- Strong networks across sectors and regions fill information gaps;
- Improved data and tools for assessing hazards and risks to enable communities to better understand and act;
- Current information is available on websites or other forms and appropriate tailored to the audience as needed;
- Vulnerable individuals have equitable access to information;
- Compatibility of information sharing technologies is promoted;
- Local communities have expertise of local risk;
- Accurate and authoritative risk information is provided and tailored to the audience's needs;
- Communities are aware of vulnerable elements and consider their needs in the development of programs and plans;
- Infrastructure retreat by storm surge and erosion risk;
- Coastal protection measures from local wave, climate, and storm data;
- Fishery and aquaculture productivity by seasonal patterns and predicted trends;
- Drainage and stormwater flows by sea levels and flood patterns;
- Planning of evacuation routes by flood patterns and elevation.

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Box 2: National Strategy for Disaster Resiliency (derived from COAG 2011; Mummery 2016)

One potential disaster resiliency application could be in support of the Groote Eylandt Local Emergency Plan, which identifies disaster response and recovery procedures (Hollamby, 2024). Community consultation, repairs, infrastructure, evacuation, and impact assessments are specific categories that can benefit from awareness of SLR and erosion risk. Sacred sites and cultural heritage are also named as contextual concerns, which could be supported by the participatory mapping process. Similar to monitoring and evaluation (below), disaster resilience is best accomplished by Indigenous leadership with relevant contextual and cultural awareness (Hadlos et al. 2022). Thus, providing physical hazard models on the Groote Archipelago scale directly to the relevant decision-makers and community enhances their capacity for disaster resilient planning.

Integration with monitoring and evaluation strategies

Monitoring on Country already exists within the ALC; climate change awareness and natural systems' analysis are present, including early identification of changes and trends (Taylor 2016). By not prescribing monitoring and evaluation strategies, this research allows Indigenous-led management to develop culturally sensitive metrics of Country and relational health (Lansbury et al. 2023). Biocultural indicators can indicate SES health trends and inform Indigenously defined sustainability goals (GHAC 2022; NBY 2021; McElwee et al. 2020). Indigenous monitoring and enforcement are uniquely suited, efficient, and ethically viable for managing their remote and conservational significant estates (Reed et al. 2021: Artelle et al. 2019). By combining quantitative modelling of SLR risks and explicitly naming sites of cultural, Rangers and TOs can better predict the compound risks, threats, and processes on Country. Further, the combination of contextualisation of biophysical data into a systems' aware risk assessment is essential for effective climate response and sustainable decision-making (Mummery 2016). The combination of SES awareness, Anindilyakwa values, and physical hazards is evidenced in the mangrove example and the development site assessment. These models can inform Ranger management strategies, selection of sites for closer observation, and potential documentation of changes over time.

Assessment of limitations and future avenues

The motivation for this thesis is to support the management of the Anindilyakwa estate by making cultural values and physical risks known and accessible in a spatially explicit dataset.

Australia, despite being a high-income nation, lacks sufficient climate response, both in the cessation of fossil fuel use and application of adaptation strategies; this lack of foreplanning can

result in unintended consequences that exacerbate existing inequities (Xu et al. 2023; Whyte 2020). Moreover, due to significant uncertainty in future climate scenarios because of socio-ecological dynamics on the planetary scale, it is imperative to employ high-risk thresholds on the relevant spatiotemporal scale (Petheram et al. 2010). Within the Indigenous context, relational tipping points may be crossed before the SES changes are measured (Whyte 2020). Climate risk is defined at the intersection of physical hazards and SES values and decision-makers must consider both likelihood and impact when assessing risk (Sutton 2019). Where climate change exacerbates existing inequities and lack of impactful policy furthers colonial impacts, Indigenous forward capacity must be prioritized (Lansbury et al. 2023; Lee et al. 2023; Birkmann et al. 2022). Sustainable development is oft-touted as a positive perspective and opportunity-laden future within the drastic systemic shifts necessary to mitigate the worst of climate change (Claudet et al. 2020; Bennett 2019; Henderson 2019). Climate change vulnerability, sustainability, and resilience are social concepts, and Indigenous goals, values, and strategies must be Indigenously defined (Ali et al. 2021, Ford et al. 2016).

The bathtub SLR model and erosion MCRA exceed existing datasets in their refinement, complexity, and utility. Future physical hazard analysis will be enhanced by better understanding of Australian specific climate modes (i.e. El Niño southern oscillation and Indian ocean dipole) as well as integration of the recent DEA coastline datasets for intertidal regions (Bishop-Taylor et al. 2021). Moreover, place-based initiatives for environmental and community resiliency tend to have higher success rates, particularly when integrated with cultural stewardship programs (DHAC 2023; Stevens & Collins 2011). Indigenous groups and individuals as data end-users is still a novel research approach (Williamson et al. 2023); the success of this research design, outputs, and management integration is evidence that this modality of data sovereignty should be supported and pursued.

A number of avenues for further development were identified when evaluating the key results from this research. These avenues are outlined below in relation to key components of the project.

Bathtub SLR Model

Higher resolution topography datasets yield higher accuracy flood and inundation modelling, which supports better disaster planning and adaptive strategizing (Fereshtehpour & Karamouz 2018). The precise tidal status of the Aerometrex data is unknown; visual comparison to the standardised GA DEM shows relative agreement. High tide data and storm surges were not modelled for the

initial SLR model, but there is potential for highest astronomical tide to be integrated per final consults via the Canute 3.0 modelling tool (Jakob et al. 2023). Evaluation of extreme sea level events is a shortcoming of both this research and climate research at large (Wahl et al. 2017). Future developments could also include: connected analysis with terrestrial hydrological networks and better incorporation of local tidal variation and extreme weather events (NOAA 2017). Analysis with terrestrial flows will improve understanding of flood events, which can support disaster resiliency and infrastructure planning. More refined tidal data can increase the relevancy on shorter temporal scales, i.e. the decades between now and 2100.

MCRA erosion model

The MCRA erosion model is an index that summarises broad risks across ASC, where its scope measures hazard possibility on an indefinite scale of several decades. The ability to consult its six criteria components is of particular use for the Rangers and ALC decision-makers (D. Keynes, personal communications, 13 November 2024). Because of the combinatory capacity of GIS, additional criteria and different risk indices could be developed with the existing model or its criteria.

The MCRA could be expatiated to include benthic biophysical criteria; this would better represent the complex dynamics of coastal zones and provide more comprehensive mapping of ASC extent (currently limited to terrestrial). Time constraints, expertise limitations, data inaccessibility, and minimal previous case-studies inhibited the inclusion of benthic criteria for the final erosion model. Bathymetry can change significantly on scales of months to years due to currents and sediment deposition, which further limits long-term analysis (Nanson et al. 2022; Le Cozannet et al. 2013). Similar multi-criteria assessments can be developed with the datasets produced herein, such as storm surge, wetland vulnerability, or saline intrusion risk (Gatdula & Blanco 2024; Gallina et al. 2020; Al-Nasrawi et al. 2016). Future research could be supported by the DEA intertidal extent datasets and the Mapping Makarda project, which was also co-developed with the ALC (Nanson et al. 2022; Davies et al. 2020). Any future AHP analyses would also benefit from increased breadth and depth of consultation with local and disciplinary experts (Le Cozannet et al. 2013).

Site-specific analyses of areas of interest

The resolution of the provisioning datasets (particularly the Aerometrex DEM) is high enough that zooming to areas of interest is feasible and accessible (due to the dynamic interface within ESRI story maps). Site specific analysis would be particularly valuable for estuaries, mudflats, and

valuable ecosystem extents, as they are both highly vulnerable and would benefit from more precise calibration of impacts and responses (Konlechner et al. 2020; Al-Nasrawi et al. 2016). Because of the intensity, duration, and recent abrupt cessation of mining activities, particular interest in the run-off area and adjacent benthic environs could be particularly beneficial for analysis, due to the intensity of anthropogenic influence on shorelines (Konlechner et al. 2020).

Participatory sketch mapping and story maps

The experience of knowledge sharing that occurred during the participatory mapping process exceeded the value of the static map outputs (Maclean et al. 2022). The process of sketch mapping has been shown to enhance Indigenous epistemology, and ownership of the outputs ensures that any newly developed knowledge is properly available and appropriately managed for community use (Robinson et al. 2016). Indexing and quantification of vulnerability and values is a difficult task that requires translating Indigenous and Western (Campion et al. 2024a; Holcombe 2023). In this instance, there was insufficient Knowledge, due to limited involvement of community members, such that an index could not be derived to accurately and effectively encapsulate cultural values.

The primary outcomes were of a less tangible nature: awareness of climate change, development of future tools, and building of trust and capacity for further collaboration. Explicit outputs were also present, in the form of the list of emerging concerns and changes and the integration of mangroves and roads into final model assessments.

Story maps have been used as tools for climate communication, though their potential has not been fully explored (Oubennaceur et al. 2021; Vollstedt et al. 2021). Story maps are well-suited for conceptual narratives with spatiotemporal analysis, such as climate change, which is enhanced by their capacity for dynamic layering and integration of multiple datasets (Cope et al. 2018; Alemy et al. 2017; Caquard & Dimitrovas 2017). There are a plethora of web-based applications displaying climate related data and risk analysis; however these are often directed toward an expert audience on the state or national level (Vollstedt et al. 2021). A locally oriented approach designed for public awareness and relevant decision-makers is both novel and necessary (Oubennaceur et al. 2021; Vollstedt et al. 2021). The development process, publication, response, and feedback has been overwhelmingly positive, and future climate-solution oriented story maps are strongly endorsed for similar communities.

4.7 Conclusion - Toward better Indigenous engagement

The working knowledge outputs were developed in alignment with the following principles: free prior informed consent, a co-designed and transdisciplinary approach, Traditional and Western knowledge sharing, and Indigenous capacity for decision-making and sovereignty (Campion et al. 2024b; Lansbury et al. 2022; Woodward et al. 2020). By underpinning the utilitarian goals with principled values, the outcomes of this research have greater applicability, relevancy, and cultural appropriateness imperative (Van Kerkhoff, 2014). The intentional approach at the outset facilitated reflexivity and a learning-mindset throughout. Most of the ideals were intentionally integrated throughout research design and development; however, the necessity of sovereignty is beyond the scope of a thesis and addressed in further detail below. The most unexpected and pertinent finding throughout this research is the value of pre-emptively sharing tangible, useful information, knowledge, and outputs. In the first scoping trip, a visual demonstration of the SLR spurred conversation, aligned understanding, and established the relationship between the researcher and the Anindilyakwa community. This theme arose throughout the duration of the partnership.

UNDRIP is the highest level of recognition of Indigenous rights to self-governance, economic freedom, and cultural protections (Yap & Watene 2019; Duane 2013). The best way to ensure conservation goals, a climate sustainable future on Country, and the wellbeing of Indigenous Peoples is to uphold UNDRIP on a national and local level and grant self-determination and sovereignty (McAvoy 2024; Reed et al. 2021). Currently, the Ranger program enforces Western sovereignty and enforces the structures of bureaucracy on Indigenous land management and connection to Country (Fache 2014). The ALC commenced initiatives to expand their tenure over Sea Country and open waters (Taylor 2016). Songlines are associated with ceremonial law, spiritual linkages between islands, and the social exchanges between Anindilyakwa people and their neighbours; they are also threatened by mining interests and climate change impacts (ALC 2012).

This research engages and supports the Ranger and IPA programs on Anindilyakwa Country toward greater decision-making capacity in lieu of the necessary national acknowledgment of sovereignty. Indigeneity should not be classified as a 'sector' or 'stakeholders', particularly as the necessity of agency becomes more apparent under intensifying climate change (Reed et al. 2021; Ogar et al. 2020; Petheram et al. 2010). There is increasing recognition of the value of Indigenous stewardship and potentially a cohesive Australian sea management peak body (McAvoy 2024; Dedekorkut-Howes et al. 2021). Management strategies often face challenges such as financial

and human capacity constraints (Rosendo et al. 2018); the partnership through the CRCNA circumvents these issues and enables better outcomes for the ALC, although it is not a replacement for continuous, sustained funding and support.

One of the most pertinent and unexpected findings of this research are the benefits of proactive sharing of Western Knowledge in an appropriate and accessible medium. Both the output portfolio and the introductory story map were integral to commencing the knowledge exchange, where coastal climate change concerns were researched and presented before solicitation of insights or local concerns. This exchange fostered mutual trust which enabled better co-design and enhanced applicability and relevancy toward ALC usage (Maclean et al. 2022). The completion and presentation of the SLR model early in the research process indicated the authenticity of the researcher's intent to provide useful outputs to the community. The shared efforts of the participatory mapping session avoided the common pitfall of quantitative data extraction. Further to this point, systems thinking and knowledge sharing is considered a participatory "world generating process" unto itself (Romm 2024). This is indicative of how the discussion and shared Knowledges were an output unto themselves. The trajectory of this research is reflective of the Our Knowledge framework (Figure), specifically: i) prepared and strengthened by the existing grant framework, ii) communicating Western Knowledges and expertise in advance of research design and development, iii) discussing in culturally appropriate settings, both in-person and remote, iv) bring together through the principles of data sovereignty and publication within the ALC, and v) applicability through the MMP publication and ensuring suitability for Indigenous integration through methodology and methods (Woodward et al. 2020).

Rather than superimpose a Western index upon Indigenous ontologies, it is better support the expression, documentation, and self-determination to enact values on Country. While Indigenous Knowledges never could (nor should) be fully represented within a software program, GIS offers greater creativity, collaboration, and interpretation (Williams, 2021). This research integrates the concept of relationality in a way that allows Indigenous data users to draw conclusions and develop sustainable solutions that are culturally contextual and relevant (Gould et al., 2023). A relationality-informed partnership, such as this, can enhance adaptive capacity on ASC; this capacity will be further bolstered by forthcoming community training sessions on Country (Lansbury et al. 2023). Appropriate publication and context (story maps) enhances local decision-making, including adaptive strategies as well as communication with regional and national agencies (Vollstedt et al. 2021). Active, collaborative management development is one of the most useful opportunities for Indigenous communities navigating their climate change futures (Fischer et

al. 2022). The partnerships of the CRCNA grant and the Anindilyakwa-led directive set a foundational motivation for the ethics and efficacy of this research.

Chapter 5: Looking to the future – capitalising on innovation and embedding the benefits of spatial enablement

This chapter provides an assessment of the project in relation to the central and evolving role of the ALC data unit. It also presents a number of emergent future avenues and concludes with some reflections from a knowledge exchange between the ALC and two other Indigenous organisations.

5.1 The central role of the ALC data unit in operationalising IDS and IDG

A key factor in the success of this project has been the central role of the ALC data unit in coordinating activities between partners and Traditional Owners to ensure that data creation and research is conducted according to IDS and IDG principles to deliver genuine benefit to community. This work has served to support Anindilyakwa land and cultural management. Indeed, the impact of the project was recognised by the Geospatial Council of Australia (GCA) with the 2024 *NT Geospatial Excellence Award for Community Impact* being granted to the project. As stated in the award (Figure 51):

> ‘This project has delivered a community led GIS system, based on the Anindilyakwa’s cultural priorities that can be utilised by the ALC going forwards within initiatives aimed at activating their Indigenous estate for an ambitious economic and social development program in years to come. The project has generated datasets and associated story maps which are integrated into a GIS, providing a platform for community voices in Country planning. This data can be utilised as a layer of cultural information for use in education programs such as Learning on Country, assist the board in their preparations for mine closure, and as critical data to unlock the economic potential of future community lead development projects. Some of the initial project outputs are proving to be powerful proofs of concept for other Indigenous organisations. For example, Story Maps for Anindilyakwa cultural education programs have been co-designed with partner organisations whilst remaining been entirely ‘in-house’ with no data leaving Country’



Figure 51: Bruce Doran and Sam Holt (second and third from right) accepting the GCA 2024 NT Geospatial Excellence Award for Community Impact on behalf of the project team (photograph: Cate Bonthuys, GCA)

The data capture by Aerometrex was a foundational stage for developing products that could be used in further research and planning led by the ALC. The identification of 'no-fly' zones by Anindilyakwa Traditional owners, due to cultural considerations, ensured that raw data was obtained in a sensitive and appropriate manner. There were two-way learning opportunities at this stage - Aerometrex were able to adapt their procedures to accommodate cultural concerns and the ALC participated the inner-workings of a leading geospatial company. It is noteworthy that the imagery captured of Groote Eylandt in this project is of unprecedented quality for the area, and it is now fully owned by the ALC. The research conducted in partnership with the ANU operationalised core IDS and IDG principles in a nuanced manner and integrated high-resolution imagery and LiDAR products to address some core Anindilyakwa priorities. Spatial methods such as digitized sketch mapping proved to be a highly effective '*common language'*, adapting well-established techniques to specific Anindilyakwa contexts. The facilitation of workshops and sketch mapping interviews by the ALC data unit was crucial here – assisting in building relationships between community members and partner agencies and ensuring that interview settings were optimal. Story Mapping also emerged as a key geospatial tool during the research phase of the project. In Gill's (2024) research, the data never left Anindilyakwa country at any stage, establishing a clear benchmark for collaborative story mapping with Traditional Owners. This was possible due to the

ALC data unit having full control of the GIS software, enabling Gill to access their system through a user-defined password. Typically, research data is gathered on country, analysed using university systems and repatriated as filtered products. Withrow's (2024) research into climate change impacts on Anindilyakwa Country was strongly informed by ALC priorities and the specific issues of sea level rise and coastal erosion. The use of high-resolution data captured by Aerometrex and pre-existing GA products such as the 'shorelines' dataset, enabled detailed local analysis of potential impacts, and tailored interpretation of specific sites. Significantly, geospatial models were interpreted directly with Anindilyakwa Traditional owners using Story Maps, sketch maps and interviews. This phase, namely '*what do the modelling results mean for the people who own this Country?*', is often neglected in academic research or concluded in a rushed manner. In this case, the ALC data unit facilitated workshops to interpret findings in a measured manner, and the results and outputs were directly integrated into ALC strategic planning initiatives.

The ALC data unit played a key role in ensuring their direct collaborations with each project partner were conducted according to IDS and IDG principles, but also when acting as key facilitators when external project partners collaborated to make planning and decision making was done in line with cultural priorities. Good examples of this function were sessions facilitated by the ALC that included discussions between ANU researchers, Geoscience Australia members and Aerometrex to discuss the execution of work outlined in Chapters 4 and 5. Although portions of these meetings were aimed at establishing plans for external project partners to collaborate of technical aspects such as data processing, visualisation and data sharing, The ALC Data Units guidance at these sessions ensured the projects direction was governed not by what would be technologically innovative or what would be novel for the industry, but what the priorities of the Anindilyakwa Community were within the scope of the project.

5.2 Future avenues for building Indigenous geospatial capacity

Taken more broadly, the ALC must be commended on investing in the establishment of the data unit. The benefits from this project are significant and tangible in terms of operationalising IDS and IDG principles within a geospatial context. It is important to note that the data unit is funded in an ongoing manner, ensuring that the benefits of spatial enablement remain in-situ and ongoing. From a strategic perspective, there is clear scope to use the ALC data unit as a blueprint for establishing, and further developing, geospatial capacity for Indigenous organisations such as land councils and prescribed body corporates (PBCs) across the north.

A further strategic avenue emerging from this project relates to the fact that, whilst the literature reviews for the research projects identified increasing use of geospatial technology by Indigenous organisations within Australia, there is no single co-ordinating or peak body to foster connections, facilitate knowledge sharing or develop collaborations. The closest entity at the current time is Winyama Digital Solutions, an outstanding Indigenous-owned geospatial consultancy who have trained over 1000 Traditional owners in geospatial mapping. There are national-level examples in other countries that could be adapted to the Australian context:

- The **Indigenous Mapping Network** in northern America has a mission to '*empower native communities by connecting them with the tools they need to protect, preserve, and enhance their way of life within their aboriginal territories*', serve as a '*conduit for native individuals and groups to meet and build relationships, and assist one another in accomplishing sovereignty goals'* and to '*bridge the gap between traditional "mapping" practices and modern mapping technologies'* (IMN 2016).
    - **Māori GIS** provides practical guidance for Māori organisations, iwi, hapū, whānau, and practitioners doing spatial work in Aotearoa. This includes GIS maps to support decisions about land and culture, working with Māori place names, sites and sensitive locations as well as publishing Māori maps and stories without oversharing (Maori GIS 2026).

Knowledge exchange emerged as one of the key benefits of this project, as noted in the chapter summaries for collaborations between the ALC, Aerometrex and ANU researchers. Through connections with the ANU *Mapping a New Path* (MaNP) project, the ALC attended two geospatial knowledge exchange workshops held in December 2023 (ANU and Arakwal Country) and July 2024 (Yawuru Country). The workshops built on ongoing relationships with ANU and the visiting delegations, with a strong focus on facilitating introductions and the sharing of successes, opportunities and challenges in using geospatial technologies for Indigenous land and cultural management (Figure 53). Specific sessions included the use of Metro Maps, story maps, cultural monitoring programs and environmental accounting to incorporate Indigenous perspectives. On-Country sessions involved visit to specific sites to discuss key issues and use-cases for geospatial technologies.

The following organisations attended one or both workshops:

Indigenous organisations:

- Anindilyakwa Land Council (ALC)
- Bundjalung of Byron Bay Aboriginal Corporation- Arakwal (BBOBAC)
- Nyamba Buru Yawuru (NBY)

Non-Indigenous organisations

- Australian National University (Fenner School of Environment and Society and First Nations Portfolio)
- Aerometrex
- Commonwealth Scientific and Industrial Research Organisation (CSIRO):
- Department of Climate Change, Energy, Environment and Water (DCCEW)



Figure 52: Attendees at the first knowledge exchange workshop in 2023

At the conclusion of the second knowledge exchange workshop on Yawuru country, a number of perspectives were recorded by participants which portray the benefits of Indigenous organisations investing in geospatial technology to support in-house land and cultural management and decision

making (Figure 53). Dean Mathews, a Yawuru man and assistant manager (environmental services), reflected on the deeper wellbeing benefits arising from over 10 years of the NBY geospatial program:

> ‘To think about the narrative of the journey we’ve been on, we could look back to the establishment of [the NBY geospatial partnership] since that demographic study that we undertook… We got some spatial representation …In the context of moving forward and how the benefits of these opportunities can be realized, I think that's evidenced in the people coming out and sharing knowledge. That's what we do as Indigenous people: share amongst each other. We’ve invested in this [geospatial] program, and we are seeing transformative change within individuals…That's mabu liyan, you know, when we talk about real mabu liyan’ (Dean Matthews, NBY).

Leon Kelly, an Arakwal man and BBOBAC representative noted the inspiration gained from the knowledge exchange on Country and the importance of respect underpinning Indigenous mapping collaborations:

> ‘I’ve been on the journey with Arakwal from the first stage with the ANU team and the first thing they said...they said we'll do this in a respectful way. That was a few years ago and to this day, I still feel a lot of respect from everyone right now. And I was moved a bit. There’s a bit of emotion going around because of that respect, you know, and we wouldn't give this affirmation or wouldn't be sitting here if it wasn't built on respect…I'm a big believer of face-to-face. The sharing of culture is always going to be done face-to-face. If we’ve got to travel five thousand kilometres to come and see the brothers and sisters in Broome and see their beautiful Country, I'm glad to come over’ (Leon Kelly, BOBBAC).

Jonah Lafferty from the ALC noted the impact of the knowledge sharing process, expressed in terms of growing confidence of Anindilyakwa attendee Josh Barra, who had earlier presented a collaborative story map developed during the CRCNA project. Desmond Billy, a Yawuru Country manager noted the benefits of this aspect of the workshop in terms of inspiration and wellbeing.

‘I got a bit emotional this morning when I sat down and heard Josh talk… Joshy, I just wanted to shout out in front of everyone how proud I am of you and your work and what you've done over the last year. Seeing you come out of your shell and talk to all these people in your second language, that makes me so proud that’ (Jonah Lafferty, ALC, 2024).

‘It's been an honor to show you guys around on Country… For me it's been a real privilege. I did come out of my shell kind of a way too, you know. And with that kind of feeling, it makes my liyan feel good, you know. Speaking up and things. I just want to (to Josh) appreciate this young bloke here… you did a good job (Desmond Billy, NBY, 2024).

A final set of perspectives demonstrate that the use of geospatial technology by Indigenous organisations is seen in an holistic manner, to protect living cultural landscapes for future generations:

‘I brought my daughter. I’m very proud of her. Watching her through this cultural exchange program this morning... I was pretty proud’ (Leon Kelly, BOBBAC, 2024).

‘We’re not just forging our future; we're forging all our children's future. We're doing this and we're creating those pathways for them’ (Monica Edgar, NBY, 2024).

‘It's a hope for the future that new ways of thinking and talking are coming through. That we can support the next generation by seeing what's happening here and that's what's been such a great journey. Looking at the different groups and us all coming together, it allows us to aspire’ (Norm Graham, BOBBAC, 2024).



Figure 53: The second knowledge exchange workshop on Yawuru country in 2024 (photo: Bruce Doran)

5.3 Strategic recommendations

Key priority actions for sector development	Action owner and key partners	Intended industry impacts
CONTINUED DEVELOPMENT OF IN-SITU GEOSPATIAL CAPACITY FOR INDIGENOUS ORGANISATIONS • **The investment by the ALC to establish 'in-house' geospatial capacity through applied IDS and IDG principles has been central to the success of this project. This model is scalable and can be extended to other land councils and Indigenous organisations (e.g. PBCs).**	Primary responsibility: Federal government departments and state Partners: First Nations organisations, Tertiary sector (universities and TAFEs), Geospatial industry, state and federal government departments (e.g. NTG, GA)	Reliable and culturally secure data for community-driven decision making and planning. On-country training in geospatial skills for Traditional Owners
DEVELOP A FIRST NATIONS PORTFOLIO OF APPLIED GEOSPATIAL RESEARCH CASE STUDIES • Whilst there is an increased use of geospatial technologies by Indigenous organisations, there would be clear benefit in	Primary responsibility: Federal government departments Partners: First Nations organisations, Geospatial industry and the Tertiary sector	Cataloguing Indigenous-led use of geospatial technology to share successes and improve collaboration.

developing a dynamic portfolio of case studies in different settings. **EXPANDED GEOSPATIAL KNOWLEDGE EXCHANGE BETWEEN INDIGENOUS ORGANISATIONS** • Increased opportunity for direct sharing between first nations organisations using geospatial technology.	Primary responsibility: State and federal government departments Partners: First Nations organisations, Tertiary sector (universities and TAFEs), Geospatial industry	Innovation and transfer of methods through assessing what works, identifying practical solutions to land and cultural management problems

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