Noosa & District Landcare

Keeping it in Kin Kin
Priority Implementation Plan

CONTENTS

Noosa & District Landcare acknowledges the ongoing connection to country of the traditional custodians of the Kin Kin region, the Kabi Kabi people. The works on land and caring for country pertaining to this document is drawn from connection to the people and stories of the Kabi Kabi, and we pay our respect to elders past, present and emerging.

Project Summary

Lake Cootharaba and its related ecosystems in the Noosa River Catchment, South East Queensland is suffering. Studies have revealed the Lake to have unnaturally high levels of Total Nitrogen at the southern end of the water system along with high levels of sediment load on the benthic floor. This, along with recreational and commercial fishing pressures, are endangering the health of the lake.

Lake Cootharaba is fed primarily by two main river systems; Noosa River, fed by Teerwah Creek, flows through Cooloola National Park, and secondly Kin Kin Creek. Of the two systems, University of Sunshine Coast (USC) researchers identified that Kin Kin creek is the major contributor of sediment influx due to the nature of land use in its upper catchment, predominantly agricultural and farming, with a history of land clearance.

In addition to the threat to Lake Cootharaba, the riparian ecosystem for this area has a percentage of remnant Lowland Rainforest of Subtropical Australia (LRFSTA), listed as critically endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). This ecological vegetation community is under threat from clearing and weed infestation of Cats Claw Creeper (*Dolichandra unguis-cati*) and Madeira vine (*Andredera cordifolia*).

To begin to address this problem, the Keeping It In Kin Kin (KIIKK) project was initiated. KIIKK aims to identify the origin of the sediment, the nature and type of points of erosion, and the possible remediation processes to reduce sediment levels. Analysis of remote sensing imagery, Light Detection and Ranging (LiDaR) and the layering of images collected over the period of 2008 – 2015, establish the origin of sediment and erosion type. Comparing elevation and slope, geological and soil type and increase or loss of soil levels, problems areas, soil movement, the type of erosion and the likelihood of erosion could be determined.

Once these hot spots became evident, for ease of assessment the region was divided into 17 sub catchments, thus establishing the best chance of success of remediation. Prioritisation criteria became defined through a number of influences. With some ground truthing, individual property assessment and active engagement of the local landholders within those sub catchments, remediation processes could commence.

The project, led by Noosa & District Landcare Group, is a partnership between a number of organisations including Noosa Biosphere Reserve Foundation, Healthy Land and Water, The Thomas Foundation, Noosa Integrated Catchment Association, Noosa Parks Association, Noosa Council, Country Noosa, and Kin Kin Community Group.

1.0 Introduction

1.1 Overview

The Keeping it in Kin Kin project is aimed at keeping Kin Kin's soils in place through reduction of soil movement, stream erosion and fine sediment mobilisation. This will see an overall improvement of waterway health and water quality within the Noosa River and Lake Cootharaba systems and an increase in agricultural productivity.

The predominant influence of nutrient level influx into the Lake Cootharaba ecosystem is from sediment deposition sourced from the Kin Kin Catchment. This nutrient rich sediment is contributing to the overall degradation of the benthic layer of the Lake system, essentially mobilised during heavy rain periods and flooding events that occur frequently on the Sunshine Coast.

Soil can be at risk of erosion for a number of reasons: change in land use and unsustainable management practices of pasture both past and present; weed infestation reducing the loss of riparian biodiversity; and loss of pasture cover due to Pasture Dieback. This coupled with the underlying geology of the region are the contributors of sediment movement in the Kin Kin catchment.

1.2 Project objectives

KIKK Desired Outcome:

Reduction of nutrient laden sediment entering Lake Cootharaba, via the Kin Kin Creek Catchment.

KIKK Intermediate Aims:

- Remediate active and high risk erosion sites
- Reduce additional areas from future sediment erosion contributions

KIIKK Objectives

- Restore riparian zones
- Rehabilitate active erosion sites
- Improve soil health and increase quality and quantity of productive top soil on farming properties in the Kin Kin Catchment.
- Improve water quality of local Kin Kin creek and its tributaries ensuring the access to clean water for agricultural and livestock use
- Management of environmental weeds
- Actively engage landholders to enhance sustainable production and management of the agricultural landscape within the Kin Kin region, assisting them to achieve sustainable practices and improve soil production capacity, while improving local water sources.

1.3 Plan objectives

The purpose of this plan is to identify and map areas in the Kin Kin Catchment, targeting areas for soil stabilisation investment in order to address erosion and nutrient movement within the Catchment.

Desired Outputs:

The investigation and development of:

1. GIS generated maps with associated data sets that indicate areas of sediment movement and deposition within the Kin Kin Catchment,
2. Identify the priority investment areas at a sub catchment level according to prioritisation criteria identified in section 2.0 of this report,
3. Recommendations of on-ground activities suitable to address sediment movement, and
4. The engagement of local landholders in active participation of these recommended activities.

1.4 Geographic scope

Kin Kin Catchment is a major tributary of the Noosa River, encompassing the township of Kin Kin and the locality of Kin Kin and Cootharaba; this includes a number of creek reaches including, but not limited to, Kin Kin Creek, Wahpunga Creek and Sandy Creek.

The Kin Kin Catchment covers an area of approximately 205km^2 or 20,839 hectares consisting of a number of minor tributaries that run into Kin Kin Creek. Aside from the upper most reaches in the headwater streams, which are confined, the majority of these reaches are unconfined, flowing through alluvial flood plains.

Similarities in geological elements along particular creeks, or reaches determined the division of the Kin Kin Catchment into 17 sub catchments for ease of management. Identifying these sub catchments is an integral part of stage 2 of this implementation plan see section 2.1. Table 1 lists these sub catchments and Appendix 4 presents a map of the sub catchments and the creek reaches that contribute.

Table 1 Sub-catchments Delineated (Support Map included see appendix 4)

Subcatchment Name	Area (ha)
Banyan Creek	2,316
Boreen	1,952
Cooloothin Creek	1,852
Elanda Point	1,638
Eulama Creek	1,928
Golden Gully	272
Kin Kin Creek East Branch	862
Kin Kin Creek Gallen Gully	808
Kin Kin Creek Kin Kin	946
Kin Kin Creek Lower Wahpunga	672
Kin Kin Creek Wahpunga	1,272
Kin Kin Creek West Branch	863
Kinmond Creek	963
Pender Creek	559
Sandy Creek	2,364
Sister Tree Creek	486
Wahpunga Creek	1,086
Total area (ha)	**20,839**

1.5 Historical Background

The catchment and its original majestic Kin Kin Scrub was extensively cleared between 1866 and 1900 for timber and since this time has had a myriad of farming uses, including beef cattle, dairy, bananas, beans, peas, pineapples, sugar cane, and other small crops.

The tenure of land is primarily freehold, with a small percentage of State land, Council managed reserves, National Park, and State Forest.

Current land use within the catchment is primarily grazing with increasing lifestyle properties, mixed farming and horticulture. In recent years there has been an increase in landholders who are looking to diversify, seeking more sustainable uses of the land and the area has seen an increase in boutique crops such as coffee beans, organic greens, alpacas for the fleece and dairy goat farms specialising in milk and cheese production.

Areas of remnant and regrowth vegetation exist across the landscape, particularly in National Park, Council Reserves and steeper parts of the Catchment. Exotic Pine Forests exist within State Forest in the north.

1.6 Geological Background and hydrology

The Catchment has two major distinct landscapes separated by the Wahpunga Range that runs north south through the centre. East of the range is dominated by extensive floodplains feeding into Lake Cootharaba. To the west of the range is steep headwater areas and alluvial valleys once vegetated in expansive ‘Lowland Rainforest of Subtropical Australia’, threatened ecological community, listed as critically endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The basalt plain and hill landscapes of the Kin Kin catchment can contain one or more unconfined aquifers where groundwater is stored and transmitted through intergranular pore space, fractures, vesicles and/or weathered zone of the rock. When basalt plains and hills overlie lower permeability rock, vertical groundwater movement is restricted at the interface or contact. While groundwater will often continue to leak through the lower permeability rock to some degree (through fractures), typically, groundwater will move laterally and is commonly discharged to the surface along the contact between the two rocks. **Figure 1** is a conceptual model of the processes involved.

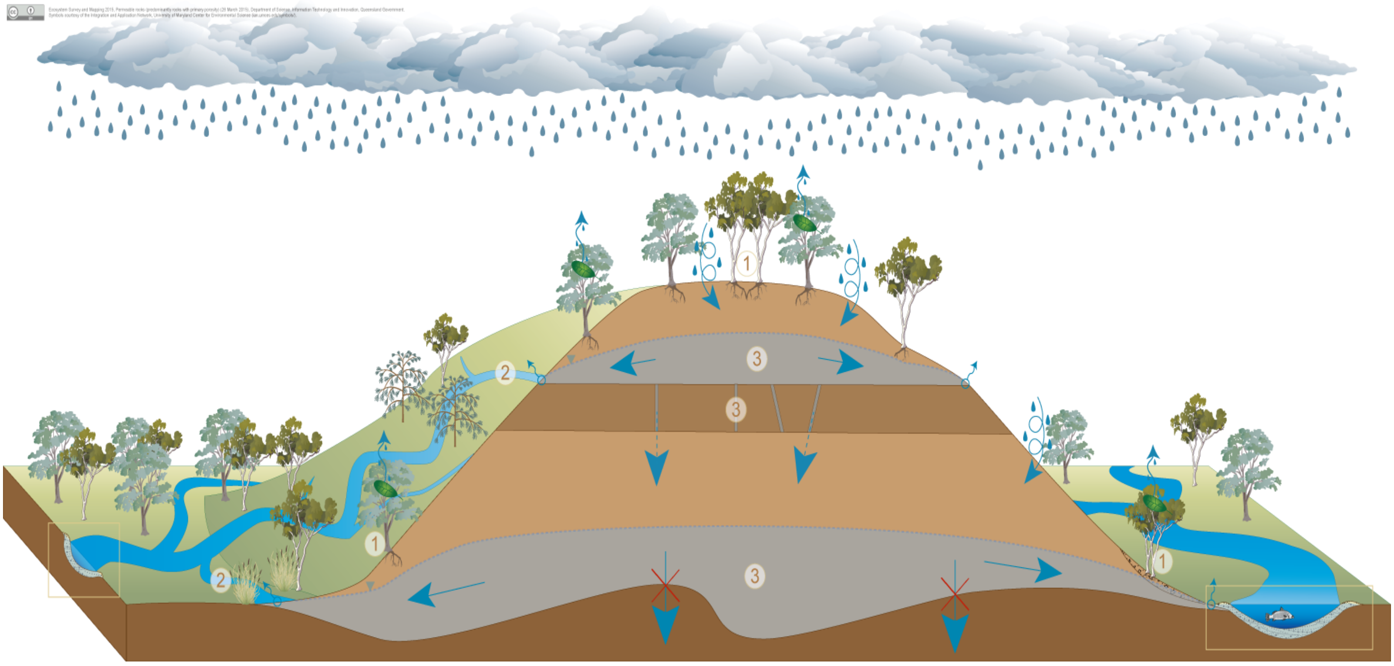

Figure 1 Conceptual model of the ground water process of the Kin Kin catchment

Ecosystem legend: 1 – Terrestrial GDEs, 2 – Surface expression GDEs, and 3 – Subterranean GDEs

Blue arrow indicates the direction of flow

Permeable rocks, WetlandInfo 2013, Queensland Government, Queensland, viewed 29 January 2019, <https://wetlandinfo.des.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/permeable-rocks/>.

The majority of the upper catchment is comprises heavy underlying clays of the Kin Kin beds, a moderately hard, fine grained Phyllite mudstone with finely spaced layering that dominates the geology in the upper catchment. A central north-south band of sedimentary Myrtle Creek Sandstones and quaternary alluvial occupies the river valley and expansive lower catchment floodplains. **Figure 2** illustrates the areas of geological interest as determined by ancient processes and the resulting underlying soilscape.

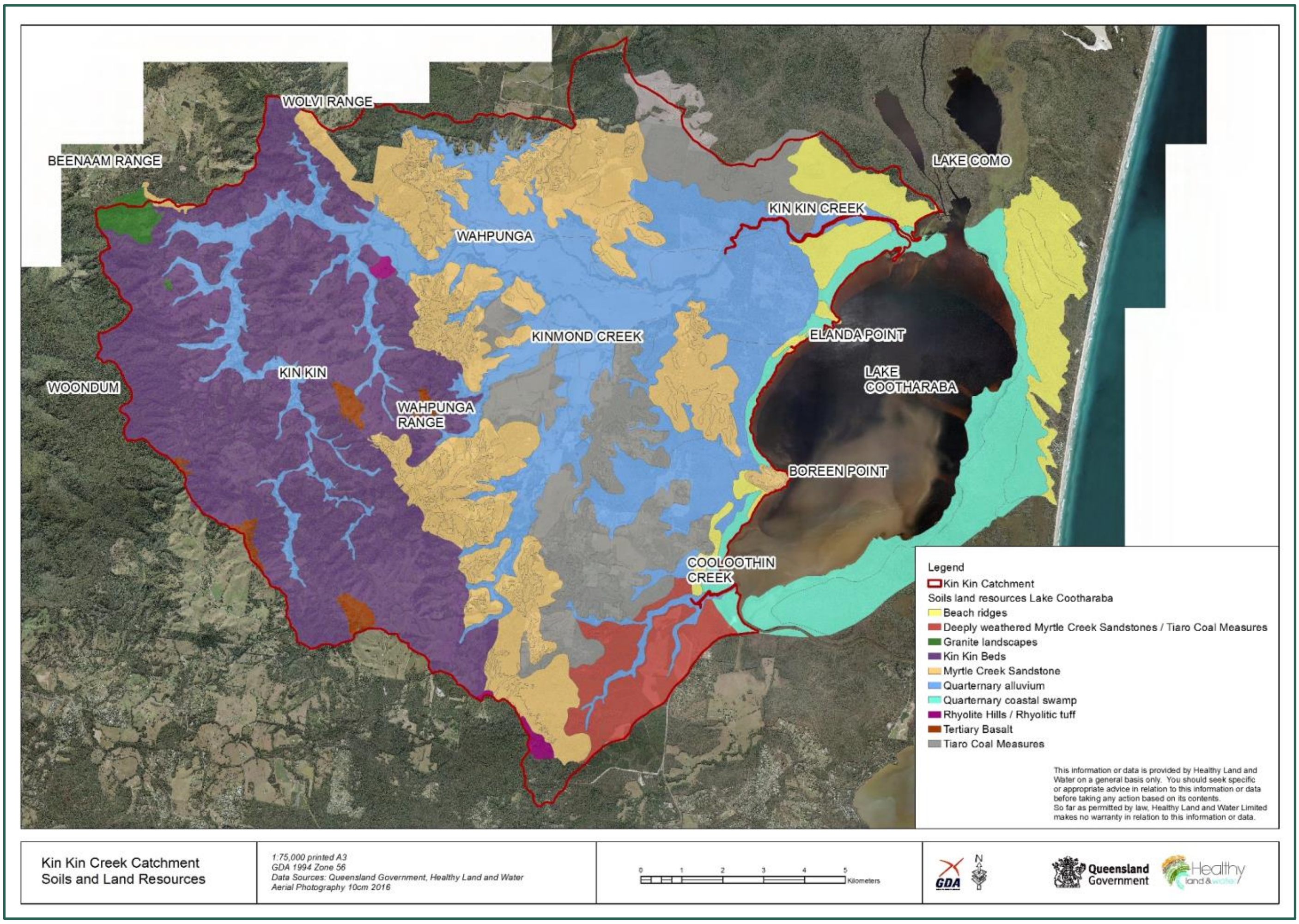

Figure 2 Geological origin information of the underlying soil of the entire Noosa River Catchment.
Note the Kin Kin region is essentially lies on Kin Kin beds, mudstone of the early Triassic age converted under pressure to Phyllite; young in geological terms.

1.7 Previous studies

Previous studies undertaken researching Lake Cootharaba and its receiving waters of the Kin Kin Catchment, have been based on concern for the health of Lake Cootharaba and the inherent nutrient and sedimentation problems, in particular the declining status of the benthic layer of the lake system.

Lake Cootharaba Nitrogen Study

In the early 2000's, the annual Healthy Waterways Report Card monitoring detected issues with the high level of Total Nitrogen (TN) in the southern section of Lake Cootharaba. A study in 2003 by Rissik and Grinham pointed out the natural shallow water levels of the lake and natural processing within the lake system such as wind creating resuspension within the water would contribute to the levels of TN (Rissik & Grinham 2003). The same study also suggested that high input from disturbed catchments were more likely to explain observed TN changes. The 2009 'Lake Cootharaba Nitrogen Study' (Brooks et al 2009) ruled out significant nitrogen contribution from the local on-site sewerage systems of Boreen Point and put the source of the majority of nitrogen and sediment entering the lake as originating in the Kin Kin Catchment.

Suncoast Farm FLOW Honours Studies

Sediment and nitrogen mobilisation within the Kin Kin Catchment was particularly explored in 2011-2012 in the Suncoast Farm FLOW project and the two University of the Sunshine Coast funded Honours Projects:

- *Tracing Sources & Dating Sediments of Lake Cootharaba, South East Queensland, Lamb, K, 2011.*
- *Sources and Speciation of Dissolved Inorganic Nutrients in Lake Cootharaba and the Noosa River Catchment Tully, N, 2012.*

The project by Lamb (Lamb et al 2011) identified that Lake Cootharaba has a high deposition rate averaging 1cm /yr. Lake core samples show an increasing trend of Nitrogen levels over the past 120 years, with sediment bound Nitrogen levels increased by >40%. (Lamb 2012).

Total Suspended Sediment, sediment bound Nitrogen and Phosphorous loads, 97%, 91% and 92% respectively, into Lake Cootharaba was estimated to originate from the Kin Kin Creek, despite Upper Noosa River contributing orders of magnitude more water by volume (Lamb 2012).

Kin Kin suspended sediment (mainly clay and silt fractions) carries the majority of Nitrogen and Phosphorous in the water column of the two main inputs into Lake Cootharaba. (Tully 2012).

Total Suspended Sediment fluxes and metals fingerprint analysis (Principle Component Analysis) showed that the sources of Total Suspended Sediment into Lake Cootharaba from the Kin Kin Creek sub-catchment are most likely non-point or diffuse in source (Lamb 2012).

Total Suspended Sediment concentrations are highly impacted by precipitation events (Lamb 2012).

The study undertaken by Tully (Tully 2012) estimated that Kin Kin Creek delivers 1400-3700kg Dissolved Inorganic Nitrogen (DIN) / day average whilst the Upper Noosa River delivers 600-1600kg DIN / day average. (**Figure 3**)

The report also advised that Kin Kin Creek delivers three times the coliform bacteria levels than Upper Noosa River (Tully 2012).

The estimated contributions of TSS, SBN, and SBP from the Upper Noosa River and Kin Kin Creek into Lake Cootharaba.

Estimated contributions	Upper Noosa River	Kin Kin Creek
Total Suspended Sediment (tons/year)	280	3840
Sediment Bound Nitrogen (tons/year)	24	45
Sediment Bound Phosphorus (tons/year)	2	7

Figure 3 The levels of Nitrogen and Phosphorous and where it the estimated origin (Tully 2012)

1.8 Kin Kin Catchment LIDAR Change Analysis

More recently, Healthy Land and Water (HL&W), commissioned by Noosa & District Landcare, undertook a study to help identify the specific areas subjected to sedimentation and deposition in the catchment. This is to assist in the identification and analysis of the erosion prone locations within the catchment.

The purpose of the LIDAR study was to identify and prioritise areas that contribute to soil loss so that targeted mitigation activities can take place. The primary identification tool used was a LIDAR digital elevation model (DEM) of change (the change analysis). The report outlined the methodology used to develop the change analysis for the Kin Kin Catchment. Preliminary results of the change analysis were tabled to assist with sub-catchment prioritisation and to address sediment risk hotspots.

A combination of manual and automated change analysis undertaken in the report identified 258 'Areas of Interest'. The process involved applying filters and masks to improve reliability in results, and verification using desktop high resolution aerial photography.

The LIDAR and DEM revealed an incredible 2,486,691 tonnes of soil was mobilised over the 20,000ha of the Kin Kin Catchment during the period of 2008-2015. This is equivalent to 191,284 large dual-axel soil delivery trucks or 765 Olympic sized swimming pools filled with soil. Based on average soil replacement cost at $30/tonne soil productivity is estimated to exceed $74 million.

Higher levels of erosion were found to be in the mid to upper region of the catchment due to the naturally steep geological formation, with most deposition generally occurring on the lower flood plain regions. Natural levee banks can be found to occur as the velocity reduces and sediment is dropped out above creek banks.

Areas were characterised by erosion type, including: gully; hillslope; mass movement; sheet/rill; and stream bank erosion, all predominantly influenced by slope inclination and land use. Additional analysis allowed the 'Areas of Interest' to be prioritised based on soil loss (tonnes) and erosion rate (tonnes/ha) for the time interval of 2008-2015. As part of the assessment of the report, ground-truthing was undertaken by the steering committee and the results presented and discussed with the community.

Snap Shot Stats

KIIKK LIDAR REPORT - SNAP SHOT STATS

- *Kin Kin Catchment approximately 20,000 ha*
- *LIDAR DEM analysis based on satellite imagery form 2008 & 2015*
- *2,486,691 tonnes of soil was mobilised – 191,284 large dual-axel soil delivery trucks or 765 Olympic sized swimming pools filled with soil*
- *At $30/tonne that's calculates to exceed $74 million*
- *258 'Areas of Interest'*

1.9 Definitions

Barrier remediation is the improvement or removal of instream barriers to restore stream connectivity and aquatic habitat condition.

Confined through to unconfined creek reach. The natural flow of creeks determined by geological properties. A **confined** creek is one that is restricted by 'hard' barriers such as granite out-crops, and there is little change in the channeling of the creek line. An **unconfined** creek is not bound by geology, usually found on flatter, alluvial plains and will change direction, or meander, according to water velocity and flow, sometimes over a short time period.

Connectivity refers to the spatial linkages of biological, physical and chemical processes across landscapes and seascapes.

Conservation reserves are areas that are near pristine ecosystems and protected from change or development.

Landuse in this plan refers to the allocation of natural resources of the land, both physical and chemical. It is also important to remember the relevance of changes in the utilisation of these resources and extra pressures that placed on the land through the clearance of native forest and vegetation, intensive grazing and cropping, the inappropriate use of fertiliser and chemical, and the altering of watercourse through dams and creek redirection.

LiDAR Light Detection and Ranging is a remote sensing, satellite imaging method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.

Reach/ waterway management unit defines discrete management sections of similar geomorphic character.

Remediation in this context refers to the action of structurally changing a site to better suit flow of water reducing speed of water flow and channeling water or sediment runoff to where it can be better dealt with.

Riparian: "*The structural formation and vegetation of the banks of the river at least to the bank full flood height. It generally includes a further vegetated 'buffer' back from the top of the high bank*." (Queensland Wetlands Program)

Services refers to all other landuse other than agricultural and farming. This would include recreational and cultural use, commercial use such as quarries, mining or military, and public services such as recycling centers. In the Kin Kin Catchment, the main services are commercial, recreational and cultural.

Waterway within this assessment is the same meaning as 'wetland' in accordance with the Queensland Wetlands Program definition described as:
*"*Areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres".

Wetland to be a wetland the area must have one or more of the following attributes:

- at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or
- the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or
- the substratum is not soil and is saturated with water, or covered by water at some time.

1.10 Definition of Erosion Type

Gully Erosion is an erosion path or channel that has a depth of exceeding 0.3m and has active erosion at the head (origin) or along the walls. (Day & Shepherd 2019). Uphill progression of the gully through banks being undercut and collapsing consequently occur (figure 4).

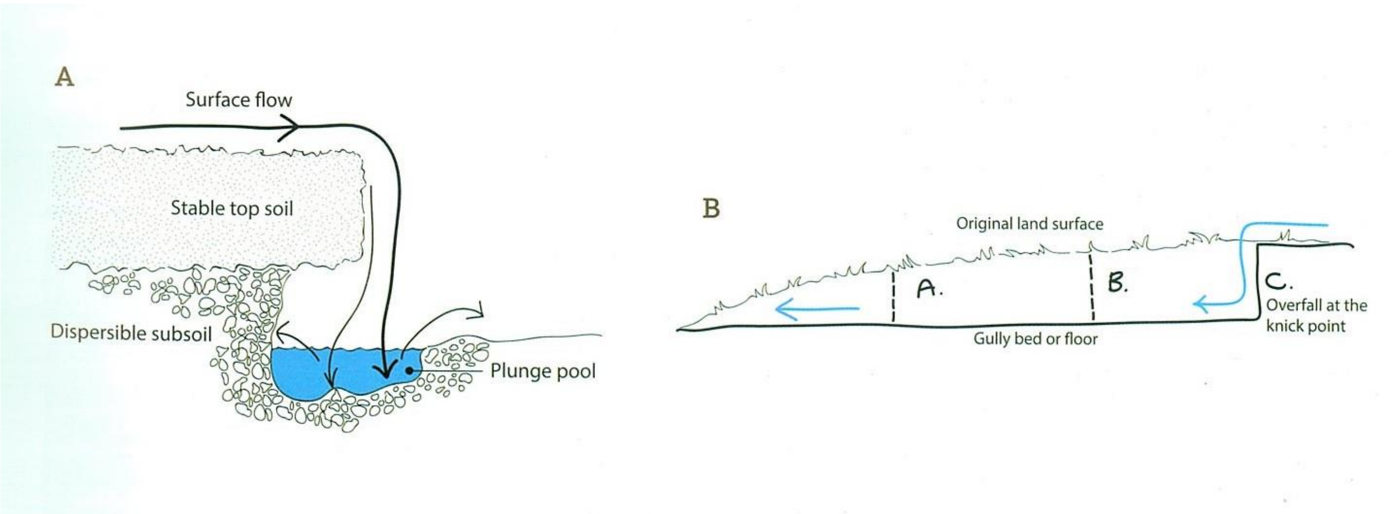

Figure 4 example of gully erosion adapted from Day and Shepherd 2019

Hillslope Erosion is a collective term referring to the exposure of soil through the removal of ground cover vegetation, which then becomes subject to splash (figure 5) or sheet erosion losing the fine shallow surface soil particles. This will often result in rill and gully erosion.

Figure 5 splash erosion occurs when individual raindrops fall on bare soil. This will usually result in rill and gully erosion and is collectively known as hillslope erosion Adapted from Saving Soil, NSW DPI.

Stream Bank (figure 6) is a naturally occurring process when high velocity water flow scours the stream bank. Issues arise when the natural process is exaggerated when the bank has been compromised through the of removal of deep rooted vegetation and protective reeds and ground covers from riparian sites or trampling of banks from heavy livestock.

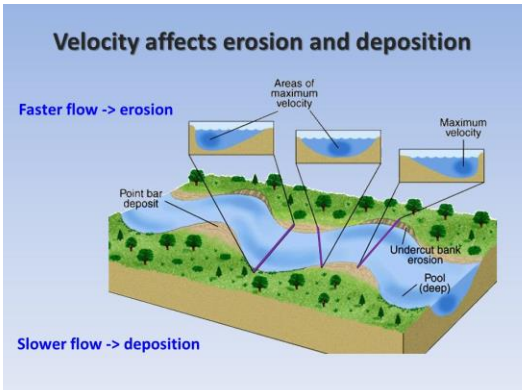

Figure 6 Stream bank erosion is a naturally occurring event and meandering streams will change course over a regular time span. It is exaggerated with removal of vegetation and compromised banks from livestock trampling. Taken from presentation by Leslie A. Morrissey UVM 2012

Mass movement also known as landslip or slumping is the downward movement of soil under the influence of gravity and both above and below surface water movement. Most frequently found on slopes with a gradient >25° in areas cleared of deep-rooted vegetation. Water saturates soil particles allowing them to move freely and disperse creating an unstable surface area (figure 7) breaking the surface tension. Once the surface layer becomes saturated, water infiltrates and collects to the impervious rock layer below creating an unstable slope that will slip through gravity (figure 8) In Kin Kin area analysis has identified landslip and slumping under large patches of the shallow rooted vegetation such as *Lantana camara.*

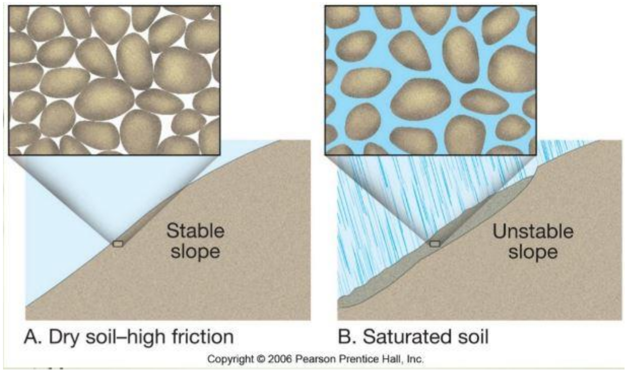

Figure 7 when surface soil particles become saturated they move freely and disperse easily. Adapted from presentation by Umar Bhatti 2017

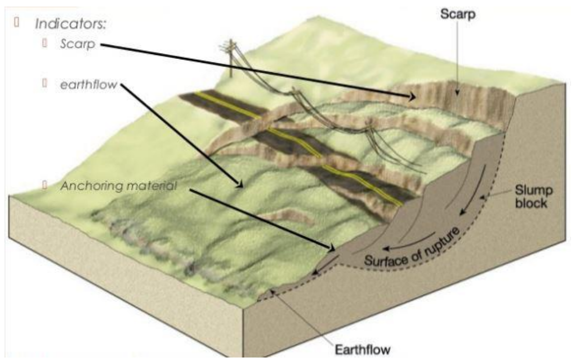

Figure 8 slumping a form of mass movement occurs when water saturates the surface layer of soil, hits the impervious rock layer below and then flows down the slope taking the surface layer with it. Adapted from presentation by Umar Bhatti 2017

2.0 Prioritisation Methodology

The prioritisation criteria and matrix utilised in this plan is comparatively simple and uses existing quality data sets where possible.

2.1 Prioritisation

Based on the LIDAR Digital Elevation Model and Surface Slope, sub-catchments were generated for Kin Kin Creek. These align with existing watercourse lines (NRM Southern Section) and the Noosa Shire Waterways Assessment (2017). The mapping undertaken at 1:15,000 with the results providing local management areas to assess and prioritise erosion potential and remediation works. Refer to section 7.0 of this document for the maps resulting from this analysis. Appendix 5 describes the defined erosion hot spots of the region and Appendix 6 depicts the type of erosion found. These maps define general areas and type of erosion in the region enabling on ground progress as the project is implemented.

The Prioritisation comprises three stages:

STAGE 1: Further analysis of the LIDAR Report data to identify trends in scale and occurrence of sediment mobilisation results within the landscape.

Each Erosion type was analysed for its frequency and scale of occurrence against base biophysical parameters:

Riparian and Gully Erosion types:

- by river style
- by landuse

Slip and Hillslope erosion:

- by soil type
- by land use
- by erosion risk mapping

STAGE 2: The definition of sub-catchments within the Kin Kin Catchment and an analysis of the potential contribution of the sub-catchment to the objectives of this strategy.

STAGE 3: define the specific prioritisation criteria that will determine the allocation of on ground works to achieve the best desired outcome with the resources available

STAGE 1 – Spatial Analysis and Prioritisation

To better understand the dominant underlying factors driving potential erosion, an assessment of biophysical factors was undertaken using GIS mapping tools, and summarized per sub-catchment area. Erosion types were analysed by soils and landuse.

Summarised in **Tables 2 & 3** are the dominant soil types and landuse with observed high soil loss for erosion types. Hillslope erosion is the predominant cause of soil movement, occurring on the steeper slopes of the Kin Kin beds where a dramatic change in landuse has occurred.

Table 2 Erosion Type and Soil Type

Erosion Type and Soil Type (observed high's)	Total Loss (t)	T/ha
Gully Erosion		
• Kin Kin Beds - Slopes >25%	168,978	1,224
• Kin Kin Beds - Mid and lower slopes <25%	79,248	1,036
• Kin Kin Beds - Crests and ridges	30,832	1,276
• Quarternary alluvium - Phyllite dominated alluvium	3,045	1,147
Hill slope erosion		
• Kin Kin Beds - Slopes >25%	1,004,120	3,863
• Kin Kin Beds - Crests and ridges	241,905	4,076
• Kin Kin Beds - Mid and lower slopes <25%	160,720	3,419
• Granite landscapes	148,715	3,876
• Quarternary alluvium - Phyllite dominated alluvium	4,593	4,339
Mass Movement		
• Kin Kin Beds - Slopes >25%	186,486	1,611
• Kin Kin Beds - Crests and ridges	53,763	2,370
• Myrtle Creek Sandstone - Western and southern facing slopes - Crests and ridges	1,961	2,010
Stream Bank Erosion		
• Quarternary alluvium - mixed origin alluvium	80,409	1,252
• Quarternary alluvium - Phyllite dominated alluvium	45,029	1,053
• Kin Kin Beds - Crests and ridges	3,726	2,301

Table 3 Erosion Type and Landuse

Erosion Type and Landuse (observed high's)	Total Loss (t)	T/ha
Gully Erosion		
• Production from relatively natural environments	224,6771	989
○ Grazing native vegetation	224,6771	989
• Intensive uses	37,609	2,311
○ Residential	37,320	2,325
○ Services	289	1,319
Hill slope erosion		
• Conservation and natural environments	543,103	3,703
○ Managed resource protection (State forestry and timber harvest)	8,239	4,177
○ Nature conservation	1,498	1,138
○ Other minimal use	533,366	3,720
• Intensive uses	194,708	3,461
○ Mining	502	1,889
○ Residential	189,512	3,602
○ Services	4,694	1,393
• Production from relatively natural environments	911,323	3,653
○ Grazing native vegetation	895,607	3,719

○ Livestock grazing	7,145	3,231
○ Production forestry	8,571	1,340
Mass Movement		
• Intensive uses	11,084	2,797
○ Residential	7,782	3,901
○ Services	3,302	1,677
• Production from relatively natural environments	288,877	1,362
○ Grazing native vegetation	287,456	1,358
○ Livestock grazing	1,183	5,245
○ Production forestry	238	2,010
Stream Bank Erosion		
• Conservation and natural environments	38,598	1,808
○ Managed resource protection (State forestry and timber harvest)	1,038	1,363
○ Nature conservation	8,781	2,263
○ Other minimal use	28,779	1,722
• Production from relatively natural environments	136,089	990
○ Grazing native vegetation	136,089	990

STAGE 2 Definition of Sub Catchments

Definition of sub catchments developed through tributaries of Kin Kin Creek with geographical and geological similarities in creek reach. The breaking up of the entire Kin Kin catchment into 17 sub catchments became necessary for ease of management and application of priority selection criteria.

STAGE 3 Prioritisation

Listed below are eight criteria points that selected to define sub catchment priority. A full description of each criteria is found in section 2.2. The criteria is listed in no particular order of preference.

- Scale of sediment mobilisation
- Number of detected erosion hotspots within the sub catchment zone
- Distance of Areas of Interest (AoI) from waterway
- Geological substrate and soil type
- Reach recovery potential
- Diversity of erosion types
- Remediation action assessment
- Landholder willingness to participate

Appendix 4A indicates the prioritisation of the sub catchments based on the listed criteria.

2.2 Full description of 8 prioritisation criteria

- Scale of sediment mobilisation

  Calculations of total soil movement of tonnes per hectare. The point of origin of the sediment movement within the Kin Kin Catchment was an important calculation using the LiDAR analysis and subsequent DEM of Difference, using the high confidence range of 0.5 - 2m of change.

- Number of detected erosion hotspots
  Detected using analysis of DEM of difference over the period of 7 years (2008 – 2015) the level of elevation change could be identified, creating clear hot spots of erosion and deposition.

- Distance of AoI from waterways and Lake Cootharaba
  Based on the likelihood percentage of sediment reaching the lake system; the further the reach was in kilometres from Lake Cootharaba, the greater the chance sediment would be deposited in other stream reaches.

- Geological substrate and soil type
  The relationship between the type of geological substrate and soil type and the type of erosion occurring is illustrated below in **Table 4**. The combined elements relates to the amount of soil loss occurring.

- Reach Recovery Potential
  The basis for establishing Reach Recovery Potential was assessed according to the Reach Prioritisation and the Ecological Function scoring of the 'Noosa Waterways Assessment' (Lyons et al, 2017). Appendix 1 is a table of assessment used in the analysis of this assessment.

- Diversity of erosion types
  (for full description of erosion types refer to section 1.10 of this document)
  The types of erosion occurring in the Kin Kin catchment include:
  Hillslope – a collective term referring to areas subject to exposure due to removal of ground cover vegetation resulting in splash or sheet erosion losing the fine, shallow surface particles. This will frequently lead to rill and gully erosion occurring.
  Gully - channels deeper than 300mm occurring when water flow has created a channel through bare soil becoming subject to head cut erosion. Uphill progression of the gully through banks being undercut and collapsing consequently occur.
  Stream bank – occurs when high velocity water flow scours the stream bank usually when bank has been compromised through loss of vegetation or heavy stock trampling.
  Mass Movement - also known as, landslip or slumping is the downward movement of soil under the influence of gravity. Most frequently found on slopes over 25º, in areas cleared of deep rooted vegetation and annual rainfall ≥ 900ml.

- Remediation Action Assessment
  Linking closely with the type of erosion occurring, action will depend on the on-ground assessment of what type of remediation is required, how cost effective it will be and the risks involved with the implementation of the remediation. Table 7 is a detailed look at remediation types and their cost effectiveness for implementation.

- Landholder willingness to participate
  Taken into consideration, is the number of landholders within the sub-catchment and type of land use. Landholder willingness to participate is used to prioritise projects that could be actioned immediately or when funding becomes available. A property with a low score on this criterion is a property that has not been engaged to date. It is anticipated that these scores will change as the project progresses and more landholders become aware of the program.

Table 4 Areas of erosion and relation to soil type

Soil Types	Sum of Area/ha	TOTAL

	Hill Slope Soils	Gully Soils	Stream Bank Soils	Mass Movement	Sheet Soils	
Granite landscapes	38.36					38.36
Kin Kin Beds - Crests and ridges	59.35	24.16	1.62	22.69		107.83
Kin Kin Beds - Mid and lower slopes <25%	47.01	76.53	23.89	32.29		179.72
Kin Kin Beds - Slopes >25%	259.91	138.10	8.64	115.73		522.38
Kin Kin Beds - Pediments and fans		0.70	0.15	1.34		2.20
Myrtle Creek Sandstone - Northern and eastern facing slopes - Podosol soils	0.21		0.21		0.25	0.66
Myrtle Creek Sandstone - Northern and eastern facing slopes - Crests and ridges	3.22	0.17	0.12	1.45		4.96
Myrtle Creek Sandstone - Northern and eastern facing slopes - Mid and lower slopes	4.40	7.50	3.18	2.55		17.62
Myrtle Creek Sandstone - Northern and eastern facing slopes - Mid and lower slopes <10%	1.15	6.64	3.55			11.34
Myrtle Creek Sandstone - Northern and eastern facing slopes - Upper and mid slopes of steep & rolling hills	13.31		0.15	0.28		13.74
Myrtle Creek Sandstone - Western and southern facing slopes - Crests and ridges		6.99	4.53	0.98		12.50
Myrtle Creek Sandstone - Western and southern facing slopes - Mid and lower slopes <10%			0.84			0.84
Myrtle Creek Sandstone - Western and southern facing slopes - Upper and mid slopes of steep and rolling hills			1.23			1.23
Quarternary alluvium - Phyllite dominated alluvium	1.06	2.66	42.76	1.89	0.04	48.40
Quarternary alluvium - Sandstone derived alluvium	0.36	2.13	10.30			12.80
Rhyolitic tuff - Crests and slopes of low hills			0.28			0.28
Rhyolite Hills - Crests and ridges	2.83					2.83
Tertiary Basalt - Crests and ridges	4.85	0.42		10.63		15.89
Tertiary Basalt - Slopes of steep rolling hills and low hills	4.70	0.47		33.20		38.37
Tiaro Coal Measures - Deeply weathered mudstones - Crests, ridges and upper slopes	0.19					0.19
Tiaro Coal Measures - Deeply weathered mudstones - Mid and lower slopes	0.40					0.40
Tiaro Coal Measures - Slopes of undulating rises	1.29					1.29
Grand Total	442.40	274.35	165.66	223.03	0.28	1105.72

3.0 Prioritisation Results

Further to the analysis of stage 1 & 2 , stage 3 assesses the subcatchments of the region against established criteria. Table 5 lays out the complete Prioritisation Matrix, detailing each of the subcatchment, set against the selected criteria. Highlighted are sub-catchments that fulfil a number of the prioritisation criteria, indicated as significant.

Table 5 Prioritisation Table of Selection Criteria

Subcatchment Name	Area (ha)	Erosion Hotspot	Erosion Type	Total Loss (t)	AOI (ha)	Noosa Waterways - Eco Priority	Distance to Lake Cootharaba	Landholder Willingness	Subcatchment Priorities
Banyan Creek	2,316	3	Hillslope x 2 Stream Bank x 1	8,608	5	BAN1 - 1 Protected reach in good condition throughout BAN2 - 4 Deteriorating strategic reach BAN3 - 5 Linking reach and significant remnant section Borders Kin Kin Creek KK3 - 4 Deteriorating strategic reach	0-12 km	2 Lot plans - clients	
Boreen	1,952	1	Hillslope x 1	1,881	4	nil	0 km	36 Lot plans - clients 8 Lot plans - members 6 Lot plans - council land	
Cooloothin Creek	1,852	3	Hillslope x 3	12,737	8	COT1 - 4 Deteriorating strategic reach COT2 - 2 Unprotected reach of regional conservation significance	0-6 km	4 Lot plans - clients 3 Lot plans - council land	
Elanda Point	1,638	2	Stream Bank x 2	3,546	2	Borders Kin Kin Creek KK3 - 4 Deteriorating strategic reach	0 km	8 Lot plans - clients 1 Lot plans - council land	
Eulama Creek	1,928	6	Hillslope x 2 Mass Movement x 1 Stream Bank x 3	52,976	60	EUL - 4 Deteriorating strategic reach	6-17km	6 Lot plans - clients 1 Lot plans - members	
Golden Gully	272	6	Hillslope x 4 Stream Bank x 2	279,610	72	GOL1 - no data GOL2 - 5 Linking reach and significant remnant section GOL3 - 5 Linking reach and significant remnant section	30-34 km	4 Lot plans - clients	

Subcatchment Name	Area (ha)	Erosion Hotspot	Erosion Type	Total Loss (t)	AOI (ha)	Noosa Waterways - Eco Priority	Distance to Lake Cootharaba	Landholder Willingness	Subcatchment Priorities
Kin Kin Creek East Branch	862	19	Gully x 10 Hillslope x 4 Mass Movement x 4 Stream Bank x 1	256,532	109	KKE1 - 2 Unprotected reach of regional conservation significance KKE2 - 7 Reaches requiring significant levels of investment for recovery	36-43 km	5 Lot plans - clients 1 Lot plans - members	**Focus for works** **-further engagement**
Kin Kin Creek Gallen Gully	808	22	Gully x 6 Hillslope x 4 Mass Movement x 7 Stream Bank x 5	202,158	114	KK2 - 5 Linking reach and significant remnant section (flows through subcatchment) Borders KK1 - 6 Reach with moderate recovery potential	26-30 km	10 Lot plans - clients 1 Lot plans - members	
Kin Kin Creek Kin Kin	946	35	Gully x 14 Hillslope x 13 Mass Movement x 4 Stream Bank x 4	353,108	118	KK1 - 6 Reach with moderate recovery potential	31-36 km	25 Lot plans - clients 2 Lot plans - members 8 Lot plans - council land	**-focus for more works** **-Strong engagement**
Kin Kin Creek Lower Wahpunga	672	5	Stream Bank x 5	29,164	18	KK3 - 4 Deteriorating strategic reach	7-18 km	2 Lot plans - clients 1 Lot plans - members 2 Lot plans - council land	
Kin Kin Creek Wahpunga	1,272	24	Gully x 12 Hillslope x 4 Mass Movement x 2 Stream Bank x 6	323,744	146	KK2 - 5 Linking reach and significant remnant section (flows through subcatchment)	18-27 km	16 Lot plans - clients 3 Lot plans - members 1 Lot plans - council land	**-focus for more works** **-Strong engagement**
Kin Kin Creek West Branch	863	19	Gully x 5 Hillslope x 7 Mass Movement x 5 Stream Bank x 2	145,665	77	KKW1 - 4 Deteriorating strategic reach KKW2 - 4 Deteriorating strategic reach	36-43 km	14 Lot plans - clients 2 Lot plans - members 1 Lot plans - council land	

Subcatchment Name	Area (ha)	Erosion Hotspot	Erosion Type	Total Loss (t)	AOI (ha)	Noosa Waterways - Eco Priority	Distance to Lake Cootharaba	Landholder Willingness	Subcatchment Priorities
Kinmond Creek	963	32	Gully x 10 Hillslope x 6 Mass Movement x 2 Sheet x 1 Stream Bank x 13	95,662	64	KIN1 - 2 Unprotected reach of regional conservation significance KIN2 - 5 Linking reach and significant remnant section KIN3 - 5 Linking reach and significant remnant section KIN4 - 5 Linking reach and significant remnant section	11-19 km	6 Lot plans - clients	**-focus for more works** **-More engagement**
Pender Creek	559	18	Gully x 1 Hillslope x 16 Stream Bank x 1	222,035	54	PEN1 - no data PEN2 - 4 Deteriorating strategic reach PEN3 - 5 Linking reach and significant remnant section PDS1 - no data PDS2 - 4 Deteriorating strategic reach	31-34 km	11 Lot plans - clients 1 Lot plans - members	
Sandy Creek	2,364	27	Gully x 16 Hillslope x 5 Mass Movement x 3 Stream Bank x 3	415,009	154	FER1 - no data FER2 - 5 Linking reach and significant remnant section SAND1 - 2 Unprotected reach of regional conservation significance SAND2 - 2 Unprotected reach of regional conservation significance SAND3 - 5 Linking reach and significant remnant section SAND4 - 7 Reaches requiring significant levels of investment for recovery SBB1 - no data SBB2 - no data SBB3 - 5 Linking reach and significant remnant section SDL1 - 5 Linking reach and significant remnant section SDL2 - 6 Reach with moderate recovery potential SDL3 - 5 Linking reach and significant remnant section TOM1 - no data TOM2 - 5 Linking reach and significant remnant section TOM3 - 4 Deteriorating strategic reach	11-22 km	9 Lot plans - clients 1 Lot plans - members	**-focus for more works** **-More engagement**
Sister Tree Creek	486	17	Gully x 5 Hillslope x 7 Stream Bank x 5	234,655	60	ST1 - no data ST2 - no data ST3 - 6 - Reach with moderate recovery potential	26-30 km	1 Lot plans - clients 1 Lot plans - council land	

Subcatchment Name	Area (ha)	Erosion Hotspot	Erosion Type	Total Loss (t)	AOI (ha)	Noosa Waterways - Eco Priority	Distance to Lake Cootharaba	Landholder Willingness	Subcatchment Priorities
Wahpunga Creek	1,086	42	Gully x 20 Hillslope x 4 Mass Movement x 9 Stream Bank x 9	251,379	258	WAH1 - 5 Linking reach and significant remnant section WAH2 - 6 Reach with moderate recovery potential WAH3 - 6 Reach with moderate recovery potential	22-28 km	10 Lot plans - clients 2 Lot plans - members	**-focus for more works** **-More engagement**
Thresholds		**top 4 / threshold 25**	**3 or more (diversity of erosion types)**	**threshold 250,000**		**significance and recovery - 2 or more**	**0-20km**	**all three types**	**3 or more criteria (purples)**

A summary of this prioritisation process, illustrated in Table 6, indicates where the implementation of this plan can begin. Active engagement of landholders will occur within priority sub catchments to discuss areas of concern and assess the best method for remediation and on ground works.

Table 6 Summary of Prioritisation Matrix (by sub-catchment)

Rank	Erosion Hotspots	Erosion Type	Total Loss (t/ha)	Area of Interest (ha)	Noosa Waterways - Eco Priority (Scored 1-5, highest %)	Distance to Lake Cootharaba	Willingness (type count)	Willingness (Lot plans count)
1	Wahpunga Creek	Kinmond Creek	Sandy Creek	Wahpunga Creek	Kin Kin Creek Wahpunga	Cooloothin Creek	Boreen	Boreen
2	Kin Kin Creek Kin Kin	Wahpunga Creek	Kin Kin Creek Kin Kin	Sandy Creek	Kin Kin Creek West Branch	Banyan Creek	Kin Kin Creek Lower Wahpunga	Kin Kin Creek Kin Kin
3	Kinmond Creek	Kin Kin Creek Kin Kin	Kin Kin Creek Wahpunga	Kin Kin Creek Wahpunga	Kinmond Creek	Elanda Point	Kin Kin Creek Wahpunga	Kin Kin Creek Wahpunga
4	Sandy Creek	Sandy Creek	Golden Gully	Kin Kin Creek Kin Kin	Eulama Creek	Boreen	Kin Kin Creek Kin Kin	Kin Kin Creek West Branch
5	Kin Kin Creek Wahpunga	Kin Kin Creek Wahpunga	Kin Kin Creek East Branch	Kin Kin Creek Gallen Gully	Pender Creek	Eulama Creek	Kin Kin Creek West Branch	Wahpunga Creek
6	Kin Kin Creek Gallen Gully	Kin Kin Creek Gallen Gully	Wahpunga Creek	Kin Kin Creek East Branch	Kin Kin Creek Lower Wahpunga	Kin Kin Creek Lower Wahpunga	Cooloothin Creek	Pender Creek
7	Kin Kin Creek East Branch	Kin Kin Creek East Branch	Sister Tree Creek	Kin Kin Creek West Branch	Cooloothin Creek	Kinmond Creek	Elanda Point	Kin Kin Creek Gallen Gully
8	Kin Kin Creek West Branch	Kin Kin Creek West Branch	Pender Creek	Golden Gully	Banyan Creek	Sandy Creek	Eulama Creek	Sandy Creek
9	Pender Creek	Pender Creek	Kin Kin Creek Gallen Gully	Kinmond Creek	Elanda Point	Kin Kin Creek Wahpunga	Sandy Creek	Elanda Point
10	Sister Tree Creek	Sister Tree Creek	Kin Kin Creek West Branch	Sister Tree Creek	Sandy Creek	Wahpunga Creek	Wahpunga Creek	Cooloothin Creek
11	Eulama Creek	Eulama Creek	Kinmond Creek	Eulama Creek	Kin Kin Creek Gallen Gully	Sister Tree Creek	Sister Tree Creek	Eulama Creek
12	Golden Gully	Golden Gully	Eulama Creek	Pender Creek	Kin Kin Creek East Branch	Kin Kin Creek Gallen Gully	Kin Kin Creek Gallen Gully	Kin Kin Creek East Branch
13	Kin Kin Creek Lower Wahpunga	Banyan Creek	Kin Kin Creek Lower Wahpunga	Kin Kin Creek Lower Wahpunga	Wahpunga Creek	Golden Gully	Pender Creek	Kinmond Creek
14	Banyan Creek	Kin Kin Creek Lower Wahpunga	Cooloothin Creek	Cooloothin Creek	Kin Kin Creek Kin Kin	Pender Creek	Kin Kin Creek East Branch	Kin Kin Creek Lower Wahpunga
15	Cooloothin Creek	Cooloothin Creek	Banyan Creek	Banyan Creek	Golden Gully	Kin Kin Creek Kin Kin	Banyan Creek	Golden Gully
16	Elanda Point	Elanda Point	Elanda Point	Boreen	Sister Tree Creek	Kin Kin Creek West Branch	Kinmond Creek	Sister Tree Creek
17	Boreen	Boreen	Boreen	Elanda Point	Boreen	Kin Kin Creek East Branch	Golden Gully	Banyan Creek

3.1 Summary of Priority catchments

Based on the analysis in Table 5 and 6, the top 5 sub-catchments with the highest ranking for the 8 criteria were:

- Kin Kin Creek, Wahpunga (7/8),
- Kin Kin Creek, Kin Kin (6/8),
- Sandy Creek (4/8),
- Wahpunga Creek (4/8), and
- Kin Kin Creek West Branch (4/8).

Refer to Table 7.

Table 7 Summary of Priority Subcatchments

Subcatchment	Matching Criteria (observed high's)	Priority
Kin Kin Creek Wahpunga	7	High
Kin Kin Creek Kin Kin	6	
Sandy Creek	4	Medium
Wahpunga Creek	4	
Kin Kin Creek West Branch	4	
Boreen	3	Low
Kinmond Creek	3	
Eulama Creek	2	
Kin Kin Creek East Branch	2	
Kin Kin Creek Gallen Gully	2	
Pender Creek	2	
Banyan Creek	1	
Cooloothin Creek	1	
Elanda Point	1	
Golden Gully	1	
Kin Kin Creek Lower Wahpunga	1	
Sister Tree Creek	1	

The list was refined further into areas of High/Medium/Low regions.

Subcatchments in red have the highest score in the criteria process given top priority for on ground works.

Subcatchments in yellow and then green closely follow. The map on Appendix 4A outlines a clearer view of these areas indicated in Table 6 and 7.

4.0 Implementation and roll out

Results of the LIDAR imagery analysis in combination with the prioritisation process, leads to delineation of areas of high priority according to sub-catchment (illustrated in tables four and five).

NDLG wish to engage landholders in priority areas to identify specific erosion and sediment problems in sub catchment reaches that stretch across their properties and be actively involved in individual property assessment plans.

The key remediation activities for these areas can include, but not limited to:

- Improving the extent and quality of the riparian zone through revegetation; (Wilkinson *et al*, 2016);
- Improving erosion prone areas such as creek crossings through revegetation; (Polyakov *et al*, 2005);
- Installation of stock exclusion fencing along waterways, drainage lines and erosion prone areas; (Ghale, N. 2016);
- Installation of off-stream water sources;
- Recommending sustainable pasture management and agriculture practices that will improve soil health;
- Checking dams and water storage for leaks and correct construction, and installation of appropriate spillway and water flow entry points - creating water on water flow points to dissipate flow energy;
- Installation of porous dam checks or leaky weirs in gullies and runoff areas (Alt *et al,* 2009); and
- Remediation of unsealed tracks and pathways (Wade, *et* al, 2012, Freshwater, E. 2015).

There have been a number of studies into the cost effectiveness of various erosion remediation methods; evaluating the level of investment with the effectiveness of reduction in sediment movement and soil erosion. Listed in Table 8 are some of these methods, including the risk level involved in installation and operation.

Table 8 Cost effectiveness of erosion remediation

Methods	Cost Investment	Risk	Effective	Combined With…
Fencing	Low	LOW • Flood design fencing and gates are essential in high flow flood prone districts which will increase cost	HIGH	• Revegetation • Grazing management
Vegetation	Low-medium	LOW • Difficult to establish in a variable climate • Need for replant if a large rain event occurs before establishment	HIGH	• Fencing • Weed management • Grazing management
Porous dam checks (leaky weirs)	Low-medium	LOW • Effective where runoff volume is low • Minimal regular maintenance required	HIGH	• Revegetation and natural regeneration • Fencing • Grazing management
Off stream water points	Medium (pending how much piping is needed)	LOW to MEDIUM • Unlikely to reduce grazing pressure unless fencing is involved • Possibility of soil compaction and manure accumulation around water trough	MEDIUM	• Revegetation • Fencing • Creation of alternate tracks between water points away from high risk erosion areas
Grazing management	Very low	LOW	HIGH	• All activities listed

		• Limits to stock rates after project completion		
Contour banks/diversion banks	Medium - high	MEDIUM • Heavy machinery may damage catchment vegetation • Incorrect or poor design could exacerbate erosion • Suitable for non-erosive soil types	HIGH	• Fencing particularly around discharge area • Revegetation and natural regeneration • Grazing management • Porous dam checks • Water on water ponding in spill ways
Grade control and head drop structures	High	HIGH • Heavy machinery may destabilize the gully • Requires rapid revegetation	LOW	• Control livestock access • Active revegetation • Soil chemical treatment and mulching
Gully reshaping	High	MEDIUM • Heavy machinery may destabilize the gully • Requires rapid and extensive revegetation	LOW	• Absolute livestock exclusion • Active revegetation of fast growing species and grass hydro mulch • Porous dam checks • Active soil stabilization treatments
Unsealed track remediation	Medium	LOW-MEDIUM • Small machinery is needed to create whoa boys, and remedy track camber where necessary • Machinery can cause temporary sediment runoff	MEDIUM-HIGH	• Geo fabric sediment trapping socks or coir logs • Revegetation

4.1 Physical profile of the top 5 sub-catchments.

1. Kin Kin Creek Wahpunga

Receiving the highest score in the prioritisation process scoring seven of the eight observed high criteria, this large sub catchment covers 1,272 ha, of underlying geology of Kin Kin beds and Quaternary alluvium. The valley is confined in the upper reaches of the catchment and then graduates into unconfined alluvial plains. The profile in **Figure 4** shows the highest elevation is 125m then drops to 40m in less than 850m creating mainly hillslope erosion. It then travels approximately 5 km to an elevation of 30m, where agriculture and land clearance is predominant and gully and stream erosion are the main concern.

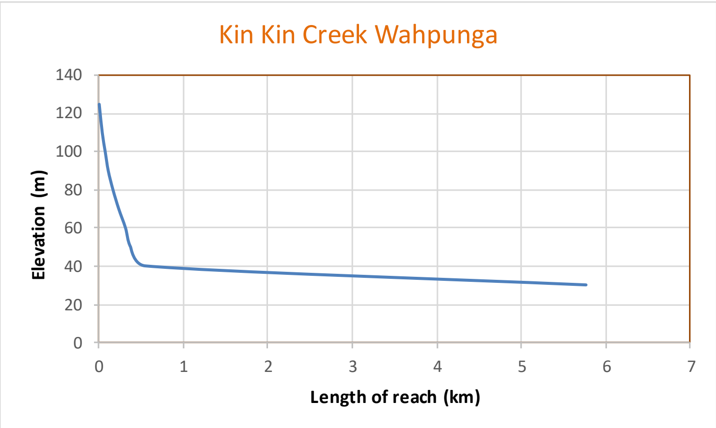

Figure 7 Contour profile Kin Kin Creek Wahpunga sub catchment

The landuse is predominantly grazing of native pastures, minor residential and some nature conservation reserves. Boutique beef production, alpaca fleece and small amount of timber production feature in this catchment.

2. Kin Kin Creek Kin Kin

This wider undulating subcatchment is 946ha in size and includes the small township of Kin Kin. It received a score of six of eight observed high criteria, with gully and hillslope erosion predominant. The underlying geology is a mix of Kin Kin beds, Quaternary alluvium and Myrtle Creek Sandstone. Some smaller specific reaches of this subcatchment are confined to semi confined creek lines, but essentially the catchment is unconfined cleared alluvial flood plains.

Landuse is a mixture of farming practices with some livestock, including horse ownership, and horticulture such as macadamia and coffee production.

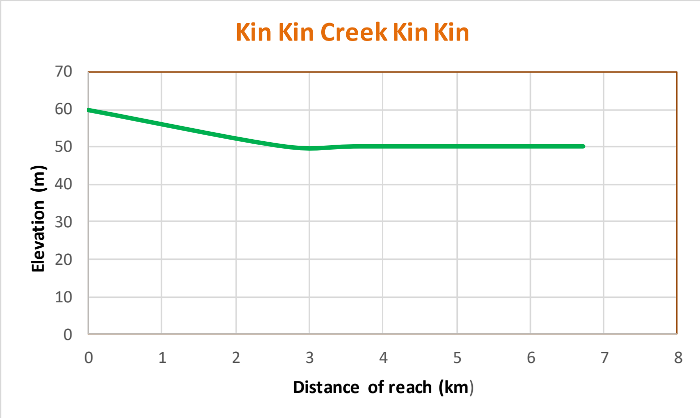

Figure 8 Kin Kin Creek Kin Kin subcatchment

The main erosion concern in this subcatchment is in-stream, where riparian vegetation has been compromised, particularly on the flatter areas and within the township itself. As observed in the profile in **Figure 5** peak elevation is only at 60m at the confluence of Eastern Branch and Western Branch of Kin Kin Creek, with the lowest point of elevation occurring at 50m at the top of Leggett's Loop. Area that is not directly on the Kin Kin creek and therefore is not indicated on the reach profile, but un-named tributaries begin at elevation of up to 200m above sea level. This contributes to the number of hotspots found in this reach.

3. Sandy creek

Of the top five, Sandy Creek subcatchment is one of less undulation and the incoming runoff area elevation is not as high, as can be seen in **Figure 6**. This subcatchment predominantly comprises Myrtle Creek Sandstone and Quaternary alluvium deposits with unconfined creek reaches, combining with highly modified land use. The subcatchment is one of the largest at 2,364ha.

A large proportion of the subcatchment landuse is grazing of native pastures and perennial horticulture and cropping. There is a high residential component with small acreage properties with horses (rather than cattle), and hobby farms. There is a small portion of managed conservation reserves and forestry component.

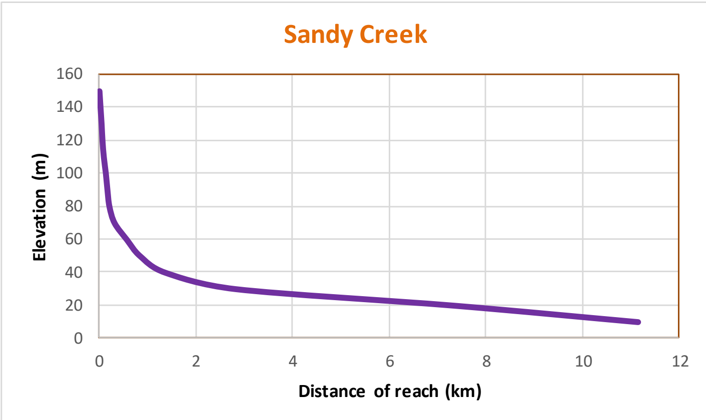

Figure 9 Sandy Creek Catchment profile

The main erosion concern is in the southern tip of the subcatchment, where there are incidences of mass movement, hillslope erosion and in particular gully erosion. Particularly landuse and management, both past and present, would need to be addressed. The reduction of deep rooted vegetation and replacement with shallow crop and grasses for grazing has seen this area particularly at risk.

4. Wahpunga creek

The fourth priority subcatchment lies on Quaternary alluvium and Myrtle Creek sandstone. The highest point of elevation is 245m dropping to 80m in just over 600m. From there it travels approximately 6.5km to reach the lowest point of elevation at 30m, illustrated in **Figure 7**. It is 1086ha in size and is essentially cleared land with little to no remnant vegetation remaining. Sections of this profile have semi confined reaches, with the majority of reaches unconfined.

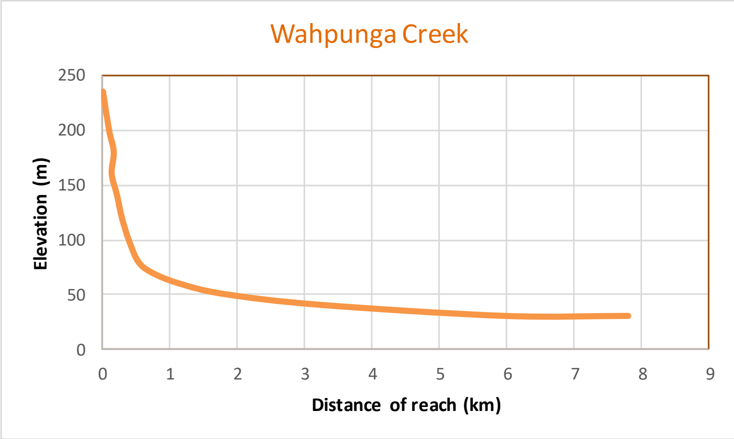

Figure 10 Wahpunga Creek reach profile

Landuse is predominantly cattle grazing of native pastures; residential acreage properties including horses; and some irrigated modified pasture land. Erosion concerns are gully erosion with 12 major incidences within the subcatchment, followed by hillslope and in-stream erosion. The reduction of deep rooted vegetation and replacement with shallow crop and grasses for grazing has seen this area particularly at risk.

5. Kin Kin Western Branch

Hillslope erosion in the western reaches of the subcatchment, and mass movement and gully erosion towards the centre of the region are the main erosion concerns in this catchment. Geographically, this catchment sits on Kin Kin beds with minimal Quaternary alluvium deposits. It is a small subcatchment at 836ha. **Figure 8** illustrates the highest elevation of 195m dropping to 60m above sea level over a distance of approximately 5km.

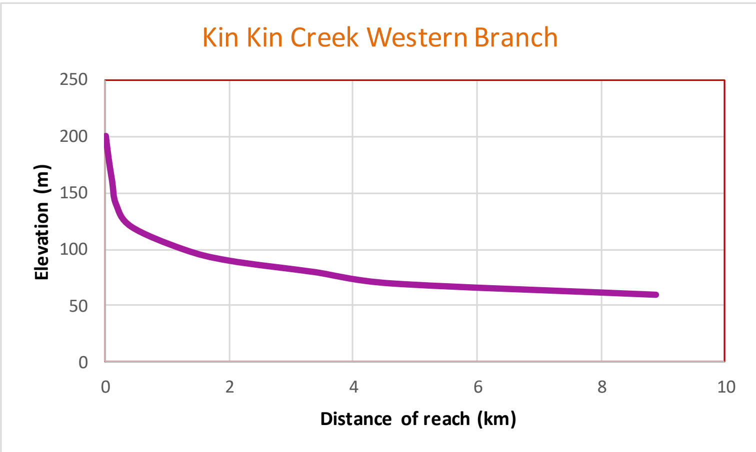

Figure 11 Kin Kin Western Branch

This catchment has strategic reaches that are deteriorating. The majority of stream reaches are confined, with highly modified land clearance. However, successful remediation can be achieved with minimal input in this region.

4.2 Weed Management

As part of the KIIKK project, a documented survey and analysis of the extent of the vine *Dolichandra unguis-cati (syn. Macfadyena unguis-cati)*, commonly known as Cats Claw Creeper (CCC), and *Anredera cordifolia* (Madeira vine) was undertaken in the Kin Kin catchment region by NDLG in partnership with HL&W and Noosa Council. (NDLG *et al* 2018)

Both CCC vine and Madeira vine are referred to as ecosystem transformer weeds, as their vigorous growth habit see them reaching the canopy of LRFSTA and riparian vegetation, and forming a dense ground cover layer, quickly smothering native growth and preventing the natural regeneration and recruitment processes. This loss of deep rooted vegetation exposes soils, leaving them open to increased soil and stream bed erosion, contributing to sediment movement in the catchment. Under this project, CCC and Madeira management is therefore considered the priority weed species. For a further list of weed species found in the region, please refer to **Table 10** in Appendix 2.

Assessment of weed species presence will be undertaken for all priority properties during site visits. Where weed species other than CCC occur on individual properties, NDLG will encourage treatment as in-kind contribution by the landholder, or where possible, costed to other complementary funding. In the case where a non-priority weed species is identified to pose a significant threat to rehabilitation works and water quality, its inclusion into the properties project plan and budget allocation will be considered under this project.

4.3 Education and Awareness Activities

Information and community awareness are paramount to the success of this project. Community events including field trips and information sessions are to be arranged as part of this project.

Topics would include but are not limited by:

- Fencing of riparian sites without compromising productivity;
- Benefits of native revegetation of creek reaches and native vegetation refuges;
- How to implement off source water points into your stock management program;
- Pasture improvement to increase productivity – species choice;
- Managing pasture or cropping areas without loss of soil or productivity;
- 10 simple and economic methods to mitigate erosion on your property;
- Geology/Soil type and simple DIY soil assessments;
- Weed management plans, including CCC, Camphor laurel, GRT and Paramatta grass;
- Management of Pasture dieback;
- “Slow it, spread it and sink it” techniques;
- Dam building and dam repairs;
- Working with your neighbour – sharing equipment/land/labour;

This list is open to further suggestion and can be modified as need arises throughout the project.

5.0 Monitoring and evaluation

Monitoring and evaluation is an integral component of all implementation plans. **Figure 9** flow chart illustrates the connection of goals and aims to the eventual results.

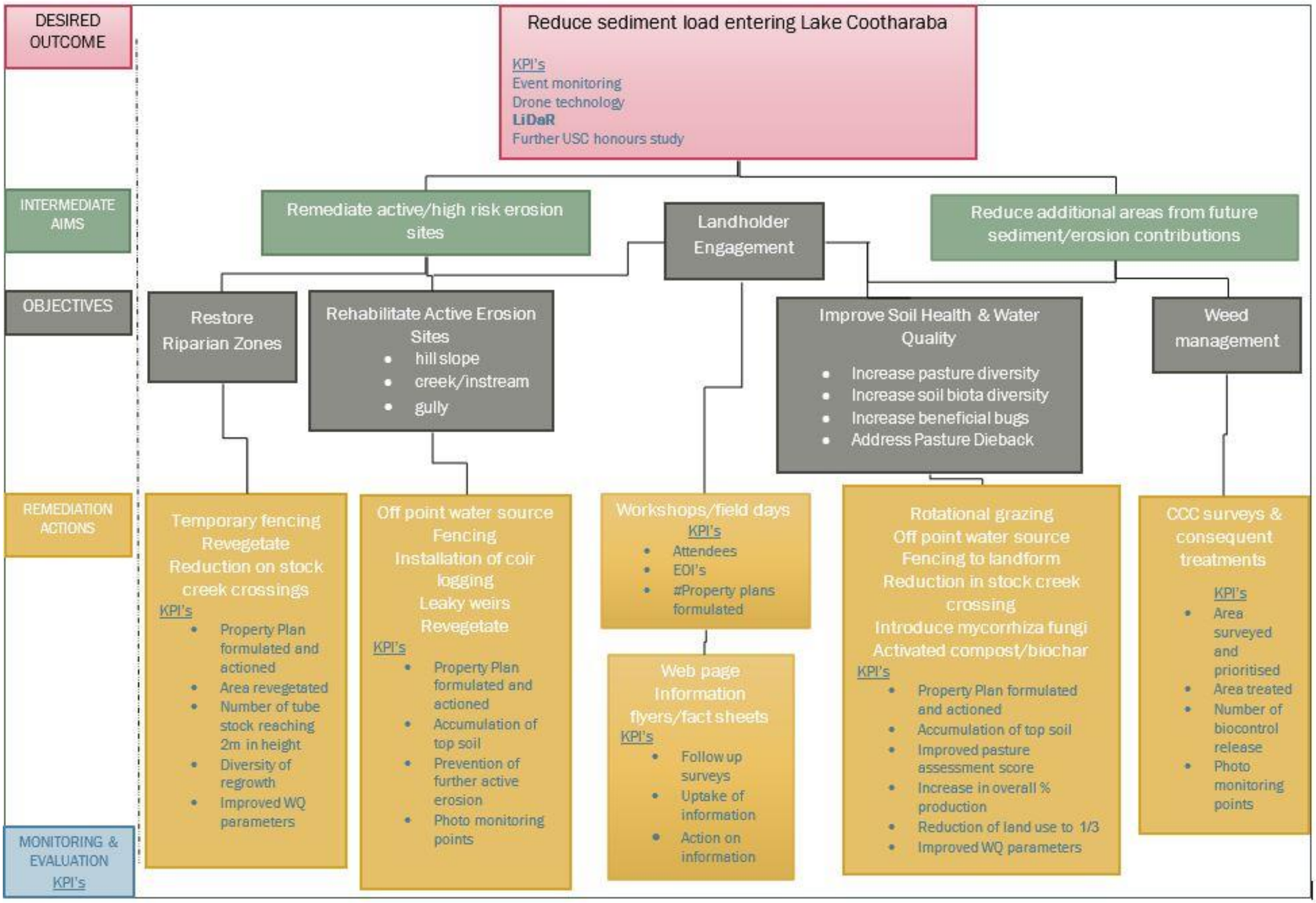

Figure 12 Monitoring and evaluation flow chart aligning goals and aims with potential results

Base line data on a number of measurable parameters with a time frame will establish the basis for evaluation and measure of success. **Table 9** outlines assessable elements of the implementation plan and the frequency of evaluation. Comparison with established environmental values and Water Quality Objectives will be carried out.

Essential for all priority properties is employment of a 'before and after' control impact sampling design for the Kin Kin Implementation plan. Obtaining baseline data for riparian condition, water quality and erosive processes prior to undertaking any on-ground works, will ensure that progress monitoring of these activities is informative. Monitoring focus will be on the top five sub catchments as identified through the priority process.

The consideration of monitoring after significant rainfall events in addition to normal conditions to capture variability in conditions is yet to be decided due to difficulties in accessing sites under extreme weather conditions and work place health and safety issues in gathering such data.

Table 9 evaluation elements of the implementation plan

Physical monitoring	Frequency	Monitoring Method- KPI's
Community Engagement and Information sharing		
The number of priority landholders engaged	Half yearly	Project plans formulated.
The number of landholders showing commitment to on-ground works/improvements to Hill slope erosion practices	Half yearly	Project plans operational.
The number of workshops/ presentations delivered	Yearly	Attendance numbers collated, Follow up communication and Information enacted on.
The number of community groups/schools/public events engaged	Yearly	Includes USC, local school groups, and volunteer groups.
Riparian and water quality restoration		
Total area of riparian revegetation undertaken	Half yearly	Number of trees/area revegetated Photo monitoring points in place and captured.
Total length of fencing installed and proportion of area unfenced to fenced waterways	Half yearly	Distance and area of fencing calculated Management practices putting place in highly sensitive areas (restricted access where applicable for grass management.)
Number of off water source points installed	Half yearly	Related to number of grazing stock and correct placement and installation, Monitoring of compaction and access, Mobility of water points to avoid compaction
Total area of weed removal undertaken	Half yearly	Area treated and maintained Number of new growth and regrowth areas to be recorded and mapped.
Length of stream with improved water quality	Yearly	Physical water parameters measured (turbidity, DO and macroinvertebrate survey).
Hillslope, Mass Movement and Gully Erosion Management		
Total area of erosion prone areas vegetated	Half yearly	Erosion remediation plans in place and implemented
The number of landholders implementing erosion mitigation techniques	Yearly	Follow up on property plans with additional support and appropriate techniques Follow up directly with landholder passing on relevant information and techniques Regular one on one communication (email)
Event Monitoring (TBC)		
Turbidity measurement and calculation of water velocity using latest technology	After a major rain event	Collation of data collection and time comparison.

5.1 Monitoring techniques to be used in the implementation of this plan

The advantages and disadvantages of certain methods of monitoring and evaluation have been well documented. Factors such as time, cost and site physicality need to be taken into account. As with every project, consideration is given to variance of subcatchments and each method is tailored specifically to each subcatchment where necessary. A breakdown of the methods considered appropriate for the KIIKK project have been illustrated in **Table 10**.

Index of Stream Condition Assessment

Within the Noosa shire, a considerable database of riparian condition assessments exist for waterways that were prepared by NDLG and MRCCC as part of on-ground project monitoring programs implemented over the past 10 years. Illustrated in Appendix 1 is this scoring system.

Photo Monitoring Points established for revegetation sites will monitor the growth of plantings. This will involve installing semi-permanent pickets that will stay on site for the entirety of the project. This will ensure that all photos will be taken from the same point of view. Photos will be captured before the revegetation has commenced, at each stage of the revegetation activities (e.g. site preparation, pre- and post-planting, post plant maintenance), and then every six months for the duration of the project.

Water Quality Parameters

Physical parameters of turbidity, pH, Dissolved Oxygen (DO), temperature, electrical conductivity and oxygen reduction potential (ORP), will be measured using the NDLG Horiba water monitoring equipment and assessed according to *Noosa River Basin Water Quality Objectives* (DERM, 2010, or soon to be superseded updated versions). Nitrogen and Phosphorous is as a small water sample at the measuring sites and tested with simple aquarium testing kit. Unity water will undertake further testing of samples.

Load Sensor Event Sensor Recorders

This technology has been developed with Healthy Land and Water and University of Queensland and is designed to measure turbidity and velocity during minor and major flood events. Three event monitoring sensors will be deployed at strategic points throughout the Kin Kin Catchment.

Vegetation Assessment and Transect Survey

In line with the regional ecosystem methodology a simplified CORVEG recording form, seen in Appendix 3

LIDAR Imagery and Small Drone Work

Remote sensing Light Detection and Ranging uses pulsed laser light to detect variable distances on the earth's surface. By comparing images dating over a specified period, changes in levels of soil can be analysed. Imagery will display soil sediment loss and deposition. The KIIKK project has utilised this technology to determine hot spots of erosion and the imagery indicates what type of erosion has occurred.

Small drone camera work will allow a similar process to occur as LIDAR, but on a smaller more localised scale.

Erosion Measures

This small scale method of collecting and weighing sediment is very useful for individual projects in particular where methods of erosion remediation have taken place.

An example of method is to use fine mesh sediment net secured instream. Collected contents are periodically weighed for the duration of the project.

Table 10 Monitoring parameters used to assess the progress of on-ground works

Monitoring Parameters	Description	Method Of Assessment	Pros	Cons	Time Frame

Water quality parameters	Assessing Physical – temp, DO, TSS. Chemical – pH, nitrogen, phosphorous.	- Index Condition Assessment - Water quality monitor - sample collection for lab analysis	- long term assessment - localised to property level	- No short term benefit - little contribution to data at catchment level	3 years
Event monitoring	Measure turbidity and calculate water velocity during extreme weather events	Water laser level (washing machine)	Long term data collection – big picture view - short term results	- Difficult to install and maintain	ad hoc
Riparian vegetation condition	Assessing streambed condition, species and structural diversity, weed species, stream bank and bed erosion.	- vegetation condition assessment - Transect survey - measurement of stream width - observation/photo points	- Evaluation of short term goals - localised - photo monitoring not costly and easy to set up	- Unlikely to give accurate measure	Length of the project
Erosive processes	Assessing the nature of erosion sites.	- Photo point - LIDAR imagery	- comparative to imagery obtained previously - low cost	Long term assessment with no short term outcome results	3 year
Hill slope erosion practice	Assess stock agricultural use and of watercourse, the riparian zone or erosion prone areas.	- photo point - change in landholder method/behaviour - implementation of recommended change of farming practice			
Revegetation progress	The installation of photo monitoring points at revegetation sites.	- photo point - vegetation transect survey/biodiversity assessment erosion measures- small scale satellite drone imagery	Photo points – low cost and easy installation	drone costly and relies on volunteer student project-achievable for the top 3 priority catchments only	Length of the project

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7.0 Appendices

Appendix 1 Noosa Shire Waterway Report 2017 – expert Panel Site Scoring System (incorporating elements of Index of Stream Condition Method)

Waterway Attribute	Green Rating Good Condition	Yellow Rating Minor Disturbance	Disturbance	Red Rating Major Disturbance
Confidence Rating				
	Score - 0	Score - 1	Score - 3	Score - 5
Local Reach				
a. Bed Material Character	Character consistent with loction in catchment, stones are clear with no sediment smothering	Partial Sediment veneers or slight reduction in expected bed material character considering position in catchment, geology and topography.	Evidence of moderate disturbance in character as sediments as a result of sedimentation, scouring or stripping.	Evidence of significant overrepresentation of one sediment size, eg dense sediment veneer, or overlarge particle size for positioning catchment.
b. In-Stream geomorphic diversity	Abundant LWD pools, riffles, bank overhangs, rock ledges and tree roots in water consistent with position in catchment.	Minor disturbance of in-stream features eg LWD common but not abundant, reduction in trailing vegetation etc.	Moderate disturbance of features, eg only occasional LWD, tree roots in water, bank overhangs and alteration of stream controls.	Major or complete disturbance, eg channelisation, no LWD present, removal of all vegetation features acting as geomorphic features.
e. Bed Stability	Bed stabilised by abundant LWD, and/or rock, vegetated point bar, riffles etc. consistent with location in catchment, no evident degradation.	Some evidence of minor instability due to factors such as LWD removal, altered hydraulic regime, increased stream power. Patchy scour and fill, but mostly stable features.	Historic Incision and minor current instability, eg sediment deficit or moderate infillin, eg sand slugs. Partly shifting sand/head cuts, unvegetated bars.	instability/lowering evident over long periods of time. Eg low flow channel wandering between banks, riffle migration, large shifts in sand etc.
Sub total A	Sum of two highest scores for condition a-e			
RIPARIAN ZONE				
f. Vegetation Structure and Condition	Native vegetation on verge and bank with intact canopy, mid and lower strat for majority of reach.	Overstory of native vegetation on bank and verge with some disturbance in mid and lower strata for majority of reach.	Riparian vegetation significantly disturbed with removal of whole strata, verge vegetation or significant weed growth.	No native bank or verge vegetation for the majority of the reach with invasion of grasses and/or weeds.
g. Bank Stability	disturbance consistent with natural levels of accretion and deposition.	Occasional to common minor erosion and/or only isolated moderate erosion.	Frequent moderate disturbance - occasional major disturbance.	Frequent Major erosion and or abundant moderate disturbance along reach.
h. Land Use Influences	Largely intact forested sub-catchment with managed access to waterways with minimal or no evidence of impacts on waterways.	Mainly extensive agricultural landuse with reasonable riparian buffers or more intensive land use with good riparian buffers.	Evidence of moderate impacts from poorly managed stock access or poorly buffered intensive land uses.	Major riparian impacts from adjoining land use as a result of active clearing / development or intensive rural activities within zone.
i. Canopy cover	Intact Riparian vegetation provides optimum canopy cover for position in catchment.	Minor loss of canopy cover results in increased lighting/ heating of waterway.	Moderate canopy disturbance significantly disturbs ecosystem values in stream	Almost complete loss of canopy cover leading to major in-stream disturbance.
Sub total B	Sum of two higest scores for criteria f. to i.			
INSTREAM HABITAT				
p. Large Woody Debris Abundance	Abudant large woody debris of size and species reflecting intact conditions	Common large woody debris with evidnce of only minor disturbance to composition.	debris and/or moderate disturbance to the size and species composition.	No large woody debris, through historical removal, riparian clearing removing source etc.
q. Bank Overhang * Bank undercuts	Ample, relatively stable bank overhangs consistent with position in catchment.	Good sections of bank overhang with only minor impacts or threats from changes to vegetation or soil movement.	Only small areas of stable bank overhang, with loss of edge vegetation and active soil movement threatening habitat.	No bank overhang due to removal of binding vegetation, erosion, infilling etc.
Sub total D	Sum of two highest scores for condition n. to q.			
TOTAL Score	Sum of Sub-total A+B+C+D			

Appendix 2 Table 10 possible weed species of the region

Generalised weed species that commonly occur in the Kin Kin Catchment to be included in management plans under this program if posing a threat to water quality and sediment movement.

***Please note**: this table is to be used as a guide only. Ensure chemical is registered for use on the weed species concerned and please read chemical label carefully and follow mix rates and instructions according to manufacturer's recommendation*

Table 11 Introduced plant species

Botanic name	**Common name**	**Size of infestaton**	**Treatment**	**Comments**
Andredera cordifolia	Madeira vine		– Foliar spray or basal bark	A number of chemicals are registered for use on permit 11463 or 9868
Celtis sinensis	Chinese celtis	– Stem > 500mm – Over 2m in height – Stem < 500mm	– Cut and paint – Larger trees can drill and filled – Foliar spray or hand weeded	
Cinnamonum camphora	Camphor Laurel	– Stem > 500mm – Over 2m in height – Stem < 500mm	– Cut and paint – Larger trees can drill and filled – Foliar spray or hand weeded	
Dolichandra ungui-cati (syn. Macfadeyna unguis-cati)	Cat's Claw Creeper	Vines going up the tree: – Vine stem > 200mm – Vine stem < 200mm – large or inaccessible infestations	– Cut at ground level and paint with **Glyphosate** 360g/L and water – Cut ~1m from the base and pull out and away from the tree, foliar spray with **Dicamba** 500g/L – Biocontrol	Ensure vines are actively growing at time of treatment Two commonly used biocontrol are the Tingid bug, *Carvalhotingis visenda* and a leaf mining jewel beetle, *Hypocosmia jureceki*
Gomphocarpus physocarpus	Balloon cotton	Pasture weed	– Foliar spray or mechanical	Can be poisonous to stock in large quantities
Ipomoea indica	Blue Morning Glory		– Foliar spray	
Lantana camera	Lantana	– Stem > 500mm – Stem < 500mm – large or inaccessible infestations	– Cut and paint with Glyphosate 360g/L – Foliar spray – Mechanical control	A number of chemicals are registered for use; choose according to situation and manufacturer recommendation.
Sporobolus spp.	Giant Rats Tail	Pasture weed	– Foliar spray	**Early identification is essential please contact local government or Biosecurity Qld for further information if you suspect this weed is on your property**
Other weed species may be located during property assessment. Please seek professional advice for correct identification and appropriate treatment				

Appendix 3 CORVEG site survey form (simplified) The original copy is held on file for better copy reproduction

Queensland Government

BioCondition Site Assessment sheet (v2.1) | **Survey number:** ....

Site:	**RE/Landtype:**	**Bioregion:**	**Property:**
Date:	**Photos** (optional) **N:** S: E: W:		
Landscape photo(s):		**Spot photo(s):**	
Datum: WGS84 or GDA94	0 m mark - Zone: 50 m mark - Zone: Plot bearing:	Easting: Easting: Recorders:	Northing: Northing:
Site description and location:			

100 x 50m area: * Ecologically Dominant Layer

Eucalypt Large tree DBH (from benchmark doc.): **Number of large eucalypt trees:**	**Non-Eucalypt Large tree DBH** (from benchmark doc.): **Number of large non-eucalypt trees:**
Total Large trees:	
Tree canopy (EDL*) height:	**Tree subcanopy and/or emergent height** (where relevant): **S:** **E:**
Proportion of dominant canopy (EDL) species with evidence of recruitment:	
Total tree (defined as single stemmed over 2m) **species richness** (all tree species in the 100 x 50m (not just EDL species)):	

50 x 10m area: (*list species if known c count if unknown)

Non-native plant cover:
Shrub (defined as single stemmed below 2m or multi-stemmed from base or below 20cm) **species richness:**
Grass species richness:
Forbs and others (non grass ground) species richness:

50 x 20m area: Coarse Woody Debris (all logs >10cm, >0.5m within 50 x 20m area measured to the plot boundary):

Length of CWD):		Length of CWD):		Length of CWD):		Length of CWD):		Length of CWD):		Length of CWD):	
1		9		17		25		33		41	
2		10		18		26		34		42	
3		11		19		27		35		43	
4		12		20		28		36		44	
5		13		21		29		37		45	
6		14		22		30		38		46	
7		15		23		31		39		47	
8		16		24		32		40		Total:	

Five 1x1m plots (* attributes are essential to assess as used in scoring, however assessment of all attributes improves your ability to more accurately visualise proportions of each of the attributes)

Ground cover:	1	2	3	4	5	Mean
Native perennial ('decreaser') grass cover*						
Native other grass cover (if relevant)*						
Native forbs and other species (non grass)						
Native shrubs (< 1m height)						
Non-native grass						
Non-native forbs and shrubs						
Litter*						
Rock						
Bare ground						
Cryptograms						
Total	=100%	=100%	=100%	=100%	=100%	

100 m transect

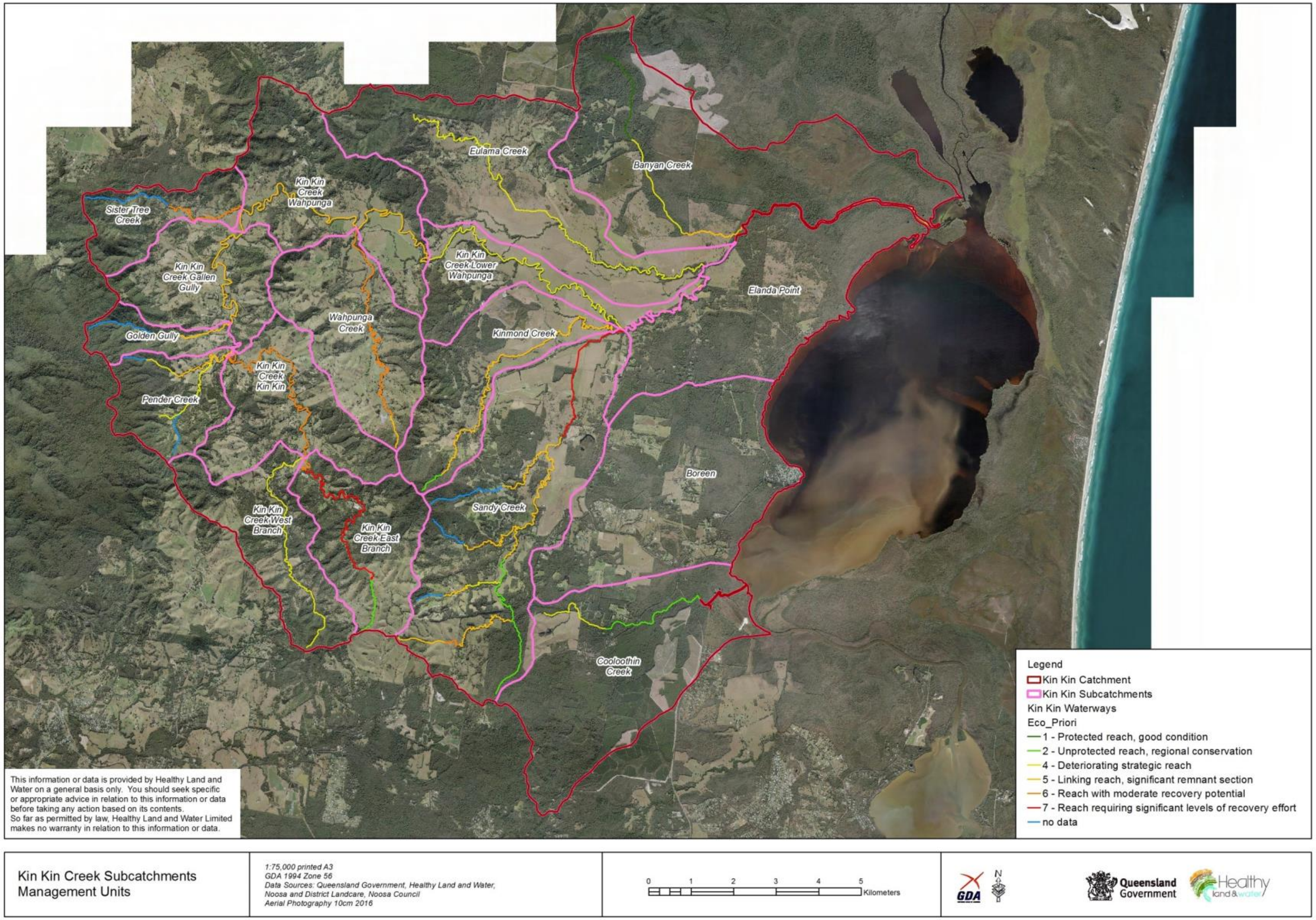
Tree canopy cover: (Only assess Emergent (E) or Subcanopy (S) layers if the benchmark document stipulates that layers are present *If trees are in the same layer and continuous along the transect you can group them)

Tree or tree group* (C or S or E)	Distance (m)	Total	Tree or tree group* (C or S or E)	Distance (m)	Total	Tree or tree group* (C or S or E)	Distance (m)	Total	Tree or tree group* (C or S or E)	Distance (m)	Total
									Total C: Total S: Total E:		

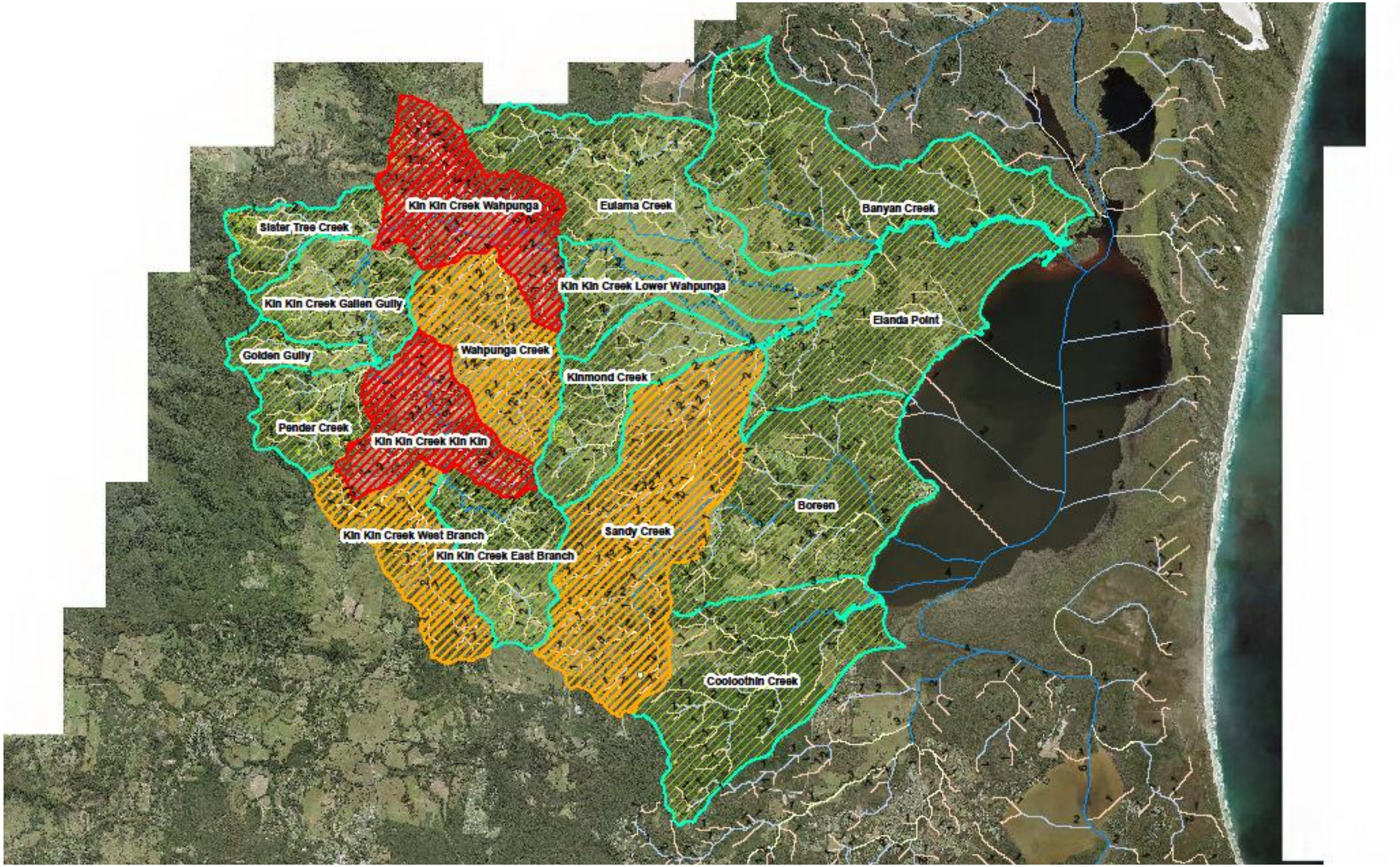
Shrub canopy cover: * denote as native or exotic. Only native shrub cover is used in the scoring

Shrubs*	Distance (m)	Total	Shrubs	Distance (m)	Total	Shrubs	Distance (m)	Total	Shrubs	Distance (m)	Total	Shrubs	Distance (m)	Total
											Total native:		
											Total exotic:		

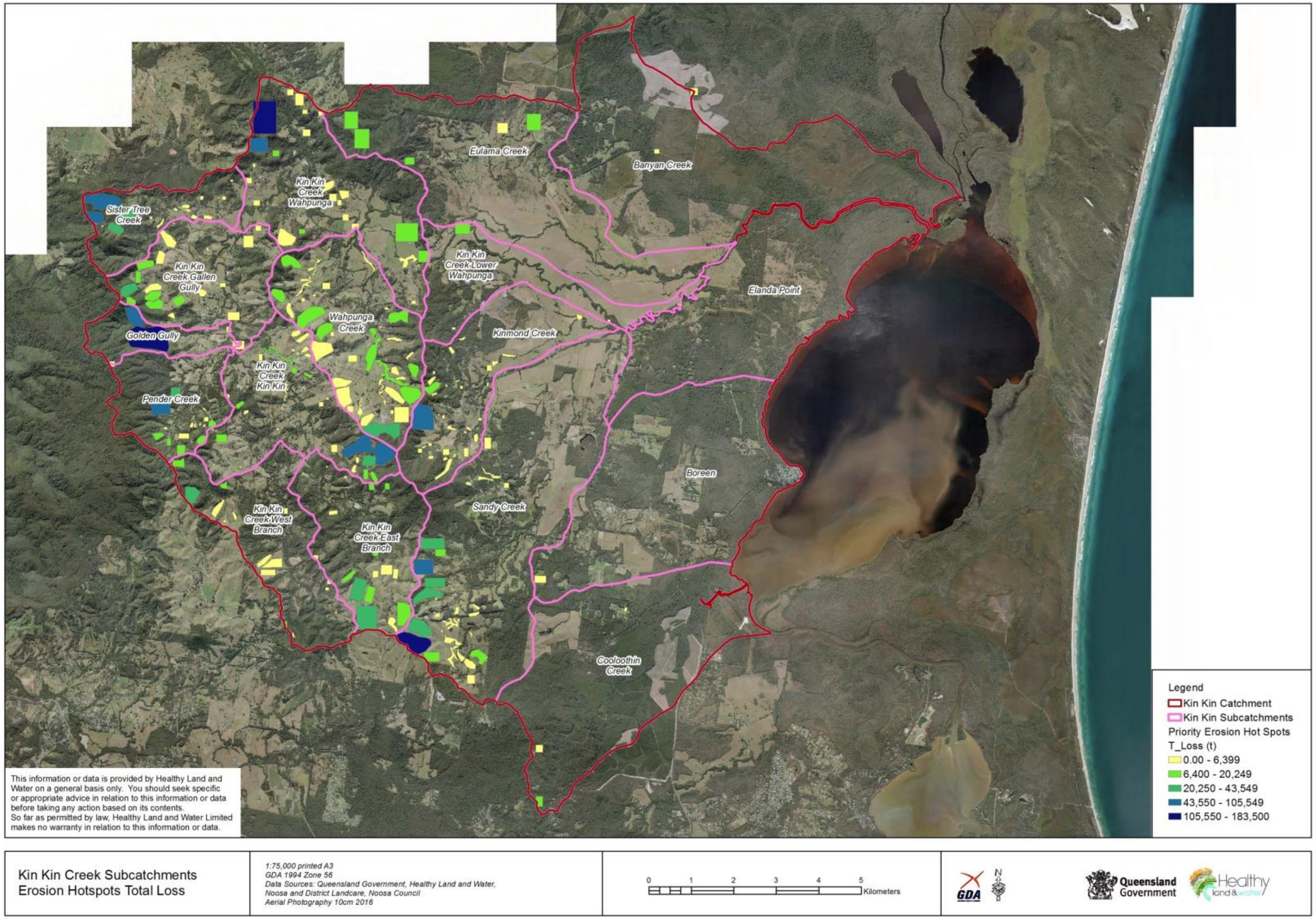
Appendix 4 – Kin Kin Catchment subcatchment divisions and strategic reaches



Appendix 4A – Level of Priority at Subcatchment Level



<u>Appendix 5 – Erosion Hot Spots determined by detailed analysis of LIDAR mapping</u>



Appendix 6 – Erosion Types within the Kin Kin Catchment