APPENDIX 22

Crudine Ridge Wind Farm Water and Soil Assessment

Eco Logical Australia Pty Ltd

Crudine Ridge Wind Farm

Water and Soil Assessment

Prepared for
Wind Prospect CWP Pty Ltd

19 August 2011

DOCUMENT TRACKING

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Contents

List of Figures

List of Tables

Abbreviations

ABBREVIATION	DESCRIPTION
AHD	Australian Height Datum
APZ	Asset Protection Zone
AWS	Automatic Weather Station
BoM	Bureau of Meteorology
CAP	Catchment Action Plan
CEMP	Construction Environmental Management Plan
CMA	Catchment Management Authority
CWCMA	Central West Catchment Management Authority
CRZ	Core Riparian Zone
DECC	Department of Environment and Climate
DGRs	Director General's Requirements
DoPI	Department of Planning and Infrastructure
DPI	Department of Primary Industries (of which NoW is part)
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities
EA	Environmental Assessment
EP&A Act	NSW Environmental Planning and Assessment Act 1979
FM Act	NSW Fisheries Management Act 1994
GDE	Groundwater Dependent Ecosystem
GIS	Geographic Information Systems
GWMA	Ground Water Management Area
NoW	New South Wales Office of Water (in the Department of Primary Industries)
POEO Act	NSW Protection of the Environment Operations Act 1997
NSW	New South Wales
SWMP	Soil and Water Management Plan
VB	Vegetated Buffer
WBZ	Water Bearing Zones
WM Act	NSW Water Management Act 2000
WSP	Water Sharing Plan

1 Introduction

1.1 INTRODUCTION

This report has been prepared to assess potential water and soil impacts of the proposed Crudine Ridge Wind Farm near Pyramul in central west NSW. The outcomes of this assessment will form part of the Crudine Ridge Wind Farm Environmental Assessment (EA).

This desktop assessment examines the soils, landform and drainage characteristics and features of the project area and identifies potential impacts of the development. Information was also sourced from field surveys conducted by Eco Logical Australia ecologists during the ecological assessment for the project. Recommended mitigation measures to avoid and reduce any identified impacts are then provided.

This report has not been written with the intention of being a ‘stand alone’ report, and as such, background and contextual information about the Crudine Ridge Wind Farm Development is not included.

1.2 REPORT OBJECTIVES

A preliminary EA has been lodged with the Department of Planning and Infrastructure (DoPI) and Director General’s Requirements (DGRs) have been issued. The aim of this report is to fulfil the requirements of the DGRs which relate to water quality and hydrology, including:

- Assessment of potential environmental impacts associated with use of identified water sources including impacts on groundwater and implications for existing users/basic landholder rights
- Assessment of the potential to intercept groundwater
- Identification of any likely impacts on waterways where the project involves water crossings or works close to waterways
- Identification and assessment of any cumulative impacts which may occur as a result of the proposed wind farm development
- Identification of measures to minimise hydrological, water quality, aquatic and riparian impacts
- Identification of how works within steep gradient land or highly erosive soil types will be managed during construction and operation.

It is noted that the DGRs related to water supply (including identifying water demands, determining whether an adequate and secure water supply is available and considering the statutory context of water supply sources) are being addressed by the proponent and are not included in this assessment. At this stage of the project planning process, water extraction points and/or sources have not been resolved; however this will be undertaken according to the requirements of the *Water Management Act 2000* and associated guidelines.

1.3 PROJECT DESCRIPTION

There are two potential turbine layouts for the proposed wind farm development ranging between:

- 77 wind turbines (broadly suitable for 80 m and 90 m rotor diameter machines) and 106 wind turbines (broadly suitable for 100 m, 110 m and 120 m rotor diameter machines)
- Associated infrastructure including
  - 6 m access tracks, passing bays and hardstand areas suitable for cranes
  - Overhead and underground electrical cabling
  - Substations (a main and secondary collector substation on site and a switching station at the point of connection)
  - Wind monitoring masts
  - Storage compounds
  - Operations buildings
- Mobile concrete batching plant(s) and rock crushing facilities
- Connection to the TransGrid 132 kV overhead transmission line 15 km east of the Crudine ridgeline

The impacts of both layouts are considered as part of this assessment.

1.4 REGULATORY CONTEXT

The *Water Management Act 2000* (WM Act) and *Water Act 1912* control the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in New South Wales (NSW). 'Water sources' are defined very broadly and include any river, lake, estuary, place where water occurs naturally on or below the surface of the ground and coastal waters.

Under s75U of the *Environmental Planning and Assessment Act 1979* (EP&A Act) certain approvals required under s89, s90 and s91 of the WM Act in relation to controlled activities (i.e. works within 40 m of a watercourse and water use or waterfront land[1]) are exempt under Part 3A. Extraction and use of water for other purposes such as a concrete batching plant or dust suppression and environmental protection provisions under the *Protection of the Environment Operations Act* (POEO Act) in relation to water quality do remain relevant.

[1] 'Waterfront land' is defined under the WM Act as the bed of any river or lake, and any land lying between the river or lake and a line drawn parallel to and forty metres (40m) inland from either the highest bank or shore (in relation to non-tidal waters) or the mean high water mark (in relation to tidal waters). It is an offence to carry out a controlled activity on waterfront land except in accordance with an approval.

Despite the EP&A Act Part 3A clauses, the DGRs indicate a need to identify likely impacts to the waterways and measures to minimise hydrological, water quality, aquatic and riparian impacts, in areas where the project involves crossing or works close to waterways.

All developments must comply with the *Fisheries Management Act 1994* (FM Act) which relates to the management of fishery resources and enforces requirements to protect aquatic habitat and conserve threatened species. Relevant to this Project are the provisions in Parts 7 and 7A related to threatened species.

The regulatory context for soil management in NSW is provided in the *Water Management Act 2000* (WM Act) and the *Protection of the Environment Operations Act 1997* (POEO Act). Standard soil and related water quality objectives for development sites as they relate to the above typically include:

- No pollution of waters (s120 of the POEO Act)
- Water sources and dependent ecosystems should be protected
- Water quality of all water sources should be protected
- Revegetation of all areas disturbed during construction
- All activities to be carried out with due diligence, duty of care and according to best management practices
- Environmental assessment to describe measures to control erosion and sedimentation
- All personnel should be made aware of their responsibilities in this regard
- Application of the guideline: Managing Urban Stormwater: Soils and Construction, 4th Edition (Landcom 2004) commonly referred to as the "Blue Book".

1.4.1 Policies and Plans

Table 1 below outlines the aim and requirements in relation to Crudine Ridge Wind Farm for soil and water related policies and plans that have been considered in this assessment.

Table 1: Relevant Policies and Plans

POLICY/PLAN	AIM/OBJECTIVES	RELEVANCE TO CRUDINE RIDGE
NSW Wetlands Policy	Establishes the framework for the management of rivers and estuaries and related ecosystems. The approach is based on Total Catchment Management philosophy defined in the *Catchment Management Act 1989*.	The construction of infrastructure associated with the proposal will need to consider the potential loss of riparian vegetation and biological diversity, and potential impacts on water quality.
NSW Weir Policy	To halt and, where possible, reduce and remediate the environmental impact of weirs. The policy defines a weir as a structure including a dam, lock, regulator, barrage or causeway across a defined watercourse that will pond water, restrict flow or hinder the movement of fish along natural flow paths, in normal flow conditions.	A requirement for construction of new access tracks or modification of existing farm tracks over the streams. Creek crossings need to be designed to avoid changes that interfere with natural water flow e.g. box culverts or spanned bridges. May represent opportunities to reduce existing impacts.

POLICY/PLAN	AIM/OBJECTIVES	RELEVANCE TO CRUDINE RIDGE
NSW Groundwater Quality Protection Policy	Acknowledges that ground water is an integral component in many aquatic and terrestrial ecosystems, especially in light of the growing concern about the declining quality of the State's groundwater and its dependent ecosystems.	Proposal will need to avoid activities that risk groundwater and soil contamination.
NSW State Groundwater Dependent Ecosystem Policy	This policy is interrelated with the Groundwater Quality Protection Policy; it has an emphasis on providing for groundwater dependant ecosystems such as wetlands.	The Project should aim to minimise adverse impacts on any local groundwater dependant ecosystems (if present) by avoiding polluting, applying ecosystem rehabilitation, and avoiding disruption to groundwater flow.
Central West Catchment Action Plan	The CAP aims to conserve, improve and manage natural and cultural resources through programs which address salinity, surface and groundwater system health, native vegetation condition and biodiversity.	By conforming to the principles of ecologically sustainable landscape function the proposal is compatible with the CAP objectives.
Water Sharing Plans	WSP prepared under the Water Management Act 2000 aim to protect the health of rivers and groundwater while sharing with the different types of water users. A Draft WSP for the *NSW Murray Darling Basin Fractured Rock Groundwater Sources* has been prepared. A Water Sharing Plan for the *Macquarie Unregulated and Alluvium Water Sources* is currently under development. A WSP for the *Macquarie and Cudgegong Regulated Rivers Water Source* has commenced.	If the Project proposes to extract water from rivers or aquifers the developer will require a water licence which will stipulate the volume of water which can be extracted over a given amount of time and other associated management rules and work approvals.
NoW Guidelines	The assessment is required to take into account the following NoW Guidelines for Controlled Activities (February 2008), as applicable: • Riparian corridors (and associated Vegetation Management Plans) • Watercourse crossings • Laying pipes and cables in watercourses • Outlet structures • In-stream works	Planning and construction recommendations are made in line with these guidelines.
Policy and Guidelines for Aquatic Habitat Management & Fish Conservation	To improve the conservation and management of aquatic habitats in NSW.	Planning and construction recommendations are made in line with these guidelines with consideration given to waterways within the Project area and creek crossings The construction of any bridges, roads, causeways, culverts or similar structures will need to refer to the Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures developed by NSW Fisheries 1999.

POLICY/PLAN	AIM/OBJECTIVES	RELEVANCE TO CRUDINE RIDGE
NSW Water Quality and River Flow Objectives for the Macquarie-Bogan River Catchment	These guidelines set out objectives that relate to water quality for different water uses (based on environmental values) and managing river flow for riverine health.	Planning and construction recommendations are made to avoid impacting the health of aquatic ecosystems in line with the river flow objectives.

2 Methods

2.1 DATA

This study was conducted using:

- Available meteorological data
- A desktop assessment of published hydrological and riparian data and reports
- A desktop assessment and review of published soil landscape and geological data and maps
- A review of vegetation data relating to riparian zones collected during the ecological assessment[2] conducted by Eco Logical Australia
- The linking of soil and landscape characteristics to erosion potential
- Existing groundwater bore locations and logs to determine water bearing zones
- GIS analysis and mapping of existing data of the proposed wind farm area.

2.2 ECOLOGICAL FEATURES ASSOCIATED WITH RIPARIAN AREAS

A literature review of web based and ELA research material was made to provide a comprehensive list of potential aquatic and/or riparian and wetland features either within or immediately downstream of the project area.

2.3 RIPARIAN BUFFERS

A desktop Strahler Stream Order categorisation was undertaken based on the 1:25,000 topographic mapping of drainage lines in the vicinity of the works and identified the extent of the recommended buffers for each stream order category.

The watercourses within and adjacent to the study area have been assessed against NoW Guidelines. These guidelines require the protection of core riparian zones (CRZs), according to stream order as illustrated in Table 2 below.

[2] *Crudine Ridge Wind Farm Part 3A Ecological Assessment*, Eco Logical Australia 2011

Table 2: Water Management Act CRZ Widths

TYPES OF WATERCOURSES	CRZ WIDTH
Any first order[1] watercourse and where there is a defined channel where water flows intermittently	10 metres
Any permanent flowing first order watercourse, or any second order[1] watercourse where there is a defined channel where water flows intermittently or permanently	20 metres
Any third order[1] or greater watercourse and where there is a defined channel where water flows intermittently or permanently. Includes estuaries, wetlands and any parts of rivers influenced by tidal waters.	20 – 40 metres[2]

[1] as classified under the Strahler System of ordering watercourses and based on current 1:25,000 topographic maps.
[2] merit assessment based on riparian functionality of the river, lake or estuary, the site and long-term land use.

There are three zones to be considered within riparian corridors, shown in Figure 1 and detailed below;

1. A Core Riparian Zone (CRZ) is the land contained within and adjacent to the channel. NoW will seek to ensure that the CRZ remains, or becomes vegetated, with fully structured native vegetation (including groundcovers, shrubs and trees). The width of the CRZ from the banks of the stream is determined by assessing the importance and riparian functionality of the watercourse, merits of the site and long-term use of the land. There should be no infrastructure such as roads, drainage, stormwater structures, services, etc. within the CRZ.

2. A Vegetated Buffer (VB) protects the environmental integrity of the CRZ from weed invasion, micro-climate changes, litter, trampling and pollution. There should be no infrastructure such as roads, drainage, stormwater structures, services, etc. within the VB. The recommended width of the VB is 10 metres but this depends on merit issues (assessment of risk, stress and conservation value for each locality).

3. An Asset Protection Zone (APZ) is a requirement of the NSW Rural Fire Service and is designed to protect assets (houses, buildings, etc.) from potential bushfire damage. The APZ must not result in clearing of the CRZ or VB. Infrastructure such as roads, drainage, stormwater structures, services, etc. can be located within APZs.

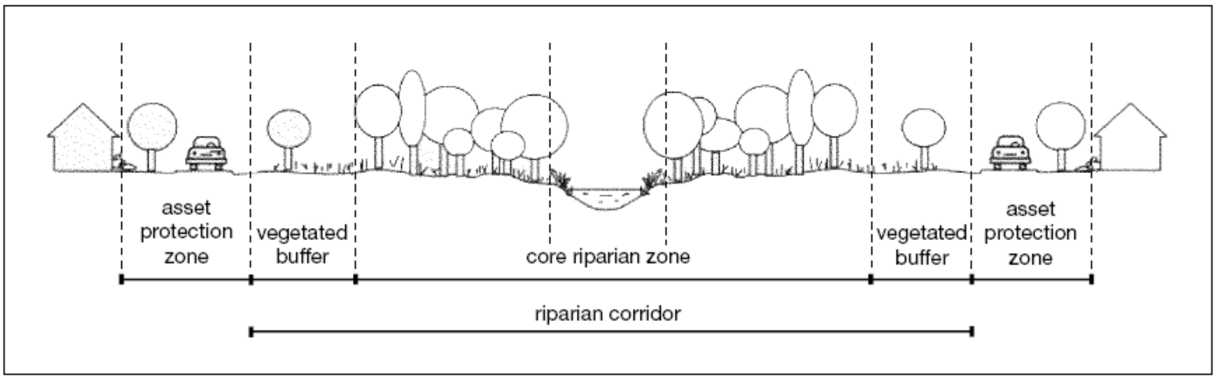

Figure 1: Zones within the riparian corridor (NoW 2010a)

The CRZ widths prescribed by the WM Act guidelines have been applied to the site in order to classify, identify and manage potential development impacts. Due to the study area being surrounded by rural land, the APZ component of the riparian corridor has not been considered in this mapping and is addressed separately in the bushfire risk assessment for this project.

2.4 GROUNDWATER

This report details the water bearing zones (WBZ) of groundwater bores (NSW Government 2011) within an approximate 10 km radius of the site in order to illustrate the depth of aquifers in the locality. The WBZ depths were correlated to expected excavation depths during construction primarily associated with the turbine footings in order to determine if there is likely to be any interaction with groundwater layers as a result of the development.

2.5 IMPACT ASSESSMENT AND MITIGATION MEASURES

The data collated during the desktop review is considered in light of the wind farm proposal to identify potential impacts of the Project on the riparian and groundwater resources of the area.

This report recommends measures to be incorporated during planning, construction and operation that will maintain water quality (including consideration of soil and erosion potential) in line with POEO Act, WM Act, and River Flow Objectives of the Macquarie-Bogan River Catchment.

3 Existing Environment

3.1 CLIMATE

Climate information was obtained from the Bureau of Meteorology Bathurst Agricultural Station AWS (Site number: 063005). Mean maximum temperatures (28ºC) occur in January and mean minimum temperatures (0.6ºC) occur in July. The area experiences slight summer dominant rainfall, with January being the wettest month with an average of 68.1 mm. The annual average rainfall is 636.3 mm (BoM 2011).

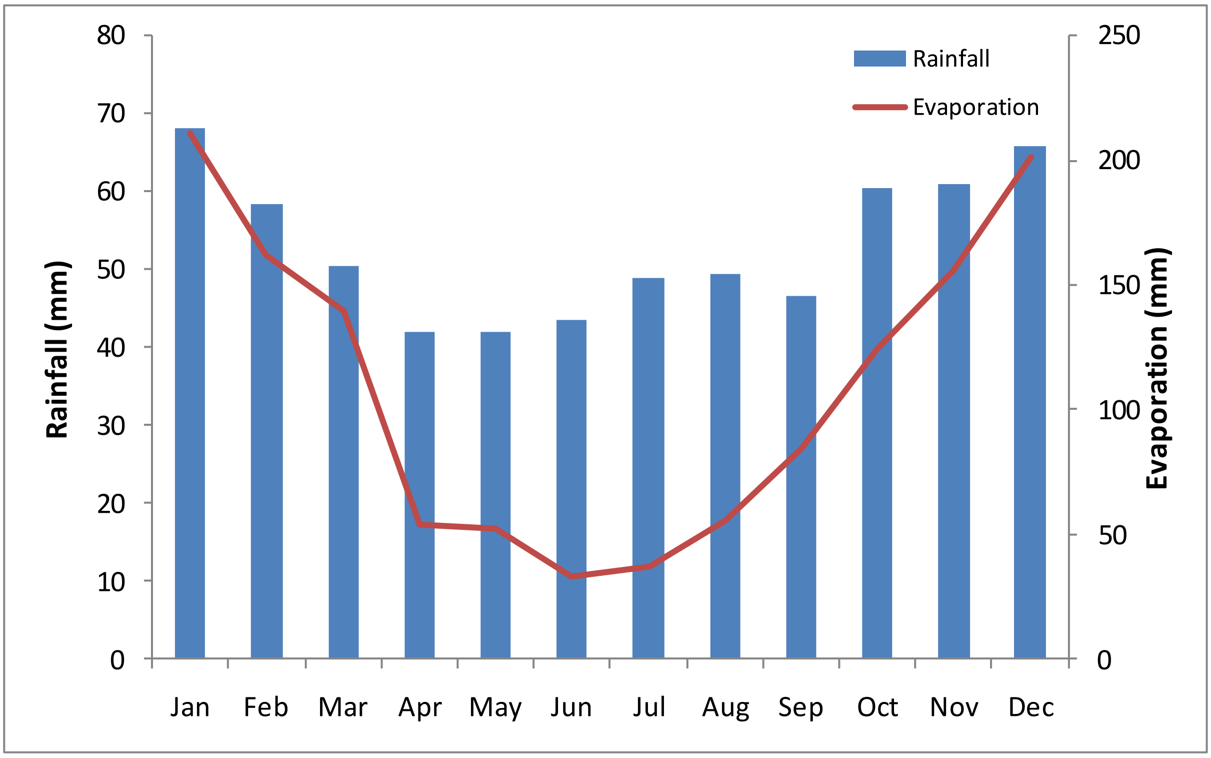

Figure 2: Average monthly rainfall and evaporation for Bathurst Agricultural Station AWS (Site Number 063005) for years 1908 – 2011 (BoM 2011)

3.2 CURRENT LANDUSE PRACTICES

The area within and surrounding the Proposal site is predominantly used for grazing, with much of the western slopes of Crudine Ridge being cleared of woody vegetation. Due to past and present land use practices the landscape has experienced various levels of degradation which is evident with the presence of eroded gullies and clearing of trees.

At present there are five wind farms existing or proposed within a 100 km radius of the proposal site. Blayney and Hampton wind farms are operational and are approximately 65 and 80 km to the south-west respectively. Proposals for other wind farms in the area include Uungula (65 km to the north-west) and Flyers Creek and Bodangora (approximately 65 and 80 km to the south-west respectively). DGRs have been issued for these projects for the environmental assessments.

3.3 LANDSCAPE AND TOPOGRAPHY

The Crudine Ridge Wind Farm proposal is located 45 km south of Mudgee and 45km north of Bathurst, New South Wales. The turbines are proposed to extend along Crudine Ridge for a distance of 16 km, south west from Aarons Pass Road (Wind Prospect CWP 2011).

Crudine Ridge extends from near Toolamanang in the north down to Cunningham. Pleasant Ridge is to the east of Crudine Ridge with Crudine River running between the two. The topography surrounding these two ridges is gently undulating. The individual turbines will be located on the western slopes of Crudine Ridge. The ridgeline is of moderate to high elevation (890 m to 1000 m Australian Height Datum (AHD)). The western slopes of the Project site are generally less than 10 degrees although some parts of the footprint fall on steeper slopes (more than 15 degrees). The eastern slopes of Crudine Ridge are steeper with slopes in excess of 20 degrees (Figure 3).

3.4 MITCHELL LANDSCAPES

Mitchell Landscape mapping provides an overview of geology, geomorphology, topography, soils and geodiversity for NSW bioregions. The vast majority of the proposed development is on the Ophir – Hargraves Plateau, with only the north-eastern arm, comprising of transmission lines and three switching station options, extending over the Mount Horrible Plateau, Cope Hills Granite and Capertee Plateau (Figure 4).

The Ophir – Hargraves Plateau has general elevations of 500 to 1000 m with a local relief of 100 to 150 m. This landscape is described as subdued strike ridges and dissected plateau, while the overlying soil ranges from thin sandy loam to thin stony red texture-contrast soils on the slopes to yellow harsh texture-contrast soil with bleached A_2 horizons in the valleys. Vegetation in this landscape ranges from woodland to open forest of eucalypt species. (Mitchell 2002).

The Mount Horrible Plateau has general elevations of 750 to 1300 m with a local relief of 250 m and is described as dissected plateau, with undulating hills and steep wooded ridges. Crests are composed of red gradational well-structured and red texture-contrast soils whilst the lower slopes are composed of yellow earths on some sandstone or yellow texture-contrast soils with bleached A_2 horizons. Broader creek lines are composed of dark clay loams and clays. Vegetation in this landscape is also dominated by eucalypts (Mitchell 2002).

The undulating and rolling hills of the Cope Hills Granite has general elevations of 500 to 740 m with a local relief of 150 m. Soils are gritty gradational red earth and red texture-contrast soils. Forest vegetation includes eucalypts and black cypress pine (Mitchell 2002).

The Capertee Plateau (800 to 1000 m) is the wide valleys and rolling hills found below the sandstone cliffs. Streamlines typically have a low gradient and are swampy. Soil profiles are generally shallow stony texture-contrast with gritty well drained A-horizons over tough yellow or grey poorly drained clays. Woodlands occur on the open valleys (*Angophora floribunda*, *Eucalyptus* spp. with a shrubby understorey and *Austrodanthonia* sp. (Wallaby Grass)).

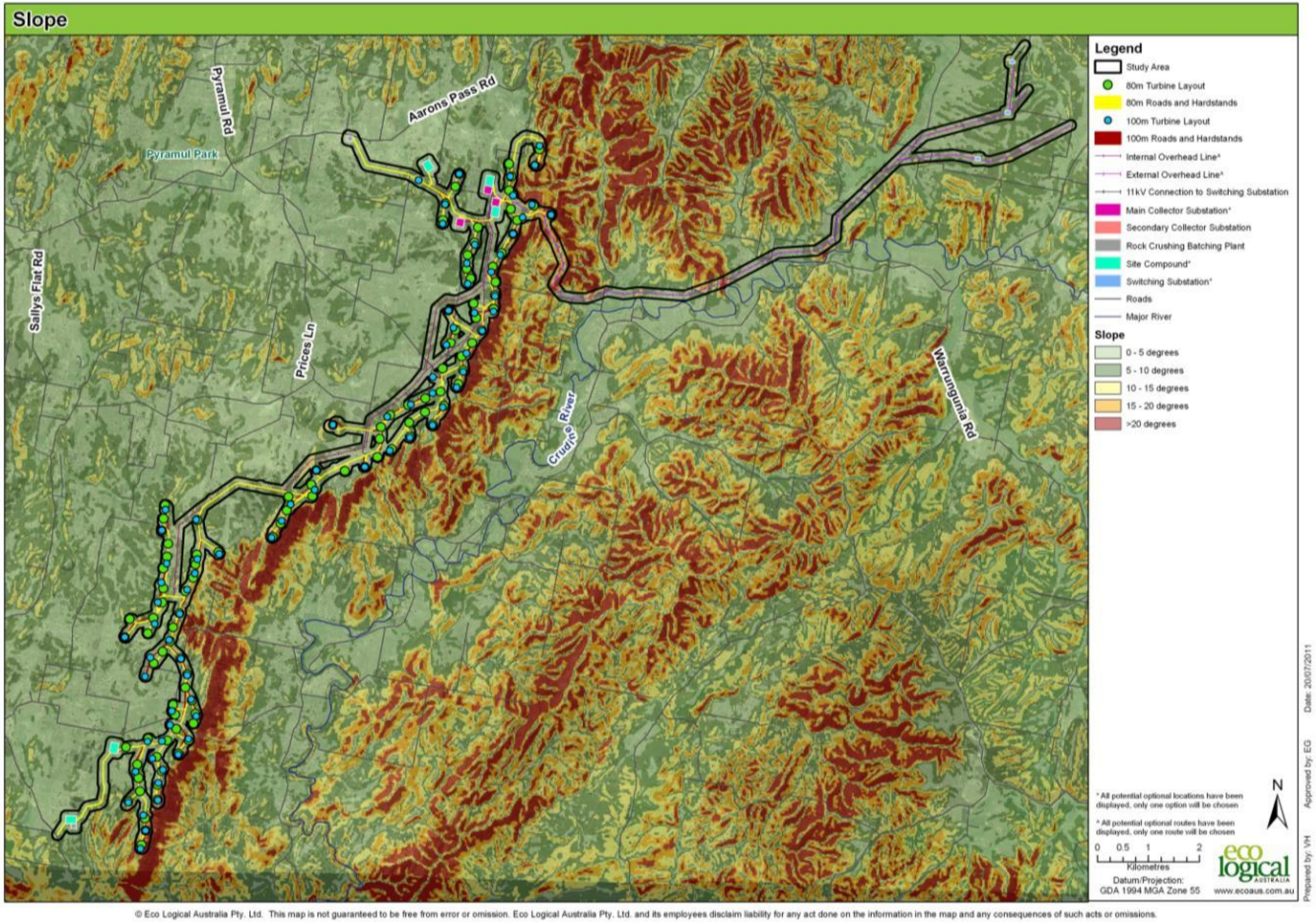

Figure 3: Slopes of the Project area

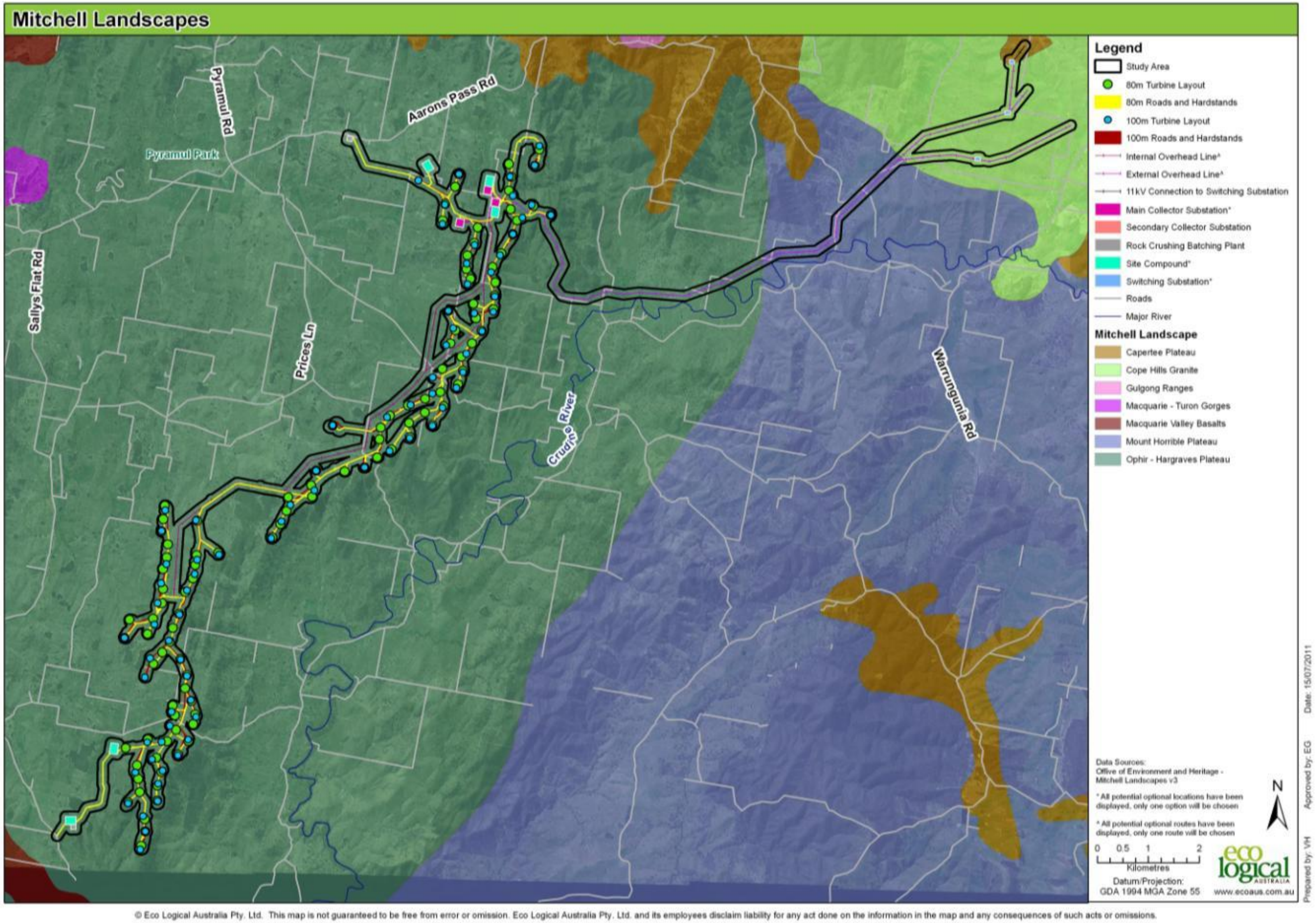

Figure 4: Mitchell Landscapes of the Project area

3.5 GEOLOGY

The proposed wind farm overlies the Hill End – Ngunnawal geological province. The Hill End – Ngunnawal province is comprised of Silurian to early Devonian clastic sediments including shale, siltstone, sandstone and conglomerate, limestone and some felsic volcanics (Geoscience Australia 2011). The associated sub-provinces include the Hill End and Capertee sub-provinces (see Figure 5 and referenced again in Appendix A). The majority of the wind farm infrastructure will be located above the Hill End sub-province, with only a small section of the north eastern arm (transmission lines and switching stations options) overlying the Capertee sub-province.

The characteristic terrain of the Hill End sub-province includes steep rolling hills and undulating low hills with exposed bedrock occurring on all slope classes. Slopes are susceptible to sheet, rill and gully erosion with drainage lines also prone to gullying. The most common soils arising from this geological province are Soloths and yellow Solodic Soils on footslopes and drainage lines and Shallow Red Podzolic Soils and shallow soils on the upper slopes and on steep terrain. Discontinuous alluvium can also be found along drainage lines (Murphy and Lawrie 1998). Associated soil landscapes of the Project area within this sub-province include Mullion Creek, Mookerawa and Burrendong.

The Capertee sub-province is predominantly a volcanic arc with substantial areas of limestone. Although the strata are strongly folded and steeply dipping the terrain is variable, ranging from rugged to undulating or rolling. Where the terrain is rugged and the slope is parallel to bedrock dip the overlying soils tends to be continuous, shallow and stony. When the slope cuts across the dip steep slopes with frequent outcrops and angular float occurs. Streams have meandering channels incised in alluvium and overlying bedrock. The typical soil types on mid-slope positions are Non-calcic Brown Soils. Where the terrain is more undulating the soils are deeper, medium textured and moderately to highly fertile (Non-calcic Brown Soils and Euchrozems). Associated soil landscapes of the Project area within this sub-province include the Aarons Pass unit.

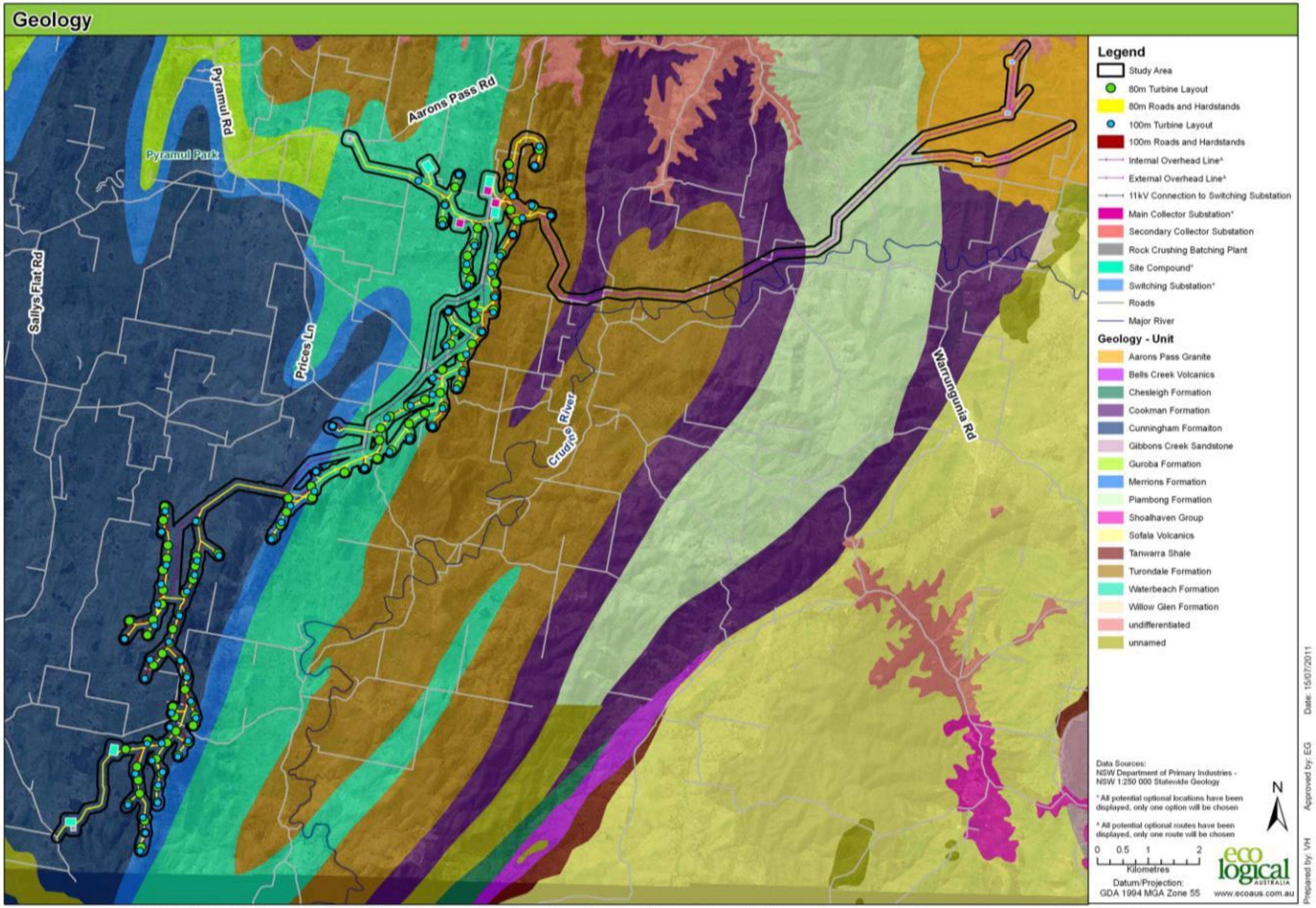

Figure 5: Geology of the Project area

3.6 SOILS AND SOIL LANDSCAPES

The mapping of soil landscapes integrates soil and landscape attributes into a single unit. Soil landscapes in the region have been mapped (Figure 6) and described by Kovac et al (1989) in the Bathurst 1:250 000 map sheet and Murphy & Lawrie (1998) in the Dubbo 1:250 000 map sheet. The main soil landscapes in the project area are the Burrendong, Mullion Creek, Mookerawa and Aaron's Pass units (Table 3), with the bulk of the infrastructure occurring on the Mookerawa and Mullion Creek units.

Table 3: Summary of soil landscapes within the Project site

SOIL LANDSCAPE	TYPICAL SOIL TYPES (AUSTRALIAN SOIL CLASSIFICATION)	PROJECT COMPONENT*
Burrendong (bd)	Red Chromosols (midslope) Yellow Sodosols (drainage lines) Inceptic Tenosols (higher slopes)	Road and hardstand areas Turbines Overhead line
Mullion Creek (mu)	Red Chromosols (higher crests) Yellow Sodosols (lower slopes and drainage lines)	Turbines Site compound Road and hardstand areas Collector Substation Overhead line
Mookerawa (mk)	Red Chromosols (crests and upper slopes) Yellow Sodosols (lower slopes and drainage lines)	Turbines Site compound Rock crushing batching plant Road and hardstand areas Collector Substation Overhead line
Aaron's Pass (ap)	Orthic Tenosols (steep slopes) Yellow Sodosols (lower slopes)	Switching Substation Overhead line

* Pending final layout

3.6.1 Burrendong

The Burrendong unit is typified by shallow soils on rolling to steep hills, with Rudosols (skeletal soils) occurring near rock outcrops on the higher slopes. Shallow Red Chromosols are found on the midslopes and Yellow Sodosols on the midslopes and drainage lines. Yellow Kandosols (massive earths) are common on the lower slopes of this unit.

Soil profiles in this unit are duplex with sandy loam topsoil overlying clay loam or medium clay. The subsoil of the Chromosols is typically heavier clays and imperfectly drained, while the Sodosols on the midslopes tend to have a bleached A2 horizon and a poorly drained profile. The profiles are shallow and weathered parent material can occur at as shallow as 500 mm in the skeletal soils higher on the slopes.

These soils have low shrink swell potential. While generally stable with sufficient ground cover, clearing can lead to sheet erosion. These soils have a moderate to high mass movement hazard and clearing of the skeletal soils on the upper slopes and crests can cause slumping. The hard-setting topsoils provide a high runoff potential and soil disturbance (such as cultivation) can cause structural breakdown to a massive condition (i.e. the soil layer becomes a solid mass devoid of aggregates). Localised sodic upper subsoils (the top 200 mm of the B horizon) also occur.

3.6.2 Mullion Creek

The Mullion Creek soil landscape forms on the undulating low hills between 560 – 980 m above sea level. Red Chromosols are found on the crests and upper slopes with Yellow Sodosols occurring on mid to lower slopes and in drainage lines.

Similar to those in the Burrendong unit, typical soil profiles are duplex and shallow (<2 m) comprising of a hard-setting topsoil (loam/sandy loam) overlying clay loam/clay. These soils exhibit shrink swell characteristics and are also highly susceptible to structural decline/degradation as a result of disturbance (such as cultivation, raindrop impact, saturation, and compaction) which can lead to increased runoff and erosion and impede plant growth. These soils also have a high runoff potential due to the hard-setting topsoils and relatively impermeable clayey subsoils.

Widespread dispersible sodic sub-surfaces on the lower slopes mean that these soils are susceptible to severe gully erosion. The soils in the lower slopes (Yellow Sodosols) are also subject to tunnelling. Moderate sheet and gully erosion is common when surface cover is low, with tunnel erosion occurring in areas of severe gully erosion. High soil salinity is common across the Mullion Creek landscape, particularly on the lower slopes and footslopes and along drainage lines and in depressions.

3.6.3 Mookerawa

The Mookerawa landscape is characterised by Red Chromosols and Yellow Sodosols formed on rolling low hills to rolling hills. Shallow siliceous sands and loams (Rudosols) are common on hills with rock outcrops. Shallow Red Chromosols are found on the crests and upper slopes while Yellow Sodosols are common on the lower slopes and in drainage depressions.

These soils are duplex with a sandy loam/sandy clay loam topsoil overlying clay loam or medium clay. The subsoil of the Chromosols are typically heavier clays (light medium to heavy) and imperfectly drained, while the Sodosols on the midslopes tend to have a bleached and dispersible A2 horizon and a poorly drained profile (clay loam to light clay subsoil). The clayey subsoils mean these soils have a low to moderate shrink swell potential. Profiles are typically shallow (<2 m) although can be less than 1 m on crests and upper slopes.

High soil salinity levels are common across the Mookerawa landscape, particularly in drainage lines, depressions and the lower slopes. Sodic subsurfaces are common and the soils are susceptible to slumping, gullying and tunnel erosion. These soils are also highly susceptible to structural degradation as a result of disturbance and have hard-setting topsoils. While generally stable with sufficient ground cover, sheet erosion can occur if cleared of native vegetation.

3.6.4 Aaron’s Pass

The north-eastern extent of the project site falls within the Aaron’s Pass soil landscape unit characterised by rolling low hills up to 100 m elevation. Orthic Tenosols (earthy sands and siliceous sands) are common on the upper and mid-slopes and Yellow Sodosols and bleached sands (Sodosols) are common on lowers slopes. Rock outcrops are also common.

Massive loamy sandy topsoils are underlain by sandy loam/clayey sands. A bleached A2 horizon is found on the lower slopes above a clayey subsoil causing poor drainage and seasonal water logging. *In situ* weathered bedrock can be found as shallow as 600 mm on the upper slopes.

Sodic upper subsoils (the top 200 mm of the B horizon) are common and the erosion hazard for this landscape is moderate which increases with the clearance of groundcover and soil cultivation. The weakly structured soils are also susceptible to structural degradation. The sandier soils encountered on the higher slopes have a low wet bearing strength and low shrink-swell potential, which increases downslope as the soils become more clayey.

3.7 SURFACE WATER

The project lies within the upland reaches of the Macquarie-Bogan catchment and is part of the Central West CMA (Figure 7). The majority of the Project area drains to the west and north-west. A number of small ephemeral creeks and gullies drain the ridges of the Project site into 3rd order steams including Stinking Water Creek, Tunnabidgee Creek, Long Gully Creek and Salters Creek (Figure 8). These streams then flow into Pyramul Creek, a major southern tributary of the Macquarie River.

Drainage from the north-eastern arm of the Project (development which consists primarily of transmission lines and a switching station option) is to the east/south-east into the Crudine River via several ephemeral creeks and gullies. The Crudine River is a tributary of the Turon River, which then flows into the Macquarie River.

Burrendong Dam is downstream of the confluence of both the Turon River and Pyramul Creek with the Macquarie River. Burrendong Dam is a water source for irrigation and stock and household needs in the Macquarie Valley and environmental flows to the Macquarie Marshes (NSW State Water 2009).

The NoW monitoring station on the Crudine River upstream of the Turon River Junction (number 421041) was operational between 1963 and 1981; no water quality data is available from this station. Similarly, the NoW monitoring station at Pyramul Creek up stream of Hill End Road (number 421100; 1975-1986) did not record water quality data.

Other NoW monitoring stations are situated further down the catchment; however water quality would be influenced by a large catchment area and would not accurately reflect system inputs close to the proposal. Therefore long term water quality data is not currently available for the study area.

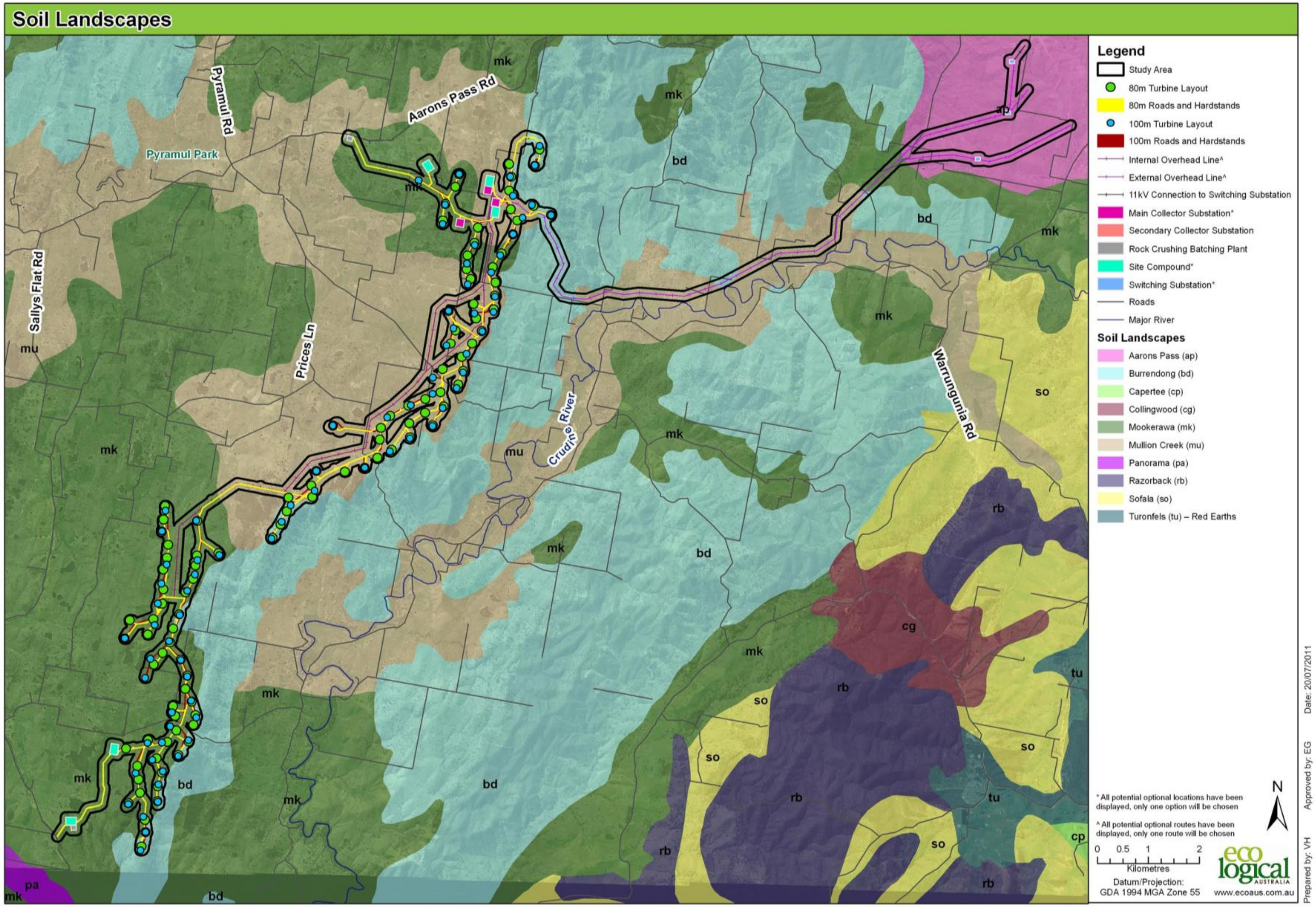

Figure 6: Soil landscape mapping of the Project Site

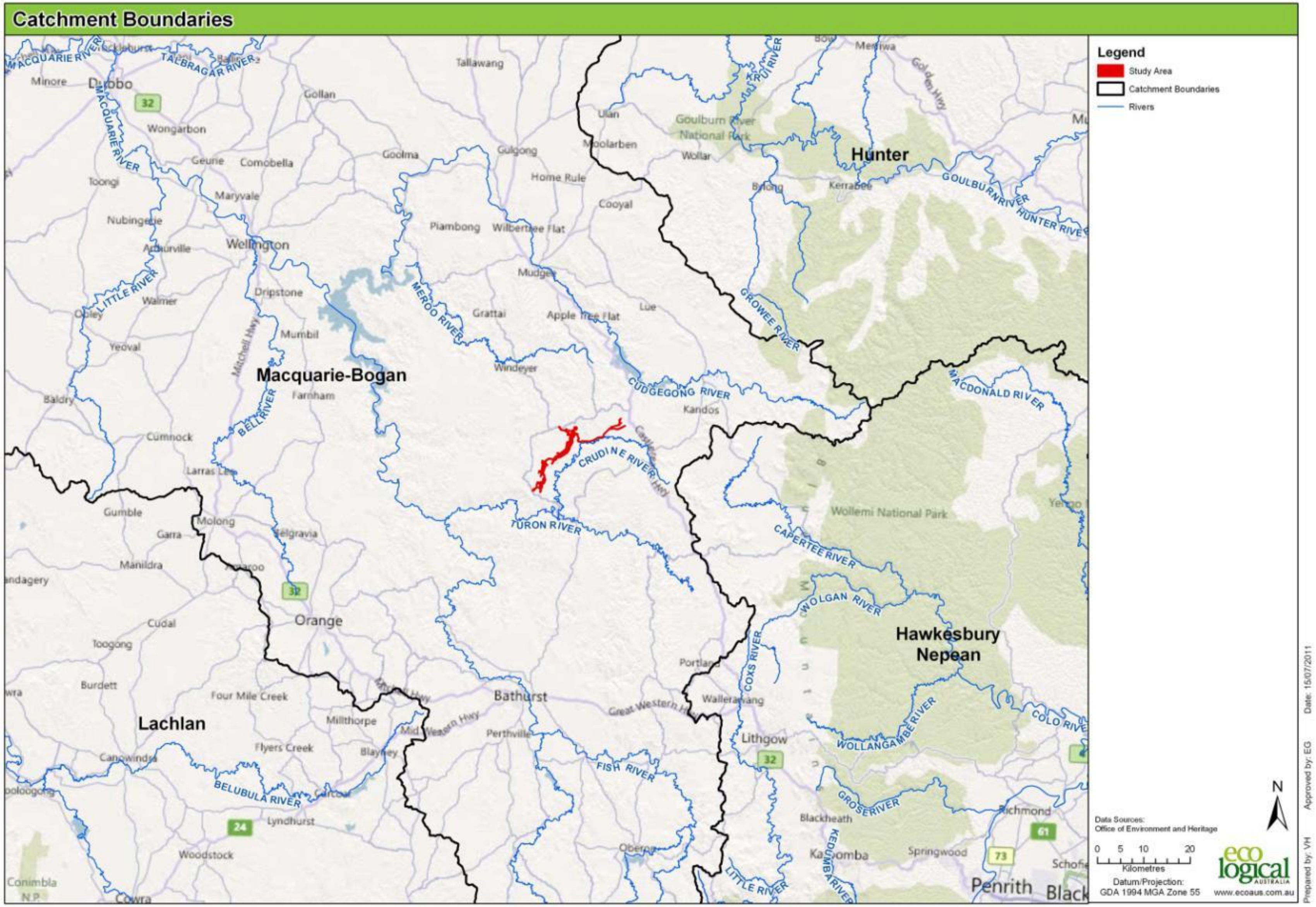

Figure 7: Project Site within the Macquarie-Bogan Catchment

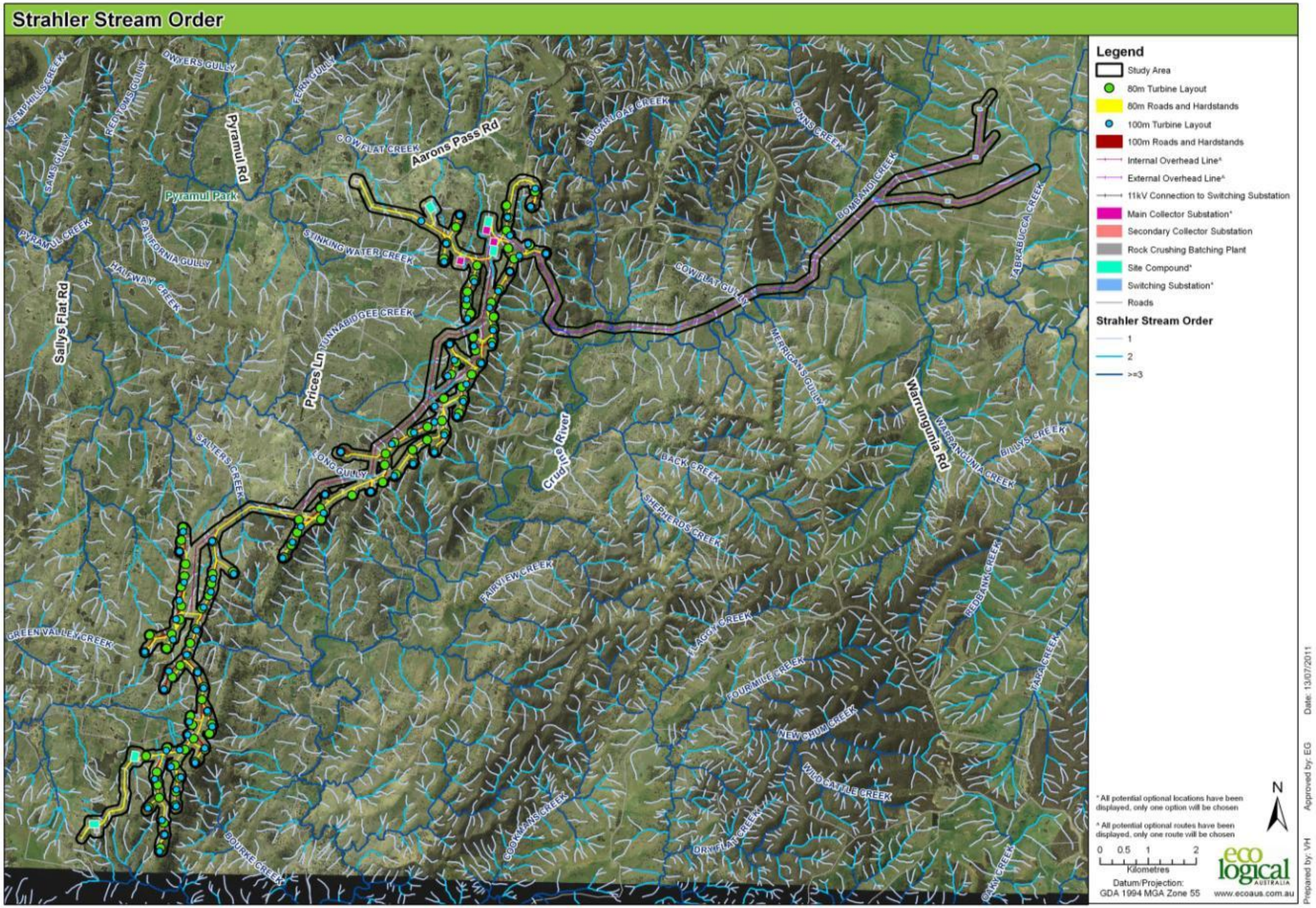

Figure 8: Strahler Stream Order

3.8 WETLANDS

Forested wetlands were identified in Central West CMA vegetation mapping along the lower reaches of the Crudine River and Two Mile Creek (Figure 10) within 10 km of the proposal. Forested wetlands are also mapped along the Turon River upstream and downstream of the confluence with the Crudine River. Forested wetlands are characterised by trees and shrubs and standing water is not present all year. They occur along riverine corridors and on flood plains.

These wetlands are not considered to be influenced by groundwater and the proposed works are not likely to influence the quantity, quality or timing of flows of the hydrology of the surface water systems upon which these wetlands depend.

3.9 GROUNDWATER

The site is located within the Lachlan Ford Belt Ground Water Management Area (GWMA) which generally provides small yields sufficient for stock and domestic supplies only due to the limited permeability of the rock sequences (NoW 2010b). Figure 11 shows borehole locations within a 10km radius of the study site and the depth to the first water bearing zone (WBZ) (in metres) for each bore. The bores are licensed for stock and/or domestic purposes. Almost half of these bores are situated on the eastern side of Pleasant Ridge. The average WBZ of these bores is approximately 20 m, with the shallowest BWZ at 5.4 m below natural surface.

With the exception of a small area of wet tussock grasslands (see below) based on the depth to groundwater it is unlikely that groundwater is significantly influencing terrestrial ecosystems. Given that the Project is located along ridgelines, the shallow depth of excavations during construction means that groundwater is unlikely to be encountered during construction.

3.10 GROUNDWATER DEPENDENT ECOSYSTEMS

Groundwater dependent ecosystems (GDEs) are ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater. Types of ecosystems that can rely upon groundwater include:

- Terrestrial vegetation that show seasonal or episodic reliance on groundwater
- River base flow systems which are aquatic and riparian ecosystems in or adjacent to streams/rivers dependent on the input of groundwater for base flows
- Aquifer and cave ecosystems
- Wetlands
- Estuarine and near-shore marine discharge ecosystems
- Fauna which either directly depend on groundwater as a source of drinking water or that live within water sourced partially or wholly from groundwater.

No GDEs have been identified for the Lachlan Ford Belt Ground Water Management Area (Australian Water Resources 2005). Wet tussock grasslands have been identified in the northern extent of the study area (Figure 9 and Figure 12) and these may have some dependence on groundwater. However, the average depth to the regional water table is approximately 20 m, so if the tussock grassland is groundwater dependent, water is likely to come from a small local perched aquifer or water overlying an impermeable cap of rock. These grasslands are in moderate to good condition with more than 50 percent native ground cover.

Figure 9: Wet tussock grassland located within the study area

3.11 ECOLOGICAL VALUES ASSOCIATED WITH RIPARIAN AREAS & GROUNDWATER

There are no endangered ecological communities listed under the EPBC Act, TSC Act or FM Act located within the study area. There are no threatened fish species (as listed under the FM Act 1994) known to be occurring in the Crudine River or its tributaries, nor is there suitable habitat for any of these species.

Ecological features associated with riparian corridors and groundwater within the broader catchment are further discussed in Section 4.3.2. These ecological features include wetlands, water plants, riparian vegetation, groundwater, bed and Bank stability, Fisheries EEC and Fish.

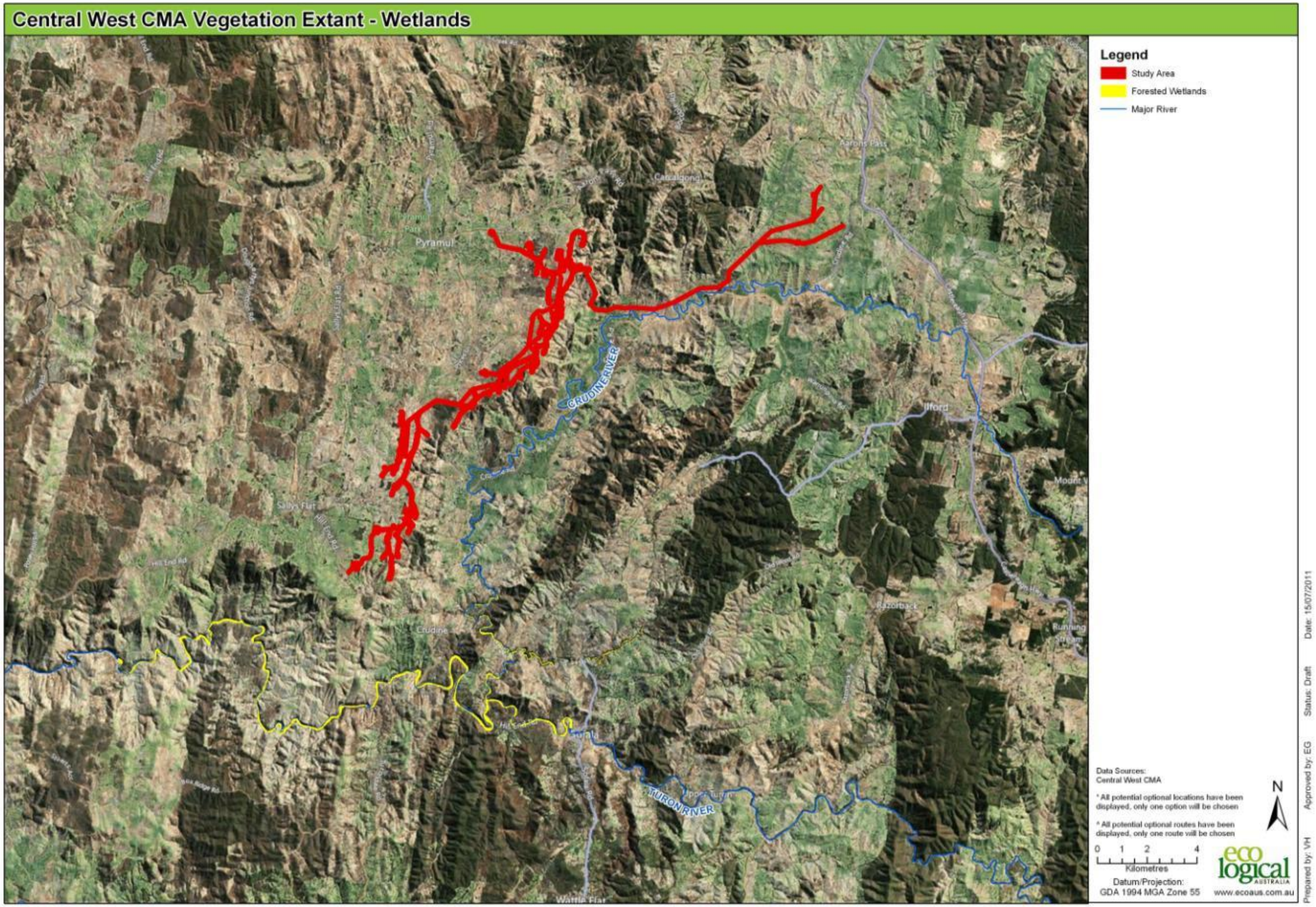

Figure 10: Wetlands identified in the Central West CMA Vegetation Mapping (10 km radius)

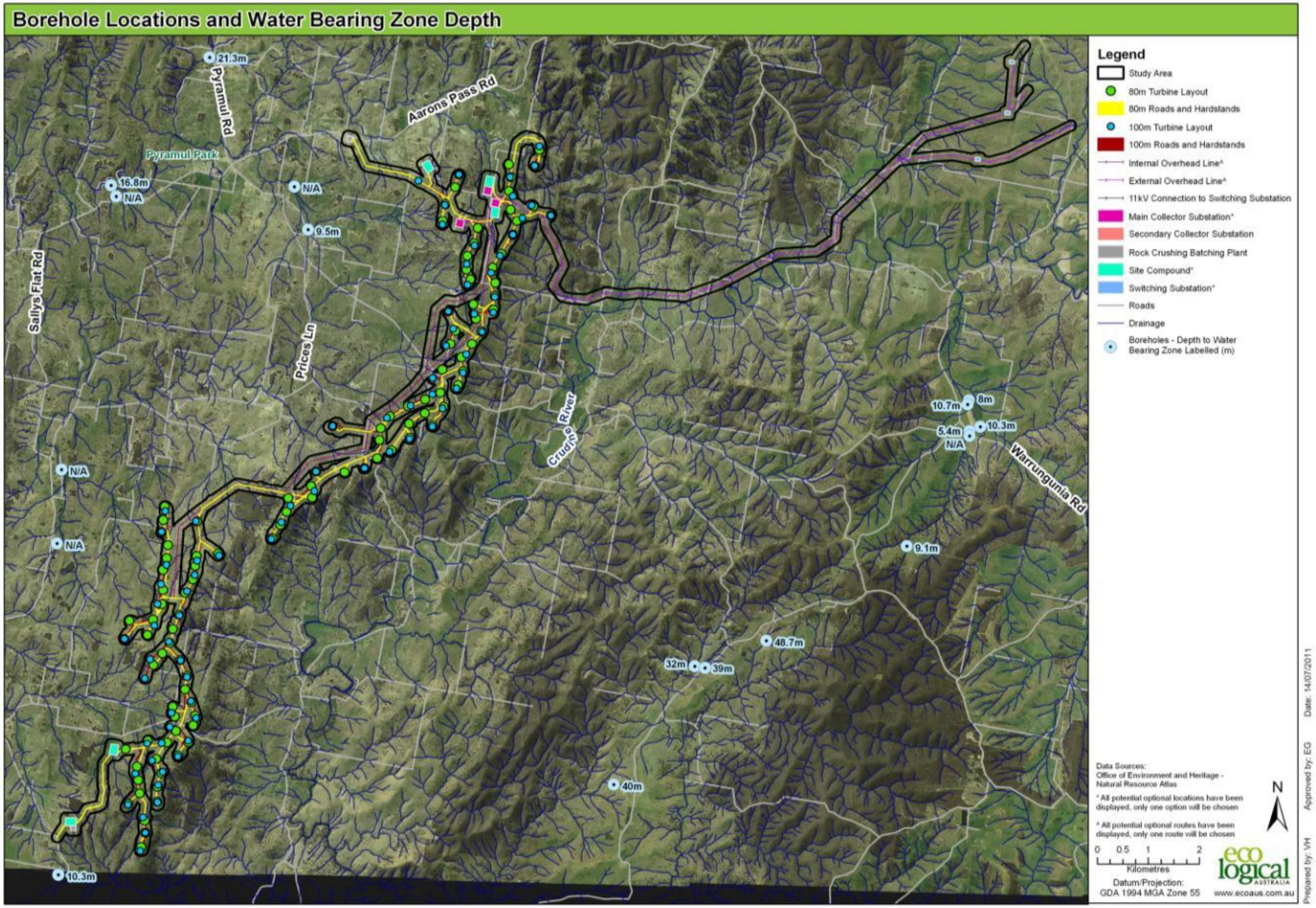

Figure 11: Groundwater bores (and water bearing zone depth) within a 10 km radius of the Project

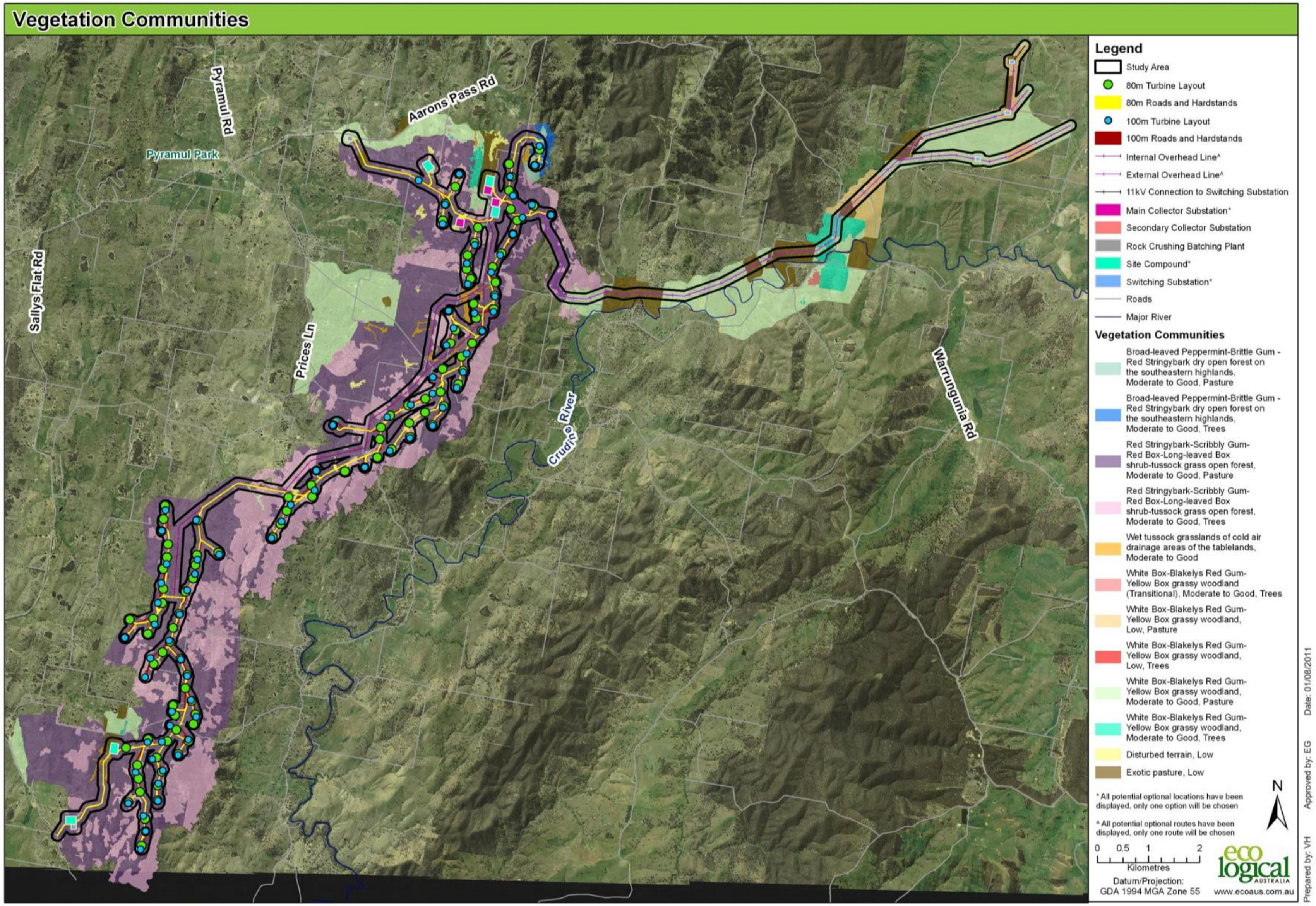

Figure 12: Vegetation communities within the study area

4 Impact Assessment

4.1 PROJECT REQUIREMENTS

The different stages of the wind farm development include pre-construction and construction works, commissioning, operation, servicing and maintenance and decommissioning. Activities associated with each of these phases that may impact on the landform, hydrology and water quality of the site include:

- Upgrading and widening of roads (including creek crossings);
- Stripping and stockpiling of soils;
- Earthworks for site compound, footings and hardstand areas (including excavation, grading and levelling)
- Above- and below-ground cabling
- Cutting or excavation of trenches (including backfilling and compaction)
- Use of water for dust suppression and concrete batching
- On-site wastewater treatment system
- Revegetation and rehabilitation works.

4.2 SITE SOIL CONSIDERATIONS

4.2.1 Potential Impacts

The works associated with the project have the potential to impact the existing soils and associated landform via:

- Vegetation clearing and general construction activities leading to soil disturbance and causing (or exacerbating) erosion processes
- Altering or impeding natural flow paths.

Areas of steep gradient (in particular works on the eastern side of Crudine Ridge) present a higher hazard for erosion and run off. Where possible, existing access tracks will be utilised or, where constructed, will be restricted to the transmission line corridor to minimise impacts. Protocol for the location and construction of access tracks will be included in a Construction Environmental Management Plan (CEMP).

The erosion hazard of soils varies across the site but generally the dominant soil types are susceptible to erosion particularly when cleared of vegetation and when either the surface soil or the soil profile is disturbed. The hard-setting nature and mobility of soils within the study area together with the elevation and occurrence of strong winds means that the potential for dust generation is also a consideration. Exposure of soils during earthworks, and the formation of stockpiles, may cause dust issues. Appropriate dust suppression measures should be implemented and addressed in the CEMP.

A Soil and Water Management Plan (SWMP) will be required as part of the CEMP order to manage, at an appropriate level of detail, the specific issues for sedimentation and erosion on site. The SWMP will be designed to practically implement the issues addressed in this assessment.

4.2.2 Soil Properties

Typically Red Chromosols are found on the crests and upper- to mid-slopes of the project site, while Yellow Sodosols are found on the lower slopes and drainage lines (which may give way to Yellow Kandosols or massive earths). Rocky outcrops and shallow skeletal soils (siliceous sands and loams) are common on hill crests. Generally the upper slopes are well drained with the profiles becoming poorly and imperfectly drained downslope.

Typical properties relating to the predominant soil types are summarised in Table 4.

Table 4: Summary of major soil types within the Project site

PROPERTY	TYPICAL SOIL TYPE		
	RED CHROMOSOLS	YELLOW SODOSOLS	TENOSOLS
Location	Crests; Upper- to mid-slopes	Mid- to lower-slopes; drainage lines	Hill crests; higher and steep slopes
USCS	CL, CH[1]	ML, CL, SC[1]	SC, SM, ML[1]
Texture	Sandy clay to heavier clay	Sandy clay; clay loam to heavier clay	Sand to light sandy clay
Erosion Hazard	Moderate-Very high	Moderate-High	Moderate-High
Sodicity	Sodic subsoils	Sodic subsoils	No
Structural degradation hazard	High	High	Moderate-high
Shrink-swell potential (geotechnical risk)	Moderate	Low to moderate	Low
Potential runoff rates	Moderate	Moderate to high	Low
Drainage	Imperfect	Imperfect to poor	Well to rapidly drained
Soil salinity	Low	Low to high	Low
Mass movement hazard	Moderate	Low	High

[1] CL Inorganic clays, gravelly clays, sandy clays, silty clays, lean clays
CH Inorganic clays of high plasticity
ML Inorganic silts and very fine sands, silty or clayey fine sands
SM Silty-sands, poorly graded sand-silt mixtures
SC Clayey-sands, poorly graded sand-clay mixtures

4.2.3 Rainfall Erosivity

Rainfall Erosivity (also called the R-Factor) is a measure of the ability of rainfall to cause erosion, and is calculated based on total energy and maximum 30 minute storm intensity (Landcom 2004).

The Rainfall Erosivity for the proposed wind farm is approximately 1,375 based on *Rainfall Erosivity Values for NSW (1:5,000,000)* in *Appendix B* of the ‘Blue Book’ (Landcom 2004). The R-Factor varies between 600 in parts of western NSW to over 10,000 on the far north coast of NSW. Given this range, the Rainfall Erosivity for the site can be considered low.

Monthly mean rainfall data collected by the Bureau of Meteorology shows that rainfall in the region is slightly summer dominant with January being the wettest month. Consideration may be given to planning of construction schedules outside of summer, particularly given the overall high erosion hazard across the Project area.

4.2.4 Soil Erodibility and Dispersibility

Soil Erodibility (also called the K-Factor) is a measure of the susceptibility of individual soil particles to detach and be transported by rainfall and runoff (Landcom 2004). The K-Factor generally ranges from 0.005 (very low) to 0.075 (very high) (Landcom 2004). While soil texture is the primary driver of the K-factor, soil structure and organic matter also influence the value.

Due to the lack of published and current mapping of soil landscape information for the study site, it is recommended that the K-Factor be derived from site specific laboratory data (such as particle size distribution and Atterberg Limits). Emerson aggregate and dispersion percentage testing should also be undertaken. Samples from each of the major soil landscapes should be collected and analysed as part of the geotechnical assessment proposed for footing design.

Characteristics of the dominant soil types found across the site are summarised below (Table 5).

Table 5: Soil erodibility of major soil types within the Project site

TYPICAL SOIL TYPE	TOPSOIL ERODIBILITY	SUBSOIL ERODIBILITY	SUSCEPTIBILTIY TO STRUCTURAL DEGRADATION
Red Chromosols	Moderate	Low to moderate	High
Yellow Sodosols	Moderate to high	Moderate to high	High
Inceptic Tenosols	Moderate	-	High
Orthic Tenosols	Moderate to high	Moderate to high	High

Sodic soils (generally defined as having an exchangeable sodium percentage of more than five percent) are common in the area. In particular, sodic subsoils (such as those of the Mookerawa unit) are subject to severe gully erosion. Examples of erosion occurring within drainage lines on the project site due to land management practices and soil types are provided below.

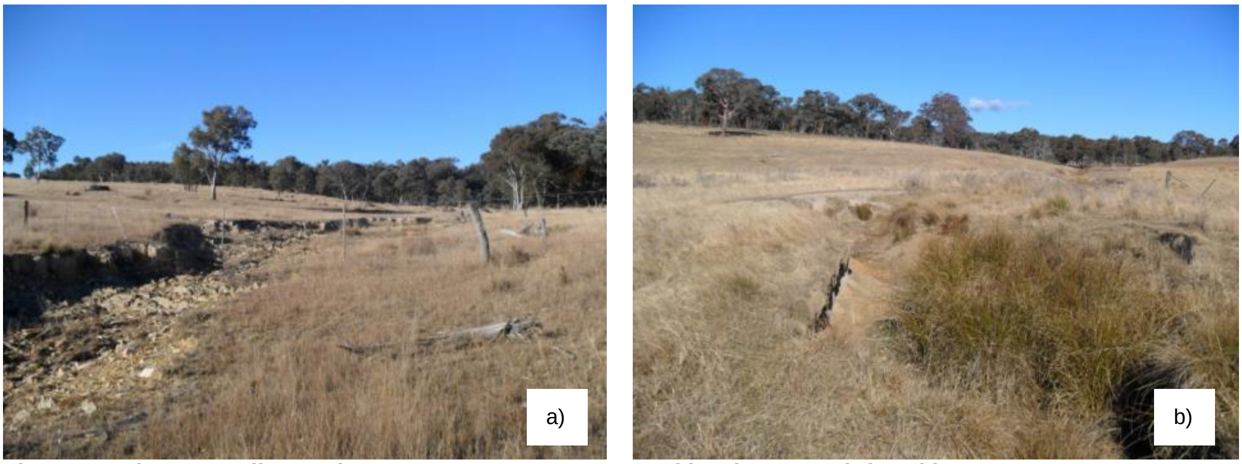

Figure 13: a) Long Gully Creek **b) Salters Creek (north)**

4.2.5 Soil Erosion Hazard

Soil erosion hazard refers to the susceptibility of a parcel of land to the prevailing agents of erosion and is typically described as high or low erosion hazard. Sites with high erosion hazard may require control measures beyond the normal suite of erosion control measures applied to construction sites. Unlike soil erodibility, which is measured from a field sample in a laboratory, soil erosion hazard considers such field conditions as climate, landform, soils (soil erodibility), ground cover and land management (Landcom 2004).

Based on the information provided in Table 6 below, the R-Factor for the region (1,375) and upper slope gradients were compared to Figure 4.6 of the 'Blue Book' to determine their potential erosion hazard. Generally areas with a slope greater than 15 percent have a high erosion hazard. The western slopes of the Project site are generally less than 10 degrees (18 percent) while the eastern slopes of Crudine Ridge are steep with slopes in excess of 20 degrees (36 percent).

Table 6: Soil landscape units – slope characteristics

SOIL LANDSCAPE	SOIL CONSTRAINTS	SLOPE RANGE (%)	EROSION HAZARD
Burrendong	Rolling to steep hills, shallow soils, low water-holding capacity, moderate to severe sheet and gully erosion	20 - 50	High
Mullion Creek	Seasonal waterlogging, sodic subsoils on lower slopes, high erosion hazard under cultivation, acidic surface soils, salinity, low permeability	3 - 6, sometimes up to 12	Low
Mookerawa	Sodic subsoils on lower slopes, high to very high erosion hazard under cultivation	8 - 30, generally less than 15	Low to high
Aarons Pass	Rolling low hills and some hills with steep scarps, acidification, low water holding capacity, seasonal waterlogging and low subsoil permeability in lower areas	4 - 8, sometimes up to 20	Generally low

However given the high erodibility of the site and the widespread presence of sodic soils, it is recommended that laboratory data is used when a SWMP is prepared for the works. Emerson aggregate and dispersion percentage testing should also be undertaken. In order to gain efficiencies, samples from each of the major soil landscapes should be collected and analysed as part of the geotechnical assessment proposed for footing design.

4.2.6 Expansion or Reactive Soils

Most soils will shrink or swell depending on changes in their moisture content. The clay content and mineral types of a soil will determine whether soils are expansive or reactive. Soils that shrink significantly are called expansive or reactive soils and may be problematic in structures such as sediment basins, roads (Landcom 2004) and building foundations. The shrink-swell potential can also contribute to the erosion hazard of bare ground.

The dominant soil types across the site (red Chromosols and yellow Sodosols) all have a moderate shrink/swell potential. Volume expansion tests can determine the shrink/swell potential; however this test has been known to underestimate the shrink/swell potential of dispersible soils (Mills et al. 1980 in Kovac et al. 1989) and should be considered when reviewing soils data. A linear shrinkage test would be recommended instream.

4.2.7 Runoff Potential

The runoff potential rate is the rate at which water moves over bare soil and are lowest for soils containing large quantities of sand and for soils with deeper surface horizons (Kovac et al. 1989). Chromosols and Sodosols with shallow hard-setting topsoils, such as those common across the project site have a high runoff potential.

The Blue Book uses a runoff coefficient which relates the ratio of catchment runoff to rainfall in a nominated storm event. It is used to estimate peak flow running through catch drains and like structures and for sizing sedimentation basins. The runoff coefficients will need to be calculated during the preparation of the SWMP for the site.

4.2.8 Depth to Water table

The design of erosion and sediment controls may be influenced by the presence of water tables near the surface, whether seasonal or permanent (Landcom 2004). Given that the Project is located along ridgelines and the shallow depth of excavations during construction, groundwater is unlikely to be encountered during construction. Seasonal waterlogging in drainage depressions is common across the soil landscapes and implications on construction will need to be considered.

4.2.9 Salinity

Due to the landscape features and land use patterns the area has a medium salinity hazard (CWCMA, 2007). Salt accumulation in soils can have adverse impacts on developments including damage to foundations, breaking up of road pavements and corrosion of underground pipes and services (Landcom 2004).

High salinity has been identified on the lower slopes, footslopes, drainage lines and depressions in the Mullion Creek and Mookerawa soil landscapes and these areas should be assessed in the SWMP.

4.2.10 Mass Movement

Identifying areas with the potential for mass movement is critical to managing soil and water during construction such that these areas can be avoided or stringent controls put in place. The Burrendong soil landscape has been known to experience localised mass movement, particularly the soils found higher in the landscape (Chromosols and Tenosols). Clearing of the shallow skeletal soils on the upper slopes and crests could cause slumping. Mass movement hazard and slumping should both be considered during preparation of the SWMP.

4.2.11 Acid Sulphate Soils

Acid Sulphate Soils (ASS) are soils or sediments that release sulphuric acid when exposed to air. While most typically associated with low lying coastal regions, ASS have been identified in inland aquatic ecosystems including lakes, wetlands, creeks and rivers (Environment Protection and Heritage Council and the NRM Ministerial Council 2011). The exposure of ASS to oxygen can lead to acidification, deoxygenation, and the release of heavy metals and damage to infrastructure. The occurrence of inland ASS is limited and is concentrated along the Murray River and its floodplains, with isolated occurrences along the Edward-Wakool, Lachlan, Murrumbidgee and Darling River systems. ASS are not expected to be present within the proposed wind farm site.

4.2.12 Soil Contamination/Toxicities/Pollution in Soils

Exposure to contaminated soils presents a health risk to construction personnel, landowners and site visitors. At the time of preparation of this risk analysis no assessment of contaminated soils had been undertaken for the proposed site. Potentially contaminating activities associated with agricultural activities include sheep dips, import of fill material, demolition of old buildings and stockpiling of wastes.

Known areas of potential land contamination based on current and past activities should be avoided if possible by relocating facilities and roads; alternatively a soil contamination assessment would be required.

4.2.13 Limitations

This desktop soils assessment was conducted using published maps and reports. Prior to construction activities a site specific geotechnical assessment and SWMP must be undertaken and prepared.

Normal engineering practice of regular inspection and maintenance of operational areas should be carried out in accordance with the SWMP and geotechnical report.

4.3 SITE WATER CONSIDERATIONS

4.3.1 Potential Impacts

The works associated with the project have the potential to impact the hydrology, water supply and water quality of the site by:

- Vegetation clearing and general construction activities leading to soil disturbance and causing (or exacerbating) erosion processes
- Disturbing, altering or impeding natural flow paths
- Modifying the dynamics of surface- and ground-water flows
- Pollution of surface- and ground-waters through accidental spills, drilling and excavation works
- Altering general water quality through any of the above processes.

These impacts are likely to occurring during the pre-construction and construction phases.

Efforts to minimise potential hydrological impacts have been made in the layout of the project, including utilising existing access tracks or restricting access tracks to the transmission line corridor and minimising creek crossings. Protocol for the location and construction of access tracks will be included in the CEMP.

4.3.2 Ecological Values associated with Riparian Areas

Table 7 below outlines the ecological values associated with the broader catchment and describes any potential interactions with the proposed project. These interactions are then considered in the following sections.

Table 7: Identified ecological features associated with riparian corridors within the broader catchment

ECOLOGICAL FEATURE	LOCATION OF FEATURE	PROJECT INTERACTION
Wetlands	There are no Nationally Important Wetlands or Ramsar Wetlands located within the vicinity of Crudine Ridge. Pyramul Creek and the Turon River ultimately discharge to the Macquarie River which is regulated at Burrendong Dam. Burrendong Dam provides environmental flows to the Macquarie Marshes, a Nationally Important Wetland and a Ramsar Wetland (DSEWPC 2011). Forested wetlands are located on the lower reaches of the Crudine River and Two Mile Creek.	**Flow requirements** These areas rely on natural flow variability (timing, frequency and magnitude) to maintain health and diversity. **Application to Crudine** The development does not propose to alter natural flows.
Water plants	No significant aquatic plants are known from the Crudine Ridge. Aquatic plants in the Crudine River may be important aquatic habitat for fish and invertebrates.	**Flow requirements** These areas rely on natural flow variability and medium floods to maintain health and diversity. Aquatic plants also require sufficient sunlight to allow photosynthesis, which can be impaired by silt-laden runoff in areas of high erosion. **Application to Crudine** The development does not propose to alter the natural hydrology, therefore water plants are unlikely to be impacted. Parts of the overhead line run adjacent to Crudine River. Care should be taken during construction of the lines and along access tracks to reduce the silt content of any runoff.
Riparian vegetation	Forested wetlands were identified in Central West CMA vegetation mapping along the lower reaches of the Crudine River and Two Mile Creek within 10 km of the proposal. Forested wetlands are also mapped along the Turon River upstream and downstream of the confluence with the Crudine River. Forested wetlands are characterised by trees and shrubs and standing water is not present all year. They occur along riverine corridors and on flood plains. Riparian corridors in the upper catchment where most of the creek crossings will occur are either patchy or absent.	**Flow requirements** Riparian vegetation requires natural flow variation and medium to high floods to maintain habitats. **Application to Crudine** Impacts to in-stream and riparian ecology are considered in this assessment. The main areas where riparian vegetation are likely to be impacted by this project are along the overhead power line corridor north of Crudine River.
Groundwater	The study site is situated within the Lachlan Fold Belt Ground Water Management Area.	**Flow requirements** The impact on groundwater is expected to be minimal unless there are some particularly unusual construction features extending to the water table. **Application to Crudine** There are unlikely to be any construction activities (excavations or drilling) that will intercept water bearing zones. Any sourcing of ground water for use during construction will be done in accordance with the licensing requirement under the WM Act and relevant WSPs.

ECOLOGICAL FEATURE	LOCATION OF FEATURE	PROJECT INTERACTION
Bed and Bank stability	NoW have requested an assessment of water courses to be crossed and section of appropriate techniques and measures to minimise impact. Significant water courses must be protected through directional drilling techniques where underground cabling is required.	**Flow requirements** Maintenance of natural flow regime. **Application to Crudine** Creek crossings and any works within riparian corridors must minimize any impacts of hydrology, water quality and aquatic and riparian ecology. Impacts to in-stream and riparian ecology are considered in this assessment.
Fisheries EEC	The endangered aquatic ecological community of the lowland Darling River was gazetted under the *Fisheries Management Act 1994*. This ecological community refers to all native fish and aquatic invertebrates within all natural creeks, rivers, streams and associated lagoons, billabongs, lakes, flow inversions to anabranches, the anabranches and the floodplains of the Darling River within NSW.	**Flow requirements** Maintenance of natural flow regime as the proposal is upstream of these areas. **Application to Crudine** This EEC applies to the lowland Darling River and includes *regulated* tributaries of the Macquarie River. Both Crudine River and Pyramul Creek are unregulated rivers; therefore there is no direct application to this project.
Fish	Macquarie Perch are listed as endangered federally and in NSW. They occur in the Murray-Darling Basin, particularly in the upstream reaches of the Lachlan, Murrumbidgee and Murray rivers. They are found in both river and lake habitats, especially in the upper reaches of rivers and their tributaries (NSW DPI 2011)	**Flow requirements** Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures. **Application to Crudine** Macquarie Perch are not known from the Crudine River.
	Trout Cod are listed as endangered federally and in NSW. They are endemic to the Southern Murray-Darling River System, including the Macquarie River. At present only two potentially sustainable breeding populations are known; a naturally occurring population in the Murray River (NSW) d/s of Yarrawonga Weir between Yarrawonga and Barmah, and a translocated population in Seven Creeks (Vic) (Trout Cod Recovery Team 2008a).	**Flow requirements** Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures. **Application to Crudine** At present only two potentially sustainable, breeding populations are known, neither of these occur in the study area.
	Murray Cod are listed as vulnerable federally. They are endemic to the Murray-Darling river system and were once widespread and abundant with the exception of some of the upper reaches of tributaries. The species occurs throughout most of its historic range, with some localized extinctions in the upper tributaries (National Murray Cod Recovery Team 2010).	**Flow requirements** Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation, maintain complex structural cover and using effective erosion control measures. **Application to Crudine**

ECOLOGICAL FEATURE	LOCATION OF FEATURE	PROJECT INTERACTION
		Murray Cod are present in the Macquarie River system, but are not known from the Crudine Ridge area or Crudine River.
	Silver perch are listed as a vulnerable species in NSW. They are endemic to the Murray-Darling river system and were once widespread and abundant except for cooler high altitude streams (NSW DPI 2011).	**Flow requirements**
		Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures.
		Application to Crudine
		Silver perch prefer fast-flowing, open waters, especially where there are rapids and races. Such habitat does not occur in the study area.
	Purple spotted gudgeons (endangered) occur in inland drainages of the Murray-Darling basin as well as coastal drainages of northern NSW and Queensland (NSW DPI 2011).	**Flow requirements**
		Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures.
		Application to Crudine
		Unlikely to occur in the study area as it prefers slow-moving or still waters of rivers, creeks and billabongs, often amongst weeds, rocks or large woody debris (snags).
	Olive perchlet are listed as an endangered population in NSW and occur in the eastern (coastal) and western (Murray-Darling) drainages. The western population was once widespread and is now found only in the Darling River drainage (NSW DPI 2011).	**Flow requirements**
		Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures.
		Application to Crudine
		Unlikely to occur in the study area as it prefers slow-moving or still waters of rivers, creeks and billabongs, often amongst weeds, rocks or large woody debris (snags).
Invertebrates	River snail (*Notopala sublineata)* are listed as endangered in NSW and occur in the Murray-Darling River System. It is now virtually extinct through its natural range although some populations have been recorded as surviving in artificial habitats (NSW DPI 2011).	**Flow requirements**
		Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures.
		Application to Crudine
		Unlikely to occur in the study area as it is virtually extinct in its natural range.
Frogs	The Booroolong Frog (*Litoria*	**Flow requirements**

ECOLOGICAL FEATURE	LOCATION OF FEATURE	PROJECT INTERACTION
	booroolongensis) is predicted to occur near Capertee and known to occur near Hill End. They are associated with forested wetlands, grassy woodlands and wet sclerophyll forests. Habitat includes permanent rocky streams with fringing groundcover or understorey vegetation, stream banks or vegetation and fallen timber within 100 m either side of streams or creeks, cobble banks or exposed bedrock (DECC 2011)	Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures. **Application to Crudine** This species could potentially occur in some parts of the project area. This is addressed in the Ecological Assessment (ELA 2011).
	The Green and Golden Bell Frog (*Litoria aurea*) is known to occur near Capertee and Hill End. Associated with freshwater wetlands, grasslands, grassy woodlands, wet and dry sclerophyll forests. Breeds in any still, slow flowing waterbodies and artificial waterbodies. This species forages in emergent aquatic or riparian vegetation and amongst vegetation, fallen timber adjacent to and within 500 m of breeding habitat. Takes shelter in vegetation, rocks, fallen timber, leaf litter, artificial ground cover, debris and soil cracks up to 1 km from waterbodies (DECC 2011)	**Flow requirements** Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures. **Application to Crudine** This species could potentially occur in some parts of the project area. This is addressed in the Ecological Assessment (ELA 2011).
	Sloane's Froglet (*Crinia sloanei)* is typically associated with periodically inundated areas in grassland, woodland and disturbed habitats. This species shelters in vegetation, ground debris, or cracks in the soil.	**Flow requirements** Prevent sedimentation and poor water quality by improving land management practices, conserving and restoring riparian (river bank) vegetation and using effective erosion control measures. **Application to Crudine** This species could potentially occur in some parts of the project area. This is addressed in the Ecological Assessment (ELA 2011).

4.3.3 Surface Water

A number of ephemeral creeks and gullies drain the Project site, many of which are minor tributaries that drain off the ridgelines. Most of these streams are considered to be first order; second order streams include Long Gully and Tunnabidgee Creeks. Third order streams that the project site intersects include Stinking Water Creek and Salters Creek.

Internal access roads and overhead cables will cross a number of small (unnamed) first order streams and gullies, as well as Salters Creek, Long Gully, Tunnabidgee Creek (and its tributaries) and Cowflat Creek. The (external) overhead cable will cross Sugarloaf Creek, Cowflat Gully and Bombandi Creek (third order streams). It is noted that riparian corridors in some areas are either patchy or absent; for example along Long Gully and Salters Creek.

Plants species typically found in riparian zones within the project area include:

- *Aristida*
- *Austrodantonia*
- *Phalaris*
- *Cirsium*

- *Joycea*
- *Stipa*
- *Juncas*
- *Paricum*
- *Carex*
- *Lachnagrostic.*
- *Cyperus*
- *Hypochaeris*
- *Isolepis*
- *Lythreum*
- *Aster* sub.
- *Persicaria*

Figure 14 shows the application of the recommended CRZ width and additional 10 m vegetated buffer. That is, the project will require works within and across the CRZ of the riparian corridors. As part of the project design it is intended that all crossings will be in line with NoW[3] and DPI guidelines (Fairfull & Witheridge 2003) for watercourse crossings through the use of causeways or bed level crossings on first order streams and box culverts on second order streams and above.

Scour protection, including permanent bed and bank stabilisation, must be incorporated. Sediment and erosion control measures during construction and post-construction should be addressed in the SWMP.

The final layout of the project should locate infrastructure, such as site compounds and substations, such that they are not located within the riparian zones.

The use of overhead cables avoids the requirement for underground cabling through any water courses. The average span length of the overhead transmission is around 200 to 250 m and poles should be located such that they are not located within riparian zones.

4.3.4 Wetlands

No wetlands occur within the project area. Forested wetlands have been mapped along the lower reaches of the Crudine River and Two Mile Creek and the Turon River; the proposed works are not likely to influence the hydrology of the surface water systems upon which these wetlands depend.

4.3.5 Groundwater

No groundwater bores are located within the project area. Given the average WBZ of bores in the area, groundwater is unlikely to be encountered during construction activities.

Three types of foundations for the wind turbines are being considered pending geotechnical investigations. Slab (gravity) foundations would require excavation to a depth of around 2.5 m. Slab plus rock anchor foundations would require excavation of material to a similar depth as well as drilling of rock anchor piles up to a depth of up to approximately 20 m. A single mono-pile foundation (rock anchor) would involve drilling to a depth of approximately 10 m. Groundwater surveys are recommended prior to footing construction that requires drilling at depths.

It is unlikely that groundwater will be encountered during the other construction activities, including earthworks for access roads and hardstand areas, given that these works will be confined to the existing ground level or minimal depths below natural surface.

Any sourcing of water for the construction requirements will be done in accordance with licensing requirements under the WM Act and relevant WSPs.

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[3] see http://www.water.nsw.gov.au/Water-Licensing/Approvals/Controlled-activities/default.aspx

4.3.6 Groundwater Dependant Ecosystems

No GDEs have been identified for the Lachlan Ford Belt Ground Water Management Area; however, wet tussock grasslands were identified during the ecological assessment. The proposed works are not likely to impact groundwater flows into these wetlands.

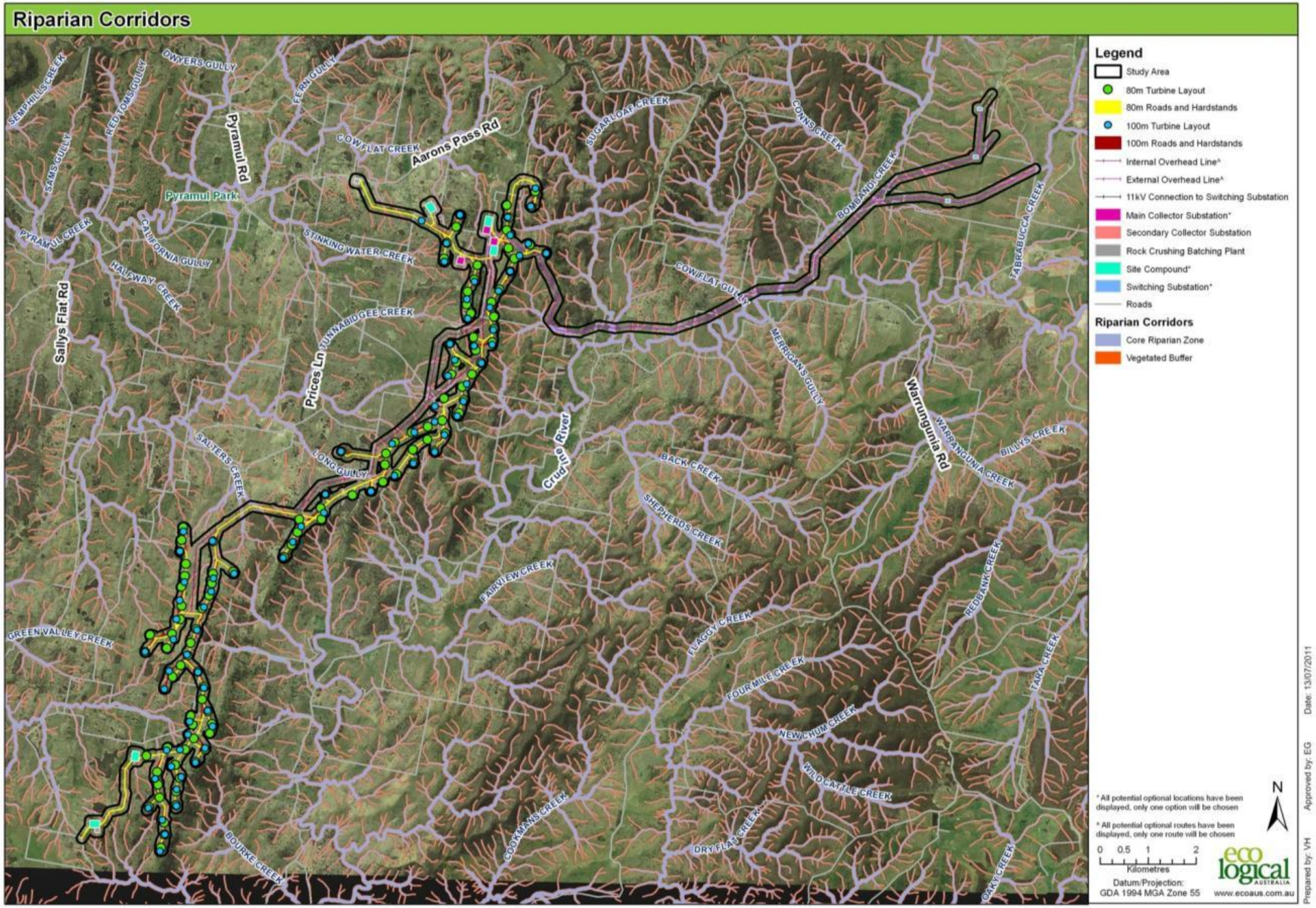

Figure 14: Core Riparian Zone Widths (CRZ)

4.3.7 Water Sources

Where possible water shall be sourced locally using existing onsite dams (i.e. utilising harvestable rights) or groundwater purchased from involved or adjacent landowner properties who hold groundwater licences and have unused allocations. Alternative water sources include the Crudine or Turon Rivers and Windermere Dam. All water sourcing will be done in accordance with licensing requirements under the WM Act and relevant WSPs through NoW. Access points would be determined post-consent on award of construction contracts.

4.4 CUMULATIVE IMPACTS

4.4.1 Introduction

Cumulative impacts arise when a number of activities with similar impacts interact with the environment in a region. Cumulative impacts can occur due to either spatial or temporal characteristics of an activity (Department of Planning NSW 2002). The review of the cumulative impacts of the Crudine Ridge Wind Farm considers the following:

- The impact of this particular wind farm on water and soil resources when considered with the combined impacts of existing and proposed wind farms within the Central West Catchment
- Potential long and short term cumulative impacts the development may have on water and soil resources
- The impact of the wind farm on water and soil resources, when added to the combined impacts of other land-use practices and environmental characteristics of the area.

At the time of writing there are five wind farms existing or proposed within a 100 km radius of the proposal site. Blayney and Hampton wind farms are operational and are approximately 65 and 80 km to the south-west respectively. Proposals for other wind farms in the area include Uungula (65 km to the north-west) and Flyers Creek and Bodangora (approximately 65 and 80 km to the south-west respectively). DGRs have been issued for these projects for the environmental assessments.

4.4.2 Cumulative impacts of wind farms within the Central West Catchment

The proximity of the Project to existing or proposed wind farms is of sufficient distance that there are not expected to be cumulative impacts on water and soil to the catchment as a result of the Crudine Ridge Wind Farm. The development does not propose to alter the existing hydrology of any water courses in the area; any groundwater extracted will be undertaken according to the relevant WSPs. Impacts relating to soil and erosion are site specific and will be controlled at source.

4.4.3 Long term cumulative impacts

The project area and land in the vicinity has been subject to environmental impacts due to the clearing of native vegetation for grazing. The development of the wind farm is expected to have minimal additional impact on the existing condition of soil and water resources. Impacts, such as those identified in this report, will be managed via the Project's CEMP which will include mitigation and control measures relating to soil and erosion in the SWMP. The existing hydrology will not be altered and if groundwater extraction is undertaken, it will be in accordance with the relevant WSPs.

4.4.4 Short term cumulative impacts

Short term cumulative impacts are primarily related to the construction phase of the project where soil and groundcover are likely to be disturbed during the construction of access roads, turbines, hardstands, transmission lines and substations. Combined with current land use practices there is potential for increased rates of erosion and increased levels of dust in the absence of control measures.

Should additional wind farms be developed in the vicinity in the future, these developments would also need to abide by relevant WSPs which will ensure equitable sharing of water for users and the environment (including surface and ground waters). It is likely that impacts relating to soil and erosion would be mostly site specific and would be avoided or mitigated at source.

Short term cumulative impacts can be minimised by dust suppression, controlling soil erosion by putting in place barriers and by restoring groundcover on exposed soils as soon as practicable.

4.4.5 Other industry in the area

Current land use practices are generally agricultural with the land being extensively cleared in the past, resulting in soil erosion and altered surface flow regimes due to changes in vegetative cover. The cumulative impact of the wind farm alongside these current land use practices is expected to be minor and able to be mitigated through the project's environmental management plan.

5 Mitigation and Management

Recommended management and mitigation measures are detailed in the chapter below to address potential environmental impacts as they relate to soil and water. This report is not intended to act as detailed management plan for erosion and sediment control; rather this section of the report addresses the principles of the ‘Blue Book’ (Landcom 2004) and undertakes an initial assessment of their applicability to the project.

Land disturbance (including vegetation clearing and general earthworks) during construction and ongoing operation and maintenance activities have the potential to cause erosion, displacing soil which can then be deposited onto adjacent or nearby land or into waterways. Of particular concern are fine, dispersible sediments that can carry other pollutants, which will not settle until they reach saline waters, and which can result in poor water quality. The steep slopes and erosion potential of soil groups within the study area will need to be a particular focus of the SWMP.

5.1 SOIL AND WATER MANAGEMENT PRINCIPLES

The following principles generally provide effective soil and water management during land disturbance:

- Adequate investigation of where soil disturbance is likely to expose and/ or exacerbate pre-existing problems
- Plan for erosion and sediment control concurrently with engineering design, prior to any works commencing, and integrate other landscape components (e.g.: riparian, ecological)
- Install the necessary control measures prior to works commencing
- Minimise the area of soil disturbed and exposed to erosion (including appropriate vehicle management to restrict traffic to nominated access roads)
- Install water slowing and diversion devices around construction areas including measures to manage surface run-off from hardstand areas and surfaced access tracks
- Conserve topsoil for later site rehabilitation/ revegetation
- Divert clean run-on water around disturbed areas
- Control water flow from the top of, and through the development area
- Progressively rehabilitate disturbed lands as soon as practically possible
- Inspect and maintain soil and water management measures appropriately during the construction and operation phase, with regular inspections and maintenance scheduled.

These principles should be further detailed and adopted within a SWMP, and implemented in the detailed design phase of footings, trenching and access roads prior to pre-construction activities.

Additional soils information obtained from soil testing (such as particle size distribution and dispersibility) should be considered during the preparation of a SWMP as this will influence the type and extent of control measures necessary.

A SWMP (informed by more detailed geotechnical investigations) should outline management actions for the development site(s) and include the full suite of erosion and sediment controls.

Design, construction and maintenance will be carried out in accordance with recognised guidelines and standards, including:

- Managing Urban Stormwater: Soils and Construction, Volume 1, 4th Edition, Landcom 2004
- Managing Urban Stormwater: Soils and Construction, Volume 2C Unsealed roads, DECC
- Guidelines for Controlled Activities, NSW Office of Water
- Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings, NSW DPI (Fisheries) (Fairfull & Witheridge 2003).

5.2 ACCESS TRACKS AND TRENCHING

In accordance with *Managing Urban Stormwater: Soils and Construction, Volume 2C Unsealed roads* (DECC) the following will be incorporated into the SWMP:

- **Location** – site tracks located to reduce the risk of sediment entering drainage lines, avoid perched water tables, maintain effective vegetative buffers and to be kept above flood levels
- **Grades** – tracks will have a slight grade to allow free surface drainage and to avoid ponding in wheel tracks
- **Surfacing** – in areas of steep terrain (>20% or 10 degrees) and dispersible soils bitumen or gravel surfacing may be required
- **Surface Drainage** – runoff will be prevented from concentrating and reaching erosive speeds; drain and channel linings may be required if flow velocities exceed erosive levels for the in-situ soil material; upslope clean water should be diverted away from disturbed areas through the use of catch drains and berm drains
- **Crossfall Drainage and Outlets** – outfall and/or infall drainage will be used for cross bank construction and located such that flow is not directed back onto the track
- **Earthworks** – disturbance of soil and vegetation will be minimised as much as possible, both on and adjacent to tracks and will follow land contours to minimise the amount of cut and fill
- **Drainage Line Crossing –**
    - Drainage lines will be crossed with culverts and will not obstruct flows or create turbulent flows that will cause erosion
    - Crossing approaches should be perpendicular (or nearly so) to the drainage line, unless using an angled approach for further reduced disturbance
    - Culvert inlets and outlets must be adequately protected
    - Maintenance of existing or natural hydraulic, hydrologic, geomorphic and ecological functions of the watercourse

- Stabilise and rehabilitate all disturbed areas in order to restore the integrity of the riparian corridor

- **Revegetation** – revegetation will be undertaken immediately following works and use locally native species as a base mix to stabilise soils to prevent erosion. In circumstances where 'Type D' soils are present and ecological values are low, a cover crop may be required using sterile seed sources

- **Maintenance** – inspection of all tracks regularly and following heavy traffic use or heavy rainfall will be undertaken as part of both the Construction and Operational Environmental Management Plans.

5.3 WORKS WITHIN RIPARIAN ZONES

There are over one hundred creek crossings associated with the project (including crossings by transmission lines). Of these, 23 are located on second order streams and six on third order or higher (Salters Creek, Long Gully, Tunnabidgee Creek, Sugarloaf Creek, Cow Flat Gully and Bombandi Creek). Crossings over second order creeks or higher will require more detailed design in order to comply with NoW Guidelines. NoW and DPI guidelines for river crossing design will be followed in the design and upgrading of any existing roads.

Hardstand areas for site office, concrete batching plants, rock crusher, substation and construction compounds should be located, where possible, outside of the CRZ to minimise construction and operational impacts on watercourse and riparian corridors. Requirements to be considered include but are not limited to;

- Drainage line crossings will not obstruct flows or create turbulent flows that will cause erosion
- Drainage line crossings will maintain existing or natural hydraulic, hydrologic, geomorphic and ecological functions of the watercourse
- The approach of drainage line crossings should be perpendicular (or nearly so) to the drainage line to reduce the disturbance distance
- Culvert inlets and outlets must be adequately protected
- Any stormwater outlets should aim to be 'natural', yet provide a stable transition from a constructed drainage system to a natural flow regime
- All ancillary drainage infrastructure e.g. sediment and litter traps should be located outside the riparian corridor. Runoff should be of an appropriate water quality and quantity before discharge into a riparian corridor or watercourse
- Discharge from an outlet should not cause bed or bank instability
- All stockpiles are to be located away from drainage lines, natural watercourses, road surfaces and trees and are to be appropriately protected to contain sediment and runoff e.g. sediment fencing
- All water run-off that contains high silt content should be filtered and flocculated before it drains from the site

- Changes to the quantity and quality of the receiving waters are to be monitored at suitable intervals (daily during construction, monthly during operation) to demonstrate that there is no adverse impact on discharge volumes or water quality parameters

- Regular inspection, maintenance and cleaning of water quality and sedimentation control devices.

5.4 FOOTINGS

Detailed geotechnical investigations will be required to ascertain the type and extent of footings, however soil management to avoid erosion and sedimentation will adhere to the mitigation measures detailed in the SWMP.

5.5 CONTAMINATION

Potential surface water and groundwater contamination may result from uncontained spillage of hazardous substances used at the substation and potentially from activities and vehicles on site during construction.

Where used, a concrete batching plant should be located outside the CRZ and away from creeks. The site should be bunded to contain any potential spills and controls used to prevent any loss of sediment or other contaminated material.

Design measures will be implemented for primary and secondary containment of any oil that may leak or spill from transformers or associated components, such as constructed concrete bunds around each transformer and a spill oil retention basin or oil/water separator outside the MCS compound.

Specifically in relation to the hydrology of the site, the following measures are required to be implemented as part of the SWMP:

- The establishment and operation of the concrete batching plants must be in accordance with the Environment Protection Authority's Environmental Guidelines for the Concrete Batching Industry and the Environment Protection Licence issued by OEH

- Concrete and cement carrying vehicles should be washed out in appropriate wash-down facilities off-site

- Management of hazardous materials, waste and sewage will ensure no contamination of water resources occur

- Refuse and rubbish is appropriately contained on-site

- Wastewater produced during construction from temporary onsite toilets to be stored before being trucked off site or disposed of via a septic or composting toilet system which complies with Council requirements and meets necessary health regulations

- Any hazardous products will be stored and transported appropriately in accordance with relevant DECCW and Workcover guidelines and regulations, to avoid release to the environment

- All hazardous materials are to be properly classified, stored away from flood prone areas and drainage lines. Appropriate spill kits and fire protection are to be provided on-site during construction.
- Any on-site refuelling must occur in an area greater than 100 m from the nearest drainage line and ensure correct practices are in place, including:
    - Refuelling to be carried out in a specified bunded area, according to regulatory requirements
    - Use of drip trays and spill mats
    - No refuelling to be carried out in the vicinity of a waterway.

5.6 MONITORING

Changes to the quantity and quality of the receiving waters are to be monitored at suitable intervals (daily during construction, monthly during operation) to demonstrate that there is no adverse impact on discharge volumes or water quality parameters.

Monitoring of low- and high-flow conditions should be regularly undertaken prior to the commencement of works to determine baseline water quality parameters.

Surface water monitoring locations should include:

- Crudine River (downstream of the confluence with Sugarloaf Creek)
- Cowflat Creek (upstream of confluence with Stinking Water Creek)
- Downstream of confluence with Tunnabidgee Creek and Long Gully
- Salters Creek (upstream of confluence with Tunnabidgee Creek).

6 Conclusions and Recommendations

The site is characterised by:

- Ephemeral drainage lines
- Soil types that are generally susceptible to erosion particularly when cleared of vegetation and when either the surface soil or the soil profile is disturbed
- Areas of steep gradient (in particular works on the eastern side of Crudine Ridge)
- Limited (if any) groundwater impacts (further assessment is required if rock anchor turbine footings are required)
- The absence of impacts to wetlands, groundwater dependent ecosystems and threatened species listed under the FM Act.

A number of activities associated with the wind farm development have the potential to impact the soils, hydrology and water quality of the area if not managed appropriately. A SWMP incorporated into the CEMP and OEMP will be required for the works.

This SWMP will include and adopt the principles of soil and water management and include the design of access roads, creek crossings, site drainage and erosion and sediment controls. The SWMP should contain a detailed design template utilising box culverts for road crossings of second order streams or higher (Salters Creek, Long Gully, Tunnabidgee Creek, Sugarloaf Creek, Cow Flat Gully and Bombandi Creek) in line with NoW guidelines.

Additional soils information (obtained from laboratory soil testing such as particle size distribution and dispersibility) is necessary for the preparation of a SWMP as this will influence the type and extent of control measures required in accordance with the NoW guidelines and the 'Blue Book' (Landcom 2004). Options for water sourcing are still being considered. Where possible, water shall be sourced locally, with alternative water sources including the Crudine or Turon Rivers and Windermere Dam. All water sourcing will be done in accordance with licensing requirements under the WM Act and relevant WSPs through NoW. Access points will be determined post-consent on award of construction contracts.

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Appendix A:

Geology underlying the proposed Crudine Ridge Wind Farm

PARENT PROVINCE	GEOLOGICAL SUBPROVINCE	FORMATION	PROJECT CONTEXT	DOMINANT LITHOLOGY	OVERLYING SOIL
Hill End - Ngunnawal	Hill End Sub province	Cunningham	Southern turbine section	Phyllite, slate, shale, siltstone, sandstone, tuff	Mookerawa and Mullion Creek
		Merrions	Intersects midway along southern turbine section	Sandstone, rhyodacite, conglomerate, siltstone, tuff	Mullion Creek and Burrendong
		Turondale	Northern turbine section and western end of north-eastern arm Transmission lines only	Sandstone, siltstone, conglomerate	Mookerawa, Mullion Creek and Burrendong
		Waterbeach	Northern turbine section and midway down southern turbine section	Siltstone, shale, sandstone	Mullion Creek and Mookerawa
		Guroba	End of north western arm is within close proximity	Sandstone	Mullion Creek
		Cookman	Midway along north-eastern arm Transmission lines only	Sandstone, siltstone, slate	Mookerawa, Mullion Creek and Burrendong
		Piambong	Midway along north-eastern arm Transmission lines only	Rhyolite, sandstone, siltstone, breccia, tuff	Mookerawa, Mullion Creek and Burrendong
	Capertee Subprovince	Aaron's Pass Granite	At the end of the north-eastern arm Transmission lines only	Granite	Aaron's Pass
		Undifferentiated	At the end of the north-eastern arm Transmission lines only	Conglomerate, sandstone, shale, siltstone, claystone	Aaron's Pass

HEAD OFFICE
Suite 4, Level 1
2-4 Merton Street
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

SYDNEY
Level 6
299 Sussex Street
Sydney NSW 2000
T 02 9993 0566
F 02 9993 0573

ST GEORGES BASIN
8/128 Island Point Road
St Georges Basin NSW 2540
T 02 4443 5555
F 02 4443 6655

CANBERRA
Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 6103 0148

NEWCASTLE
Suite 17, Level 4
19 Bolton Street
Newcastle NSW 2300
T 02 4910 0125
F 02 4910 0126

NAROOMA
5/20 Canty Street
Narooma NSW 2546
T 02 4476 1151
F 02 4476 1161

COFFS HARBOUR
35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

ARMIDALE
92 Taylor Street
Armidale NSW 2350
T 02 8081 2681
F 02 6772 1279

BRISBANE
93 Boundary St
West End QLD 4101
T 1300 646 131

PERTH
Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 08 9322 1358

WOLLONGONG
Suite 204, Level 2
62 Moore Street
Austinmer NSW 2515
T 02 4201 2200
F 02 4268 4361

GOSFORD
Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1220
F 02 4322 2897