Critical Review of Hills of Gold Environmental Impact Statement - Soils Sections.

SoilFutures Consulting Pty Ltd January 2021

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1. Introduction

This review has been made at the request of Hills of Gold Preservation Incorporated, a community interest group from the surrounds of Nundle. The request was to review introductory and material and sections 3, 16 of the Hills of Gold Wind Farm EIS (ERM, 2020), and associated Appendix O with respect to soil and landscape information provided in the EIS.

Suitability of Reviewer and Code of Conduct in Case of Court Proceedings

This review was conducted by soil scientist and geomorphologist Dr Robert Banks. Dr Robert Banks is a Certified Professional Soil Scientists (CPSS) as required for BSAL assessments/review and preferred for EIS work and review in NSW. Dr Vera Banks of SoilFutures Consulting Pty Ltd edited the review.

In preparing this review, I made all the inquiries I believed were necessary and appropriate and to my knowledge there have not been any relevant matters omitted from this review. I believe that the facts within my knowledge that have been stated in this review are true.

The opinions I have expressed in this review are independent and impartial, based on my training and abilities as a recognised soil scientist. I have read and understand *Schedule 7* to the *Uniform Civil Procedure Rules* and have used my best endeavours to comply with it.

In the case where I might appear in court regarding this review, I understand my duty to the Court and state that I have complied with it and will continue to do so. I believe I have the relevant expertise to be able to provide such information as requested for this review. A full copy of my Resume is found in Appendix 1.

2. Review of Water and Soils Sections of EIS

Methodology of Review

This review takes a stepwise approach to the relevant sections of the EIS and initially comments or discusses issues arising on a page by page basis.

Following the page by page review, an analysis of mapped information is given compared with the most current soil information available for the development footprint and how this impacts on proposals and plans for a wind farm and associated infrastructure. A discussion follows the stepwise review, identifying issues of accuracy and suitability of the EIS for its purposes

The review is presented in tabular form in Table 1

Stepwise Review

Table 1: Page-wise review of EIS and Appendix O

ESI Section/ Page Number	Paragraph	Comment
EIS Section 3. Project description		
3. Project description	All	No specific comments about this section. It discusses the development in general and gives the size of permanent and temporary footprints of the development as 512 ha.
EIS Section 16.Water and Soils.		
16.Water and Soils. P 310	All	This section is almost identical to Appendix O, rather than summarising Appendix O as such a section normally would. It should be noted that the soil and water assessments are a simple desktop review with some general explanations, rather than in situ soil and water assessments of the project areas. The author's qualifications of this section (i.e. CPSS status) have not been provided.
16.2 Methodology p 310	All	The methodology employed in the soil and water assessments show that they are at best, desktop reviews of information from broad (and freely available) databases. As the section develops, the author shows little understanding of how these maps are derived (ie. the detailed data upon which they are built), not the limitations of the broad data. A state significant development of this size would normally be expected to provide data at 1:25 000 or 1:10 000 scale (Gunn *et al.*, 1988; McKenzie *et al.*, 2008).
16.3.1 Landform section p310		The summary of landform is adequate to summarise the topography of the development footprint and area, however it does not use Australian Standard terms as per NCST (2009), which is required in any scientific report in Australia.
Bioregions pp310-311		The use of broad bioregional data as scoping material is misleading, as it shows a large range of geologies and associated landforms, soils and vegetation. Many of those data are irrelevant for the development footprint and the larger Nundle area and their potential effect on the development. Soil types given in this section are not to the Australian Standard (Isbell & NCST, 2016) which has long replaced the Great Soil Groups (Stace *et al.*, 1969) used in these Interim Bioregional (IBRA) descriptions.

Table 1: Page-wise review of EIS and Appendix O

16.3.2 Land and Soil Capability P311		The use of broad state mapping has issues when it is being used in planning for a detailed development. At best, the LSC classes are based on broad published Soil Landscape maps (meant for use at 1:100 000 Scale). Areas without detailed Soil Landscape Mapping use the best available information which is reconnaissance soil landscape mapping or other mapping types of land and soil mapping (generally to be used at 1:250 000 scale) Soil Landscape maps have limitations of scale and cannot be used for detailed planning of a development An example of the limitations of use of these data is given in Appendix 2 of this review from Banks (2001) page 18. Areas of LSC mapping which are not based on Soil Landscape mapping have even greater limitations for use in development applications because of the limitations of scale as described in McKenzie et al. (2008), Gunn et al. (1988) and Banks (2001).
16.3.2 Land and Soil Capability P312-13		Being the author of the original soil landscape material upon which much of the LSC classes have been developed, I noticed that a mistake was made by OEH in the creation of the LSC's. The base data for the southern side of the range has been mapped as either Mount Royal or Coober-Bulga Soil Landscapes in detailed and reconnaissance mapping across the development footprint. Both of these soil landscapes are Class 8. This has been amended in the state data base and will be placed online in late January 2021. If the author of this EIS section had knowledge of LSC and soil landscape mapping they should have identified this mistake. The results of the use of the low detail mapping and not noticing the mistake in the mapping flow through the remainder of the soil sections in the EIS. Most of the development footprint is Class 8. This will be discussed in detail below.
BSAL, p313	6	BSAL is mapped in the development area. This has relevance if there is any activity under the mining act including quarrying as mentioned later in Appendix O. This will be taken up in the discussion below.
Australian Soil Classifications P313	7 to 8	There are no Podosols mentioned in the soil data presented – yet they are mentioned here. In addition to the sudden mention of Podosols, there is no explanation of how the dominant Ferrosols in the development area behave under development conditions on mass movement prone slopes or when compacted.
Soil Summary p 313	last Para	This is incorrect. The base data for Langs Neck, Coober-Bulga and Mt Royal Soil Landscapes show that the soils have high erodibility and the entire development footprint has high mass movement hazard Appendix 3 (McInnes-Clarke, 2004) and E-SPADE.
Table 16-6. p 321		There is no mention of potential hazards moving soil or water based pathogens between sites and no plan for wash down facilities to avoid contamination of rare and endangered fauna and flora. This is important for adjacent forestry activities as well as for example soil fungus transport which can affect frog populations.

Table 1: Page-wise review of EIS and Appendix O

16.6 Conclusions p 322.	There has been no onsite soil assessment conducted to verify data / information used in the desktop studies, which are based on broad soil landscape mapping only. The lack of a critical interpretation of this published broad scale information resulted in most of the assumptions made about slope and mass movement hazards as being incorrect. The fact is that erosion hazards are high to extreme across much of the footprint of the development. This will be further discussed below.
General	The Appendix has mixed soil and water sections throughout which should have been separated into one section for soil and one section for water. As mentioned above, Appendix O and Section 16 of the EIS are almost identical, where under normal circumstances the EIS would summarise the findings in the Appendix. The information presented may not be relevant to the project footprint or (major) parts of it, because it is based on broad landscape mapping (1:100.000), without onsite verification. The proponent did not take any notice of the clear instruction in the available reference and metadata that this information is not suitable for any kind of detailed development planning due to the limitation of scale which normally has to be ground proved. The fact that the proponent has neglected to conduct detailed on-site assessments suggests that the authors of the EIS lack appropriate qualifications in soil survey. At this stage, there is no indication of the CPSS status or the qualifications of the Soil Scientists, Soil Surveyors or Geomorphologists who prepared Section 16 and this Appendix.
Page 1. 4	The executive summary is incorrect in stating that erosion hazards in the project area are low to moderate. The area is mapped as high to extreme in soil landscape mapping (Banks, 1998, 2001; McInnes-Clarke, 2004) and Mt Royal (E-SPADE) and in the base information for the creation of LSC classes. This will be considered in the discussion of this review.
1.2 Objectives p2	As will be shown in the discussion of this review, the three of the objectives are clearly not met. 1. Existing soil conditions have not been adequately described at within or adjacent to the planned footprint of the development. 2. Because no field verified mapping was undertaken the key soil impacts have not been assessed. 3. Management and mitigation measures for soil related topics are incorrect because the soil information used is both incorrect and insufficient to base these on.
Table 1-2. P5	It is interesting that this table shows that the agencies who must be consulted have given no response. As there has been no response, these agencies have not been consulted. A reply must be sought to confirm that these agencies are aware of the development and if they have any requirements to be addressed.
Table 1-3, p.9	The rainfall information at Nundle which is not within the footprint of the development is useful background but in no way describes the rainfall patterns along the tops of the range where the development is proposed. At least an understanding of how much it rains within the development footprint would be useful for erosion and mass movement modeling purposes. Modeled rainfall will be considered in the discussion of this review.

Table 1: Page-wise review of EIS and Appendix O

4.1 Methodology, p19	All	As mentioned above, the use of very broad soil and landscape information is not suitable for specific site developments, and may in fact result in serious errors in onsite planning because of factors of scale and accuracy. This will be discussed below
Bioregions p19-20		This information is so broad as to be irrelevant to the development. Specific geological information on the site would be far more appropriate.
4.2 Land and soil capability. P20 -22		This information is of limited value for specific planning purposes because of the issues of scale discussed above. Unfortunately further calculation based on this information in Appendix O is therefore incorrect.
4.2 BSAL Lands		If there is to be any quarrying or activities controlled under the NSW Mining legislation then a BSAL assessment would be required. If there is to be no on site quarrying then BSAL is irrelevant to the development.
Table 4.4. p 23		Only two of the soils in this table use the Australian Soil Classification (Isbell & NCST, 2016). The others should have some correlation at least mentioned.
Soil Regoiloth Stability p23		The R rankings given are for sheet erosion of normal land or well constructed batters, but do not have any relevance to mass movement which is the most important risk factor in the development footprint
Hydrological groups p 23.	last Para	Although mapped as Class A Hydrological group, the soils are not sands and gravels. This indicates that the soils expert writing the EIS is unfamiliar with the area and has probably not been within the footprint of the development.
Soil Summary p. 24		Many of the definitions and planning maps presented here relate primarily to rural activities and interpretations, not extension engineering activities. None of the broad mapping has been verified with site visits and soil profile descriptions, despite the baseline data underlying the maps indicating soil engineering hazards as well as significant mass movement hazards. The statement beginning with "*Detailed design has...*"is clearly incorrect, because detailed design requires excellent onsite information and a good working knowledge of a project area, which are not demonstrated in this document. Again, there is no onsite soil data, soil engineering testing, no detailed plans showing the application of special engineering across the footprint of the site. It is not acceptable to make this statement without supporting hard data.
Flood comments and Photographs P. 24. P. C1-C2.		The statement that there is no mapped flood prone land in the development footprint may be accurate however, the creek crossing photographs in the document have clearly defined floodplains and are known to flood regularly following summer storms. Engineering of crossings on floodplains for heavy vehicles must take flooding into account and not ignore these landscape characteristics. Most floodplain mapping is done on broad floodplains where water harvesting or low banks can interfere with widely spread water flows. The fact that there are no maps of flood prone land in the project area or access areas to the project area is a reflection of the scale and purpose of NSW Flood and floodplain mapping which to protect urban and broad agricultural enterprise.

Table 1: Page-wise review of EIS and Appendix O

4.3.2 Operational impacts and Table 4-8. P.34	The table does not take into account potential transport of soil pathogens and weed movements which are important biological hazards in highland environments. The effects of building a large number of permanent interception surfaces (concrete pads etc) on catchment hydrology and erosion potential is not considered at all. These will have close to 100% runoff during rain events.
4.3.3 Soil and Water Assessment. P 34	The "baseline data" presented in this EIS is incorrect, because the data set used has an error. Furthermore, erosion conclusions are incorrect because of an incorrect interpretation of slope constraints to development. Most of the development footprint is in a high erosion hazard area with high mass movement and erosion hazards. Resulting from this error, calculations presented in this EIS are mostly irrelevant to the development proposal. These issues would not have arisen if the proponent would have visited the project area and verified their data by conducting proper onsite soil survey / assessments.
USLE calculations. P A1 - A3	This section is strange. Soil Loss values are calculated using Hird (1991), which are soil data measured for the Goulburn area, located 577 km away from the development at Nundle and therefore irrelevant to this proposal. This may be a carryover from a previous report and it is certainly misleading. No site relevant planning decisions can be made using these data.
	K values which have been measured for detailed soil landscapes on or directly to the West of the development footprint for both Coober-Bulga (also relevant to Mount Royal Landscape), and Langs Neck soil landscapes which make up most of the Class 8 land within the development footprint. Appendices 7.2.4-5 from Banks (1998, 2001) and McInnes-Clarke (2004) provide this data clearly for each soil layer and type. Use of these data would have been better than nothing and infinitely more relevant than that for Goulburn. The variation within soil type that occurs over such a distance and range of climates and parent materials between the Nundle area and the Goulburn area is not acceptable.
Conclusion. P. 49	As stated above, the use of broad planning data, failure to look at the underlying mapping for those data, failure to understand that the data were obviously incorrect, and the use of data from other regions, means that most statements and conclusions made within this EIS and Appendix O are incorrect. Without proper site validation across the development footprint the real and present high erosion risk and mass movement hazards cannot be realistically assessed. It is unclear to the reviewer of this EIS how this large project can be approved, budgeted for, built and maintained based on merely a very broad desktop study.

3. Discussion of Points Raised

This section provides some detailed discussion of points of confusion, or error within the soil section of the EIS.

Accreditation of Consultant

The soils sections of the EIS and Appendix O are of relatively low quality. A CPSS accredited or equivalent person would have written the soils sections such that they were directly relevant to the development, with detailed plans and maps showing soil and landscape hazards to the development. An adequate planning scale for such a development which should be 1:25 000 at least and preferably at 1:10 000 (Gunn et al., 1988; McKenzie et al., 2008)

It is of concern that the developer or the consultants have not had communication with many of the required NSW Government agencies, and thus no requirements from those agencies have been set.

Confusion in Layout

On point that should be made is that the soils sections are dispersed and mixed with the water sections of the EIS and Appendix O. This segments the soils section and makes it harder to review, with *Soil and Water* – used as a title to soils conclusions as well as water conclusions in various sections throughout the EIS and Appendix.

Significant Errors in Data Used

Please note that as a part of a review of the information in the EIS, a large error in LSC coding was found, and corrected in the State Data base following necessary NSW Government protocols. Digital data were provided for corrected LSC classes by DPIE to the reviewer. The new and current map is called Land *and Soil Capability Mapping for NSW,* V.4.1 Draft (DPIE, 2021, V4.1) This information is currently available on request and will be placed in ESpade and SEED in late January 2021. An accredited soil scientist would normally have noticed this discrepancy as part of the preparation of the EIS, especially if site visits had been undertaken.

Discussion of Maps and Suggestions

Digital data for the footprint of the development and the general area of the development (shown in the maps of the public documents, the EIS and Appendix O) were provided by the proponent under an agreement to be used for the purpose of this review only.

Although the use of the large area mapping is considered inadequate for detailed planning such as for a state significant development, it does outline potential problems for the development area. Normally, if hazards are identified, then more detailed soil survey within the development area would normally be required for detailed planning purposes.

The LSC maps presented in the EIS and the Appendix are incorrect as noted by this reviewer. A revision of the mapping gives more serious weight to erosion hazard recognition with respect to the area of proposed development. Figure 1 shows the map provided in the EIS for LSC. Figure 2 shows the corrected LSC data for the area.

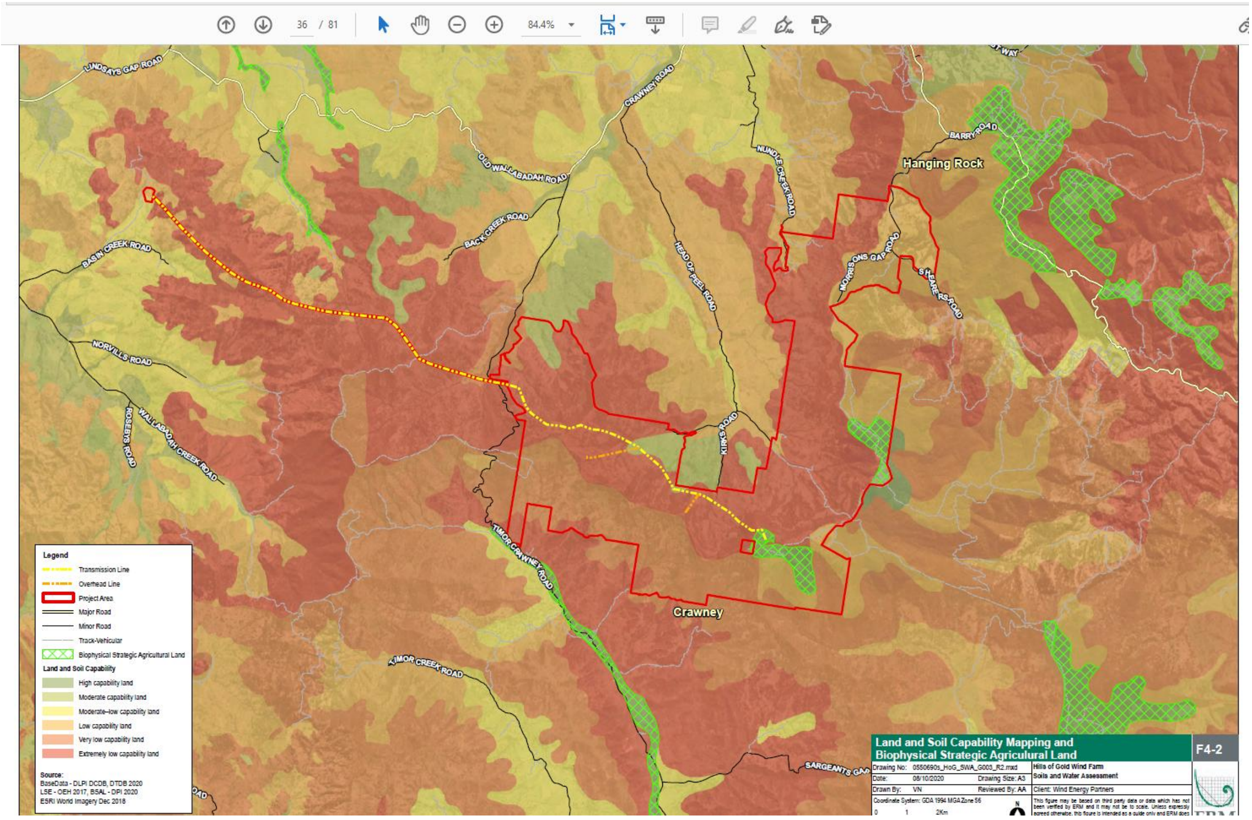

Figure 1: Copy of map from p30 Appendix O

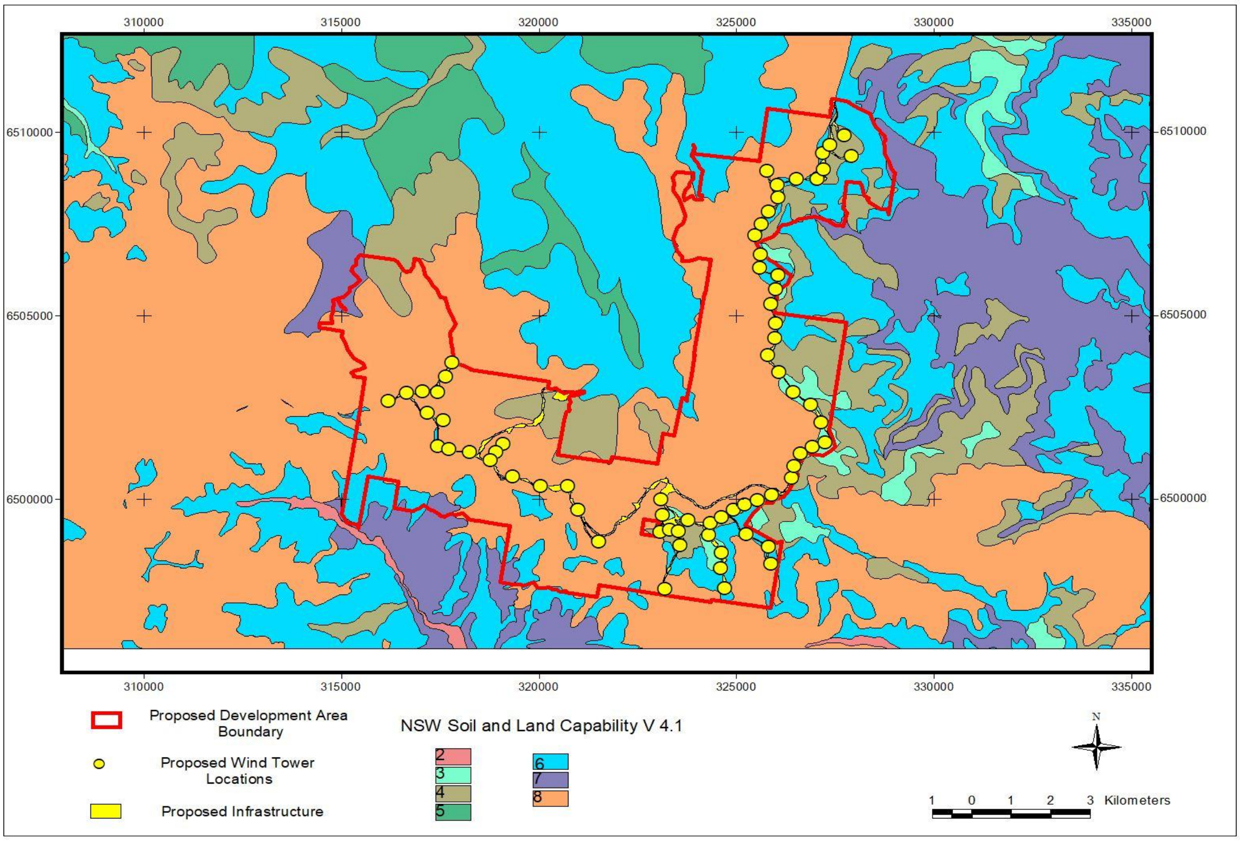

Figure 2: Corrected LSC mapping with broad development footprint provided by SOMEVA

A summary of the significance of the information presented in Figure 2 is summarised in Tables 2 – 4 below.

Table 2: Area of LSC Classes within greater proposed development area.

LSC	Development Area (ha)	% of Development Area
3	188.6	2.3
4	842.9	10.2
6	1224.8	14.9
7	134.5	1.6
8	5843.9	71.0

Table 3: Number of wind towers in each corrected LSC class

LSC Class	Number of Wind Towers	% of Wind Tower/LSC
3	9	12.9
4	8	11.4

6	20	28.6
8	33	47.1

Table 4: Area of Development footprint within each LSC class

LSC	Devel Footprint (ha)	% of Devel Footprint
3	25.3	9.7
4	46.4	17.8
6	47.5	18.2
7	0.8	0.3
8	140.9	54.0

As can be seen in the summary tables 2 – 4, 71% of the greater development area is Class 8 lands, 47% of proposed wind towers are in Class 8 lands and 54% of the development footprint is in Class 8 Lands. This means, at the scale of mapping, that around half of the proposed development is on mass movement dominated land with very high erosion risk. If these data had been correctly used by the consultant, then normally a field exercise to verify the soils and the slopes along the development footprint would have been made. Adjacent soil landscape mapping from McInnes provides erosion hazard and USLE factors. These could have at least been used as background data prior to a site visit.

Figure 3 shows the relative reliabilities of the base data used to construct the LSC classes. Once again, the issues of scale have not been questioned by the consultant, and the correct response would have been to go and map soil along the footprint of the development. The practical difference between building stable access roads in mass movement prone land versus gentle sloping land to a high standard could be in hundreds of millions of dollars and make the steeper areas prohibitive to develop.

Figure 3: Reliability of LSC mapping base data

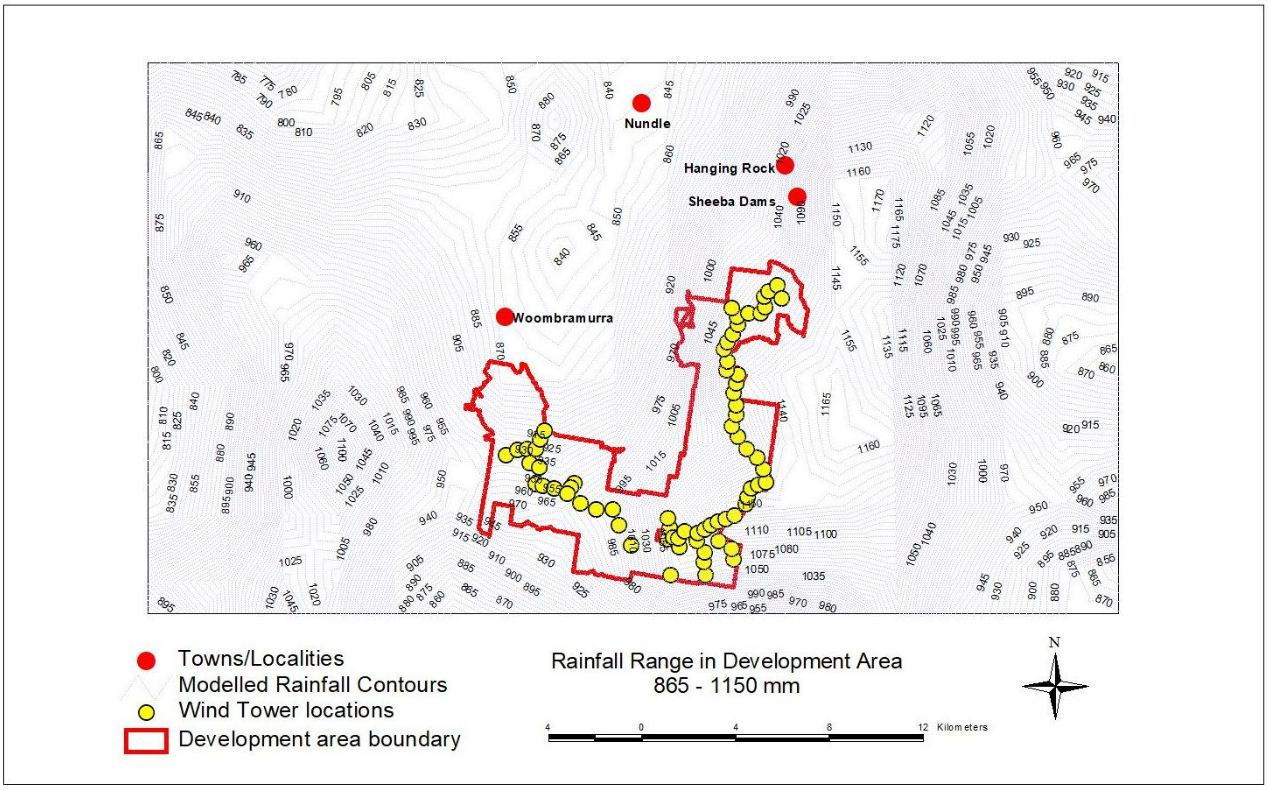

Figure 4: Modeled Rainfall in Region around Development Area

Figure 4 shows modeled rainfall surfaces for the Nundle area (Hutchinson *et al.*, 2002). Clearly this indicates that the amount and probably the intensity of rainfall within the development area is much higher than that provided for Nundle, and likely to vary in intensity accordingly. This impacts on erosion hazard and modeling of engineering structures immensely, but little has been done with the rainfall data. Areas covered in concrete pads and footings, will experience a modeled runoff of 865 – 1150 ML/ha based on Figure 4. With a permanent development footprint of 242 ha (EIS P. 59), the potential average annual runoff would range from 209 330 – 278 300 ML. This proposes significant drainage and erosion hazard issues, even aside from the placement of access roads.

Other maps which would have been useful in the document include geology mapping, and LiDAR (remotely sensed elevation) mapping, which would have detailed the slopes within the development footprint very accurately. 2 m density LIDAR is free within NSW and easy to use to asses slope, especially in steeper lands.

Use of available and corrected local broad scale soil information would normally have been acceptable as scoping material for the EIS, but because of the scale issues, field mapping, site inspection and soil profile description should have followed to provide soil information at a scale that is appropriate for the development.

Use of Goulburn Data

This section is confusing as it purports to modeling of erosion hazard using soil information from a large distance away from the proposed development. It is misleading and results are not relevant for the development footprint at all. More relevant data on soil K –factors for the RUSLE are available from adjacent soil landscape mapping in McInnes-Clarke (2004). Even if this data were used, the results would be proximal to the development and onsite soil survey would normally be recommended.

4. Conclusions

The Hills of Gold Wind Farm EIS (ERM, 2020) and associated Appendix O (Soils Sections) should be considered background information at best. The layout of both documents appears to randomly mix soil and water issues, rather than separating them into appropriate subsections.

The objectives of the EIS soils sections have not been met.

1. Existing soil conditions have not been adequately described within the planning footprint or wider area due to lack of understanding of the limitations of the data used and use of inappropriate or data containing obvious errors which as site inspection would have revealed.
2. Because no field verification has been carried out, soil impacts have been inaccurately detailed, and calculations of soil impacts have been made using

inadequate data, erroneous data, or data from another region of Australia which is highly inappropriate. Data for at least a desktop study to calculate likely erosion hazards and USLE equations could at least have been sourced locally from McInnes-Clarke (2004). Even such a study would still require onsite verification and field measurement and mapping of soil profile attributes and how they would impact on the proposed development.

3. Because of the errors in achieving objective 2., mitigations measures are based on insufficient or erroneous data. No plan at appropriate scale has been given showing how soil hazards are distributed and how and where mitigation measures will be placed within the footprint of the proposed development, and potential offsite impact areas.

The Soils sections within the EIS and Appendix O currently provide inadequate information for detailed planning of a wind farm. Currently it represents a simple scoping study, with highly erroneous data and use of inappropriate data which cannot be used for the purposes of an EIS

5. References

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6. Appendices

Appendix 1: Qualifications of Reviewer

Academic Curriculum Vitae

Personal Details

Name:	5th June 1967
Date of Birth:	
Nationality:	Australian
Contact Details:	139 Blackjack Forest Road PO BOX 582, Gunnedah NSW 2380 Phone: (02) 67 427 489; mobile: 0427 431 512 e-mail: soilfuturess@clearmail.com.au

Tertiary Education

2019 **The University of Queensland, School of Agriculture and Food Sciences**
Doctor of Philosophy
Thesis Title: Rapid Soil Development in Response to Land Use Change. Case Studies from northern New South Wales Slopes, Plains and the New England Tablelands.

2004 **TAFE Gunnedah**
Diploma in Frontline Business Management

1989 - 1990 **Macquarie University, School of Earth Sciences**
BSc Hons 2(1) Geomorphology
Research Hons. Thesis Title: *The Relationship between Floodplain Pollution and Exotic Weed Distribution in an Urban Floodplain: A Case Study of the Lane Cove River Valley.* Cross disciplinary study including fluvial geomorphology, soils and plant ecology.

1986 – 1989 **Macquarie University, School of Biological Sciences**
BSc Ecology and Soils

Honours and Awards - Accreditations

2017 **Second best Research Presentation.**
Awarded at Meat and Livestock Postgraduate Conference, November 2017.

1994 - present **Certified Professional Soil Scientist Level 2. Experienced Professional.**
Accreditation scheme run by Australian Soil Science Society Inc. ensuring appropriate standards and training are adhered to by accredited members.

2013	**Adjunct Research Fellow University of Queensland.** Coordinator, UniQuest – UQ-International Development: Liverpool Plains component Australia. Awarded Fellowship for contribution to African short courses.
2012	**University Brawijaya School of Agriculture Medal** Medal Presented by Dean of Faculty in recognition of training provided to local students, and procurement of EU funding for The soil science program at Uni Brawijaya.
2011	**LandCare Award for Communication of Soil Science** Presented by the Liverpool Plains Land Management Committee In recognition of publications, input to best management practice, and communication of soil science to members of the Liverpool Plains Community.

Employment History

2014 – 2018 **PhD Candidate. The University of Queensland.**

- Conducted research on significant soil type and characteristic changes which occur with common land use changes in northern NSW
- Presented findings to funding bodies and community groups as research was developed and subsequently completed
- Provided training and supervision to colleague post graduate students in field pedology and sampling
- Provided training and teaching to Honours students in pedology, field pedology and soil physics laboratory techniques

2004 – 2019 **Director and Consultant SoilFutures Consulting Pty Ltd.**

- Produced over 150 technical reports, maps and documents for national and international clients in agriculture, government and community groups
- Invited speaker at 150 (plus) Field Days (Australia)
- Supervised University students at University Brawijaya (Indonesia)
- Contributed to international training programs for professionals from 41 African countries and Iraq through UQ and Sydney University
- Contributed to national research programs with UNSW (Hydrogeology), Sydney University (Soil Science), ANU (Soil Science and Geomorphology) and Wollongong University (Soil Engineering).
- Rice Paddy Soil research in Java / Indonesia with Technical University Munich, Bonn and Halle Universities (Field Pedology and Soil Physics)
- Established business and academic relationships with University Brawijaya (Indonesia) and EU funded research programs
-

1990 – 2004 **Senior Soil Surveyor. Soil Conservation Service of NSW**

- conducted and published broad scale Soil Landscapes Surveys (maps and Reports)
- Supervised a team of regional soil survey staff and contributed locally and nationally to research particularly in salinity, hydrogeology, agronomy and new spatial analysis technologies
- Advising landholders, speaking at field days, supervising Honours Students from Australia and German Students from Goettingen, Hamburg and Berlin Universities.
- 18 months period of Secondment to Hong Kong government as part of the Systematic Investigation of Features of the Territory (SIFT) project, mapping cut and fill slopes and ranking them in terms of hazard of failing in tropical storms

Publications

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Languages

English	Native Language. Advanced listening, speaking reading and writing
German	Intermediate spoken and written word
Cantonese	Low level conversational
Bhasa Indonesian	Low level conversational and written

Appendix 2: Standard Limitations of Soil Landscape Mapping – requirement for detailed survey

provisional soil landscapes were mapped using stereoscopic interpretation of 1984 1:40 000 scale black-and-white aerial photographs. LANDSAT thematic mapper imagery from 1990 was also used to help with perception and charting of provisional soil landscapes. These boundaries were transferred onto 1:25 000 topographic base maps. Principal component analyses of LANDSAT imagery (of various dates) were used to determine the boundaries of landscapes with little surface expression, such as Glenmore (**gm**). Airborne Gamma Radiometrics imagery (AGSO) was used in the Liverpool Plains portion of the map to more precisely define soil landscape boundaries.

After field checking boundaries and detailed investigation of the soils, the provisional landscapes were confirmed, amalgamated or sub-divided. The resulting soil landscapes are presented on the map in groups based on their dominant geomorphic processes. A colour has been allocated to each group. Where soil landscape variants occur, it is often the case that they are due to a different geomorphic process. Consequently, all landscape variants have been allocated a colour corresponding to their dominant geomorphic process. This may or may not be the same as the parent soil landscape.

Soils were examined and described in detail at 335 sites, and observed and inspected at more than 2000 locations over the 52 soil landscapes. At each described site, soil morphological data and site information were recorded on Soil and Land Information System (SALIS) data cards. At the inspection sites, the correct landscape classification was confirmed. Soil descriptions were made from road cuttings, quarries, drains, pits, augered holes and core samples. Sufficient fieldwork was undertaken within each soil landscape to identify the range of soil materials present and to enable their distribution within the landscape to be described.

3.4 Soil Sampling

Four-hundred-ninety-seven soil samples were analysed at Department of Land and Water Conservation laboratories located within the Cowra, Gunnedah and Wellington Research Centres. It was desirable to test at least one sample from each of the soil materials, but unfortunately, some samples were contaminated in storage, so some soil materials may not be represented in soil test results.

Samples were selected from morphologically representative examples of each soil material. Samples were collected from each soil material present in each type profile. Where possible, samples were taken from comparatively undisturbed sites to reduce the impact of land use. These sites serve as benchmarks that can be used to compare test results on more intensively used sites for indications of land degradation.

Topsoil subsamples were bulked and thoroughly mixed prior to laboratory analysis. Individual subsoil samples were taken from representative described subsoils and were not bulked. Further details about soil sampling are included in Appendix 7.2.

3.5 Soil Data Access

Soil profile and site data can be accessed through the Soil and Land Information System (SALIS) on application to the SALIS Operations Manager, Department of Land and Water Conservation, P.O. Box 3720, Parramatta NSW 2150; or telephone 02 9895 6211.

3.6 Data Quality

Previous soil and geological map boundaries have been checked and adjusted by air photo interpretation and field observations.

Soil landscape boundaries are drawn directly from air photograph and satellite image interpretation onto standard 1:25 000 topographic field sheets. Boundaries have been checked and refined using an iterative field edit as well as air photo checks. Solid line boundaries are accurate generally within 100 m. Generally, dashed-line boundaries are accurate within 100 - 250 m, and indicate boundaries that are diffuse or difficult to identify. Generally, fine-dashed line boundaries are accurate within 250 - 400 m, and indicate very diffuse or inferred boundaries. Soil landscape polygons less than 40 ha and elongated polygons less than 300 m wide are generally not shown if they are not locally significant. In other instances, polygons as small as 20 ha are shown if they are of local importance.

Observations and soil profile numbers are located onto the field sheets in the field. Location is determined by map reading (with accuracy to 25 m) and where this is not possible, using Global Positioning Systems (with accuracy within 30 m on 95% of occasions). Soil profile descriptions are then more precisely located using site notes.

Continuity with other soil landscape maps is ensured by plotting boundaries up to 5 km beyond the perimeter of the mapping area. These are field-checked to ensure accuracy. Type locations for soil landscapes from other map sheets are visited to ensure conceptual continuity across map sheets.

For this soil landscape map, the number of soil and landscape observations and soil profile descriptions well exceed the minimum recommended range of ground observation densities specified in the *Australian Soil and Land Survey Handbook* (McDonald *et al.* 1984).

Generally, each soil landscape with difficult access due to obvious landscape limitations has at least three soil observations along with three soil profile descriptions. This is generally exceeded if the soil landscape is extensive or if extra fieldwork is required to determine the pattern of soil variation across the soil landscape. Absolute minimum sampling density is one complete profile per soil landscape and at least one observation per landform element.

The 1:25 000 field sheets are digitised and then reduced to 1:100 000 scale for publishing.

Soil material physical attributes and test results are considered to be reliable indicators of soil conditions. Soil material chemical test results may be more variable since they cannot be evaluated during field survey (see Explanations of Soil Test Results in Appendix 7.2).

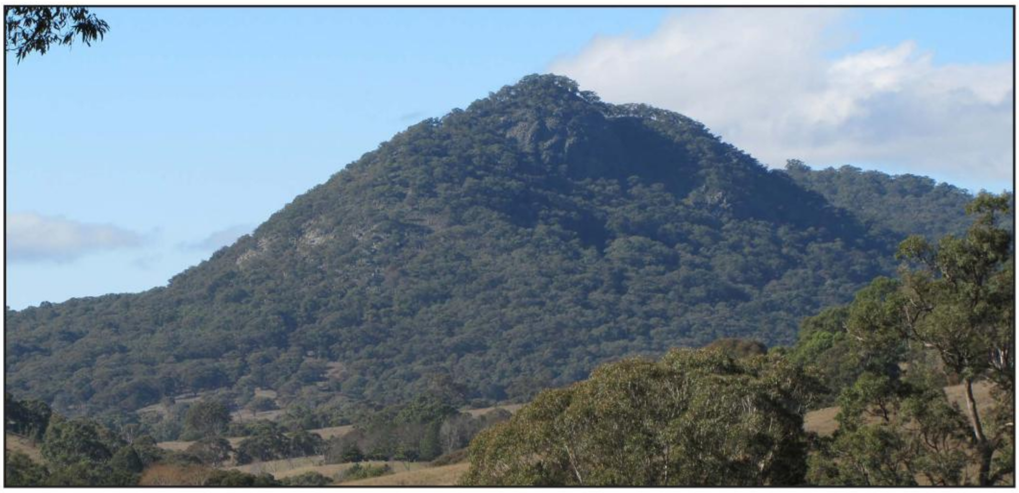
3.7 Data Reliability

The information in this report and the accompanying map should be used at the scale at which it is published. Enlarging the map cannot be expected to reveal further information and will produce distortions whereby map boundaries will no longer correspond to boundaries on-the-ground. If more detailed information is required, specific purpose surveys should be conducted or professional advice sought.

Single test results provided for each soil material are intended to provide only an indication of typical soil properties. The chemical and physical test results provided should be used only as a guide and not as an implicit basis for determining specific land uses. Variation in physical

Appendix 3: Published Soil Landscape Descriptions – from which LSC Class 8 are derived

cb COOBER BULGA



Landscape—122.4 km^2 very steep to precipitous colluvial mountains and hillslopes on Tertiary basalt of the southern Liverpool Range. Total relief <600m, local relief 80–220 m; elevation 500–1300 m; long, benched slopes >33%. Continuous, erosional, convergent and tributary drainage. 20% cleared open-forest and dense woodlands with rainforest on sheltered southerly slopes and along drainage lines.

Soils— well to moderately well-drained, moderate to deep (50–>150 cm) Red Dermosols (Euchrozems and Chocolate Soils) and Red Ferrosols (Euchrozems) on crests and upper slopes. Well to imperfectly drained, shallow to very deep (20–>200 cm) Black Dermosols (Chocolate Soils and Black Earths) and moderately well-drained, deep to very deep (150–250 cm) Brown Chromosols (Prairie Soils) on mid to lower slopes and drainage lines.

Qualities and Limitations—soils with high organic matter content, low permeability, high shrink-swell, acidity, and stoniness. Localised low permeability, low wet bearing strength, high plasticity, high erodibility, and hardsetting surfaces. Widespread steep slopes, mass movement hazard, high runoff, high sheet and rill erosion risk, and engineering hazard. Localised limitations include rock outcrop, shallow soils, rockfall hazard, high run-on (lower slopes) and gully erosion risk (drainage lines).

LOCATION AND SIGNIFICANCE

122.4 km^2 very steep to precipitous mountainsides and hillslopes of the southern Liverpool Range extending onto the adjacent Blackville sheet. The main difference between this landscape and Langs Neck (**ln**) on the north side of the Liverpool Range is that the generally moister conditions and a southerly aspect have resulted in slightly different soils and very different vegetation. Type location is at Cedar Brush (map reference: 2 81000E, 64 74000N).

LANDSCAPE

Geology and Regolith

Liverpool Range Beds (Tl)—Tertiary basalt, dolerites and occasional tuffs and zeolitised breccias and colluvium derived from these rocks. Soils have developed on unconsolidated material ranging in depth from a few centimetres to tens of metres. Degree of weathering ranges from moderate to massive saprolites.

Terrain

Steep to precipitous mountain slopes of >33%, but typically 50–90%. Slopes are moderately long (500 m) to very long (2500 m), but are typically 1300 m. Elevation ranges 500–1300 m. Total relief is <600 m, local relief (<300 m) is 80–220 m. Crests are very narrow (<100 m), sideslopes are long and uneven with flow benches up to 40 m wide. Drainage is deeply incised, erosional and spaced at regular intervals across the slope.

Vegetation

Vegetation in this landscape is complex and diverse. Generally dominated by tall, moist open-forest and woodlands, with patches of *Poa* sp. (snow grass) in frost hollows on lower slopes. Species are limited due to site access problems. Many more species are likely to dominate this landscape across its mosaic of microclimates and soil types.

Species encountered on mid to upper slopes include *Eucalyptus melliodora* (yellow box), *E. goniocalyx* (long-leaved box), *E. laevopinea* (silvertop stringybark), *E. viminalis* (manna gum), *E. dalrympleana* (mountain gum), *E. moluccana* (grey box) and *E. pauciflora* (snow gum). Common species in the understorey include *Acmena smithii* (lilly pilly), *Acacia dealbata* (silver wattle), *Acacia melanoxylon* (blackwood), *Acacia implexa* (hickory wattle), *Myoporum montanum* (water bush), *Allocasuarina torulosa* (forest oak) and *Hymenosporum flavum* (native frangipani).

McInnes-Clarke, S.K. 2002, Soil Landscapes of the Murrurundi 1:100 000 Sheet, Department of Land and Water Conservation, Sydney.

Lower slopes are dominated by *Eucalyptus moluccana* (grey box), *E. melliodora* (yellow box), *E. goniocalyx* (long-leaved box), *E. bridgesiana* (apple box), *Allocasuarina torulosa* (forest oak) and *Angophora floribunda* (rough-barked apple). Common understorey species include *Hymenanthera dentata* (tree violet), unidentified *Acacia* spp. (wattles), *Dodonaea viscosa* (giant hopbush) and *Cassinia laevis* (cough bush).

Common herbs in the above vegetation communities are *Themeda australis* (kangaroo grass), *Danthonia* spp. (wallaby grasses), *Aristida* spp. (wiregrasses), *Dichanthium sericeum* (Queensland blue grass), *Poa* sp. (snow grass) and *Stipa* spp. (spear grasses). *Culcita dubia* (soft bracken), *Helipterum anthemoides* (chamomile sunray) and *Swainsona galegifolia* (smooth darling pea) also occur.

Deeply incised drainage lines and sheltered slopes support rainforest and moist forest. The following species were identified—*Pittosporum undulatum* (mock orange), *Daphnandra micrantha* (socket wood), *Ficus rubiginosa* (Port Jackson fig), *Ficus obliqua* (small-leaved fig), *Toona australis* (red cedar), *Hymenosporum flavum* (native frangipani), *Pennantia cunninghamii* (brown beech), *Acmena smithii* (lilly pilly), *Myoporum montanum* (water bush), *Alectryon subcinereus* (wild quince), *Hedycarya angustifolia* (native mulberry), *Eupomatia laurina* (bolwarra), *Casuarina cunninghamiana* (river oak) and *Hymenanthera dentata* (tree violet). Other species include *Clematis glycinoides* (forest clematis), *Cissus antarctica* (water vine), *Marsdenia rostrata* (common milk vine) and *Smilax australis* (lawyer vine). Eucalypts from upslope form emergents from the denser rainforest canopy. Ground cover species in this part of the landscape are generally unidentified fern species.

Land Use

Generally uncleared bushland with small cleared areas used for light grazing on native and improved pastures.

Land Degradation

Sheet erosion is a common feature of the landscape, with mass movement (debris flows, slumps and slides) characteristic of steeper benched slopes. Some gully erosion occurs in areas of over-clearing, heavy stocking or where road and track culverts have concentrated water.

Included Soil Landscapes

Small areas of the Ant Hill (**ah**) soil landscape have been included on broader benches and near the lower boundary of the Coober Bulga (**cb**) soil landscape. Small areas of Yarramoor (**ym**) occur along lower drainage lines, with small areas of Warung (**wg**) on crests.

LANDSCAPE QUALITIES AND LIMITATIONS

Widespread steep slopes, mass movement hazard, high runoff, high sheet and rill erosion risk and engineering hazard. Localised rock outcrop, shallow soils, rockfall hazard, high run-on (lower slopes) and gully erosion risk (drainage lines).

Erodibility

	Non-concentrated Flows	Concentrated Flows	Wind
cb2	low	high	very low–low
cb3	very low–high	high	very low
cb6	moderate–high	high	very low
cb7	moderate	moderate	very low

Erosion Hazard

	Non-concentrated Flows	Concentrated Flows	Wind
Grazing	low	high	low
Cultivation	low	very high	low
Urban	low	high	low

SOILS

Variation and Distribution

Soils are generally consistent and predictable, varying with site exposure and position in the landscape. Shallow to very deep, well to imperfectly drained Black Dermosols (Chocolate Soils and Black Earths) dominate sideslopes and drainage lines. Moderately deep to deep, well to moderately well-drained Red Ferrosols (Euchrozems) and Red Dermosols (Euchrozems and Chocolate Soils) occur on crests and upper slopes. Occasionally, deep to very deep, moderately well-drained Brown Chromosols (Prairie Soils) occur on mid to lower slopes. Soil map confidence—85%.

Dominant Soil Materials—Qualities and Limitations

cb2—very fine, self-mulching clay loam (topsoil—A1 horizon).

Black (5YR 2.5/1) to very dark grey (5YR 3/1) to very dark brown (7.5YR 2.5/2) clay loam to silty clay to light clay; strong to moderate structure, polyhedral peds <2–5 mm; field pH 5.5–7.0. Generally occurs in conjunction with good ground cover. High organic matter; acidity; localised stoniness, high shrink-swell and low permeability.

cb3—self-mulching clay (topsoil—A1 horizon).

Black (5YR 2.5/1) to dark reddish brown (5YR 2.5/2) to very dark brown (7.5YR 2.5/2) generally silty clay, also silty clay loam and clay loam; strong to moderate structure, polyhedral to sub-angular blocky peds 5–20 mm; field pH 5.5–8.0. High organic matter content; localised high shrink-swell, stoniness, high erodibility, hardsetting surface, acidity and low wet bearing strength.

cb6—dark reddish brown structured clay (subsoil—B2, B21, B22 horizon).

Dark reddish brown (5YR 3/3–2.5YR 3/3) to dark brown (7.5YR 3/4) medium clay extending to silty clay and heavy clay; strong to moderate structure, sub-angular blocky to polyhedral to columnar peds 10–50 mm; field pH 6.0–6.5. Includes materials previously described by Banks (1998) as **cb8**. Low wet bearing strength; low permeability; localised high shrink-swell, high plasticity, high organic matter content, high erodibility and acidity.

McInnes-Clarke, S.K. 2002, Soil Landscapes of the Murrurundi 1:100 000 Sheet, Department of Land and Water Conservation, Sydney.

cb7—dark grey heavy clay (subsoil—B2, B3 horizons).

Very dark grey (5YR 3/1) to dark reddish grey (5YR 4/2) light-medium to heavy clay; strong to moderate structure, prismatic, columnar to sub-angular blocky peds 20–100 mm; field pH 7.0–8.0. The description of this material has been expanded from that provided by Banks (1998). High organic matter content; low permeability; localised high shrink-swell, stoniness and acidity.

Associated Soil Material

cb1—dark organic loam (surface—O horizon).

Reddish black (2.5YR 2.5/1) organic rich clay loam; strong pedality, polyhedral peds 2–5 mm; field pH 6.5. Occurs in moist positions under a good litter layer.

Type Profiles

Type Profile 1: midslope
Dominance: ~55% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Haplic, Eutrophic, Black Dermosol (Chocolate Soil); medium, gravelly, clayey, clayey, moderately deep
Surface condition: self-mulched; gravels absent
Drainage: moderately well-drained
Depth: 50 cm; **rooting depth:** ~70 cm
General soil fertility: high
Location: TOWARRI 1:25 000 sheet, upper Dart Brook Road (map reference: 2 72450E, 64 71200N). Profile 128. Voluntary/native pasture

Soil Material Description

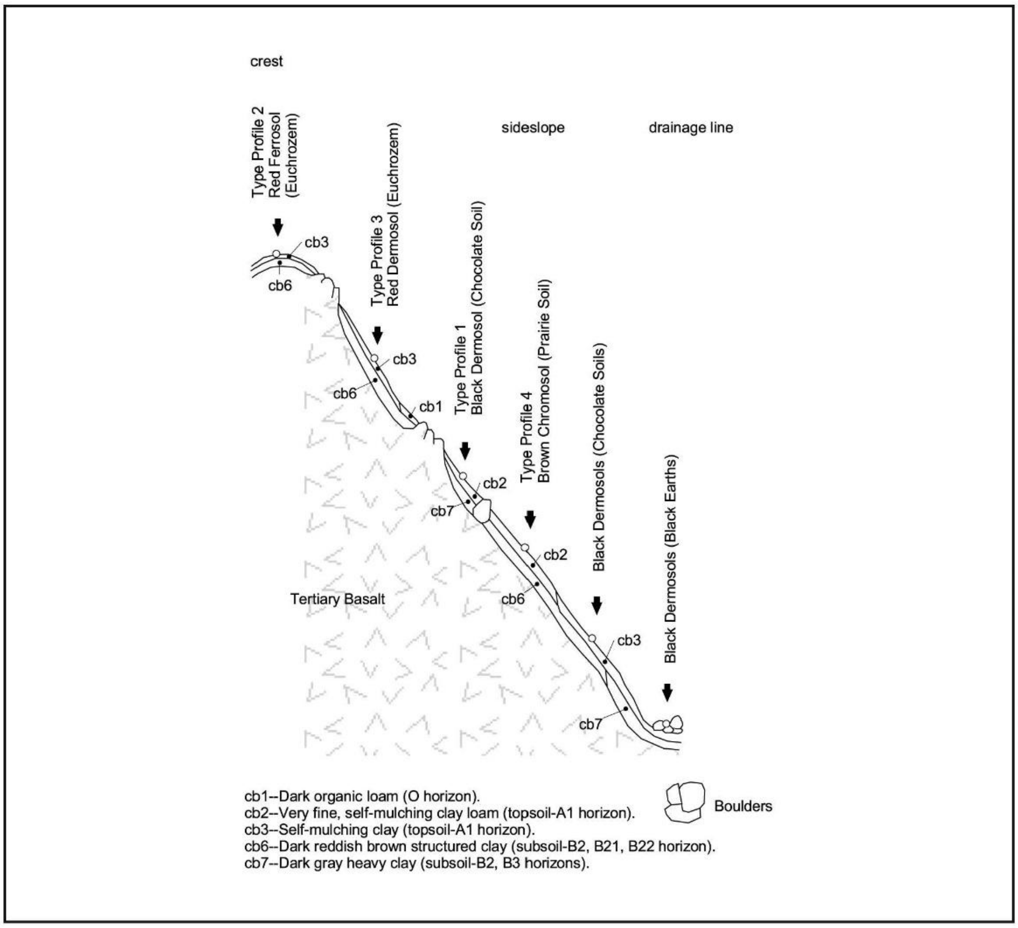
Layer 1, A1 **cb2**, 0–10 cm	very dark grey (5YR 3/1) light clay; strong, 2–5 mm polyhedral peds are dominant with 5–10 mm sub-dominant, smooth-faced, moderately weak and crumbly (dry); field pH 7.0; moderately permeable; common (10–20%) fine gravels (2–6 mm); common <1 mm roots; clear boundary to…
Layer 2, B2 **cb7**,10–20 cm	very dark grey (5YR 3/1) light-medium clay; strong 20–50 mm prismatic peds, smooth-faced, very firm (dry), crumbly; field pH 7.0; slowly permeable; common (10–20%) fine gravels and gravels (2–20 mm); common <1 mm roots and few 1–2 mm roots; gradual boundary to…
Layer 3, B3 **cb7**, 20–50 cm	dark reddish grey (5YR 4/2) heavy clay; moderate, 50–100 mm prismatic peds, rough-faced, very firm (dry), crumbly; field pH 7.0; slowly permeable; many (20–50%) fine gravels and gravels (2–20 mm); common <1 mm roots; bedrock reached.

Type Profile 2: crest
Dominance: ~10% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Humose, Eutrophic, Red Ferrosol (Euchrozem); medium, slightly gravelly, silty, clayey, moderately deep
Surface condition: self-mulched; few surface coarse gravels and cobbles
Drainage: well-drained
Depth: 50 cm; **rooting depth:** ~70 cm
General soil fertility: high
Location: TOWARRI 1:25 000 sheet, Cedar Brush Nature Reserve on Cedar Brush Stock Route (map reference: 2 81467E, 64 74874N). Profile 321. National/State park

Soil Material Description

Layer 1, A1 **cb3**, 0–20 cm	very dark grey (5YR 3/1) silty clay loam; strong 5–10 mm granular peds, rough-faced, moderately weak (moderately moist), crumbly; field pH 6.0; moderately permeable; coarse fragments absent; few <1 mm roots; clear boundary to…
Layer 2, B2 **cb6**, 20–>50 cm	dark reddish brown (5YR 3/3) light-medium clay; moderate 20–50 mm sub-angular blocky and 10–20 mm polyhedral peds, rough-faced, moderately firm (moderately moist), plastic; field pH 6.0; slowly permeable; coarse fragments absent; few <1 mm roots; layer continues.

Type Profile 3: upper slope
Dominance: ~10% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Melanic, Eutrophic, Red Dermosol (Chocolate Soil); thick, gravelly, silty, clayey, very deep
Surface condition: self-mulched, few surface coarse gravels and cobbles
Drainage: moderately well-drained
Depth: >150 cm, **rooting depth:** ~150 cm
General soil fertility: high



■ ***Distribution diagram of Coober Bulga soil landscape illustrating occurrence and relationship of dominant soil materials.***

McInnes-Clarke, S.K. 2002, Soil Landscapes of the Murrurundi 1:100 000 Sheet, Department of Land and Water Conservation, Sydney.

ln LANGS NECK

Landscape—166.4 km^2 steep to precipitous mountain slopes and scarps on Tertiary basalt in the Liverpool Ranges. Total relief <450 m, local relief 100–200 m; elevation 500–1250 m; slopes 30–200%. Slopes generally quite long; rock outcrop <10%. Woodland to very tall open-forest, with rainforest restricted to some moist drainage lines, 20% cleared.

Soils—moderately well to well-drained, shallow to moderately deep (40–>90 cm) Black Dermosols (Black Earths and Chocolate Soils) on sideslopes and crests. Well-drained, very shallow (<20 cm) Leptic Tenosols (Lithosols) on crests and flow benches. Well to moderately well-drained, moderately deep (>50 cm) Red Dermosols and Ferrosols (Euchrozems) on upper and midslopes. Moderately well-drained, moderately deep (>60 cm) Black Vertosols (Chocolate Soils) on mid to lower slopes.

Qualities and Limitations—soils of low permeability and high organic matter content. Localised high plasticity, low wet bearing strength, stoniness, hardsetting surfaces and acidity. Steep slopes, mass movement hazard, high runoff, high erosion hazard, shallow soils and engineering hazard. Localised rock outcrop, rockfall hazard, high run-on (lower slopes) and gully erosion risk (drainage lines).

LOCATION AND SIGNIFICANCE

166.4 km^2 extensive, largely inaccessible, steep to precipitous mountains of the northern Liverpool Ranges extending onto the adjacent Blackville sheet. Langs Neck (**ln**) occurs on the northern side of the Liverpool Range and is the equivalent of the Coober Bulga (**cb**) soil landscape that occurs on the southern side of the Liverpool Range. It is distinguished by a drier climate that has resulted in drier, more open vegetation and slightly different soils. Examples occur on Cedar Brush stock route, Brees Mountain, Mount Gregson and Mount Helen. Type location is on the Merriwa Road on the Liverpool Range (map reference: 2 66000E, 64 74000N).

This soil landscape was originally described on the Blackville sheet, but has been modified to include the former Mount Tamarang (**mt**) soil landscape in this survey.

LANDSCAPE

Geology and Regolith

Liverpool Range Beds (Tl)—Tertiary basalt, dolerites with occasional tuffs and zeolitised breccias and colluvium derived from these rocks. Soils have formed on unconsolidated material that may vary from a few centimetres to tens of metres deep. Soil depths are also extremely variable from <10–>150 cm.

Terrain

Steep to precipitous hills and mountains that are occasionally capped with vertical escarpments. Slopes range from 30–200%, although typically range 30–50%. Slopes are typically 500–2000m long. Elevation ranges 500–1250 m. Total relief is <450 m, local relief is <200 m. Typical landform elements include narrow crests, occasional scree slopes below cliff faces and long, benched sideslopes. Rock outcrop is <10%. Drainage lines are deeply incised and unidirectional.

Vegetation

Species composition is dependent on location. There are three main divisions in this landscape into which the different plant communities fall.

The tall, open-forest of mid to upper slopes includes some areas of woodland (lower slopes). Dominant species are variable. Tree species include *Angophora floribunda* (rough-barked apple), *Eucalyptus laevopinea* (silvertop stringybark), *E. viminalis* (manna gum), *E. macrorhyncha* (red stringybark) (localised), *E. dalrympleana* (mountain gum), *E. moluccana* (grey box), *E. melliodora* (yellow box), *E. tereticornis* (forest red gum), *E. albens* (white box), *E. blakelyi* (Blakely's red gum), *E. pauciflora* (snow gum) and *E. goniocalyx* (long-leaved box) on crests and upper slopes.

Other species include *Notelaea microcarpa* (native olive), occasional *Callitris glaucophylla* (white cypress pine) and *Allocasuarina torulosa* (forest oak), with *Pittosporum undulatum* (mock orange) in moist sites. Common understorey species include *Acacia implexa* (hickory), unidentified *Acacia* species (wattles), *Hymenanthera dentata* (tree violet), *Cassinia laevis* (cough bush), *Cassinia laevis* (cough bush) and *Myoporum montanum* (water bush).

Common understorey species include *Themeda australis* (kangaroo grass), *Danthonia* spp. (wallaby grasses), *Aristida* spp. (wiregrasses), *Chloris ventricosa* (tall windmill grass), *Dichanthium sericeum* (Queensland blue grasses), *Poa* sp. (snow grass), *Bothriochloa macra* (red grass), *Cymbopogon refractus* (barbed-wire grass), *Stipa verticillata* (slender bamboo grass) and *Stipa* spp. (spear grasses). Other species include *Wahlenbergia* sp. (bluebells), *Helipterum anthemoides* (chamomile sunray) and *Swainsona galegifolia* (smooth darling pea).

Small pockets of dry rainforest (vine scrub) occur in sheltered gullies and passes such as at Cedar Brush (Fisher 1985) and species typical of Coober Bulga (**cb**) soil landscape. Common species include *Acmena smithii* (lilly pilly), *Daphnandra micrantha* (socketwood), *Pittosporum undulatum* (mock orange), *Dendrocnide excelsa* (giant stinging tree), *Ficus obliqua* (small-leaved fig) and *Doryphora sassafras* (sassafras). *Eucalyptus viminalis* (ribbon gum) occurs as an emergent near the boundary to other communities. There is little vegetative ground cover in these vine scrub areas except for some fern species.

Land Use

Predominantly unused, some light grazing under green timber. Small areas of conservation, such as Cedar Brush Nature Reserve.

Land Degradation

Uncleared areas are subject to natural mass movements in the form of rockfalls, slumps, landslides and debris flows. Cleared areas commonly exhibit severe sheet, rill and gully erosion with increased incidence of mass movement.

Included Soil Landscapes

Small areas of the Moan (**mn**) soil landscape have been included on broader rock benches. Small areas of the Warung (**wg**) soil landscape have been included on crests.

LANDSCAPE QUALITIES AND LIMITATIONS

Steep slopes; mass movement hazard; high runoff; high erosion hazard; shallow soils; engineering hazard. Localised rock outcrop, rockfall hazard, high run-on (lower slopes) and gully erosion risk (drainage lines).

Erodibility

	Non-concentrated Flows	Concentrated Flows	Wind
ln2	very low–moderate	moderate–high	very low
ln4	moderate	high	very low
ln5	moderate–high	high	very low
ln6	low–moderate	high	very low
ln7	moderate	high	very low

Erosion Hazard

	Non-concentrated Flows	Concentrated Flows	Wind
Grazing	moderate–high	high	low
Cultivation	very high	very high	low
Urban	very high	very high	low

SOILS **Variation and Distribution**

Field survey in this landscape was limited due to severe access restrictions. The following is an account of the soils encountered during this survey.

Moderately well to well-drained, shallow to moderately deep Black Dermosols (Black Earths and Chocolate Soils) on sideslopes and crests. Well-drained, very shallow Leptic Tenosols (Lithosols) on crests and leading edges of flow benches. Well to moderately well-drained, moderately deep Red Dermosols and Ferrosols (Euchrozems) in upper and midslope positions. Moderately well-drained, moderately deep (>60 cm) Black Vertosols (Chocolate Soils) on mid to lower slopes. Soil map confidence—75%.

Dominant Soil Materials—Qualities and Limitations

ln2—dark crumbly clay loam (topsoil—A1 horizon).

Very dark grey (5YR 3/1) to dark reddish brown (5YR 3/2) typically light clay to silty clay loam, rarely heavy clay; moderate to strong structure, polyhedral to granular peds 2–20 mm; field pH 6.5–7.0. This material has been expanded from its original description to include materials previously described by Banks (1998) as **ln3**. High organic; matter content; localised stoniness, hardsetting surface, acidity, low permeability and low wet bearing strength.

ln4—dark reddish brown plastic clay (subsoil—B2 horizon).

Dark reddish brown (5YR 3/2) light-medium clay to heavy clay; moderate to strong structure, polyhedral (10–20 mm) to sub-angular blocky or columnar peds 20–50 mm; field pH 6.5–7.5. High shrink-swell; high organic matter; low permeability; localised stoniness.

McInnes-Clarke, S.K. 2002, Soil Landscapes of the Murrurundi 1:100 000 Sheet, Department of Land and Water Conservation, Sydney.

ln5—reddish brown medium clay (subsoil—B2 horizon).

Dark reddish brown (5YR 3/3) to reddish brown (5YR 4/3) medium to heavy clay; moderate structure, polyhedral peds 10–20 mm and sub-angular blocky peds 20–50 mm; field pH 6.0–7.0. Low permeability; localised acidity, high organic matter and low wet bearing strength.

ln6—dark cracking heavy clay (subsoil—B21, B22 horizons).

Very dark grey (5YR 3/1) to dark reddish brown (5YR 3/3) medium-heavy to heavy clay; strong structure, prismatic 50–100 mm and polyhedral peds 10–20 mm; field pH 6.5–7.0. High shrink-swell; low permeability; acidity; localised high plasticity and high organic matter content.

ln7—hardsetting light clay (topsoil—A1 horizon).

Dark reddish brown (5YR 3/3) to dark brown (7.5YR 3/2) to brown (7.5YR 4/2) clay loam to light-medium clay; weak to moderate structure, granular and polyhedral peds 5–20 mm; field pH 6.5–7.5. Hardsetting surface; high organic matter; low permeability; localised stoniness.

Associated Soil Materials

ln1—black clayey peat (surface—O horizon).

This material was identified on the adjacent Blackville sheet (Banks 1998). It was not encountered during this survey, but may occur in moist sites at high elevations.

Structured basaltic saprolite (subsoil—C horizon).

Highly weathered basaltic materials are common. Texture ranges from gravelly to sandy to clay loam and clay. Colour is highly variable including red, grey, brown and purple.

Rock and boulder scree.

Areas with little soil development are common on cliff footslopes and steeper sideslopes. Basalt flow edges often have the appearance of loose scree in disjunct positions on the slope and are characterised by large boulders held firmly into the rock mass on the slope.

Leaf litter and decomposing organic debris.

In areas of good vegetation cover, litter and organic debris in various stages of decomposition occurs on the soil surface. This layer may be up to 10 cm thick.

Type Profiles

Type Profile 1: midslope
Dominance: ~30% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Haplic, Eutrophic, Black Dermosol (Black Earth); medium, gravelly, clayey, clayey, moderately deep
Surface condition: self-mulching
Drainage: moderately well-drained
Depth: >60cm; **rooting depth:** >60 cm
General soil fertility: high
Location: TOWARRI 1:25 000 sheet, gully on Merriwa Road (map reference: 2 65503E, 64 74468N). Profile 324. Timber/scrub/unused

Soil Material Description

Layer 1, A1 **ln2,** 0–15 cm	very dark grey (5YR 3/1) light clay; moderate pedality 10–20 mm granular peds, rough-faced fabric, moderately weak and brittle (moderately moist); field pH 8.0; slowly permeable; common (10–20%) fine gravels (2–6 mm), gravels (6–20 mm) and coarse gravels (20–60 mm); few <1–2 mm roots; clear boundary to…
Layer 2, B2 **ln4**, 15–>60 cm	dark reddish brown (5YR 3/2) light-medium clay; moderate pedality, 20–50 mm sub-angular blocky peds, rough-faced fabric, moderately weak and plastic (moderately moist); field pH 7.5; slowly permeable; many (20–50%) coarse gravels (20–60 mm), and cobbles (60–200 mm), few <1–2 mm roots; layer continues.

Type Profile 2: midslope
Dominance: ~20% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Haplic, Eutrophic, Red Dermosol (Euchrozem); thin, slightly gravelly, clayey, clayey, moderately deep
Surface condition: hardsetting
Drainage: moderately well-drained
Depth: 50 cm; **rooting depth:** ~60 cm
General soil fertility: high

Location: QUIRINDI 1:25 000 sheet, auger hole/pit on "Mirrabooka" (map reference: 2 77636E, 65 03500N). Profile 315. Voluntary/native pasture

Soil Material Description

Layer 1, A1 **ln7**, 0–5 cm	very dark grey (5YR 3/1) light clay; moderate pedality, 5–10 mm granular peds, rough-faced fabric, moderately weak and crumbly (moderately moist); field pH 7.0; slowly permeable; few (2–10%) gravels (6–20 mm) and coarse gravels (20–60 mm); common <1 mm roots; few 1–2 mm roots; clear boundary to…
Layer 2, B2 **ln5**, 5–30 cm	dark reddish brown (5YR 3/3) medium-heavy clay; moderate pedality, 10–20 mm polyhedral peds, rough-faced fabric, moderately weak and crumbly (moderately moist); field pH 7.0; slowly permeable; few (2–10%) gravels (6–20 mm) and coarse gravels (20–60 mm); common <1 mm roots, few 1–2 mm roots; clear boundary to…
Layer 3, C **associated**, 30–50 cm	brown (7.5YR 4/3) sandy clay; moderately weak and crumbly (dry); field pH 7.0; bedrock reached.

Type Profile 3: lower midslope
Dominance: ~20% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Haplic, Epipedal, Black Vertosol (Chocolate Soil); medium, slightly gravelly, silty, clayey, moderately deep
Surface condition: seasonally cracking
Drainage: moderately well-drained
Depth: >60 cm; **rooting depth:** >60 cm
General soil fertility: high
Location: TOWARRI 1:25 000 sheet, batter on Cedar Brush Stock Route (map reference: 2 81449E, 64 75294N). Profile 320. Voluntary/native pasture

Soil Material Description

Layer 1, A1 **ln2**, 0–10 cm	dark reddish brown (5YR 3/2) silty clay loam; moderate pedality, 2–5 mm polyhedral peds, rough-faced fabric, moderately weak and crumbly (moderately moist); field pH 6.5; moderately permeable; few (2–10%) cobbles (60–200 mm); many <1 mm roots, few 1–2 mm roots; clear boundary to…
Layer 2, B2 **ln6**, 10–40 cm	very dark grey (5YR 3/1) medium-heavy clay; strong pedality, 50–100 mm prismatic peds, smooth-faced fabric, moderately weak and plastic (moist); field pH 6.5; slowly permeable; few (2–10%) cobbles (60–200 mm); few <1–2 mm roots; gradual (50–100 mm) boundary to…
Layer 3, B22 **ln6**, 40–>60 cm	dark reddish brown (5YR 3/3) heavy clay; strong pedality, 50–100 mm prismatic peds, smooth-faced fabric, moderately firm and plastic (moist); field pH 7.0; slowly permeable; few <1–2 mm roots; layer continues.

Type Profile 4: crest
Dominance: ~20% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Ochric, Lithic, Leptic Tenosol (Lithosol); moderate, moderately gravelly, clayey, very shallow
Surface condition: hardsetting
Drainage: well-drained
Depth: 10 cm; **rooting depth:** ~15 cm
General soil fertility: low
Location: QUIRINDI 1:25 000 sheet, auger hole/pit on "Mirrabooka" (map reference: 2 77613E, 65 03442N). Profile 316. Voluntary/native pasture

Soil Material Description

Layer 1, A1 **ln7**, 0–10 cm	brown (7.5YR 4/2) clay; moderate pedality, 10–20 mm granular peds, rough-faced fabric, moderately weak and crumbly (dry); field pH 7.5; slowly permeable; many (20–50%) gravels (6–20 mm), coarse gravels (20–60 mm) and cobbles (60–200 mm); common <1 mm roots; layer overlies slightly weathered basalt.

Type Profile 5: upper slope
Dominance: ~10% of soil landscape
Soil classification (Isbell 1996 (Stace *et al.* 1968)): Humose-Acidic, Eutrophic, Red Ferrosol (Euchrozem); medium, non-gravelly, clayey, clayey, moderately deep
Drainage: well-drained
Depth: >60 cm
General soil fertility: high
Location: TOWARRI 1:25 000 sheet, auger hole/pit near Cedar Brush Stock Route (map reference: 2 81511E, 64 74965N). Profile 322. Voluntary/native pasture

Soil Material Description

Layer 1, A1 **ln2,** 0–20 cm	very dark grey (5YR 3/1) light clay; strong pedality, 10–20 mm polyhedral peds, smooth-faced fabric, moderately firm and crumbly (moderately moist); field pH 7.0; moderately permeable; <1–2 mm roots are common; gradual boundary to…
Layer 2, B2 **ln5,** 20–60 cm	reddish brown (5YR 4/3) heavy clay; moderate pedality, 20–50 mm sub-angular blocky peds, rough-faced fabric, moderately firm and plastic (moderately moist); field pH 6.0; few <1 mm roots; layer continues.

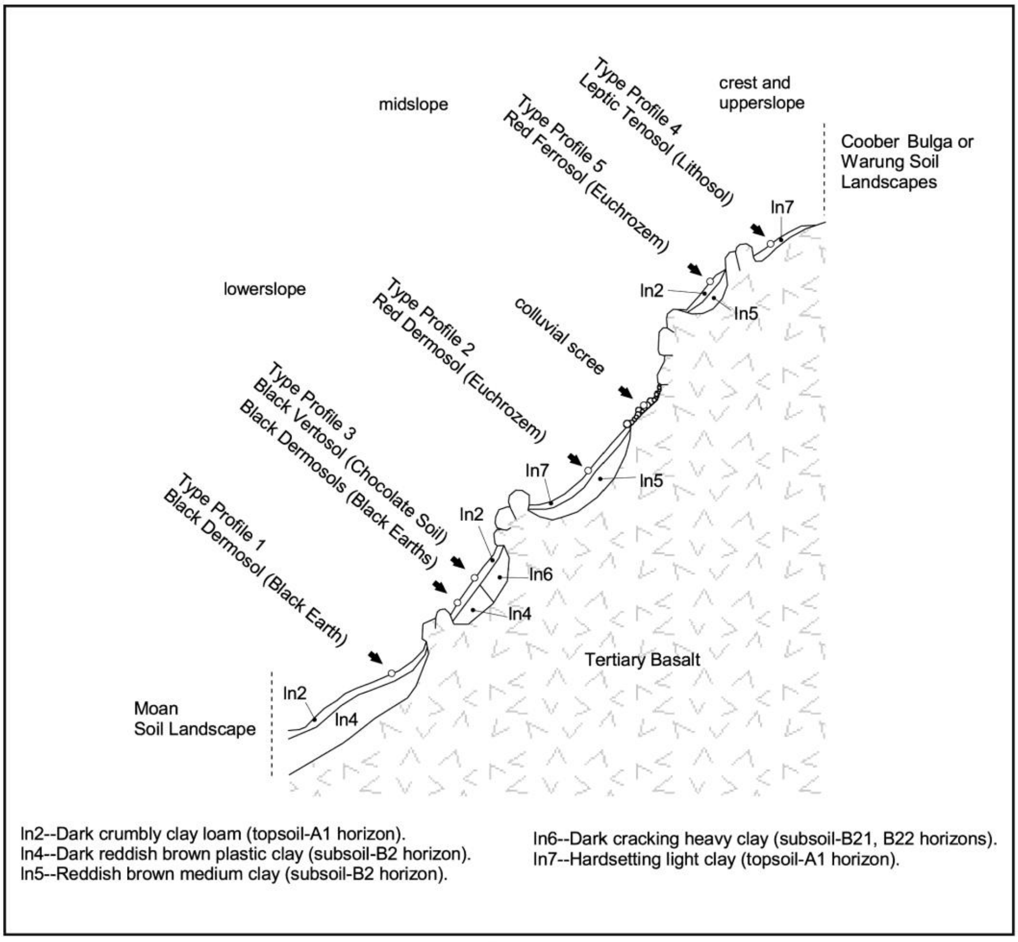
SOIL QUALITIES AND LIMITATIONS

Soil Fertility

General soil fertility and nutrient holding capacity is high to very high. Organic matter content is high to very high in **ln2**, **ln4** and **ln7**, and moderate to high in **ln5** and **ln6**. Soil pH ranges from moderately acid to mildly alkaline. Plant available waterholding capacity is generally moderate to very high. Plant available phosphorus is very high in **ln2**, **ln4** and **ln7**, low to very high in **ln5,** and moderate in **ln6**. Exchangeable calcium is generally low, exchangeable potassium balanced to deficient.

Foundation Hazard

Foundation hazard is extreme for all soil materials. Soils have high to extreme shrink-swell potential, localised low wet bearing strength and high organic matter content. Landscape considerations include very steep slopes, mass movement hazard, rockfall hazard and localised high run-on (lower slopes). Soils have formed on unconsolidated material that varies from a few centimetres to tens of metres deep. Soil depths are also extremely variable from <10–>150 cm.



■ ***Distribution diagram of Langs Neck soil landscape illustrating occurrence and relationship of dominant soil materials.***

McInnes-Clarke, S.K. 2002, Soil Landscapes of the Murrurundi 1:100 000 Sheet, Department of Land and Water Conservation, Sydney.

Urban and Rural Capability

Generally high to severe limitations exist for urban development due to steep slopes, mass movement hazard, high erosion hazard, engineering hazard and high soil high organic matter content, with localised rockfall hazard and high run-on (lower slopes).

Generally high to severe limitations exist for cultivation.

There are high (with localised areas of moderate) limitations for grazing. Considerations include steep slopes, mass movement hazard, high erosion hazard, shallow soils, localised rock outcrop, high run-on (lower slopes) and gully erosion risk (drainage lines).

Sustainable Land Management Suggestions

In cleared areas, maintain/promote a minimum of 80% ground cover to prevent sheet, rill and gully erosion, and mass movement. Agroforestry is the recommended land use. Maintain/enhance all vegetation cover to reduce erosion risk. On slopes >50%, retain or promote tree cover to 100% tree cover. On slopes <50%, retain or promote to 50% tree cover, and retain pasture.

Includes areas mapped as protected land under the Soil Conservation Act (1938). Contact officers of the Department of Land and Water Conservation at Quirindi for advice with regards to planning, clearing and construction in this area:

Department of Land and Water Conservation
138-140 George Street (PO Box 50)
Quirindi NSW 2343
Telephone: 02 6746 1344; Fax: 02 6746 1076

McInnes-Clarke, S.K. 2002, Soil Landscapes of the Murrurundi 1:100 000 Sheet, Department of Land and Water Conservation, Sydney.

mrd	MOUNT ROYAL RANGE	Colluvial

Landscape— Steep to very steep mountains of escarpments and ridges on Tertiary basalt in the central north of the Hunter Region. Slopes 30 - 100%, local relief 300 - 700 m, elevation 600 - 1500 m. Partially to extensively cleared mix of vegetation types depending on rainfall, shelter and elevation, including alpine open forest, tall open forest, temperate rainforest, sub-tropical rainforest, dry rainforest and grassy woodlands.

Soils— Moderately deep (50 - <100 cm), well-drained Red Ferrosols (Krasnozems) and Brown Ferrosols (Chocolate Soils) and shallow (25 - <50 cm), well-drained Orthic / Leptic Tenosols (Lithosols).

Qualities and limitations— widespread shallow soils, widespread steep slopes, localised rock outcrop hazard, widespread rockfall hazard, widespread mass movement hazard, widespread foundation hazard, widespread recharge zone, widespread sheet erosion hazard, localised high run-on.

LOCATION AND SIGNIFICANCE

Steep to very steep mountain escarpments and ranges on basalt below the Walcha Plateau and western Barrington Tops, with significant conservation and catchment protection values. Similar to Coober Bulga (cbw) on the Merriwa Plateau. Type location is Barirngton Tops Forest Road near Prospero Trig (MGA grid reference 340000E, 6466000N, grid zone 56).

Variants

None.

Included landscapes

Includes Myrtle Scrub (myl) at high elevations and Crawney (cri) at low elevations on rolling slopes, and Kangaroo Ridge (kaw) on Tamworth Block sediments.

LANDSCAPE

Landform

Steep to very steep mountain escarpments and ridges. Slopes are 30 - 100% (up to 1,000 m long), local relief 300 - 700 m and elevation 600 - 1500 m. Drainage lines are closely spaced (50 - 400 m), low order tributary and convergent and streams are deeply incising to bedrock. Rock outcrop, cliffs and talus slopes are common. Run-on is concentrated by convergent drainage. Aquifers occur in porous regolith, fractured basalt, and in basal and intercalated sediments, where groundwater discharges as springs and seepages.

Geology

Geology is Comboyne Basalt (Tv), comprising strongly jointed basalt and dolerite, plus interbedded polymictic conglomerate, quartzose and ferruginous sandstone, mudstone, tuff and bole. These are Late Tertiary (Miocene) aged, dated at 16 million years. Includes basal Tertiary gravels and unconsolidated sediments (Tx2). Regolith is up to 1 metre deep, consisting of ferruginised kaolinitic saprolite of weak strength.

Source: DMR (2002).

Vegetation

On the Woko and Chichester Mountains, at high elevations (generally >1,000m), alpine open forests on high rainfall areas, merging to moist tall open forests with Nothofagus moorei (Antarctic beech) - Doryphora sassafras (sassafras) - Elaeocarpus holopetalus (black olive berry) and Elaeocarpus holopetalus (black olive berry) - Atherosperma moschatum (black sassafras) cool temperate rainforests occur on high rainfall sites. At lower elevations, these merge to Eucalyptus saligna (Sydney blue gum) - E. microcorys (tallow-wood) - Syncarpia glomulifera (turpentine) and E. campanulata (New England blackbutt) - E. quadrangulata (whitetop box) - E. laevopinea (silvertop stringybark) moist tall open forests on ranges, with E. pilularis (blackbutt) - E. propinqua (small-fruited grey gum) - Themeda australis (kangaroo grass) grassy tall open forest on open sites and Dysoxylum fraserianum (rosewood) - Pennantia cunninghamii (brown beech) sub-tropical rainforest on sheltered sites.

On the Woolooma Mountains, at high elevations, alpine open forests comprising Eucalyptus obliqua (messmate) - E. nobilis (forest ribbon gum) - E. campanulata (New England blackbutt) - E. cameronii (diehard stringybark) and E. dalrympleana (mountain gum) - E. fastigata (brown barrel) tall open forests, often with grassy understoreys of Poa sp. (tussock grasses). At lower elevations, these merge to grassy woodlands dominated by Eucalyptus laevopinea (silvertop stringybark) are widespread, with Angophora floribunda (rough-barked apple), E. nortonii (bundy), E. albens (white box) and E. melliodora (yellow box). Poa sp. (tussock grass) and Bursaria spinosa (boxthorn) predominate in the understoreys. Daphnandra apatela (socketwood) - Acmena smithii (lillipilli) - Pittosporum undulatum (sweet pittosporum) dry rainforests occur in sheltered sites.

Source: McCauley (2006).

Land use

Native forestry in various State Forests and on private land, nature conservation in National Parks, with some clearing and grazing on accessible lower slopes. Logging of red cedar (Toona ciliata) in the wetter areas has occurred in the past.

Land degradation

Subject to landslips, even on uncleared slopes, and debris avalanches and rockfalls occur on precipitous slopes. Mass movement is especially common after periods of heavy rain. Sheet erosion is common after high-intensity fires and where soil surface has been disturbed by road construction and forestry activities, and gully erosion occurs where drainage is concentrated. Areas where basal sediments are exposed exhibit locally severe rill and gully erosion.

Existing erosion

Land use	Non-concentrated flows	Concentrated flows	Wind
grazing	moderate	very high	not assessed
protected	slight	moderate	not assessed

SOILS

Soil variation and distribution

Moderately deep (50 - <100 cm), well-drained Red Ferrosols (Krasnozems) and Brown Ferrosols (Chocolate Soils) developed on weathered substrates and on talus, and shallow (25 - <50 cm), well-drained Orthic / Leptic Tenosols (Lithosols) developed on resistant substrates.

QUALITIES AND LIMITATIONS

Land capability

Urban Capability	E	**Soil Regolith Class**	R1

Limitations to land use

Grazing	very high	**Cultivation**	extreme
Urban	extreme		

Landscape

Steep slopes	widespread	**Mass movement hazard**	widespread
Rock outcrop	localised	**Rockfall hazard**	widespread
Foundation hazard	widespread	**Woody weeds**	not observed
Complex terrain	not observed	**Productive arable land**	not observed

Dieback	not observed		
Soils			
Shallow soils	widespread	**Complex soils**	not observed
Poor moisture availability	not observed	**Non-cohesive soils**	not observed
Hydrology			
High run-on	localised	**Poor drainage**	not observed
Permanently high watertables	not observed	**Permanent waterlogging**	not observed
Seasonal waterlogging	not observed	**Flood hazard**	not observed
Erosion			
Wind erosion hazard	not observed	**Wave erosion hazard**	not observed
Gully erosion hazard	not observed	**Sheet erosion hazard**	widespread
Streambank erosion hazard	not observed		
Salinity			
Recharge zone	widespread	**Discharge zone**	not observed
Salinity hazard	not observed	**Seepage scalds**	not observed
Salt stores	low		

FACETS

mrd(1)— Deep soils developed on weathered substrates, side-slopes

Soils	Moderately deep (50 - <100 cm), well-drained Red Ferrosols (Krasnozems) and Brown Ferrosols (Chocolate Soils).
Type Profile(s)	Hunter Soil and Land Resources (1005268) profile 206

mrd(2)— Shallow soils developed on resistant substrates, upper slopes

Soils	Shallow (25 - <50 cm), well-drained Orthic / Leptic Tenosols (Lithosols).
Type Profile(s)	Hunter Soil and Land Resources (1005268) profile 233

REFERENCES

DMR 2002. New South Wales Statewide Geology coverage - 1:250,000 scale. Department of Mineral Resources, Sydney.

McCauley, A. (2006). Vegetation Survey and Mapping of the Hunter, Central and Lower North Coast Region of NSW. A report prepared for the Hunter-Central Rivers Catchment Management Authority by the HCCREMS team at the Environment Division of Hunter Councils.

NOTES

(1) This report describes reconnaissance soil landscape information mapped at 1:100,000 scale and does not negate the need for site assessment at a scale suitable to the land use or development under consideration.

(2) 'Not observed' means unlikely to be found. 'Localised' means observed to a level considered significant for land management. 'Widespread' means prevalent and significant over most of the landscape. 'None recorded' means no occurrence has been recorded. 'Not assessed' means no result has been recorded for this attribute and it may or may not be present in the soil landscape.

SLAM Soil Landscape Report for Hunter Region v 1.01, Thu Feb 08 14:54:57 2018