We are now accepting email submissions. The form below must be filled out and attached in an email and sent to ifoa.remake@epa.nsw.gov.au If this form is not attached or incomplete the submission will be lodged as confidential and will not be published.

Make a submission – Contact Details

First Name*: Lyn

Lyn Orrego on behalf of the North Coast Environment Council

Last Name*: Orrego

Phone: [redacted]

Mobile*: [redacted]

Email [redacted]

Postcode*: [redacted]

Country*: Australia

Stakeholder type (circle)*:

Community group	Local Government	Aboriginal group
Industry group	Other government	Forest user group
Environment group	Individual	Staff

Other, please specify:

Organisation name: North Coast Environment Council Inc

What is you preferred contact method (circle): Mobile, Email or phone? Email

Would you like to receive further information and updates on IFOA and forestry matters?

yes

Can the EPA make your submission public* (circle)?

Yes No Yes, but anonymous

Have you previously engaged with the EPA on forestry issues?

Yes

Make a submission – Form

1. What parts of the draft Coastal IFOA are most important to you? Why?

Protecting the native forests of the public estate is most important to the North Coast Environment Council (NCEC). I am lodging this special submission on behalf of NCEC. It specifically concerns the impacts of forestry operations on soils and water. Attached are two reports by Mr Michael Eddie retired senior soil scientist who previously worked in that capacity for the Science Division of the Department of Environment and Heritage. He

wrote the definite work Soil Landscapes of the Macksville and Nambucca 1:1000,000 sheets (Department of Conservation and Land Management.

Together these reports raise significant issues of concern about the lack of adequacy of the current IFOA conditions to protect soils and waterways during and after forestry operations.

We request the two reports be studied, addressed in full and all recommendations brought into any new Coastal IFOA.

The reports show that the soil and water assessments and consequent prohibitions and restrictions on logging and roading are NOT stringent enough to adequately control soil erosion and water pollution arising from the disturbance of forestry operations. All claims, comments and recommendations are backed up with the highest level of expert soil science and valid reasons and data. We commend these reports to you.

The two report attached to this email submission to the draft Coastal IFOA are:

A critique of the proposed new Coastal Integrated Forestry Operations Approvals as they relate to soils and water issues. Michael Eddie, June 2018.
Senior Soil Scientist (retired), formerly of the Science Division, NSW Office of Environment and Heritage. Member, Australian Soil Science Society.   **and**

Land and Soil Hazards on the Nambucca Beds, Northeast NSW
Michael Eddie March 2018
Senior Soil Scientist (retired), formerly of the Science Division, NSW Office of Environment and Heritage. Author, Eddie M.W. (2000). *Soil Landscapes of the Macksville & Nambucca 1:100 000 Sheets*, DLWC, Sydney. Member, Australian Soil Science Society.

2. **What parts of the draft Coastal IFOA do you think have a positive outcome on the management of environmental values or the production of sustainable timber? Why?**

See attached

3. **What parts of the draft Coastal IFOA do you think have a negative outcome on the management of environmental values or the production of sustainable timber? Why?**

See attached

4. **What are your views on the effectiveness of the combination of permanent environmental protections at the regional, landscape and operational scales (multi-scale protection)?**

See attached

5. **In your opinion, would the draft Coastal IFOA be effective in managing environmental values and a sustainable timber industry? Why?**

See attached

6. **General comments**
   This is a special section of the NCEC submission related to soil and water issues. Another submission on other matters will also be made by NCEC.

Please feel free to contact me if you have any questions regarding these 2 reports or if you would like to let NCEC know your response to the recommendations they contain.

Nothing in these reports should infer that NCEC any longer supports the logging of the public forest estate in NSW. Our view is that the forests have been so damaged under the current IFOA and during the current RFA period that they need to be reserved and the NSW timber industry make a rapid transition to a 100% plantation based timber industry.

This submission and the 2 reports attached are an attempt to present evidence regarding serious weaknesses in the current and proposed IFOA rules regarding soils and water protection in the hope that, should the government go ahead with continuing to allow logging in public native forests, that they apply strong and scientifically based rules to protect soils and waterways effected by the forestry operations they allow.

Thank you for your attention to our special soils and water issues submission and the two reports attached.
Sincerely,

[redacted]

Lyn Orrego on behalf of NCEC

July 11, 2018

A critique of the proposed new Coastal Integrated Forestry Operations Approvals as they relate to soils and water issues.

Michael Eddie, June 2018.

Senior Soil Scientist (retired), formerly of the Science Division, NSW Office of Environment and Heritage.

Member, Australian Soil Science Society.

INTRODUCTION

This report was commissioned by the North Coast Environment Council (NCEC), in response to concerns about the proposed changes to the Coastal Integrated Forestry Operations Approvals (IFOA). One of the main concerns is proposed increases in logging intensity, particularly in north-east NSW, and the consequences of increased rates of soil erosion and water pollution likely to be generated from the intensified logging. Concerns relating to the changes are clearly articulated in the National Parks Association's briefing note (Sweeny, 2018)—

> *The largest changes will accrue in north-east NSW, with a logging regime hitherto confined to the Eden area extended to 140,000ha of coastal forests in an intensive harvesting zone between Taree and Grafton. So-called 'selective' harvesting will also increase greatly in intensity, and will be able to be applied throughout the entire coastal zone managed under the new IFOA.*
>
> *The maximum size of legal clearfelling in northern NSW under the old IFOA was 0.25ha (defined under Australian Group Selection). The new proposals will see a maximum size of 45ha—a 180-fold intensification of logging—throughout a 140,000ha zone with 2,200 hectares allowed to be clearfelled each year.*
>
> *The transition arrangements permit logging intensity even greater than proposed in the new regime over the first five years by permitting five coupes of 60ha (compared to the 45 proposed) to be logged each year (25 in total) and reducing the return time to an adjacent coupe from 10 years to seven years.*

The conditions under which the proposed IFOA will operate are presented in NSW an Environment Protection Authority (2018a); these will be referred to in this report as the Conditions. The Protocols for the proposed IFOA are presented in NSW Environment Protection Authority (2018b); these will be referred to in this report as the Protocols. This report will address and critique the Protocols relevant to soils and water issues—

- Protocol 6: Suitably Qualified Persons – Training and Experience
- Protocol 10: Road design
- Protocol 11: Soil Dispersibility Assessment
- Protocol 12: Seasonality Restrictions
- Protocol 13: Mass Movement Assessment
- Protocol 15: Inherent Soil Erosion and Water Pollution Hazard Assessment
- Protocol 16: Riparian Protection
- Protocol 20: Pre-Operational Surveys
- Protocol 38: Monitoring Program.

Given the potentially far-reaching consequences of the intensification of logging regimes in the proposed IFOA, of increased rates soil erosion and water pollution likely to be created from the intensified logging, the Protocols need to be considerably tightened and to be properly enforced.

SUMMARY

Protocol 6: Suitably Qualified Persons – Training and Experience. Because decisions undertaken by environmental assessors require professional judgement, it is expected that minimum training requirements should be appropriate Tertiary qualifications. Approved soil assessors require Tertiary qualifications in soils, geomorphology or geotechnical engineering and be independent of FCNSW, and it is important that the training for approved environmental assessors is independent of FCNSW.

Protocol 10: Road design

Best management practices should be documented, adhered to and enforced. Road design should be subject to independent audit under Protocol 38, and road construction and maintenance should be subject to independent inspection. The assessment of stability of roads must include a consideration of factors relating to mass movement and erosion hazards. This requires Tertiary qualifications e.g. in geotechnical engineering.

Protocol 11: Soil Dispersibility Assessment. A soil survey should be undertaken by the assessor to determine the range of soil dispersibility, as described in Protocol 20: Pre-Operational Surveys. Maps generated by the approved soil assessor should be subject to independent audit under Protocol 38.

The Emerson Aggregate Test (EAT) is the industry standard for assessment of aggregate stability. It should replace the Soil Dispersibility Testing Method. An EAT result indicating dispersion or slaking should be verified by Dispersion Percentage / Ritchie Method.

Protocol 12: Seasonality Restrictions. Information or maps relating to rainfall erosivity zones was unavailable. In the absence of such information, the most conservative case must be assumed.

Protocol 13: Mass Movement Assessment. It should be assumed that all land on slopes greater than 20^o has the potential for mass movement. Maps generated by the approved soil assessor should be subject to independent audit under Protocol 38. The approved soil assessor requires Tertiary qualifications in soils, geomorphology or geotechnical engineering.

Protocol 15: Inherent Soil Erosion and Water Pollution Hazard Assessment. A soil survey of the landscape or compartment should be undertaken by the approved soil assessor to determine the range of soil regolith stability class, as described in Protocol 20: Pre-Operational Surveys, and to determine whether or not the soil regolith class is consistent with the information specified in the GIS dataset. Maps generated by the approved soil assessor should be subject to independent audit under Protocol 38. The approved soil assessor requires Tertiary qualifications in soils because professional judgement is required in determinations.

The Inherent Hazard Level (IHL) Tables should be modified to reflect the harvesting intensities proposed under the Coastal IFOA, because the soil exposure could vary greatly as it depends on the condition of the forest before the operation. This is unknown and undocumented.

The IHL should be adjusted to take account of the local relief of the terrain and mass movement hazards. The addition of weightings for terrain and mass movement variables to the slope classes in the IHL Tables is proposed. The weighted slopes classes might be called Slope Hazard Classes. The IHL Tables can be readily digitised and calculated using software such as a spreadsheet for a consistent and quick outcome. The concept of Slope Hazard Classes should account for exceptional erosion and mass movement hazards on mountainous terrain.

Further consideration is needed to determine appropriate weightings. Until the Slope Hazard Class is used to calculate IHL, it is incumbent on the approved assessor to judiciously evaluate mass movement hazards and to make conservative recommendations on forestry operations. As in the discussion on Protocol 13, the point “slopes greater than 20 degrees” should be included in the indicative mass movement lists under Paragraph 13.2.

Protocol 16: Riparian Protection.

Assuming that Protocol 16 will be updated to the requirement for the use of Drainage Class (using catchment area) as specified in the Conditions, then the Unmapped Drainage Lines and 1st Order streams will have Riparian Exclusion Zone minimum width reduced from 10 metres to 5 metres.

Riparian exclusion zones should be mapped at an appropriate scale. Maps generated by the approved assessor should be subject to independent audit under Protocol 38. The proper assessment of the Riparian Exclusion Zone requires the skill set of Tertiary qualifications in geomorphology or soils.

Protocol 20: Pre-Operational Surveys.

Under Protocol 11: Soil Dispersibility Assessment, it is recommended that a soil survey should be undertaken by the assessor to determine the range of soil dispersibility.

Under Protocol 15: Inherent Soil Erosion and Water Pollution Hazard Assessment, it is recommended that a soil survey of the landscape or compartment should be undertaken by the approved soil assessor to determine the range of Soil Regolith Stability Class.

It is necessary therefore that the approved soil assessor conduct a soil survey to NSW standards, by describing a sufficient number of soil profile data points to determine the representative range of soil types and soil materials in the area. These data points should be used to generate map units such as Soil Regolith Stability Classes and mass movement classes.

The approved soil assessor requires Tertiary qualifications in soils and/or geomorphology because professional judgement is required in determinations.

Soil data can be captured in the field using the Electronic Digital Infield Regolith Tool (eDIRT) system, and soil profile information collected by the appropriately qualified soil assessor should be provided for inclusion in the Soil and Land Information System (SALIS) database.

Protocol 38: Monitoring Program.

The case for independent environmental assessors with appropriate Tertiary qualifications is reinforced in the Monitoring program. This program should conduct independent audits into report, maps and designs generated under the above Protocols.

Monitoring and reporting should be undertaken on water quality of streams entering and exiting any compartments considered for forestry operations, before, during and after forestry operations, and catchment hydrological modelling of surface and channel flows should be undertaken. This will provide insights on any changes in water quality and erosion and sedimentation risks.

PROTOCOL 6: SUITABLY QUALIFIED PERSONS – TRAINING AND EXPERIENCE

This Protocol deals with the training requirements and experience necessary for environmental assessors for forestry operations. From the Protocols—

6.2 training requirements for an approved soil assessor

1) FCNSW must run courses, approved by the EPA, in soil regolith assessment and dispersible soil identification and management on a needs basis for the purpose of qualifying soil assessors as approved soil assessors.
2) These courses can include:

(a) the course developed and approved by the EPA in 2007 and previously delivered by the Soil and Land Conservation Consulting and TAFE NSW Riverina Institute; or

(b) another course developed and approved by the EPA for the purposes of condition 6.2.

The EPA does not own any soil-related course and has no plans to offer such a course in the future (Papenbrock, 2018). The course is run for staff from FCNSW and EPA by the Forestry Institute Training Centre (FITC) of the TAFE Riverina Institute at Tumut in Soil and Water Protection, for which the qualification is a Statement of Attainment (https://www.rit.tafensw.edu.au/courses/detail/soil-and-water-protection-statement-of-attainment-2018-855009). The course units are FWPCOT3258 Comply with soil and water protection, and FWPCOR2203 Follow environmental care procedures. It seems that the substance of this course concentrates on compliance and procedures within forestry operations without providing broader perspectives of soil properties, and might be lacking in independence from SFNSW.

I am concerned that training specified under Protocol 6.1 is not sufficiently independent of FCNSW, and the level of tuition is inadequate for the important tasks of assessing and managing soils for potentially intense logging operations under the proposed Coastal IFOA.

Training requirements for most of the other environmental assessors assume Tertiary qualifications:

- 6.3 Aquatic habitat assessment: "Tertiary biological or ecological qualifications are preferable".
- 6.4 Broad area habitat search: "be properly trained and proficient, to EPA's satisfaction, in the identification of flora and fauna subject species and habitat".
- 6.5 Targeted survey: "ecologically trained and capable of identifying flora and fauna subject species in their area to the EPA's satisfaction".
- 6.6 Threatened Ecological Communities: "extensive and bioregionally-specific experience in the field identification of TECs".
- 6.7 Assessment of Koala presence: "properly trained and proficient, to the EPA's satisfaction".

Training "to EPA's satisfaction" is unspecified. However, because decisions undertaken by environmental assessors require professional judgement, it is expected that minimum training requirements should be appropriate Tertiary qualifications.

Approved soil assessors require Tertiary qualifications in soils, geomorphology or geotechnical engineering and be independent of FCNSW. It is important that training for approved environmental assessors is independent of FCNSW.

PROTOCOL 10: ROAD DESIGN

Improperly designed and maintained roads and tracks are a major source of soil erosion and sediment transport. **Best management practices should be adhered to and enforced. Road design should be subject to independent audit under Protocol 38, and road construction and maintenance should be subject to independent inspection. The assessment of stability of roads requires a consideration of factors relating to mass movement and erosion hazards; this requires Tertiary qualifications e.g. in geotechnical engineering.**

PROTOCOL 11: SOIL DISPERSIBILITY ASSESSMENT

Pre-operational plans require information on the occurrence and distribution of dispersible soils, because soil dispersibility has a direct bearing on soil erosion.

Soil surveys.

Soil distribution can vary widely according to terrain facets and substrate lithology. This information requires assessing each soil layer that will be disturbed by the proposed forestry operations within the operational area. **A soil survey should be undertaken by the assessor to determine the range of soil dispersibility, as described in Protocol 20: Pre-Operational Surveys. Maps generated by the approved soil assessor should be subject to independent audit under Protocol 38.**

Soil dispersibility assessment.

There are three methods for assessing soil dispersibility—

1. The **Soil Dispersibility Testing Method** is prescribed in Protocol 11. This is the current standard for assessing soil dispersibility (NSW EPA, 1997). The approved soil assessor must record a dispersibility rating for each air-dry aggregate that was observed and recorded in accordance with this Protocol in Table 1 as follows:

Table 1. Dispersibility rating (Protocol 11).

Rating	Observation of aggregate
0	No dispersion within two hours of placement in water
1	Slight dispersion within two hours of placement in water
2	Slight dispersion within 10 minutes of placement in water and strong dispersion within two hours of placement
3	Strong dispersion within 10 minutes of placement in water and complete dispersion within two hours of placement
4	Complete dispersion within 10 minutes of placement in water

2. The **Emerson Aggregate Test** (EAT) is an eight-class classification of soil aggregate coherence (slaking and dispersion) in distilled water. It can easily be tested in the field. The EAT is the industry standard for assessment of dispersion. More information on the EAT can be found in Charman and Murphy (2000) and in Hazelton and Murphy (2013).

Table 2. Emerson Aggregate Test classes.

Class		Result
1	Slakes	Complete dispersion
2	Slakes	Some dispersion
3	Slakes	Some dispersion after remoulding
4	Slakes	No dispersion (carbonate or gypsum present)
5	Slakes	Dispersion in shaken suspension
6	Slakes	Flocculates in shaken suspension
7	No slaking	Swells in water
8	No slaking	Does not swell

EAT Classes 2 and 3 can be divided into subclasses. The subclass is put in brackets. For example, a Class 3 aggregate that disperses completely on working leaving only sand grains is noted as Class 3(4). Class 2(4) is equivalent to Class 1.

Table 2a. Classes 2 and 3 subclasses.

Subclass	Dispersion
(1)	Slight milkiness immediately adjacent to the
(2)	Obvious milkiness, <50% of the aggregate affected
(3)	Obvious milkiness, >50% of the aggregate affected
(4)	Total dispersion, leaving only sand grains.

3. **Dispersion percentage** (DP) is a laboratory test that estimates the proportion of the clay fraction that has dispersed (Hazelton and Murphy, 2013). DP is sometimes presented as the Dispersal Index Ratio, also known as the Ritchie Method (Ritchie, 1963), which is the inverse of DP x 100. Ratings for Dispersion Percentage is shown in Table 3.

Table 3. Ratings for Dispersion Percentage (Hazelton and Murphy, 2013).

Dispersion %	Dispersal Index Ratio (Ritchie)	Dispersibility rating
<6	>16	Negligible
6 – 30	3 – 16	Slight
30 – 50	2.0 – 3.0	Moderate
50 – 65	1.5 – 2.0	High
>65	<1.65	Very high

The Soil Dispersibility Testing Method is a very much reduced version of the Emerson Aggregate Test. The EAT includes more information on aggregate stability.

The Emerson Aggregate Test (EAT) is the industry standard for assessment of aggregate stability. It should replace the Soil Dispersibility Testing Method as prescribed in Protocol 11. An EAT result indicating dispersion or slaking should be verified by Dispersion Percentage / Ritchie Method.

Soils tested to be dispersible should be assessed as Soil Regolith Stability Class 3 (Protocol 15) due to low coherence.

PROTOCOL 12: SEASONALITY RESTRICTIONS

This provides the methodology for determining applicable seasonality restrictions, having regard to inherent hazard level classified under Protocol 15: Inherent Soil Erosion and Water Pollution Hazard Assessment and Soil Regolith Class (see below), and Rainfall Erosivity and Rainfall Zone.

Paragraph 15.2(1) specifies the Rainfall Zone data source as “FCNSW’s GIS as supplied to the EPA (1998)”. The reference to EPA is not included. The NSW Department of Primary Industries / Trade and Investment is now the data custodian but at the time of writing, information relating to rainfall erosivity zones was not available. **In the absence of such information, the most conservative case must be applied.**

PROTOCOL 13: MASS MOVEMENT ASSESSMENT

FCNSW must apply the assessment procedures set out in this Protocol to determine the mass movement hazard for any proposed forestry operation.

Mass movement hazards increase with slope gradient, from about 20^{o} upwards, although some slopes on particularly susceptible geology (for example, the Nambucca Beds in northern NSW) have been observed to be susceptible to mass movement on gradients as low as 7^{o} (Eddie, 2000). Debris avalanches and talus slopes occur under the influence of gravity on slopes greater than the natural angle of repose of unconsolidated sediment, about 25^{o}. **In the absence of other information, it should be assumed that all land on slopes greater than 20^{o} has the potential for mass movement.**

13.2 Procedure for assessing mass movement hazard. Modules 1 and 2 have outlined methodology for assessment of mass movement potential, and listed some identifying features under “Evidence of mass movement or potential mass movement includes, but is not limited to”. **This should include the point “slopes greater than 20 degrees”.**

The risks involved in failure to properly assess mass movement hazards for a forestry operation include damage to infrastructure, increased erosion hazards, and sedimentation and pollution of waterways. Ground disturbance on susceptible slopes risks re-activating old landslips, and mass movement may initiate sheet and gully erosion and stream sedimentation.

The offsite consequences of mass movement are significant. McGarity (1988) observed in the Mistake State Forest that eroded material, especially from gullies and mass movement events, moves into drainage lines with the finer sediments being transported away, and the coarser gravels and boulders accumulating in the bed of the channel. Slumping of subsoils in road batters is a common source of sediment movement into streams.

Proper assessment prior to any proposed disturbance requires the exercise of professional judgement and a conservative approach. **The approved soil assessor requires Tertiary qualifications in soils, geomorphology or geotechnical engineering.**

Mapping exercises prior to any proposed disturbance should be undertaken to determine mass movement hazards; these are site-specific and must be geo-located. **Maps generated by the approved soil assessor should be subject to independent audit under Protocol 38.**

PROTOCOL 15: INHERENT SOIL EROSION AND WATER POLLUTION HAZARD ASSESSMENT

This Protocol sets out the procedure for FCNSW to determine the Inherent Hazard Level (IHL) for harvesting operations covered by the approval. The IHL for a particular forestry operation is currently determined on the basis of rainfall erosivity, slope class, and soil regolith stability. Certain forestry activities are limited or prohibited according to the IHL (Table 4).

Rainfall erosivity.

Paragraph 15.2(1) specifies the Rainfall Zone data source as “FCNSW’s GIS as supplied to the EPA (1998)”. The reference to EPA is not included. The NSW Department of Primary Industries / Trade and Investment is now the data custodian but at the time of writing, information relating to rainfall erosivity zones was not available. **In the absence of such information, the most conservative case must be applied.**

Soil Regolith Stability Class.

The approved soil assessor must not rely exclusively on the Soil Regolith Stability Class mapping (Murphy *et al.,* 1998) which is at regional scale, for accuracy at the landscape or compartment scale. Field assessment at local scale will verify the accuracy of the broader scale soil regolith stability classification for particular compartments and describe significant variability at a more localised scale. It is assessed by field observation and *requires professional judgement.*

Paragraph 15.2(3)(c) provides for the assessor’s judgement to differ from the Soil Regolith Stability Class mapping.

Paragraph 15.3(1)(a)(iv)(F) provides for the assessor to undertake a field investigation of the compartment to determine the soil regolith class where a soil regolith class is not consistent with the information specified in the GIS dataset.

A soil survey of the landscape or compartment should be undertaken by the approved soil assessor to determine the range of soil regolith stability class, as described in Protocol 20: Pre-Operational Surveys, and to determine whether or not the soil regolith class is consistent with the information specified in the GIS dataset. Maps generated by the approved soil assessor should be subject to independent audit under Protocol 38.

Paragraph 15.3(1)(a)(iv)(I) states that in all field inspections and investigations, the approved soil assessor must take a conservative approach. The level of investigation, inspection and testing required is to be determined by the approved soil assessor, *based on their professional judgement*.

The approved soil assessor requires Tertiary qualifications in soils because professional judgement is required in determinations.

Inherent Hazard Level (IHL).

The Inherent Hazard Levels are presented in a matrix table for each IHL Table and uses Slope Class, Rainfall Erosivity and Soil Regolith Stability Class. The IHLs are depicted in Paragraph 15.4(3) and in Table 4 below. There are three inherent hazard level (IHL) tables which apply depending on the forestry operation and harvesting intensity, as in Table 5.

Table 4. Inherent Hazard Levels.

IHL	Meaning	Restrictions
Level 1	Low soil erosion and water pollution hazard	None
Level 2	High soil erosion and water pollution hazard	Burning regimes restricted
Level 3	Very high soil erosion and water pollution hazard	Burning regimes restricted; seasonality restrictions
Level 4	Extreme soil erosion and water pollution hazard	Forestry operations prohibited

Table 5. IHL Table number for forestry operation and harvest intensity within the net harvest area.

IHL Table no.	Forest type	Harvesting intensity
IHL Table 1	Native forest harvesting	Greater than or equal to 50% canopy removal
IHL Table 2	Native forest harvesting	Less than 50% canopy removal
IHL Table 3	Native forest thinning	Any intensity

Harvesting intensity is prescribed in the Conditions in Division 2 – Distribution of harvesting across the landscape. The proposed new rules identify 3 types—

1. Intensive,
2. Selective in the regrowth zone (i.e. along coast) where $10m^2$ basal area per ha must be left after logging,
3. Selective in the non-regrowth zone (further inland) where $12m^2$ basal area per ha must be left after logging.

The IHL Tables should be modified to reflect the harvesting intensities proposed under the Coastal IFOA, because the soil exposure and (erosion hazards) could vary greatly as it depends on the condition of the forest before the operation. This is unknown and not documented.

The IHL tables are deficient for two other reasons—

1. **Slope length or local relief is not applied to the slope class, and**
2. **There is no mass movement hazard applied to the IHL.**

Slope length or local relief.

Local relief is the terrain within 300m of a site, measured as the difference in elevation between the top and base of a slope. Erosion and mass movement hazards are significantly greater on mountainous terrain (with local relief of more than 300m) than on low hills (with local relief of less than 100m), because of greater run-on and runoff potential. Under the Universal Soil Loss Equation (USLE) method which was used previously, slope length was one of the factors. **Therefore, the IHL should be adjusted to take account of local relief of the terrain.**

Mass movement hazard.

Some slopes on particularly susceptible geology e.g. the Nambucca Beds in northern NSW (Eddie, 2000, 2018) have significantly greater mass movement hazards than others, for a given slope gradient. It should be noted that soils with Regolith Stability Class 1 (high coherence with low sediment delivery potential) have the potential for the greatest mass movement hazard on steep slopes because of their combined good drainage and high water holding capacity; this means that they can become hydrologically loaded following rainfall and be susceptible to mass movement. The mass movement hazards will again differ with terrain facets, e.g. mountain mid and lower slopes will have a greater hazard than ridge crests and upper slopes. **Therefore, the IHL should be adjusted to take account of mass movement hazards.**

Considering the additional mass movement and terrain variables, a proposed approach is to add weightings for local relief and mass movement to the slope classes in the IHL Tables.

Slope Hazard Classes.

Weighted slopes classes might be called Slope Hazard Classes which are based on the terrain and mass movement hazards of each slope class. Indicative mass movement is listed in Protocol 13.2. The five Slope Hazard Classes and their hazard potentials are rated in Table 6. Mass movement hazards and local relief are entered into Table 7 for calculation. This includes an example entry.

Table 6. Slope Hazard Classes.

Slope Hazard Class	
1	Low hazard potential
2	Moderate hazard potential
3	High hazard potential
4	Very high hazard potential
5	Extreme hazard potential

Table 7. Slope Hazard Class calculation based on erosion and mass movement hazards.

Slope Hazard Class		Y/N	Weight	Score
Slopes. Score one of:	Slopes < 10°		1	
	Slopes 10° to < 20°		2	
	Slopes 20° to < 25°		3	
	Slopes 25° to < 30°	y	4	4
	Slopes 30°+		5	
Local relief. Score one of:	Local relief < 90m (low hills, rises, plains, etc)		0	
	90m to < 300m (hills)	y	1	1
	300m+ (mountains)		2	
Mass movement. Score as many as applicable:	Scarps or small cliffs		4	
	Steep curving concave slopes		3	
	Reverse slopes		4	
	Hummocky terrain		4	
	Disturbed drainage patterns	y	2	2
	Convex bulges on lower slopes		4	
	Sharp vegetation boundaries		2	
	Different vegetation patterns		2	
	Recent or revegetated scars, where >10m^3 of soil has slipped or moved downslope		4	
	Slumped or slipped road batters	y	3	3
	Tension cracks along fill batters	y	3	3
	Bedding planes dipping at an angle parallel to the ground surface		4	
	Mixed or buried soil profiles	y	3	3
	Bent timber		3	
	Split timber		2	
	Springs at the toe of the slope.		3	

A proposed methodology.

The weighted scores for local relief and mass movement hazards, each divided by their maximum scores (2 and 4 respectively), are added to the weight for the slope class, to a maximum of 5, giving the Slope Hazard Class. Thus, in the example in Table 7,

1. Slope class is 25° – 30° with a score of 4;
2. Local relief is 90 – 300m, with a score of 1; which when divided by the maximum weight of 2, gives weight for local relief = 0.5;
3. The maximum score for mass movement is 3, which when divided by the maximum weight of 4, gives weight for mass movement = 0.75;
4. Add the weights for local relief and mass movement together = 1.25;
5. Add the weighting (1.25) to the score for slope class (4) = 5.25;
6. Round the score (5.25) to 5 = Slope Hazard Class 5, with Extreme hazard potential (Table 6);
7. The IHLs are calculated using the modified IHL tables as in the Modified IHL Table (Table 9).

Further to the above example, if R-factor = 4000-5000 and Soil Regolith Stability Class = 1:

1. With Slope class = 25° – 30°, then under the current IHL Table (Table 8), IHL = 2;
2. With Slope Hazard Class = 5, then under the modified IHL Table (Table 9), IHL = 4. The addition of terrain relief and mass movement hazards has raised the IHL from 2 to 4.

Table 8. The current IHL Table 1 (for native forest harvesting with greater than or equal to 50% canopy removal), using Slope Class (from Protocol 16).

Average annual R-factor	Slope class (degrees)									
	0<10		10<20		20<25		25<30		30+	
0–2000	1	1	1	2	1	2	2	2	4	4
	1	2	2	2	2	2	2	2	4	4
2000–3000	1	1	1	2	1	2	2	2	4	4
	1	2	2	2	2	2	2	4	4	4
3000–4000	1	2	2	2	2	2	2	2	4	4
	1	2	2	2	2	4	4	4	4	4
4000–5000	1	2	2	2	2	2	2	4	4	4
	2	2	2	2	4	4	4	4	4	4
5000–6000	2	2	2	2	2	2	2	4	4	4
	2	2	2	4	4	4	4	4	4	4
6000+	2	2	2	2	2	4	4	4	4	4
	2	2	4	4	4	4	4	4	4	4

Soil regolith key

Yellow (top left) = R1 Green (top right) = R3

Orange (bottom left) = R2 Blue (bottom right) = R4

Table 9. The proposed modified IHL Table 1 using Slope Hazard Class.

Average annual R-factor	Slope Hazard Class									
	1		2		3		4		5	
0–2000	1	1	1	2	1	2	2	2	4	4
	1	2	2	2	2	2	2	2	4	4
2000–3000	1	1	1	2	1	2	2	2	4	4
	1	2	2	2	2	2	2	4	4	4
3000–4000	1	2	2	2	2	2	2	2	4	4
	1	2	2	2	2	4	4	4	4	4
4000–5000	1	2	2	2	2	2	2	4	4	4
	2	2	2	2	4	4	4	4	4	4
5000–6000	2	2	2	2	2	2	2	4	4	4
	2	2	2	4	4	4	4	4	4	4
6000+	2	2	2	2	2	4	4	4	4	4
	2	2	4	4	4	4	4	4	4	4

The Slope Hazard Class table and the IHL tables can be easily digitised and calculated using software such as spreadsheets for a consistent and quick outcome.

Until the Slope Hazard Class is used to calculate IHL, it is incumbent on the approved assessor to judiciously evaluate mass movement hazards and to make conservative recommendations on forestry operations. As in the discussion on Protocol 13 above, the point “slopes greater than 20 degrees” should be included in the indicative mass movement lists under Paragraph 13.2.

Further consideration is needed to determine appropriate weightings. The concept of Slope Hazard Classes should account for exceptional erosion and mass movement hazards on mountainous terrain in, for example, the Nambucca Beds in northern NSW and Tertiary Basalts.

PROTOCOL 16: RIPARIAN PROTECTION

Riparian Exclusion Zones.

Exclusion of riparian zones from forestry operations is essential to the prevention of streambank erosion and consequent sedimentation and pollution of downstream waterways.

According to Protocol 19, where LiDAR data exists, the applicable drainage class, based on the catchment area, for a mapped drainage line must be determined; otherwise, the applicable stream order for drainage feature protection must be determined. Protocol 16, however, specifies the use of Strahler stream order classification system, as in Table 10.

Table 6a and Table 6b under Paragraph 102 of the Conditions specify the minimum Riparian Exclusion Zone and ground protection zone widths, where Table 6b is applicable to the Coastal IFOA. These tables depend on Drainage Class which is based on the catchment area of each riparian line, derived from interpretation of LiDAR data. See Table 11.

The ground protection zone is defined in Protocol 39 as “a strip of vegetation or groundcover that must be retained adjacent to specified riparian features … where modified harvesting practices are required to minimise soil disturbance”.

Table 10. Minimum Riparian Exclusion Zones. From Protocol 16, Table 1 (NSW EPA, 2018b).

Drainage category (stream order)	Riparian Exclusion Zone minimum width (metres)
Drainage feature	n/a
Unmapped drainage line	10
1st Order	10
2nd Order	20
3rd Order	30
4th Order (and above)	50

Table 11. The minimum Riparian Exclusion Zones and ground protection zone widths applicable to the Coastal IFOA. From Paragraph 102 Table 6b (NSW EPA, 2018a).

Drainage category (Drainage Class)	Riparian Exclusion Zone minimum width (metres)	Ground Protection Zone minimum width (metres)
Drainage depression (mapped or unmapped)	n/a	5
Unmapped drainage line	5	10
Class 1 classified drainage line, area < 20 ha	5	10
Class 1 classified drainage line within the class 1 aquatic habitat map, area < 20 ha	10	10
Class 2 classified drainage line, area 20 – 100 ha	20	0
Class 3 classified drainage line, area 100 – 400 ha	30	0
Class 4 (and above) classified drainage line, area > 400 ha	50	0

It is assumed that Stream Orders are equivalent to Drainage Classes for the purposes of the IFOA. But comparing Tables 10 and 11 above, the category Unmapped drainage lines has a Riparian Exclusion Zone minimum width of 5m based on Drainage Class and 10m based on Stream Order. Similarly, Class 1 classified drainage line not within the class 1 aquatic habitat map also has a Riparian Exclusion Zone minimum width of 5m, whereas 1st Order streams are given 10m.

The ground protection zone minimum width is zero metres for Classes 2, 3 and 4 drainage categories. Assuming that Protocol 16 will be updated to the requirement for the use of Drainage Class as specified in the Conditions, then the Unmapped Drainage Lines and 1st Order streams will have Riparian Exclusion Zone minimum width reduced from 10m to 5m.

The potential consequences of reduction of minimum Riparian Exclusion Zone from 10 to 5 metres and the lack of ground protection zones for Class 2, 3 and 4 drainage categories are significant and would have a direct impact on erosion and runoff.

Whether using either Drainage Classes or Stream orders, **Riparian Exclusion Zones should be mapped at a scale such that the riparian exclusion zones can be easily be shown. Maps generated by the approved assessor should be subject to independent audit under Protocol 38.**

Riparian protection should comply with the Water Management Act 2000 which is regulated by the NSW Office of Water. The riparian corridor (RC) is defined in NSW Office of Water (2012) as consisting of the channel which comprises the bed and banks of the watercourse (to the highest bank), and the vegetated riparian zone (VRZ) adjoining the channel. The Officer of Water recommends a VRZ width based on watercourse order (see Table 12). This should be the minimum recommendation for the Coastal IFOA. The width of the VRZ should be measured from the top of the highest bank on both sides of the watercourse; this is similar to that in Protocol 16 except for 4th order and greater where the Riparian Exclusion Zone minimum width is 50m, which is commendable.

Table 12. Recommended riparian corridor (RC) widths (NSW Office of Water, 2012).

Watercourse type	VRZ width (each side of watercourse)	Total RC width
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

Paragraph 16.3 specifies that the Riparian Exclusion Zone must be measured along the ground surface from the bank-full level of the drainage line in the field, presumably to the bank-full level on the opposite bank.

Streambank erosion and sedimentation.

The offsite consequences of streambank erosion are sedimentation and pollution of downstream waterways, which are potentially severe. Stream sedimentation occurs when debris is transported at high energy and then deposited in channels of lower energy, while the suspended clays and silts are transported further and therefore contribute to turbidity in waterways. It is likely that this would contribute to changes in the flow characteristics of the streams. McGarity (1993a) stated that erosion of stream banks increases the sediment load. The accumulation of woody debris in drainage lines also alters stream flow at times of high runoff and further destabilised stream banks.

The potential consequences of improper protection of the riparian zone are significant. The proper assessment of the Riparian Exclusion Zone requires the skill set of Tertiary qualifications in geomorphology or soils.

PROTOCOL 20: PRE-OPERATIONAL SURVEYS

This Protocol currently relates to broad-area habitat searches and targeted flora and fauna surveys. This is necessary but not sufficient.

Soil surveys.

Under Protocol 11: Soil Dispersibility Assessment, as discussed above, it is recommended that a soil survey should be undertaken by the assessor to determine the range of soil dispersibility.

Under Protocol 15: Inherent Soil Erosion and Water Pollution Hazard Assessment, as discussed above, it is recommended that a soil survey of the landscape or compartment should be undertaken by the approved soil assessor to determine the range of soil regolith stability class.

Further, it is noted that under paragraph 20.4(9)(b)(vi)(B), soil fertility must be assessed and recorded at each survey grid point for Koala surveys.

It is necessary therefore to conduct a soil survey at the compartment or landscape scale (1:25,000 to 1:10,000) or larger to NSW standards, by describing a sufficient number of soil profile data points to determine the representative range of soil types and soil materials in the area. These

data points should be used to generate map units such as Soil Regolith Stability Classes and mass movement classes. Maps generated by the approved assessor should be subject to independent audit under Protocol 38.

Soil samples should be collected on representative terrain facets and substrate lithology. Soil profiles should be classified according to the Australian Soil Classification (ASC) system (Isbell, 2002). Data should not be averaged, and the worst case should be assumed in a conservative approach for assessment of risks. Standards for conducting soil surveys, including the correct understanding of mapping scales, are found in McKenzie *et al* (2008).

Soil data can be captured in the field using the *Electronic Digital Infield Regolith Tool (eDIRT)* system*:* http://www.environment.nsw.gov.au/topics/land-and-soil/soil-data/edirt.

Soil profile information (including regolith stability etc) collected by the appropriately qualified soil assessor should be provided for inclusion in the *Soil and Land Information System (SALIS)* database: http://www.environment.nsw.gov.au/topics/land-and-soil/soil-data/salis.

Further information on soil mapping may be obtained from the NSW Office of Environment & Heritage http://www.environment.nsw.gov.au/topics/land-and-soil/soil-data/soil-maps

The approved soil assessor requires Tertiary qualifications in soils and/or geomorphology because professional judgement is required in determinations.

PROTOCOL 38: MONITORING PROGRAM

Paragraph 38.2(1) requires that FCNSW must establish a monitoring steering committee, required under condition 129.1 of the approval, with the following composition:

(a) a minimum of three independent and suitably qualified scientists that have demonstrated expertise in:

- (i) ecology;
- (ii) soil erosion and water quality/pollution; and
- (iii) forest regeneration and Principles of Ecologically Sustainable Forest Management (ESFM).

This reinforces the case for independent environmental assessors with appropriate Tertiary qualifications.

Best management practices should be documented, adhered to and enforced.

Monitoring and reporting should be undertaken on water quality of streams entering and exiting any compartments considered for forestry operations, before, during and after forestry operations, and catchment hydrological modelling of surface and channel flows should be undertaken. This information will provide insights on any changes in water quality and erosion and sedimentation risks.

This program should conduct independent audits into report, maps and designs generated under the above Protocols. Independent auditors should be specialists in the field of audit and have appropriate Tertiary qualifications.

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APPENDIX 1 Papenbrock, C. (June 2018). Email reply to enquiry. EPA NSW.

Michael Eddie

From:	Cynthia Papenbrock <Cynthia.Papenbrock@epa.nsw.gov.au>
Sent:	Tuesday, 26 June 2018 10:52
To:	Michael Eddie
Cc:	Kiah Hunter
Subject:	RE: soil assessment course

Good morning Mr Eddie

This course has been run by FCNSW. Assessment is conducted throughout the course based on demonstrated competency. On completion of the course, the names of the successful EPA participants are provided. EPA staff that have successfully completed the course are then authorised to complete the soil assessment modules in the EPL.

Regards,
Cynthia Papenbrock

From: Michael Eddie [mailto:mikedd@bigpond.com] Sent: Monday, 25 June 2018 2:10 PM
To: Cynthia Papenbrock <Cynthia.Papenbrock@epa.nsw.gov.au> Subject: RE: soil assessment course

I am interested in courses approved by the EPA, in soil assessment and management for the purpose of qualifying soil assessors for the NSW Forestry Corporation. Such courses are specified under Protocol 6 of Coastal Integrated Forestry Operations Approval - Protocols (Consultation draft May 2018, NSW EPA).

From Protocol 6—

6.1 Training requirements for an approved soil assessor.

1) FCNSW must run courses, approved by the EPA, in soil regolith assessment and dispersible soil identification and management on a needs basis for the purpose of qualifying soil assessors as approved soil assessors.
2) These courses can include:
   (a) the course developed and approved by the EPA in 2007 and previously delivered by the Soil and Land Conservation Consulting and TAFE NSW Riverina Institute; or
   (b) another course developed and approved by the EPA

How are such courses assessed? What criteria are used for approval?

Many thanks,
Michael Eddie
mikedd@bigpond.com

From: Cynthia Papenbrock <Cynthia.Papenbrock@epa.nsw.gov.au> Sent: Tuesday, 19 June 2018 1:29 PM
To: mikedd@bigpond.com
Cc: Vineeta Vudatala <Vineeta.Vudatala@epa.nsw.gov.au> Subject: soil assessment course

Hi Mike,
Thanks for your enquiry – the EPA does not own this course and has no plans to offer this course in the future.

Cynthia Papenbrock
Training Unit
NSW Environment Protection Authority
cynthia.papenbrock@epa.nsw.gov.au Direct: 02 99956425
www.epa.nsw.gov.au @EPA_NSW

Report pollution and environmental incidents 131 555 (NSW only) or +61 2 9995 5555

NSW EPA

Land and Soil Hazards on the Nambucca Beds, Northeast NSW

Michael Eddie

March 2018

Senior Soil Scientist (retired), formerly of the Science Division, NSW Office of Environment and Heritage.

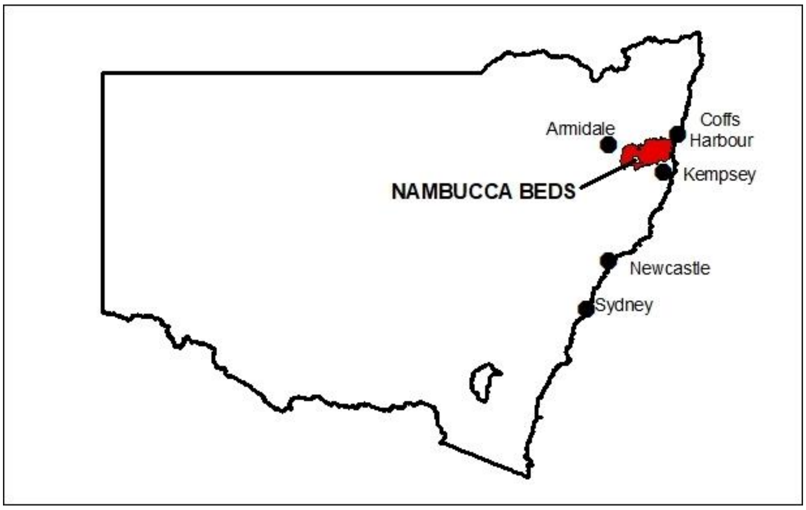
Author, Eddie M.W. (2000). *Soil Landscapes of the Macksville & Nambucca 1:100 000 Sheets*, DLWC, Sydney.

Member, Australian Soil Science Society.

INTRODUCTION

This report was commissioned by Mr Ashley Love of the Bellingen Environment Centre, on behalf of the North Coast Environment Council (NCEC), due to concerns about proposed logging activities on steep land by the NSW Forestry Corporation in river catchments on the Nambucca Beds on the NSW mid north coast. The concerns primarily relate to the impacts of proposed forestry operations in the steep headwaters on soil erosion and its effects on pollution and sedimentation in downstream waterways.

Figure 1. Location.



Two reports were recently commissioned regarding logging risks in the upper Nambucca and Kalang catchments—

1. A report was commissioned through the Environmental Defender's Office on behalf of Ms Joy van Son, landowner, in relation to her concerns about the adequacy of the methods proposed to be used by the Forestry Corporation of NSW (FC) to assess the impacts on soils and downstream waterways of proposed forestry operations in Mistake State Forest in the upper Nambucca catchment (Eddie, 2017a).
2. A report was requested by Mr Ashley Love (Bellingen Environment Centre), who represented residents concerned about proposed logging activities on steep land by the Forestry Corporation (Forestry Corporation of NSW, 2017) in the Oakes, Roses Creek and Scotchman State Forests in the headwaters of the Kalang River catchment (Eddie, 2017b).

Logging and associated erosion and mass movement on steep land in Oakes SF was investigated by Atkinson *et al* (1992).

Residents downstream of these State Forests are concerned that the soil assessment methods used to prepare the draft Harvest Plans are inadequate and that Forests NSW might not sufficiently adhere to them. These are termed "Methods for assessing the soil erosion and water pollution hazard associated with scheduled and non-scheduled forestry activities" (Soil and Water Methodology). The current version of the Soil and Water Methodology can be found at Schedule 3 of the Lower North East Region Environmental Protection Licence (EPL), which is Attachment A to the IFOA.

The most severe impacts occur on the underlying Nambucca Beds geology, which have been identified as having especially severe erosion and mass movement hazards. The Nambucca Beds cover all of the Kalang River catchment, most of the Bellingen and Nambucca catchments and much of the middle Macleay in the Macleay Gorges (Map 2).

State Forests on the Nambucca Beds are the Buckra Bendinni, Gladstone, Irishman, Lower Creek, Mistake, Nulla-Five Day, Oakes, Pee Dee, Roses Creek, Scotchman, Styx River, and Thumb Creek State Forests. Forestry operations in these State Forests are currently regulated by the Integrated Forestry Operations Approval for the Lower North East Region (IFOA).

This report will—

- Focus on the steep mountainous terrain on the Nambucca Beds;
- Address the critical nature of soils and regolith on the Nambucca Beds and the special case to be made for the Nambucca Beds with regard to erodibility of their soils and regolith;
- Address the thresholds of settings of the Inherent Hazard Levels, and the restrictions on logging for each level, in preventing erosion and water pollution;
- Address catchment management issues.

Relevant maps are presented in Appendix 1.

PHYSICAL ASPECTS

Physiography

The area covered by the Nambucca Beds falls within the **NSW North Coast** and **New England Tablelands** Biogeographic Regions (Thackway and Cresswell, 1995). See Map 1.

The IBRA **New England Tablelands** Biogeographic Region is described as "Elevated plateau of hills and plains on Palaeozoic sediments, granites and basalts; dominated by stringy bark/peppermint/box species, including *Eucalyptus caliginosa*, *E. nova-anglica*, *E. melliodora* and *E. blakleyi*". The relevant Subregions of the New England Tablelands include the Armidale Plateau, Walcha Plateau, Carrai Plateau and Round Mountain Subregions. The Armidale and Walcha Plateaus can be treated as a single unit (Tablelands).

Figure 2. Steep ridge and ravine terrain of the upper Nambucca catchment in the Coffs Escarpment.

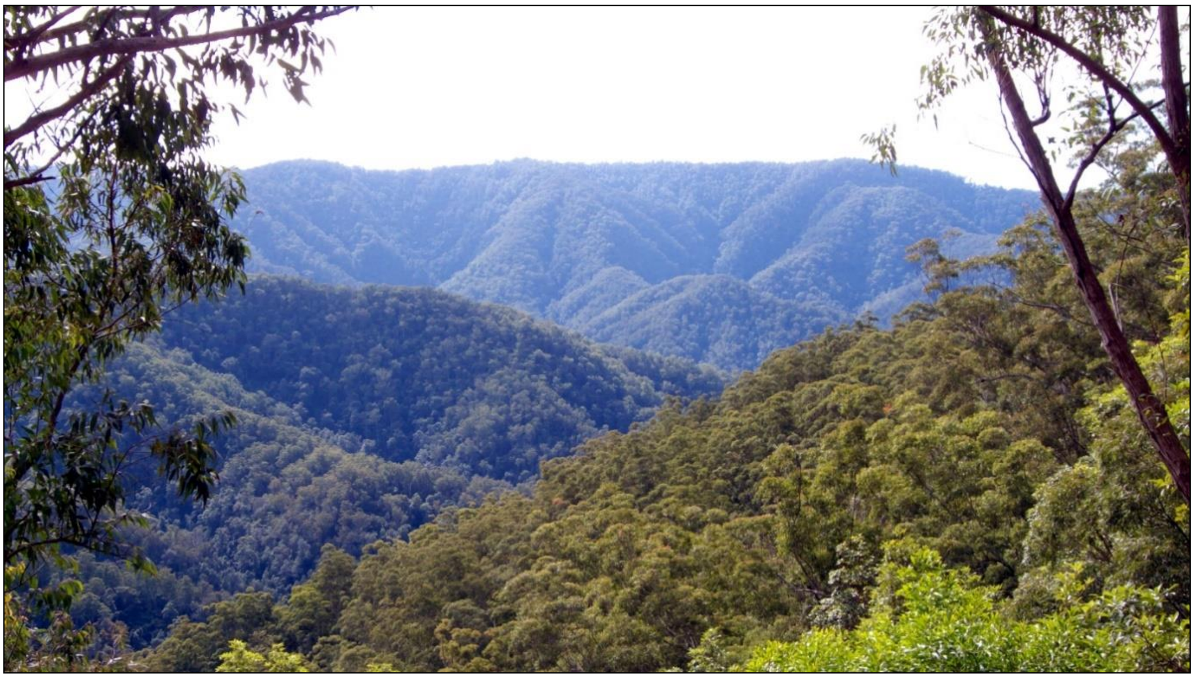


Figure 3. Precipitous terrain at Wollomombi Falls at the head of the Macleay Gorges below the Armidale Plateau.

The **Armidale – Walcha Plateaus** occur on mostly undulating with some steeper areas associated with scattered small hills and some strongly dissected terrain adjoining the Macleay Gorges. Some flat to very gently undulating plains also occur (King, 2004). Elevation is from approximately 800m rising to 1500m.

The IBRA **NSW North Coast** Biogeographic Region is described as "Humid; hills, coastal plains and sand dunes; *Eucalyptus - Lophostemon confertus* tall open forests, *Eucalyptus* open forests and woodlands, rainforest, *Melaleuca quinquenervia* wetlands, and heaths". This is a complex Region; the relevant Subregions of the NSW North Coast include the Coffs Escarpment, Macleay Gorges, Macleay - Upper Manning and Nambucca – Macleay Subregions.

The **Coffs Escarpment** subregion occurs below the Ebor – Dorrigo Plateau west to the Armidale Plateau. Drainage is south to the mid-Macleay River and east to the Bellinger – Nambucca catchment. The terrain is predominately rolling to very steep dissected mountain slopes, dominated by ridge and ravine terrain of narrow ridges and deeply incised valleys with interlocking spurs (Eddie 2000). Slope gradients range from 25% to 60 - 70%, local relief is 150m rising to 1,000m, and elevation range from 1,500m at Point Lookout down to 100m near the coast. Ridge crests are narrow (50 - 150m), and sideslopes are long to very long (800m to up to 3,000m). The long side-slopes often comprise the colluvial footslopes to steeper upper slopes and ridges. Rock outcrop is uncommon, but there may be areas of talus slopes. More detailed information on physiography is provided in McGarity (1988).

The **Macleay Gorges** are narrow escarpments of the Macleay River and its tributaries and are actively retreating into the New England Tablelands. Terrain is comprised of deeply incised valleys with talus slopes, bedrock confined streams, cliffs and steep to precipitous sideslopes and footslopes. The gorges begin as small gullies on the Tablelands, then widen downstream to 11 km wide below the Carrai Plateau. Rivers which enter the gorge do so by way of waterfalls and other steep entry points (King, 2004). Much of the Macleay Gorges are reserved in the Oxley Wild Rivers National Park and the Macleay Gorge Wilderness area, and World heritage listed as part of the Central Eastern Rainforest Reserves (Australia).

Because of their mountainous terrain, this report will focus on the **Coffs Escarpment** and **Macleay Gorges** subregions. The complexity of this terrain exerts a major influence on climate and therefore on vegetation communities.

Geology

The Nambucca Block or Nambucca Slate Belt is a major structural unit in the eastern part of the New England Fold Belt (Brownlow et al., 1988), faulted against the Coffs Harbour Block to the north and the Hastings Block to the south. It comprises moderately to intensely folded and Late Carboniferous to Early Permian metasediments, and generally interpreted as products of accretionary prism accumulation east of a northerly-trending volcanic arc and fore-arc marine basin. Intense orogenic deformation occurred during the Late Permian, characterised by regional dynamic and thermal metamorphism, most intensely in the core of the belt. The distribution of lithologies is complex, owing to large-scale displacement. The Nambucca Beds (Pn) are a major component (Gilligan *et al*., 1992; Leitch, 1978; Lennox & Roberts, 1988).

The Nambucca Beds are Permian metasediments, at least 3 - 4km thick. The lower Nambucca Beds (Parrabel Beds, Pnpx) are dominated by diamictites. The upper Nambucca Beds (Bellingen slate, Pnbf; Five Day phyllites, Pnfm; Pee Dee Beds, Pnpf) are dominated by fine-grained sediments with conspicuous soft micaceous sandstones and siltstones. Rocks are moderately to intensely cleaved, fractured and deformed, with schistose foliation especially in shear zones. Higher-grade metamorphism occurred in the “Bowra culmination” in the central region, a reflection of greater uplift of the slate belt compared with the periphery. The total area of the Nambucca Beds is 5,137 km^2.

Injected quartz veins are distinctive and very common. Slip planes (which may be indicated by the presence of springs) may form when substrate dip angles are parallel to the ground surface, and when quartz veins occur in deeply weathered substrate. There are some Tertiary basalt caps (Tb) on some high ridges. More detailed information is provided in McGarity (1988).

Other geological units within the area covered by the Nambucca Beds, which are not under consideration in this report, are Triassic granitic batholith intrusions (Round Mountain, Carrai, etc), Tertiary volcanics (Ebor basalts), and Quaternary sediments (coastal and riverine).

Regolith on the Nambucca Beds is weathered rock of weak strength, with up to 4 m depth of strongly weathered silty clays (often deep red, with mottling at depth) on colluvium and footslopes in areas of weathered substrate, to very shallow on ridges and upper slopes. Soils developed on the deep regolith are red, strongly structured, and with weak texture contrast. Soils are acidic clays and slaking when wet but generally moderately fertile. Mica flakes impart silty textures to the soil materials. Quartz gravels are common as surface lag deposits (Eddie, 2000).

Figure 4. Detail of the Five Day Phyllites (Pnfm) substrate.

Soil landscapes

The soil landscapes in the area have been mapped at regional scale (1:100,000) by Eddie (2000) and King (2004), and at reconnaissance scale (1:250,000) by the NSW Comprehensive Regional Assessments (1999). Soil landscapes are indicative at the scale of mapping and enlarging the map cannot be expected to reveal further information, and it will produce distortions whereby map boundaries will no longer correspond to boundaries on-the-ground.

The mountainous area has been mapped as the Snowy Range (sn), Macleay Gorges (mg) and Mistake (mk) soil landscapes (Table 1). Mountainous terrain is defined as land with local relief of greater than 300 metres; this comprises 46% of the area of the Nambucca Beds.

Soil landscapes with slopes greater than 20º are Snowy Range (sn) and Macleay Gorge (mg). These are 50% of the total area of the above SFs, and 46% of the total area of the Nambucca Beds. Slopes above 20º are increasingly prone to mass movement and erosion hazards.

The Styx River SF is partly on the Armidale Tablelands and has the lowest proportion of mountainous terrain (Table 2).

Table 1. Soil landscapes of the mountainous terrain.

Soil landscape	IBRA Subregion	Slope class	Terrain	Area (km^2)	Percent on Nambucca Beds
Snowy Range (sn)	Coffs Escarpment	>30º	Ridge and ravine terrain. Very steep to precipitous rectilinear slopes.	1,498	29%
Mistake (mk)	Coffs Escarpment	15-30º	Rolling to steep slopes; long side-slopes and footslopes below Snowy Range (sn).	1,035	20%
Macleay Gorge (mg)	Macleay Gorges	>30º	Ridge and ravine terrain. Very steep to precipitous rectilinear slopes in deeply incised gorges.	885	17%
			Totals	3,588	70%

Soils

Soils in the Coffs Escarpment are described by Eddie (2000) as well drained, stony, shallow to moderately deep, Red Dermosols (Brown Earths) widespread on side-slopes on weathered substrate, with deep well drained Red Ferrosols and Red Dermosols (Krasnozems) on colluvium, and shallow Paralithic Leptic Rudosols and Paralithic Tenosols (Lithosols) mainly on upper slopes.

Major soil types of the Macleay Gorge (King 2004) are Rudosols (Lithosols) and other shallow soils such as Red Kurosols (Red Podzolic Soils), Yellow Kurosols (Yellow Podzolic Soils), Yellow Chromosols (Yellow Podzolic Soils) and Yellow and Red Kandosols (Yellow and Red Earths).

These soils are spatially heterogeneous according to variations in parent material lithology and mineralogy, weathering and mass movement history; this is in accordance with the views of McGarity (1993c). Beavis (2009) provided a comparison of previous and current soil assessments.

Weathering of mica flakes imparts silty textures to soils and are slaking when wet. There is often a stone line between the A and B horizons, which indicates a colluvial history, and quartz gravels are common as surface lag deposits.

Table 2. Proportional areas of mountainous terrain within each State Forest on the Nambucca Beds.

State Forest (SF)	Area (km^2)	Soil landscape	Area (km^2)	Percent of SF	Slopes > 20º		Percent of SF in mountainous terrain
					Area (km^2)	Percent	
Buckra Bendinni	17.6	Mistake (mk)	12.9	74%	4.7	26%	100%
		Snowy Range (sn)	4.7	26%			
Gladstone	68.2	Mistake (mk)	8.0	12%	26.7	39%	51%
		Snowy Range (sn)	26.7	39%			
Irishman	27.3	Mistake (mk)	13.1	48%	13.2	48%	96%
		Snowy Range (sn)	13.2	48%			
Lower Creek	12.7	Snowy Range (sn)	12.7	100%	12.7	100%	100%
Mistake	51.2	Mistake (mk)	24.5	48%	26.0	51%	99%
		Snowy Range (sn)	26.0	51%			
Nulla-five Day	32.4	Mistake (mk)	4.7	15%	27.4	85%	99%
		Snowy Range (sn)	27.4	85%			
Oakes	76.2	Mistake (mk)	21.2	28%	53.8	71%	98%
		Snowy Range (sn)	53.8	71%			
Pee Dee	0.6	Mistake (mk)	0.6	100%	0.0	0%	100%
Roses Creek	30.7	Mistake (mk)	12.0	39%	16.9	55%	94%
		Snowy Range (sn)	16.9	55%			
Scotchman	31.4	Mistake (mk)	3.0	10%	9.6	31%	40%
		Snowy Range (sn)	9.6	31%			
Styx River	163.8	Macleay Gorge (mg)	32.3	20%	70.8	43%	46%
		Mistake (mk)	5.1	3%			
		Snowy Range (sn)	38.5	23%			
Thumb Creek	40.8	Mistake (mk)	27.9	68%	12.8	31%	100%
		Snowy Range (sn)	12.8	31%			

Native vegetation

In the Coffs Escarpment, tall open forests (wet sclerophyll forest) of the *Eucalyptus pilularis - E. microcorys* suballiance (Hager and Benson, 1994) are common, with a *Corymbia intermedia - E. acmenoides* suballiance on exposed sites, and *Argyrodendron actinophyllum* subtropical rainforests (Floyd 1990) on sheltered slopes. The *Eucalyptus campanulata* alliance occurs above about 700m elevation, merging to subtropical rainforest of the *Sloanea woollsii - Dysoxylon fraserianum -*

Argyrodenron actinophyllum - Caldcluvia paniculosa suballiance. The *Eucalyptus grandis* suballiance occurs on sheltered lower slopes (Eddie, 2000).

In the Macleay Gorges, open woodland to open forest communities of the *Eucalyptus tereticornis - E. laevopinea* - *E. melliodora* - *Angophora floribunda* suballiance are dominant. Areas of dry rainforest are to be found on sheltered hillslopes and gullies and more commonly in incised drainage depressions and valley lines, on gradients of moisture, exposure and soil depth. Species composition is variable according to location. They are dominated by the *Backhousia sciadophora – Dendrocnide – Drypetes* and *Alectyron forsythii* - *Notelaea microcarpa* - *Olea paniculata* suballiances (Floyd 1990). Some more exposed slopes and rocky sites and on talus slopes have small stands of shrublands and vine thicket with *Pomaderris lanigera*, *Olearia elliptica*, *Cassinia quinquefaria*, *Prosanthera lasianthos*, *Bursaria spinosa* and *Acacia diphylla* (King, 2004).

Climate and Hydrology

Rainfall is summer-dominated, with a marked spring dry season and summer-autumn wet period. This pattern is fairly reliable in its relative monthly distribution whether in drought or wet years. About 60% of average annual rainfall occurs in the five-month period between December and April. Drier conditions are experienced between July and November with only about 30% of annual rainfall occurring during that five-month period. Thunder storms break the spring droughts usually in November and continue through the summer, building up convectively on hot summer days or accompanying the passage of cold fronts through the area. There are very intense orographic effects. Microclimatic effects due to relative exposure produce cooler and wetter conditions on southerly and easterly aspects, especially in the deep valleys of the ranges, and there is a strong rainshadow effect in the Macleay Gorges. Drainage lines are closely spaced (80 - 300m), low order tributary, trellised, convergent and eroding. McGarity (1988) provided further information on climate.

Rainfall

Average annual rainfall ranges from 900mm per annum in the upper Macleay Gorges and 900 – 1,300mm on the Tablelands, while the Coffs Escarpment receives 1,000mm on the lower slopes and alluvial flats and up to 2,000mm at the top below the Dorrigo Plateau (B.o.M., 1997). See Map 3.

Rainfall Erosivity

Rainfall erosivity is a critical issue to land management in the mountainous terrain. High intensity rainfall is generally associated with cyclonic depressions occurring off the NSW north coast during summer. Over a 30 minute period the intensity of rainfall can vary from 40 mm/hr for a one-year return period up to 145 mm/hr for a 100-year return period (State Forests, 1993). On average, rainfall intensities of 75 mm/hr for a 30 minute period can be expected to occur within a five-year period. Total rainfall of 200mm over a 24hr period is not uncommon. Under these conditions extensive runoff and flooding can occur, resulting in significant property damage.

Rainfall erosivity is a measure of the ability of rainfall to cause soil erosion. Average annual rainfall erosivity (USLE R-factor) has been calculated from rainfall statistics and mapped for NSW (Rosewell and Turner, 1992). There is a progressive increase in rainfall erosivity from about 1,500 in the Macleay Gorges to 7,000 in the Coffs Escarpment (Map 4). Rainfall erosivity, like rainfall, is heavily skewed towards the summer months. Rosewell and Turner (1992) demonstrated that a high percentage of erosive rainfall occurs in the four months from December to March. Rainfall erosivity in the study area is very high (R 5000), which results in very high rates of runoff.

Erosion

Moderate to severe sheet and rill erosion with minor gully erosion has been observed on steep slopes associated with road works and forestry operations (Milford, 1995; Eddie, 2000). Soils are especially erodible due to the weathered mica flakes which impart silty textures to the soil materials, and induces slaking when wet.

Figure 5. Sheet erosion and roadside slumping.

Mass Movement

The Nambucca Beds are especially prone to mass movement. Slip planes may form with shear failure of steeply dipping decomposed phyllites and slates (Atkinson *et al.*, 1992), and with water entering deeply weathered regolith via quartz veins (Baker *et al.*, 1983). This is exacerbated where the shear plane is dipping in the direction of the slope (McGarity, 1988). Slip planes may be indicated by the presence of springs; mass movement may be identified by hummocky terrain.

Mass movement hazards increase with slope gradient, from about 20º upwards, although some slopes on the Nambucca Beds have been observed to be susceptible to mass movement on gradients as low as 7º (Eddie, 2000). This is because the deep regolith which can be hydrostatically loaded with groundwater following rain; this tension is released as mass movement when disturbed.

Debris avalanches occur on slopes greater than the natural angle of repose of unconsolidated sediment (about (25º), creating talus slopes. Ground disturbance on steep slopes risks re-activating old landslips. Large-scale slips and debris avalanches are quite common on the very steep slopes in the ranges, particularly where road cuts occur; slumping of subsoils in road batters is common, as observed by McGarity (1988).

Streambank erosion and sedimentation

The offsite consequences of erosion and mass movement are potentially severe, as sedimentation and pollution of downstream waterways. McGarity (1988) observed that eroded material, especially from gullies and mass movement events, moves into drainage lines with the finer sediments being transported away, and the coarser gravels and boulders accumulating in the bed of the channel. Slumping of subsoils in road batters is a common source of sediment movement into streams. Stream sedimentation occurs when debris is transported at high energy and then deposited in channels of lower energy, while the suspended clays and silts are transported further and therefore contribute to turbidity in waterways. It is likely that this would contribute to changes in the flow characteristics of the streams.

An estimated 46% of land within the Nambucca Beds (based on soil landscape mapping) is of slopes gradients greater than 20º. Erosion hazards increase closer to the Great Escarpment where rainfall erosivity is greater.

McGarity (1993a) stated that erosion of stream banks increases the sediment load “although the importance of this factor is unknown”. The accumulation of woody debris in drainage lines also alters stream flow at times of high runoff and further destabilised stream banks.

EROSION HAZARD ASSESSMENTS

There are four methods in use for assessing soil erodibility—

1. **Soil Dispersibility**.

   a. The **Emerson Aggregate Test** (EAT) is an eight-class classification of soil aggregate coherence (slaking and dispersion) in distilled water. It can easily be tested in the field.

   Table 3. Emerson Aggregate Test classes (Hazelton and Murphy, 2013).

Class	Result	
1	Slakes	Complete dispersion
2	Slakes	Some dispersion
3	Slakes	Some dispersion after remoulding
4	Slakes	No dispersion (carbonate or gypsum present)
5	Slakes	Dispersion in shaken suspension
6	Slakes	Flocculates in shaken suspension
7	No slaking	Swells in water
8	No slaking	Does not swell

   Table 4. EAT Classes 2 and 3 can be divided into subclasses —

Subclass	Dispersion
(1)	Slight milkiness immediately adjacent to the aggregate
(2)	Obvious milkiness, <50% of the aggregate affected
(3)	Obvious milkiness, >50% of the aggregate affected
(4)	Total dispersion, leaving only sand grains.

   The subclass is put in brackets. For example, a Class 3 aggregate that disperses completely on working leaving only sand grains is noted as Class 3(4). Class 2(4) is equal to Class 1.

   b. **Dispersion percentage** (DP) is a laboratory test that estimates the proportion of the clay fraction that has dispersed (Hazelton and Murphy, 2013). DP is sometimes presented as the Dispersal Index Ratio, also known as the Ritchie Method (Ritchie, 1963), which is the inverse of DP x 100. Ratings for Dispersion Percentage is shown in Table 3.

   Table 5. Ratings for Dispersion Percentage (Hazelton and Murphy, 2013).

Dispersion Percentage	Dispersal Index Ratio (Ritchie)	Dispersibility
<6	>16	Negligible
6 – 30	3 – 16	Slight
30 – 50	2.0 – 3.0	Moderate
50 – 65	1.5 – 2.0	High
>65	<1.65	Very high

c. The **Soil Dispersibility Testing Method** prescribed in Section 3 of the EPL guidelines is a very much reduced version of the EAT. After observing the behaviour of soil aggregates in water, score—

0 for no dispersion within 2 hours;

1 for slight dispersion within 2 hours;

2 for slight dispersion within 10 minutes and complete dispersion within 2 hours;

3 for strong dispersion within 10 minutes or complete dispersion within 2 hours;

4 for complete dispersion within 10 minutes.

2. Water erodibility (USLE K factor)

The Unified Soil Loss Equation (USLE) includes a soil erodibility factor known as K (Wischmeier & Smith 1978), an index of the susceptibility of a soil sample to particle detachability through sheet and rill erosion. It is derived from particle size analysis which is done in the soil laboratory. The formula used to derive K factor is USLE modified for Australian conditions and based on that used in SOILOSS (Rosewell & Edwards 1988) with profile permeability modified to follow that used by Soil and Water Conservation Society (1993).

There are limitations in the use of the K Factor, as noted by Murphy *et al* (1998): “The USLE soil erodibility factor, K, has been shown by field experience in many situations to relate poorly to the behaviour of forest soils. The K factor relates specifically to the detachment of soil through sheet and rill erosion and not to other processes of erosion, most notably gully [and slump] erosion. The K factor also does not account for susceptibility of soil material to transport and delivery to receiving waters”.

3. Soil Regolith Stability Class.

The limitations of the K factor led to the development of the Soil Regolith Stability Class. This concept has two components, coherence and sediment delivery potential, to reflect the dual requirement to assess both soil erosion and water pollution hazard at the landscape level.

This approach permits a broad scale assessment which incorporates experience and knowledge of soil behaviour for the particular landscape unit from a range of similar sites. Subsequent site assessment at the harvest planning stage will verify the accuracy of the broader scale soil regolith stability classification for particular logging compartments and describe significant variability at a more localised scale (Murphy *et al*, 1998). It is assessed by field observation and requires professional judgement.

Table 6. Soil Regolith Stability Classes (Murphy *et al*, 1998).

	Low sediment delivery	**High sediment delivery**
High coherence	**R1** High ferro-mangnesium soil regolith, eg basalt, dolerite; Fine-grained argillaceous soil regolith with high gravel content, eg siltstones, metasediments; Highly organic soil regolith, eg peats.	**R3** Fine-grained argillaceous (clay) soil regolith with low/no gravel contents; Fine-grained massive soil regolith.
Low coherence	**R2** Unconsolidated sands; Medium to coarse-grained felspathic-quartzose soil regolith, eg adamellite, quartz sandstone.	**R4** Unconsolidated deposits of silt and clay; Unconsolidated fine-grained weathered soil regolith (saprolite).

4. Inherent Hazard Assessment Levels for Native Forests.

This is presented in a matrix table and uses information from a number of sources—

a. Rainfall Erosivity (6500 in the Compartments)

b. Slope Class

c. Soil Regolith Stability Class (R3 in the Compartments).

See Table 7 below.

DISCUSSION

Assessment of dispersion

K factors for soils in the Snowy Range (sn) and Mistake (mk) soil landscapes have been calculated and presented in Milford (1995) and Eddie (2000). K factors for topsoils are low (0.005 - 0.020), while K-factors for subsoils are high to very high (0.030 – 0.080). The high K factors for subsoils is probably due to their high mica content and silty textures. The subsoils typically slake when wet. McGarity (1993a, 1993c) also found a high proportion of soils have dispersible subsoils. However, Beavis (2009) noted that K values are only meant as a guide as a regional planning tool and do not preclude the need to do more intensive soil survey for detailed planning or operations.

Of twelve subsoil samples of these soil landscapes collected by Milford (1995) and Eddie (2000), Ritchie Method dispersion results range from 4.4 (slight, on metabasalt) to 1.9 (high, on phyllite).

EAT results indicate slaking with mostly high dispersibility—

- Ten samples, class 2(1): slakes, some dispersion, slight milkiness adjacent to the aggregate (high dispersibility);
- One sample, class 3(3): slakes, some dispersion after remoulding, obvious milkiness, >50% of the aggregate (high dispersibility);
- One sample (on metabasalt), class 6: slakes, flocculates in shaken suspension (low dispersibility).

These figures are indicative only and do not necessarily represent soil profiles that may be present in any study area. However, it provides sufficient evidence for moderate to high dispersion in some subsoil samples. The key feature though is the variability of the dispersibility data, undoubtedly due to variability and unpredictability in the substrate lithology and mineralogy.

The Emerson Aggregate Test (EAT) is the minimum standard for assessment of dispersion and should be backed by Dispersion Percentage / Rithie Method.

Soil Regolith Stability Class assessment

Soil Regolith Stability Class was assessed as R1, high coherence with low sediment delivery, throughout compartments 340 and 341, consistent with the mapped regolith. Murphy *et al* (1998), p.45, 48, assigned R1 for all soils developed on the Nambucca Beds. **I believe that the Soil Regolith Stability Class has been incorrectly assigned to R1 throughout the Nambucca Beds.** Several lines of evidence indicate high sediment delivery potential because of the high erodibility of the Nambucca Beds—

1. In the Snowy Range (sn) and Mistake (mk) soil landscapes (Milford, 1995; Eddie, 2000), the **subsoils typically slake when wet** due to the weathered mica content. Slaking means that the soil particles detach readily when wet, as reflected in the moderate to high ratings for the K factors in those soil landscapes. McGarity (1993a) and Eddie (2000) found a range of dispersibility in subsoils from low to high.
2. The soils typically have a **high stone content** in the form of **quartz gravels** derived from the **injected quartz veins within the substrate**. **Surface lag gravels** are also common. The stoniness and lag gravels may have some armouring effect in resisting erosion (Murphy *et al,* 1998), but the lag gravels are present because they lag behind after the fine material has been removed by erosion. Indeed, gravel may increase erosion by reducing infiltration rates and by channelling surface flow on steep slopes (McGarity, 1993a).
3. The erodibility of the Nambucca Beds is demonstrated by the fact that they are much more subject to erosion than adjacent geological units. The Eastern Escarpment within the Nambucca Block has retreated through **differential erosion to the more resistant basement rocks** of adjacent the Coffs Harbour and Dyamberin blocks, undermining the overlying Tertiary Volcanics of the Dorrigo Plateau (Ollier, 1982). See Figure 6. This observation is supported by Milford (1995). Further, the Carrai Plateau and Round Mountain granitic batholiths have persisted against erosion by escarpment retreat or by riparian erosion by the Macleay River because of their resistant nature relative to the Nambucca Beds.
4. **Soil Regolith Stability Class R3 should therefore be applied throughout the Nambucca Beds**, because of the soils with high coherence due to the high clay content and high sediment delivery due to the slaking subsoils. The rare soils developed on metabasalt which would be

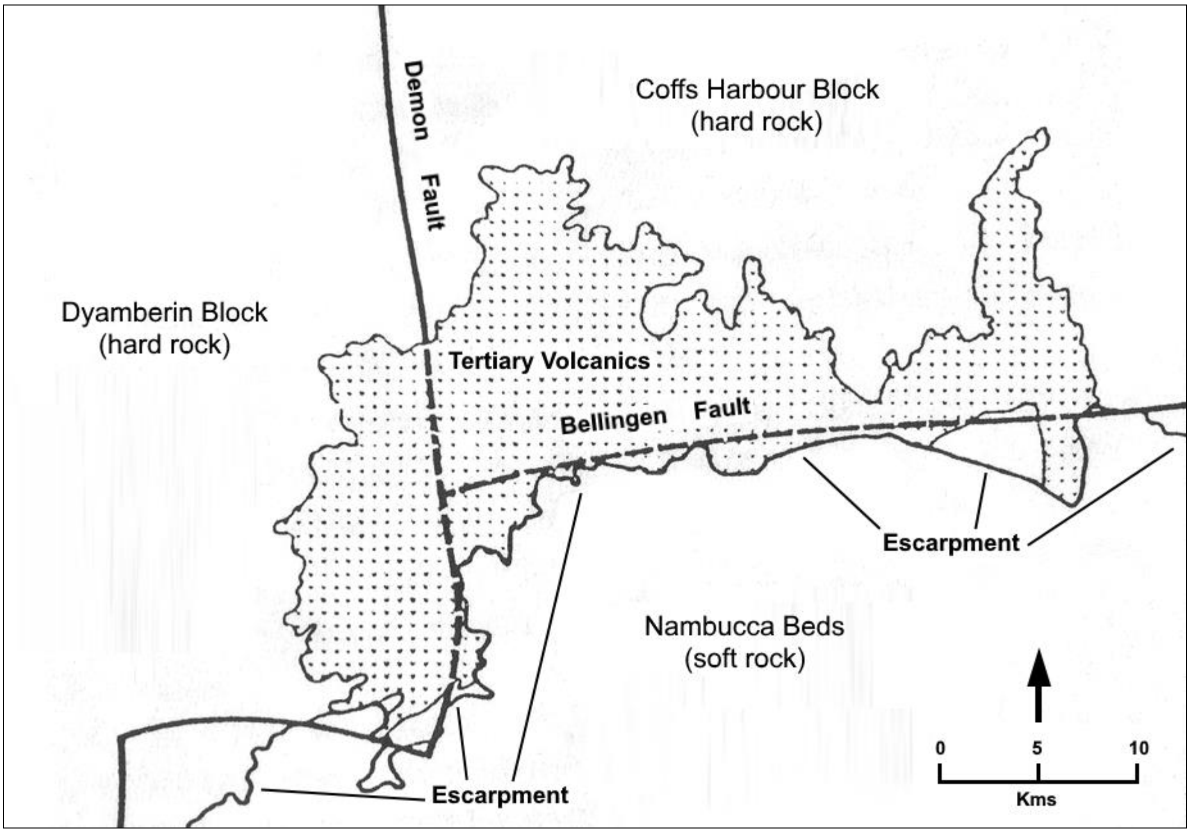
assessed as Class R1 are too rare to consider; in any case their subsoils do slake. Class R3 soil, where exposed, may display common rilling, minor gully development in drainage lines and moderate incision along road gutters (Murphy *et al*, 1998). This has been commonly observed in the field by McGarity (1993a, 1993c), Milford (1995) and Eddie (2000). Erosion on this regolith will generate material that is susceptible to transport well beyond the source and potentially into receiving waters. The R3 soils include the Red and Brown Dermosols on deeply weathered regolith with slaking subsoils (Eddie, 2000) and the Yellow Podzolic and Red Podzolic soils identified and described by McGarity (1993a, 1993c).

Mass movement assessment

The mountainous area is susceptible to significant soil erosion and mass movement hazards. This is because of the steep dissected terrain, locally deep regolith which can be hydrostatically loaded with groundwater following rain, the presence of quartz veins which can charge slip planes, metamorphic cleavage planes dip angles parallel to the slope, and high erodibility of the regolith. These carry significant risks for forestry operations. Mass movement risk is exacerbated by tree removal, which will increase the risk by reducing soil cohesiveness and increasing infiltration of water into potential slip planes. Maintaining forest cover on potential groundwater recharge sites upslope may reduce landslip risks.

Geotechnical investigation of mass movement is recommended prior to any proposed disturbance, and to be undertaken by a suitably qualified geophysical surveyor. Mass movement hazards are site-specific and must be geo-located in some way. Mapping exercises should determine mass movement risk, including where the metamorphic cleavage planes dip angles are approximately parallel to the slope. In the absence of such information, it should be assumed that all land on slopes greater than 20º is subject to mass movement.

Figure 6. The relationships between hard (resistant to erosion) basement rock, preserved volcanic rocks, and the Great Escarpment. From Ollier (1982).



Subsoil erodibility assessment

It follows that from the soil variability and unpredictability, there is expected to be variability in dispersibility. The worst case should be assumed in a conservative approach required in Schedule 3 of the EPL; McGarity (1993a) found this in his investigation in Mistake SF. Data should not be averaged for assessment of risks. Subsoil samples should therefore be collected on representative terrain facets for—

1. The Dispersion Percentage test, which should be undertaken and tested in a NATA registered laboratory. The dispersion percentage test is the most useful, quick way of determining the degree of dispersion susceptibility (Craze and Hamilton, 2000). The results can be presented as percentage or as Dispersal Index Ratio (Ritchie Method) as in Table 3 above.
2. The Emerson Aggregate Test. The Soil Dispersibility Testing Method as prescribed in Section 3 of the EPL guidelines is inadequate. Aggregate erodibility should be determined by using the Emerson Aggregate Test as a minimum standard.
3. Soil Regolith Stability Class. Soils mapping at the compartment scale (1:25,000 to 1:10,000) should be undertaken to determine the range and variability of regolith stability; this may not necessary when in the assessor's professional judgement the Soil Regolith Stability Class is applied uniformly (in this case at R3).

Information on the EAT and DP tests can be obtained in Charman and Murphy (2000).

The special case to be made for the Nambucca Beds

As discussed above, soils developed on the Nambucca Beds are highly erodible, because of the soils with high coherence due to the high clay content, and high sediment delivery due to the slaking subsoils due to the mica content. This is consistent with Regolith Stability Class assessment of R3 (Murphy *et al*, 1998). Eddie (2017a, 2017b) noted that it is not known whether subsoil erodibility assessments had been undertaken within the compartments under consideration in the Mistake SF and State forests in the Kalang catchment.

In soil surveys for logging plans, subsoil samples should be collected on representative terrain facets. Soils should be classified according to the Australian Soil Classification (ASC) system (Isbell, 2002), and soil profile information should be provided to the NSW Office of Environment and Heritage SALIS database. Terrain and soils should be mapped at the compartment scale (1:25,000 to 1:10,000) to account for variability.

In the absence of information on soil erodibility, it should be assumed that on the Nambucca Beds—

1. **All land on slopes greater than 20º should have a high erosion rating,**
2. **All land on slopes greater than 25º should have an extreme rating (McGarity, 1993a, 1993b),**
3. **Soil Regolith Stability Class R3 should be applied to regolith on the Nambucca Beds throughout their extent.**

The thresholds of settings of the Inherent Hazard Levels

Charman & Murphy (2000) recommend against disturbance on slopes greater than 20º due to mass movement risks. Sheet and gully erosion risks are also raised with operations on slopes greater than 20º. Disturbance on slopes above this gradient risks re-activating old landslips, and mass movement may also initiate sheet and gully erosion and stream sedimentation.

On the Nambucca Beds, in the absence of such information, to limit the potential for mass movement and erosion due to surface disturbance by forestry operations, **it should be assumed that all land on slopes greater than 20º is subject to mass movement.**

As a result of this, the Inherent Hazard Assessment Levels (Table 7) are redefined for forestry operations on the Nambucca Beds (and Soil Regolith Stability Class R3), by shifting the slope risk classes (Table 8).

The Inherent Hazard Assessment Levels are—

Level 1: Low soil erosion and water pollution risk;

Level 2: High soil erosion and water pollution risk;

Level 3: Very high soil erosion and water pollution risk;

Level 4: Extreme soil erosion and water pollution risk— scheduled or non-scheduled forestry activities prohibited for the proposed method of timber harvesting and extraction.

Table 7. Inherent Hazard Assessment Levels for Native Forests, for slopes > 10º, and Soil Regolith Stability Class R3 (modified from EPA, 1997).

Forestry Operation	Rainfall Erosivity (R-factors)	Slope Classes			
		10<20º	20<25º	25<30º	>30º
Logging with greater than or equal to 50% canopy removal within the net harvestable area	0-2000	2	2	2	4
	2000-3000	2	2	2	4
	3000-4000	2	2	2	4
	4000-5000	2	2	4	4
	5000-6000	2	2	4	4
	6000+	2	4	4	4
Logging with less than 50% canopy removal within the net harvestable area	0-2000	2	2	2	4
	2000-3000	2	2	2	4
	3000-4000	2	2	2	4
	4000-5000	2	2	3	4
	5000-6000	2	2	3	4
	6000+	2	3	4	4
Native Forest Thinning Operation	0-2000	1	1	2	4
	2000-3000	1	1	2	4
	3000-4000	1	1	2	4
	5000-6000	1	2	2	4
	6000+	2	2	2	4

Table 8. Revised Inherent Hazard Assessment Levels for Soil Regolith Stability Class R3 (modified from EPA, 1997).

Forestry Operation	Rainfall Erosivity (R-factors)	Slope Classes			
		0<10º	10<20º	20<25º	>25º
Logging with greater than or equal to 50% canopy removal within the net harvestable area	0-2000	2	2	2	4
	2000-3000	2	2	2	4
	3000-4000	2	2	2	4
	4000-5000	2	2	4	4
	5000-6000	2	2	4	4
	6000+	2	4	4	4
Logging with less than 50% canopy removal within the net harvestable area	0-2000	2	2	2	4
	2000-3000	2	2	2	4
	3000-4000	2	2	2	4
	4000-5000	2	2	3	4
	5000-6000	2	2	3	4
	6000+	2	3	4	4
Native Forest Thinning Operation	0-2000	1	1	2	4
	2000-3000	1	1	2	4
	3000-4000	1	1	2	4
	5000-6000	1	2	2	4
	6000+	2	2	2	4

Therefore, because of the extreme rainfall erosivity and extreme erosion and mass movement risks on the Nambucca beds, to limit erosion and runoff and alleviate streambank erosion and sedimentation, **native forest logging is limited to slopes below 25º**.

Logging on slopes below 25º must take heed of the potential soil erosion and water pollution risks according to the Revised Inherent Hazard Assessment Levels.

Offsite effects of logging operations on steep terrain

Monitoring and reporting should be undertaken on water quality of streams entering and exiting any compartments considered for forestry operations, before, during and after forestry operations. This will provide information on any changes in water quality as a consequence of forestry operations.

Catchment hydrological modelling should be undertaken to model the surface and channel flows into, within and out of proposed logging compartments. This will provide insights to the erosion and sedimentation risks under various weather events.

Guidelines

McGarity (1988) noted that "the Standard Erosion Mitigation Conditions [at that time] are unsuitable guidelines for erosion control in the catchments examined in the Mistake State Forest". As an outcome of the RFA in 1999 the Environment Protection Licences (EPLs) were introduced and applied to all logging operations on public land in north-east NSW (Pugh, 2104).

Discrepancies between the Environment Protection Licence guidelines and the 2009 Harvest Plan for Compartments in the Mistake SF have been noted by Eddie (2017a).

CONCLUSION

The case is made for the special case to be made for the Nambucca Beds—

- There is strong evidence that the Soil Regolith Stability Class on the Nambucca Beds is high coherence with high sediment delivery (Class R3),
- The thresholds of settings of the Inherent Hazard Level matrix table are revised,
- Logging is limited to slopes below 25º.

On the Nambucca Beds, on slopes greater than 20º, in the absence of information to the contrary, it is assumed that—

- It is subject to mass movement;
- It has a high erosion rating;
- It has an extreme erosion rating;
- Native forest logging is prohibited.

In data collection—

- The Emerson Aggregate Test (EAT) is the minimum standard for assessment of dispersion and should be backed by Dispersion Percentage / Rithie Method.
- Data should not be averaged for assessment of risks.
- The worst case should be assumed in a conservative approach required in Schedule 3 of the EPL.

To ameliorate the offsite effects of logging on steep slopes on the Nambucca Beds—

- Monitoring and reporting should be undertaken on water quality of streams entering and exiting any compartments considered for forestry operations, before, during and after forestry operations.
- Catchment hydrological modelling should be undertaken to model the surface and channel flows into, within and out of proposed logging compartments.

Mountainous land on the Nambucca Beds on gradients greater than 20º should be reserved for catchment protection.

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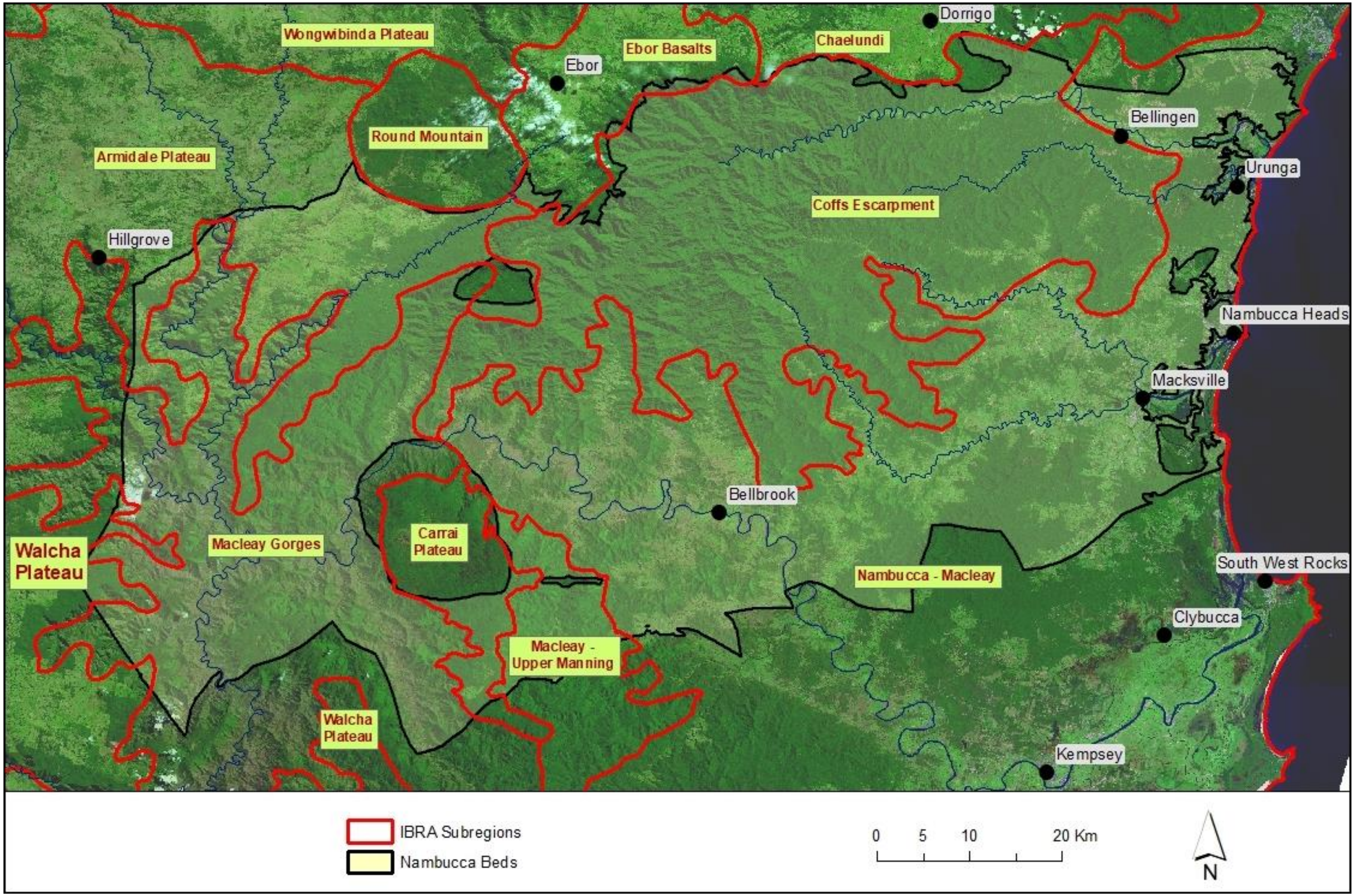
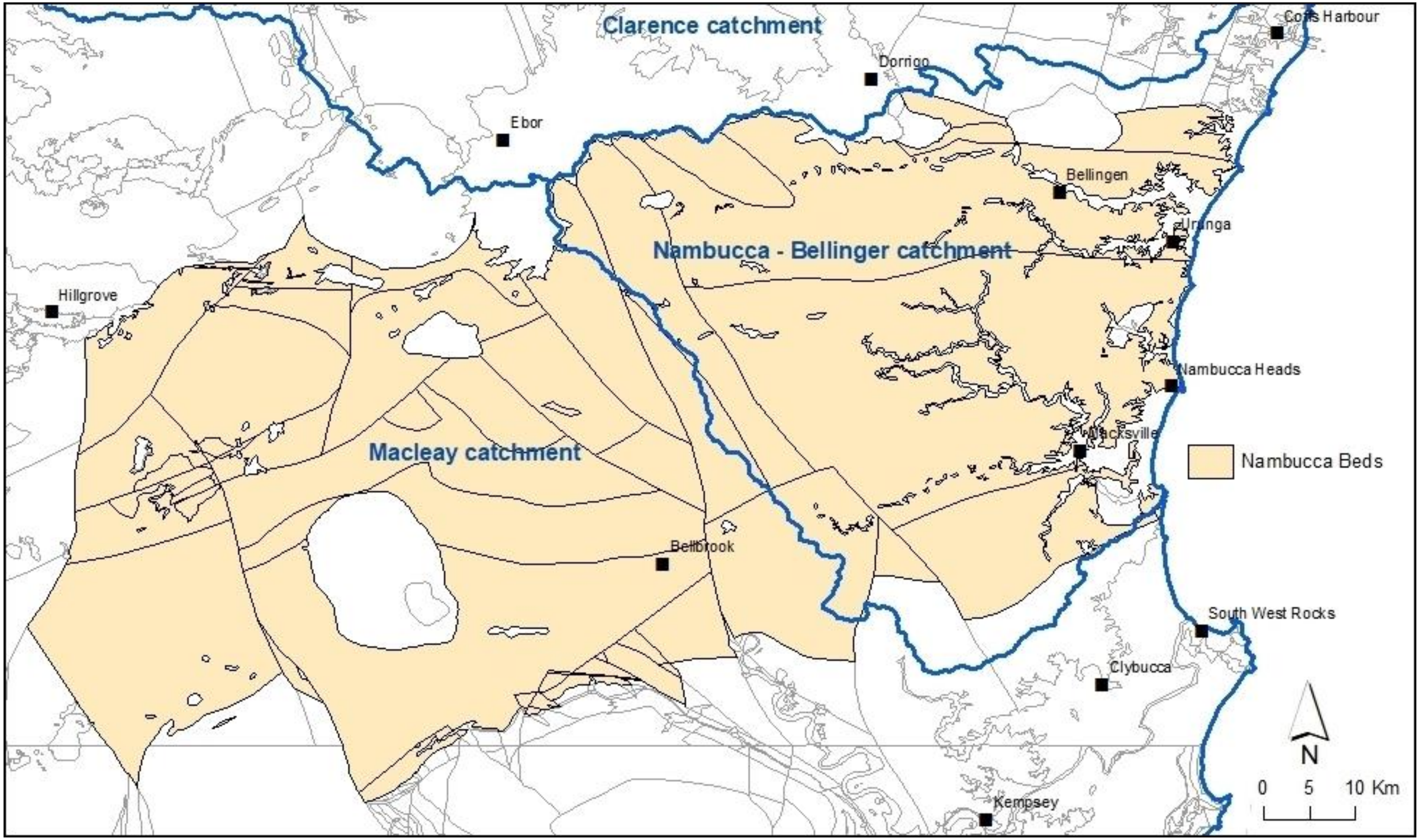
APPENDIX 1. MAPS.

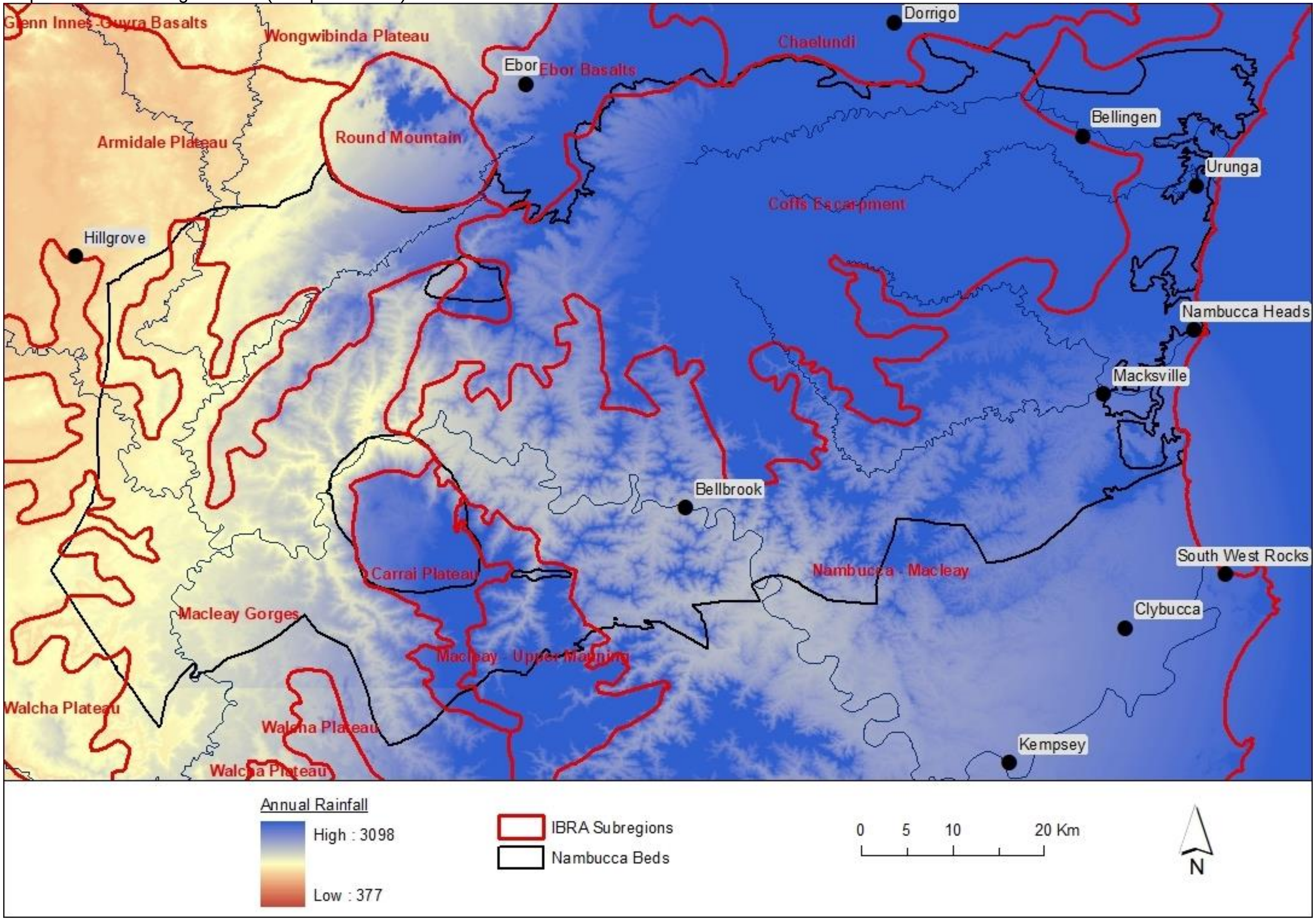
Map 1. The IBRA Subregions.



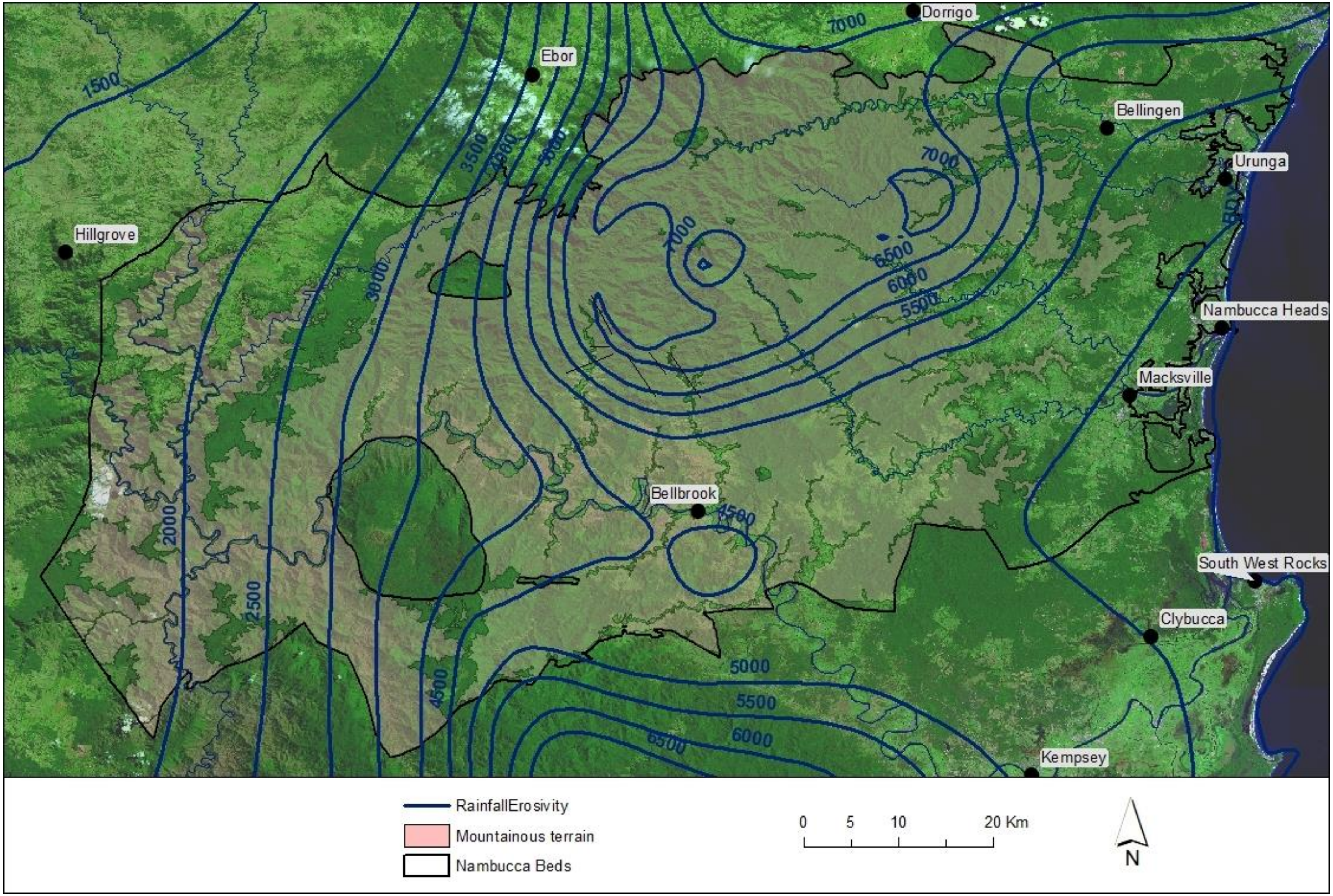
Map 2. The extent of the Nambucca Beds.



Map 3. Annual average rainfall (mm per annum).



Map 4. Rainfall Erosivity.



Map 5. State Forests on indicative mountainous terrain on the Nambucca Beds.