A framework for prioritising gully management in the Normanby Basin Cape York

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Appendix 2: A report to South Cape York Catchments for the Cape York Water Quality Improvement Plan

Griffith UNIVERSITY

IMPORTANT

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CAPE YORK WATER QUALITY

Background

It is increasingly becoming recognised that the relatively intact northern Great Barrier Reef (GBR) represents a fundamentally important stronghold of resilient coral reefs that might hold the key to the survival of the entire GBR in a warming global ocean. With multiple stressors such as the warming of global oceans, ocean acidification, increasing cyclone magnitude and frequency and declining catchment water quality all impacting the coral reefs of the GBR, it is only catchment water quality that we can directly influence on short (<10 year) timescales (De'ath et al. 2010). Given the severe declines in the coral reef cover documented in the central and southern parts of the GBR (De'ath et al. 2012), the northern GBR is the last stronghold of healthy reefs and could well hold the key to the long term survival of the reefs to the south as the oceans warm to become more like the conditions currently found in the northern GBR. Hence the maintenance and improvement of the water quality to the Northern GBR is one of the highest priorities for the overall management of the GBR. As outlined in Brooks et al., (2013) the major accelerated sediment source that is delivering sediment to the Northern GBR is associated with gully erosion and particularly alluvial gully erosion in the Normanby catchment. Consequently, the management of gully erosion in this key catchment is fundamental to the persistence of healthy reefs in the northern GBR.

A detailed review of the processes driving gully erosion in the Normanby catchment and approaches to gully management is contained within a report by Shellberg and Brooks (2013) http://www.capeyorkwaterquality.info/references/cywq-223, and this report forms the basis for ongoing gully management. This builds on a broader body of work on alluvial gullies erosion processes in northern Australia (e.g. Brooks et al., 2009; Shellberg et al., 2013a,b; Rose et al., 2015).

The gully management prioritisation framework outlined in this document builds on the extensive body of work undertaken for the Normanby Sediment Budget project (Brooks et al., 2013). The prioritisation framework outlined here is only possible thanks to the previous investment by the Federal Government in the collection of high quality data that enables us to know where all the gullies are, how much sediment they are producing and hence which gullies are the priorities for focusing initial rehabilitation efforts in the most cost effective way. The only measure of cost effectiveness that counts is how much current sediment loads can be reduced, over what timeframe and at what cost per tonne of sediment. At present this is the only GBR region where such data exists, and it should be a high priority for similar data to be acquired in strategic high sediment yielding catchments across the rest of the GBR.

A full description of the technical details underpinning the mapping protocols across the Normanby catchment can be found in the appendices associated with the Normanby Sediment Budget report (Brooks et al., 2013; http://www.capeyorkwaterquality.info/references/cywq-229. Before outlining the approach adopted for prioritising the management of gullies in this catchment an overview of the approach used to map and characterise gully erosion rates in the Normanby catchment is provided. We then outline a process for beginning to prioritise the rehabilitation of the key accelerated sediment sources in the Normanby catchment

1. Overview of Normanby Gully Prioritisation Framework

The following describes the broad prioritization approach:

1) Development of catchment wide gully distribution mapping
   a. Map all bare ground gullies across the catchment in Google Earth (GE)
   b. Map all gullies within selected LiDAR blocks across the catchment (in this case a sample of 41 blocks with a total area of 782.5 km^2 (or 3.2% of the total catchment area).
   c. Compare GE gullies with LiDAR derived gullies in the areas of data overlap and derive underestimation ratio (bare ground gullies mapped in GE will always be an underestimate due to the presence of varying degrees of vegetation that obscure some portion of large alluvial gully complexes).
   d. Derive minimum sediment yields from gullies using repeat LiDAR (in this case a 14 blocks were re-flown in 2011 - total area 163 km^2 or ~21% of the original acquisition.
   e. These data (a-e) then form the basis for deriving catchment scale (minimum) sediment contributions from gullies at the scale of the 9621 sub-catchments derived for the

Australian Hydrological Geospatial Fabric (AHGF) catchment dataset in the Normanby Basion. Sediment yields are interpolated at the AHGF sub-catchment scale using the combined GE and LiDAR derived gully datasets.

f. The output from this is used to derive the catchment scale gully distribution as shown in Figure 1

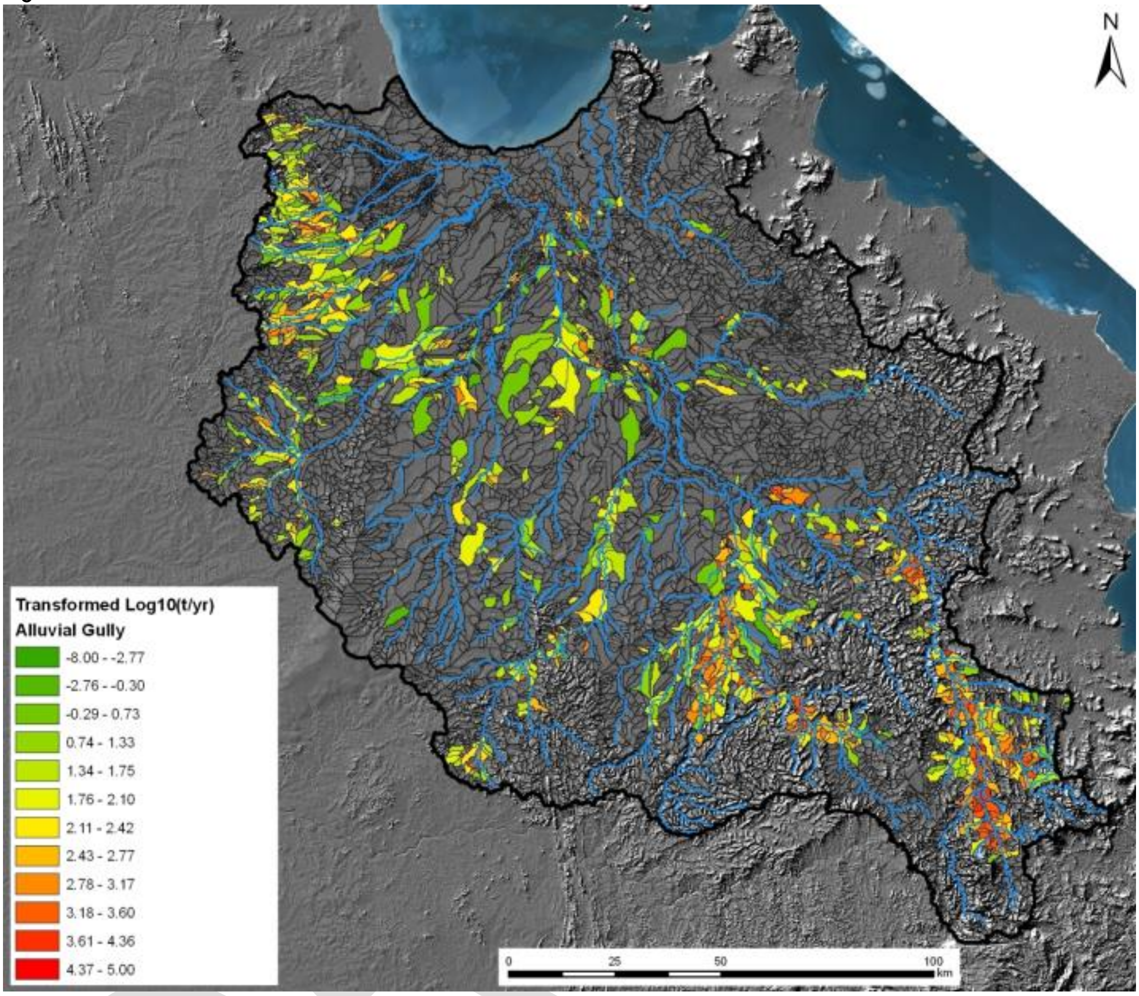


Figure 1 Alluvial gully erosion distribution within the Normanby catchment from Brooks et al (2013).

g. The output from the catchment mapping at the AHGF sub-catchment scale is then used to rank the top 100 sub-catchments contributing both alluvial and colluvial gully erosion (Figure 2).

h. Additional filters are then added to include such things as:
    i. The location of LiDAR data (which improves confidence in the analysis and provides baseline data against which the quantum erosion mitigation can then be measured)
    ii. Location of road access
    iii. Landholder participation

i. Having ranked the top 100 sub-catchments individual gully complexes are then identified within the top 100 sub-catchments and clusters of gullies are then identified within each block.

j. Tables are then produced showing the relative sediment contributions from specific gully management units.

k. The most tractable gullies are then selected. This equates to the ones that can be most effectively managed to produce the greatest sediment reductions with a high degree of certainty (lowest risk) over management timeframes for the lowest cost per tonne of sediment reduction.

l. Coupled with on-ground information, decisions can then be made as to the most appropriate strategies to be employed in different areas. In the example shown in Figure 2, two areas are identified for stock exclusion as a long term strategy. Other areas will need to be targeted using direct intervention techniques. (NB – it should be pointed out that there is NO ONE SIZE FITS ALL SOLUTUION). There are a wide diversity of gullies that are a function of their soil type, landscape position, landscape evolutionary history, land-use history, vegetation community composition, rainfall and flood regime. Ensuring that the right strategy is applied to the right gully is a major challenge requiring an ongoing adaptive management approach.

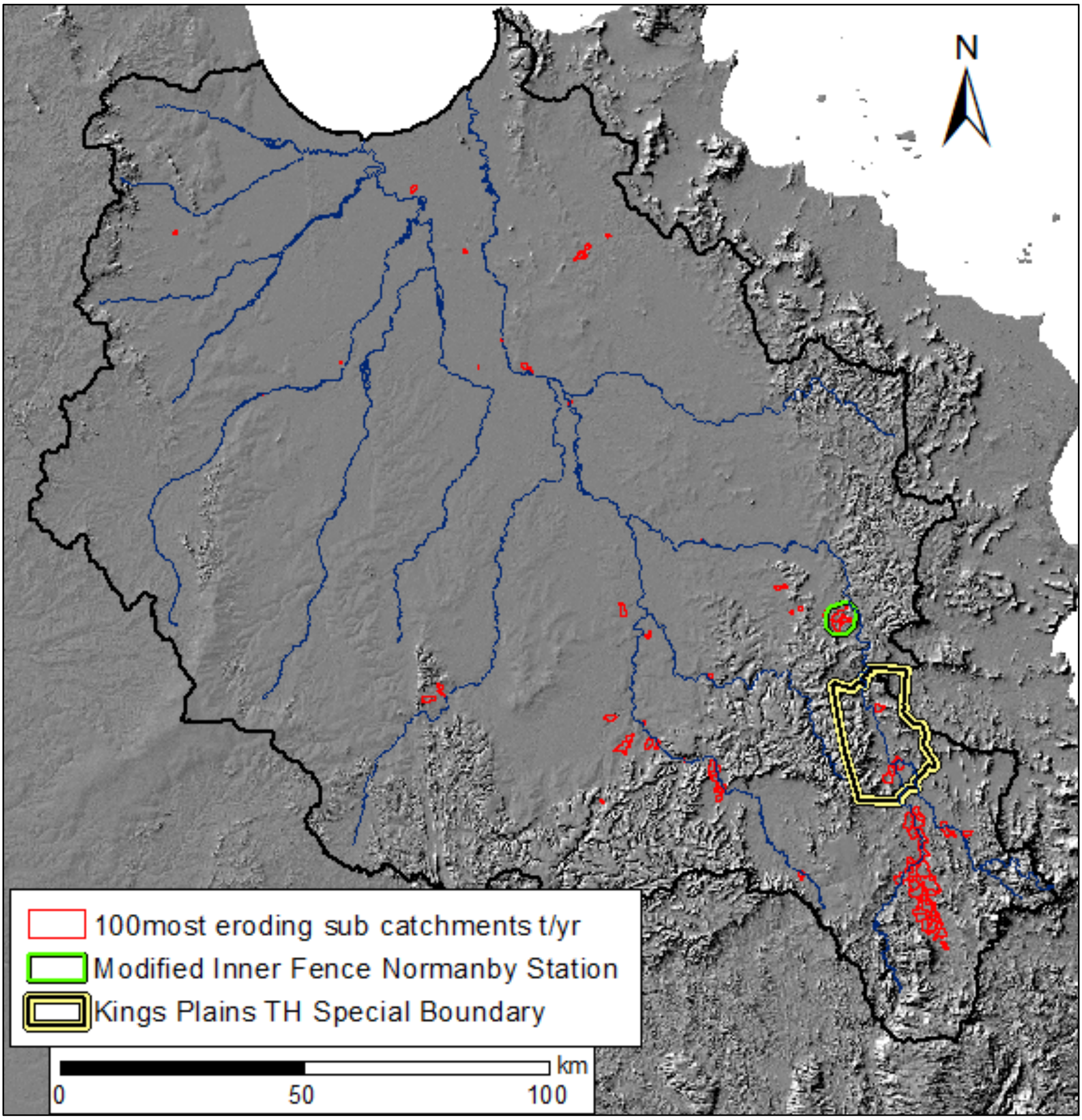


Figure 2 Map of the 100 highest sediment producing sub-catchments within the Normanby Catchment shown in Red. Also shown are the two areas proposed to be managed by stock exclusion fencing under the Reef Trust gully programme (in addition to a comprehensive programme that is focused on more direct gully management in high priority gully complexes).

2. Overview of Normanby Gully Mapping

2.1 Google Earth Mapping

Previous attempts to map alluvial gullies through remote sensing in the Gulf Country have met with mixed success (Brooks et al., 2007; Brooks et al., 2008, Brooks and Spencer, 2015) and so based on that experience, it was decided that the manual digitisation of bare ground gullies in Google Earth was a more efficient, accurate and cost effective method for determining the broad distribution of gullies across the catchment. The majority of the catchment in Google Earth is now covered by 2.5m resolution SPOT imagery, and with a significant proportion of the catchment now covered by ~1m resolution Quickbird imagery. Imagery at this resolution is sufficient to map bare earth gullies that have a width of ~5m and greater. Figure 3 shows an example of hand digitised gullies on the Google Earth imagery. The area shown contains a boundary between the two sources of satellite imagery, i.e. 2.5m SPOT and ~1m Quickbird. Digitizing across imagery with different resolutions requires a significant effort to maintain a consistent dataset across the whole catchment. Since the mapping was done in 2010 the proportion of <1m resolution imagery across the catchment has increased significantly, meaning that it is even more feasible than ever to undertake such an exercise, and indeed it may be necessary to update some of the earlier mapping now that we have access to these improved datasets.

Figure 3: Example of gully digitizing on Google Earth imagery. Note the boundary between the two sources of satellite imagery, i.e. the 2.5m SPOT and the ~1m Quickbird, through the middle of the image.

A total of 9670 gullies were digitised, with a minimum area of $3m^2$, maximum area of 12.7 ha, mean area 0.16 ha and total area 1566.7 ha, which is 0.06% of the Normanby catchment. Figure 6 shows the gully mapping derived from Google Earth imagery produced for this project.

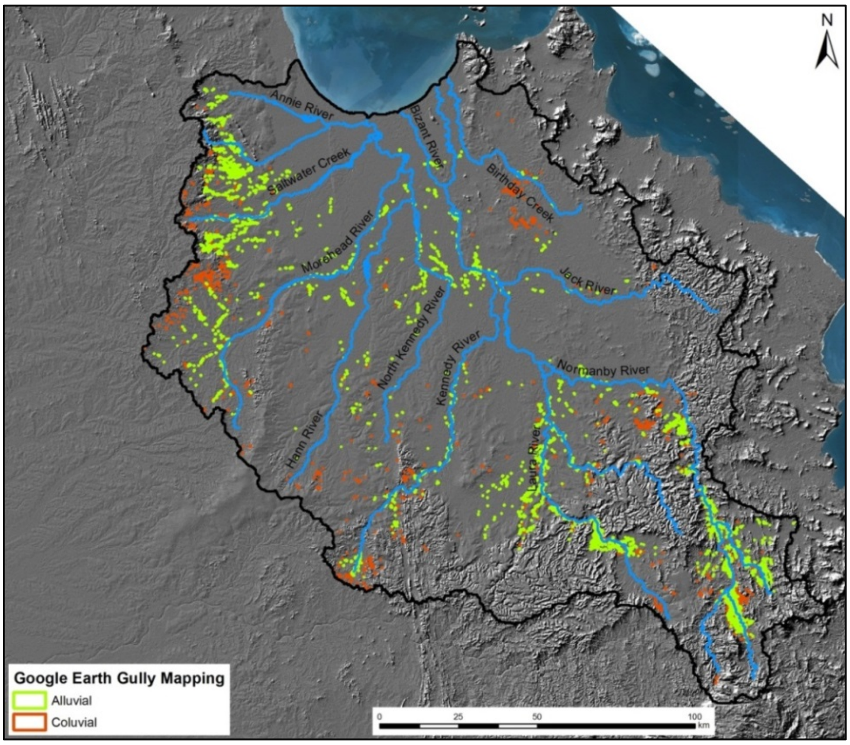


Figure 4: Distribution of gullies mapped from Google Earth in the Normanby catchment.

2.2 Aerial LiDAR Data

Along with the GE mapping, which provides the broad distribution of the most active gullies at the catchment scale, the Airborne LiDAR data is the key dataset that underpins the gully sediment yield data across the Normanby. By extension this now provides an unprecedented basis for the prioritisation of gully management in what is arguably one of the highest priority catchments draining to the Great Barrier Reef.

A total of 50 blocks of LiDAR were flown between May and August 2009 by Terranean (now RPS); covering a total area of 1065.4 km^2. This includes 41 blocks in the Normanby (782.5 km^2), 5 blocks in the Stewart (88.9 km^2), 3 blocks in the Jeannie (107.1 km^2) and 1 block in the Annan (86.7 km^2) (**Error! Reference source not found.**).

The Normanby catchment has an area of 24,353 km2; the 2009 LiDAR covered 3.2% of the catchment. A subset of the LiDAR blocks was re-flown the on 16th and 17th September 2011. The areas with both 2009 and 2011 LiDAR data comprised 14 blocks covering 163.1 km2, which is 0.7% of the catchment.

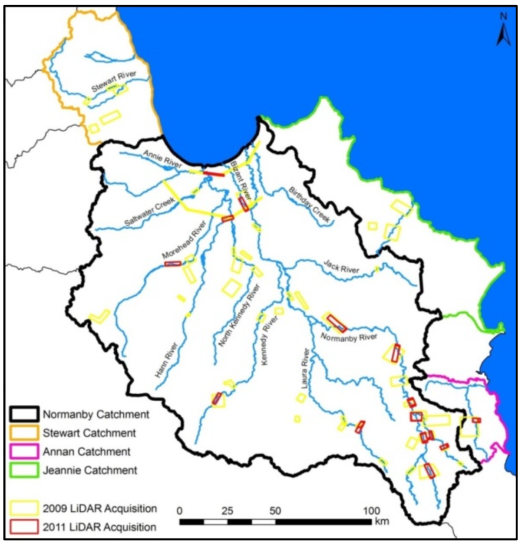


Figure 5: LiDAR blocks in the Normanby and adjacent catchments.

3. Gully Mapping at different resolutions

A comparison of Google Earth mapped gullies and LiDAR mapped gullies (described below) showed that the Google Earth mapping underestimates the extent of gullies, on average, by a factor of 7.6 (Table 1, **Error! Reference source not found.**). The difference is due to the amount of gully that is covered by vegetation, which cannot be seen in satellite imagery, but is captured in LiDAR data. Therefore we consider the Google Earth gully mapping as a minimum gully extent. While it is the case that the full gully extent is significantly under-represented by the Google Earth mapping alone, it is also the case that the bare ground gullies that are visible in Google Earth are likely to be the highest sediment yielding gullies of all the gullies. Nevertheless, at the catchment scale we have used the GE gullies as the basis for extrapolating gully sediment yield data across the catchment, using an underestimation correction factor to account for the likely underestimation in GE..

Table 1: Repeat LiDAR blocks showing the extent of mapped alluvial gully from LiDAR data and Google Earth (GE).

LiDAR Block #	LiDAR gully area (ha)	GE gully area (ha)	Ratio of LiDAR gully area to GE gully area
N2	117.57	0.04	2654.4
N4	223.20	27.98	8.0
N5	344.79	39.57	8.7
N7	229.07	70.65	3.2
N9	76.96	5.86	13.1
N10	122.81	7.26	16.9
N13	246.38	22.64	10.9
N14	126.99	24.81	5.1
N16	158.06	30.35	5.2
N17	37.43	1.76	21.2
N20	147.50	12.16	12.1
N21	29.12	1.07	27.3
N25	8.52	0.11	76.5
N40	0.58	0.45	1.3
total	**1868.98**	**244.71**	**7.6**

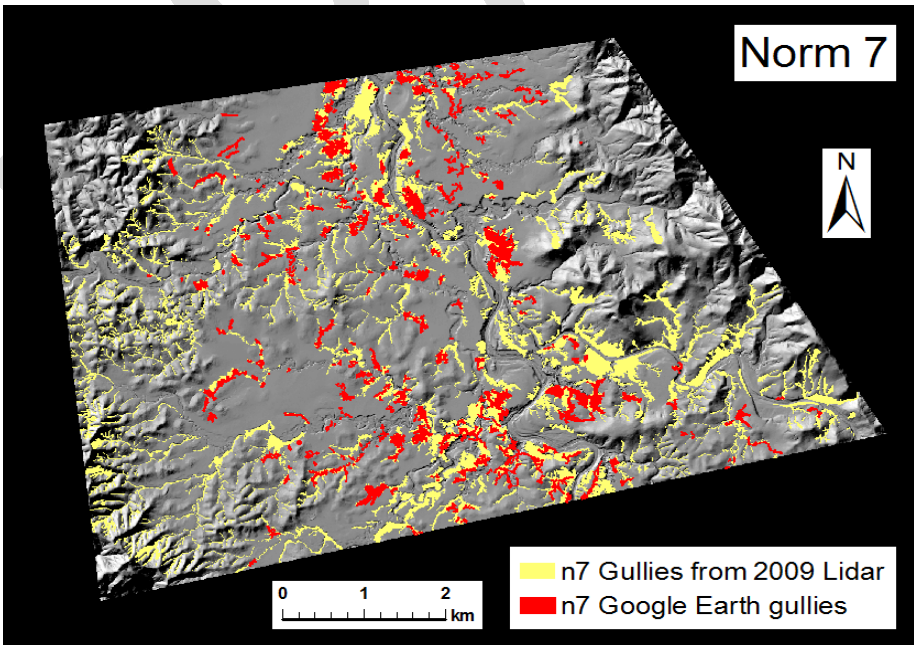


Figure 6: Hillshade relief image of LiDAR block 7. Shown here is the extent of gullies as mapped on Google Earth imagery and as mapped on LiDAR DEM data.

3.1 LiDAR Gully Mapping

A total of 16,959 features were hand digitised on hillshade relief rasters generated from the 2009 LiDAR data, defining features in the landscape formed by fluvial processes; including water bodies, bars on open riverbed, vegetated bars, benches, terraces, floodplains, gullies, banks, islands, secondary channels. The use of image segmentation software to delineate these features was attempted but it was found this was too complex a task for such an automated process and that hand digitizing gave a better delineation of features. The area of fluvial features digitised from 2009 LiDAR was 126.84km^2 which is 0.5% of the Normanby catchment. Figure 7 shows an example of digitized features.

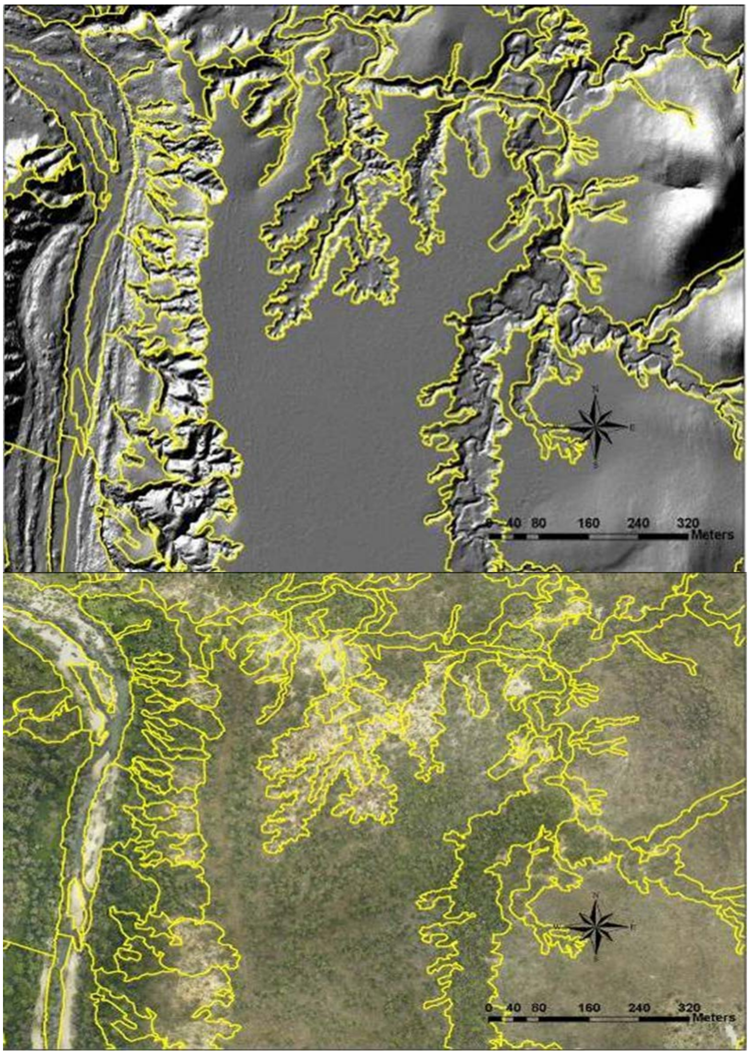


Figure 7: Example of digitising of features on a hillshade relief image (top). The same area is shown (bottom) with the ortho-photo mosaic (capture simultaneously during LiDAR acquisition) displayed. This location is on the upper-mid reaches of the Normanby. Within the alluvial gully in the centre of the image can be seen a gully inset within a gully, this is an example of the multiple phases of gully activity which are evident in parts of the catchment.

4. Change Detection Analysis – Measurement of Short Term Sediment Production

A change detection analysis was undertaken to determine the volume of surface change that occurred between the 2009 and 2011 LiDAR acquisition dates. A change detection analysis involves subtracting one raster dataset from another and examining the difference. In this study the analysis involved the difference between the digital elevation models (DEM) derived from the 2009 and 2011 LiDAR data. The volume change is interpreted as erosion or deposition. The initial change detection analysis highlighted that the 2009 and 2011 LiDAR data contained substantial random error from measurement limitations and substantial systematic error from processing methods. These errors produced so many false positives in the change detection dataset that the signal to noise ratio becomes too low to separate actual change from error.

Data accuracy and processing issues included:

- There was a difference of spatial registration of up ~3m between the 2009 and 2011 data. That is, obvious locations visible in 2009 and 2011, such as a road or the edge of a gully, were misaligned up to ~3m. This type of error is observed in the DEM difference rasters as an unnatural pattern of erosion on one side of a gully and deposition on the other
- The point cloud LiDAR data is a mass of points with X, Y, and Z values that represent anything the laser struck, be that vegetation, cattle, buildings, or the ground. Classifying points as ground or non-ground points is an involved process. It begins with an automated process which has sensitivity adjustments and settings done when generating the point cloud from the raw LiDAR data. The automated classification can be followed by manual reclassification. The points classified as ground are used to generate the DEM which represents the ground surface. Inconsistent classification creates errors in the change detection analysis, such as;
    - Areas of complex gully topography occasionally had areas of ground surface removed as vegetation. These areas were either at the edge of gullies or remnant pedestals within gullies
    - In consistent vegetation removal on heavily vegetated steep slopes within gullies creating DEM difference errors of up to 1m.
- Vertical misalignment between mosaicked swaths in the same block, resulting in step changes in values in the difference raster.

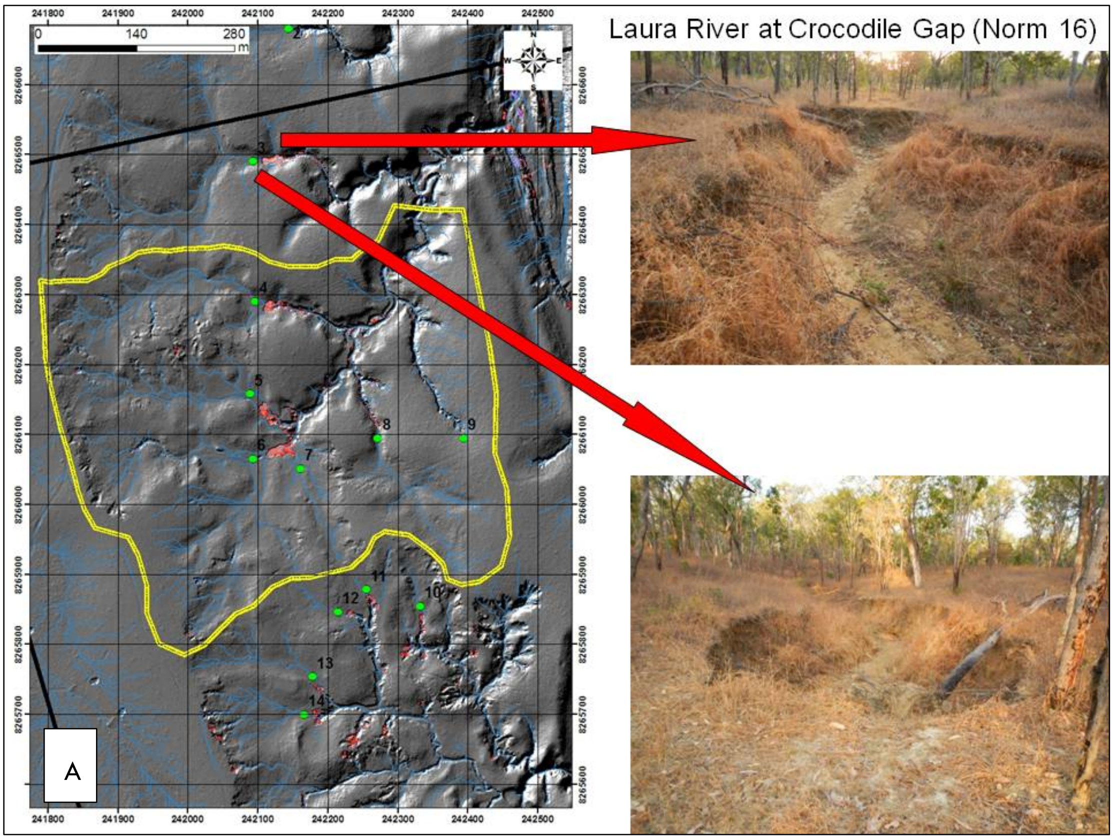
These data accuracy and processing issues are a consequence of operating in remote areas and cost-benefit decisions and are not inherent issues with the LiDAR acquisition or the equipment operation and were addressed in conjunction with the data supplier (RPS), including being contracted to reprocess some of the 2009 LiDAR to match the 2011 LiDAR processing, which required several iterations. Consequences of reprocessing the 2009 LiDAR data were that the landscape unit polygons (that were hand digitising on the original 2009 data) and the CHM and PFC rasters had to be shifted on a block by block basis to align with the reprocessed 2009 data. Notably, a GPS base station located at Cooktown airport was the source of the LiDAR GPS differential correction data during the 2009 LiDAR acquisition. Most of the Normanby LiDAR blocks are beyond the recommended 30km radius (Saylam, 2009) from this base station. This is thought to be a significant source of the spatial positioning error observed between the 2009 and 2011 data.

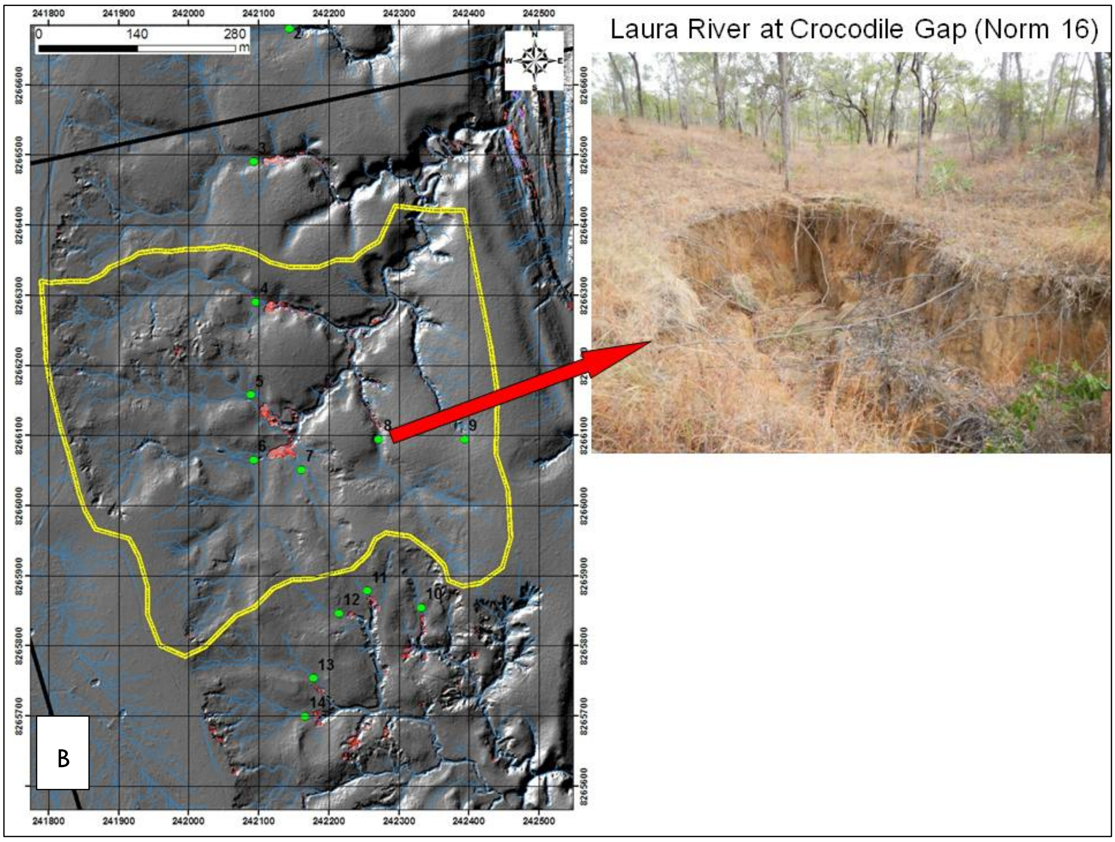
DEM difference rasters were supplied for 14 blocks with a total area of 163.1 km^2, and an average 11.6 km^2 per block.

A full description of the change detection processing can be found in Appendix 3 of Brooks et al.,(2013)

4.1 Ground Validation at Selected Gullies

A series of gullies that changed significantly in the erosion dataset between the 2009 and 2011 were inspected on-ground to validate that this change was actually erosion (**Error! Reference source not found.**. Overlain on the hillshade image is the final erosion raster dataset (small red sections at head of gullies). These examples demonstrate that the filtering and editing procedure is capturing major gully erosion between 2009 and 2011. Ground inspection also highlights the substantial amount of subtle change associated with scalding and gully wall processes which is not being captured in the LiDAR data and the change detection analysis.


Laura River at Crocodile Gap (Norm 16)
0 140 280 m
241800 241900 242000 242100 242200 242300 242400 242500
A


Laura River at Crocodile Gap (Norm 16)
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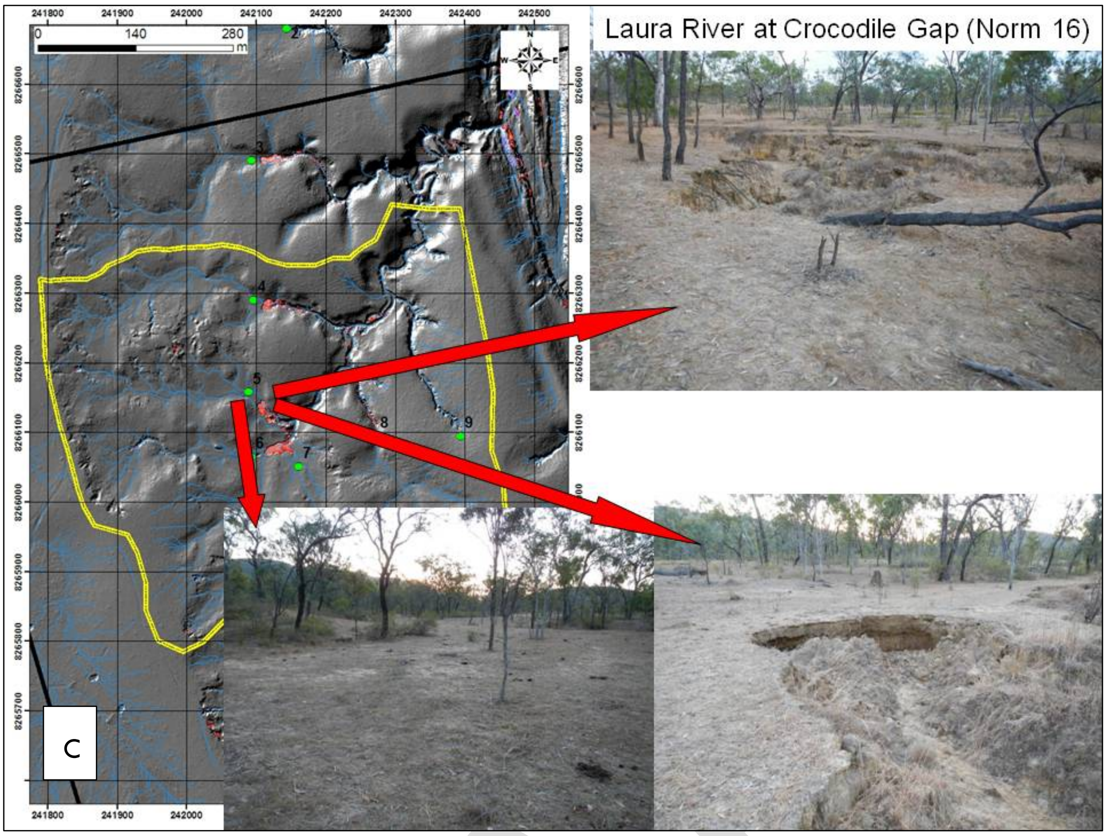


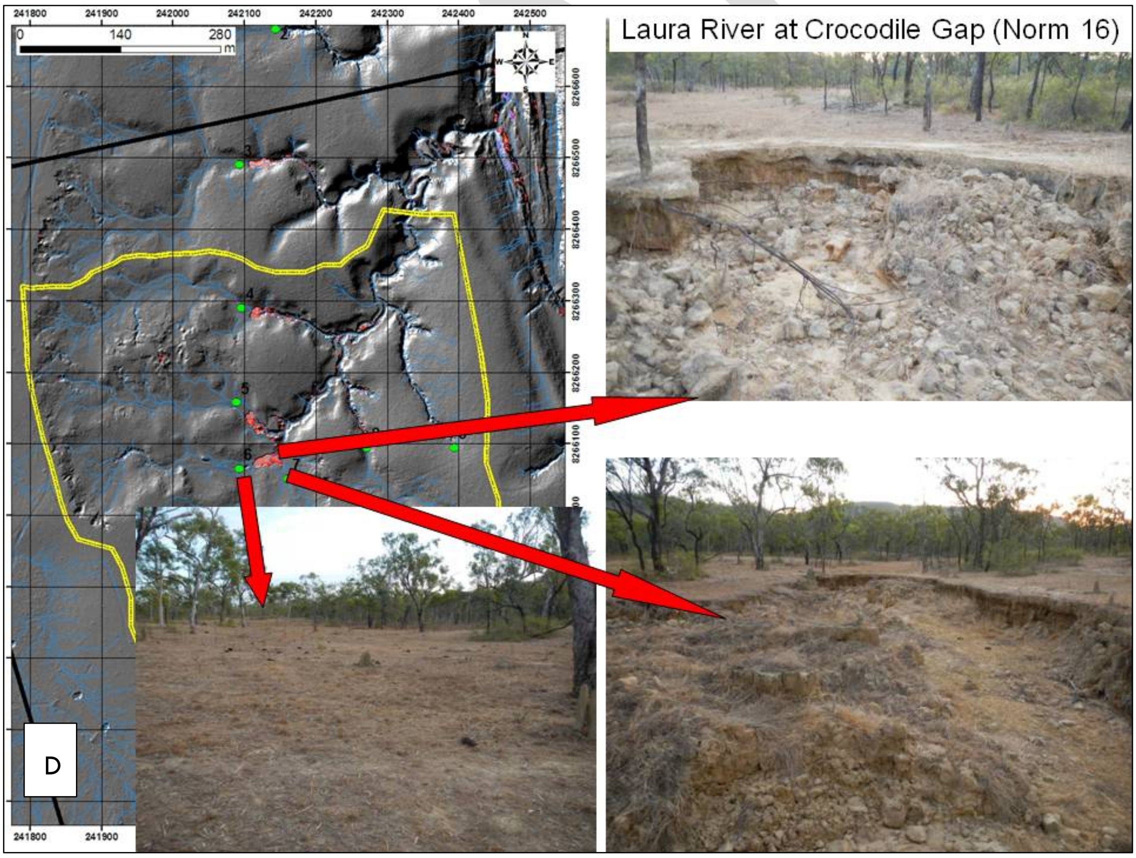


Figure 8: (A-D) Hillshade relief images and ground photos at gully site visited to validate LiDAR derived change detection analysis. Overlain on the hillshade image is the erosion raster dataset (small red sections at head of gullies). These gullies were identified as changing significantly in the LiDAR data between 2009 and 2011. (Photos: Jeff Shellberg).

5. Gully Prioritisation

The following provides further detail on the key steps undertaken to identify the highest priority gullies within the highest priority sub-catchments.

1) From the framework outlined in section 1the process of arriving at the sub-catchment map of gully sediment contributions across the basin has already been well described in Brooks et al., (2013) and no further explanation is required here.
2) For the purposes of this prioritization we have combined the colluvial and alluvial gullies, given that there is a relatively close spatial association with most of the colluvial gullies and the major alluvial gully hotspots. With this information as the base data set the next step in the process was to rank the top 100 sub-catchments across the whole Normanby Basin.

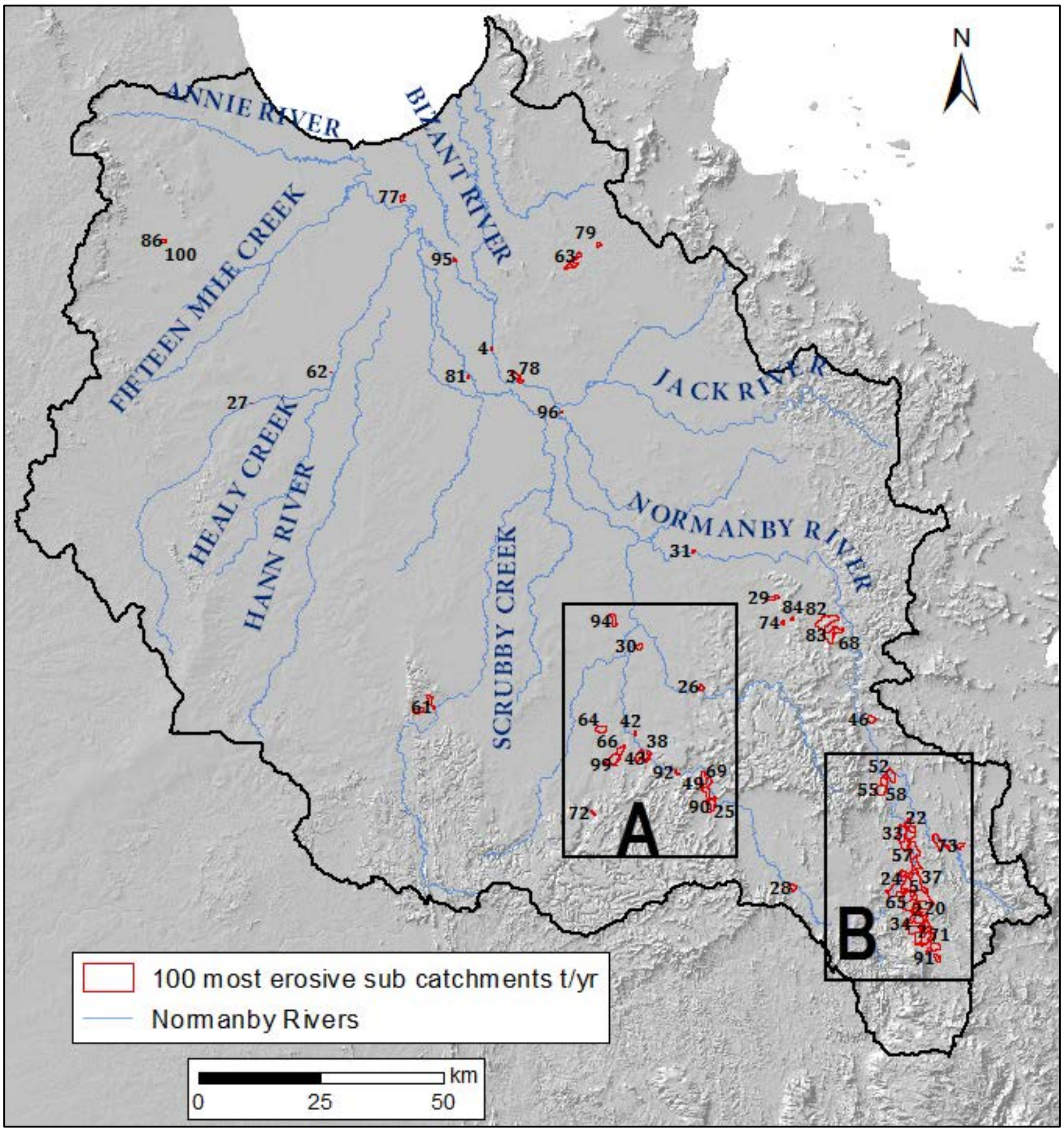


Figure 9 Erosion from alluvial and colluvial sources (i.e. total gully output) were ranked to show the top 100 sub catchments by TOTAL gully output. Sub-catchment numbers are those referred to in Table 3

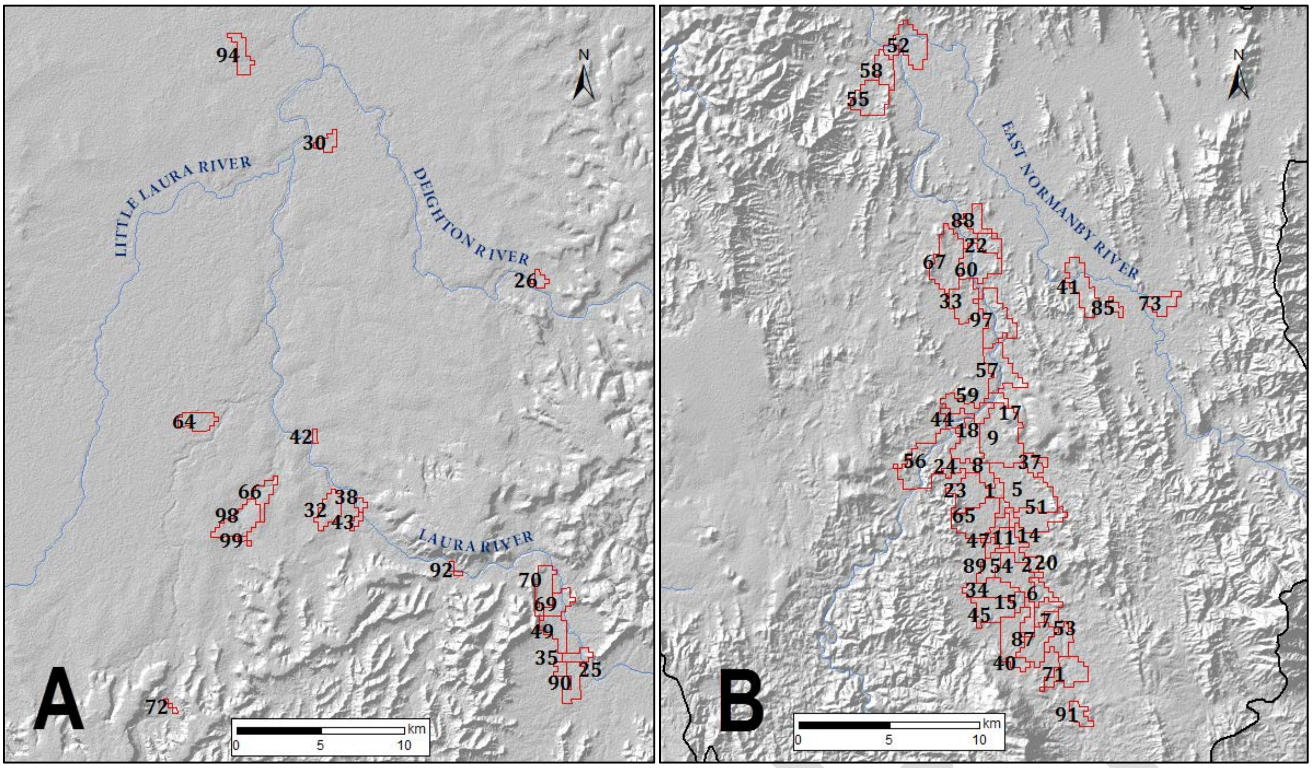


Figure 10 A & B   Detail of Laura River and Granite Normanby areas

As summarised in Table 2, the total catchment wide (minimum) sediment yield from gullies is 1.14Mt/yr, and of this total the yield from the top 100 AHGF sub-catchments represents 56% of this total - or around 645 Kt/yr . A breakdown of the individual contributions from the top 100 sub-catchments are shown in Table 3.

3) To further narrow down the priority gullies, and increase our certainty of the predicted rates and the potentially achievable reduction rates, the top 100 gullies were filtered further to identify those sites that include LiDAR and GE gully data. By focusing on those sites with LiDAR data we are more confident of the baseline sediment yields that will form the basis for ongoing monitoring. We also added a filter of road accessibility as this is critical if cost-effective management actions are to be undertaken in these areas. With these additional filters we have narrowed the selection of sites down to 35 sub-catchments which still represent 32% of the total gully derived sediment yield across the whole Normanby basin.

Table 2   Normanby catchment Gully erosion from sub catchments

Source	**Sediment yield**
Erosion from Colluvial gullies t/yr	411,802
Erosion from Alluvial gullies t/yr	731,938
SUM Alluvial and Colluvial gully erosion at the t/yr	***1,143,740***
top 100 sub catchments (sum of Al and Col) t/yr	645,553
% contribution to total	**56%**
Total of S.Cs that have full or partial repeat LiDAR coverage	362,758
% contribution to total	**32%**

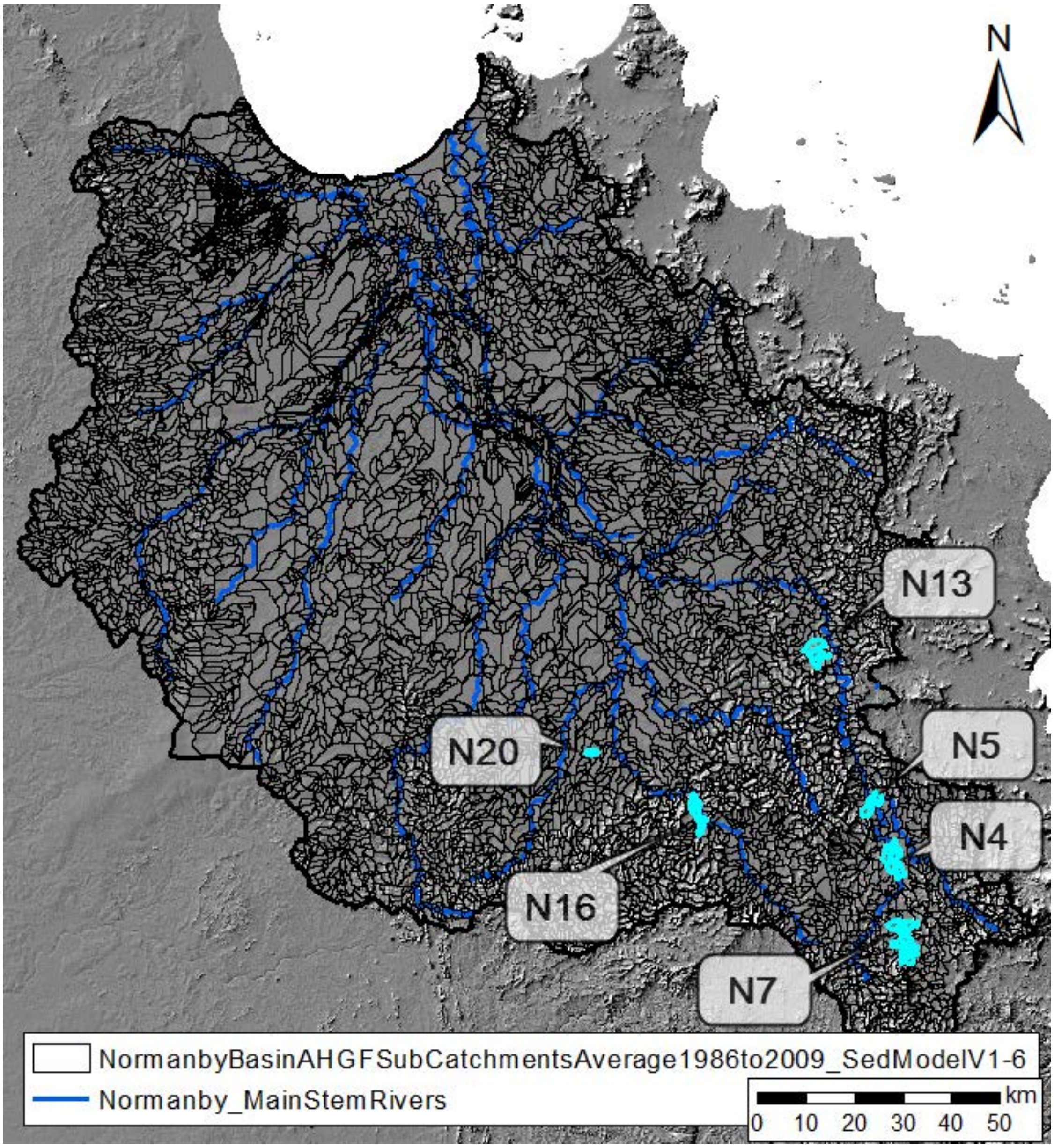


Figure 11 Filtered sub catchments which include Lidar, Google Earth gullies, road Access of some sort AND were in the top 100 by total production are shown here. This narrows the priority sub-catchments down to 35 sub-catchments.

Table 3 Top 100 sub catchments ranked by contribution to total erosion

Sub catchment ranked by contribution to total erosion	Erosion t/yr	% of total erosion	Sub catchment ranked by contribution to total erosion	Erosion t/yr	% of total erosion
1	24647.9	2.16	51	4595.5	0.40
2	23856.3	2.09	52	4589.7	0.40
3	22662.3	1.98	53	4439.1	0.39
4	19121.8	1.67	54	4400.8	0.38
5	15776.9	1.38	55	4361.5	0.38
6	15559.4	1.36	56	4346.5	0.38
7	15219.0	1.33	57	4299.3	0.38
8	13590.3	1.19	58	4291.0	0.38
9	12965.0	1.13	59	4282.0	0.37
10	12695.3	1.11	60	4018.6	0.35
11	11884.0	1.04	61	3965.4	0.35
12	11751.8	1.03	62	3949.7	0.35
13	11740.8	1.03	63	3946.2	0.35
14	11735.9	1.03	64	3782.4	0.33
15	11614.7	1.02	65	3666.4	0.32
16	11326.6	0.99	66	3635.3	0.32
17	11120.0	0.97	67	3629.5	0.32
18	10319.4	0.90	68	3596.0	0.31
19	9968.6	0.87	69	3574.9	0.31
20	9801.6	0.86	70	3535.6	0.31
21	9737.8	0.85	71	3507.3	0.31
22	9414.4	0.82	72	3316.3	0.29
23	8433.7	0.74	73	3285.9	0.29
24	8409.4	0.74	74	3249.2	0.28
25	8006.9	0.70	75	3249.0	0.28
26	7820.6	0.68	76	3237.3	0.28
27	7365.7	0.64	77	3232.9	0.28
28	7107.8	0.62	78	3228.5	0.28
29	6949.1	0.61	79	3214.1	0.28
30	6797.7	0.59	80	3100.2	0.27
31	6520.6	0.57	81	3043.1	0.27
32	6384.3	0.56	82	3014.4	0.26
33	6349.6	0.56	83	2989.9	0.26
34	6239.1	0.55	84	2977.7	0.26
35	6212.0	0.54	85	2957.4	0.26
36	5583.5	0.49	86	2939.6	0.26
37	5518.0	0.48	87	2923.0	0.26
38	5501.5	0.48	88	2894.1	0.25
39	5416.3	0.47	89	2885.0	0.25
40	5401.9	0.47	90	2879.3	0.25
41	5275.3	0.46	91	2842.8	0.25
42	5104.1	0.45	92	2793.3	0.24
43	5017.2	0.44	93	2718.5	0.24
44	5014.1	0.44	94	2696.9	0.24
45	4961.4	0.43	95	2679.9	0.23
46	4888.0	0.43	96	2642.6	0.23
47	4810.5	0.42	97	2606.0	0.23
48	4760.3	0.42	98	2604.9	0.23
49	4750.8	0.42	99	2577.9	0.23
50	4673.6	0.41	100	2577.9	0.23

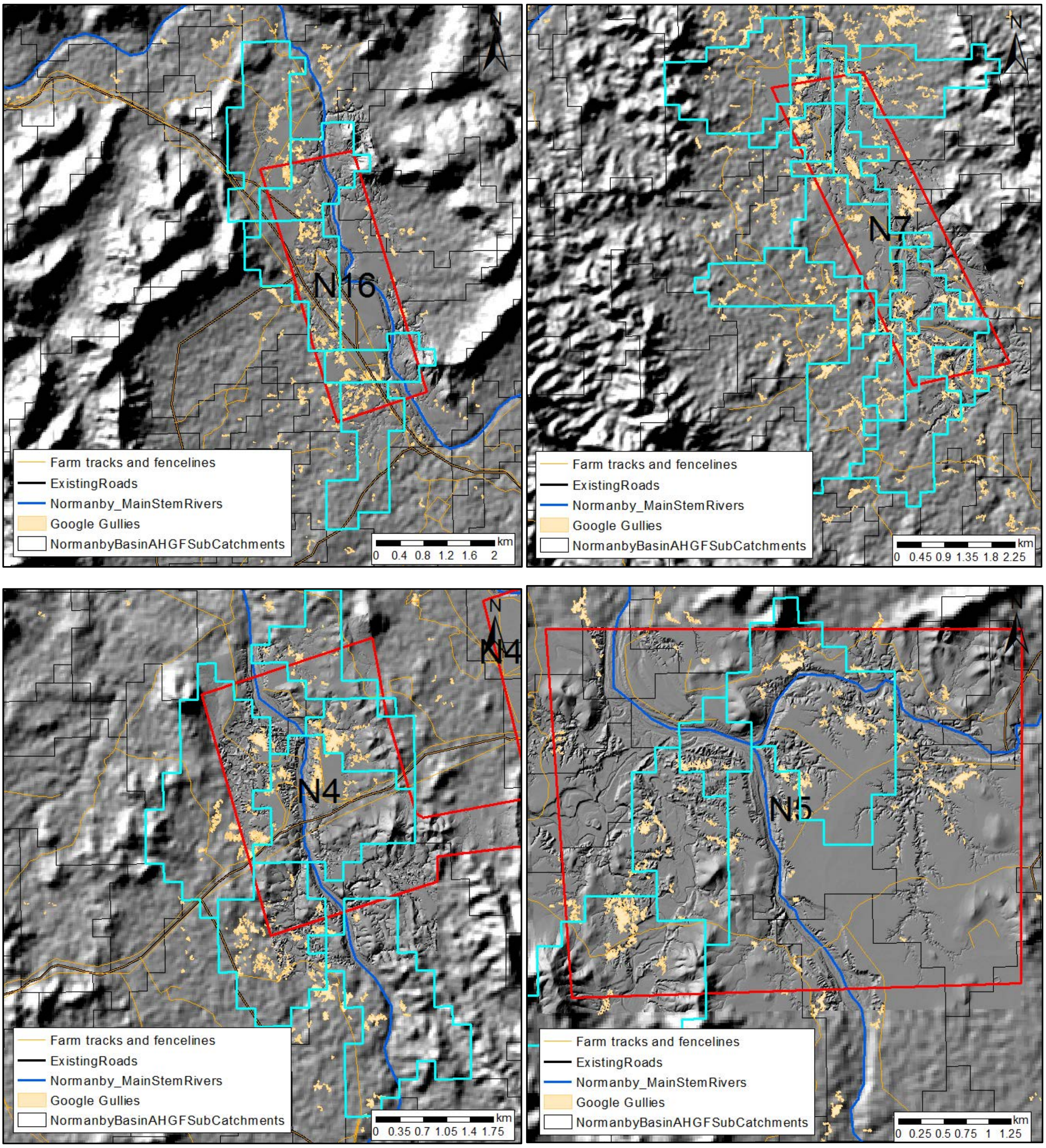


Figure 12 Detail of blocks N4, N5, N7, N16 showing the mapped gullies and the AHGF sub-catchments overlaid

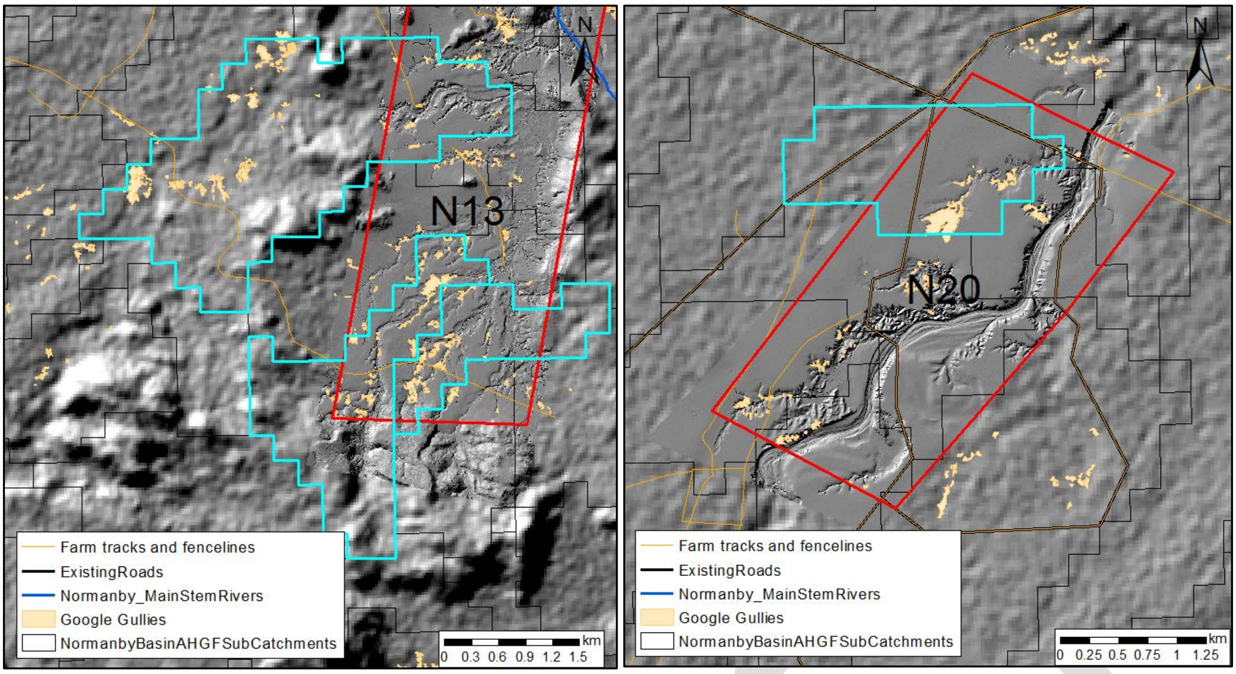


Figure 13 Detail of blocks N13 and N20 showing the mapped gullies and AHGF sub-catchments.

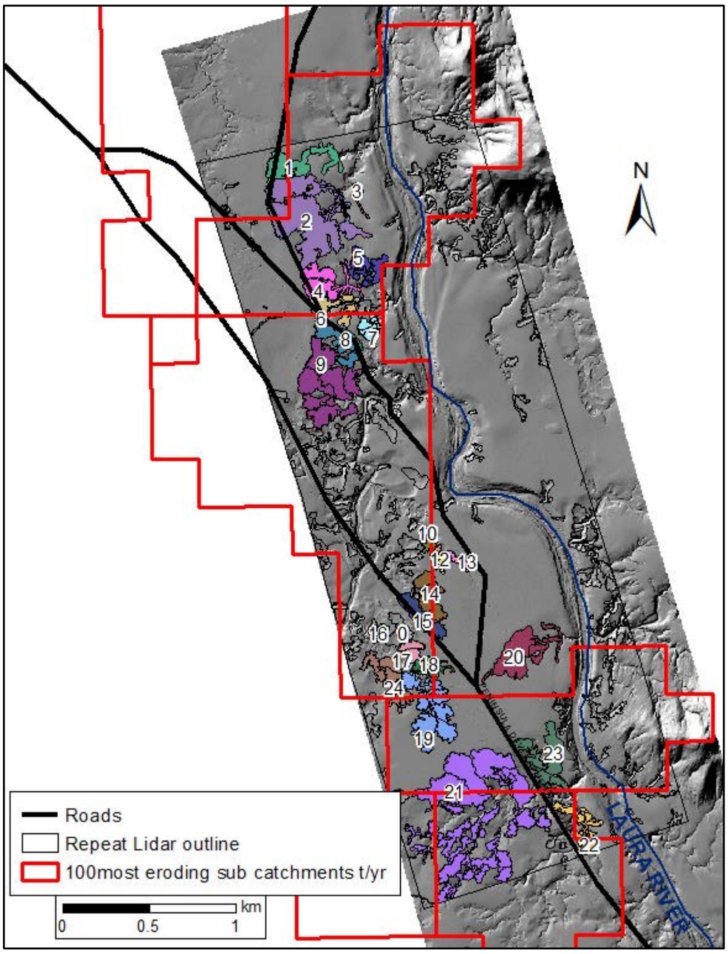
6. Detailed breakdown of priority sub-catchments to individual gully complex scale

Block 16 – Crocodile Gap.

A total of 24 gully complexes have been identified in this area on both sides of the Peninsular Development road. The proximity of the main PDR makes this the easiest of all sites to access, which should make the rehabilitation of these sites some of the most cost effective in the whole catchment.

The 6 sub-catchments that overlay LiDAR block 16 are in the top 86 sediment yielding sub-catchments.

Total erosion from these 24 complexes, was 7107 t/yr for the sample period. Individual lobes of gully complexes range in area from 40m^2 to 10 hectares. A detailed map of the individual gully complexes is shown in Figure 14



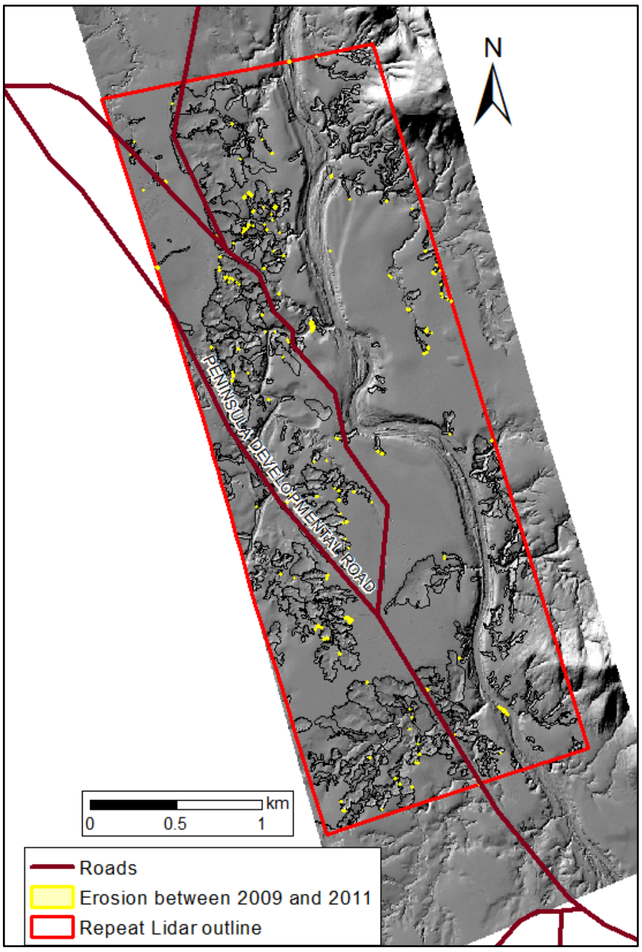


Figure 14 Lidar Block 16 showing selected gully complexes, sub catchment boundaries and the peninsular development road. Also shown on the right are the areas of actively eroding head-scarps (in yellow)

Table 4 LiDAR Block 16 sediment contribution by gully complex

Gully_ID	Sediment yield t/yr	Area (Ha)	Gully_ID	Sediment yield t/yr	Area (Ha)
1	988.8	4.21	13	64	0.48
2	2249.6	15.78	14	136	2.82
3	32	0.39	15	179.2	2.70
4	601.6	4.08	16	9.6	0.51
5	323.2	2.79	17	97.6	1.13
6	57.6	2.51	18	25.6	1.56
7	64	1.25	19	480	6.93
8	88	3.08	20	24	6.00
9	396.8	10.49	21	1112	26.27
10	6.4	0.48	22	62.4	2.42
11	8	0.26	23	8	4.95
12	73.6	0.50	24	19.2	3.56
			total	**7107.2**	**105.2**

Block 7 – Granite Normanby

Block 7 contains 18 of the top 87 gully sediment yielding sub-catchments across the entire Normanby Basin. Within these 18 sub-catchments, 44 gully complexes made up of 160 lobes have been identified for consideration as management units. The total sediment yield from these 44 gully complexes is 15,963 t

A farm track through the middle of the block provides for vehicle access, but the Granite Normanby River also splits the block along the long axis, making it difficult to access blocks on the other side to the track. Access will be difficult in some areas.

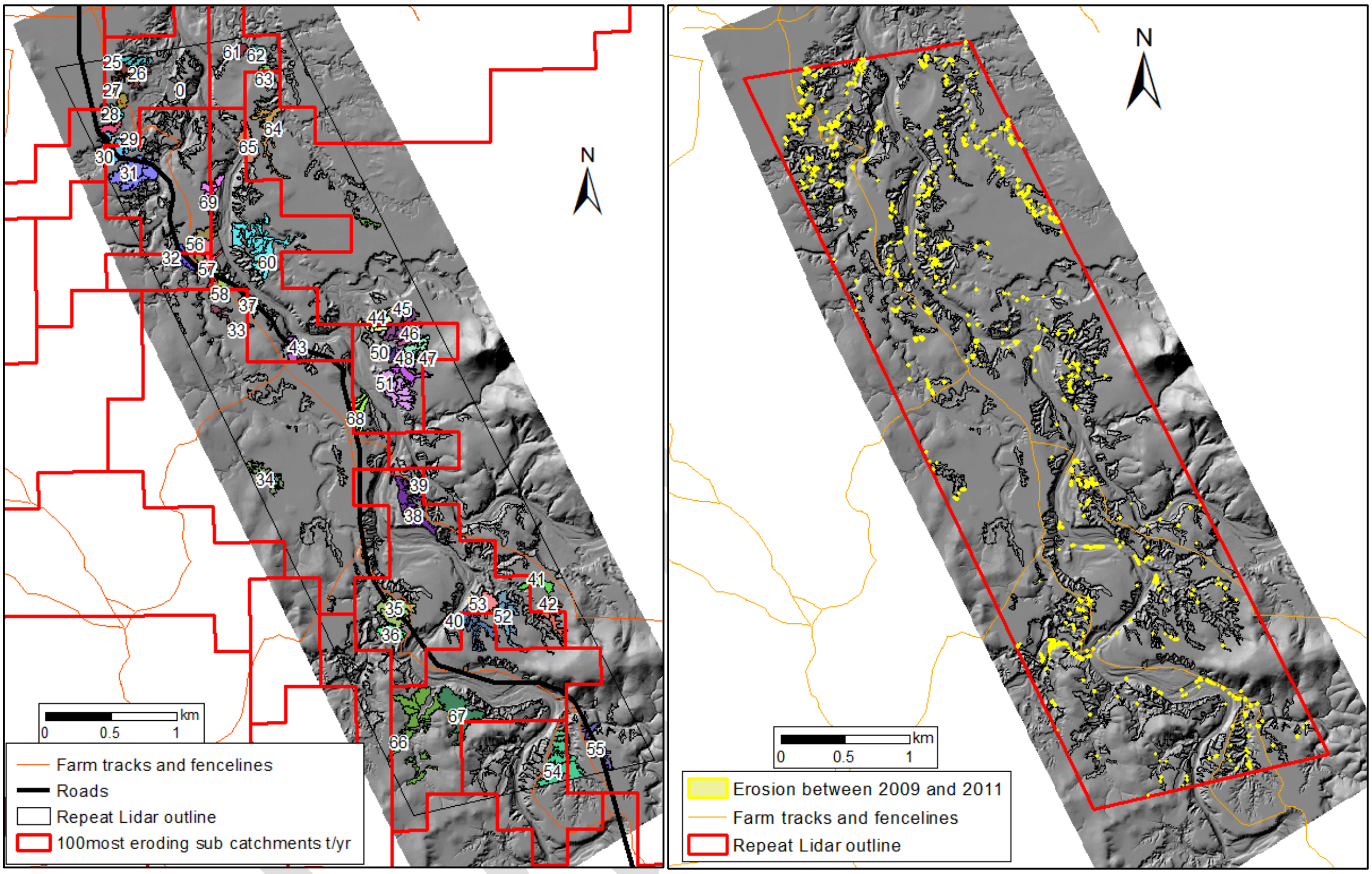


Figure 15 Lidar block 7 showing selected gully units, farm access track and sub catchments

Table 5 Breakdown of individual gully complexes within Block 7

Gully_ID	Sediment yield t/yr	Area (Ha)	Gully_ID	Sediment yield t/yr	Area (Ha)
25	1024	1.36	47	12.8	1.53
26	649.6	2.86	48	540.8	2.91
27	576	0.77	49	180.8	0.40
28	393.6	1.46	50	16	0.43
29	123.2	0.89	51	852.8	4.67
30	252.8	3.55	52	104	3.66
31	1328	6.06	53	17.6	1.51
32	54.4	1.49	54	254.4	5.98
33	156.8	1.22	55	174.4	1.89
34	243.2	1.95	56	43.2	2.39
35	470.4	3.97	57	796.8	1.78
36	267.2	1.47	58	252.8	0.79
37	329.6	0.62	59	22.4	0.62
38	1550.4	4.98	60	1507.2	7.36
39	75.2	0.23	61	860.8	0.70
40	166.4	3.65	62	182.4	1.07
41	171.2	1.33	63	132.8	1.21
42	65.6	2.22	64	145.6	3.07
43	598.4	1.84	65	299.2	2.51
44	140.8	2.17	66	344	8.87
45	171.2	2.37	67	40	6.06
46	0	0.93	68	0	2.15
			69	374.4	2.10
			total	**15963.2**	**111.03**

Block 4 East and West Normanby Bridges

22 gully complexes with 95 sub lobes had 2201m³ of erosion between 2009 and 2011.

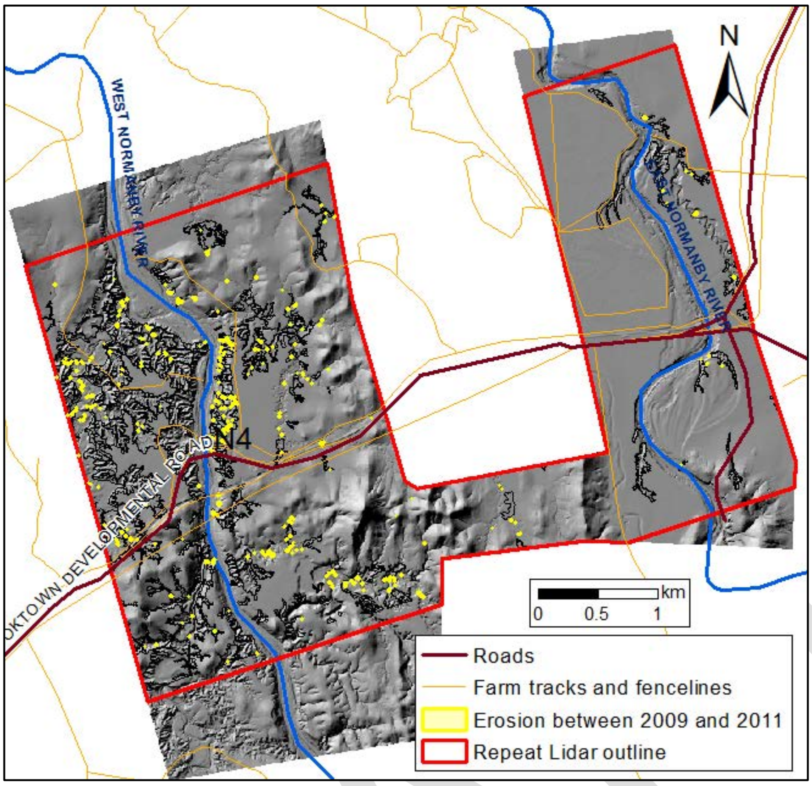


Figure 16 Detail of erosion between 2009 and 2011in Lidar block 4. Alluvial gullies have been lined with black, access routes are shown.

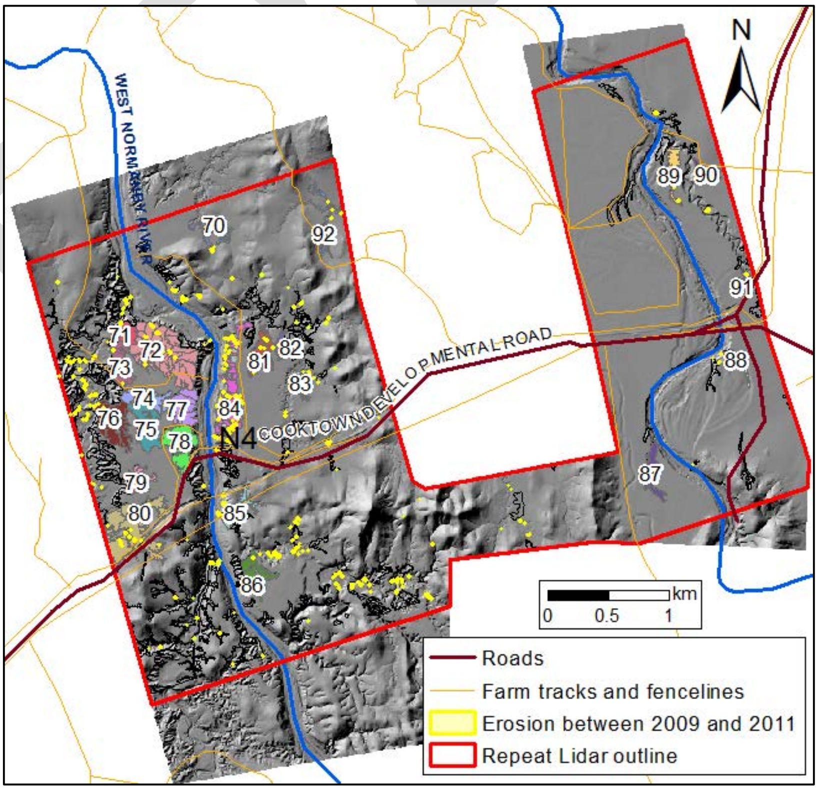


Figure 17 Selected gully complexes with identifier number. Complex 72 is a mass of gullies covering the area between the West Normanby and a secondary creek. Gully 81 has a good sequence of historical air photos mapping development.

Block 4 East & West Normanby Bridge Gully Complex details

Gully_ID	Sediment yield t/yr	Area (Ha)	Gully_ID	Sediment yield t/yr	Area (Ha)
71	57.6	2.33	82	24	0.95
72	371.2	18.10	83	0	0.94
73	80	4.69	84	1697.6	9.05
74	8	4.75	85	276.8	2.63
75	70.4	6.32	86	67.2	4.59
76	68.8	7.73	87	0	2.82
77	0	5.15	88	25.6	1.49
78	0	6.93	89	41.6	2.74
79	0	2.69	90	32	0.89
80	272	14.50	91	76.8	1.12
81	292.8	4.68	92	52.8	2.19
			total	3515.2	107.2764

Block 5 – Kings Plains @ East/West Normanby R Confluence

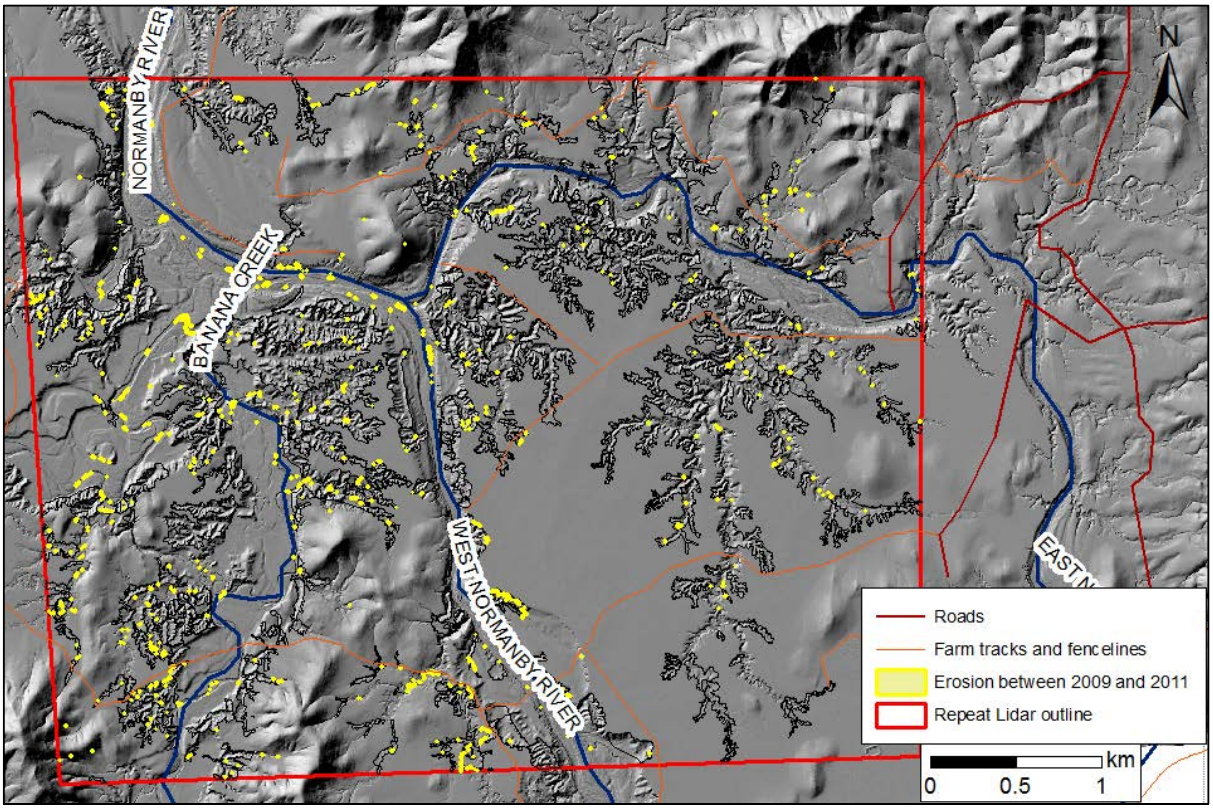


Figure 18 Lidar block 5 with detail of gullies, erosion between 2009-2011 and access tracks

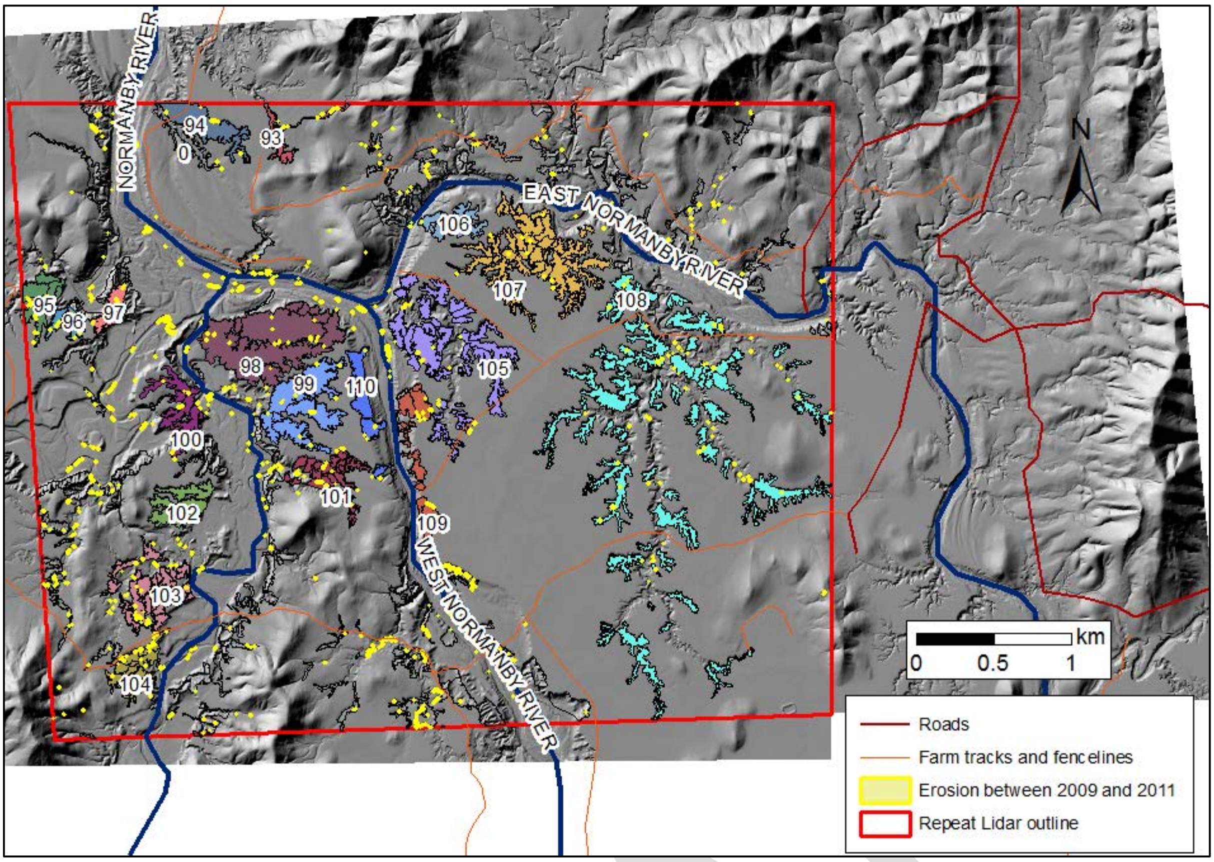


Figure 19 Gully management units in Bkock 5 showing numbered gully units

Table 6 Sediment yields from gully units in Block 5

Gully_ID	Sediment yield t/yr	Area (Ha)	Gully_ID	Sediment yield t/yr	Area (Ha)
93	347.2	3.06	102	0.00	6.83
94	204.8	8.08	103	265.6	12.50
95	336	6.06	104	616	6.11
96	192	2.81	105	284.8	24.78
97	147.2	3.09	106	265.6	5.47
98	272	29.97	107	211.2	25.98
99	473.6	16.50	108	622.4	61.25
100	304	8.16	109	614.4	7.63
101	465.6	7.59	110	152	5.903
			total	**5774.40**	**241.78**

Priority Cattle Exclusion Area – Kings Plains and Normanby Stations

One of the approaches to managing gully erosion in a catchment like the Normanby is to simply exclude cattle from large areas of intensively gullied terrain in the hope that over the longer terms (> 20 years) the gullies will ultimately stabilise and the sediment yields reduce. For the most intensive areas of active gullies exclusion on its own will be insufficient to halt erosion, and additional activities will be required. Fencing alone in such areas is a high risk strategy because at present there is no guarantee that such a passive approach will significantly reduce the rates of erosion in these alluvial gullies. Nevertheless, the large area proposed for exclusion on Kings Plains includes large areas of only moderately active gullies and as such a proposal to exclude ~ 40,000 ha of country on Kings Plains Station represents an unprecedented opportunity to test the effectiveness of exclusion over a large area. The proposed area to be fenced shown in Figure 20 encompasses 110 km^2 of alluvial plains that are subject to alluvial gully erosion, and the area is currently generating around 33,000 tonnes of sediment per year into the Normanby River. Detailed monitoring of these sites over the next decade will be extremely informative as to the effectiveness of exclusion, along with other passive management approaches (e.g. feral management, burning, weed management).

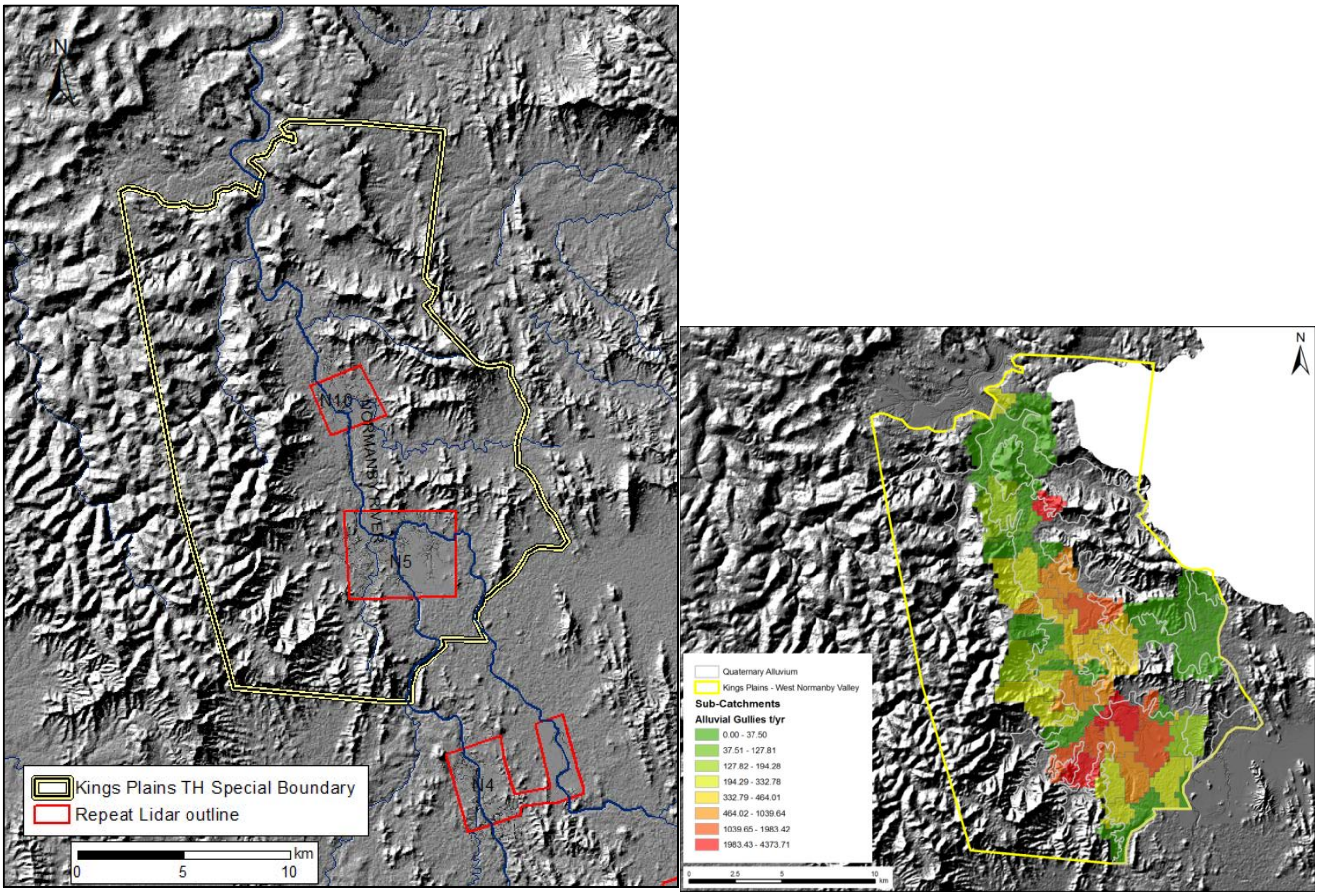


Figure 20 The proposed cattle exclusion area on Kings Plains Station which incorporates all of Block 5 and 10 as well as a large area of alluvial land between these two blocks

Block 13 Normanby Station

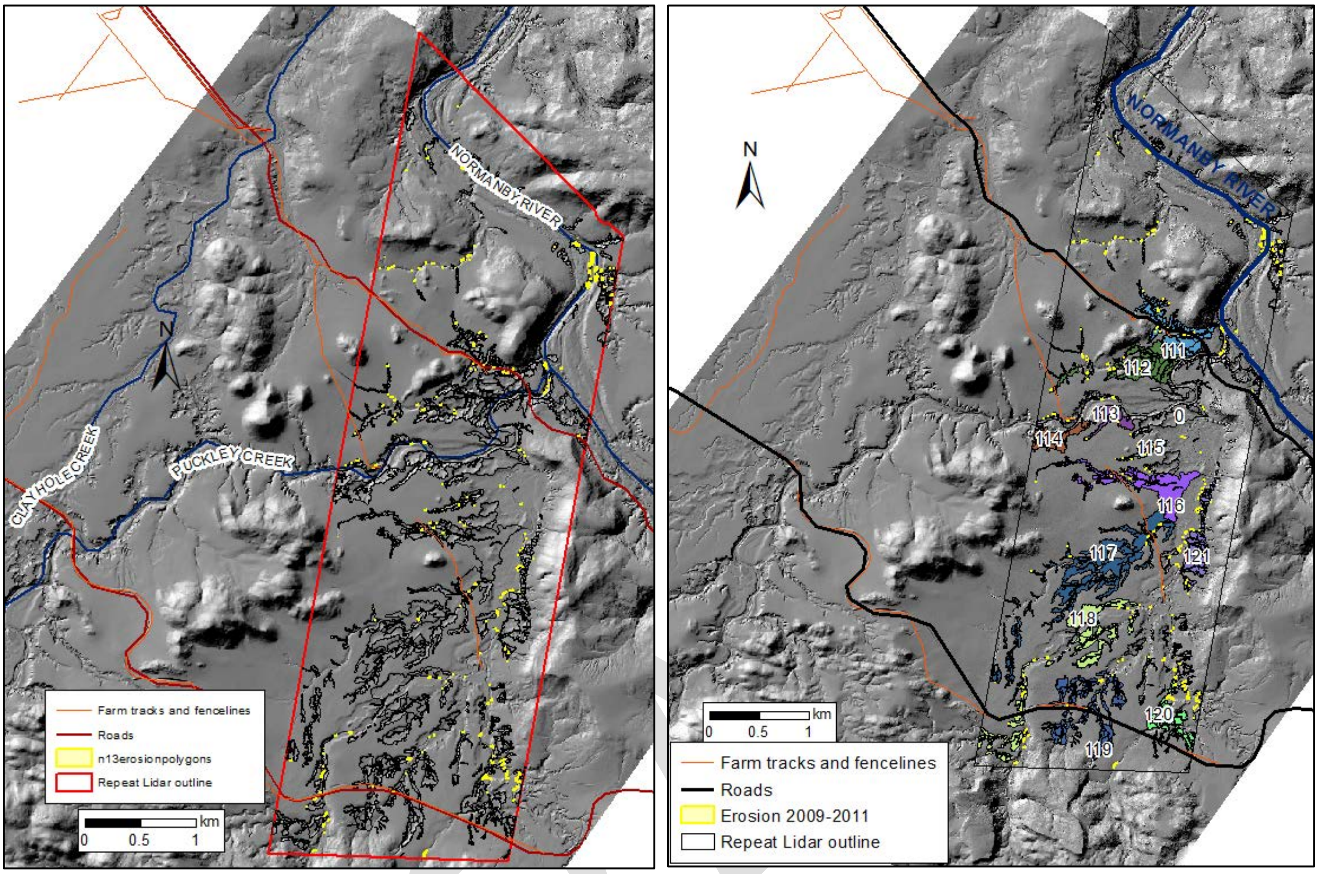


Figure 21   Block 13 overview – showing erosion polygons (2009-11) in yellow, access tracks and numbered gully units

Table 7 Block 13 Gully management unit data

Gully_ID	Sediment yield t/yr	Area (Ha)
111	209.6	15.64
112	214.4	18.28
113	48	5.40
114	0	7.37
115	156.8	2.78
116	118.4	19.89
117	62.4	39.75
118	126.4	24.62
119	3.2	19.15
120	3.2	9.48
121	75.2	10.91
total	**1017.6**	**173.28**

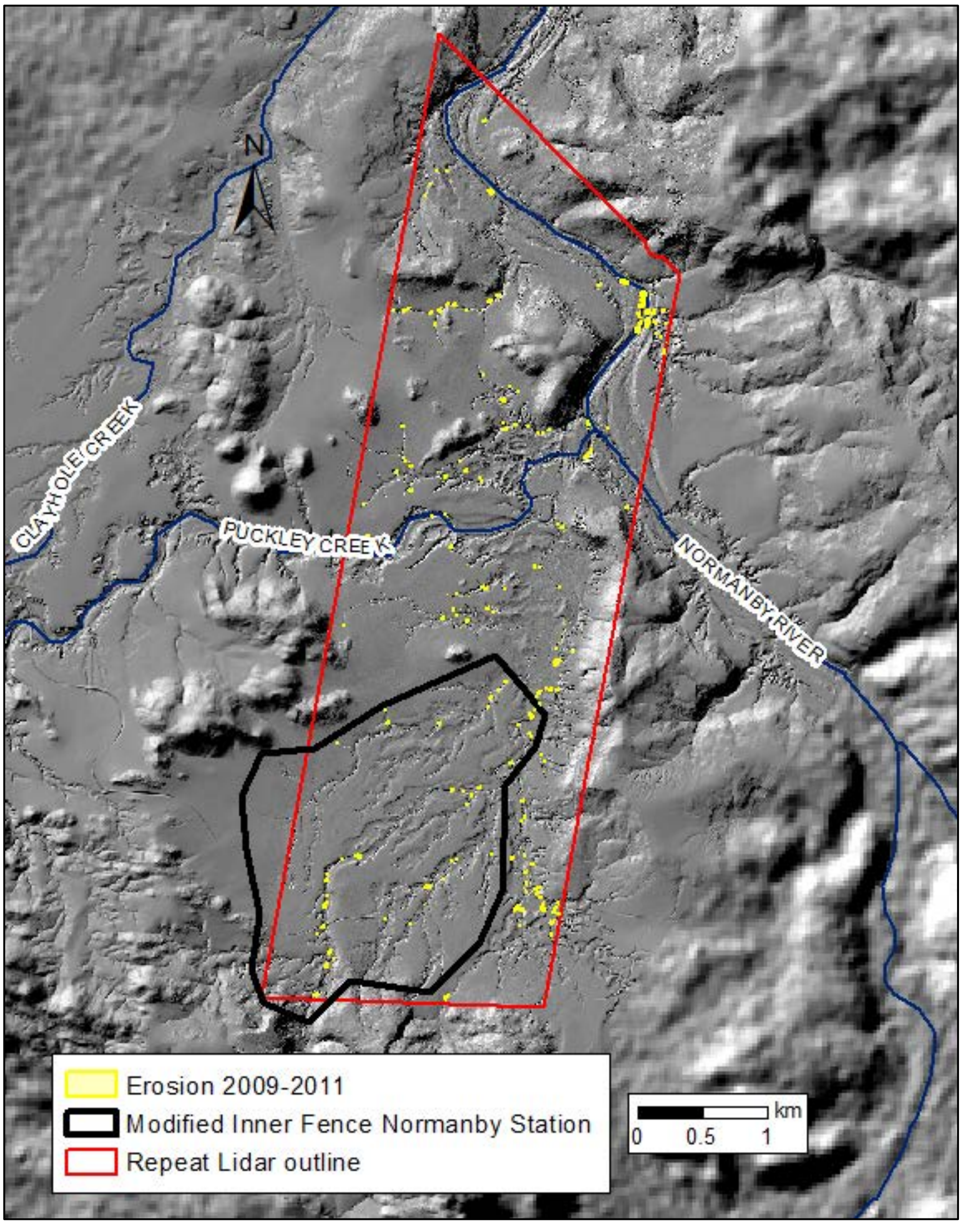


Figure 22 Location of proposed exclusion fence to in an area of moderately active gullies on Normanby Station

Second Exclusion Area - Normanby Station

The area shown in Figure 22 is another site with a large number of gullies than are only moderately active, and presents an ideal opportunity to test the effectiveness of passive stock exclusion on longer term erosion rates. The area is currently producing around 300 t/yr, with more from the associated minor channel erosion. The fencing of around 400 ha of land around these gullies is an appropriate response for these intermediate level gullies.

Block 20 - Mosman River near Olive Vale

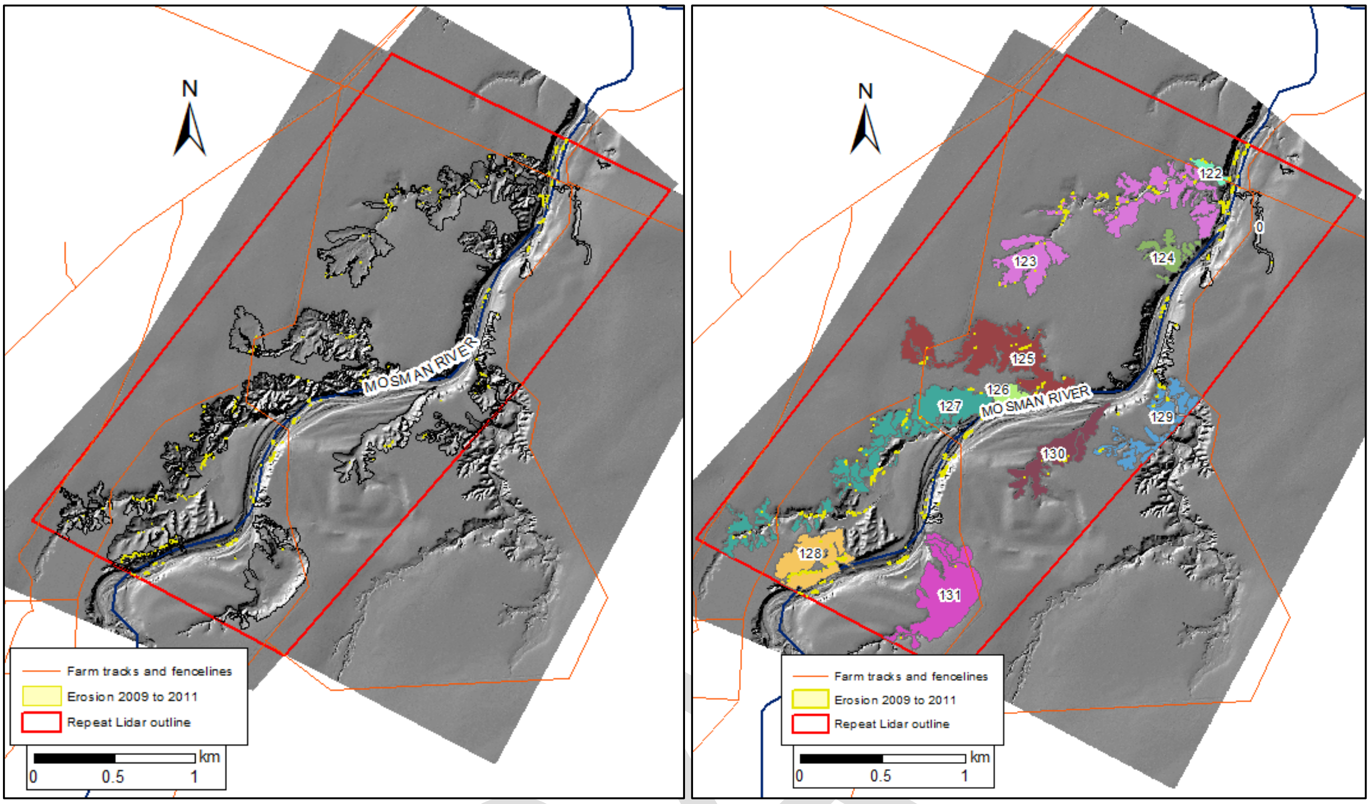


Figure 23 Detail of erosion, numbered gullies and access tracks in Block 20

Table 8 Sediment yield data for Gully management units in Block 20

Gully_ID	Sediment yield t/yr	Area (Ha)
122	62.4	1.54
123	180.8	23.77
124	4.8	4.65
125	630.4	21.03
126	0	2.68
127	1427.2	23.89
128	585.6	10.06
129	152	9.08
130	168	9.20
131	22.4	17.33
total	**3233.6**	**123.21**

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