APPENDIX 21

Bango Wind Farm Water and Soil Assessment

Bango Wind Farm Pty Ltd

UPDATES TO THE ENVIRONMENTAL IMPACT STATEMENT

During the preparation of this Environmental Impact Statement, a number of changes occurred.

Please consider these changes while reviewing this Appendix.

- The Assessment Type of the Bango Wind Farm has transitioned from Part 3A, after its repeal, and is now being assessed as a State Significant Development under Part 4 of the EP&A Act. Any reference to a Part 3A assessment in attached technical assessments may be disregarded, and considered as State Significant Development;

- Rugby Wind Farm, a wind farm that was proposed to the north of the Project has been withdrawn. Where references are made to cumulative impacts with the Rugby Wind Farm, please disregard these;

- Slight changes have occurred to the Rye Park Wind Farm layout, a wind farm under development to the east of the Project. The changes made to the layout are not significant and therefore sit within the cumulative impact assessment undertaken for this EIS. The revised layout has been considered in the Environmental Noise Assessment and Landscape Visual Impact Assessment. Where further references are made to the Rye Park Wind Farm layout, these will be incorporated into future documentation where required;

- Four turbines at the south east extent of the Project, situated in the Mt Buffalo cluster have been removed through consultation with landowners. This change has been highlighted in maps and a review of all technical assessments has deemed that the removal of the four turbines has resulted in a reduced. This change will be incorporated into future documentation. These wind turbines are identified as “removed wind turbines” in the Project maps in Volume 2; and

- A number of changes were made to the residence information for the Project, as a result of construction of houses and change in occupancy status of existing buildings. These changes have been incorporated into the EIS.

Bango Wind Farm

Soil and Water Assessment

April 2013

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1 Introduction

1.1 Report objectives

This report has been prepared to assess potential impacts to soil and water resources by the proposed Bango Wind Farm. It is important to note that this report is not designed to be a stand-alone document, but rather part of the Bango Wind Farm Environmental Assessment (EA) prepared by Wind Prospect CWP Pty Ltd (WPCWP).

The aim of this report is to address the Director General's Requirements (DGRs) issued by the Department of Planning and Infrastructure (DoPI) and additional agency requirements provided by the NSW Office of Water (NOW) and the Department of Industry and Investment (DII) that relate to water quality and hydrology, excluding those related to water supply. Specifically, these are:

- Assess potential environmental impacts associated with the use of the identified water sources including impacts on groundwater and implications for existing licensed users/basic landholder rights (DoPI);
- Assess the potential to intercept groundwater, including predicted dewatering volumes, zone of drawdown and associated impact, water quality and disposal methods (DoPI);
- Where the project involves crossing or works close to waterways, identify likely impacts to the waterways, how the waterways are proposed to be crossed and be designed in accordance with the NSW Office of Water *Guidelines for Controlled Activities* (August 2010) (DoPI);
- Describe the measures to minimise hydrological, water quality, aquatic and riparian impacts (DoPI);
- Identify how works within steep gradient land or highly erosive soil types will be managed during construction and operation (DoPI);
- Identification and assessment of any cumulative impacts which may occur as a result of the proposed wind farm development (DoPI);
- An assessment of impact of tower construction due to blasting, road and crossing construction, and underground cable installation on adjacent licenced water users, basic landholder rights and groundwater dependant ecosystems (NOW);
- An assessment of watercourses to be crossed and selection of appropriate techniques and mitigating measures to minimise impact. Design and construction works within 40m of watercourses are to be in accordance with "NSW Office of Water Guidelines for Controlled Activities (August 2010)". Significant watercourses in terms of hydrological and hydraulic characteristics or high sensitivity due to ecological or stability characteristics need to be protected though directional drilling techniques where underground cabling is required. Temporary and permanent vehicle crossings would also need to be assessed within the EA and constructed in accordance with the Office's Guidelines for Controlled Activities (NOW)
- Details of the predicted highest groundwater table at the development site (NOW);
- Details of any works likely to intercept, connect with or result in pollutants infiltrating into groundwater sources (NOW);
- Details of the predicted impact of any final landform on the groundwater regime (NOW);

- Details of how the proposed development will not potentially diminish the current quality of groundwater, both in the short and long term (NOW);
- Quantification of impacts on groundwater dependant ecosystems (NOW);
- Details of stream order (using the Strahler system) (NOW)

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) have either been addressed within the EA document or will be addressed as part of the Soil and Water Management Plan (SWMP) (see below) and hence are not included in this report. These DGRs are:

- Identify water sources (surface and groundwater), water disposal methods and water storage structures in the form of a water balance (DoPI);
- Include the statutory (licensing) context of the water supply sources (DoPI);
- Adequate mitigating, monitoring and contingency requirements to address surface water impacts (NOW);
- Demonstrate adequate and secure water supply for the proposal. Confirmation that water supplies for construction and associated activities are sources from an appropriately authorised and reliable supply (NOW);
- Identification of site water demands, water sources (surface and groundwater), water disposal methods and water storage structures in the form of water balance. This is also to include any details water reticulation infrastructure / vehicles that supply water to the site (NOW);
- A description and assessment of any potential requirements to intercept groundwater, zone of drawdown and associated impact, water quality and disposal methods (NOW);
- Existing and proposed water licensing requirements are in accordance with the *Water Act 1912* and / or the *Water Management Act 2000* (whichever is relevant) and the NSW Inland Groundwater Storages Zones Order No. 1 & 2, 2008 (19 December 2008). This is to demonstrate that existing licences (include licence numbers) and licensed uses for *Water Act* licences are appropriate, and to identify where additional licences are proposed (NOW).
- Details of proposed groundwater extraction; including purpose, location and construction details of all proposed bores and expected annual extraction rates (NOW);
- Describe the flow directions and rates and the physical and chemical characteristics of the groundwater source (NOW);
- Details of the existing groundwater users in the area (including the environment) and include details of any potential impacts on these users (NOW);Assessment of the quality of groundwater for the local catchment (NOW);
- Details on preventing groundwater pollution so remediation is not required (NOW);
- Details on protective measures to minimise any impacts on groundwater dependant ecosystems (NOW);
- Details of proposed methods of disposal of the waste water and approval from the relevant authority (NOW);
- Assessment of the potential for saline intrusion of the groundwater and measures to prevent such intrusion into the groundwater aquifer (NOW);

- Details of the results of any models or predictive tools used to predict groundwater drawdown, inflows to the site and impacts on affected water sources.
- Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependant groundwater environment or water users (NOW);
- All proposed groundwater works must be identified in the proposal and an approval obtained from the Office prior to their installation (NOW);
- All predicted groundwater extractions must be accounted for though adequate licensing (NOW);
- Identify sources of surface water (NOW);
- Details of any proposed surface water extraction, including quantity, purpose, location fo existing pumps, dams, diversions, cuttings and levees (NOW);
- Details of available surface water licences that could be purchased to account for any proposed extractions (NOW);
- Detailed description of any proposed development or diversion works including all construction, clearing, draining, excavation and filling (NOW);
- An assessment of the proposed methods of excavation, construction and material placement on the watercourse and associated vegetation (NOW);
- A detailed description of all potential water related environmental impacts of any proposed development in terms of riparian vegetation, sediment movement, water quality, hydrologic regime (NOW);
- A description of the design features and measures to be incorporated into any proposed development to guard against anything more than minimal long term actual and potential environmental disturbances, particularly in respect of maintaining the natural hydrologic regime and sediment movement patterns and the identification of riparian buffers (NOW);
- Details of the impact on [surface] water quality and remedial measures proposed to address more than minimal adverse effects (NOW)

It is important to note that this report constitutes a desktop assessment using published maps and reports. Prior to construction activities a site specific geotechnical assessment must be undertaken and a Construction Environmental Management Plan (CEMP), an Operation Environmental Management Plan (OEMP) and a Soil and Water Management Plan (SWMP) prepared. Since the DGRs were received, the NSW Office of Water *Guidelines for Controlled Activities* (August 2010) have been updated. The most recent version, *Guidelines for Riparian Corridors on Waterfront Land*, came into effect on 1st July 2012. The rules contained within the 2012 guidelines have been used in this report.

1.2 Project location

The proposed Bango Wind Farm (the Project) is located in the Tablelands region of New South Wales, approximately 20km north of Yass, approximately 7km south-east of Boorowa and approximately 17km northeast of Binalong. Two boundaries have defined for the Project: the Project Site (encompasses the entirety of all cadastral parcels that intersect infrastructure features associated with the Project) and the Study Area (a buffer zone of approximately 200 metres around all infrastructure associated with the Project and the area of investigation for field work) (**Figure 1.1**). The Project Site:

- is within the Lachlan Catchment Management Authority (CMA) region (Upper Slopes sub-region);
- spans two local government areas (LGAs): Boorowa LGA and Yass Valley LGA; and
- is within two IBRA (Interim Biogeographic Regionalisation of Australia) regions: NSW South Western Slopes (sub-region: Northern Inland Slopes Upper Slopes) and South Eastern Highlands (subregion: South Eastern Highlands).

The Project comprises three 'Clusters' of wind turbines, the Project Site and Study Area. The Mt Buffalo Cluster incorporates the east of the Project, the Kangiara Cluster incorporates the centre of the project, with the Langs Creek Cluster incorporating the north west of the Project. The Project Site has been defined as land within the cadastre boundaries of all properties subject to this proposal, comprising an area of 7,683 ha. The Study Area has been defined as a 200 m wide corridor in which all proposed infrastructure will be contained, comprising an area of 1,888 ha. Rolling hills to the east and agricultural plains to the west form the landscape of the Project Site. The majority of native vegetation has been partially or fully cleared for grazing and a small amount of cropping. Some patches of woodland and open forest remain, however these are predominantly restricted to poorer soils.

1.3 Project description

Two potential turbine layouts will be submitted to DoPI for the EA:

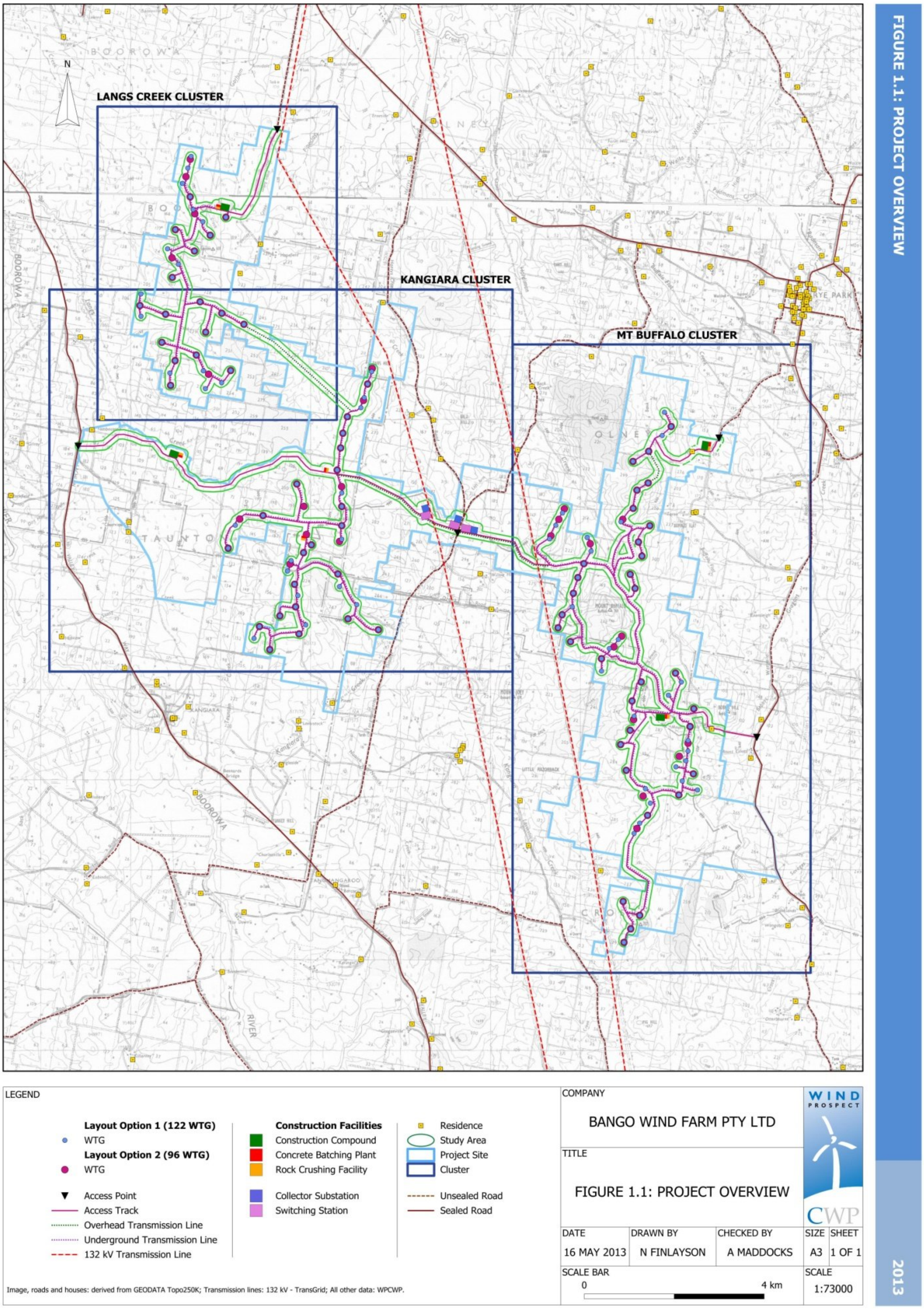
- Layout 1: Up to 122 wind turbine generators. The largest tower height under consideration is 120 m with a maximum rotor diameter of 144m. Alternative tower heights between 80 and 120 m are also under consideration
- Layout 2: Up 96 wind turbine generators. The largest tower height under consideration is 120 m with a maximum rotor diameter of 144m. Alternative tower heights between 80 and 120 m are also under consideration

Associated infrastructure including

- 6 m access tracks, passing bays and hardstand areas suitable for cranes
- Approximately 61 km of up to 66 kV underground transmission lines and control cables;
- Overhead transmission lines with easements of varying widths:
  - 0.86km of single circuit 33kV line with easement width of 30m;
  - 7.82km of double circuit 33kV line with easement width of 45m; and
  - 0.65km of double circuit 33kV and 132kV with easement width of 75m
- One 150 by 150 m collector substation;
- One 220 by 160 m switching station at point of connection;
- One or more operation facilities building to house control and communications equipment
- Wind monitoring masts
- Temporary construction facilities (site compound and office, mobile concrete batching plants, rock crushing facilities)
- Connection to TransGrid's 330 kV transmission network

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

Figure 1.1: Project Overview



2 Regulatory context

2.1 NSW Legislation

The key piece of legislation relating to surface water and groundwater management in NSW is the *Water Management Act 2000* (*WM Act*). The key pieces of legislation relating to soil management are the *WM Act* and the *Protection of the Environment (Operations) Act 1997 (POEO Act).* Other relevant pieces of NSW legislation include:

- *Soil Conservation Act 1938 (SC Act)*
- *Water Act 1912*
- *Environmental Planning and Assessment Act 1979 (EP&A Act)*
- *Fisheries Management Act 1994 (FM Act)*
- *Contaminated Land Management Act 1997 (CLM Act)*
- *Water Management (General) Regulation 2011 (WM Regulation)*

The *WM Act* provides the statutory framework for managing water in NSW, recognising the need to allocate water for environmental flows and groundwater systems, while providing licence holders with secure access to water and opportunities to trade water through the separation of water licences from land (NOW 2013a). In relation to soils management it states that:

- The WM Act aims to *integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna* (Chapter 1 Section 3f)
- Water use / drainage activities / floodplain management / controlled activities / aquifer interference activities "*should avoid or minimise land degradation, including soil erosion, compaction, geomorphic instability, contamination, acidity, waterlogging, decline of native vegetation or, where appropriate, salinity and, where possible, land should be rehabilitated*"(Chapter 2 Part 1 Division 1 Section 5)

The *Water Act 1912* is being progressively phased out and replaced by the *WM Act*. Some provisions are still in force

The *Water Act 1912* is being progressively phased out and replaced by the *WM Act. The Act* now has only a limited role in regulation limited to the issue of new water licences and the trade of water licences and allocations in those water sources (rivers, lakes and groundwater aquifers) in NSW where water sharing plans have not commenced. The Act will be repealed in its entirety once the whole of the *WM Act* becomes operational.

The *POEO Act* regulates water and land pollution, which may cause contamination (EDO 2012a). It enables the creation of explicit protection of the environment policies (PEPs) and provides a single licensing arrangement for environment protection licenses issued by the Environment Protection Authority (EPA).

The *CLM Act* regulates seriously contaminated sites in NSW and establishes a process for the EPA to identify, investigate and (where appropriate) order the remediation of land if the EPA considers the land to be significantly contaminated (EDO 2012a)

The *SC Act* provides for the conservation of soil and farm water resources and for the mitigation of erosion.

The *EP&A Act* is the is the regulatory framework governing urban planning. The Act requires the relevant control authority to take into consideration the impacts of a proposed development or land-use change on the natural and built environment and the community.

The *FM Act* provides the regulatory framework for managing NSW's fisheries resource and sets out the legal requirements for commercial and recreational fishing and aquaculture activities. It also provides for the conservation of certain fish and fish habitat and includes a management framework for threatened fish and marine vegetation species and their habitats (Industry and Investment NSW 2010).

The *WM Regulation* contains details of exemptions to the requirement to hold a controlled activity approval. In particular it creates an exemption from the need for an approval under the *WM Act* for the construction or use of certain water supply works that are included in a project under the *SC Act.*

2.2 Policies and plans

Numerous policies and plans relate to soil and water management within NSW. The following table includes those policies listed in the DGRs, and issued by NOW as well as policies listed by ELA (2011) and EDO (2012b) (**Table 2.1**). Of the policies listed in the NOW DGRs, several are not relevant to the Bango Project. These include the *NSW Inland Groundwater Shortage Zones Embargo Order 1 and 2* (December 2008) – not relevant as the project area is not located within any of the groundwater management areas or parishes listed in the Embargo; the *Murray Darling Basin Section 22B Embargo Order on Part 2 applications under the Water Act 1912* - not relevant as two water-sharing plans have commenced within the Project Area; *Guideline to the Policy for Groundwater Transfers in Inland NSW Outside Water Sharing Plan Areas* (August 2009) - not relevant as two water-sharing plans have commenced within the Project Area; and *State Environmental Planning Policy No 52—Farm Dams and Other Works in Land and Water Management Plan Areas* (2008) – not relevant as no dams are proposed to be constructed as part of the Project. It should be noted that the Catchment Action Plan for the Lachlan Catchment has been recently upgraded by the Lachlan Catchment Management Authority and was submitted to Minister Hodgkinson on the 1st February 2013.

Table 2.1: Policies and plans relevant to the Project

Policy / Plan	Aim / Objectives	Relevance to Bango Wind Farm
NSW State Rivers and Estuaries Policy (1991)	Aims to manage the rivers of NSW in ways which: slow, halt or reverse the overall rate of degradation in their systems; ensure the long-term sustainability of their essential biophysical functions; maintain the beneficial use of their resources. It is a framework policy primarily directed at the broad regulatory, informational and operational environments of resource management agencies and applies to rivers and estuaries and adjacent riverine plains. Describes six broad principles to achieve the policy aims and provides for a set of ten component polices.	Broad principles for managing construction and operation to minimise the effect on watercourses
NSW Sand and Gravel Extraction Policy for Non-Tidal Rivers (1992)	A component policy of the NSW State Rivers and Estuaries Policy 1991. Aims to ensure that extraction of sand and gravel from the state's non-tidal rivers is undertaken on a sustainable use basis; to manage the extraction in such a way which minimises any detrimental effects on the riverine environment; to ensure that the policy is	Relevant if sand or gravel needs to extracted from watercourses for construction.

Policy / Plan	Aim / Objectives	Relevance to Bango Wind Farm
	consistent with the aims of other government policies and initiatives. Scope of management strategies outlined in the policy are limited to extraction of sand and gravel from active river channels.	
NSW Weir Policy (1997)	Halt and where possible, reduce and remediate the environmental impacts of weirs	Construction / upgrade of access tracks over watercourses. Crossings must not impede natural water flows.
NSW State Groundwater Policy Framework Document (1997)	Adoption of the State Groundwater Policy means that the sustainability of groundwater resources and their ecosystem support function will be given explicit consideration in resource management decision making (DLWC 1997).	Impacts of construction and operation on groundwater need to be to be identified and avoided or minimised where possible. This includes soil contamination.
NSW Groundwater Quality Protection Policy (1998)	The Groundwater Quality Protection Policy is specifically designed to protect groundwater resources against pollution. Adoption of the State Groundwater Policy, means that the sustainability of groundwater resources and their ecosystem support functions will be given explicit consideration in resource management decision making (DLWC 1998).	Impacts on groundwater flow and quality during construction and / or operation should be avoided if possible or minimised. This includes containing pollutants and avoiding disruption to groundwater flow
Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (1999)	Prepared by NSW Fisheries in order to improve the conservation and management of aquatic habitats in NSW. It is targeted at local and state government authorities, proponents of developments and their advisors, and individuals or organisations concerned with the planning and management of our aquatic resources, including conservation organisations (NSW Fisheries 1999). Contains descriptions of important freshwater, estuarine and marine fish habitats, and developments that may impact upon them. It also contains NSW Fisheries' legal requirements, policies and application forms for a number of activities (NSW Fisheries 1999).	Guidelines should be consulted when making planning and construction decisions, particularly in relation to watercourses within the Study Area and along access routes.
Advice to Water Management Committees No. 8 Groundwater Quantity Management (undated)	This document is a cut down version of the 2003 NSW Groundwater Quantity Management Policy, which was never released (G. Smith, pers. comm.). This document aims to achieve the efficient, equitable and sustainable use of the state's groundwater via 14 principles that outline how groundwater resources shall be utilised and monitored.	The 14 principles in the policy should be consulted when making planning and construction decisions, particularly in relation to excavation activities within the Study Area and along access routes.
NSW State Groundwater Dependent Ecosystem Policy (2002)	The Groundwater Dependent Ecosystem Policy specifically sets out a process by which the water management plans prepared by water management committees will apply the principles of the Policy at a local level, identify and classify groundwater dependant ecosystems and ensure that water is provided to meet environmental needs and the needs of present and future users (DLWC 2002)	Impacts on groundwater dependant ecosystems during construction and / or operation should be avoided if possible or minimised. This includes containing pollutants, avoiding disruption to groundwater flow and undertaking rehabilitation works if

Policy / Plan	Aim / Objectives	Relevance to Bango Wind Farm
		necessary
NSW Water Quality and River Flow Objectives for the Lachlan River Catchment (2006)	Lists the water quality and river flow objectives for the Lachlan River catchment, which should be used to develop plans and actions affecting water quality and river health (DECCW 2006). The Boorowa River and surrounding streams are categorized as uncontrolled streams with largely natural flow patterns. Water quality objectives are the protection of aquatic ecosystems, visual amenity, primary and secondary contact recreation, water supply for livestock, irrigation, homesteads and drinking, and cooked aquatic foods. River flow objectives are protect pools in dry times, natural low flows, important rises in water levels, maintain wetland and flood plan inundation, manage groundwater for ecosystems and minimise the effects of weirs and other structures (DECCW 2006).	Should be consulted when making planning and construction decisions.
NSW Wetlands Policy (2010)	Protect and sustainably manage a statewide network of wetlands by setting priorities for wetland programs, supporting integrated water management in the Murray Darling Basin, and complement the existing statutory framework relating to wetlands (DECCW 2010a)	Consideration must be given to loss of riparian vegetation, biodiversity and impacts on water quality
NSW Policy for Managing Access to Buried Groundwater Sources (2011)	Sets out a framework for how access to water will be managed in groundwater sources that are fully buried or partly buried. Specifically it outlines the limits to access to water from storage in porous rock groundwater sources excluding the groundwater sources of the Great Artesian Basin and provides the licensing and approval requirements for the take of water from all contributing water sources.	The Project Site overlies the Lachlan Fold Belt Groundwater Management Area – a fully buried groundwater source.
Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources (2012)	Water sharing plans are prepared under the *WM Act*, and establish rules for sharing water between the environmental needs of the river or aquifer and water users, and between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation. The Lachlan Unregulated Plan covers 22 unregulated surface water sources that are grouped into one extraction management unit and two alluvial groundwater sources (Upper Lachlan and Belubula Valley). The plan does not cover the regulated reaches of the Lachlan River nor the fractured rock aquifers, porous rock aquifers and the alluvial aquifers of the lower Lachlan catchment. These water sources are covered in other water sharing plans.	A water licence will be required if the Project proposes to extract water from watercourses.
Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources (2012)	The MDB Fractured Rock Plan area includes all fractured rock groundwater sources and miscellaneous, unmapped alluvial sediments that overly outcropping fractured rock groundwater sources as well as porous rock sediments that occur within groundwater sources that are predominantly fractured rock that are not included in other water sharing plans. Ten groundwater sources are covered by the plan, including the Lachlan Fold Belt province. The Plan provides greater certainty for water users and clear trading and access rules, protection for groundwater sources from over-extraction, and imposes	A water licence will be required if the Project proposed to extract water from the Lachlan Fold Belt groundwater source.

Policy / Plan	Aim / Objectives	Relevance to Bango Wind Farm
	new restrictions on access that may be applied to specific areas that need protection or to manage groundwater surface water connectivity.	
NSW Office of Water Guidelines for Controlled Activities on Waterfront Land (2012)	The assessment is required to take into account the following NOW guidelines: • In-stream works • Laying pipes and cables in watercourses • Outlet structures • Riparian corridors • Vegetation Management Plans • Watercourse crossings	Guidelines should be consulted when making planning and construction decisions, particularly in relation to watercourses within the Study Area and along access routes.
NSW Office of Water Guidelines for Riparian Corridors on Waterfront Land (2012)	Provides guidance on new rules regarding controlled activities on waterfront land and in riparian corridors. Defines a riparian corridor, provides a methodology for calculation of their width, and includes matrix that enables applicants to identify certain works and activities that can occur on waterfront land and in riparian corridors (NOW 2012).	Guidelines should be consulted when making planning and construction decisions, particularly in relation to watercourses within the Project area and along access routes.
NSW Aquifer Interference Policy (2012)	Clarifies the requirements for obtaining water licences for aquifer interference activities under NSW water legislation, and establishes and objectively defines considerations in assessing and providing advice on whether more than minimal impacts might occur to a key water-dependent asset.	If any aquifer (a groundwater system that is sufficiently permeable to allow water to move within it) is penetrated or dewatered for construction purposes this Policy applies.

3 Methodology

3.1 Desktop review

The following databases and resources were used to compile information for this report:

- Bureau of Meteorology climate averages;
- Soil Landscapes of the 1:250,000 Goulburn mapsheet;
- NSW Mitchell Landscapes;
- Geological mapping of the 1:100,000 Boorowa and Yass mapsheets; and
- Surface water monitoring stations and groundwater bore locations from NSW Office of Water.

3.2 GIS Analysis

3.2.1 Stream definition and stream order

In accordance with the NSW Office of Water (NOW) guidelines for riparian corridors on waterfront land, the 1:25,000 (where applicable) and 1:50,000 (where applicable) Digital Topographic Database mapping has been used to define streams within the Project Site. Each stream has been categorised by NOW using the Strahler Stream Order hierarchy. According to this hierarchy, a first order stream is the smallest and almost always ephemeral. As water flows down the catchment, and streams converge, the stream order number increases.

Using the Strahler number, the guidelines for riparian corridors on waterfront land (NOW 2012) recommend variable widths for vegetated riparian zones (VRZs) (**Table 3.1** and **Figure 3.1**). Streams within the Project Site were buffered to the maximum distance specified in the guidelines to create VRZs within the GIS. It is worth noting that streams have been mapped as lines and thus have no channel width within the GIS. As a consequence, VRZs are likely to be wider on the ground, to accommodate the variable width of the channel.

Table 3.1 Recommended vegetated riparian zone widths under the *Water Management Act 2000* (NOW 2012)

Watercourse type (Strahler number)	VRZ width (metres) (each side of watercourse)	Total Riparian Corridor width (metres) (plus channel width)
1st order	10	20
2nd order	20	40
3rd order	30	60
4th order and greater	40	80

*Includes estuaries, wetlands and any parts of rivers influenced by tidal waters

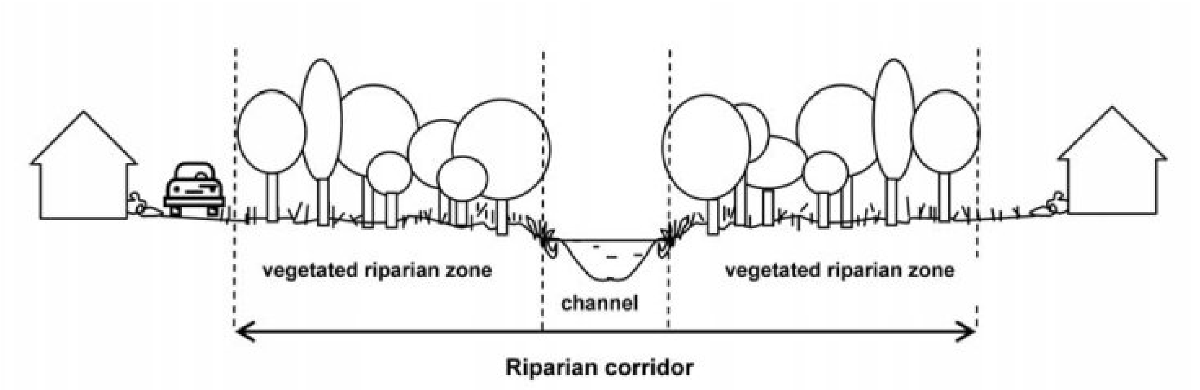


Figure 3.1: Riparian corridor and Vegetated Riparian Zones (NOW 2012)

3.2.2 Groundwater

The relevant Groundwater Management Areas were identified using GIS data created by ABARES (2012). The average upper limit of the water bearing zone (WBZ) of groundwater bores that intersect the Study Area or are within approximately 500m of the Study Area was determined using data from OEH (2013). The average WBZ for the Study Area was compared to expected excavation depths during construction primarily associated with the turbine footings to determine if there is likely to be any interaction with groundwater layers as a result of the development.

4 Climate

The Bango Wind Farm Project area is located on the boundary of the South Western Slopes and South Eastern Highlands bioregions of NSW. The local climate is characteristic of the South Eastern Highlands bioregion: temperate with warm summers and no dry season (OEH 2011). Rainfall is reasonably evenly distributed throughout the year, with slightly less rainfall recorded between February and May (Bureau of Meteorology 2013).

A summary of climate data from Kangiara (Laverstock) (Station No 73023, elevation 560 m), Boorowa Post Office (Station No 70220, elevation 488 m) and Yass (Linton Hostel) (Station No 70091, elevation 520 m) from the Bureau of Meteorology (Bureau of Meteorology 2013) is presented in **Table 4.1**.

Table 4.1 Annual weather conditions (BoM 2013)

Weather Conditions	Measurements	
	Kangiara (Laverstock)	**Boorowa Post Office**
Annual mean rainfall	689.5 mm	612.6 mm
Highest mean monthly rainfall	66.4 mm (July)	57.9 mm (October)
Lowest mean monthly rainfall	43.7 mm (February)	42.7 mm (February)
	Yass (Linton Hostel)	**Boorowa Post Office**
Annual mean minimum / maximum temperature	7.2 °C / 20.7 °C	5.1 °C / 19.3 °C
Highest mean monthly maximum temperature	29.5 °C (January)	26.1 °C (January)
Lowest mean monthly minimum temperature	1.1 °C (July)	-3.2 °C (June)

The Wellington (Agrowplow) Station (Station No 65034, elevation 305 m) is the closest station with records for the annual number of clear, cloudy and rainy days. Data recorded at this station indicates an annual average of 138.1 clear days, 91.9 cloudy days and 61.4 days with rainfall greater than or equal to 1mm (BoM 2013).

5 Landforms and Geology

5.1 Topography and Land capability

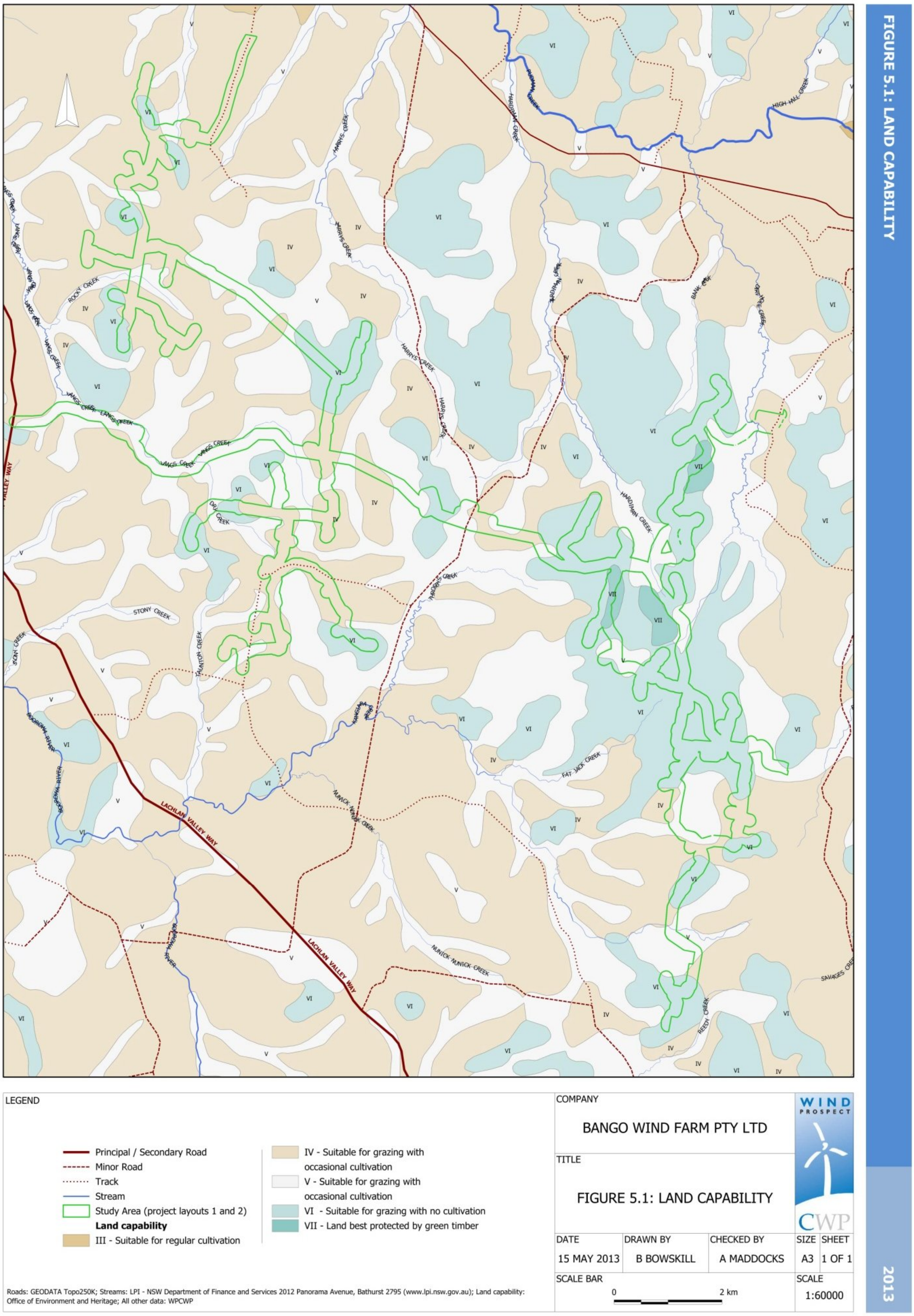
Rolling hills dominate the landscape of the Study Area. Approximately 4% of the Study Area has slopes greater than 15%, these mostly occur in the Mt Buffalo Cluster.

Five land capability classes intersect the Study Area (Emery 1986) (**Table 5.1** and **Figure 5.1**). Capability classes categorise land in terms of its general limitations and are based on an assessment of the biophysical characteristics, the extent to which these will limit a particular type of land use, and the current technology that is available for the management of land (Emery 1986).

Table 5.1: Land capability classes mapped within the Study Area (Emery 1986)

Class	Description	Interpretation and Implications
III	Suitable for regular cultivation	Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotation.
IV	Suitable for grazing with occasional cultivation	Soil conservation practices such as pasture improvement, stock control, application of fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture.
V	Suitable for grazing with occasional cultivation	Structural soil conservation works such as absorption banks, diversion banks and contour ripping, together with the practices as in Class IV.
VI	Suitable for grazing with no cultivation	Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. May include some isolated structural works.
VII	Other	Land best protected by green timber.

Figure 5.1: Land capability



The most widespread land capability class within the Project area is IV, followed by VI, III, V and VII in descending order. The majority of land classified as IV occurs in the Langs Creek and Kangiara Clusters, with small occurrences in the Mt Buffalo Cluster in areas with slopes less than 15%.

Almost all areas with slopes greater than or equal to 15%, have a land capability value between V and VII. Other areas in the Langs Creek and Kangiara Clusters with land capability values of V or VI have slopes less than 15%, indicating that a range of factors, including slope, determine the capability value

5.2 Mitchell Landscapes

Mitchell Landscapes, otherwise known as NSW Landscapes, are defined ecosystem units based upon geologic, geomorphic and pedologic (soil) factors (Mitchell 2002a).

One Mitchell landscape intersects the Project area: Boorowa Volcanics. This landscape consists of undulating low hills and rocky rises and has a general elevation 550 to 650 metres above sea-level, with peaks to 780 metres (Mitchell 2002b). The geology consists of Silurian dacite, crystal tuff, andesite and minor sandstone. Soils are described as red and yellow gradational earths, and yellow structured loams, thin stony loams within rock outcrops (Mitchell 2002b). The predominant vegetation is a grassy woodland of yellow box (*Eucalyptus melliodora*), grey box (*Eucalyptus microcarpa*), Blakely's red gum (*Eucalyptus blakelyii*), red stringy bark (*Eucalyptus macrorhyncha*) with the occasional kurrajong (*Brachychiton populneus*) (Mitchell 2002b).

5.3 Geology

Two geological maps cover the Study Area:

- Yass 1:100 000 Geological Sheet (Colquhoun *et al.* 2008)
- Boorowa 1:100 000 Geological Sheet (Johnson *et al.* 2002)

The geology of the Study Area is uniform, consisting of one formation, namely the Silurian / Devonian Hawkins Volcanics Unit of the Douro Group. Slight variations in the geology within this formation are expressed via different map codes described in **Table 5.2** and illustrated in **Figure 5.2**.

Table 5.2: Geological variations within the Hawkins Volcanics Unit

Map Code	Geological description
Qa / Sdh	Alluvial gravel, sand, silt and clay overlying biotite-cordierite-garnet rhyolitic to dacitic ignimbrite. Flow-banded, vesicular rhyodacitic to dacitic lava, volcanic sandstone, minor rhyodacitic agglomerate and rhyolitic lapilli tuff are also present
Qc / Sdh	Colluvial gravel, sand and silt overlying biotite-cordierite-garnet rhyolitic to dacitic ignimbrite. Flow-banded, vesicular rhyodacitic to dacitic lava, volcanic sandstone, minor rhyodacitic agglomerate and rhyolitic lapilli tuff are also present
Qr / Sdh	Residual-eluvial-saprolite deposits overlying biotite-cordierite-garnet rhyolitic to dacitic ignimbrite. Flow-banded, vesicular rhyodacitic to dacitic lava, volcanic sandstone, minor rhyodacitic agglomerate and rhyolitic lapilli tuff are also present
Sdh	Biotite?cordierite?garnet rhyolitic to dacitic ignimbrite. Flow-banded, vesicular rhyodacitic to dacitic lava, volcanic sandstone, minor rhyodacitic agglomerate and rhyolitic lapilli tuff are also present.

Figure 5.2: Geological formations

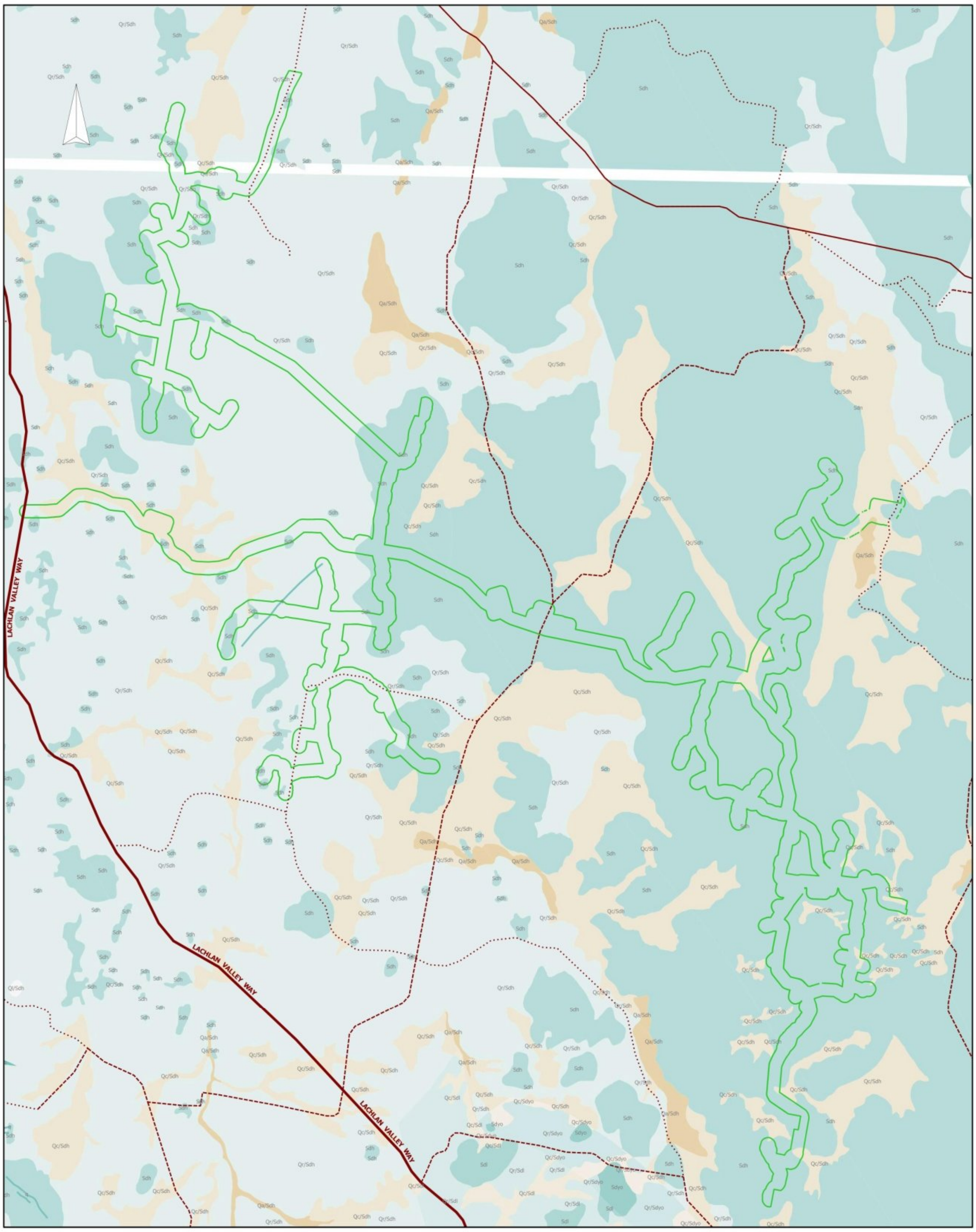


FIGURE 5.2: GEOLOGICAL FORMATIONS

LEGEND

- Principal / Secondary Road
- Minor Road
- Track
- Study Area (project layouts 1 and 2)

GEOLOGY: DOURO GROUP

- Qa/Sdh - Alluvial gravel, sand, silt and clay overlying biotite-cordierite-garnet rhyolitic to dacitic ignimbrite
- Qc/Sdh - Colluvial gravel, sand and silt overlying biotite-cordierite-garnet rhyolitic to dacitic ignimbrite
- Qr/Sdh - Residual-eluvial-saprolite deposits overlying biotite-cordierite-garnet rhyolitic to dacitic ignimbrite
- Sdh - Biotite?cordierite?garnet rhyolitic to dacitic ignimbrite

Roads: GEODATA Topo250K; Geology: Department of Trade and Investment - Resources and Energy; All other data: WPCWP

COMPANY				
BANGO WIND FARM PTY LTD				
TITLE				
FIGURE 5.2: GEOLOGICAL FORMATIONS				
DATE	DRAWN BY	CHECKED BY	SIZE	SHEET
15 MAY 2013	B BOWSKILL	A MADDOCKS	A3	1 OF 1
SCALE BAR			SCALE	
0 — 2 km			1:60000	

WIND PROSPECT CWP

2013

6 Soils

6.1 Soil landscapes

Three soil groups divided into four soil landscapes underlie the Study Area (**Table 6.1** and **Figure 6.1**). For the purposes of mapping the soils of the Goulburn 1:250,000 mapsheet, Hird (1991) has described a soil landscape as a tract of land with a relatively uniform landform pattern, climate, parent material and array of soil classes.

Table 6.1: Soil groups and soil landscapes that intersect the Study Area (Hird 1991)

Great Soil Group	Soil Landscape
Yellow Earths	Binalong, Cockatoo
Yellow Podzolic Soils	Boorowa
Shallow Soils	Oak Creek

The majority of the wind farm overlies Yellow Earths (roughly evenly split between the Binalong and Cockatoo soil landscapes). One patch of Yellow Podzolic Soil occurs in the Langs Creek Cluster and a single patch of shallow soil occurs in the Mt Buffalo Cluster, primarily on slopes greater than 15%. **Table 6.2** provides a more comprehensive description of the soil types mapped within each soil landscape and the relationship between soil landscapes and Project components.

Table 6.2: Summary of soil landscapes that intersect the Study Area (Hird 1991)

Soil Landscape	Typical soil types	Project component
Binalong	Lithosols (crests and side slopes) Stony Earths (crests and side-slopes) Colluvial Podzolic Soils (footslopes)	Turbines, site compound, concrete batching and rock crushing; substation options; overhead powerline
Cockatoo	Red Earths (side-slopes) Yellow Earths (side-slopes)	Turbines, site compound, concrete batching and rock crushing; overhead powerline
Boorowa	Yellow Podzolic Soils (side-slopes)	Access tracks
Oak Creek	Siliceous Sands (crests and side-slopes) Sandy Earths (crests and side-slopes) Podzolic Soils (footslopes)	Turbines, access tracks

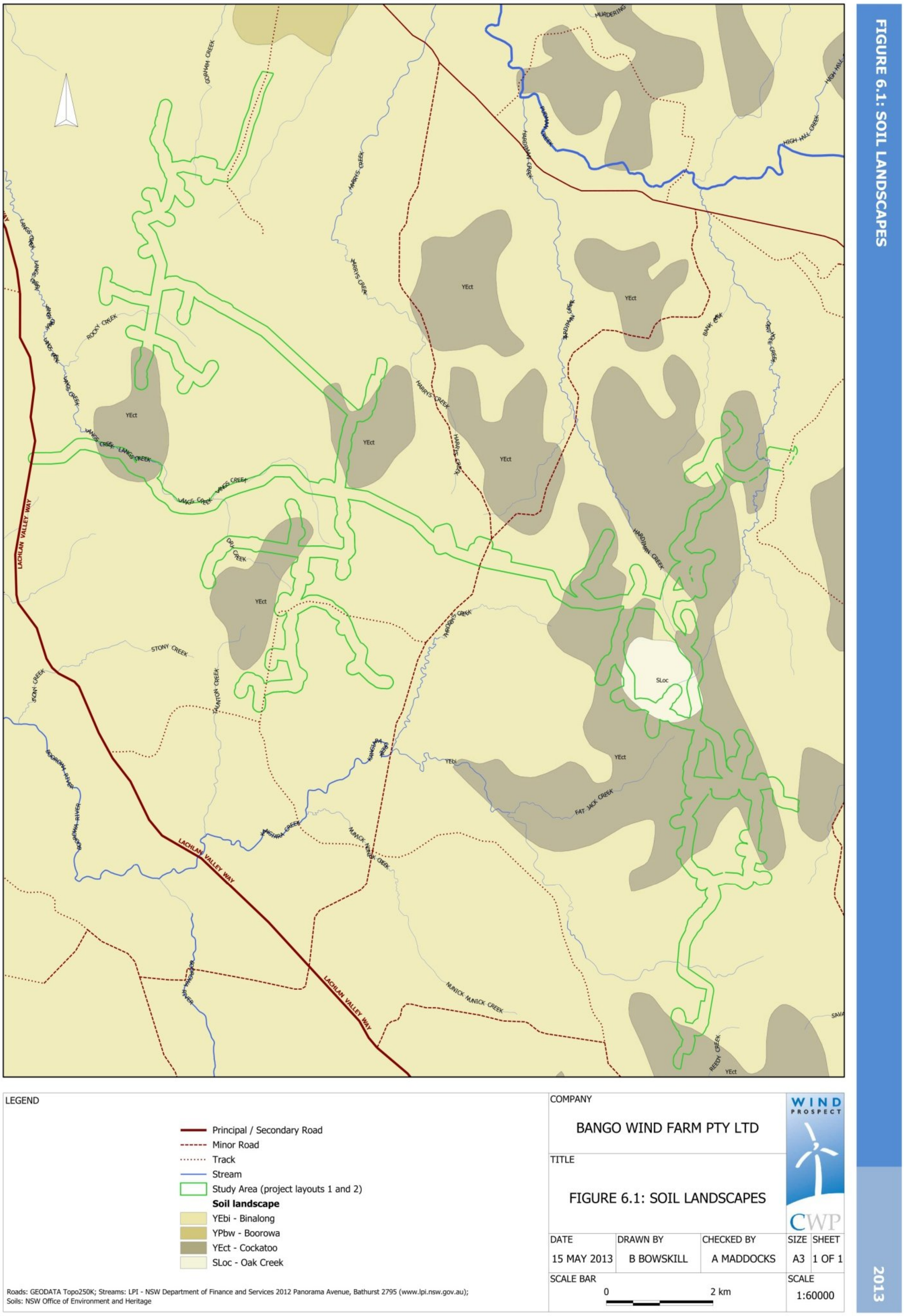
6.1.1 *Binalong*

The topography of the Binalong soil landscape consists of undulating low hills 500 to 630 metres above sea level. Slopes are gently inclined (3 to 10%). A permanent erosional stream or convergent integrated tributary pattern occurs across the landscape (Hird 1991).

Three soil types occur in this soil landscape: Lithosols and Stony Earths are co-dominant, with colluvial Podzolic Soils a minor component. Lithosols and Stony Earths occur on crests and side slopes and colluvial Podzolic Soils occur on the footslopes (Hird 1991). Lithosols are stony or gravelly soils overlying bedrock at shallow depth. They usually consist of shallow sands or clay loams with minimal structure development and usually only an A_1 horizon. Podzolic Soils have a pronounced texture contrast and clear boundaries between the medium to coarse textured A horizon and clay B horizon.

Fertility is moderate (Podzolic Soils) to low (Lithosols and Stony Earths) and the surface soils are acidic (Hird 1991). Due to the fragile light texture of the surface soils, they are susceptible to

Figure 6.1: Soil landscapes



structural degradation and the erosion hazard is extreme (Lithosols), very high (Stony Earths) to high (Podzolic Soils). A land capability rating of VII for Lithosols and Stony Earths indicates areas where these soils occur are generally unsuitable for agriculture and best protected by green timber. Podzolic Soils are suitable for grazing with occasional cultivation in certain areas. Water-holding capacity is low (Lithosols and Stony Earths) to high (Podzolic Soils), Lithosols and Stony Earths being highly permeable and Podzolic Soils having moderate permeability (Hird 1991). There is no evidence of salinity within any of the soil types in this soil landscape.

6.1.2 Cockatoo

The topography of the Cockatoo soil landscape consists of rolling low hills and hills 600 to 730 metres above sea level. Slopes are moderately to steeply inclined (10 to 30%). Permanent erosional stream patterns, closely to very widely spaced, form a non-directional tributary pattern across the landscape (Hird 1991).

Two co-dominant soil types occur in this soil landscape: Red Earths and Yellow Earths. Both soil types occur on side-slopes. Red Earths are red-brown to red massively structured soils with predominantly sandy textures and a porous earth fabric throughout. Differentiation between horizons is weak, with a gradual increase in clay content with depth (Hird 1991). Yellow Earths are yellow brown to yellow massively structured soils with predominantly sandy textures and a porous earth fabric throughout. Differentiation between horizons is weak with gradual or diffuse boundaries except for the darker A_1 horizon (Hird 1991). Yellow Earths are often associated with sites that are less-well drained than those occupied by Red Earths (Hird 1991).

Fertility is moderate and the surface soils are acidic for both soil types (Hird 1991). Both soil types are moderately susceptible to structural degradation and have a high erosion hazard (Hird 1991), particularly when the soils are cultivated or the surface cover is low. A land capability rating of VI indicates that this soil landscape is suitable for grazing but not cultivation. Water-holding capacity is moderate, both soil types being moderately permeable (Hird 1991).

There is no evidence of salinity within either of the soil types in this soil landscape.

6.1.3 Boorowa

The topography of the Boorowa soil landscape consists of gently undulating rises 530 to 600 metres above sea level. Slopes are gently to moderately inclined (1 to 10%). Permanent erosional stream channels, closely to very widely spaced, form a non-directional to convergent, integrated or interrupted tributary pattern across the landscape (Hird 1991).

A single soil type occurs within this soil landscape on side-slopes – Yellow Podzolic Soils. This soil type has strongly differentiated profile with coarse to medium textured A horizons and clayey B horizon, often with orange and yellow mottles.

Fertility is moderate and the surface soils are acidic (Hird 1991). The soil is moderately susceptible to structural degradation and the erosion hazard is considered to be low to moderate (Hird 1991). Water-holding capacity is moderate to high with moderate permeability. Soil salinity problems are absent (Hird 1991).

6.1.4 Oak Creek

The topography of the Oak Creek soil landscape consists of steep hills 600 to 750 metres above sea level. Slopes are steeply inclined (30 to 50%). Closely space, permanent erosional stream channels form a non-directional and diverging tributary network (Hird 1991).

Siliceous Sands and Sandy Earths are co-dominant, with Podzolic Soils a minor component. Siliceous Sands and Sandy Earths occur on crests and side-slopes, where as podzolic soils are restricted to the footslopes (Hird 1991). Siliceous Sands vary considerably in colour from pale yellow to reddish brown and are characterised by their quartzose nature and uniform sand to clayey sand texture. The profile is usually deep with an organic A_1 horizon (Hird 1991). Podzolic Soils have a pronounced texture contrast and clear boundaries between the medium to coarse textured A horizon and clay B horizon.

Fertility is low (Siliceous Sands and Sandy Earths) to moderate (Podzolic Soils) and the surface soils are acidic (Hird 1991). Due to the fragile light texture of the surface soils, they are susceptible to structural degradation. Water-holding capacity varies from low (Siliceous Sands) to moderate (Sandy Earths) to high (Podzolic Soils) and profile permeability is moderate (Podzolic Soils) to high (Siliceous Sands and Sandy Earths). Steep slopes combined with soil characteristics contribute to an extreme erosion hazard for Siliceous Sands, very high hazard for Sandy Earths and high hazard for Podzolic Soils (Hird 1991). No areas of salinity were evident.

6.2 Soil Properties

Of the soils mapped, four main soil types occur within the Project area. The predominant soil types are Yellow Soloths and Red Podzolic soils. A summary of the four main soil types is presented in **Table 6.3.** Descriptions of each soil property are provided in the following sections.

Table 6.3: summary of characteristics of major soil types in the Project area (Hird 1991)

	Lithosols	**Podzolic Soils**	**Siliceous sands**	**Yellow Earths**
Location	Crests and side-slopes	Side-slopes and footslopes	Crests and side-slopes	Side-slopes
USCS	GM, GC	SC, CL, CH	GM, GC	SC, CL
Texture	Topsoil: shallow sand, loam or clay loam with organic matter Subsoil: shallow sand, loam or clay loam with fragmented rock	Topsoil: loamy sand – clay loam loam Subsoil: light-medium clay, angular blocky	Topsoil: sand to clayey sand Subsoil: sand to clayey sand	Topsoil: sandy loam to sandy clay loam Subsoil: sandy clay loam to sandy clay
Erodability	Topsoil: high Subsoil: high	Topsoil: moderate - high Subsoil: low - moderate	Topsoil: high Subsoil: high	Topsoil: moderate Subsoil: moderate
Erosion hazard	High	Low - moderate	Extreme	High
Salinity	No salting evident	Not present	No salting evident	Not present
Structural degradation hazard	High	Moderate - high	High	Moderate
Shrink-swell potential / reactivity	None	Low - moderate	None	Low

	Lithosols	Podzolic Soils	Siliceous sands	Yellow Earths
Permeability	High	Moderate	High	Moderate
Drainage	High	Moderate to imperfect	Rapid	Moderate
Mass-movement hazard	Likely	Not likely. Possible on slopes > 15%	Likely	None
Relative run-off potential	Low - moderate	Low - moderate	Low	Low - moderate
Depth to bedrock	>50cm	>150cm	>50cm	50 – 100cm

USCS = Unified Soil Classification System. Used as a guide for the suitability of soil materials for use in earthworks, optimal conditions for their construction, special precautions which may be needed such as soil ameliorants, and final batter grades to ensure stability (Murphy and Lawrie 1998).
CL = inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays lean clays
CH = inorganic clays of high plasticity, fat clays
GM = silty gravels, poorly graded gravel sand-sand-silt mixtures
GC = clayey gravels, poorly graded gravel-sand-clay mixtures
SC = clayey sands, poorly graded sand-clay mixture

6.2.1 Soil erodibility

Soil erodibility (also known as the K-factor), is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff once the vegetated cover is removed (Landcom 2004). The K-factor is a numeric value and one of several factors input into the Universal Soil Loss Equation, to predict the long term, average, annual soil loss from sheet and rill flow at nominated sites under specified management conditions (Landcom 2004). Soil texture is the principle component affecting K, but soil structure, organic matter and profile permeability also contribute (Landcom 2004).

Often the erodibility of the surface soil and subsoil can be very different – surface erodibility primarily relating to sheet and rill erosion, and subsoil erodibility relating to gully erosion (Murphy and Lawrie 1998). Due to the lack of published K-factor numbers for the Study Area, it is recommended that samples from each for the soil landscapes be collected and analysed as part of the geotechnical design, during preparation of the CEMP.

6.2.2 Soil erosion hazard

Erosion can be due to wind or water. Water erosion is the detachment and transportation of soil particles from a site and their deposition by action of water (Murphy and Lawrie 1998). The corresponding water erosion hazard is the susceptibility of an area to water erosion and is determined by rainfall, slope grade and length and land use (Murphy and Lawrie 1998). Soil erodibility should also be considered when determining the erosion hazard.

Wind erosion is the detachment and transportation of soil particles from a site and their deposition by action of wind. Generally light textured soils in a loose condition or with no vegetation cover are the most susceptible to wind erosion, particularly those with high fine sand content (Murphy and Lawrie 1998).

According to the map in Appendix B of the Blue Book (Landcom 2004), the R-factor (rainfall erosivity) for the region is approximately 1,175. Rainfall erosivity is the ability of rainfall to cause erosion and can be used in conjunction with slope (%) to calculate the erosion hazard for a soil landscape. Using Figure 4.6 of the Blue Book (Landcom 2004), for an R-factor of 1,175 slopes roughly less than 17%

can be considered to have a low erosion hazard, while those greater than 17% can be considered to have a high erosion hazard. Results for soil landscapes that intersect the Study Area are presented in **Table 6.4.**

Table 6.4: Slope characteristics and corresponding erosion hazard of soil landscapes that intersect the Study Area (Hird 1991; Landcom 2004)

Soil landscape	Limitations	Slope range	Erosion hazard
Binalong	Low to moderate fertility, weakly to moderately structured surface soils, low to high available waterholding capacity. Some gullying of drainage lines. Sheet and wind erosion are significant following dry periods	3 - 10%	Low
Boorowa	Moderate fertility; moderate to high available waterholding capacity. Minor gullying of drainage lines. Sheet and wind erosion are significant during dry times and following cultivation.	1 – 10%	Low
Cockatoo	Moderate fertility; areas of rock outcrop and shallow soils; weakly to moderately structured surface soils; moderate available waterholding capacity. Minor sheet erosion particularly following dry periods, very little gully erosion.	10 – 30%	Low to high
Oak Creek	Steep slopes, areas of rock outcrop and shallow soils; low – moderate fertility. Minor to moderate sheet erosion, soil creep, gullying and streambank erosion.	30 – 50%	High

6.2.3 Salinity and Sodicity

As excessive salt is toxic to most plants, saline surface soils often have little to no vegetation cover. The lack of vegetation cover in itself can lead to a high erosion hazard. The rise in watertables following clearing increases the movement of salts downstream resulting in an increase in the dispersibility of affected soil horizons leading to an increase in gully erosion hazard (Hird 1991). As saline outbreaks and rising watertables often occur in areas of lower relief, high salt loads can find their ways into local watercourses (Hird 1991). According to Hird (1991), early Silurian metasediments have been the most affected by dryland salinity. Salinity was not evident in any of the four soil landscapes that intersect the Study Area.

A related factor – sodicity – relates to the percentage of exchangeable sodium in the soil. A sodic soil is generally defined as having an exchangeable sodium percentage of more than 5 or 6% (Murphy and Lawrie 1998). Soils with low natural levels of calcium and magnesium may become sodic even with low inputs of sodium from rainfall and dust. Sodic surface soils exhibit severe structural problems and sodic subsoils are subject to severe gully erosion (Murphy and Lawrie 1998). Although Hird (1991) has not specifically mentioned sodicity in the soil landscape descriptions, the occurrence of gully erosion in the Binalong, Boorowa and Oak Creek soil landscapes suggest the possible presence of sodic subsoils.

6.2.4 Structural degradation hazard

Soil structure can be developed by either biotic processes or can be due to the physical and chemical properties of the clay particles and the shrink-swell potential of the soil (Murphy and Lawrie 1998). Structural degradation hazard relates to the susceptibility of soil structure to break down as a consequence of raindrop impact, wetting to saturation, excessive cultivation, compaction, loss of organic matter or poor plant growth (Murphy and Lawrie 1998). Surface soils with poor structure are susceptible to increased runoff and erosion, and reduced emergence, plant growth and productivity (Murphy and Lawrie 1998). The consequence is increased costs of production.

6.2.5 Shrink-swell potential / reactivity

Most soils shrink or swell depending on changes in their moisture content (Landcom 2004). Soils that significantly shrink on drying and swell on wetting, are called expansive or reactive soils. The primary determinants of the shrink-swell potential of the soils are the percentage of clay content and mineral composition. Soils with a high shrink-swell potential can cause severe damage to buildings and earthworks unless preventative precautions are taken (Landcom 2004, Murphy and Lawrie 1998).

Based on the soil landscape descriptions, reactive soils are not considered to be of concern in the Study Area.

6.2.6 Permeability and drainage

Soil profile permeability is controlled by the capability of the least permeable layers in the soil to transmit water (McDonald *et al.* 1990 in Murphy and Lawrie 1998). As a guide, the following rates of saturated hydraulic conductivity can be used to establish permeability classes:

- Slowly permeable – Less than 0.01 metres/day or 0.4 millimetres/hour
- Moderately permeable - 0.01 to 1 metre/day or 0.4 to 42 millimetres/hour
- Highly permeable – Greater than 1 metre/day or 42 millimetres/hour

Highly permeable soils include those with a content of sand throughout the profile and highly aggregated clays. Soils of low permeability are likely to pond water at the soil surface and where they are on a slope will produce high runoff under rainfall. If only certain layers of the soil profile have low permeability (e.g. clay layers) it can result in a perched watertable. Highly sodic and dispersible subsoils have extremely low permeability (Murphy and Lawrie 1998).

6.2.7 Mass movement

Mass movement is a general term for a number of forms of slope failure, including rockfalls and earth slumps, slips and flows on steep and often wet slopes (Murphy and Lawrie 1998). Two general types of mass movement are common: movement of colluvial material down steep slopes and movement of deep subsoils on slopes of various gradients (Landcom 2004). The most common triggering agent for mass movement is water in the slip zone that reduces shear strength and increases slope loads (Landcom 2004). According the Landcom (2004), other common human induced mass movement generating factors include:

- removal of material from the foot of a slope (especially on or below a former slip plane)
- concentration of surface water or groundwater in slip-prone areas
- removal of trees and other plants that might “pump“ the watertable downwards.

Soils with light textures (sandy soils) at depth (greater than 50cm), steep slopes and deep deposits of unconsolidated colluvial debris on steep slopes are all susceptible to mass movement (Murphy and Lawrie 1998). Mass movement may lead to severe damage to buildings, roads and services and can cause recurrent problems such as shifting foundations.

6.2.8 *Relative runoff potential*

As actual run-off rates at any particular location are dependent on rainfall, land use history, vegetation cover, slope length and shape, antecedent moisture content and other factors, estimates of potential runoff are tentative (Murphy and Lawrie 1998). Runoff potential is lowest for soils containing large amounts of sand and for those with deeper surface horizons.

Rates for relative potential run-off are difficult to predict, however surface infiltration rates are one of the key factors in their determination (Murphy and Lawrie 1998). A measure called a runoff coefficient can be used to quantify the amount of rainfall expected to run off at a certain location and point in time. It relates to the ratio of catchment runoff to the rainfall in a nominated storm event (either in terms of rates or volumes) (Landcom 2004). The choice of a particular runoff coefficient can have considerable influence on the design of soil and water management structures for a particular site. Hence, runoff coefficients should always be recorded in the SWMP along with the assumptions and methods used in their estimation. The value of the coefficient is dependent on the soil hydrologic group and hydraulic factors.

6.3 Acid sulphate soils

Acid sulphate soils occur naturally in both coastal (tidal) and inland or upland (freshwater) settings (CSIRO 2011). Left undisturbed these soils are harmless, but when excavated or drained the sulphides within the soil react with the oxygen in the air to form sulphuric acid (CSIRO 2011). This acid, together with associated toxic elements such as heavy metals and other contaminants, can kill plants and animals, contaminate drinking water and corrode concrete and steel (CSIRO 2011).

According to the Atlas of Australian Acid Sulphate Soils (CSIRO 2008), the probably of acid sulphate soils occurring within the Study Area is low, however this classification is provisional. One NatCASS (National Committee for Acid Sulphate Soils) zone intersects the project area: Bn(p4). An explanation of this code is provided in **Table 6.5**.

Table 6.5: NatCASS code descriptions for acid sulphate soils (CSIRO 2008)

Code and Map Unit	Distinguishing soil/sediment properties, vegetation, landforms, or other characteristics
Probability of Occurence of Acid Sulphate Soils (ASS):	
B - Low Probability of occurrence	6-70% chance of occurrence in mapping unit
Non-Tidal Zones Inland (i.e. not coastal15) landscapes (greater than 10 m AHD) in wet / riparian areas associated with:	
n - Sodosols, Chromosols and Dermosols	ASS1 generally within upper 1 m in wet / riparian areas with Sodosols, Chromosols and Dermosols
Subscripts to Codes	
(p) - Potential ASS (PASS)	Potential acid sulphate soil (PASS) = sulphidic material)
Confidence Levels - Map polygon contains ASS, and:	
(4) - No necessary analytical data are available and classifier has little knowledge or experience with ASS, hence classification is provisional	

6.4 Contamination

Sources of potential soil contamination in agricultural areas include:

- Previous land uses where chemical concentrations have accumulated over time (eg cattle / sheep dip sites);
- Import of fill;
- Stockpiling of waste; and
- Demolition of old buildings.

Exposure to contaminated soils presents a health risk, hence potential areas of contamination (based on past and current activities) should be avoided if possible. Associated landowners were consulted to determine if there were any known contamination sites on their land. Many landowners indicated that whilst potentially contaminating activities (e.g. sheep dips, fuel storage, and herbicide spraying) occur on-site, these activities do not take place on ridge top locations that will be disturbed by the proposed development.

7 Water

7.1 Catchments and Surface water

The Project Site is within the upper reaches of the Lachlan catchment. Streams that intersect the Study Area drain west and south into the Boorowa River and north into Pudman Creek. According to a classification of streams within the Digital Topographic Database completed by NOW, first, second, third and fourth order streams intersect the Study Area. Many are unnamed, however named streams are listed in **Table 7.1**. **Figure 7.1** illustrates the streams and corresponding VRZs.

Table 7.1: Named streams that intersect the Study Area

1st Order	Gorham Creek
2nd Order	Bobby's Creek, Hardiman Creek, Rocky Creek
3rd Order	Dry Creek, Harry's Creek, Kangiara Creek
4th Order	Dirt Hole Creek, Langs Creek

There are no NOW monitoring stations on drainage lines within the immediate vicinity of Study Area. The closest monitoring station to the Study Area is on the Yass River at Yass. As a consequence, no data relating to stream water level (metres), discharge rate (megalitres/day), discharge volume (megalitres), electrical conductivity at 25˚C (microsiemens/cm) and water temperature (˚C) is available.

7.2 Wetlands

Three wetlands listed under the Ramsar Convention occur within 200km (approx) of the Study Area to the east, west and south, however none of these are downstream of the Study Area. The closest wetland listed in the Directory of Important Wetlands (DSEWPaC 2008) is located upstream of the Study Area approximately 65km to the south-east in the Lake George Catchment. The closest wetland downstream of the Study Area that is listed in the Directory of Important Wetlands (DSEWPaC 2008) is located approximately 150km to the west. Numerous small features mapped in the database of NSW wetlands (OEH 1987) occur within the immediate vicinity of the Study Area, the closest being a reservoir 3km to the south. Lake Burrinjuck is located approximately 27km south

Figure 7.1: Vegetated Riparian Zones

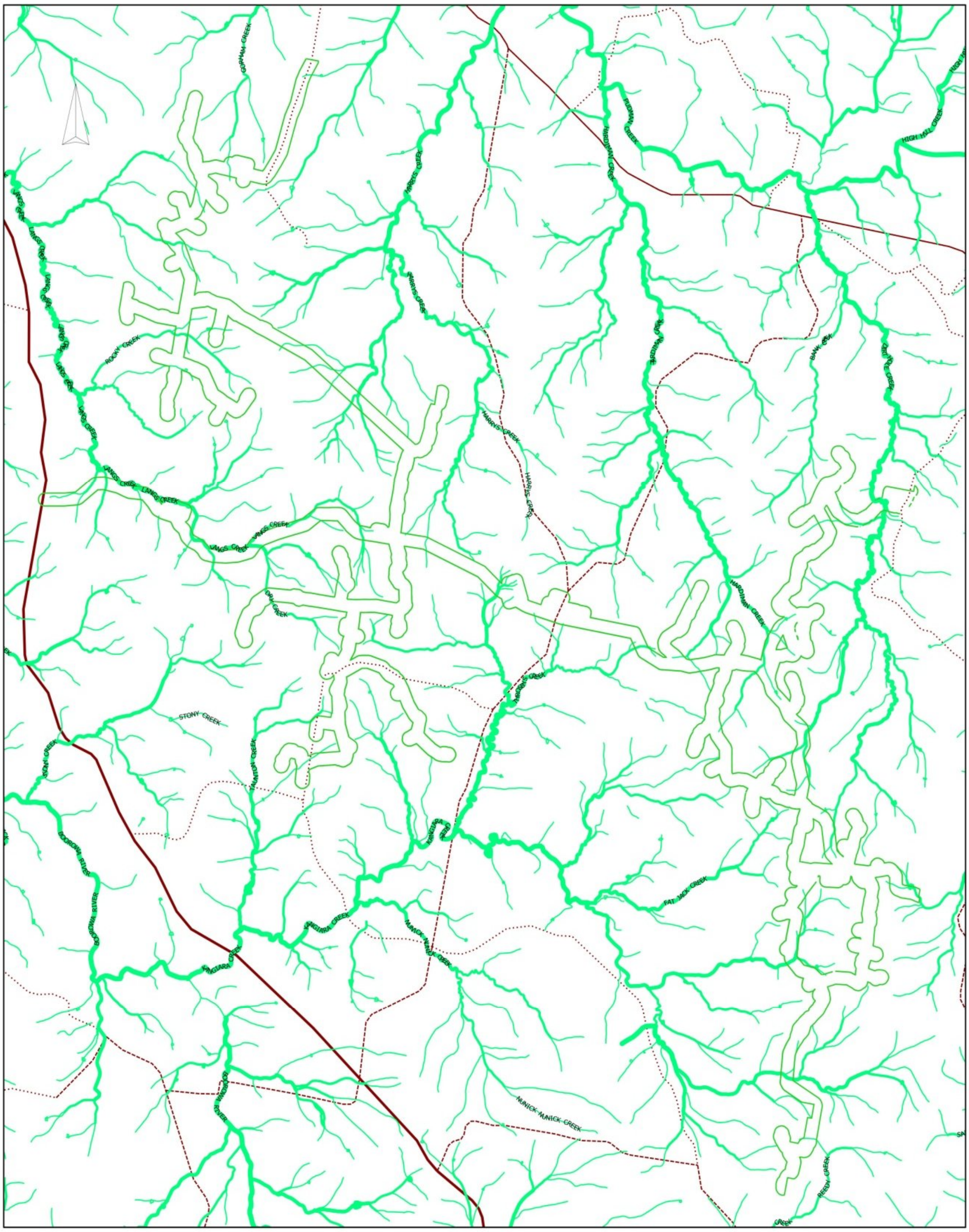


FIGURE 7.1: VEGETATED RIPARIAN ZONES

LEGEND

- Principal / Secondary Road
- Minor Road
- Track
- Study Area (project layouts 1 and 2)
- Vegetated riparian zone:
  1st order stream: 10m either side of channel
  2nd order stream: 20m either side of channel
  3rd order stream: 30m either side of channel
  4th order (and above) stream: 40m either side of channel

Roads: GEODATA Topo250K; Vegetated riparian zones: derived from stream data from LPI - NSW Department of Finance and Services 2012 Panorama Avenue, Bathurst 2795 (www.lpi.nsw.gov.au); All other data: WPCWP

COMPANY

BANGO WIND FARM PTY LTD

TITLE

FIGURE 7.1: VEGETATED RIPARIAN ZONES

DATE	DRAWN BY	CHECKED BY	SIZE	SHEET
15 MAY 2013	B BOWSKILL	A MADDOCKS	A3	1 OF 1

SCALE BAR: 0 — 2 km

SCALE: 1:60000

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of the Study Area. Vegetation mapping of the Boorowa Shire (NPWS 2002) and the Southern Forests (Gellie 2005) indicates that no forested wetlands occur within 10km of the Study Area.

7.3 Groundwater and Groundwater dependant ecosystems

According to ABARES (2012), the Study Area does not overlie any major aquifers, but rather occurs over the Lachlan Fold Belt Province. This province is categorised by DECCW (2010) as a Fractured Rock Groundwater Management Area (GWMA) and as an Unincorporated Area by ABARES (2012). Unincorporated Areas are defined as "*those areas not included as groundwater management units for the major aquifers*" (ABARES 2012). Lachlan Fold Belt GWMA covers approximately 50% of the Lachlan Catchment Management Area and forms the catchment basement. Average depth to the watertable for the Lachlan Fold Belt GWMA is 40 metres (ABARES 2012). Typically bore yields are small and sufficient for stock and domestic supplies only, due to the limited permeability of the rock sequences (DECCW 2010b).

Although numerous groundwater bores occur within a 10km radius of the Study Area, only eight bores occur within the Study Area / within approximately 500m of the Study Area (NOW 2013b) (**Figure 7.2**). Table 7.2 provides details (OEH 2013).

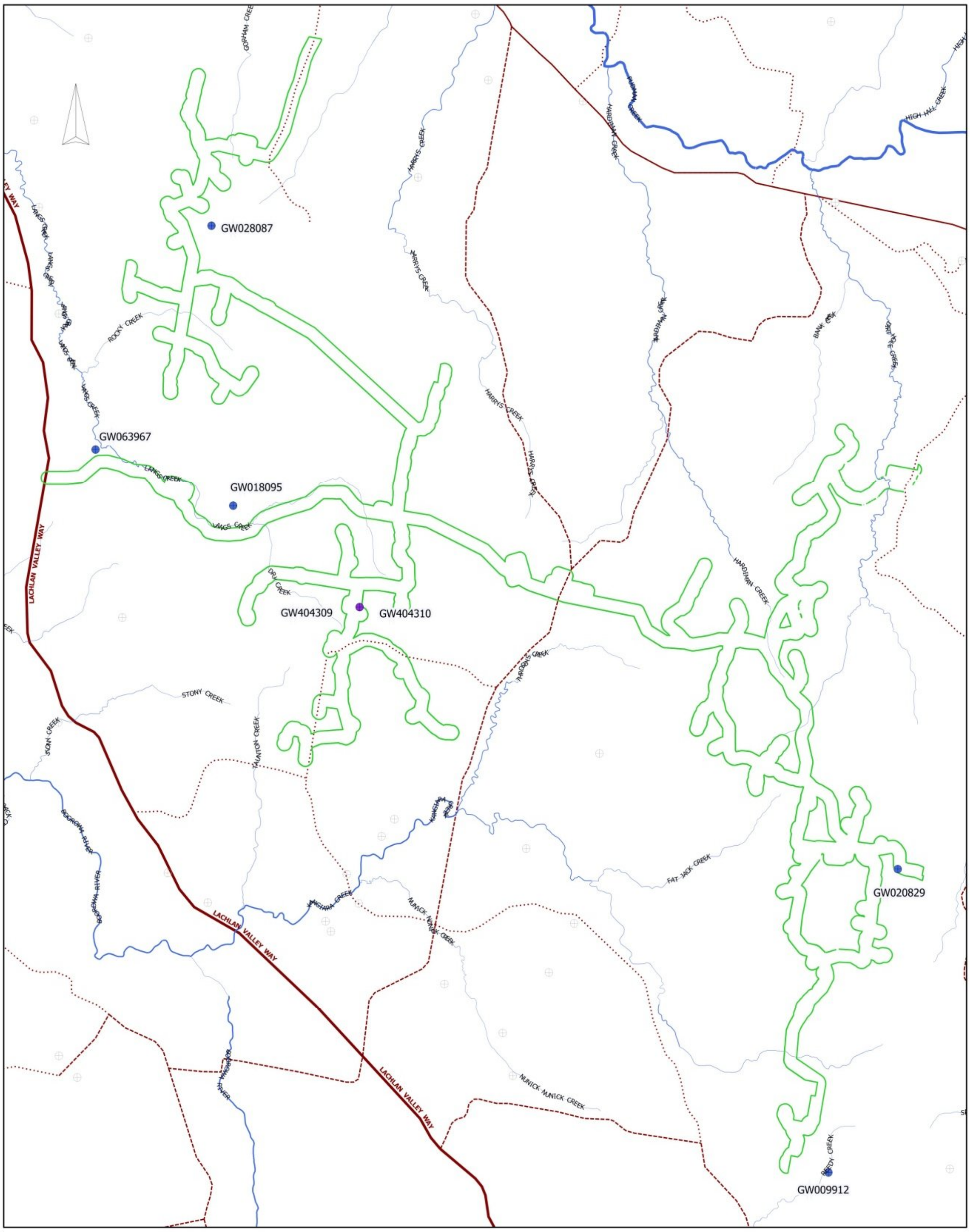
Table 7.2: Groundwater wells within the Study Area / within 100m of the Study Area (OEH 2013)

Well ID	Authorised purpose	Owner	Water Bearing Zone - From Depth (metres)	Water Bearing Zone - To Depth (metres)	Thickness (metres)	Yield (litres / second)
GW009912	Not stated	Private	No details	No details	No details	No details
GW018095	Stock	Private	11.6	22.8	11.2	1.07
GW020829	Not stated	Private	5.5	5.5	0	0
			24.7	24.7	0	2.04
GW028087	Stock	Private	21.3	25.9	4.6	No details
			30.5	30.5	0	
			33.5	33.5	0	
GW063967	Domestic	Private	20.0	24.0	4.0	2.0
GW404309	Domestic Stock	Private	No details	No details	No details	No details
GW404310	No details	No details	No details	No details	No details	No details
Average			**14.6 ***	**26.25 ****	**-**	**-**

*Average includes uppermost water-bearing zone only ** Average includes lowermost water-bearing zone only

Groundwater and surface water systems are closely integrated in the water cycle. Surface water tends to flow to groundwater, and groundwater can be important in providing base flows to surface water systems. Ecosystems that are fully or partially reliant on groundwater to maintain ecosystem function are known as groundwater dependent ecosystems (GDEs). These occur across both surface and subsurface landscapes and are highly variable (DECCW 2010b). According to Australian Water Resources (2005), no GDEs have been identified for the Lachlan Fold Belt GWMA, however River Red Gum riparian grassy forest has been mapped within 10km of the Study Area along Pudman Creek to the north and the Boorowa River to the west as part of vegetation mapping of the Boorowa Shire (NPWS 2002). The ecological survey of the project area completed by ERM (2013) did not identify any GDEs within the Study Area.

Figure 7.2: Groundwater bores



LEGEND

- Groundwater bore
- Groundwater bore in immediate vicinity of Study Area
- Principal / Secondary Road
- Minor Road
- Track
- Study Area (project layouts 1 and 2)

Roads: GEODATA Topo250K; Streams: LPI - NSW Department of Finance and Services 2012 Panorama Avenue, Bathurst 2795 (www.lpi.nsw.gov.au); Groundwater bores: NSW Office of Water; All other data: WPCWP

COMPANY				
BANGO WIND FARM PTY LTD				
TITLE				
FIGURE 7.2: GROUNDWATER BORES				
DATE	DRAWN BY	CHECKED BY	SIZE	SHEET
15 MAY 2013	B BOWSKILL	A MADDOCKS	A3	1 OF 1
SCALE BAR: 0 – 2 km			SCALE: 1:60000	

WIND PROSPECT CWP

FIGURE 7.2: GROUNDWATER BORES

2013

8 Impact Assessment

8.1 Proposed works

A range of activities will be undertaken in the Study Area during construction, operation and decommissioning of the Project. Details are provided in **Chapter 3** Project Description. Broadly these include:

- Upgrading / widening of existing public roads and private roads on-site; construction of culverts across watercourses
- Installation of cabling – above and below ground
- Cutting, excavation, backfill and compaction of trenches
- Dust suppression and concrete batching using water
- Stripping and stockpiling of topsoil
- On-site sewage and waste water treatment
- Revegation and rehabilitation works

8.2 Potential impact on soils

To preserve landscape stability and biodiversity and to prevent sedimentation of surrounding watercourses, it is important that soil disturbance is kept to a minimum and undertaken in a manner that is unlikely to result in topsoil loss or erosion. Existing soils and landforms may be impacted by works associated with the Project via:

- Vegetation clearing and general construction activities leading to soil disturbance and causing (or exacerbating) erosion processes
- Disturbance, alteration or impedance of surface watercourses and flow paths

Of the four major soil types mapped across the Study Area, Yellow Earths – the most widespread - have a high erosion hazard, the remaining three have erosion hazards varying from low-moderate to high to extreme (Hird 1991). Extreme erosion hazard is only applicable to the relatively small patch of shallow soils (Oak Creek) in the eastern section of the project area.

All four soil types also have a moderate to high to high structural degradation hazard; as a consequence, all areas with steep gradients or low amounts vegetation cover are particularly susceptible to water or wind erosion. In these areas, existing tracks will be used / upgraded wherever possible. Exposure of soils during construction and stockpiling of soil may cause dust issues. The exact locations of tracks and protocol for their construction and dust suppression measures will be included in a CEMP. The main objectives of the CEMP will be to minimise soil disturbance, minimise erosion events from increased surface runoff, and minimise disturbance of water resources in the area. Included in the CEMP will be a SWMP, which will be based on detailed geotechnical investigations, and will provide detail regarding the management of sedimentation and erosion and practical amelioration measures. If materials are found during excavation that are not suitable for re-use on site, these should be stockpiled and disposed of by a qualified contractor in accordance with the NSW Environment Protection Authority guidelines.

8.3 Potential impact on water resources

Preservation of the movement, distribution, supply and quality of water within the Study Area is critical to the viability of the rural landscape and ecology of the Project Site and surrounding landscape.

8.3.1 Impacts during the construction and decommissioning phase

During construction and decommissioning, water resources may be affected by one or more of the following processes:

- Soil disturbance due to vegetation clearance / construction activities resulting in siltation;
- Disturbance, alteration or impedance of surface watercourses and flow paths;
- Disturbance or modification of groundwater flows;
- Pollution of surface water or groundwater via accidental spills, sedimentation etc.

Soil disturbance may cause erosion or exacerbate existing erosion processes. If sodic subsoils are exposed or saline soils disturbed, large amounts of sediment and / or salts may enter watercourses. Sedimentation of watercourses may alter flow patterns; an increase in water salinity will likely render the environment less hospitable to a range of aquatic species and may make the water unsuitable for use as a water supply for stock. The reduction or disappearance of flow from surface watercourses due to alteration or impedance of their flow path will have consequences for the ecology of the area that relies on the water supply from those water courses, possibly resulting in loss of vegetation and species habitat. Scour protection, including permanent bed and bank stabilisation, must be implemented along watercourses that are to be directly impacted during construction works. Sediment and erosion control measures to be implemented during construction and operation should be addressed in the SWMP.

Groundwater flows and distribution are often poorly understood. Should contact with groundwater occur during the construction of footings, the result is that a volume of natural soil is replaced with impermeable or low-permeable construction materials, forming a barrier to groundwater movement and possibly resulting in changes in groundwater level (Ding *et al*, 2007). Two types of foundations will be considered for the Project:

- Slab (gravity) foundation - involves the excavation of approximately 750 cubic metres (m^3) of ground material to a depth of approximately 2.5 m ; and / or
- Slab plus rock anchor foundation - involves the excavation of approximately 570 m^3 of ground material to a depth of approximately 2.5 m and the drilling of rock anchor piles up to a maximum depth of 20 m.

Any modification / pollution of groundwater flows may impact upon groundwater dependant ecosystems outside the Study Area and upon the quality and quantity of water available in bores used as a rural water supply. The average upper limit of the water bearing zone (WBZ) of boreholes in the vicinity of the Study Area is approximately 14.6 m (NSW OEH 2013). Due to the shallow excavation depth, the probability of groundwater contact occurring, is expected to be low due the location of the turbines on hill crests. However, the drilling of rock anchors has the potential to intersect with the WBZ due to their potential depth below ground level, particularly for wind turbines located at lower elevations.

It is unlikely that earthworks for roads, hardstand areas and underground cabling will interfere with groundwater flows due to their shallow construction depths. If water is extracted from bores within the Project Site for use during construction, there may be a localised and temporary impact on the groundwater regime. River Red Gum forest mapped along the Boorowa River and Pudman Creek is not likely to be affected by the proposed project, due to distance from the Study Area. No groundwater dependant ecosystems have been identified within the Project Site.

As the final foundation design is yet to be confirmed, the requirement for any further assessment of groundwater impacts will be undertaken at the detailed foundation design stage and included in the CEMP. Should the Project require bore water, detailed geotechnical studies will be undertaken to locate suitable bore holes, where permissible. This will be undertaken in combination with the necessary licensing requirements from the NOW and permissive occupancy rights of the affected landowners

8.3.2 Impacts during the operational phase

Impacts on water resources during the operational phase are expected to be minimal. Care should be taken to avoid oil leaks or chemical spills which may affect surface water and or groundwater. Continual sediment and erosion control measures should be addressed in the SWMP.

8.3.3 Impacts on riparian ecological values

Table 8.1 lists identified ecological features associated with riparian corridors within the broader catchment and how they may be affected by the Project.

Table 8.1: Ecological features associated with riparian corridors within the broader catchment area

Ecological feature	Location of feature	Project interaction
Endangered aquatic ecological community	The aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River is listed as an Endangered Ecological Community under the *FM Act*. The community includes all native fish and aquatic invertebrates within all natural creeks, rivers, streams and associated lagoons, billabongs, lakes, wetlands, paleo-channels, flood-runners, floodplains and effluent streams of the Lachlan River (DPI 2007a). The listing includes several major rivers including the Boorowa River	<u>Flow requirements</u>: Aquatic communities rely on variable inflows to maintain health and biodiversity. The natural flow regime should be maintained as the proposal is upstream of the EEC <u>Application to the Project</u>: the development does not propose to alter the magnitude or direction of surface water flows from the Study Area.
Riparian vegetation	River Red Gum woodland has been mapped along the Boorowa River and Pudman Creek (NPWS 2002). A marginal amount of riparian vegetation exists along drainage lines that intersect the Study Area.	<u>Flow requirements</u>: Riparian vegetation requires variable flows and medium to high floods to remain healthy. <u>Application to the Project</u>: It is likely that the majority of creek crossings will occur where riparian vegetation is patchy or absent, utilising existing crossings where practicable. The impacts on in-stream or riparian ecology are considered as part of the ecological assessment.
Threatened freshwater	Searches of the Commonwealth *Environment Protection and Biodiversity Conservation Act*	<u>Flow requirements</u>: All aquatic plants require variable inflows of water to maintain health.

Ecological feature	**Location of feature**	**Project interaction**
flora species	*1997* (*EPBC Act*) database and the NSW Wildlife Atlas did not indicate that any freshwater plants listed under the *EPBC Act* or NSW *Threatened Species Conservation Act 1995* (*TSC Act*) are known or predicted to occur within 15km of the Study Area. A search of the Royal Botanic Gardens Database indicated that Floating Swamp Wallaby-grass (*Amphibromus fluitans*) is known to occur within the locality of the Project Site (Murrumbidgee Catchment Management Area)	They also require light for photosynthesis, which may be reduced if the water becomes silty due to erosion. Floating Swamp Wallaby-grass occurs periodically waterlogged sites (including table drains and farm dams). Application to the Project: As the Project is not expected to alter the hydrology of the Study Area, no impacts on aquatic flora are expected.
Threatened fish species	A database search for matters protected under the *EPBC Act* identified two threatened species that may occur or have habitat that may occur within 30km of the Study Area: Macquarie Perch *(Macquaria australasica*) listed as endangered under the *EPBC Act* and *FM Act* and Murray Cod (*Maccullochella peelii peelii*) listed as vulnerable under the *EPBC Act*. Additional species listed under the *FM Act* that are known to occur within the Lachlan Catchment include Silver Perch (*Bidyanus bidyanus*), and Olive Perchlet (*Ambassis agassizi*) The NSW Rivers Survey (1994–1996) demonstrated that, in NSW, Macquarie Perch were present only in low numbers at three sites in streams above Lake Wyangala (approximately 55km north of the Project area) and Burrinjuck Dam (approximately 27km south of the Project area) (DSEWPaC 2012).	Flow requirements: Macquarie Perch prefers clear water and deep, rocky holes with lots of cover - aquatic vegetation, large boulders, debris and overhanging banks (DSEWPaC 2012). Reduce sedimentation by applying appropriate sediment control practices and maintaining vegetated cover wherever possible, including riparian vegetation. Application to the Project: None of the known populations occur within, or close by, the Study Area.
	The Murray Cod historically occurred throughout the entire Murray Darling Basin, with the exception of the upper reaches of some tributaries. Today the species is found extensively throughout the Basin (DSEWPaC 2012).	Flow requirements: Occurs in range of habitats from clear rocky streams to slow flowing, turbid rivers and billabongs. Requires complex structural cover such as large rocks, snags, overhanging vegetation and other woody structures (DSEWPaC 2012). Reduce sedimentation by applying appropriate sediment control practices and maintaining vegetated cover wherever possible, including riparian vegetation. Application to the Project: Known to occur in the Lachlan River system (MDBC n.d. A). May occur in the Boorowa River or Pudman Creek

Ecological feature	Location of feature	Project interaction
	Silver Perch was formerly widespread over much of the Murray-Darling Basin, excluding the most upper reaches, but has declined over most of its range. The species is still patchily abundant in the mid-Murray (MDBC n.d. B).	Flow requirements: Occurs in lowland, turbid and slow-flowing rivers (MDBC n.d. B). Application to the Project: Although few records for this species exist within the Lachlan catchment, one is located close to the Project area. It is possible that the species may occur adjacent to the Project area. Reduce sedimentation by applying appropriate sediment control practices and maintaining vegetated cover wherever possible, including riparian vegetation.
	Olive Perchlet is still present in coastal streams from northern NSW to north Qld, but has undergone a significant decline in most of the Murray-Darling Basin. The species has been recorded at two locations in the Lachlan catchment in NSW before 1980 (MDBC n.d. C)	Flow requirements: Inhabits the vegetated edges of lakes, creeks, swamps, wetlands and rivers, where it is often associated with woody habitat and aquatic vegetation in areas with little or no flow, particularly backwaters (MDBC n.d. C). Application to the Project: Species has been recorded within the upper reaches of the Lachlan catchment. It is it is possible that the species may occur in or adjacent to the Study Area. Reduce sedimentation by applying appropriate sediment control practices and maintaining vegetated cover wherever possible, including riparian vegetation.
Threatened aquatic invertebrate species	River Snail (*Notopala sublineata*) is listed as endangered under the *FM Act* and was once common and widely distributed throughout the Murray Darling Basin. The species is currently considered extinct throughout its natural range and over the last decade living specimens have only been recorded from water supply irrigation pipelines (DPI 2007).	Flow requirements: Found along riverbanks attached to logs and rocks or crawling in the mud. Application to the Project: Due to the severely restricted extent of this species, the project is not considered to have an impact upon this species.
Threatened frog species	A database search for matters protected under the *EPBC Act* identified two threatened species that may occur or have habitat that may occur within 30km of the Study Area: Booroolong Frog (*Litoria booroolongensis*) and Growling Grass Frog (*Litoria raniformis*). The Booroolong Frog was also identified by OEH as likely to occur within the Locality. No records of any threatened frog species exist in the Atlas of NSW Wildlife within 30km of the Study Area. Prior to 1990, the Booroolong Frog was considered both common and secure. It is estimated that fewer than 5000 individuals now remain in the wild (DSEWPaC 2012). The species occurs along permanent streams with some fringing vegetation cover such as ferns, sedges or grasses. Streams range from small slow-flowing creeks to large rivers in both forested areas and open pasture (DSEWPaC 2012).	Flow requirements: The Booroolong Frog requires perennial streams that are flowing. Application to the Project: Due to the ephemeral nature of the creeks and the lack of key habitat features within the Study Area it is unlikely that these areas would provide suitable habitat to support the Booroolong Frog (ERM 2013). Nevertheless it is prudent to reduce sedimentation by applying appropriate sediment control practices and maintaining vegetated cover wherever possible, including riparian vegetation,

Ecological feature	Location of feature	Project interaction
	In NSW, the Growling Grass Frog occurs in a mosaic of permanent and ephemeral waterbodies which flood in the spring of most years. It is frequently found basking on grassy banks near water and can inhabit agricultural areas (DSEWPaC 2012). In NSW the species is known from Bondi State Forest, Boomanoomana State Forest, Mulwala State Forest, Berry Jerry State Forest, Euston State Forest, Woomargama State Forest, Buckingbong State Forest, Cocoparra National Park, Willandra Lakes World Heritage Area (DSEWPaC 2012).	Flow requirements: Mostly occurs amongst emergent vegetation in or at the edges of still or slow-flowing water bodies such as lagoons, swamps, lakes, ponds and farm dams (DSEWPaC 2012). Seasonal flooding is an important habitat requirement. Application to the Project: The majority of the farm dams investigated during the field surveys conducted by ERM (2013) have a long history of being used for stock watering and as such, limited habitat remains to support threatened amphibian species such as the Growling Grass Frog. Nevertheless it is prudent to reduce sedimentation by applying appropriate sediment control practices and maintaining vegetated cover wherever possible, including riparian vegetation
Groundwater	The Study Area is located within the Lachlan Fold Belt GWMA. Eight groundwater bores intersect / occur within approximately 500m the Study Area (NOW 2013b) with an average upper limit of the water bearing zone 14.6m below the surface. . No GDEs have been identified for the Lachlan Fold Belt GWMA, however River Red Gum woodland has been mapped along the Boorowa River and Pudman Creek (NPWS 2002). Ecological investigations by ERM (2013), did not identify any GDEs within the Study Area.	Flow requirements: Impact on groundwater is considered to be minimal. Application to the Project: 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 Water Sharing Plans.
Bed and bank stability	NoW have requested an assessment of watercourses to be crossed and descriptions of appropriate techniques and measures to minimise impact. Significant watercourses must be protected through directional drilling techniques where underground cabling is required.	Flow requirements: To preserve the structural integrity of the creekbanks and creekbed, the natural flow regime should be maintained. Application to the Project: Impacts on the hydrology, water quality and aquatic and riparian vegetation should be minimised. These impacts are addressed within this assessment.

8.4 Cumulative Impacts

8.4.1 Overview

An assessment of cumulative environmental impacts considers the potential impact of a proposal in the context of existing and future developments to ensure that any potential environmental impacts are not considered in isolation. In assessing the cumulative impacts of the Project on soil and water resources, the following aspects have been considered:

- Potential long and short term impacts Project may have on soil and water resources in light of the combined impacts of several specific proposed developments as stated in the DGRs, namely Rugby Wind Farm (52 wind turbines), Rye Park Wind Farm (greater than 100 wind turbines), Yass Valley Wind Farm (up to 152 turbines) and Dalton Power Plant (500 - 1000 megawatt gas turbine power station); and

- The impact of Project on soil and water resources, in light of the combined impacts of other land-use practices and environmental characteristics of the area.

The proposed Rye Park Wind Farm is the closest to the Project, located approximately 8 km to the north-east and east. The proposed Rugby Wind Farm will be located approximately 12km north-east of the Project, the proposed Yass Valley Wind Farm will be located approximately 25km south-west of the Project and the approved Dalton Power Plant will be located approximately 30 km south-east of the Project. Rye Park, Rugby and Yass Valley Wind Farms have not yet been approved by the DoPI.

8.4.2 Cumulative impacts of wind farms within the Lachlan Catchment

Three of the four proposed developments are located with the Lachlan Catchment, with the proposed Yass Valley Wind Farm located in the Murrumbidgee Catchment. All four proposed developments are located within the Lachlan Fold Belt GWMA.

The relatively close proximity of the proposed Rye Park and Rugby Wind Farms to the Project, increase the potential for cumulative impacts on water resources, particularly on Pudman Creek which drains into the Boorowa River. The construction of all three wind farms is unlikely to occur simultaneously, resulting in the potential for an increase in the amount of sediment flowing into Pudman Creek over an extended period. Increased sediment load can have an impact on riparian and watercourse corridors and wetlands via an increase in turbidity, nutrient levels (potentially) and changes in the topography of the stream bed. Turbid waters create less favourable conditions for the majority of aquatic flora and fauna species, increases in nutrient load favour invasive riparian plant species / aquatic macrophytes and changes to the topography of the stream bed may alter the existing natural bank and bed erosion process. Consequently particular care will need to be taken to minimise the movement of soil off-site by all three wind farm developments.

As all projects overlie a fractured rock aquifer, groundwater supply is low and hence less likely to be utilised as a water source during construction. Impacts on groundwater sources are expected to be confined to the immediate area due to the nature of fractured rock providing limited channels for groundwater flow. The potential for the movement of contaminants between projects is considered to be negligible. Should it occur, it is expected to progress at a slow rate due to the process of matrix diffusion (Cook 2003).

The Project is of sufficient distance from the approved Dalton Power Plant and proposed Yass Valley Wind Farm, that it is anticipated that there will be no cumulative effect on groundwater, riparian and watercourse corridors and wetlands from the introduction of the proposed development into the area.

8.4.3 Short term cumulative impacts

As the majority of soil and water disturbance will occur during the construction phase of the Project, short term impacts will primarily be of concern during this time. The combination of current agricultural activities such as grazing and cropping, and construction activities such as excavation, track construction and vehicle movements create potential for increased rates of erosion and increased levels of dust in the absence of control measures. The potential for increased rates of erosion and increased levels of dust within the general locality over an extended period is compounded by the close proximity of the proposed Rye Park and Rugby Wind Farms to the Project. Nevertheless, it is expected that soil and erosion impacts will be largely site-specific and hence can be avoided or mitigated at source. Short term cumulative impacts can be minimised by dust suppression, the use of sediment fences and barriers and by restoring groundcover on exposed soils as soon as practicable.

The close proximity of the proposed Rye Park and Rugby Wind Farms to the Project places increased demand on local water resources, particularly during the construction phase. The Project, Rye Park and Rugby Wind Farms and Dalton Power Plant are all subject to the same Water Sharing Plans, meaning that each development will need to abide by the rules outlined in the Plans to ensure equitable sharing of water for all users and the environment (surface and ground water). It may be that equitable water shares are inadequate for construction and water may need to be brought in.

8.4.4 Long term cumulative impacts

Grazing within the Project Site has a continual and sustained impact on the local environment, due the clearance of native vegetation, soil erosion and increases in soil nutrient load. It is anticipated that the Project will create minimal additional impact to the existing condition of soil and water resources within the Project Site. Impacts, such as those identified in this report, will be managed via a CEMP and SWMP. The existing hydrology will not be altered and if groundwater extraction is undertaken, it will be in accordance with the relevant Water Sharing Plan(s).

9 Mitigation and management

9.1 Soil and water management principles

According to Landcom (1994), effective soil and water management during a land disturbance phase involves the following seven principles:

(i) assess the soil and water implications of development at the site planning stage, including those relating to ecologically sustainable development (ESD). Investigate the salinity and, on coastal lands, the acid sulphate potentials of the soils where their disturbance is likely to expose and/or exacerbate this problem;

(ii) plan for erosion and sediment control concurrently with engineering design and before earthworks begin, ensuring proper assessment of site constraints and integration of the various components;

(iii) minimise the area of soil disturbed and exposed to erosion;

(iv) conserve topsoil for later site rehabilitation/revegetation;

(v) control water flow from the top of, and through the development area;

(vi) rehabilitate disturbed lands quickly; and

(vii) maintain soil and water management measures appropriately during the construction phase.

Further to the above seven principles, devices that slow or divert the flow of water should be erected around construction areas, hardstand areas and surfaced access tracks; and inspection and maintenance of soil water management measures should be continued throughout the operational and decommissioning phases. These principles should be outlined in detail in the SWMP (pending the results of a geotechnical assessment) and implemented during the civil design stage.

Any sourcing of water for construction requirements should be done in accordance with licensing requirements under the *WM Act*. Where possible water should 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.

The following recognised guidelines and standards should also be adhered to:

- *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 and Witheridge 2003).

9.2 Access tracks and trenching

Appropriate planning and design, good construction practice and active maintenance of unsealed roads can significantly minimise erosion and off-site sedimentation. The guidelines *Managing Urban Stormwater: Soils and Construction, Volume 2C Unsealed Roads* (DECC 2008) provide guidance in applying the principles and practices of erosion and sediment control described by Landcom (2004) to the planning, design, construction and maintenance of unsealed roads. A number of measures are described in the guidelines that should be incorporated into the SWMP and are discussed below.

Route selection heavily influences the long-term erosion and sedimentation from an unsealed road. Where the choice of route selection is limited, the application of other principles of erosion and sediment control becomes increasingly important. Where few limitations exist, an appropriate route can minimise adverse environmental impacts as well as the costs of construction, temporary control measures and on-going maintenance by minimising the potential for erosion (DECC 2008). Basic principles of route selection are to reduce the catchment area above the road or track, minimise disturbance to soil and vegetation and the number of drainage line crossings, and to avoid steep cross-slopes, high erosion-hazard soils, areas of riparian vegetation, perched water tables, areas prone to mass movement and soil types having poor construction quality (DECC 2008).

The **longitudinal grade** of an unsealed road or track should ideally be less than 10 degrees (18%) (DECC 2008). However, short lengths of steeper grade (up to 15 degrees or 27%) may be needed to avoid or negotiate rocky outcrops or unstable / poorly drained soils, take advantage of the topography or soils which are more suitable for the construction and drainage of the road, or to reduce the catchment area above the road. Gravelling and more sophisticated road drainage may be required where grades are required to exceed 15 degrees on soils of low erodibility or 12 degrees on soils of moderate erodibility (DECC 2008).

The large, sometimes steep, areas exposed during cut and fill operations can present a significant erosion problem. These areas, known as **batters,** should be designed to be no steeper than the in-situ soil stability permits and fills higher than 1.5 metres constructed from soils with a moderate or high erodibility will require special stabilisation works (DECC 2008). Fill material should not contain large rocks or vegetative debris, catch drains above a cut batter may be required to prevent run-on water flowing onto the cut batter, batter drains may be required to transfer water down the slope over a fill batter (if alternative discharge sites are not available), berm drains should be installed on batters that have been breached, permanent drainage should be provided at the toe of cut batters and at the top of fill batters and energy dissipaters will be required at the end of chutes and culverts (DECC 2008).

Effective **surface drainage** is required on unsealed roads and tracks to minimise erosion by controlling runoff. All unsealed roads and tracks should be constructed with adequate permanent drainage to convey at least a 5-to-10-year ARI design flow (DECC 2008). A number of drainage structures can be used to prevent runoff from concentrating and reaching erosive speeds such as crowning, cross-fall drainage, cross banks or cross-drains, rolled grades, table drains, mitre/spoon drains, catch drains and flumes / batter drains (DECC 2008)

To minimise turbulence and avoid disturbance to natural water flows, **drainage line crossings** should consist of fords /causeways, culverts or bridges. A ford should be used where stable natural crossings exist with no defined bank or bed and minimal earthworks are required (DECC 2008). It should be aligned as close as possible to perpendicular to the direction of the drainage line, unless an angled approach would reduce ground and soil disturbance and not impede or disturb the flow between the banks of the drainage line. To create a stable surface, rock can be placed in the drainage line or the ford concreted. The upstream side of the ford should merge with the natural surface of the watercourse bed, however the downstream side may be higher than the bed level (DECC 2008).

Culverts carry water away from a table drain or a drainage line that passes under a road and are often used on roads that require use in all weather conditions and by all types of vehicle (DECC 2008). Culverts should be designed with a headwall or box inlet to force the culvert to run at its greatest capacity to self-scour sediment and debris. Culverts installed in drainage lines should be installed as close as possible to the natural alignment of the drainage line to avoid diverting flow into the stream banks or creating scour of the drainage line (DECC 2008).

It is most appropriate to use a bridge when all-weather, all-vehicle access is required, river flows are high, flow lines are deeply incised and / or have wide cross-sections. Bridges do not normally restrict stream flows nor impede the movement of aquatic fauna but their design and construction can be expensive. Bridges should be located the area of least environmental value and impact, use the minimum number of in-stream piers located away from the banks to minimise turbulence and reduce risk of scour, have adequate scour protection around piers and along abutments and creek banks and have appropriate bridge drainage to avoid causing erosion (DECC 2008). Disturbance to the riparian corridor should be rectified immediately following completion of works.

Revegetation for site stabilistaion should be undertaken immediately following the completion of works and use locally native species as a base mix. Where ecological values are low, a cover crop of a sterile seed source may be used.

Other considerations include the location of borrow pits away from drainage lines, with topsoil and litter debris stockpiled in an area of low erosion hazard, and the possible need for sediment basins during construction in areas of high conservation value. During construction, traffic should also be managed on site to minimise the potential for dust generation and erosion. A water truck can be used to minimise dust.

9.3 Works in riparian zones

There are potentially 173 stream crossings associated with the Project. Of these 93 are located on first order streams, 48 on second order streams, 24 on third order streams and eight on fourth order streams. Of these, 53 are access track crossings – 33 over first order streams, and the remaining 20 over second order and higher streams. All work within and across the VRZ of the riparian corridors has been designed to be in line with NOW and DoPI guidelines 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.

To minimse construction and operation impacts on watercourses and riparian corridors, hardstand areas for the site office, concrete batching plants, rock crusher, substation and construction compounds should be located, where possible, outside of the VRZ. The following requirements that should be considered have been adapted from ELA (2011):

- 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;
- Regular inspection, maintenance and cleaning of water quality and sedimentation control devices;
- Changes to the quantity and quality of waters flowing from the Project area should 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 Suggested surface water monitoring locations include
    - Junction of Langs Creek and Rocky Creek;
    - Junction of Dry Creek and Langs Creek;
    - Upper reaches of Fat Jack Creek (outside Study Area);
    - Upper reaches of Gorham Creek;
    - Upper reaches of Hardiman Creek;
    - Upper reaches of Kangiara Creek; and
    - Upper reaches of Thorsby Creek

9.4 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.

9.5 Contamination

Contamination of surface water or groundwater may result from spillage of hazardous substances used at the substation or during construction or from oil / fuel used in vehicles on-site. Concrete batching plants should be located outside the VRZ and as far away from creeks as practicable. Bunding should be erected to contain any potential spills and controls used to prevent any loss of sediment or other contaminated material. Design measures such as constructed concrete bunds around each transformer and a spill oil retention basin or oil/water separator outside the MCS compound, should be implemented for primary and secondary containment of any oil that may leak or spill from transformers or associated components. The following measures have been adapted from ELA (2011) and should 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 occurs;
- Refuse and rubbish is appropriately contained on-site;
- Wastewater produced during construction from temporary onsite toilets should 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; and
- 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.

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