NEILLY GROUP
ENGINEERING

MACKAY WHITSUNDAY REGIONAL EROSION IDENTIFICATION, PRIORITISATION AND REMEDIATION STUDY

REEF CATCHMENTS

20 NOVEMBER 2023

Document Control

Details and distribution

	Details
Document Title	Mackay Whitsunday Regional Erosion Identification, Prioritisation and Remediation Study
Revision Number	3
Project Reference	22085
Author(s)	Reece Fraser Rosan Pandey Lisa Hutchinson Kirstina Ihme Brent Hennekam Luke Sunner Elle Searston Jacob Dearlove Adam Neilly Brett Twycross James Allen Sarah Bloom
Distribution	Carla Lambropoulos (Reef Catchments) Brendan Smith (Reef Catchments)
Citation	Neilly Group, 2023. *Mackay Whitsunday Regional Erosion Identification, Prioritisation and Remediation Study*, prepared by Neilly Group for Reef Catchments

Revision History

Revision	Date	By	Nature of change	Checked By	Approved By
1	14 June 2023	Reece Fraser Rosan Pandey Lisa Hutchinson Kristina Ihme Brent Hennekam Luke Sunner Elle Searston Jacob Dearlove Adam Neilly Brett Twycross James Allen Sarah Bloom	Draft for comment	Adam Neilly Lisa Hutchinson Brett Twycross	Adam Neilly
2	8 September 2023	As above	Final	Brett Twycross	Adam Neilly
3	8 November 2023	As above	Final, minor updates	Brett Twycross	Adam Neilly
4	20 November 2023	As above	Final, minor updates	Reece Fraser	Adam Neilly

Executive Summary

The Need for the Study

In 2021, the Australian Federal Government initiated the Preparing Australian Communities Program (PACP) to bolster the resilience of local communities against natural disasters, particularly as a result of climate change. This initiative arose due to the critical need to reduce both recovery time and costs after such disasters. The program's focus has been on regions highly susceptible to bushfires, cyclones, and flooding. The Mackay Whitsunday Isaac region, overseen by Reef Catchments, falls within these high-risk zones for cyclone and flood resilience and successfully secured funding for a comprehensive regional erosion study.

The Great Barrier Reef, worth an estimated $56 billion and supporting 64,000 jobs, is at the heart of this issue. With threats to the reef posed by climate change, like rising sea temperatures and acidification, it is paramount that additional pressures such as poor water quality, exacerbated by erosion, are managed. Cyclones and floods degrade the water quality in the Mackay Whitsunday region, severely impacting both tourism and agriculture. The influx of sediments and pollutants affects the Reef's health and consequently threatens tourism—a vital industry for the region. Similarly, agriculture, a strong pillar of the region's economy, faces challenges from erosion resulting from loss of topsoil and loss of good quality agricultural land.

Recent history bears testimony to the importance of this study. In 2017, Severe Tropical Cyclone Debbie caused substantial damage. Across the Reef Catchments region, 33 projects were funded from National Disaster Recovery and Relief Arrangements (NDRRA) to address stream bank erosion, for a total value of around $6.2 million. These works prevented an estimated 17,600 tonnes of fine sediment from reaching the Great Barrier Reef lagoon annually.

Similarly, the 2019 Monsoon Trough further stressed the region's environment. Additional funding was secured to address erosion resulting from that event.

Past efforts, backed by significant funding, have aimed at rehabilitating damage, but often miss the chance for a comprehensive assessment of all the identified erosion sites. While various programs have tried to address the issue, there's been a lack of strategy in choosing sites, leading to potential inefficiencies.

The criticality of this study lies in its focus on proactive identification of erosion sites and providing management pathways to protect the Great Barrier Reef and the economic lifelines of the Mackay Whitsunday region – tourism and agriculture. Effective erosion management not only fortifies the region against future natural disasters but also supports the broader Australian community and economy.

Goals and Aims

The aim of the study was to identify critical locations where erosion threatened riparian connectivity, infrastructure, cultural heritage, and/or generated large volumes of fine sediment that would impact Reef water quality. Identification of these areas pre-emptively, rather than retro-actively following disasters or large flow events, would reduce future recovery expenses, bolster disaster preparedness, and ensure resilience against events like those witnessed over the past decade.

Recognising these priority sites allows Reef Catchments and other stakeholders to make informed decisions about future funding applications, ensuring resources are used effectively to maximise benefits to the region.

Moreover, the study intends to leverage sediment-reduction funding to yield broader regional benefits. By channelling this funding, the region could mitigate potential threats to not just the Great Barrier Reef but also infrastructure, ecosystem services, and other crucial assets. This holistic strategy ensures sediment-focused funding also bolsters the region's overall resilience.

Method

Aerial photography and LIDAR analysis was undertaken to identify all locations of potential erosion throughout the region. Photogrammetry processes were leveraged to create a 1970s orthomosaic covering 90% of the Reef Catchments region for comparison with contemporary orthomosaics to provide a large time interval for analysis. Maps comparing the 1970s river positions to contemporary positions are provided in Appendix B for all major streams in the area. Newer imagery was sourced from multiple online streaming services such as Google Earth and ESRI. Analysis between all of this data, as well as government-held and Reef Catchments LIDAR data identified 591 locations of apparent bank erosion or movement.

The subsequent phase of the study involved conducting evaluations of the identified sites. The aim was to select sites, for which costed concept designs would be developed, for:

- The top five locations prioritised based on risk to infrastructure;
- The top five locations prioritised based on riparian (dis)connectivity;
- The top five locations based on Cultural Heritage prioritisation; and
- The top five locations prioritised based on fine sediment export to the Great Barrier Reef.

Cultural Heritage Prioritisation

It is recognised that waterways are culturally significant for Traditional Owners and through collaboration between Neilly Group and Reef Catchments it was agreed that there was limited availability of data relating to areas of cultural significance and Traditional Knowledge for the MWI Region within the DATSIP Database. It was believed that more tangible input from those Traditional Owners with local knowledge would assist in the identification of sites with Cultural Heritage significance. In consultation with Reef Catchments, it was decided that assessments for Cultural Heritage would depend on the outcomes of these future conversations and be undertaken on a site-by-site basis for all sites that progressed to the rehabilitation stage.

Riparian Connectivity

Utilising government vegetation datasets, nine locations were prioritised based on riparian disconnectivity. The method involved finding locations where vegetation has been cleared (non-remnant or Category X vegetation) at a site, and high-quality vegetation (Category A or Category B) were located within a distance upstream or downstream. Therefore, this represents a location where riparian vegetation can be restored to enhance riparian connectivity. This methodology resulted in four locations which were shortlisted for Concept Design.

Infrastructure Locations

Selected land use classifications reflecting high value infrastructure (i.e. transport) were extracted from spatial data available from the 2016 Mackay Whitsunday Regional Land Use Study undertaken by the Queensland Government. The proximity of each location to these selected land uses was then evaluated. The top 5 sites were identified, but none were progressed through to Concept Design.

Sediment Export

There were a large number of locations that were identified, making it impractical to conduct sediment assessments on all of them. Consequently, the sites were screened based on the following criteria:

- The site must show activity since 2017 on the justification that a viable site for sediment funding would need to have been impacted by the Cyclone Debbie (2017), the 2019 Monsoon Trough, or later high intensity events.
- The site must not be remote, isolated in upland areas, or in tidal / delta area of major river systems, fringed by mangroves or other tidal vegetation.
- There must be suitable desktop data for a sediment assessment to be undertaken.

A total of 137 were determined to meet the aforementioned criteria.

An assessment of the sediment delivery to the coast was undertaken for each site in accordance with the Stream bank Erosion Control Assessment Tool (SECAT) user guide and the Reef Trust Toolbox. The sites were ranked with the top locations shortlisted for Concept Design.

Landholder Consultation

Landholders of the shortlisted sites were consulted for site access to inform the Concept Design. Where sites were shortlisted and landholders were not amenable to site visits, or potential future works on their properties, the sites were removed from the shortlist and replaced with other sites lower on the prioritised list.

Cattle Creek Reach Scale Site

Landholders along Cattle Creek contacted Reef Catchments with stream bank erosion concerns during the study. These locations have suffered a long history of erosion and the reduce vegetation from recent bushfires in the area also exacerbated erosion. Intense rainfall during the 2022-2023 wet season caused further stream bank movements, prompting the residents to contact Reef Catchments.

As a consequence, these locations were evaluated in accordance with the study and included as a reach scale site, comprising eight individual sites, in the shortlist for Concept Design.

Concept Design

Concept Designs were developed for:

- Eight locations prioritised for sediment export;
- The Upper Cattle Creek reach scale site, which consists of 8 discrete locations; and
- 4 locations prioritised for riparian connectivity.

Concept Design involved:

- Site visits
- Soil sampling
- UAV flights
- Determination of a recommended remediation approach
- Determine high-level quantities of material and earthworks to implement remediation
- Determine high-level (+/- 30%) costing to implement the recommended approach
- Re-evaluate the sediment assessment undertaken for the site in more detail to ensure accuracy, and assign a cost effectiveness ($ per tonne of sediment saved per year).

Costed concepts for the remediation of the sites include a mixture of:

- bank battering;
- rock toe protection;
- pile fields;
- log jams / large woody debris / log fillets;
- rock groynes;
- revegetation; and

- maintenance.

Concept Design reports for each location are provided in Appendix C. A breakdown of the quantities of materials, earthworks, revegetation and the expected costs for the sites is provided in Table 17 within the report.

Results

Overall, the study found approximately 35,000 tonnes of fine sediment delivered to the coast across the 134 locations which exhibited riverbank movement since 2017. The updated sediment export estimates for the 16 sites shortlisted for Concept Design account for 13,000 tonnes.

The total tonnes for each Basin are shown below in Table A. Figure A shows graphs of the breakdown of total sediment found and the amount targeted for Concept Design within each basin, within each subcatchment, and then a breakdown by individual locations, respectively.

Table A. Total number of locations and fine sediment found in each basin of the Reef Catchments area

Basin	Number of Locations	Number of SECAT Locations	Total Fine Sediment (t/y)	Number of Concept Design Locations	Concept Design Fine Sediment (t/y)*
Proserpine	186	21	2,153	5	1,136
O'Connell	224	62	19,795	7	8,356
Pioneer	100	27	3,465	8	3,391
Plane	81	27	9,124	-	-
Total	591	137	34,537	20	12,884

It is important to note that the revised sediment assessment undertaken for the Concept Design resulted in alteration of the sediment export values for those locations, as the assessment was undertaken in more detail than the rapid assessment across 134 locations for the broader study. In most instances the revised sediment assessment resulted in an increase in the tonnes of fine sediment exported from the site. The revised volume of sediment export for each of the Concept Design locations is shown in Figure A.

Major Outcome – Future Sites Ready for Funding Submission

The sites selected for Concept Design, and the resulting reports (provided in Appendix C), are almost ready for submission upon release of future funding opportunities, with slight adjustments likely needed based on the nuances of the future funding criteria.

While 12 individual sites are provided with Concept Designs, in addition to the eight individual locations comprising the Cattle Creek reach scale site, each of the locations have differing strengths and weaknesses. Depending on the emphasis of future funding and priorities, the most appropriate site or sites can be selected and put forward.

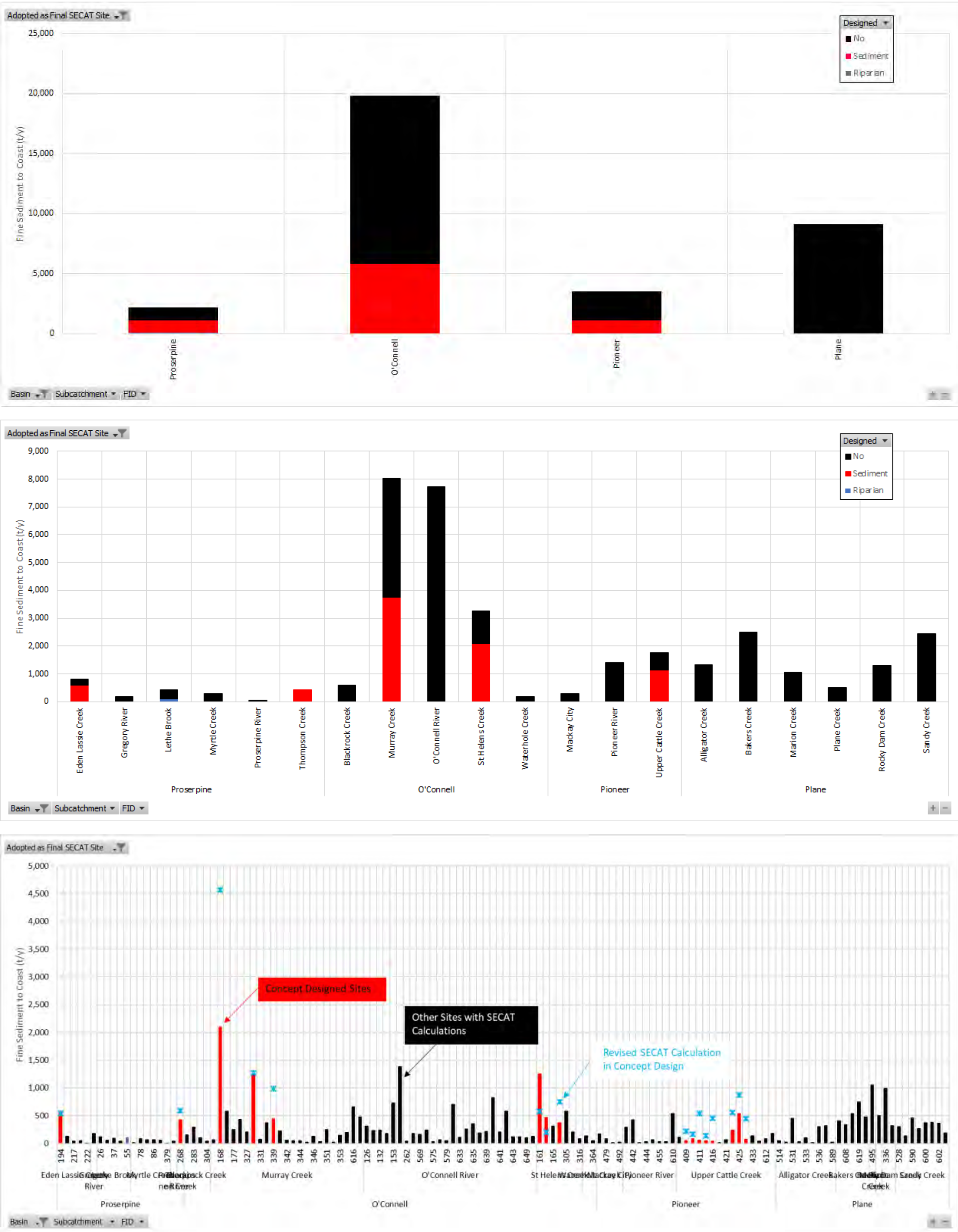


Figure A. Graphs of the total sediment exported by Basin, by Subcatchment and by Individual Location respectively.

Table of Contents

List of Figures

List of Tables

Acronyms

ACS	Aspirations Capacity & Stewardship
AEP	Annual Exceedance Probability
BMP	Best Management Practice
BOM	Bureau of Meteorology
DATSIP	Department of Aboriginal and Torres Strait Islander Partnerships
DEECW	Department of Energy, Environment, Climate and Water
DEM	Digital Elevation Model
DEMoD	Digital Elevation Model of Difference
DES	Department of Environment and Science
DIWA	Directory of Important Wetlands of Australia
DRFA	Disaster Recovery Funding Arrangements
EPP	Environmental Protection Policy
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
GDE	Groundwater Dependent Ecosystems
GECAT	Gully Erosion Control Assessment Tool
HEV	High Ecological Value
LGA	Local government areas
LiDAR	Light Detection and Ranging
MCDA	Multi-Criteria Decision Analysis
MSES	Matters of State Environmental Significance
NDRRA	Natural Disaster Relief and Recovery Arrangements
NP	National Park
NRM	Natural Resource Management
PACP	Preparing Australian Communities Program
QRA	Queensland Reconstruction Authority
QRRMG	Queensland River Rehabilitation Management Guideline
SECAT	Stream Erosion Control Assessment Tool
SEQ	South East Queensland

SLATS	Statewide Land and Tree Survey
RSDR	Residual Sediment Delivery Ratio
SECAT	Stream bank Erosion Control Assessment Tool
SISP	Spatial Imagery Services Program
TORG	Traditional Owner Reference Group
TSS	Total Suspended Solids
WQIP	Water Quality Improvement Plan

1 Introduction

1.1 Preparing Australian Communities Program (PACP)

In 2021 the Australian Federal Government launched the Preparing Australian Communities Program (PACP). The program is aimed at improving the resilience of Australian communities against natural disasters, especially in the face of climate change, and reducing the time and cost of recovery after future disasters.

Round 1 of the PACP provided funding opportunities for locally identified and led projects that focused specifically on improving resilience against bushfires, cyclones and flooding with a specific emphasis on high priority local government areas (LGAs) for each disaster type.

Reef Catchments is the Natural Resource Management (NRM) group for the Mackay Whitsunday Isaac region, which falls within high priority LGAs for cyclone and flood resilience (see Figure 1). Reef Catchments were approved funding for this project that includes a regional erosion identification, prioritisation and remediation study.

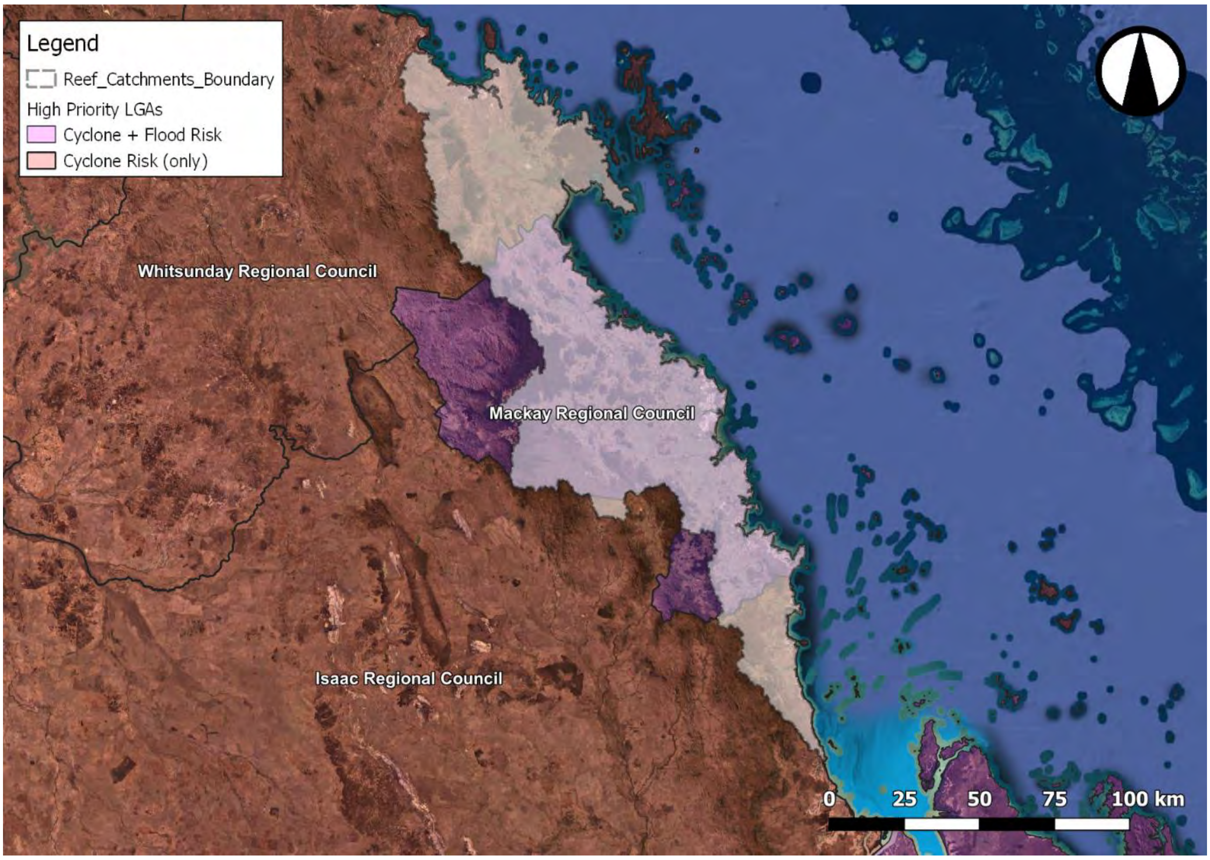


Figure 1. The entire Reef Catchments NRM area sits within High Priority LGA's under the PACP Local Stream guidelines

1.2 Reef Catchments

Reef Catchments are the Natural Resource Management group responsible for ensuring the environmental and natural resources of the Mackay Whitsunday Isaac region are sustained and protected for the future. Spanning over 900,000 hectares (see Figure 1), the area is primarily agricultural, with small, scattered population centres and nine nationally important wetlands. A infographic representation of the Reef Catchments area is provided in Figure 2 below.

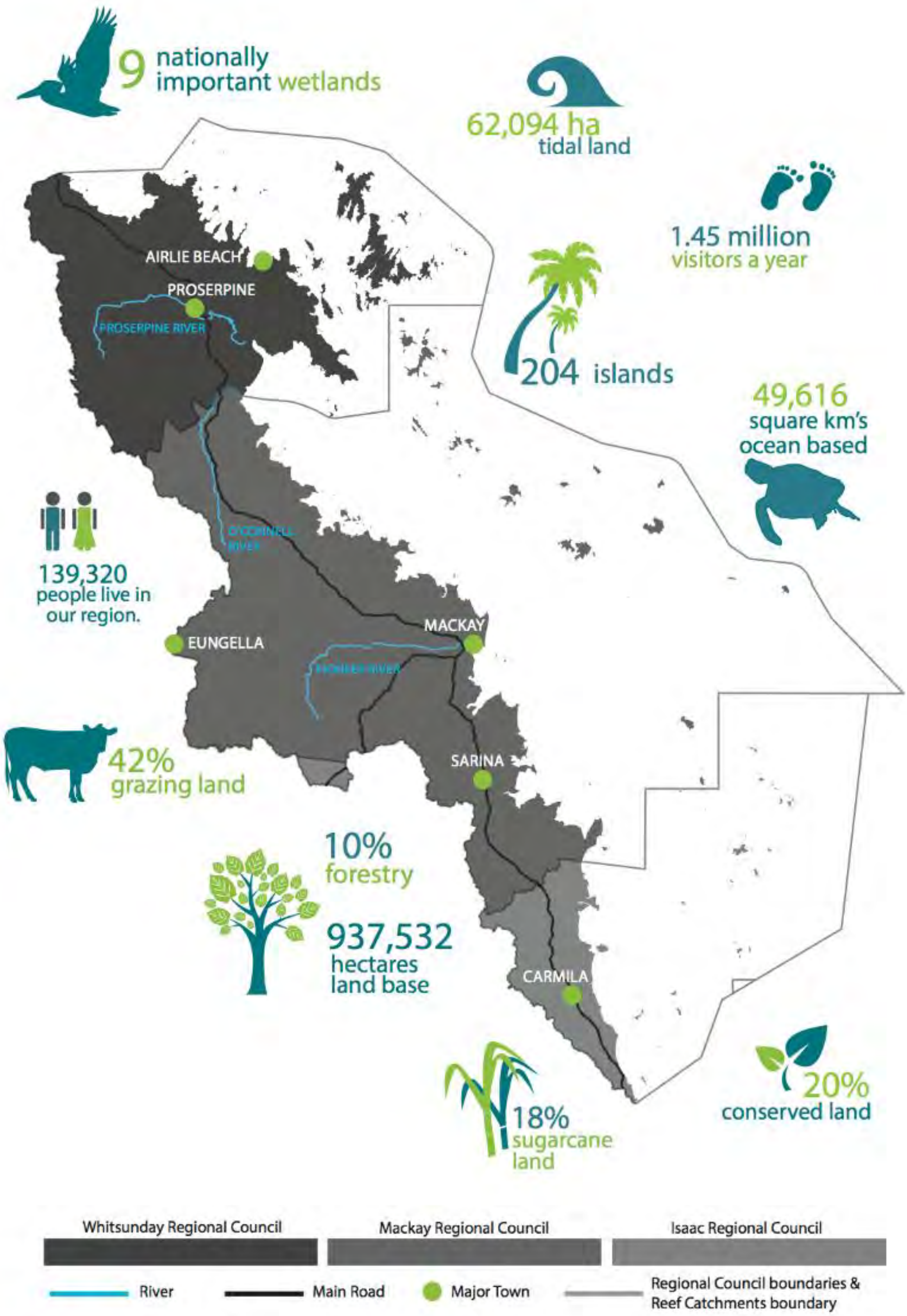


Figure 2. Main features of the Reef Catchments NRM area

The main river basins that make up the Reef Catchments area are, from north to south, the Proserpine, O'Connell, Pioneer and Plane Creek Basins, all of which run into the Great Barrier Reef lagoon. Additionally, Reef Catchments have oversight of almost 50,000 square kilometres of ocean including over 200 islands, which fall outside the scope of this study.

1.2.1 Mackay **Whitsunday's region** economy

Mackay Regional Council (Mackay Regional Council 2023) identifies six key industries in the region. In addition to Mining, Construction, Health Services and Education, the region's economy is also driven by Tourism and Agriculture.

According to the Council's website:

> *The tourism industry is a growing component of the Mackay economy with an estimated economic output of $543 million in 2016. Over the 12 months from January 2015, the region attracted over 750,000 domestic and 40,000 international overnight visitors, equating to an estimated expenditure of $300 million.*

The economic contribution from the Great Barrier Reef towards the Mackay Whitsunday's region has been quantified as follows (Deloitte Access Economics 2017):

- Tourism – $633 million;
- Commercial fishing and aquaculture - $8 million;
- Recreation - $35 million;
- Total of 7,428 full time equivalent people employed (FTE) across the three sectors; and
- Scientific Research and Reef Management in Queensland is worth - $98 million and 456 FTE, but the data is not further specified by NRM region.

Agriculture also significantly contributes to the Greater Whitsunday region's economy, with an estimated worth of $1.46 billion (Queensland Government 2022).

With respect to this study, the economic contribution from industry related to The Great Barrier Reef and Agriculture have been determined to be of major significance, as these industries are most likely to be impacted by erosion.

1.2.2 The Great Barrier Reef

According to the foreword in the Reef 2050 Water Quality Improvement Plan (WQIP) 2017-2022 (The State of Queensland and Commonwealth of Australia 2018):

> *The Great Barrier Reef (the Reef) is precious to all Australians as well as to citizens across the globe who recognise its scale, beauty and biodiversity. For Australia's Traditional Owners, it is an integral part of their culture and identity. The Reef's economic, social and iconic value as a global asset is estimated at $56 billion. It supports 64,000 jobs and contributes $6.4 billion annually to the Australian economy.*

Damage to reef associated with climate change arises from sea surface temperature increases, ocean acidification, altered weather patterns (such as more intense storms and cyclones) and rising sea levels. This means that now, more than ever, it is important to reduce the many pressures on the Great Barrier Reef, one of which is poor water quality. Sediments, nutrients and pesticides flowing to the Great Barrier Reef affect the health of coral and seagrass habitats, making the Great Barrier Reef less able to withstand or recover from events like the coral bleaching experienced in 2016 and 2017. Equally, the health of the Great Barrier Reef affects the resilience of Reef-dependent and Reef-associated communities.

The WQIP is a five-year plan that is nested within the Australian and Queensland governments' Reef 2050 Long-Term Sustainability Plan (Commonwealth of Australia 2021). It provides an overarching framework to deliver strategic priorities across Great Barrier Reef catchments. In particular, the Reef 2050 WQIP seeks to improve the quality of water flowing from the catchments adjacent to the Great Barrier Reef. The plan builds on previous water quality plans developed in 2003 (The State of Queensland and Commonwealth of Australia 2003), 2009 (The State of Queensland and Commonwealth of Australia 2009) and 2013 (The State of Queensland and Commonwealth of Australia 2013). Regional Water Quality Improvement Plans support the Reef 2050 WQIP by providing locally relevant information and guiding the implementation of projects within regions and specific catchments.

1.2.3 Further pressures on the Reef and the region due to Natural Disasters

Natural disasters, such as cyclones, floods, and associated events like erosion, can have significant impacts on both tourism and agriculture in the Mackay Whitsunday region. One of the key consequences of these disasters is the degradation of water quality, which adversely affects the Great Barrier Reef and agricultural activities in the area.

Poor water quality resulting from erosion can harm the health and vitality of the Great Barrier Reef ecosystem. Erosion, particularly from river systems and floodplains, can introduce sediments, pollutants, and excess nutrients into the water, leading to increased turbidity and reduced visibility. Refer to Section 2.3 for more detail on the specific impacts that fine sediment has upon the Great Barrier Reef.

Beyond these impacts, the health of the Great Barrier Reef itself is likely to be impacted, causing long-term implications for tourism. The Whitsundays is recognised as one of the world's premier holiday destinations, with beautiful islands, iconic natural wonders, and luxurious resorts. It supports an array of water sports and leisure activities such as snorkelling, scuba diving, and coral viewing – all reliant on the health and vitality of the coral reef systems. While the region is economically diverse, tourism is critical to the financial security of the region and any deterioration in water quality has the potential to adversely impact the tourism trade. Consequently, natural disasters and subsequent erosion have the potential to cause significant financial impacts to the region.

In addition to impacting tourism, natural disasters and erosion also directly impact agriculture in the Mackay Whitsunday region. The area is known for its productive agricultural land, including sugar cane, horticulture, and grazing activities. Erosion from rivers, creeks, and floodplains can result in the loss of topsoil, nutrient depletion, and damage to crops and pastures. Excessive sedimentation in waterways can impact irrigation systems, leading to decreased agricultural productivity (The State of Queensland 2022).

Furthermore, infrastructure in the region, including roads, bridges, and water supply systems, can be significantly affected by erosion. Floods and intense rainfall events can erode and undermine the foundations of infrastructure, leading to damage or even complete destruction. This can hamper access to tourist destinations, disrupt agricultural supply chains, and impede the overall development and functioning of the region.

1.2.4 Benefits of identifying sources of erosion now

Identifying erosion early and understanding its extent in the local community can have significant benefits in terms of reducing the time and cost of recovery after future disasters. Below are key ways in which the early identification of erosion helps the local community and contributes to effective disaster management and improved community resilience:

1. **Early assessment and planning:** By identifying erosion-prone areas in advance, local communities can conduct thorough assessments of vulnerable locations, including rivers, creeks, and floodplains. This information enables the development of comprehensive disaster management plans, including strategies for erosion control and mitigation measures.
2. **Targeted resource allocation:** Knowing the specific locations and extent of erosion allows for more targeted allocation of resources. It allows the community to demonstrate the urgency and severity of erosion issues when applying for grants or financial assistance for recovery and mitigation projects. By having a clear understanding of the erosion hotspots, the community can make a stronger case for funding and secure the necessary resources for effective erosion management, ensuring that limited resources are efficiently utilised to address the most critical erosion issues.
3. **Preventing further damage:** Identifying erosion enables proactive measures to be taken to prevent further degradation and damage. This may involve implementing landscape restoration projects, revegetation efforts, or constructing erosion control structures in vulnerable areas. By understanding the underlying causes of erosion, appropriate interventions can be implemented to provide erosion control measures, stabilise soils, and restore vegetation. This can help prevent erosion from worsening and minimise the potential impacts of future disasters. By addressing the underlying causes of erosion in advance, the community can enhance the resilience of the landscape and minimise the impacts of future disasters.
4. **Enhanced disaster response and recovery:** When a disaster does occur, knowing the locations of previously identified erosion areas enables swift response and prioritisation of recovery efforts. It allows emergency management teams to quickly assess the extent of erosion damage, develop targeted recovery plans, and allocate resources efficiently. This can significantly reduce the time required for recovery and minimise the associated costs.

By proactively identifying and addressing erosion issues, local communities can reduce the vulnerability of their region to future disasters. Taking a holistic approach that includes reach scale remediation of degraded streams and addressing the underlying causes of erosion throughout the entire region can contribute to long-term resilience and minimise the potential impacts of erosion during future disasters.

1.3 Need for the Study

1.3.1 Recent natural disasters

Two flood related natural disasters have occurred in the Mackay Whitsunday region in recent years:

- Severe Tropical Cyclone Debbie which made landfall on March 28, 2017, causing widespread damage and flooding. According to Mayor Greg Williamson “Debbie was slow-moving and destructive, causing property damage, erosion, landslips, flooding and loss of livestock and crops”.
- The 2019 North and Far North Queensland Monsoon Trough, which caused widespread environmental damage to vulnerable areas throughout 39 local council areas in northern Queensland, particularly to waterways and areas of pre-existing erosion, including in the Mackay Whitsundays Isaac region.

1.3.2 Previous funding to address erosion

To address the environmental impacts of Severe Tropical Cyclone Debbie, Category D Exceptional Circumstances assistance was provided through the Natural Disaster Relief and Recovery

Arrangements (NDRRA) program which was jointly funded by the Australian and Queensland Governments for eligible events that occurred prior to 31 October 2018. Across all the areas impacted, a total of $35 million was provided under the Category D funding, $15.5 million of which was allocated to riparian, mapping and watercourse recovery. Across the Reef Catchments region, 33 projects were funded to address stream bank erosion, for a total value of around $6.2 million. These works prevent more than 17,600 tonnes of total sediment from reaching the Great Barrier Reef lagoon annually (The State of Queensland and Commonwealth of Australia n.d.)

For the 2019 North and Far North Queensland Monsoon Trough, approximately $46 million was provided under Category D Environmental Recovery funding by the Queensland Reconstruction Authority (QRA) through the Disaster Recovery Funding Arrangements (DRFA) program to fund the rehabilitation, stabilisation and restoration of riverine, wetland, riparian and coastal environments affected by the event (Queensland Reconstruction Authority 2023).

In addition to the disaster recovery arrangements, Natural Resource Management (NRM) groups have undertaken remediation of streambank and gully erosion within the reef catchments with the primary objective of reducing fine sediment export to the Great Barrier Reef lagoon through programmes funded by State and Federal Government, primarily:

- Reef Trust
- Reef Assist
- Great Barrier Reef Foundation (GBRF) Reef Trust partnership
- Natural Resources Investment Program (NRIP)
- Large-scale Major Integrated Projects in the Wet and Dry Tropics.

Across this investment, the selection of sites suitable for remediation has largely been undertaken in an ad hoc and reactionary manner, mainly due to the time constraints imposed by both the grant application process and on-ground delivery timeframes. This often results in an opportunity cost to the funder as no comprehensive assessment of sites is undertaken to identify and prioritise sites suitable for intervention or remediation of erosion.

1.3.3 Reef Water Quality

Since 2003, the joint efforts of government, industry, land managers and communities have helped to deliver land management and water quality improvement across the Reef Catchments region. The agricultural sector is taking positive steps to support progress towards the targets set under the WQIP. Best Management Practice (BMP) programs such as the Smartcane BMP and Grazing BMP have been rolled out with good uptake for farm management and are examples of strong partnerships involving the agricultural industry, Natural Resource Management bodies, land managers and governments. These programs have supported improvement in productivity, profitability, and sustainability of farm enterprises.

Although agriculture contributes more to the Mackay Whitsunday economy than the Great Barrier Reef, this study primarily focuses on reef impacts rather than agricultural impacts. There are two key reasons for this approach. Firstly, the study's main focus is on erosion, which arguably has a lesser impact on agriculture compared to sediment's effects on the Great Barrier Reef. Secondly, the funding allocated to address erosion is typically tied to meeting Water Quality Improvement Plan (WQIP) targets for the reef. Therefore, if we aim to address sites that impact other aspects such as agriculture and infrastructure, it is necessary to leverage the funding specifically designated for reef-focused initiatives.

1.3.3.1 *Catchment water quality targets*

The nutrient and sediment targets for the catchment (or river basin) are derived from the Water Quality Guidelines for the Great Barrier Reef Marine Park, established by the Great Barrier Reef Marine Park Authority. These targets are specified as reductions in the load of pollutants at the end of each catchment (as shown in Table 1). They consider the discharge of sediment, nutrients, and pesticides from each river basin, which directly affect the waters of the Great Barrier Reef. Furthermore, setting specific targets for pollution reduction in water quality from each catchment enables more efficient prioritisation of actions and allocation of funding.

Table 1. Regional Water Quality Targets (Reef Catchments 2014)

Region	Dissolved inorganic nitrogen		Fine sediment		Particulate nutrients			
					Particulate phosphorus		Particulate nitrogen	
	tonnes	% reduction	kilotonnes	% reduction	tonnes	% reduction	tonnes	% reduction
Cape York	MCL	MCL	23	5	14	5	48	5
Wet Tropics	1700	60	240	25	360	30	850	25
Burdekin	820	60	890	30	490	25	800	25
Mackay Whitsunday	630	70	130	20	150	20	310	20
Fitzroy	MCL	MCL	410	25	430	20	760	15
Burnett Mary	470	55	240	20	210	20	590	20

Catchment water quality targets are established with the aim of enhancing the health and resilience of the Great Barrier Reef. These targets are determined through a combination of catchment modelling, which estimates the required reductions through improved land management practices, and eReefs marine water modelling, which assesses the impact of pollutants on the Reef. By setting targets specific to each river basin, the goal is to effectively address water quality issues and support the overall well-being of the Great Barrier Reef ecosystem.

The establishment of the targets for catchment water quality is informed by expert scientific advice and technical expertise, ensuring the credibility and reliability of the modelling outputs. These targets align with the framework of previous Water Quality Improvement Plans (WQIPs) and are now further informed by a scientific understanding of the unique water quality requirements for each river catchment (as presented in Table 2). Targets take into account the specific impact of each river on different areas of the Great Barrier Reef, enabling a more tailored and targeted approach to addressing water quality concerns.

Table 2. Reef Water Quality Improvement Plan 2050 Subbasin targets (Queensland Government 2018)

Management priority					
	Very high		Moderate		Minimal
	High		Low		Not assessed

Mackay/ Whitsunday	Proserpine River	249,440	**110**	70	**MCL**	MCL	**MCL**	MCL	**MCL**	MCL	
	O'Connell River	238,760	**130**	70	**96**	40	**120**	40	**250**	40	
	Pioneer River	157,360	**140**	70	**35**	20	**23**	20	**61**	20	
	Plane Creek	253,870	**260**	70	**MCL**	MCL	**MCL**	MCL	**MCL**	MCL	

The targets for catchment management are concentrated around promoting increased ground cover and riparian vegetation, while also preventing any further loss of wetland areas. A ground cover exceeding 70% and the presence of healthy riparian vegetation are essential for minimising erosion susceptibility. Additionally, robust riparian vegetation and thriving wetlands contribute to the filtration of pollutants from the water. Catchment management objectives concentrate on preserving the current health of wetlands, and aim for zero net loss of natural wetland areas. The condition of wetlands within the Great Barrier Reef is considered an important aspect of improved water quality, falling under the ecosystem health theme outlined in the Reef 2050 Plan. The riparian vegetation target primarily emphasises the extent of riparian vegetation coverage.

More recently the importance of human interaction with the environment has been recognised. Human dimensions are defined as the human factors that exist at all social scales and are known to play a role in shaping social, economic, cultural and environmental outcomes associated with the Great Barrier Reef (Figure 3). The focus on human dimensions recognises that the Great Barrier Reef needs to be considered as a socio-ecological system. In the context of water quality, human dimensions include social, cultural, institutional and economic factors: which include landholder attributes such as ACS (Aspirations Capacity & Stewardship), industries and communities, stewardship practices, and broader governance of the Great Barrier Reef. The human dimensions target recognises that actively engaging communities and land managers who influence water quality is critical in supporting progress towards land and catchment management outcomes.

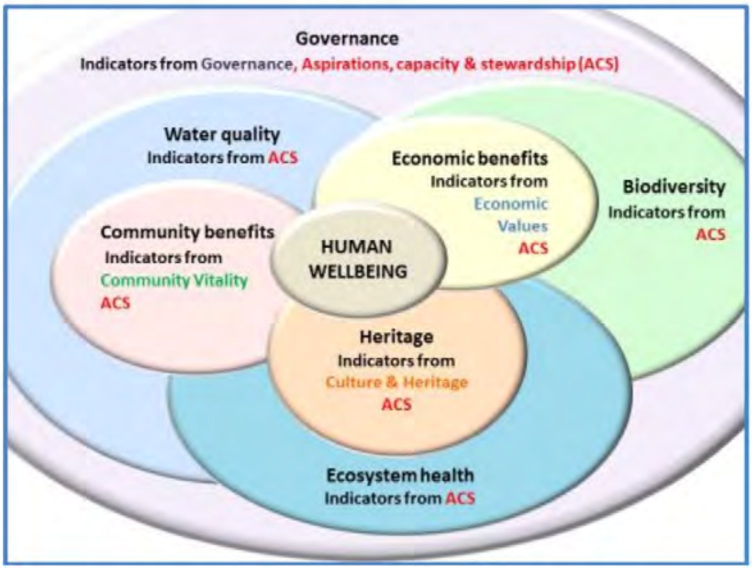


Figure 3. Alignment of human dimensions indicator clusters with Reef 2050 Plan themes

1.3.4 Climate Change

Climate change is expected to impact the Mackay Whitsunday region in the following ways:

- Higher temperatures and more frequent hot days;
- Decreased annual rainfall but more intense rainfall events;
- More frequent and more intense cyclones; and
- Rising sea level and more frequent sea level extremes.

The average mean surface temperature of the Reef Catchments region has already increased by approximately 1.1 degrees (1950-1970 period) with annual minimum temperatures increasing by approximately 1.4 degrees (1950-2007 period) (Reef Catchments 2014). The average annual projected temperature increase for the Whitsunday Region is between 0.5 – 1 degree by 2030 to 1.5 – 3 degrees by 2050 compared to the 1981-2010 average. This temperature rise will increase the number of maximum temperature days. These increased temperatures will go hand in hand with changes in rainfall (between -18% to +3 by 2030 and -24% to +1.4% by 2050) (Whitsunday Regional Council 2016).

Despite the overall decrease in rainfall, there will be an increase in Tropical Cyclones and rainfall intensity. State Planning Policies in Queensland suggest that there will be an approximate 5.2% increase in rainfall intensity by 2050 in the Whitsunday region. Currently, a 24-hour duration rainfall event of 460mm has a probability of 1% AEP (1 in 100-year ARI), however by 2050 it is expected this same event will have a probability of approximately 1.67% AEP (1 in 60-year ARI) (Reef Catchments 2014). Furthermore, the climate of Mackay is expected to be more like the climate of Proserpine by 2030 under a high emissions climate change scenario (Queensland Government 2019). With several primarily ephemeral streams and rivers throughout the region supporting dense and valuable riparian vegetation, climate change will affect the magnitude and frequency of flows.

Therefore, this is likely to create more frequent, and higher, flow events in rivers which has the potential to increase instability and erosion, particularly for stream banks and depressions which are un-protected by vegetation. This will significantly increase the potential to impact productive land, infrastructure, cultural heritage values and assets while delivering fine sediment from this erosion to the Great Barrier Reef lagoon.

1.4 Project Aims

The study's objective is to identify areas where proactive measures can be taken to address streambank erosion and channel migration. Specifically, sites have been identified where erosion poses risks to riparian connectivity, infrastructure, cultural heritage and fine sediment export. By implementing preventive measures at these sites, the future recovery costs can be minimised, while also increasing disaster preparedness and resilience against future natural disasters, similar to those experienced in the past decade. Furthermore, it minimises downtime caused by damage to nearby infrastructure, agriculture, industry, or residential assets.

The identification of these priority sites is valuable for Reef Catchments (and others) in making informed decisions regarding future funding applications. It allows Reef Catchments (and others) to optimise resource allocation and maximise the benefits of intervention works in the region.

Additionally, this study seeks to leverage the funding allocated for sediment prevention measures towards achieving broader benefits for the region. By utilising the sediment-focused funding, the region can also address potential impacts on infrastructure, ecosystem services, and other valuable assets beyond the Great Barrier Reef. This integrated approach ensures that future funding's emphasis on sediment aligns with the overarching objective of enhancing overall resilience within the region.

1.5 Integration with the Queensland River Rehabilitation Management Guideline

The Reef 2050 WQIP (The State of Queensland and Commonwealth of Australia 2018) builds on previous iterations by incorporating the human dimensions of change. The 2050 WQIP includes social, cultural, institutional and economic factors and include collaborative objectives such as fostering the aspirations and capacities of landholders, industries and communities to develop stewardship practices, and the broader governance of the Great Barrier Reef.

The Reef 2050 WQIP approach will support industries and communities to build a culture of innovation and stewardship. This will deliver further improvements to water quality by building capacity of land managers to exceed minimum practice standards and trial innovations through a range of approaches that maintain viable communities and support lasting change.

Catchment restoration will address legacy issues of land development and past practices, while targeted restoration of riparian vegetation, streambanks, gullies, waterways and wetlands is needed to achieve ambitious water quality improvement targets.

The Queensland River Rehabilitation Management (QRRM) Guideline (Department of Environment and Science 2022) was released in June 2022, which coincided with the commencement of this study. The QRRM Guideline follows on from the 2050 WQIP by providing a whole-of-system, values-based management framework for approaching river rehabilitation. It also provides a consistent and transparent approach to guiding the development of a well scoped Rehabilitation Plan. The approach, known as the Rehabilitation Process, and the underpinning framework has been designed to ensure that management decisions are informed by linking an understanding of the biophysical components (parts) and processes of rivers to the broader landscape, while incorporating an understanding of the ecosystem services society derives from rivers. This enables consideration of the value of these services to different beneficiaries and the threats and pressures relevant to each system.

In practical terms the QRRMG provides a rationale for selecting sites for rehabilitation, while ensuring a consistent and transparent approach is undertaken to river rehabilitation. The QRRMG theorises that river rehabilitation can be triggered by an event (recent or historical) or can be triggered through an initiative to address a responsibility or a need. It states also that natural triggers can include disasters such as cyclones, floods and fires, while societal triggers can include the need to protect at-risk infrastructure, market mechanisms, and drivers such as government policy, legislation or planning requirements.

While the QRRM Guideline was not published at the time of scoping this study and applying for funding through the PACP grants, Neilly Group have made all attempts to apply the principles of the QRRM Guideline throughout this study, within the constraints of the original scope. Refer to Figure 4 to see how this report aligns with the QRRM Guideline.

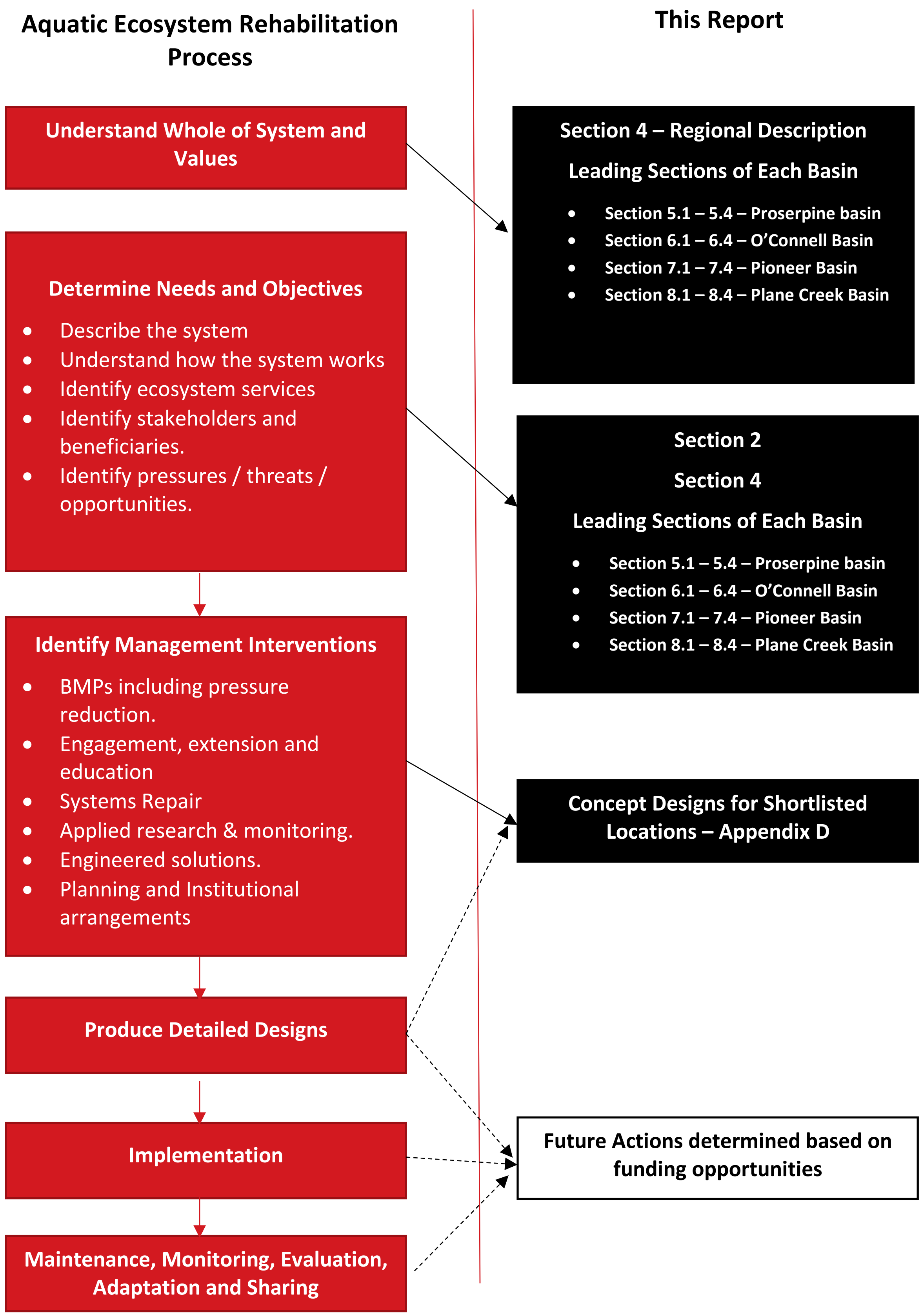


Figure 4. Study Alignment to QRRMG Aquatic Ecosystem Rehabilitation Process

2 Drivers, Causes and Consequences of Erosion in the Reef Catchments NRM Region

This section has been included in the report to provide the reader with a clearer understanding of the processes discussed throughout. By exploring the natural dynamics of streams and rivers, as well as the impacts of human activities and environmental factors, we aim to enhance readers' comprehension of the concepts and actions presented.

This section also highlights the disproportionate volume of fine sediment delivered to the Great Barrier Reef from certain basins, such as the Pioneer and O'Connell basins, compared to pre-European estimates. These findings underscore the importance of targeted interventions to mitigate sediment delivery and protect the health of the Great Barrier Reef.

Streams and rivers are always changing as a natural part of their life cycle (Queensland Government 2014). This includes erosion of the stream bed and banks, the transport of sediment by the water, and the shifting of the stream's path. These processes work together to create floodplains, terraces, benches and inset floodplains (Figure 5).

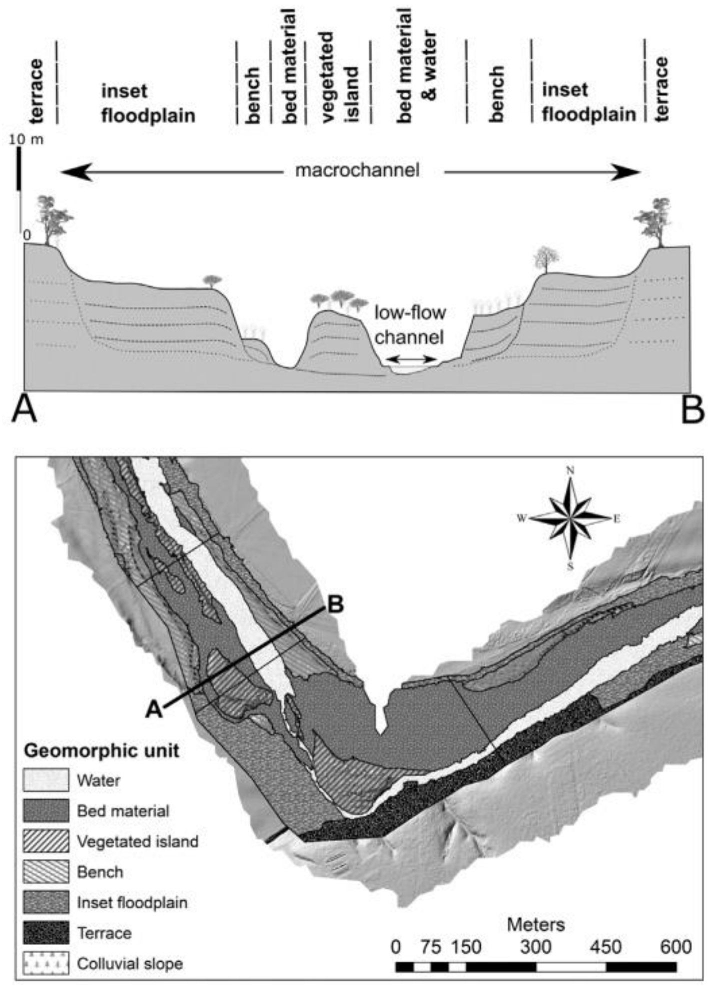


Figure 5. Geomorphic units typically referred to throughout this and other studies (McMahon, et al. 2017)

Rivers and their adjacent floodplains continuously evolve, influenced by different factors like sea level, weather conditions, and runoff. Any change in the landscape or land use also greatly affects how rivers change over time. The pace at which these factors change is usually quicker than the river's ability to adapt, making current river systems a product of both current activities and past conditions, like sea level, previous rainfall and climate regimes, and runoff.

Sometimes, the changes in a stream are slow and almost unnoticeable. However, events like floods can bring about rapid, significant changes that can impact the stream's stability for many years. A striking example of this change is seen across parts of Australia, where large-scale land clearing for farming by early European settlers has led to rivers and streams reacting more quickly and dramatically to rainfall. This accelerated reaction, known as a 'flashier' response, causes the river channels to deepen, a process called channel incision. This leads to more sediment in the water and the loss of diverse river features, like pools and riffles, which get filled with excess sediment or erode due to the faster water flow.

As river channels deepen, the banks become steeper. This can lead to over-steepening, resulting in large-scale bank failures and channel widening as outlined in the channel evolution model (Figure 6). The fallen material gets carried away during high water flow events, leaving the riverbank exposed to high-velocity flows and further intensifying erosion and decreasing the resistance of the channel’s banks to further erosion.

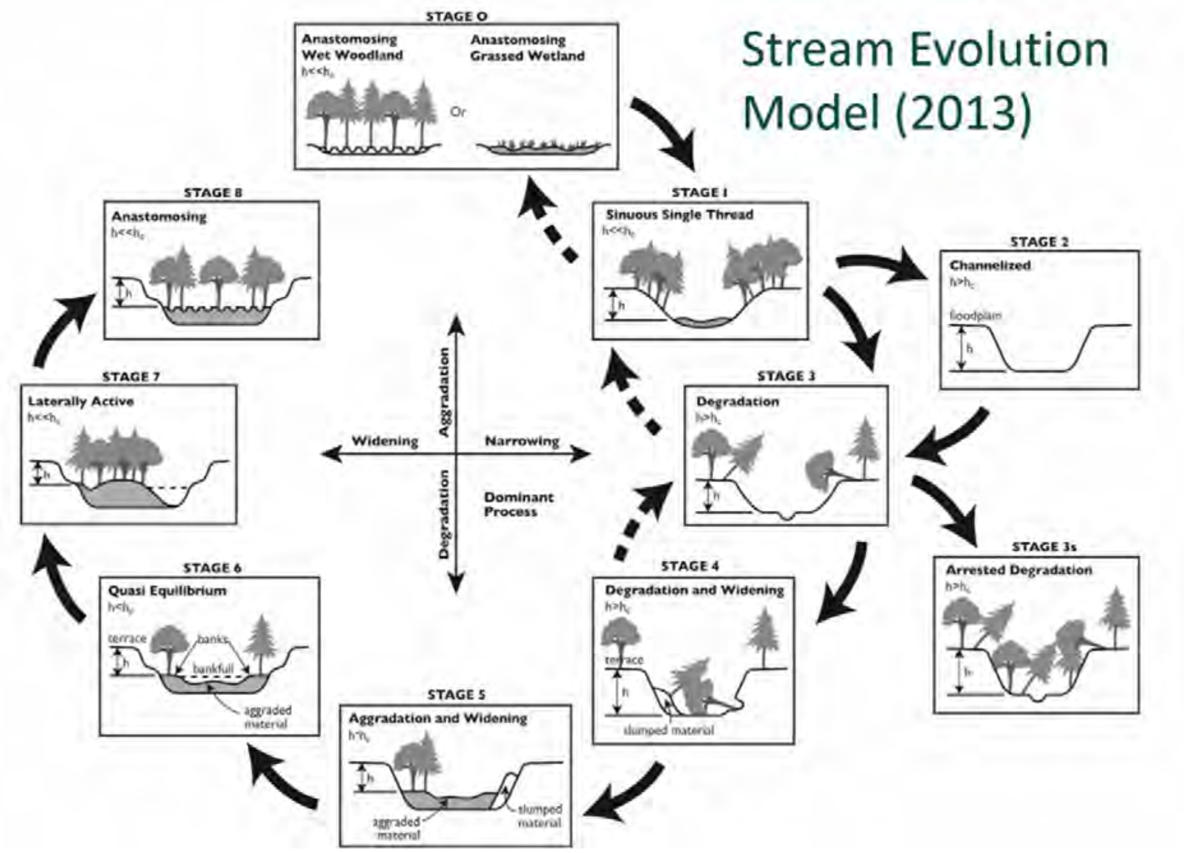


Figure 6. Channel evolution model showing the potential for stream widening following deepening

Land use change such as clearing native vegetation for horticulture and grazing will increase the total volume of runoff entering the river system as well as decrease the flood immunity of the stream system as well. This in turn increases the sediment entering the system, and the incision and subsequent widening caused by land use change will then increase the volume of sediment moving through the system as bed and bank material is eroded. The majority of bed and bank material will travel down the system as a series of sand slugs (Witheridge 2021). Based on the flow regime (the magnitude and frequency of flow events) these sand slugs can take decades to travel down the system after the majority of land use change has occurred.

The increased amount of sand slugs moving through the river system can also contribute to bank erosion as outlined in Figure 7 (b) whereby a sediment slug can deposit within the centre of the channel, be colonised by vegetation (therefore increasing its resistance to flow and erosion) and subsequently cause the adjacent bank to erode as subsequent flows are compressed around the sand slug island.

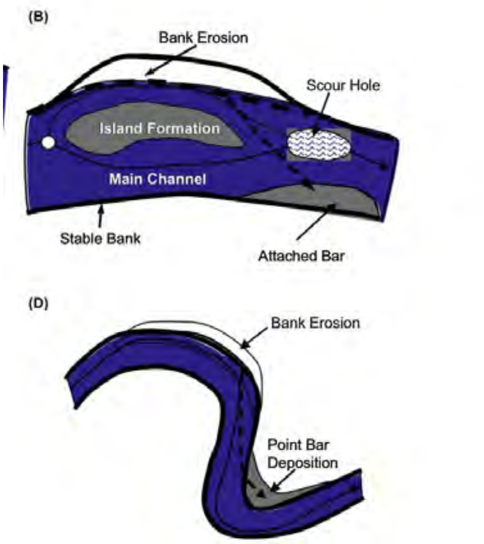


Figure 7. Examples of how bank erosion can occur (Lorang and Hauer 2017)

2.1 Bank Erosion

Stream bank erosion is a naturally occurring process in all river systems. It takes place when the forces exerted on the bed and banks, a function of the depth, velocity and duration of flows, surpasses the resisting strength of the stream bank, resulting in erosion (Queensland Government 2014).

This resistance primarily originates from two factors. The first is the inherent cohesion of the material making up the stream bank, such as soil or sediment particles. The cohesion is dictated by particle size, with clay particles increasing the soil's internal cohesion. The second factor is the resistance offered by vegetation and roots growing on and around the stream bank. These plant components not only fortify the bank but also provide a physical barrier against the erosive forces of flowing water.

Changes in land use, vegetation cover, and climate in the recent centuries have amplified the rate of bank erosion, pushing it beyond natural levels (Bartley, et al. 2015). This process is driven by various mechanisms including mass failure (which is a large-scale collapse of the bank), scour by moving water (which is the direct erosion caused by water movement) and slippage (see Figure 8).

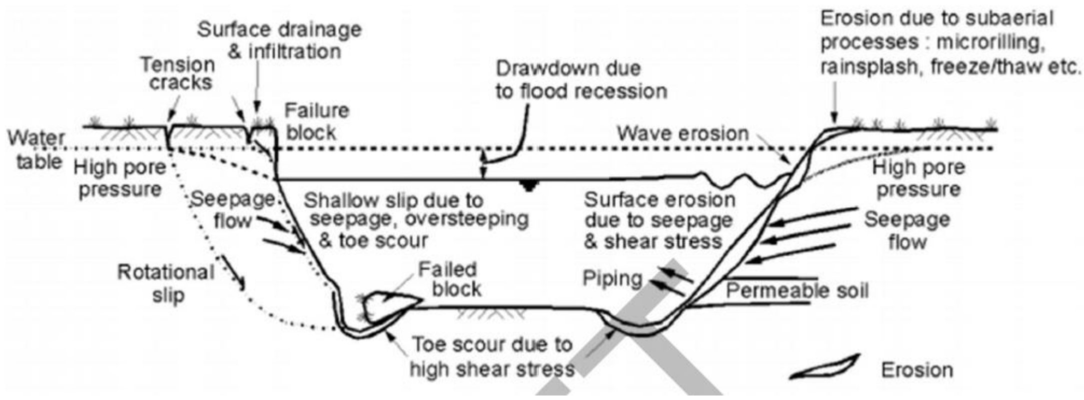


Figure 8. Types and forms of bank erosion (SKM 2011)

2.2 Riparian Vegetation

Erosion is a natural process in alluvial systems, but human activities like land clearing and removing riparian vegetation can accelerate erosion rates, leading to harmful changes in the river channel. Different erosional processes can occur independently or together, causing channel change.

Riparian vegetation has a significant impact on reducing erosion rates in these processes. A study in the Daintree found that sites with riparian vegetation experienced 85% less erosion compared to those without it (Bartley, et al. 2015). The type of vegetation affects each process differently, and the location within the catchment also influences vegetation's impact. For example, riparian trees reinforce the bank substrate through their roots, increasing cohesion and resistance to mass failure. Larger root networks provide stronger reinforcement compared to smaller shrubs and grasses.

Vegetation also plays a role in reducing bank saturation and resisting fluvial scour. All vegetation types decrease bank saturation by intercepting precipitation and transpiring water. Vegetation on the bank increases cohesion and strength through root networks, limiting the potential for sediment entrainment. Smaller shrubs and grasses will provide coverage of the riverbank and will reduce the force of water on riverbank soils, therefore reducing the opportunities for erosion.

Near bank velocities are reduced by vegetation, as it increases hydraulic roughness. This reduction in velocity reduces shear force against the bank, protecting it from erosion. The impact of vegetation on hydraulic roughness varies with vegetation type and discharge. During low flow, rigid grasses and shrubs provide high wetted surface area and hydraulic resistance. However, as discharge increases, herbaceous vegetation is flattened against the bank, reducing hydraulic resistance but still protecting the bank substrate. Large trees offer minimal resistance during low flow but provide significant resistance as discharge increases.

A diverse suite of vegetation types, including in-stream vegetation, stream bank ground covers, shrubs, and trees, is required to effectively control erosion and downstream flood wave speed. Single vegetation species, such as large trees or grasses, cannot fulfil all the roles provided by a diverse suite of vegetation.

2.3 Sediment Transport to the Great Barrier Reef

Not all sediment eroded from a stream bank is exported to the Great Barrier Reef. Clays, consisting of sediments generally less than 2µm, will remain suspended until the runoff event stops. In larger flood events the fine sediment fraction is likely to be exported to the coast (Bartley, et al. 2015). Once these clays reach the estuarine environment the sediment-laden freshwater will often float over the top of saline seawater, therefore promoting turbulence and the further transportation of clay sized particles into the marine environment (Witheridge 2021).

This fine sediment is detrimental to the Great Barrier Reef for the following reasons (Great Barrier Reef Marine Park Authority 2022):

- High concentrations of fine sediment can reduce coral diversity, affect reproduction, disrupt coral recruitment and increase susceptibility to disease. It can also damage gills and affect the metabolism of some fish species.
- Suspended sediment, together with nutrients and other organic particles, reduces the amount of available light for seagrass and corals to grow.

Tracing studies suggest that subsurface soils from gullies and stream bank erosion is the primary source of sediment, contributing 90% towards end of catchment loads with the fine fraction of sediment (<16µm) having the most chances of reaching the reef (Queensland Government 2017). Therefore, stream bank and gully erosion remediation must directly address fine sediment which is delivered into the waterway and unlikely to settle.

Early modelled sediment loads from bank erosion to the Great Barrier Reef indicate that the Pioneer Basin has a disproportionate volume of fine sediment delivered to the Great Barrier Reef given its catchment area, compared to other areas (Figure 9). The modelling suggests that the volume of bank erosion delivered to the Great Barrier Reef in the Pioneer and O'Connell basins has increased by 800% compared to pre-European estimates and by approximately 400-600% in the Plane Creek and Proserpine basins respectively.

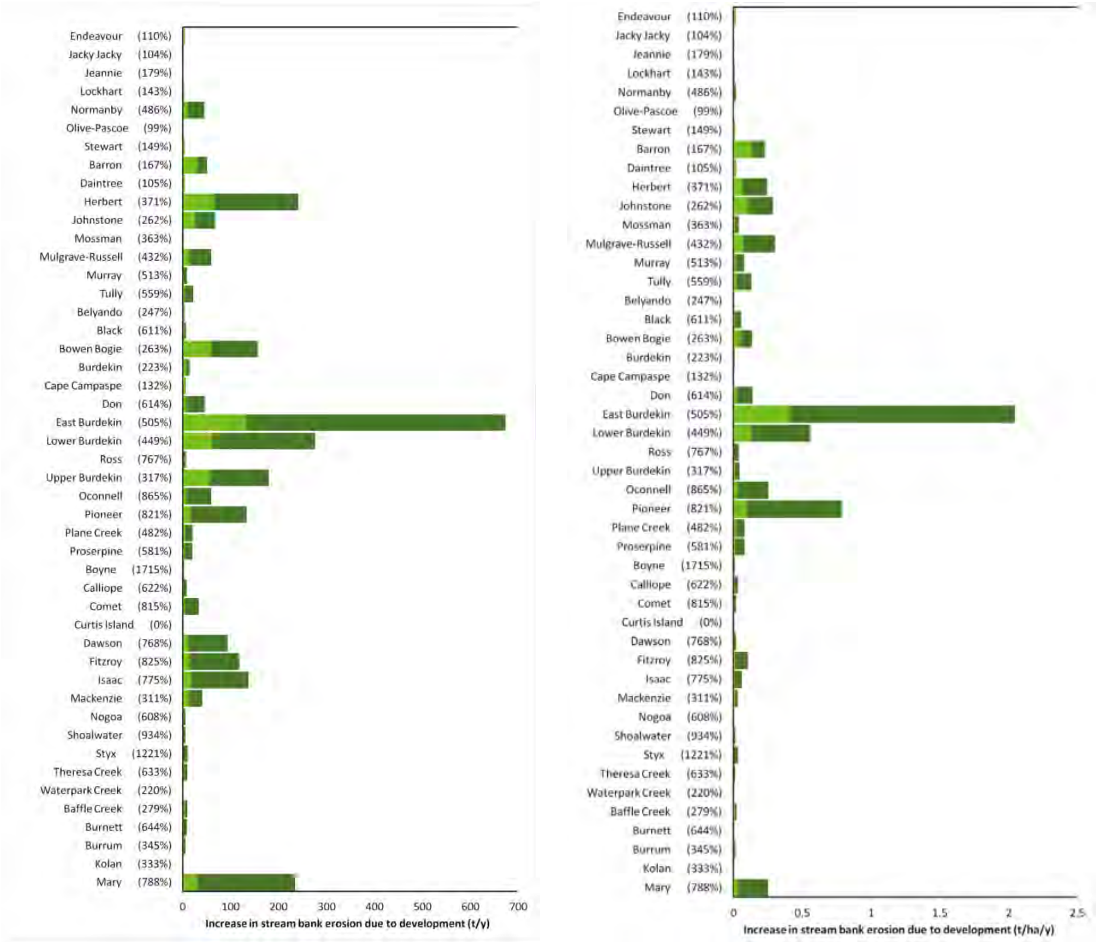


Figure 9. Sediment contributions from bank erosion with an increase (%) from pre-development levels in brackets. Left: kt/y. Right: t/ha/y. (Bartley, et al. 2015)

3 Methodology

To meet the aims of this study, Neilly Group have conducted a thorough examination of subcatchments, major waterways, and their tributaries within Reef Catchments' operational area, encompassing the Proserpine River, Pioneer River, O'Connell River, and Plane Creek Basins.

The scope of this study was to identify instances of streambank erosion and channel migration within the specified basins through a desktop analysis. The locations of erosion were pinpointed through a method that can be duplicated and, when feasible, relies on quantitative evaluation. The intention behind this strategy is to enable its replication in various NRM regions, ensuring uniform and comparable findings similar to those in this study.

The initial site identification process utilised temporal analysis of aerial photography and analysis of LiDAR data to identify all potential sites of erosion. This process is outlined in detail in Section 3.2 and Section 3.3 and it resulted in over 900 potential erosion sites initially.

After the initial site identification process, a rationalisation procedure was employed to review all erosion sites. This step involved excluding sites from further analysis if they were either of a small scale or situated in remote upland areas surrounded by dense forest. Details of this rationalisation process are included in Section 3.4. This rationalisation process resulted in 594 potential erosion sites remaining.

The subsequent phase of the study involved conducting evaluations of the remaining potential erosion sites. The aim was to select sites for which costed concept designs would be developed for:

- The top five locations prioritised based on risk to infrastructure;
- The top five locations prioritised based on riparian (dis)connectivity;
- The top five locations based on Cultural Heritage prioritisation; and
- The top five locations prioritised based on fine sediment export to the Great Barrier Reef.

The methodology for each of the above prioritisations is presented in Section 3.5 to Section 3.8.

It is recognised that waterways are culturally significant for Traditional Owners and through collaboration between Neilly Group and Reef Catchments it was agreed that there was limited availability of data relating to areas of cultural significance and Traditional Knowledge for the MWI Region within the DATSIP Database. It was believed that more tangible input from those Traditional Owners with local knowledge would assist in the identification of sites with Cultural Heritage significance. In consultation with Reef Catchments, it was decided that assessments for Cultural Heritage would depend on the outcomes of these future conversations and be undertaken on a site-by-site basis for all sites that progressed to the rehabilitation stage.

Subsequently, the categorisation of five locations based on Cultural Heritage prioritisation was removed. In addition to this, Reef Catchments requested that Neilly Group expand the assessment of Cattle Creek in the Pioneer River Basin due to the impact of extreme weather events over the past five years. Subsequently, eight erosion sites on Cattle Creek were grouped together and evaluated as a single reach scale site. Further details regarding this are included in Section 3.9 and 3.10.

Reef Catchments also requested that the Infrastructure sites were substituted for additional Sediment Export sites in order to leverage the next round of Reef Trust funding announced by the Federal Government in 2022 (Australian Government Department of Climate Change, Energy, the Environment and Water 2023). Note that while Infrastructure sites have been excluded from concept design, the top six sites identified under this category are presented in Table 12 in Section 9.

Site visits occurred between April and May 2023, covering four of the five prioritised Riparian Connectivity sites. The 5th site was excluded due to the landholder's non-cooperation. All 16 Sediment Export sites were visited, but two proved unsuitable due to resolved erosion issues.

Consequently, two new sediment export sites (Sites 168 and 329) were added after site visits. These sites, being the largest tidal ones not fully surrounded by vegetation, were chosen based on potential for remediation.

An overview of the above methodology used is provided below in a visual representation in Figure 10. The following sections below provide further detail on each step identified in Figure 10, with the figure intended to be used as a guide to navigate through this Methodology section.

In total four Riparian Connectivity sites and 16 Sediment Export sites (including eight sites combined for the Cattle Creek reach scale site) had costed concept designs developed for remediation/mitigation works for each of the identified sites.

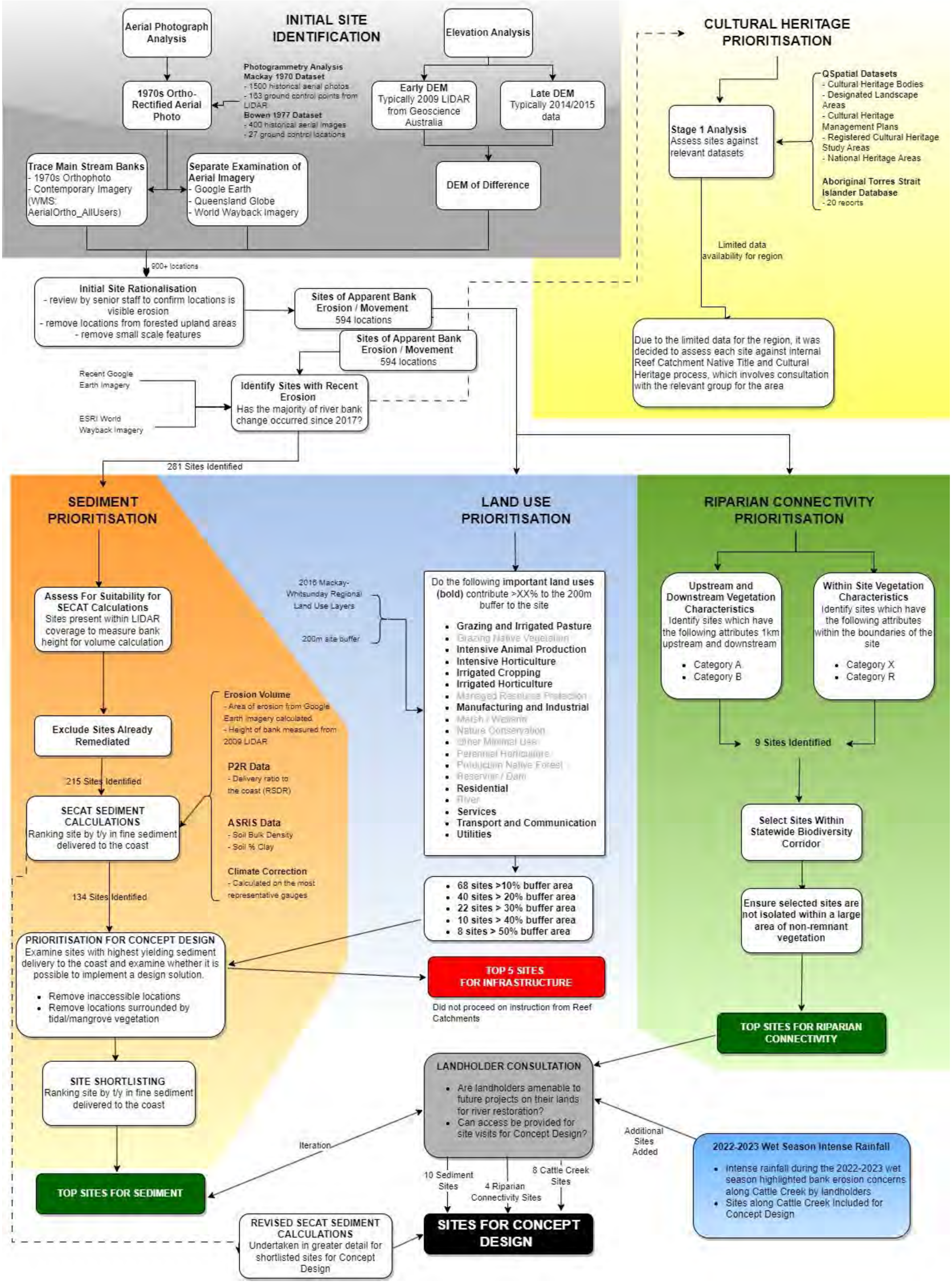


Figure 10. Overview of methodology applied for the study

3.1 Initial Erosion Site Identification

To facilitate initial erosion site identification and organise the reporting of the final results, the Reef Catchments NRM study area was divided into four primary basins, outlined below, and as shown on Figure 11:

- Proserpine River;
- O'Connell River;
- Pioneer River; and
- Plane Creek.

Each of the main basins were subsequently broken up further into subcatchments as delineated in the Environmental Protection Policy (EPP) (Water and Wetland Biodiversity) 2019.

To identify the initial erosion site locations, two methods of data analysis were employed:

1. Temporal Analysis of Aerial Photography:
   This method involved examining historical and contemporary aerial photographs to manually delineate the top of bank for all streams within the study area. Erosion site locations were identified where the delineated top of bank showed evidence of retreat between the historical and contemporary aerial photographs. A comprehensive description of this process can be found in Section 3.2.
2. Analysis of LiDAR Data:
   In areas where two LiDAR datasets were available, captured at different times, a Digital Elevation Model of Difference (DEMoD) was generated. By comparing the elevation differences between the two datasets, erosion site locations could be rapidly identified. The detailed procedure for this method is explained in Section 3.3.

To manage the abundance of potential erosion sites discovered, the identification of individual locations relied on numerical values instead of site names based on river basins or subcatchments.

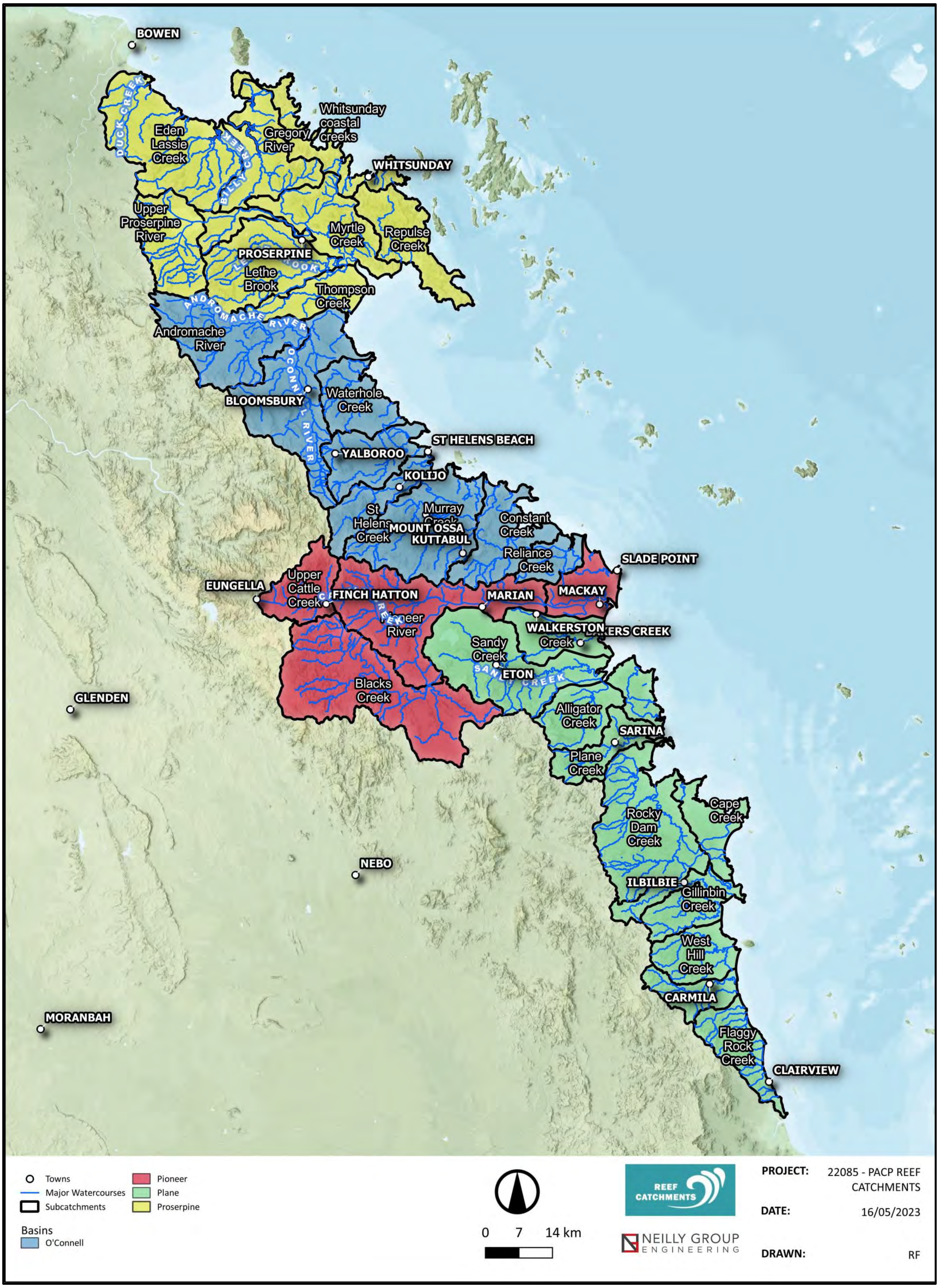


Figure 11. Overview of the four main River/Creek Basins within the Reef Catchments NRM study area

3.2 Temporal Analysis of Aerial Photography

This section provides further details regarding the temporal analysis of aerial photography, which played a central role in identifying the majority of initial erosion site locations.

3.2.1 Processing of 1970s Historical Orthophoto

Historical aerial photography footprints of the region were reviewed to identify the historical dataset which provided the most coverage of the Reef Catchments NRM region. Aerials from the Mackay Regional Study 1970 covered the 90% of the region and were acquired at a scale of 1:24,000, with the remainder of the region that did not have coverage extending into heavily forested upland areas where both streambank delineation was not possible, and erosion was less likely to have occurred. The one exception to this was a small area in the Eden Lassie Creek subcatchment that required historical orthophoto coverage and subsequently a 1977 orthophoto was developed.

Approximately 1,500 images from the 1970 dataset, were downloaded from QSpatial and cropped to remove black film edges. A photogrammetry processing workflow was then applied to merge all images into one seamless orthophoto which covered the entire region. During this process, the capture coordinates of each individual image were utilised, as obtained from Queensland Spatial, to accurately apply the location information to the respective aerial photographs.

LiDAR point clouds were obtained for the whole region from the online ELVIS – Elevation and Depth – Foundation Spatial Data portal and 163 locations were used across the region from the available LiDAR data to provide ground control. Each of these ground control points were chosen as the locations were identified as not having changed from the 1970s images to the 2009/2010 LiDAR dataset. Typically, the locations were the corner roof return points from historic buildings.

The photogrammetry processing procedure produced an orthophoto (Figure 12) with a resolution of 1.46m/pixel across the region with an average accuracy of 2.58m compared to 2009/2010 LiDAR (Figure 15). Considering the relatively coarse point cloud in the 2009/2010 LiDAR and the resolution of the input images (11MP), the achieved accuracy can be considered reasonable. A report that provides further information about the results of processing undertaken (i.e. photo overlap, accuracy etc) is provided as Attachment A.

The small area in the Eden Lassie Creek subcatchment utilised 400 images, acquired at a scale of 1:24,900, from the Bowen 1977 dataset. The same photogrammetry processing workflow was applied as described above using 27 ground control locations. The photogrammetry procedure produced an orthophoto (Figure 13) with a resolution of 1.9m/pixel with an average accuracy of 5m compared to the 2009/2010 LiDAR. The majority of the inaccuracy is outside of the study area as the entire photo set was downloaded but only referenced to areas within the study area. A report that provides further information about the results of processing undertaken (i.e. photo overlap, accuracy etc) is provided as Attachment A.

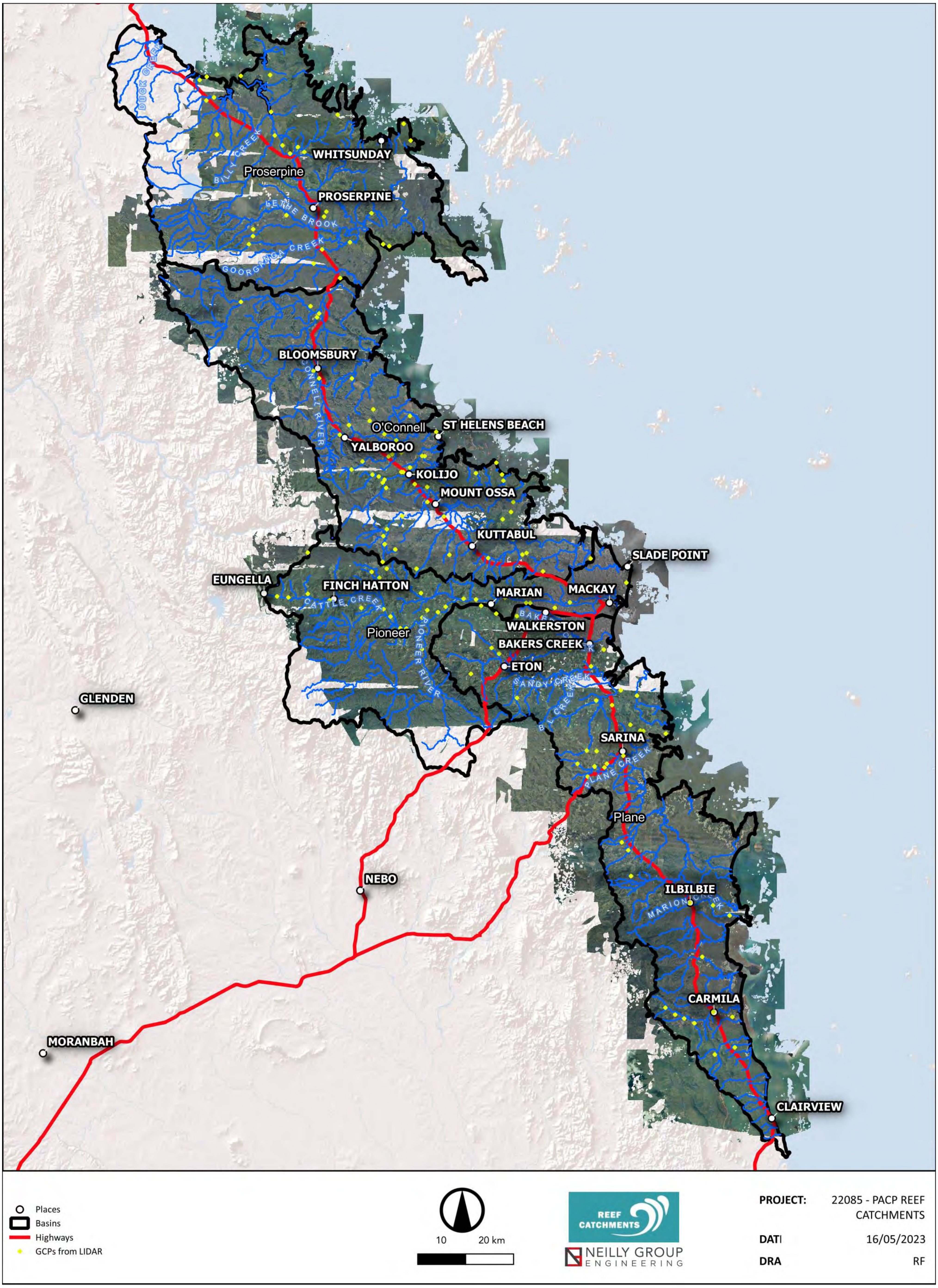


Figure 12. 1970s historical aerial created during this study.

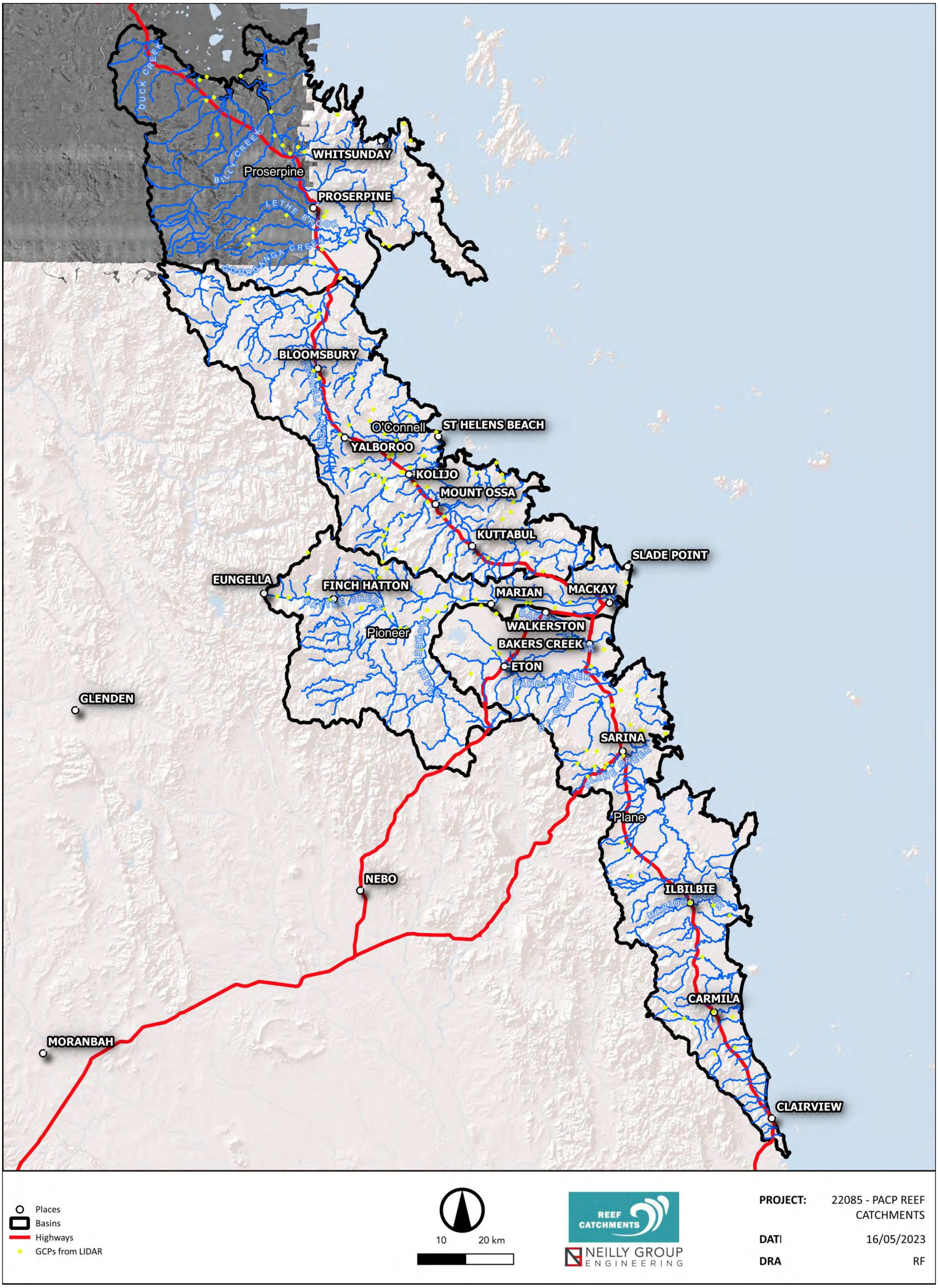


Figure 13. 1977 orthophoto created to cover the Eden Lassie Creek subcatchment in the Pioneer Basin

3.2.2 Selection of Contemporary Aerial Photography

The contemporary aerial photography for the Reef Catchments NRM region was streamed as a layer in QGIS using the "AerialOrtho_AllUsers" data source available from the Queensland Government as a Web Map Service[1]. The service is described by the Queensland Government as follows:

> "*This service is designed to provide public access to the State Remotely Sensed Image Library collection of aerial imagery captured under government projects and programs that is not otherwise restricted under licensing or information security classifications. Aerial imagery that is three years or older captured under the Spatial Imagery Services Program (SISP) is made available for public use openly by the Department of Resources, Queensland. The service is dynamic and can be used to filter and display individual aerial photo projects. The projects range from 0.5cm to 50cm resolution. Accuracy is dependent on the individual projects. Periodical updates will be made to the service as new projects are released to the public domain.*"

The available imagery was captured between June and December 2019. This period was considered acceptable as it followed the significant flooding event caused by the 2019 Monsoon Trough. Furthermore, no other major flood events were recorded in the region between 2019 and 2022, which is when the temporal analysis of aerial photography for this study took place.

Therefore, it is unlikely that any significant erosion sites had developed since mid-2019 and subsequently remained unidentified during the temporal analysis of aerial photography.

Refer to Section 4.6 for further information on the regional flood history.

3.2.3 Tracing of Top of Bank Position

Delineation of the top of bank position of all waterways within the study area was undertaken using manual delineation from the 1970s historical aerial photography and the contemporary aerial photography. A comprehensive set of figures which show the full extent of this top of bank tracing are included in Attachment B. It can be observed from this set of figures that the magnitude of this task was significant, with approximately 400 hours spent on this task alone across the project team.

The top of bank tracing from each time was subsequently compared by visually examining the complete length of the traced top of bank positions. This process aimed to identify locations where significant riverbank movement had occurred over the span of approximately 50 years between the historical 1970s period and the contemporary period starting in 2019. These identified locations constituted a significant majority of the initial erosion sites that were detected.

Figure 14 below provides an example of the comparison of the top of bank tracing and the subsequent identification of initial erosion sites.

[1] https://spatial-img.information.qld.gov.au/arcgis/rest/services/TimeSeries/AerialOrtho_AllUsers/ImageServer/WMSServer?request=GetCapabilities&service=WMS

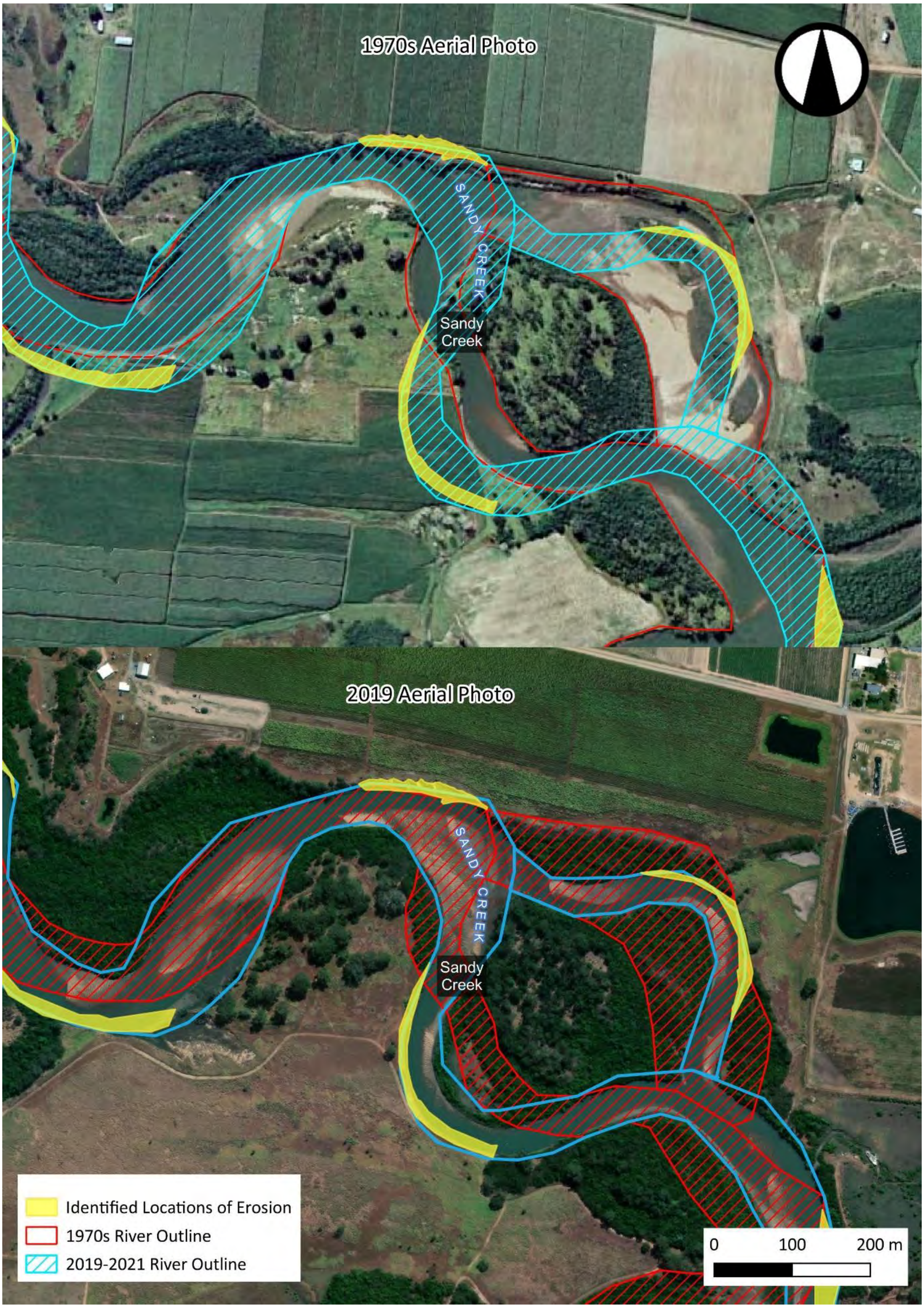


Figure 14. Example of river plan form changes

3.2.4 Examination of Aerial Imagery

In addition to the top of bank trace lines, a comprehensive assessment of aerial imagery across the study region was conducted to ensure that any erosion not captured by the previous process was included in this study.

For this purpose, a visual examination of current aerial imagery was carried out using diverse sources, including Queensland Globe, Google Earth, World Wayback, and Queensland Government Web Map Service imagery time series. The purpose was to identify additional instances of riverbank erosion, gully erosion, and landscape scalding that may have been missed during the initial analysis. All identified locations were recorded and later assessed by a different reviewer for validation. These additional sites were then incorporated into the compilation of initial erosion sites for the study.

3.3 Elevation Analysis

The majority of the study region is covered by LiDAR captured in 2009/2010. There is also a second, comparatively small, section of the study area that is covered by another dataset, captured in 2014/2015 and a third, even smaller dataset, focused solely on parts of the river systems which was captured in 2021. The coverage of the different LiDAR datasets across the region is shown below in Figure 15.

Details of each of the three datasets are summarised as follows:

- 2009/2010 1m DEM comprised of multiple datasets including Whitsunday 2009 CTL, Whitsunday 2009 PRJ, Whitsunday 2009 RGN, Mackay 2009 PRJ, Mackay 2009 PRJ, Isaac 2009 PRJ, Isaac 2009 CTL.
- 2014/2015 1m DEM comprised of multiple datasets including Midge Point 2015 TWN, Bloomsbury 2015 TWN, Seaforth Ball Bay 2015 RGN, Mackay 2015 RGN, Eton 2015 TWN, Ilbilbie 2014 LOC, Carmila 2014 TWN.
- 2021 0.5m DEM comprised of multiple datasets including Gregory 2021, O'Connell Andromache 2021, St Helens 2021, Minor Creek 2021, Murray 2021, Pioneer 2021, Cattle Creek 2021.

A DEM of Difference (DEMoD) was calculated for all areas where two or more of the three LiDAR datasets overlapped.

DEMoDs between the 2009/2010 and 2014/2015 datasets and the 2009/2010 and 2021 datasets were produced at a grid size of 1m by undertaking a raster calculation to subtract the DEM elevations of the older datasets from the DEM elevations of the more recent datasets. The result is a DEMoD where erosion that has occurred between the two datasets is represented by negative values, and deposition (or aggradation) is represented by positive values. An example of the DEMoD between the 2021 DEM and 2009 DEM at St Helens Creek is presented in Figure 16 where all aggradation, and erosion below 0.5m depth, has been removed to allow for clear identification of major streambank erosion.

The resultant DEMoDs were reviewed and erosion locations were identified and included in the compilation of initial erosion sites. Cross-sections were drawn through each site and each DEM profiled to confirm that the DEMoD was representing bank erosion and not a water surface that may have been captured during the data collection (which can create false positives). Figure 16 demonstrates this with the erosion hotspots identified in the DEMoD delineated within the initial erosion site dataset. Please note that differences in water level also show up in DEMoD assessments.

The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.

Figure 15. Availability of LIDAR datasets across the region

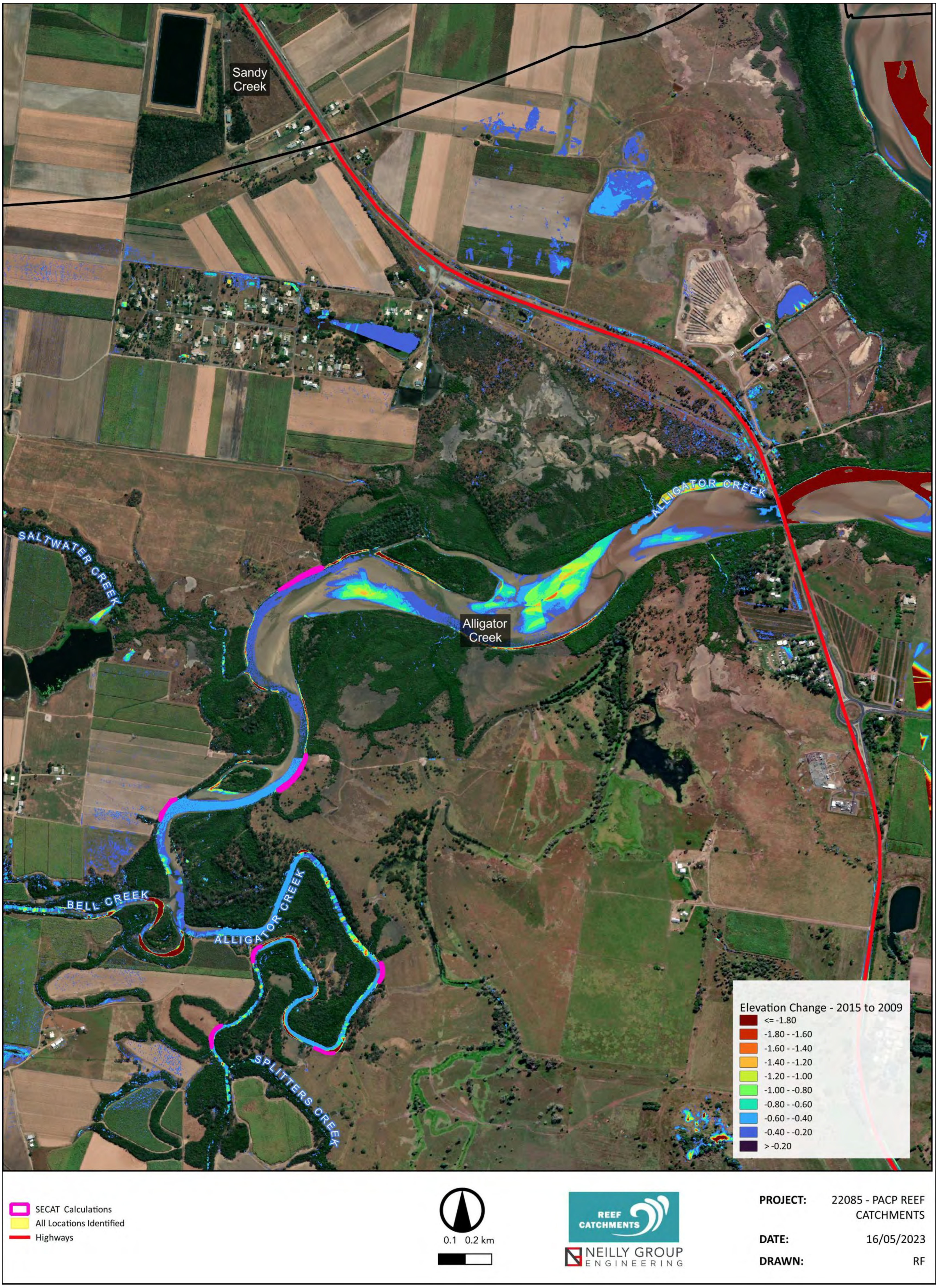


Figure 16. DEMoD between 2021 DEM and 2009 DEM at Alligator Creek

3.4 Initial Erosion Site Rationalisation

The primary objective of the initial erosion site identification process was to identify all potential erosion sites, regardless of their location, size, or type. As a result of this process, over 900 erosion sites were initially identified. The subsequent step involved rationalising and refining these locations to determine which ones were suitable for further analysis.

The rationalisation was undertaken by senior staff of Neilly Group with extensive experience in:

- Erosion assessment for programs such as NDRRA, Reef Trust, DRFA; and
- Analysis of geomorphology and erosion within the wet and seasonally arid tropics of North Queensland.

Following the initial erosion site rationalisation, sites were excluded from further analysis based on the following attributes:

- Small scale – e.g. rill erosion on electricity substation batters; or localised erosion of table drains associated with roads or highways; or
- Isolation (Upland Areas) – areas of natural movement of rivers in upland, forested catchments with little impacts from human land uses. As this erosion was typically occurring at a natural rate remediation is not recommended. Furthermore, remediation would require significant removal of vegetation to access the sites, causing more environmental harm than the benefits achieved by remediation.

On completion of this process, there were 594 remaining sites of riverbank movement or other apparent erosion identified across the region.

The remaining erosion sites were then assessed using the relevant methodologies in order to allow for prioritisation of the sites to identify the following:

- Top 5 prioritised erosion sites presenting a risk to infrastructure (Section 3.5);
- Top 5 prioritised erosion sites impacting on riparian connectivity (Section 3.6);
- Top 5 prioritised erosion sites impacting on cultural heritage (Section 3.7); and
- Top 5 prioritised erosion sites resulting in fine sediment export to the Great Barrier Reef Lagoon (Section 3.8).

3.5 Risk to Infrastructure

The erosion sites were evaluated to determine if they posed any risks to infrastructure. This evaluation was conducted by analysing the land use of each site, ensuring that the process of identifying infrastructure risks followed a quantitative and replicable methodology.

An alternative approach would have been to visually inspect the sites using aerial photography and assess their proximity to infrastructure. However, this method was considered subjective, qualitative, and lacked sufficient replicability.

3.5.1 Land Use Analysis

The remaining locations were evaluated against the 2016 Mackay Whitsunday Regional Land Use study layers from QSpatial. Land uses are classified according to the Australian Land Use and Management Classification produced as part of the Queensland Land Use Mapping Program. Land uses are developed at a scale of 1:50,000 and are divided into six Primary classes, a number of Secondary classes as well as Tertiary classes. The Secondary classes were used for this analysis.

A 200m buffer was applied to each site and the proportion of Secondary Class land uses was determined. A shortlist of Secondary Class land uses was created to identify erosion sites which were likely to be affecting infrastructure. All of the available Secondary Classes including those that were selected for this study are listed in Table 3.

Table 3. Land use categories chosen for prioritisation of erosion sites

Primary Classes	Secondary Classes	Selected for Prioritisation
Conservation and Natural Environments	Nature conservation	-
	Managed resource protection	-
	Other minimal use	-
Production from Relatively Natural Environments	Grazing native vegetation	-
	Production native forests	-
Production from Dryland Agriculture and Plantations	Plantation forests	-
	Grazing modified pastures	-
	Cropping	-
	Perennial horticulture	-
	Seasonal horticulture	-
	Land in transition	-
Production from Irrigated Agriculture and Plantations	Irrigated plantation forests	-
	Grazing irrigated modified pastures	-
	Irrigated cropping	Yes
	Irrigated perennial horticulture	Yes
	Irrigated seasonal horticulture	Yes
	Irrigated land in transition	-
Intensive Uses	Intensive horticulture	Yes
	Intensive animal production	Yes
	Manufacturing and industrial	Yes
	Residential and farm infrastructure	Yes
	Services	Yes
	Utilities	Yes
	Transport and communication	Yes
	Mining	-
	Waste treatment and disposal	-
Water	Lake	-
	Reservoir/dam	-
	River	-
	Channel/aqueduct	-
	Marsh/wetland	-
	Estuary/coastal waters	-

New Land Use Mapping data was released by the Queensland Government for all Great Barrier Reef regions on 21 December 2022. This data was released too late for incorporation into the analysis above, and therefore the 2016 data was used.

3.5.2 Prioritisation of Risk to Infrastructure Sites for Concept Design

The prioritisation of erosion sites to identify the top 5 for their potential risk to infrastructure was undertaken by ranking the sites in descending order based on the percentage of nearby selected land uses as presented in Table 3 above. The top priority sites resulting from this prioritisation are presented in Table 12, Section 9. Note that six have been provided.

3.6 Riparian Connectivity

The remaining erosion sites underwent a comparison process with the following categories to evaluate riparian connectivity:

1. Non-remnant (Category X) vegetation: The presence of non-remnant (Category X) vegetation at each location was assessed. Category X vegetation usually refers to areas where native vegetation has been significantly cleared or replaced by non-native species. The absence of non-remnant vegetation suggests a more natural and connected riparian corridor.
2. Category A or B vegetation: The presence of Category A or B vegetation 1km upstream or downstream from the site and its adjacent riverbank was determined. Category A vegetation typically refers to intact or near-intact native vegetation, while Category B vegetation may include some modifications or disturbances. The presence of such vegetation indicates a healthier riparian zone and better connectivity.
3. State-wide Biodiversity Corridor: Biodiversity corridors are designated areas that facilitate the movement of species, promoting connectivity between different habitats. Being within a mapped corridor indicates enhanced riparian connectivity and ecological value.

After the analysis, nine priority riparian connectivity sites were identified. These sites were the only ones that fulfilled all three criteria mentioned above, indicating their significance in maintaining riparian connectivity and preserving biodiversity. These priority sites may require special attention and conservation efforts to ensure their protection and restoration.

3.6.1 Prioritisation of Riparian Connectivity Sites for Concept Design

To prioritise the nine sites and determine the top five, Neilly Group conducted a visual assessment using aerial photography.

The top five consist of sites that:

- best indicated the presence of an area of erosion;
- have high value vegetation within 1km upstream and downstream but lacking high-quality vegetation within the footprint of the site; and
- were located within a State-wide Biodiversity Corridor, demonstrating riparian value not just within their boundaries but also contribute to the larger landscape-level connectivity and biodiversity conservation goals.

An example of the selection method for one of the top five sites (Riparian Site 107) is shown in Figure 17. The figure shows:

- regrowth vegetation (Category R) within the site, demonstrating that the site has been cleared in the past, with remnant vegetation (Category B) both upstream and downstream in close vicinity to the site; and
- the site is also located within a mapped State-wide Biodiversity Corridor demonstrating that remediating this site would restore riparian connectivity as well as restoring connectivity values in the broader landscape.

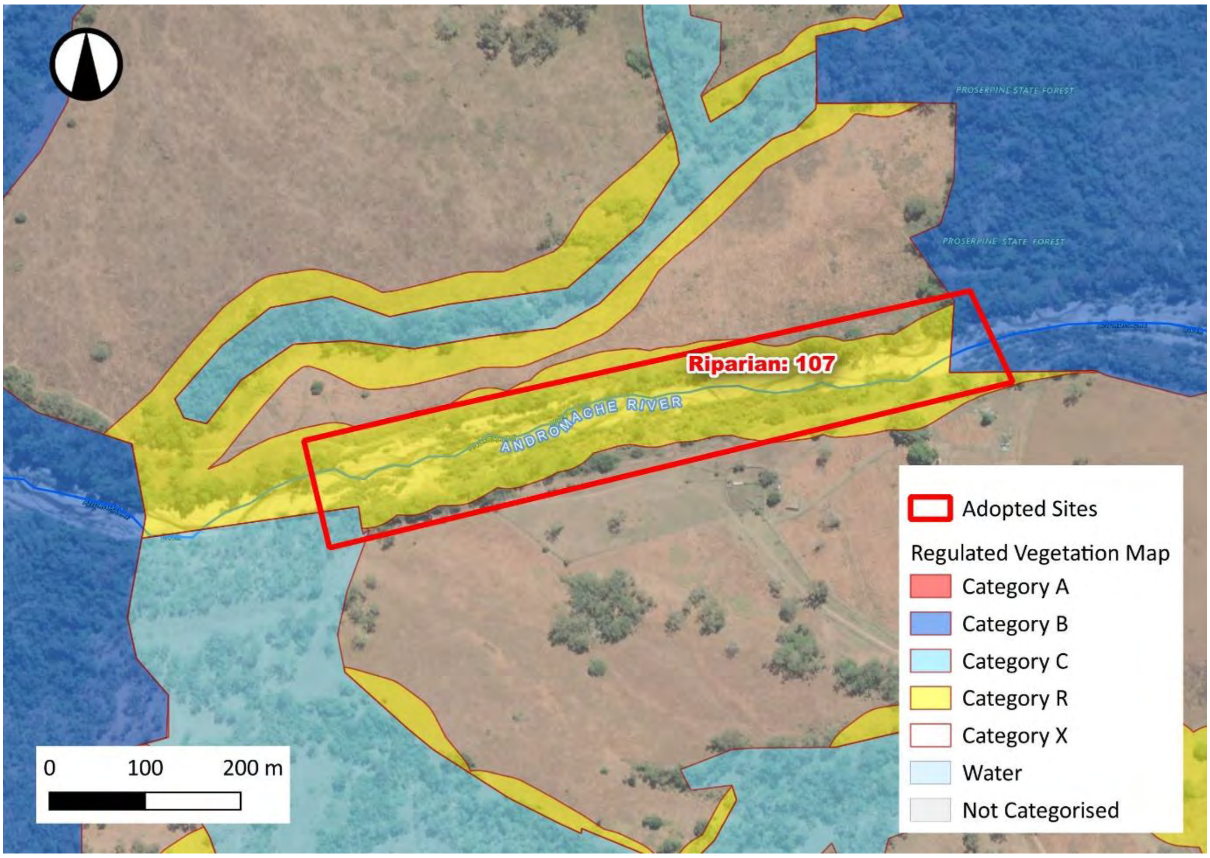


Figure 17. Example of riparian connectivity assessment

The top 5 priority sites resulting from this prioritisation are presented in Table 13, Section 9.

3.6.2 Assumptions

Please note the following assumptions which were applied when assessing riparian connectivity:

- Vegetation mapping is intended to reflect the latest on-ground situation but is not always accurate – i.e. erosion may be present that is not reflected in that vegetation category.
- If the vegetation management category within the site is classified as remnant (Category A or B) then the site is assumed to have connectivity.
- If the vegetation management category within the site is cleared (non-remnant Category X), it is assumed that connectivity is impacted.
- Areas mapped as State-wide Biodiversity Corridors have higher landscape values than areas that are not within a State-wide Biodiversity Corridor.
- If most of the vegetation near the site (upstream and downstream) is classified as non-remnant, then rehabilitating that site is assumed to have lower connectivity value, as it would not improve broader landscape connectivity values, but rather be an island surrounded by non-remnant areas, unless broad scale clearing is also addressed.
- If the vegetation classes bordering the site are classified as regrowth or remnant vegetation, then connectivity can be established to those areas.

3.7 Cultural Heritage Prioritisation

3.7.1 Stage 1

The proposed methodology for the identification of sites with Cultural Heritage significance involved a two-stage desktop analysis for each site. The objective was to identify five priority sites that held Cultural Heritage significance.

Due to the time-intensive nature of this task, the site selection was further refined, reducing the number of sites from 594 to a subset of 112. This subset of sites was produced by using the results from the Riparian and Infrastructure assessments to create a priority order of all the sites. The sites were ordered from highest to lowest combined score, with a natural break occurring after site 112.

The identified sites were assessed against relevant data sets from QSpatial and the Aboriginal Torres Strait Islander Cultural Heritage Data Base as it was expected that indicators for prioritisation would include a site flagging at least one of these datasets.

3.7.1.1 QSpatial

All Cultural Heritage geospatial data was obtained from the QSpatial database. Any sites with proximity to mapped criteria from the data set were cross-referenced using the Aboriginal Torres Strait Islander Cultural Heritage Data Base, identified either by Lot on Plan or Latitude and Longitude Coordinates.

Datasets reviewed were:

- Cultural Heritage Bodies;
- Designated Landscape Areas;
- Cultural Heritage Management Plans;
- Registered Cultural Heritage Study Areas; and
- National Heritage Areas.

Across the 112 sites assessed, none directly intersected with the five datasets listed above although several sites were identified with relative proximity to Management Plan Boundaries. There were no Registered Cultural Heritage Study Areas within Queensland.

3.7.1.2 Aboriginal Torres Strait Islander Cultural Heritage Database

All 112 sites were searched by individual Lot on Plan numbers or Latitude and Longitude Coordinates against the Aboriginal Torres Strait Islander Cultural Heritage Database. Twenty reports were generated using this process for the sites that had flagged as having relative proximity to Management Plan Boundaries, however, no sites directly flagged any of the searched criteria.

3.7.2 Stage 2

It is recognised that waterways are culturally significant for Traditional Owners and through collaboration between Neilly Group and Reef Catchments it was agreed that there was limited availability of data relating to areas of cultural significance and Traditional Knowledge for the MWI Region within the DATSIP Database. It was believed that more tangible input from those Traditional Owners with local knowledge would assist in the identification of sites with Cultural Heritage significance.

Therefore, it was decided that site prioritisation would progress without the use of Cultural Heritage data, and that rather post works Reef Catchments would engage individual Cultural Heritage Parties to present the outcomes of the study relevant for each group's area. This collaborative effort will assist in identifying any sites of Cultural Heritage significance while providing each group with the knowledge and background of the degraded streambanks identified in the study.

In consultation with Reef Catchments, it was decided that assessments for Cultural Heritage would depend on the outcomes of these future conversations and be undertaken on a site-by-site basis for all sites that progressed to the rehabilitation stage.

3.8 Fine Sediment Export Prioritisation

Historically, fine sediment exported to the coast, and ultimately the Great Barrier Reef Lagoon, has been a major component in determining priorities for erosion remediation under both State and Federal Government funding programs, including Reef Trust, GBRF and the Major Integrated Projects in the Wet and Dry tropics. The primary aims of these programs to date has been to reduce the fine sediment export from priority catchments with the goal of achieving the fine sediment reduction targets set out in the Reef 2050 WQIP (Queensland Government 2018).

Once the baseline fine sediment export to the coast (tonnes/year) from a potential erosion remediation site has been estimated, the proposed cost of remediating the site is coupled with the proportion of this ongoing fine sediment export that the proposed remediation measures will prevent, to determine the cost effectiveness of a site in terms of remediation cost per tonnes of fine sediment saved per year ($/tonnes/year).

This cost effectiveness is used to determine if an erosion site should be remediated, or if funding should be directed to other, more cost-effective, sites to ensure the best return on investment for funders through the greatest reduction of fine sediment from available funding.

The original scope of works for this study proposed to undertake baseline fine sediment export to the coast estimates for the top 100 sites identified and prioritised by the study. However, it was quickly determined that without first estimating the baseline fine sediment export to the coast for all sites, it was likely that any prioritisation method to reduce the 594 initial erosion sites down to 100 erosion sites would inadvertently eliminate a proportion of the highest priority erosion sites. Subsequently, it was determined that the baseline fine sediment export to the coast estimates needed to be undertaken for all applicable sites.

Undertaking baseline fine sediment export estimates is a time-consuming task and completing 594 of these would go well beyond the 100 defined by the original scope for this study. Subsequently, a second round of site rationalisation was undertaken to further refine the selection for completing baseline fine sediment export estimates to:

- Only identify sites that are still undergoing active erosion; and
- Eliminate sites that have already been remediated by Reef Catchments, or others.

3.8.1 Second Erosion Site Rationalisation

To conduct the second erosion site rationalisation, it was established that sites currently experiencing active erosion would likely have incurred additional erosion during significant flood events, such as Severe Tropical Cyclone Debbie in 2017 and the Monsoon Trough flooding event in 2019. Therefore, within the context of this study, sites undergoing active erosion were classified as those that experienced erosion between 2017 and the present.

Subsequently, the 594 erosion sites were evaluated using recent aerial photography starting from 2017, to determine if erosion had occurred during this timeframe. This assessment led to a reduction in the total potential erosion sites to 281.

This approach is consistent with the principles of the QRRM Guideline (Department of Environment and Science 2022), where understanding the temporal response of the waterways in a catchment to flood events is an important aspect of understanding whole-of-system and values. Identifying sites that are no longer actively eroding is part of determining the needs and objectives of a potential rehabilitation site. Nevertheless, although the site might initially seem to require remediation, the absence of ongoing erosion implies that the erosion process has naturally concluded at that location, rendering intervention unnecessary.

Rehabilitation efforts can then be better focused elsewhere by addressing sites that are still actively eroding and pose greater risks to the ecosystem and the economy. In the case of the Mackay Whitsundays region, the most significant ecosystem services at a whole-of-system level that are directly impacted by the health of the Great Barrier Reef include tourism, commercial fishing and aquaculture, recreation and scientific research and reef management.

Figure 18 shows an example that was identified as a potential erosion site undergoing significant streambank erosion between 1970 and 2018. However, the same site is shown in Figure 19, which illustrates the site underwent no further erosion since 2017, as judged by comparison between a 2015 and 2023 aerial image. This site was subsequently removed from the selection of potential erosion sites as it was no longer actively eroding, despite the O'Connell River experiencing two major flood events in 2017 and 2019 as detailed in Section 4.6.

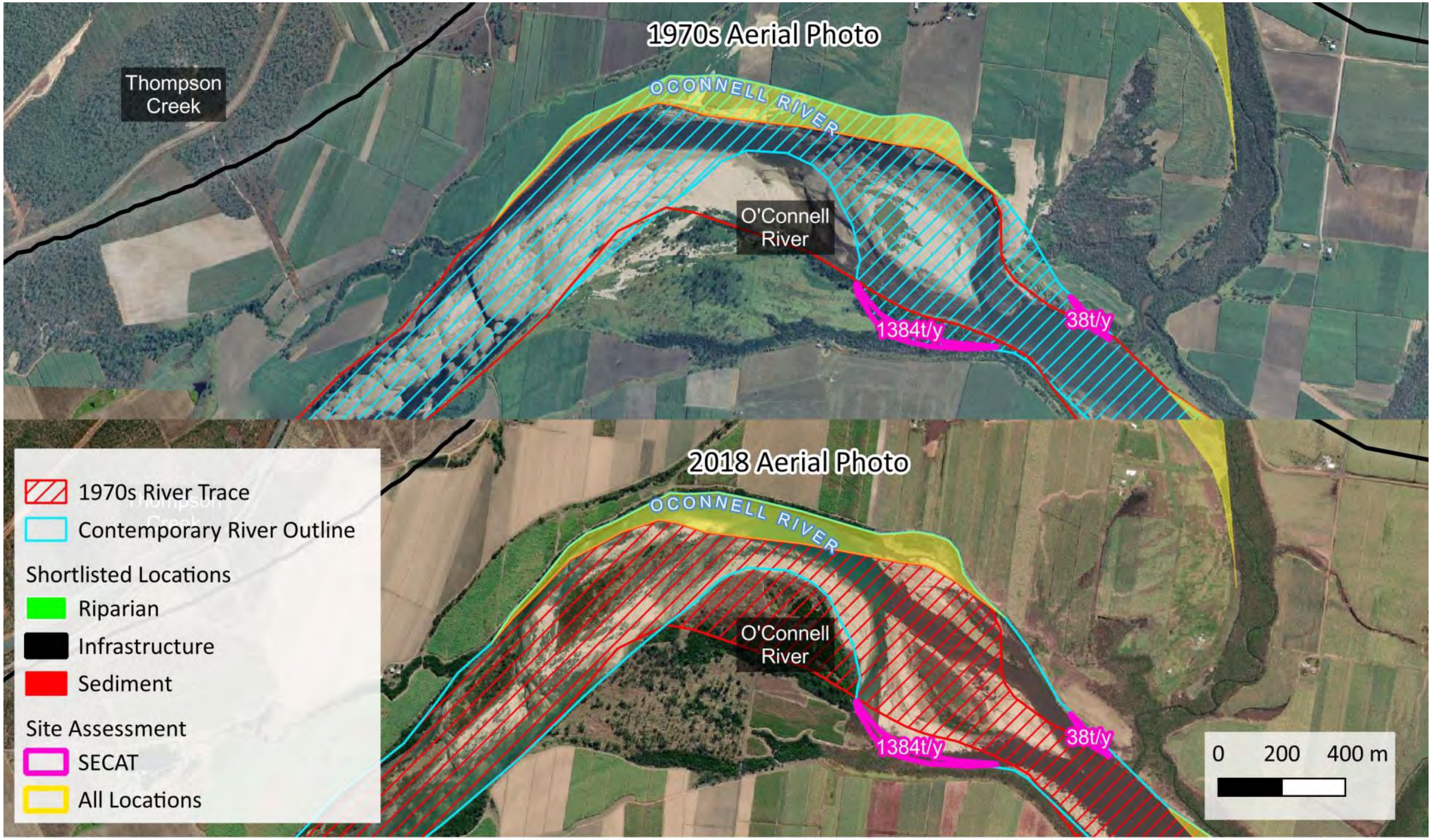


Figure 18. Significant historical erosion site at the mouth of the O'Connell River as identified in the initial erosion site identification process using top of bank lines between 1970 and 2018.

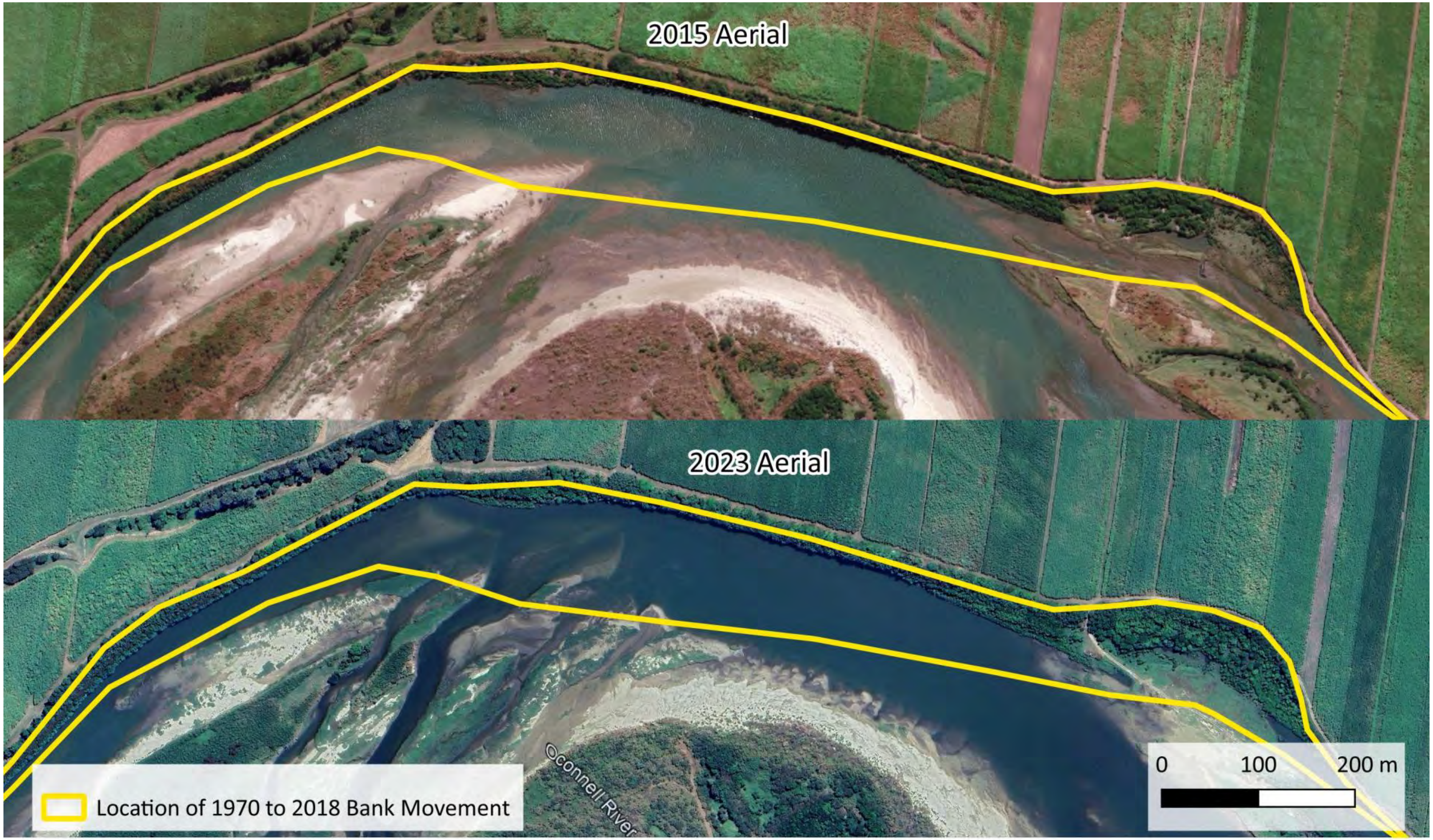


Figure 19. Significant historical erosion at at the mouth of the O'Connell River demonstrated to be no longer actively eroding since 2017

Once the 281 actively eroding erosion sites were identified, an additional step was necessary to determine the sites where creating baseline fine sediment export estimates was viable. This procedure involved considering the following factors:

- A key component of baseline fine sediment export estimates is determining the volume of total sediment that has been eroded from a site over a known period. As the study did not include the scope to ground truth or gather data such as ground survey data at every site, it was established that a potential erosion site must be situated within any of the existing LiDAR datasets for baseline sediment export estimates to be possible. Sites situated outside available LiDAR datasets were subsequently excluded.
- Reef Catchments (and others) are regularly undertaking erosion remediation in the region, which may not be identifiable at potential sites depending on the timing of the works and capture of satellite imagery. A list of known remediated sites was provided by Reef Catchments and where the list overlapped with sites identified by Neilly Group the sites were excluded.
- Actively eroding potential erosion sites situated within isolated tidal areas, such as river deltas and estuaries surrounded by dense mangroves/marine plants, were eliminated prior to conducting sediment calculations. This is due to the considerable environmental impact that would result from removing the mangroves/marine plants for site access, which would likely outweigh the benefits gained from site remediation.

After completing further rationalisation, a total of 134 actively eroding potential erosion sites remained. Baseline fine sediment export estimates were undertaken for all of these sites.

3.8.2 Estimation of Baseline Fine Sediment Export to the Coast

An estimate of the baseline fine sediment exported to the coast from each of the remaining 134 sites was undertaken using the Streambank Erosion Control Assessment Tool (SECAT) in accordance with the requirements of the Stream bank Erosion Control Assessment Tool (SECAT) Survey User Guide (Humphreys and Wilkinson 2021).

The SECAT baseline fine sediment export to the coast estimate involves the equations, variables and coefficients outlined in Table 4 below.

The resultant SECAT baseline fine sediment export to the coast estimates and all variables and coefficients used for each of the 134 sites are presented in Attachment C.

3.8.3 Prioritisation of Fine Sediment Export Sites for Concept Design

The prioritisation of fine sediment export sites was undertaken by ranking the sites in order from highest baseline fine sediment export to the coast values to the lowest.

The top 9 priority sites resulting from this prioritisation are presented in Table 14 in Section 9.

Table 4. Overview of the SECAT equations, variables and coefficients

	Description	Methodology Used
1	**Erosion volume over time (m^3)**: This is the volumetric rate of soil loss from a stream bank over time. It can be calculated over a known historic period if the volume of erosion that has occurred can be defined at the site between the beginning and end of the period.	• Trace the erosion polygon at a stream bank site using aerial photography between two successive dates and multiply the resulting erosion area by the average bank height as measured in the DEM; or • DEMoD (where two datasets were available at different times)
2	**Time period (years):** This is the time in years between the beginning and end period over which the erosion volume has been calculated.	• Time in years between the successive aerial photography used to delineate the erosion polygon. • Time in years between the dates of the DEMs used in the DEMoD
3	**Historic erosion rate (m^3/year)**	• Historic erosion rate = (Erosion volume over time) / (Time period)
4	**Climate correction factor:** The climate correction factor is used to correct the historic erosion rate by considering the ratio between a measure of long-term average stream flow and the stream flow in the time period over which the erosion volume has been determined.	• Applicable stream flow gauges were chosen to determine the Climate Correction Factor for all sites
5	**Baseline erosion rate (m^3/year)**	• Baseline erosion rate = (historic erosion rate) x (climate correction factor)
6	**Dry Bulk Density:** The dry bulk density of material eroded.	• Evaluated using the Australian Soil Resource Information System (ASRIS)
7	**Estimated silt and clay content** The proportion of soil volume comprising particles <20µm. This is made up of the percentage of clay (<2µm) and silt (2-20µm) in the material eroded.	• Evaluated using the Australian Soil Resource Information System (ASRIS)
8	**Baseline fine sediment supply from the site (t/year)**	• Baseline fine sediment supply from the site = (Baseline erosion rate) x (Dry Bulk Density) x (Estimated silt and clay content)
9	**Fine Sediment Delivery to Coast (proportion):**	• P2R Residual Sediment Delivery Ratio (RSDR) applied as per Figure 20.
10	**Baseline fine sediment export to the coast (t/year)**	• Baseline fine sediment export to the coast = (Baseline fine sediment supply from the site) x (Fine Sediment Delivery to Coast)

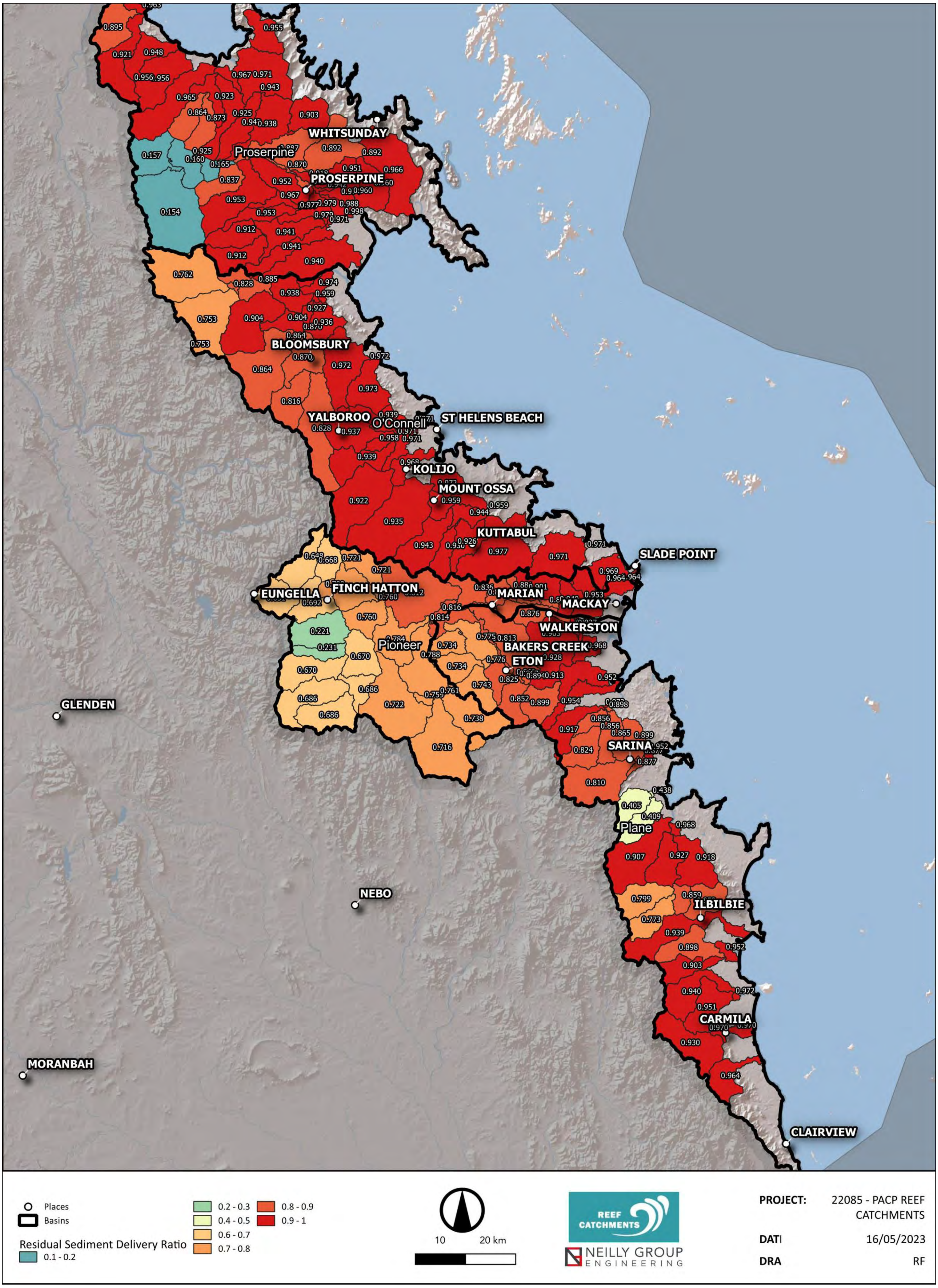


Figure 20. RSDR values for Reef Catchments NRM Region

3.9 2022-2023 Reach Scale Additional Sites

In April 2023, Reef Catchments requested Neilly Group expand the assessment of Cattle Creek in the Pioneer River Basin. The purpose was to evaluate the potential for including a number of individual sites along Cattle Creek as a single reach scale site. The reason behind this request was the significant impact of three extreme weather events on the system within the last five years. Furthermore, in November 2018, a bushfire devastated approximately 53,000 hectares in the Eungella National Park, affecting the headwaters of the Cattle Creek system. This fire compounded the effects of the rainfall events and left the downstream portion of the system susceptible to erosion and channel change.

Initially, when Neilly Group assessed these sites individually, they did not meet the criteria to qualify as top priority sediment export sites. However, when evaluated as a reach scale site (which is consistent with the QRRMG approach of considering “whole-of-system” and the desire to address a need), the sites ranked highly among the top priority sites.

3.10Landholder Consultation

The process of facilitating landholder engagement to arrange site access for fieldwork was primarily managed by Reef Catchments. However, it was noted that this engagement occurred retrospectively, after completion of the site prioritisation work.

The landholders Neilly Group met during the site visits in the Cattle Creek region are generational farmers who are invested and passionate about restoring the creek to its former health. These landholders had lobbied Reef Catchments to increase awareness of the damage within the Cattle Creek system with the aim to secure funding for rehabilitation.

Elsewhere, most landholders were amenable to having the site assessments completed and from preliminary conversations appear willing to have remediation work undertaken on their land.

3.11Concept Designs and Costings

The initial plan encompassed creating costed concept designs for remediation efforts on the top 5 sites in each category of Infrastructure, Cultural Heritage, Riparian Connectivity, and Sediment Export. However, this study did not identify any sites for Cultural Heritage, and Reef Catchments requested substituting developing concept designs for the Infrastructure sites with additional Sediment Export sites. This adjustment was aimed at capitalising on the subsequent round of Reef Trust funding announced by the Federal Government in 2022. (Australian Government Department of Climate Change, Energy, the Environment and Water 2023).

Site visits were undertaken in April and May of 2023. These site visits covered four of the five prioritised Riparian Connectivity sites, as the landholder for the 5th site was not amenable to having the site assessment completed and this site was subsequently removed from the prioritisation. Site visits were also undertaken for all 16 Sediment Export sites; however, it was identified through ground truthing that two of these sites were not suitable Sediment Export sites as the erosion issues that were identified during the desktop assessment had already resolved themselves through natural regeneration.

Subsequently, two new sediment export sites were included in the Sediment Export prioritisation after the site visits had taken place. These sites were selected as they ranked as the two largest tidal sites (Sites 168 and 329) that were not completely fringed by mangroves/marine plants and have the potential to be remediated.

In total, four Riparian Connectivity sites and 16 Sediment Export sites (8 sites combined for the Cattle Creek reach scale site) had costed concept designs developed for remediation/mitigation works. The concept designs include sufficient detail to later progress to detail design should they be successful in obtaining funding. The designs were developed to provide the greatest likelihood of success and included remediation designs drawing from the following remediation measures:

- revegetation;
- bank reprofiling;
- timber pile fields;
- large wood installations;
- rock beaching;
- rock groynes; and
- log fillets.

A schedule of quantities for the remediation options at each site has been determined, with a cost estimate provided based on Neilly Group's experience of unit rate estimates for similar works that have been undertaken in the region. Generally, cost estimates will be +/- 30% at the time of preparation.

The initial SECAT calculations for the 20 sites were also refined during the concept design stage to provide more confidence in these estimates. The reporting for each site includes discussion of the proposed works, refined SECAT calculations, typical concept design details, concept design characteristics, a schedule of quantities and estimated construction costs.

Refer to Attachment D for details of concept designs undertaken for the final 20 sites.

3.12 Assumptions and Limitations

The following bullet points outline the assumptions and limitations of the methods:

- The aim of this study was to adopt a quantitative and repeatable approach.
- It is acknowledged that the method employed may not have identified all instances of erosion or bank movement due to lack of data and the large scale of the project.
- Due to the prevalence of a specific type of erosion in the region, the study primarily focused on stream bank erosion, with gully erosion being rare.
- Past erosion locations do not necessarily indicate future erosion locations.
- The methodology is unable to detect erosion in areas with dense vegetation coverage within the riparian corridor. However, minimal erosion is anticipated in these areas.
- While the Neilly Group made every effort to obtain the most up to date data sources, the assessment is constrained by the quality of the input data. Recent years' (2021, 2022) publicly available aerial imagery is not readily accessible for significant portions of the study area. Consequently, the analysis is based on the most recently available data, which, in some cases, may be from 2018 or 2019.

4 Regional Description

4.1 Geology and Soils

The Proserpine, O'Connell, Pioneer, and Plane Creek Basins originate on the eastern slopes of the Clarke Connors Ranges and flow eastward into the Great Barrier Reef Marine Park. The geology, soils, and landforms of these basins are influenced by a variety of factors, including their geological history, land use, and human activities.

In terms of geology, the upper catchments of these basins are dominated by intrusive granitoid rock formations from the late Carboniferous to early Permian period. These rocks form the steep, mountainous regions associated with the Clarke Conners Ranges. These igneous granitoids are highly erosive and weather to sands and clays. Another major geological unit in the region is the early Permian Carmila beds, which consist of a mix of volcanic and sedimentary rocks. This unit primarily forms the lower hillslopes across the region. The alluvial/colluvial deposits consist of clays, silts, and sands in which the waterways have developed. There are also extensive terrace formations throughout the region, which are more resistant to erosion than the Holocene floodplain deposits.

The soils in the southern half of the region are dominated by dermasols with a sealing loamy surface. Dermasols can vary from stony hard setting soils to friable deeper profiles. Within the region, these dermasols are typically non-sodic. Sodosols with a loamy surface are dominant in the northern half of the catchment. These sodosols include sodic chromosols/kurosols/kandosols and calcarosols.

In terms of landforms, apart from the headwaters in the Clarke Connors Ranges, most streams flow through relatively low relief and gently sloping landscapes across the coastal floodplain. The Proserpine, O'Connell, and Plane Creek catchments contain distributed stream networks with many significant and minor streams that drain directly to the Great Barrier Reef lagoon.

Physical processes such as groundwater recharge/discharge, sedimentation/erosion of soils, and deposition and mobilisation processes transport and mobilise elements such as water, sediments, and minerals. Declines in delivery of physical processes that retain sediments are generally reflected by an increase in total suspended solids.

4.2 Sugarcane Production, Cattle Stocking, and Pollutant Loads in the Mackay Whitsunday Region

Since European Settlement, sugarcane production within the region has increased over time (Figure 21) with a sharp increase in total sugarcane area in the 1970s and later between 1995 and 2000. The region has seen a twofold increase in the area under sugarcane since the 1960s (Lewis, et al. 2021).

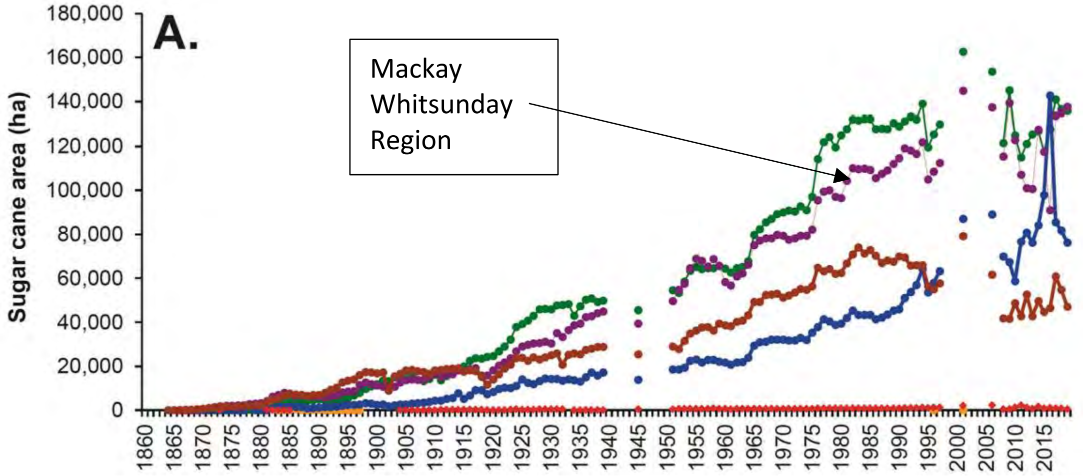


Figure 21. Time history of areas under sugarcane production (Lewis, et al. 2021)

Figures of the number of cattle in the Mackay Whitsunday region indicate that stocking densities are relatively high (>25 cattle per km^2) compared to other NRM regions (6 – 22 cattle per km^2) (Lewis, et al. 2021).

In the 2014 review of the Mackay Whitsunday region's pollutant loads and abatement targets, streambank erosion contributed approximately 45% of the modelled TSS load followed by sugarcane (25%) and grazing areas (14%) (Packett, et al. 2014).

In 2014 the total baseline load of TSS for the Mackay Whitsunday region is 511kt/y with the anthropogenic baseline load of 360kt/y. The anthropogenic load reduction (due to investment) between 2008-2013 is approximately 9% (Packett, et al. 2014).

(Baird, Margvelashvili and Cantin 2019) show that an emphasis on the finest size of land derived sediments is more important in the Whitsundays region than it is in more northern areas of the Great Barrier Reef because of the long residence time of sediment within the coastal environment.

4.3 Current Sources of Sediment

Regional monitored gauges data was obtained from the Great Barrier Reef Catchment Loads Monitoring Program (Investigations 2021). Figure 22 and Figure 23 plot the total sediment load, and total sediment load per catchment area, respectively.

The figures show that the total load is variable across the basins:

- The Proserpine River at Glen Isla gauge had the highest load in 2017-2018 and the 2019-2020 reporting periods.
- The O'Connell River at the Caravan Park had the highest load in the two other reporting periods, second highest in the third (2017-2018) and is in the middle of the fourth (the most recent period of 2019-2020). This gauge monitors 97% of the catchment. Of the sediment generated in the O'Connell Region, the majority is modelled to come from hillslope erosion and streambank erosion with roughly 4x the amount of hillslope erosion as streambank erosion.
- The Pioneer Region typically sits in the middle of the pack. According to the 2020 report card, most anthropogenic erosion comes from streambank erosion.
- Plane Creek had the smallest total load in every reporting period.

The Reef Report Card for 2019-2020 (the most recent with available data) notes that sources of sediment during the reporting period were:

- Proserpine River generated 30kt of fine sediment (55t/km2)
- O'Connell River generated 16kt (19t/km2)
- Pioneer River generated 22kt of fine sediment (15t/km2)
- Plane Creek generated 6.3kt (38t/km2)

The above loads were among the lowest monitored by the monitoring program.

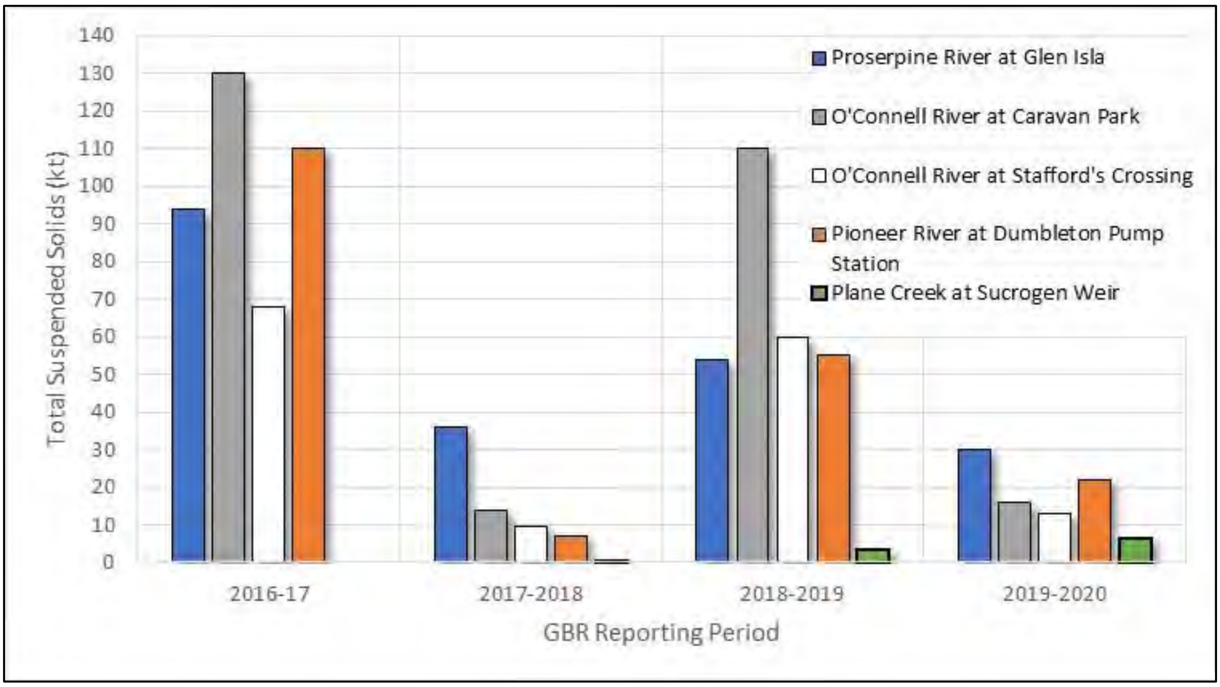


Figure 22. Monitored sediment loads as outlined in the Reef Report Card and P2R program (DEECW n.d.)

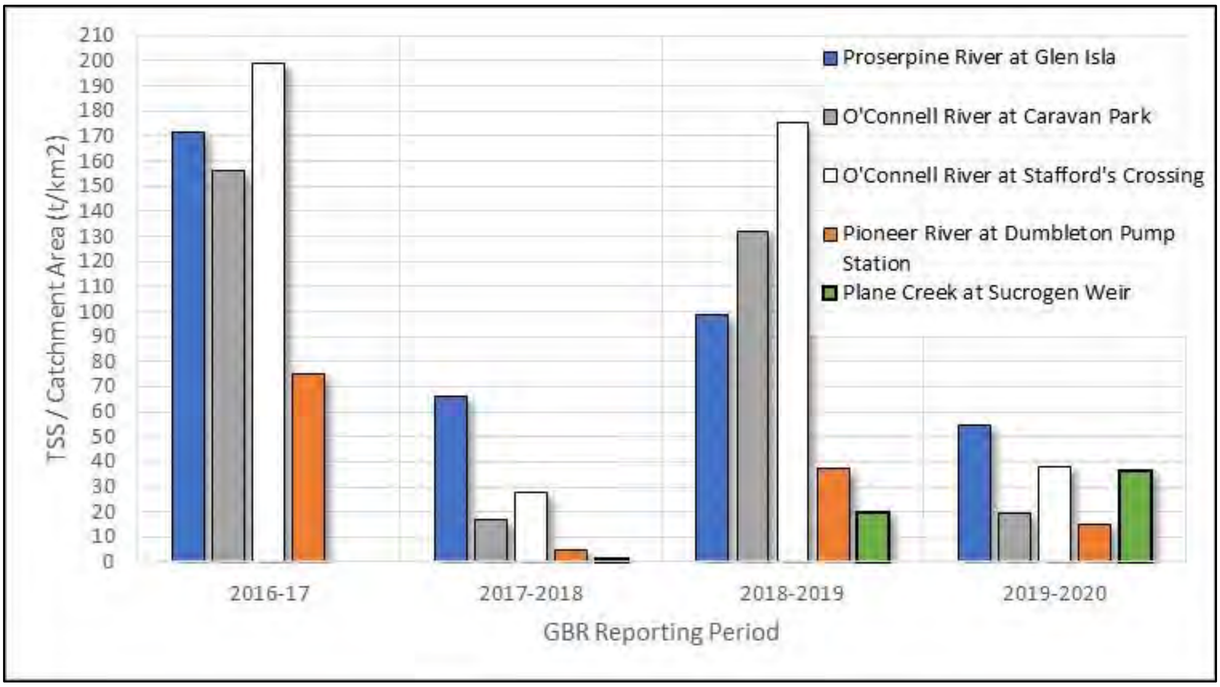


Figure 23. Monitored sediment loads per catchment area

Comparison between the total discharge and total load shows that sediment increases with flow in a relatively linear manner in the same relationship for all gauges except the Pioneer River at

Dumbleton (Figure 24). This indicates that the water quality (i.e. suspended solids) in the Pioneer River is expected to be of better quality than the other basins.

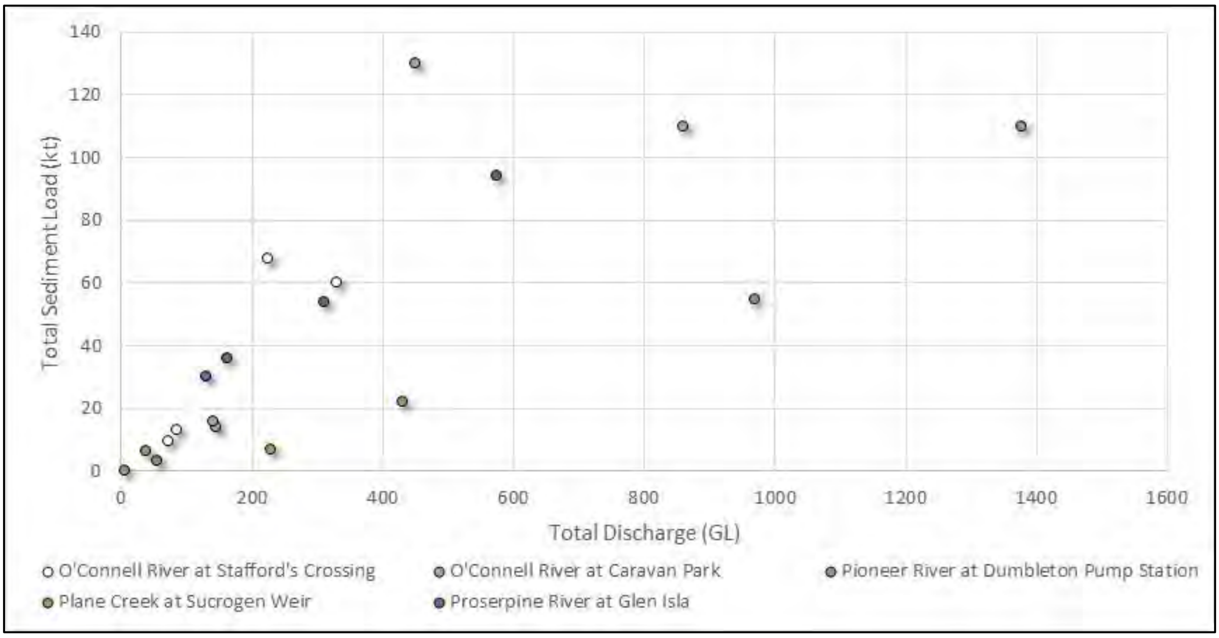


Figure 24. Total discharge vs total sediment load for selected gauges

The 2020 Reef Report Card shows that the Mackay Whitsunday Region has made 13.1% of its required 25% reduction in fine sediment (data until June 2020). See Table 5.

Table 5. Report Card results for the Mackay Whitsunday region.

Reporting Period	Progress towards 25% reduction target	Actions to achieve progress
2017-2018 Report Card	12.5% reduction to date	• 1,120ha and 43km of streambank management practices NRIP • 8017ha of improved grazing management practices
2019 Report Card	12.5% reduction to date	• Soil management projects in sugarcane areas across the catchments
2020 Report Card	13.1% reduction to date	• 49,269ha of improved grazing and gully management through Project Pioneer (Reef Trust) • 8153ha management practice improvements through Smartcane BMP program • 1,641 tonnes of sediment saved through streambank stabilisation works through Reef Trust

The report card shows 1,641 tonnes of sediment saved through streambank stabilisation through the Australian Government's Reef Trust: High Priority Streambank Erosion in the Mackay Whitsunday Region[2]. Of these areas, the Proserpine and Plane basins have a target of "Maintain Current Load" (as outlined in Section 1.3.3.1). Within the O'Connell catchment, 17.2% sediment reduction has occurred. In contrast, the Pioneer catchment has only achieved a 6% reduction to

---

[2] Sourced from the Interactive Reef Report Card 2020, 2025 Catchment Targets, Change Indicator: Sediment – Change Location: Mackay Whitsunday Region. Date accessed: 23/05/2023. https://reportcard.reefplan.qld.gov.au/home?report=target&year=611f443aba3074128316eb07&measure=FS&area=MW

date. It should be noted that while the Proserpine and Plane basins have hit their targets, erosion sites are present and are still contributing fine sediment to the Great Barrier Reef.

4.4 Riparian Vegetation Extent

The multiple plants growing along the water's edge, the banks of rivers and creeks and along the edges of wetlands are referred to as 'riparian vegetation'. Riparian vegetation can include trees, shrubs, grasses and vines and in their natural state form a complex ecosystem which includes groundcovers, understorey and canopy. Drought and rising temperatures due to climate change, exotic species invasions, and human activities, such as grazing and recreation all impact riparian ecosystems.

The first Reef Report Card (Queensland and Australian Governments 2011) shows that the total riparian vegetation extent in the region was measured as 130,000 hectares, with 650 hectares being susceptible to erosion due to being low-forested with little groundcover. Approximately 389 hectares (1.16%) of riparian vegetation was cleared in the O'Connell Catchment between 2004-2008 (Queensland and Australian Governments 2011).

Similarly, stream bank erosion rates have accelerated because of widespread degradation and clearing, the installation of weirs and the physical disturbance of stream corridors by livestock. Many of the issues confronting current land managers are legacy issues and have been inherited largely from historical management practices.

The lowest cost approach to managing streambank erosion, and risk of future bank erosion, is to improve riparian vegetation by passive (for example, livestock exclusion and weed control) or active means (for example, planting).

Clearing for Agriculture and Urban development has been prevalent in all four river basins assessed under the Reef Report Card, but particularly so in the Proserpine and Pioneer basins, which reached their lowest levels of Riparian Vegetation extent in the period 2009-2013. From 2013-2017 there has been a marked improvement in the extent of riparian vegetation across all catchments except for the O'Çonnell catchment.

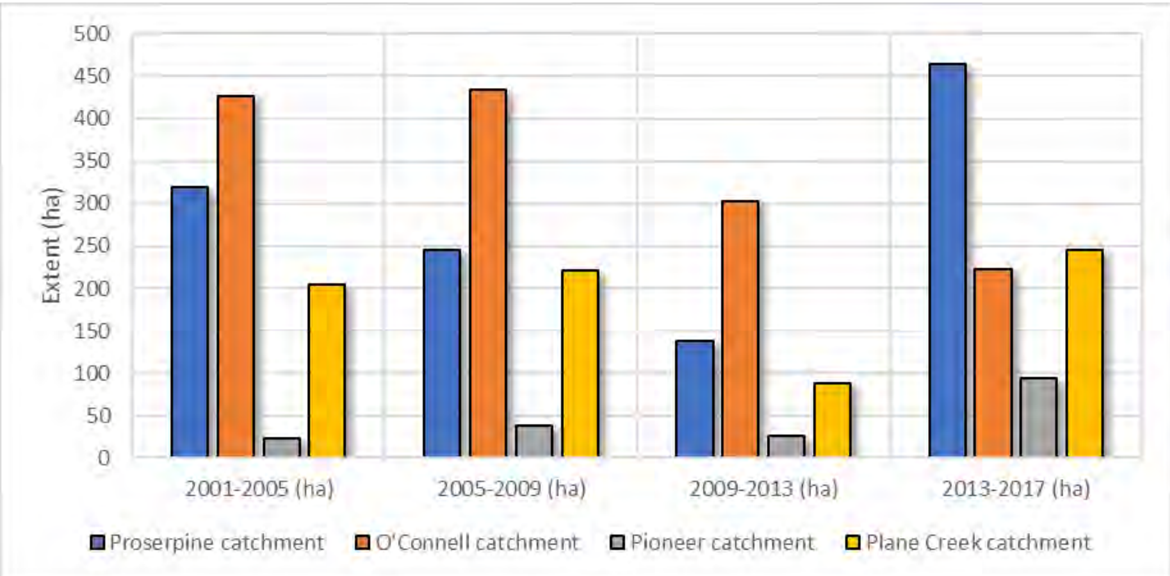


Figure 25. Riparian vegetation extent from Reef Report Cards

4.5 Cyclones

The dates and intensity of major cyclones affecting the Mackay Whitsunday region have been compiled in Table 6 below.

Table 6. Floods and cyclones majorly affecting the Mackay Whitsunday Region[3]

Date	Name	Category Affecting Reef Catchments NRM Region
January 1910	Unnamed	1
February 1911	Unnamed	3
December 1916	Unnamed	3
December 1917	Unnamed	3
April 1928	Unnamed	2
February 1929	Unnamed	1
March 1940	Unnamed	4
February 1943	Unnamed	3
February 1949	Unnamed	3
March 1955	Unnamed	4
January 1956	Unnamed	1
March 1956	Agnes	3
January 1970	Ada	1
January 1976	David	
March 1976	Dawn	2
January 1979	Gordon	5
February 1979	Kerry	3
January 1980	Paul	2
March 1990	Ivor	2
March 2003	Erica	4
March 2010	Ului	2
January 2014	Dylan	2
April 2014	Ita	1
March 2017	Debbie	3

A description of the cyclones since 2010 with relation to the Mackay Whitsunday region is provided below. Severe Tropical Cyclone Debbie had the largest impact in terms of sediment and erosion.

4.5.1 Cyclone Ului (2010)

Significant wind damage was reported around the Central Coast and Whitsundays district, mainly between Airlie Beach and Mackay. Reports of damage include widespread tree damage, large areas of sugarcane destroyed and localised structural damage, particularly to roofs. About 50,000 homes

[3] Compiled using the Bureau of Meteorology's Interactive Cyclone Data Portal, Available at: http://www.bom.gov.au/cyclone/tropical-cyclone-knowledge-centre/history/tracks/, Date Accessed: 27/05/2023

lost power following the passage of the system. Many boats were also damaged or destroyed due to large seas and swell created by Ului, particularly around Shute Harbour near Airlie Beach.

4.5.2 Cyclone Dylan (2014)

Cyclone Dylan crossed at Dingo Beach near Proserpine as a category 2 system. It combined with a high-pressure ridge to cause increased tides along the coast in the days leading up to it crossing the coast. A 1.4m storm surge occurred at Laguna Quays on 31st of January, and up to 515mm rainfall was recorded in 24 hours.

4.5.3 Cyclone Ita (2014)

Cyclone Ita made landfall around Cape Flattery in Cape York Peninsula and then travelled south-east along the coast as a category 1 system. The main impact of Cyclone Ita was rainfall and flooding with 300-400mm recorded in 24 hours. Over 110mm was recorded in 1 hour at Bowen.

4.5.4 Severe Tropical Cyclone Debbie (2017)

Severe Tropical Cyclone Debbie, a category 4 cyclone, hit Queensland's Whitsunday coast including Airlie Beach and the Whitsunday Islands, on March 28, 2017[4]. Cyclone Debbie inflicted extensive damage on regions including Hamilton and Daydream Islands, Airlie Beach, Proserpine, and Bowen, while also bringing category 2 strength winds to the inland area of Collinsville. When the remnants of the storm shifted southeast, it triggered serious flooding in central and southeast Queensland and northeast New South Wales, resulting in fatalities and school shutdowns. Refer to Figure 26 which shows the track of the cyclone.

On March 28, a maximum wind gust of 263 km/h was recorded at Hamilton Island, making it the strongest gust ever observed in Queensland's history. The cyclone made landfall near Airlie Beach, moving at a slow pace and subjecting various areas to prolonged destructive winds.

A storm surge reaching 2.6 meters, which exceeded the Highest Astronomical Tide by 0.9 meters, was documented at Laguna Quays. Debbie began to weaken in the early hours of March 29, yet it continued to generate damaging winds and torrential rain from central Queensland down to the southeast. Exceptional levels of rainfall were noted in locations such as Clarke Range and Mt Jukes, leading to significant flooding in the Mackay and Fitzroy River basin. According to Alluvium (2017), the Mackay Whitsunday region received approximately 800mm in rainfall in a four day period with 355mm recorded in 24 hours in the Plane Creek Basin, 206mm in Mackay and 396mm in Crystal Brook.

---

[4] From: http://www.bom.gov.au/cyclone/history/debbie17.shtml. Date accessed: 05/05/2023

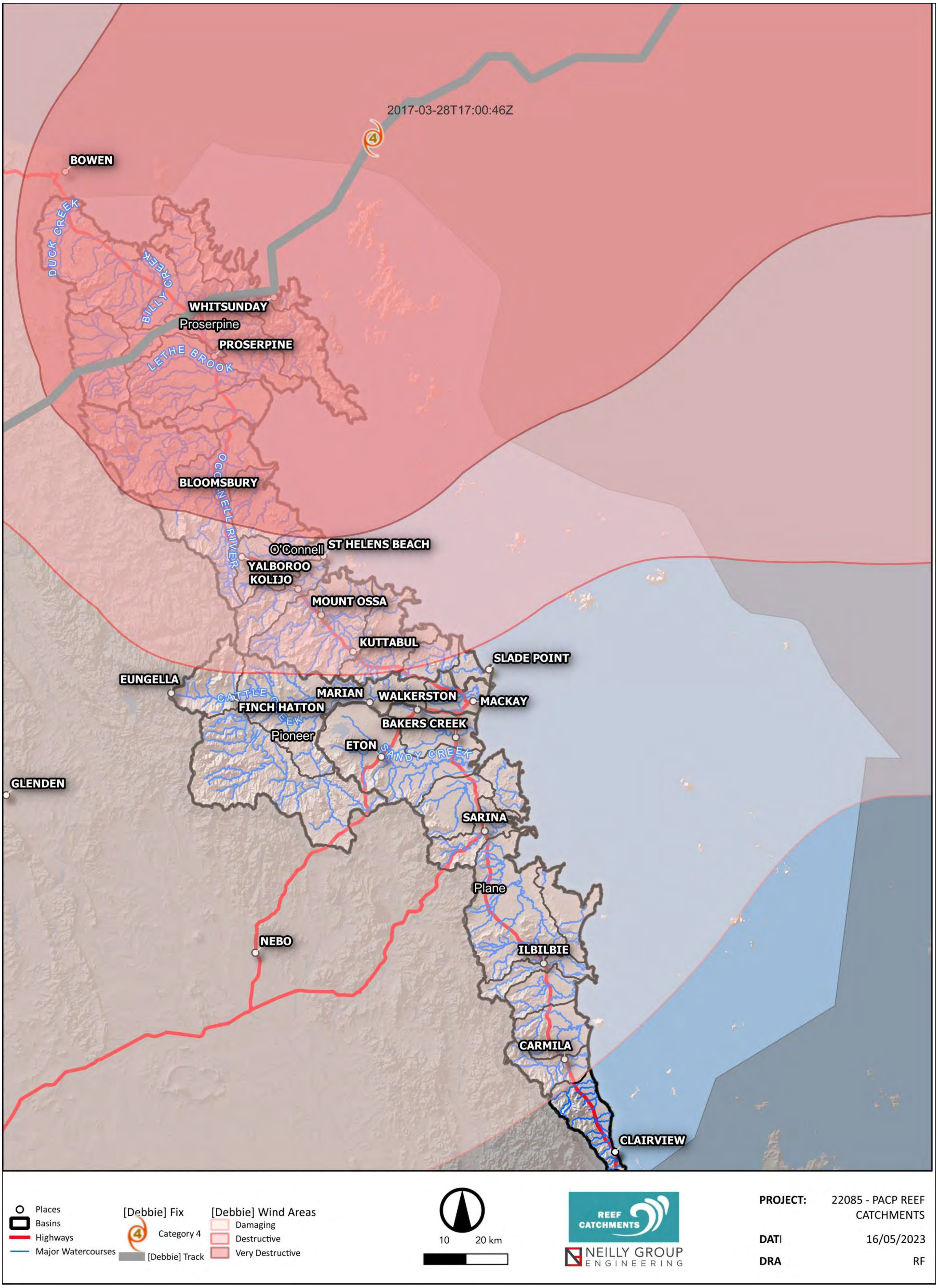


Figure 26. Cyclone track and extent of Severe Tropical Cyclone Debbie

4.6 Floods

Table 7 presents the larger flood events (i.e. typically greater than the 20-year ARI) in each basin since 1958. The table shows floods often do not occur simultaneously within each basin, indicating the role of different climate systems affecting runoff within each basin.

Table 7. Flood history for the Mackay Whitsunday region River

Year	Proserpine	O'Connell	Pioneer (WRM 2021)		Plane
			Finch Hatton	Mackay	
1958	-	-	N/A	100y	-
1970	-	10-20y	10-20y	100y	-
1978	<5y	5-10y	10-20y	20-50y	<5y
1979	5-10y	5-10y	20y	50y	<5y
1980	<5y	50-100y	10-20y	20-50y	<5y
1988	<5y	<5y	<5y	-	100y
1989	10-20y	10-20y	<5y	-	<5y
1990	<5y	<5y	50-100y	20-50y	<5y
2008	<5y	5-10y	10-20y	20y	5-10y
2010	5–10y	<5y	<5y	-	20-50y
2011	<5y	<5y	20-50y	10-20y	5-10y
2012	<5y	<5y	50-100y	-	5-10y
2017	10y	5-10y	50-100y	20-50y	50y
2019	<5y	<5y			<5y
2023	5–10y	<5y			<5y

Refer to Figure 27 for gauged flood height data for the Proserpine and Pioneer Rivers. There is limited flood information available for the O'Connell Basin and the Plane Creek Basin so these two basins are not included.

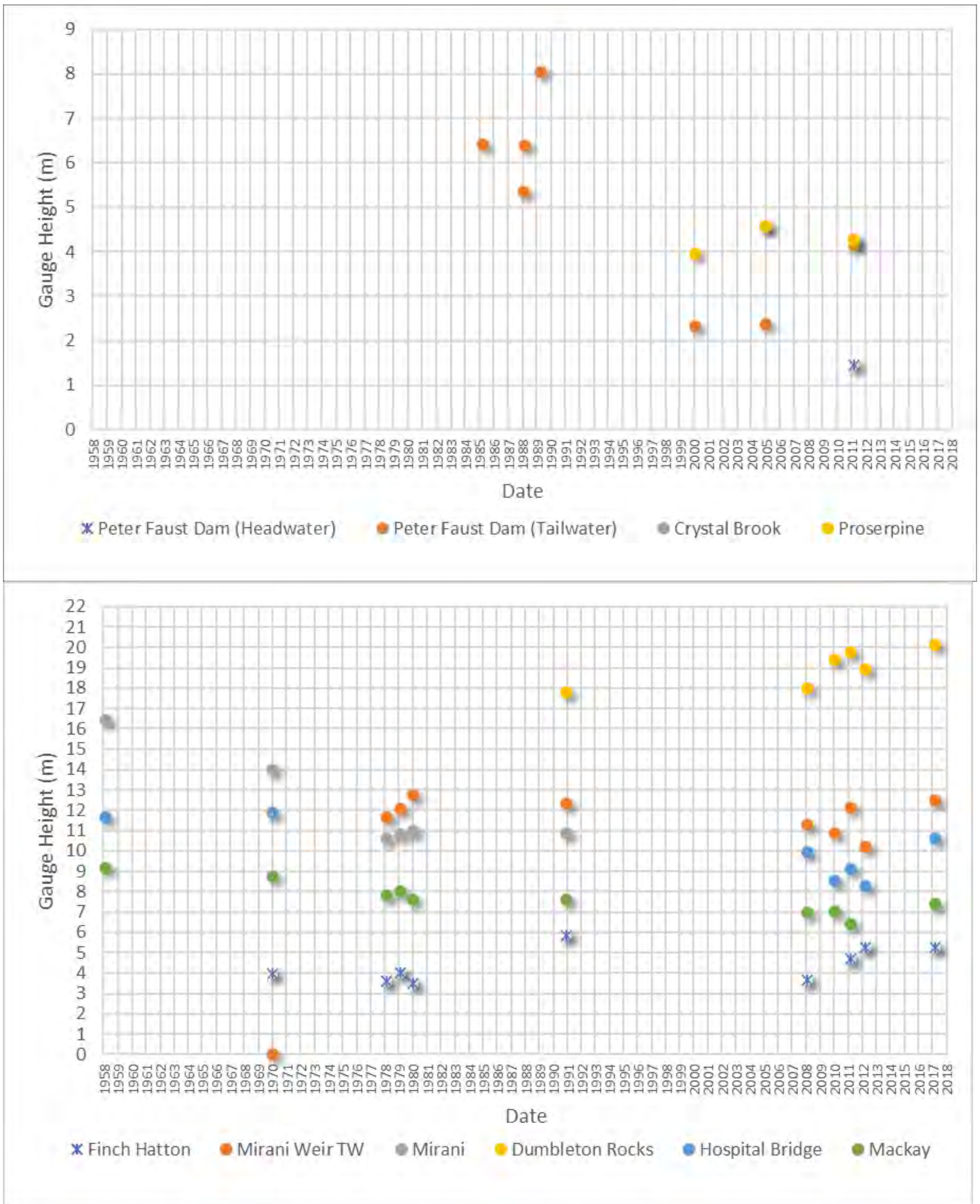


Figure 27. Flood gauge heights for the Proserpine River Catchment (top) and Pioneer River Catchment (bottom). Data sourced from (BOM 2021)

4.6.1 Recent storm events

Of particular interest to this study are the two major storm events, which caused flooding, to have occurred in the last decade in the Mackay Whitsunday region, Severe Tropical Cyclone Debbie (in 2017) and the 2019 Monsoon Trough which are discussed below.

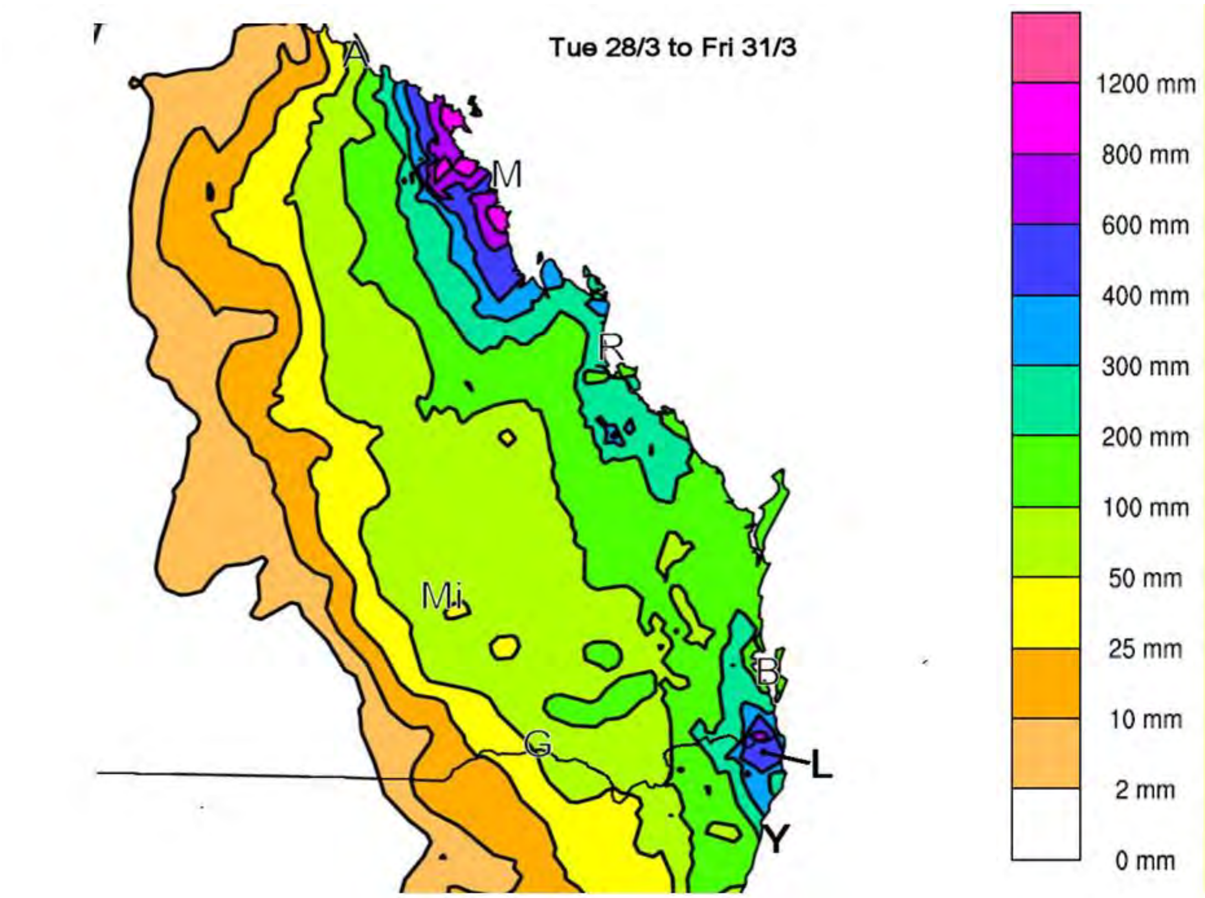
4.6.1.1 Severe Tropical Cyclone Debbie (2017)

As explained by the Bureau of Meteorology, Cyclone "Debbie produced very large rainfall accumulations over much of eastern Queensland and northern NSW during the four-day period from Tuesday 28 to Friday 31 March" (BOM 2018).

"This occurred roughly east of a line through Ayr, Mitchell, Goondiwindi and Yamba. Virtually all locations within the eastern half of this area received over 100mm for the event, while those in the west generally recorded totals in the 50 to 100mm range. The highest rainfall totals occurred near the east coast, particularly the Clarke, Connors and other coastal ranges of central Queensland; and also the southeast Queensland and northern NSW, where many locations recorded between 500 and 1000mm" (BOM 2018).

The spatial variation of rainfall is depicted in Figure 28. The highest rainfall totals were around Mackay (BOM 2018).

More detail can be found for Cyclone Debbie in Section 4.5.4.



Four-day total rainfall totals between 28 -31 March. Locations indicated are: A (Ayr), M (Mackay), R (Rockhampton), Mi (Mitchell), G (Goondiwindi), B (Brisbane), L (Lismore), Y (Yamba).

Figure 28. Rainfall totals from 28 March to 31 March 2017 (BOM 2018)

4.6.1.2 2019 Monsoon Trough

The 2019 Monsoon Trough saw intense rainfall occur across the Townsville coastal plain and inland areas to Mt Isa. Further south, in the Reef Catchments NRM region, experienced intense rainfall with 800-1200mm over the 19-day period of the event. The spatial variation of rainfall is depicted in Figure 29. The highest rainfall totals were around Townsville as well as between Proserpine and Sarina (BOM 2019).

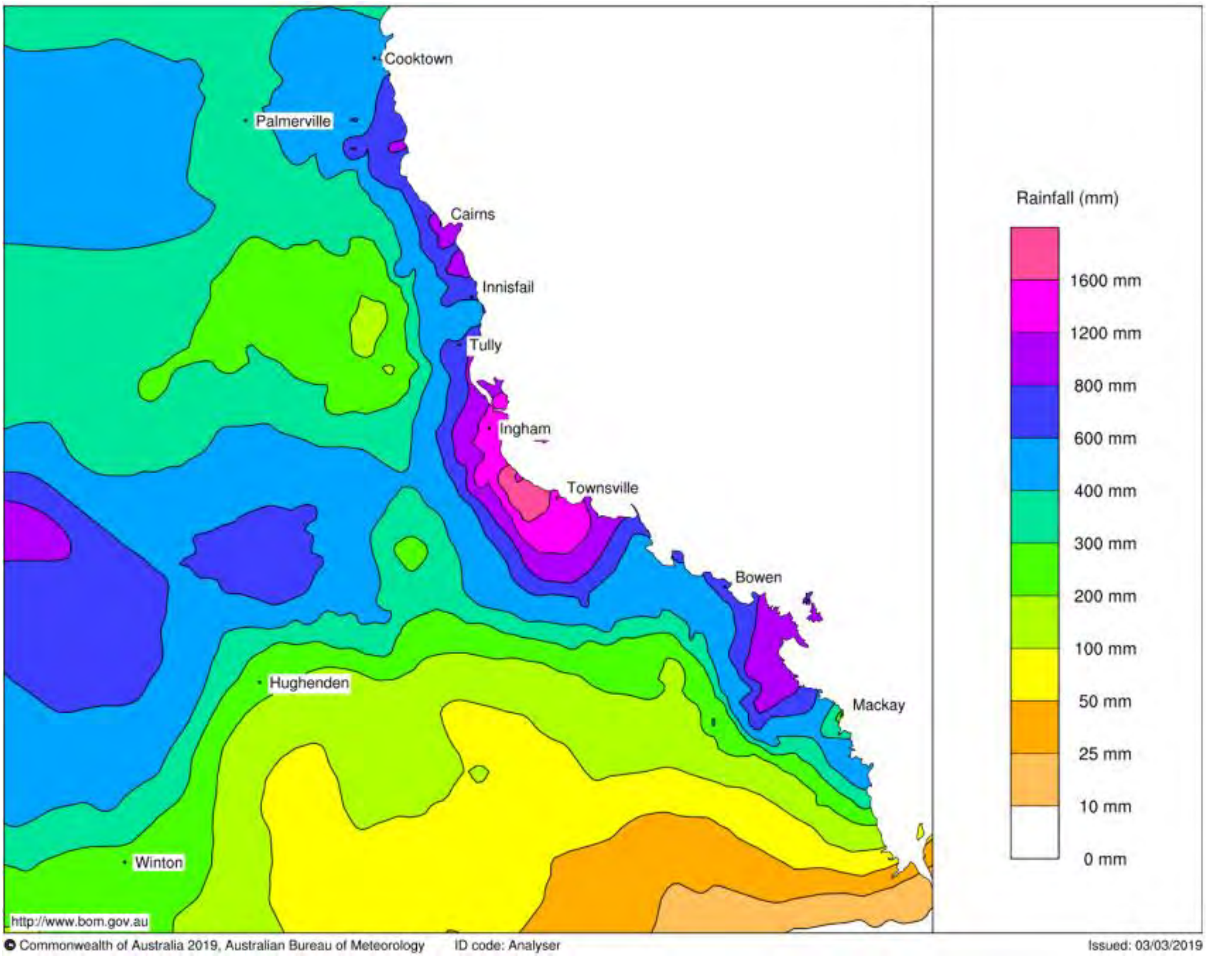


Figure 29. Rainfall totals from 26 January to 9 February 2019 (BOM 2019)

4.6.2 Individual Basins

4.6.2.1 Proserpine Basin

The only current stream monitoring gauges in operation are on the Gregory River at Lower Gregory (122004A) which commenced in 1972 and 2022 and the Proserpine River at the Bruce Highway (122006A) which has only operated since 2020.

Figure 30 shows the maximum daily discharge at Gregory River at Lower Gregory (122004A) overlaid with the Flood Frequency Analysis (FFA) curve available from the Bureau of Meteorology's Water Data Online (see Figure 31), the largest recorded floods and Average Recurrence Intervals (ARI) for Gregory River at Lower Gregory are:

- January 1991 at 634m3/s (above a 10-year ARI event)
- March 2017 at 586m3/s (equal to a 10-year ARI event)
- February 2002 at 529 (between a 5-year and 10-year ARI event)
- Floods just above a 5-year ARI event, comprising:
  - December 1975
  - March 1979
  - January 1993
  - February 2007
  - September 2010
  - April 2014

– January 2023.

The 2017 event was associated with Severe Tropical Cyclone Debbie and was the largest in recent history (using the Gregory River gauge as an indicator for the entire basin). With the exception of April 2014, which coincided with Cyclone Ita, the remaining flood events appear not to be associated with a tropical cyclone in the region. Even Cyclone Ului (2010) which caused relatively large amounts of destruction in the Proserpine and Whitsunday areas did not cause excessive flooding, with a peak discharge occurring between the 2-year and the 5-year ARI event in the Gregory River (Figure 30). The 2019 Tropical Monsoon event, which was associated with flooding across most of North Queensland, only resulted in a peak discharge between a 2-year and the 5-year ARI.

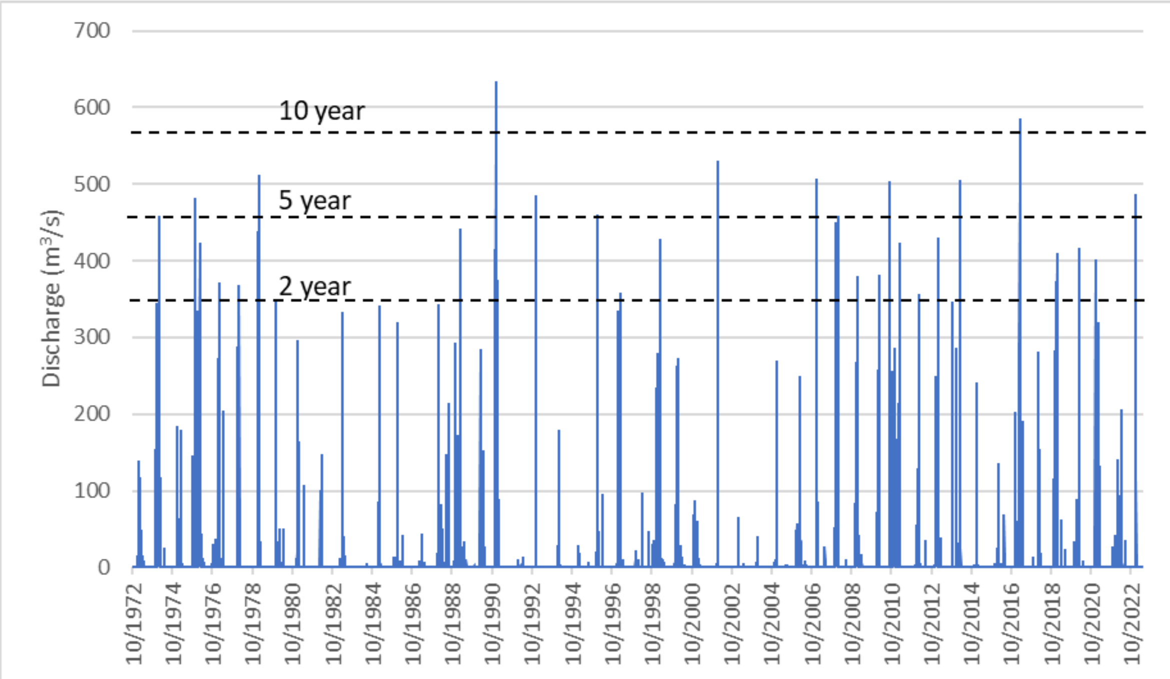


Figure 30. Discharge history for the Gregory River at Lower Gregory

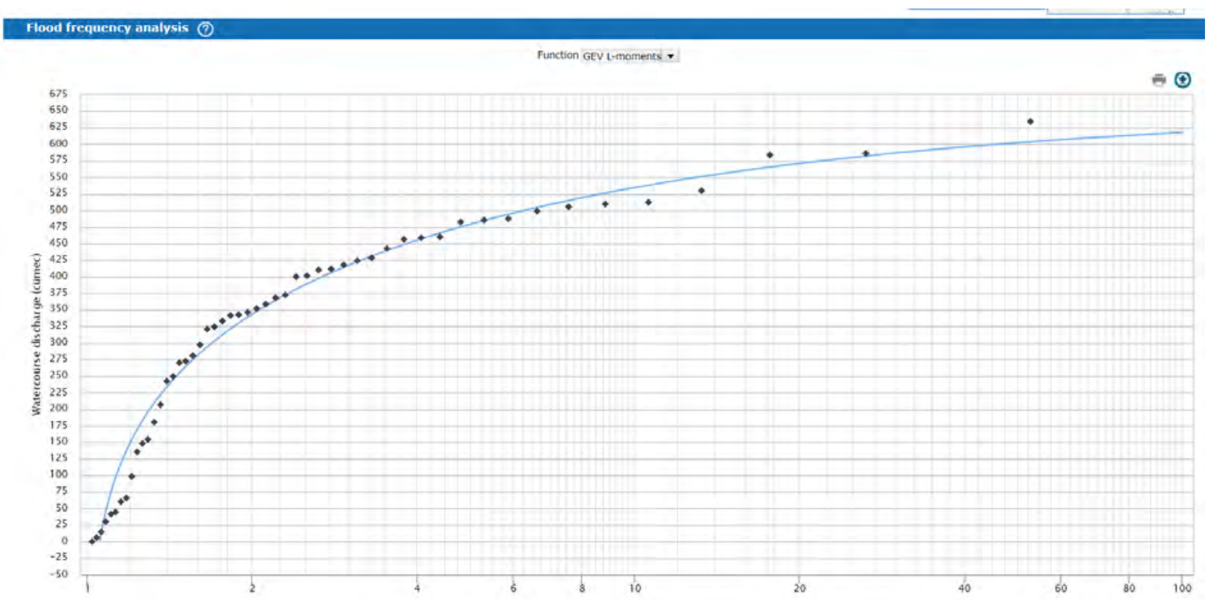


Figure 31. FFA for Gregory River at Lower Gregory from the Bureau of Meteorology

4.6.2.2 O'Connell Basin

The longest running and currently operational stream monitoring gauge in the basin is Andromache River at Jochheims (124003A) which has been operational since 1976. Another long-term stream flow gauge was located at O'Connell River at Caping Siding (124001A) but ceased operation in 2005.

Figure 32 shows the maximum daily discharge at Andromache River at Jochheims (124003A) overlaid with the Flood Frequency Analysis (FFA) curve available from the Bureau of Meteorology's Water Data Online (see Figure 33), the largest recorded floods and Average Recurrence Intervals (ARI) for Andromache River at Jochheims are:

- January 1980 at 2173m3/s (between a 50-year and 100-year ARI event)
- April 1989 at 1666m3/s (between a 10-year to 20-year ARI event)
- Flood just above a 5-year event, comprising:
    - March 1977
    - February 1979
    - March 1990
    - December 1990
    - February 2007
    - February 2008
    - March 2017

In January 1970, at O'Connell River at Caping Siding (124001A), a 3265m^3/s (10-year to 20-year event) was recorded.

If the Andromarche River gauge can be used as an indicator for the entire basin the January 1980 event, associated with Cyclone Paul, was the largest in recent history. However, data from O'Connell River at Caping Siding (124001A) suggests the event may only be within the 10 largest recorded events.

The flood events recorded in April 1989, and February in 2007 and 2008, appear not to be associated with a tropical cyclone in the region. The 2019 Tropical Monsoon event, which was associated with flooding across most of North Queensland, only resulted in a peak discharge around the 2-year ARI.

An assessment by Alluvium Consulting (2017) indicates that St Helen's Creek received an approximately 1 in 30-year ARI event during Severe Tropical Cyclone Debbie however, other stream systems within the basin recorded flows approximately equal to the 5– to 10-year ARI.

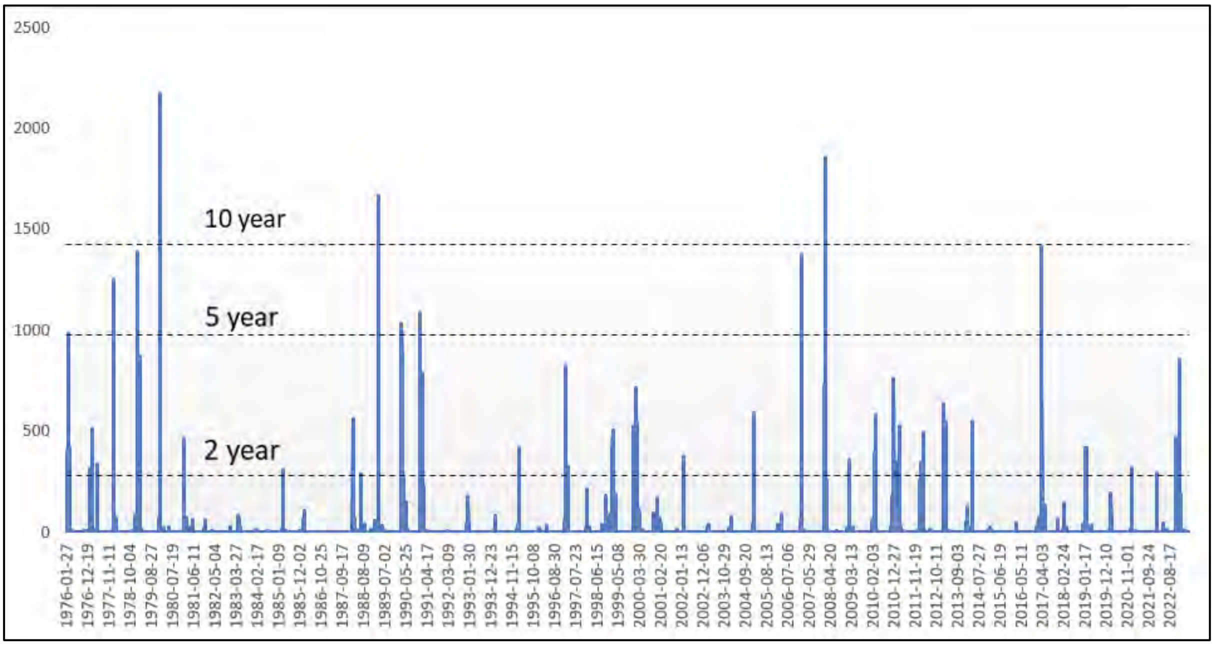


Figure 32. Discharge history for Andromache River at Jochheims

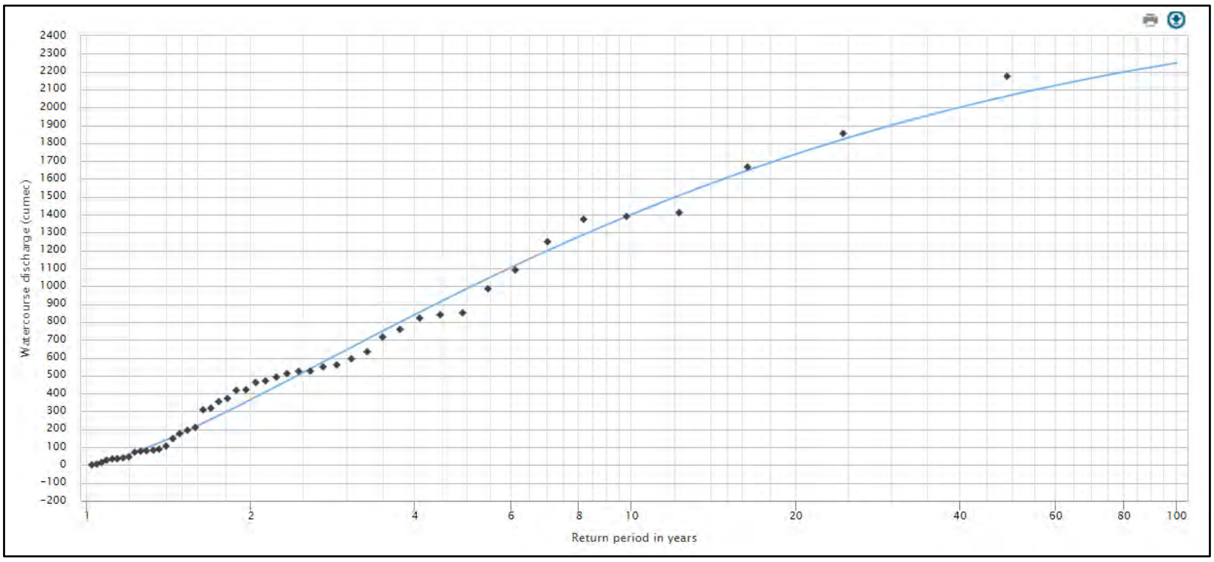


Figure 33. FFA for Andromache River at Jochheims from the Bureau of Meteorology

4.6.2.3 Pioneer Basin

Table 8, lists peak flood levels at multiple flow gauges within the Pioneer River catchment. The table also indicates that the largest event recorded at the Dumbleton Rocks gauge (Pioneer River at Dumbleton Weir Tailwater(125016A)), which is near the outlet of the Pioneer River and commenced recording in 2005, was during Severe Tropical Cyclone Debbie in March 2017.

Flood studies for the region indicate that this flood was between a 5% AEP and 2% AEP event at Mackay, and a 2% AEP and 1% AEP event further up the catchment at Finch Hatton (WRM 2021).

The nearby gauge at Pioneer River at Pleystowe Mill (125001A, operational from 1916 to 1978) recorded larger events in 1958 and 1918. The 1958 event caused a 9.14m flood height at the Mackay Flood Warning Gauge at Forgan Bridge (BOM 2021).

Black's Creek in the upper Pioneer Basin experienced a 1% AEP flow event during Severe Tropical Cyclone Debbie (March 2017) (Alluvium 2017).

Table 8. Peak flood heights from the 2019 event in the Pioneer Basin (sourced from (BOM 2019)).

Station name	Height of Peak (m)	Date and Time of Recorded Peak	Flood Classification (m)			Flood class reached	Rank	Years of Record	Highest on record	
			Minor	Mod	Major				Ht (m)	Date
Pioneer River										
Dumbleton Rocks[1]	17.53	06/02/2019 10:00 PM	17.3	20	21	Minor	29	31	21.20	Mar 2017
Finch Hatton[2]	4.01	30/01/2019 4:13 AM	3	4	5	Moderate	=27	49	6.5	1989
Gargett[1]	5.68	30/01/2019 06:00 AM	5.5	8	9	Minor	59	51	10.7	Apr 1989
Hospital Bridge AL	6.95	20/02/2019 12:50 PM	7	10.5	11.5	Below Minor	21	101	11.84	Jan 1918 & Jan 1970
Mirani Weir TW[1]	7.61	06/02/2019 8:15 PM	7	9	10	Minor	46	41	15.52	Apr 1989
Mirani	No data provided		6	8	9	N/A	-	135	16.46	Feb 1958
Sarich's[1]	7.43	29/01/2019 10:00 PM	6.5	8	9.5	Minor	66	61	14.78	Jan 1970
Whiteford's[1]	5.05	29/01/2019 8:50 PM	5	6.5	7.5	Minor	55	46	11.25	Mar 1988

During the 2019 Monsoon Trough the Pioneer catchment experienced several periods of heavy rainfall in the upper sections. The Ridgelands gauge recorded the highest daily total of 274mm on 29-30 January. However, the Eungella alert station recorded the highest rainfall totals over the whole event within the Pioneer Catchment receiving 1277mm. Although the Eungella alert station recorded the highest rainfall totals across the event, the total intensity did not exceed the 10-year ARI for any duration. In fact, daily and weekly rainfall totals over the catchment were not significant compared to other historical flood events (BOM 2019). Flood levels from the 2019 Monsoon Trough event did not exceed the 'minor' flood level except at Finch Hatton, which recorded a 'moderate' flood level.

The catchment averaged daily total rainfall for the 2019 event ranked 199th at 98.59mm compared to other daily rainfall totals, with the highest catchment daily rainfall averaged event being the 1958 event at 415mm. Likewise, the weekly catchment averaged rainfall total ranked 628th at 256mm with the highest weekly catchment averaged rainfall of 1169mm from the 1991 event (BOM 2019).

Figure 34 shows the maximum daily discharge at Pioneer River at Dumbelton Weir Tailwater (125016A) overlaid with the Flood Frequency Analysis (FFA) curve available from the Bureau of Meteorology's Water Data Online (see Figure 35).

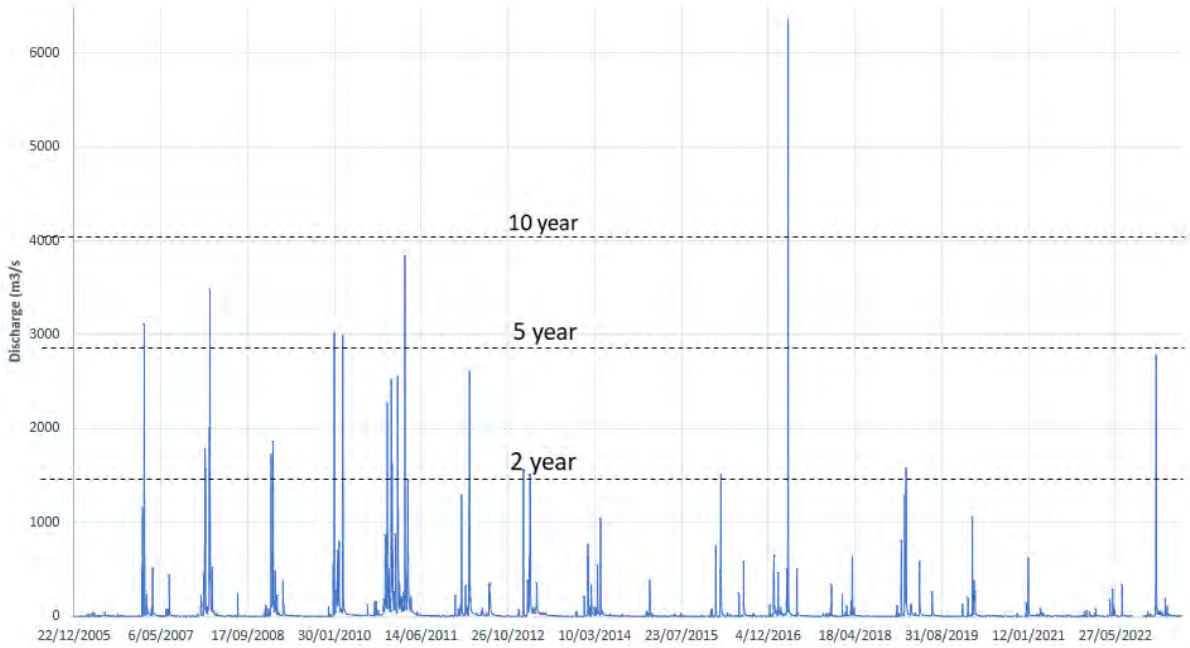


Figure 34. Discharge history for Pioneer River at Dumbelton Weir Tailwater

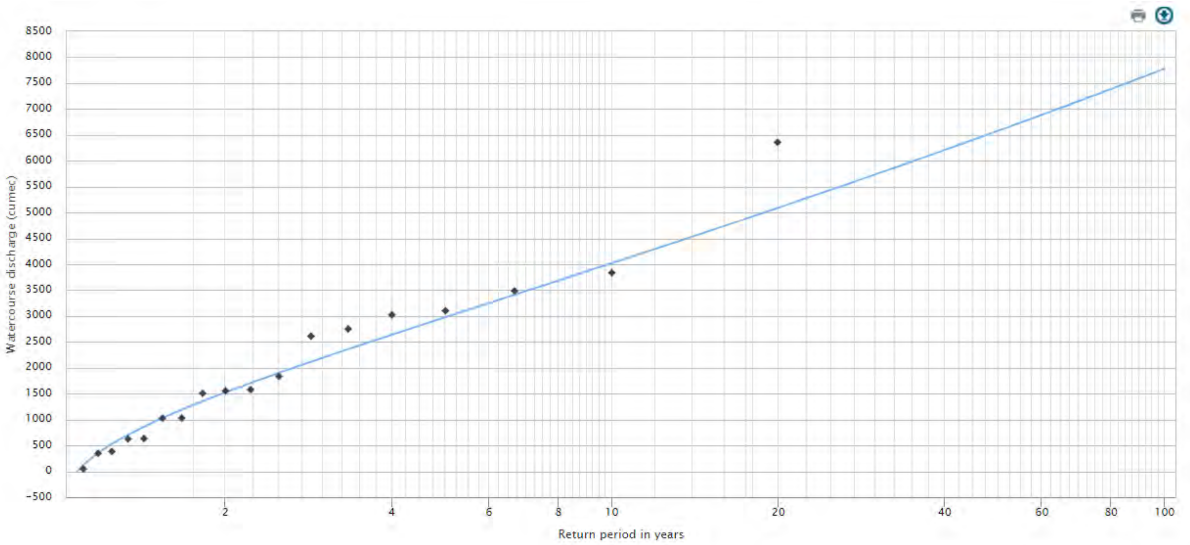


Figure 35. FFA for Pioneer River at Dumbelton Weir Tailwater from the Bureau of Meteorology

Figure 36 shows the maximum daily discharge at Flinch Hatton Creek at Gorge Road (125006A) overlaid with the Flood Frequency Analysis (FFA) curve available from the Bureau of Meteorology's Water Data Online (see Figure 37).

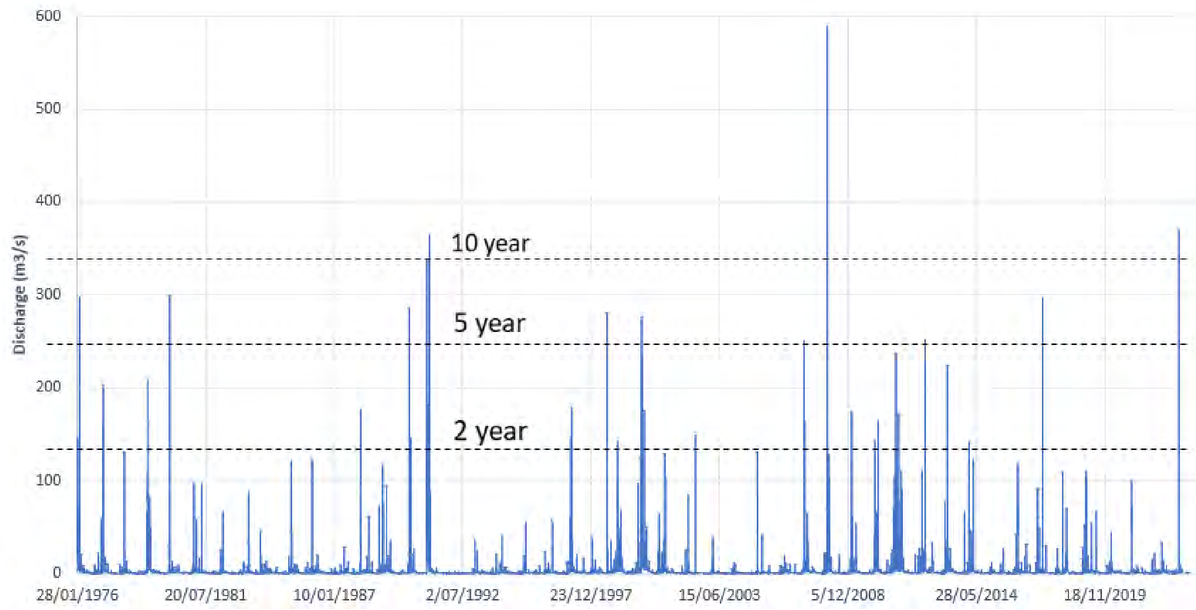


Figure 36. Discharge history for Flinch Hatton Creek at Gorge Road

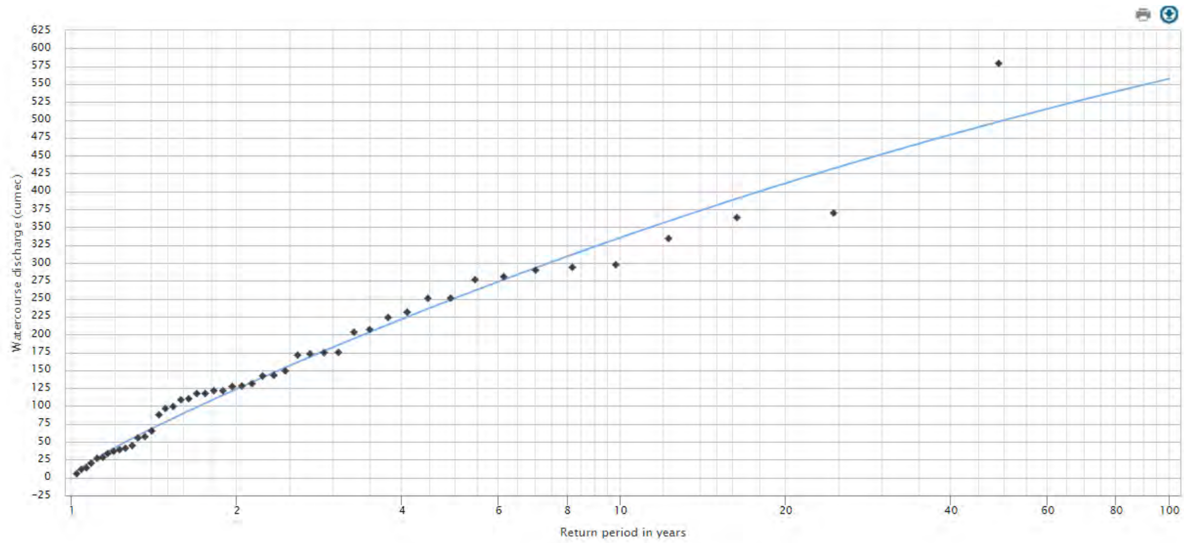


Figure 37. FFA for Flinch Hatton Creek at Gorge Road from the Bureau of Meteorology

4.6.2.4 Plane Basin

An approximate 1 in 75-year flood event occurred in Carmilla Creek from Severe Tropical Cyclone Debbie, peaking at around 1079m^3/s on 28 March 2017. Sandy Creek received an approximate 30-year event, however, the duration of the event was extended with approximately 2 and a half days of flow above the 1 year flood (Alluvium 2017).

Here is the summary of flood history based on the maximum daily discharge (Figure 38) and flood frequency analysis data (Figure 39) obtained from the gauge station at Carmila Creek at Carmila station number 126003A from the Bureau of Meteorology:

- March 1988 at 1303m3/s (100-year ARI event)
- March 2017 at 1079m3/s (50-year ARI event)
- January 2010 at 902m3/s (20 to 50-year ARI event)
- January 1993 at 697m3/s (10-year ARI event)

- Flood just above a 5-year event, comprising:
  - February 1989
  - January 1991
  - February 2001
  - February 2008
  - March 2011
  - March 2012
  - January 2013.

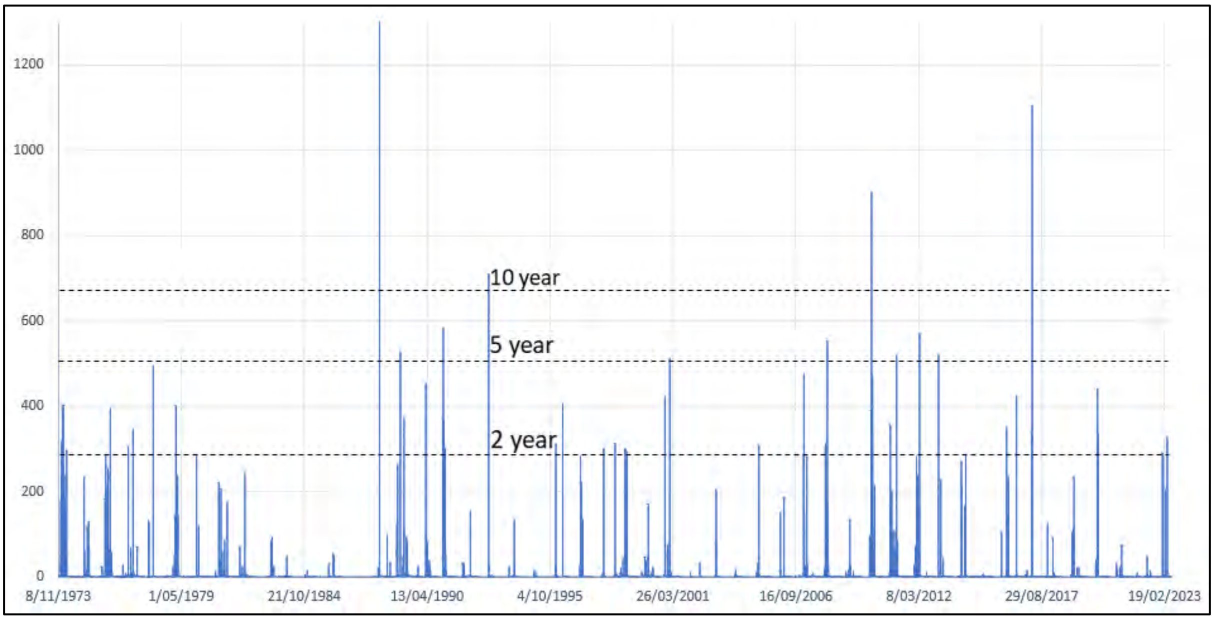


Figure 38. Discharge history for Carmila Creek at Carmila

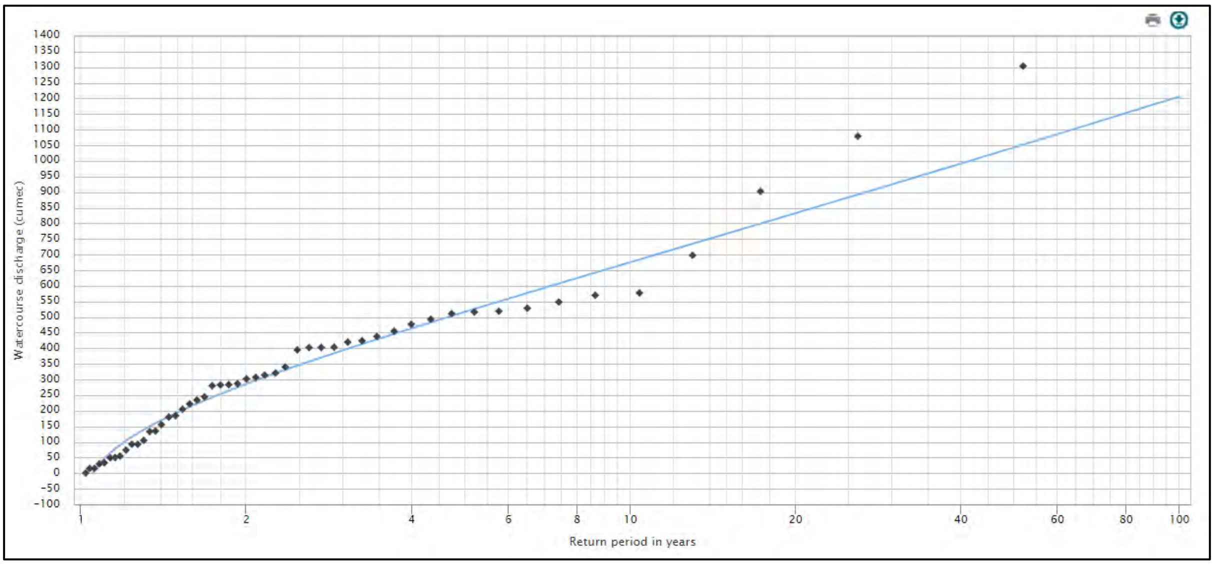


Figure 39. FFA for Carmila Creek at Carmila from Bureau of Meteorology

4.7 Cultural Heritage

Reef Catchment's works closely with the Mackay Whitsunday Isaac Traditional Owner Reference Group. Traditional Owner heritage values are part of the spiritual connection and story of the Indigenous peoples and include customs, lore and places. Values are attributed to tangible and non-tangible assets and include:

- sacred sites, sites of particular significance and places important for cultural tradition, tools and archaeology;
- stories, song-lines, totems and languages; and
- cultural practices, observances, customs and lore.

The Department of Aboriginal and Torres Strait Islander Partnerships (DATSIP) is responsible for administering a cultural heritage database and cultural heritage register which have been established under Part 5 of the Aboriginal Cultural Heritage Act 2003 and the Torres Strait Islander Cultural Heritage Act 2003. There are a substantial number of Aboriginal sites scattered throughout the Mackay Whitsunday region with site types including:

- artefact scatters;
- burials;
- ceremonial sites;
- contact sites;
- engravings;
- hearths;
- paintings;
- quarries;
- rock shelters;
- scarred trees;
- shell middens;
- stone arrangements;
- weirs; and
- fish traps.

Given the density of sites, it suggests that the coast was frequently used by Aboriginal people and was a focus for activity within the late Holocene period.

Fieldwork conducted by Terra Rosa for Reef Catchments unveiled a notable level of inaccuracy in the previously recorded sites within the Mackay Whitsunday region on the DATSIP register. The study also found that the existing record is incomplete. Although some sites can still be identified at their registered locations, the heritage team observed discrepancies where sites were not located in the areas as recorded on the DATSIP register.

In stark contrast, non-indigenous values and perceptions are varied and can change rapidly, they may include buildings, industrial sites, and more. That said, characteristics of a healthy and resilient system include the promotion of community benefit through an invested and informed community, preservation of heritage both indigenous and non- indigenous, effective coordination and management of activities through good governance and the provision of economic benefits by safeguarding the universal value of the Great Barrier Reef.

5 Proserpine Basin

The Proserpine Basin covers approximately 250,000 hectares and is comprised of the following catchments[5] and major waterways (see Figure 40):

- Eden Lassie Creek
- Gregory River
- Upper Proserpine River (above Peter Faust Dam)
- Lower Proserpine River (below Peter Faust Dam)
- Myrtle Creek
- Repulse Creek
- Lethe Brook
- Thompson Creek
- The Whitsunday Coastal Creeks.

All rivers within the basin flow into Edgecumbe Bay, the Whitsunday Coast and Repulse Bay (Department of Environment and Science 2021). The Proserpine River and Eden Lassie Creek begin westward of the range that runs north-west to south-east and consists of Mt Challenger, Mt Pluto and Mt Quandong which make up the Proserpine State Forest. Lake Proserpine is captured westward of this range.

5.1 Riverine Environmental Values

Conway National Park, Proserpine State Forest and Dryander Forest Reserve are all protected areas and the Andromache Conservation Park was gazetted in July 2016.

The catchment also contains two wetlands listed in the Directory of Important Wetlands of Australia (DIWA):

- Edgecumbe Bay, in the north; and
- Goorganga Plains, in the south-east.

Drainage lines coming from the Proserpine State Forest and Mount Quandong area are mapped as Matters of state environmental significance (MSES) high ecological value watercourses. These areas also correspond to waterways with a High Ecological Value (HEV) management intent as defined under the Environmental Protection Policy (EPP) (Water and Wetland Biodiversity) 2019 (see Figure 40). The HEV management intent is a stringent measure aiming to ensure that these waters maintain their non-disturbed 20th, 50th and 80th percentile water quality indicator levels as calculated in non-disturbed areas. Most of the remaining catchment is mapped as a Moderately Disturbed (MD) management intent outside of national parks, allowing for water quality to be maintained to less stringent criteria.

The Goorganga wetlands are 19km in length and have a maximum width of 12km, creating an area of 16,850ha in area (Hardy 2004) (Reef Catchments 2014). They are mapped as "Wetland Environmental Values" on Figure 40 and occupy the mouths of the Thompson Creek and Proserpine River catchments. The wetlands are listed on the DIWA. Floodwater detention by the wetlands adsorbs nutrients and sediments transported from upstream (Reef Catchments 2014).

Ten Mile Creek, Gregory River, Proserpine River, Lethe Brook, Goorganga Creek, Andromache River and Boundary Creek all comprise state significant biodiversity corridors (Figure 40).

---

[5] Subcatchments are those outlined in the EPP (Water and Wetland Biodiversity) 2019

In 2017, Alluvium Consulting completed the Stream Type assessment of Mackay Whitsunday. This study analysed all major stream systems of the Mackay Whitsunday region using a method similar to RiverStyles and determined the condition of Riparian Vegetation, Stream Stability and Stream Type.

Most of the Proserpine Basin was assessed as having streams with 'stable' or 'minor instabilities' (Figure 42) and 'good' to 'moderate' riparian vegetation for all major streams except the Pioneer River (Figure 43). The majority of streams were assessed as confined by terraces or bedrock with very little assessed as unconfined (Figure 44). Further reference is made to this study and the stream types, riparian condition and stability in the following sections.

5.2 Land Use History

The Proserpine Basin includes urban centres at Airlie Beach, Cannonvale and Proserpine, and a number of smaller regional towns. Major land uses within the catchment include (see Figure 41):

- Grazing (45%)
- Conservation and Natural Environments (29%)
- Sugarcane (10%)
- Water (7%).

The Peter Faust Dam, commissioned in the 1990's, sits in the west of the catchment in the upper reaches of the Proserpine River and is the primary water source in the catchment, providing drinking water to Proserpine and the Whitsundays (Department of Environment and Science 2021). The installation of the dam has significantly reduced the effects of flooding in the lower reaches of the Proserpine River Basin.

Agricultural land around the Proserpine area serves as some of the best agricultural land in the region (Reef Catchments 2014). However, the Lethe Brook subcatchment has had the most land clearing (since 1988) as mapped by the SLATS program.

The total area of mapped riparian vegetation as assessed by the Reef Report Cards was approximately:

- 320ha for the 2001-2005 report card
- 240ha in the 2005-2009 report card
- 140ha in the 2009-2013 report card
- 460ha in the 2013-2017 report card.

The Proserpine Basin scored an "E" rating in the 2020 Reef Water Quality report card for Riparian Extent.

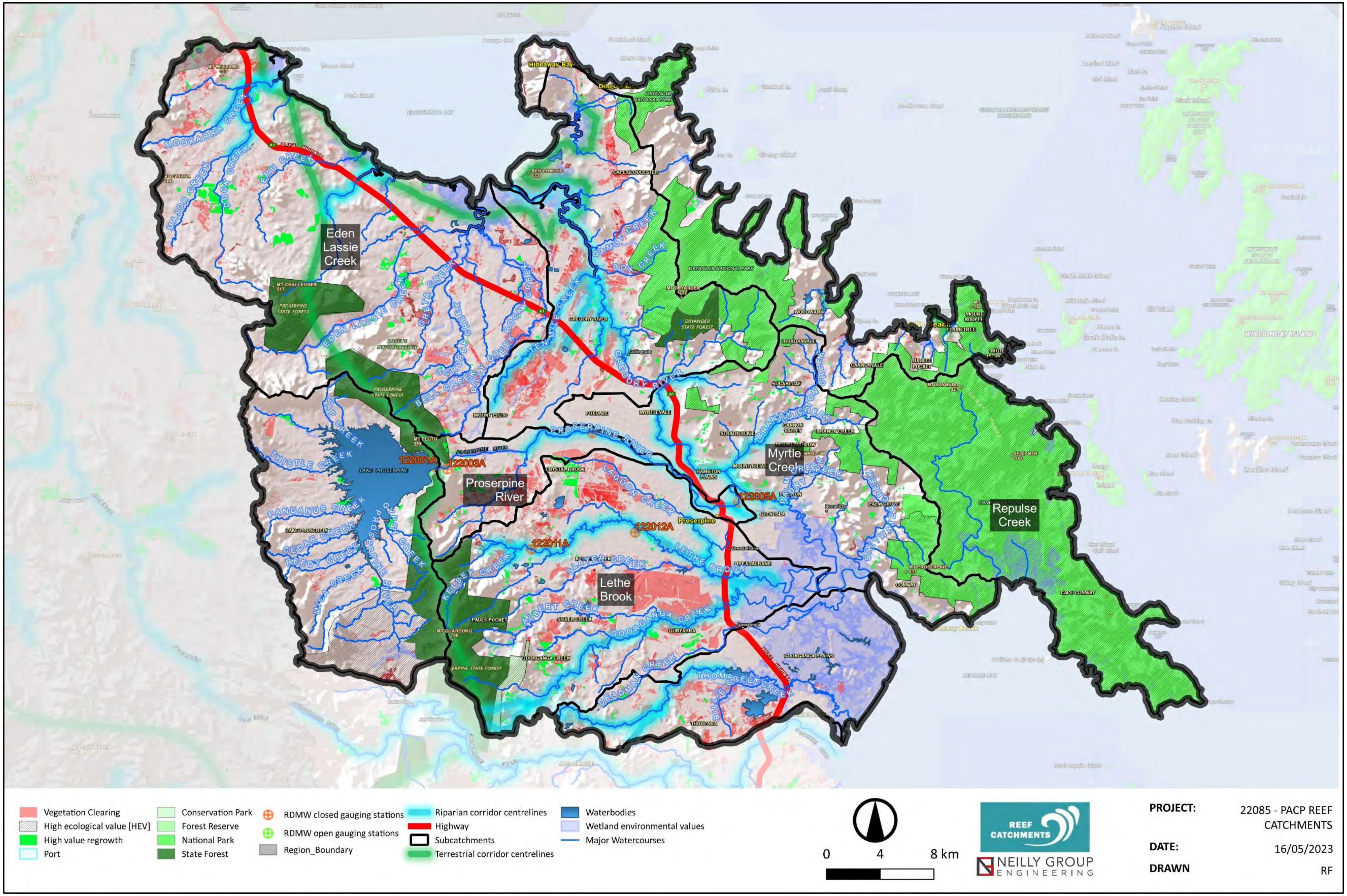


Figure 40. Overview of the Proserpine Basin

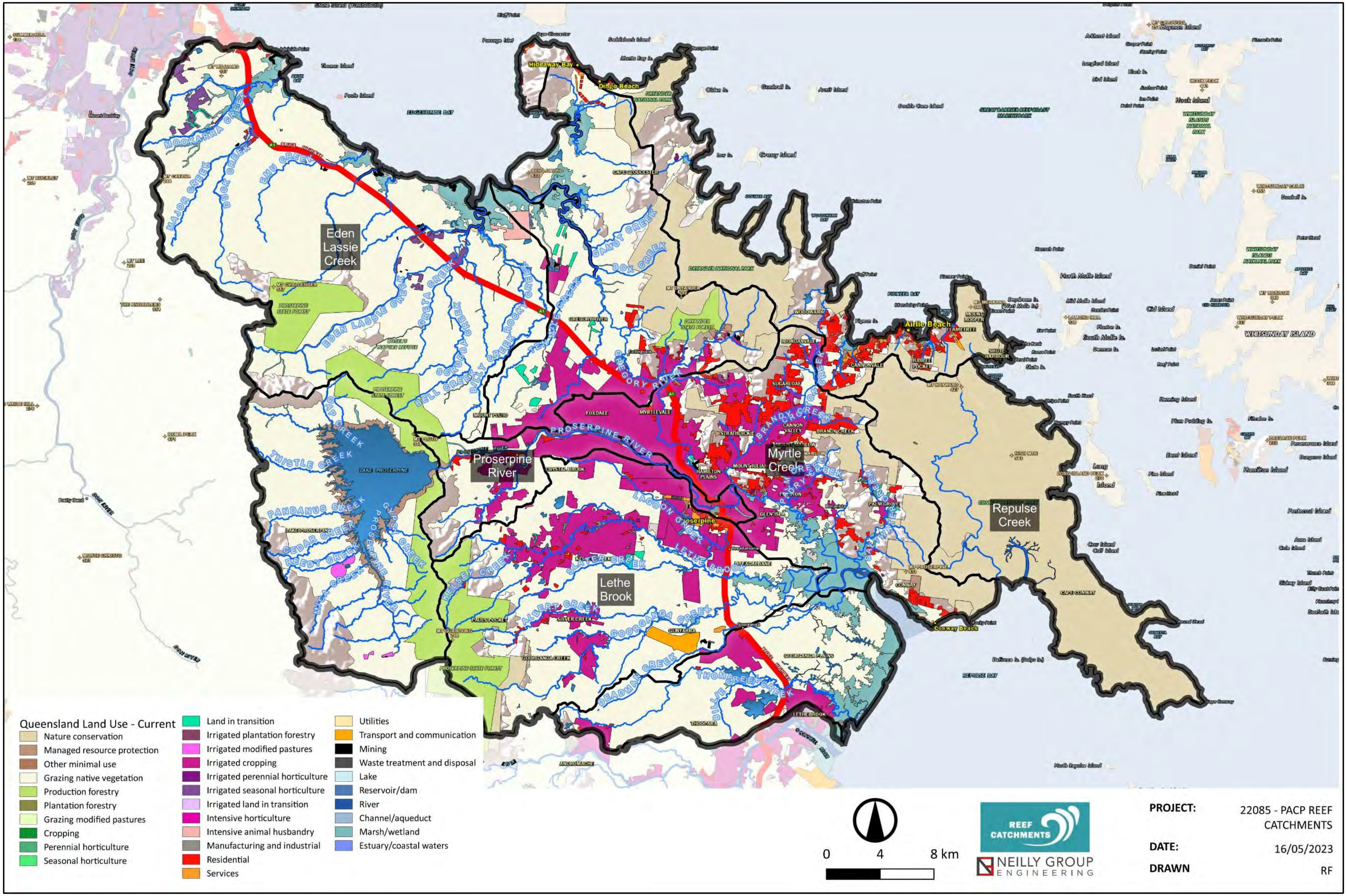


Figure 41. Land Use in the Proserpine Basin

Figure 42. Channel Stability assessment compared to adopted, shortlisted and final sites found from this study

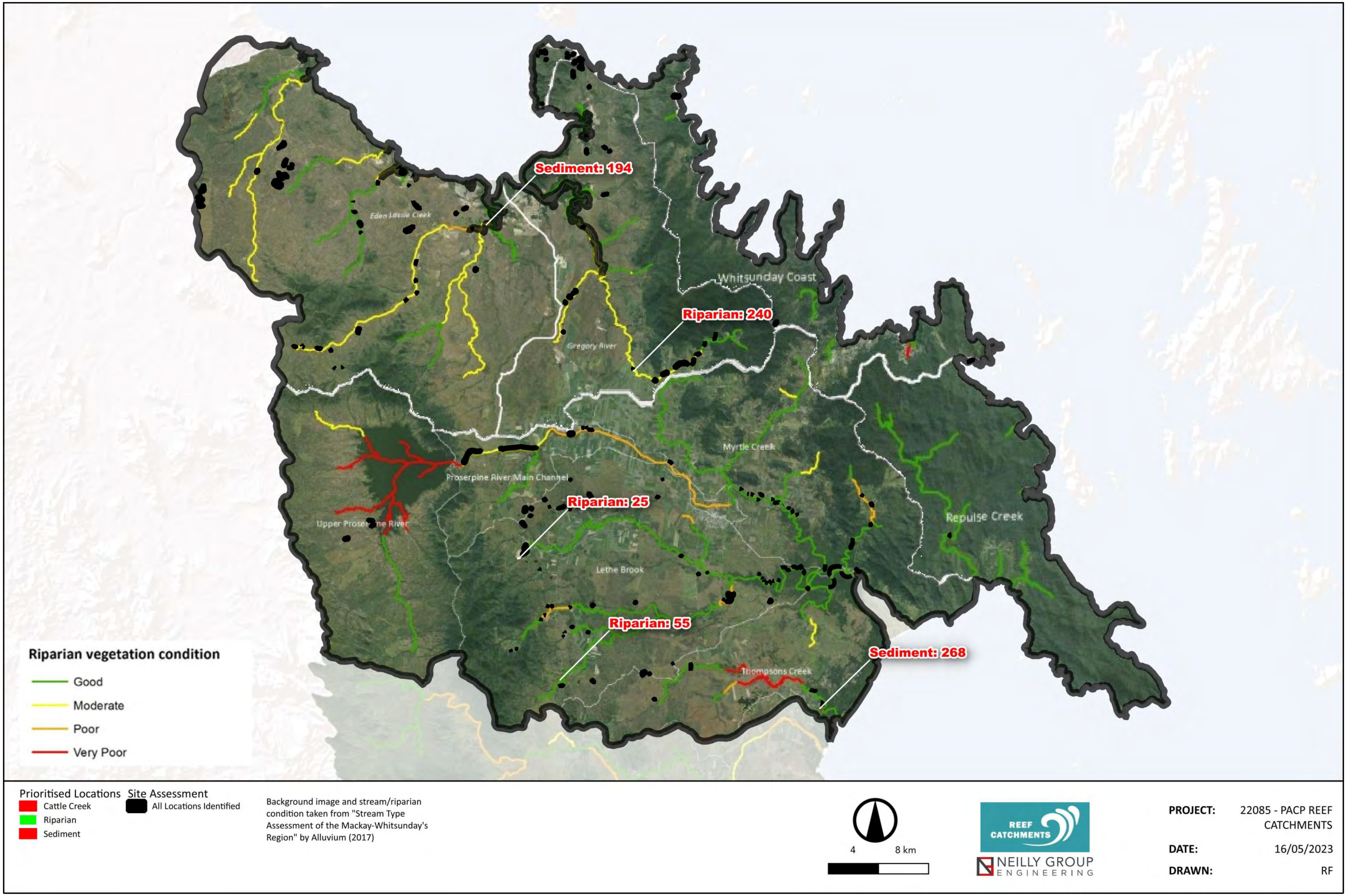


Figure 43. Riparian condition assessment compared to all sites, shortlisted and final adopted sites from this study

Figure 44. Stream type compared to all identified locations, shortlisted and final adopted locations from this study

5.3 Climate

The Proserpine Basin has a decreasing rainfall gradient from east to west mainly due to the north-facing coastline and the high relief areas of Repulse Creek, Myrtle Creek and Gregory River catchments (Figure 45). Rainfall datasets were obtained from the SILO database which shows estimated rainfall between all available rainfall stations on a 5km by 5km grid across the country. Monthly rainfall grids were obtained from 1890 to 2022 and converted to yearly grids and resultant climate metrics derived.

The SILO rainfall shows that the average yearly rainfall in the east of the catchment is >1900mm per year but this decreases to 900-1100mm per year in the western part of the basin, closest to the boundary of the Don River. Likewise, the maximum rainfall experienced in any individual year decreases from >4000mm to approximately 2000mm over the same gradient. The smallest year of recorded rainfall experienced in the Repulse Creek Catchment was 600-700mm compared to the 200-300mm in the west of the Eden Lassie Creek catchment. This plays an important role in the geomorphology of the basin, with the Gregory River having more persistent flows than Eden Lassie Creek for example, because its headwaters are situated in upland areas with more persistent rainfall.

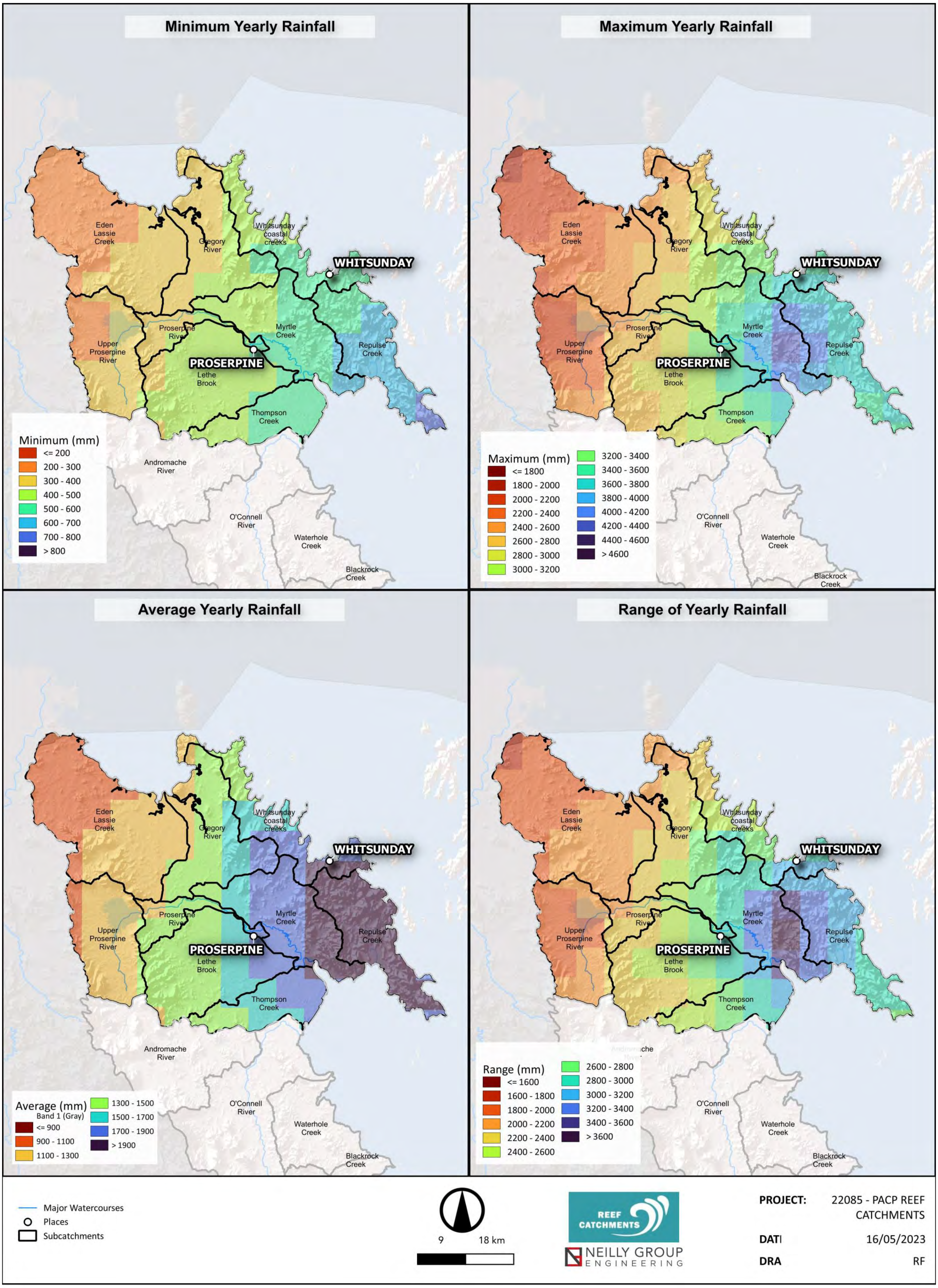


Figure 45. Climate of the Proserpine Basin based on gridded SILO data

5.4 River Geomorphology

An overview of geomorphic conditions of the major subcatchments throughout the Pioneer Basin are provided below.

5.4.1 Proserpine River

The construction of the Peter Faust Dam has led to a reduction in the available energy within the main channel downstream. This has resulted in a highly vegetated channel, potentially exacerbating bank overtopping (Department of Environment and Science 2021). As there is less energy available in the river system for sediment transportation, several waterholes have infilled with sand (Department of Environment and Science 2021).

The analysis of historical aerial photographs in this study corroborates the aforementioned findings, highlighting a growing indication of inadequate energy to effectively transport the sediment load within the river system. Over time, the main channel has witnessed the gradual establishment of vegetation due to the absence of flood events with the necessary energy to dislodge the larger vegetation that has established itself within the channel (Figure 46). Therefore, it is expected that there will be less locations of bank erosion along the main channel of the Proserpine River. Any erosion which is occurring is likely to be a response to vegetation colonisation within the main flow path diverting localised, low flows, into previously stable banks.

The installation of the Peter Faust Dam has also disconnected the main channel of the Proserpine River from its floodplain. Several signs are evident of floodplain flows in the 1970s aerial photograph which are not present in the 2018 aerial photograph (Figure 46).

The lower reaches of the Proserpine River are relatively sinuous and meandering with a large degree of channel migration since the 1970s (Figure 47). Unlike the lower reaches of other major river systems in the Basin, there is sugarcane production in the lower estuarine sections with sugarcane paddocks cleared to the top of bank in some instances. Most other major streams in the area have grazing lands within the lower confines of the river systems. The high channel mobility of the lower Proserpine River is evidenced by several meander cutoffs visible in the aerial imagery (Figure 47).

SECAT sediment assessments were undertaken for several locations identified to have experienced significant bank movement since 2017 (Figure 47). Several of these areas represent riverbank movement into productive lands (mostly sugarcane production).

5.4.1.1 Myrtle Creek

The Myrtle Creek subcatchment consists of the area between Proserpine and Cannonvale and includes areas of the Proserpine Main Channel. During high flow events the entire area is considered part of the Proserpine River floodplain.

Figure 46. Aerial photograph showing changes in the Proserpine River since 1970s

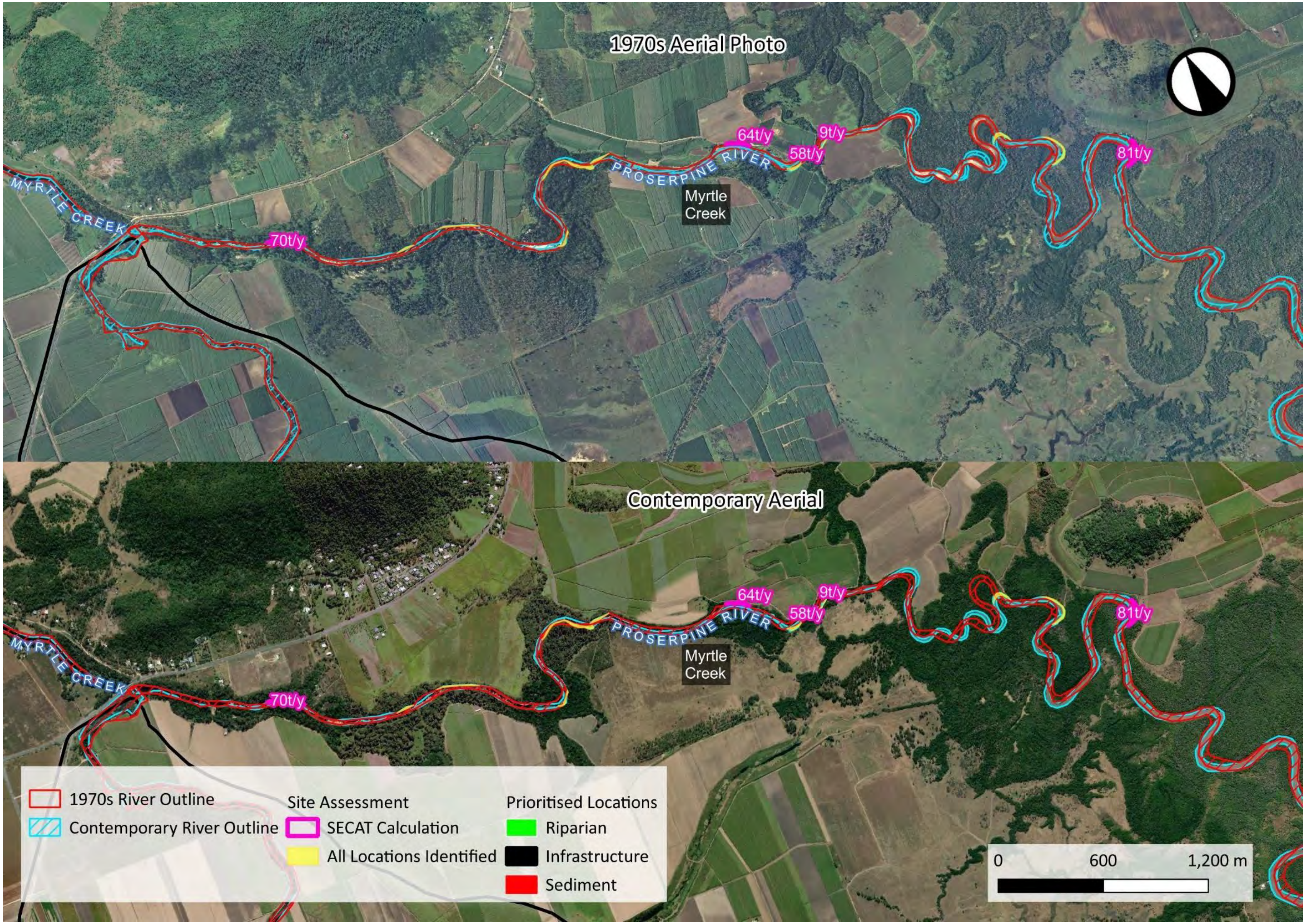


Figure 47. Aerial photograph showing changes in the Lower Proserpine River since the 1970s

5.4.2 Eden Lassie Creek

Water is lost much faster in Eden Lassie Creek than in the adjoining Hays and Duck Creeks (Department of Environment and Science 2021). The headwaters of Eden Lassie Creek are located in conservation areas and wetlands occur at the mouth; however, the mid-catchment of Eden Lassie Creek has been cleared for agriculture.

Most flow paths within the Eden Lassie Creek system are wholly or partially confined by bedrock, meaning that there is little room for long-term lateral shifting of the river system (Alluvium 2017). This observation is confirmed by comparison of 1970 to 2010's aerial imagery undertaken as part of this study. Overall, the longitudinal gradient of Eden Lassie Creek is much flatter than other streams within the study area. Combined with the lower rainfall and areas of whole/partial bedrock confinement, there is less opportunity for significant river migration.

Lower in the catchment the river system is not confined by bedrock and is relatively free to meander across the broad floodplain and consequently the river system is relatively sinuous. However, the majority of sinuosity and river channel change is restricted to areas of heavy mangroves or tidal vegetation (Figure 48). Locations of bank erosion were identified within the estuarine reaches where the river changes from a relatively straight channel to a meandering planform associated with the tidal influence and reduced gradient. However, the rates of river meander migration are sufficiently low that the resulting rates of fine sediment erosion to the Great Barrier Reef are also low. One area of recent bank erosion (since 2017) was prioritised for remediation Concept Design (Site 194) because of the volume of fine sediment released into the waterway (Figure 48).

Yeates Creek and Kangaroo Creek are also other significant drainage lines within the Eden Lassie Creek subcatchment. Yeates Creek drains the northern faces of Mt Challenger. The main channel is relatively active, having moved at least one channel width in many areas between 1970 and at present (Figure 49). Scalding is evident along drainage lines that enter Duck Creek. These have been persistent since at least 2016 (Figure 50). It is unknown how much fine sediment will be generated from these areas and delivered to the Great Barrier Reef.

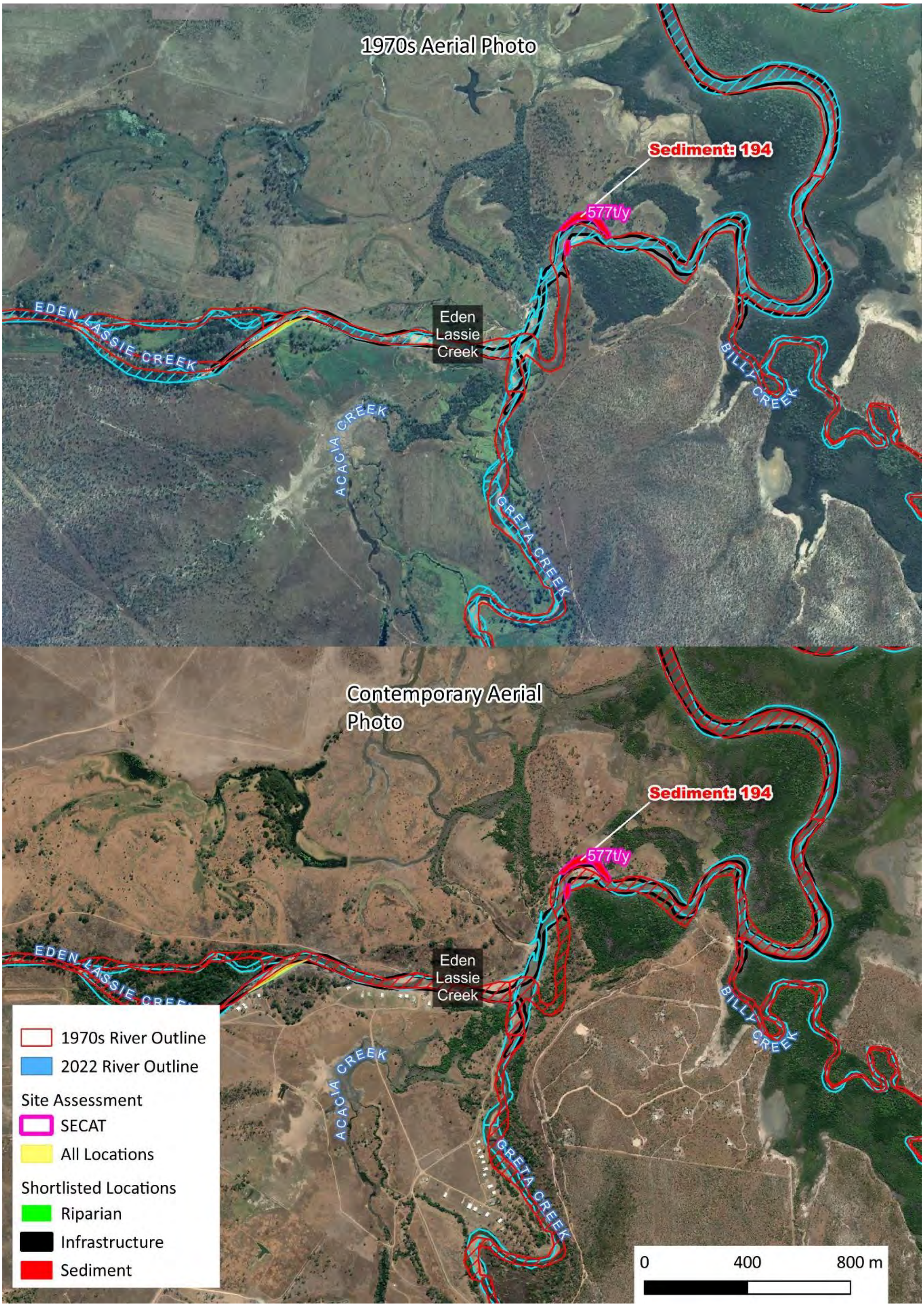


Figure 48. Example of increasing sinuosity and channel change at the downstream tidal areas of Eden Lassie Creek. The position of the 1970s channel is provided in red and the position of the 2020 channel is provided in blue.

Figure 49. Channel outlines of Yeates Creek between 1970 (red) and 2018 (blue)

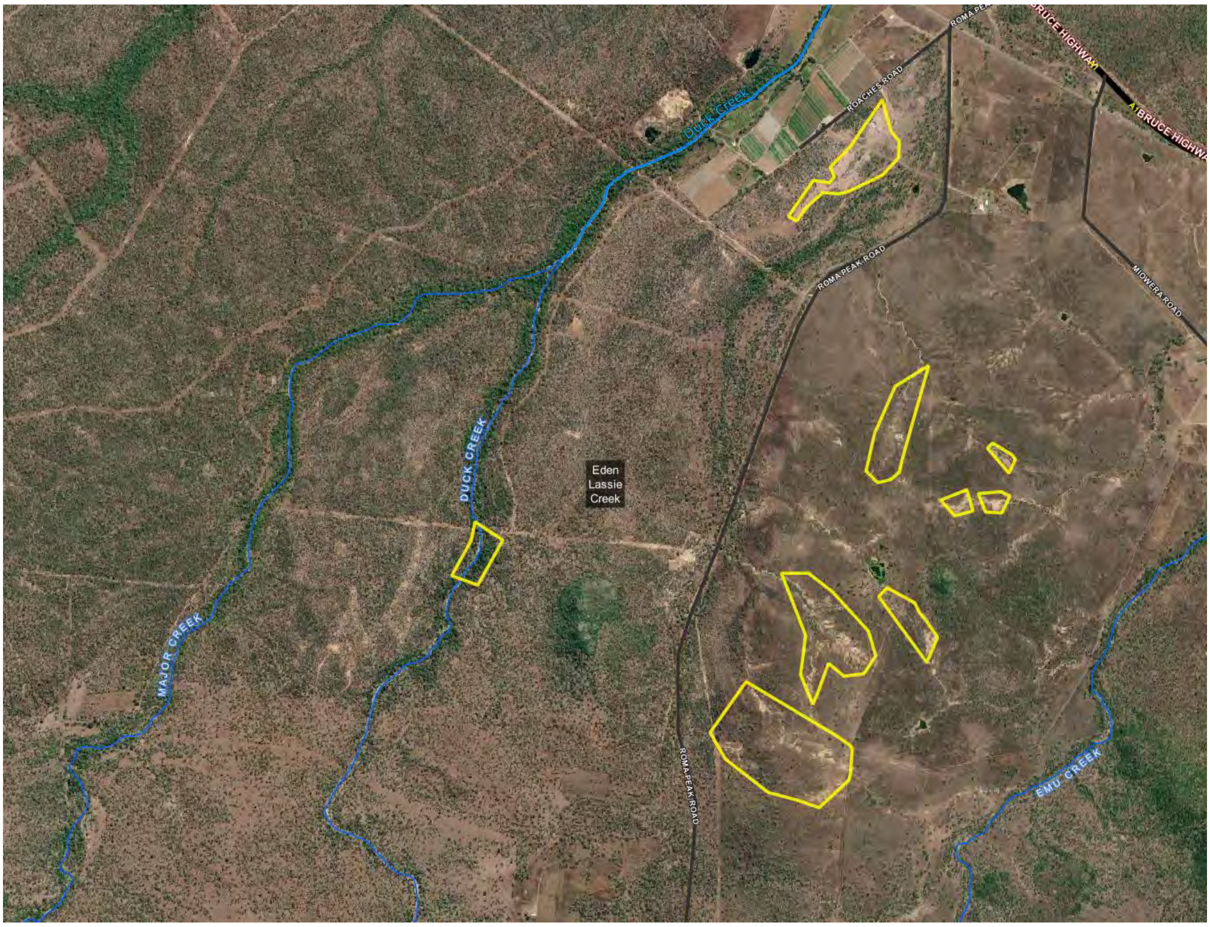


Figure 50. Scalding evident along drainage lines that enter Duck Creek

5.4.3 Gregory River

The headwaters of the Gregory River are located in the Dryander state forest at 650m above sea level and receive much more rainfall than the surrounding lower elevated areas (Figure 45). This ensures that flows persist in the Gregory River for a relatively long duration compared to other systems. Riparian vegetation along the Gregory River plays an important role as a corridor for fruit bats, micro bats and other fauna (Department of Environment and Science 2021).

The headwaters of the Gregory River are steep and confined by bedrock, with outcrops evident within the river channel (Alluvium 2017). The morphology of the river system shifts to an extensive floodplain at the base of the hillslopes. Despite the extensive floodplain, the river system is confined by shallow bedrock associated with the low hills surrounding the valley (Alluvium 2017).

Severe Tropical Cyclone Debbie resulted in several channel changes in the system (Alluvium Consulting 2017b), including:

- Approximately 2,300m3 of sediment loss from the left bank and right banks around the Rosetti Road crossing; and
- Cobble deposition in several areas.

The estuary of the Gregory River is comprised of a highly meandering wide channel which has remained in-place since the 1970s.

There are several small incising headcuts and small channel changes found within Miranda Creek, a predominantly estuarine flow path within the Gregory River subcatchment (Figure 51).

A number of locations along the Gregory River have already been remediated by Reef Catchments.

Figure 51. Small locations of erosion and channel change evident in Miranda Creek

5.4.4 Whitsunday Coastal Creeks

The Whitsunday Coastal Creeks subcatchment includes the coast from Cape Gloucester to Shute Harbour and the population centres of Dingo Beach, Airlie Beach and Cannonvale. Approximately 15 features were identified within this area, most of which are minor erosion or landslides. Therefore, no SECAT analysis was undertaken.

5.4.5 Lethe Brook and Thompson Creek

The Goorganga plains area comprises Lethe Brook and Thompson Creek and is a combination of estuarine and alluvial deposits. The low gradient, as well as several paleo-channels, ensures that this is a highly complex area (Department of Environment and Science 2021). A fault line runs through the catchment from Bowen in the north-west and through the centre of the Goorganga wetlands (Department of Environment and Science 2021).

The upper subcatchments consist of multiple drainage lines originating from the Proserpine State Forest while much of the floodplain has been cleared for sugarcane production. Several areas of Goorganga Creek are devoid of riparian vegetation immediately prior to the wetlands downstream (Figure 52).

Riparian vegetation along a 10km stretch of the Thompson River has generally improved between the 1970s and 2020. Around three-quarters downstream from the mouth of the river system, natural wetland areas have been impounded to transform them into water storage reservoirs. (see Figure 53).

The lower stages of Thompson Creek consist of a highly meandering, sinuous, river channel within the estuarine areas like most other rivers of the Proserpine Basin. However, along the Thompson River there are areas of sugarcane production up to the top of bank of the main channel. The estuarine reaches of the river have undergone significant channel change since the 1970s (Figure 54) with some of the channel migration occurring into sugarcane production areas. Three of these locations were prioritised for concept design due to the volume of fine sediment delivered to the Great Barrier Reef, as calculated by SECAT calculations.

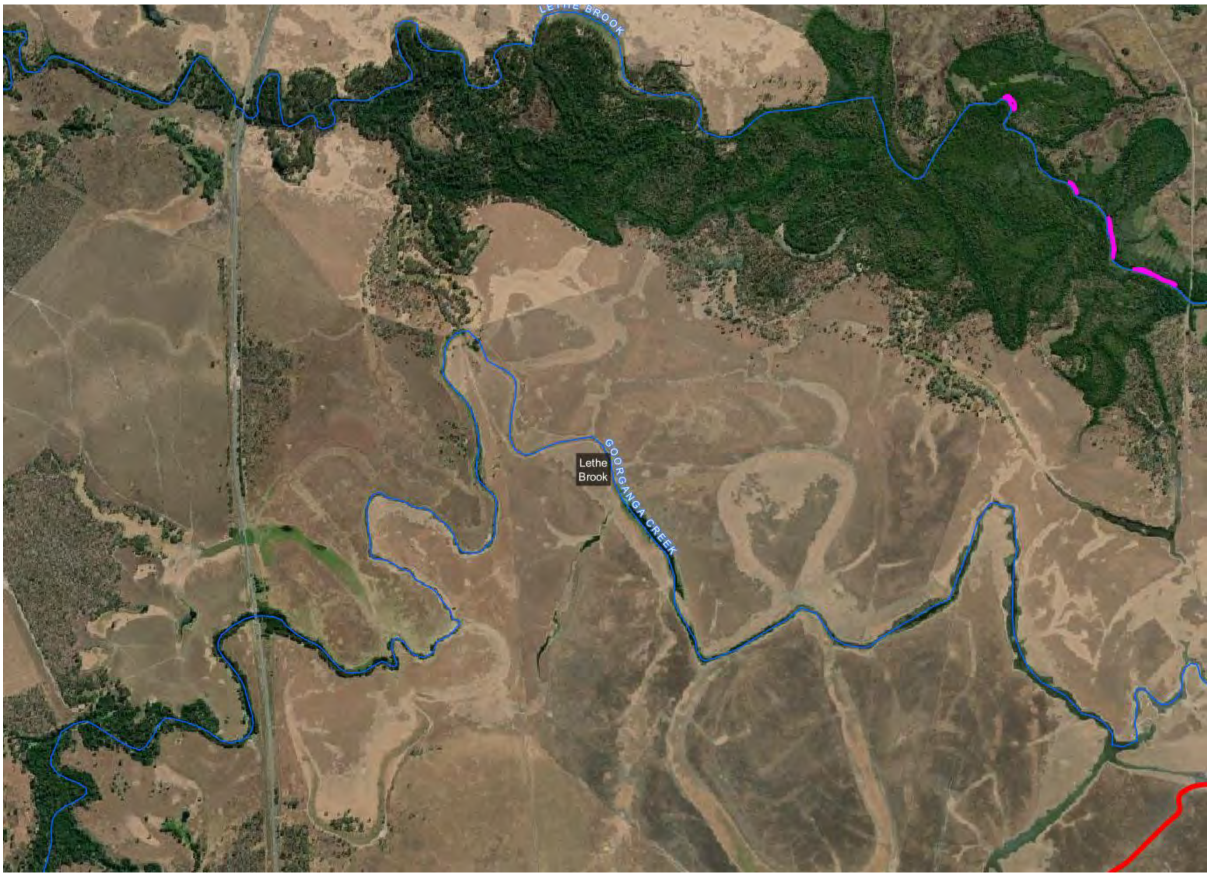


Figure 52. Aerial photograph showing lack of riparian vegetation along Goorganga Creek immediately upstream of the Goorganga Plains wetlands

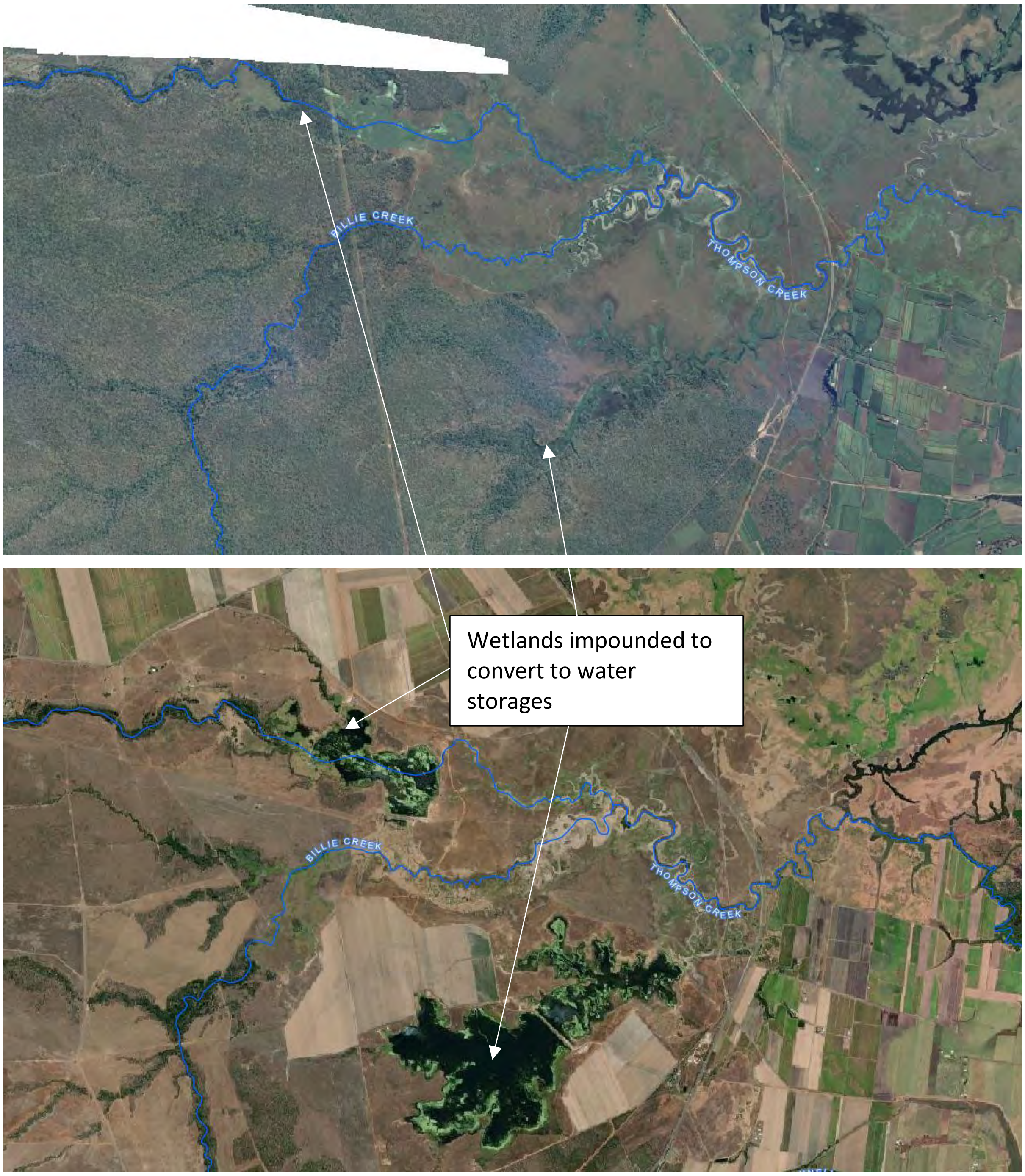


Figure 53. Areas of Thompson Creek where wetlands have been impounded to water storages. Top photo shows 1970s aerial while bottom photo shows 2020 aerial.

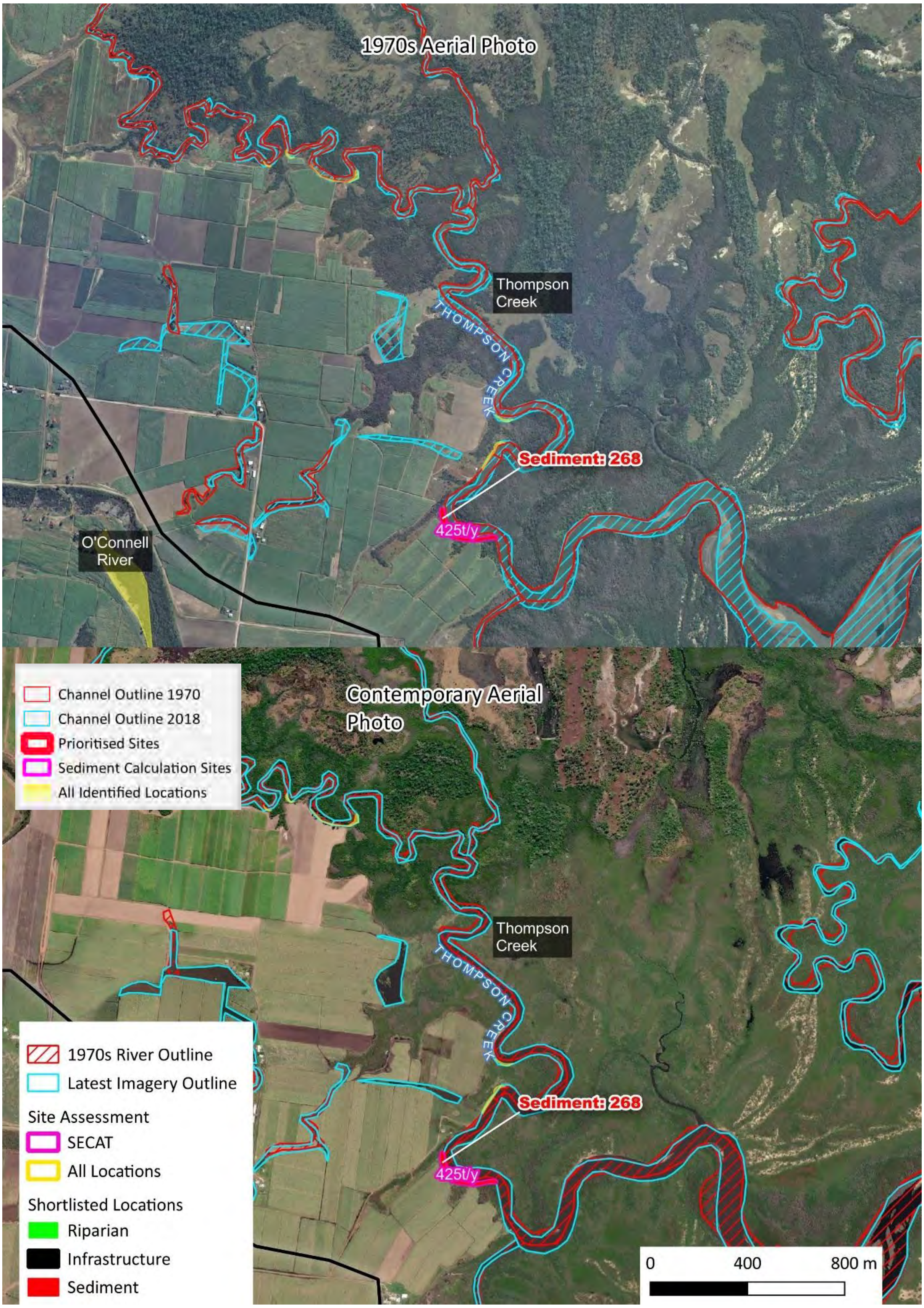


Figure 54. Highly variable Thompson Creek estuary. Red outlines are the 1970s channel; blue outlines are the 2018 channel. Three locations prioritised for concept design are highlighted in bold red.

5.5 Identified Sites

5.5.1 All Locations

Of the total 591 sites identified, 186 are located in the Proserpine Basin (Figure 55) with the majority found within the Eden Lassie Creek and Lethe Brook catchments (Figure 55, Figure 56). This correlates with the higher level of land clearing undertaken within the Eden Lassie Creek subcatchment. This can be attributed to its predominant land use for grazing purposes and the presence of relatively intricate stream systems.

The majority of the 186 sites were within areas of “Minor Instabilities” as documented by the 2017 Stream Type Assessment of the Mackay Whitsunday Region (Alluvium 2017).

SECAT sediment assessment was undertaken on 21 of the 186 identified locations in the Proserpine Basin. A number of the unassessed locations had either:

- the majority of erosion occurring prior to 2017; or
- insufficient data to undertake a SECAT or Gully Erosion Control Assessment Tool (GECAT) calculation for sediment assessment; or
- areas of significant bank movement within tidal reaches bordered by marine plants and mangroves and were excluded from the SECAT assessments as detailed in Section 3.8.

5.5.2 Total Sediment Reductions

SECAT calculations for the 21 Proserpine Basin locations yielded an estimated 2,153 tonnes of fine sediment (Figure 56).

The sites selected for remediation concept design (2 locations; 194, 268) totalled 1,221t/y of the total 2,153 calculated throughout the entire basin.

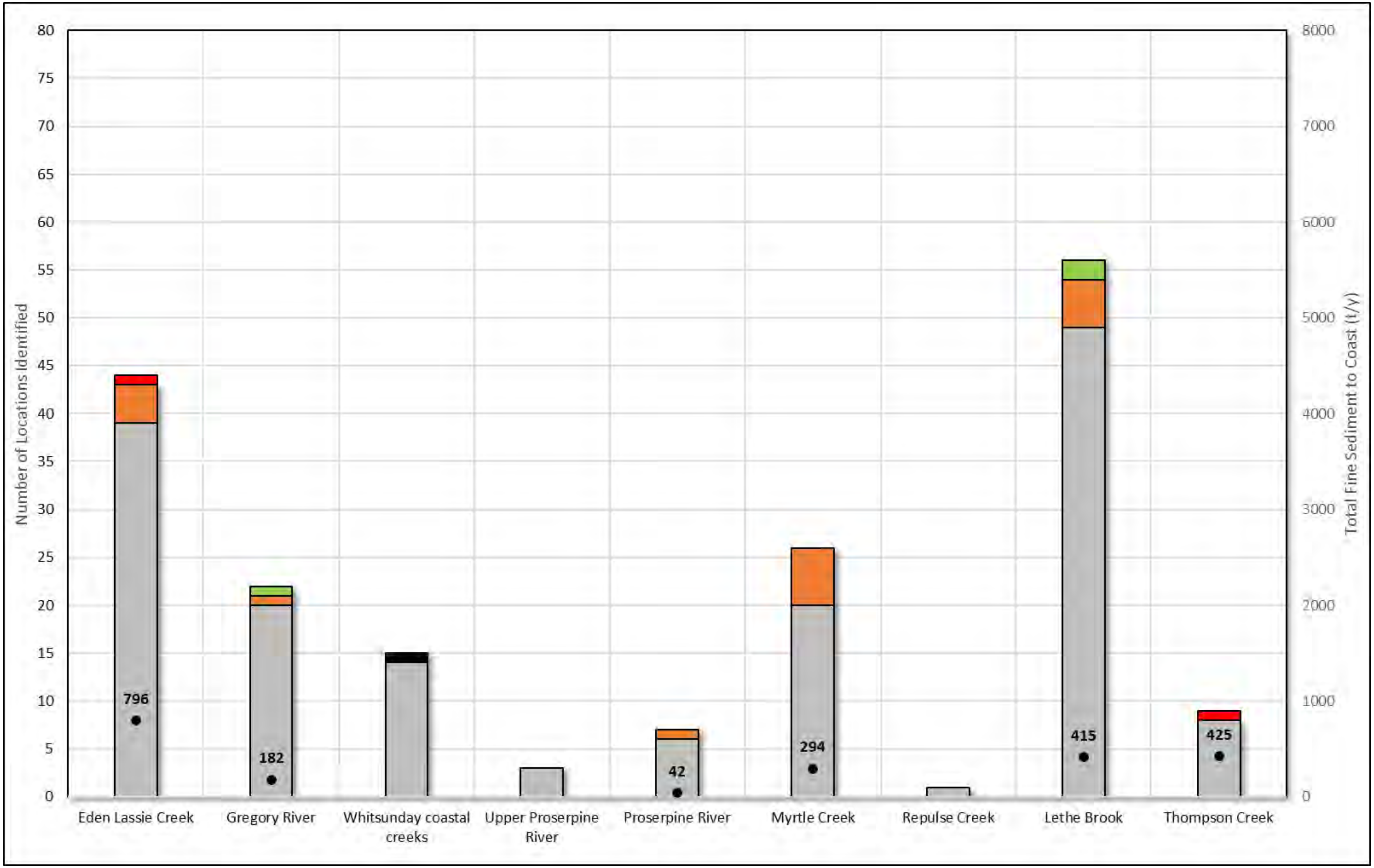
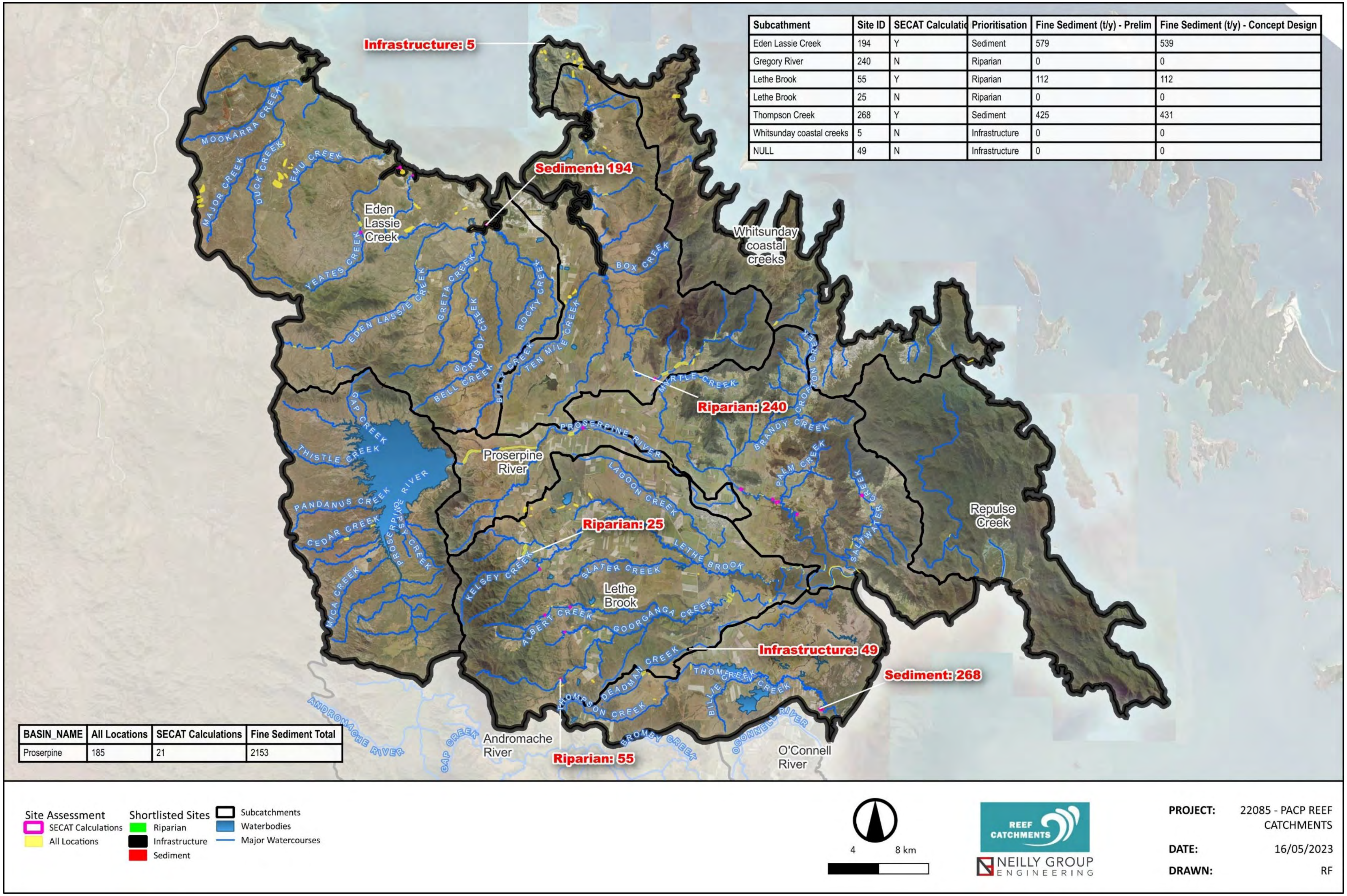


Figure 55. Results of the analysis within the Proserpine Basin



Subcathment	Site ID	SECAT Calculatio	Prioritisation	Fine Sediment (t/y) - Prelim	Fine Sediment (t/y) - Concept Design
Eden Lassie Creek	194	Y	Sediment	579	539
Gregory River	240	N	Riparian	0	0
Lethe Brook	55	Y	Riparian	112	112
Lethe Brook	25	N	Riparian	0	0
Thompson Creek	268	Y	Sediment	425	431
Whitsunday coastal creeks	5	N	Infrastructure	0	0
NULL	49	N	Infrastructure	0	0

BASIN_NAME	All Locations	SECAT Calculations	Fine Sediment Total
Proserpine	185	21	2153

Figure 56. Overview of all locations, SECAT calculations and shortlisted sites in the Proserpine Basin

5.5.3 Infrastructure Sites

There were two locations shortlisted for prioritisation based on infrastructure (Site 5 and Site 49) however, as explained in Section 3.11, did not progress to concept design. Refer to Table 12.

5.5.4 Sites Progressing to Concept Design

Five sites from the Proserpine Basin were chosen to progress through to Concept Design (Table 9). Two of these sites were prioritised based on Sediment Export and three sites prioritised based on Riparian Connectivity.

Table 9. Sites progressing to Concept Design from the Proserpine Basin

Site ID	Major River	Subcatchment	Prioritisation Reason	Preliminary SECAT (t/y)	Revised SECAT (t/y)
194	Greta Creek	Eden Lassie Creek	Sediment Export	577	539
268	Thompson Creek	Thompson Creek	Sediment Export	425	597
24	Kelsey Creek	Lethe Brook	Riparian Connectivity		
25	Kelsey Creek	Lethe Brook	Riparian Connectivity		
55	Goorganga Creek	Lethe Brook	Riparian Connectivity		

6 O’Connell Basin

The O’Connell Basin, with a total area of 2,388.7 km², is comprised of the following catchments[6] and major waterways (Figure 57):

- The O’Connell River (Dingo Creek, Gibson Creek and Boundary Creek)
- Andromache River
- Waterhole Creek
- Blackrock Creek
- St Helen’s Creek
- Constant Creek
- Reliance Creek.

While there are a number of subcatchments in the basin, the main rivers are the O’Connell and the Andromache River (Brooks, et al. 2014). In terms of groundwater hydrology, there were 299 licensed bores operating in the O’Connell Basin in 2006, used mostly for irrigated sugar cane production.

Please note that the subcatchments of the O’Connell River, as mapped by the EPP (Water and Wetland Biodiversity) 2019, were adopted for this study. These subcatchments have the Murray Creek subcatchment incorrectly mapped as “Lake Kinchant (Kinchant Dam)” subcatchment. The subcatchment data was sourced from Queensland Spatial in late 2022, and as of May 2023, the Queensland Globe layer (the most up to date data held by the Queensland Government) remained incorrectly named. Lake Kinchant occurs in the Plane Creek Basin within the “Sandy Creek” subcatchment.

6.1 Riverine Environmental Values

The O'Connell River Basin in Queensland, is a complex system with varied environmental features. Notably, Groundwater Dependent Ecosystems (GDEs) have been identified in a number of its waterways including the O’Connell River, Reedy Creek, One Mile and Blackrock Creeks (Department of Environment and Science 2021). These GDEs form an integral part of the riverine environment, contributing significantly to its biodiversity. Waterholes occur in the upland areas of the catchment (Queensland Wetlands Program 2016). While the non-coastal waterways in the basin have limited wetland development, the overall wetland area amounts to 7.3% of the total area. The riverine system accounts for 16.3% of the wetlands area, indicating a high sediment transport capacity. Major riparian corridors include the major waterways, particularly the Andromache, O’Connell and Boundary/Baldwin Creek and Murray Creek (Figure 57).

Historically, nearly half of the basin has been subjected to clearing or partial clearing, undertaken primarily for activities like grazing, forestry and irrigated/non-irrigated cropping (Department of Environment and Science 2021). This has had a profound effect on the landscape and the natural ecosystems. The headwaters of the O’Connell Basin, for instance, have seen considerable vegetation loss, resulting in stream bank and gully erosion (Queensland Government 2021).

Within this changing landscape, efforts have been made to protect certain areas, especially those on steeper landforms. These protected areas serve as sanctuaries for the diverse flora and fauna of the region. Specific sites, such as Mount Ossa and Mount Martin, are notable for their ecological significance (Reef Catchments 2014). These mountains host elevated, remnant vegetation that lies across a range of environmental gradients, underlining their conservation importance (Reef Catchments 2014). The headwaters of the Andromache catchment are designated as HEV waters

[6] Subcatchments are those outlined in the EPP (Water and Wetland Biodiversity) 2019

under the EPP (Waterway and Wetland Biodiversity) 2019 despite not being within a protected area (Figure 57).

The O'Connell River Basin also contains unique geological features. Cape Hillsborough, for example, stands out for its distinct geology that differs substantially from the rest of the Mackay coast (Reef Catchments 2014). However, some of these features are under threat. The semi-deciduous notophyll/mesophyll vine forest at Reliance Creek National Park is endangered, with less than 10% of its pre-European extent remaining (Reef Catchments 2014).

Significant erosion generally occurs where the main channel of the O'Connell River adjoins inset floodplains (Alluvium 2014). Subsequently several river restoration projects have been undertaken by Reef Catchments.

Stream type assessment of the basin (Alluvium 2017) was undertaken and is replicated in Figure 59 to Figure 61 which will be referred to in later sections.

6.2 Land Use History

Spanning around 230,000 hectares, the O'Connell Basin houses various populated areas including Ball Bay, Bloomsbury, Calen, Kuttabul, Midge Point, Mount Ossa, Seaforth, and St Helens Beach, among others. Certain northern suburbs of Mackay also extend into this basin from the southern Pioneer catchment. The basin represents a quarter of the total Mackay Whitsundays region.

The major land usage is diverse and is distributed as follows (Figure 58):

- Grazing constitutes 42%
- Conservation and land management take up 28%
- Sugarcane cultivation occupies 13%
- Water bodies account for 7%.

The O'Connell Basin has been a hub for farming activities since the late 19th century (GBRMPA 2013). However, water scarcity has restricted sugarcane production to an extent. Historically, grazing was the primary land use in the region but the introduction of advanced irrigation techniques in the early 20th century led to a pivot towards sugarcane cultivation. This shift was also facilitated by a decrease in live cattle trade and the growing economic value of sugar. Despite these transformations, grazing remains a prevalent land use practice, along with sugarcane production and urban development (GBRMPA 2013).

The predominance of sugarcane cultivation is evident in the southern subcatchments of the basin. As per the 2013 assessment by the Queensland Government (GBRMPA 2013), certain areas were found to have been cleared for cane growth up to the creek banks.

From 1999 to 2009, land use remained relatively stable in the basin, with only a few landholders transitioning between grazing, irrigated, and non-irrigated properties. There's clear evidence of irrigated sugarcane in the floodplain. Grazing primarily occurs in the northern part, and the southern areas have seen enhanced protection.

Ecologically, a large portion of the coastline is significant. The catchment area includes three designated Fish Habitat Areas, an extensive Dugong Protection Zone, numerous important estuaries, turtle nesting sites, and habitat for migratory shorebirds. It also drains into the Great Barrier Reef lagoon.

Around 50% of the basin's vegetation is classified as non-remnant and the basin has witnessed considerable wetland loss since European settlement. Despite sugarcane cultivation taking up only a small percentage (13%) of land use, it generates approximately 50% of all fine sediment (DEECW n.d.). A further 33% results from streambank erosion.

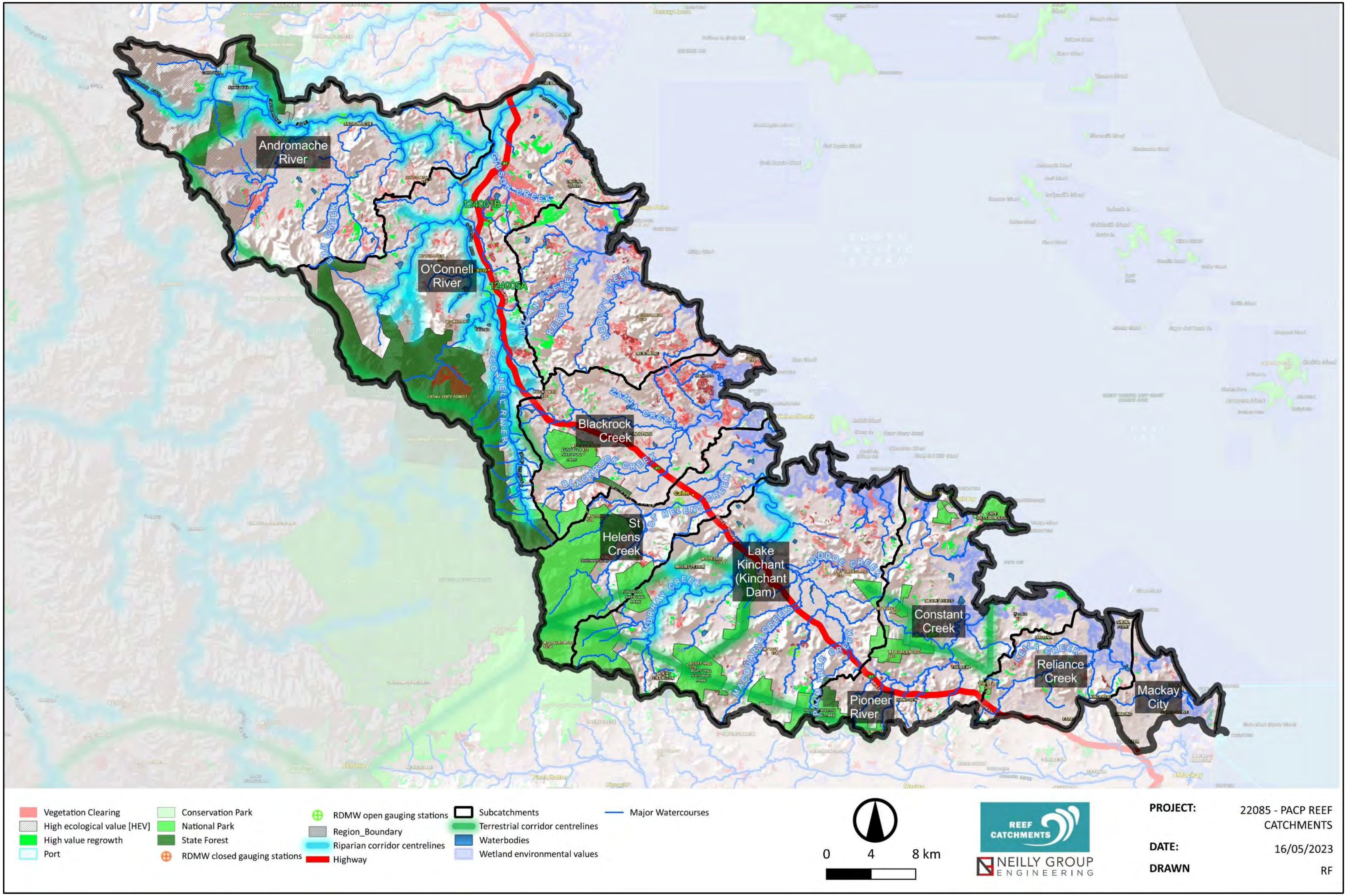


Figure 57. Overview of the O'Connell Basin

The picture can't be displayed.

Figure 58. Land Use in the O'Connell Basin

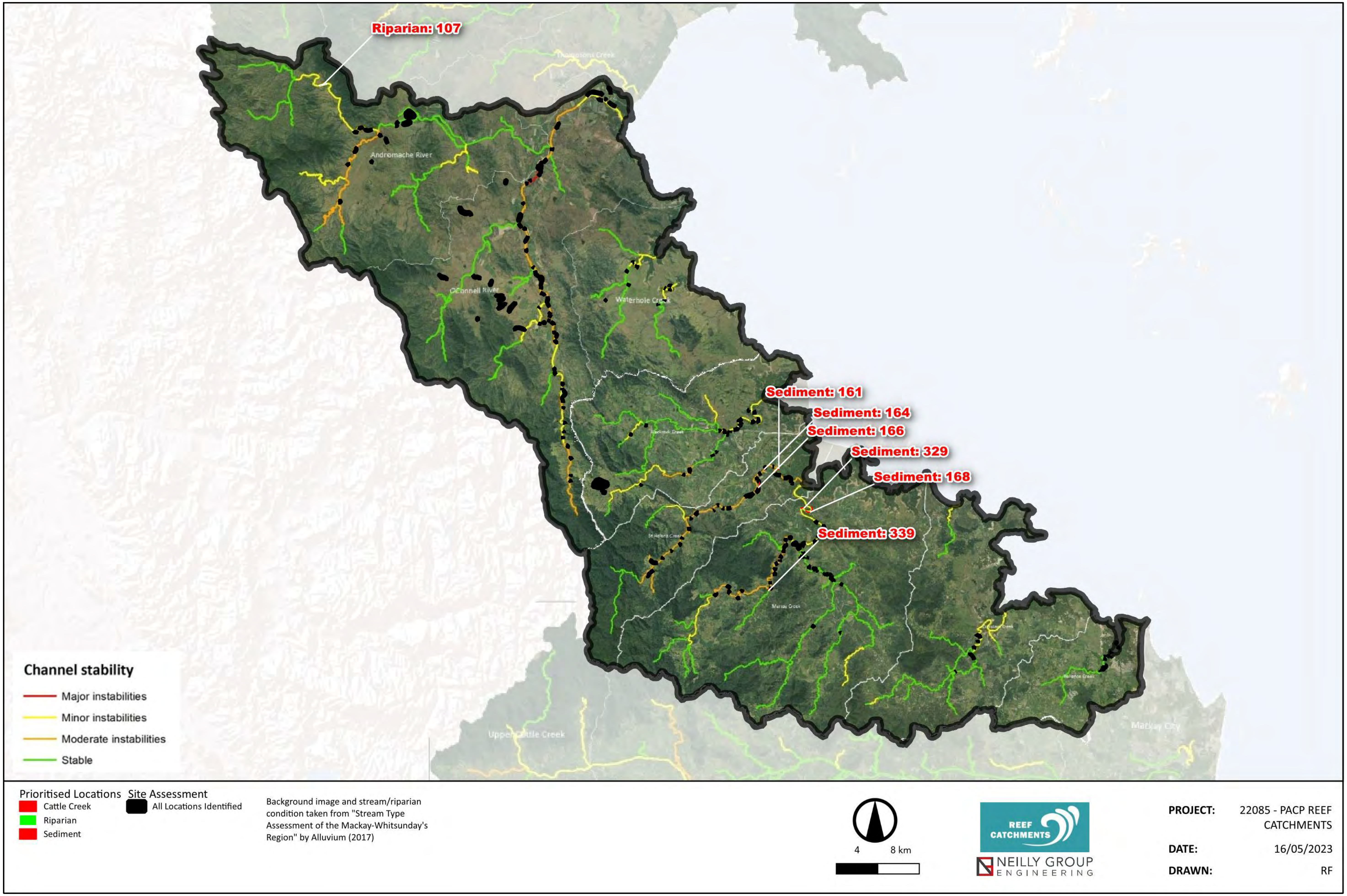


Figure 59. Channel stability of the O'Connell Basin (Alluvium 2017) with sites overlaid

Figure 60. Riparian vegetation condition of the O'Connell Basin (Alluvium 2017) with sites overlaid

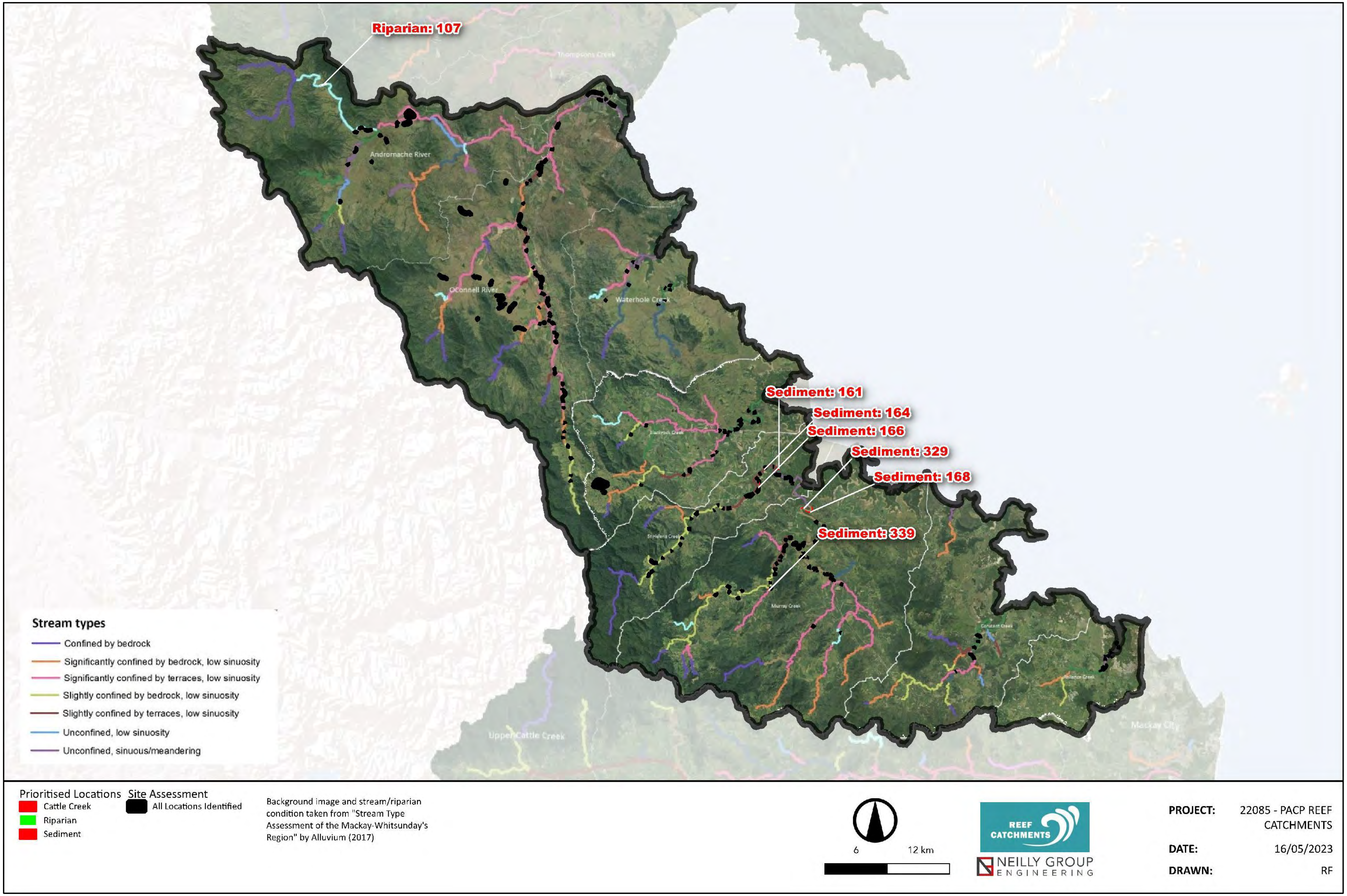


Figure 61. Stream type of the O'Connell Basin (Alluvium 2017) with sites overlaid

6.3 Climate

There is a distinct rainfall gradient of decreasing maximum, average and minimum rainfall through the O'Connell Basin from south-east (near Mackay) to north-west (in the upper reaches of the Andromache River). This drives the flow regime of the area with the rivers in the southern part of the basin having more persistent flow than those in the north which show a flashier catchment response. The Andromache River is expected to have far less occurrence of continual flow than the Constant Creek and Blackrock Creek for example.

Interestingly the rainfall gradient appears to be dominated more by north–south trends rather than elevation trends (i.e. more rainfall against the western basin divide).

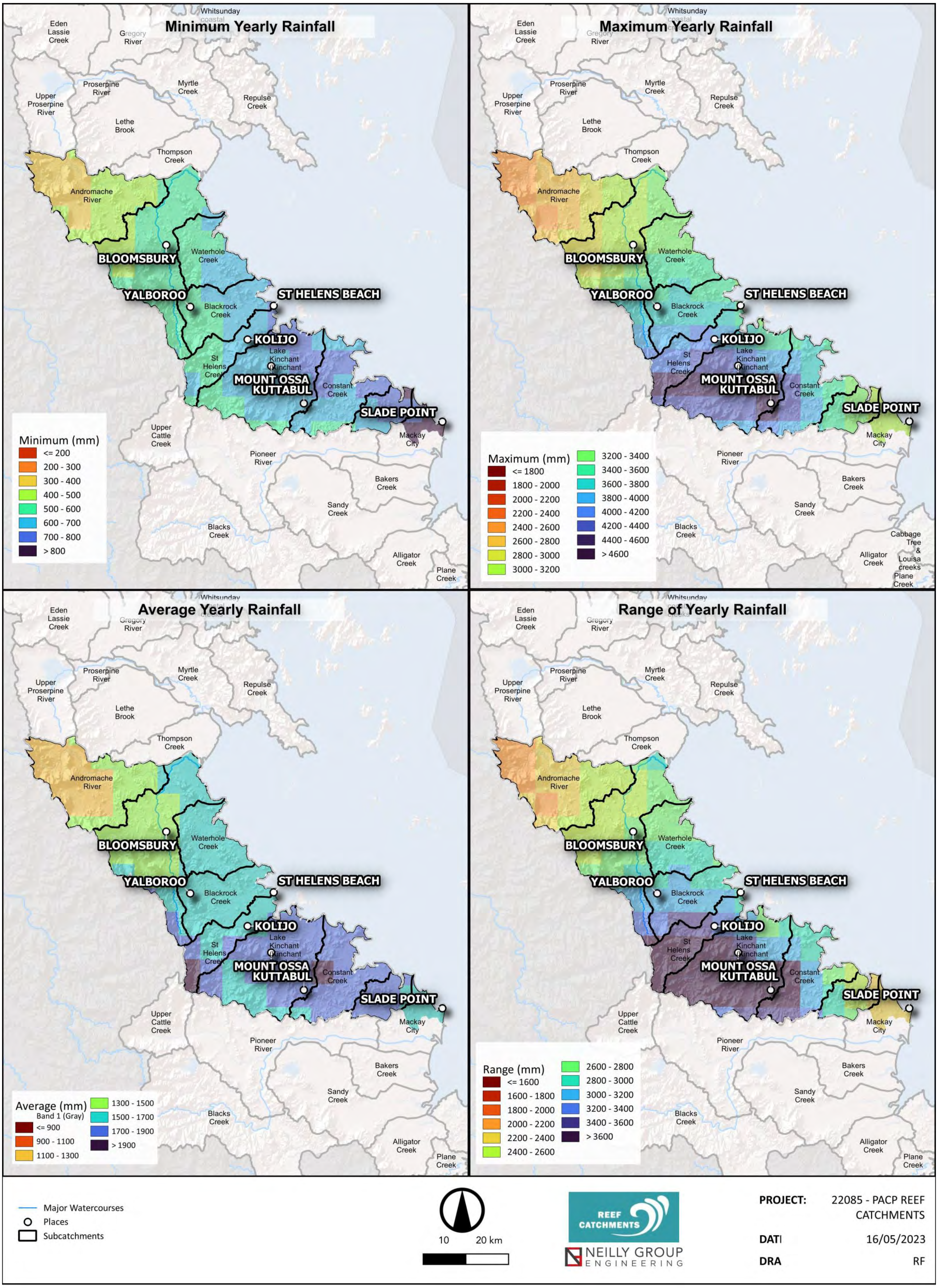


Figure 62. Climate of the O'Connell Basin

6.4 River Geomorphology

6.4.1 Andromache River

The upper Andromache subcatchment is comprised of the Andromache River as well as Birds Nest and Mares Nest creeks. The majority of Birds Nest / Mares Nest Creek is mapped as having poor stability (Figure 59), poor riparian condition (Figure 60) and being relatively unconfined (Figure 61).

The upper Andromache River is generally confined in the upper and lower reaches by bedrock or terraces respectively (Alluvium 2017). Riparian vegetation is poor in the upper catchment where cattle have access to the channel (Figure 60) (Alluvium 2017). Small inset floodplains within the channel are too small to clear and therefore contribute towards reasonable riparian vegetation condition along other sections of the waterways (Department of Environment and Science 2021).

Increased sediment loads associated with clearing since European settlement have caused the disappearance of multiple in stream pools (Alluvium 2017). However, ecologically significant waterholes persist at the confluence of the Andromache and O'Connell Rivers (Department of Environment and Science 2021). Approximately 17% of the catchment is under protected areas with the remainder of the catchment cleared for grazing or cane production (Department of Environment and Science 2021).

Despite the loss of in stream pools there are several areas along the main channel of the Andromache where the inset floodplains appear to be comprised of mobile sand in the 1970s and have since been colonised by vegetation in contemporary aerial imagery (Figure 63 and Figure 64). This indicates that the frequency of events capable of inundating the inset floodplains has decreased as there has not been sufficiently large flows to re-mobilise sediment. This change is expected to lead to downstream erosion due to the previously mobile sand, which used to migrate downstream, is now trapped beneath the vegetation and not being replenished.

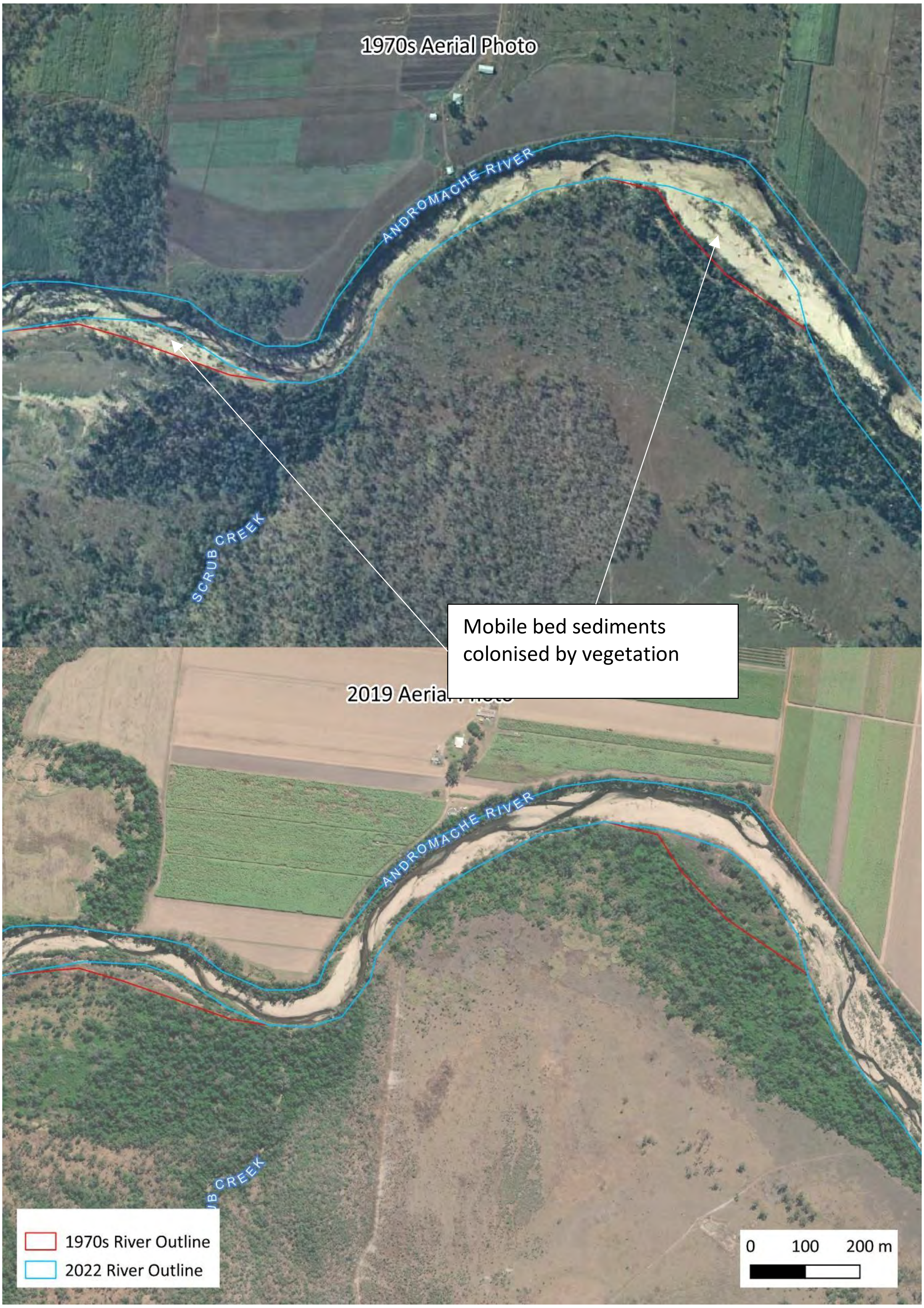


Figure 63. Vegetation colonisation of previously mobile bed sediments

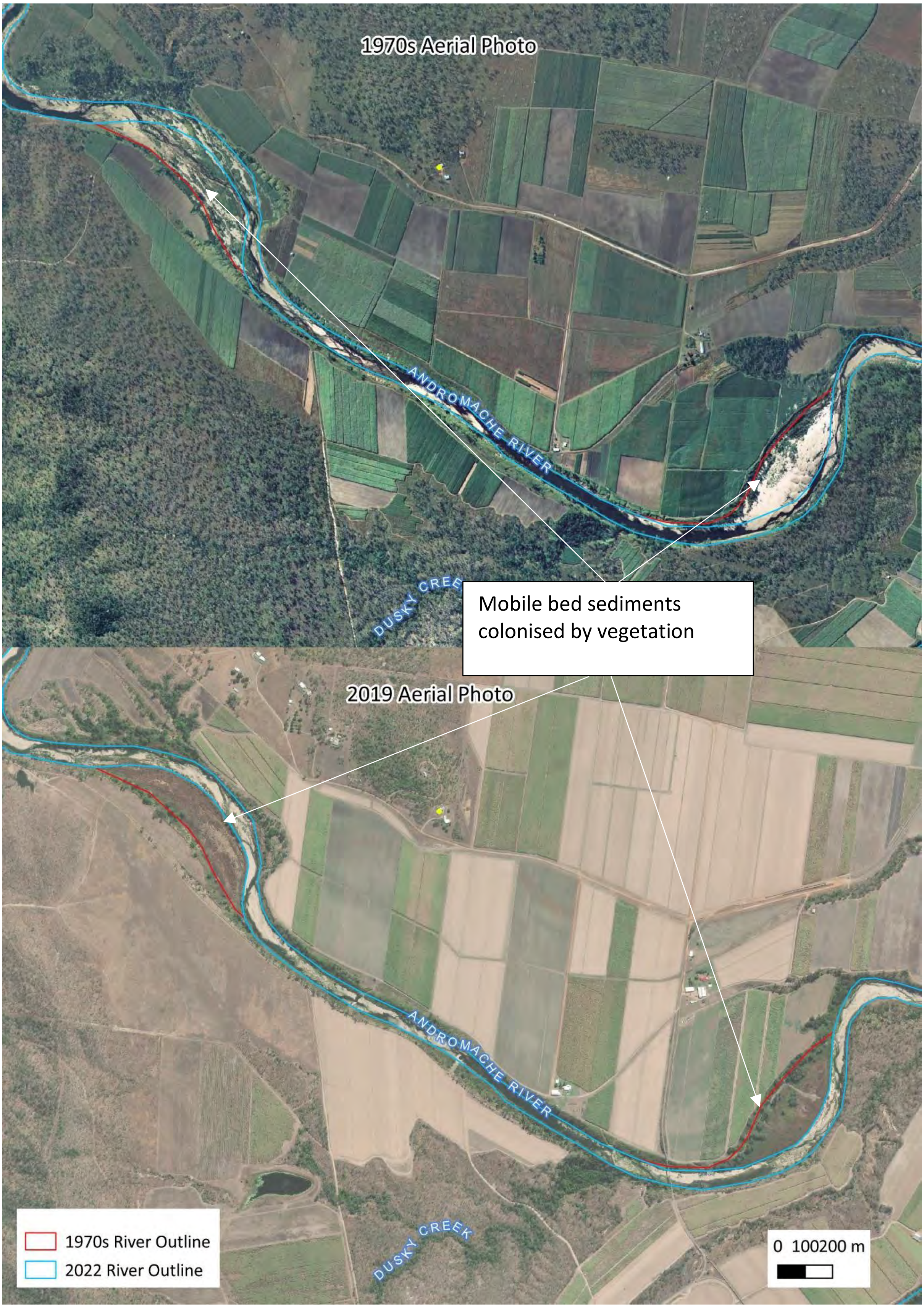


Figure 64. Vegetation colonisation of previously mobile bed sediments

6.4.2 O’Connell River

The O'Connell River has experienced considerable geomorphological changes over the years, significantly impacting its water quality and overall environmental state. Notably, the O'Connell River has the poorest water quality among water bodies in the basin, a testament to the environmental issues plaguing the area (GBRMPA 2013). A stream type assessment mapped almost the entire waterway as ‘stable’ (Figure 59), having good riparian condition (Figure 60) and as significantly confined by terraces (Figure 61).

Much of the River's degradation can be attributed to sedimentation, a result of altered land use since European settlement. As sediments accumulate, the riverbed elevation increases, inducing bank erosion and consequently widening the channel. This aggradation process has led to decreased flood immunity in certain locations (GBRMPA 2013). Further exacerbating the sedimentation problem were substantial flow events that occurred in the late 2000s and early 2010s, causing significant sediment influx into the system (GBRMPA 2013).

Geomorphologically, the O'Connell River features a macrochannel with a series of inset floodplains, which has experienced substantial changes due to these sedimentation events (Alluvium Consulting, 2017b). The floods carried larger and coarser sediments that have been gradually depositing in the system, leading to further bed aggradation and channel widening (GBRMPA 2013).

Deforestation for agricultural purposes has also played a significant role in the degradation of the O'Connell River's environment. Almost all alluvial surfaces have been cleared for intensive sugarcane cultivation and other agricultural practices, leaving only a narrow, fragmented strip of riparian vegetation along the river (Brooks, et al. 2014). This widespread clearing, especially in the river's elevated headwaters, has triggered substantial stream bank and gully erosion, as these upland areas possess high sediment transport capacity (Queensland Wetlands Program 2016).

Notably, the O’Connell River's bank full discharge ranges between 400 and 600 m^3/s, which is less than a 1 in 2-year event. In contrast, the mid-reaches of the river, where it is confined, the channel capacity exceeds 3,000 m^3/s, surpassing the 30-year ARI event (Alluvium 2020).

LiDAR analysis comparing 2009 and 2018 datasets revealed that approximately 279,000 cubic meters of sediment were mobilised from major erosion zones, particularly between the confluence of Horse Creek and the Andromache River just upstream of the Bruce Highway (Alluvium 2020). The river is partially confined by the overall landform, restricting potential historical migration paths (Alluvium 2014).

A 2014 study by Brooks et al. estimated an annual total erosion volume of approximately 197,708m^3/y (from three years of data), with considerable uncertainty skewed towards the positive side. The study also found that most of the erosion was due to discrete failure sites, which they defined as erosion polygons. They identified 508 such polygons, with the bulk (50%) of the total volume of erosion sourced from just 14 polygons. Much of the O’Connell and Andromache rivers were found to be undergoing bed lowering as well (Brooks, et al. 2014).

In the upper O’Connell River, the prevalent erosion process is toe erosion, followed by mass failure on the outer bends. Major erosion occurs on meanders in the lower reaches (Alluvium 2020). Selected parts of the mid-reaches of the O’Connell River have experienced stream migration of more than one stream width between 1970 and 2018 (Figure 65).

Evidence of the large-scale of meander migration in the lower, tidal, reach of the river system is provided in Figure 18 and Figure 19, page 37, where there has been 100m of bank migration. However, the majority of this has occurred between 1970 and the early 2000s and has since stabilised.

Of note, Boundary Creek, a tributary of the O'Connell River, is home to several significant waterholes (Queensland Wetlands Program 2016). The region also suffered as a result of the 2017 Severe Tropical Cyclone Debbie event, which led to bank erosion upstream of the Bruce Highway and damage to the existing bank (Alluvium Consulting 2017b).

Figure 65. Significant movement of the O'Connell River between 1970 and 2018

6.4.3 Waterhole Creek

Waterhole Creek consists of Stony Creek and Julian Creek which all converge near the coast into Dempster Creek which outlets at the southern end of Midge Point (C&R Consulting 2013). Midge point has been undergoing coastal erosion for decades with significant impacts in Cyclone Ului (C&R Consulting 2013). Hervey Creek and Cedar Creeks form the remainder of the basin. Like most other smaller waterways, these rivers only begin to meander within the lower reaches at or near the tidal extent. This is reflected in the stream type assessment for the waterways within the Waterhole Creek catchment which show good channel stability (Figure 59), good riparian vegetation condition for the majority of the reach (Figure 60), and that the main channels are relatively confined by terraces (Figure 61) (Alluvium 2017).

Figure 66 show the locations of potential erosion which were found within the Waterhole Creek catchment. A number of locations were assessed for sediment generation using SECAT, however, the majority of these locations are within naturally vegetated areas of the estuary.

Figure 66. Locations found within the Waterhole Creek catchment. Yellow polygons are all locations found; pink polygons represent locations of SECAT calculations; red outlined indicate 1970s channel delineations

6.4.4 Blackrock Creek

Like the Waterhole Creek subcatchment the majority of channel change occurs in the lower reaches of Blackrock Creek. However, the upper reaches are heavily cleared. Significant proportions of the upper catchment have been cleared in comparison between the 1970 and 2022 aerial photographs. This results in a relatively flashy (i.e. quick) catchment runoff response time (Queensland Wetlands Program 2016). The majority of Blackrock Creek is identified as being significantly confined by terraces and the main channel having a low sinuosity as outlined in the 2017 Mackay Whitsundays Stream Type Assessment (Alluvium 2017). Therefore, channel migration and erosion are expected to be minimal. The assessment during this study confirms this with no channel migration or erosion (outside the estuary) when comparing the 1970 and 2018-2020 aerial photographs (Figure 67).

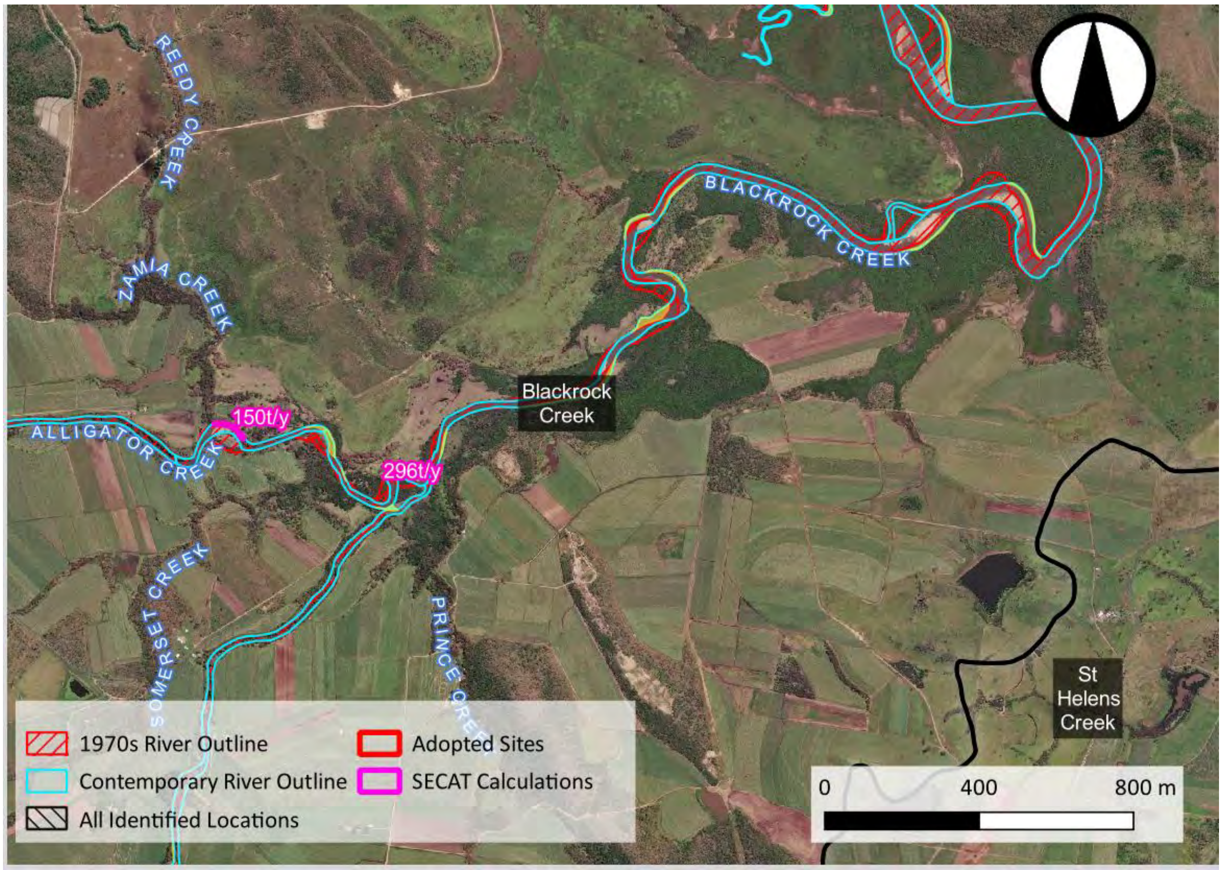


Figure 67. Channel changes in the lower Blackrock Creek reach

6.4.5 St Helen's Creek

St Helen's Creek has a large length within the Eungella National Park, therefore with good water quality and riparian vegetation (Queensland Wetlands Program 2016). However, once the waterway descends to the floodplain from the national park, the catchment is heavily cleared leaving only a thin strip of riparian vegetation along the waterway which is rated as "Poor" condition in the 2017 Mackay Whitsunday Stream Type Assessment (Alluvium 2017) (Figure 60, page 93). St. Helen's Creek is noted as having one of the steepest overall valley gradients in the region (Alluvium 2017). The clearing in this area and poor riparian condition has led towards sedimentation as recorded in the Walking the Landscape Process (Queensland Wetlands Program 2016).

Terraces confine St Helen's Creek however there are extensive zones of inset floodplains (Alluvium Consulting 2017b). Four locations above the Bruce Highway and with visible river channel movement since 2017 were identified and SECAT calculations performed. These four locations deliver 2401t/y of fine sediment to the coast.

The area downstream of the Bruce Highway is within the lower reach of St Helen's Creek and is highly active. Since 1954 there are two meanders which have cutoff through sugarcane, resulting in a reduction in stream length from 2000m to 1,100m (Alluvium Consulting 2017b). These are identified in Figure 68 which shows a highly active lower reach of St Helen's Creek with three locations identified for SECAT calculations. The three areas deliver a total of 862t/y of fine sediment to the coast. Two of these sites have been adopted for Concept Design.

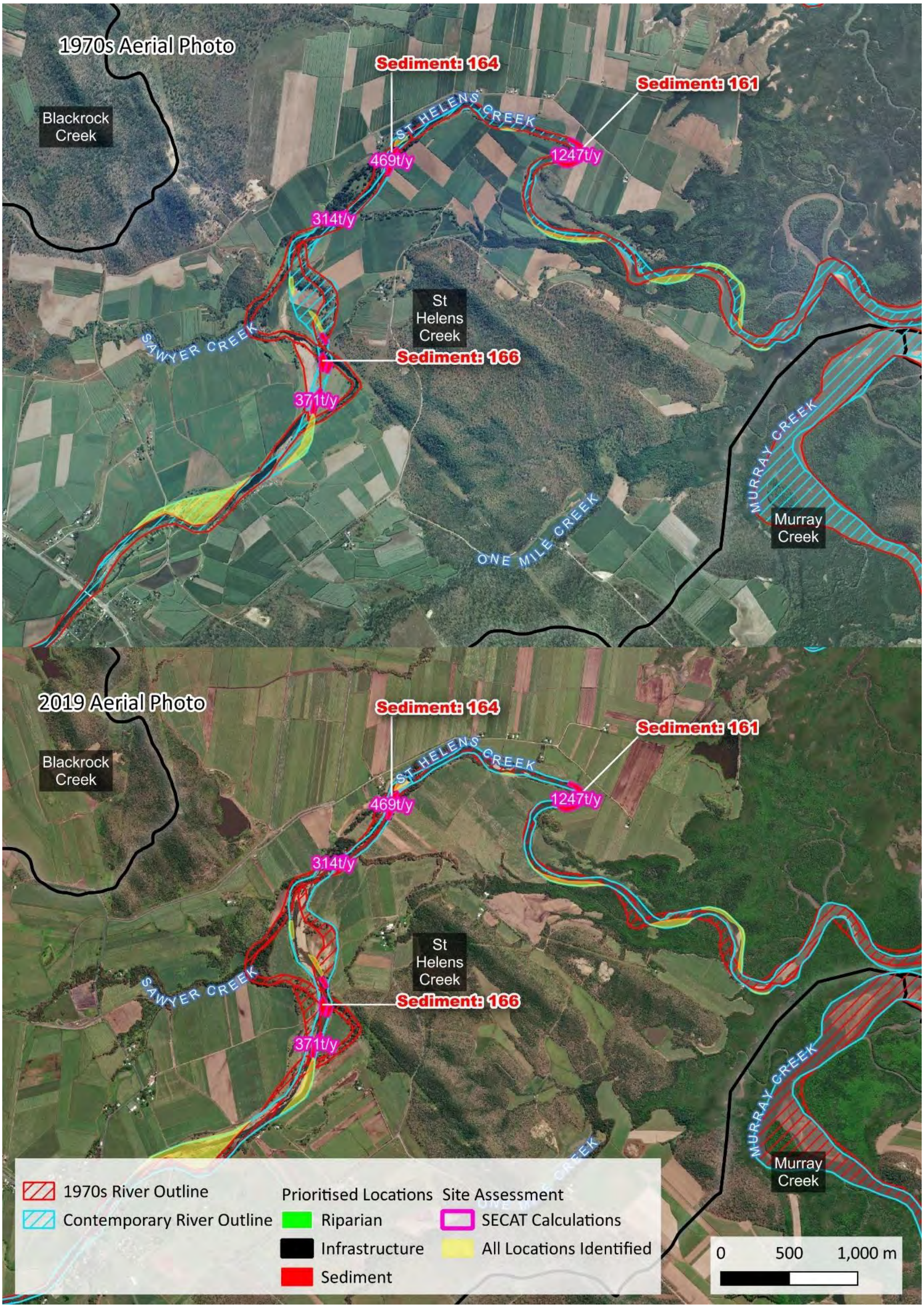


Figure 68. 1970s to 2019 aerial image comparison at the lower reaches of St. Helen's Creek

6.4.6 Murray Creek

Most of the Murray Creek catchment is cleared, including the headwaters. This has resulted in a moderate to poor rating of riparian vegetation as documented in the Stream Type Mapping (Figure 60, page 93). The stream system has near-permanent flows, fed by fractured rock aquifers that capture and drain water from the foothills (Queensland Wetlands Program 2016). Therefore, there are waterholes along the river system, despite there being mobile bedload of sand slugs which migrate downstream (Queensland Wetlands Program 2016). The creek upstream of the Bruce Highway is mapped as "Significantly confined by bedrock" according to the Mackay Whitsunday stream type mapping (Figure 61).

The lower reaches of Murray Creek are highly active. At the north-eastern base of Mt Lewis, Murray Creek has changed course between 1970 and the present day. Several meanders have completely shifted and migrated in a succession of meander cutoffs, bank erosion and infilling. These meanders have shifted in a downstream direction in an effort for the stream to maintain its sinuosity. Once Murray Creek and Jolimont Creek converge the sinuosity of the stream system greatly decreases, however, bank erosion is still present on either side of the river.

Twenty-three locations were identified as having active bank movement between 2017 and 2021/2022 and were selected for SECAT calculations. These 23 locations provide an estimated 8,035t/y of fine sediment delivered to the coast. Three of the 23 locations were adopted for Concept Design as part of this report. Initially, these three locations were estimated to provide approximately 3,760t/y of fine sediment to the coast however this was re-calculated to 6,830t/y during the Concept Design, indicating that the total volume of sediment from other locations within the catchment may increase upon closer scrutiny as well.

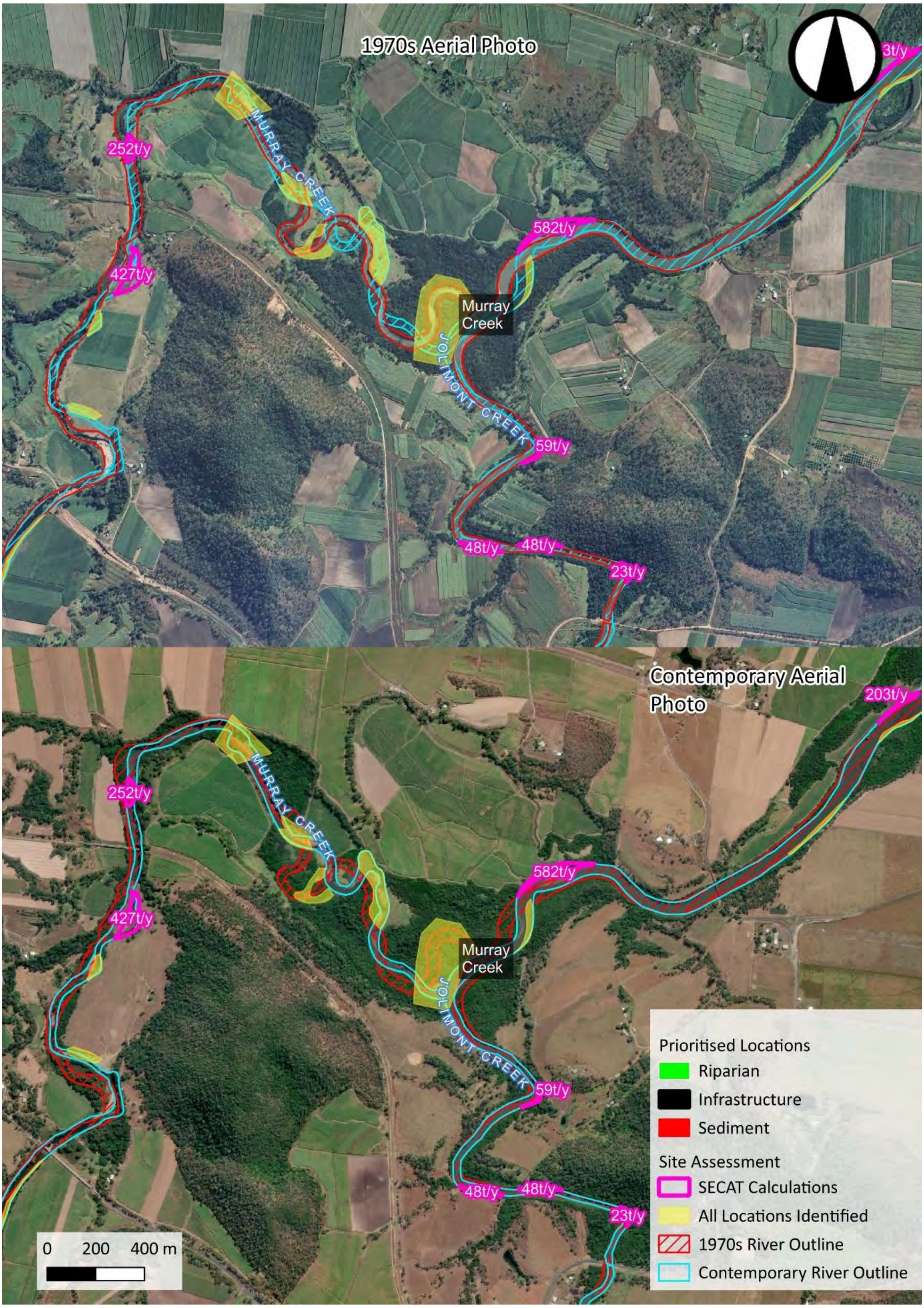


Figure 69. Lower reach of Murray Creek showing highly active area with meander wavelength migration

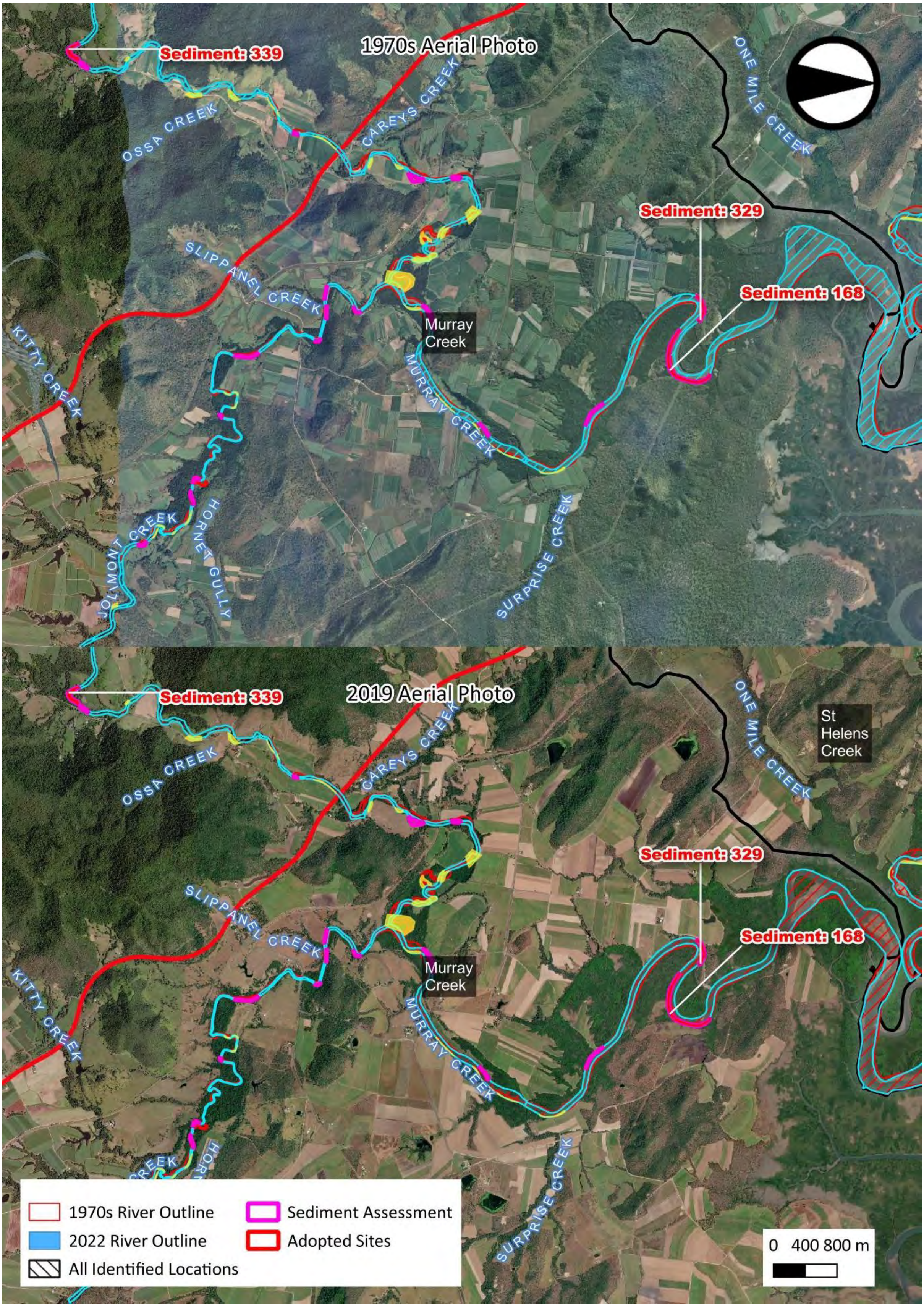


Figure 70. Lower Reach of Murray Creek with locations prioritised for Sediment adopted.

Please note that the subcatchments adopted for this study from the EPP (Waterway and Wetland Biodiversity) 2019 have the Murray Creek catchment named as “Lake Kinchant (Kinchant Dam)”.

6.4.7 Constant Creek and Reliance Creeks

Constant Creek and Reliance Creek subcatchments receive runoff from the northern suburbs of Mackay. Constant Creek drains The Leap area and contains Cape Hillsborough National Park on the coast. The main waterway has near year-round flows (Queensland Wetlands Program 2016) with reasonable riparian connectivity along the whole stream system, even though there are several large portions of the mid-catchment cleared for sugarcane production.

The Mackay Whitsunday 2017 Stream Type Assessment identifies most of the larger channels in the Constant Creek and Reliance Creek catchments as 'Stable' (Figure 59). Although there were several areas of identified stream migration from 1970 to present day the stream migration was relatively minor, and not identified as recent. There were no sites identified for SECAT calculations in the Constant Creek catchment.

Most of the Reliance Creek catchment is cleared for sugarcane production with small areas of rural-residential land uses spread throughout the catchment. Riparian vegetation along most of the waterway is rated as 'Moderate' in the upper catchment and 'Good' in the mid-lower catchment (Figure 60). However, this may be because the main waterway is relatively narrow compared to other streams such as Constant Creek and Murray Creek.

Temporal aerial photography interpretation did not find any locations of major channel changes outside the lower, estuarine, or near-estuarine reaches. This is primarily because of the narrow but thick riparian vegetation along most of the waterway, making delineation of the river position difficult from repeat aerial photography. In addition, qualitative inspection of the repeat aerial photography indicates that the main waterway is not likely to have shifted or suffered significant bank erosion. Outcomes from the Walking the Landscape Process indicate that areas of Reliance Creek have very gradual sloped banks, some waterholes present and non-permanent flows (Queensland Wetlands Program 2016). This channel form is less vulnerable to bank erosion.

Meander migration occurs in the lower reaches of Reliance Creek but with no locations identified as having bank migration since 2017 and being subject to SECAT calculations as all locations of bank movement are identified within heavily vegetated areas (Figure 71).

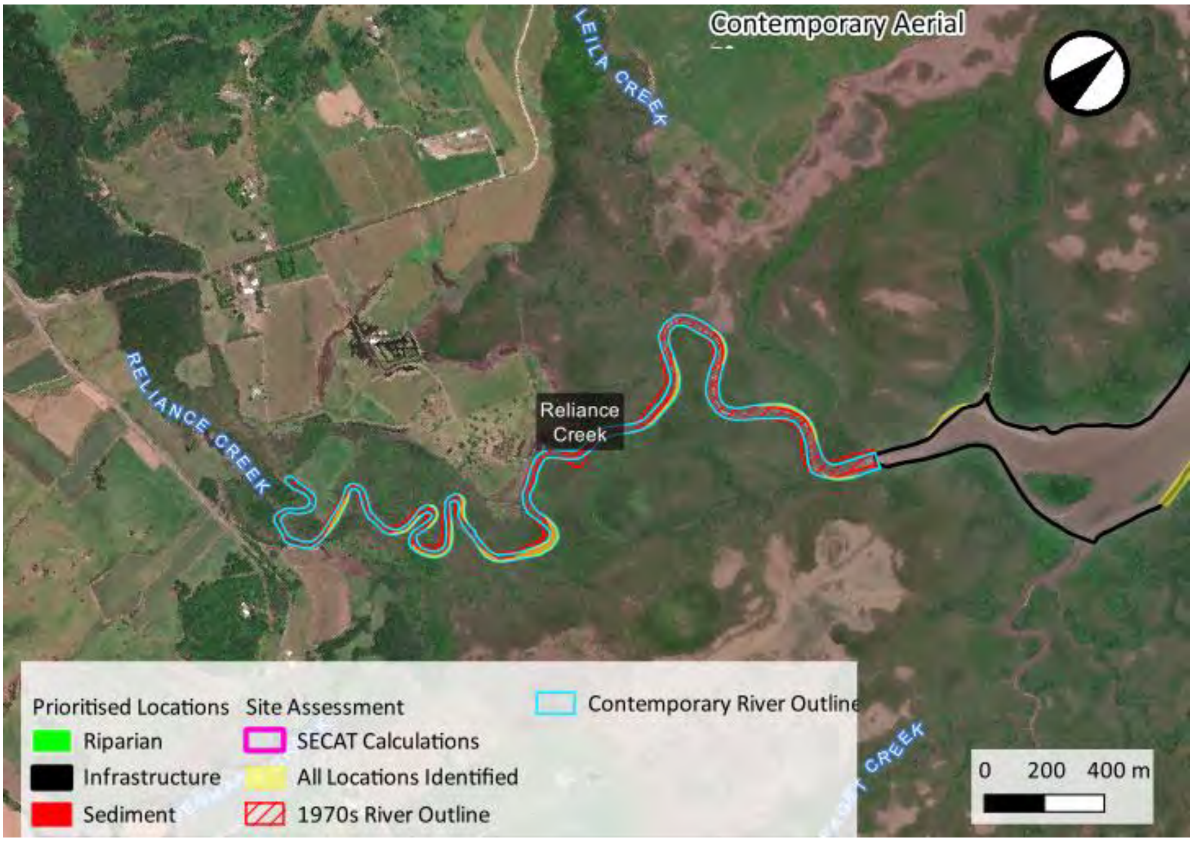


Figure 71. Bank traces between 1970s and present with locations of recent movement highlighted

6.5 Identified Sites

6.5.1 All Locations

There were 224 locations from the O'Connell Basin of the total 591 from the study. The majority were found within the O'Connell River subcatchment, followed by Murray Creek, St Helen's Creek and Blackrock Creek (Figure 72). The locations of all features identified and the shortlisted sites are provided in Figure 73. Of the total identified, 62 were subjected to SECAT calculations to determine the volume of fine sediment entering the Great Barrier Reef.

6.5.2 Total Sediment Reductions

Across the 62 locations within the O'Connell Basin subject to SECAT calculations, it was determined that 19,795 tonnes per year of fine sediment are delivered to the coast (Figure 72).

The six sites which were selected for remediation Concept Design totalled 8,356t/y, 43% of the total calculated across the entire basin.

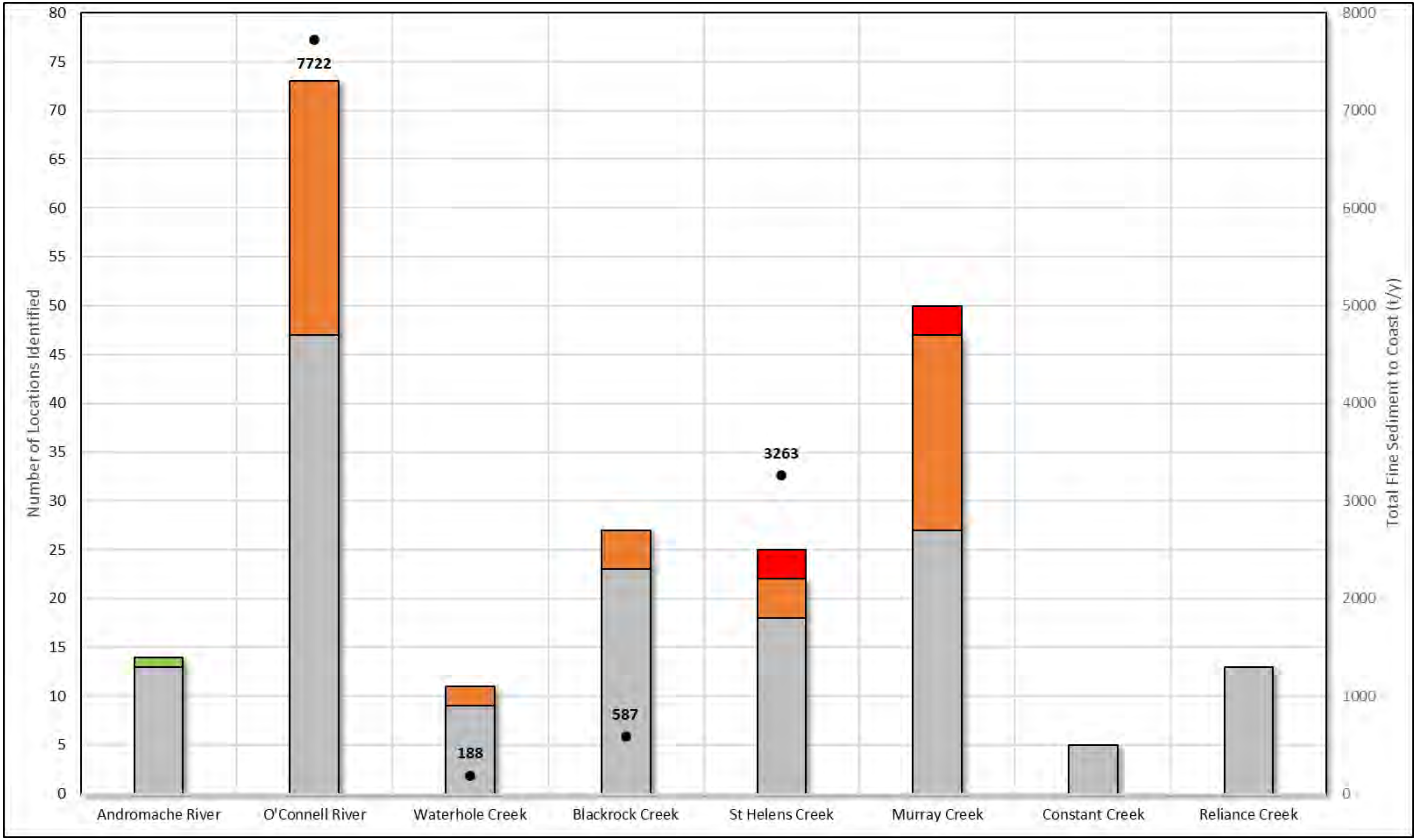
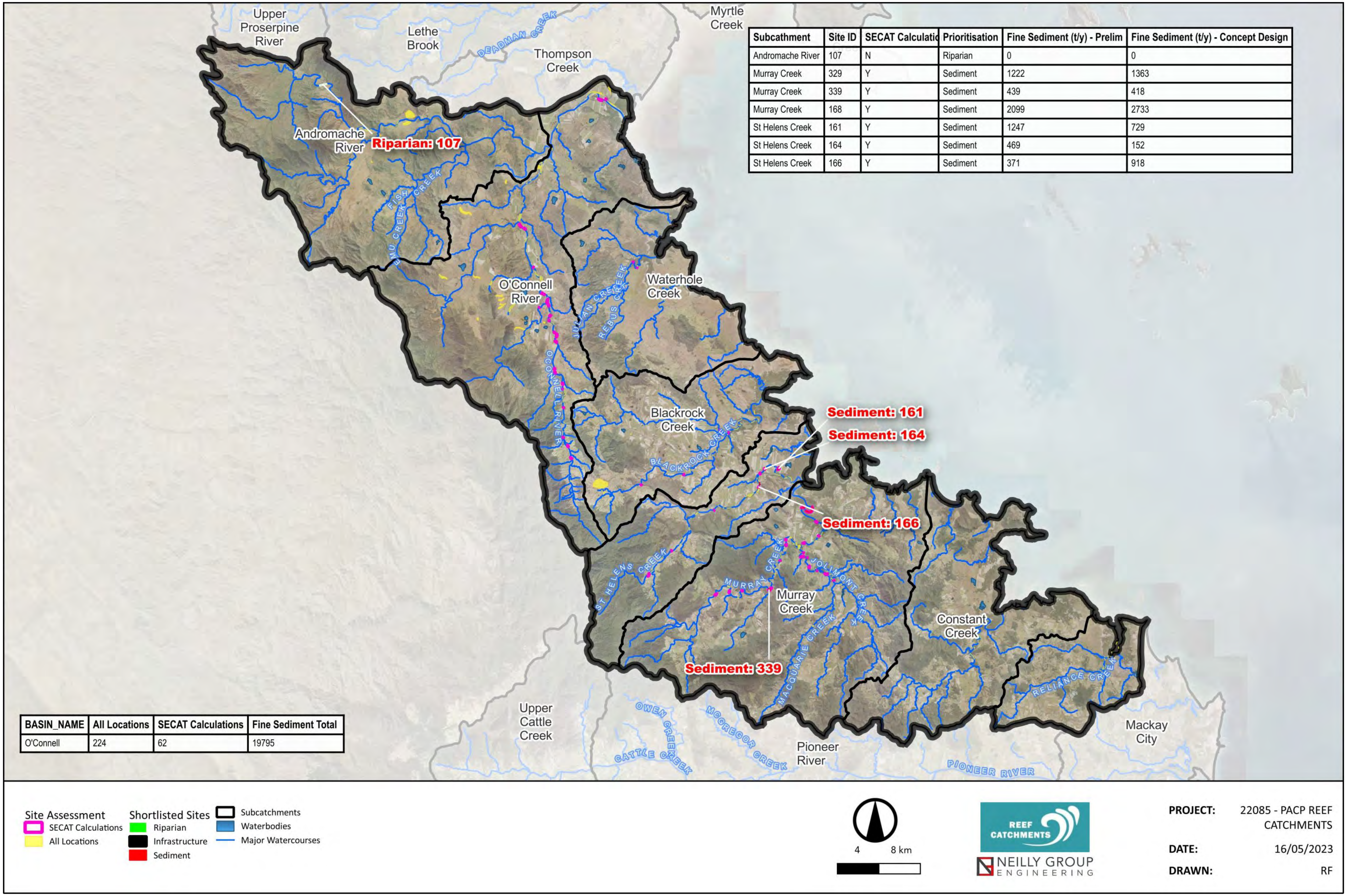


Figure 72. Overall results for the O'Connell River Basin



Subcathment	Site ID	SECAT Calculatic	Prioritisation	Fine Sediment (t/y) - Prelim	Fine Sediment (t/y) - Concept Design
Andromache River	107	N	Riparian	0	0
Murray Creek	329	Y	Sediment	1222	1363
Murray Creek	339	Y	Sediment	439	418
Murray Creek	168	Y	Sediment	2099	2733
St Helens Creek	161	Y	Sediment	1247	729
St Helens Creek	164	Y	Sediment	469	152
St Helens Creek	166	Y	Sediment	371	918

BASIN_NAME	All Locations	SECAT Calculations	Fine Sediment Total
O'Connell	224	62	19795

Figure 73. All locations, SECAT calculations and sites shortlisted for Concept Design in the O'Connell Catchment

6.5.3 Infrastructure Sites

There were no infrastructure sites prioritised as part of the study within the O'Connell Basin.

6.5.4 Sites Progressing to Concept Design

Seven sites from the O'Connell Basin were chosen to progress through to Concept Design (Table 10). Six of these sites are prioritised based on Sediment and one prioritised for Riparian Connectivity.

Table 10. Sites progressing to Concept Design from the O'Connell Basin

Site ID	Subcatchment	Proiritisation Reason	Preliminary SECAT (t/y)	Revised SECAT (t/y)
107	Andromache River	Riparian		
164	St Helens Creek	Sediment	469	202
166	St Helens Creek	Sediment	371	751
161	St Helens Creek	Sediment	1247	573
168	Murray Creek	Sediment	2099	4568
329	Murray Creek	Sediment	1222	1272
339	Murray Creek	Sediment	439	989

7 Pioneer Basin

The Pioneer River, with a catchment area covering 157,360 hectares, starts in the Pinnacle Ranges below Mount McBryde, near Pinevale, and outfalls into the Coral Sea at Mackay. The upper parts of the catchment are steep and remain covered by rainforests and open woodlands. The river is joined by ten tributaries, including Cattle Creek and Blacks Creek. The EPP (Waterway and Wetland Biodiversity) 2019 subcatchments for the basin include:

- Upper Cattle Creek
- Blacks Creek
- Pioneer River
- Mackay City.

Much of the upper catchment is declared protected area, and while the coastline is dominated by Mackay, Bassett Basin is a Declared Fish Habitat adjoining Pioneer River just prior to the ocean. As with all other major catchments in the Reef Catchments area, the Pioneer Basin outfalls to the World Heritage-listed Great Barrier Reef lagoon.

7.1 Riverine Environmental Values

The Clarke Connors Range reaches an altitude of 1276m at Mt Dalrymple near the Eungella township. The area is listed on the Register of the National Estate as one of the largest wilderness areas in Queensland with outstanding natural values (Reef Catchments 2014). The Pioneer River catchment has all streams draining into the Pioneer River before discharging into Sandringham Bay receiving waters in Mackay.

The Clarke Connors Range around Eungella is an area that has remained relatively stable during historic climate changes (Reef Catchments 2014), therefore supporting a number of endemic species, such as:

- 3 frogs
- 1 gecko
- 2 skinks
- Eungella honeyeater.

One of the key environmental values of the river is its rich biodiversity. The river hosts 34 species of native ray-finned fish, including the speckled goby, striped gudgeon, empire gudgeon, sea mullet, barramundi, and several types of catfish and eels (Queensland Government 2021). The river is known for its 'blue water' and is a vital habitat for various local and migratory bird species, including ducks, swans, pelicans, and cormorants. Freshwater turtles also frequent the river. The riverbanks are home to groups of platypuses (Ornithorhynchus anatinus) with burrows on the northern bank behind Melba House.

The river also provides recreational opportunities to the local community and visitors. Access to the river is mostly restricted due to freehold ownership, but there are some public access points, such as Edward Lloyd Park, Pleystowe (boat ramp), Mirani (Platypus Beach - next to the road bridge), Mia Mia, Pinevale, Gargett, and Neem Hall (Finch Hatton). The river is popular for canoeing, kayaking, platypus spotting, and swimming. It's also a favourite fishing spot, with local residents fishing for sooty grunter and barramundi.

High Ecological Value (HEV) waters under the EPP (Waterway and Wetland Biodiversity) 2019 are restricted to protected areas as well as the upper, forested, catchment of Blacks Creek. Stockyard Creek consists of the only riparian corridor within the basin (Figure 74).

The Clarke Connors range is listed in the Whitsunday NRM plan as being susceptible to erosion given its high elevation (Reef Catchments 2014).

The Mackay Whitsunday Stream Type Assessment (Alluvium 2017) shows that most streams in the region are considered as stable or only having minor instabilities, have good to moderate riparian vegetation coverage and are significantly confined by terraces. This is evident within the main channel of the Pioneer River itself which forms a large channel relatively disconnected from its floodplain except in the lower reaches.

Stream type assessment of the basin (Alluvium 2017) was undertaken and is replicated in Figure 76 to Figure 78 which will be referred to in later sections.

7.2 Land Use History

The Pioneer Basin includes Mackay and many of its surrounding suburbs, plus Marian and a few smaller regional towns. Approximately 29% of the region is designated “Conservation & Natural Environments”, including Pelion, Crediton & Mia Mia State Forests, which dominate the upper catchment. Approximately four percent of the catchment is designated as “Water”, including Teemburra Dam, built in 1997, which releases water into both Pioneer River and Cattle Creek.

The Pioneer Basin is dominated by primary production, with split between grazing (~23%), horticulture and crop production including sugar cane (~20%) and forestry (~18%). The Teemburra dam was constructed in 1997 for irrigation and town water storages. It releases water into Cattle Creek and the Pioneer River at a rate of 100ML/d regardless of downstream demand (Queensland Government 2021).

Vegetation clearing in the catchment between 1989 to present is relatively minor (Figure 75). However, the majority of cleared land was cleared prior to the 1980s to make way for sugarcane production around the hubs of Marian, Eton and Mirani.

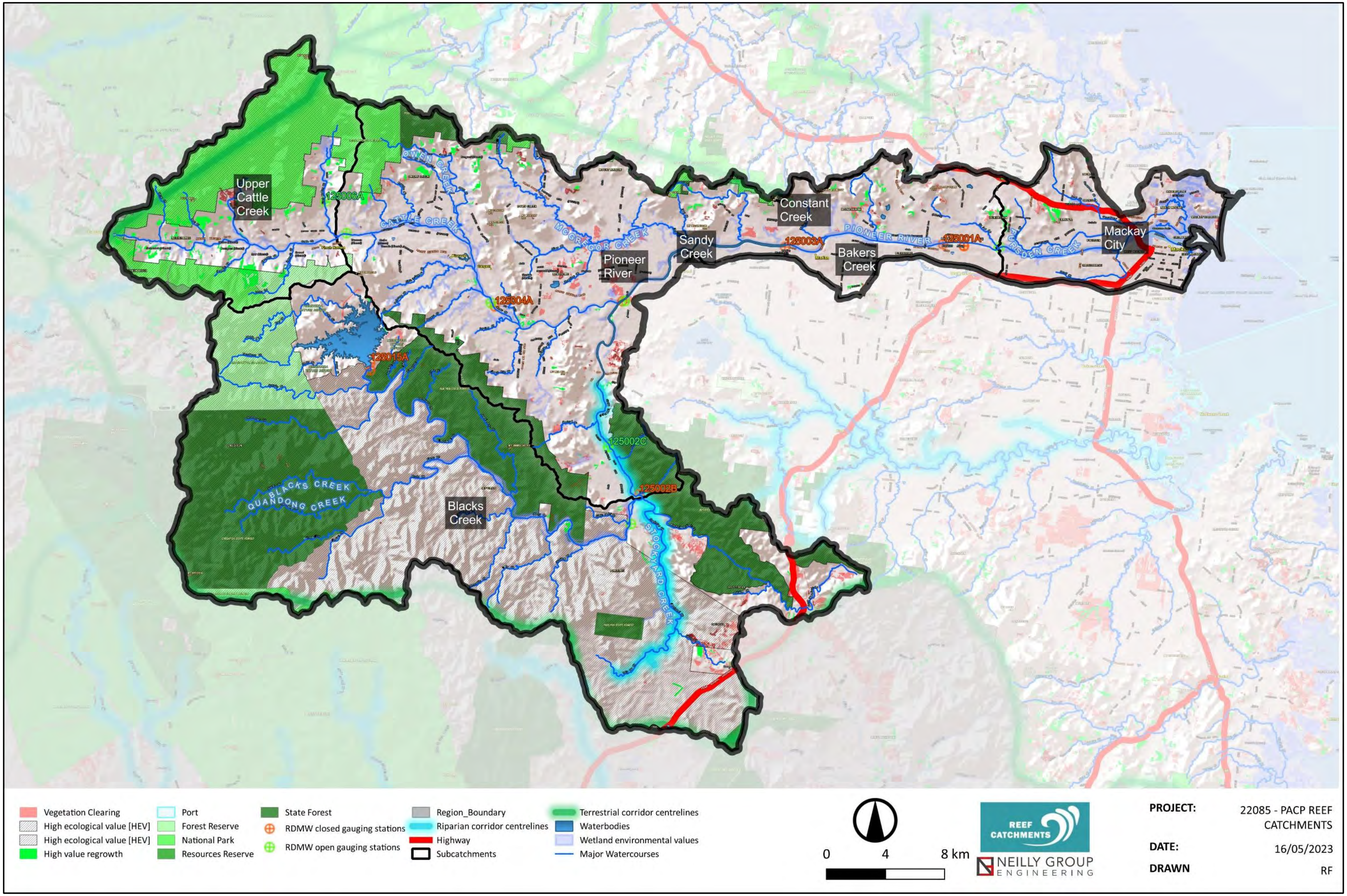


Figure 74. Overview of the Pioneer Basin

The picture can't be displayed.

Figure 75. Land Use in the Pioneer Basin

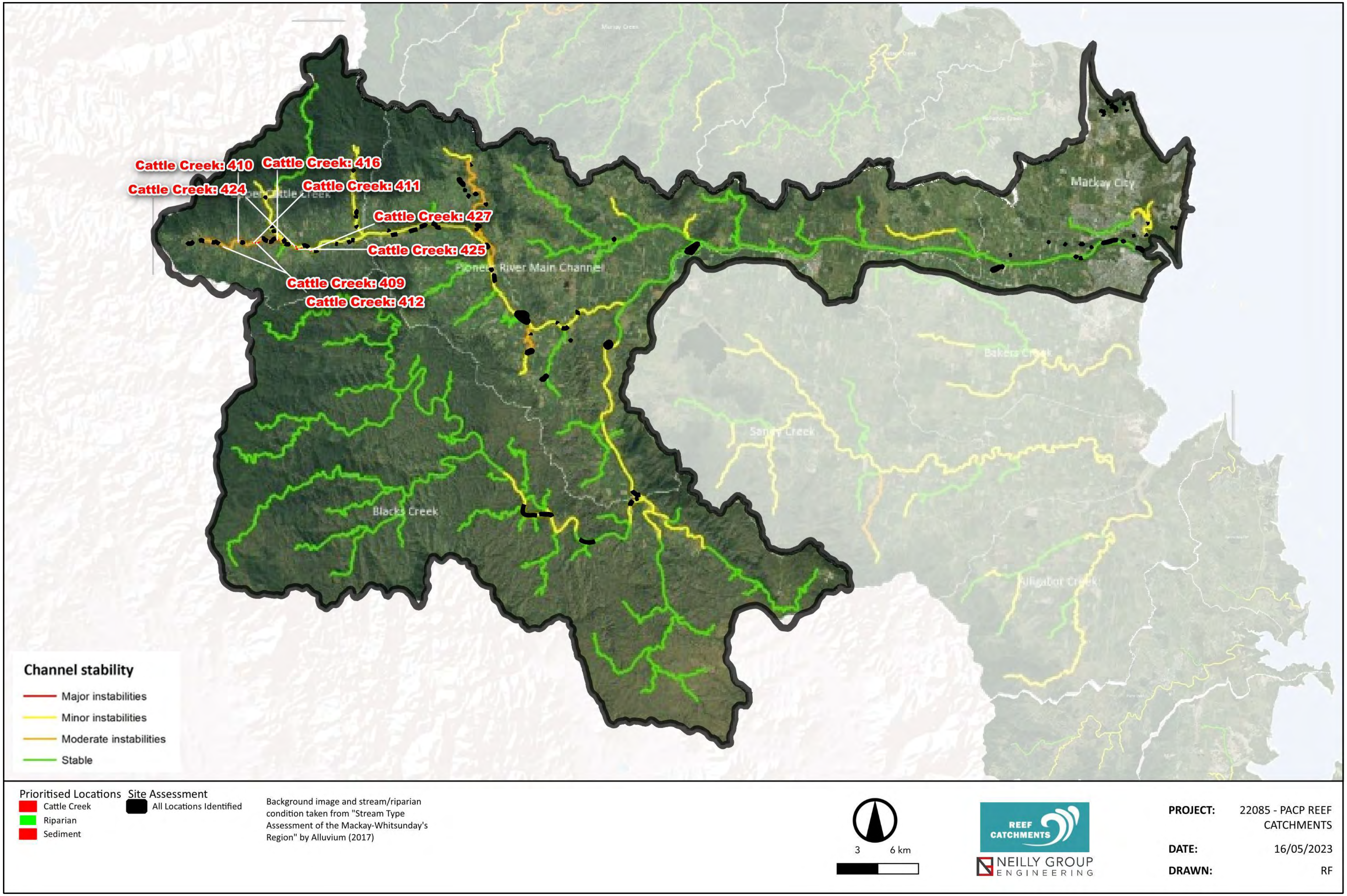


Figure 76. Channel stability for the Pioneer Basin as outlined in the Mackay Whitsunday Stream Type Assessment (Alluvium 2017)

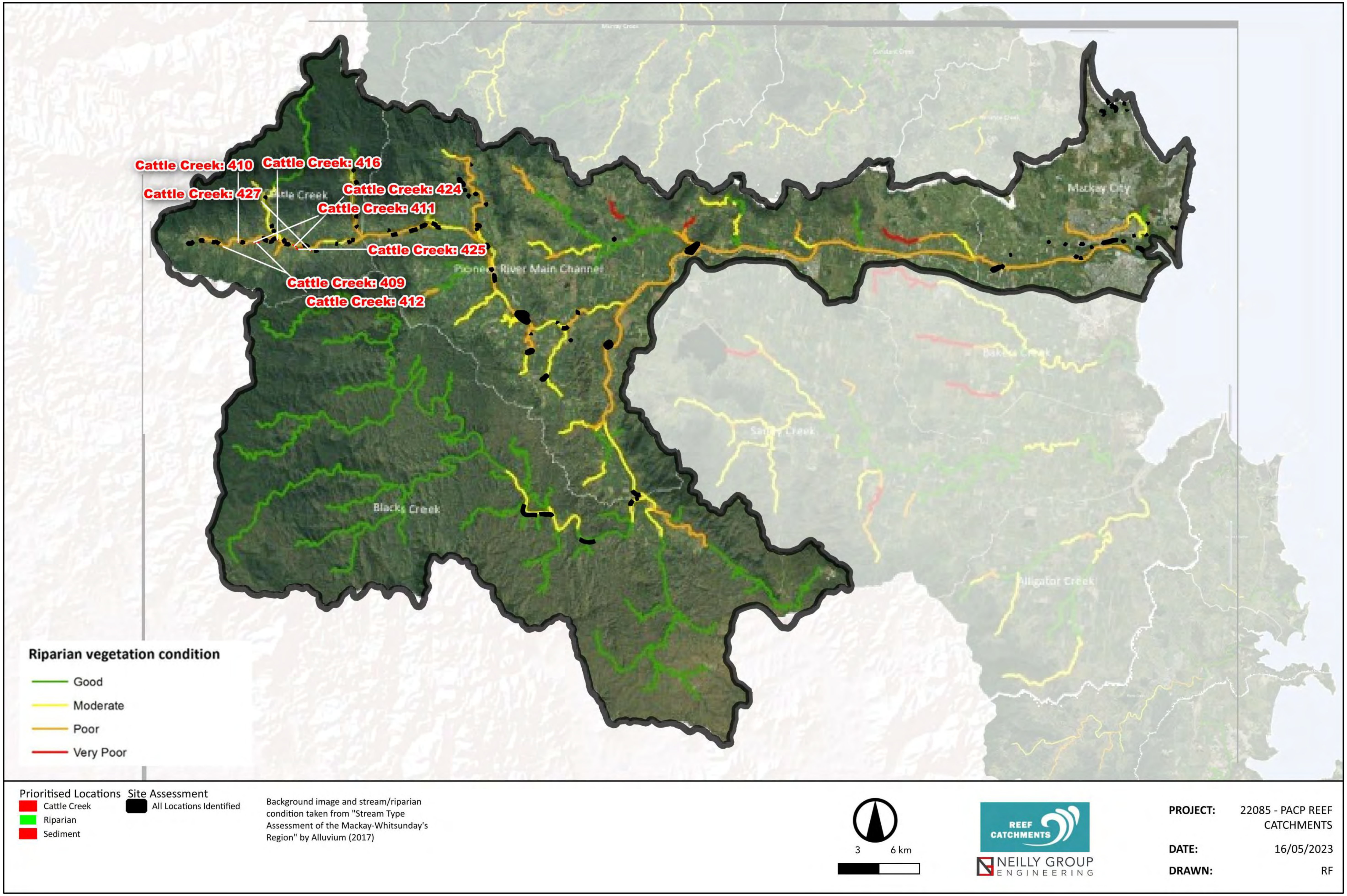


Figure 77. Riparian condition for the Pioneer Basin as outlined in the Mackay Whitsunday Stream Type Assessment (Alluvium 2017)

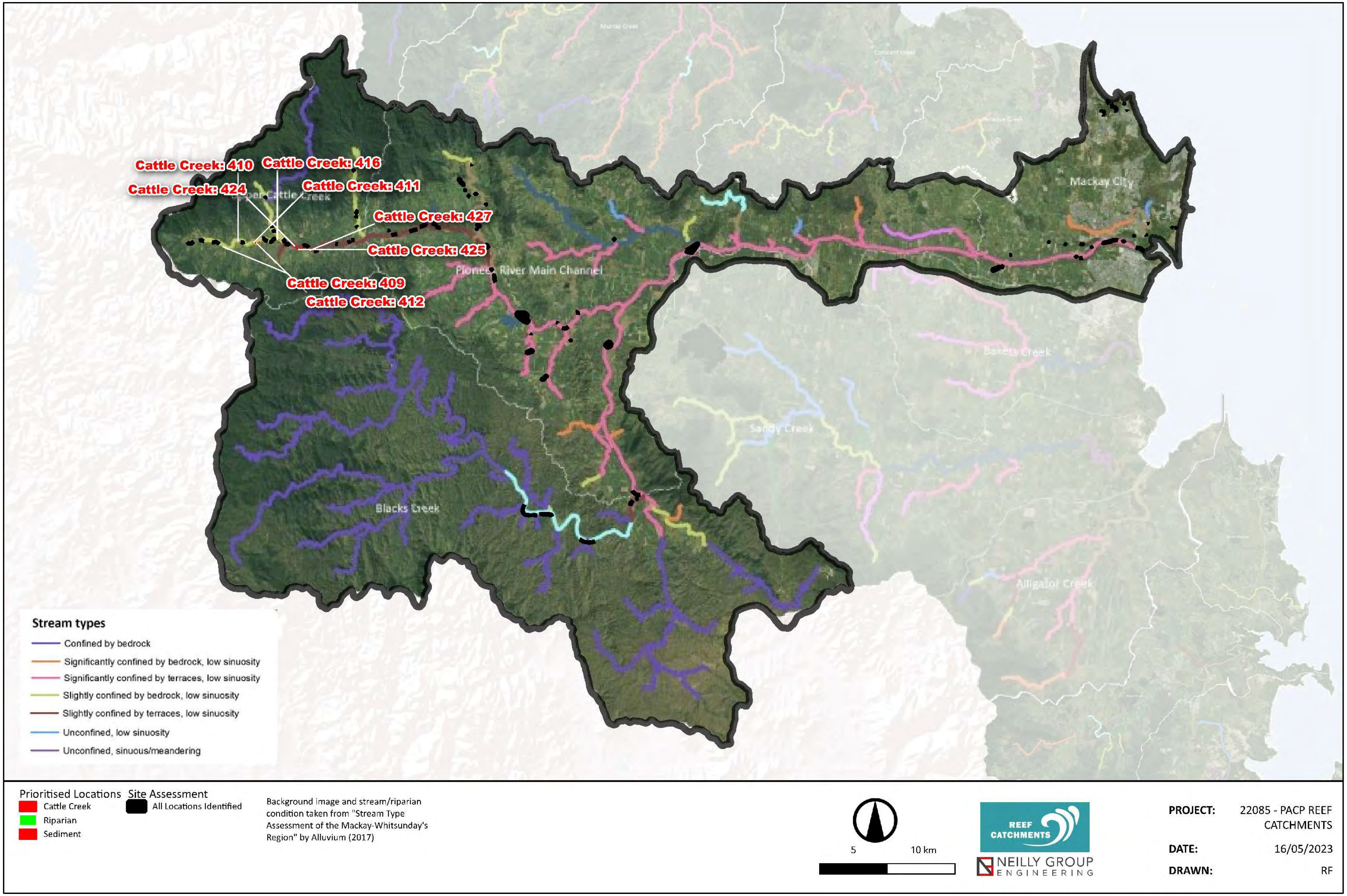


Figure 78. Stream type mapping for the Pioneer Basin as outlined in the Mackay Whitsunday Stream Type Assessment (Alluvium 2017)

7.3 Climate

The rainfall regime of the Pioneer Basin is described in Figure 79 which plots SILO gridded rainfall products across the basin (minimum yearly rainfall; maximum yearly rainfall; average yearly rainfall and the range of yearly rainfall).

Rainfall is more consistent on the coast compared to the upland areas of the Pioneer Basin. The average yearly rainfall is 1500-1700mm for the most populated areas of the basin, increasing beyond 1700mm in upland areas while Blacks Creek has a lower average annual rainfall of 1100-1300mm. Therefore, it is expected that discharge from the Cattle Creek catchment would be greater (on a per hectare basis) than Blacks Creek.

The range acts as a climate change refuge (Reef Catchments 2014) with the range likely to be wetter and cooler than elsewhere. Cyclone Ului caused major damage to the Eungella township in 2010 (Reef Catchments 2014).

Cattle Creek typically records the highest rainfall in the Pioneer catchment (Reef Catchments 2014). The steep elevation of the upper range ensures that downstream runoff is relatively rapid (Reef Catchments 2014).

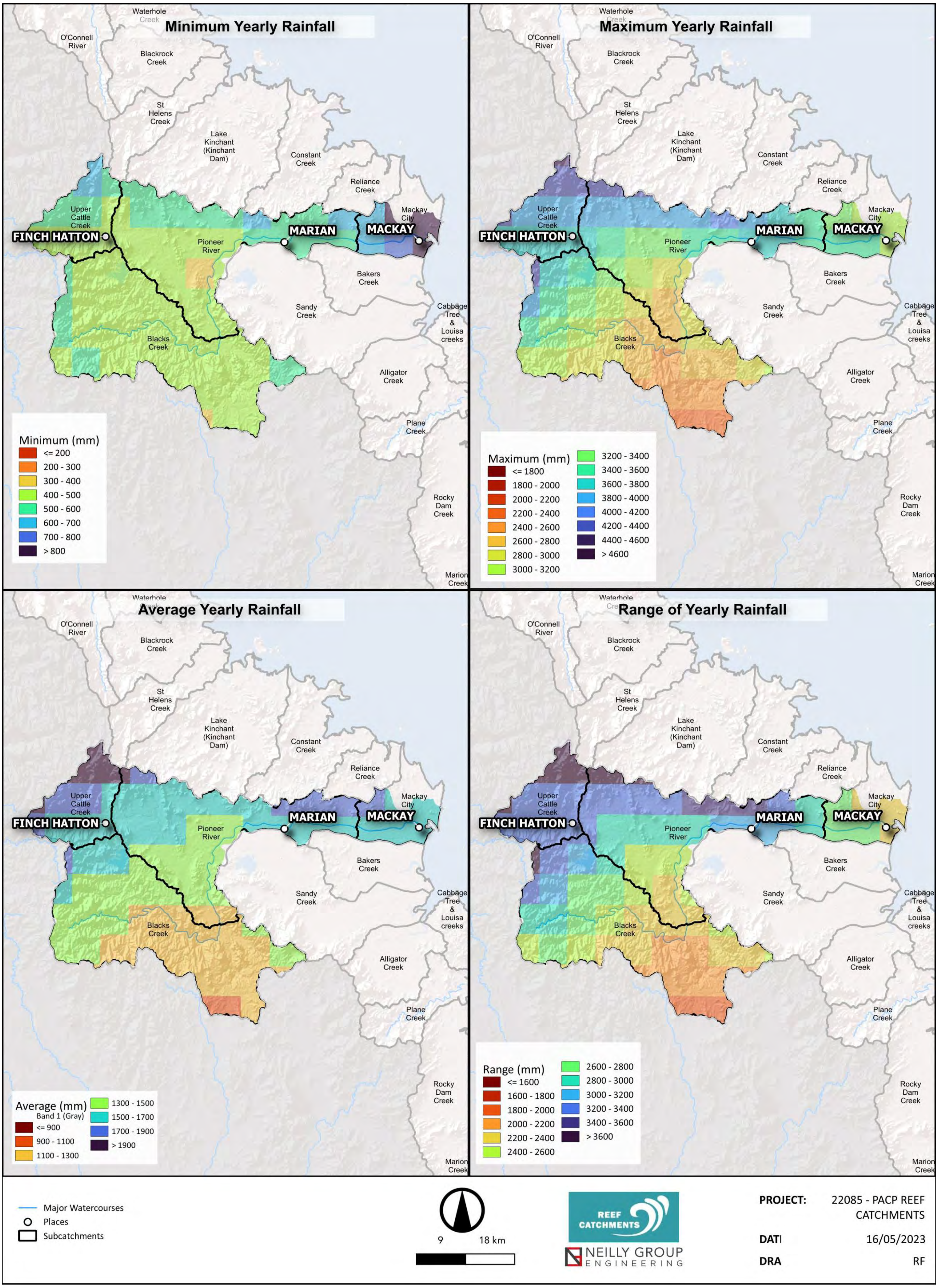


Figure 79. Climate of the Pioneer Basin

7.4 River Geomorphology

7.4.1 Cattle Creek

The headwaters of Cattle Creek originate in granite hills associated with the Eungella range. The width of the Creek has widened due to erosion and landslips (Queensland Government 2021). Granites have eroded into sodic soils.

As the region is in an elevated valley it receives higher rainfall than typical of the region with an average rainfall of 1500-1700mm compared to the lower floodplain with an average yearly rainfall of 1300-1500mm (Figure 79). Much of the higher yearly average is a result of more frequent, low intensity storms.

The Teemburra Dam releases 100ML/d into the lower areas of Cattle Creek regardless of demand. This combined with the higher and more frequent rainfall and the supply of baseflow from fractured rock aquifers in the surrounding foothills extends the flow duration of the system (Queensland Government 2021).

Cattle creek has a coarser sediment load than the Pioneer River or the adjacent Blacks Creek primarily due to the steep longitudinal gradient of the river system, increasing the influence of catchment clearing and sediment delivery to the main channel (Queensland Government 2021).

Successive floods have changed the river from a meandering system to a straighter channel due to the need to transport higher flood and sediment volumes (Queensland Government 2021). This was observed in this study during the comparison between 1970s imagery and recent imagery (Figure 80). The figure shows the main watercourse is highly active and has moved more than one stream width in several locations since the 1970s. Much of the older erosion has stabilised as the stream has cut down to bedrock (Queensland Government 2021).

Many of the farmers who manage the land parcels adjacent to Cattle Creek are third and fourth generation farmers. They recount stories of how, as teenagers, the local farming families would meet at the waterhole (Fellini's Hole) for picnics and barbeques and to swim in the "big deep holes". But over the last 10 to 15 years the cobbles and rocky rubble have deposited in the bed of the creek causing the main channel to choke up with vegetation and the channel to widen and migrate.

Bushfires around the Finch Hatton region in 2018 resulted in the burn-off of large areas of vegetation. Subsequent intense rainfall in the 2019 Monsoon Trough event transported an increased sediment load to Cattle Creek. This sediment load moves through the system in a series of slugs and is likely coarser than the typical sediments delivered to Cattle Creek.

Reef Catchments NRM was contacted by local landholders following intense storms in the 2022-2023 wet season which had caused further erosion at multiple locations. Field inspection by Neilly Group on the 18th of April 2023 identified several locations along the stream system which were adopted for Concept Design as a reach scale site.

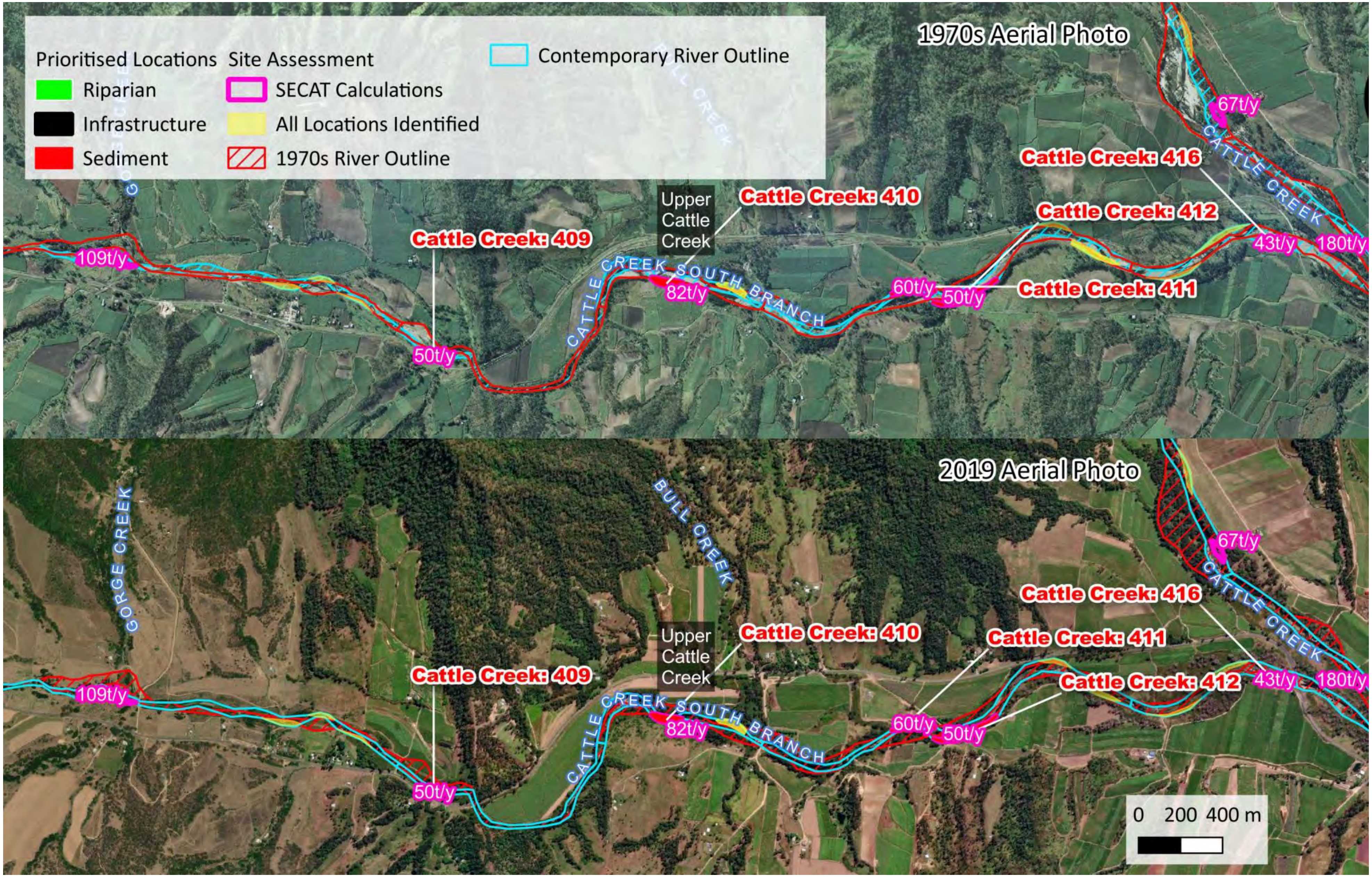


Figure 80. Channel changes in Cattle Creek from 1970 to present

7.4.2 Blacks Creek

The headwaters of Blacks Creek occur in steep bedrock-controlled valleys (Alluvium 2017). A significant proportion of the Blacks Creek catchment occurs in undisturbed steep forested mountain streams, therefore promoting high water quality. The headwaters of Blacks Creek typically receive far less rainfall than the adjoining Upper Cattle Creek catchment, however the upper areas of the catchment cover a much larger area (Figure 79). The Teemburra Dam captures a portion of the upper catchment with some releases into Cattle Creek.

In the mid-channel areas and towards the confluence with Cattle Creek, Blacks Creek is significantly confined by alluvial terraces (Figure 78) (Alluvium 2017). Blacks Creek and Cattle Creek merge to form the Pioneer River.

7.4.3 Pioneer River and Mackay City

The Pioneer River also has its headwaters in granite rocks associated with the Eungella range. However, the river system cuts through alluvial soils, as well as siltstone and mudstones, conglomerates and basaltic outcrops in some areas (Queensland Government 2021). The river primarily runs along a fault line. Historically the river channel may have occupied Cattle Creek and then down Sandy Creek (Queensland Government 2021).

The Pioneer River is the main river running through Mackay City. The river channel is significantly incised and confined to its relatively straight valley, ensuring that major flood events are effectively conveyed towards Mackay where they spill out across the floodplain. Weirs are installed in the river at:

- Marian Weir
- Mirani Weir
- Dumbleton Rocks Weir.

The presence of the weirs reduces the likelihood of erosion along the bank by reducing the hydraulic gradient longitudinally along the river. The large incision of the watercourse also ensures that there is limited opportunity for large-scale sediment entrainment along much of the river.

However, the river has been subject to historical sand and gravel extraction works, particularly in the lower reaches where it continues to this day.

Since the Pioneer River is heavily confined to its valley, temporal analysis of aerial imagery indicates there is little evidence of erosion or river migration between 1970 to present day along its entire length. Locations found were isolated areas of small lengths of bank movement, some of which it was difficult to determine whether it was purposeful / man-made structures or erosion of the high bank.

7.5 Identified Sites

7.5.1 All Locations

There were a total of 100 locations of potential erosion identified in the Pioneer Basin (Figure 81). The majority were found in the Upper Cattle Creek catchment followed by the Pioneer River and Mackay City catchments (Figure 82). There were five locations identified in the Blacks Creek subcatchment, three of which may be natural river migration at the upper end of land clearing within the catchment.

7.5.2 Total Sediment Reductions

The initial total estimated volume of fine sediment found within the Pioneer River Basin is 3465t/y with 1769t/y found within Cattle Creek and its tributaries and the remainder found in the Pioneer River and Mackay City subcatchments on relatively small sites.

Concept Design SECAT calculations undertaken for each site greatly increased the volume of sediment (Table 11). For example, in the case of upper Cattle Creek, the revised assessment (undertaken in more detail than the initial assessment) identifies fine sediment loss from these sites as 3391t/y.

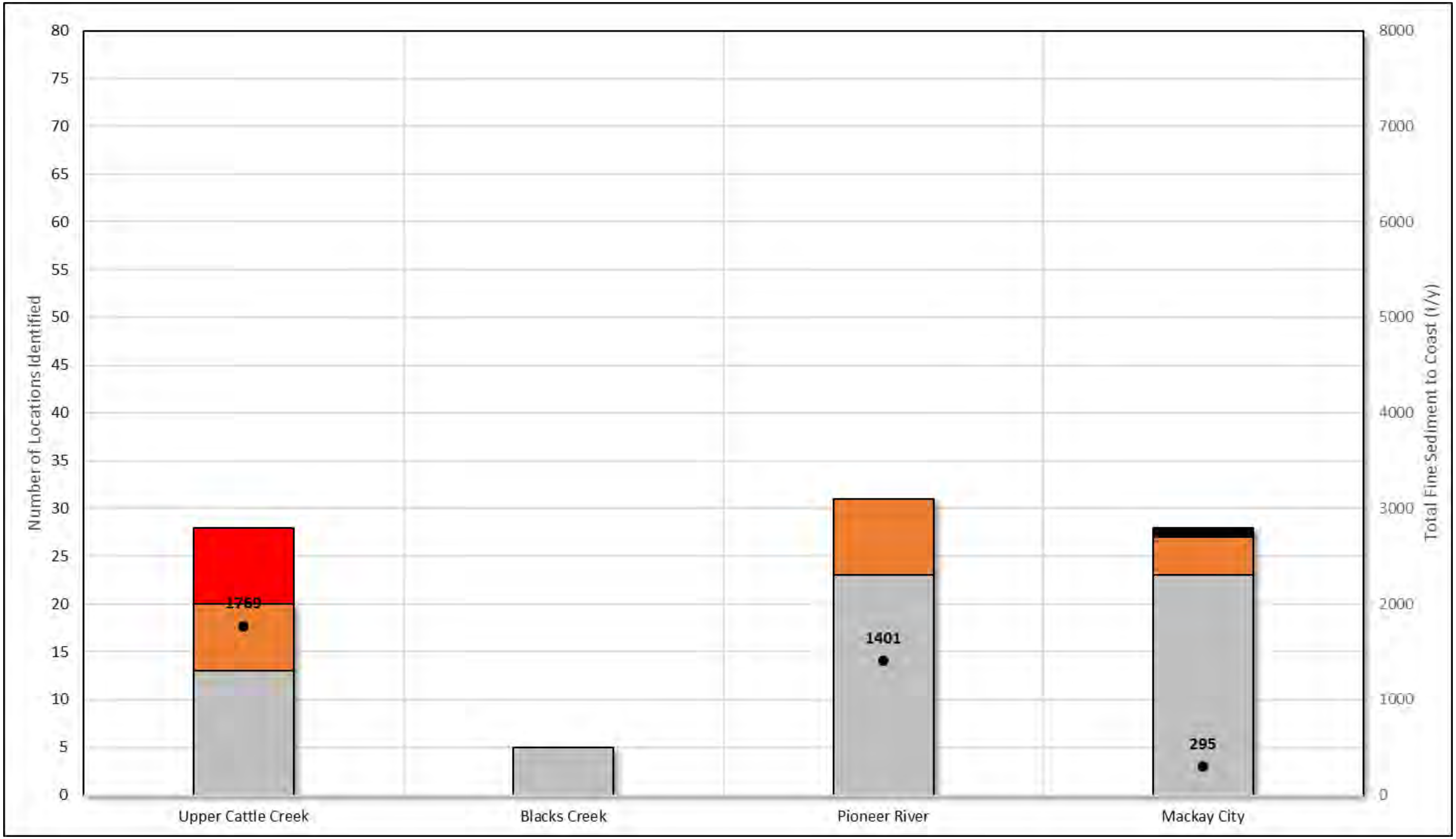
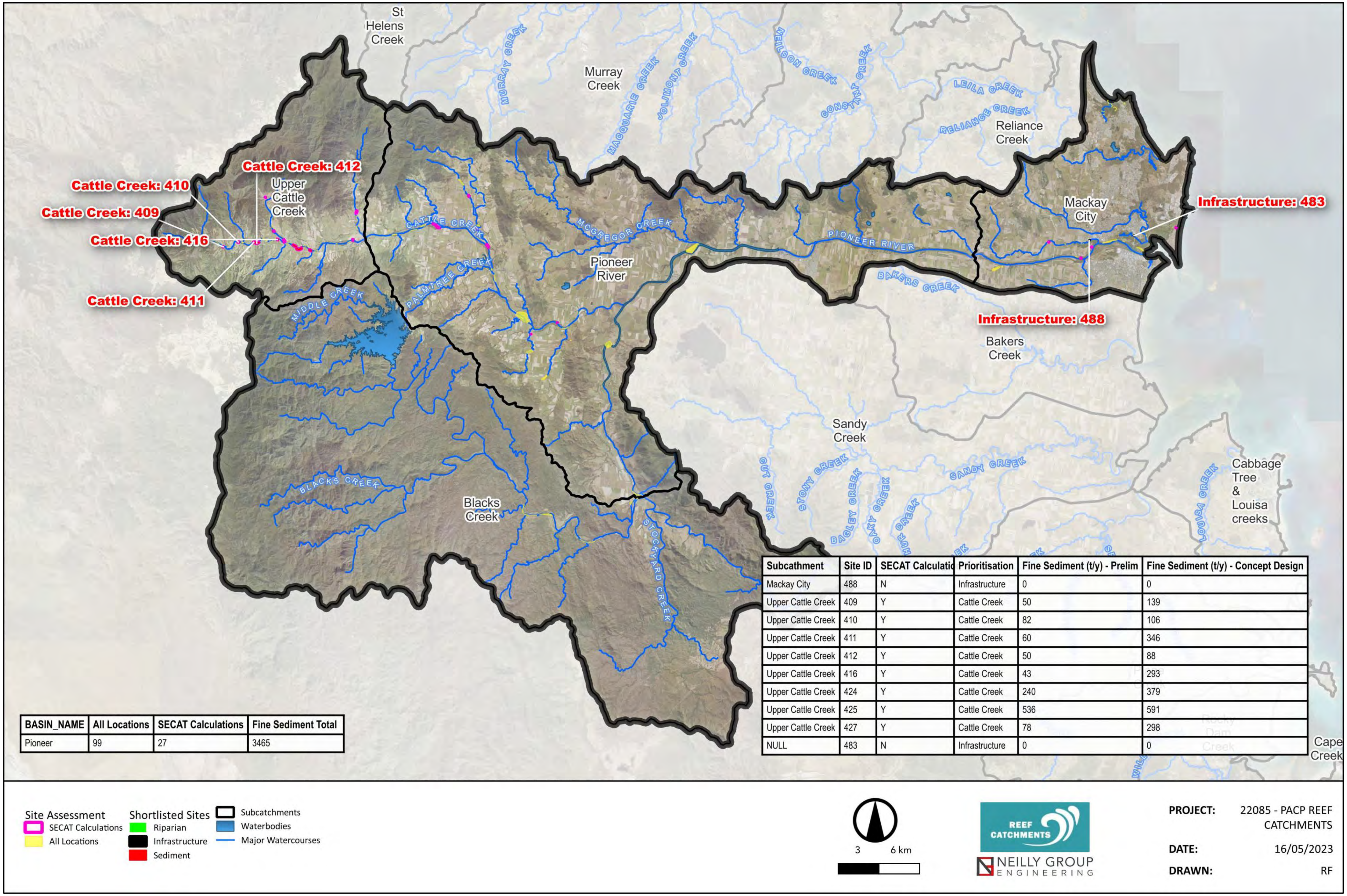


Figure 81. Overall results for the Pioneer Basin



BASIN_NAME	All Locations	SECAT Calculations	Fine Sediment Total
Pioneer	99	27	3465

Subcatchment	Site ID	SECAT Calculatio	Prioritisation	Fine Sediment (t/y) - Prelim	Fine Sediment (t/y) - Concept Design
Mackay City	488	N	Infrastructure	0	0
Upper Cattle Creek	409	Y	Cattle Creek	50	139
Upper Cattle Creek	410	Y	Cattle Creek	82	106
Upper Cattle Creek	411	Y	Cattle Creek	60	346
Upper Cattle Creek	412	Y	Cattle Creek	50	88
Upper Cattle Creek	416	Y	Cattle Creek	43	293
Upper Cattle Creek	424	Y	Cattle Creek	240	379
Upper Cattle Creek	425	Y	Cattle Creek	536	591
Upper Cattle Creek	427	Y	Cattle Creek	78	298
NULL	483	N	Infrastructure	0	0

PROJECT: 22085 - PACP REEF CATCHMENTS

DATE: 16/05/2023

DRAWN: RF

Figure 82. Overall of all locations, SECAT calculations and sites shortlisted for Concept Design in the O'Connell Catchment

7.5.3 Infrastructure Sites

There were two locations prioritised based on infrastructure criteria. An 80m long section of bank erosion is visible along Fursden Creek adjacent to a footpath / bike path. The other is a small section of Barnes Creek which is lacking in riparian vegetation immediately adjacent to a road, upstream of the intersection of Barnes Creek Road and Sams Road (Figure 83).

Figure 83. Prioritised infrastructure location in Mackay City – Site 488 (top) and Site 483 (bottom)

7.5.4 Individual Cattle Creek Sites Aggregated into Single Site

In April 2023, Reef Catchments contacted Neilly Group to request that the Cattle Creek system be assessed in more detail due to the impacts of three extreme weather events in the last three years. Cattle Creek is a fluid system which is experiencing significant channel change after each weather event.

The study identified eight individual sites but the nature of the cattle creek system and its position in the catchment meant that each of these individual sites were not prioritised within the top 20. However, once aggregated into a single "reach scale" site, the result was vastly different. Key criteria of the reach scale site include:

- Total fine sediment delivered to the coast: 3,319t/y
- Total fine sediment abated at the coast: 1,991t/y (0.6 effectiveness)
- Revegetation footprint: ~58,000m2 (~25,000 trees and shrubs).

The proposed remediation measures across the "reach scale" Cattle Creek sites are a combination of rock groynes, timber piles fields, bank battering and revegetation. Rootballs will be installed at some of the sites to improve habitat diversity. Rock groynes have been incorporated at some sites where piles are not viable due to the prevalence of large cobbles and boulders within the bed and banks.

Pile fields and rock groynes function in protecting the eroding bank by deflecting high velocity flow away from the toe of bank as well as creating a zone of low velocity against the toe to encourage sediment deposition. Rock groynes are substantially less permeable than timber piles, so create more scour off the end of the structure, as well as immediately downstream during overtopping of the structure. The impact of the overtopping causing further erosion is negated because the bed and bank material comprises a high boulder/cobble load. Any scour off the end of the groynes will be beneficial long-term as it will create deeper pools like the pre-developed, natural state of Cattle Creek and will provide improved geomorphic diversity and habitat for aquatic flora and fauna.

7.5.5 Sites Progressing to Concept Design

The locations which were progressed to the Concept Design are outlined in Table 11.

Table 11. Sites progressing to Concept Design from the Pioneer Basin

Site ID	Subcatchment	Prioritisation Reason	Preliminary SECAT (t/y)	Revised SECAT (t/y)
409	Upper Cattle Creek	Cattle Creek	50	216
410	Upper Cattle Creek	Cattle Creek	82	165
411	Upper Cattle Creek	Cattle Creek	60	537
412	Upper Cattle Creek	Cattle Creek	50	137
416	Upper Cattle Creek	Cattle Creek	43	455
424	Upper Cattle Creek	Cattle Creek	240	562
425	Upper Cattle Creek	Cattle Creek	536	876
427	Upper Cattle Creek	Cattle Creek	78	443
483	Mackay City	Infrastructure		
488	Mackay City	Infrastructure		
TOTAL			**1139**	**3391**

8 Plane Basin

Subcatchments of the Plane Creek Basin listed under the EPP (Waterway and Wetland Biodiversity) 2019 include:

- Bakers Creek
- Sandy Creek
- Alligator Creek
- Plane Creek
- Rocky Dam Creek
- Marion Creek
- Gilinbin Creek
- West Hill Creek
- Carmila Creek
- Flaggy Rock Creek.

Despite often being treated as a single catchment, the Plane Basin is a group of smaller river basins, with a total catchment area of approximately 250,000 hectares (Figure 84). Larger towns include Mirani and Walkerston and Sarina in the northern end of the basin. Other larger towns in the region include Bakers Creek, Eton, Koumala, Ilbilbie, Carmila and Clareview.

8.1 Riverine Environmental Values

Much of the upper catchment is declared protected area, along with Cape Palmerston National Park. Three DIWA-listed wetlands exist within the catchment bounds - Sandringham Bay, Sarina Inlet and Four Mile Beach, plus the Great Barrier Reef Lagoon borders the entire coastline of the catchment. Fish Habitat Areas and Dugong Protection Zones also cover much of the coastline.

Eucalypt woodlands historically occupied large portions of the basin with rainforests found at the ranges and foothills (Department of Environment and Science 2021). Most of the basin's original vegetation has been cleared in the last century for grazing and irrigated horticulture (Figure 85), and this has resulted in the direct loss of coastal ecosystems (Great Barrier Reef Marine Park Authority 2013). Woodlands that are still present should be protected to prevent further decline in connectivity with coastal ecoystems (Great Barrier Reef Marine Park Authority 2013). Many of the creeks and streams in the basin have poor water quality year-round (Great Barrier Reef Marine Park Authority 2013).

Sandy Creek and Cut Creek form a riparian corridor in the north leading from state forests in the west to the coast. Rivers within the Rocky Dam Creek, Marion Creek and Gillinbin Creek subcatchments also form major riparian corridors (Figure 84).

The results of the Mackay Whitsunday Stream Type Assessment (Alluvium 2017) are presented in Figure 86 to Figure 88 and are referenced in the following sections.

8.2 Land Use History

Approximately 32% of the region is designated "Conservation & Natural Environments", including Ben Mohr, Kelvin, Spencer Gap & West Hill State Forests, Mount Blarney CP and Cape Palmerston NP. Almost 9% of the catchment is designated as "Water", including Lake Kinchant, which sits in the upper reaches of the catchment and was formed by the construction of Kinchant Dam in 1977.

Collectively, land use in Plane Basin is split into horticulture and crop production including sugar cane (~26%), grazing (~22%) and forestry (~6%). This varies largely with location, however, with most of the horticulture and crop production occurring north of Sarina, or around Koumala, grazing fairly evenly distributed down to Carmila, and most of the “Conservation & Natural Environments” occurring from Cape Palmerston National Park and to the south. Sugarcane generally occurs in the northern areas with grazing occurring towards the southern areas of the basin (Figure 85).

Also of note in the catchment is the Port of Hay Point, one of the world’s largest coal export ports.

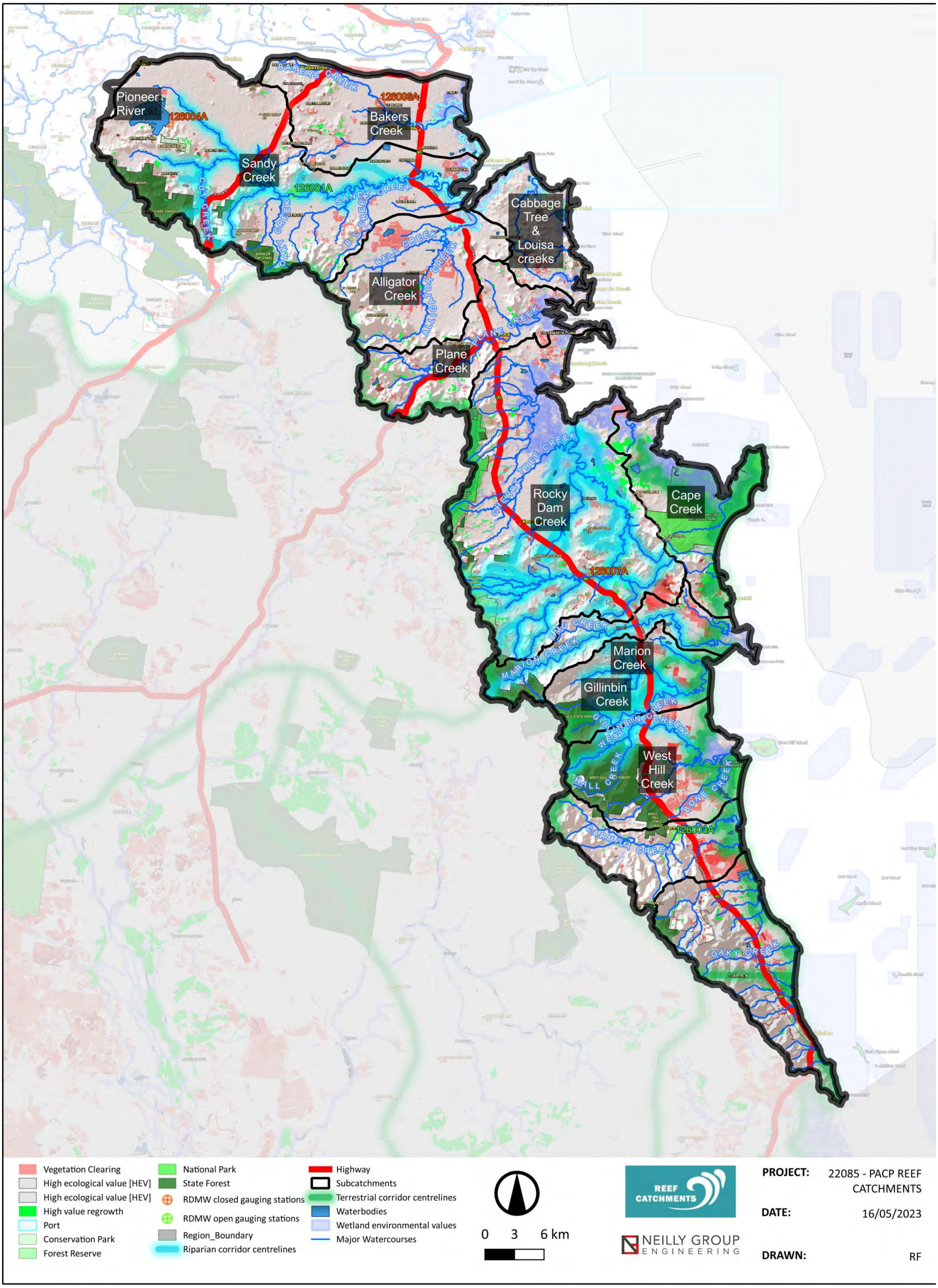


Figure 84. Overview of the Plane Creek Basin

The picture can't be displayed.

Figure 85. Land Use in the Plane Basin

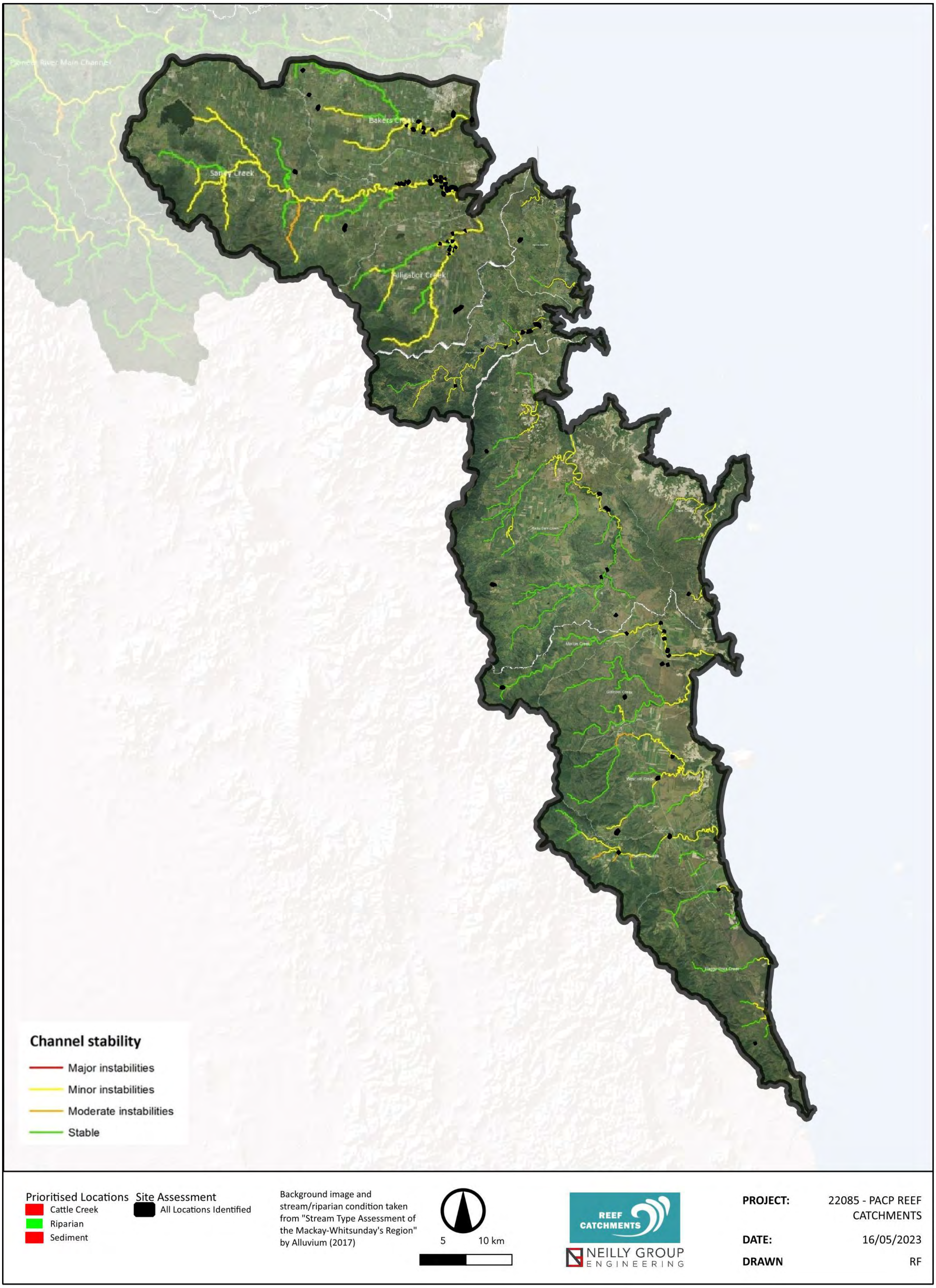


Figure 86. Channel stability of the Plane Creek Basin as outlined in the Mackay-Whitsunday Stream Type Assessment (Alluvium 2017)

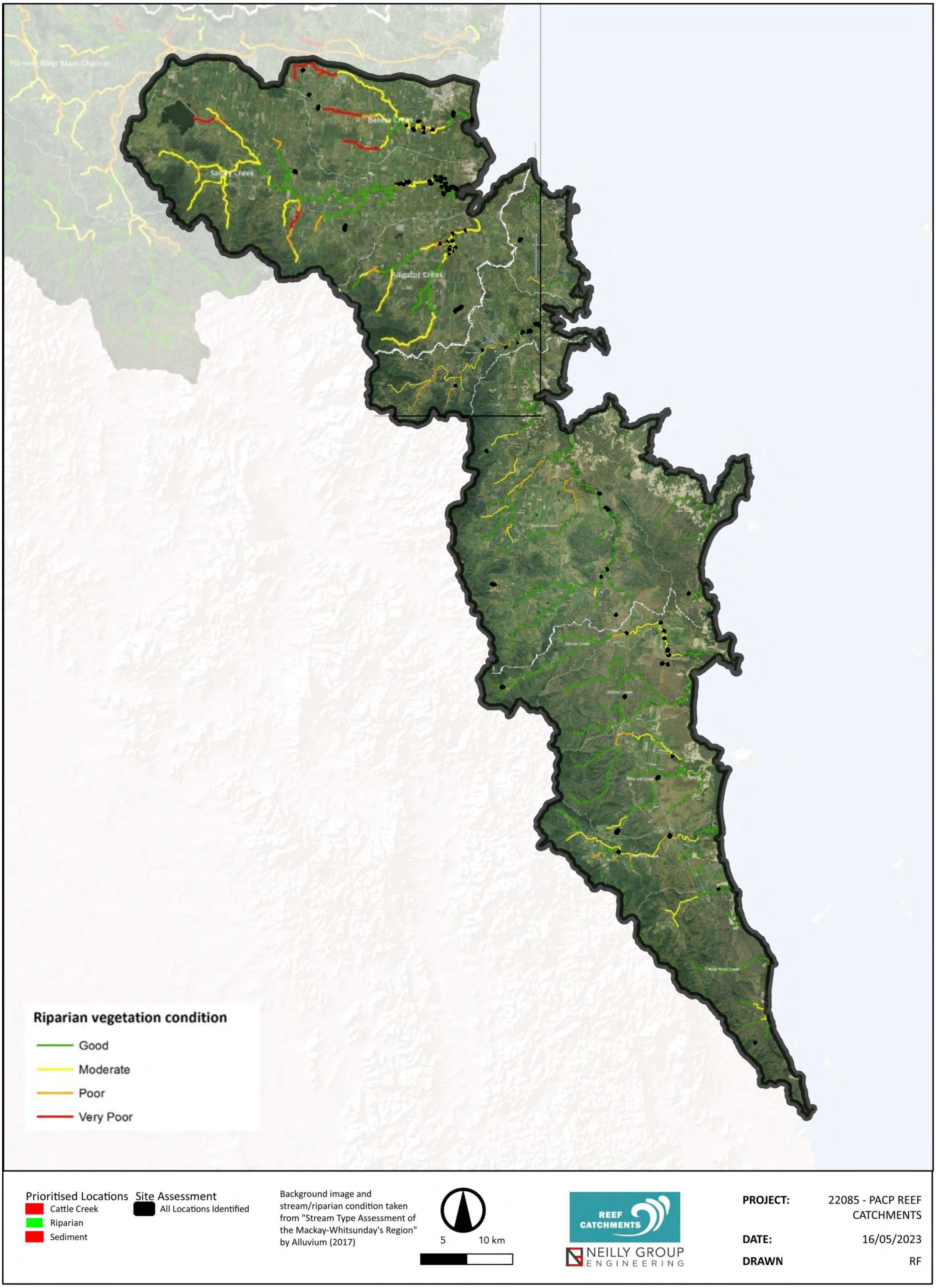


Figure 87. Riparian vegetation condition of the Plane Creek Basin as outlined in the Mackay-Whitsunday Stream Type Mapping (Alluvium 2017)

Figure 88. Stream type in the Plane Basin as outlined in the Mackay-Whitsunday Stream Type Mapping (Alluvium 2017)

8.3 Climate

The climate of the Plane Creek basin is generally drier than the other basins within the Reef Catchments NRM region. There is a distinct north-south trend in annual rainfall statistics (Figure 89). Rainfall is generally higher in the northern region and the foothills of the ranges.

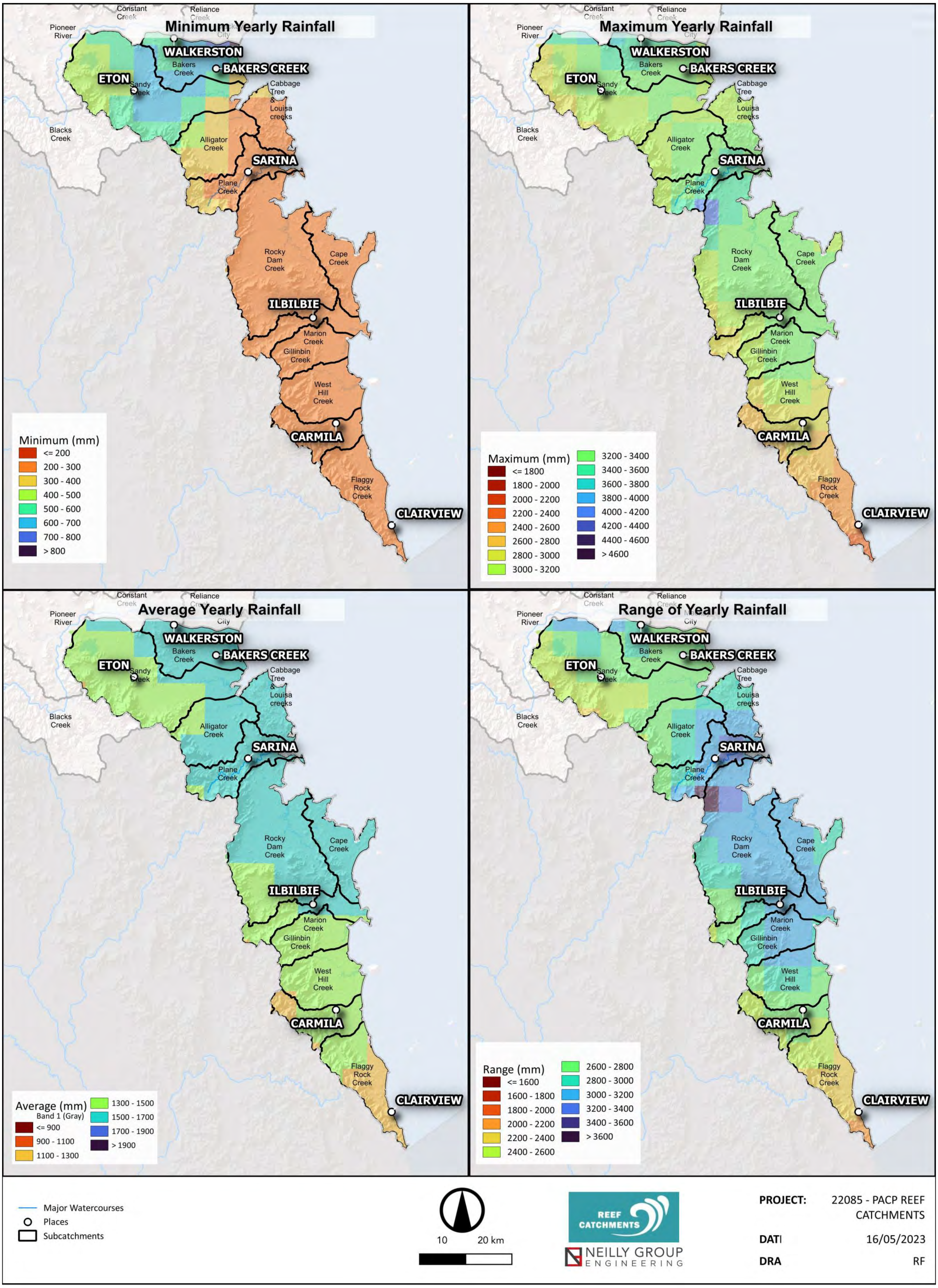


Figure 89. Climate of the Plane Creek Basin

8.4 River Geomorphology

The Plane Basin contains a number of drainage depressions, which either lack riparian vegetation through paddocks or have a complete absence of remnant vegetation, particularly in the north of the basin. An increase in waterway turbidity, which contributes to poor water quality, was observed in the northern basin when compared to the southern basin (Great Barrier Reef Marine Park Authority 2013).

8.4.1 Bakers Creek

The catchments of Sandy, Alligator, and Bakers Creek cover a region of 900 square kilometres within the southern Pioneer floodplain. Stretching from the headwaters of the Pioneer River near Mia Mia, it reaches the coastline situated between Mackay and Hay Point (Marsden, et al. 2006). Predominantly, this catchment area is influenced by sugarcane farming, along with some smaller regions dedicated to cattle rearing and forested areas. The catchment has witnessed substantial development, with approximately half of it being utilised for intensive agricultural practices. The area suffers from point-source pollution originating from Walkerston, which notably impacts Bakers Creek. The main channel of Bakers Creek is generally between 20-30 meters wide for the majority of its length before widening to 100-600 meters wide near the mouth (Queensland Government 2021). The riparian vegetation corridor is narrow and restricted to a few meters above the high bank however it has good longitudinal connectivity (Queensland Government 2021).

Reef Catchments have constructed a treatment train of sediment basins, a bio-retention basin and a fish ladder downstream of the Cowley's Road crossing (Alluvium Consulting 2017b). Flooding from Severe Tropical Cyclone Debbie in March 2017 caused undercutting of the fish ladder (Alluvium Consulting 2017b).

Based on a comparison of aerial imagery from the 1970s and present day an area of approximately 5ha has infilled downstream of the Bruce Highway (Figure 90). This area has been colonised by marine vegetation, which is found upstream, downstream and opposite the location.

Four locations were assessed for fine sediment loss either side of the Bruce Highway (Figure 90). These locations are identified as having recent bank movements since 2017.

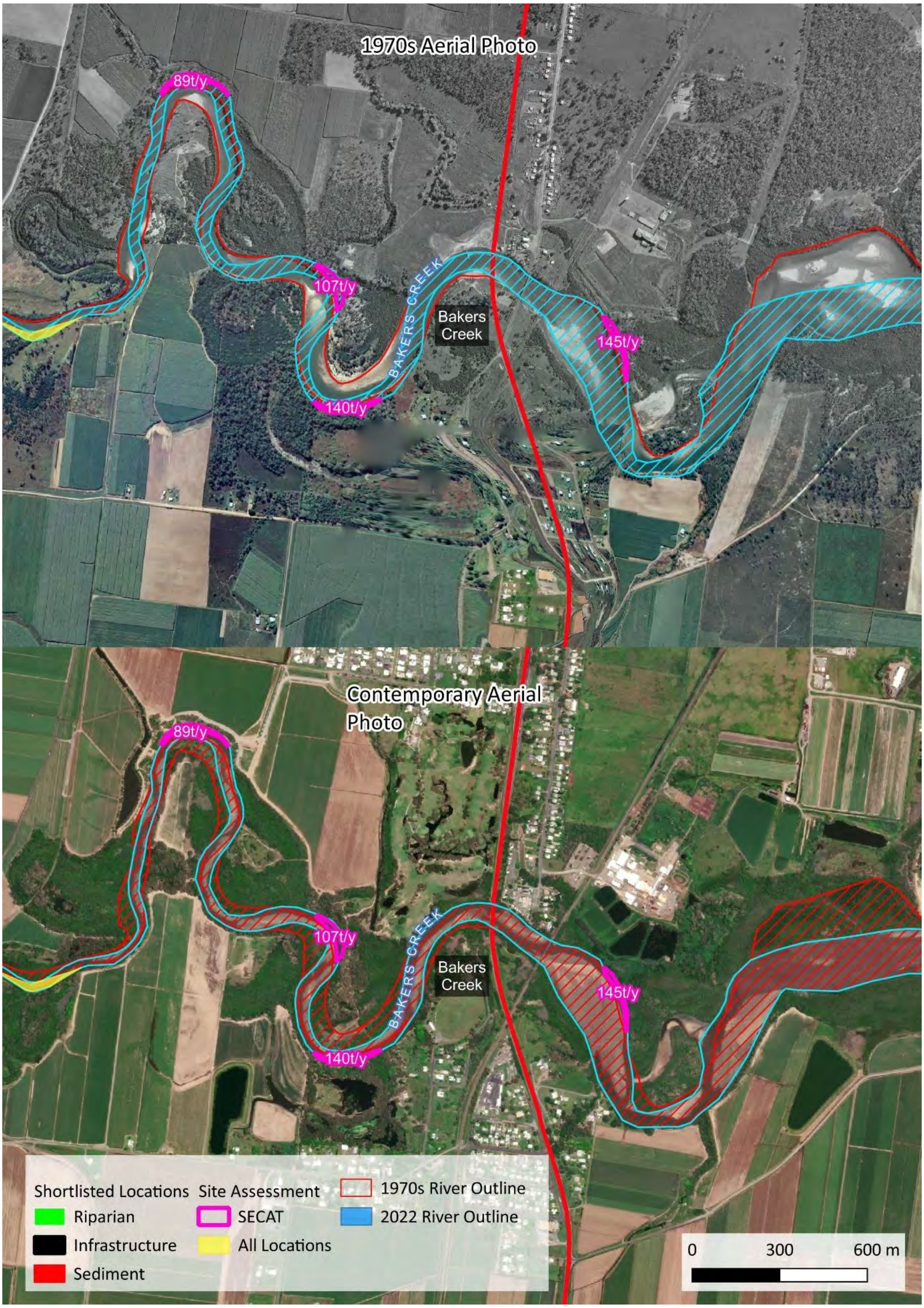


Figure 90. Area that has infilled in Bakers Creek downstream of the highway

Despite being at the very mouth of the river system the Bakers Creek Conservation Park, including infrastructure such as small buildings and roads, is at risk of riverine erosion in the longer term.

Based on a comparison of aerial imagery from the 1970s and present day, the riverbank shows approximately 81m of retreat over 50 years (Figure 91). There is the potential for a large storm event to cause significant riverine damage to the shoreline as identified in the image below. In the longer term there is the potential for the river to break through and create a new mouth to the ocean.

Figure 91. Bakers Creek Conservation Park at risk of further erosion

8.4.2 Sandy Creek

The Sandy Creek catchment is predominantly lowland and contains the Kinchant Dam. The subcatchment drains from the Ben Mohr State Forest and Mt Kinchant. The main population centre within the Sandy Creek catchment is Eton. Sandy Creek is perennial.

The Mackay Whitsunday Stream Type Assessment (Alluvium 2017) indicates that much of the non-estuarine reaches of Sandy Creek are significantly confined by bedrock and terraces with most of the main waterway having good riparian vegetation. However, the upper reaches of Sandy Creek are mapped as having moderate condition riparian vegetation. This is verified from examination of contemporary aerial imagery in which the banks of Sandy Creek are not visible due to the thick riparian vegetation coverage therefore it was not possible to delineate major changes in the river system. However, since the banks are highly vegetated, it is unlikely that major erosion features are present.

There are several backwater wetlands and old meanders cutoffs visible along the mid-lower reaches of Sandy Creek, indicating that the stream system is highly active in recent geological history. However, no features of discernible bank movement were detected as part of this study until the lower reaches approximately 4.3km upstream of the Bruce Highway and further downstream. There are several locations where stream bank erosion is occurring into or in very close proximity to sugarcane paddocks which have been cultivated to the top of bank. In the area downstream of the Bruce Highway, approximately the Sandy Creek estuary, extensive clearing has occurred at almost each meander bend of the highly sinuous lower reach. Subsequently bank movement features were identified. Comparison between the 1970 orthophoto and contemporary imagery indicates that this section of Sandy Creek is highly active with a total of 22 sites found. However, only a nine of these features were identified as having any activity since 2017 and therefore underwent SEACAT calculations (Figure 92).

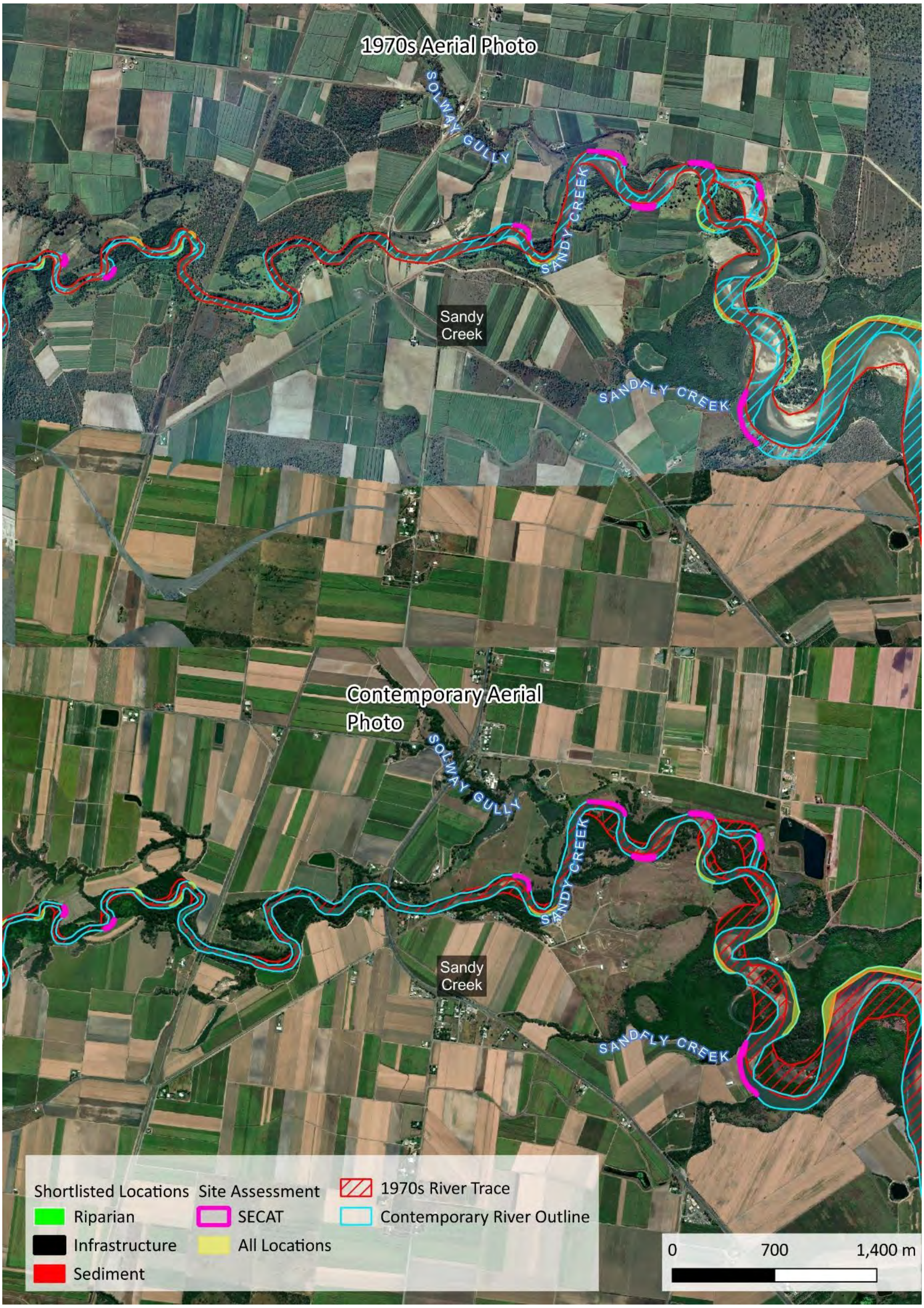


Figure 92. Historical river migration of Sandy Creek

According to the report titled Mackay-Whitsundays Cyclone Debbie Post Flood Assessments: Overview of Flood Events and Channel Change (Alluvium Consulting 2017b), Oaky Creek converges with Sandy Creek. The report further elaborates that the lower segments of Oaky Creek wind their way through sugarcane and horticultural plantations. A longstanding history of limited riparian vegetation cover has led to the stream channel undergoing straightening through meander cutoffs.

The report goes on to highlight that this alteration in the channel's course had significant repercussions during periods of high-flow intensity linked to Severe Tropical Cyclone Debbie in 2017. The erosion prompted by Cyclone Debbie posed a potential threat to farmland, access roads, a water main, and a power pole. Additionally, there has been considerable deposition of cobbles within sugarcane fields in certain areas.

8.4.3 Alligator Creek

The Alligator Creek Basin consists of Bell Creek, Alligator Creek and Splitters Creek that drain from Mt Alice and the Shylo and Roxy nature refuges, respectively. Based on a comparison of aerial imagery from the 1970s and present day, most of the catchment has been cleared in the last 50 years. This would have increased the sediment load to these major creeks. There has not been much channel change since 1970 outside of the lower reach within and/or near the tidal zone (Figure 93). However, 11 locations of recent erosion were identified.

Saltwater Creek is also within the Alligator Creek Basin but does not originate in the range, instead commencing in the lowlands as a floodplain channel.

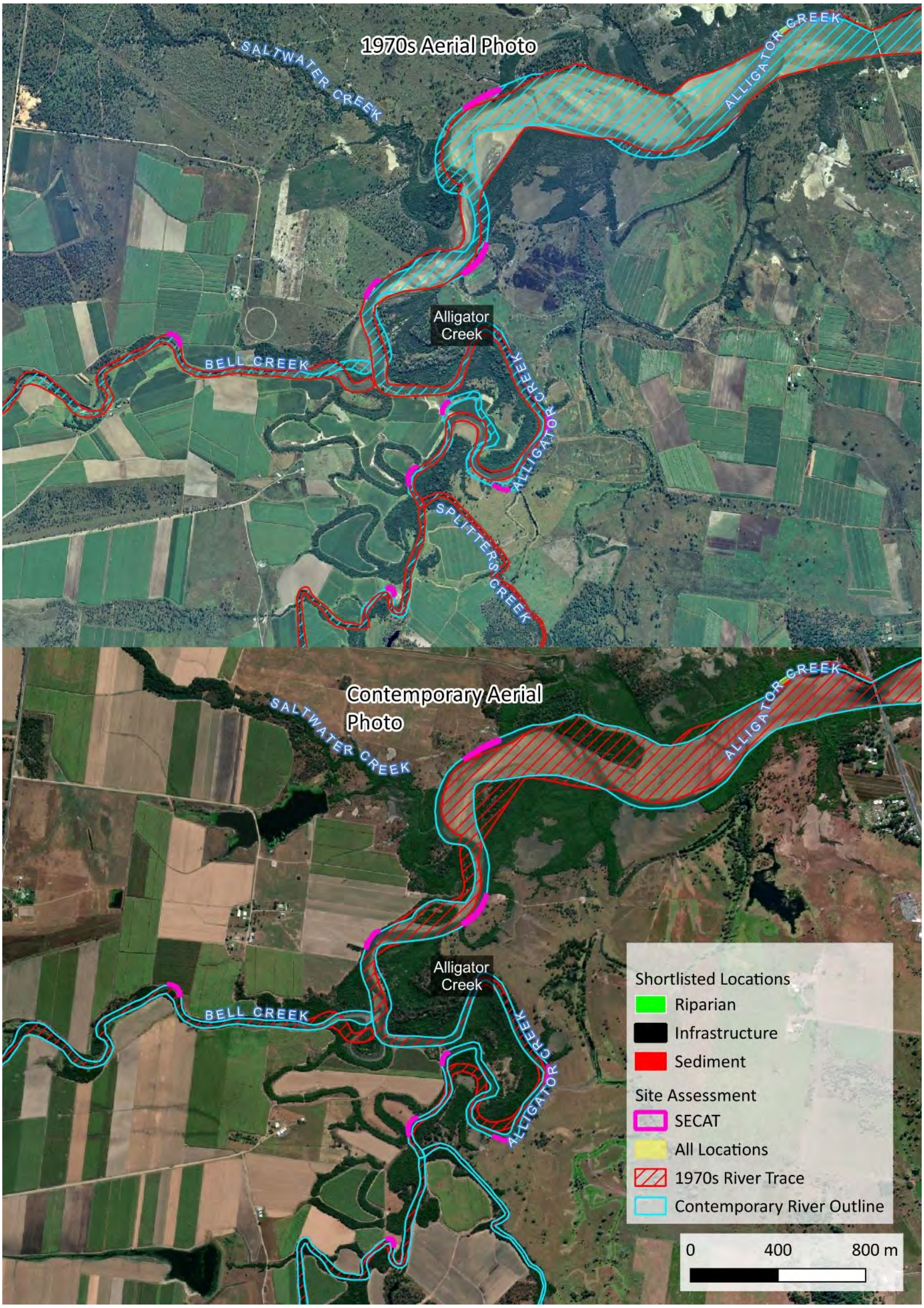


Figure 93. Recent bank movements along Alligator Creek

8.4.4 Plane Creek

The headwaters of Plane Creek occur in hard siltstone, mudstone, sandstone and conglomerates with a fault line running along the coast (Department of Environment and Science 2021). Rainfall is generally higher over the upland areas of the subcatchment which increases the flow duration further downstream (Department of Environment and Science 2021). However, there are a number of weirs that regulate flow along the length of the system.

Fish habitat within Plane Creek is expected to be poor, with a reduction in riverine habitat a result of infrastructure development which has ponded the stream for much of its length (Marsden, et al. 2006).

Downstream of the Bruce Highway, Plane Creek experiences a mild constriction due to terraces, as described in the report "Mackay-Whitsundays Cyclone Debbie Post Flood Assessments: Overview of Flood Events and Channel Change" (Alluvium Consulting 2017b). The report indicates that the flows associated with Severe Tropical Cyclone Debbie led to erosion occurring around 150 meters downstream of the Bruce Highway. However, a more significant impact was observed in the town of Sarina. During the cyclone event, a substantial portion of Sichter Street in Sarina was eroded due to the migration of the riverbank, resulting in the removal of around 12 to 15 meters of land, as documented in the same report. This erosion left behind a steep, vertical bank towering approximately 5 to 7 meters in height near a local park.

Notable bank movement downstream of the Bruce highway was found as part of this study. This site (510) has been prioritised for its potential impact on the nearby Brewers Road and associated houses (Figure 94).

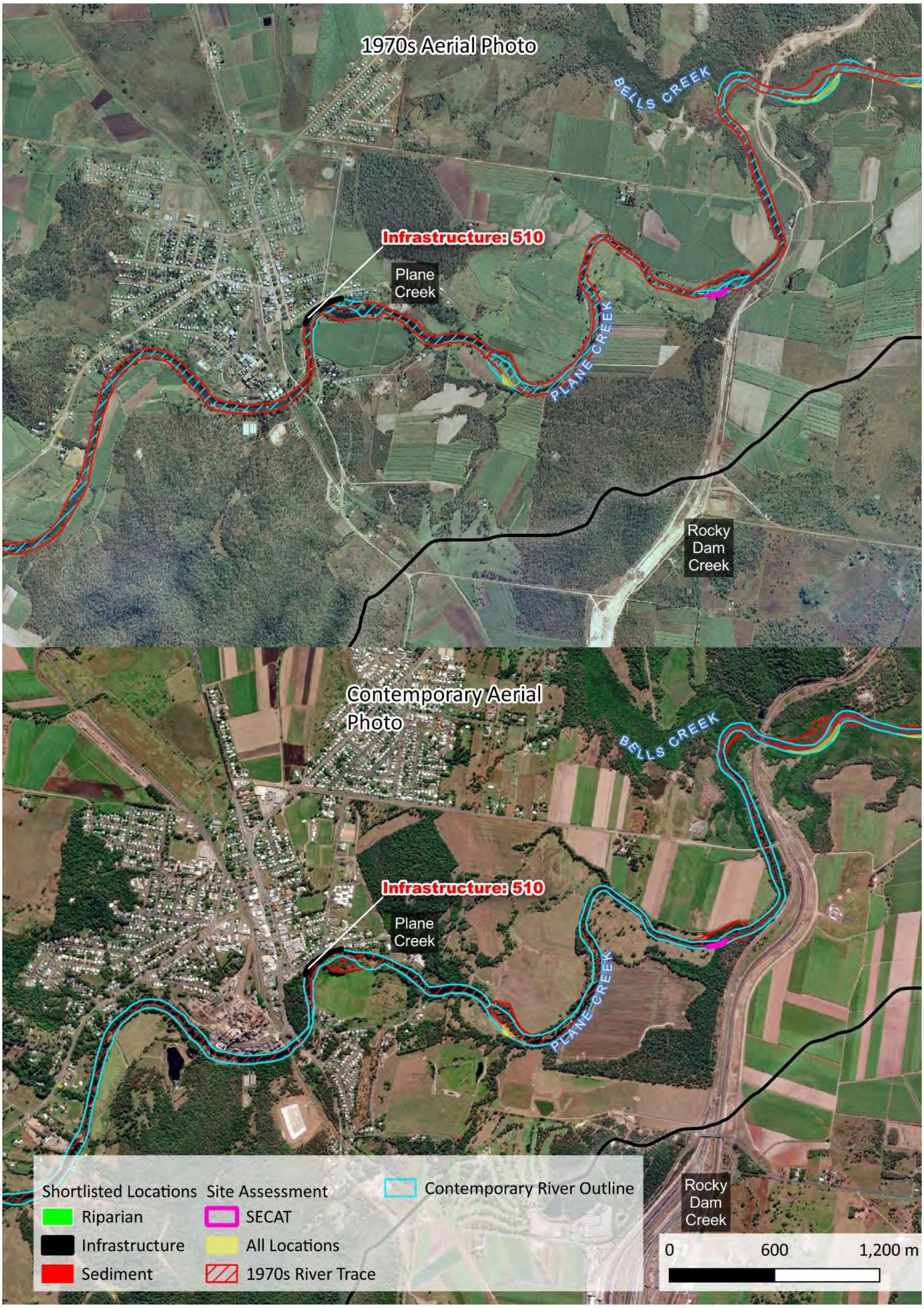


Figure 94. Bank movements of Plane Creek from the 1970s to present

8.4.5 Rocky Dam Creek

The Rocky Dam catchment covers 500km^2 stretching from south of Sarina to Ilbilbie with the dominant land uses comprising cattle grazing and sugarcane (Marsden, et al. 2006). Riparian habitat is moderately disturbed (Marsden, et al. 2006) with the areas around smaller streams in the upper catchment being completely cleared. Most of the catchment has been cleared for sugarcane, leaving a narrow strip of riparian vegetation along the major waterways further downstream.

The upper channel of Rocky Dam Creek is relatively narrow and confined by bedrock (Alluvium 2017). In the mid-reaches the waterway is significantly confined by terraces with pockets of reduced terraces revealing inset floodplains (Alluvium 2017).

The subcatchment has a relatively flat gradient with the majority of Rocky Dam Creek consisting of heavily meandering estuarine channel. Even in the mid reaches, Rocky Dam Creek is relatively sinuous. The lower reaches are heavily meandering and indicate a channel that has been active over the recent geological timescale. There are multiple meander cutoffs visible in aerial imagery.

Even with two DEM's to create a DEMoD over most of the catchment, which makes this assessment easier, there were few erosion sites identified. The only active locations of stream migration are within the highly meandering estuarine sections of Rocky Dam Creek which are surrounded by salt flats, mangroves and other sensitive species. Two locations outside of this zone were identified as having recent bank movements and were subject to SECAT calculations (Figure 95). The extent of land clearing within the catchment is also evident, as well as the riparian corridor which still remains around Rocky Dam Creek, forming an official biodiversity corridor.

Preliminary SECAT calculations for the two sites identified a total of 1306t/y, with Site 336 having 991t/y and site 504 having 315t/y of fine sediment delivered to the coast. Site 336 is a large 12m high, 116m long near-vertical bank of Rocky Dam Creek which has lost riparian vegetation along the top of bank (Figure 96). Because of its height and near-vertical nature, small shifts in the top of bank position will result in relatively large sediment volumes.

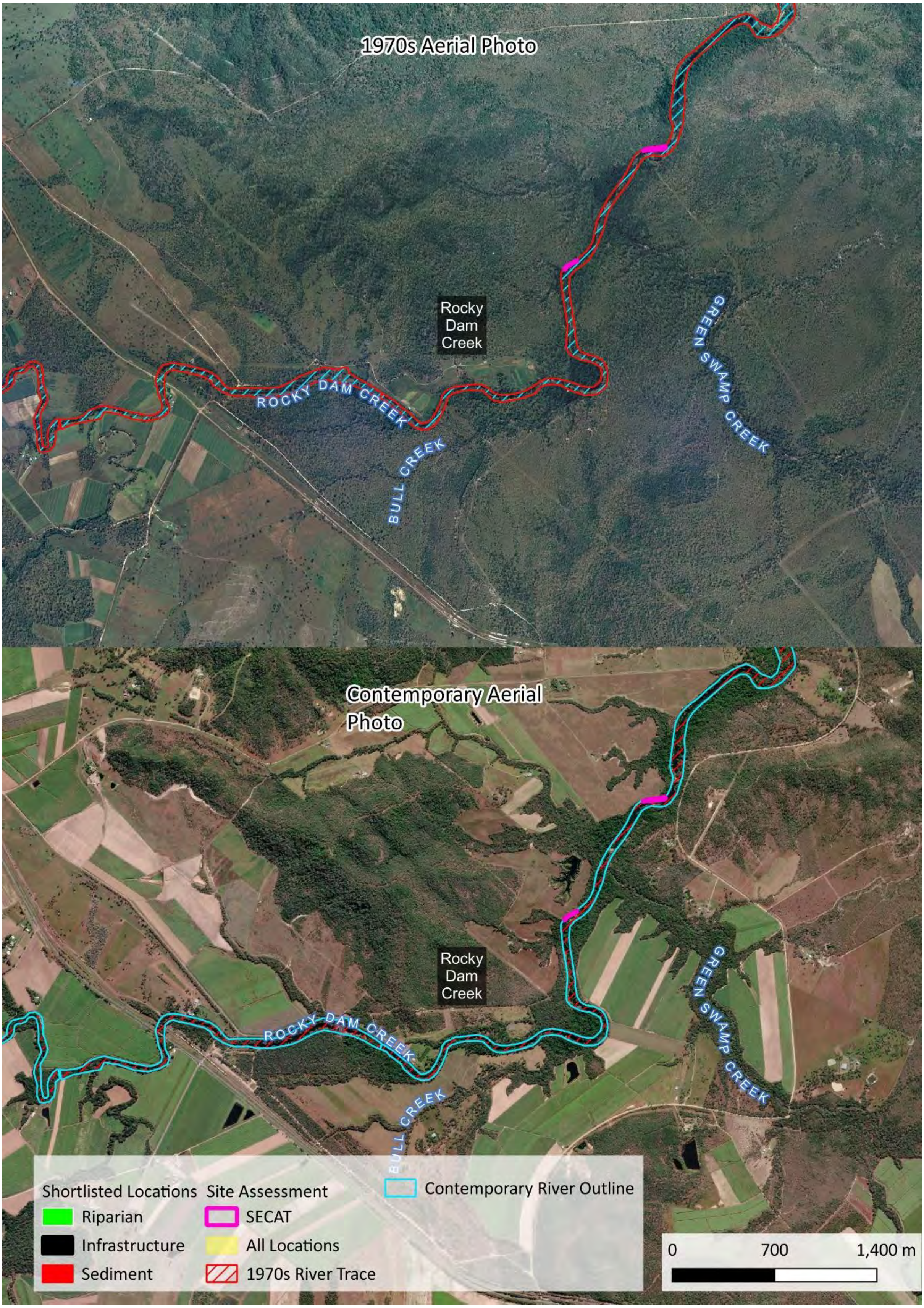


Figure 95. Bank movements between 1970 and present in Rocky Dam Creek

Figure 96. Close up aerial of Site 336, a near-vertical 12m high bank on Rocky Dam Creek

8.4.6 Marion Creek

The upper reaches of Marion Creek, above the Bruce Highway, are described as "Stable" (Figure 86), with a "Good" riparian condition (Figure 87) and as "Slightly Confined by Bedrock" (Figure 88) in the Mackay-Whitsunday Stream Type Assessment. Below the highway the channel has minor instabilities, moderate riparian vegetation condition and is slightly confined by terraces with low sinuosity.

Aerial imagery analysis reveals that a relatively intact riparian corridor exists along much of the length of Marion Creek, especially in the upper reaches and even extending downstream of the Bruce Highway. However, there are several locations before the estuary where sugarcane farming has significantly reduced the riparian corridor and subsequent bank movements are identified. It was not possible to identify whether these bank movements have been recent (i.e. since 2017).

The mouth of Marion Creek is used by a prawn farm as their main outlet and is subject to recent bank movements (Figure 97). This location was assessed for SECAT calculations. Neilly Group undertook Concept Design of this location for Reef Catchments as part of the DRFA program for 2021 flooding events.

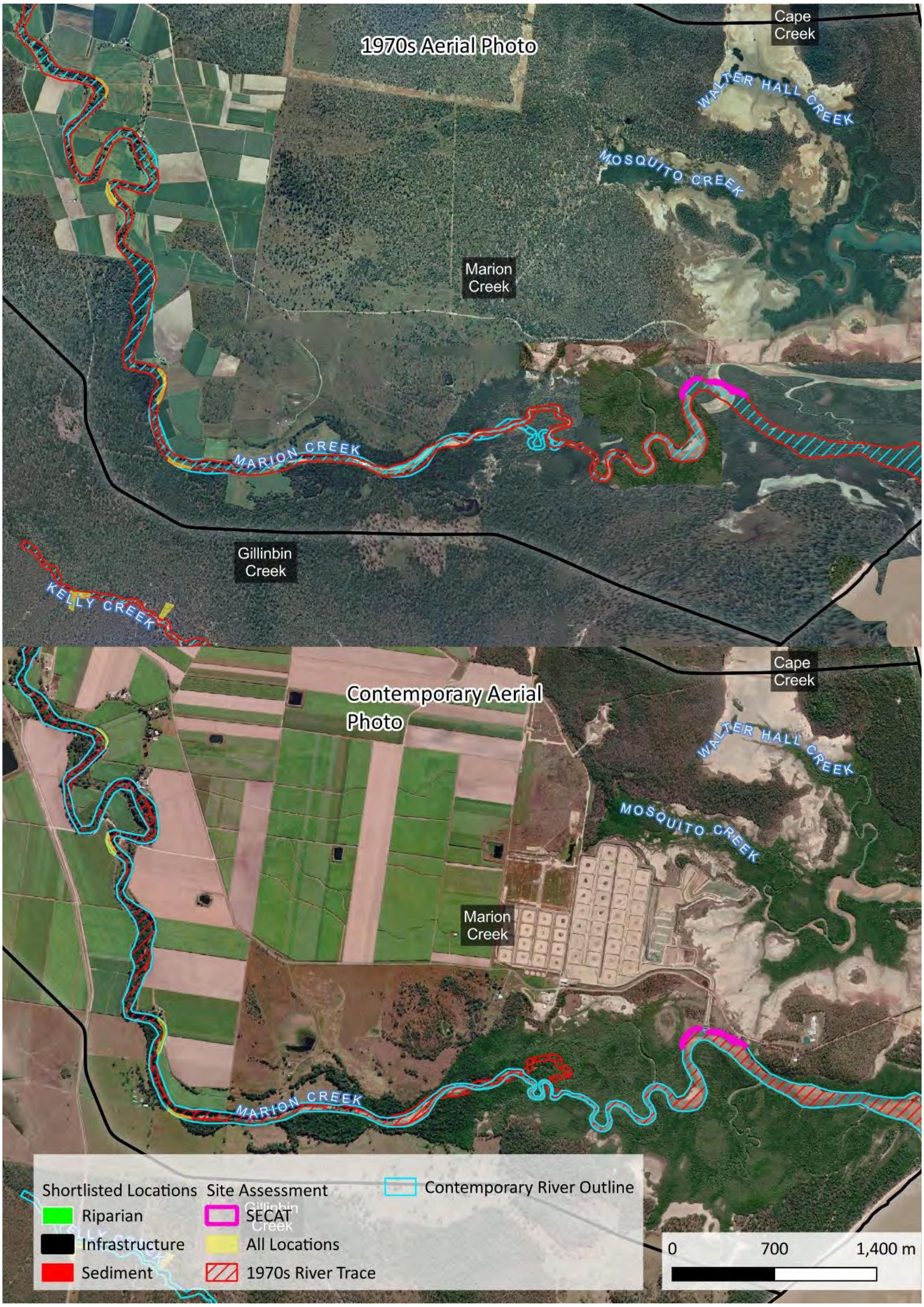


Figure 97. Bank movements between 1970 and present with SECAT calculations along the banks of Marion Creek highlighted at a Prawn Farm

8.4.7 Gilinbin Creek

The Bruce Highway dissects the Gilinbin Creek subcatchment. To the west, the catchment has not been cleared and remains well forested. To the east of the highway the catchment has been mostly cleared for sugarcane production or grazing. Based on available aerial imagery, there has been very little detectable channel adjustment from 1970 to present day.

Only three features were identified within the catchment from the aerial imagery assessment, one of which is shown below in Figure 98, a near vertical bank on Kelly Creek downstream of the rail line. This feature is difficult to detect in temporal analysis of aerial imagery and therefore was not considered for SECAT calculations.

Figure 98. Photo of feature 516 along Kelly Creek downstream of a rail crossing

8.4.8 West Hill Creek

The West Hill Creek catchment consists of the major waterways West Hill Creek, Three Mile Creek, Spider Creek and Bone Creek. All of these waterways are relatively short, draining from the West Hill State Forest to the west of the Bruce Highway to the West Hill Creek inlet, 8.5km east of the Bruce Highway. Over half of the catchment consists of the upland forested areas of the West Hill State Forest. Peak runoff volumes in these streams are relatively small because of the short length of the streams; limiting opportunities for significant bank movement.

According to Alluvium Consulting (2017b) West Hill Creek is relatively straight with low sinuosity as it is confined by terraces. The study notes severe riverbank erosion, in the magnitude of 10 to 15 meters, occurred approximately 1.3 kilometres upstream from the Bruce Highway due to the impact of Severe Tropical Cyclone Debbie and that, further upstream, bank retreat was less, but still considerable at 5m from the same event.

Bank erosion is occurring in West Hill Creek as the high bank out-flanks riparian vegetation present on the terrace (Figure 99). This is difficult to identify and track from the aerial imagery assessment and no DEMoD was available for this area.

There were no site locations identified for SECAT calculations on West Hill Creek as all detectable channel change was in the estuary or bordered by thick, established, vegetation.

Figure 99. Example of bank erosion along West Hill Creek. Photo taken from helicopter reconnaissance from DRFA 2022.

8.4.9 Carmila Creek

Carmila Creek is a larger catchment and watercourse than the adjacent West Hill Creek catchment. The waterway drains the foothills of the Connors Range and the Collaroy State Forest. Various drainage lines descend from the range in forested areas to the catchment cleared for sugarcane production at the base of the escarpment.

Only two erosion feature were identified in Carmila Creek. One is immediately downstream of the Bruce Highway where Carmila Creek meanders sharply to the south (Figure 100). However, this has stabilised and has not been active since 2017.

Figure 100. Example of Carmilla Creek, looking upstream at the highway, with a location of historical identified.

8.4.10 Flaggy Rock Creek

The Flaggy Rock Creek subcatchment is the southernmost subcatchment within the Reef Catchments NRM region and consists of the main waterways of Flaggy Rock Creek and Oaky Creek. Clairview is situated in the southern extent of this subcatchment.

All waterways within this subcatchment have experienced very little change since the 1970s, despite some extensive clearing of the catchment. This is primarily expected due to the small catchment area of each waterway which reduces the opportunity to dramatically increase the catchment response. Almost all waterways within the subcatchment have 'good' riparian vegetation and are stable as identified in the Mackay Whitsunday Stream Type Assessment (Alluvium 2017). This is confirmed from aerial photography inspection undertaken for this project.

Subsequently, outside of natural meandering estuaries consisting of native vegetation, there were no erosion features identified within the Flaggy Rock Creek subcatchment suitable for progressing further.

8.5 Identified Sites

8.5.1 All Locations

Of the 81 locations identified in the Plane Creek Basin, 45 are located in the Sandy Creek, Bakers Creek and Alligator Creek subcatchments (Figure 101, Figure 102). Additionally of all 27 SECAT calculations undertaken in the Plane Creek Basin, 23 of these are in these subcatchments.

Detection of erosion features is more difficult progressing southwards through the Plane Creek basin. This is a result of the range moving closer to the coast, causing the catchments of the waterways to become smaller the further south along the basin.

8.5.2 Total Sediment Reductions

SECAT calculations for the 27 locations identified in the Plane Creek Basin identified 9,124t/y of fine sediment exported to the coast as a result of stream bank movements. Of this, 6,268t/y (68%) is from the Sandy Creek, Bakers Creek and Alligator Creek subcatchments. However, the eroding bank at the outlet of a prawn farm site in the Marion Creek subcatchment has an initial SECAT estimate of 1050t/y. Two sites total 1306t/y (site 336 at 991t/y and site 504 at 315t/y) in the Rocky Dam Creek subcatchment.

8.5.3 Infrastructure

There are two sites prioritised based on “Infrastructure” in the Plane Creek Catchment:

- Site 495: Bank of Marion Creek at the Prawn Farm
- Site 510: Bank of Plane Creek adjacent to Brewers Road.

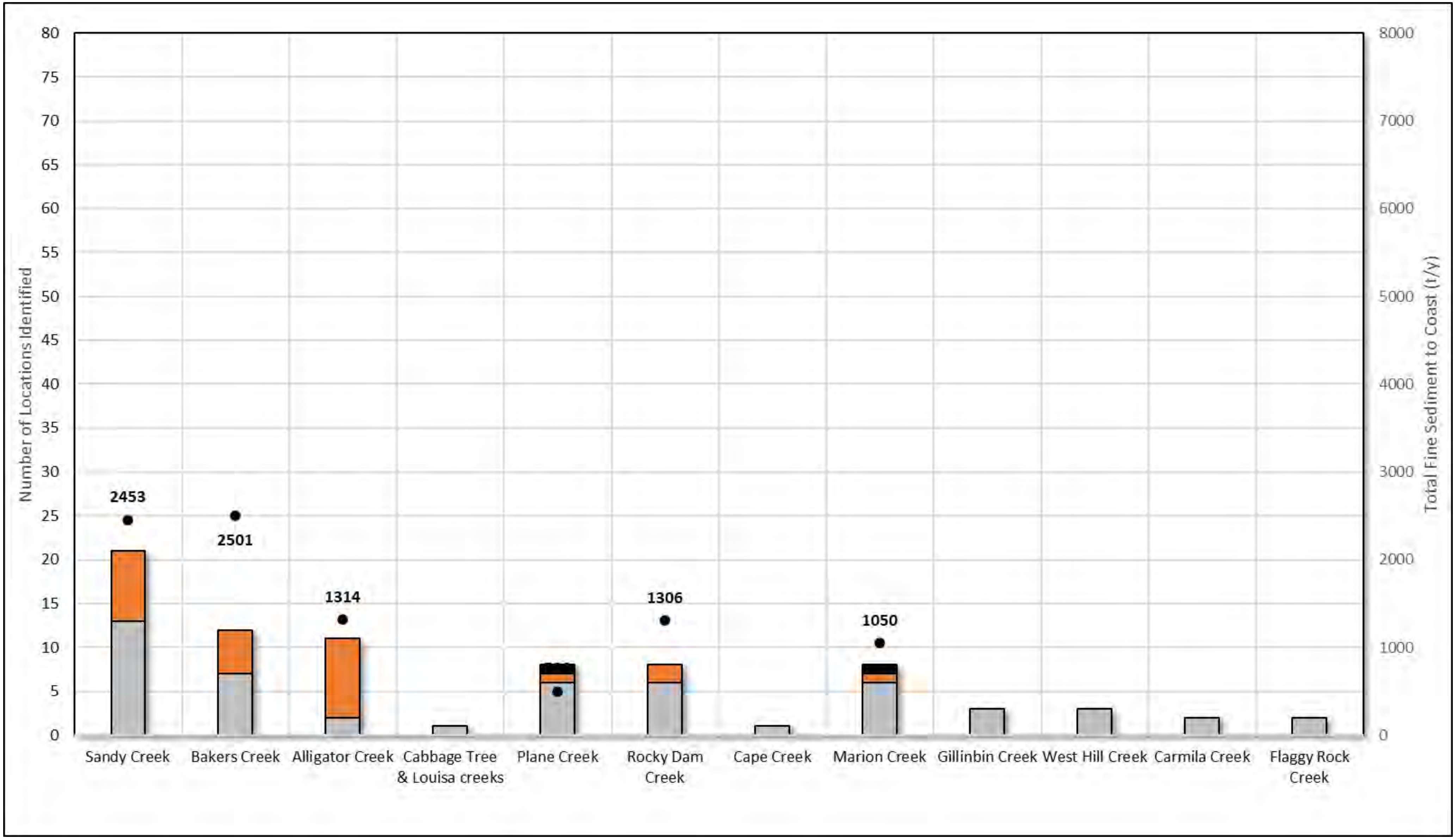
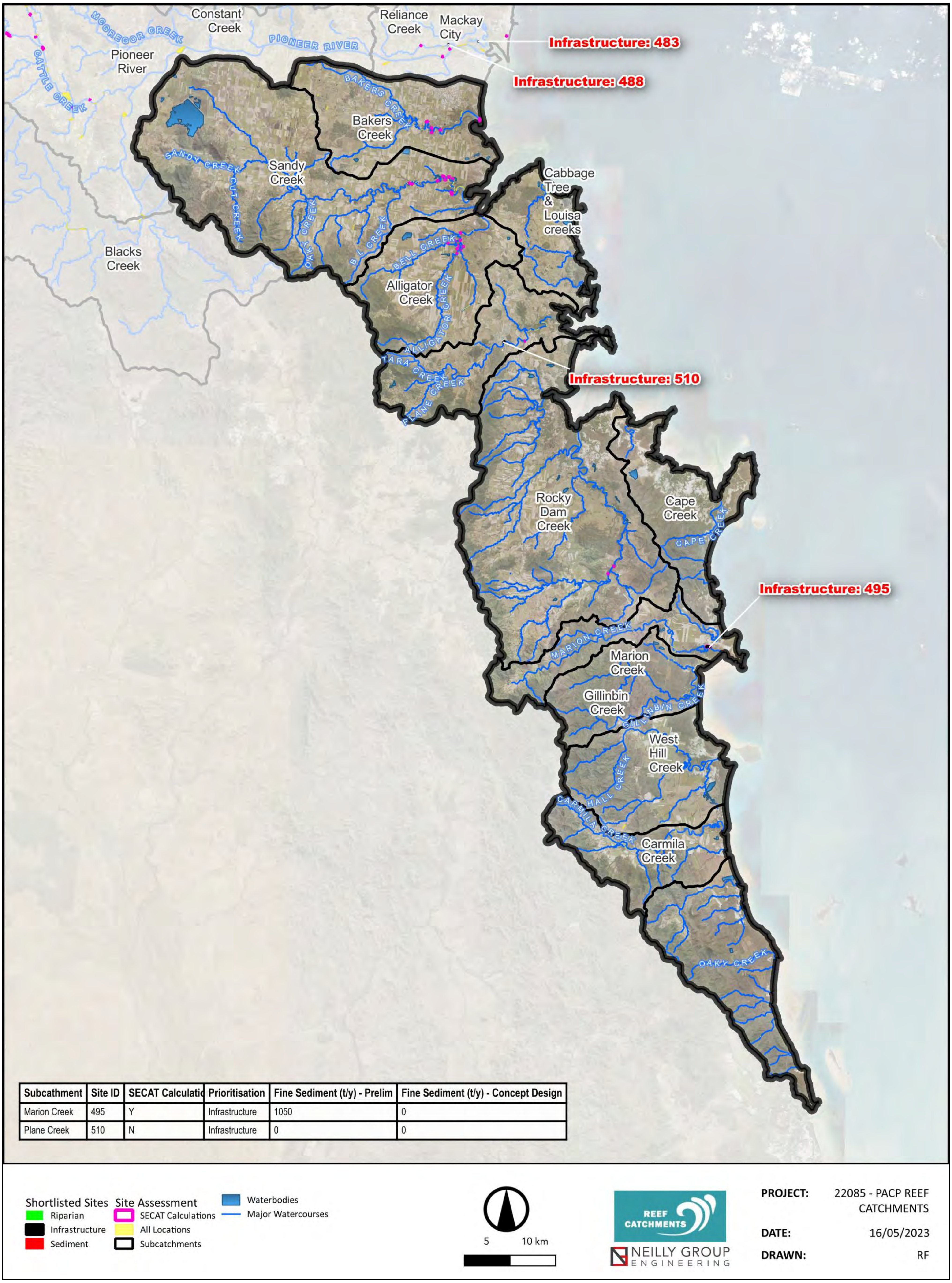


Figure 101. Overall results for the Plane Creek Basin



Subcathment	Site ID	SECAT Calculatio	Prioritisation	Fine Sediment (t/y) - Prelim	Fine Sediment (t/y) - Concept Design
Marion Creek	495	Y	Infrastructure	1050	0
Plane Creek	510	N	Infrastructure	0	0

Figure 102. Overview of locations found in the Plane Creek Basin

8.5.4 Sites Progressing to Concept Design

There were no sites that were chosen to progress to Concept Design in the Plane Creek Basin based on Sediment or Riparian Connectivity. While site 495 was shortlisted because of Infrastructure as well as Sediment impact, the Concept Design for this site was undertaken previously by Neilly Group for Reef Catchments for the 2021 DRFA.

9 Summary of Prioritised Sites

This section presents a summary of the prioritised sites for the Infrastructure, Riparian Connectivity and Sediment Export categories in Table 12, Table 13 and Table 14 respectively. The location of all prioritised locations is provided in Figure 103. Table 15 summarises the total number of locations found, SECAT calculations, SECAT tonnes as well as prioritised locations in each subcatchment across the study area.

Table 12. Summary of infrastructure sites

Site ID	Description	Coordinates
5	Coastal urban creek adjacent to Montes Reef Resort, Hideaway Bay. The site spans 210m estuary with little to no riparian vegetation. Erosion is visible along the creek's banks.	Latitude: -20.065139 Longitude: 148.450127
510	Located along Plane Creek in Sarina, this site has undergone erosion since 1970, with sparse riparian vegetation. The erosion could potentially affect the adjacent Brewers Road.	Latitude: -21.424771 Longitude: 149.220180
488	Erosion located on a tributary to the Pioneer River in Mackay. The site has eroded and lost much of its riparian vegetation, although it appears new vegetation has colonised at the toe of bank in recent aerial imagery. The site has the potential to impact on the adjacent residential development and parkland.	Latitude: -21.131413 Longitude: 149.157044
49	Degraded creek located immediately to the west of Proserpine Airport. The creek has very limited riparian vegetation, which is likely a result of its proximity to the airport runway. However, there appears to be potential gully erosion instigating towards the airport runway from the degraded creek.	Latitude: -20.499890, Longitude: 148.564870
495	Erosion located on the downstream, tidal extents of Marion Creek. Stream bank erosion is occurring either side of the water discharge infrastructure of an adjacent prawn farm facility. The downstream extents of the erosion could also pose a risk to the current access road in the future.	Latitude: -21.723101 Longitude: 149.440640
483	A small section of Barnes Creek which is lacking in riparian vegetation immediately adjacent to a road, upstream of the intersection of Barnes Creek Road and Sams Road	Latitude: -21.128017, Longitude: 149.188613

Table 13. Summary of riparian connectivity sites

Site ID	Description	Coordinates
24 + 25	The project area consists of several small erosion sites within close vicinity. Most vegetation appears to be in channel and not on the banks in those sections. Vegetation is identified as Category X vegetation within the site, surrounded by Category A/B within 1km of the site.	Latitude: -20.432856 Longitude: 148.436300
55	No vegetation at all on western bank. Banks are steep and need reprofiling as well as revegetation. The site is within a State-wide Biodiversity corridor and surrounded by Category A/B vegetation within 1km of the site.	Latitude: -20.522759 Longitude: 148.466377
240 + 241	No vegetation at all on site, about 350m length of streambank. The site needs bank reprofiling on the western bank as well as revegetation on both banks. Identified as Category X vegetation within the site, surrounded by Category A/B vegetation within 1km of the site and located in a State-wide biodiversity corridor.	Latitude: -20.298877 Longitude: 148.520069

Site ID	Description	Coordinates
107	Erosion present in sections on both sides of the banks (mostly the northern bank), in areas where riparian vegetation is thin. Landholders have constructed a small (0.5-1m high) levy along the northern riparian banks to protect their cane access track from further erosion. The site is surrounded by valuable remnant vegetation.	Latitude: -20.542638 Longitude: 148.387981

Table 14. Summary of sediment export sites

Original Rank	Site ID	Location	Original Baseline Fine Sediment Export to coast (t/yr)	Assessed Rank	Refined Baseline Fine Sediment Export to Coast (t/yr)
1	168	Murray Creek O'Connell Basin Latitude: -20.909381 Longitude: 148.844401	2,099	1	4,568
4	409, 410, 411, 412, 416, 424, 425, 427	Upper Cattle Creek Pioneer Basin Latitude: -21.137244 Longitude: 148.580315	1,139	2	3,391
3	329	Murray Creek O'Connell Basin Latitude: -20.906814 Longitude: 148.835542	1,222	3	1,272
7	339	Murray Creek O'Connell Basin Latitude: -20.979026 Longitude: 148.805753	439	4	989
9	166	St Helens Creek O'Connell Basin Latitude: -20.889423, Longitude: 148.795111	371	5	751
8	268	Thompson Creek Proserpine Basin Latitude: -20.542238 Longitude: 148.665625	425	6	597
2	161	St Helens Creek O'Connell Basin Latitude: -20.873053 Longitude: 148.813588	1,247	7	573
5	194	Eden Lassie Creek Proserpine Basine Latitude: -20.195062 Longitude: 148.406823	577	8	539
6	164	St Helens Creek O'Connell Basin Latitude: -20.873564 Longitude: 148.800237	469	9	202
TOTAL			**7,988**		**12,882**

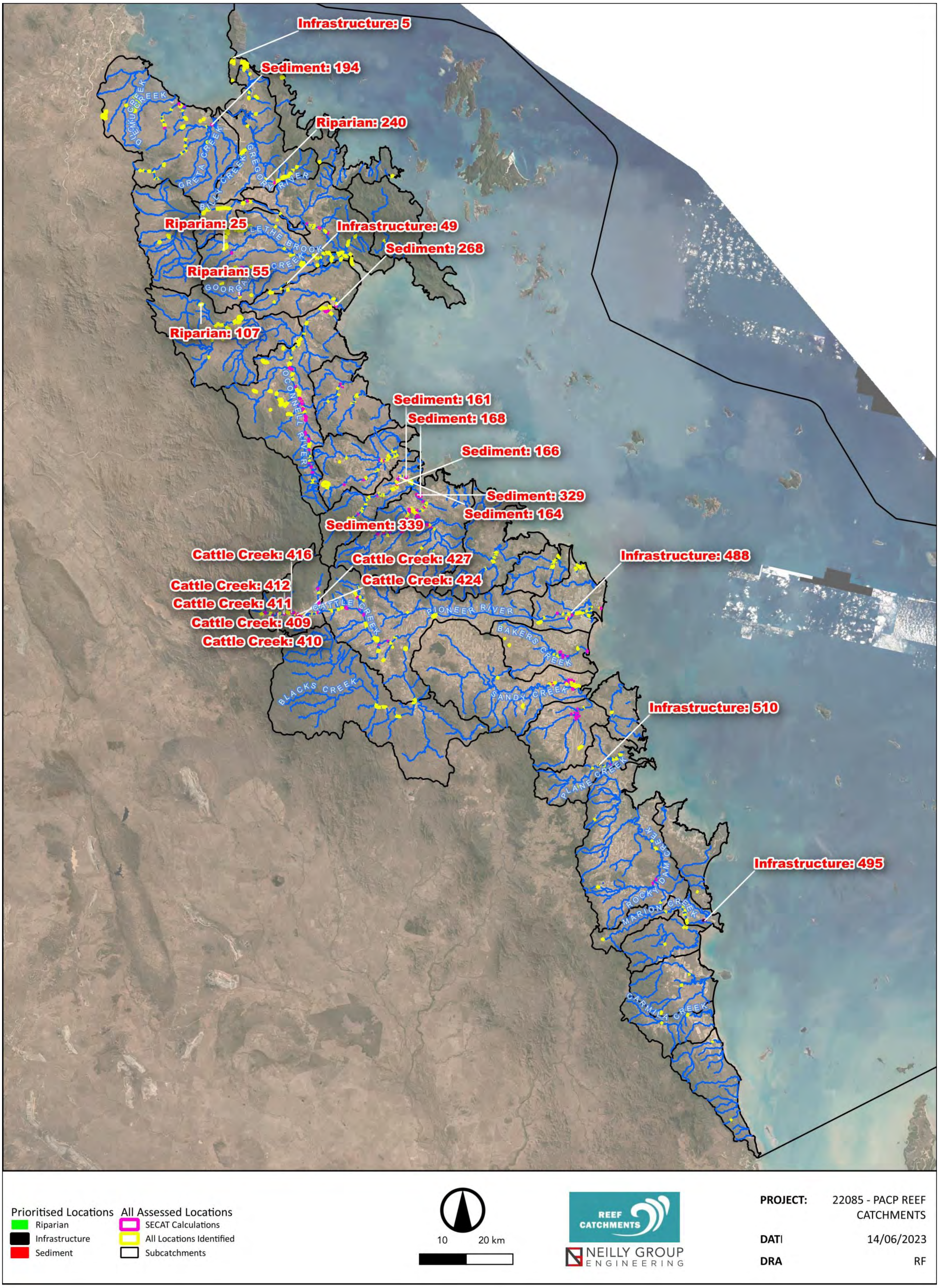


Figure 103. All sites found and the shortlisted sites

Table 15. Overall number of sites identified and refined for the study

Basin	Subcatchment	Total Number of Locations	SECAT Calculations	Sediment Prioritised	Riparian Prioritised	Infrastructure Prioritised	Total Fine Sediment to Coast from all SECAT sites (t/y)	Total Fine Sediment to Coast from all Prioritised sites (t/y)
Proserpine	Eden Lassie Creek	45	5	1			796	539
	Gregory River	22	1		1		182	
	Whitsunday coastal creeks	15				1		
	Upper Proserpine River	3						
	Proserpine River	7	1				42	
	Myrtle Creek	26	6				294	
	Repulse Creek	1						
	Lethe Brook	57	5		2	1	415	
	Thompson Creek	10	3	1			425	597
	Sub-Total	**186**	**21**	**2**	**3**	**2**	**2,153**	**1,136**
O'Connell	Andromache River	14			1			
	O'Connell River	73	26				7,722	
	Waterhole Creek	11	2				188	
	Blackrock Creek	27	4				587	
	St Helens Creek	28	7	3			3,263	1,527
	Murray Creek	53	23	3			8,035	6,830
	Constant Creek	5						
	Reliance Creek	13						
	Sub-Total	**224**	**62**	**6**	**1**	**0**	**19,795**	**8,356**
Pioneer	Upper Cattle Creek	36	15	8			1,769	3,391
	Blacks Creek	5						
	Pioneer River	31	8				1,401	
	Mackay City	28	4			2	295	
	Sub-Total	**100**	**27**	**8**	**0**	**2**	**3,465**	**3,391**
Plane Creek Basin	Sandy Creek	22	9				2,453	
	Bakers Creek	12	5				2,501	
	Alligator Creek	11	9				1,314	
	Cabbage Tree & Louisa creeks	1						
	Plane Creek	8	1			1	500	
	Rocky Dam Creek	8	2				1,306	
	Cape Creek	1						
	Marion Creek	8	1			1	1,050	
	Gillinbin Creek	3						
	West Hill Creek	3						
	Carmila Creek	2						
	Flaggy Rock Creek	2						
	Sub-Total	**81**	**27**	**0**	**0**	**2**	**9,124**	**0**
Total		**591**	**137**	**16**	**4**	**5**	**34,537**	**12,884**

10 Management Interventions

10.1Overview of Intervention Options

The Aquatic Ecosystem Rehabilitation Framework provided by the Queensland Government, which also provides the QRRMG, outlines a number of intervention options for river restoration. A selection of these techniques has been applied to the sites adopted for Concept Design. This section provides a general overview of different elements applied across the locations.

10.1.1 Bank Battering

This technique uses excavation to reduce the bank slope (Figure 104). The aim is to improve riverbank stability and create conditions more conducive for vegetation growth. Typically, bank battering is limited to the upper bank profile. It requires a combination of vegetation management and physical intervention. This technique alone does not address the cause of bank steepening therefore, it is recommended to deal with the processes responsible for any channel changes, rather than simply managing the symptoms.

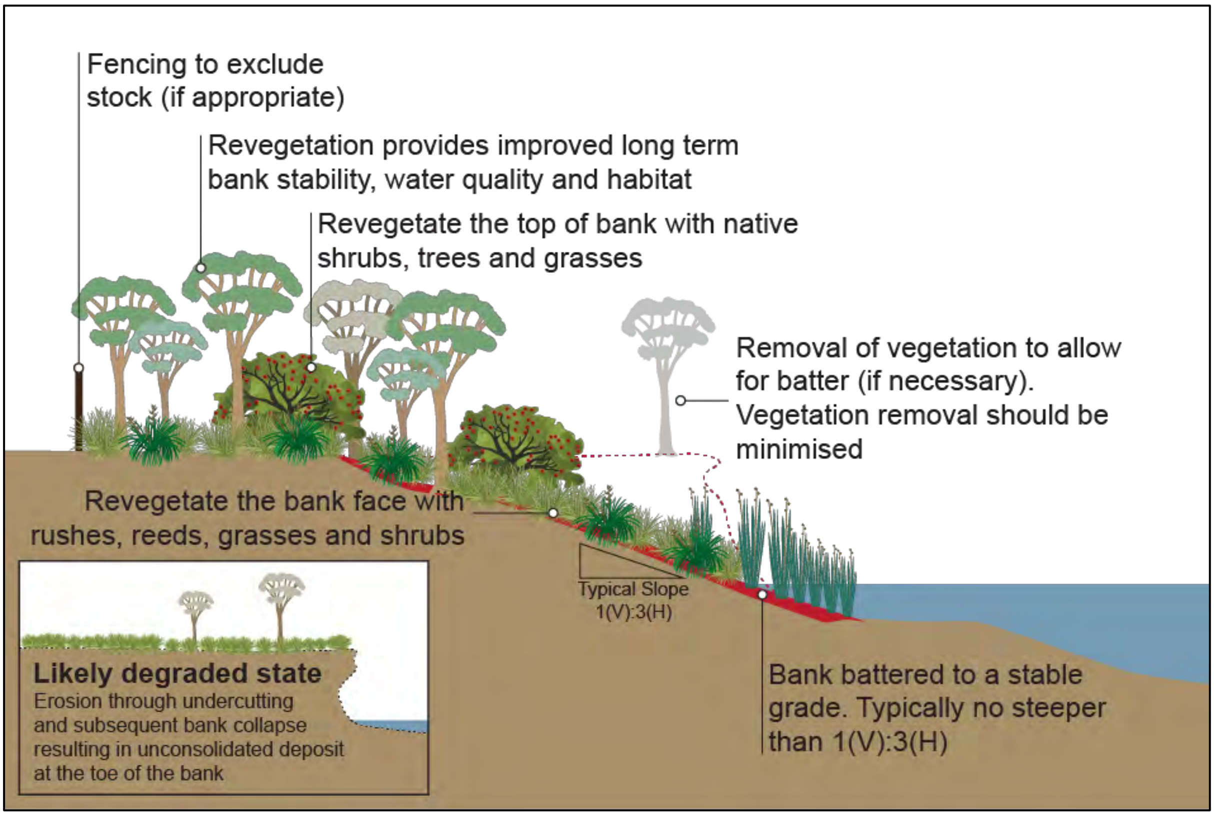


Figure 104. Typical section through Bank Battering (Queensland Government 2022c)

10.1.2 Timber Pile Fields

This river restoration technique combines vegetation management with physical intervention. It involves driving wooden pile (pole) structures to divert fast moving flows away from the bank and provide shelter for vegetation establishment (Figure 105). This reduces riverbank erosion and promotes sediment deposition at the bank toe. Revegetation is then employed to solidify the deposited sediments and increase hydraulic roughness, further slowing down the water velocity against the bank.

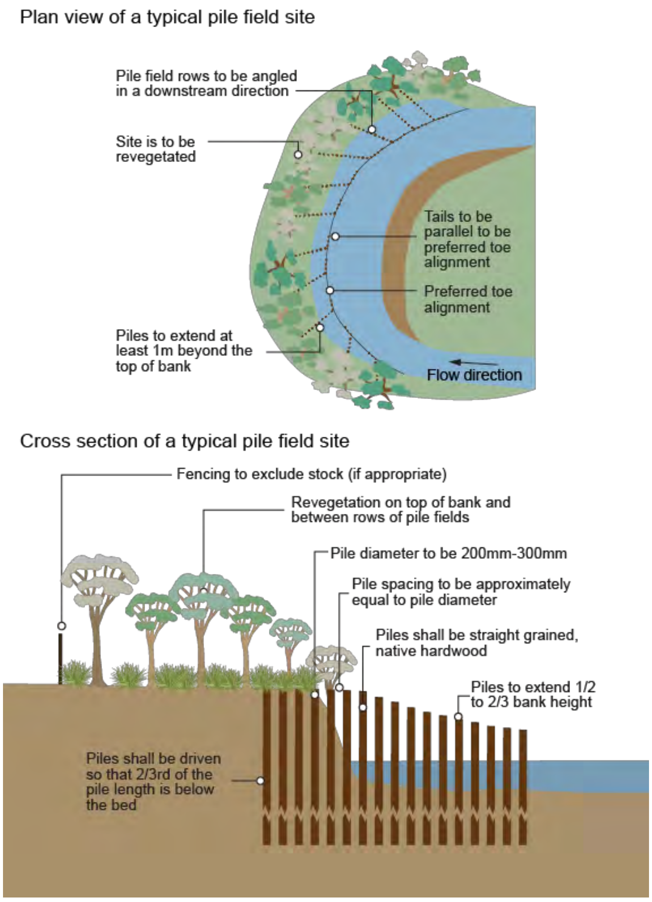


Figure 105. Typical aspects of a timber pile field (Queensland Government 2022c)

10.1.3 Active Revegetation

This technique involves reintroducing and reestablishing vegetation at a site through various methods. These can include planting advanced tubestock germinated in nurseries, obtaining transplants from within or outside the rehabilitation site, direct seeding, or hydromulching. Active revegetation is most suitable for sites where native vegetation has been removed and is not naturally recruiting. It's also ideal for sites where rapid vegetation cover is necessary to prevent soil erosion or where engineered solutions have disturbed the existing vegetation.

Key to successful revegetation in North Queensland is irrigation during the establishment period (depending on location) and provision of active maintenance.

10.1.4 Large Wood Placement and Log Jams

This involves the placement of large native timber (at least 0.1 meter in diameter and 1 meter in length) into a river, typically to deflect flow away from the bank. The placement of large wood can enhance habitat, increase hydraulic roughness, and accelerate the increase in geomorphic complexity and diversity beyond the natural rate. The use of native hardwood logs with root balls is preferred.

The specific arrangement and orientation of the placed large wood will depend on project objectives, river type, riverbed load, and river energy (Figure 106). Large wood arrangements can vary from single logs to entire trees or engineered timber structures.

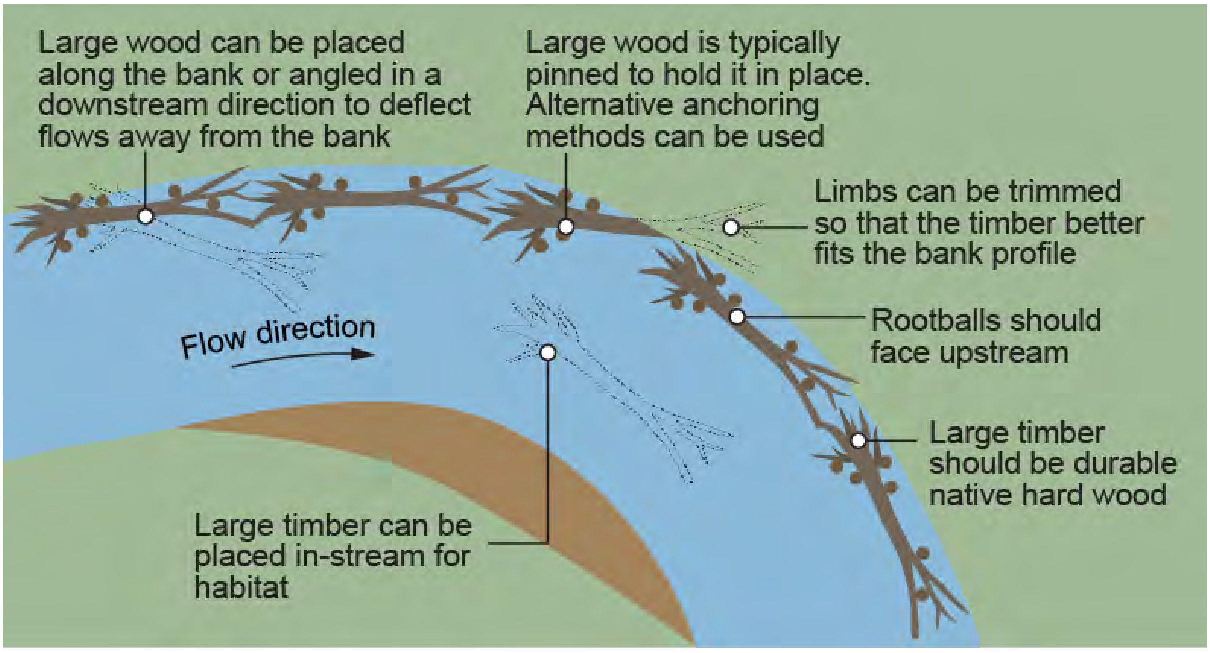


Figure 106. Schematic diagram of Large Wood Placement (Queensland Government 2022c)

Depending on stream power and bed load, stabilisation of the wood may be necessary to manage risks associated with the large wood moving and causing damage instead of improving ecological value. Vertically driven timber piles or ballast blocks can effectively stabilise large wood.

Log Jams are engineered arrangements of logs, typically held in place with vertically driven piles. Log jams aim to temporarily modify the near-bank hydraulics at a specific site by resisting flow. This resistance is naturally offered by large woody debris. If used to manage bank erosion, a series of log jams may be necessary to significantly reduce the flow velocity and erosion. Log jams generally enhance fish habitat and contribute to localised scour and deposition, thereby improving the geomorphic diversity of the reach. These structures are used when there is a lack of large wood supply or the conditions lead to quick burial or transport of the wood, making it ineffective, or both. The long-term goal should be to address any underlying issues in large wood supply or transport/burial.

10.1.5 Rock Armouring

Also known as rock rip rap, rock revetment, or rock beaching, this involves the placement of quarried, angular rock against a riverbank to prevent further erosion. This technique is often used to protect infrastructure, such as bridges and culverts. The rock is graded and placed to a design thickness to ensure that it forms an interlocking mass (Figure 107). The design of the rock armouring requires hydraulic calculations (typically undertaken by modelling) to determine an appropriate rock size that won't be washed away.

Often, this intervention is used alongside vegetation establishment to stabilise the bank, eventually making the engineered structure redundant.

4

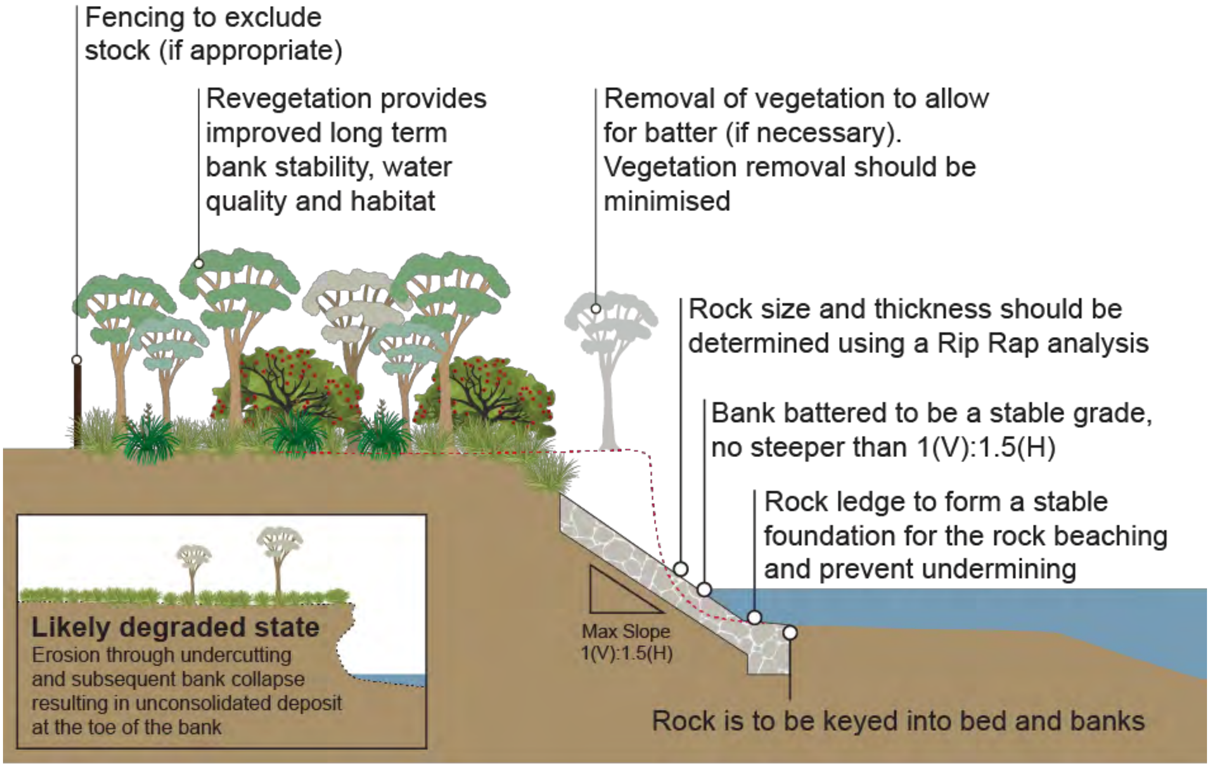


Figure 107. Typical section of rock armouring (Queensland Government 2022c)

10.2 Management Interventions

The overall management interventions, as well as initial quantities and estimated construction costs for the shortlisted sites are provided in Table 16 below. Further details are provided in the individual Concept Design reports outlined in Attachment D.

Table 16. Summary table of Top 20 sites, sediment, management interventions and budget required to implement the concept designs.

Basin	Subcatchment	Prioritisation Reason	Site ID	Sediment Delivery to the Coast		Management Interventions							Costed Concept Design Budget ($ ±30%)	Costed Concept Design Budget On-Ground component only ($ ±30%)	Sediment Delivery to the Coast	Cost Effectiveness Range with costs ±30% ($/t)
				Initial Baseline Fine Sediment Export To Coast (t/y)	Refined Baseline Fine Sediment Export To Coast (t/y)	Cut/Fill (m^3)	Rock Protection (m^3)	Pile Field (number of piles)	Rock Groynes (m^3)	Log fillets (number)	Large Wood/Rootballs/Log Jams (number)	Revegetation Area (ha)			Refined Baseline Fine Sediment Export to the Coast incorporating works effectiveness (t/y)	
Proserpine	Eden Lassie Creek	Sediment	**194**	577	539	4,916	1,162	1,008	-	-	-	0.81	1,669,351	1,403,031	323	3,041 – 5,647
	Gregory River	Riparian	**240 + 241**	N/A	N/A	17,114	-	-	-	-	-	2.93	1,013,114	839,894	N/A	N/A
	Lethe Brook	Riparian	**24 + 25**	N/A	N/A	-	-	-	-	-	-	2.11	295,233	270,233	N/A	N/A
	Lethe Brook	Riparian	**55**	N/A	N/A	5,628	-	-	-	-	-	1.98	703,227	567,247	N/A	N/A
	Thompson Creek	Sediment	**268**	425	597	5,820	-	-	-	-	8	0.27	835,580	643,740	358	1,259 – 2,338
O'Connell	Andromache River	Riparian	**107**	N/A	N/A	-	-	-	-	-	-	6.84	846,977	796,977	N/A	N/A
	Murray Creek	Sediment	**168**	2,099	4,568	43,330	-	-	-	160	-	1.66	2,009,684	1,668,884	2741	426 - 792
	Murray Creek	Sediment	**329**	1,222	1,272	34,643	4,643	-	-	116	-	1.78	2,500,420	2,137,650	763	1,961 – 3,642
	Murray Creek	Sediment	**339**	439	989	8,224	522	448	-	-	-	0.40	1,051,124	859,284	593	1,014 – 1,884
	St Helens Creek	Sediment	**161**	1,247	573	21,046	1,046	916	-	-	-	1.05	1,837,973	1,524,797	344	3,103 – 5,762
	St Helens Creek	Sediment	**164**	469	202	3,962	1,610	-	-	-	5	0.51	745,802	614,163	121	3,553 – 6,598
	St Helens Creek	Sediment	**166**	371	751	12,833	993	878	-	-	-	1.09	1,628,953	1,371,991	451	2,129 – 3,955
Pioneer	Upper Cattle Creek	Sediment	**409**	1,139	3,391	1,303	-	-	552	-	-	0.05	3,983,013	3,528,093	2,035	1,214 - 2,254
	Upper Cattle Creek	Sediment	**410**			1,543	350	268	-	-	-	0.12				
	Upper Cattle Creek	Sediment	**411**			937	-	-	1,174	-	-	1.41				
	Upper Cattle Creek	Sediment	**412**			540	540	-	404	-	-	0.56				
	Upper Cattle Creek	Sediment	**416**			757	757	-	-	-	-	0.40				
	Upper Cattle Creek	Sediment	**424**			2,146	-	-	863	-	-	1.03				
	Upper Cattle Creek	Sediment	**425**			6,784	2,065	299	-	-	19	2.06				
	Upper Cattle Creek	Sediment	**427**			342	342	-	-	-	-	0.31				
TOTAL RIPARIAN CONNECTIVITY SITES				**N/A**	**N/A**	**22,742**	**-**	**-**	**-**	**-**	**-**	**13.86**	**2,858,551**	**2,474,351**	**N/A**	**N/A**
TOTAL (or AVERAGE) SEDIMENT EXPORT SITES				**7,988**	**12,882**	**149,126**	**14,030**	**3,817**	**2,993**	**276**	**32**	**13.51**	**16,261,900**	**13,751,633**	**7,729**	**1,245 - 2313**

11 References

AECOM. 2018. *Bakers Creek South Mackay Stormwater Trunk Infrastructure Study.* Mackay, Queensland: AECOM Australia for Mackay Regional Council.

AECOM. 2011. *Proserpine Flood and Drainage Study.* Mackay, Queensland: Whitsunday Regional Council.

Alluvium Consulting. 2017b. *Mackay-Whitsundays Cyclone Debbie Post Flood Assessments: Overview of Flood Events and Channel Change.* Alluvium Consulting.

Alluvium. 2014. *O'Connell River Stability Assessment .* Townsville, QLD: Alluvium Consulting.

Alluvium. 2020. *Review of river reach case studies and Dynamic SedNet model parameterisation. .* Brisbane, QLD: Queensland Water Modelling Network.

Alluvium. 2017. *Stream Type Assessment of the Mackay-Whitsundays Region.* Townsville, QLD: Alluvium Consulting.

Australian Government Department of Climate Change, Energy, the Environment and Water. 2023. *The Reef Trust.* 6 February . Accessed June 6, 2023. https://www.dcceew.gov.au/parks-heritage/great-barrier-reef/protecting/our-investments/reef-trust.

Baird, M, N Margvelashvili, and N Cantin. 2019. *Historical context and causes of water quality decline in the Whitsunday region.* CSIRO.

Bartley, R, Anne Henderson, Scott Wilkinson, Stuart Whitten, and Ian Rutherfurd. 2015. *Stream bank management in the Great Barrier Reef Catchments: A Handbook.* Brisbane, QLD: CSIRO.

BOM. 2021. *Flood Warning for the Pioneer River.* February. http://www.bom.gov.au/qld/flood/brochures/pioneer/pioneer.shtml.

BOM. 2019. *North Queensland Monsoon Trough Technical Flood Report.* Melbourne, Vic: Bureau of Meteorology.

BOM. 2019. *Special Climate Statement 69 - an extended period of heavy rainfall and flooding in tropical Queensland.* Melbourne, VIC: Bureau of Meteorology.

BOM. 2018. *Tropical Cyclone Debbie - Technical Report.* Melbourne, Victoria: Bureau of Meteorology.

Brooks, A P, J Olley, F Iwashita, J Spencer, J McMahon, G Curwen, N Saxton, and S Gibson. 2014. *Reducing Sediment Pollution in Queensland Rivers: Towards the Development of a Method to Quantify and Priortise Bank Erosion in Queensland Rivers based on Field Evidence from the Upper Brisbane, O'Connell, and Normanby Rivers.* Brisbane, Queensland: Final Report to Queensland State Government.

C&R Consulting . 2013. *Midge Point Shoreline Erosion Management Plan.* Mackay, Queensland: Mackay Regional Council.

Commonwealth of Australia. 2021. “Reef 2050 Long-Term Sustainability Plan.” Department of Agriculture, Water and the Environment. https://www.dcceew.gov.au/sites/default/files/documents/reef-2050-long-term-sustainability-plan-2021-2025.pdf.

DEECW. n.d. *2020.* https://reportcard.reefplan.qld.gov.au/home?report=target&year=611f443aba3074128316eb07&measure=ALL&area=MW.

Deloitte Access Economics. 2017. "At what price? The economic, social and icon value of the Great Barrier Reef."

Department of Environment and Science. 2021. *Plane Catchment Story, Wetland Info.* Accessed June 13, 2023. https://wetlandinfo.des.qld.gov.au/wetlands/ecology/processes-systems/water/catchment-stories/transcript-plane.html.

—. 2021. *Proserpine Catchment Story.* 25 August. https://wetlandinfo.des.qld.gov.au/wetlands/ecology/processes-systems/water/catchment-stories/transcript-proserpine.html.

Department of Environment and Science. 2022. *Queensland River Rehabilitation Mangement Guideline, Version 1.0.* Brisbane, Queensland: DES.

GBRMPA. 2013. *O'Connell Baisn Assessment: Mackay-Whitsunday Natural Resource Management Region.* Townsville, QLD: GBRMPA.

Great Barrier Reef Marine Park Authority. 2022. *Declining Water Quality .* 20 August. Accessed June 12, 2023. https://www2.gbrmpa.gov.au/learn/threats/declining-water-quality#:~:text=High%20concentrations%20of%20fine%20sediment,metabolism%20of%20some%20fish%20species.

Great Barrier Reef Marine Park Authority. 2013. *Plane Basin Assessment: Mackay-Whitsunday Natural Resource Management Region.* Townsville, Australia: GBRMPA.

Hardy, S M. 2004. "A Pedogeomorphological analysis of Goorganga Wetlands to assist with managing the aeras ecosystems." *International Soil Conservation Organisation Conference.* Brisbane: Conserving Soil and Water for Society: Sharing Solutions.

Humphreys, P, and S Wilkinson. 2021. *Stream bank Erosion Control Assessment Tool (SECAT) Survey User Guide, Paddock to Reef Integrated Monitoring, Modelling and Reporting Program, version 1.0.0.* Brisbane, Australia: State of Queensland.

Investigations, Water Quality &. 2021. *Great Barrier Reef Catchment Loads Monitoring Program: Loads and Yields for sediment and nutrients, and Pesticide Risk Meric results (2019-2020) for rivers that discharge to the Great Barrier Reef.* Brisbane, Australia: Department of Environment and Science.

Lewis, Stephen E, Rebecca Bartley, Scott N Wilkinson, Zoe T Bainbridge, Anne E Henderson, Cassandra S James, Scott A Irvine, and Jon E Brodie. 2021. "Land use change in the river basins of the Great Barrier Reef, 1860 to 2019: A foundational understanding for environmental history acros the catchment to reef consortium." *Marine Pollution Bulletin 166.*

Lorang, Mark S, and F. Richard Hauer. 2017. "Chapter 5 - Fluvial Geomorphic Processes." In *Mehtods in Stream Ecology, Volume 1 - Ecosystem Structure*, by F. Richard Hauer and Gary A Lamberti, 89-107. Academic Press.

Mackay Regional Council. 2023. Accessed June 4, 2023. https://www.mackay.qld.gov.au/business/invest_mackay/regional_economy/key_industries.

Marsden, Tim, Richard Stewart, Kristen Woods, Darren Jennings, Shantele Ianna, and Gary Thorncraft. 2006. *Freshwater Fish Habitat Rehabilitation in the Mackay Whitsunday Region.* Brisbane, Australia: Queensland Department of Primary Industries.

McMahon, Joseph M, Jon M Olley, Andrew P Brooks, James C.R. Smart, Calvin W.\ Rose, Graeme Curwen, John Spencer, and Ben Stewart-Koster. 2017. "An investigation of controlling variables of riverbank erosion in sub-tropical Australia." *Environmental Modelling & Software (97)* 1-15.

Packett, R, C Dougall, R Ellis, D Waters, and C Carroll. 2014. *Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments - Mackay Whitsunday NRM Region: Technical Report, Volume 5.* Rockhampton, Queensland: Queensland Department of Natural Resources and Mines.

Queensland and Australian Governments. 2011. *Reef Water Quality Protection Plan.* First Report 2009 Baseline.

Queensland Government. 2017. *2017 Scientific Consensus Statement - Land Use Impacts on the Great Barrier Reef Water Quality and Ecosystem Condition .* Brisbane ,Queensland: Queensland Government.

—. 2019. *Mackay-Whitsunday Climate Change Impact Summary - Version 1.* https://www.qld.gov.au/__data/assets/pdf_file/0026/68561/mackay-whitsunday-climate-change-impact-summary.pdf.

—. 2021. *Pioneer River Catchment Story.* Accessed 05 31, 2023. https://qgsp.maps.arcgis.com/apps/MapJournal/index.html?appid=a762698a93e24e07a8744660b3f0704c#.

Queensland Government. 2018. *Reef Water Quality Improvement Plan 2050.* Brisbane, Qld: Queensland Government.

Queensland Government. 2014. *Soil Conservatoin Guidelines for Queensland.* Brisbane, Queensland: Queensland Government.

—. 2022. *State Development, Infrastructure, Local Government and Planning - Greater Whitsunday Region.* 16 September. Accessed June 2, 2023. https://www.statedevelopment.qld.gov.au/regions/queensland/greater-whitsunday.

—. 2022c. *Whole of System, Values-Based Framework, Wetland Info.* Accessed 05 30, 2023. https://wetlandinfo.des.qld.gov.au/wetlands/management/whole-system-values-framework/.

Queensland Reconstruction Authority. 2023. *2019 North and Far North Queensland Monsoon Trough Riparian and Coastal Recovery Program.* Accessed June 10, 2023. https://www.qra.qld.gov.au/recovery/recovery-operations/2019-north-and-far-north-queensland-monsoon-trough/exceptional-3.

Queensland Wetlands Program. 2016. *O'Connell Basin - Key Messages - Prepared from information gathered using the Walking the Landscape Methodology by the Queensland Wetlands Program in collaboration with Reef Catchments NRm.* Mackay, Queensland: Queensland Wtelands Program.

Reef Catchments. 2014. *Mackay-Whitsunday Water Quality Improvement Plan 2014-2021.* Reef Catchments.

SKM. 2011. *Brisbane River Flood, January 2011 - Report on River Bank Erosion.* Melbourne, Victoria: SKM.

The State of Queensland and Commonwealth of Australia. 2018. *Reef 2050 Water Quality Improvement Plan 2017-2022.* Brisbane: State of Queensland.

The State of Queensland and Commonwealth of Australia. 2009. *Reef Water Quality Protection Plan 2009 For the Great Barrier Reef World Heritage Area and adjacent catchments.* Brisbane: Department of the Premier and Cabinet.

The State of Queensland and Commonwealth of Australia. 2013. *Reef Water Quality Protection Plan 2013 Securing the health and resilience of the Great Barrier Reef World Heritage Area and adjacent catchments.* Brisbane: Reef Water Quality Protection Plan Secretariat.

The State of Queensland and Commonwealth of Australia. 2003. *Reef Water Quality Protection Plan; for catchments adjacent to the Great Barrier Reef World Heritage Area.* Brisbane: Queensland Department of Premier and Cabinet.

—. n.d. *Severe Tropical Cyclone Debbie (March 2017) Natural Disaster Relief and Recovery Arrangements Category D Enviornmental Recovery Package: Riparian, mapping and watercourse recovery.* Accessed June 5, 2023. https://environment.des.qld.gov.au/__data/assets/pdf_file/0025/222649/natural-disaster-relief-recovery-arrangements-summary-report.pdf.

The State of Queensland. 2022. *Impacts of Erosion.* 7 June. Accessed June 10, 2023. https://www.qld.gov.au/environment/land/management/soil/erosion/impacts.

Whitsunday Regional Council . 2016. "Whitsunday Regional Council Climate Change Adaptation Strategy."

Witheridge, Grant. 2021. *Creek Erosion Field Guide Part 1 - Introduction.* Bargara, Queensland: Catchments & Creeks Pty Ltd.

WRM. 2021. "Pioneer River Flood Study."