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The Department of Primary Industries

CCMA Erosion and Landslide Trend Mapping Project Using Aerial Photo Interpretation.

Part B - Results

Supporting Document to the Corangamite Soil Health Strategy

Report No: 356.2/01/07

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Contents

1. Introduction

The Corangamite Catchment Management Authority (CCMA) has developed the Corangamite Soil Health Strategy (CSHS) as a sub strategy of the Corangamite Regional Catchment Strategy (CRCS). The CSHS links to state and federal frameworks and aims to compliment other sub strategies under the CRCS. This will allow an integrated approach to the protection of key assets identified under this and other sub-strategies.

The CSHS addresses a diverse range of soil health issues and will provide the basis for investment in regional soil health over the coming years. As such, a key aim of the CSHS is to assist the CCMA and other stakeholders in guiding investment to protect and enhance assets in the region that are at risk from threatening processes associated with soil health.

The CSHS uses a relative risk to asset based approach to identify priority areas where soil threatening processes are impacting important assets. The process considered 12 different soil threatening processes in 15 sub catchment or landscape zones. By superimposing the distribution of 5 primary assets classes with these threats, a series of risk to assets combinations were evaluated and the top 20 combinations of threats, assets and landscape zones were chosen as the initial priority zones for the CSHS.

The resulting top 20 priority zones contained 15 combinations including threats of landslides or erosion, emphasizing the importance of these soil threats within the CCMA region. As a result much of the initial research and focus has been placed on landslide and erosion in the early phases of the CSHS.

A key element of the erosion and landslide research has been the establishment of CCMA erosion and landslide database. Whilst the erosion and landslide inventory provides valuable information about the extent and distribution of these hazards throughout the CCMA region, it provides limited information about their likelihood of occurrence.

The need for a better understanding of the likelihood or the frequency of occurrences was duly noted in the early stages of the CSHS project and it was decided under the current 2006/2007CSHS program to address this deficiency by undertaking trend analysis. The trend analysis approach aims to establish process rates of the hazard over a defined temporal window or period thus giving insight into how active and possible likelihoods associated with the hazard. This report describes the results from the analysis whilst the earlier companion report (ASMG Report No 356.1/01/07) describes the initial phase of establishing a trend analysis methodology.

2. Background, Aims and Scope of Commission

A "Slope Hazard Study in the Otway Ranges" aimed at identifying the distribution and extent of landslides in the Otway region was commenced in 1979 by the Department of Minerals and Energy (DM&E) under the direction of John Neilson and Tony Cooney. The progress report produced in 1980 indicated the initial two phases of a five stage program had been completed. These initial stages included:

1. Delineation of slope failures and zones of potential failure from aerial photographs: provisional classification of them.
2. Field mapping to check photo-interpretation and study environments, causes and mechanisms of failure: revision of photo-mapping.

The study area was extensive, covering approximately 4,300 km^2 and was bounded by Curdies River in the west, the volcanic plains in the north and the Victorian coastline to the east and south.

Due to the complexity of the disturbed areas contained within many of the landslides, only headscarps were mapped for the majority of the slides in the study area. This has been a major impediment to using this data set in future modelling and analysis projects

A later project was commissioned by Colac Otway Shire in 2005 to revise the initial Cooney mapping using stereo aerial photograph interpretation (API) techniques. It was expected that the landslides could be better represented with components such as headscarps, scarp faces, slide bodies and runout areas clearly defined. Whilst an appropriate API method and mapping pathway was developed by Ian Roberts from Earth Resources Analysis in conjunction with A.S. Miner Geotechnical, it was only feasible to complete a small proportion of the previous study area assessed by Cooney.

Given the current lack on information on likelihoods and rates of occurrences for both landslides and erosion, it was decided to undertake a trend mapping analysis under the current 2006/2007 CSHS program utilising the API techniques developed for the previous COS project as described above.

As a result, A.S. Miner Geotechnical was commissioned by Troy Clarkson (DPI project manager for the Corangamite Soil Health Strategy) in a number of separate but related projects to undertake the interpretation of aerial photographs to ascertain spatial extents of erosion and landslides in a number of key locations within the CCMA region over a specific temporal window or series of historical aerial photos.. In order to complete this task external consulting resources were utilised as follows:

- Stereo Aerial Photo Interpretation (API) undertaken by Ian Roberts from Earth Resource Analysis (ERA).
- Data transfer, geo-referencing and GIS presentation undertaken by David Windle (specialist GIS sub contractor).

Tasks involved in the various projects have included:

- Adaptation of the API method developed for the earlier COS project to allow trends and rates of occurrences to be assessed from historical photos.
- Selection of suitable sites and locations for trend mapping analysis which were consistent with previous priority target areas.
- Obtaining suitable hard copy photos from the Department of Primary Industries (DPI). Generally hard copies flown in the last few years were obtained for each site to serve as a high quality reference for the analysis.
- Obtaining one or more series of historical aerial photos for each site from the state Archives at Cherry Lane in Laverton. In order to fit in with budget constraints and to facilitate analysis for the maximum number of sites, the time sequence series of photos were obtained as good quality laser prints scanned directly from the original hard copy prints.
- Mapping of landslide and erosion features by Ian Roberts using the API methodology formulated by in the earlier COS project.
- Transfer of the hard copy marked ups to GIS format by David Windle.
- Comparison and analysis in a GIS platform of the spatial areas and linear measurements of landslides and/or erosion.
- Presentation of the results in a suitable format.

As previously indicated the earlier companion report entitled “CCMA Erosion and Landslide Trend Mapping Project Using Aerial Photo Interpretation. Part A Methodology” (Report No 356.1/01/07) details the development of an aerial photograph interpretation methodology used in assessing trends at various sites during the course of three separate projects. Additional historical information on some of the sites initially assessed by Ian Roberts was also collected from various external sources and studies. In addition trend analysis on other sites by other researchers is also presented.

The timeframes and schedules involved for each project and the chronological sequence in which the work was completed has complicated the discussion of results. This report aims to address this issue by presenting results collectively for each specific geographic location, irrespective of when the trend analysis was done, what variation of the assessment method was used or who conducted the assessment. These details have been adequately dealt with in the earlier companion report.

As a result, this report details the trends and rates of increase (or decrease) for both landslides and erosion in selected areas within key target zones of the CCMA region. Comments on associated issues relating to possible reasons for the observed performance are provided where possible.

3. Summary of Trend Analysis Mapping Locations

As discussed in the previous companion report, aerial photo interpretation of landslides and erosion has been continuing over the past 3 years under a number of various projects. As a result a diverse range of sites has been assessed for historical rates of occurrence across the entire CCMA region. These sites can be divided into landslide sites and erosion sites as follows:

Type	Location	Municipality and Landscape Zone
Landslide locations and individual sites where trend analysis has been conducted	Wild Dog Creek (Apollo Bay)	Colac Otway (Otway Coast)
	The “1952 Slide” site in the Wild Dog Creek Valley	Colac Otway (Otway Coast)
	The Heytesbury Settlement	Corangamite (Curdies)
	Happy Valley (Heytesbury Region)	Corangamite (Curdies)
	The Melba Parade landslide at Anglesea	Surfcoast (Thompsons)
	Lake Bullen Merri landslides	Corangamite (outside CCMA)
	Barham River Valley and Beauty Creek Apollo Bay	Colac Otway (Otway Coast)
	Barwon River at Birregurra (incomplete to date)	Colac Otway (Upper Barwon)
Erosion locations and sites where trend analysis has been conducted	Misery Moonlight	Golden Plains (Woady Yalloak)
	Eclipse Creek	Golden Plains and Moorabool (Moorabool)
	Shelford Mt Mercer Rd	Golden Plains (Leigh)
	Yeodene (Boundary Creek)	Colac Otway (Upper Barwon)
	Illabarook	Golden Plains (Woady Yalloak)

Table 1 List of Sites where Trend Analysis Mapping has been undertaken.

4. Landslide Trend Analysis Mapping Results

4.1 Background

Trend analysis mapping using temporal windows established from historical aerial photos has been used to establish data on the rates of spatial increase (or decrease) and the level of activity. Study areas were chosen from key target areas identified in an earlier field verification program conducted in August 2006 (see A.S. Miner Geotechnical report Nos. 352.0/01/07 and 352.1/01/06).

An arbitrary boundary was then assigned to each study area so that comparisons between the spatial extents of landslides could be more accurately made by comparing similar areas at different times. Where possible the study area was defined in such a way so as not to cross drainage or ridge line but the area acts more as a spatial study control than a geomorphic boundary.

The following sections provide a summary of results from the historical trend analysis mapping conducted for each site. A brief overview of the analysis and additional comments are also provided.

4.2 Wild Dog Creek (Apollo Bay)

Location: Wild Dog Creek Apollo Bay

Landscape Zone: Otway Coast

Target Area: OC9

Area	Assessor	Mapping Methodology	Date of Photo used
Wild Dog Creek	Ian Roberts	Headscarps and Active Landslides only	1946
	Ian Roberts	Active Landslides only	1952
	Peter Wood	Stereo Photo Interpretation plus detailed field inspections	1980
	Ian Roberts	Comprehensive Assessment	2004
	Warren Feltham	Ortho Photo Interpretation	2004

Table 2 Details of API methodology applied at Wild Dog Creek

Results:

Wild Dog Creek Landslide Trend Analysis

Landslide Study Date	Count	Area (ha)	% Change from 1946	% Change from 1952	% Change from 1982	% Study Area
1946 Active	22	9.79	0.0%	-69%	7%	1.8%
1952 Active	*33*	*32.00*	*227%*	*0.00*	*251%*	*5.7%*
1982 Active	15	9.12	-7%	-72%	0.00	1.6%
2004 Active A only	7	5.56	-43%	-83%	-39%	1.0%
2004 all type 3	*95*	*427.78*				*76.5%*
Total Study Area		***559.42***				

Table 3 Results of Trend Mapping at Wild Dog Creek

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A

Comments:

The Wild Dog Creek area is well known for its potential for landsliding and a number of studies have been completed in the immediate area (.e.g. Wood 1982). The overall terrain assessment and trend mapping analysis provide significant insight into this region. Over 76% of the defined study area has been effected by landsliding at some point in the past. This is thought to be due to a general over-steepening of the Wild Dog Creek river valley due to rapid down cutting at the mouth of the valley

However generally only 1 to 2% of the study area shows active landslides as interpreted from the aerial analysis which indicates a lower likelihood of landslides than is first suggested by the overall presence of what may be much older and larger landslides.

The significant exception to this is the analysis of the 1952 aerial photo which is reflective of much wetter conditions than any of the other photos. Inspection of the photos shows significant landslide activity and the percentage of the effected study area has increased to approximately 6%. The relationship between rainfall and landsliding is well established and 1952 contains the 14th (72.4 mm) and 22nd (65.3mm) ranked daily rainfall events out of a total of 36,764 rainfall records. Such rainfall events have an antecedent rainfall probability of excedence (or ARPET) of approximately 0.04%. Or in other words, there is a 0.04% probability that this or higher daily rainfall has been exceeded in the past 100 or so years of rainfall records. In addition the annual rainfall total in 1952 was also one of the highest on record.

4.3 The "1952 Slide" in Wild Dog Creek Valley

Location: Wild Dog Creek Apollo Bay

Landscape Zone: Otway Coast

Target Area: OC9

Area	Assessor	Mapping Methodology	Date of Photo used
The "1952 Slide" in the Wild Dog Creek Valley	Ian Roberts	Headscarp and Active Landslides only	1946
	Ian Roberts	Headscarp and Active Landslides only	1952
	Ian Roberts	Headscarp and Active Landslides only	1980

Table 4 Details of API methodology applied at the Big Slide Wild Dog Creek

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

The evolution of the 1952 slide provides a valuable insight into the evolution of a landslide at site scale. The early 1947 photo interpretation suggests the site had experienced previous movement of an unknown age. This is considered significant in the behaviour during the 1952 extended wet period as this slide assumed flow characteristics and travelled some 700 m downslope before blocking the Wild Dog Creek. The presence of previous landslide debris material is almost certainly responsible for this movement type and indicates materials at greatly reduced strengths and with increased void ratio allowing quicker infiltration and saturation.

The 1982 interpretation shows ongoing activity within the slide mass but of a much reduced size. A number of smaller headscarps and displaced material masses are evident and the analysis highlights the importance previous sites of instability play in the generation of new slides and/or reactivations along old planes of weakness.

4.4 The Heytesbury Settlement

Location: The Heytesbury Settlement

Landscape Zone: Curdies

Target Area: Incorporating C1, C2 and C3

Area	Assessor	Mapping Methodology	Date of Photo used
Heytesbury Settlement	Bard Buenen	Stereo Photo Interpretation	1946
	Bard Buenen	Stereo Photo Interpretation	1982
	Bard Buenen	Stereo Photo Interpretation	1991

Table 5 Details of API methodology applied at Heytesbury Settlement

Results:

Heytesbury Landslide Trend Analysis					
Landslide Date	**Count**	**Area (ha)**	**% Change from 1946**	**% Settlement Area**	**% Study Area**
Buenen 1946	53	725.10	0.0%	1.6%	0.5%
Buenen 1982	105	2,358.72	325.3%	5.2%	1.7%
Buenen 1991	301	6,393.75	881.8%	14.1%	4.5%
Settlement Area (1946)		45,495.69			
Total Study Area		***141,935.19***			

Table 6 Results of Trend Mapping for The Heytesbury Settlement

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

Buenen's study of landslides in the Heytesbury was undertaken at the University of Ballart in the late 1990's and sought to establish rates of landsliding in the Heytesbury settlement region of South Western Victoria.

The study was conducted using aerial photo interpretation techniques and concluded significant increases in the spatial extent of landslides from 1946 (prior to deforestation of the area) to 1991.

Results of the study indicated very significant increases in the spatial extant of landslides with in excess of 800% increase over the 45 year study period. The increases occurred throughout the Heytesbury settlement and in an area to the north of the settlement towards Timboon.

Significant rainfall was known to have occurred in the early 1950's and it is probable this extended period of wet weather accounted for much of the early increases. However the increasing trend has continued through to the present and it is postulated that the removal of the tree cover and conversion of the land to intensive dairying activities has also significantly contributed to the observed acceleration in landslide occurrence.

Further discussion is presented in the next section on Happy Valley which is contained within the Buenen study area,

4.5 Happy Valley (Heytesbury)

Location: The Heytesbury Settlement

Landscape Zone: Curdies

Target Area: C2

Area	Assessor	Mapping Methodology	Date of Photo used
Happy Valley (Williams Rd in the Heytesbury)	Andrew West	Single Photo Interpretation	1969
	Andrew West	Single Photo Interpretation	1969

Table 7 Details of API methodology applied at Happy Valley, Heytesbury Region

Results:

Happy Valley Landslide Trend Analysis				
Date/Type	**Count** ***(polygons)***	**Area** ***(ha)***	**% Change from 1969**	**% Study Area**
1969 Landslide	1	0.28	0.0%	0.004%
1969 Hummocky or Complex Slope	15	196.62	0.0%	3.1%
Total 1969	*16*	*196.90*	0.0%	3.1%
1991 Landslide	13	5.22	1764.3%	0.1%
1991 Hummocky or Complex Slope	28	734.48	273.6%	11.7%
Total 1991	*41*	*739.70*	275.7%	11.8%
Study Area		**6,265.38**		

Table 8 Results of Trend Mapping for Happy Valley, Heytesbury Region

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

The Happy Valley area is located within the Heytesbury settlement and has been the subject of a number of landslide studies at the University of Ballarat. The area was deforested in the late 50s and has since been used as prime dairying country. Hence land use change is considered a major potential triggering factor for both this study area and indeed much of the Heytesbury.

A degree on uncertainty exists about the exact definition of terms used in the study although “hummocky and complex slopes” are clear indicators of shallow slope movement. However such movement may be due to shallow surficial translational slides and/or slow creep type movement indicative of slow longer term movement.

Notwithstanding such limitations in the terminology, it is clear however that there has been a significant increase in both the number of distinct separate landslide events and a significant spatial increase in the areal extent of the “hummocky and complex slopes”.

Comparisons with landslide inventory and landslide susceptibility mapping conducted as part of the overall Soil Health Strategy show a good correlation with the current spatial extent of effected ground and high susceptibility areas.

The rate of increase is also very significant (being of the order of 270 %) over the 22 year period. This is somewhat less than the other Heytesbury study by Buenen but is indicative of real changes in the region since the late 1940’s. Given this period corresponds with the last major deforestation in Victoria and intensive land use through the establishment of a viable dairy industry within the Heytesbury soldier settlement, it is probable that such anthropogenic changes have played a key role in the observed increase in landsliding in the area. Factors such as loss of the tree root stabilising effect, alterations to surface and sub-surface water flows, alterations to the micro climate through deforestation, farming activities and construction of farm infrastructure have all probably played a role in the increase in occurrence of landslides in the region.

It should however be noted that the removal of trees in the 1950s has allowed much easier interpretation of large areas of the region through remote aerial interpretation. As such it is also possible that many previous slides may have been missed or not have been able to be assessed due to tree cover prior to the 1950’s and the baseline data should be viewed with this in mind.

However the ongoing increase in landslide occurrence after deforestation still strongly points to a significant anthropogenic initiator in this landscape.

4.6 Melba Parade Landslide at Anglesea

Location: Melba Parade, near Point Roadknight Anglesea

Landscape Zone: Thompsons

Target Area: NA

Area	Assessor	Mapping Methodology	Date of Photo used
Wild Dog Creek	GC Black and Associates	Single Photo Interpretation	1947
	GC Black and Associates	Single Photo Interpretation	1981
	GC Black and Associates	Single Photo Interpretation	1997

Table 9 Details of API methodology applied at the Melba Parade, Anglesea

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A

Comments:

Anecdotal evidence suggests the slide occurred around December 1973 after heavy rainfall. Whist this was a major movement event earlier aerial photo interpretation by GC Black and associates shows a smaller spatial extent of a “failed mass” in 1947. The interpreted landslide is shown without a major headscarp as associated with the 1973 event but it is clear previous movement had taken place at this location.

The 1973 movement probably indicates a major reactivation and significant retrogressive failure of the earlier slides resulting in a much enlarged headscarp extending southwards for some considerable distance.

Later aerial interpretation carried out on 1997 photos does not indicate any increase in the length of the headscarp nor does it indicate any further retrogressive migrations west towards Seventh Avenue. Field observations indicate a protective toe emplacement was constructed some time after the 1973 movement and this combined with improvements to site drainage and probable upgrades to the septic systems in the area may have been responsible for the relatively low level of ongoing movement at the site since 1973.

4.7 Lake Bullen Merri (Corangamite)

Location: Lake Bullen Merri, South west of Camperdown

Landscape Zone: Curdies/Stoney Rises

Target Area: NA

Area	Assessor	Mapping Methodology	Date of Photo used
Lake Bullen Merri (nr Camperdown)	Joyce and Evans	Active Landslides Only	1972
	Warren Feltham	Ortho Photo Interpretation	2004

Table 10 Details of API methodology applied at the Lake Bullen Merri

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

Landslides at Lake Bullen Merri were initially identified by Joyce and Evans in a bored paper on landslide activity in Victoria. The slides were observed and mapped in the field and occur on the steep slopes of a volcanic crater. Feltham later observed these slides during the ortho photographic mapping project carried out in 2005 at the University of Ballarat. A comparison of the two mapped inventories shows little change not withstanding the differences in data capture methods. Whilst some of the earlier features have degraded and been lost in the landscape the majority were identified by Feltham and there is no indication of any significant increase in landslide distribution over this 30 year period.

Whilst fresh, relatively active slides were observed by Feltham during field reconnaissance, these appear to be reactivations of previous slides or smaller slides occurring in the previously disturbed materials. The overall conclusion at this site is that landslide activity has been relatively constant over an extended period with few new slides occurring. This would suggest no land use modification or introduction of new triggering mechanisms and may indicate rainfall as the trigger in combination of the preparatory factors of steep slopes and susceptible geology.

4.8 Barham River Valley including Beauty Creek

Location: Barham River Valley near Apollo Bay

Landscape Zone: Otway Coast

Target Area: OC10

Area	Assessor	Mapping Methodology	Date of Photo used
Barham River Valley and Beauty Creek	Ian Roberts	Comprehensive Assessment	1991
	Ian Roberts	Active Landslides Only	2000

Table 11 Details of API methodology applied at the Barham River Valley

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

Only preliminary analysis work has been completed at this time with an initial aerial mapping assessment carried out by Ian Roberts on the 1991 set of aerial photos. This assessment indicates the presence of some very large features one of which is thought to have moved up to 10 metres during a local earthquake circa 1964. The Barham River valley has an abundance of older landslide features on both flanks and is typical of a landscape shaped through a process of ongoing mass movements.

Only very preliminary work has been completed on a set of aerial photos from 2000 and it is hoped this work can be completed in the upcoming years budget.

4.9 Barwon River at Birregurra

Location: West bank of the Barwon River near Birregurra

Landscape Zone: Upper Barwon

Target Area: UB6

Area	Assessor	Mapping Methodology	Date of Photo used
Wild Dog Creek	Ian Roberts	Comprehensive Assessment	1946
	Ian Roberts	To be completed	1969
	Ian Roberts	To be completed	1991
	Warren Feltham	Ortho Photo Interpretation	2000??

Table 12 Details of API methodology applied at the west bank of the Barwon River at Birregurra

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

Due to budget and time restraints only a single temporal window has been completed at this location. As such no comments regarding any trends can be made.

Comparisons with both inventory maps and the modelled susceptibility show excellent correlation with the aerial interpretation and it is hoped this study can be completed in the upcoming years program.

5. Erosion Trend Mapping Results

5.1 Background

As with landslide trend mapping, trend analysis mapping for erosion using temporal windows established from historical aerial photos has been used to establish data on the rates of spatial increase (or decrease). The process of analysis examines both gully erosion (including streambank erosion) and sheet/rill erosion. Study areas were again chosen from key target areas identified in an earlier field verification program conducted in August 2006 (see A.S. Miner Geotechnical Report Nos. 352.0/01/07 and 352.1/01/06).

An arbitrary boundary was assigned to each study area so that comparisons between the spatial extents of erosion could be more accurately made by comparing similar areas at different times. In addition estimates of length per area (i.e. km/km2) and length of gully per total stream length (i.e. km/km) have also been calculated for gully erosion. Study areas have been defined as simple rectangular type polygons encompassing the extents of the mapped erosion and allowing estimates of both erosion and stream length in a study area.

The following sections provide a summary of results from the historical trend analysis mapping conducted for each site. A brief overview of the analysis and additional comments are also provided.

5.2 Misery Moonlight

Location: Misery Moonlight Creek, Berringa

Landscape Zone: Woady Yalloak

Target Area: WY1

Area	Assessor	Mapping Methodology	Date of Photo used
Misery Moonlight Creek	Ian Roberts	Erosion Activity Method	1970
	Ian Roberts	Erosion Activity Method	2000

Table 13 Details of API methodology applied at Misery Moonlight Creek.

Results:

Misery Moonlight Sheet-Rill Erosion Trend Analysis				
Date	**Count** *(polygons)*	**Area** *(ha)*	**% Change from 1970**	**% Study Area**
1970	90	248.37	0.0%	1.4%
2000	121	284.04	14.4%	1.6%
Study Area		***17,968.00***		

Misery Moonlight Gully and Streambank Erosion Trend Analysis					
Date	**Count** *(polylines)*	**Length** *(metres)*	**% Change from 1970**	**km Gully per km Stream Length in Study Area**	**km Gully per sq km Study Area**
1970	188	38,268	0.0%	0.07	0.21
2000	300	55,060	43.9%	0.10	0.31
Total Stream Length within Study Area		***571,074***			

Table 14 Results of Trend Mapping for Misery Moonlight Creek

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A

Comments:

The study area is located within one of the state's most degraded areas. Due to a shortage of earlier quality aerial photos at a suitable scale, a start date of 1970 was adopted for this analysis. An assessment of both sheet/rill erosion and gully/streambank erosion was carried out over two sets of photos (1970 and 2000).

Whilst sheet and rill erosion was found to be less prevalent than indicated on the modelled susceptibility maps, gully and streambank erosion were found to have increased significantly over the study period and correlates well with modelled susceptibility. Whilst sheet and rill erosion was found to have only increased by 14% over the 30 year study window, gully and streambank erosion has increased by approximately 44%. This has since been confirmed through on site inspections and the initiation of remedial works within the region.

Aggressive farming practices are thought to have been the major source of ongoing erosion in this region and much work has been directed into the area in the past 10 years to address land management issues.

It is hoped further analysis can be conducted on later photos to asses the effectiveness of improved land management practices.

5.3 Eclipse Creek

Location: Eclipse Creek north east of Meredith

Landscape Zone: Moorabool

Target Area: M1

Area	Assessor	Mapping Methodology	Date of Photo used
Eclipse Creek	Ian Roberts	Erosion Activity Method	1985
	Ian Roberts	Erosion Activity Method	2000

Table 15 Details of API methodology applied at Eclipse Creek

Results:

Eclipse Creek Sheet-Rill Erosion Trend Analysis				
Date	**Count** *(polygons)*	**Area** *(ha)*	**% Change from 1985**	**% Study Area**
1985	93	150.90	0.00	1.4%
2000	205	407.74	170.2%	3.8%
Study Area		***10,839.68***		

Eclipse Creek Gully and Streambank Erosion Trend Analysis					
Date	**Count** *(polylines)*	**Length** *(metres)*	**% Change from 1985**	**km Gully per km Stream Length in Study Area**	**km Gully per sq km Study Area**
1985	169	34,125	0.00	0.10	0.31
2000	205	38,379	12.5%	0.11	0.35
Total Stream Length within study area		***353,024***			

Table 16 Results of Trend Mapping for Eclipse Creek

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A.

Comments:

The Eclipse Creek study area straddles the municipal boundary between Moorabool Shire and Golden Plains Shire and is located within geologic deposit highly susceptible to erosion. Again a lack of quality aerial photos meant the initial temporal study only spanned 15 years from 1985 to 2000.

Despite this short time frame, results showed significant increases in sheet and rill erosion with rates of increase exceeding 170% over 15 years. Gully and streambank erosion only marginally increased over this period with an increase in linear length of erosion of the order of 12%.

The results compare very well with both inventory and susceptibility maps. In particular the sheet and rill susceptibility for the area is shown to be moderate-high to high and is a good indicator of the potential for ongoing erosion which in turn is reflected in the results.

Similar to the misery moonlight area, aggressive land management practices in the past have contributed to ongoing and in fact, increasing rates of erosion. There is now a strong indication that this area will require continuing priority action to address the erosion potential.

5.4 Shelford-Mt Mercer Rd

Location: The Shelford Mt Mercer Road near Shelford

Landscape Zone: Leigh

Target Area: L4

Area	Assessor	Mapping Methodology	Date of Photo used
Shelford-Mt Mercer Rd	Ian Roberts	Erosion Activity Method	1970
	Ian Roberts	Erosion Activity Method	2000

Table 17 Details of API methodology applied at Shelford-Mt Mercer Rd Shelfrod.

Results:

Shelford-Mt Mercer Sheet-Rill Erosion Trend Analysis				
Date	**Count** *(polygons)*	**Area** *(ha)*	**% Change from 1970**	**% Study Area**
1970	52	1,472.55	0.00	5.8%
2000	83	683.98	-53.6%	2.7%
Study Area		***25,316.01***		

Shelford-Mt Mercer Gully and Streambank Erosion Trend Analysis					
Date	**Count** *(polylines)*	**Length** *(metres)*	**% Change from 1970**	**km Gully per km Stream Length in Study Area**	**km Gully per sq km Study Area**
1970	251	71,693	0.00	0.15	0.28
2000	209	44,957	-37.3%	0.09	0.18
Total Stream Length within Study Area		***478,680***			

Table 16 Results of Trend Mapping for Shelford Mt Mercer Rd

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A

Comments:

The Shelford-Mt Mercer study area is situated in between the Misery Moonlight study area to the west and the Eclipse Creek area to the north east. Susceptibility maps for the area generally show a slightly less susceptible region but still with moderate potential along the drainage lines and creeks.

Results from this study showed a decrease in the spatial extent of both sheet/rill erosion (-53%) and gully/streambank erosion (-37%).The 30 year study period is similar in span to the Misery Moonlight area with the same baseline starting date in 1970.

The reasons for such a decline are as yet unresolved although it has been postulated that this area may have been more active in erosion control and remediation projects and as such this may account for the observed decrease in erosion.

It is recommended that detailed on ground assessments be carried out to further assess the reasons for this result. It is hence possible that valuable lessons may be learnt from any revised land use practice implemented in this region over the past 30 years.

5.5 Yeodene Barongarook (Boundary Creek)

Location: Boundary Creek in the Yeodene-Barongarook area

Landscape Zone: Upper Barwon

Target Area: NA

Area	Assessor	Mapping Methodology	Date of Photo used
Yeodene Barongarook	Ian Roberts	Trial comprehensive Erosion method	1946
	Ian Roberts	Trial comprehensive Erosion method	2004

Table 17 Details of API methodology applied at Boundary Creek

Results:

Yeodene-Barongarook Gully and Streambank Erosion Trend Analysis					
Date	**Count** *(polylines)*	**Length** *(metres)*	**% Change from 1946**	**km Gully per km Stream Length in Study Area**	**km Gully per sq km Study Area**
1946	14	2,899	0.00	0.03	0.06
2004	93	27,617	852.5%	0.27	0.53
Study Area		***5,177.47***			

Total Stream Length within Study Area	***102,056***

Table 18 Results of Trend Mapping for boundary Creek

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A

Comments:

The Yeodene study area was one of the first areas to which this trial erosion trend mapping methodology was applied. Although the area is located within a low susceptibility area, significant increases in gully/ streambank erosion were observed form 1946 to 2004. The length of gully and streambank erosion has increased over 800% in the study area going from being negligible to now being considered moderate to high based on the parameter of km of gully erosion per sq km of study area.

The most significant trigger for this erosion has undoubtedly been land use change and anthropogenic influences. Early aerial photos show the area to be heavily forested and minimal erosion was evident. The area was later cleared to provide pasture and habitable space and increased levels of erosion are clear on the 2004 aerial photos. It is likely increased runoff and drainage have significantly contributed to increased flows in the boundary creek while possible groundwater changes may also have increased streambank erosion.

5.6 Illabarook

Location: Pitfield Illabarook area

Landscape Zone: Woady Yalloak

Target Area: WY2

Area	Assessor	Mapping Methodology	Date of Photo used
Illabarook	Warren Feltham	Orth Photo interpretation	1970
	Warren Feltham	Orth Photo interpretation	1981
	Warren Feltham	Orth Photo interpretation	1990
	Warren Feltham	Orth Photo interpretation	2004

Table 19 Details of API methodology applied at Illabarook

Results:

Illabarook Sheet-Rill Erosion Trend Analysis				
Date	**Count** *(polygons)*	**Area** *(ha)*	**% Change from 1970**	**% Study Area**
1970	42	77.05	0.0%	1.0%
1981	48	236.08	206.4%	3.2%
1990	32	106.67	38.4%	1.4%
2004	59	200.61	106.36	2.36%
Study Area		***7,466.51***		

Illabarook Gully and Streambank Erosion Trend Analysis					
Date	**Count** *(polylines)*	**Length** *(metres)*	**% Change from 1970**	**km Gully per km Stream Length in Study Area**	**km Gully per sq km Study Area**
1970	75	33,727	0.00	0.28	0.45
1981	84	38,977	15.6%	0.33	0.52
1990	66	35,610	5.6%	0.30	0.48
2004	141	29,970	-11.14%	0.25	0.40
Total Stream Length within Study Area		***118,727***			

Table 20 Results of Trend Mapping for Illabarook

Note: The historical aerial photo interpretation is also presented in plan format in Appendix A

Comments:

This study was conducted by Warren Feltham at the University of Ballarat in 2005 as part of his honours thesis. The assessment was conducted on non stereo ortho photos and as such is not considered to be as accurate as the studies by Ian Roberts.

Results show a variable response with the extent of both sheet and gully erosion fluctuating between successive temporal photos. The initial baseline photos were flown in 1970 with the first comparison in 1981 during an extended dry period. It is postulated that due to the non stereo assessment techniques adopted, the extent of erosion in 1981 may have been overestimated due to vegetation die off and exposure of bare earth which may not be indicative of erosion features.

A comparison between the initial spatial extent of baseline erosion and that assessed from the 1990 aerial photos was of a similar area in 1990 but was again observed to expand again in 2004.

It is recommended that this particular study area be re-assessed using the detailed Ian Roberts stereo method and as such the current analysis should be viewed cautiously.

Not withstanding the above limitations, the assessment of the Illabarook area appears to have similarities to the Misery Moonlight area located just to the north when viewed over the 30 year period starting in 1970. The rates of increase over this longer period appear to be moderate but still indicate a significant overall amount of erosion. Land use and previous land management are considered to be major factors in both the extent and ongoing rates of erosion within this study area and the Misery Moonlight area to the north.

6. Comments and Discussion

The results of trend analysis detailed in this report provide valuable insight into the rates of occurrence of both landslide and erosion throughout the Corangamite region. Whilst the assessment methodology has been developed as the project has progressed, it is clear that quality and scale of the aerial photos play a role in the ability of the assessor to accurately interpret the spatial extent and nature of both erosion and to a lesser degree landslides. The use of non-stereo interpretation presents further problems and results from this technique should be viewed cautiously.

The results from the various study areas vary widely in the extent and rate of increase in the occurrences of erosion and landslide. In fact in some cases such as erosion in the Shelford-Mt Mercer Road area, both sheet and gully erosion were observed to decrease.

Land use and land management also appear to play significant roles in the rates at which these hazards are observed to be changing. Deforestation in the Heytesbury and the introduction of intensive dairying activities are thought to be the major initiators for the extreme rates of increase in landsliding in this region. Similarly removal of native vegetation and land use change in the Yeodene -Barongarook area has probably accelerated gully and streambank erosion in a region where very little existed before these changes.

It is recommended that the current studies be extended where possible to include a common baseline starting date. The early black and white photos form 1946 are an excellent reference set and should be used in all assessments where possible. Whilst the use of black and white laser copies of photos held by the state archives has allowed an economical approach for assessment in a wide range of sites during this study, it is recommended that actual sets of contact prints be used wherever available.

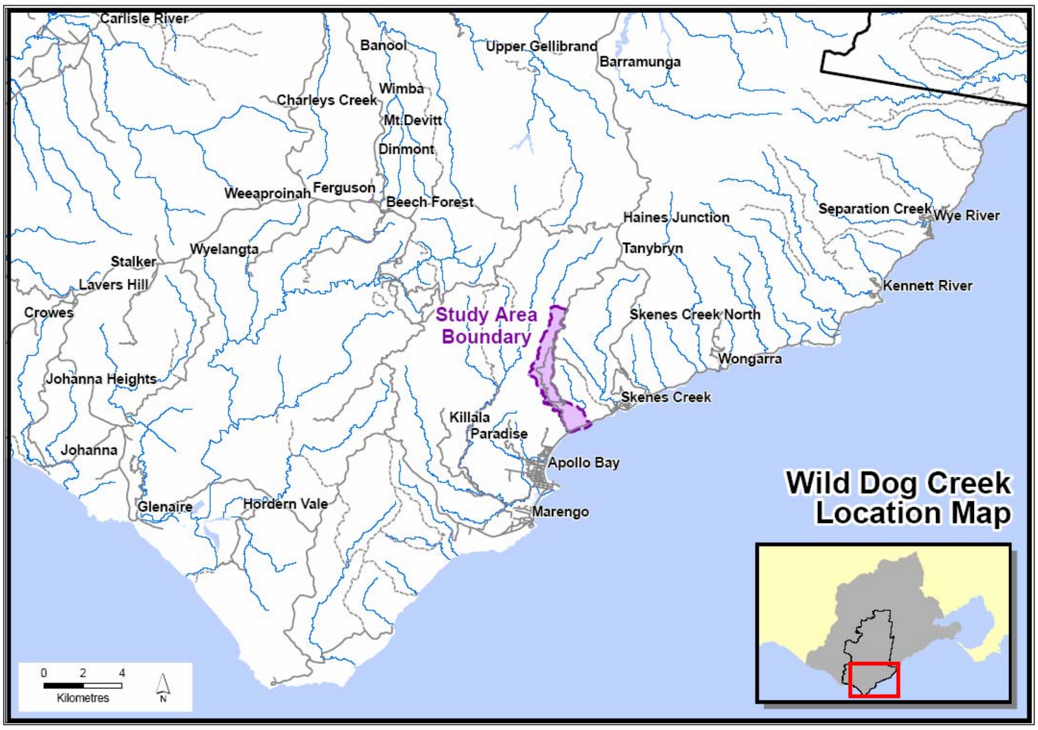
The influence of prevailing climatic conditions has been postulated in some of the studies (i.e.Illabarook). Dry and drought periods may accentuate loss of ground vegetation and bare earth and the interpretation of the extent and nature of erosion appears to be more difficult. The correlation of climatic conditions with aerial photo dates should be considered further in future works.

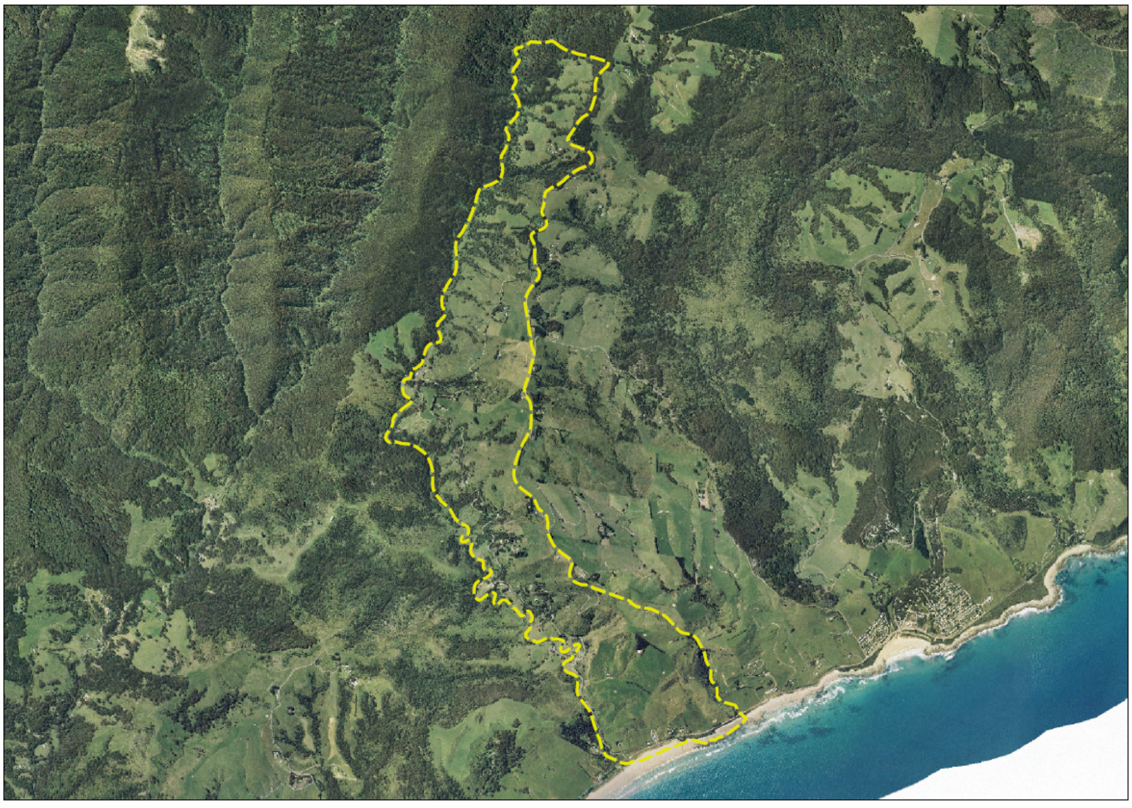
The use of this trend assessment methodology has proven to be a viable method and should be useful in the assessment of the likelihood component of any landslide and/or erosion risk assessment. The continuation of this project is highly recommended for future soil health programs

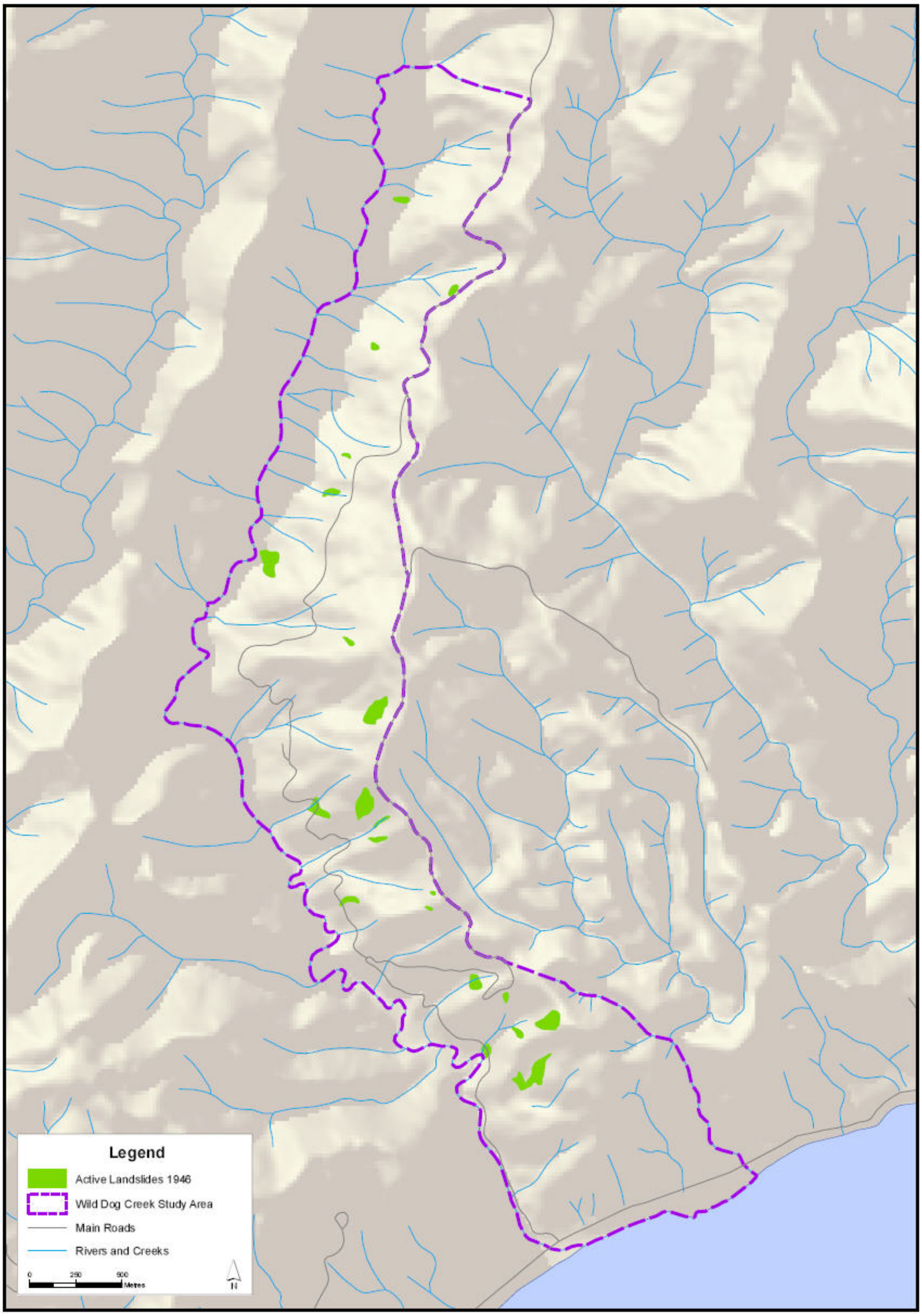
Landslide Trend Mapping Results

Plans of Temporal Windows.

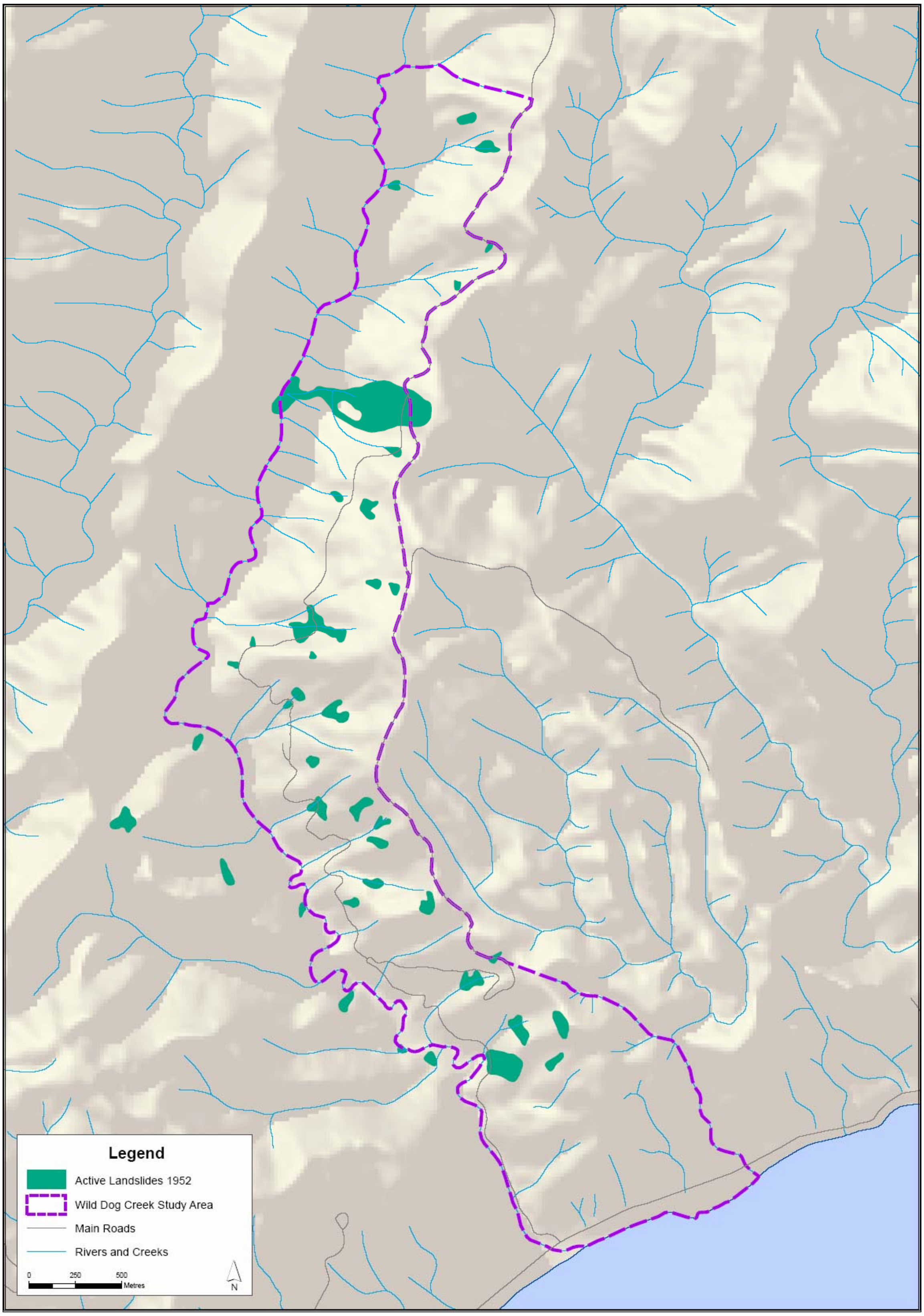
Wild Dog Creek Valley



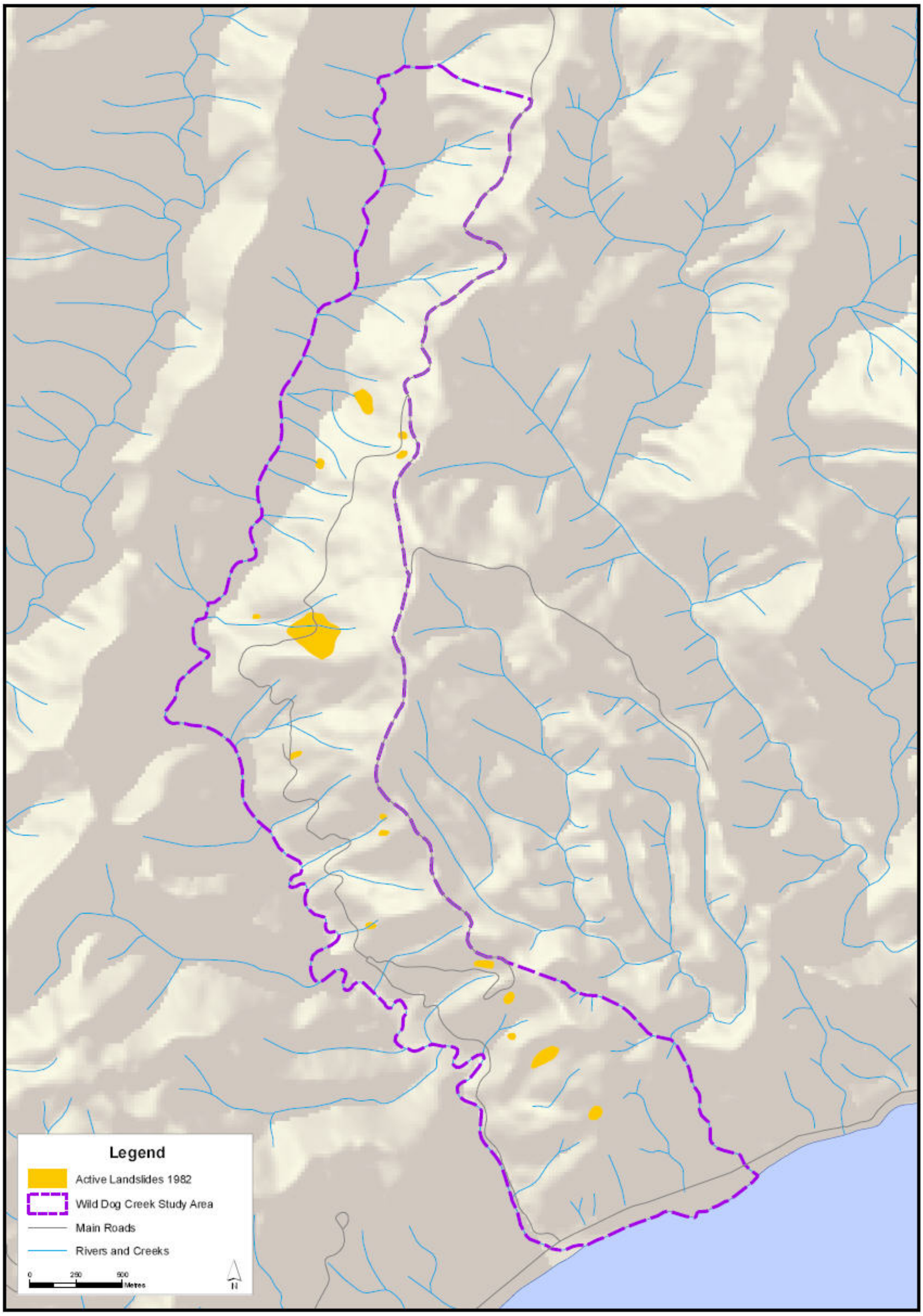




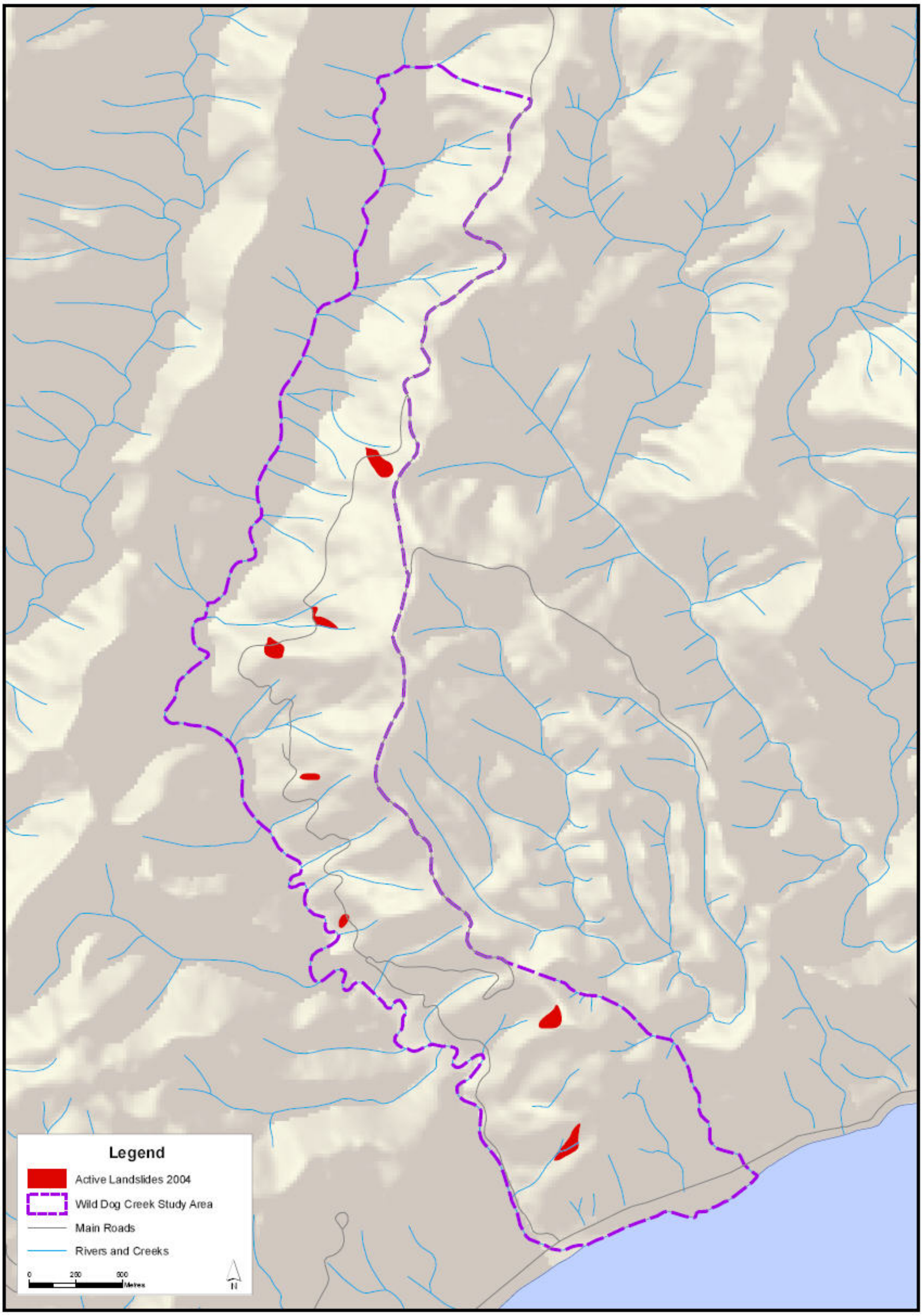
Wild Dog Creek 1946 (Roberts 2006)



Wild Dog Creek 1952 (Roberts 2006)

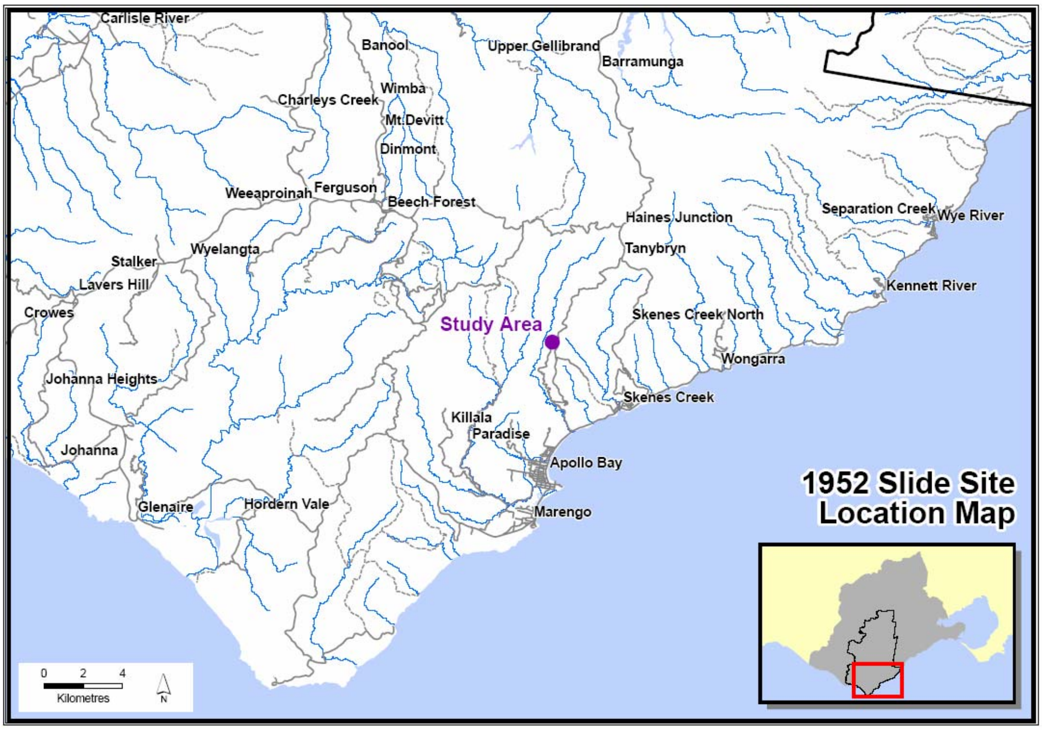


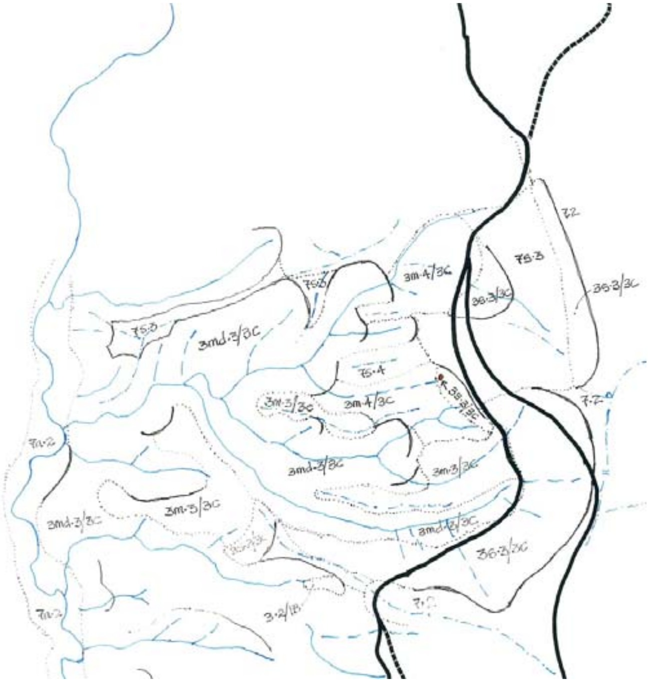
Wild Dog Creek 1982 (Roberts 2006)



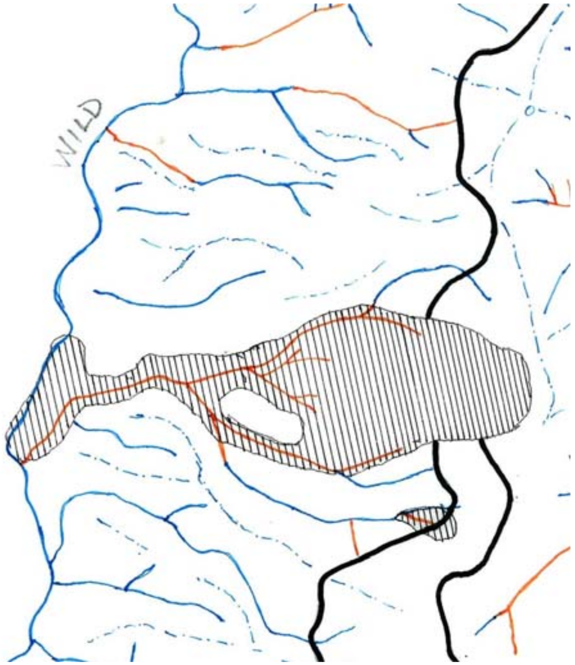
Wild Dog Creek 2004 (Roberts 2006)

The “1952 Slide” in the Wild Dog Creek Valley

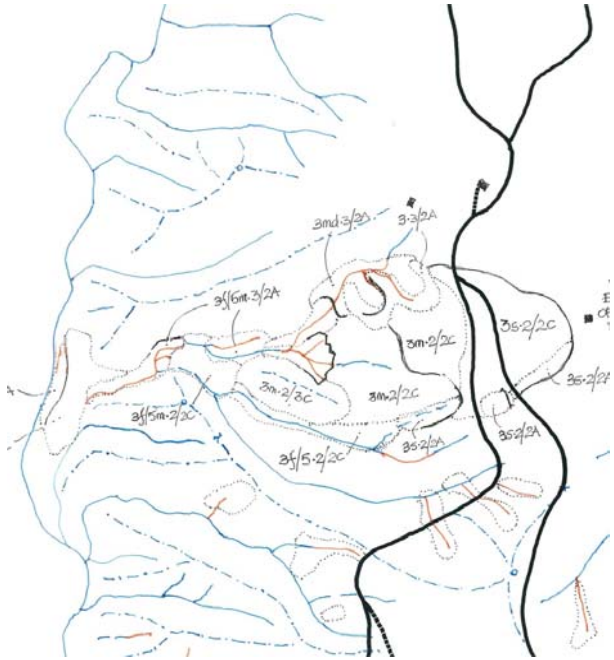




1952 Slide 1946 (Roberts 2006)

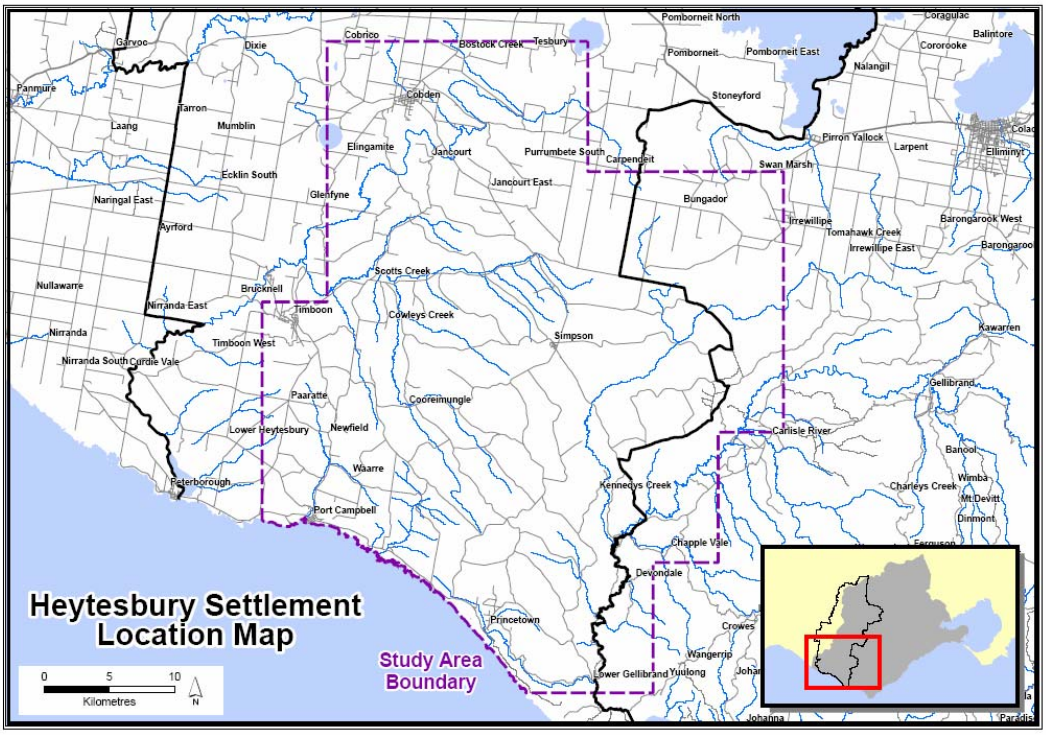


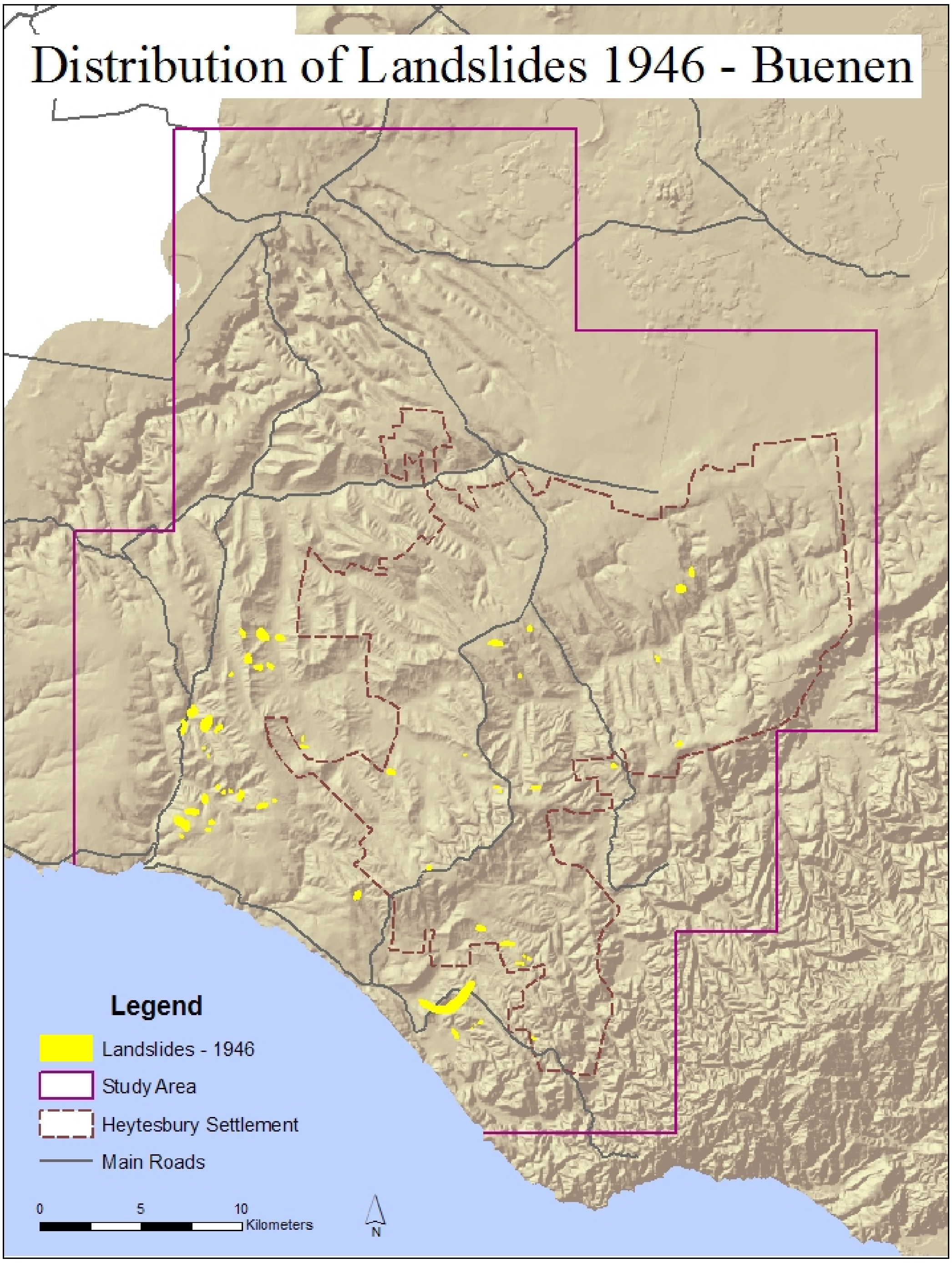
1952 Slide 1952 (Roberts 2006)



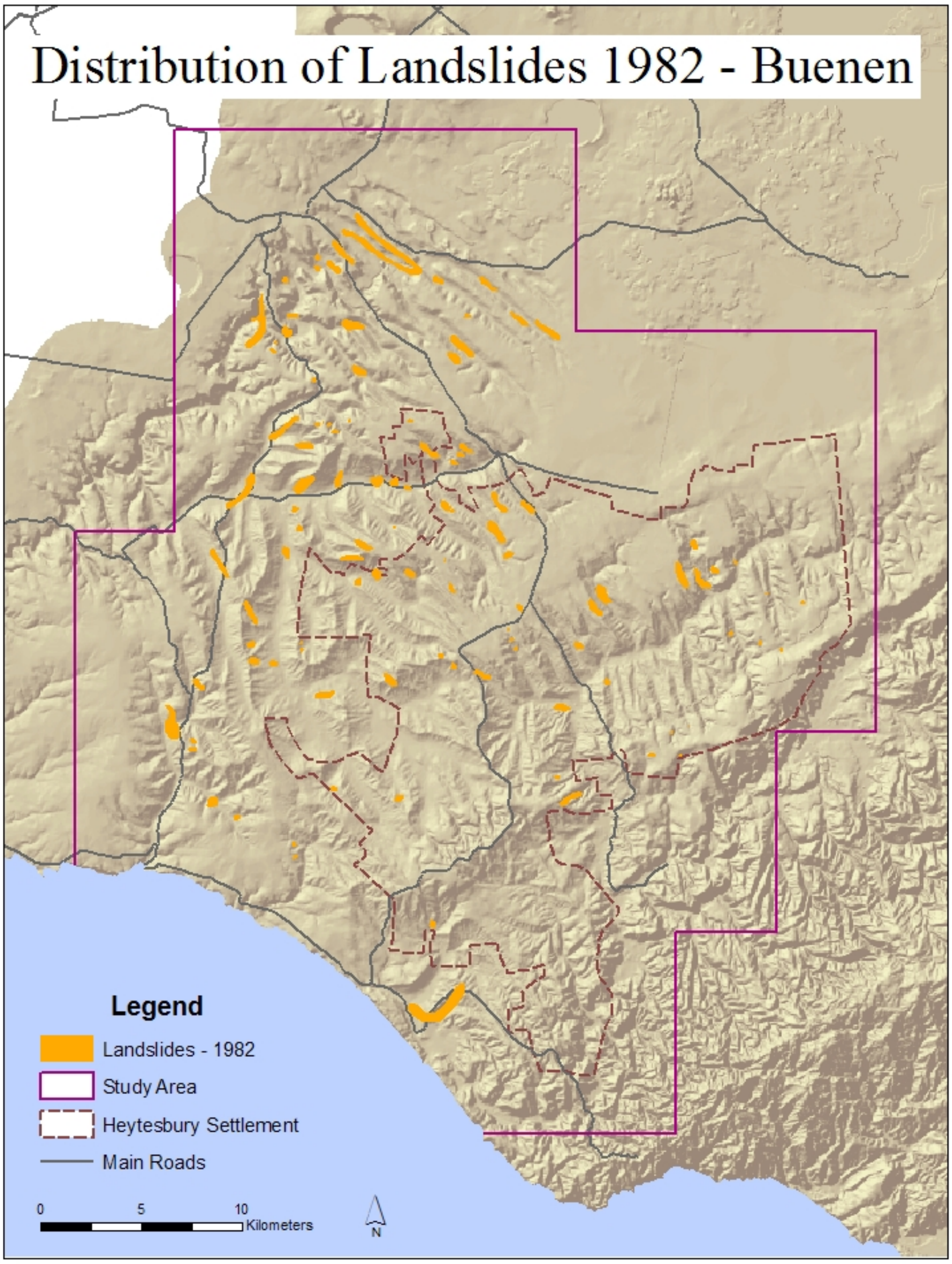
1952 Slide 1980 (Roberts 2006)

The Heytesbury Settlement

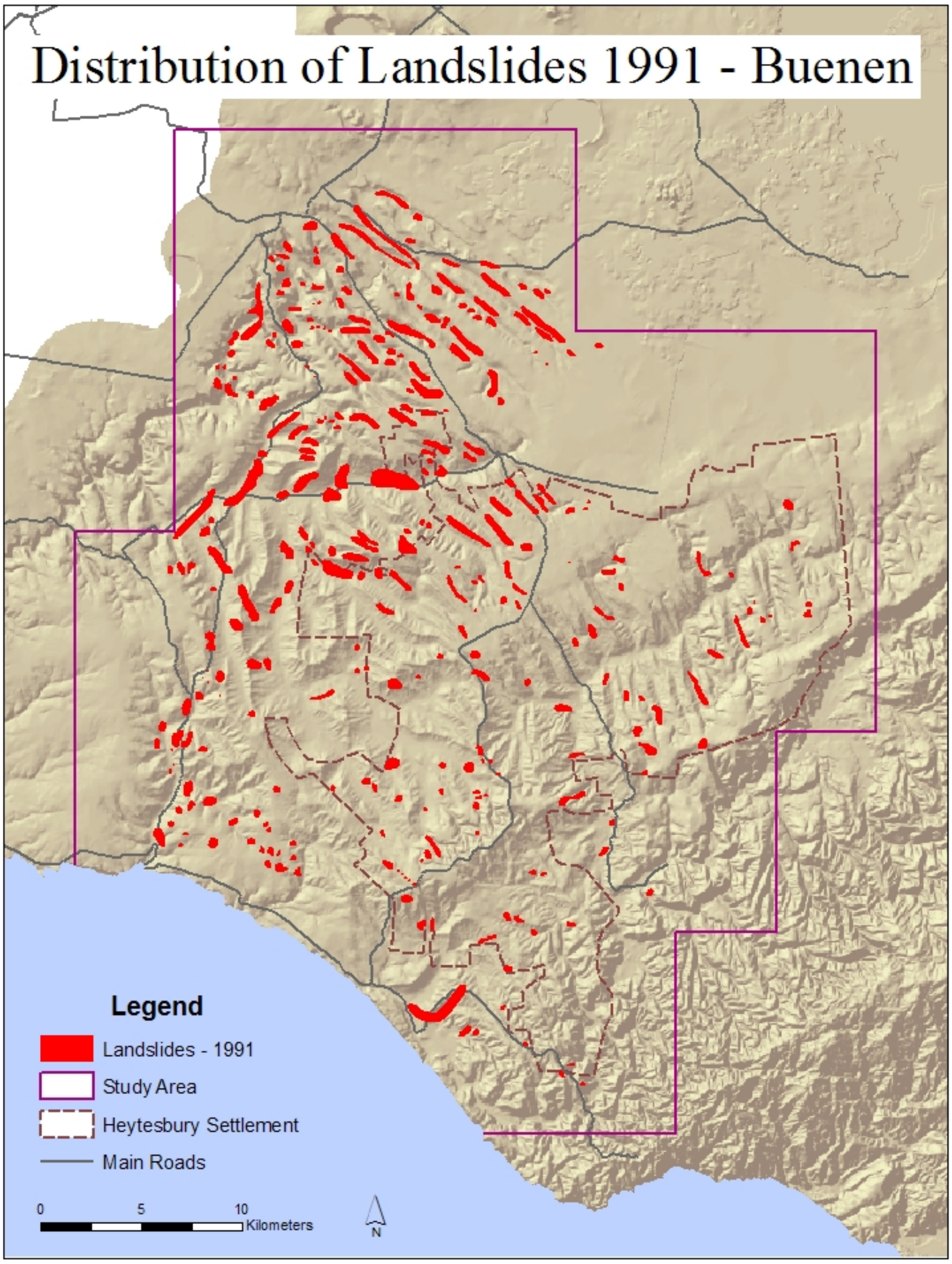




Heytesbury 1946 (Buenen 1995)

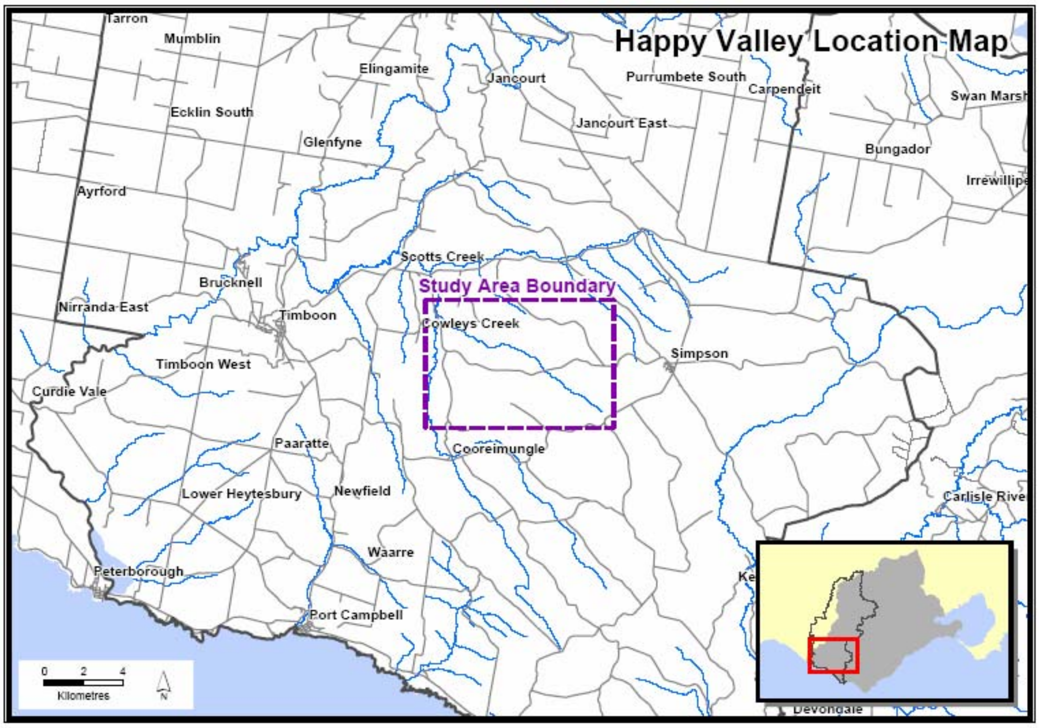


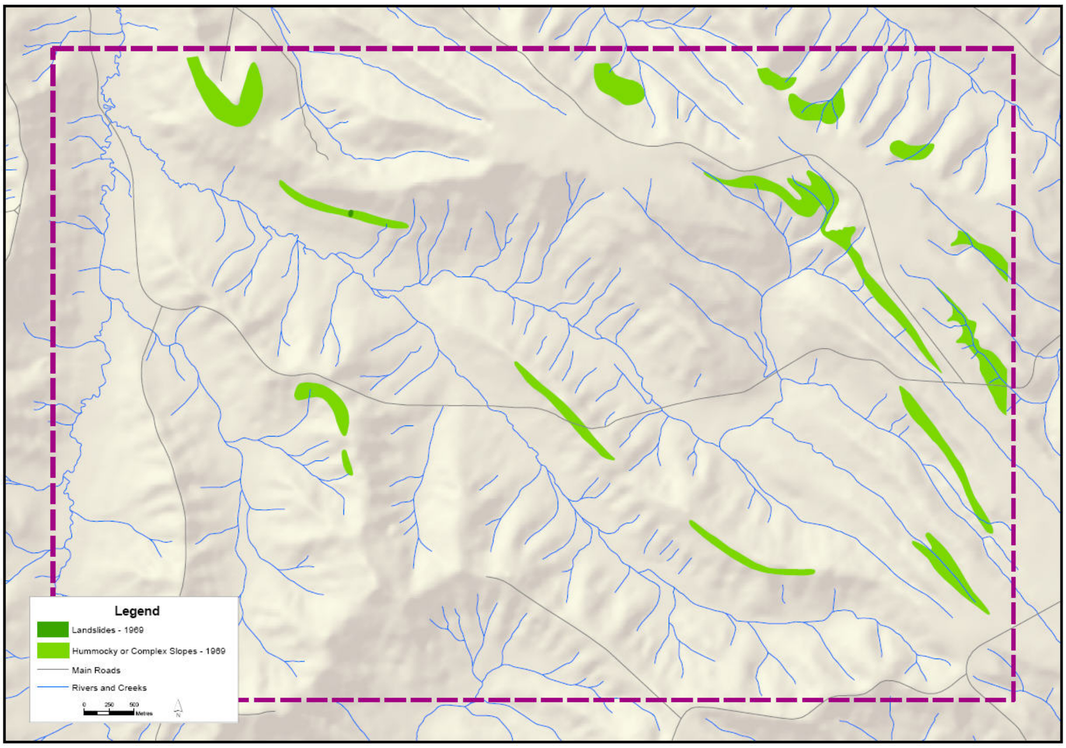
Heytesbury 1982 (Buenen 1995)



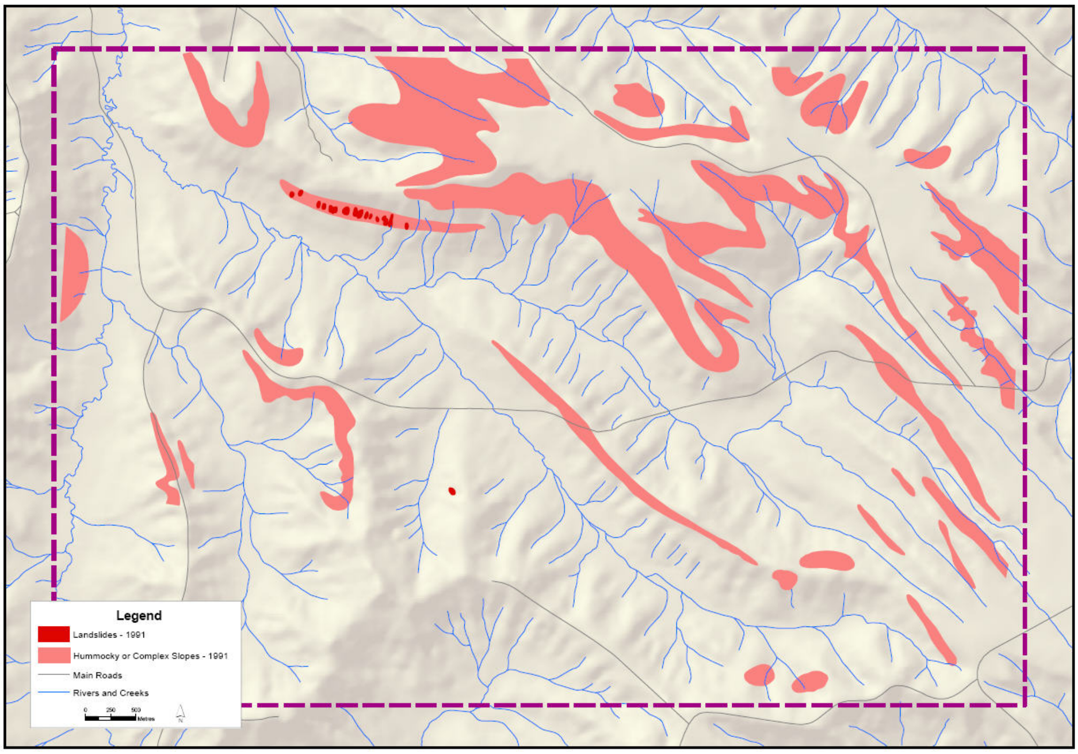
Heytesbury 1991 (Buenen 1995)

Happy Valley (Scotts Creek in the Heytesbury)



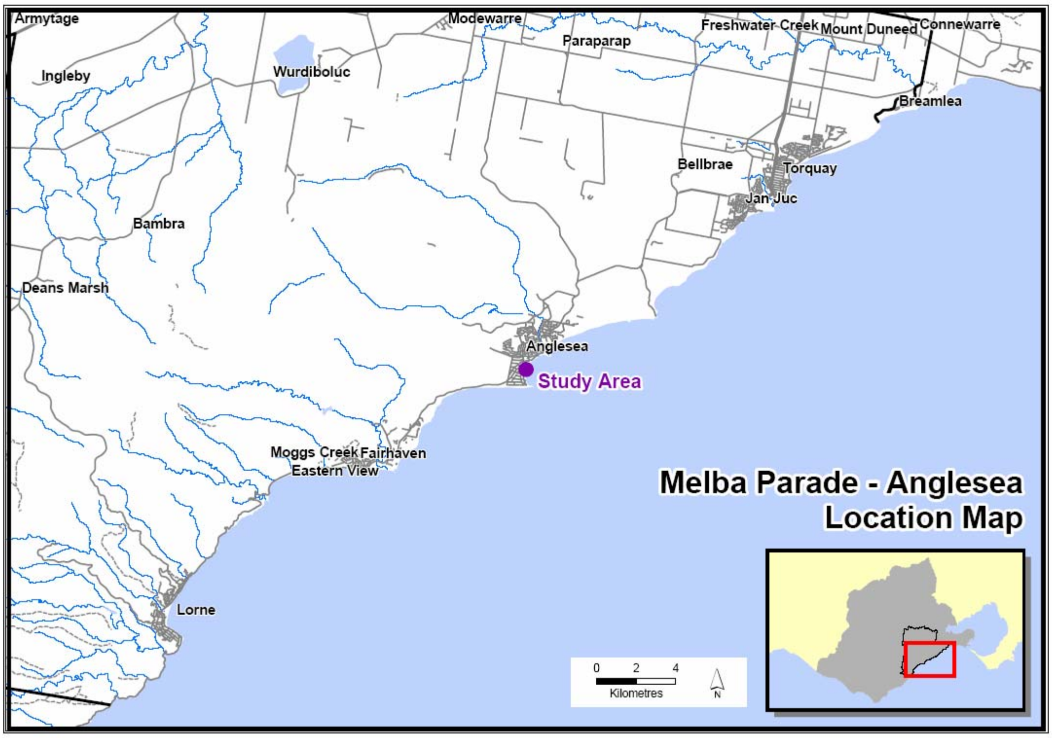


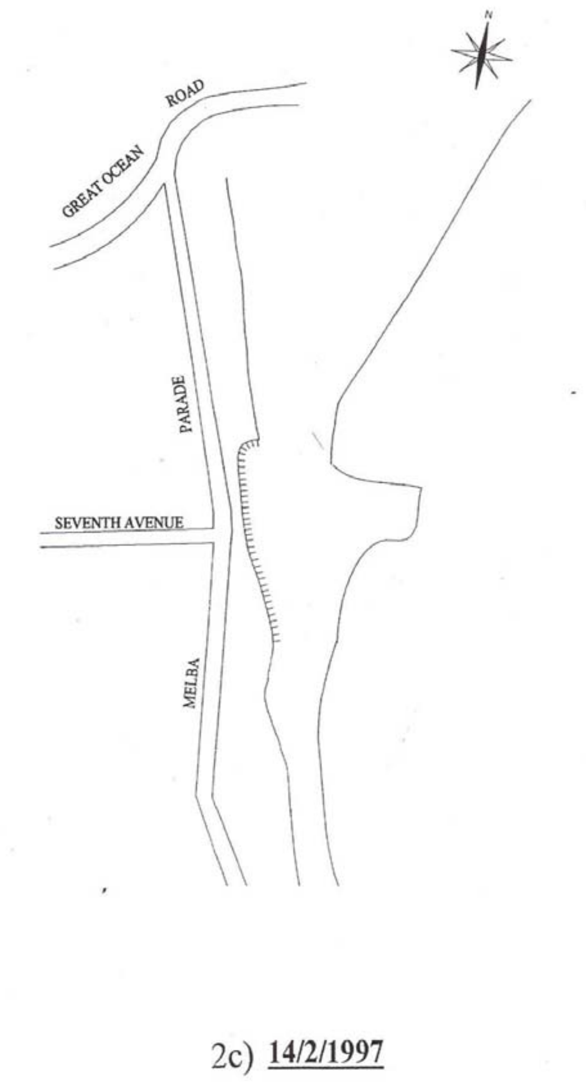
Happy Valley 1969 (West 1993)

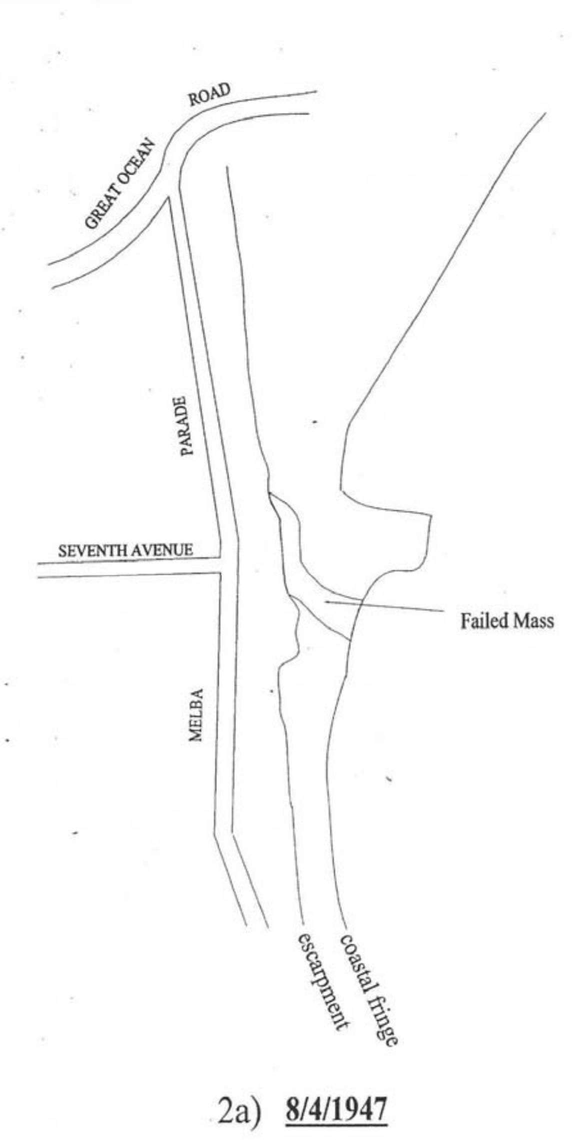


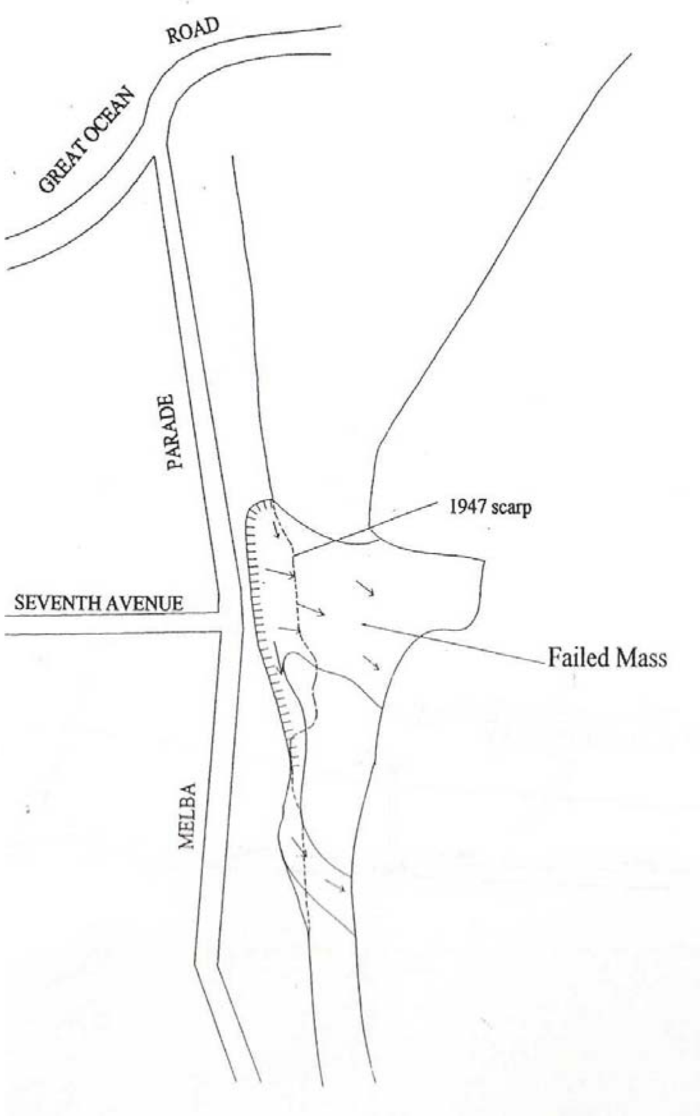
Happy Valley 1991 (West 1993)

Melba Parade Landslide at Anglesea



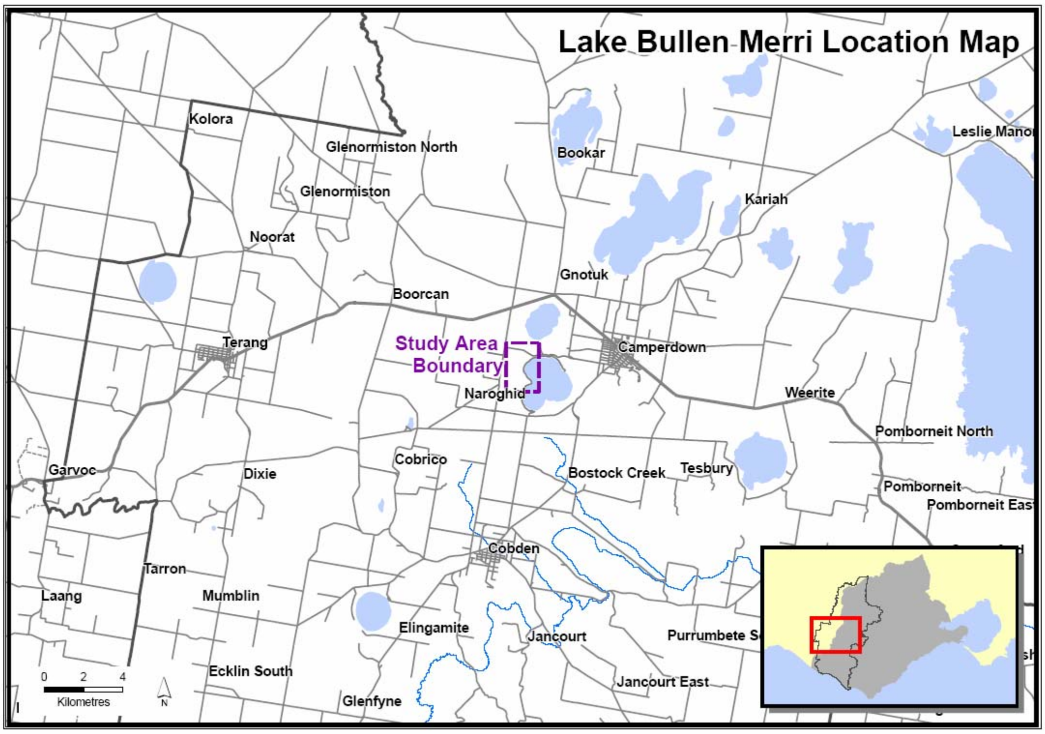


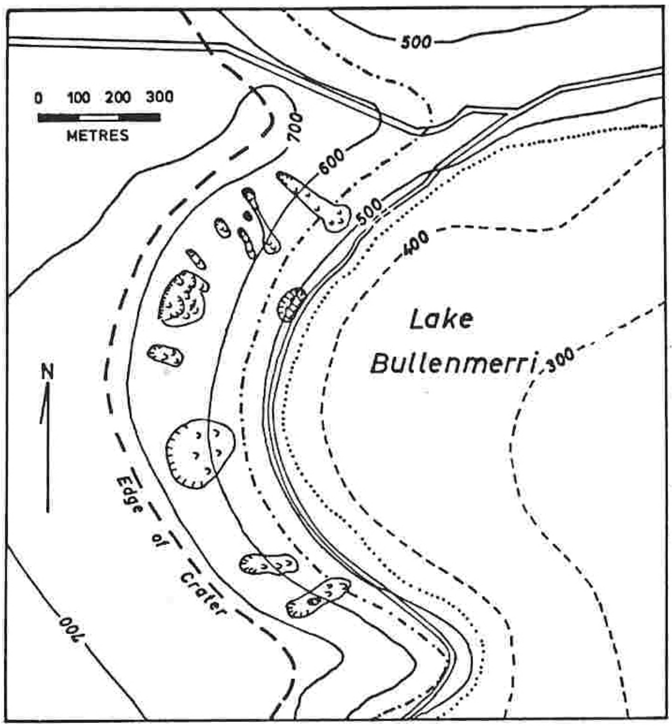




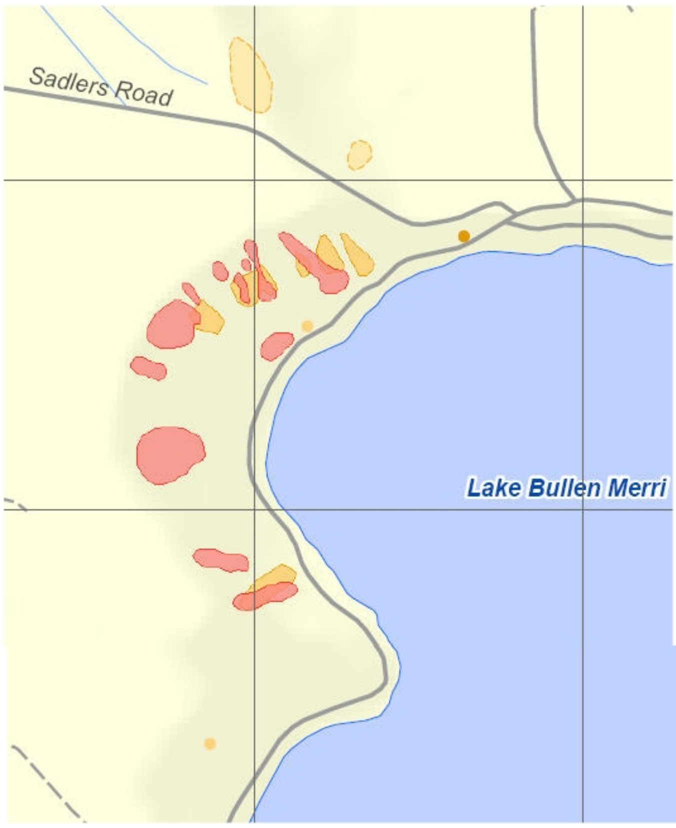
Melba Pde 1947 (GC Black 1997) **Melba Pde 1977 (GC Black 1993)** **Melba Pde 1997 (GC Black 1993)**

Lake Bullen Merri (at Camperdown)



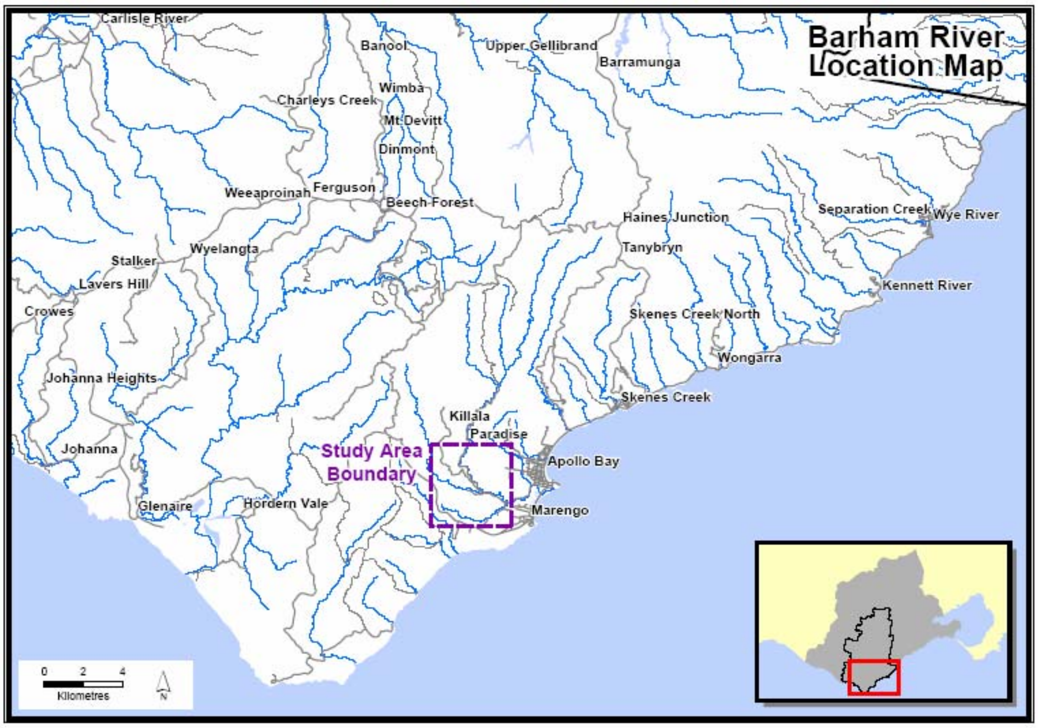


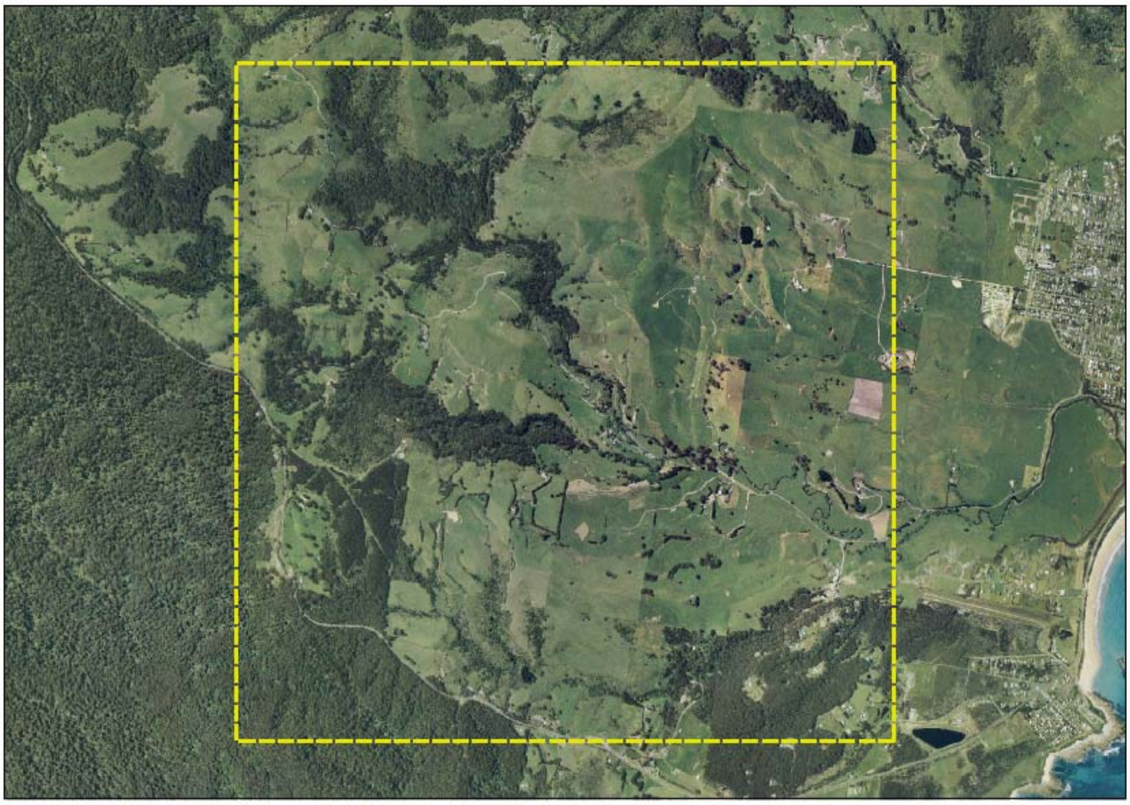
Lake Bullen Merri 1973 (Joyce and Evans 1973)

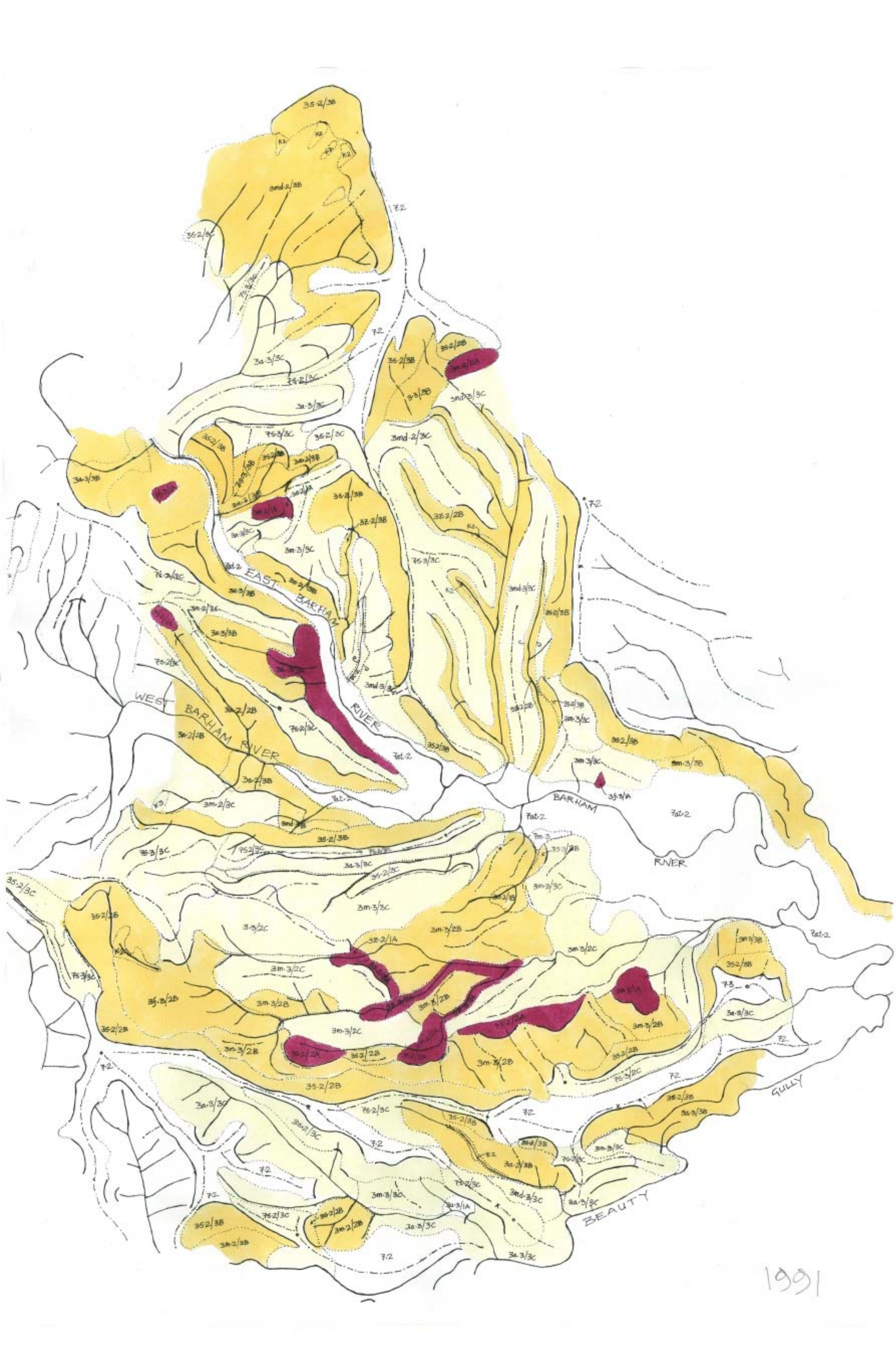


Lake Bullen Merri 2007 (CCMA Inventory 2007)

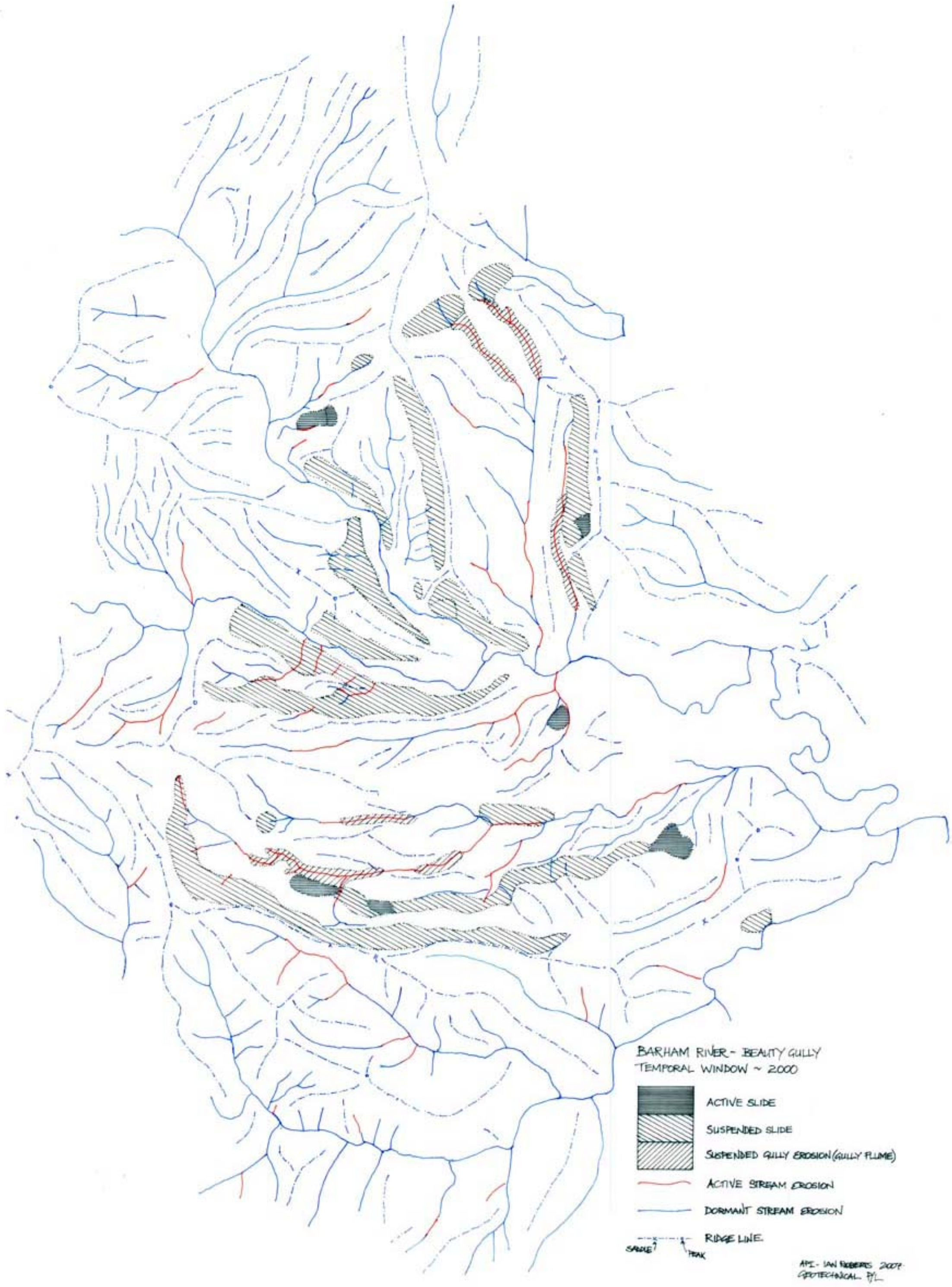
Barham River Valley and Beauty Creek





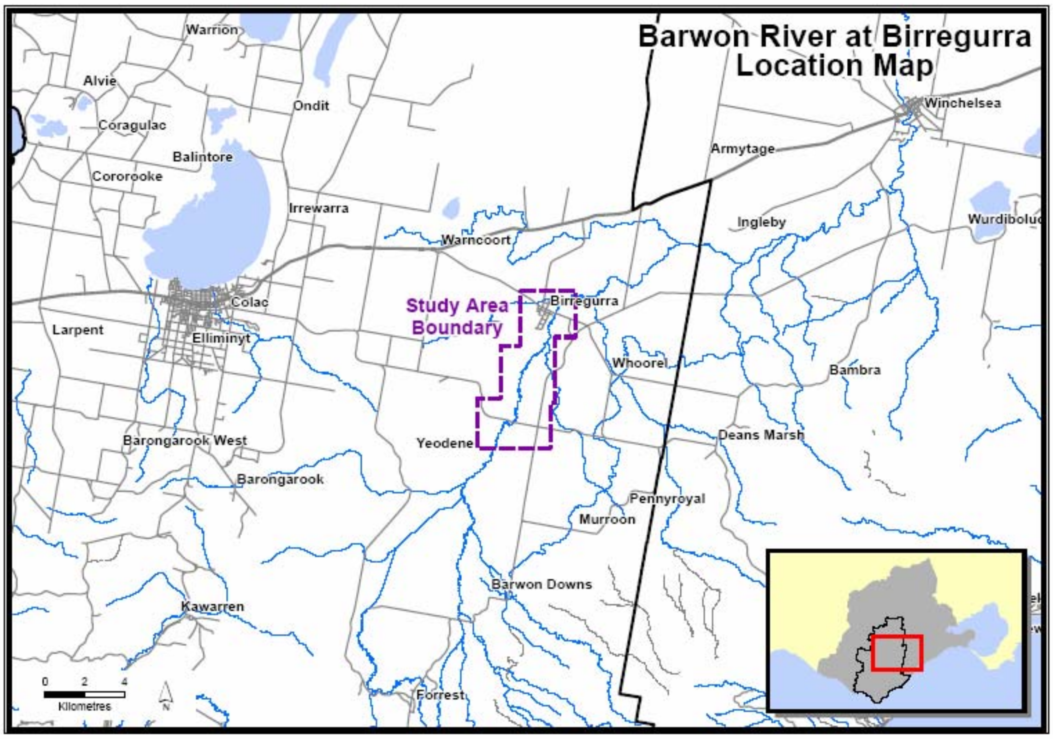


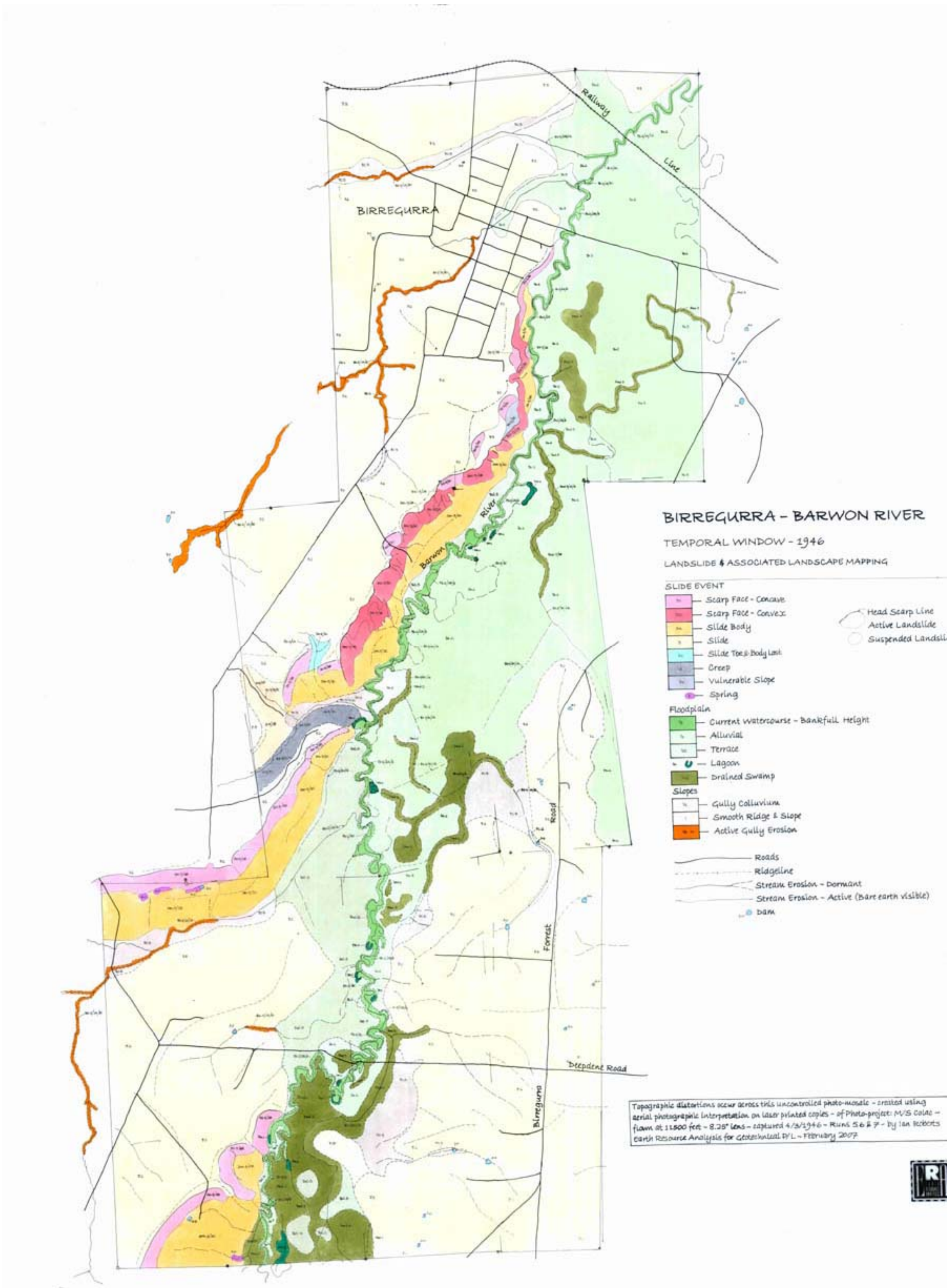
Barham River 1991 Preliminary (Roberts 2007)



Barham River 2000 Preliminary (Roberts 2007)

Barwon River at Birregurra



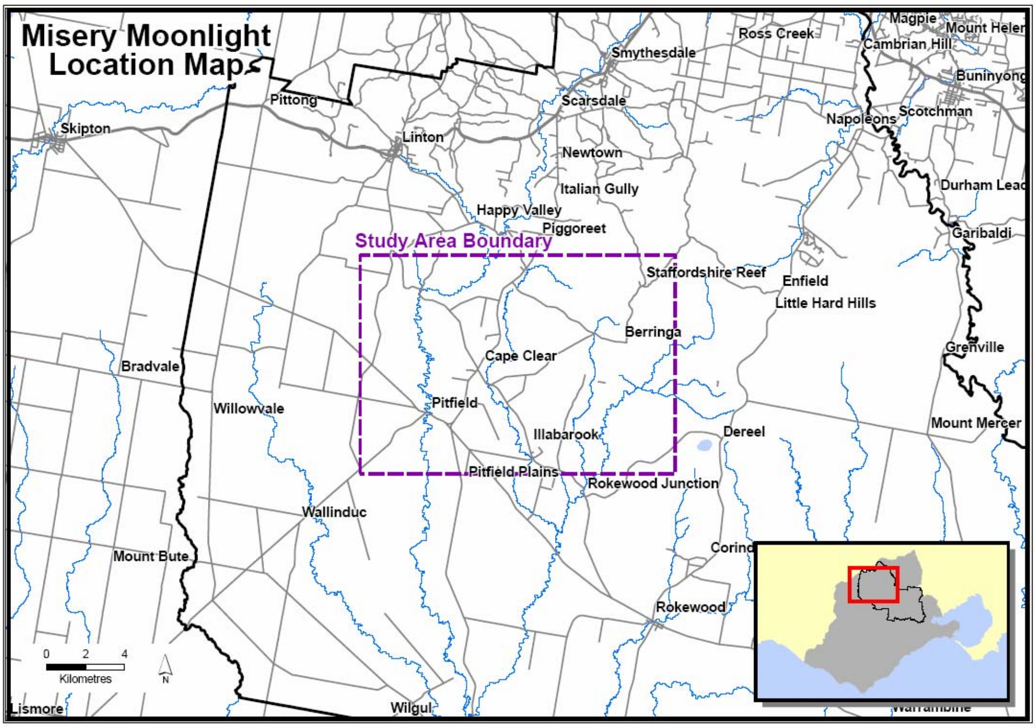


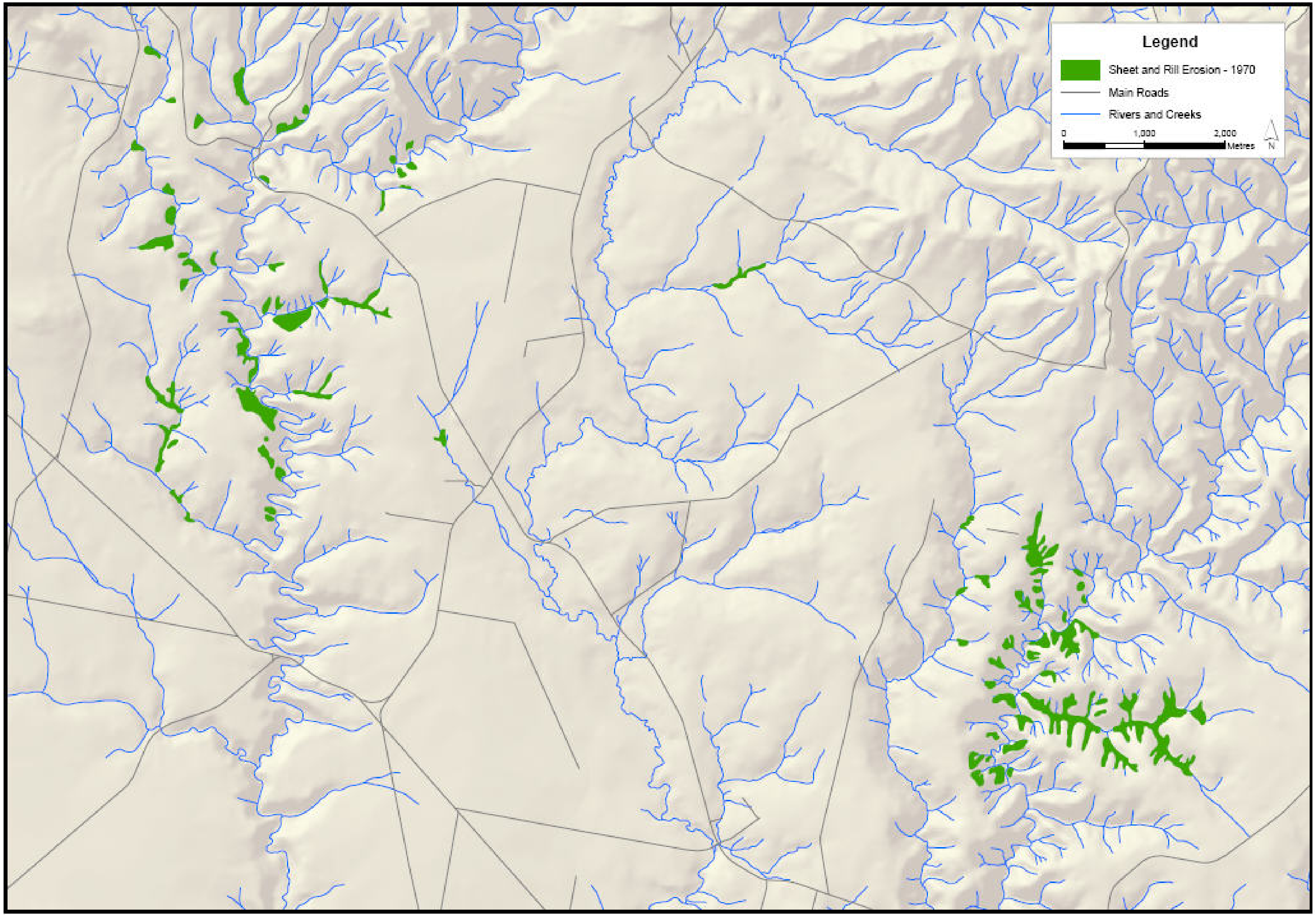
Barwon River at Birregurra 1946 (Roberts 2007)

Appendix A

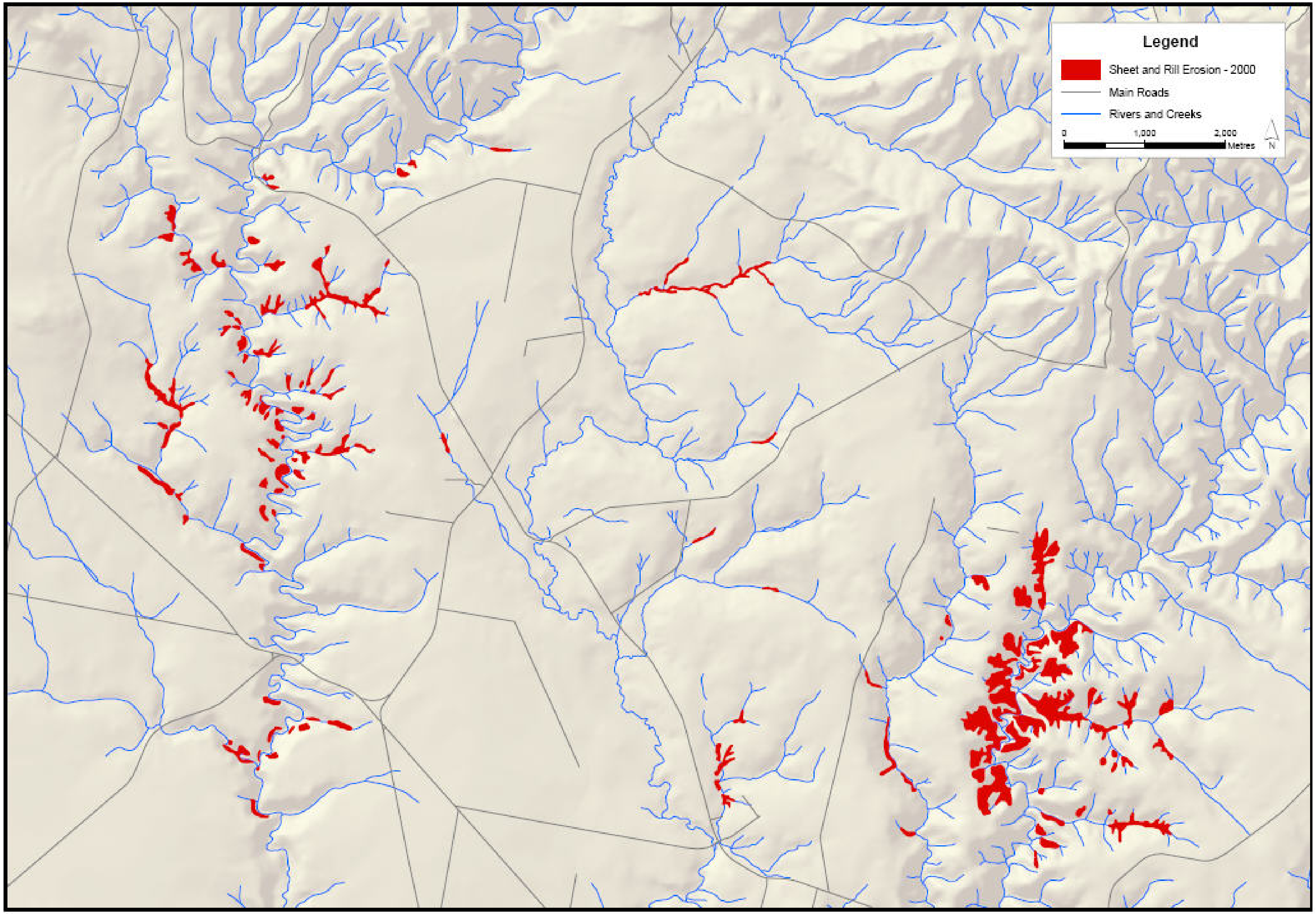
Erosion Trend Mapping Results

Misery Moonlight Creek

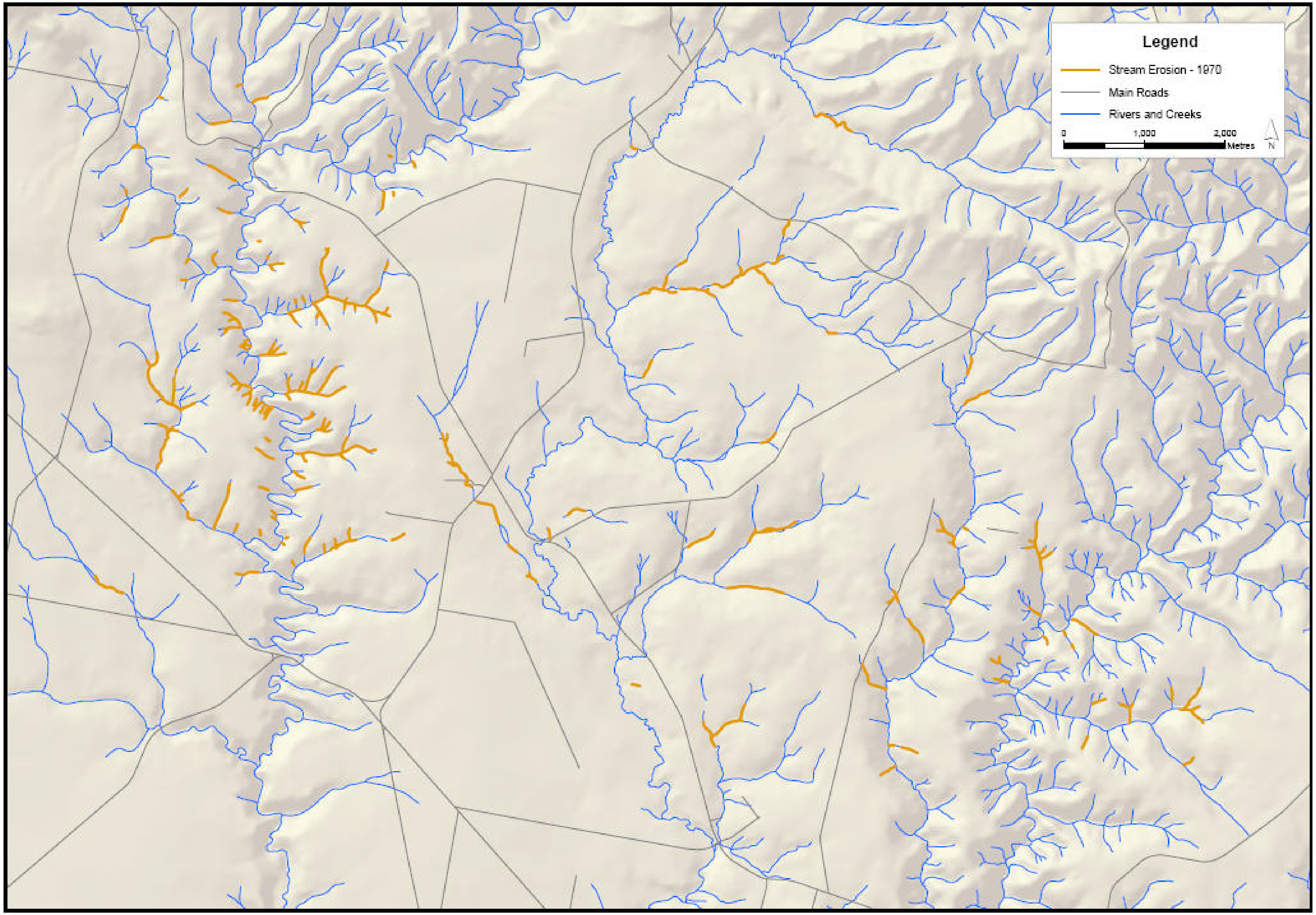




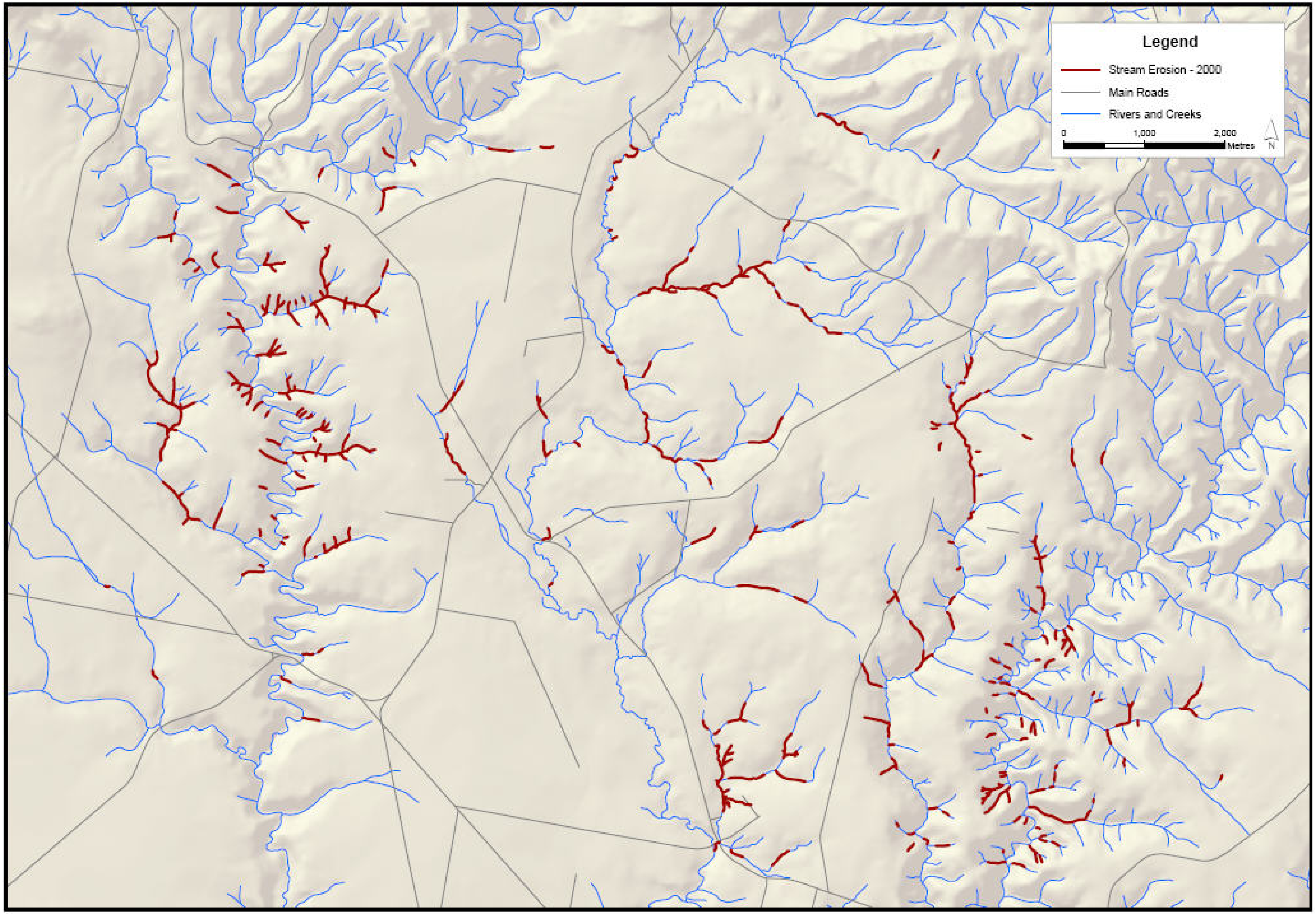
Misery Moonlight Sheet Erosion1970 (Roberts 2006)



Misery Moonlight Sheet Erosion 2000 (Roberts 2006)

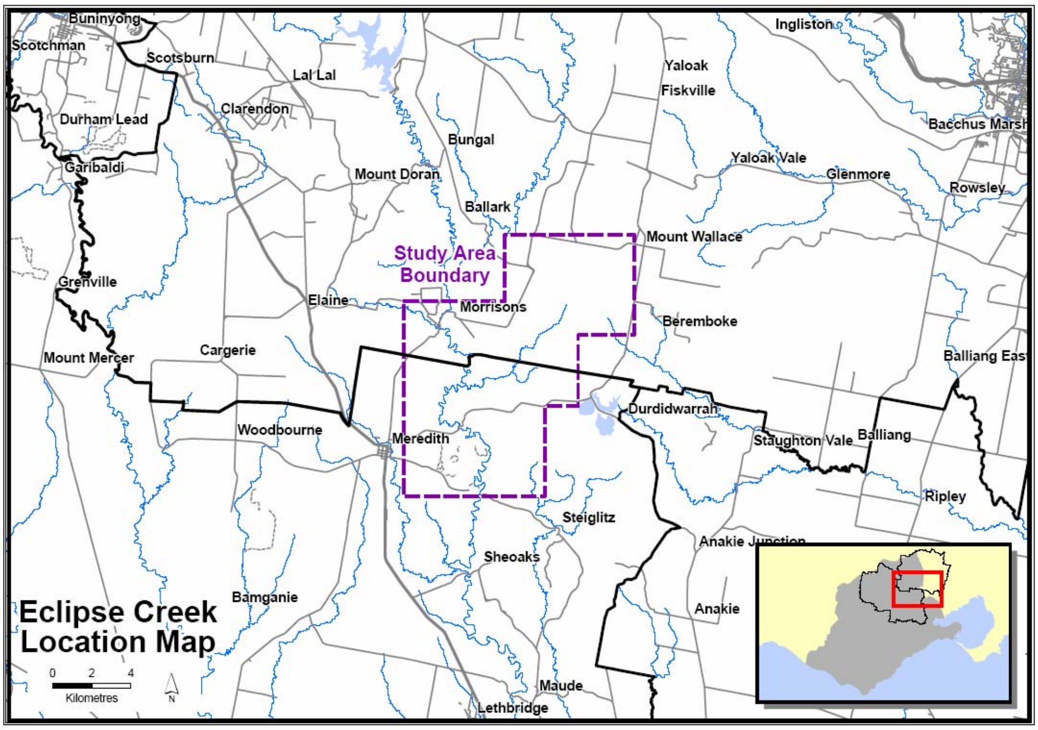


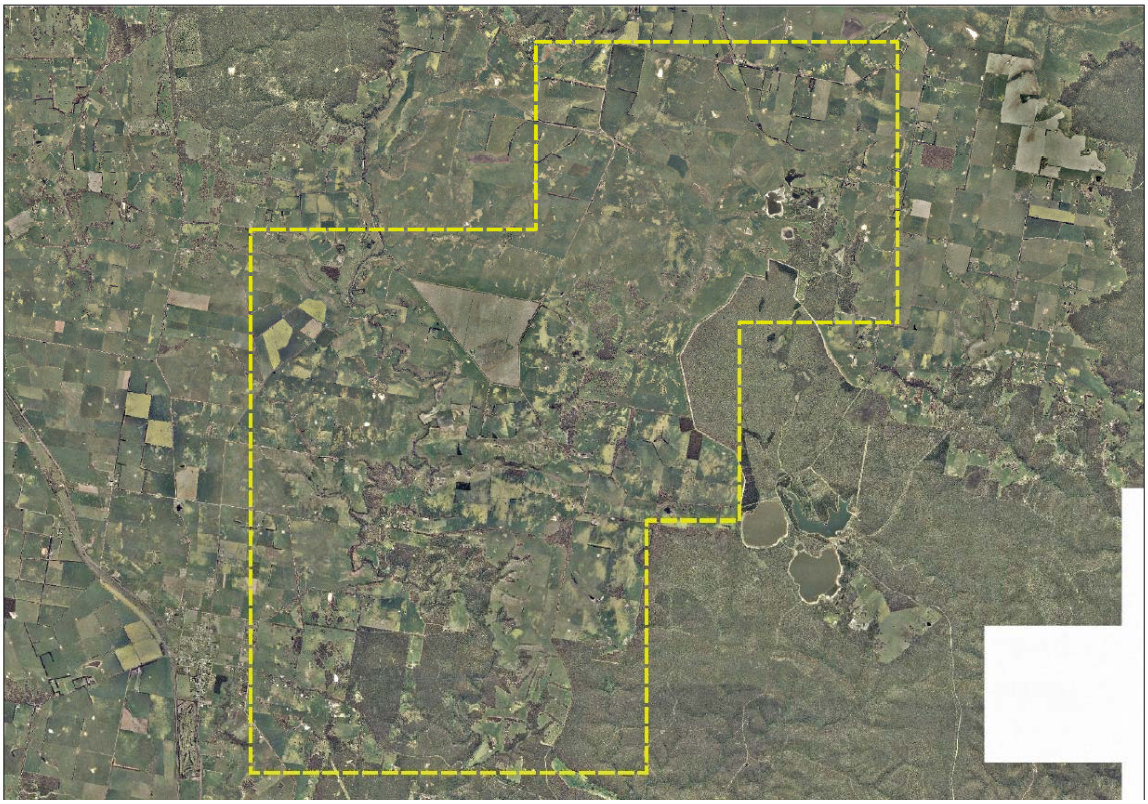
Misery Moonlight Gully and Streambank Erosion1970 (Roberts 2006)

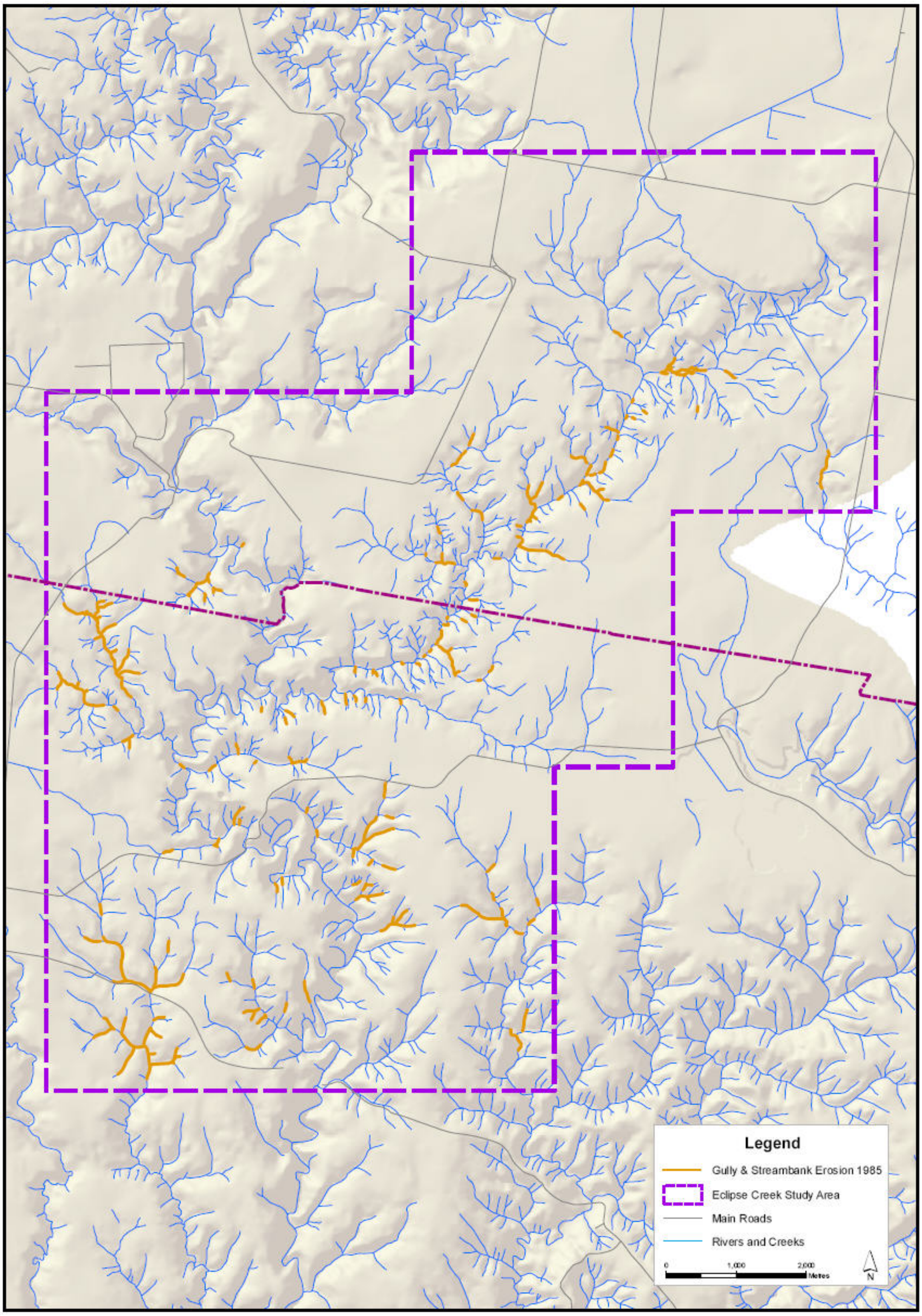


Misery Moonlight Gully and Streambank Erosion 2000 (Roberts 2006)

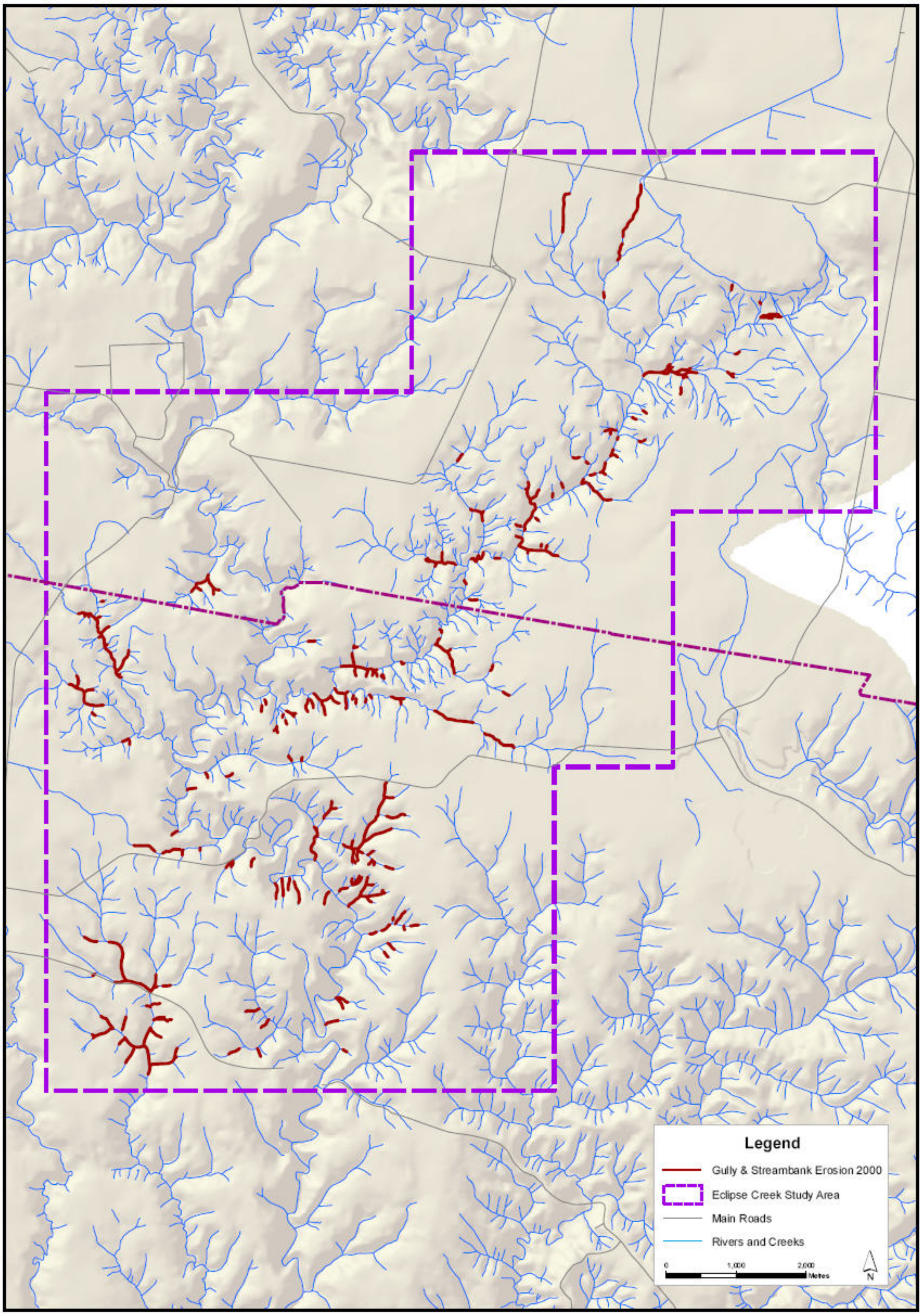
Eclipse Creek



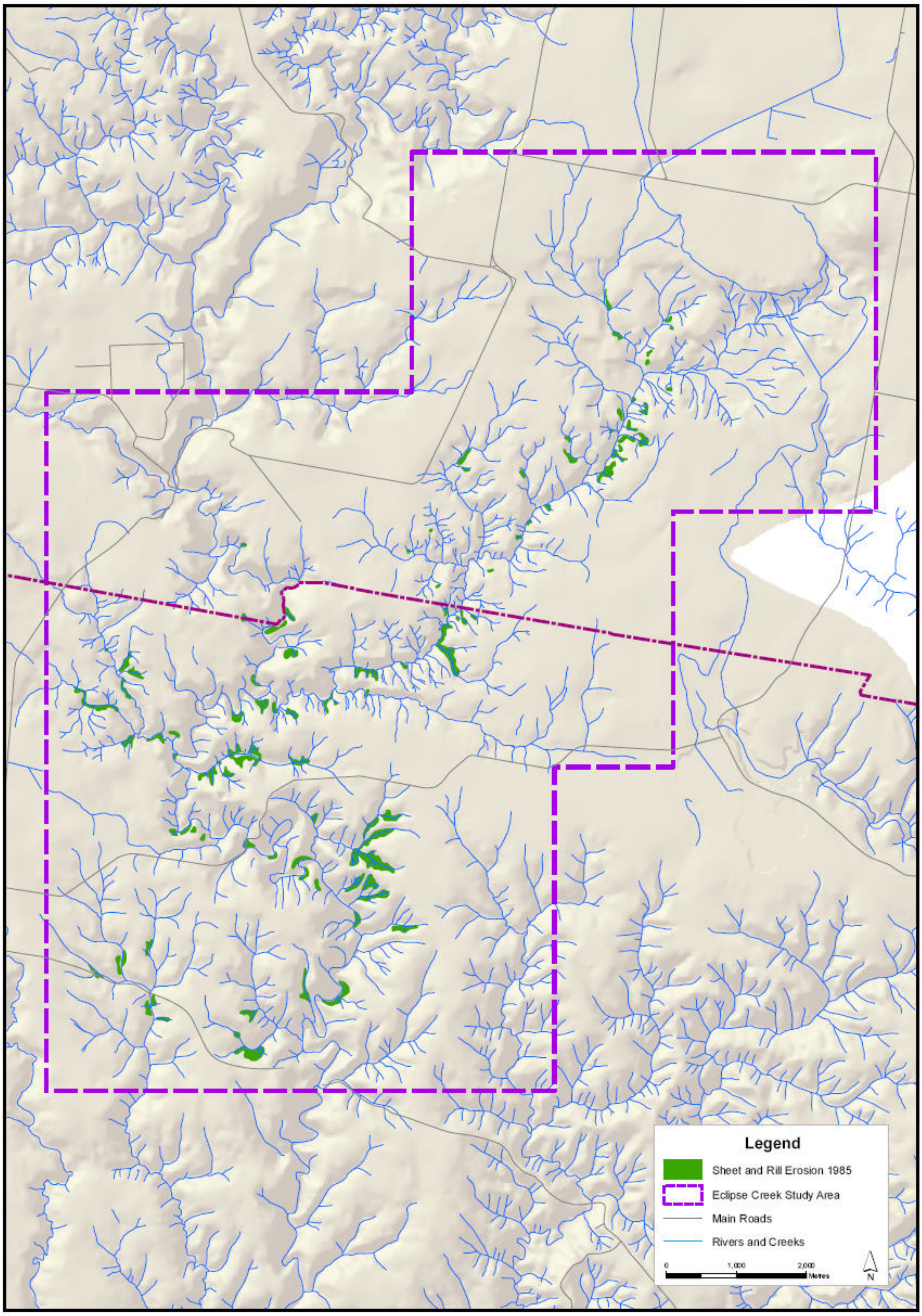




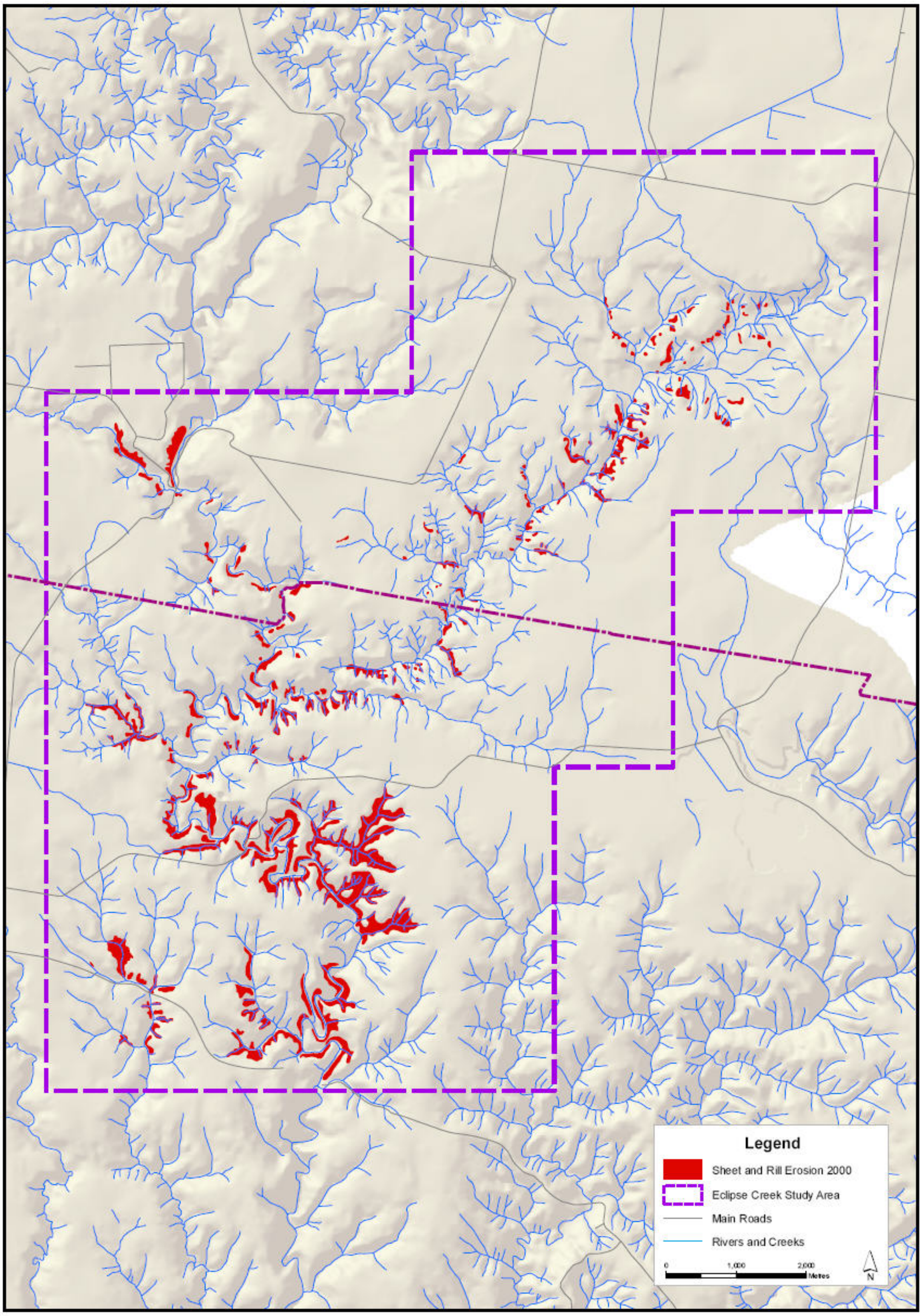
Eclipse Creek Gully and Streambank Erosion 1985 (Roberts 2006)



Eclipse Creek Gully and Streambank Erosion 2000 (Roberts 2006)

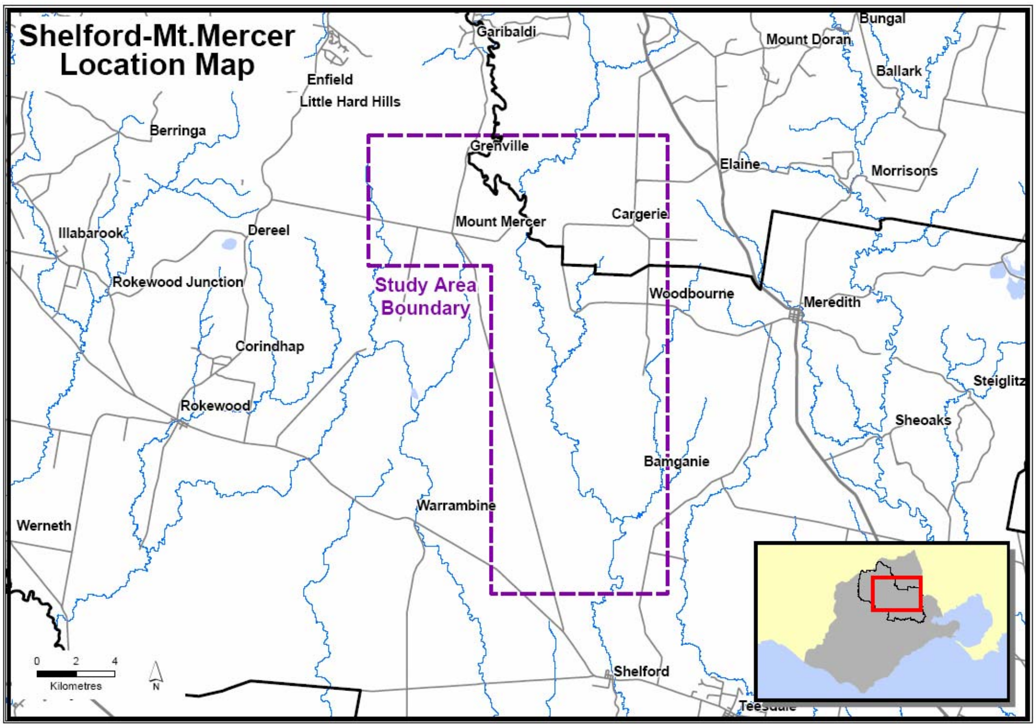


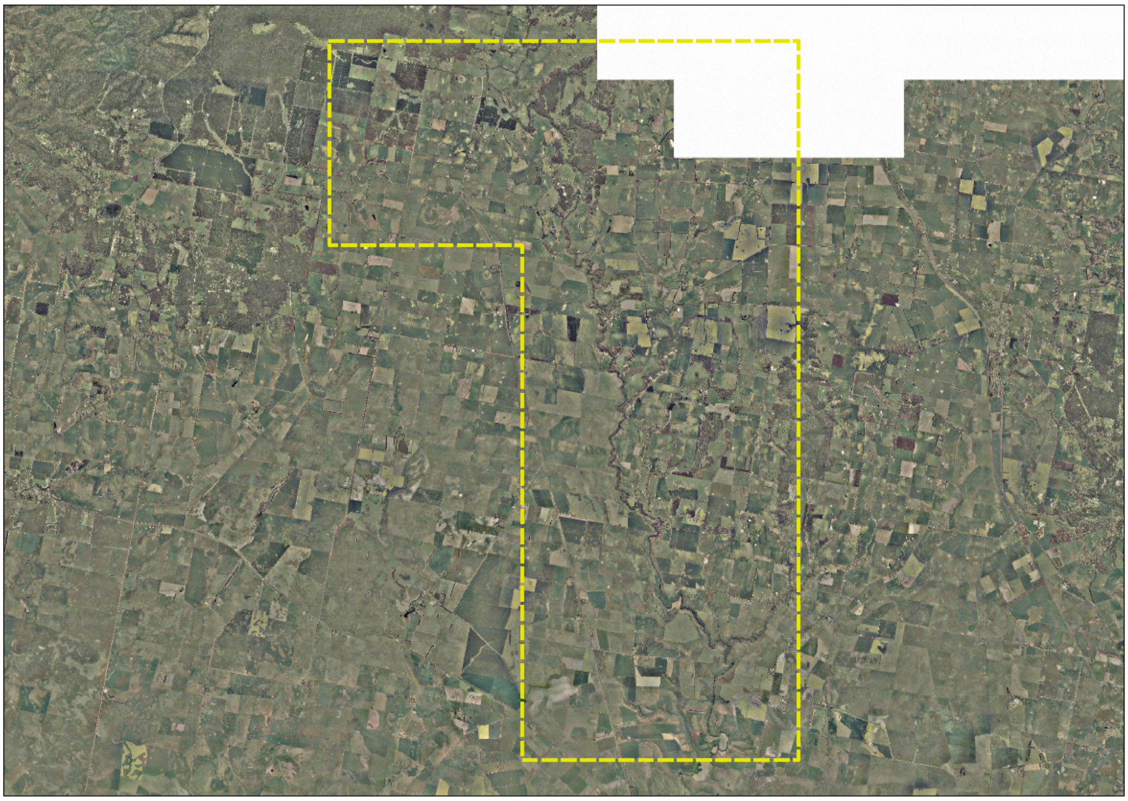
Eclipse Creek Sheet Erosion 1985 (Roberts 2006)

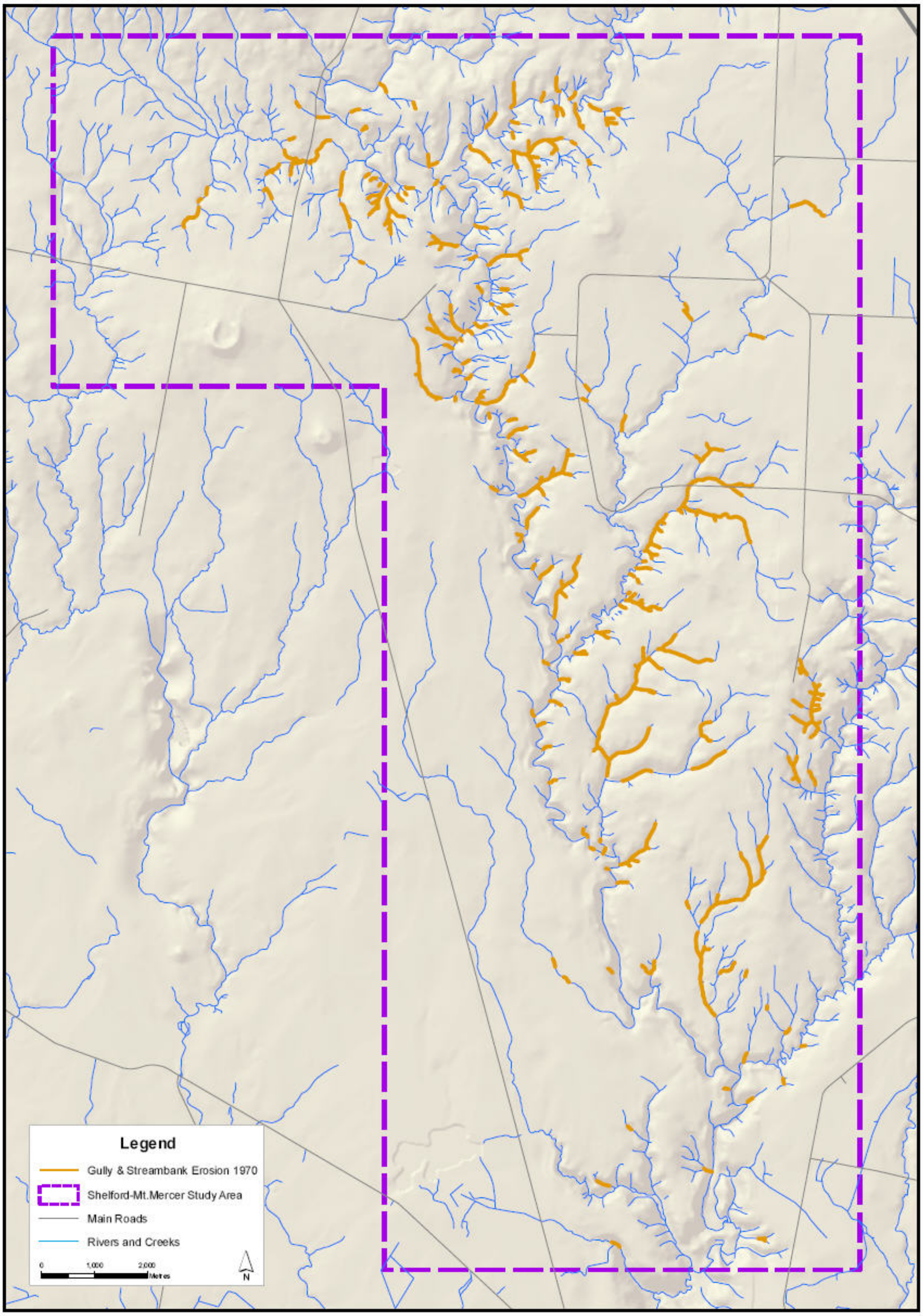


Eclipse Creek Sheet Erosion 2000 (Roberts 2006)

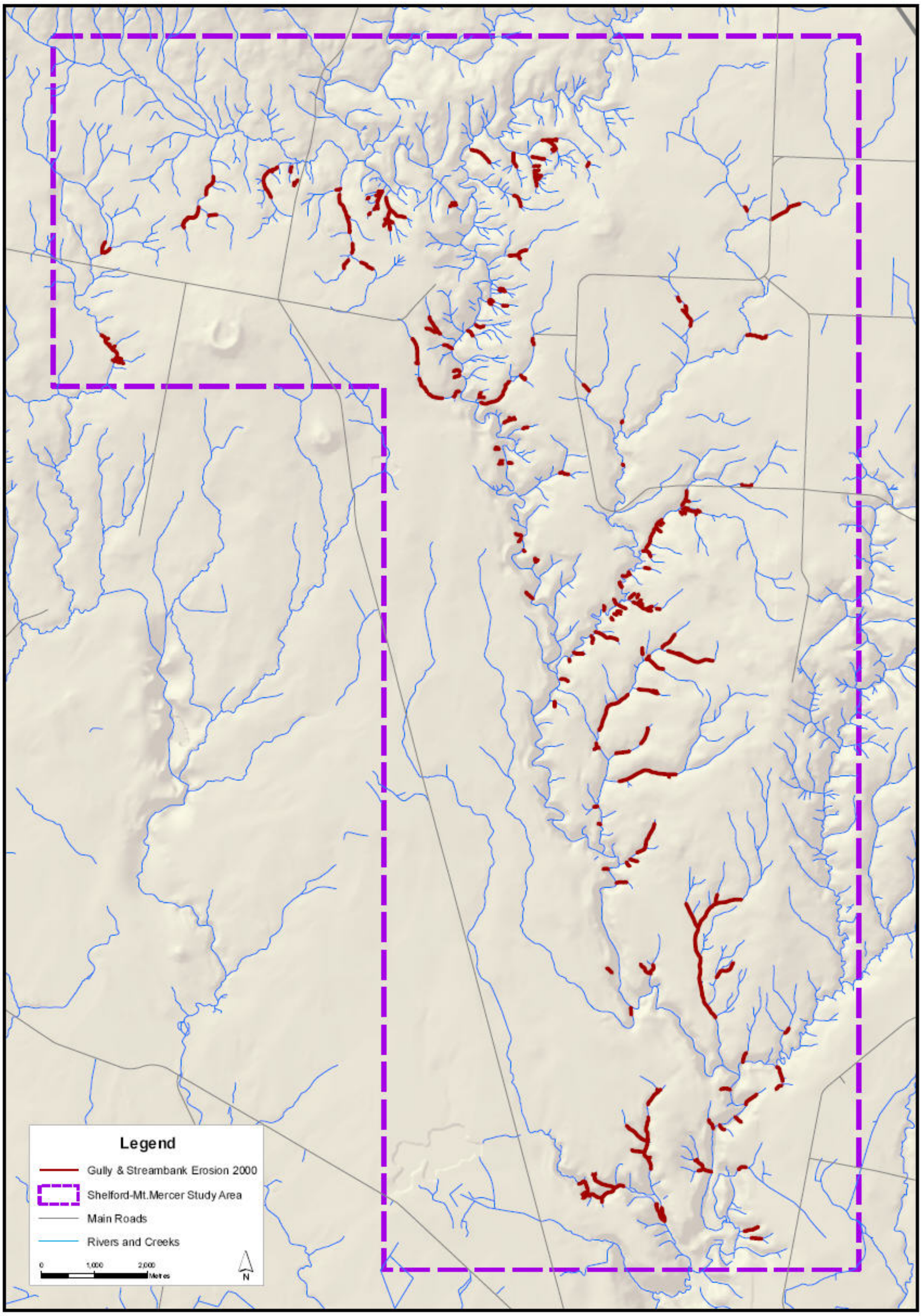
Shelford –Mt Mercer Rd



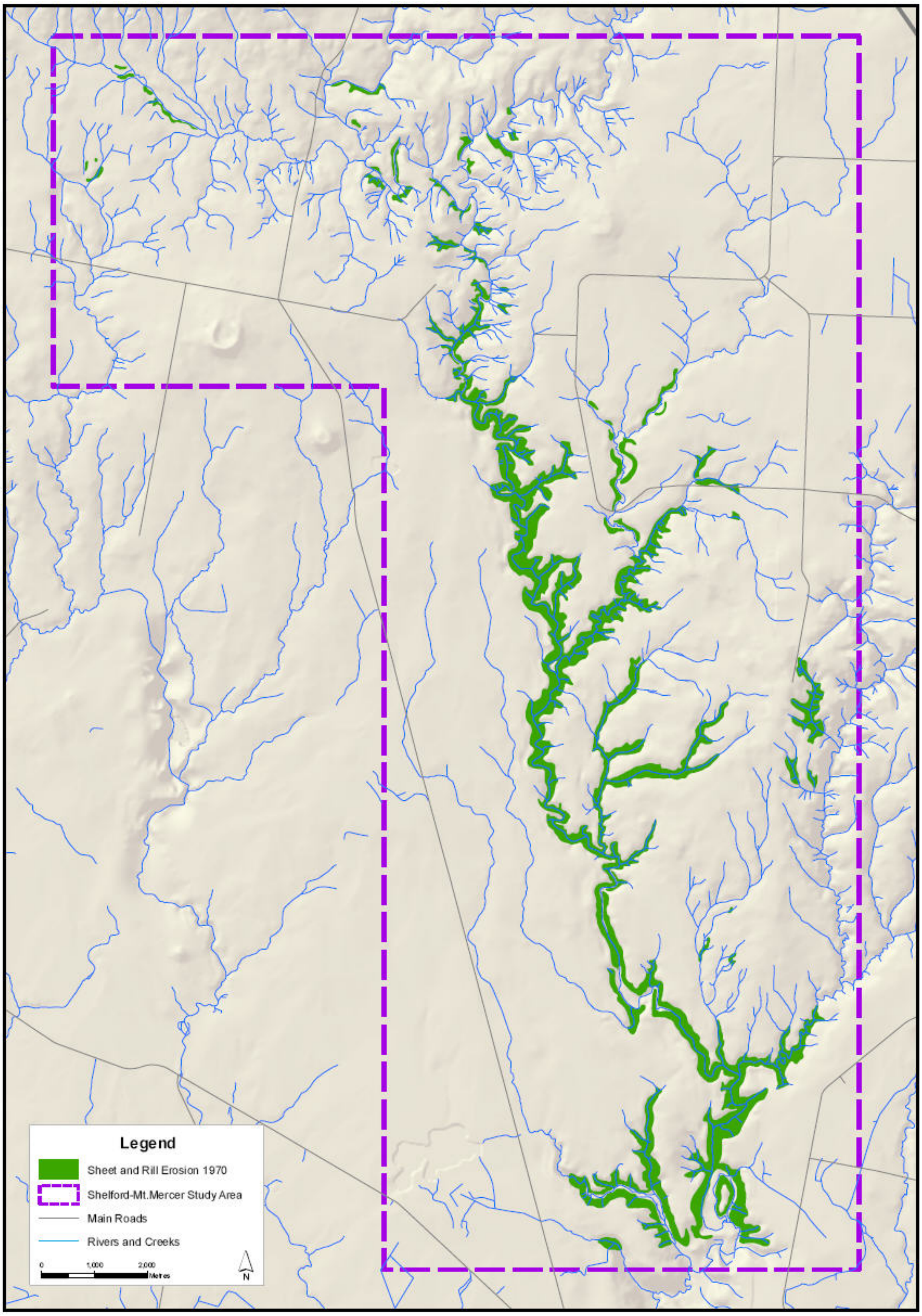




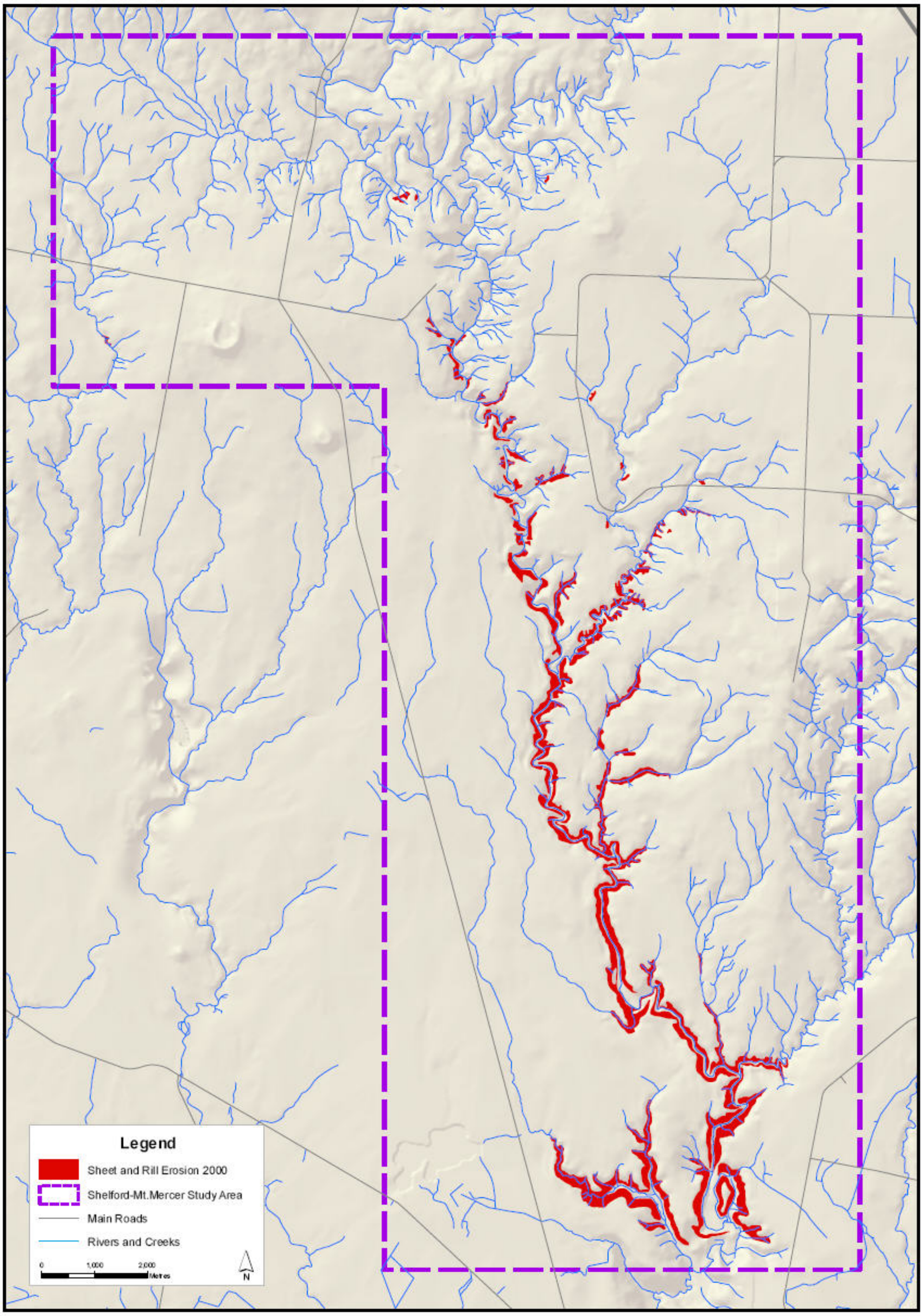
Shelford-Mt Mercer Rd Gully and Streambank Erosion 1970 (Roberts 2006)



Shelford-Mt Mercer Rd Gully and Streambank Erosion 2000 (Roberts 2006)

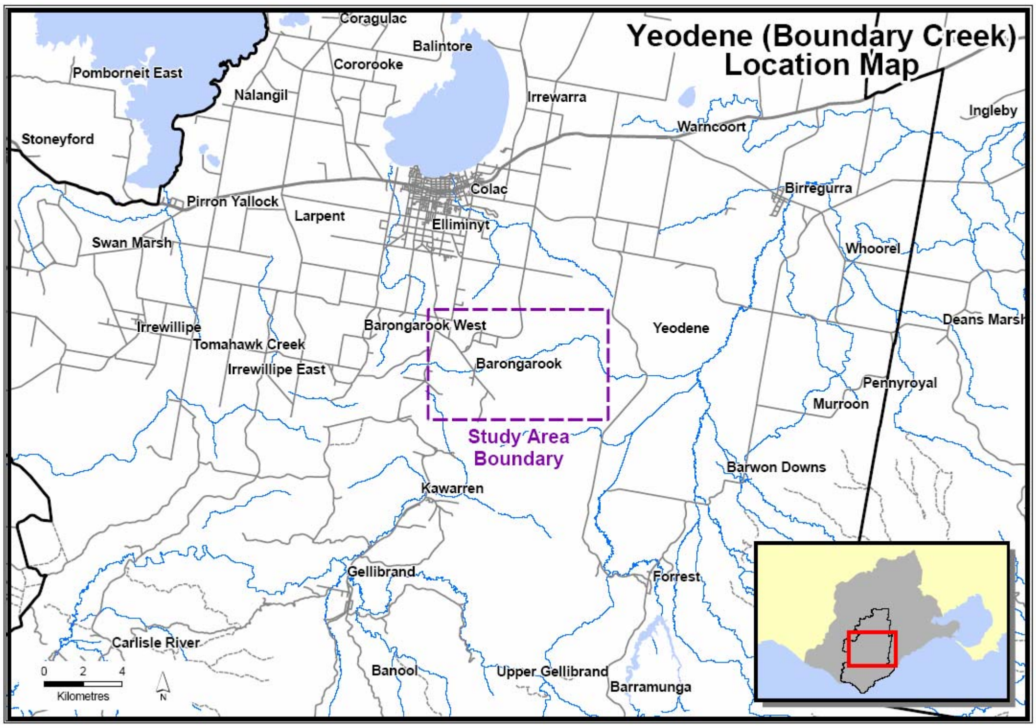


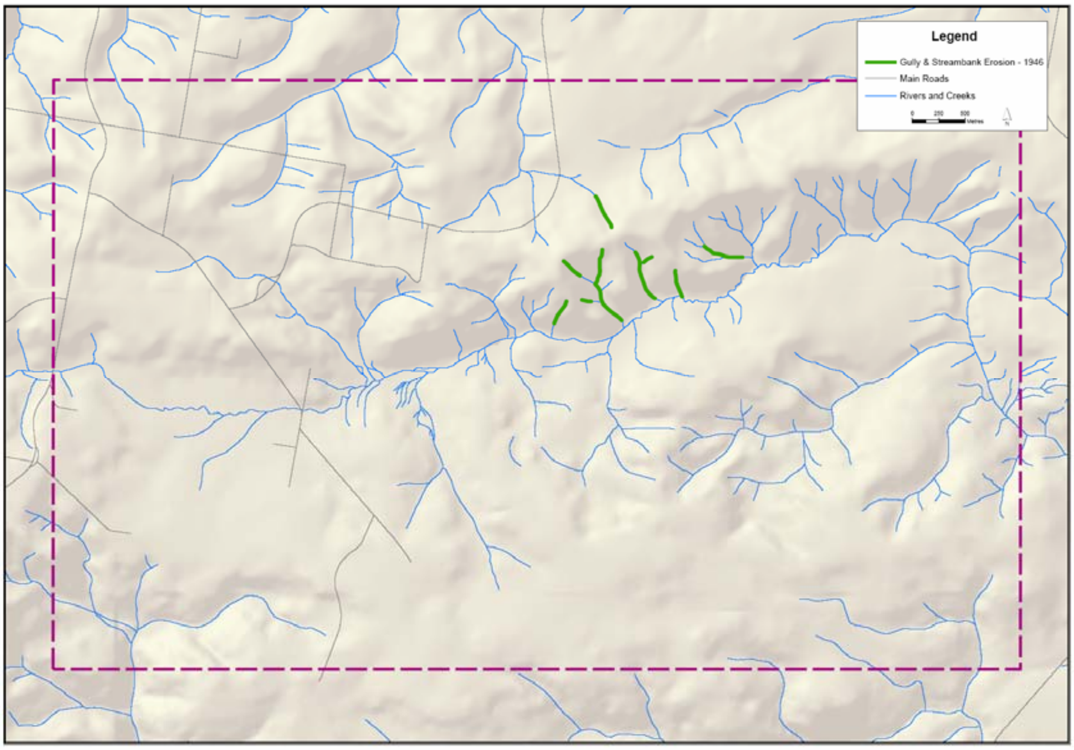
Shelford-Mt Mercer Rd Sheet Erosion 1970 (Roberts 2006)



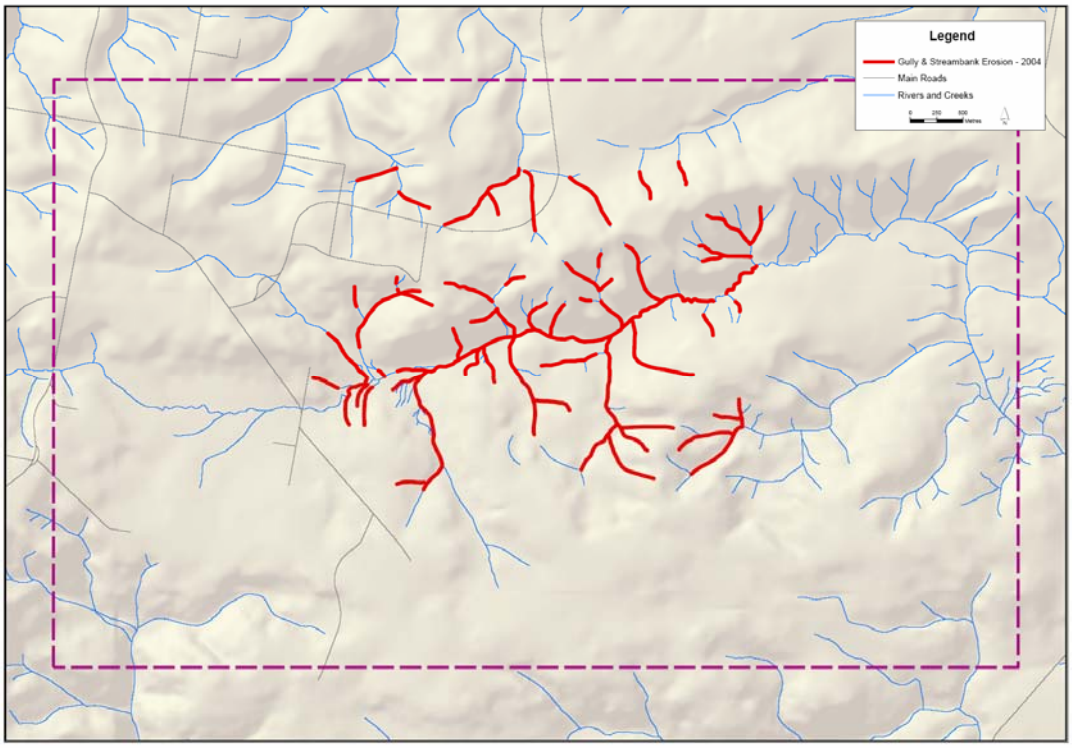
Shelford-Mt Mercer Rd Sheet Erosion 2000 (Roberts 2006)

Yeodene Barongarook (Boundary Creek)



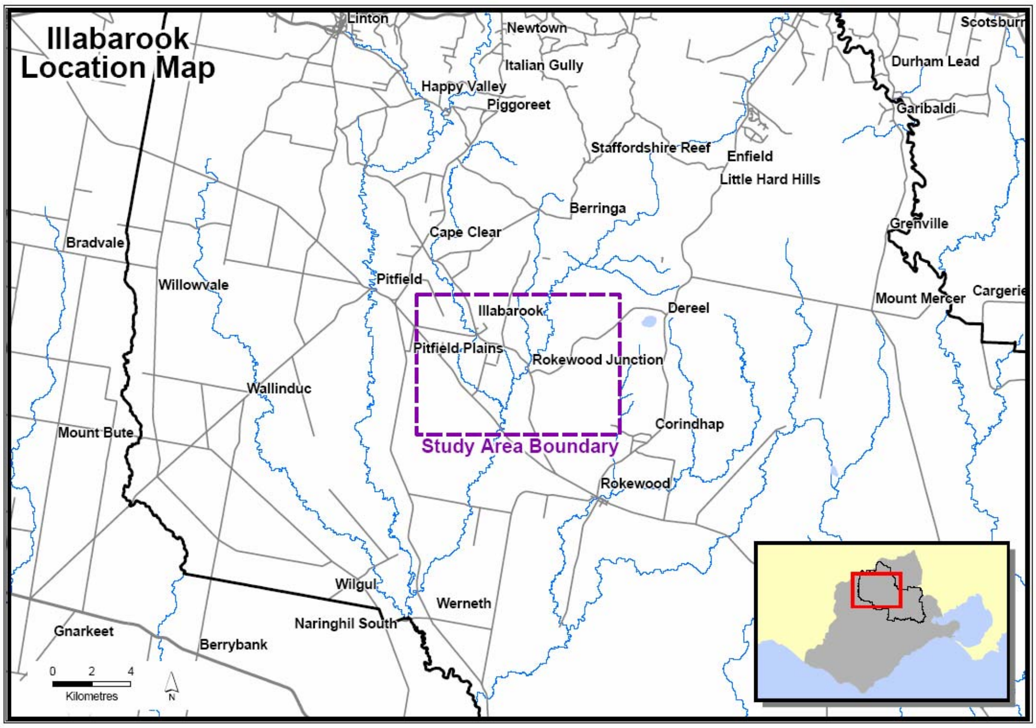


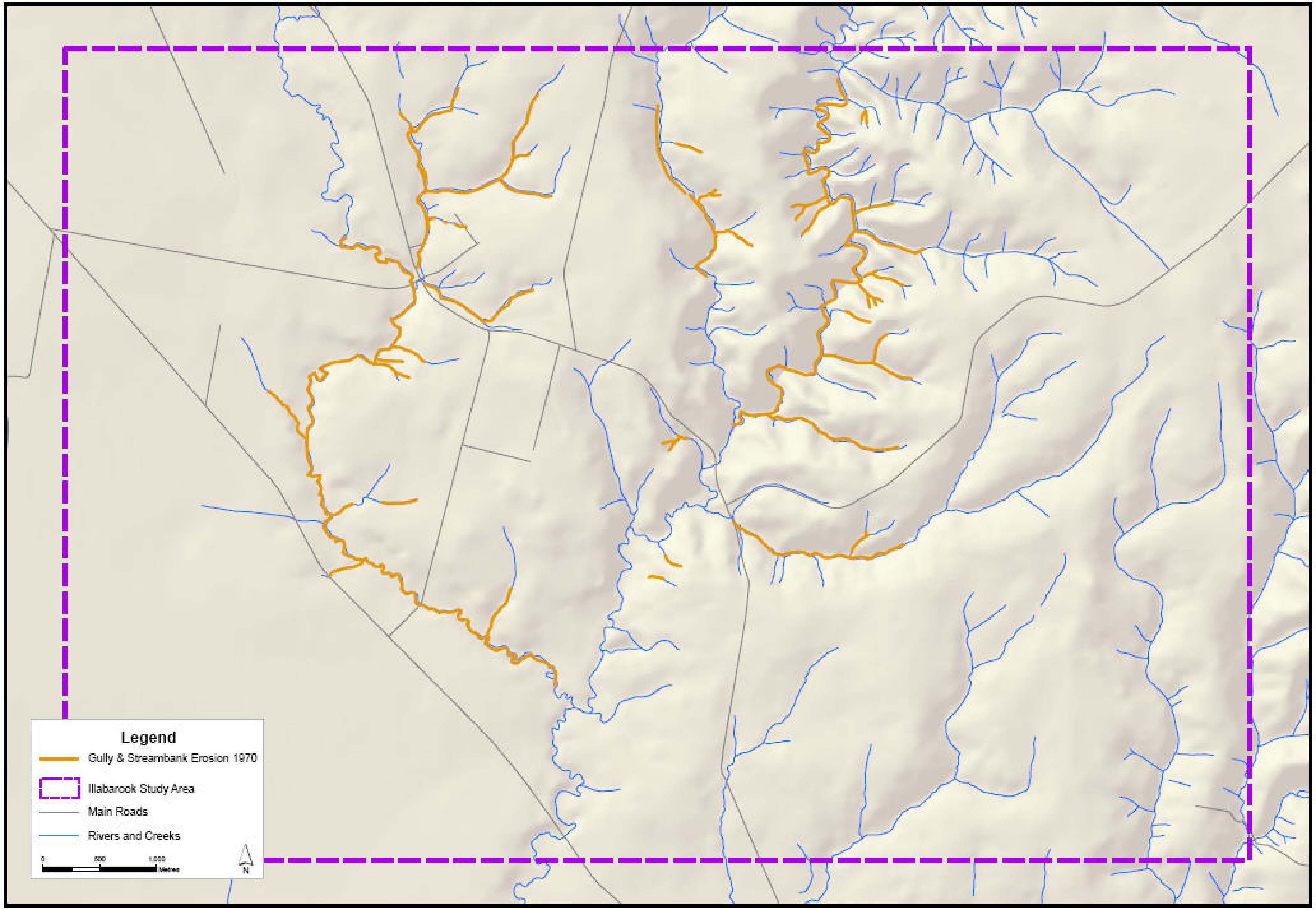
Yeodene (Boundary Creek) 1946 (Roberts 2006)



Yeodene (Boundary Creek) 2004 (Roberts 2006)

Illabarook


Illabarook
Location Map
Linton
Newtown
Italian Gully
Happy Valley
Piggoreet
Staffordshire Reef
Enfield
Little Hard Hills
Berringa
Cape Clear
Bradvale
Willowvale
Pitfield
Illabarook
Dereel
Pitfield Plains
Rokewood Junction
Wallinduc
Mount Bute
Corindhap
Study Area Boundary
Rokewood
Wilgul
Werneth
Naringhil South
Gnarkeet
Berrybank
Scotsburn
Durham Lead
Garibaldi
Grenville
Mount Mercer
Cargerie
0 2 4
Kilometres
N



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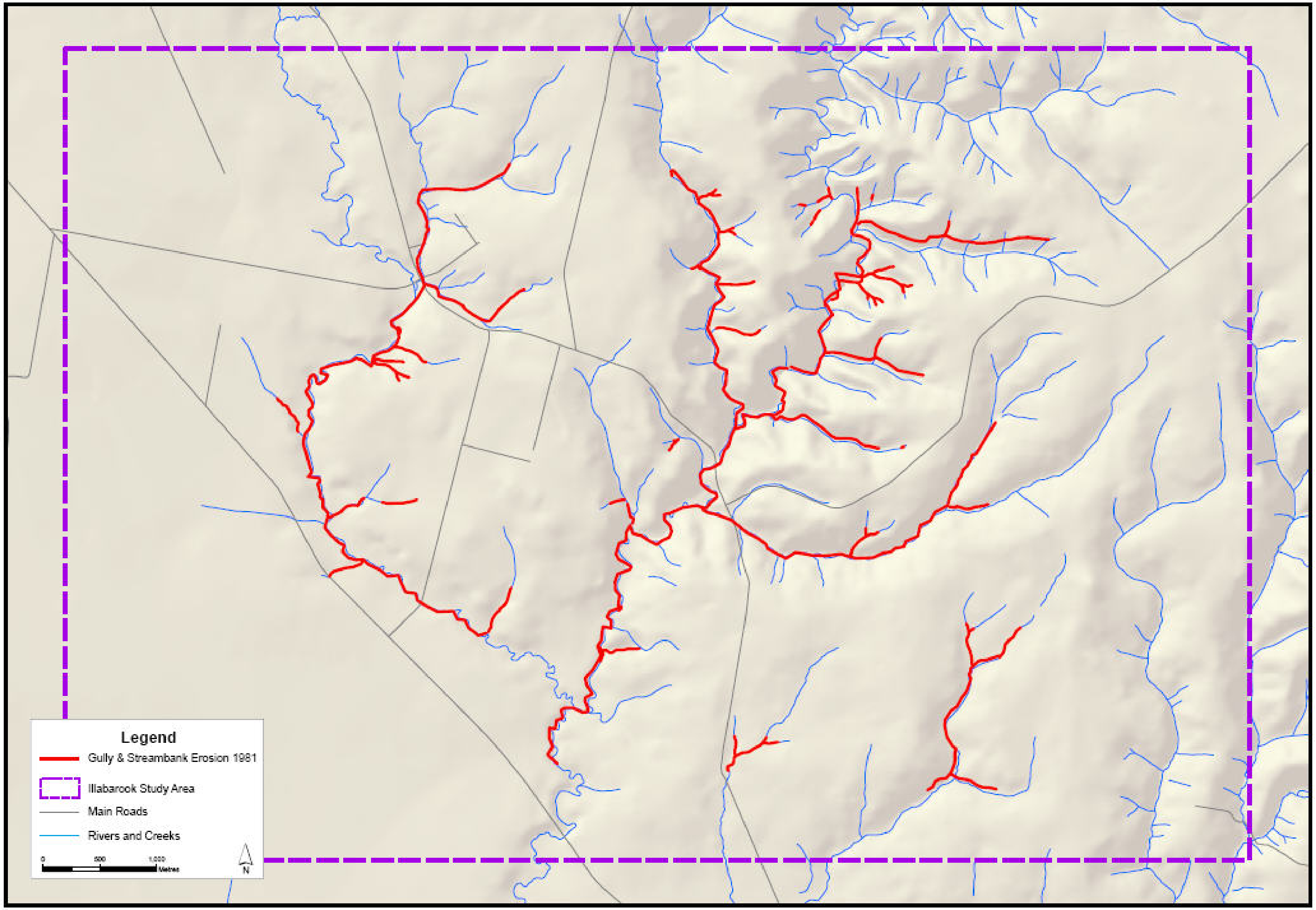

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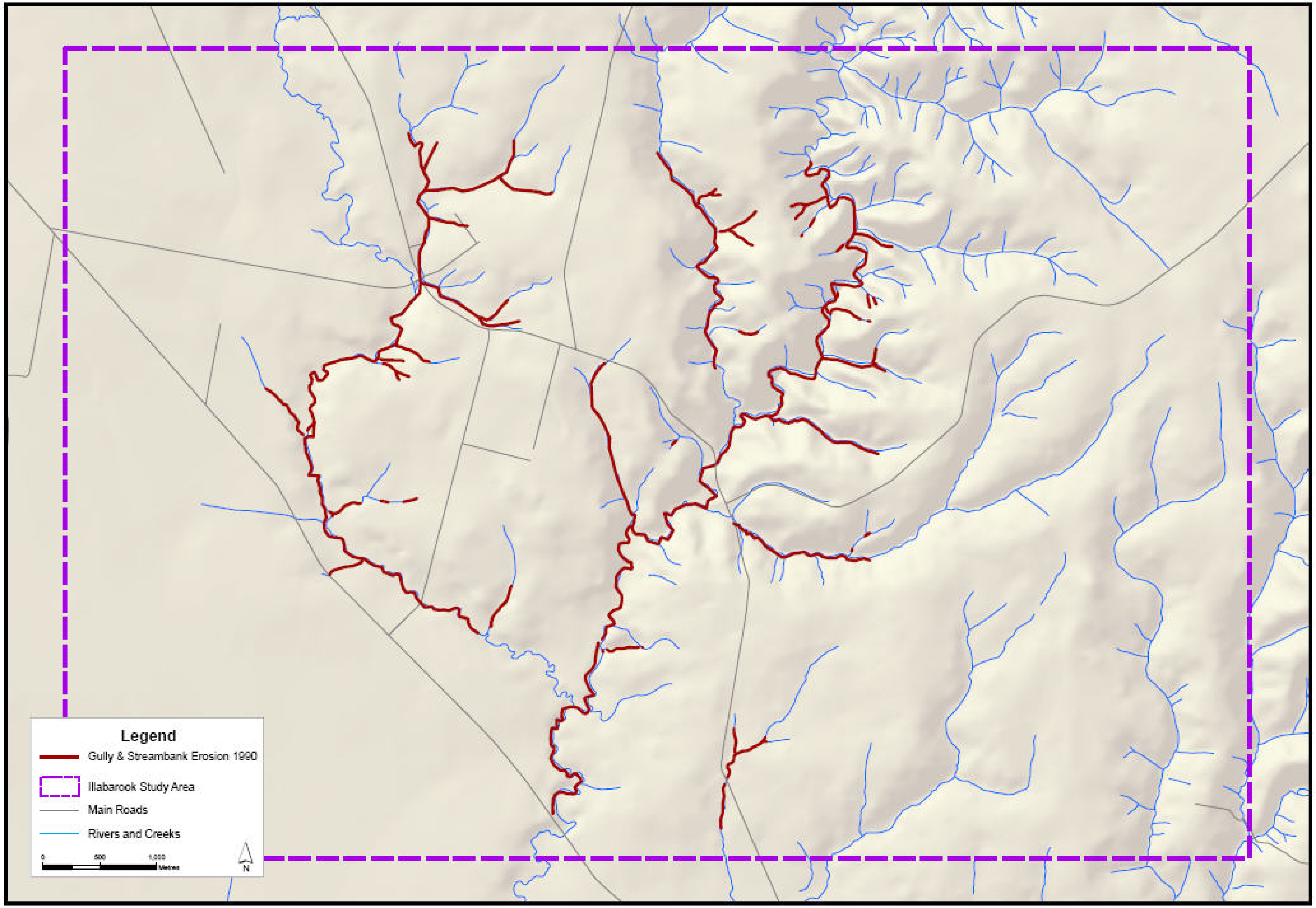

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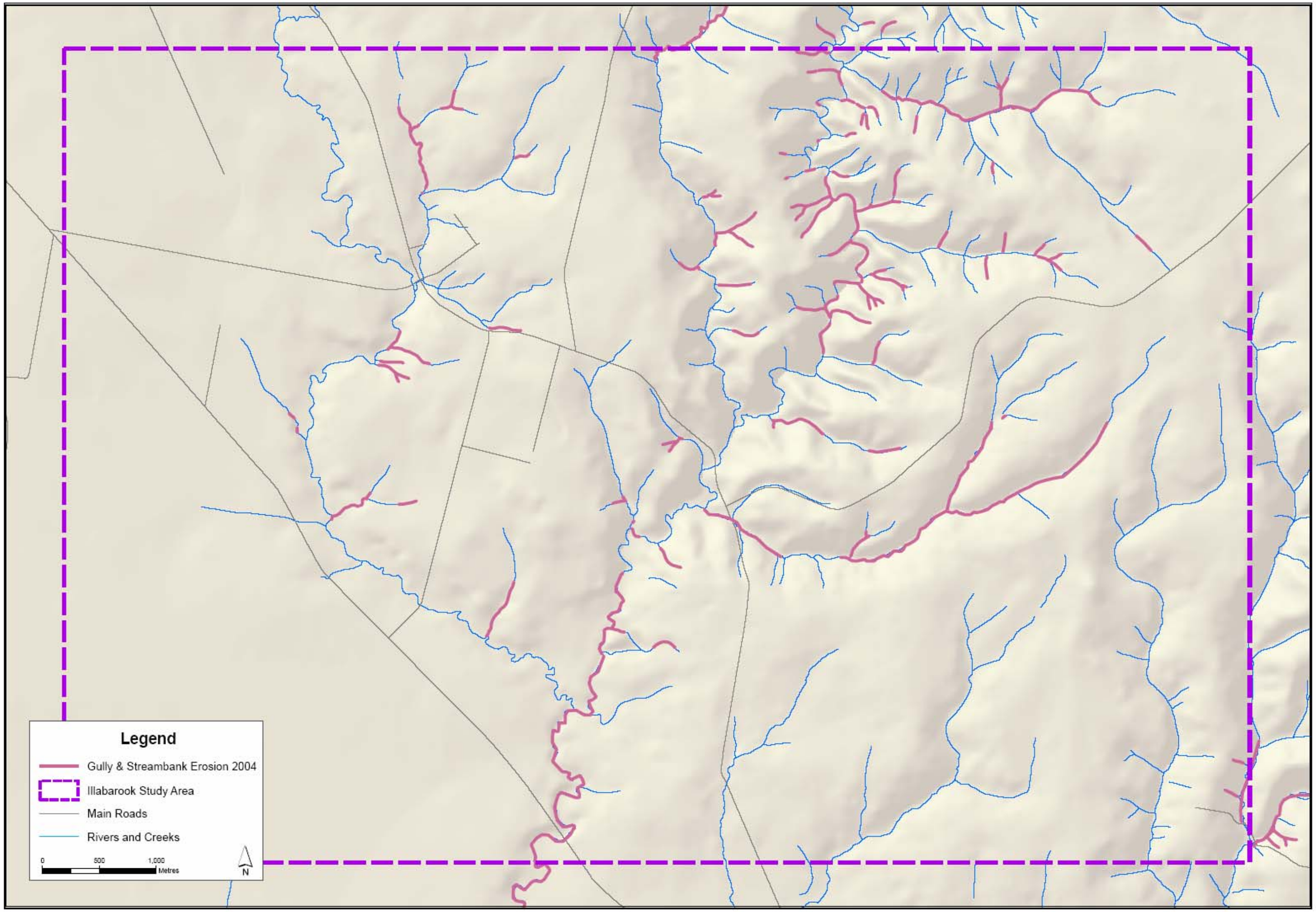

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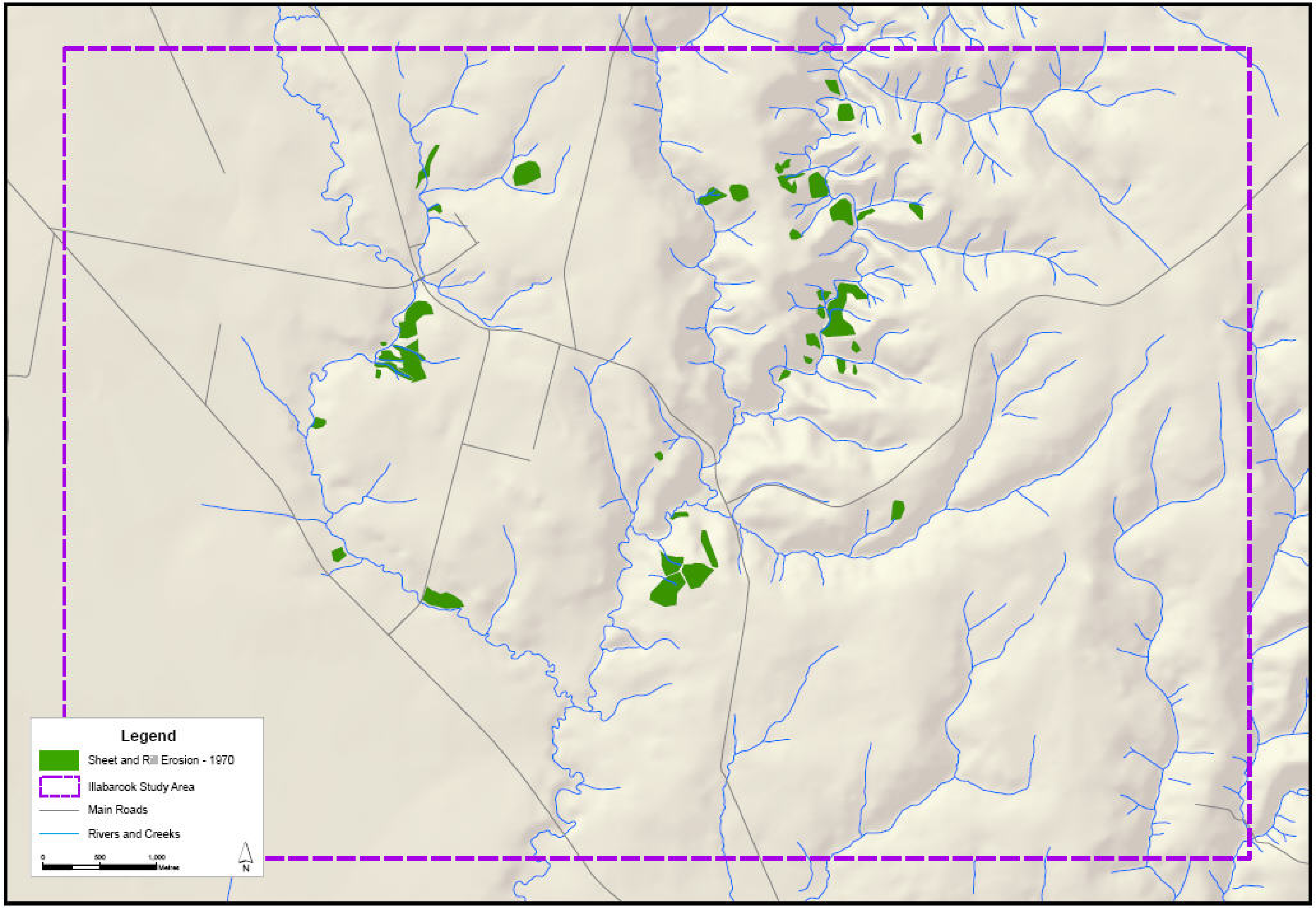

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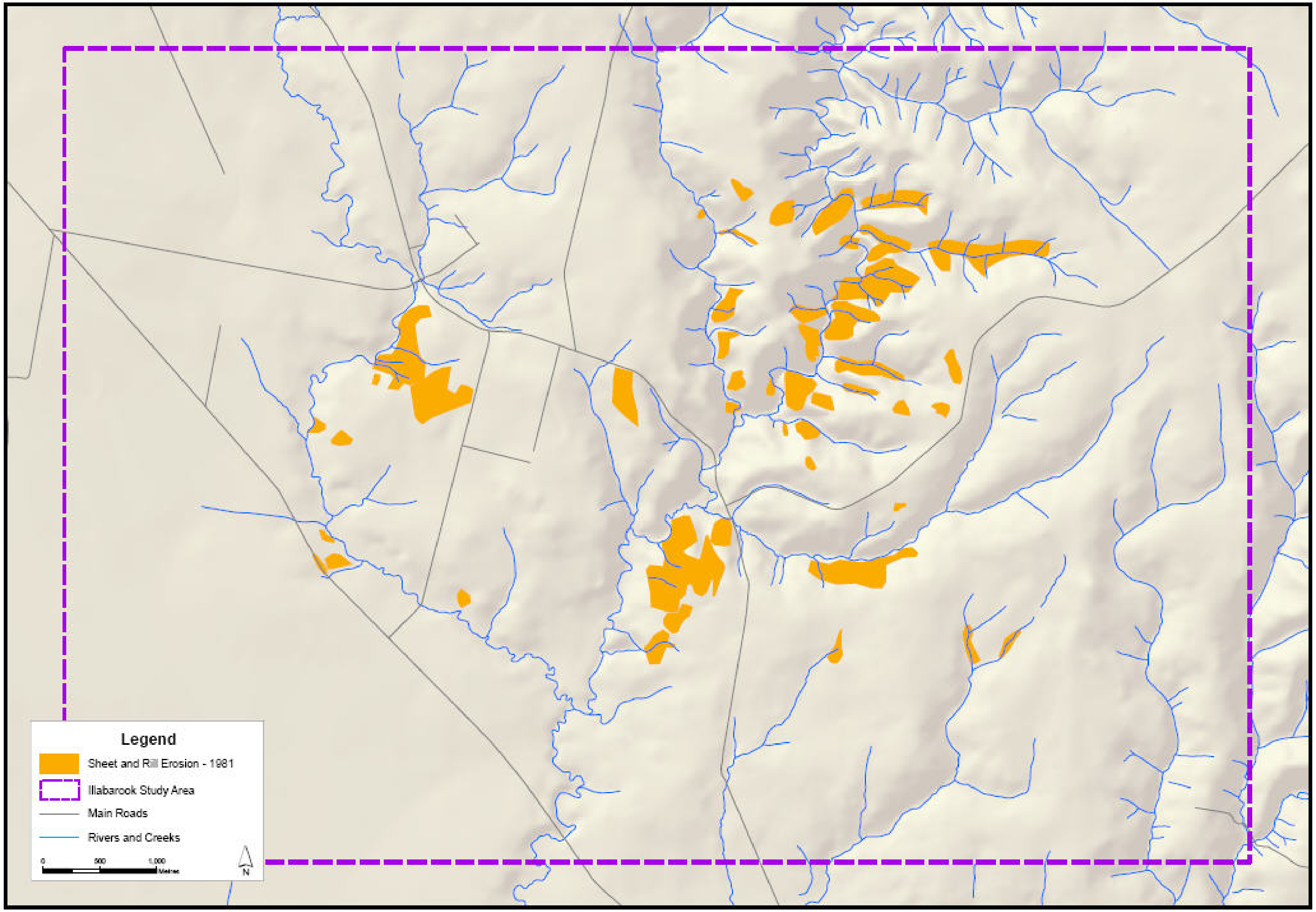

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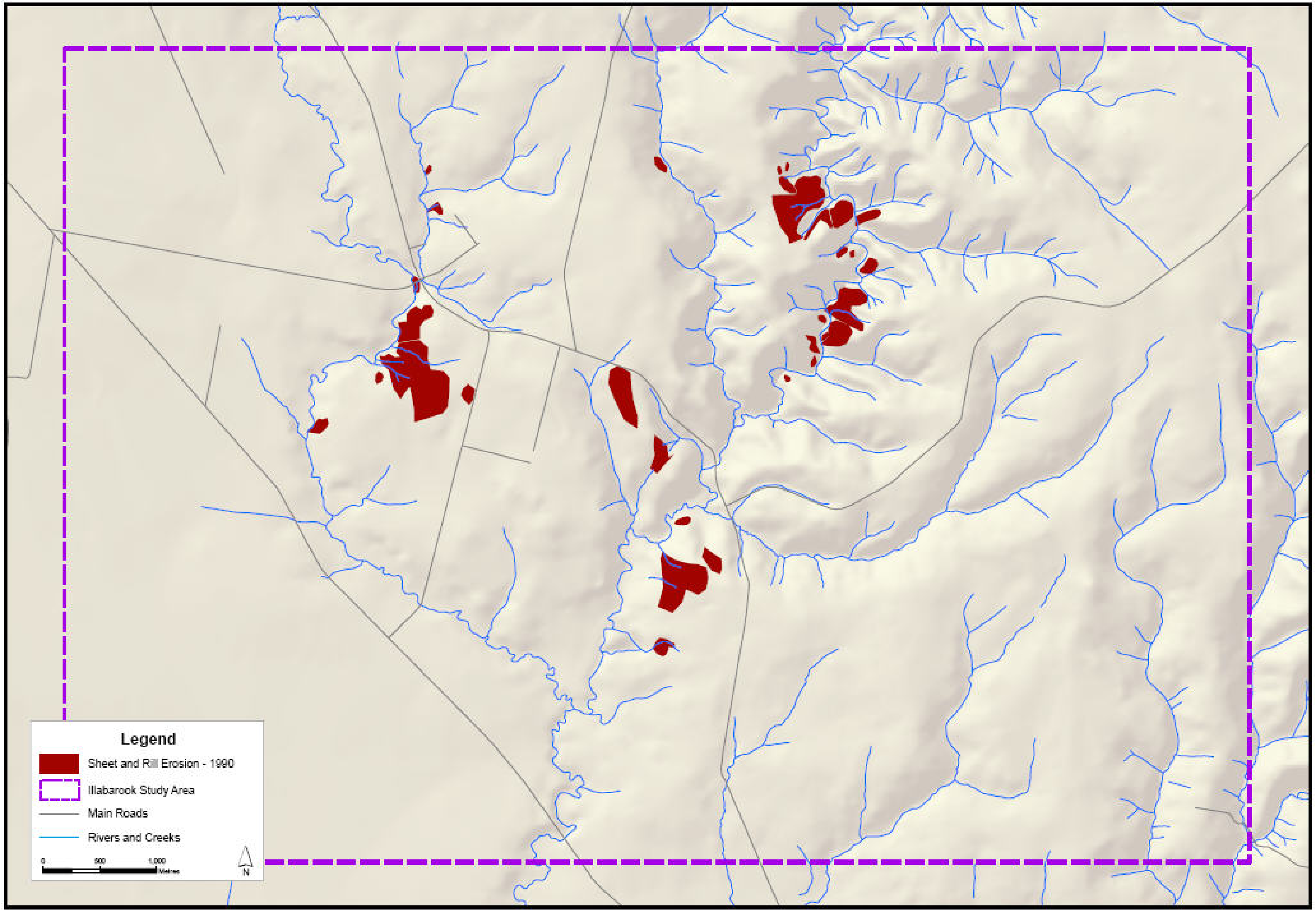

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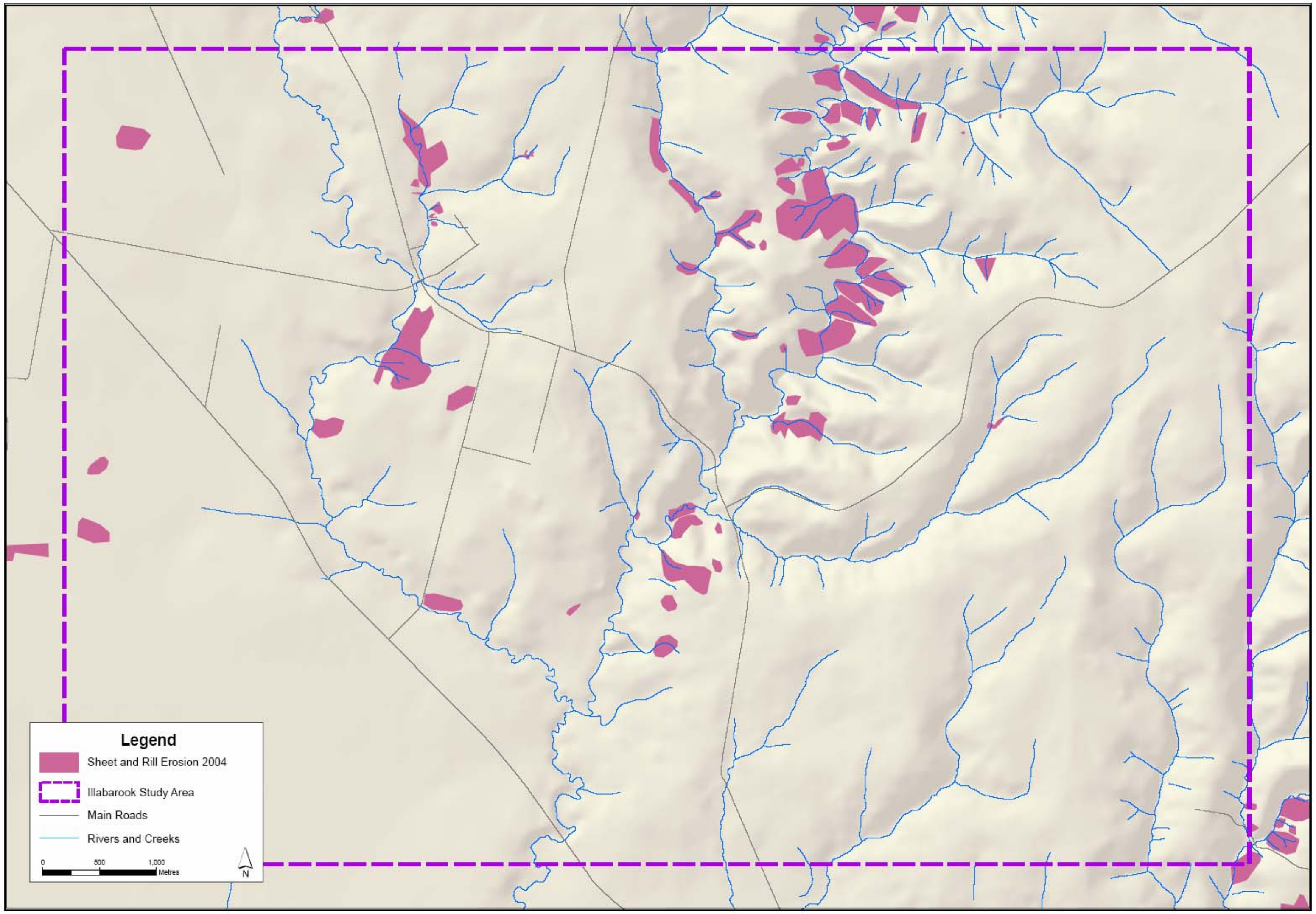

Illabarook Sheet Erosion 2004 (Feltham 2005)