Healthy Waterways and Catchments

Keeping It In Kin Kin – Applying LiDAR Change to Identify Erosion Hotspots

DRAFT November 2016

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Acknowledgements

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Noosa and District Landcare Group

Noosa Biosphere Foundation

The Thomas Foundation

Noosa Parks Association

Noosa Integrated Catchment Association

Noosa Council

Table of Contents

Background

The Kin Kin Catchment loses a significant amount of soil each year to erosion. This reduces the Kin Kin's available farmland and decreases water quality in the overall Noosa River Catchment. The purpose of this study is to identify and prioritise areas that contribute to this loss so that targeted mitigation activities can take place. The primary identification tool used is a LiDAR digital elevation model of change (the change analysis). This report outlines the methodology used to develop the change analysis for the Kin Kin Catchment. Preliminary results of the change analysis are tabled to assist with subcatchment prioritisation and to address sediment risk hotspots.

A combination of manual and automated change analysis identified 259 'Areas of Interest'. Areas were then characterised by erosion type including Gully, Hillslope, Land Management, Mass Movement, Sheet /Rill, and Stream Bank Erosion.

The total amount of sediment mobilised within the Areas of Interest was calculated. This was to ensure a greater level of confidence of actual sediment mobilised based on aerial photography verification. Further ground-truthing will confirm Areas of Interest and identify additional areas for future investigation.

This work will help program managers and research scientists determine remediation priorities to achieve the biggest water quality improvement for Kin Kin and the Noosa River, while maintaining farm productivity for the area.

Objective

The Kin Kin Catchment has been identified as a high sediment export catchment in previous scientific studies, in particular the Lake Cootharaba Sediment and Nutrient Study (Grinham, 2012). There is the need to focus attention on key areas to maximise the impact that limited financial investment can make.

In most catchments, 60-80% of sediment export comes from 20% of the catchment area, hence it is critical to identify priority areas for rehabilitation works to ensure resources are utilised efficiently.

Historically, sediment and nutrient area prioritisation was undertaken using multi-criteria spatial tools including 'Confluence of Issues' and 'Catchment Rehabilitation Planner'. Technologically advanced spatial analysis methods and techniques now exist that allow additional evidence-based prioritisation exercises to occur.

Light Detection and Ranging (LiDAR) topographic change data is now being utilised in government and landcare projects as a means of identifying areas of past and current soil movement. LiDAR change analysis is the calculation of elevation differences between LiDAR imagery runs undertaken at different times.

The change analysis compared latest capture (2015) against baseline data (2008) for Kin Kin, resulting in the generation of a LiDAR Topographic Change map. The change analysis identified active erosion sites and areas of soil deposition. This will support subcatchment remediation work prioritisation.

Application

All relevant and available scientific information and data was assessed for use as part of the prioritisation process. This included existing land erosion risk mapping for the Kin Kin area.

Information developed from the change analysis will inform the Keeping it in the Kin Kin Project including:

- Phase 1 – Area prioritisation, Engagement and Selection of Demonstration / On-ground Activities
- Phase 2 – Full implementation of the 'Keeping it in Kin Kin Action Plan'.

Other uses of the information may include informing waterways strategies /action plans and integrated catchment management activities (property planning, weed control and creek restoration).

The change analysis provides a current baseline and snapshot of erosion/deposition rates in the Kin Kin Creek catchment.

Outputs

The change analysis outputs include:

- A digital elevation model change map
- Areas of interest identified as having significant erosion and deposition
- 'Erosion Hot Spots' map of priority areas showing high erosion rates
- Kin Kin Waterbodies

General Approach

The change analysis was carried out following methodologies developed by the Healthy Country Program, Department of Science, Information Technology and Innovation (DSITI), and the Australian Rivers Institute (ARI). This was to ensure that the analysis took advantage of the significant work already completed in this field and that it was consistent with similar assessments across the state.

The two raster digital elevation models (2008 and 2015) were standardised and analysed to:

- account for sources of uncertainty
- identify and classify changes to generate 'areas of interest'
- verify 'areas of interest'
- broadly classify erosion types within 'areas of interest'
- calculate the volumetric rates of change within 'areas of interest'

Overview of Steps

- Verification and standardization of LiDAR digital elevation models
- Generate change analysis
- Identify areas of high elevation change based on change analysis
- Select areas of elevation loss for identification of 'Erosion Hot Spots'
- Workshop with project contributors and partners for discussion and general consensus
- Prioritise areas based on multiple criteria and other factors (e.g. erosion material volume, treatment viability, landuse, soils)
- Ground-truthing workshop with Noosa Landcare and Kin Kin landholders
- Generate Keeping it in Kin Kin Action Plan for implementation Works
- Independent academic scientific review before and during the prioritisation process. (undertaken by Research Institution)

The approach described is often referred as topographic change assessment (looking at changes to the elevation of a surface between different time periods). Geomorphic change assessment is the process of identifying why topographic change is occurring.

The methodology of generating LiDAR DEM Change Maps removes field-observer bias and creates a repeatable approach for identifying and mapping topographic change which can be further strengthened and validated through ground-truthing. (Wyrick and Pasternack, 2015)

LiDAR Change Analysis

LiDAR is a remote sensing method where a pulsed laser is used to measure the distance from the laser sensor to the earth, to create accurate digital elevation and canopy height models. LiDAR DEM Change or DEM of Difference (DoD) (Croke et al, 2012) allows the calculation of elevation differences between LiDAR imagery capture projects. This modelling provides elevation gain/loss values for the whole of Kin Kin Creek Catchment, allowing properties and areas suffering the highest erosion rates to be determined. (Parker, 2015)

DEMs collected at different times are compared by subtracting, or 'differencing', oldest from most recent (for example, 2015 DEM less 2008 DEM) to identify whether a loss or gain in elevation has occurred. Areas showing an increase in elevation could be areas of deposition, where a decrease in elevation generally indicates that active erosion is present. (Wyrick and Pasternack, 2015)

Once erosion hot spots are identified, the high resolution of the LiDAR elevation data (+ or – 0.15m) allows the calculation of the net volume change (m3) and the amount of sediment lost or mobilized during the time series. DEM differencing provides an accurate estimate of volumetric change and the development of sediment budgets for an area.

The resulting change file identifies spatial patterns of 'cut and fill' often presented as red to blue maps. LiDAR generated slope maps and high resolution aerial photography used in conjunction with the LiDAR DEM Change Map helped with verifying identified and active change.

Waterbodies visible in the change map were often represented as loss in elevation. It was noted that 2015 was a dry year for rainfall, with 2008 having high rainfall levels, hence waterbodies showing a negative change in elevation. (elevation is now low, elevation was higher).

For this set of LiDAR images, slope analysis revealed waterbodies having a value of '0' (no slope), and areas with this value were selected and re-classified as LiDAR generated waterbodies. Further manual analysis captured additional waterbodies with a total waterbody count in excess of 504. This mostly represented farm dams and natural waterbodies, and also identified stretches of instream and open waterways.

Waterbodies were then masked / removed from the final LiDAR DEM Change Map to provide a more accurate representation of volumetric change.

In line with geomorphic change detection principles, low pass filters were applied to the individual elevation models to reduce any noise and errors in the LiDAR DEM Change map. This action traverses a low pass 3 by 3 filter (9 m2) over the raster and smooths the entire elevation model reducing the significance of anomalous cells and overall 'bumpiness' of the local topography. (ESRI Arc Map Toolbox)

For the final LiDAR DEM Change Map, any differences +-0.5m were considered within the bounds of uncertainty and labelled as 'no detectable change'. This is consistent with the +- 0.4m vertical accuracy of the 2015 LiDAR specifications. (See Attachments – LiDAR Specifications)

The final LiDAR DEM Change Map represents the net change in topographic elevation over the 7 year period.

Summary of Methodology

LiDAR Collation and Processing

- 2008 LiDAR elevation tiles compiled to establish baseline elevation model for Kin Kin Catchment

Mosaic of tiles developed, including digital elevation model, slope degrees and relative slope

- 2015 LiDAR elevation tiles sourced and compiled to establish most current elevation model for Kin Kin Catchment
- Mosaic of tiles developed, including digital elevation model, slope degrees and relative slope.
- A low pass filter was also applied to smooth the DEMs and reduce the significance of anomalous cells.

Geomorphic Change Detection

- A Geomorphic Change file was developed for Kin Kin Catchment based on 2015 Mosaic DEM less 2008 Mosaic DEM
- Water bodies were identified in the change file as having a loss in elevation and manually exported as a separate layer (assumption is 2008 was wetter and 2015 a dry year for rainfall).
- Water bodies were also extracted through automation based on LiDAR Slope 2015 and how the data was processed (value = 0). This has provided an accurate baseline of bio-available water during a dry year.

Applying filters to confirm losses and gains (Wheaton et al, 2010)

- Landcover Forest mask was used to target change within cleared areas
- 2015 LiDAR slope was used to confirm change / disturbance within forested areas and non-forested areas
- High resolution aerial photography for 2015 (10cm) and 2009 (50cm) was used to confirm change and disturbance

Erosion Hotspots

- Areas of Interest were manually selected based on the lidar analysis support files previously mentioned. Identified areas were showing active erosion processes and were captured at a landscape level averaging 3 – 7 ha in size. (See Table 1)
- Areas of Interest were classified by erosion type and used as a mask to select from the geomorphic change file
- Erosion and deposition rates were calculated within Areas of Interest for the catchment having higher confidence levels of sediment budgets

Findings

Based on the change analysis for Kin Kin, erosion and general land management is a catchment wide issue and opportunity. At a catchment overview, there is a clear distinction of higher levels of erosion occurring in the mid to upper catchment areas upstream of the Kin Kin Creek - Wahpunga Pass. Higher levels of deposition were observed in the lower catchment areas, with areas of natural levee banks forming along lower Kin Kin Creek from reduced velocities and sediment drop-out.

Higher levels of disturbance were noted on the slopes even though forests were showing signs of recovery from previous land uses. Old landslips were also picked up on the forested slopes, with ground-truthing required to verify whether these are still active.

Areas with numerous tracks were identified along the western range / Woondum Range presenting a high risk of erosion. Some of these valleys presented signs of heavy weed infestations (e.g. lantana) and very unstable conditions.

On the cleared slopes, areas of mass movement and gullies were noted. Across the catchment, many sediment inputs were identified that could become mobilised during rainfall events. A number of these areas with high erosion risk showed signs of remediation effort through the construction of contour banks. Further landholder support is required to continue these efforts.

Stream bank erosion was mostly confined to the mid to upper reaches of the study area. Lower Kin Kin Creek does have riparian / creek vegetation in good condition although in some reaches the overall width is quite narrow. With increased flows and velocities from intense rainfall events, outside creek bends will show signs of stress and erosion risk even when vegetated.

Areas with creek vegetation showed signs of greater stability with the LiDAR Change Map showing deposition and some erosion signals. Some mapping interference was observed coming from the instream water within the riparian zone, mostly as a loss of elevation. This may be from reduced water levels between the two lidar captures, 2015 – 2008. Analysis within the riparian zone was given to creek banks with higher slope, large clusters of erosion and un-vegetated waterways.

The management of existing vegetation across the catchment is a priority to reduce further erosion risk and to maintain waterway health. High slopes (>10 degrees) should be forested or contain good grass cover. Slopes currently supporting weeds (e.g. lantana) and regrowth are showing signs of erosion, with drainage and track management required.

The Areas of interest represent sites showing active erosion based on the LiDAR Change Map. High resolution aerial photography was used to confirm areas at a desktop level for greater confidence in the process. It is recommended that ground-truthing be undertaken and local feedback received to advance this work.

Types of erosion classified included Gully Erosion, Stream Bank Erosion and Mass Movement / Landslips. Erosion associated with land management through ground disturbance and weeds was also included as was found to be a significant factor. Table 1 summarises the erosion classification with a total of 258 sites identified.

Table 1: Areas of Interest identified for Kin Kin Creek Catchment

Erosion Type	Areas Identified (number)	Area (ha) based on 'Area of Interest'	Mean Area (ha)
Gully Erosion	96	274	3
Land Management – Disturbance and Weeds	72	480	7
Mass Movement	35	223	6
Sheet and Rill Erosion	1	1	-
Stream Bank Erosion	54	173	3
Total	258	1,151	4

The LiDAR Change was further analysed based on the identified Areas of Interest, applying filters and masks. Further corrections were applied through removing errors associated with water bodies. Greater confidence was also assigned to elevation changes between the ranges of 0.5 – 2.0 m both for gain and loss. Table 2 presents the findings of this analysis.

Over 90% of observed LiDAR Change values were within the 0.5 - 2.0 m range and in terms of erosion rates for the Noosa River Catchment are more realistic. Cut and fill activities for housing and infrastructure, and topographic features (steep embankments and waterfalls) were observed through aerial photography in the 2.0 - 5.0 m and > 5.0 m LiDAR Change ranges. A moderate confidence level was given to the 2.0 – 5.0 m range.

The total observed range was slightly higher for elevation loss and this need further investigation. These higher ranges represent less than 2% of the totals.

Table 2: Total Soil Loss and Gain from Geomorphic Change for **Areas of Interest** (based on LiDAR DEM Change Map)

Soil Loss	Values	Soil Gain	Values
Total Observed Range			
Elevation 0.5-9 m	-1,912,839	Elevation 0.5-7 m	277,444
Tonnes of sediment mobilised	-2,486,691	Tonnes of sediment deposited	360,678
Area of loss (m2)	2,086,812	Area of gain (m2)	261,733
Area of loss (ha)	208	Area of gain (ha)	26
High Confidence Range			
Elevation 0.5-2 m	-1,800,015	Elevation 0.5-2 m	212,197
Tonnes of sediment mobilised	-2,340,020	Tonnes of sediment deposited	275,856
Area of loss (m2)	2,042,305	Area of gain (m2)	239,00
Area of loss (ha)	204	Area of gain (ha)	23
Moderate Confidence Range			
Elevation 2.0-5 m	-110,024	Elevation 2.0-5 m	60,698
Tonnes of sediment mobilised	-143,031	Tonnes of sediment deposited	78,908
Area of loss (m2)	44,156	Area of gain (m2)	21,750
Area of loss (ha)	4	Area of gain (ha)	2

Within the high confidence range of 0.5 – 2.0 m for elevation gain / loss, the data showed that up to 2.3 million tonnes of sediment was mobilised during 2008 - 2015. Only 275,856 tonnes of sediment was found to be deposited and not necessarily coming from the identified Areas of Interest and Erosion Hotspots. Based on average soil replacement costs of $30 / tonne[1], if this amount of soil is leaving the catchment the cost of soil productivity loss exceeds $6 million.

Soil erosion control for maintaining productive farmland and waterway health requires a catchment wide approach and focus. The LiDAR DEM Change Map has provided evidence of where in the landscape is attention needed to help reduce the loss of soils impacting on downstream properties and environments.

References

- Croke, J., Todd, P., Thompson, C., Watson, F., Denham, R., Khana, G. (2012) The use of multi temporal LiDAR to assess basin-scale erosion and deposition following the catastrophic January 2011 Lockyer flood, SE Queensland, Australia. Published in Geomporphology (184, 111-126, 2013).
- ESRI ArcMap Toolbox http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-filter-works.htm
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- Queensland Government (2013) Types of erosion. https://www.qld.gov.au/environment/land/soil/erosion/types/
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- Wyrick, J., Pasternack, G. (2015) Revealing the natural complexity of topographic change processes through repeat surveys and decision-tree classification. Published in Earth Surface Processes and Landforms (41, 723-737, 2016).

[1] Trade garden soil cost for bulk purchase

Attachments

LiDAR Specifications

Queensland LiDAR Data – Sunshine Coast LGA 2008 Re-Classified Project

http://qldspatial.information.qld.gov.au/catalogueadmin/catalog/search/resource/details.page?uuid=%7B1C053805-289E-40F5-8211-992555905EE1%7D

Date: 2008-10-31

Abstract: This LiDAR dataset covers the entire Sunshine Coast Local Government Area including areas within the current Noosa Shire. In 2012, the original LiDAR dataset was reclassified to C2 and C3 level of classification, under a Queensland Government project.

Coordinate System

Projection: MGA56

Horizontal Datum: GDA94

Vertical Datum: AHD

Data Quality

Vertical Accuracy: 0.15m

Horizontal Accuracy: 0.2m

Acquisition

Airborne Laser Scanning (ALS) data was acquired for the Sunshine Coast project from a fixed wing aircraft between October 2008 and July 2009.

Ground control points were used as check points against the remotely sensed data. These points were measured using Rapid Static GPS methodologies and consisted of approximately 105 locations throughout the project area.

Flying Height: 1000m

Swath Width: 924m

Side Overlap: 30%

Average Point Separation: 1m

Queensland LiDAR Data – Noosa Gympie 2015 Project

http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=noosa+2015+lidar

Date: 2016-05-12

Abstract: This project captured high resolution elevation data using LiDAR technology over the entire Local Government Area of Noosa and the town of Gympie and the surrounding urban area within the Gympie Regional Council.

Coordinate System

Projection: MGA56

Horizontal Datum: GDA94

Vertical Datum: AHD

Data Quality

Vertical Accuracy: +/- 0.4m

Horizontal Accuracy: +/- 0.15m

Acquisition

Airborne Laser Scanning (ALS) data was acquired from a fixed wing aircraft between August 18th and 24th 2015. Areas under tidal influence were captured at two hours either side of low tide.

Ground support GPS base station support was provided by the client without incident. The ground check points acquired by the company allowed an assessment of the accuracy of the ALS data.

GIS Processing Notes

- Create Mosaic Dataset
  GDA_1994_MGA_Zone_56
  UNIT ['Meter',1.0]
  Add Rasters To Mosaic Dataset
  Build Pyramids and Statistics

- Copy Raster lidar 2008 Mosaic
  Copy Raster lidar 2015 Mosaic

- Filter kinkin_lidar2008.img
  LOW DATA
  kinkin_lidar_2008_lowpass.img
  Filter kinkin_lidar2015.img
  LOW DATA
  kinkin_lidar_2015_lowpass.img

- Raster Calculator
  Minus kinkin_lidar2015.img - kinkin_lidar2008.img
  KinKin_dem_change15_08_v1.img
  kinkin_lidar_2015_lowpass.img - kinkin_lidar_2008_lowpass.img
  KinKin_dem_change15_08_vLowpass.img

- Slope kinkin_lidar2015.img
  Focal Statistics kinkin_lidar2015_slope.img
  Rectangle 10 10 CELL
  MEAN DATA
  kinkin_lidar2015_slope_avg10m.img
  Relative Slope
  Minus kinkin_lidar2015_slope.img - kinkin_lidar2015_slope_avg10m.img
  kinkin_lidar2015_relslope10m.img

- Slope kinkin_lidar2008.img
  Focal Statistics kinkin_lidar2008_slope.img
  Rectangle 10 10 CELL
  MEAN DATA
  kinkin_lidar2008_slope_avg10m.img

- Intergerise dem change to calculate loss and gain
  x10
  Raster Calculator Int("N:\Projects\Kin_Kin\KinKin_dem_change15_08_v1.img" * 10)
  KinKin_dem_change15_08_v1_x10_int.img
  Extract By Attributes
  KinKin_dem_change15_08_v1_x10_int.img ""Value" <= -10" (-1.0m)

- Areas of Interest manual identification up to 1:3,000
  Extract lidar by mask of AoI
  Extract By Mask
  KinKin_dem_change_15_08_lt1m_AoI.img
  KinKin_dem_change_15_08_lt1m_AoIv2.img
  KinKin_dem_change_15_08_lt1m_AoIv3.img
  KinKin_dem_change_15_08_lt1m_AoIv4.img
  KinKin_dem_change_15_08_lt1m_AoIv5.img

- Waterbodies to raster
  Polygon To Raster
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  kin_kin_waterbodies_1m.img
  Reclassify
  kin_kin_waterbodies_1m_rc.img
  kin_kin_waterbodies_1m_rc_inverse.img
  Raster Calculator
  KinKin_dem_change_15_08_lt1m_AoIv4.img *
  kin_kin_waterbodies_1m_rc_inverse.img
  Raster Calculator
  Int("N:\Projects\Kin_Kin\KinKin_dem_change_15_08_lt1m_AoIv4_revised.img" * 1000)
  KinKin_dem_change_15_08_lt1m_AoIv4_revisedInt.img

Types of Erosion – Definitions

Source: Taken from https://www.qld.gov.au/environment/land/soil/erosion/types/

Gully Erosion: Gully erosion happens when runoff concentrates and flows strongly enough to detach and move soil particles. A small waterfall may form, with runoff picking up energy as it plunges over the gully head. Splashback at the base of the gully head erodes the subsoil and the gully eats its way up the slope. Gullies may develop in watercourses or other places where runoff concentrates.

Land Management – Disturbance and Weeds: This category was included to capture erosion processes caused by disturbance and weeds. The LiDAR DEM Change Map was showing soil loss associated with tracks, general land disturbance and areas infested with weeds. Further ground-truthing required to classify into other erosion type categories.

Mass Movement: Mass movement occurs on cleared slopes in coastal and hinterland areas. Gravity moves earth, rock and soil material downslope both slowly and suddenly generally associated with rainfall events.

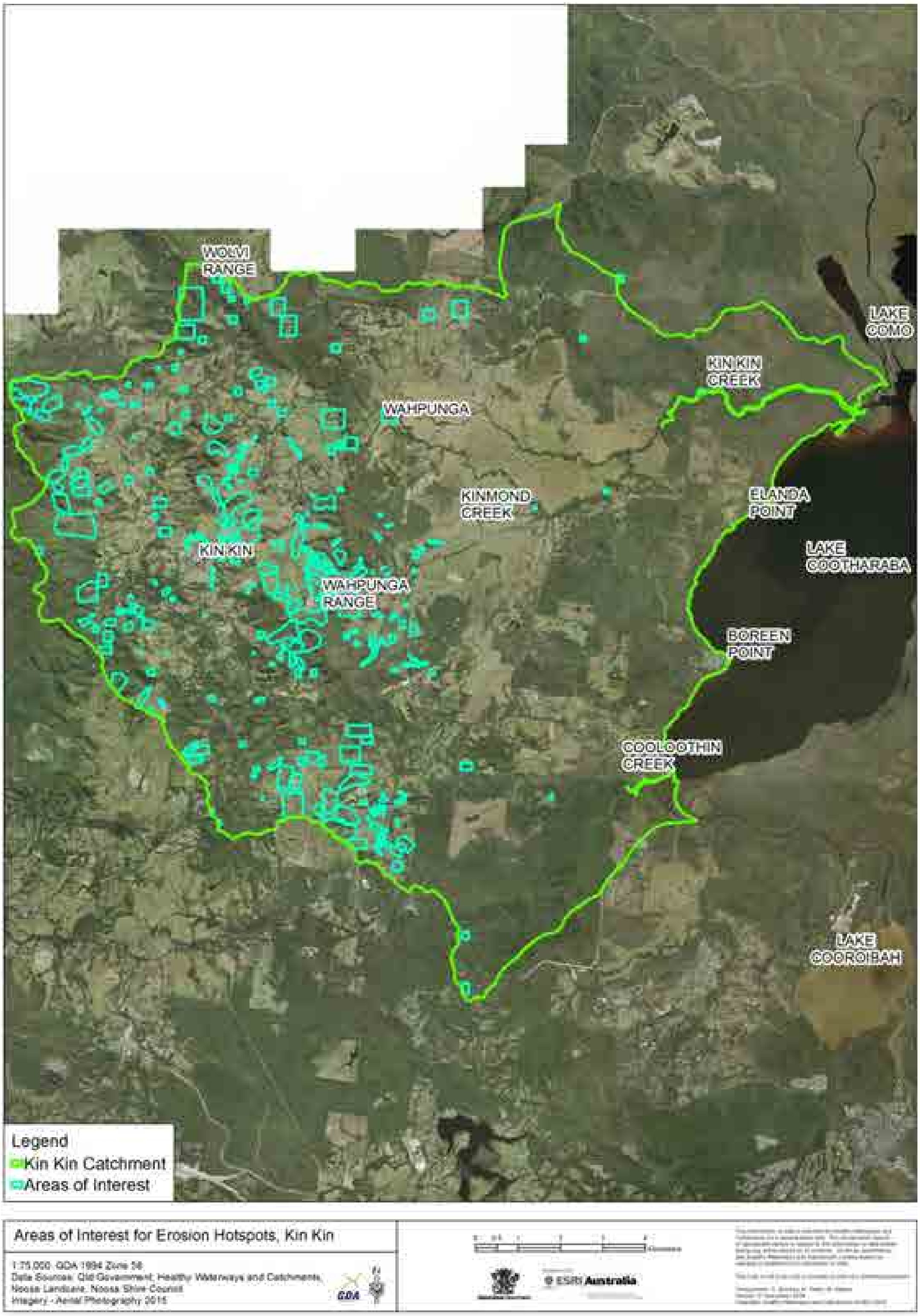
During periods of prolonged and heavy rainfall, water entering permeable soils can be stopped by a barrier as bedrock or a clay-rich soil horizon. The heavy weight of this saturated soil can slide downslope if it is sitting on a rock surface loosened by the build-up of water in the soil.

Sheet and Rill Erosion: Hill-slopes are prone to sheet and rill erosion. The amount of hill slope erosion largely depends on how the land is used. Sheet erosion occurs when a thin layer of topsoil is removed over a whole hillside paddock. Rill erosion occurs when runoff forms small channels as it concentrates down a slope. These rills can be up to 0.3 m deep, and if they become deeper they are referred to as gully erosion.

Stream Bank Erosion: Stream bank erosion generally happens during floods and rainfall events. The major cause of stream bank erosion is the removal of vegetation on river banks and the removal of sand and gravel from the stream bed.

Supporting Maps

Map 1: Identified Areas of Interest and Erosion Hotspots



Map 2: Cut and Fill example showing loss of elevation where soil has been removed on slope and then used as fill as gain in elevation to create a level pad for shed/house.

Map 3a: Aerial photography 2015 showing Erosion Type of "gully erosion" (not visible)

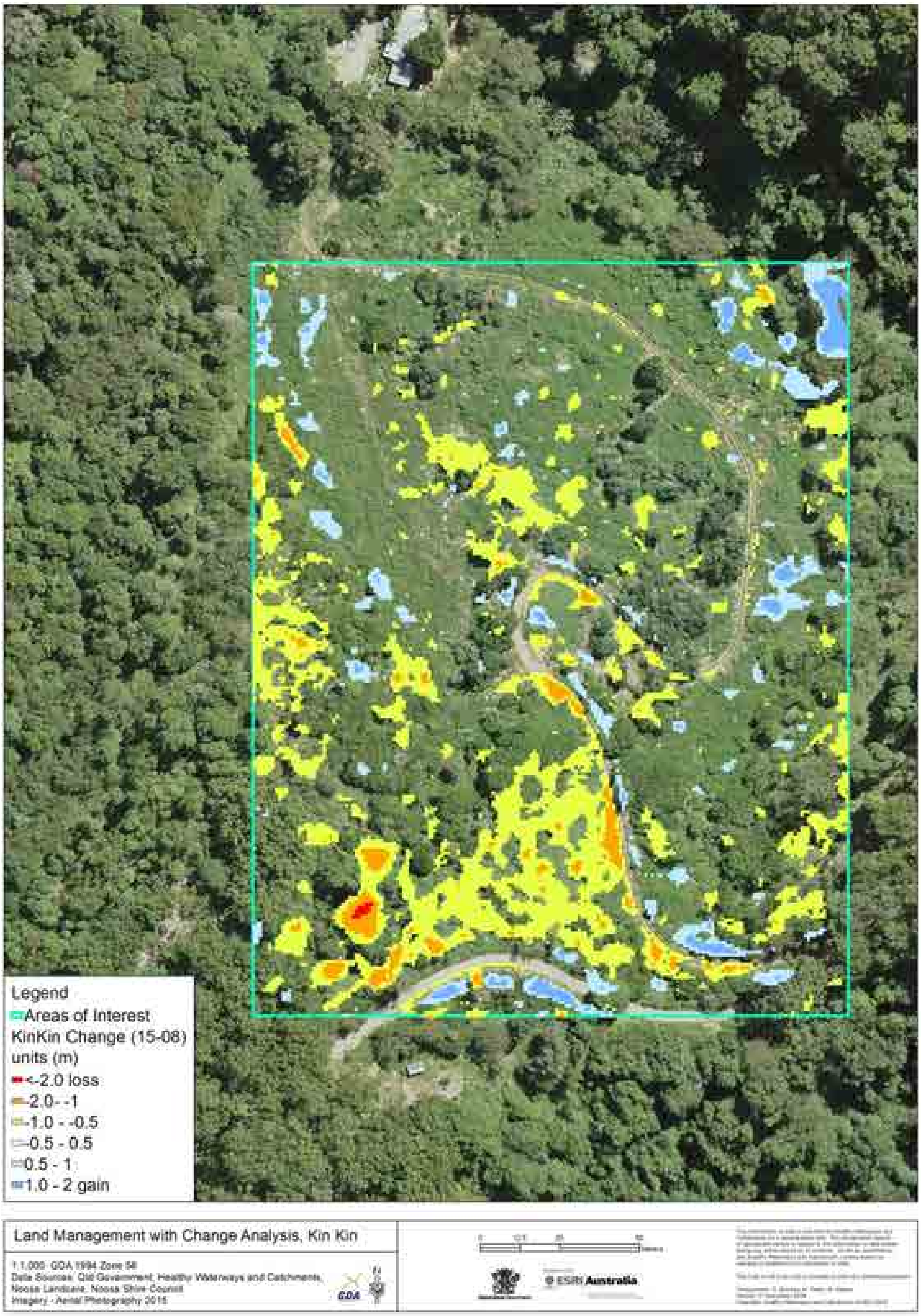
Map 3b: LiDAR slope showing Erosion Type of "gully erosion" where dark slope represents steeper areas and light slope are flatter areas

Map 3c: Change analysis over Erosion Type of "gully erosion" showing loss in elevation (active erosion) mostly at the head of the gully system

Map 4a: Aerial photography 2015 of Erosion Type "Land Management" (disturbance and weeds)

Map 4b: LiDAR slope showing Erosion Type of "Land Management" highlighting tracks and general disturbance on steeper slopes. The lidar slope is generally showing unstable conditions on previously cleared lands with potential weeds as regrowth

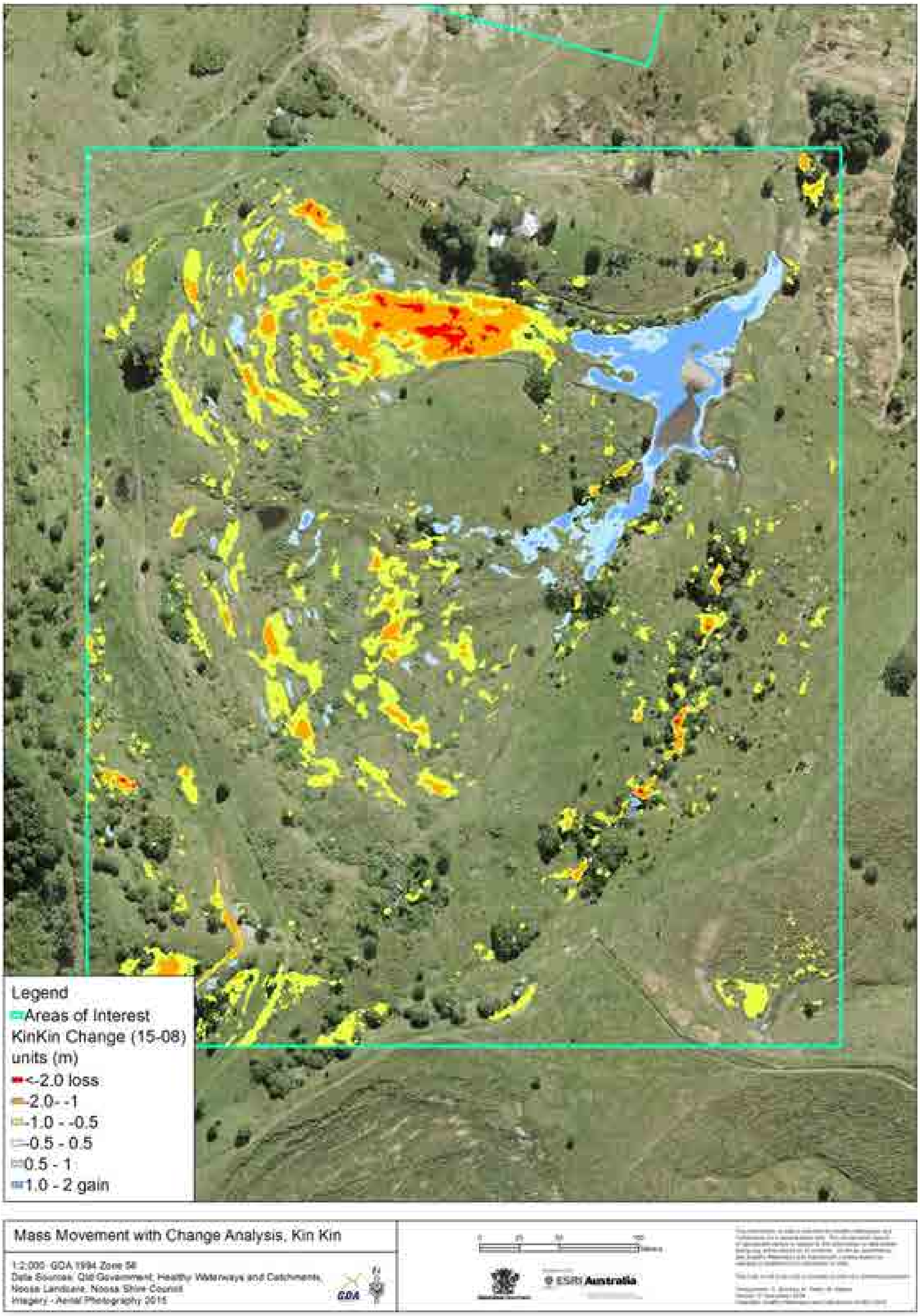
Map 4c: Change analysis over Erosion Type of "Land Management" showing higher loss in elevation (active erosion) along track and in steeper southern area



Map 5a: Aerial photography 2015 of Erosion Type "Mass Movement" – landslip

Map 5b: LiDAR slope showing 2 distinct areas of Erosion Type "Mass Movement" highlighting rippling affect as soil slumps down the slope

Map 5c: Change analysis over Erosion Type "Mass Movement" showing northern landslip being more active with higher rates of soil loss. High levels of deposition observed in the valley and entering waterway.



Map 6a: Aerial photography 2015 showing Erosion Type "stream bank erosion"

Map 6b: LiDAR slope showing Erosion Type "stream bank erosion" with steeper creek banks and high slope as dark colour with a steep gully on the eastern side of the waterway

Map 6c: Change analysis over Erosion Type “stream bank erosion” showing areas of erosion and deposition along the waterway. Steep gully on eastern side also showing signs of erosion.