An Empirically-based sediment budget for the Normanby Basin: Key Findings & Implications

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Sediment Sinks Sources & Drivers in the Normanby Basin

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Reef Rescue Research & Development

Griffith UNIVERSITY

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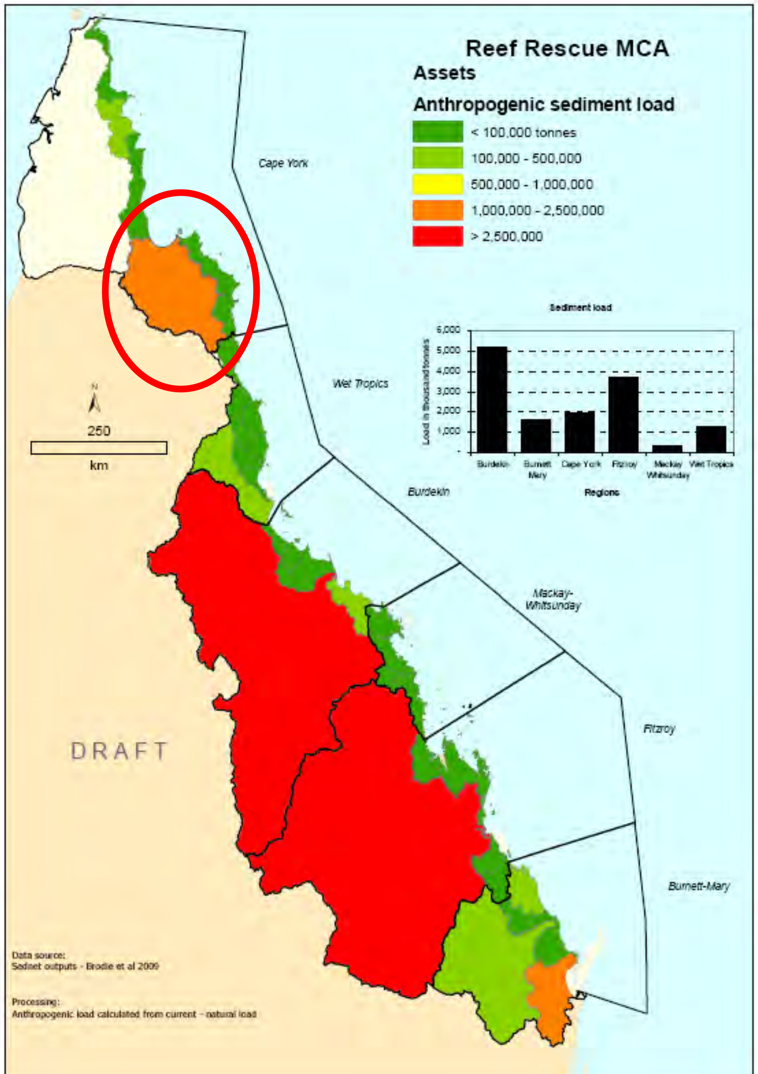
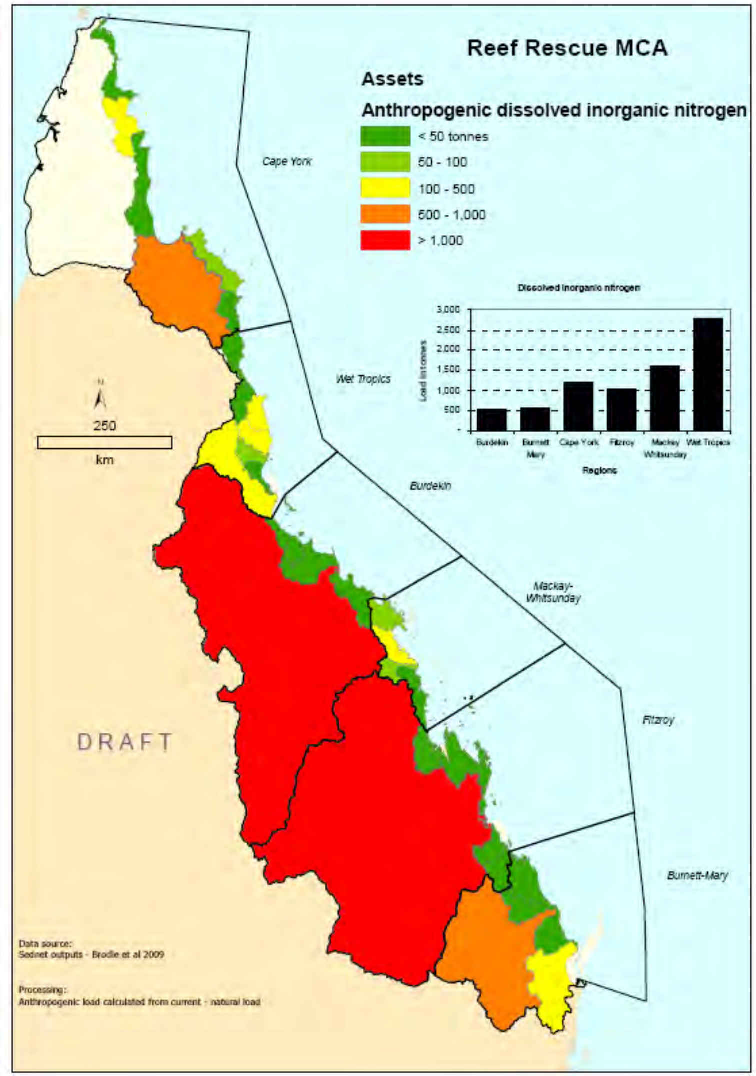
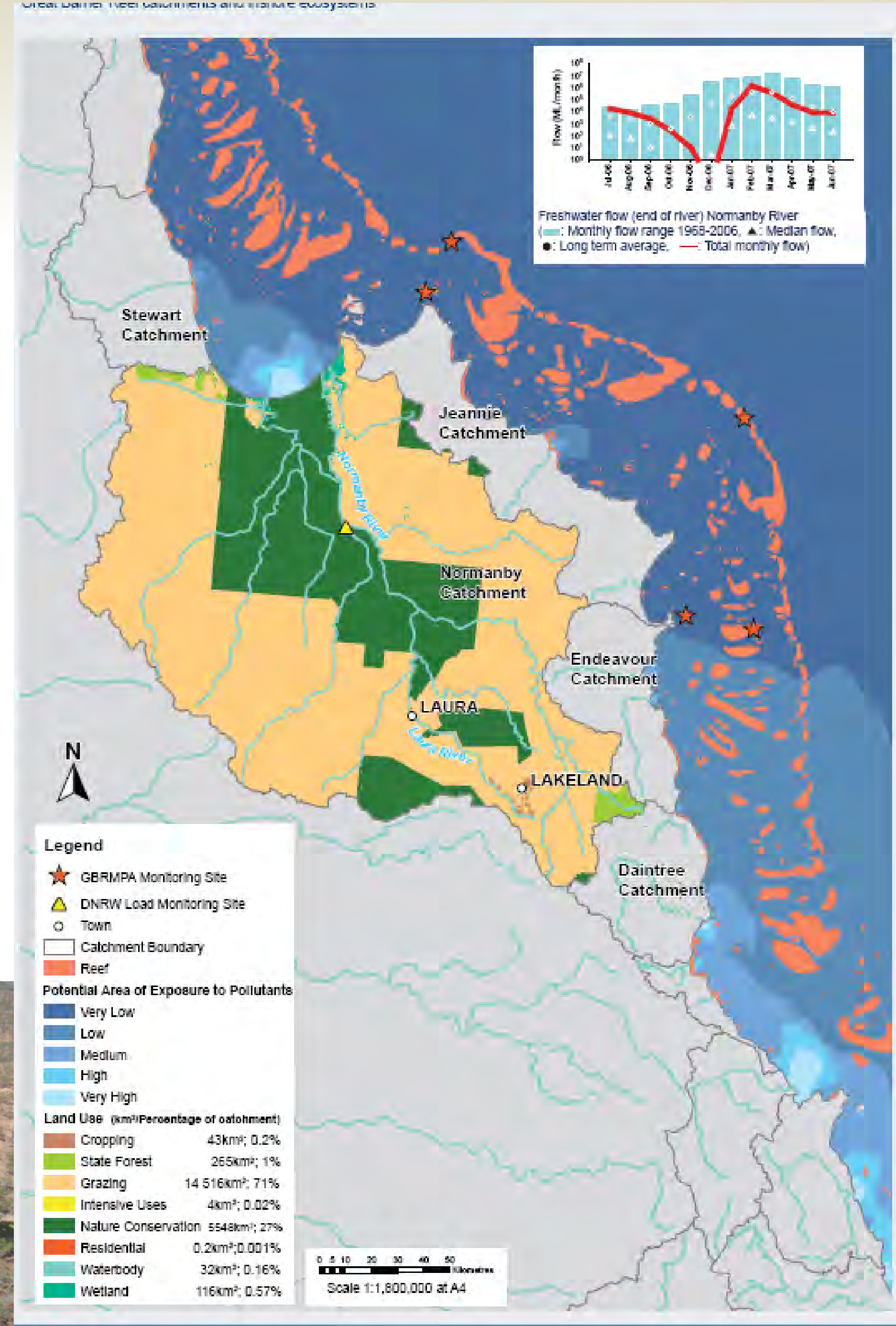
Normanby Catchment
(1 of 10 Reef Plan priority catchments)





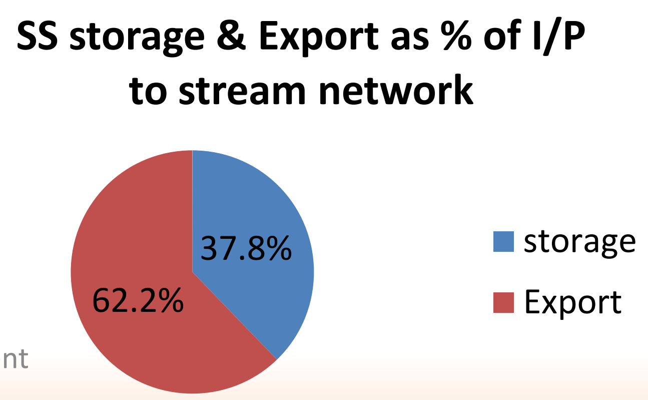
Land-use

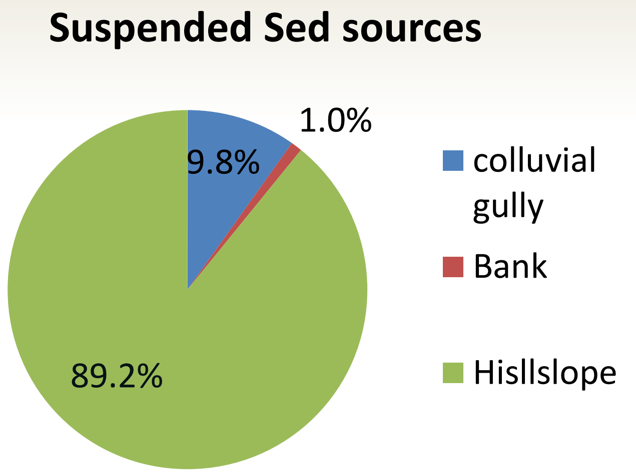
- Grazing – 71%
- Conservation (Nat Parks) – 27%
- Intensive agriculture (Lakeland basalt country) 0.2%
- Alluvial gold & tin mining (minor)

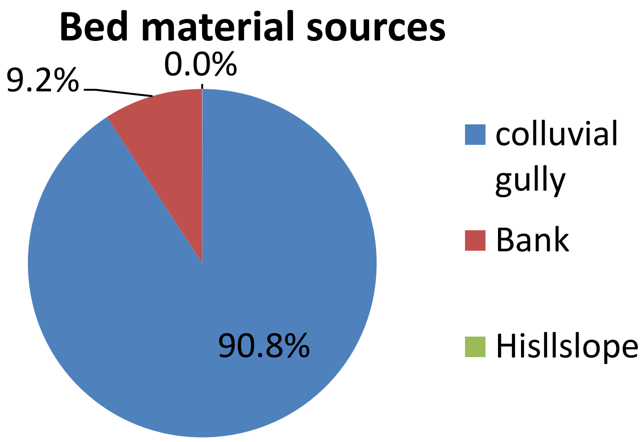


Normanby Sediment Budget Summary (Brodie et.al. 2003)

	SS Inputs Kt/yr	BL Inputs Kt/yr
colluvial gully	173	173
Bank	17.5	17.5
Total Hillslope	15,670	
Hillslope delivered	1,567	0
tot inputs	1,758	190.5
storage	664	115
Export	1,094	76

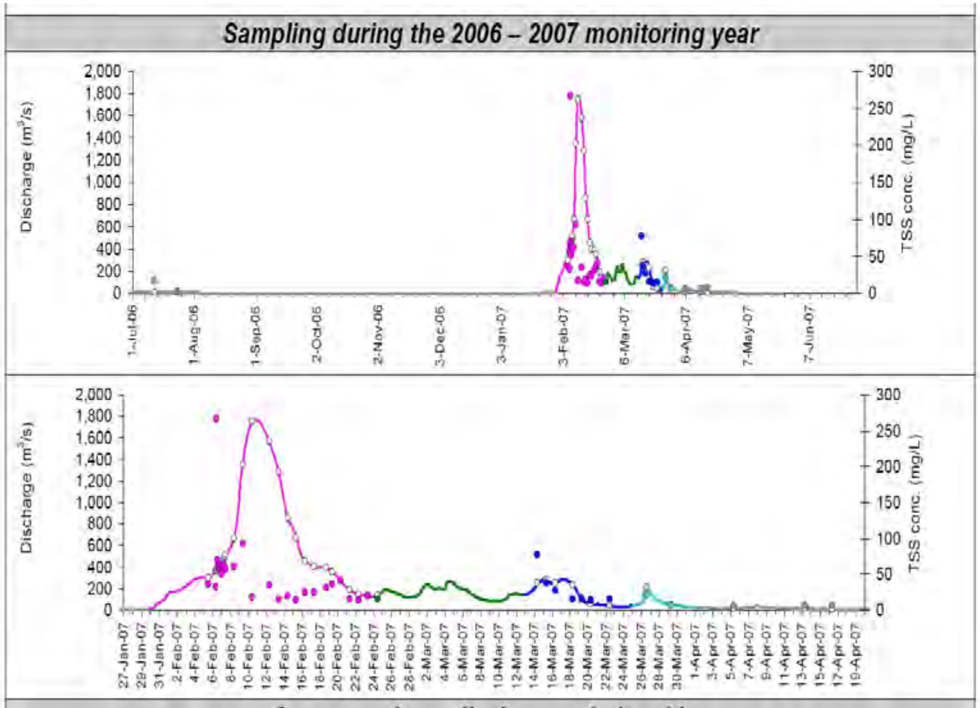


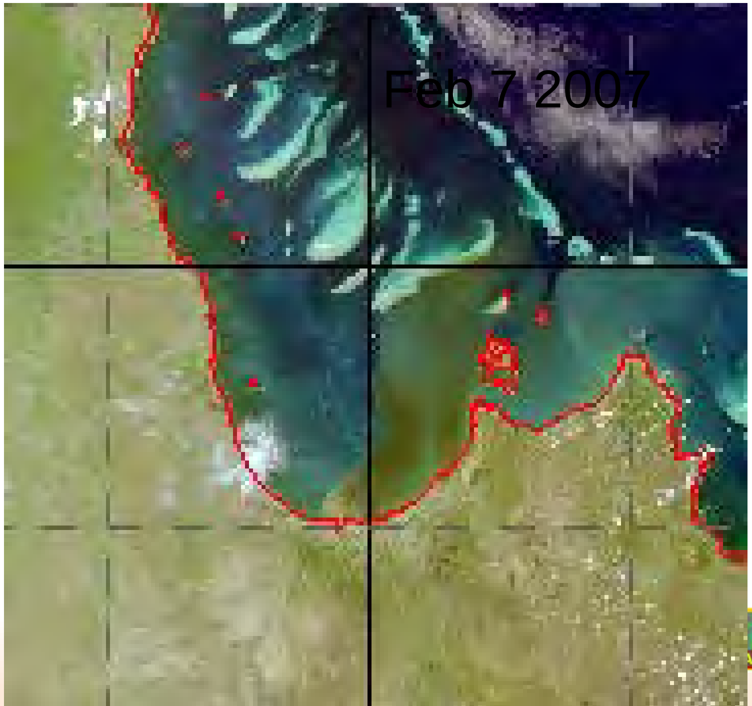




What did we actually know about sediment loads in this catchment in 2009?

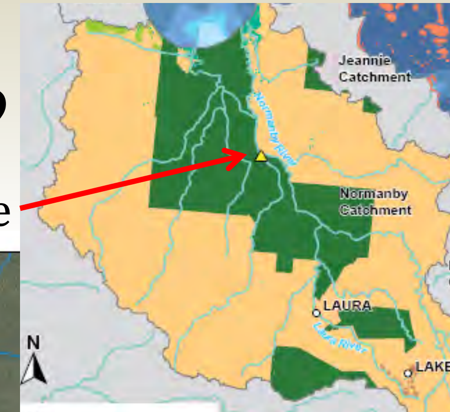
- Very few empirical data..
  - Some TSS data from Kalpowar gauge - DERM
  - Several years nutrient load data & TSS – Furnas AIMS (Kalpowar)
  - Baseline WQM data (turbidity data) – CYMAG/Howley (2006 – 2010)
  - Some Imagery

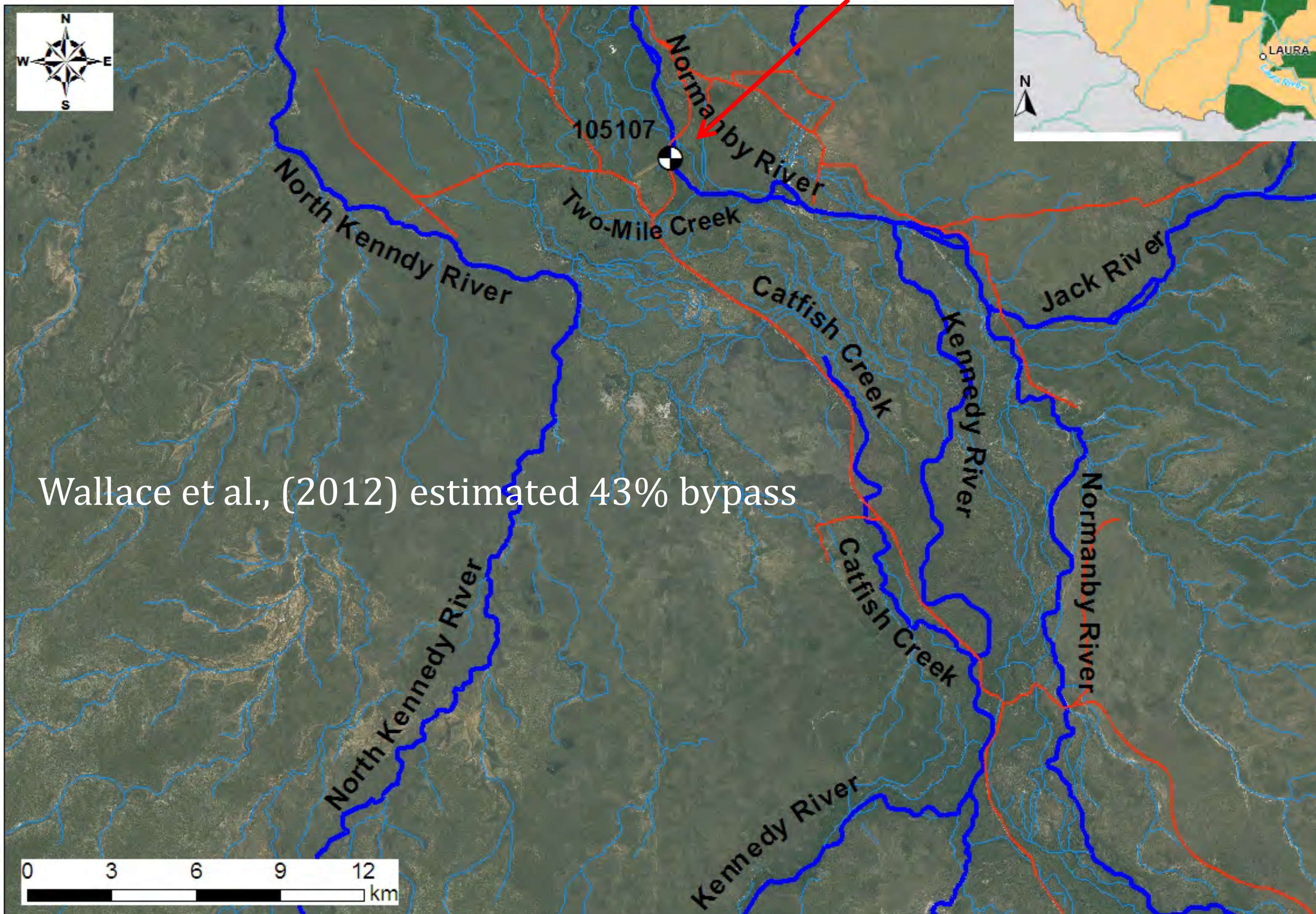




Kalpowar gauge bypass??

Kalpowar Gauge





Wallace et al., (2012) estimated 43% bypass

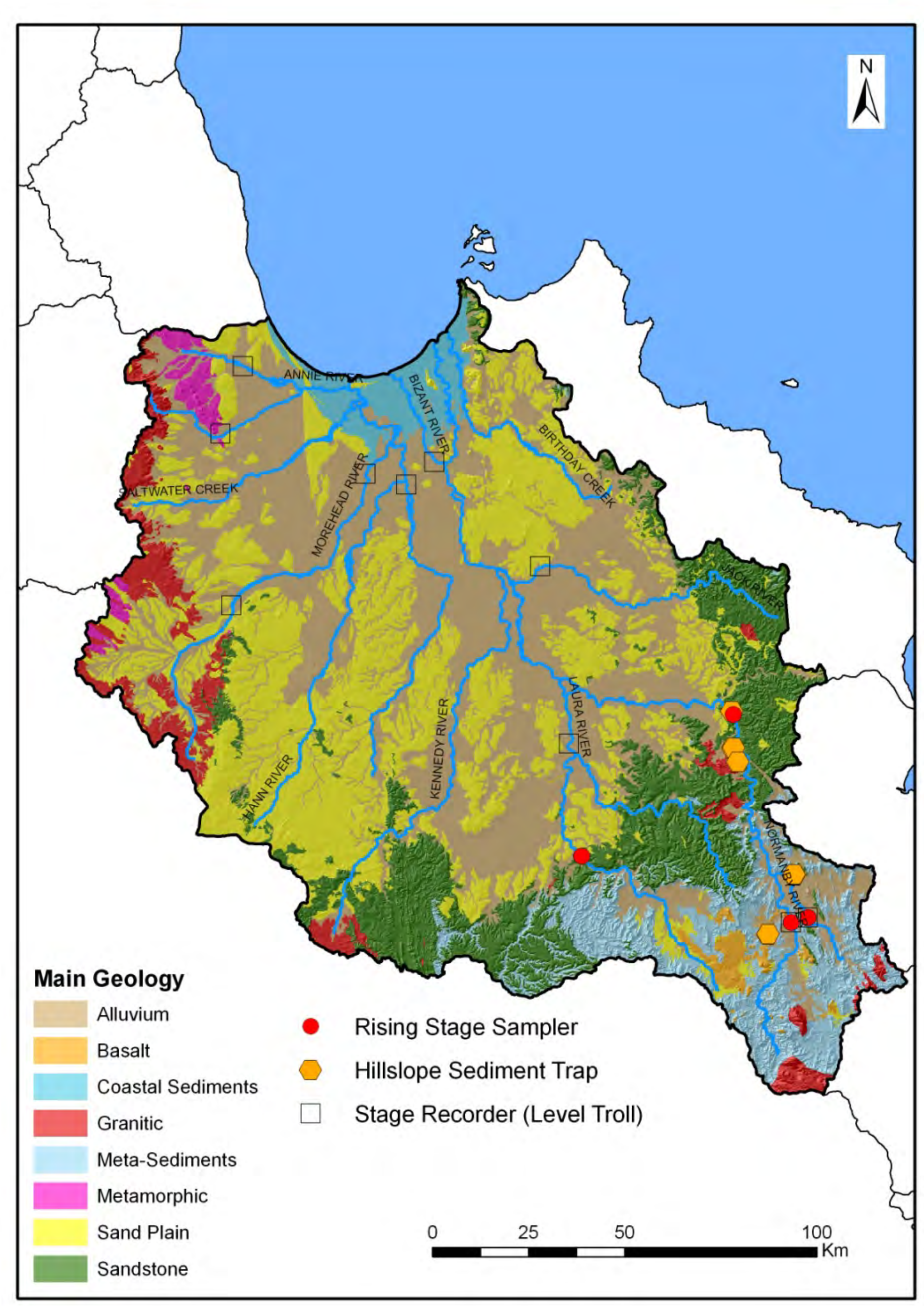
Background to this study

- Two views of the Normanby
  1) Based on the SedNet modelling – that it is a major sediment source to the reef - and yet another fairly heavily impacted tropical catchment (5 x increase in Post-European supply)
  2) That it represents a reference catchment, which to date appears to have had relatively little impact on the adjacent reefs

Key question – Which of these views is correct? Are they both right? Something in between?

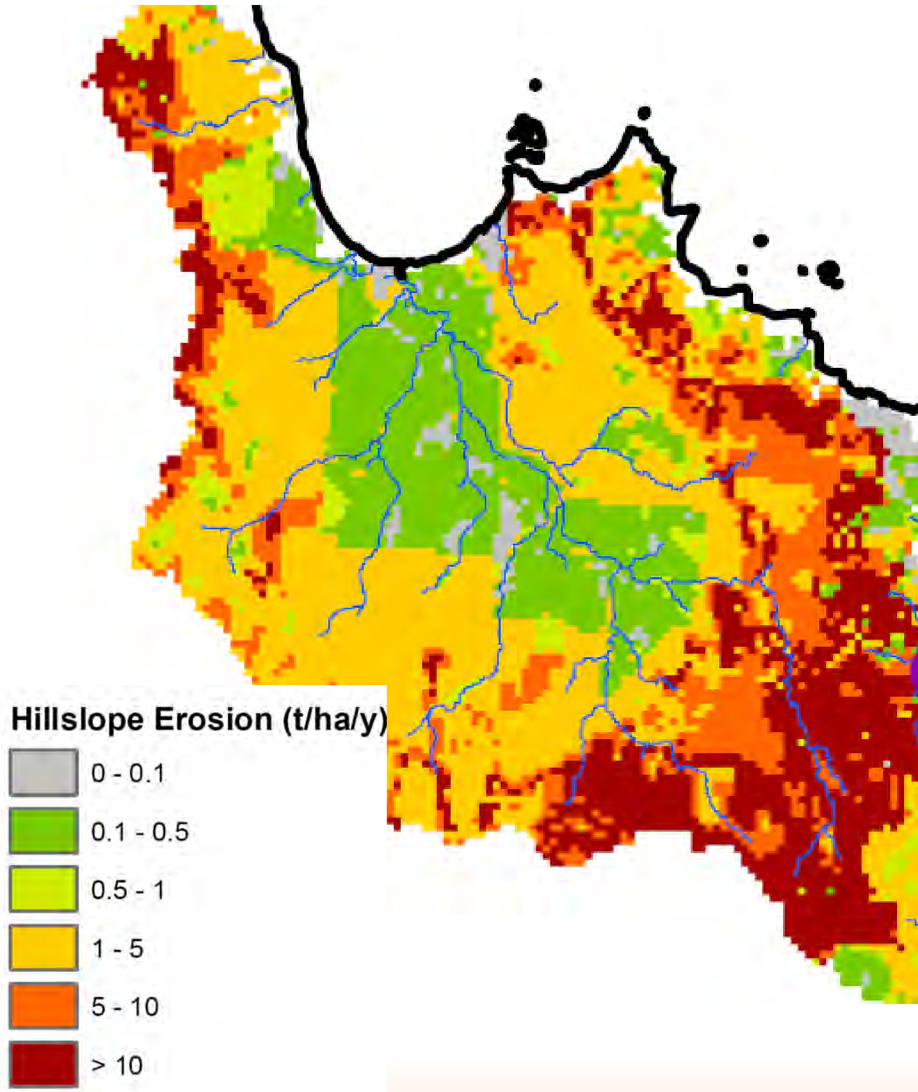
Focus for our study

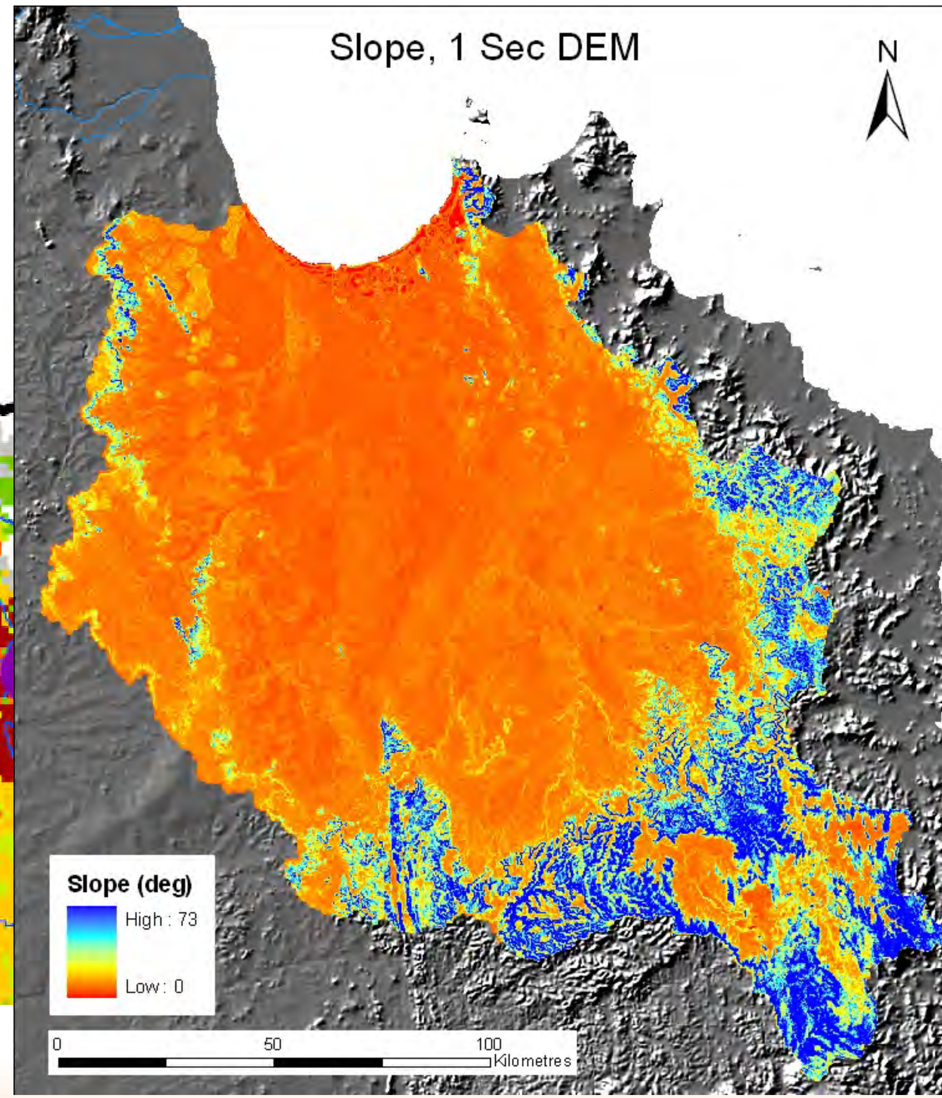
- Re-parameterisation a new model from the ground up -
  - Measure hillslope erosion rates
  - Map location and extent of gullies in catchment
  - Measure gully & bank erosion rates (repeat LiDAR & A/P analysis)
  - Sediment tracing (radionuclides & geochem) (sfce/sub-sfce sources + major source locations)
  - In-stream load measurements (RSS network)
  - Geochronology of benches, floodplain, and gully systems (evidence for post-European change) ~ 90 OSL dates



- Sediment tracing – source to sink (210Pb, 137 Cs, REE)
- Repeat LiDAR (2009/11) ~3% of catchment; 0.5 % repeat
- OSL dating (Gullies, Benches, FPs) - 90 dates
- Sediment load sampling (RSSs @ gauge stations)
- Hillslope Erosion Measurement (HSTs)

Does Hillslope erosion dominate?: Model predicts high rates on high slopes

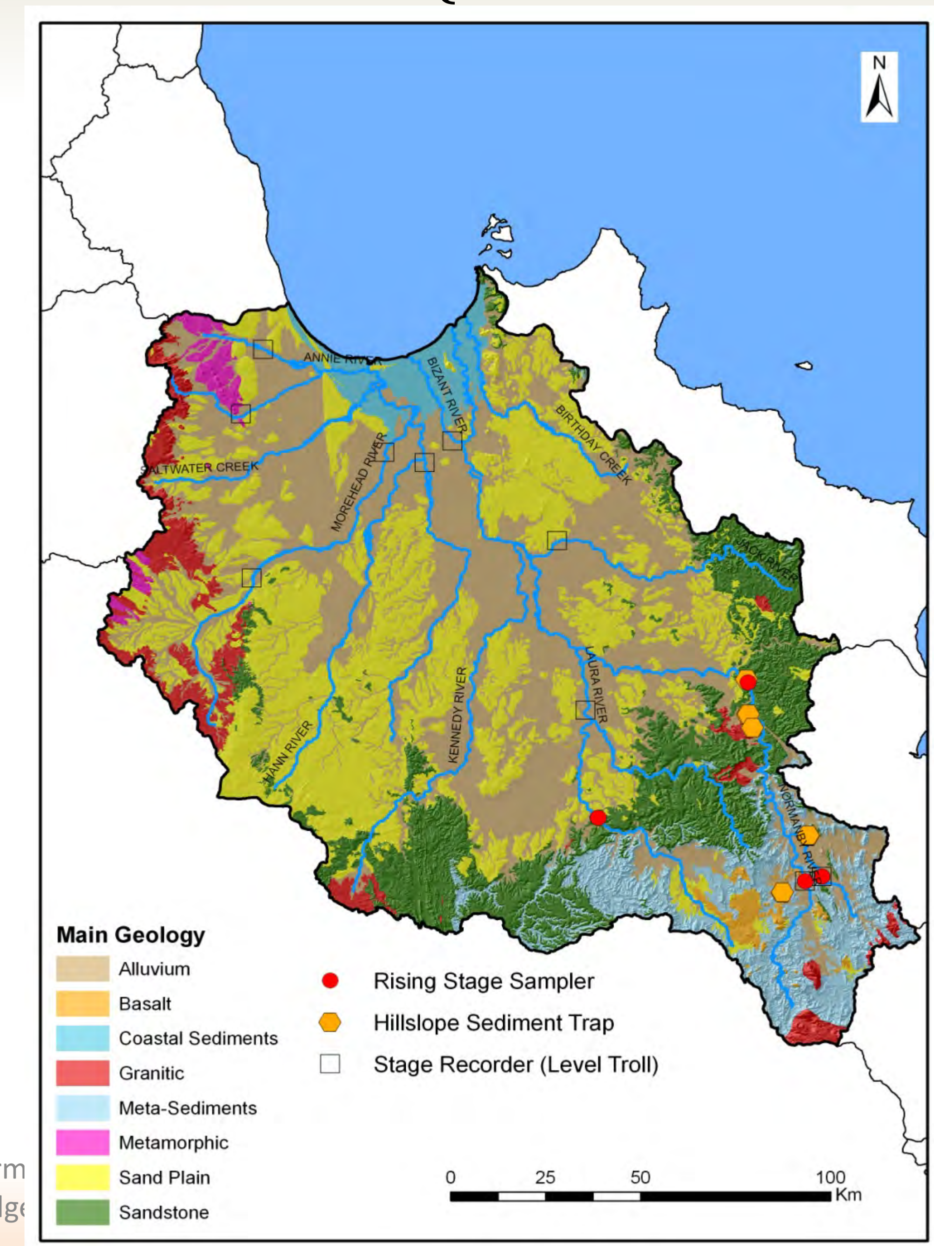




Previous modelling predicted these areas to be the dominant sediment sources

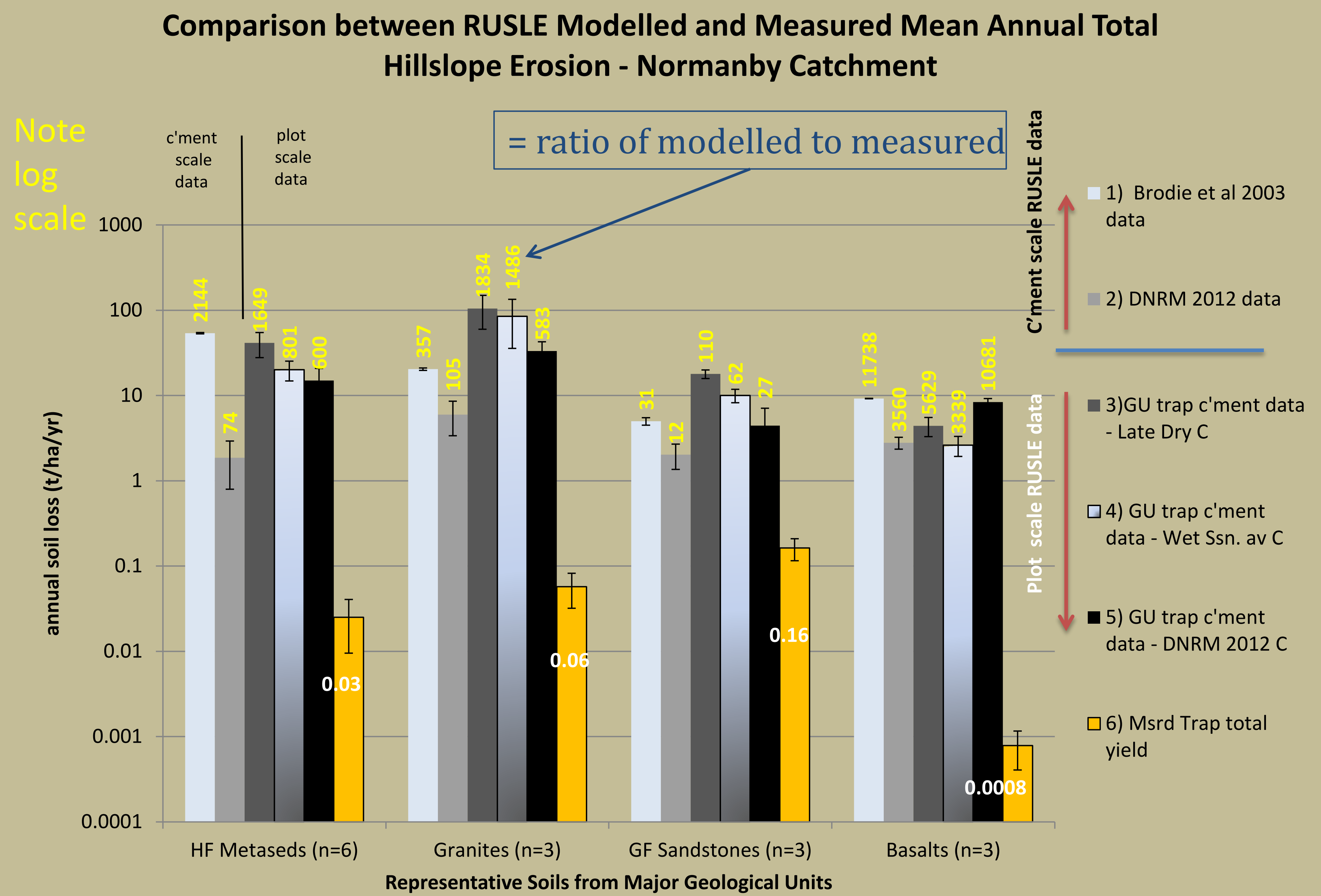
Many slopes are bare rock with v little soil – supply limited.

measured hillslope sediment production rates (2009-10; 10-11 Wet season)



11 traps located on
4 main geologies – in high sediment production zone. 2 wet seasons – within LiDAR blocks

Measured all RUSLE parameters at plot scale except K



Comparison between RUSLE Modelled and Measured Mean Annual Total Hillslope Erosion - Normanby Catchment
Note log scale
c'ment scale data
plot scale data
= ratio of modelled to measured
annual soil loss (t/ha/yr)
1000
100
10
1
0.1
0.01
0.001
0.0001
2144
74
1649
801
600
0.03
357
105
1834
1486
583
0.06
31
12
110
62
27
0.16
11738
3560
5629
3339
10681
0.0008
HF Metaseds (n=6)
Granites (n=3)
GF Sandstones (n=3)
Basalts (n=3)
Representative Soils from Major Geological Units
C'ment scale RUSLE data
Plot scale RUSLE data
1) Brodie et al 2003 data
2) DNRM 2012 data
3)GU trap c'ment data - Late Dry C
4) GU trap c'ment data - Wet Ssn. av C
5) GU trap c'ment data - DNRM 2012 C
6) Msrd Trap total yield

Hillslope Erosion at Catchment Scale...modelled vs measured

- **Total** Hillslope suspended sediment production across the Normanby basin = approx 33,590 t/yr

  (*cf* 15,760,000 by previous SedNet Modelling = 470 x measured)

  (Tracing data (below) suggests ~ 220 Kt/yr)

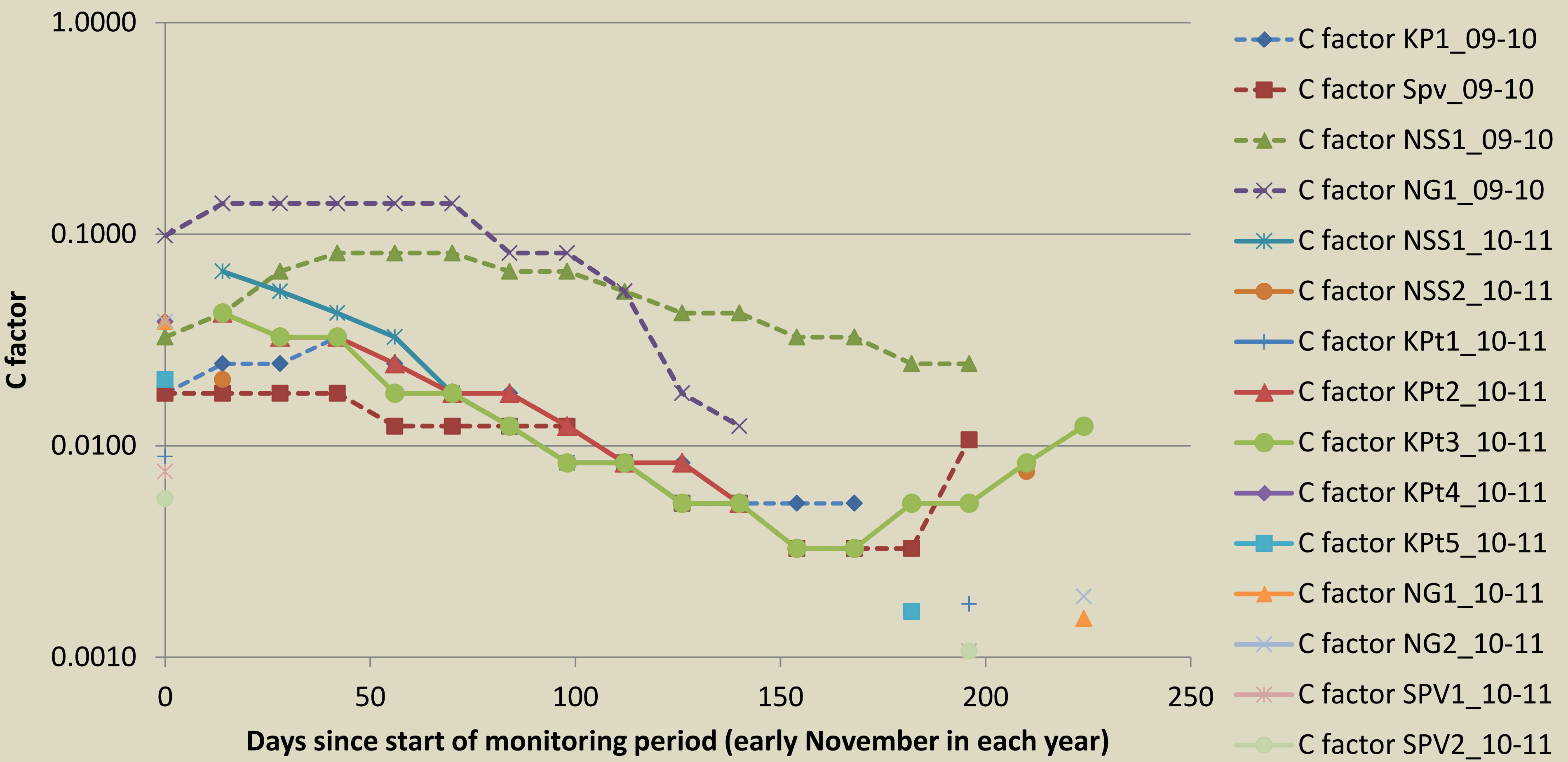
Why is RUSLE over-predicting HS Erosion?

1. Fundamental problems with understanding of K (erodibility) factors for these soils (confounded with C (cover) factor)

2. Late Dry C Factor underestimates true average cover across the wet season

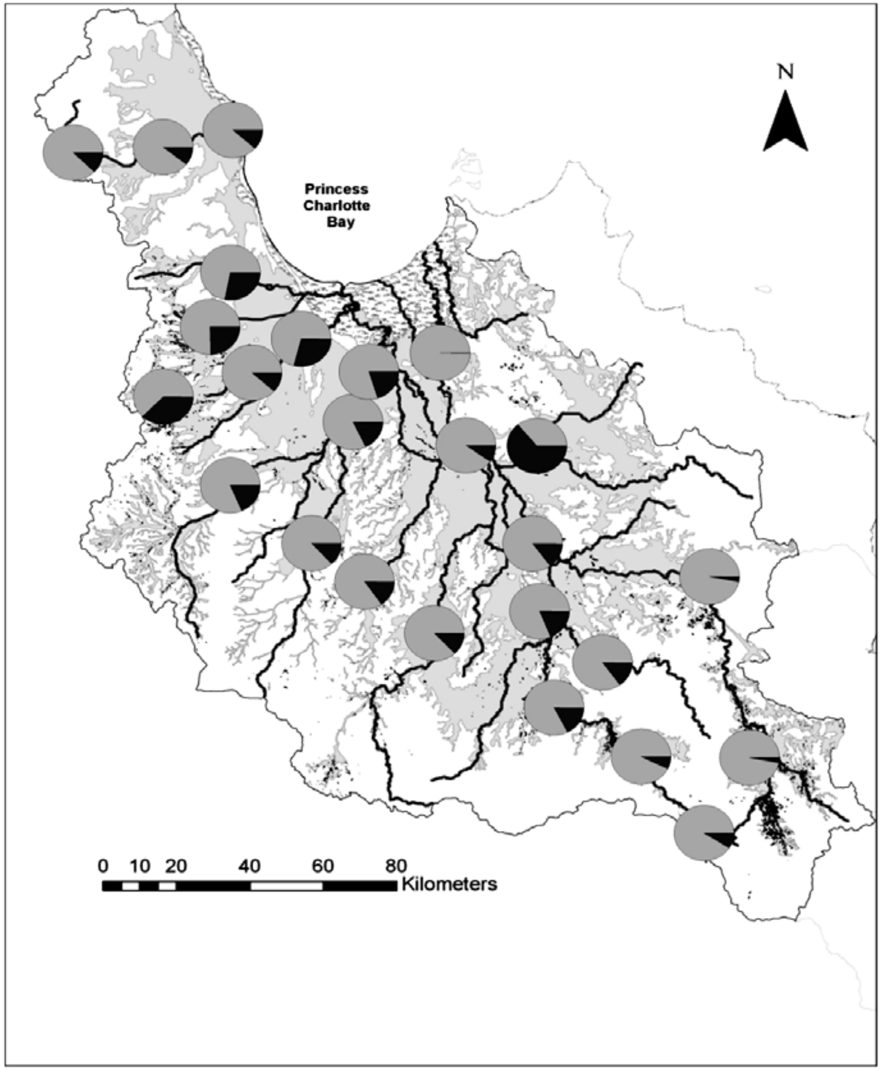
3. Data interpolation issues (e.g. R factor - erosovity)

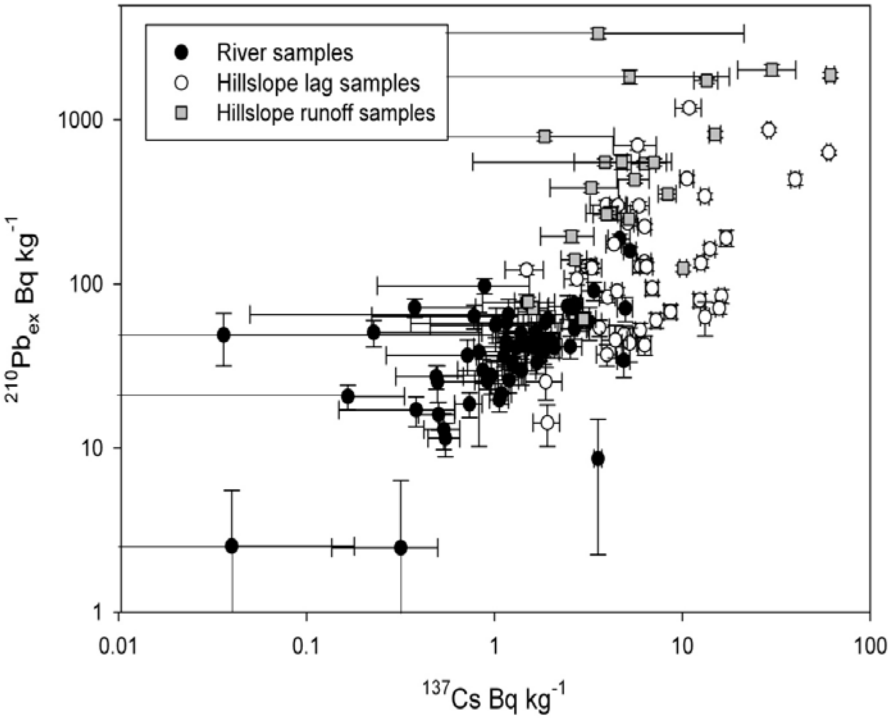
Derived C Factor across 2009-10 & 2010-11 Wet Season for selected Hillslope Sediment Trap sites



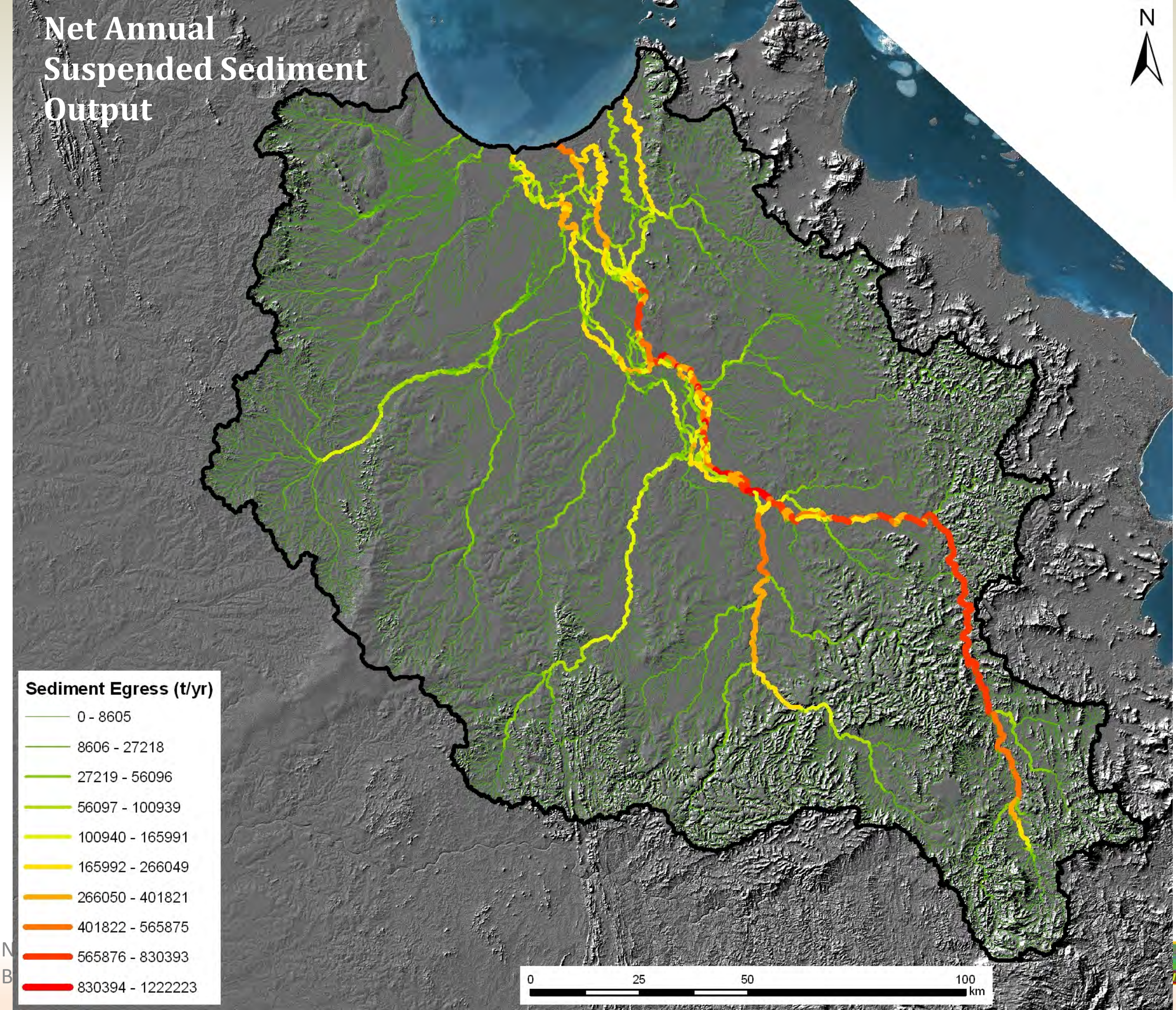
Hillslope vs channel erosion

- Fallout radionuclides (Cs-137 and Pb-210ex)
  - widely used to determine the relative contribution of hillslope and gully/channel erosion to stream sediments





Net Annual Suspended Sediment Output



Other tracing studies in northern Australia

Table 2: Tropical Australian studies that have used radionuclide tracers to estimate relative surface soil contributions to the lower catchment (after Caitcheon et al., 2012)

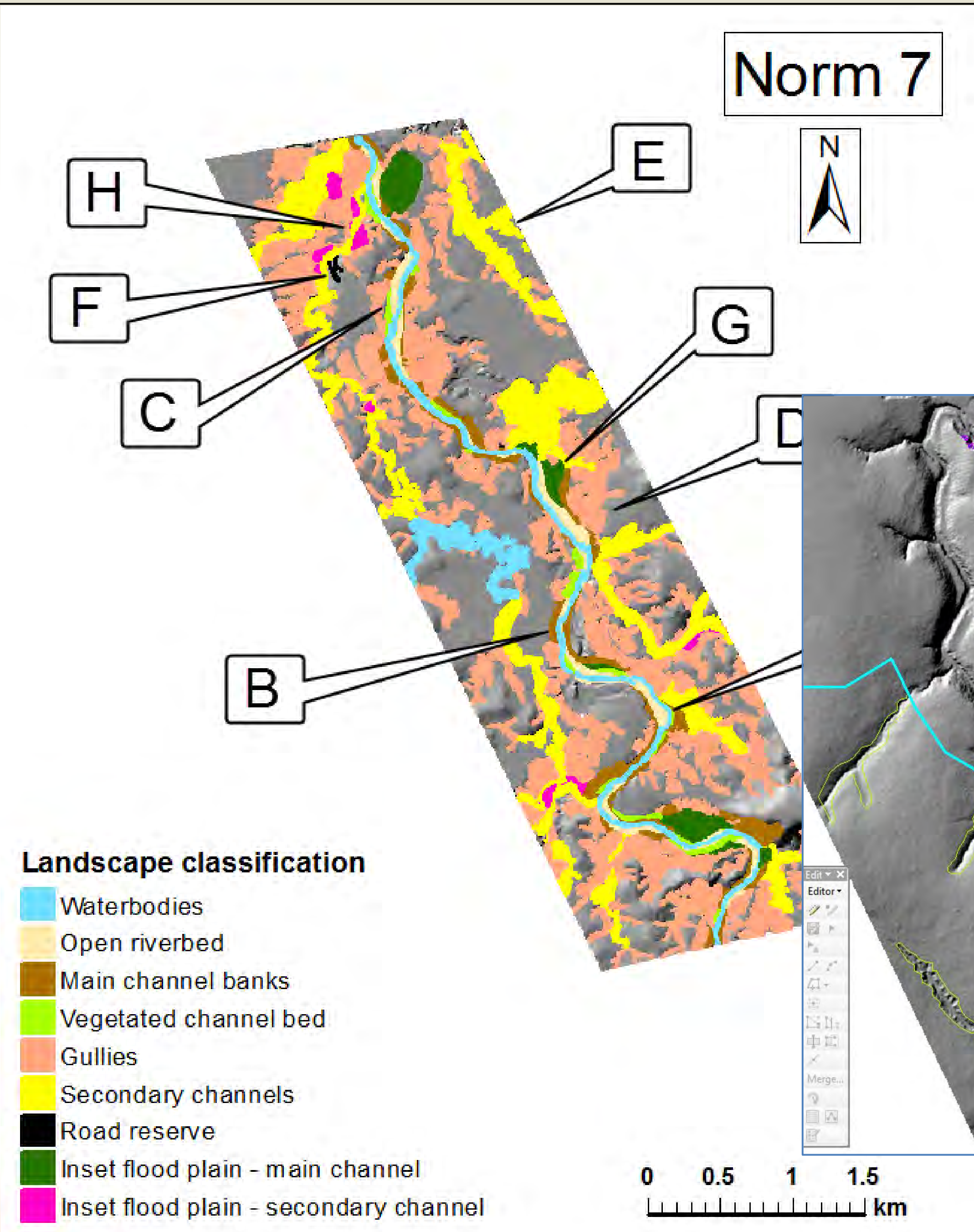
Catchment	Mean Surface Soil Contribution %	Tracer	Reference
Daly	11	^{137}Cs	Wasson et al., (2010)
Ord	10	^{137}Cs	Wasson et al., (2002)
Upper Fitzroy	20	^{137}Cs and $^{210}Pb_{ex}$	Hughes et al., (2009)
Herbert	50	^{137}Cs	Bartley et al., (2004)*
Herbert	20	^{239}Pu	Tims et al., (2010)*
Burdekin	17	^{137}Cs, $^{210}Pb_{ex, C}$	Wilkinson et al., (2012)
Mitchell	3	^{137}Cs	Caitcheon et al., (2012)
Daly	1	^{137}Cs	Caitcheon et al., (2012)
Cloncurry	0	^{137}Cs	Caitcheon et al., (2012)
Laura-Normanby	13 ± 3	^{137}Cs and $^{210}Pb_{ex}$	This study
Stewart	11 ± 1	^{137}Cs and $^{210}Pb_{ex}$	This study

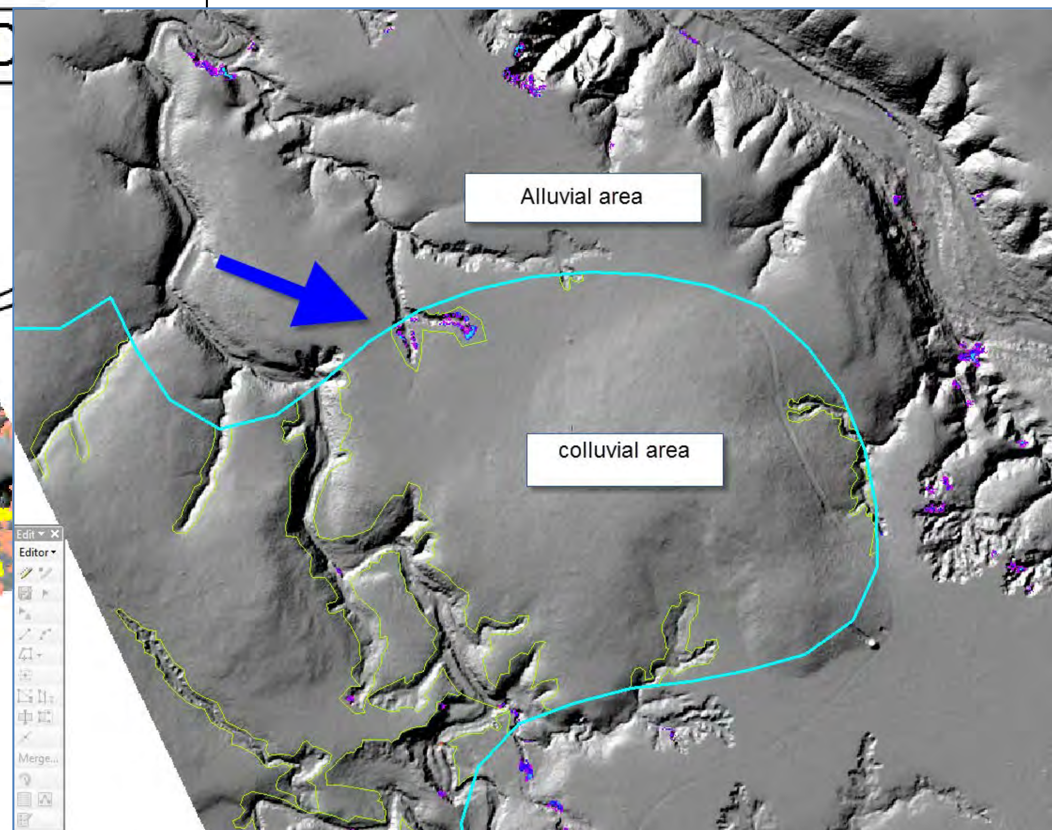
*Note these two studies were carried out pre and post cyclone Larry

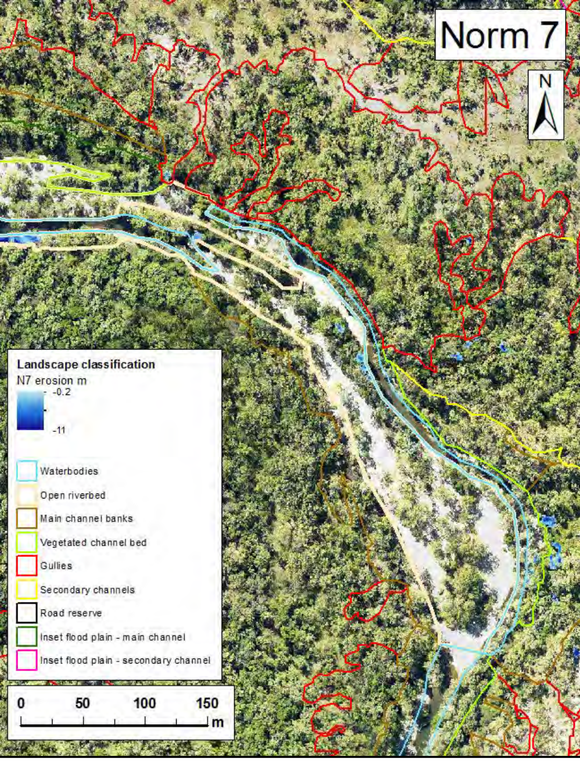
So where is the sediment really coming from?

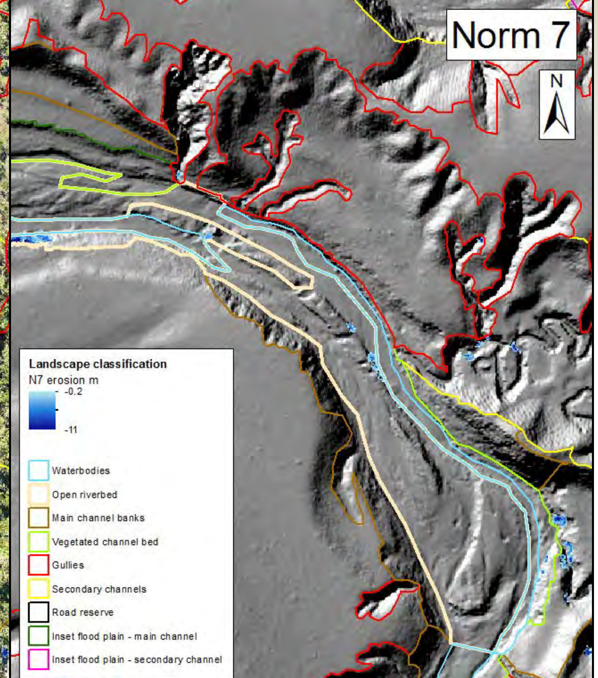
Examples of source classes

nalysis






Norm 7
N
Landscape classification
N7 erosion m
-0.2
-11
Waterbodies
Open riverbed
Main channel banks
Vegetated channel bed
Gullies
Secondary channels
Road reserve
Inset flood plain - main channel
Inset flood plain - secondary channel
0 50 100 150 m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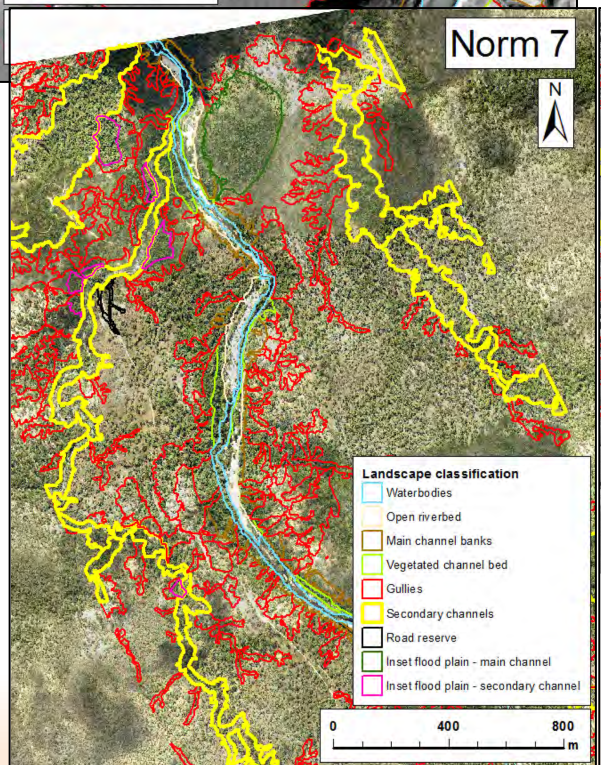
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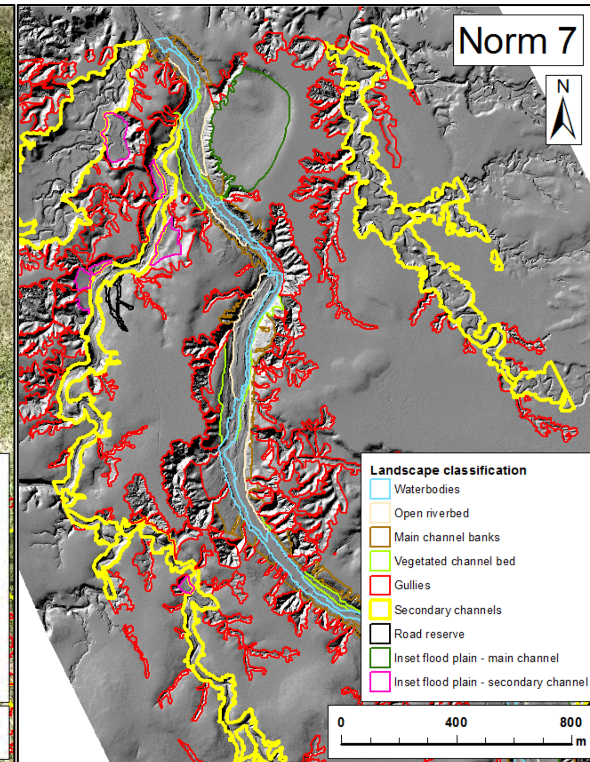
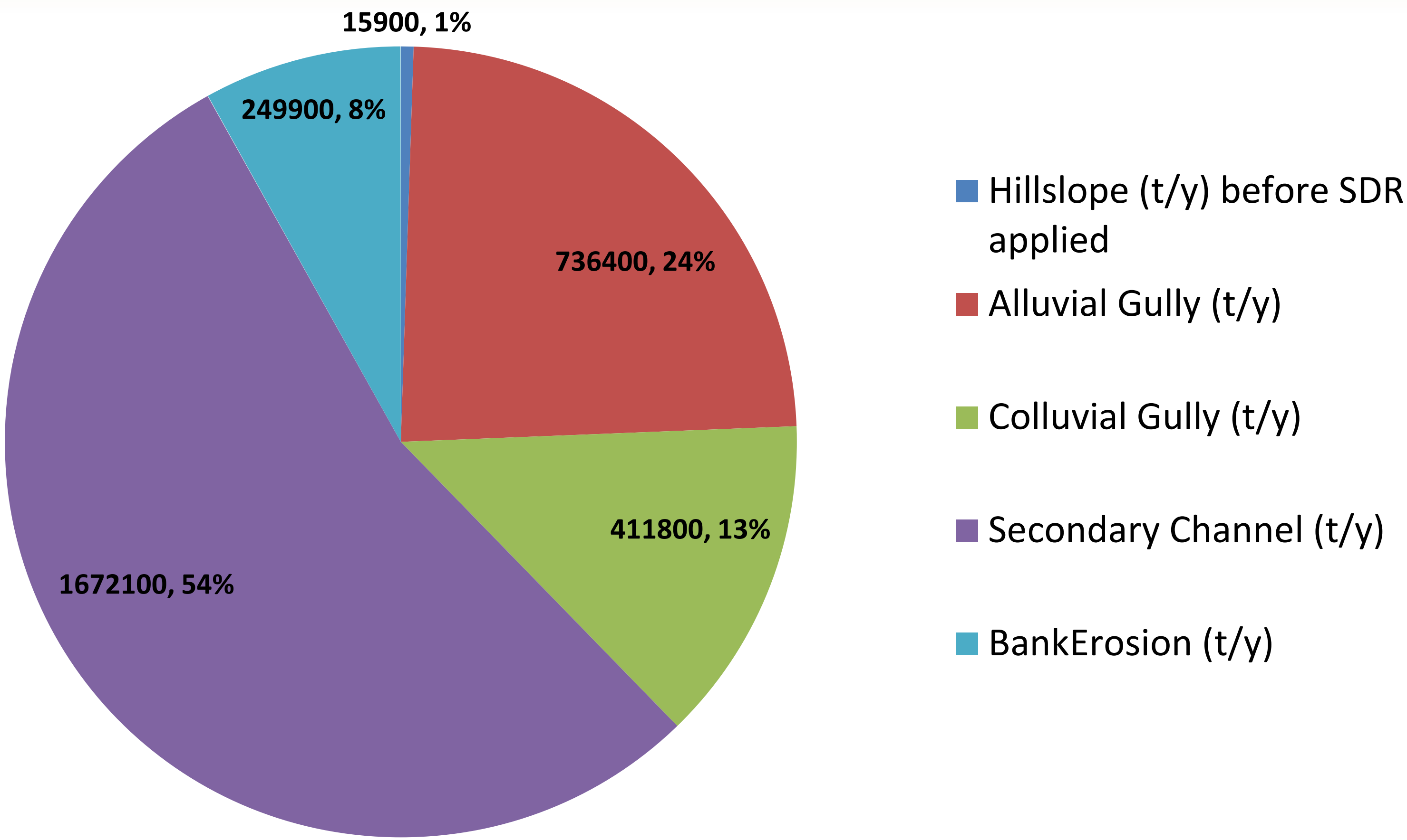
N
Landscape classification
Waterbodies
Open riverbed
Main channel banks
Vegetated channel bed
Gullies
Secondary channels
Road reserve
Inset flood plain - main channel
Inset flood plain - secondary channel
0 400 800 m


Norm 7
N
Landscape classification
Waterbodies
Open riverbed
Main channel banks
Vegetated channel bed
Gullies
Secondary channels
Road reserve
Inset flood plain - main channel
Inset flood plain - secondary channel
0 400 800 m

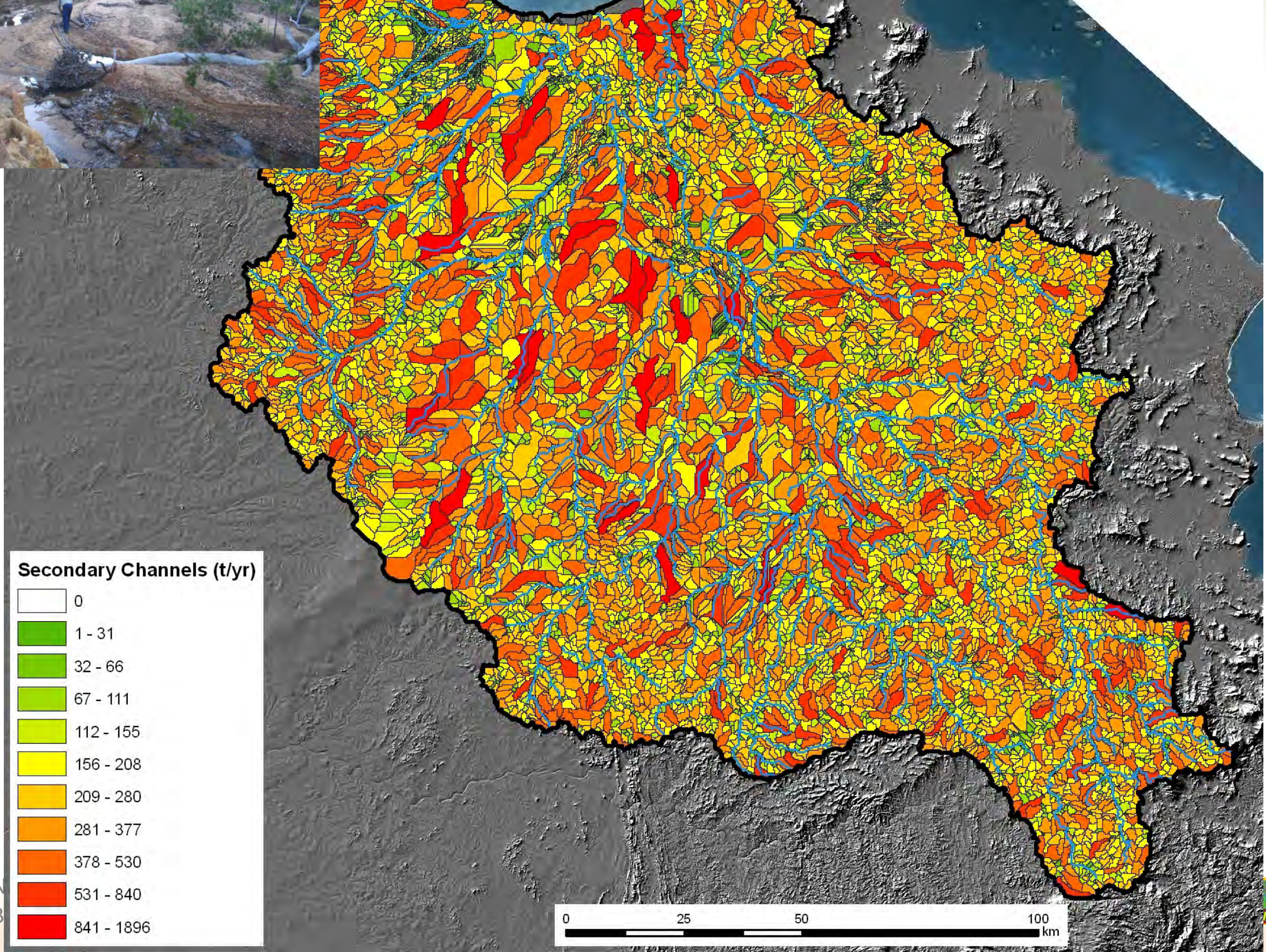
LiDAR change data + spatial interpolation forms primary input to new sediment budget model...

Normanby Suspended Sediment Inputs



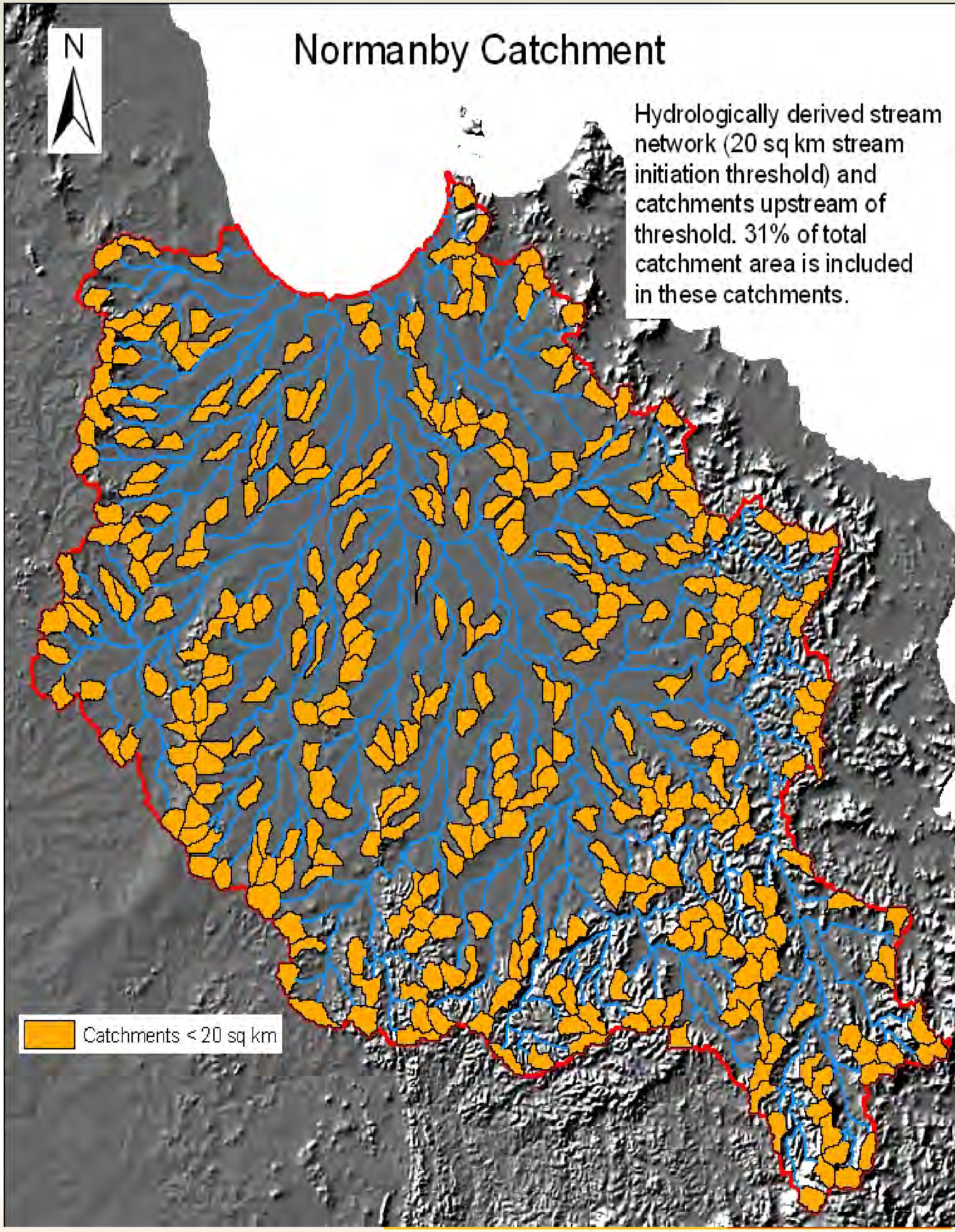
Note alluvial gullies not represented in previous modelling

Minor alluvial channel bank erosion

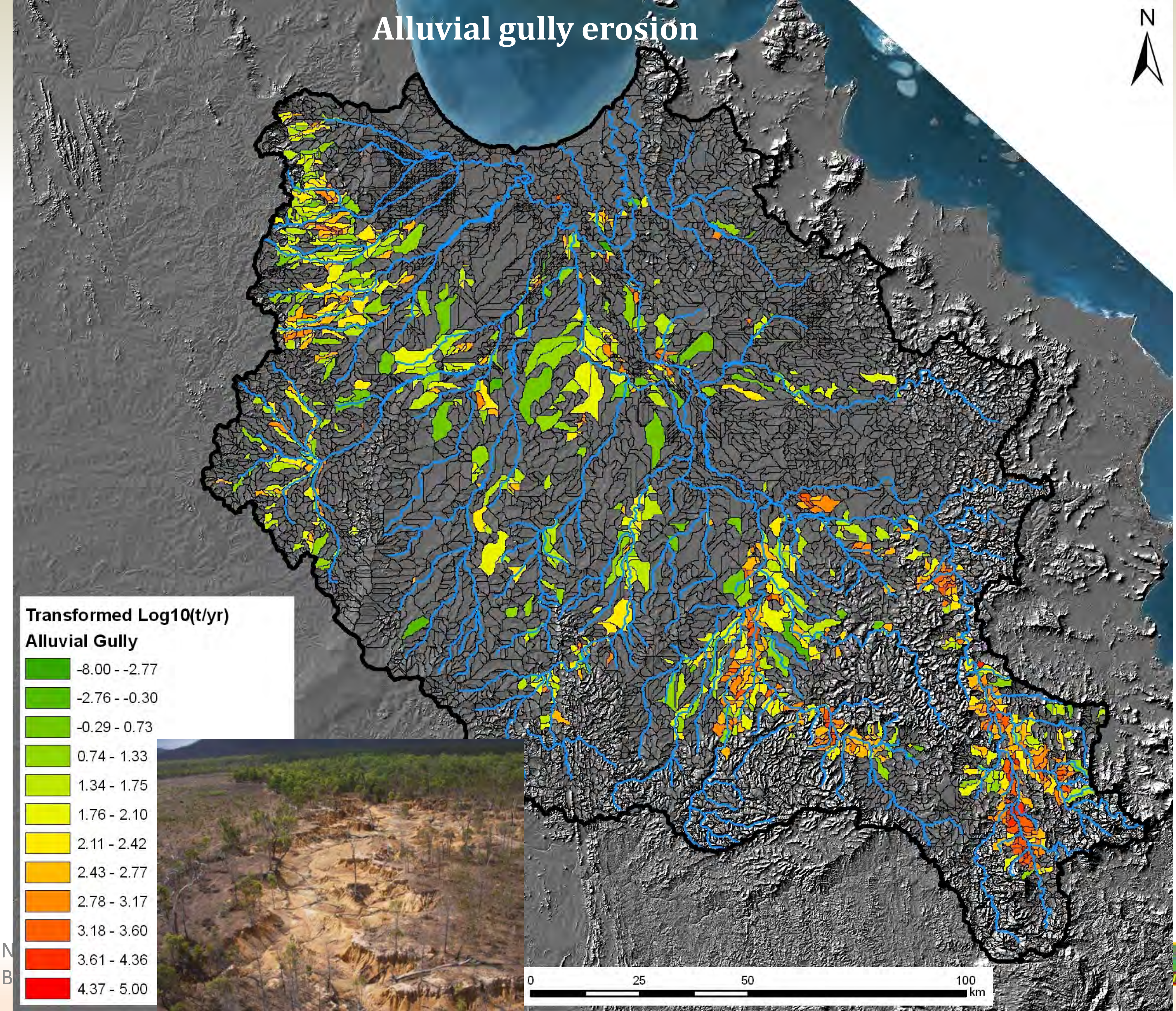


20km^2 stream initiation threshold excludes small streams from 31% of catchment (attributed to hillslope erosion).

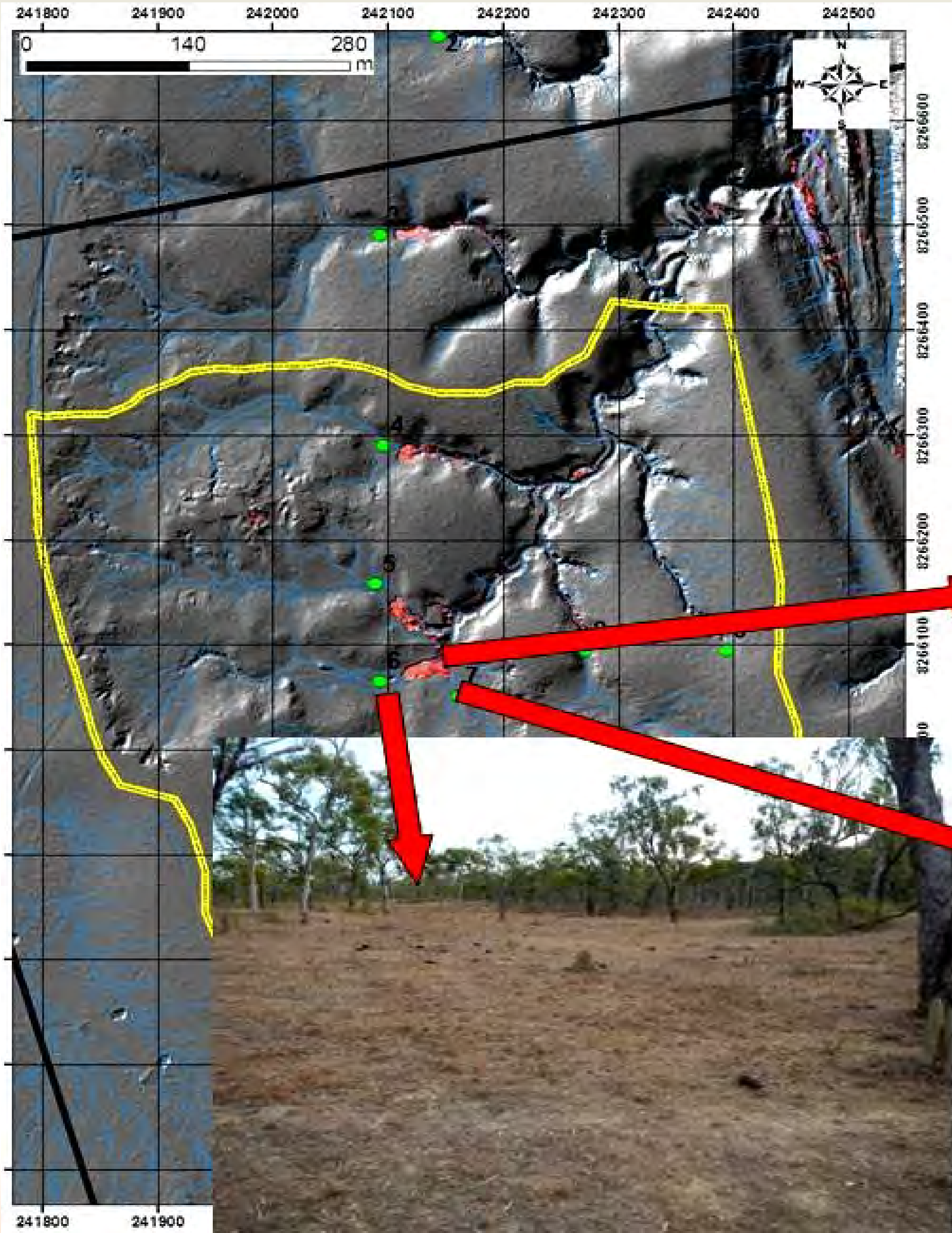
e.g. Of Channel erosion from minor trib



Alluvial gully erosion

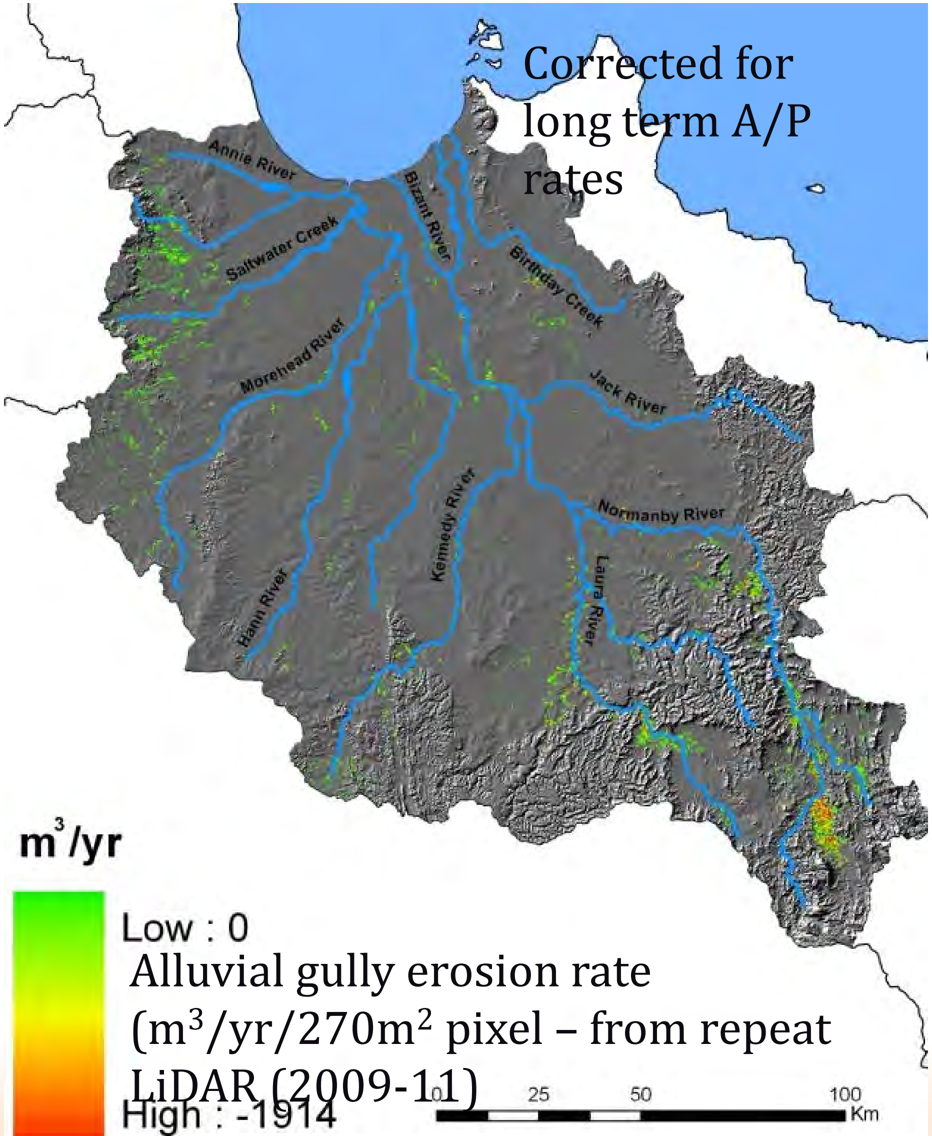


Laura River at Crocodile Gap (Norm 16)



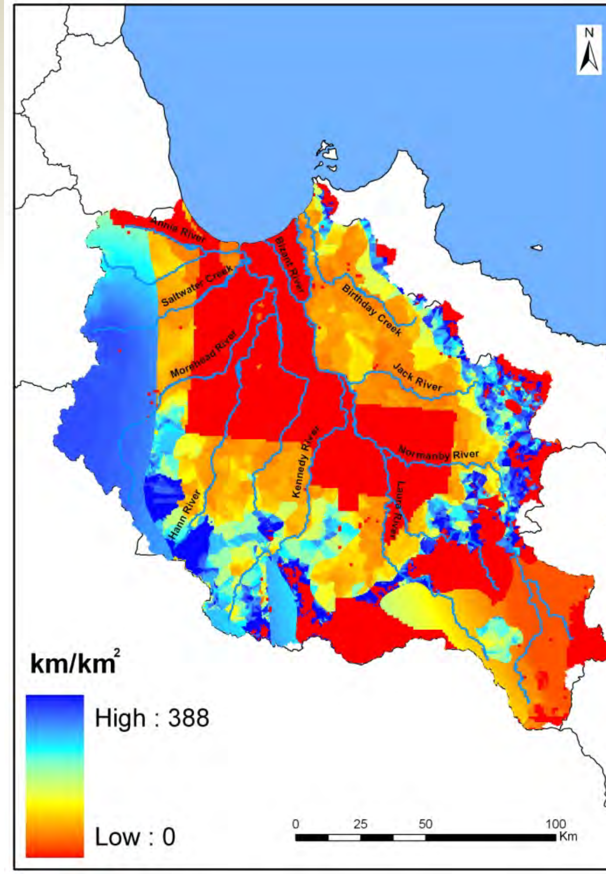
Photos Jeff Shellberg

No relationship with National Gully dataset



Corrected for long term A/P rates

Alluvial gully erosion rate ($m^3/yr/270m^2$ pixel – from repeat LiDAR (2009-11)



Total long term annual av Gully erosion rate 1.14 Mt/year

Sediment Sinks Sources & Drivers in the Normanby Basin

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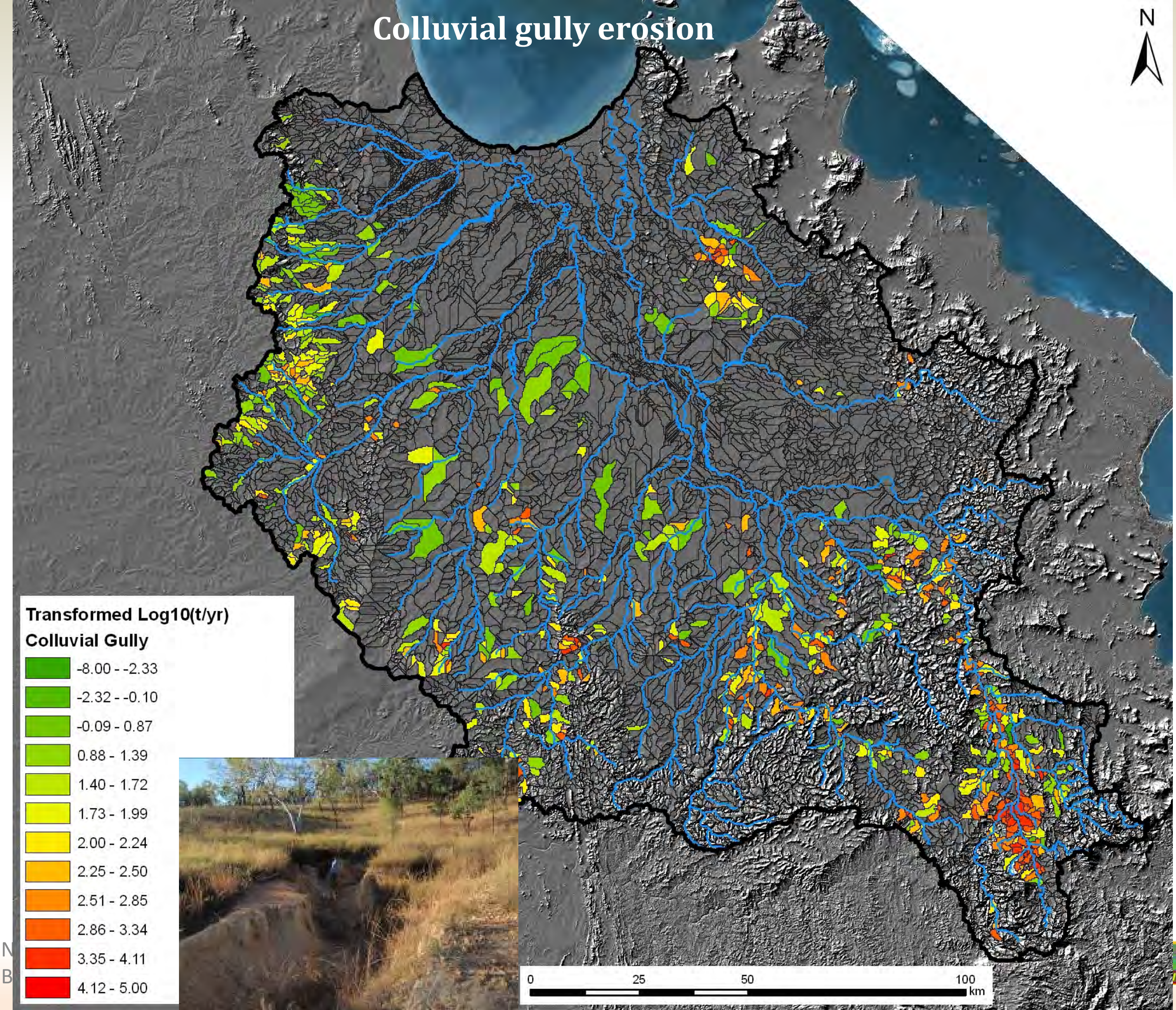
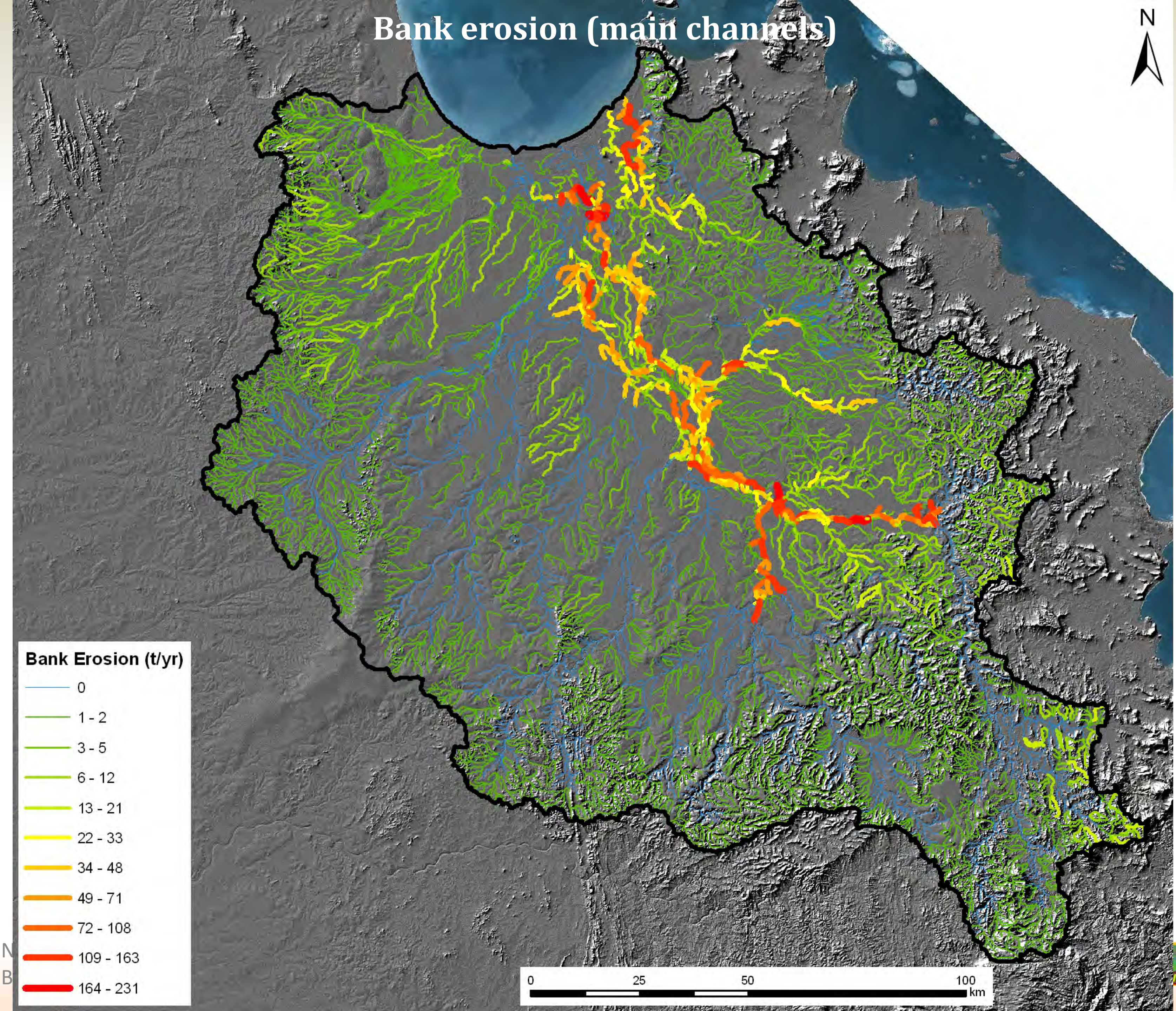
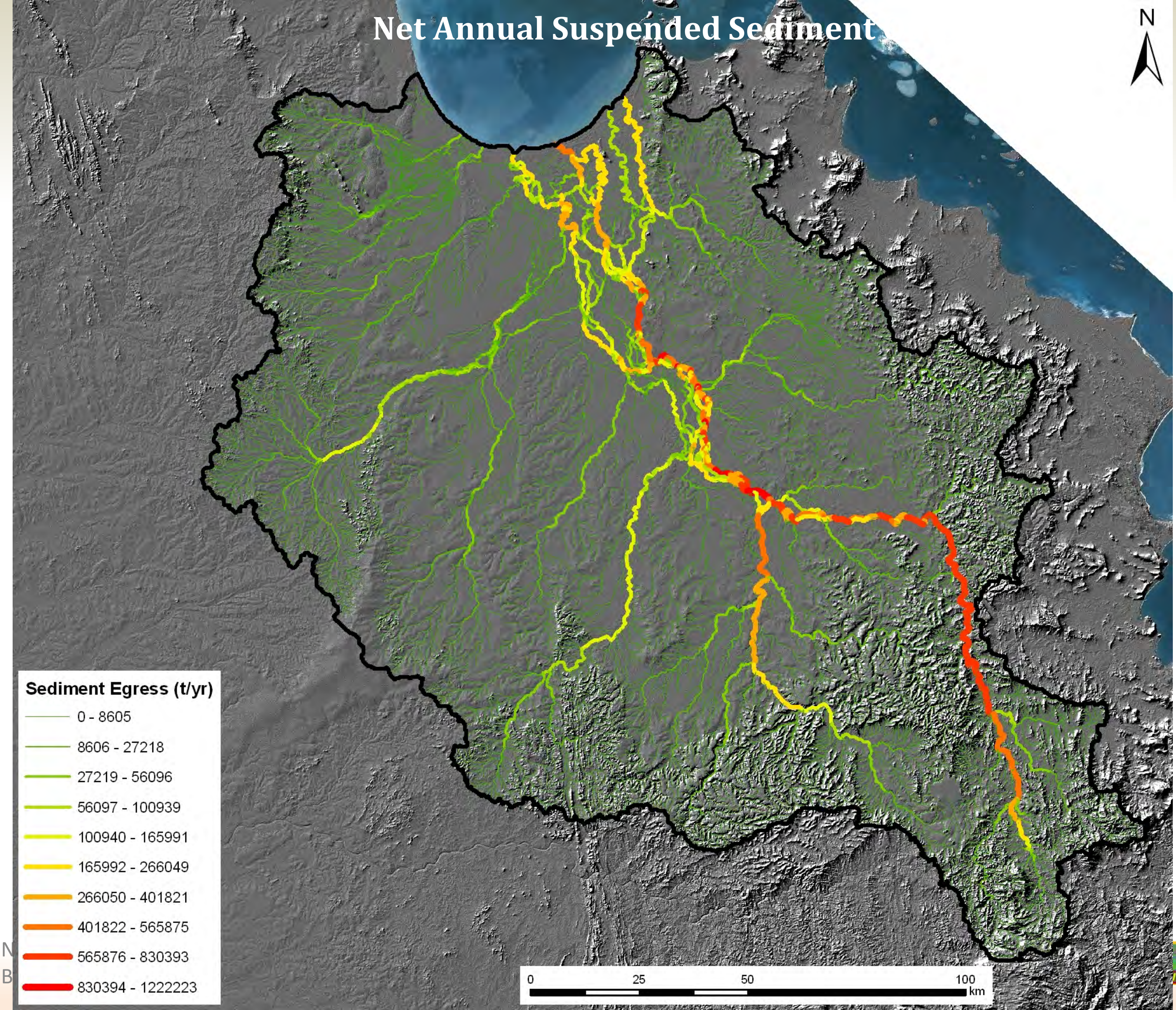
Colluvial gully erosion



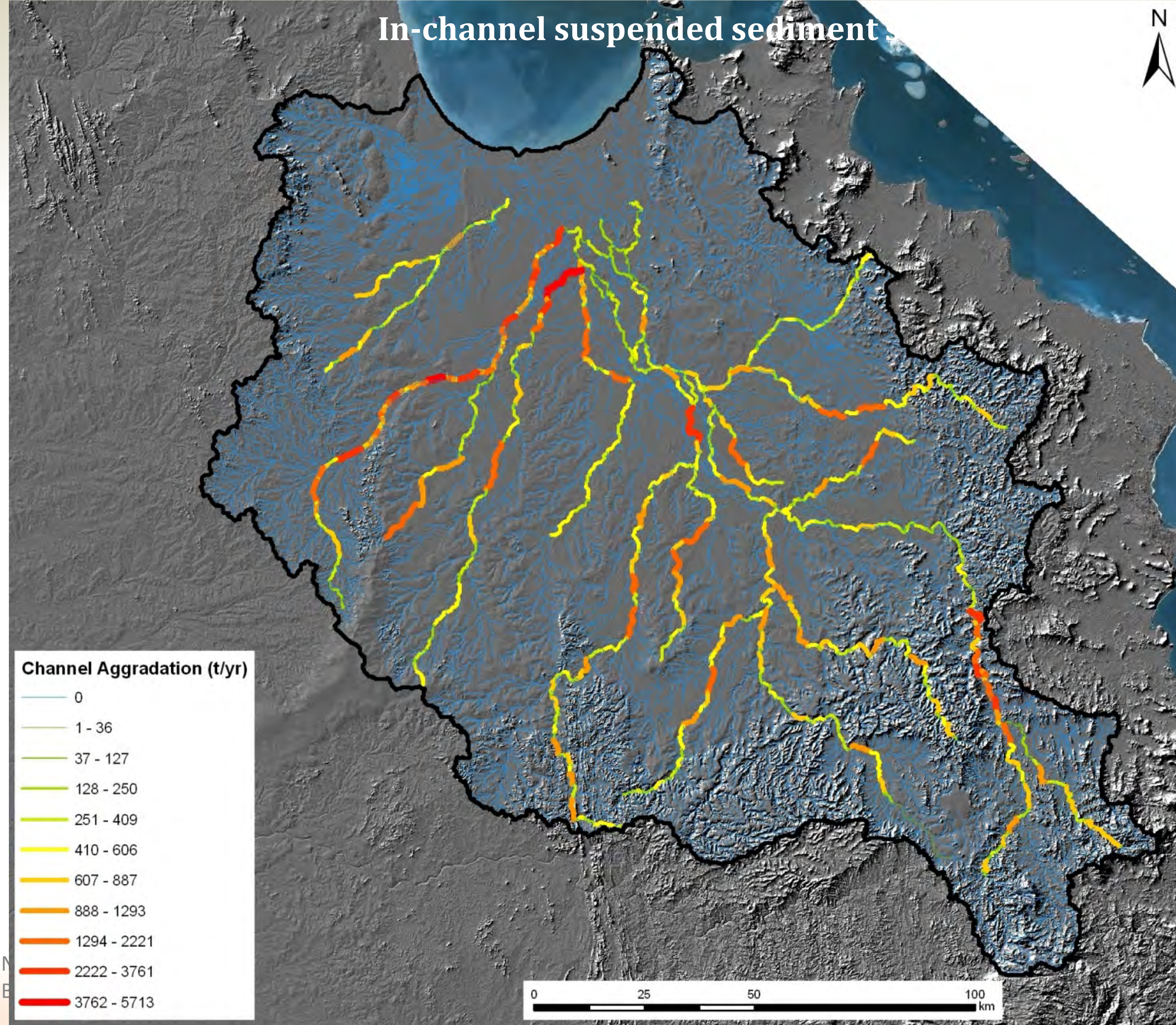
Bank erosion (main channels)



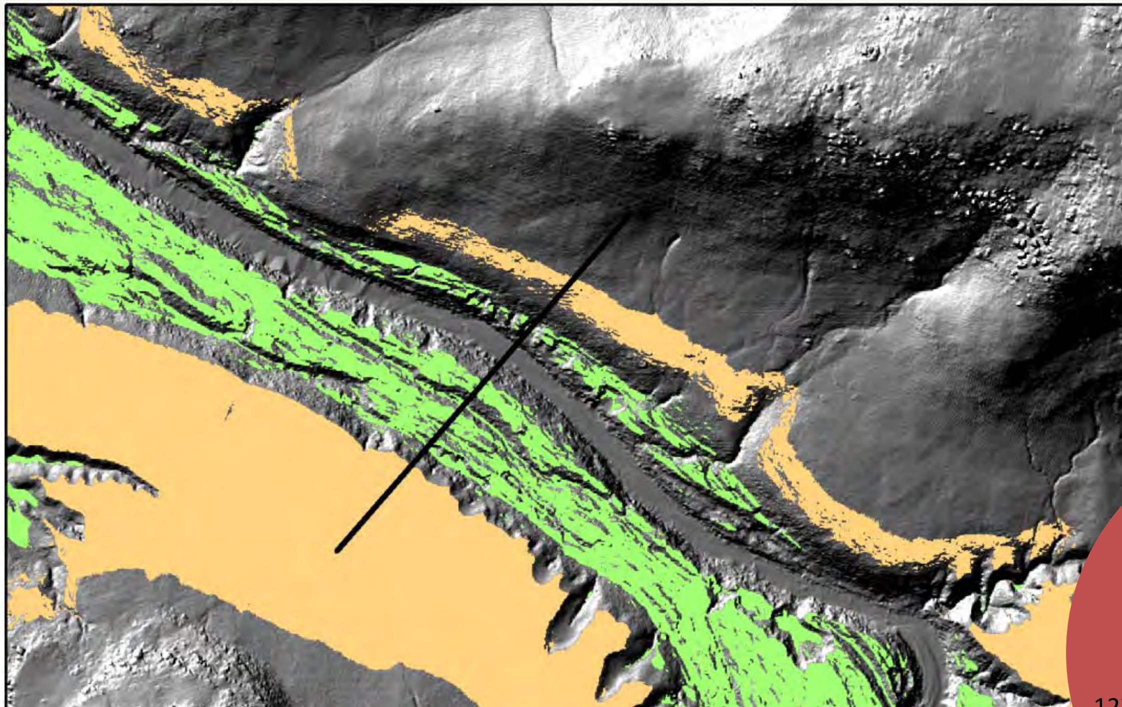
Net Annual Suspended Sediment



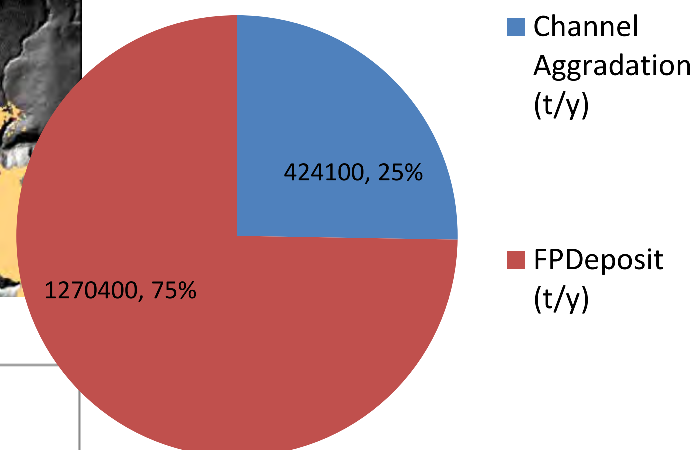
In-channel suspended sediment s

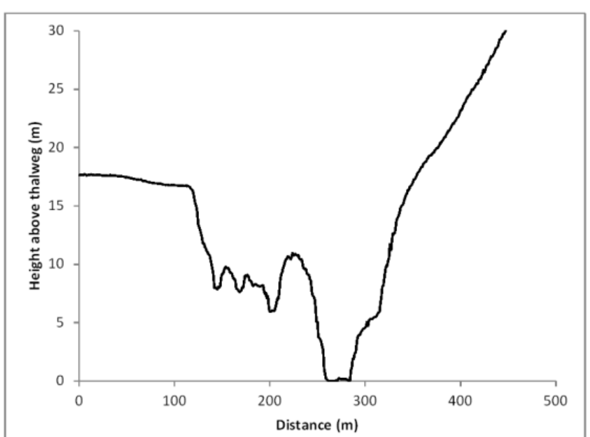


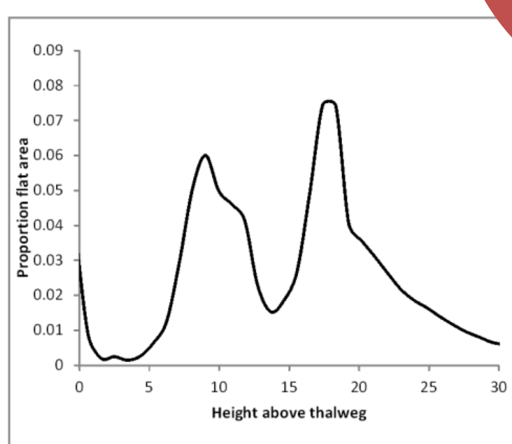
Sediment Storage – benches & floodplains



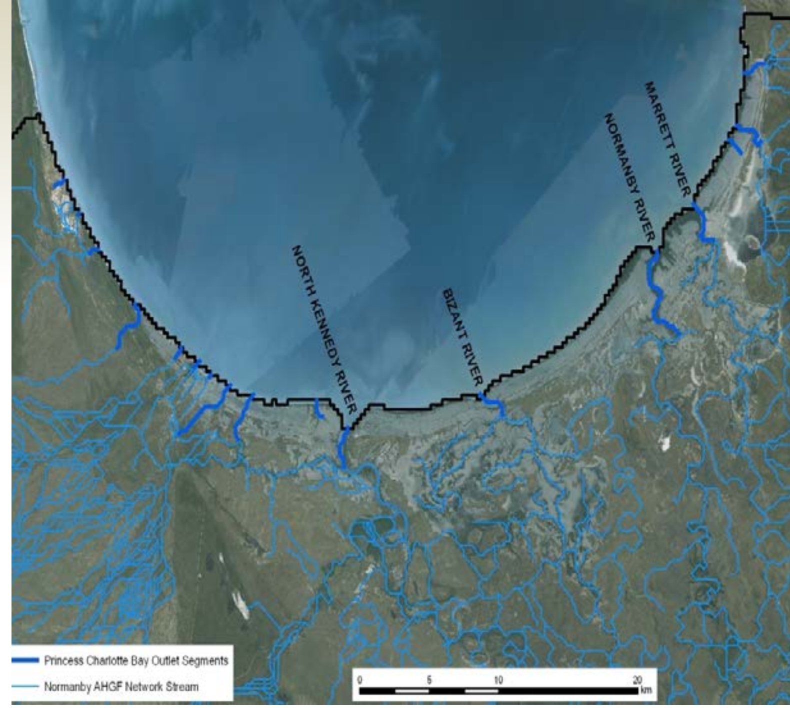
Normanby Suspended Sediment Storage



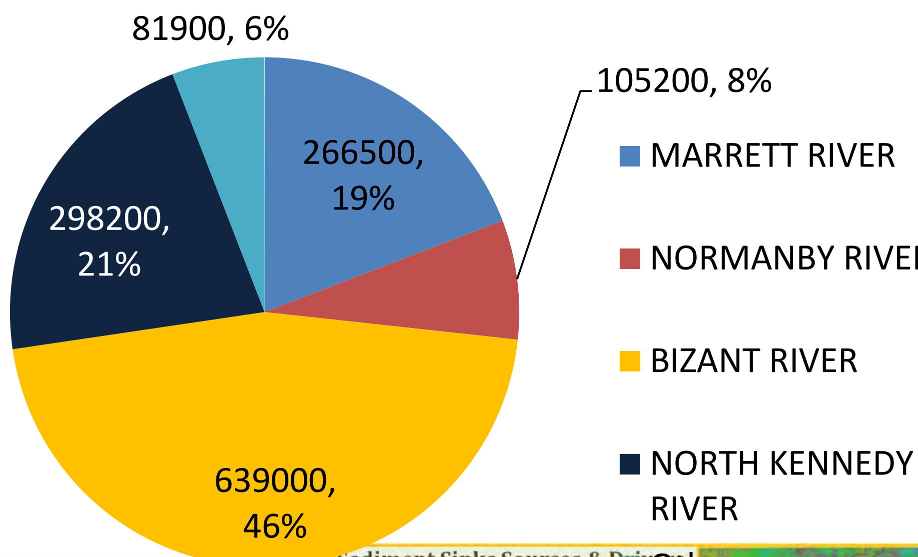




Inputs	Annual Load (t/yr)	1 stdev
Hillslope	15,901	na
Alluvial Gully	736,409	na
Colluvial Gully	411,844	na
2ndry Channel	1,672,108	na
Main ch Bank Erosion	249,879	204,861
total inputs	**3,086,140**	**204,861**
Storage		
in-channel benches	424,094	404
floodplain deposition	1,270,417	17,203
total storage	**1,694,511**	**17,607**
Net Output	**1,391,629**	**222,468**

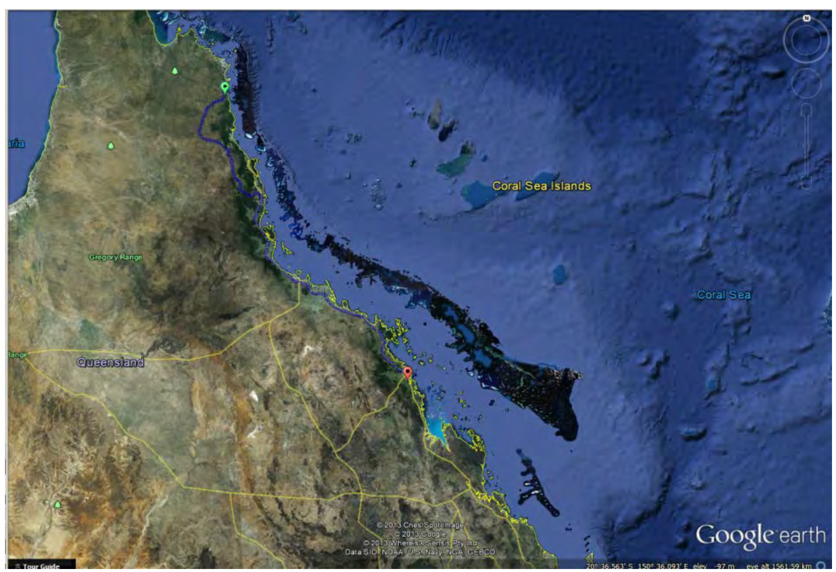


Mean annual sediment contribution to PCB



So how much sediment is 1.4Mt?

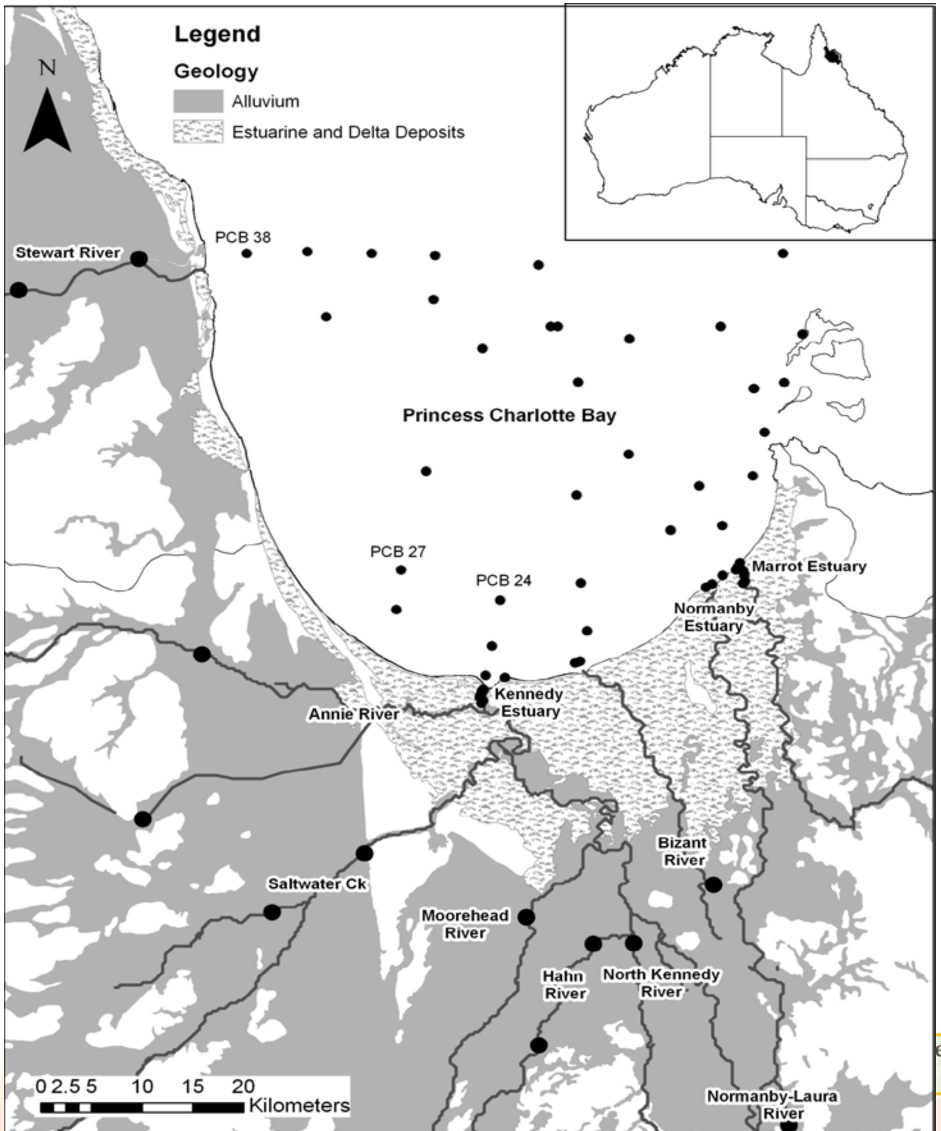
One of these holds ~ 10t



139 000 of them parked end to end would be a line of trucks from Cooktown to Mackay

- But wait – there's more...

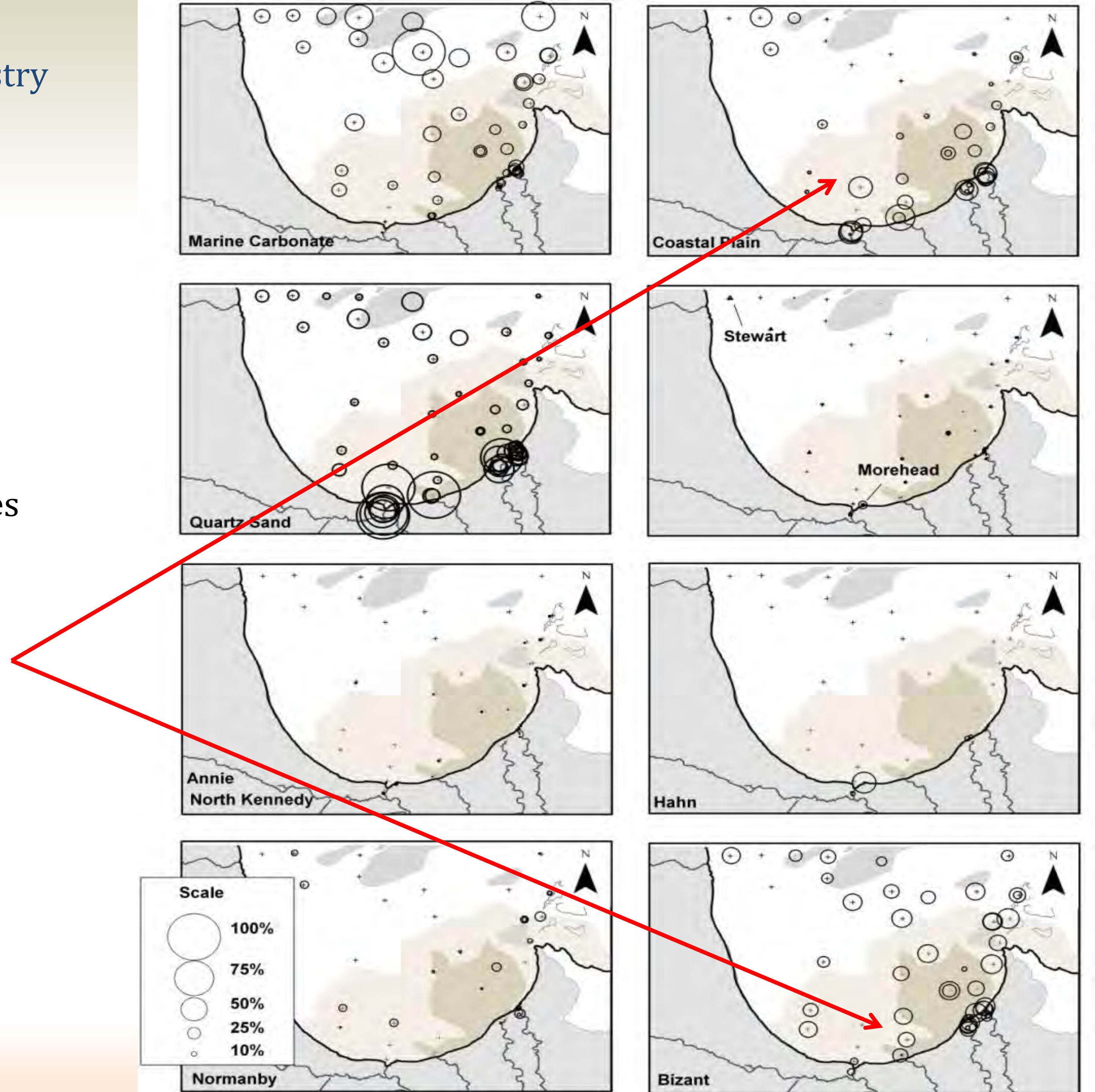
So what do the PCB sediments tell us about sources?



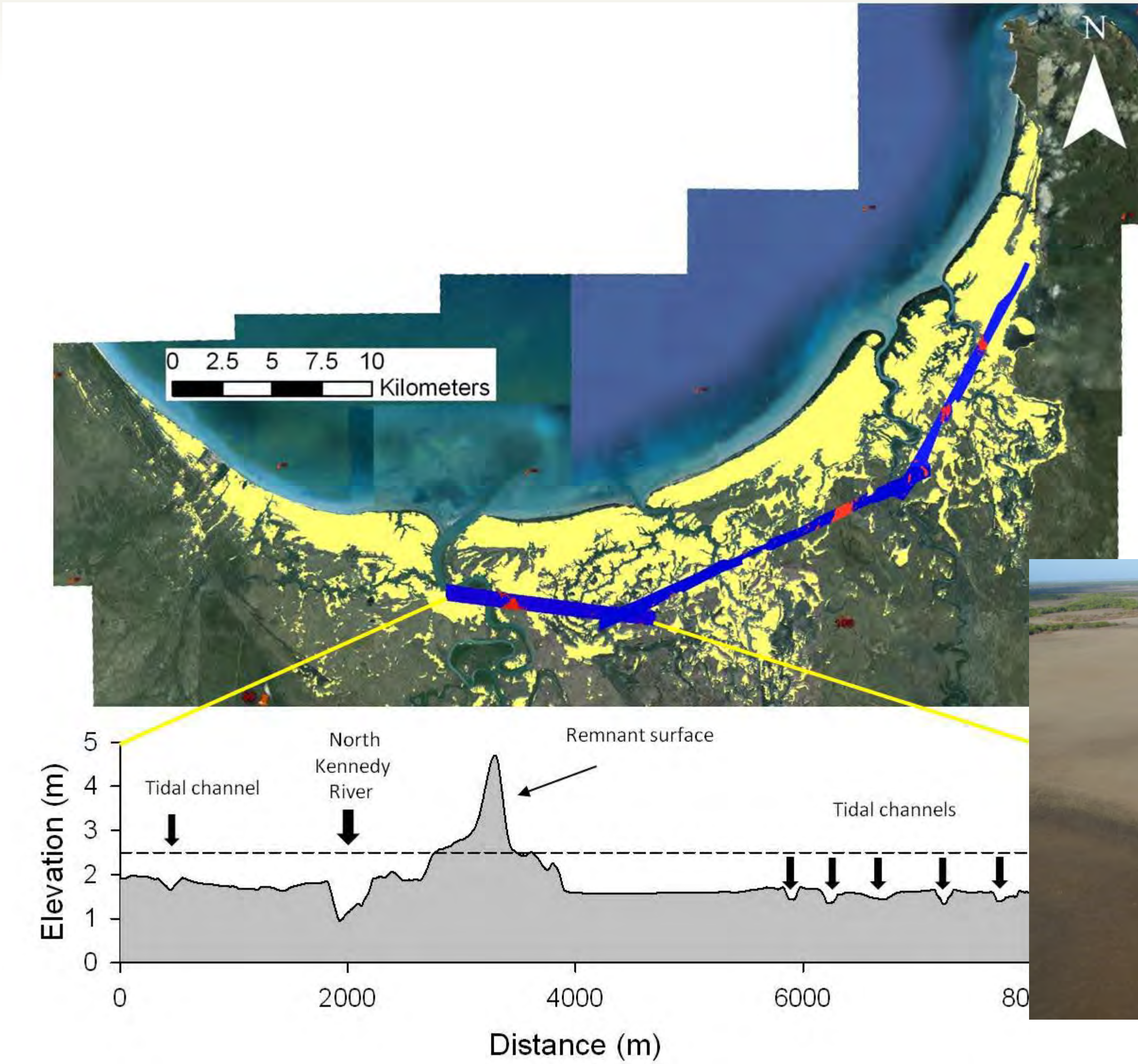
PCB bottom sediment source REE geochemistry

Upper Catchment Sediment sources not well represented.

Appears lower floodplain & coastal plain are key sources



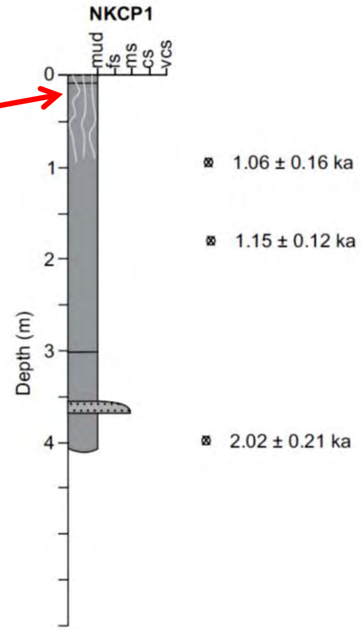
Coastal plain stripping



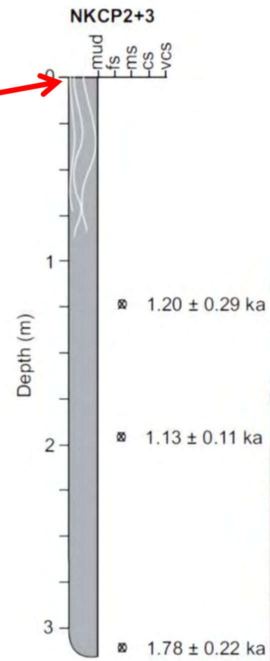
Conservative estimate ~ 220Mt from ~ 185 km^2 area

Sfce age ~ 0.7ka

Coastal plain remnant pedestals



Sfce age ~ 0.45ka



PCB Deposition rates by source (our data) based on Torgersen et al., (1983) accretion rates

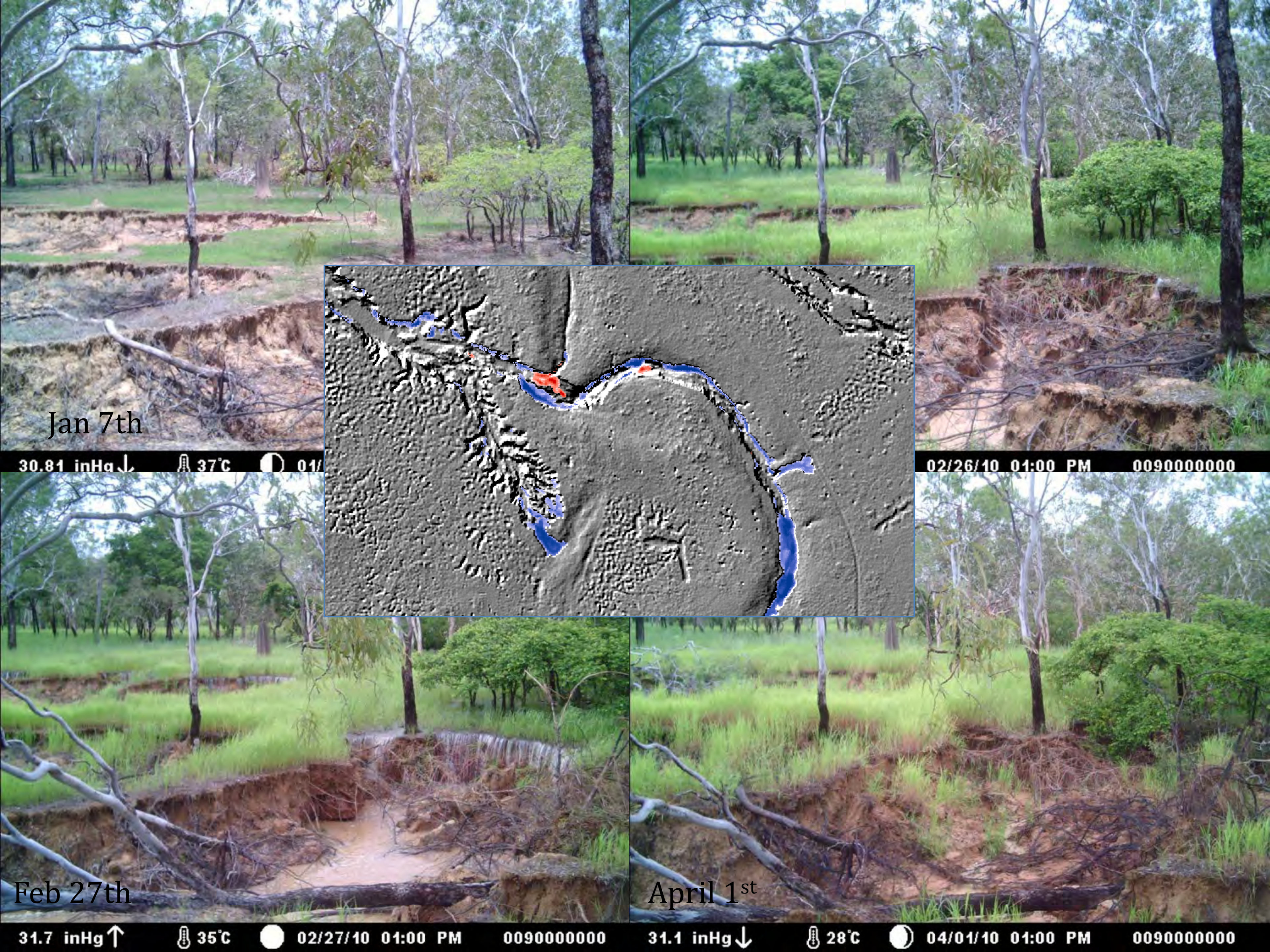
	Annie	Bizant	North Kenne dy	Hann	Moorehe ad	Norman by	Saltwat er	Stewar t	Coastal plain	Sand	Marin e
Mean	0.012	0.239	0.002	0.012	0.009	0.039	0.002	0.011	0.138	0.260	0.276
Std Deviation	0.019	0.141	0.007	0.069	0.031	0.062	0.009	0.022	0.150	0.222	0.171
Std error	0.003	0.021	0.001	0.010	0.005	0.009	0.001	0.003	0.022	0.033	0.026
Deposition rates	Ktonnes per year derived from each source										
6.1 mm/yr	189	3839	27	195	143	633	27	185	2207	4172	4432
2.3 mm/yr	71	1448	10	74	54	239	10	70	832	1573	1671

Delta & coastal plain sources = 2.3 – 6 Mt/yr -

Torgersen, T., Chivas, A.R., Chapman, A., (1983). Chemical and Isotopic characterisation and sedimentation rates in Princess Charlotte Bay Queensland. BMR Journal of Australian Geology and Geophysics 8, 191-200.

Tidally driven sediment plumes entering PCB

pics Jan McCollum


Jan 7th
30.81 inHg 37°C 01/
02/26/10 01:00 PM 0090000000
Feb 27th
31.7 inHg 35°C 02/27/10 01:00 PM 0090000000
April 1st
31.1 inHg 28°C 04/01/10 01:00 PM 0090000000

Summary (upper catchment sources) i.e. Excl. Coastal plain

	GU 2012 SS I/Ps (t)	%	Brodie et al 2003	%
colluvial gully	411800	13%	173000	10%
alluvial gully	736400	24%	0	0%
hillslope delivered	15900	1%	1576000	89%
Mainstem bank erosion	249900	8%	17500	1%
2ndry alluvial channel erosion	1672000	54%	0	0
total	**3086000**	**100%**	**1766500**	**100%**
storage	**1697300**	**55%**	**664000**	**37%**
Net (=18% of PCB accretion)	**1,390,000**		**1,102,000**	

Coastal plain/delta contrbt'n ~4 MT

Conclusions

1. Hillslope erosion not the dominant source
2. Gully erosion, and bank erosion dominate
3. Still considerable uncertainty – and unmeasured residuals...
4. Can't find evidence for 5 fold post-European increase in sed yield from Catchment (pre-European rates probably under-predicted)
5. But – land use clearly has elevated sed supply (1.4Mt/yr still 3rd highest catchment contribution to GBR – without coastal erosion source)
6. Storage within the system has absorbed a large amount of the additional yield
7. We would regard the empirical data underpinning this study to be the bare minimum!

Conclusions Cont.

Management conclusions to follow at 12:10.

"Modelling is an important accompaniment to measurement, but is no substitute for it; science requires observation, and without that we will cease to progress in understanding our environment, and therefore in managing it appropriately"

Silbertstein, 2006

CARING FOR OUR COUNTRY

- Acknowledgements:

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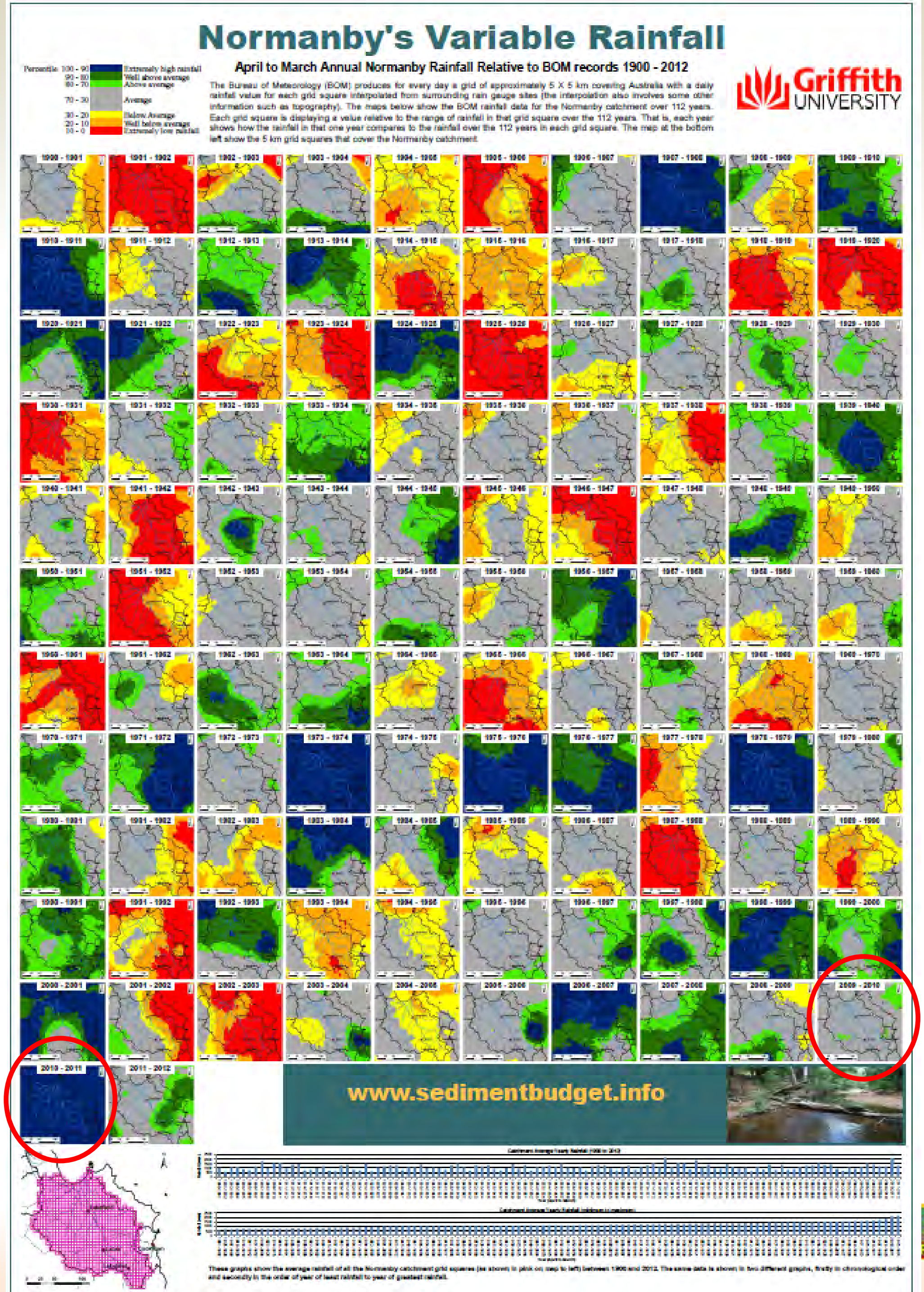
- E.g. KPHST1 – modelled rates ~75t/ha/yr


6 Tonne pile of dirt
1 kg pile of dirt

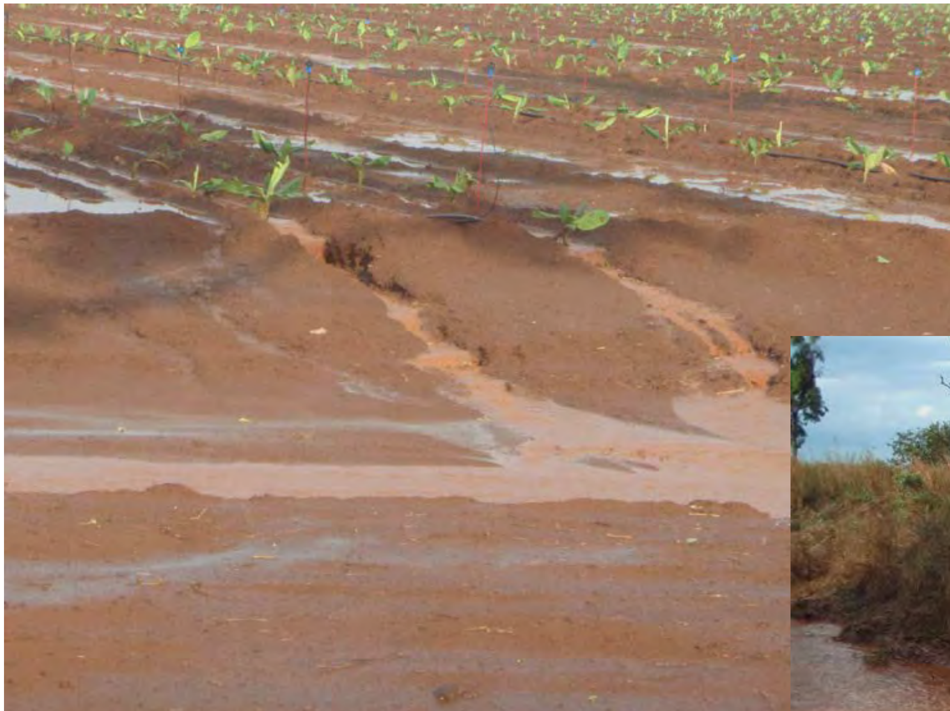
Measured annual yield= 0.1-0.2 kg
RUSLE predictions for this trap per year = 30 tonnes

How do we explain this discrepancy?

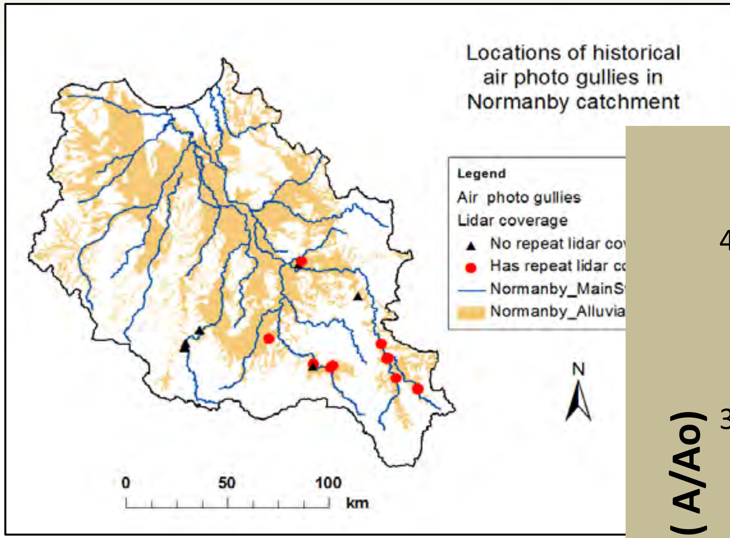
Was our sampling period not representative?

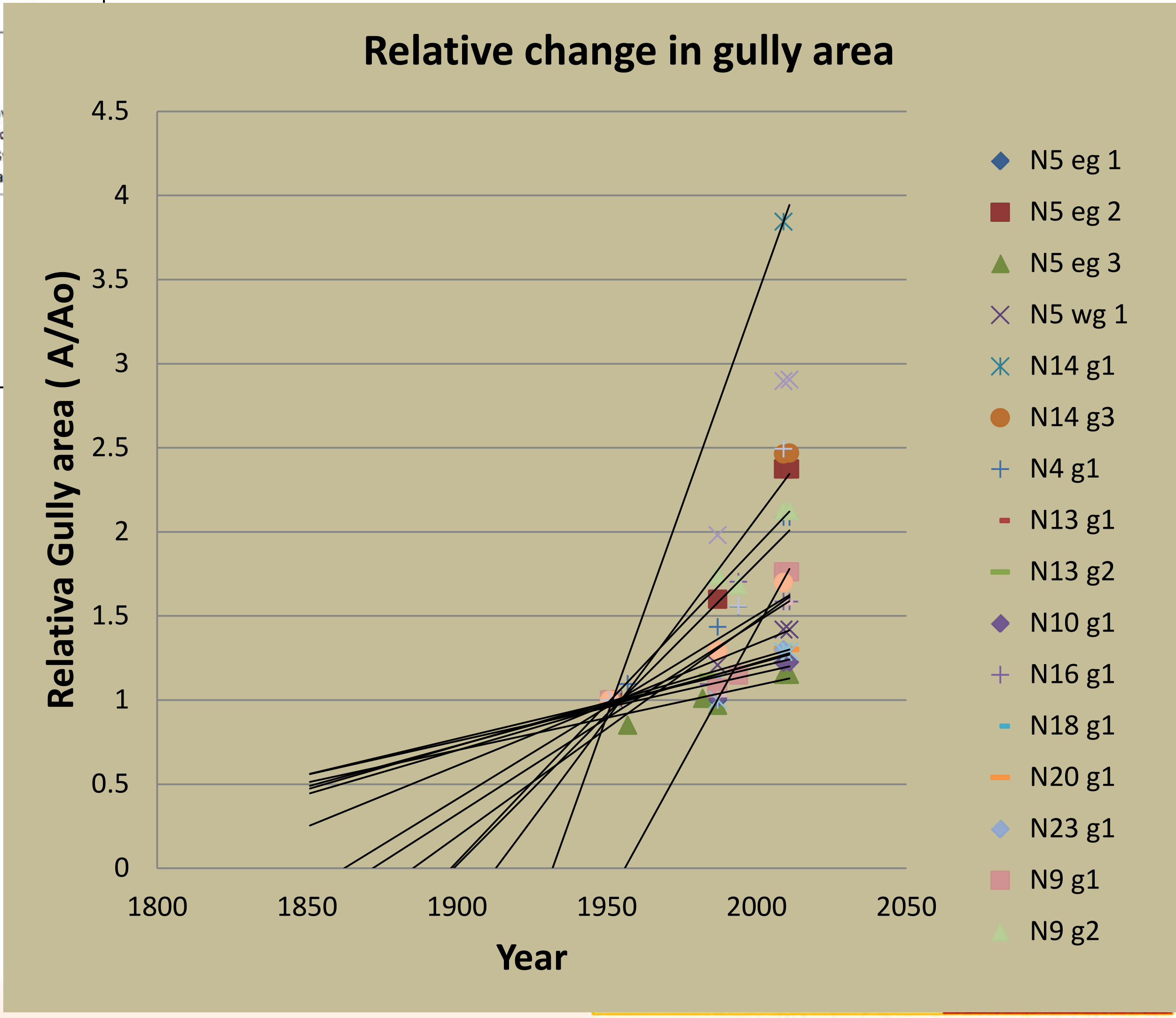


Key Landuse Drivers



Historical A/P analysis of gully erosion





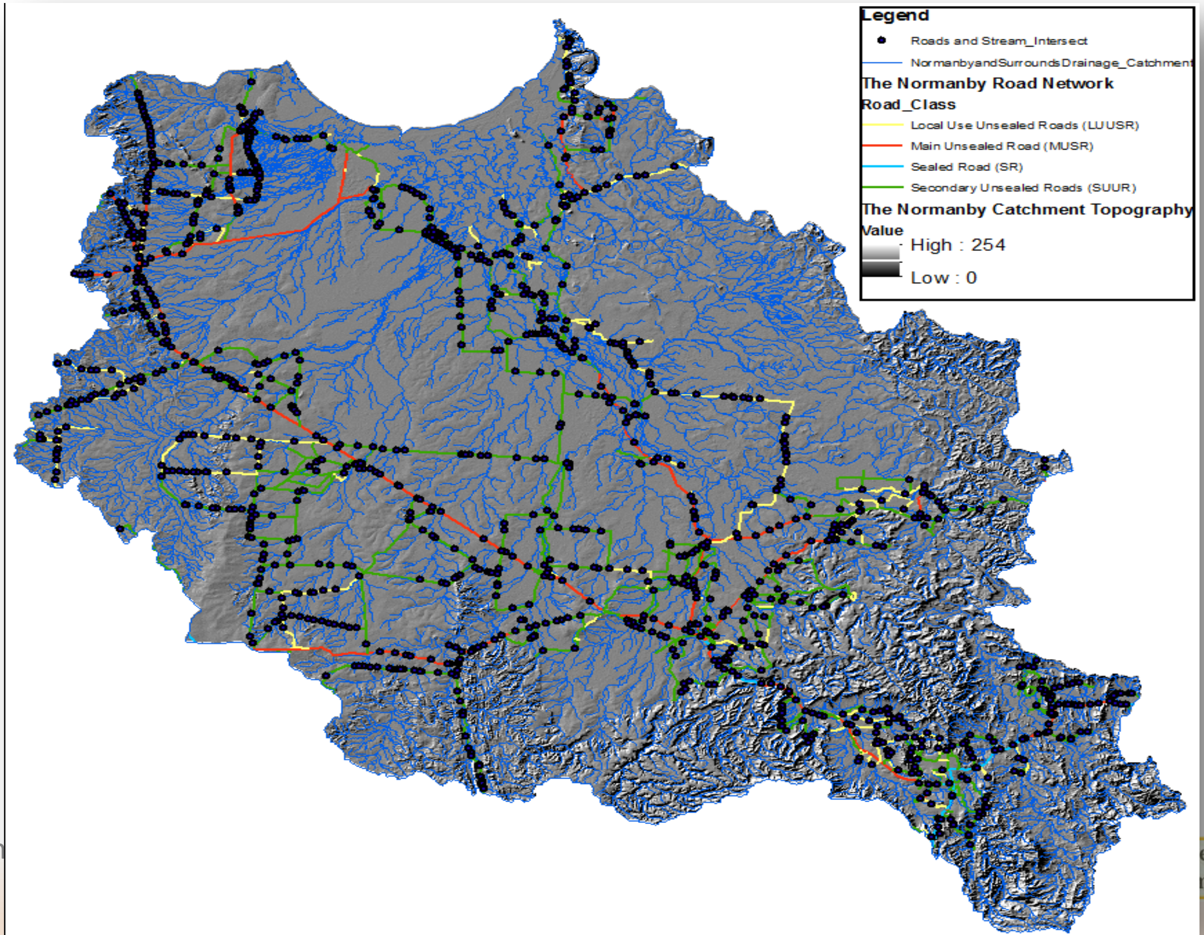
Gullies found to be both pre- and post-European – backed up by geochronology

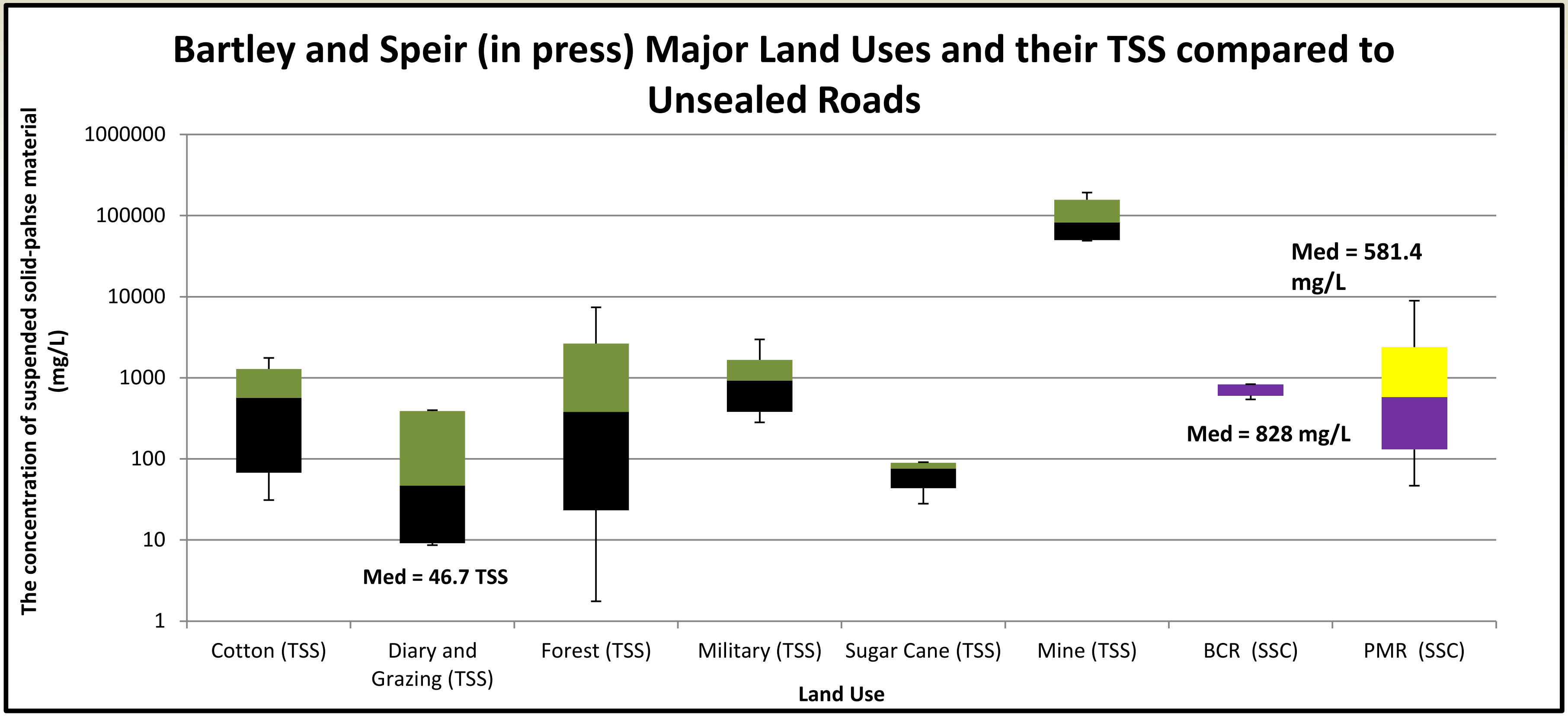
These data provide longer term rate data

Roads as sediment sources

Road Runoff - Unsealed Road Runoff – Normanby Catchment *(Angela Gleeson Hons Thesis, 2012)*

- Surface area of roads = 56.76km² and intersects 1190 times with the surrounding stream network (40.4 km² unsealed);
- The network is 34.91km² greater than total area of intensive agriculture (21.85km²) (ABS, 2005-2006);





- EMCs from road runoff ~ 2nd only to Mining from Bartley et al's data
- 3-4 orders of magnitude > Hillslope erosion EMCs
- Roads should be considered as a major landuse

Based on rainfall data over 2009 – 2011 – annual runoff from roads ~ 7500t (25% of all hillslope runoff)

42% of the experimental V-Drains were found to have associated gullies (Gleeson, 2012) -

a sample from ~10km of road - indicated ~ 2,260 tonnes of additional erosion from V drain induced gullies (timescale unknown) (i.e. this adds to total road sed load)