Sediment and Erosion Management Plan

Chalumbin Wind Farm

Prepared for:
Chalumbin Wind Farm Pty Ltd

November 2022

Document Information

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REVIEWED BY	Chris Cantwell, Principal Consultant

Quality Information

REVISION	DATE	DETAILS	AUTHORISATION	
			Name/Position	**Signature**
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1	09-09-2022	Final – Updated following adequacy review	Original Signed	Original Signed
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1.0 Introduction

This Plan has been prepared to support the Public Environmental Report (PER) for the Chalumbin Wind Farm Project (the Project) and should be read in conjunction with the PER. Specifically, this Plan addresses section 7.2.3 of the *Guidelines for the Content of a Draft Public Environmental Report: Chalumbin Wind Farm, near Ravenshoe, Queensland (reference: 2021/8983)* (PER Guidelines), issued by the Department of Agriculture, Water and the Environment (DAWE) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Section 7.2.3 of the PER Guidelines requires:

> *A sediment and erosion management plan outlining mitigation and monitoring of sediment loads. The Herbert River flows into the Great Barrier Reef Marine Park and is currently listed under high (orange) management priority for high sediment loads. The sediment and erosion management plan should outline how it takes into consideration the Reef 2050 Water Quality Improvement Plan, and how the Project will be consistent with the Plan.*

This Plan is not intended as an erosion and sediment control plan (ESCP) for implementation purposes, nor as a stand-alone report, and therefore does not:

- Describe the Project (a comprehensive Project description is provided within section 2.0 of the PER).
- Describe the proposed Project construction works (a description of the proposed construction activities is provided within section 2.3 of the PER).
- Provide a detailed site analysis for Erosion and Sediment Control (ESC) planning.
- Identify specific erosion, drainage and sediment controls for on-site implementation.

If the Project is approved, relevant elements of this Plan will be incorporated into construction ESCPs.

The base case of the assessment in this Plan is for the construction of both Stage 1 and Stage 2 using access from Wooroora Road to the north. Further details on the Project stages are presented in the PER.

1.1 Definitions

The terms and acronyms used within this document are defined in **Table 1.1**.

Table 1-1 Definitions

Term / acronym	Meaning
2017 Scientific Consensus Statement	2017 Scientific Consensus Statement: Land Use impacts on Great Barrier reef Water Quality and Ecosystem Condition
Attexo	Attexo Group Pty. Ltd.
BoM	Bureau of Meteorology
BPEM	Best Practice Erosion and Sediment Control Manual 2008
CEMP	Construction Environmental Management Plan
CPESC	Certified Professional in Erosion and Sediment Control

Term / acronym	Meaning
CWF	Chalumbin Wind Farm Pty. Ltd.
DAWE	Department of Agriculture, Water and the Environment
EMP	Environmental Management Plan
EP Act 1994	*Queensland Environmental Protection Act 1994*
EPBC Act	*Commonwealth Environment Protection and Biodiversity Conservation Act 1999*
ESC	Erosion and Sediment Control
ESCP	Erosion and Sediment Control Plan
GBR	Great Barrier Reef
GBRCA	Great Barrier Reef Catchment Area
IECA	International Erosion Control Association
IECA 2008 BPESC Standard	International Erosion Control Association 2008 Best Practice Erosion and Sediment Control Standard
PER	Public Environment Report
PER Guidelines	Guidelines for the Content of a Draft Public Environmental Report: Chalumbin Wind Farm, near Ravenshoe, Queensland (reference: 2021/8983)
P-ESCP	Preliminary Erosion and Sediment Control Plan
Project area	Refers to the entire area of the land parcels within which the Project is located and excluding any part of the Wet Tropics of Queensland World Heritage Area
Project footprint	Refers to the maximum area potentially disturbed by construction of the Project within the Project area
Project Owner	Chalumbin Wind Farm Pty. Ltd.
Reef 2050 Plan	Reef 2050 Long-Term Sustainability Plan
Reef 2050 WQIP	Reef 2050 Water Quality Improvement Plan
SEMP	Sediment and Erosion Management Plan (this Plan)
The Project	The Chalumbin Wind Farm Project

2.0 Reef 2050 Water Quality Improvement Plan

The Project is situated within the upper portion of the Herbert River Drainage Basin of the Great Barrier Reef Catchment Area (GBRCA), within the Wet Tropics Natural Resource Management Area. Overland flows from the Herbert River Drainage Basin discharge to the Great Barrier Reef (GBR) via the Hinchinbrook Channel approximately 22 km north-east of Ingham (**Figure 2-1**).

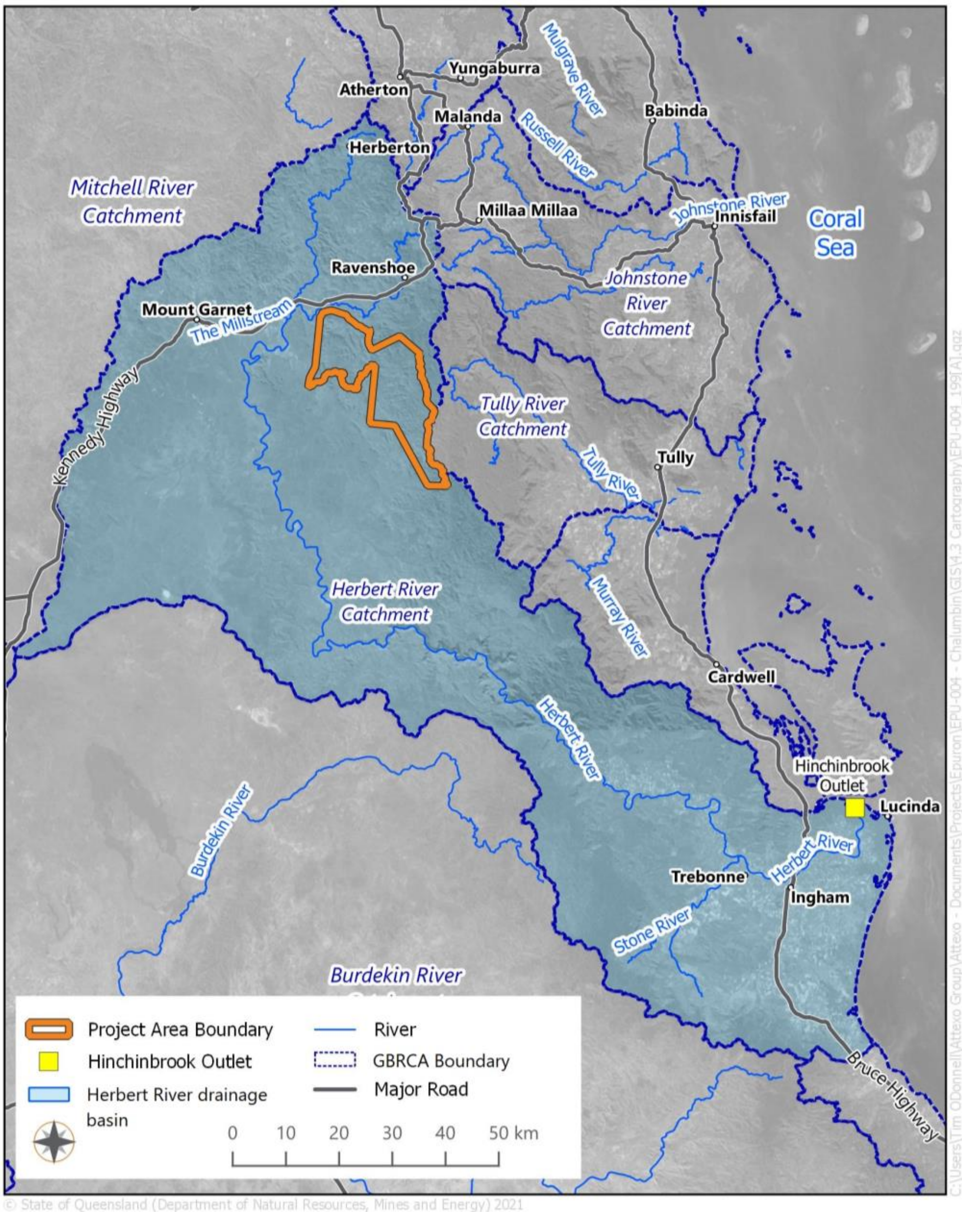


Figure 2-1 Location of the Project within the GBRCA and Herbert River drainage basin

Sea surface temperature rise, and severe weather events associated with climate change, are placing significant pressure on the GBR. Marine water quality decline, attributed to pollutants delivered to the GBR via land-based runoff, exacerbate these impacts by placing further pressure on reef ecosystems, thereby reducing the GBR's resilience to climate change related events, which are expected to increase in frequency, duration and intensity in the future (Waterhouse *et al.*, 2017).

In recognition of these threats, and the social, environmental, and economic importance of the GBR, the Commonwealth and Queensland Governments have partnered to develop the five-year Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP). The Reef 2050 WQIP forms part of the Australian and Queensland Governments' Reef 2050 Long-Term Sustainability Plan (Reef 2050 Plan), its purpose being to identify management and monitoring requirements for land-based pollution to improve the quality of water discharged from GBR catchments to the Reef.

The Reef 2050 WQIP is underpinned by the *2017 Scientific Consensus Statement: Land Use impacts on Great Barrier reef Water Quality and Ecosystem Condition* (the 2017 Scientific Consensus Statement). The 2017 Scientific Consensus Statement identifies the primary pollutants of concern to the GBR from mainland sources as nutrients (nitrogen and phosphorus), fine sediments and pesticides, which are attributed largely to agricultural sources.

The 2017 Scientific Consensus Statement goes on to establish catchment-scale management priorities based on proximity to the GBR, pre-existing pollutant loads and the ecology of the receiving GBR ecosystem. The following priorities have been allocated to the Herbert River Basin:

- Dissolved inorganic nitrogen (DIN) – very high priority.
- Sediment and particulate nutrients – high priority.
- Pesticides – low priority.

Water quality targets for 2025 set by the Reef 2050 WQIP for the Wet Tropics Region and Herbert River Drainage Basin are provided in **Table 2-1**.

Table 2-1 Reef 2050 WQIP anthropogenic 2025 water quality targets

Area	Dissolved Inorganic Nitrogen		Fine sediment		Particulate phosphorus		Particulate nitrogen		Pesticides
	tonnes	reduction	kilotonnes	reduction	tonnes	reduction	tonnes	reduction	target
Wet Tropics Region	1700	60%	240	25%	360	30%	850	25%	To protect at least 99% of aquatic species at the end-of-catchments.
Herbert River Basin[1]	620	70%	99	30%	57	30%	200	30%	

[1] Values represent end of catchment targets, colour highlighting of targets denotes management priorities of very high and high for red and orange respectively

2.1 Project response and compliance with the Reef 2050 Plan

The Project's location in the GBRCA has a responsibility to consider and address the objectives and targets of the Reef 2050 Plan to mitigate unintended impacts on the GBRMP.

The following sections discuss how the Project will respond to the Reef 2050 Plan and contains an estimate of the sediment runoff from the Project.

2.1.1 Project actions and responses to the Reef 2050 Plan

A description of how the Project will minimise its contribution of primary pollutants of concern to the GBR is provided in **Table 2-2**.

To reduce the risk of erosion and fine sediment runoff the Project is committed to nil surface-disturbing construction works in the wet season months defined as January, February and March. During the months of January, February and March there may still be non-ground disturbing construction activities. Construction involving soil disturbance will only occur during the months of April to December and in accordance with the provisions of the project-specific Erosion and Sediment Control Plan.

Table 2-2 Management for primary pollutants of concern

Primary pollutant of concern	Project action
Fine sediment and particulate nutrients	▪ Nil surface-disturbing construction works in the wet season months defined as January, February and March. ▪ Construction planning and scheduling of ground disturbance activities will factor in weather risks using long-range weather forecasts and the potential of large / high intensity rainfall events during the wet season shoulder seasons. This will include prioritising construction on low-risk erosion sites (i.e. lower slopes, stable soils, not close to sensitive receiving environments) during these times. ▪ Minimise vegetation clearing and ground disturbance during construction. ▪ Undertake ESC throughout the Project in line with the IECA 2008 BPESC Standard. ▪ Revegetate disturbed areas outside of retained tracks and hardstands.
Dissolved inorganic nitrogen	▪ Revegetate using assisted natural regeneration methods where conditions allow. ▪ Minimise nutrient addition for revegetation via targeted soil amelioration based on soil sampling data.
Pesticides	▪ Implement weed hygiene protocols to prevent the introduction of weeds in the first instance. ▪ Revegetate disturbed areas no longer required for construction progressively, to minimise opportunity for the establishment of weeds, pests and disease. ▪ Selection of pesticides that minimise harm to the environment.

Further to the above, several land and catchment management targets aimed at improving the quality of mainland water discharged to the GBR are identified by the Reef 2020 WQIP. These are listed in **Table 2-3**, with proposed Project responses to each management target.

Table 2-3 Project response to Reef 2020 WQIP land and catchment targets

Management Target	Project response
90% of agricultural land in priority areas managed using best management practice for water quality outcomes	The Project footprint is partially used for grazing purposes, this land use will continue once construction is complete and the Project is operational. Ground disturbing operational works will be undertaken in line with the IECA 2008 BPESC Standard and will therefore contribute to achieving the management target.
90% of grazing lands with greater than 70% groundcover in the late dry season	The Project footprint is partially used for grazing purposes, this land use will continue once construction is complete and the Project is operational. A minimum of 70% groundcover[1] will established across the Project footprint upon completion of construction, and thereafter within areas disturbed for operations and maintenance purposes. Hence, the Project will contribute to achieving the management target. Note, finished surfaces such as tracks, hardstand and gravel surfaces are included within the 70% groundcover target.
Increase riparian vegetation	Impacts to riparian vegetation will be minimised and disturbed riparian areas, outside of retained track and hardstand areas, revegetated with native riparian vegetation. Further, direct offsets delivered for the Project will involve the restoration of riparian vegetation within the GBRCA and will therefore contribute to meeting the management target.
No loss of natural wetlands	No natural wetlands will be impacted by the Project.
Improved management of urban, industrial and public land uses.	The Project footprint will be managed in line with the IECA 2008 BPESC Standard and site-specific Environmental Management Plans (EMPs) which specifically address the quality of surface water runoff discharged from the Project footprint.

The *2017 Scientific Consensus Statement* is clear that improvements to governance, program design, delivery and evaluation systems are urgently needed if water quality objectives are to be met. The Reef 2050 WQIP nominates

[1] Groundcover being inclusive of revegetated areas, as well as all stabilised track and hardstand surfaces, pavement, and gravel / loose rock (e.g. aggregate) surfaces.

seven work areas for improvement which are structured around two bodies of work. The first, referred to as *responding to the challenge,* relates directly to land and catchment targets established by the plan. The second, referred to as *enabling delivery,* supports informed decision making, performance tracking and financial investment at the Government level. The specific actions and delivery mechanisms identified for each work area are primarily targeted at the governance level; those actionable by the Project are discussed in **Table 2.4**.

Table 2-4 Project response to Reef 2050 WQIP work areas

Work area	Action	Project response
Minimum practice standards	Urban, industrial and mining activities comply with requirements under the *Environment Protection and Biodiversity Conservation Act 1999*, *Planning Act 2016*, *Environmental Protection Act 1994*, and *Waste Reduction and Recycling Act 2011*.	The Project will meet and comply with all of its legislative obligations.
Culture of innovation and stewardship	Trial and implement innovative monitoring, land management and treatment system solutions that aim to deliver water quality benefits.	The Project will adopt the IECA 2008 BPESC Standard for land and water quality management. IECA is focussed on innovation and continual improvement, as demonstrated via the inclusion of a category for innovation within the annual IECA Australasian environmental excellence awards scheme. Information pertaining to innovative ESC techniques is regularly disseminated throughout the worldwide IECA community.
Catchment restoration	Not applicable - stated actions relate to Government initiatives.	Areas disturbed for Project construction, but not required for Project operations, will be rehabilitated as soon as practicable in line with the process generally described in section 7.0 of the PER.

2.1.2 Estimated Project sediment runoff

The Reef 2050 Plan and the Reef 2050 Water Quality Improvement Plan use modelled estimates of end-of-catchment fine sediment loads to examine sources of sediment loads, to set water quality targets and to examine land management change for load reduction.

To evaluate the Project's fine sediment runoff and compliance with the Reef 2050 Plan modelled estimates of fine sediment loads were performed and are described below. A review of the modelling methods used in the development of the Reef 2050 Plan was undertaken to ensure the Project estimates were as consistent as practicable. The following documents provide a useful summary of the modelling methodologies:

- Australian and Queensland governments, 2022, Catchment loads modelling methods, Reef Water Quality Report Card 2020, State of Queensland, Brisbane.
- Ellis, R & Searle, R 2013, 'An integrated water quality modelling framework for reporting on Great Barrier Reef catchments', in J Piantadosi, RS Anderssen and J Boland (eds) MODSIM2013, 20th International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand, December 2013, pp. 3183–89.
- Ellis, R.J. (2018). Dynamic SedNet Component Model Reference Guide: Update 2017, Concepts and algorithms used in Source Catchments customisation plugin for Great Barrier Reef catchment modelling. Queensland Department of Environment and Science, Bundaberg, Queensland.

To calculate sediment runoff estimates the Project used the Revised Universal Soil Loss Equation (RUSLE) to estimate the tonnes per ha per year soil loss rates resulting from sheet and rill erosion.

The detailed soil loss calculations are presented in **Attachment A** and a description of the sediment runoff calculation method for the Project using RUSLE is presented below.

RUSLE, $A = R * K * LS * C * P$

Where,

A	=	annual soil loss due to erosion (t/ha/yr)
R	=	rainfall erosivity factor
K	=	soil erodibility factor
LS	=	topographic factor derived from slope length and slope gradient
C	=	ground cover and management factor
P	=	erosion control practice factor

The R * K * LS factors were sourced from a soil data series contained in the Queensland Spatial Catalogue (based on or contains data provided by the State of Queensland 2020), which is intended to be used for predicting long term average annual hillslope erosion rates across Queensland.

Refer to **Sections 2.1.2.1**, **2.1.2.2**, and **2.1.2.3** for specific assumptions and data sources for the estimating soil loss under current conditions and the construction and operational phases of the Project.

Due to the linear nature of the Project footprint the spatial averages for input values in each RUSLE model scenario were calculated in ArcGIS to ensure accuracy.

The soil loss estimates and calculated gross sediment yield for the Project with current conditions, during construction and during the Project's operational phase are presented in **Table 2-5** for the base case where both Stage 1 and Stage 2 of the Project are constructed and **Table 2-6** that presents the soil loss estimates only for Stage 1 of the Project. The Project footprint for Stage 1 is approximately 607 ha versus 1071 ha for the base case that includes both Stage 1 and Stage 2.

Note that for comparison purposes, there are three construction-phase scenarios presented:

- Construction with no ESC (assumes year-round construction)
- Limiting ground-disturbing construction works to the months of April to December only and with no ESC measures in place; and
- Limiting ground-disturbing construction works to the months of April to December only and with efficient ESC measures in place.

The third (bold) scenario is considered a realistic representation of the Project; the previous two scenarios are provided for comparison purposes to determine the effect of (a) limiting the ground disturbance construction works to the dry season (April to December), and (b) effectively implementing efficient ESC measures (see **Section 2.1.2.2**).

Table 2-5 Project soil loss scenario estimates (Base case - Stage 1 and Stage 2)

<table>
<tr><th>Project stage</th><th>Description</th><th>Gross sediment yield (kt/yr)</th><th>Net sediment loss during 2 months (kt)</th><th>Net change to Project footprint gross sediment yield during operation (kt/yr)</th></tr>
<tr><td>Existing</td><td>Current conditions (70% cover)</td><td>16.85</td><td></td><td rowspan="5">-0.45</td></tr>
<tr><td rowspan="3">Construction</td><td>Construction no ESC (comparison only)</td><td>876.08</td><td>146.0</td></tr>
<tr><td>Limiting ground disturbance construction works to dry season no ESC (comparison only)</td><td></td><td>40.4</td></tr>
<tr><td>Limiting ground disturbance construction works to dry season with ESC 'efficiency'</td><td></td><td>6.3</td></tr>
<tr><td>Operation</td><td>Rehabilitation</td><td>16.40</td><td></td></tr>
</table>

Table 2-6 Project soil loss scenario estimates (Stage 1 only)

Project stage	Description	Gross sediment yield (kt/yr)	Net sediment loss during 2 months (kt)	Net change to Project footprint gross sediment yield during operation (kt/yr)
Existing	***Current conditions (70% cover)***	**10.07**		**-0.68**
Construction	*Construction no ESC (comparison only)*	523.57	87.3	
	Limiting ground disturbance construction works to dry season no ESC (comparison only)		27.3	
	Limiting ground disturbance construction works to dry season with ESC 'efficiency'		**3.4**	
Operation	***Rehabilitation***	**9.39**		

2.1.2.1 Soil loss estimate – current conditions

The calculation of the existing soil loss uses a C-factor of 70% cover which is the Reef 2050 WQIP target for grazing land end of dry season cover target. This 70% cover is used for grazing of open pastures as well as under native vegetation that is mapped as remnant vegetation. The same 70% cover is used for operational rehabilitated areas associated with the Project, even though the initial ESC rehabilitation target for the stabilisation of the site before the removal of temporary ESC measures is likely to be higher.

Spatial modelling of soil loss was undertaken; however, there is presently no spatial data that could be used to develop a meaningful estimate of the C-factor. Regional ecosystem and various remotely sensed data were investigated, but not used due to a lack of confidence in information / correlation with C-factor. Further ecological surveys (e.g. modified habitat quality assessment surveys based on the BioCondition methodology) are planned which may allow an update to the site-specific C-factor for future the soil loss modelling.

A sensitivity analysis of % cover and the change in soil loss was undertaken (**Table 2-7**), based on established grass cover and the relationship is a decreasing curve for increasing % cover (**Figure 2-2**). For example, a 10% increase in % cover results in a 34% reduction in soil loss, but a 10% reduction in % cover results in a soil loss increase of 172%.

The P-factor is set to 1 for soil loss estimates outside of construction and assumes there is no contouring or other control structures / measures (e.g. sediment basins or compaction) used to control erosion in the broader landscape.

Table 2-7 Sensitivity analysis of % cover and the change in soil loss

% cover	C-factor	Soil loss	Soil loss % change compared to 70% cover
10%	0.29	32.6	1160%
20%	0.2	22.5	800%
30%	0.14	15.7	560%
40%	0.1	11.2	400%
50%	0.065	7.3	260%
60%	0.043	4.8	172%
65%	0.034	3.8	136%
70%	0.025	2.8	100%
75%	0.02	2.2	80%
80%	0.016	1.8	64%
90%	0.13	1.5	52%

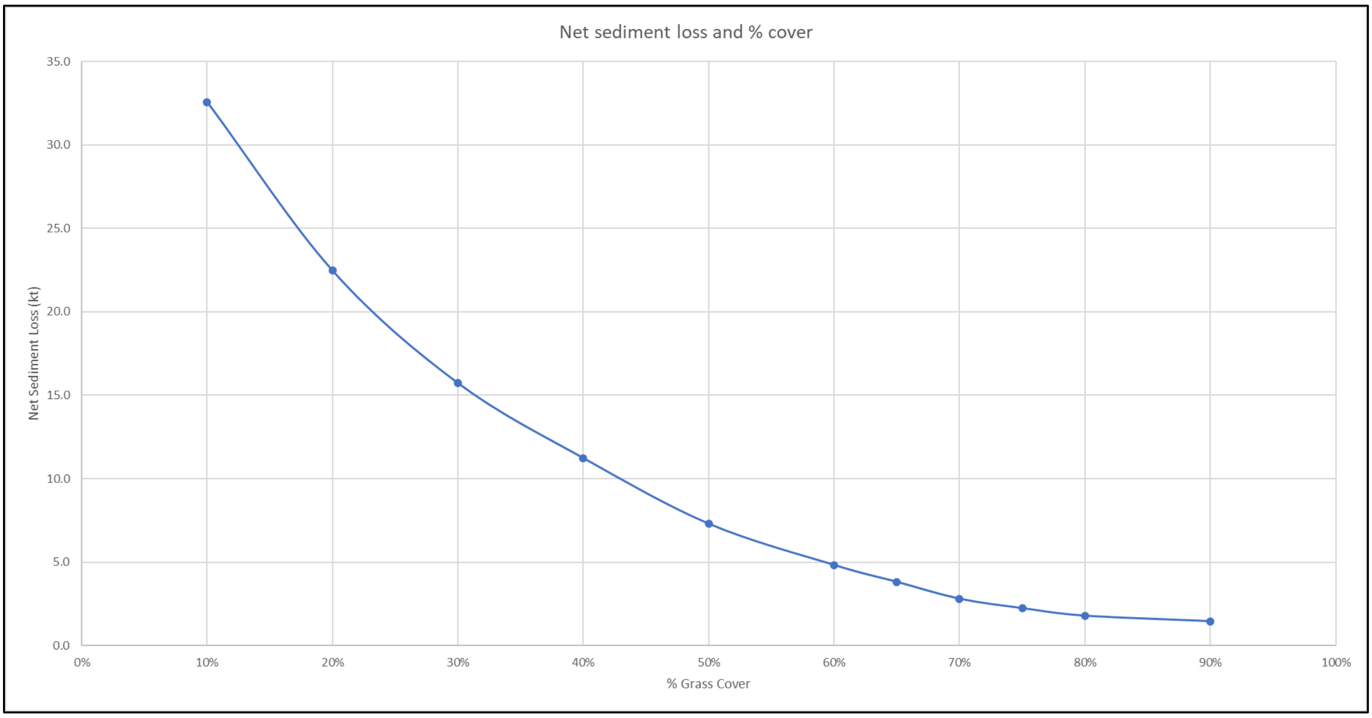


Figure 2-2 Relationship between % cover and soil loss

Notwithstanding, a 70% current cover estimate is likely to be generous for many parts of the Project footprint where cover is significantly lower. Areas that have a significantly lower cover will contribute to sediment yield by up a factor of 10 compared to the potential reduction in sediment yield for areas with higher cover. 70% cover is the Reef 2050 WQIP target for grazing catchments and the current grazing land management of the Project footprint is expected to result in less cover than this. Therefore, the overall modelled soil loss impacts from the Project are likely to be a conservative overestimate.

2.1.2.2 Soil loss estimate – construction phase

For almost all construction projects there is the potential for a short-term increase in sediment runoff during construction; however, this will depend on the weather conditions during construction and the successfulness of the ESC measures used. Further information on the efficiency and proven effectiveness of ESC measures is presented in **Section 4.3.3**. All construction phase soil loss calculations involved the use of a P-factor of 1.3 which is a compacted and smooth surface condition; a worst-case scenario. The P-factor could be reduced to 0.9 during construction by track-walking a machine up and down the slope.

The modelled soil loss scenarios in **Table 2-5** for the construction phase considered the following:

- Worst case scenario with no ESC measures applied and work occurring throughout the year (not a realistic or feasible scenario);
- Limiting ground disturbance construction works to dry season (April to December) only, with no implementation of ESC measures (not a realistic or feasible scenario); and
- Limiting ground disturbance construction works to dry season (April to December) only with the implementation of ESC measures.

The construction duration was assumed to be two months at any given location, based on progressive rehabilitation of Project disturbance areas.

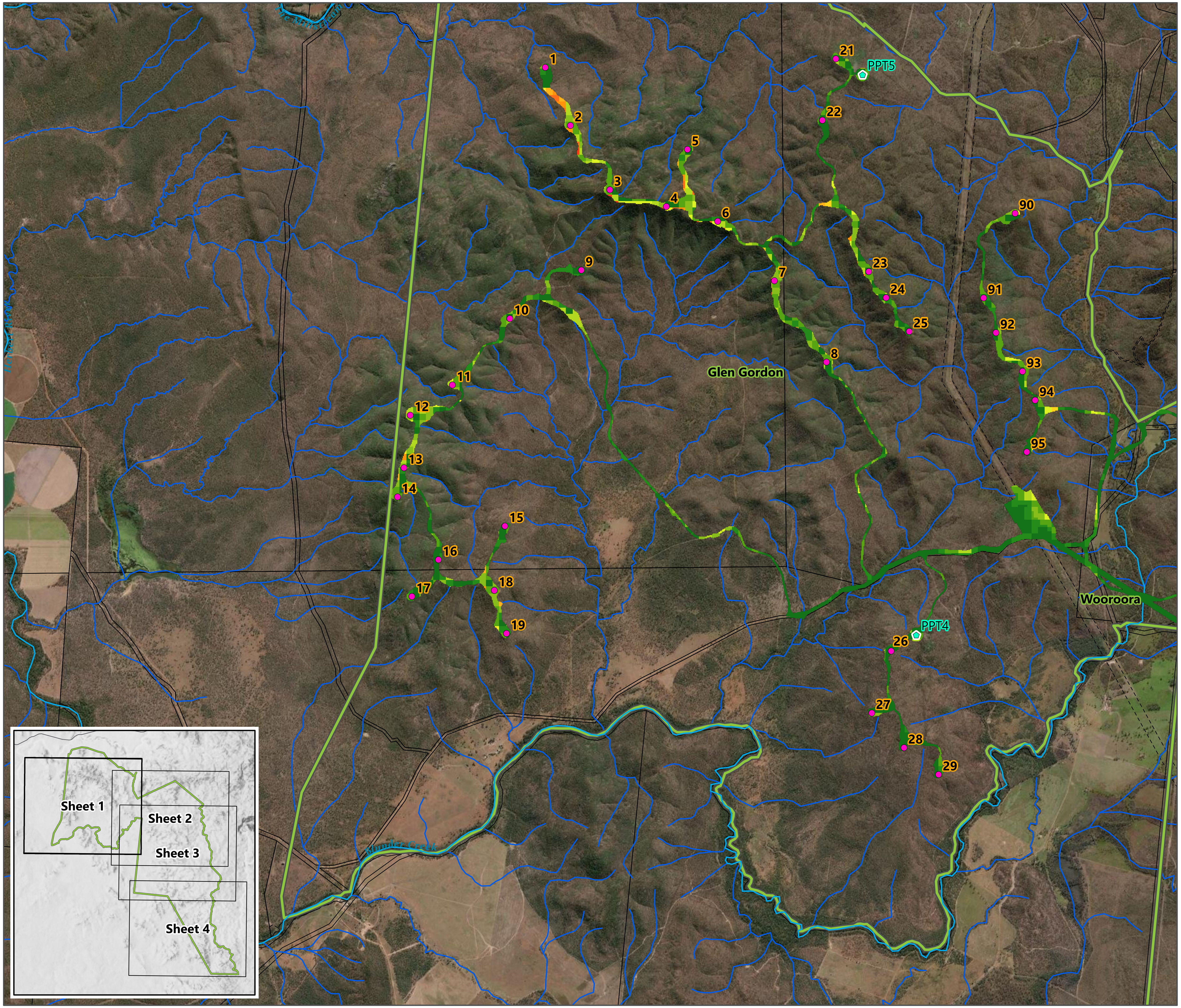
The "dry season construction only" scenarios used an average monthly R-factor. This rainfall erosivity factor was calculated by running at a daily timestep model (**Attachment A**) using the last 20 years of data for the Queensland Government stream flow monitoring site on Blunder Creek at Wooroora using the methodology described in Ellis, 2018. The average monthly R-factors (rainfall erosivity index EI30) for the three most representative rainfall stations for the Project area are presented in **Table 2-10**.

To estimate the ability of ESC measures to reduce to prevent sediment from being transported or to remove sediment once entrained, an efficiency estimate was used. Sediment control efficiency during construction is a measure of the efficiency of both erosion and sediment control measures. This removal efficiency was assumed to be 75% based on the use of best practice erosion and sediment control methods (IECA 2008 and NZTA 2014) implemented as part of a CPESC certified ESCP.

A map showing the estimated average monthly soil loss during dry season (April to December) construction (t/ha) is shown in **Figure 2-3**. This was based on scaling the spatial annual R-factor to the average monthly dry season R-factor using the three rainfall stations described in **Section 2.2.1** (an average scale factor of 3.4%).

2.1.2.3 Soil loss estimate – operational phase

For the soil loss estimates during the Project's operational phase the K, LS and C factors were modified for built infrastructure. Length and slope of operational areas were based on the civil design criteria for the Project. The K and C factors were modified to reflect the characteristics of gravel roads and hardstand areas. To be conservative, gravel capped roads were given a higher K-factor than hardstands due to operational traffic potentially increasing erosion risk. The C-factors for gravel surfaces were based on values in NZTA 2014 and used 0.15 for gravel surfaces <5% slope (met mast and turbine pads) and a conservative value of 0.2 for roads. Sediment control efficiency during operation is a measure of the stormwater system efficiency.



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Estimated monthly soil loss during dry season construction (t/ha)

Sheet 1 of 4

Figure 2.2

- Project Area Boundary
- Turbine
- Met-mast
- Watercourse
- Lot Boundary
- Easement

Estimated monthly construction soil loss (t/ha)

- 2 - 43
- 44 - 88
- 89 - 133
- 134 - 178
- 179 - 235
- 236 - 299
- 300 - 363
- 364 - 427
- 428 - 502
- 503 - 592
- 593 - 732
- 733 - 961

Date: 11/10/2022
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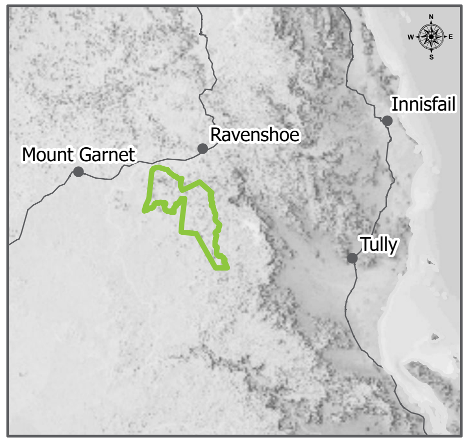
Author: TOD
Reviewed: NOD



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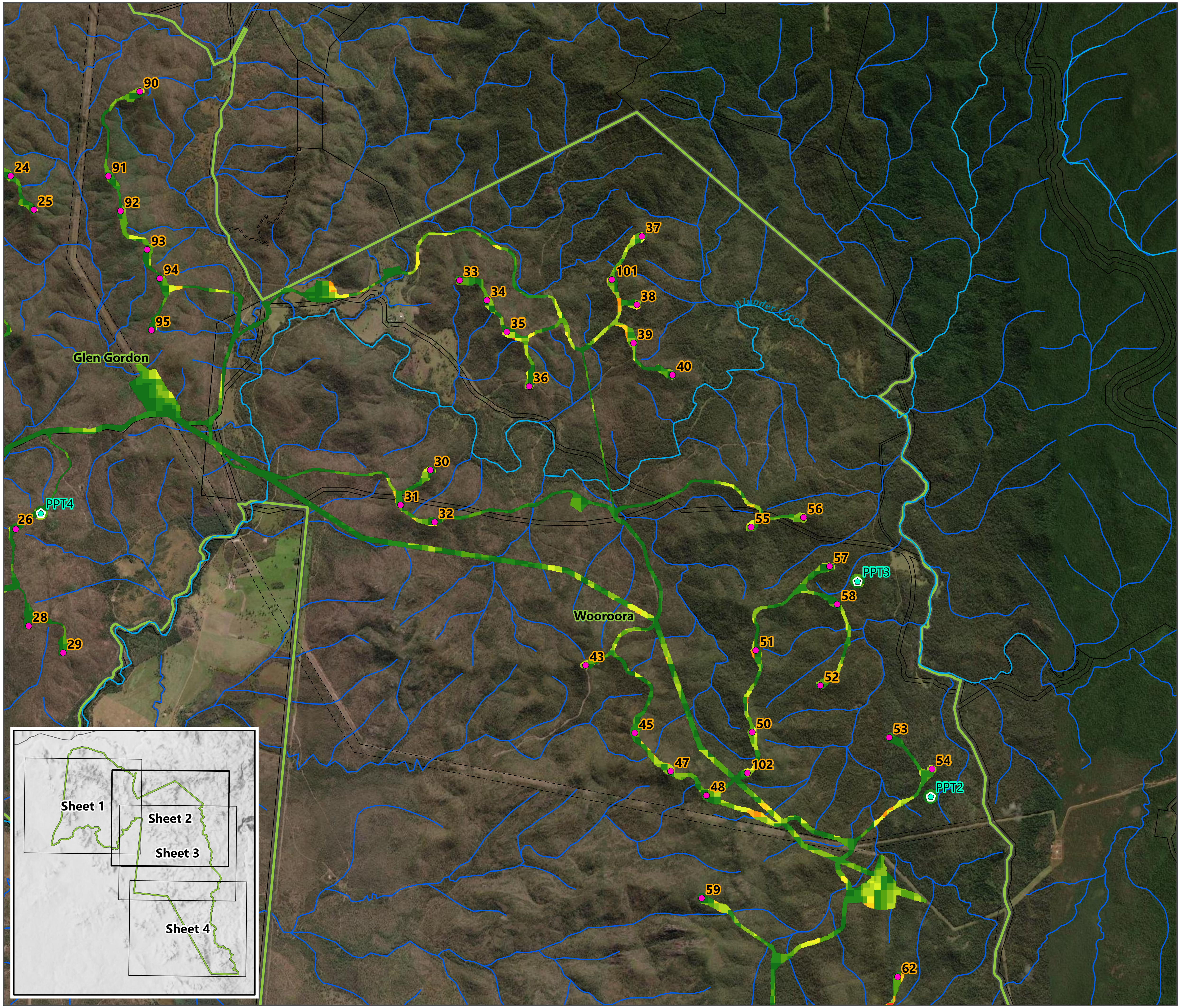

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Estimated monthly soil loss during dry season construction (t/ha)

Sheet 2 of 4

Figure 2.2

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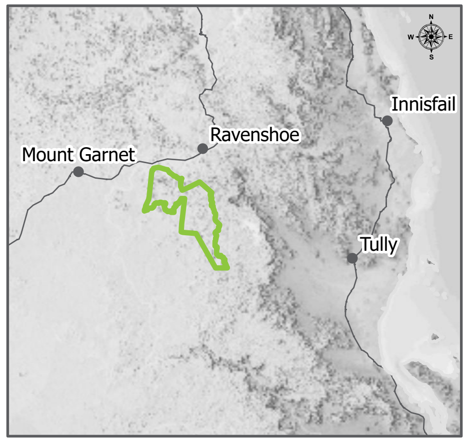

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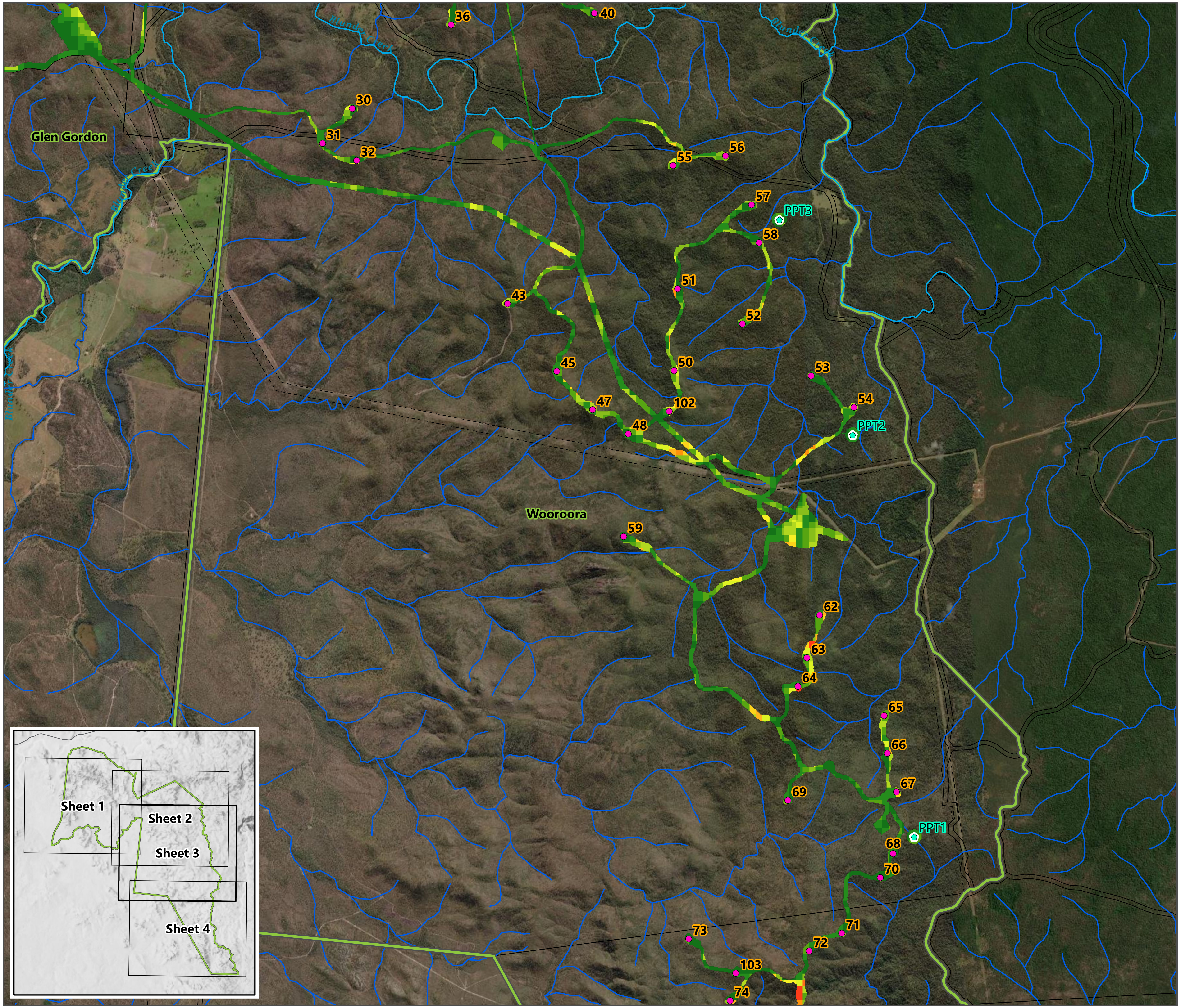

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Estimated monthly soil loss during dry season construction (t/ha)

Sheet 3 of 4

Figure 2.2

- Project Area Boundary
- Turbine
- Met-mast
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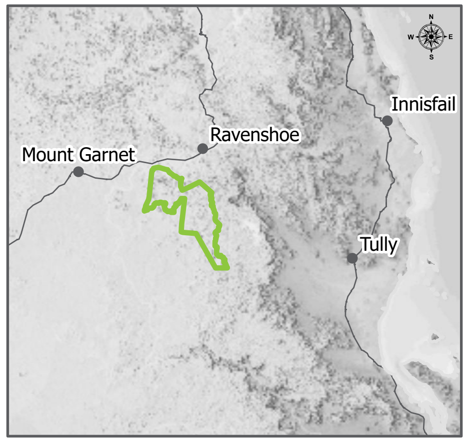

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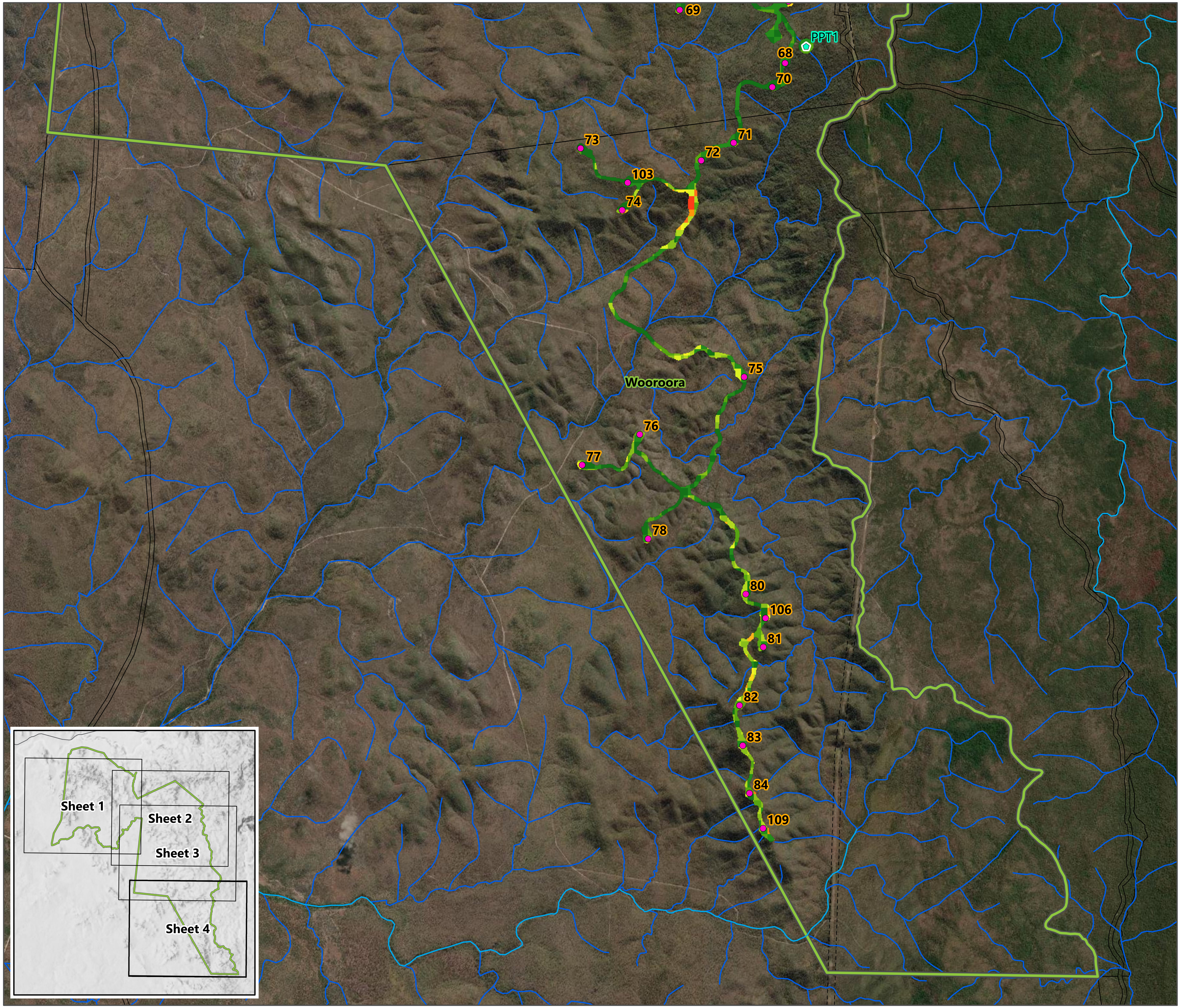

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Chalumbin Wind Farm

Estimated monthly soil loss during dry season construction (t/ha)

Sheet 4 of 4

Figure 2.2

Legend	
	Project Area Boundary
	Turbine
	Met-mast
	Watercourse
	Lot Boundary
	Easement

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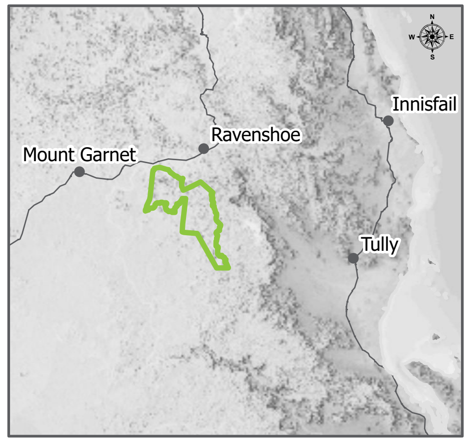
- 300 - 363
- 364 - 427
- 428 - 502
- 503 - 592
- 593 - 732
- 733 - 961

Date: 11/10/2022 Author: TOD
Project: EPU-004 Reviewed: NOD



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Data Source(s):
Digital Cadastral Database - Department of Resources (2022)

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2.1.2.4 Soil loss estimate – summary

The main findings of the RUSLE soil loss modelling for the Project include:

- The Project footprint under operational conditions has a gross sediment yield of 0.45 kt/year less than current conditions.
- The limiting of ground-disturbing construction works to the drier months of April to December, with the implementation of ESC measures, can save 139.7 kt of sediment compared to no controls.

The following is relevant to note for the modelling method and the accuracy of the soil loss estimates and/or potential sediment delivery to the Great Barrier Reef:

- RUSLE does not distinguish between the discharge of coarse or fine sediment and therefore will need to be combined with other sources of information, such as soil type and location, to determine the potential environmental hazard to relevant receiving environments.
- RUSLE measures soil loss and does not predict where entrained sediment will be deposited or if will end up in the Great Barrier Reef. The current soil loss estimates for the Project footprint are similar to Australia-wide RUSLE data published by CSIRO (Viscarra *et al.* 2016) in their Data Access Portal, although calculated at a much broader scale. Methods for the creation of the CSIRO datasets are described in Teng *et al.* 2016.
- RUSLE does not model gully erosion. Any gully erosion intersection by the Project footprint will be stabilised and rehabilitated, thereby resulting in a decrease in soil loss that is not captured in the current modelling.
- Soil loss from the operational footprint will also include landform modifications and permanent stormwater designs which are likely to further reduce the soil loss estimated for the operational scenario.
- Construction-phase soil loss is highly dynamic and a 75% sediment removal efficiency has been assumed based on the implementation of effective ESC measures; however, the ability and choice of ESC measures will vary on a site-specific basis throughout the Project footprint. Further discussion is presented in **Section 4.3.3**.
- RUSLE equations were derived using data from a range of sites dominated by medium-textured soils, thus requiring special care when applied to soils at either end of the texture range. Information on soil types is presented in **Section 3.0**.
- RUSLE was not intended to be used to model soil loss from gravel-capped roads and hardstands and is considered to overstate the soil loss in these areas. Actual soil loss from roads and hardstands will ultimately depend on gravel materials used and the type and volume of traffic.

2.2 Estimated sediment runoff and the Reef 2050 Plan

The soil loss modelling found that the Project footprint under operational conditions has a sediment yield 0.45 kt/year less than current conditions. This assumes that the soil loss equation has a C-factor of 70% cover which is the Reef 2050 WQIP target (year 2025) for grazing land, end of dry season, cover.

The construction phase of the Project will limit ground-disturbing construction works to the drier months (April to December) with the implementation of ESC measures adopting the use of best practice in erosion and sediment control methods during construction (IECA 2008). The Project is committed to the adoption of IECA rehabilitation cover targets, restoration of regional ecosystems where practicable and the use of gravel and hardstand operational areas drained through a stormwater system to further reduce sediment loads (see **Appendix K** of the PER).

Although there is an increased risk of sediment runoff during the construction phase, this will be a relatively short duration (2 months at a given location) and managed using the IECA 2008 BPESC guidelines which are considered international best practice. Calculations via RUSLE have determined the increased risk during construction to be significantly reduced for the Project footprint by limiting ground-disturbing construction works to the drier months (April to December) and by implementing effective ESC measures to appropriately manage this risk.

To minimise the risk of large / high intensity rainfall events during the dry season, the construction planning / scheduling of ground-disturbing activities will use long-range weather forecasts to stop work or undertake construction on low-risk erosion sites (i.e. lower slopes, stable soils, not close to sensitive receiving environments) where practicable during these times. Construction planning / scheduling will also factor in the increased potential of large / high intensity rainfall events during the wet season shoulder months.

The Project will also achieve a reduction in the rate of sediment runoff during the operational phase of the Project compared to current conditions. By comparison with the existing soil loss rates within the Project area, it is considered that the Project's sediment runoff is consistent with the Reef 2050 Plan.

The following sections provide a discussion of how the Project will assist to achieve the Reef 2050 WQIP outcomes, objectives, and targets for fine sediment runoff.

2.2.1 Spatial Variability of Rainfall and Erosivity over the Project Area

There are three rainfall stations with data relevant to the Project area listed in **Table 2-8** and presented on **Figure 2-4**. The Project area generally has a decreasing rainfall from east to west as shown in **Figure 2-4**.

Table 2-8 Rainfall station data

Site	Site Identifier	Source	Location
Woodleigh	Station # 031119	BOM	Lat: -17.68° Long: 145.28°
Blunder Creek at Wooroora	Site # 116015A	Qld Water Monitoring Information Portal	Lat: -17.7371° Long: 145.4363°
Chalumbin Standalone Pluvio	Site # 1160P001	Qld Water Monitoring Information Portal	Lat:-17.78031° Long:145.518644°

The average monthly rainfall data has been calculated for each of the rainfall stations over the period of record as presented in **Table 2-9**. The rainfall erosivity factor (EI30) for each of the rainfall stations was calculated by running a daily timestep model using the last 20 years of data using the methodology described in Ellis (2018) and the results are presented in **Table 2-10**.

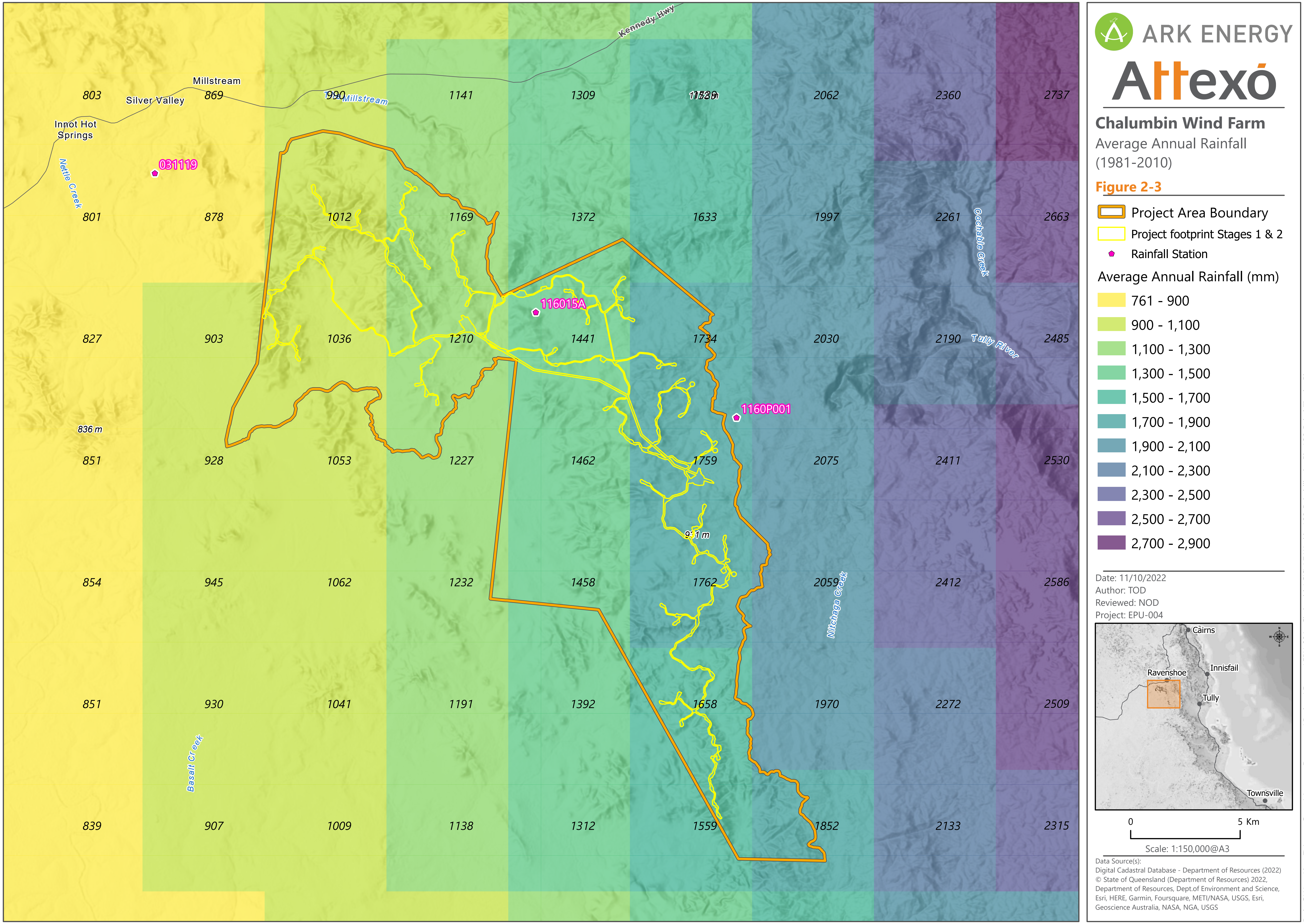

ARK ENERGY
Attexó
Chalumbin Wind Farm
Average Annual Rainfall
(1981-2010)
Figure 2-3
Project Area Boundary
Project footprint Stages 1 & 2
Rainfall Station
Average Annual Rainfall (mm)
761 - 900
900 - 1,100
1,100 - 1,300
1,300 - 1,500
1,500 - 1,700
1,700 - 1,900
1,900 - 2,100
2,100 - 2,300
2,300 - 2,500
2,500 - 2,700
2,700 - 2,900
Date: 11/10/2022
Author: TOD
Reviewed: NOD
Project: EPU-004
Cairns
Ravenshoe
Innisfail
Tully
Townsville
0
5 Km
Scale: 1:150,000@A3
Data Source(s):
Digital Cadastral Database - Department of Resources (2022)
© State of Queensland (Department of Resources) 2022,
Department of Resources, Dept.of Environment and Science,
Esri, HERE, Garmin, Foursquare, METI/NASA, USGS, Esri,
Geoscience Australia, NASA, NGA, USGS
Kennedy Hwy
Millstream
Silver Valley
Innot Hot Springs
Nettle Creek
Millstream
Basalt Creek
Cochable Creek
Tully River
Nitchaga Creek
031119
116015A
1160P001
836 m
803
869
990
1141
1309
2062
2360
2737
801
878
1012
1169
1372
1633
1997
2261
2663
827
903
1036
1210
1441
1734
2030
2190
2485
851
928
1053
1227
1462
1759
2075
2411
2530
854
945
1062
1232
1458
1762
2059
2412
2586
851
930
1041
1191
1392
1658
1970
2272
2509
839
907
1009
1138
1312
1559
1852
2133
2315

Table 2-9 Rainfall average monthly rainfall

	Woodleigh rainfall (mm)	Blunder Creek rainfall (mm)	Chalumbin Pluvio rainfall (mm)
Jan	193	211	292
Feb	214	253	347
Mar	161	180	287
Apr	42	95	182
May	25	58	118
Jun	20	45	85
Jul	9	30	67
Aug	8	18	38
Sep	8	17	32
Oct	28	39	60
Nov	69	47	68
Dec	119	105	144
Annual	**894**	**1,100**	**1,719**
Apr-Dec	327	455	793
Jan-Mar	567	645	926

Table 2-10 Average monthly erosivity index (EI30)

	Woodleigh	Blunder Creek	Chalumbin Pluvio
Jan	1,257	1,242	1,805
Feb	1,499	1,749	2,527
Mar	832	1,119	2,018
Apr	129	309	825
May	33	111	326
Jun	19	74	190
Jul	9	29	142

	Woodleigh	Blunder Creek	Chalumbin Pluvio
Aug	8	18	50
Sep	17	41	80
Oct	105	182	235
Nov	376	182	257
Dec	805	584	830
Annual	5,091	5,641	9,287
Apr-Dec	1,503	1,532	2,937
Jan-Mar	3,588	4,109	6,350

2.2.2 High Intensity Rainfall Events and Erosion

Within the Project area, high intensity rainfall events are part of the climatic regime particularly in the wet season (January to March) and associated with cyclonic or tropical low depression systems. These high intensity rainfall events have the potential to be highly erosive particularly on recently disturbed land.

In the absence of fine scale project specific rainfall intensity data, high daily rainfall totals are indicative of high intensity rainfall events. An analysis of the daily rainfall data (20 years) for Woodleigh, Blunder Creek and Chalumbin Pluvio are presented in **Figure 2-5** to **Figure 2-7** as box plots. The daily outlier events for each month are individually plotted above the outer range of the box plot.

The Blunder Creek and Chalumbin Pluvio rainfall station outlier monthly daily rainfall events are significantly larger than the Woodleigh rainfall station events for every month. Importantly, the frequency and size of high intensity of rainfall events is significantly lower in the dry season (April to December).

To assess the 'worst case scenario' impact of a high intensity rainfall event during the dry season the soil loss has been calculated using the highest daily rainfall from the last 10 years for each of the rainfall stations (**Table 2-11**). The largest proportional increase compared to average dry season soil loss is at the driest site (Woodleigh) and the smallest increase at the wettest site (Chalumbin Pluvio). The results show that a single 'worst case' rainfall event is potentially 45% to 63% of the estimated soil loss over a two-month construction period. However, it is important to note that there will only be a relatively small area of disturbance compared to the total Project footprint at increased risk of erosion from a single high intensity rainfall event. Therefore, the net impact of an unseasonal high intensity rainfall event can be minimised through construction planning, progressive rehabilitation and limiting the extent of the work front, as well as implementing standard ESC practices.

Table 2-11 Dry season comparison of soil loss estimate for high intensity rainfall events

Station	Net sediment loss during dry season 2 month construction window (kt)	Net sediment Loss during highest daily dry season rainfall event in the last 10 years (kt)
Woodleigh	6.2	2.8
Blunder Creek	6.3	3.9
Chalumbin Pluvio	12.1	7.6

As expected, the design rainfall events are also higher at the Chalumbin Pluvio site compared to Woodleigh (for example the rainfall intensity for a 1 in 2 year event (0.5 EY), 1 hour event is 39.8 mm/hr and 38.6 mm/hr respectively). Therefore, it will be important to use appropriate design rainfall data for the preparation of site based ESCPs in different parts of the Project footprint.

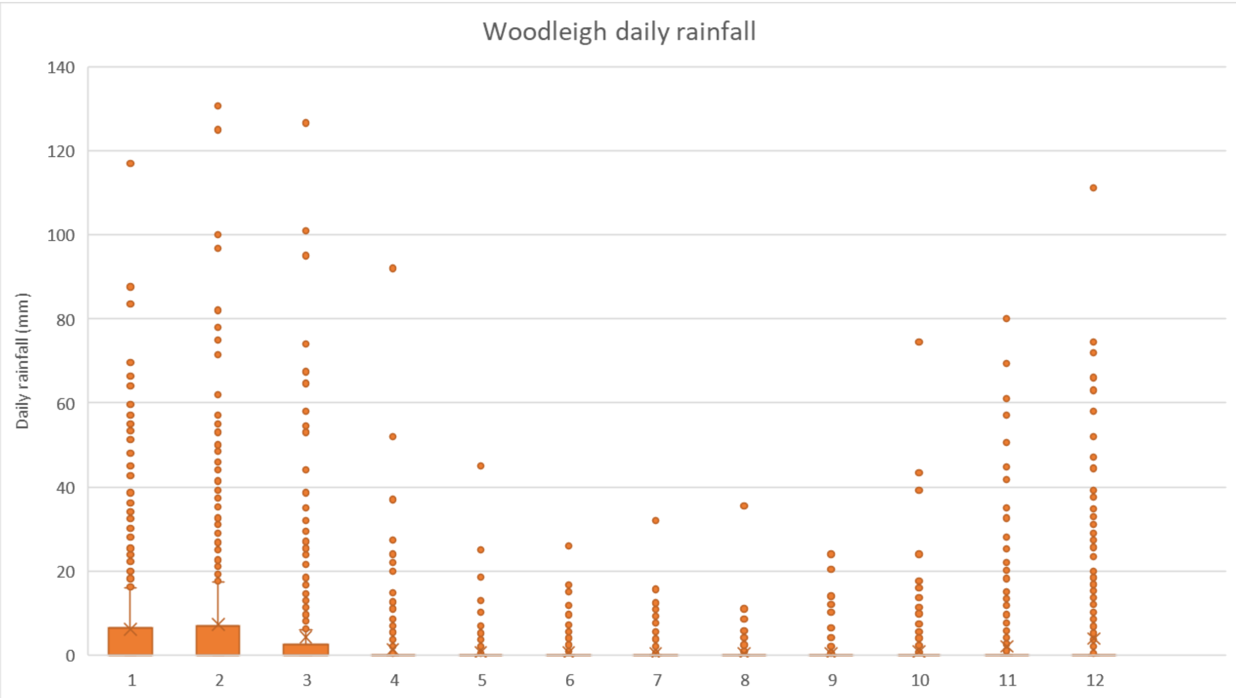


Figure 2-5 Woodleigh (Station # 031119) daily rainfall data box plot (2001-2022)

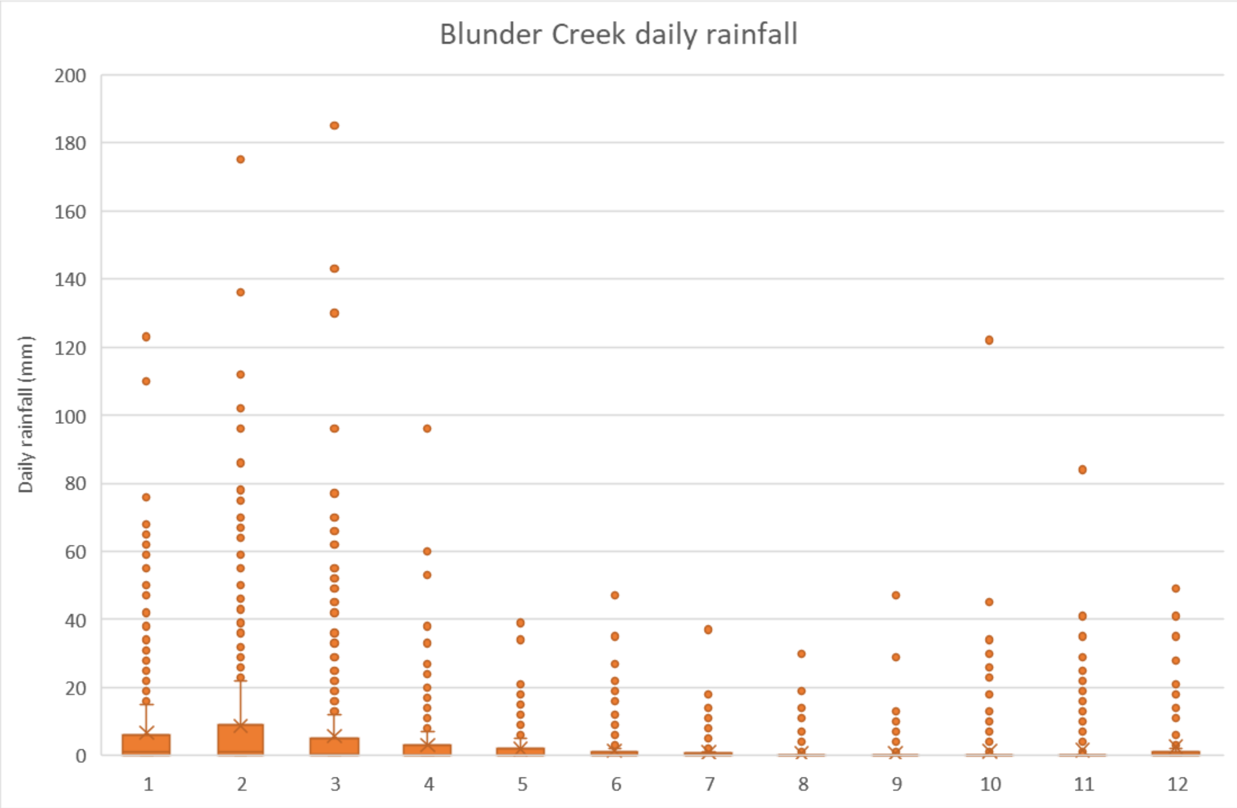


Figure 2-6 Blunder Creek (Site # 116015A) daily rainfall data box plot (2001-2022)

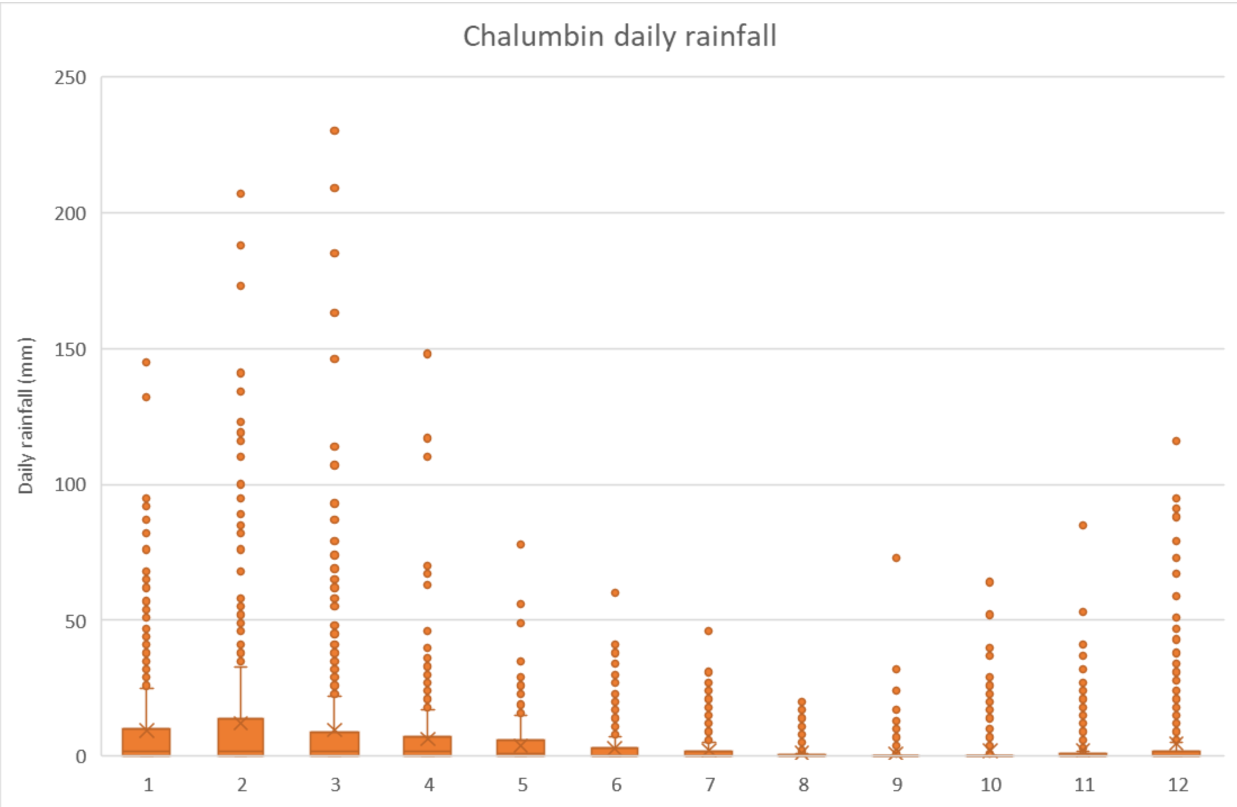


Figure 2-7 Chalumbin Standalone Pluvio (Site # 1160P001) daily rainfall data box plot (2001-2022)

2.2.3 Local Surface Water Flow Paths

High resolution LiDAR data is available for the Project area and this has allowed the identification of local surface water flow paths that intersect the proposed disturbance areas. These local flow paths are likely to contain concentrated runoff flows during high intensity rainfall events, posing an increased erosion risk which will need to be appropriately managed in the development of site-based ESCPs. This is not considered unique to this Project and is something that can be readily managed through standard best-practice erosion and sediment control construction techniques. A map series of the local flow paths in proximity to the Project footprint is presented in **Attachment C**.

The Project footprint commonly follows ridgelines and mainly occupies upper slope positions which means that water flow paths are less likely to be intersected compared to Project alignments across mid or lower slope positions. Waterway crossings where intersected will be consistent with the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* for all crossings apart from the Blunder Creek crossing (which will likely be a bridge structure) (refer to **Section 4.3.2**).

2.2.4 Cover and Catchment Management Targets

The catchment management targets in the Reef 2050 WQIP focus on late dry season ground cover levels across grazing lands at the groundcover target of 70% across 90% of grazing lands, while providing for natural variability in ground cover levels. This target recognises that water quality risk is generally highest at the onset of the wet season and that research supports a ground cover target of 70% to minimise erosion.

The Project has ESC rehabilitation cover targets of 80%, which is higher than the Reef 2050 WQIP, and the proponent is committed to re-establishing regional ecosystems in non-operational areas where they are cleared by the Project, as per the Preliminary Rehabilitation Plan (see **Appendix K** of the PER). Ongoing operational ground cover will depend on the grazing land management; however, the Project supports the adoption of a minimum 70% ground cover in the late dry season.

2.2.5 Soil Erodibility

The Project will reduce the risk of soil erosion by reducing the erodibility of the soil (or K-factor) using gravel-capped roads and hardstands and through the rehabilitation of gully erosion.

The Project's operational areas will include the use of gravel-capped roads and hardstands. Gravelling of unsealed roadways can significantly reduce the release of fine sediments and turbid runoff from the roadway (Witheridge 2017). The Project access track network will upgrade many existing tracks within the Project area that are currently not maintained and are likely a significant source of fine sediment runoff at present. Project roads will be designed and constructed to industry standards to handle the expected traffic loads and will include the installation of a stormwater drainage system to capture sediment runoff.

Gully erosion can be a significant source of fine sediment runoff. Any gully erosion intersected by the Project footprint will be rehabilitated and stabilised using measures such as reprofiling, use of topsoil / cover and amelioration thereby resulting in a reduction of soil loss from the Project area.

The distribution of soil types across the Project footprint, their fine fraction contents and sodicity are presented in **Section 3.0**.

2.2.6 Landform and Stormwater

The Project will modify the landform in operational areas that will generally reduce the risk of erosion (i.e. creating flatter slopes). All civil designs will have engineering certification and any batter slopes will receive a high level of treatment to reduce erosion risk.

The construction of the Project will use of the best practice erosion and sediment control guidelines (IECA 2008) to develop erosion and sediment control measures implemented as part of a CPESC certified ESCP. These best practice ESC measures will be integrated into the permanent stormwater system that will be designed to achieve the required water quality objectives for the Project. These water quality objectives for sediment will be achieved through the retention of sediment onsite using best practice drainage systems and sediment capture devices. Road drainage will be consistent with the Queensland Department of Transport and Main Roads 'Road Drainage Manual' (September 2019).

The Project will be designed, constructed and operated using industry standards and best practice guidelines for erosion and sediment control (IECA 2008) and stormwater management. These measures are consistent with the objectives of the Reef 2050 WQIP. The Project rehabilitation ground cover targets exceed the Reef 2050 WQIP groundcover target, which has a land and catchment target for grazing lands of 70% across 90% of grazing lands. Based on this and the RUSLE model scenarios it is expected that sediment runoff from the Project will be less than sediment runoff from the broader landscape with a sediment runoff reduction of 0.45 kt/year for the Project footprint.

2.3 Future Climate Change and Sediment Runoff

2.3.1 Climate Change Rainfall Predictions

CSIRO has recently released climate change projections for Australia based on the results from 23 global climate models (DES 2019). Projections for the Far North Queensland region have been extracted from this dataset for the Queensland Climate Change Centre of Excellence (QCCCE).

The Far North Queensland region is predicted to experience higher temperatures, greater frequency and duration of extreme temperatures (heatwaves), more intense rainfall but with increased variability, and more intense tropical cyclones but at a lower frequency (DES 2019a).

All low, medium and high emission scenarios predict that the annual rainfall will decrease from 1-2% annually, and up to 16% seasonally for spring under the 2070 high emissions scenario.

2.3.2 Change in Sediment Runoff due to Climate Change

Future climate change scenarios that will affect soil erosion are related to the amount of rainfall, its seasonal distribution and intensity. The seasonality will affect the antecedent soil moisture conditions which can significantly affect runoff.

The rainfall erosivity factor in the RULSE soil loss equation, R, is a measure of the ability of rainfall to cause erosion. It is the product of two components: total energy (E) and maximum 30-minute intensity for each storm (I30). So, the total of EI for a year is equal to the R-factor. The R-factor can be calculated using the 2-year ARI, 6-hour storm event.

Climate predictions do not include 2-year ARI, 6-hour storm events, but do contain information on intensity and the amount of rainfall. Therefore, the R factor will increase for more intense rainfall and higher amounts of rainfall.

Based on the modelled scenarios that the Project area will receive less annual rainfall, but an increase in the amount of intense rainfall and more intense tropical cyclones, there are likely to be more distinct sediment runoff events or pulses entering the aquatic environment within the Project area over time. It is likely that the R factor, and therefore sediment runoff, will increase slightly due to more intense rainfall events, but the increase in R factor due to rainfall intensity will be balanced by lower annual rainfall.

Because of the simple multiplicative function of the way R factor applied in the RUSLE soil loss model the climate change rainfall scenarios will increase or decrease all areas of land similarly with the exact change in soil loss related to the magnitude of the base soil loss rate.

Therefore, Project sediment runoff is unlikely to change significantly compared to the surrounding landscape due to future climate change scenarios and any increase, if realised, will be proportional to the broader catchment.

3.0 Desktop soils assessment

A desktop soils assessment has been undertaken to identify the soils occurring across the Project footprint and their characteristics that can be used to assess the soil erosion risk and location of clayey soils that are more likely to result in fine sediment runoff.

3.1 Soil data sources

This desktop soils assessment has sourced data from a number of locations. The information collected by Queensland's soil and land resource assessment programs is held in the Soil and Land Information (SALI) database. This data was accessed through the following services:

- Queensland Government open data portal
- Queensland Spatial Catalogue, and
- Queensland Globe.

Furthermore, soil datasets developed by CSIRO used in this assessment include:

- Soil and Landscape Grid of Australia (CSIRO) - The Grid combines historical and current data generated from sampling, laboratory sensing, modelling and remote sensing. It represents Australia as a digital grid made up of two billion 'pixels' that are about 90 by 90 metres in size. (https://www.csiro.au/en/research/natural-environment/land/soil-and-landscape-grid-of-australia)
- Australian Soil Resource Information System (ASRIS) – Contains spatial layers describing soils and landscapes, as well as more detailed information relating to soil thickness, permeability, salinity, fertility and erodibility. (https://www.asris.csiro.au/)

3.2 Soil types and properties

The majority of the Project footprint is mapped by the soil survey titled *Land resources of the Ravenshoe – Mt Garnet area north Queensland Vol 1 – Land resource inventory* (Heiner and Grundy 1994) at a scale of 1:100,000. The survey describes and maps the soil and land resources and a summary of the soil types intersected by the Project footprint.

The south-eastern portion of the Project footprint is only mapped by the Atlas of Australian Soils (Northcote et. al. 1968) which was produced between 1960 and 1968 at a scale of 1:2,000,000. The mapping units are defined on the basis of soil, landform, parent material and vegetation. Within each unit, dominant and subdominant soil types have been presented, using the Northcote Principal Profile Form (PPF). One unit in the Project area has as many as 10 PPFs recorded. These map units correspond to the Fu22 and Mf17 soil types.

A map of the soil types over the Project footprint is presented in **Figure 3-1**.

The mapped dominant soil types over the Project footprint and their soil classification as Great Soil Groups (GSG) and Australian Soil Classification (ASC) are presented in **Table 3-1**. Details of their major distinguishing attributes are presented in **Table 3-2**.

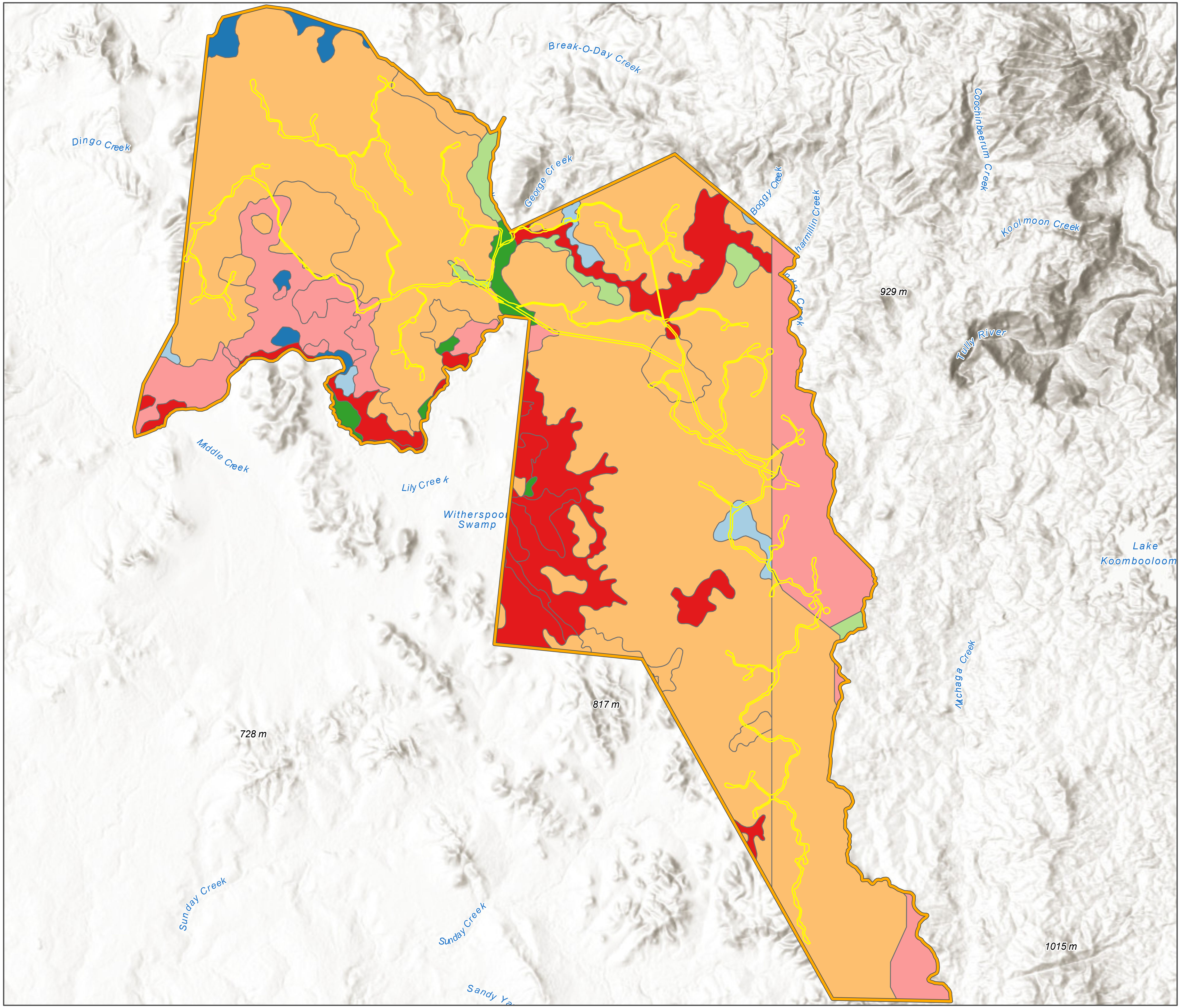
Table 3-1 Soil types of the Project footprint

Row Labels	GSG	Dominant ASC	Area (Ha)
Bally	Red podzolic soil	Chromosol	22.2
Blunder	Soloth	Sodosol	14.8
Fu22	Lithosol	Tenosol	112.5
Glengordon	Yellow earth	Kandosol	11.6
Ironbark	Euchrozem	Ferrosol	25.5
Mf17	Yellow earth	Kandosol	95.5
Nettle	Lithosol	Tenosol	50.3
Sludge	Yellow earth	Kandosol	9.9
Whelan	Lithosol	Tenosol	703.6
Wooroora	Humic gley	Hydrosol	25.4

Table 3-2 Characteristics of the Project footprint soil types

Soil Type	Major distinguishing attributes	Description	Slope (%)	Landform pattern
Bally	Red-brown clay loam A1 horizon over pale A2 horizon over acid red pedal medium clay B horizon	Deep pedal soils on acid volcanic rocks. Imperfectly or well drained soils	8.2	Undulating and rolling low hills on weathered acid volcanics
Blunder	Grey, grey-brown or dark sandy loam to silty clay loam A1 horizon over bleached A2 horizon over acid mottled grey, yellow-brown or yellow light medium to medium heavy clay pedal B horizon commonly over buried soloths	Sodic and magnesic soils. Poorly drained	7.4	Level plains on Blunder Creek alluvia
Fu22	Uniform medium, conspicuous bleached A2 horizon, non calc, underlain by a carbonate pan	Shallow bleached loams	20.9	Hilly to high hilly lands with very steep slopes
Glengordon	Dark or grey sandy clay loam to clay loam sandy A1 horizon over pale or bleached A2 horizon over acid mottled yellow or yellow-brown sandy light to light medium clay apedal B horizon with many ferromanganiferous nodules	Massive and weakly to moderately pedal yellow and grey soils. Range from imperfectly to very poorly drained	6.1	Level to gently undulating plains on transported sediments

Soil Type	Major distinguishing attributes	Description	Slope (%)	Landform pattern
	throughout over grey medium heavy clay D horizon over decomposing basalt			
Ironbark	Red or dark clay loam to light clay pedal A1 horizon over neutral red or red-brown light to light medium clay pedal B horizon over decomposing basalt	Non-cracking clay soils on basalt. Imperfectly or well-drained soils	7.6	Level to gently undulating rises on McBride basalt
Mf17	Gradational yellow, A2 horizon nonbleached, acid smooth-ped whole col or mottled B horizon	Yellow smooth-ped earths	13.8	Moderately to strongly undulating or occasionally low hilly plateaux
Nettle	Brown coarse sand to coarse sandy loam A1 horizon over bleached A2 horizon over acid yellow-brown apedal coarse sand to coarse sandy loam AC horizon over C horizon	Soils with minimal profile development. Shallow skeletal and deep sandy soils	13.8	Undulating and rolling low hills on granite
Sludge	Dark to brown sandy loam to sandy clay loam A1 horizon over pale A2 horizon over acid yellow clay loam to light clay apedal upper B horizon aver aid to neutral mottled yellow-brown light to light medium clay apedal lower B horizon	Massive and weakly to moderately pedal yellow and grey soils. Range from imperfectly to very poorly drained	6.0	Level to gently undulating plains on transported sediments
Whelan	Grey to dark sandy loam A1 horizon over bleached A2 horizon over acid grey or yellow-brown massive sandy loam AC horizon over weathered acid volcanics	Soils with minimal profile development. Shallow skeletal and deep sandy soils	16.5	Level to gently undulating rises on Atherton basalt
Wooroora	Organic horizon over dark silty loam to silty clay loam A1 horizon over acid mottled grey-brown or grey medium to heavy clay pedal B horizon	Soils on alluvia. Non-sodic soils associated with alluvia of major streams	3.0	Swamps on level plains on Blunder Creek alluvia



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Chalumbin Wind Farm

Soil Type Australian Soil Classification

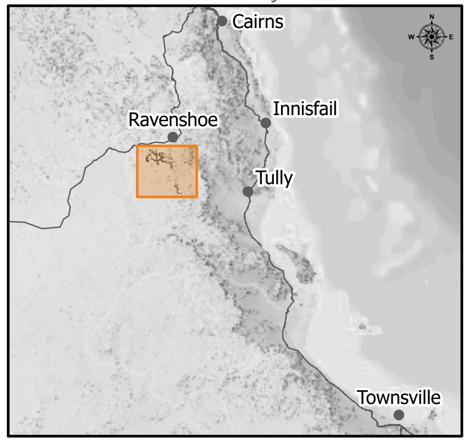
Figure 3-1

- Project Area Boundary
- Project footprint Stages 1 & 2

ASC

- Chromosol
- Dermosol
- Ferrosol
- Hydrosol
- Kandosol
- Sodosol
- Tenosol

Date: 11/10/2022 Reviewed: NOD
Author: TOD Project: EPU-004



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Data Source(s):
Digital Cadastral Database - Department of Resources (2022)
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3.3 Distribution of clay soils and erosion risk assessment

An analysis of the soils information was undertaken using laboratory analysis results from representative soil sites for each of the mapping units and a summary of the information relating to particle size and sodicity is presented in **Table 3-3**, with a map of topsoil clay content presented in **Figure 3-2**.

There is a mix of sandy and clayey soils over the Project footprint. Almost 80% of mapped dominant soils are Tenosols which are generally shallow or deep sandy and have a coarse sandy loam to sandy loam topsoil with a bleached A2 over weathered substrates. This is conceptually consistent with these soils often occurring on crests and landform positions higher in the landscape.

A clay (<0.002 mm) content of >30% is required for the soil texture to be classified as a clay (NCST 2009). Soils with clay topsoils occupy approximately 9% of the Project footprint and the majority of subsoils are also not clays due to the large areas of Lithosols. Silt (0.002-0.02 mm) sized particles although not as readily suspended in water are also generally considered part of the fine sediment fraction.

Ferrosols occur across approximately 5% of the Project footprint and have high levels of free iron oxide which gives them a high degree of structural stability and subplastic properties. The soils are usually high in clay; however, their subplasticity2 means that they are more well drained and less erodible compared to other soils with similar clay contents.

Soil sodicity is often used to infer soil physical properties and particularly its tendency to disperse. Sodicity is a measure of the proportion of sodium ions present in a soil, expressed as Exchangeable Sodium Percentage (ESP). Soils are called sodic if the ESP is greater than 6% and strongly sodic if the ESP is greater than 15%.

Although, sodicity is usually considered the dominant factor affecting soil dispersion other factors include Ca:Mg ratio, CEC, clay type, organic matter, exchangeable aluminium and electrical conductivity.

Approximately 5% of the Project footprint is mapped as having dispersible subsoils (i.e. Blunder, Glengordon and Wooroora). The Blunder soils are likely to be the most erodible based on their chemical characteristics. Sandy soils with low soil coherence are also highly erodible, but are unlikely to contribute a major source of fine sediments.

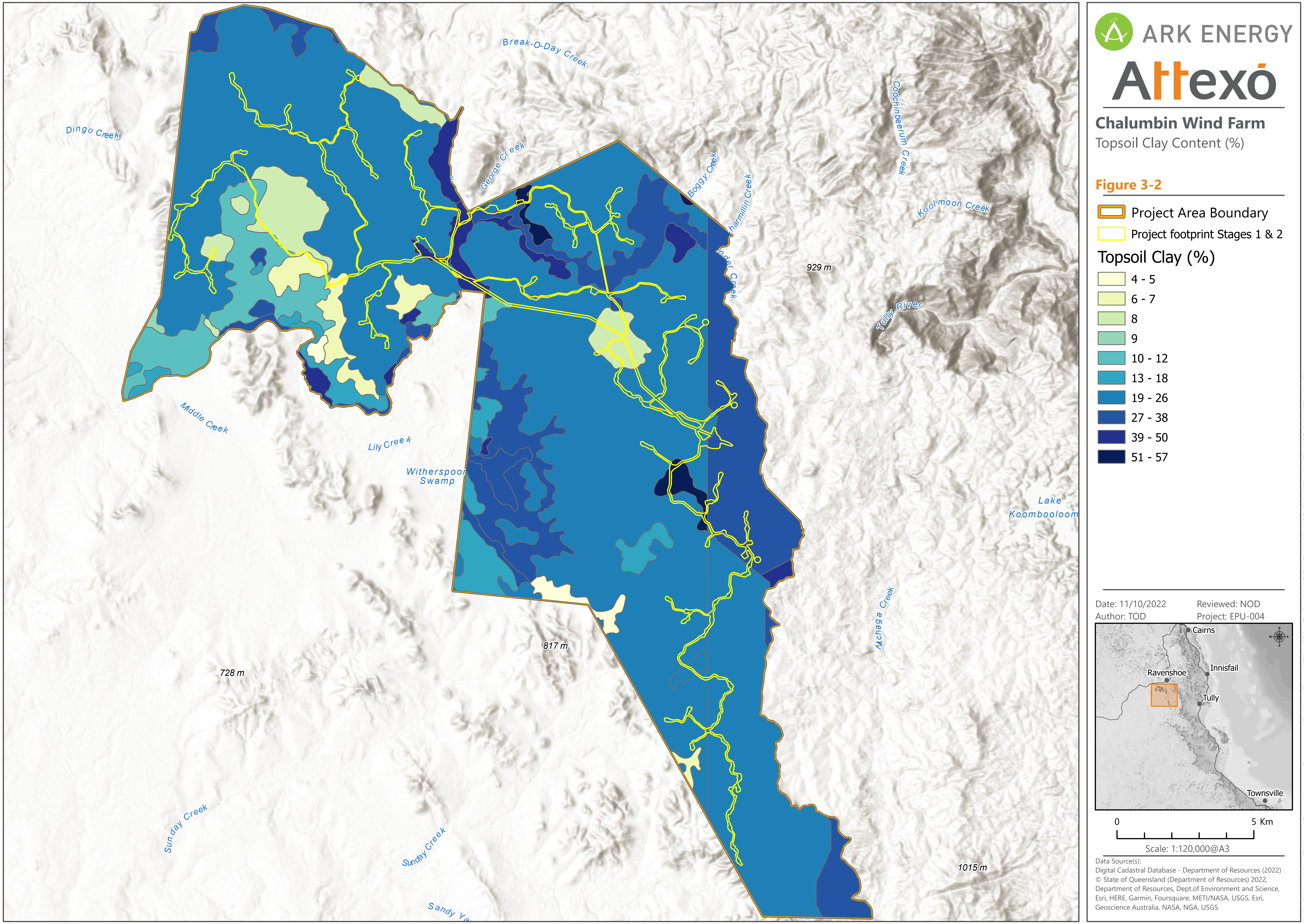
Table 3-3 Amount of fines in the representative soil types from laboratory analysis

Soil Type	Clay (%) Topsoil	Silt (%) Topsoil	Topsoil sodicity	Clay (%) Upper subsoil	Silt (%) Upper subsoil	Subsoil sodicity	% of Project footprint
Bally	57	26	Non-sodic	64	24	Non-sodic	2.1%
Blunder	32	52	Non-sodic	50	45	Strongly sodic	1.4%
Fu22*	26	18	Non-sodic	35	17	Non-sodic	10.5%
Glengordon	12	5	Non-sodic	22	8	Sodic	1.1%
Ironbark	44	18	Non-sodic	55	13	Non-sodic	2.4%
Mf17*	30	17	Non-sodic	37	16	Non-sodic/sodic	8.9%

2 Subplastic - Field texture increases 1 to 2 texture groups after 10 minutes kneading.

Soil Type	Clay (%) Topsoil	Silt (%) Topsoil	Topsoil sodicity	Clay (%) Upper subsoil	Silt (%) Upper subsoil	Subsoil sodicity	% of Project footprint
Nettle	8	6	Non-sodic			NA	4.7%
Sludge	6	7	Non-sodic	43	7	Non-sodic	0.9%
Whelan	26	46	Non-sodic			Non-sodic	65.7%
Wooroora	45	29	Sodic	55	32	Sodic	2.4%

*ATLAS soils mapping without representative site data. The particle size data source for these soils was derived from a mean value over the Project footprint of the Australian Soil Clay Content and Silt Content products (0-5cm & 30-60cm) of the Soil and Landscape Grid of Australia.


ARK ENERGY
Attexo
Chalumbin Wind Farm
Topsoil Clay Content (%)
Figure 3-2
Project Area Boundary
Project footprint Stages 1 & 2
Topsoil Clay (%)
4 - 5
6 - 7
8
9
10 - 12
13 - 18
19 - 26
27 - 38
39 - 50
51 - 57
Date: 11/10/2022
Author: TOD
Reviewed: NOD
Project: EPU-004
Cairns
Ravenshoe
Innisfail
Tully
Townsville
0
5 Km
Scale: 1:120,000@A3
Data Source(s):
Digital Cadastral Database - Department of Resources (2022)
© State of Queensland (Department of Resources) 2022,
Department of Resources, Dept.of Environment and Science,
Esri, HERE, Garmin, Foursquare, METI/NASA, USGS, Esri,
Geoscience Australia, NASA, NGA, USGS
Break-O-Day Creek
Dingo Creek
George Creek
Boggy Creek
Coochinbeerum Creek
Koolmoon Creek
Tully River
929 m
Middle Creek
Lily Creek
Witherspoon Swamp
Lake Koombooloomba
817 m
728 m
Sunday Creek
Sandy
1015 m

4.0 Sediment mitigation and monitoring

4.1 Changes to hydrological flows

A Stormwater Management Plan (**Appendix N** of the PER) has been prepared for the Project and the stormwater quantity has not been assessed at this stage, as the increase in impervious areas due to the Project is expected to be relatively small and widely distributed. No significant ponding or flow attenuation is expected due to the Project activities. Local stormwater management at Project infrastructure locations will not interrupt existing flows in waterways. All waterways are in the Project area are ephemeral; though Blunder Creek does have permanent water available in certain stretches.

Changes to hydrology as a result of the Project are expected to be negligible and insignificant for the Magnificent Brood Frog and its habitat. This is because:

- No watercourses will be diverted due to the Project;
- The intent of watercourse crossing design is to maintain fish passage and for construction to be consistent with the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* for all crossings apart from the Blunder Creek crossing (which will likely be a bridge structure);
- Due to the distributed nature of the Project throughout a large Project area, no permanent stormwater retention ponds are proposed at this stage; and
- Changes to hydrological conditions in Magnificent Brood Frog habitat areas are expected to be minor with some areas likely to experience a small increase in flows due to constructed impervious surfaces (e.g. roads and crane pads).

4.2 Sediment mitigation

4.2.1 Construction phase sediment mitigation

Sediment release is primarily of concern during the construction phase of a project, where ground disturbing activities result in the exposure of subsoils to water erosion and subsequent mobilisation of sediment (IECA, 2008). A Preliminary Erosion and Sediment Control Plan (P-ESCP) has been prepared for the construction of the Project in line with IECA 2008 BPESC Standard; the P-ESCP is separate to this Plan and is provided as an attachment to the PER. The P-ESCP provides an analysis of site conditions for ESC planning purposes, establishes the ESC standards that will be met during the Project construction phase and takes the following approach to ESC:

1. Erosion control: prevent soil erosion in the first instance by minimising ground disturbance and maintaining groundcover.
2. Drainage control: divert clean water around areas of disturbance (i.e. keep clean water clean) and control surface water run-off in a non-erosive manner, that prevents mixing of clean and dirty water and directs all dirty water to an appropriate sediment trap.
3. Sediment control: Ensure all dirty water is treated prior to release by a sediment trap which is appropriate for the erosion risk and the design rainfall standard. Treated water from sediment traps is released as overland flow, rather than direct to waterways where possible.

Site and activity specific construction ESCPs which meet the IECA 2008 BPESC Standard will be developed by construction contractor. Construction ESCPs will be reviewed and approved by the Project Owner prior to the commencement of works to ensure that the required standard is met. This is approach is appropriate as effective ESC management relies on an in-depth knowledge of, and influence over, construction methodologies.

The IECA 2008 BPESC approach is led by ten key principles for effective ESC. **Table 3.1** identifies on how these principles have been, or will be, applied by the Project.

Table 4-1 Project application of IECA 2008 ESC principles for sediment mitigation

Principle	Project application
1. Appropriately integrate the development into the site.	▪ The site has been selected specifically due to local wind speeds, the compatible surrounding land use and site topography which provides the opportunity to position wind turbines at high points in the landscape where wind speeds are greatest. ▪ The positioning of ancillary infrastructure such as permanent and temporary compounds, access tracks, powerlines, etc. has been undertaken to fit within the landscape and minimise clearing requirements, including those associated with cut and fill requirements. ▪ Project access routes have been selected to minimise watercourse crossings and instream works requirements. ▪ Watercourse crossings will be designed and constructed to accommodate the appropriate local design rainfall event.
2. Integrate erosion and sediment control issues into site and construction planning.	▪ The timing of ground disturbing activities will be prioritised to occur during lower rainfall periods where practicable. ▪ ESC standards to be applied during construction are established during the Project planning phase and will be included within construction tender packs and procurement contracts. ▪ Construction contractor will be required to develop ESCPs for their work, which are submitted to the Project Owner for acceptance prior to the commencement of work.
3. Develop effective and flexible ESCPs based on anticipated soil, weather and construction conditions.	▪ Construction ESCPs are developed and implemented by those with control over construction work, supported by a suitably experienced ESC professional. ▪ Soil sampling will be undertaken, and soil characteristics considered as part of the construction ESCP development. ▪ Weather monitoring and wet weather preparedness will be addressed by the construction ESCP. ▪ ESCs will be regularly monitored and modified as required to achieve water quality objectives.

Principle	Project application
4. Minimise the extent and duration of soil disturbance.	▪ Infrastructure footprints are co-located where infrastructure design, surface conditions and commercial considerations allow, to reduce the overall land disturbance. For example, the colocation of access tracks with electricity and communications cables. ▪ IECA 2008 best practice land clearing and rehabilitation requirements will be reflected in the construction activities.
5. Control water movement through the site.	▪ Drainage will be managed in line with the Project stormwater management plan and construction ESCPs. ▪ Drainage control standards will be applied in line with those identified by the Project stormwater management plan and IECA 2008 section 4.3.
6. Minimise soil erosion.	▪ IECA 2008 best practice land clearing and rehabilitation requirements will be reflected in the construction activities. ▪ ESCPs will prioritise erosion prevention in the first instance by maintaining groundcover and effective drainage controls.
7. Promptly stabilise disturbed areas.	▪ IECA 2008 best practice land clearing and rehabilitation requirements will be reflected in the construction activities. ▪ Progressive rehabilitation will be undertaken throughout construction.
8. Maximise sediment retention on the site.	▪ Sediment control techniques will be applied based on the standards defined by IECA 2008 for estimated soil loss or monthly erosivity. ▪ Sediment traps will be designed and positioned according to the IECA 2008 BPESC Standard by a suitably qualified person.
9. Maintain all ESC measures in proper working order at all times.	▪ Installed erosion, sediment and drainage controls will be monitored for condition at least weekly and prior to anticipated runoff producing rainfall. ▪ Controls found to be in disrepair will be restored prior to anticipated runoff producing rainfall.
10. Monitor the site and adjust ESC practices to maintain the required performance standard.	▪ Installed erosion, sediment and drainage controls will be monitored for effectiveness during and after rainfall events. ▪ Controls not meeting performance criteria will be improved or alternatives sought.

4.2.2 Operations sediment mitigation

Construction close-out will require the establishment of 70-80% groundcover across the Project footprint and the finishing of permanent drainage controls designed to move water through the footprint in a way that minimises soil erosion. The stated groundcover percentage has been determined based on the best practice rehabilitation requirements stated in Table 4.4.7 of the IECA 2008 BPESC Standard. The exact groundcover percentage being tied to erosion risk, which is a function of historical monthly rainfall averages. In this context, the term 'groundcover', refers to revegetated areas, as well as all stabilised track and hardstand areas, pavement, and gravel / loose rock (e.g. aggregate) surfaces.

Operational activities typically do not involve earthworks, hence the risk of sedimentation during this phase of the Project is low. If ground disturbance is required for the repair of sub-surface infrastructure during Project operation, this work will be undertaken in line with an ESCP for the activity which meets the IECA 2008 BPESC Standard.

4.3 Concept ESCPs for Project infrastructure

Concept ESCPs have been prepared for the Project and are indicative of the overarching ESC philosophy to be applied to the civil construction activities. These concept ESCPs and the associated principles outlined in this document will form the basis of more detailed site-based construction ESCPs.

4.3.1 ESCPs for Project infrastructure

Functional layouts and ESCPs for typical Project infrastructure types are presented in **Attachment C**.

Concept plans are presented for:

- The northern substation;
- Track 25 – part layout; and
- Longitudinal track sections with turbine construction arrangement consisting of blade laydown, crane boom and crane pads and crane hardstand and turbine.

Civil design criteria and standard drawings are included in **Appendix S** of the PER.

4.3.2 ESCPs for waterway crossings

The Project's Preliminary Stormwater Management Plan (**Appendix N** of the PER) identifies 34 waterway crossings that may be associated with the Project. Functional layouts and ESCPs for the various waterway crossing types are presented in **Attachment C**.

Instream works will be required for the installation of waterway vehicle crossings. Instream works will be undertaken in line with site-specific ESCPs developed to IECA 2008 standards which as a minimum requires the Project to:

- Consider scheduling of works to occur during periods of no or low flow where practicable.
- Establish measures to minimise channel and vegetation disturbance during works.
- Identify isolation requirements and techniques to prevent clean water entering the instream work areas.
- Identify requirements for the use of temporary groundcovers to protect disturbed areas during works.

- Identify flow diversion techniques which appropriately consider fish passage requirements.
- Identify management measures for dewatering activities which prevent sediment-laden water from entering the watercourse.
- Identify the erosion risk for the works based on either:
  - Expected channel flow conditions as described in IECA 2008 Table I9; or
  - Expected daily and average monthly rainfall as described in IECA 2008 Table I10.
- Establish channel clearing and stabilisation requirements for the work in line with the best practice channel clearing and stabilisation requirements identified in IECA 2008 Table I11.

4.3.3 Proposed ESC measures and proven effectiveness

In addition to the ESC measures included on the concept ESCPs, this section (and **Table 4-2** and **Table 4-3**) presents a range of other measures that will be employed to manage erosion and sedimentation on the Project, adapted from IECA 2008 and NZTA 2014.

The implementation of ESC best practice management measures and natural features as individual elements work together to minimise erosion and maximise sediment retention onsite. Depending on the site-specific characteristics and the construction works, multiple measures will work together to maximise sediment retention onsite and their combined relative efficiency will determine their overall effectiveness. The order of priority is (1) to prevent erosion from occurring and (2) to implement sediment control practices to capture sediment in transit and reduce its movement into receiving environments where required.

Using a number of erosion control practices where practical for each site is best practice and the cumulative effect of the erosion control practices reduces the amount of work that sediment control practices will have to perform.

Table 4-2 Efficiency of erosion control practices at sedimentation reduction (IECA 2008 & NZTA 2014)

Erosion control measure	Performance of sediment reduction
Phasing of construction	Dry season average erosion risk (EI30) is 6 to 8 times lower than the wet season across the Project area. This is a major erosion control practice that will effectively avoid the highest erosion risks throughout the Project area for the duration of construction.
Runoff diversion channels	An effective transport mechanism that reduces erosion.
Contour banks/drains	Effective at minimising flow across bare soil areas.
Slope benches	49% less erosion than a uniform slope (Zhu, Dabney, Flanagan, 1999).
Rock check dams	Reduces channel velocities to prevent channel scour.
Soil polymer sprays	
Bonded fibre matrix (BFM)	

Erosion control measure	Performance of sediment reduction
Hydromulch	Can be 90-100% effective, but will depend on application rate, slope, slope length and soil type. Refer to IECA 2008 Tables E6 to E10 for the range of C-factors.
Jute mesh	
Composite synthetic blankets	
Placement of turf	98-99% (EPA, 1993)
Level spreaders	A practice to disperse water flow and avoid concentration of flow.
Surface roughening	18% (Dane County, 2007)

Sediment control practices cannot remove 100% of incoming sediment from runoff water. The aim is to reduce the magnitude and frequency of sediment discharge by a combination of both erosion control and sediment control practices. The majority of soils do not contain significant quantities of fine material that could be a sediment transport risk. **Section 3.0** provides information on the nature and distribution of soils that have the potential to be a source of sediment. The dominant mapped soil (approximately 80%) are Tenosols which are generally shallow or deep sandy and have a coarse sandy loam to sandy loam topsoil. Clayey topsoils are likely to occur over less than 10% of the Project footprint and there is only approximately 5% of the Project footprint that contains sodic soils that are a particular risk for producing dispersive runoff.

Table 4-3 Efficiency of sediment control practices at sedimentation reduction (IECA 2008 & NZTA 2014)

Sediment control measure	Performance of sediment reduction
Sediment retention pond (no chemical treatment)	50-80%
Sediment retention pond (w/chemical treatment)	75-95%
Sediment fence	40-75% depending on type of fabric, overflow rate and detention time (Barrett et al., 1995).
Filter socks	62% - 87% depending on sock fill material.
Decanting earth bund	60% depending on sizing of device and rainfall intensity.
Sump/sediment pit	No data available
Grassed swales	Mainly coarse sediment. Depends on design including size, slope and vegetation.

There is a risk of high intensity rainfall occurring within the Project aera at any time of the year, but this risk is significantly higher in the well-defined wet season, as evidenced through climatic statistics over many decades. The erosion control and sediment control practices that are considered key for this Project are:

- Erosion control practices:
  - Phasing of construction – dry season only construction significantly reduces the erosion risk and avoids having open working sites during the highest intensity rainfall events;
  - Progressive rehabilitation and ensuring sufficient resources to implement stringent controls based on forecasted weather events – this reduces the area at risk of erosion;
  - Soil polymer sprays – allow the establishment of cover over large areas quite quickly. High erosion risk areas on batters or near waterways may need some form of composite synthetic blanket. This is considered achievable and realistic.
- Sediment control practices:
  - Sediment basins – can be very effective at removing sediment particularly with chemical treatment. Preliminary sizing is presented in **Table 4-4** and demonstrates that there is space to incorporate their use in suitable locations. Sizing is based on the IECA 2018 sediment basin factsheet for Type B basins. It should be noted that the Intensity Frequency Distribution data is for annual data not just dry season, so basins are conservatively sized. This also shows the sizing for the sediment basins is very similar across the Project area, using rainfall data from any of the three weather stations (Woodleigh, Blunder Creek or Chalumbin Pluvial).
  - Rock filter dams – sizing and filtration media can be more easily optimised for specific sites compared to sediment basins. They are more suitable than sediment basins for lower risk, small and constrained sites
  - Sediment fences – can be readily deployed and may be combined with sump/sediment pits.
  - Grassed swales/drains – can be an important early element in a treatment train removing coarse sediment from runoff particularly during the operational phase of the project.

The actual performance of erosion control measures will vary depending on site conditions, and how well the devices are constructed and maintained.

Operational practices to minimise sediment runoff will include the implementation of:

- A Stormwater Management Plan; and
- A Project Operational Environmental Management Plan (or equivalent) including:
  - Water quality and soil erosion monitoring (see **Section 4.5**); and
  - Ongoing quarterly inspection and maintenance of the constructed roads.

A Stormwater Management Plan will be prepared for the Project and the stormwater controls will be integrated into the implementation of the construction ESCP. Stormwater treatment trains will be evaluated using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC), where appropriate. MUSIC can model the best way to capture and reuse stormwater runoff, remove its contaminants, as well as reduce runoff frequency through the evaluation and optimisation of a wide range of treatment devices.

Table 4-4 Preliminary sediment basin sizing

Location	1 ha site	2 ha site
Woodleigh BOM station	Design discharge (Q) = 0.0755 m^3/s Basin surface area = 906 m^2 Width = 17.4 m Length = 52.1 m	Design discharge (Q) = 0.142 m^3/s Basin surface area = 1,704 m^2 Width = 23.8 m Length = 71.5 m

Location	1 ha site	2 ha site
Blunder Creek rainfall station	Design discharge (Q) = 0.0765 m^3/s Basin surface area = 918 m^2 Width = 17.5 m Length = 52.5 m	Design discharge (Q) = 0.143 m^3/s Basin surface area = 1,716 m^2 Width = 23.9 m Length = 71.7 m
Chalumbin Pluvial site	Design discharge (Q) = 0.76 m^3/s Basin surface area = 912 m^2 Width = 17.4 m Length = 52.3 m	Design discharge (Q) = 0.142 m^3/s Basin surface area = 1,710 m^2 Width = 23.9 m Length = 71.6 m

4.4 ESC Monitoring

An important element of ESC for the Project is the monitoring and maintenance of ESC measures onsite to ensure that they are performing as intended. To support this, regular inspections will be undertaken not only during the dry season construction period, but also during the wet season shutdown period by a suitably qualified site environmental representative. Furthermore, monitoring will also take place during the operational phase of the Project. The following sections describe the commitment to ESC monitoring for the Project.

4.4.1 Construction ESC monitoring

A formal ESC monitoring and maintenance program for construction will be developed by the construction contractor prior to commencement of works. This will include the development of inspection check sheets and other aids to facilitate thorough checks of all ESCs and discharge points. The minimum ESC monitoring requirements for Project construction are as per IECA 2008 and are summarised in **Table 4-5**.

Further to this, the Project Owner will undertake quarterly site inspections, by a suitably qualified person, to ensure that construction ESCPs are appropriately implemented and the IECA 2008 BPESC Standard is met.

Table 4-5 Minimum ESC Monitoring Requirements

Frequency	Monitoring / inspection requirement
Weekly site inspections	▪ Checks of all drainage, erosion and sediment control measures. ▪ Occurrence of excessive sediment deposition (whether on or off-site). ▪ Checks of all site discharge points (e.g. for scour or sediment deposition). Occurrences of construction materials, litter or sediment placed, deposited, washed or blown from the site, including deposition by vehicular movements. ▪ Litter and waste receptors.
Daily site inspections during periods of run-off producing rainfall (dry-season construction periods).	▪ Checks of all drainage, erosion and sediment control measures. ▪ Occurrence of excessive sediment deposition (whether on or off-site). ▪ Checks of all site discharge points (e.g. for scour or sediment deposition).

Frequency	Monitoring / inspection requirement
Prior to anticipated runoff-producing rainfall (within 24 hours of rainfall occurring) (dry-season construction periods)	▪ All drainage, erosion and sediment control measures. ▪ All temporary flow diversion and drainage works.
Following run-off producing rainfall (within 18 hours) (dry-season construction periods)	▪ Treatment and dewatering requirements for sediment basins. ▪ Sediment deposition within sediment basins and the need for its removal. ▪ All drainage, erosion and sediment controls. ▪ Occurrences of excessive sediment deposition (whether on or offsite). ▪ Occurrences of construction materials, litter or sediment placed, deposited, washed, or blown from the sites, including deposition by vehicle movements. ▪ Occurrences of excessive erosion, sedimentation or mud generation around the site office, car park and / or material storage areas.
Monthly inspections	▪ Surface coverage of finished surfaces (both area and percentage cover) ▪ Health of recently established vegetation. ▪ Proposed staging of future land clearing, earthworks and site / soil stabilisation.
Water quality monitoring	▪ To be undertaken at the locations and frequencies determined by construction ESCPs in line with the IECA BPESC Standard. ▪ Will be carried out on any controlled discharge of water from a sediment basin. ▪ Will assess total suspended solids concentrations and pH as a minimum.

4.4.2 Operations ESC monitoring

ESC monitoring during the operational phase of the Project will comprise monitoring of previously installed drainage controls and established groundcover to ensure that drainage controls remain functional, and groundcover is not diminished due to wind farm operations and maintenance. Monitoring frequency and criteria will be determined by the Project Operational Environmental Management Plan (or equivalent). Further detail on water quality and soil erosion monitoring is provided in **Section 4.5**.

4.5 Baseline water quality and soil erosion monitoring

4.5.1 Baseline water quality monitoring

To assess the Project’s impact on water quality values outlined in the Reef 2050 Water Quality Improvement Plan and potential impacts to Magnificent Brood Frog habitat a detailed baseline water quality study and monitoring program will be developed for the Project.

The baseline water quality study and monitoring program will be developed based on the management framework in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) that has also been adopted in the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*.

The focus of this water quality assessment and monitoring will be on fine sediment transport that could potentially impact the Great Barrier Reef and Magnificent Brood Frog habitat as a result of Project activities.

The proposed approach includes the development of a stressor conceptual model using the Queensland Integrated Waterways Monitoring Framework (DNRM 2013), which establishes cause-and-effect linkages amongst pressures, stressors and ecological responses. Where appropriate the monitoring program will include trigger thresholds for managing sediment run-off from the Project footprint.

The water quality monitoring program will consider:

- The location of sensitive environmental receptors and areas where the potential for soil erosion is high (e.g. due to soils present, difficult terrain or the types of work being undertaken).
- The monitoring of water quality before, during and after the completion of construction to assess the effectiveness of controls.
- The monitoring of water quality during rainfall events where safe to do so, especially at points of concentrated discharge from the site.
- The monitoring of water quality both up and downstream of instream works.

Locally derived discharge water quality objectives will be developed as part of construction ESCP development. These will consider the baseline data acquired relating to pre-existing site conditions, and water quality objectives identified for the Herbert River Basin made pursuant to the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*. In the absence of locally derived water quality objectives, the default standard offered by IECA (2008) of the 90th percentile suspended solids not exceeding 50 mg/L will be adopted as the water quality objective for discharges of stormwater from site.

All relevant standards are to be used in the collection of water quality information including the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy* (DES 2018).

4.5.2 Soil erosion monitoring

A soil erosion monitoring plan will be developed to characterise the baseline soil erosion condition of the Project footprint and to establish permanent sites for the monitoring of long-term erosion with the focus on areas with existing erosion and areas within the Project footprint that develop erosion issues during construction and operation. Monitoring will include a combination of qualitative and quantitative assessment methodologies. For example, descriptions of sheet, rill and gully erosion depth, extent, rate of change and relative stability.

Thresholds will be set for sheet and rill erosion with no tolerance for active gully erosion within the Project footprint. Corrective actions may include changes to site drainage, reprofiling, reseeding, or the use of engineering controls such as rock armouring.

Monitoring frequency will be developed to reflect the relative risk of particular sites and Project activities.

5.0 Conclusion

The Project is situated within the upper portion of the Herbert River Drainage Basin of the GBRCA. The release of poor-quality main land run-off from the GBRCA is a threat to GBR ecological function and exacerbates impacts on the GBR caused by climate change. The Reef 2050 WQIP has been developed by the Commonwealth and Queensland Governments to improve the quality of surface water run-off released from the GBRCA. The Reef 2050 WQIP identifies nutrients, sediment and pesticides as the primary water pollutants of concern and is largely focussed on agricultural activities.

Project construction will involve vegetation clearing, ground disturbance, and instream works and hence introduces a potential sedimentation risk. Sedimentation risks during Project operation are minimal, as operational activities are largely limited to site access via established tracks and non-ground disturbing works. Nutrient and pesticide run-off are not threats which are associated with the Project.

Climate change scenarios published by CSIRO all predict the Project area will receive less annual rainfall but will experience an increase in the amount of intense rainfall and more intense tropical cyclones. Consequently, there are likely to be more distinct sediment runoff events or pulses entering the aquatic environment. Therefore, Project sediment runoff is unlikely to change significantly compared to the surrounding landscape due to future climate change scenarios and any increase, if realised, will be proportional to the broader catchment.

The soil loss modelling found that the Project footprint under operational conditions has a sediment yield 0.45 kt/year less than current conditions. This assumes that the soil loss equation has a C-factor of 70% cover which is the Reef 2050 WQIP (year 2025) target for grazing land, end of dry season, cover.

The Project will use the IECA 2008 BPESC Standard for erosion control during construction. The Project is also committed to the adoption of IECA rehabilitation cover targets, restoration of regional ecosystems where practicable and the use of gravel and hardstand operational areas drained through a stormwater system to further reduce sediment loads.

The Project is committed to minimising sediment impacts and is proposing to limit ground-disturbing construction works to only the drier months (April to December), a major departure from traditional construction projects. This will reduce the risk of erosion by 6 to 8 times compared to constructing in the wetter months of January to March. The dry season-only construction has significantly lower rainfall, but also has a lower frequency of extreme (or outlier) events that are smaller than extreme events during the wet season. This means that the Project disturbance activities will have a reduced exposure to potential large high intensity rainfall events.

The majority of soils within the Project footprint do not contain significant quantities of fine material that could be a sediment transport risk. The dominant mapped soils (approximatley 80% of the Project footprint) are Tenosols which are generally shallow or deep sandy and have a coarse sandy loam to sandy loam topsoil. Clayey topsoils are likely to occur over less than 10% of the Project footprint and there is only approximately 5% of the Project footprint that contains sodic soils that are a high risk of producing dispersive runoff.

Although there is an increased risk of sediment runoff during the construction phase, this will be a relatively short duration (generally 2 months at a given location) and managed using the IECA 2008 BPESC Standard which is considered international best practice. Calculations via RUSLE have determined the increased risk during construction to be negligible for the Project footprint, with the implementation of dry season construction practices and effective ESC measures appropriately managing this risk. The Project will also achieve a reduction in the rate of sediment runoff during the operational phase of the Project compared to current conditions. By comparison with the existing soil loss rates within the Project area, it is considered that the Project's sediment runoff is consistent with the Reef 2050 Plan.

The implementation of ESC best practice management measures and natural features as individual elements work together as a treatment train to minimise erosion and maximise sediment retention onsite. There is a range of ESC measures to be used on the Project that are demonstrated to be highly effective at reducing sediment runoff. Specific measures have been identified that will be particularly important for implementation on this Project.

To assess the Project's impact on water quality values outlined in the Reef 2050 Water Quality Improvement Plan and potential impacts to Magnificent Brood Frog habitat a baseline water quality study and ongoing monitoring program will be developed for the Project. A soil erosion monitoring plan will also be developed to characterise the baseline soil erosion condition of the Project footprint and to monitor long-term erosion with the focus on areas with existing erosion and areas within the Project footprint that develop erosion issues during construction and operation. Corrective actions will be included in these monitoring programs to ensure that any identified issues are resolved in an appropriate timeframe that minimises potential adverse impacts.

Overall, this SEMP determines that the Chalumbin Wind Farm can be constructed and operated in a manner that is in line with international best practice for erosion and sediment control and in a way that will largely avoid and minimise impacts to the Great Barrier Reef, Magnificent Brood Frog habitat and the surrounding environment more generally.

6.0 References

This SEMP has been developed with reference to the following:

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Attachment A

RUSLE Calculations

Calculation of monthly rainfall erosivity

The rainfall erosivity factor was run at a daily timestep using the last 20 years of data for the rainfall stations.

Using the methodology in "Ellis, R.J. (2018). Dynamic SedNet Component Model Reference Guide: Update 2017, Concepts and algorithms used in Source Catchments customisation plugin for Great Barrier Reef catchment modelling. Queensland Department of Environment and Science, Bundaberg, Queensland".

Dynamic SedNet Component Model Reference Guide: Update 2017

Concepts and algorithms used in Source Catchments customisation plugin for Great Barrier Reef catchment modelling

4.5.2 Calculation of rainfall erosivity

The Rainfall erosivity factor (R) is calculated daily at model runtime using the relationship with daily rainfall amount documented by Yu (1998).

$$EI30 = \alpha * (1 + \eta * \text{Time Of Year Factor}) * R^{\beta}, \text{ when } R >= R_0$$

Where:

EI30 is daily rainfall erosivity (MJ.mm/ha.h)

R is daily rainfall amount (mm)

R_0 is the threshold rainfall amount (usually 12.7mm)

$\eta = 0.29$

$\beta = 1.49$

α = a calculated constant (could also be supplied as raster)

The 'Time Of Year' factor included in the daily R factor calculation is substituted by a variation of the 'Time Of Year' factor given in Scanlan *et al.* (1996):

$$\text{Time Of Year Factor} = \cos(2 * \pi * ((\text{Day Of Year} - 15)/365))$$

The variation here is using 'Day Of Year - 15' to peak intensity mid-January, the Scanlan *et al.* (1996) original uses 'Day Of Year + 30'

The purpose built RUSLE parameteriser will calculate α for each Functional Unit based on the rainfall time series available, according to (Yu 1998):

$$\alpha = 0.395 * (1 + 0.098 * e^{(3.29 * S/P)})$$

Where:

S = mean summer rainfall (mm), November – April

P = mean annual rainfall (mm)

Another approach provided by the parameteriser is to supply a spatial representation of the required α parameter, giving the modeller some control over the impact of this parameter.

Example of daily timestep calculation						
Year	Month	Day	Rainfall amount (millimetres)	Day of Year	TOYF	**EI30**
2001	1	1	15.6	1	0.9711	86.43574
2001	1	2	6	2	0.975065	0
2001	1	3	0	3	0.97874	0
2001	1	4	0	4	0.982126	0
2001	1	5	0	5	0.98522	0
2001	1	6	0	6	0.988023	0
2001	1	7	0	7	0.990532	0
2001	1	8	0	8	0.992749	0
2001	1	9	0	9	0.994671	0
2001	1	10	0	10	0.996298	0
2001	1	11	0	11	0.99763	0
2001	1	12	0	12	0.998667	0
2001	1	13	0	13	0.999407	0
2001	1	14	0	14	0.999852	0
2001	1	15	0	15	1	0
2001	1	16	0	16	0.999852	0
2001	1	17	0	17	0.999407	0
2001	1	18	0	18	0.998667	0
2001	1	19	0	19	0.99763	0
2001	1	20	17.4	20	0.996298	102.2881

Calculation of Project soil loss using RUSLE (base case - Stage 1 & 2)

Project stage	Description	Ground cover	Area (ha)	R	K	Slope (%)	Length (m)	LS	P	C	Soil loss (t/ha/yr)	Gross sediment yield (t/yr)	Gross sediment yield (kt/yr)	Sediment delivery (50%)	Sediment Control Efficiency (%)	Construction duration to stabilisation (mths)	Net sediment Loss operation (kt/yr)	Net sediment Loss during 2 months (kt)
Existing	Current conditions	Existing 70%	1071	5925	0.045			2.36	1	0.025	15.73	16848	16.85					2.8
Construction	Construction no ESC	No ground cover	1071	5925	0.045			2.36	1.3	1	818.01	876084	876.08			2		146.0
	Construction ESC (High erosion control)	Ground cover as part of ESC	1071	5925	0.045			2.36	0.9	0.4	226.52	242608	242.61			2		40.4
	Construction with ESC 'efficiency'	Ground cover as part of ESC	1071	5925	0.045			2.36	1.3	1	818.01	876084	876.08	50	75	2		18.3
Operation	Access Track	Gravel capped road	69.7	5847	0.01	8	10	0.53	1.3	0.2	8.06	562	0.56		50		0.28	
	Met-mast	Gravel hardstands	1.7	5925	0.01	1	80	0.19	1.3	0.15	2.20	4	0.00		50		0.00	
	OH Reticulation	Grass 70% cover	97.4	5926	0.042			2.16	1	0.025	13.44	1309	1.31				1.31	
	Site Infrastructure	Impervious structure	11.6	5925					1.3	0	0.00	0	0.00				0.00	
	Turbine Pad	Gravel hardstands	24.2	5925	0.01	1	80	0.19	1.3	0.15	2.20	53	0.05		50		0.03	
	Temporary Impact	Grass 70% cover	866.4	5925	0.045			2.56	1	0.025	17.06	14783	14.78				14.78	
	Totals / Averages										**15.60**	**16711**	**16.71**				**16.40**	

Construction Monthly timestep	Description	Ground cover	Area (ha)	R	K	Slope (%)	Length (m)	LS	P	C	Soil loss (t/ha/mth)	Gross sediment yield (t/mth)	Gross sediment yield (kt/mth)	Sediment delivery (50%)	Sediment Control Efficiency (%)	Construction duration to stabilisation (mths)	Net sediment Loss during 2 months (kt)
Woodleigh	Construction no ESC	No ground cover	1071	167	0.045			2.36	1.3	1	23.06	24693	24.69			2	49.4
	Construction ESC (High erosion control) (Monthly R value)	Ground cover as part of ESC	1071	167	0.045			2.36	0.9	0.4	6.38	6838	6.84			2	13.7
	Construction with ESC 'efficiency' (Monthly R value)	Ground cover as part of ESC	1071	167	0.045			2.36	1.3	1	23.06	24693	24.69	50	75	2	6.2
Blunder Creek	Construction no ESC	No ground cover	1071	170	0.045			2.36	1.3	1	23.47	25137	25.14			2	50.3
	Construction ESC (High erosion control) (Monthly R value)	Ground cover as part of ESC	1071	170	0.045			2.36	0.9	0.4	6.50	6961	6.96			2	13.9
	Construction with ESC 'efficiency' (Monthly R value)	Ground cover as part of ESC	1071	170	0.045			2.36	1.3	1	23.47	25137	25.14	50	75	2	6.3
Chalumbin Pluvio	Construction no ESC	No ground cover	1071	326	0.045			2.36	1.3	1	45.01	48203	48.20			2	96.4
	Construction ESC (High erosion control) (Monthly R value)	Ground cover as part of ESC	1071	326	0.045			2.36	0.9	0.4	12.46	13349	13.35			2	26.7
	Construction with ESC 'efficiency' (Monthly R value)	Ground cover as part of ESC	1071	326	0.045			2.36	1.3	1	45.01	48203	48.20	50	75	2	12.1

Notes:

The factors R, K and LS were downloaded from the Queensland Spatial Catalogue

Spatial averages for input values in each RUSLE model were calculated in ArcGIS

Operational areas - erosion from gravel capped roads have been given a higher K-factor, than hardstands due to traffic increasing erosion risk.

Existing conditions have a C-factor of 70% which is the reef WQIP target for grazing land end of dry season cover target. The same 70% cover is used for operational rehabilitated areas even though the initial ESC rehab target maybe higher.

Length and slope of operational areas were based on the civil design criteria for the Project

The construction monthly timestep calculations used the Dry season average monthly R-factor

The construction duration was assumed to be 2 months based on progressive rehabilitation of Project disturbance areas

Sediment control efficiency during construction is a measure of the efficiency of both erosion and sediment control measures

Sediment control efficiency during operation is a measure of the stormwater system efficiency

IECA (2008) Best Practice Erosion and Sediment Control was used in the development of these RUSLE models

Calculation of Project soil loss using RUSLE (Stage 1)

Project stage	Description	Ground cover	Area (ha)	R	K	Slope (%)	Length (m)	LS	P	C	Soil loss (t/ha/yr)	Gross sediment yield (t/yr)	Gross sediment yield (kt/yr)	Sediment delivery (50%)	Sediment Control Efficiency (%)	Construction duration to stabilisation (mths)	Net sediment Loss operation (kt/yr)	Net sediment Loss during 2 months (kt)
Existing	Current conditions	Existing 70%	606.9	6529	0.0484			2.1	1	0.025	16.59	10069	10.07					1.7
Construction	Construction no ESC	No ground cover	606.9	6529	0.0484			2.1	1.3	1	862.69	523566	523.57			2		87.3
	Construction ESC (High erosion control)	Ground cover as part of ESC	606.9	6529	0.0484			2.1	0.9	0.4	238.90	144988	144.99			2		24.2
	Construction with ESC 'efficiency'	Ground cover as part of ESC	606.9	6529	0.0484			2.1	1.3	1	862.69	523566	523.57	50	75	2		10.9
Operation	Access Track	gravel capped road	42.4	6442	**0.01**	8	10	0.53	1.3	0.2	8.88	376	0.38		50		0.19	
	Met-mast	Gravel hardstands	1.0	7257	**0.01**	1	80	0.19	1.3	0.15	2.69	3	0.00		50		0.00	
	OH Reticulation	Grass 70% cover	0.0								0.00	0	0.00				0.00	
	Site Infrastructure	impervious structure	7.6	7203					1.3	0	0.00	0	0.00				0.00	
	Turbine Pad	Gravel hardstands	14.7	6509	**0.01**	1	80	0.19	1.3	0.15	2.41	35	0.04		50		0.02	
	Temporary Impact	Grass 70% cover	541.2	6525	0.0484			2.1	1	0.025	16.58	8973	8.97				8.97	
	Totals / Averages										**15.47**	**9388**	**9.39**				**9.18**	

Construction Monthly timestep	Description	Ground cover	Area (ha)	R	K	Slope (%)	Length (m)	LS	P	C	Soil loss (t/ha/mth)	Gross sediment yield (t/mth)	Gross sediment yield (kt/mth)	Sediment delivery (50%)	Sediment Control Efficiency (%)	Construction duration to stabilisation (mths)	Net sediment Loss during 2 months (kt)
Woodleigh	Construction no ESC	No ground cover	606.9	167	0.0484			2.1	1.3	1	22.07	13392	13.39			2	26.8
	Construction ESC (High erosion control) (Monthly R value)	Ground cover as part of ESC	606.9	167	0.0484			2.1	0.9	0.4	6.11	3709	3.71			2	7.4
	Construction with ESC 'efficiency' (Monthly R value)	Ground cover as part of ESC	606.9	167	0.0484			2.1	1.3	1	22.07	13392	13.39	50	75	2	3.3
Blunder Creek	Construction no ESC	No ground cover	606.9	170	0.0484			2.1	1.3	1	22.46	13632	13.63			2	27.3
	Construction ESC (High erosion control) (Monthly R value)	Ground cover as part of ESC	606.9	170	0.0484			2.1	0.9	0.4	6.22	3775	3.78			2	7.6
	Construction with ESC 'efficiency' (Monthly R value)	Ground cover as part of ESC	606.9	170	0.0484			2.1	1.3	1	22.46	13632	13.63	50	75	2	3.4
Chalumbin Pluvio	Construction no ESC	No ground cover	606.9	326	0.0484			2.1	1.3	1	43.08	26142	26.14			2	52.3
	Construction ESC (High erosion control) (Monthly R value)	Ground cover as part of ESC	606.9	326	0.0484			2.1	0.9	0.4	11.93	7239	7.24			2	14.5
	Construction with ESC 'efficiency' (Monthly R value)	Ground cover as part of ESC	606.9	326	0.0484			2.1	1.3	1	43.08	26142	26.14	50	75	2	6.5

Notes:

The factors R, K and LS were downloaded from the Queensland Spatial Catalogue

Spatial averages for input values in each RUSLE model were calculated in ArcGIS

Operational areas - erosion from gravel capped roads have been given a higher K-factor, than hardstands due to traffic increasing erosion risk.

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The construction monthly timestep calculations used the Dry season average monthly R-factor

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Sediment control efficiency during construction is a measure of the efficiency of both erosion and sediment control measures

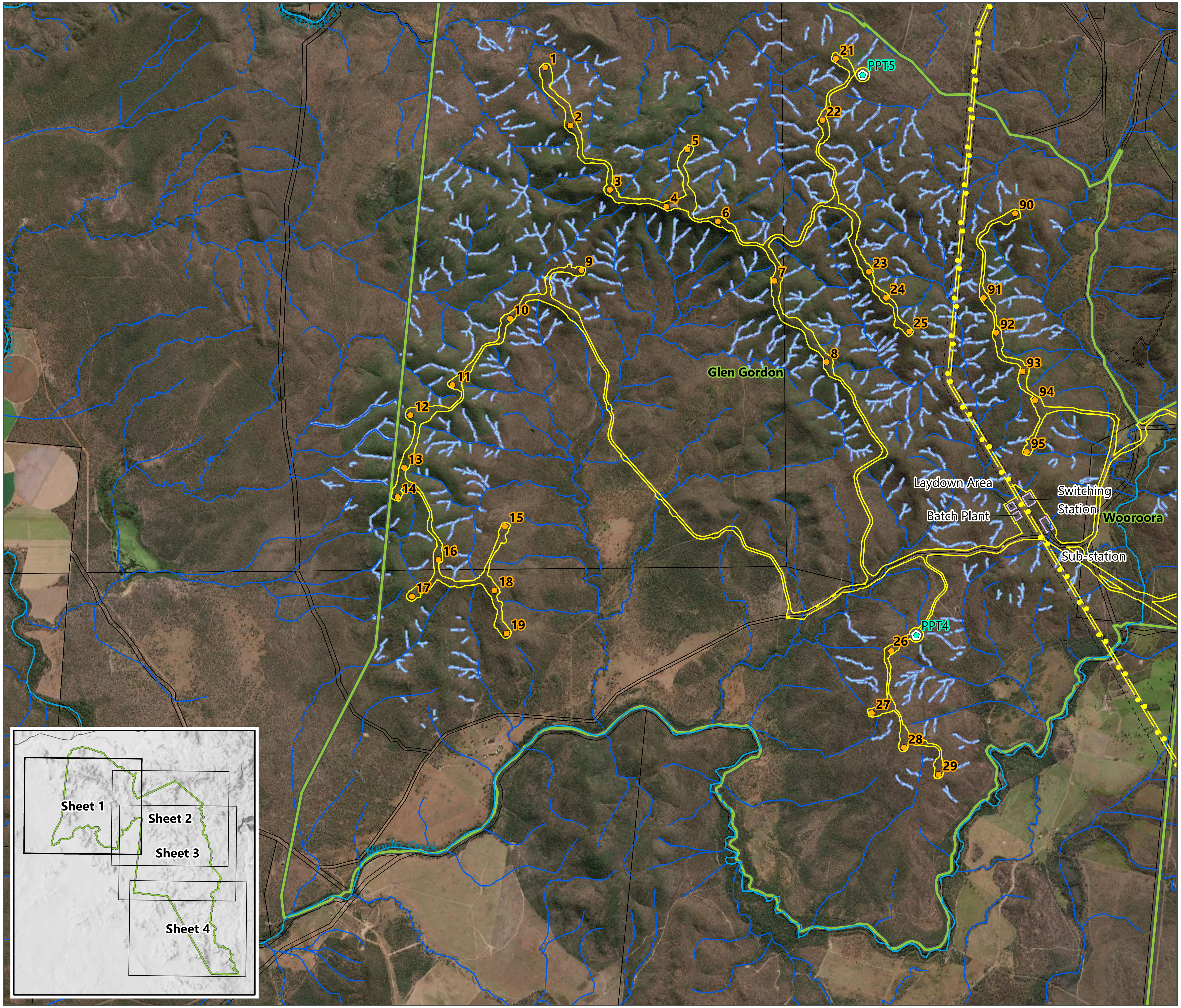
Sediment control efficiency during operation is a measure of the stormwater system efficiency

IECA (2008) Best Practice Erosion and Sediment Control was used in the development of these RUSLE models

Construction Monthly timestep	Description	Month	Area (ha)	R (EI30)	K	Slope (%)	Length (m)	LS	P	C	Soil loss (t/ha/mth)	Gross sediment yield (t/mth)	Gross sediment yield (kt/mth)	Sediment delivery (50%)	Sediment Control Efficiency (%)	Net sediment Loss (kt)	Net sediment Loss (t/ha)
Woodleigh	Construction with ESC 'efficiency' (Monthly R value)	Jan	1071	1257	0.045			2.36	1.3	1	173.59	185912	185.91	50	75	23.2	21.7
		Feb	1071	1499	0.045			2.36	1.3	1	206.93	221621	221.62	50	75	27.7	25.9
		Mar	1071	832	0.045			2.36	1.3	1	114.82	122969	122.97	50	75	15.4	14.4
		Apr	1071	129	0.045			2.36	1.3	1	17.87	19142	19.14	50	75	2.4	2.2
		May	1071	33	0.045			2.36	1.3	1	4.58	4905	4.91	50	75	0.6	0.6
		Jun	1071	19	0.045			2.36	1.3	1	2.67	2858	2.86	50	75	0.4	0.3
		Jul	1071	9	0.045			2.36	1.3	1	1.24	1326	1.33	50	75	0.2	0.2
		Aug	1071	8	0.045			2.36	1.3	1	1.08	1162	1.16	50	75	0.1	0.1
		Sep	1071	17	0.045			2.36	1.3	1	2.34	2509	2.51	50	75	0.3	0.3
		Oct	1071	105	0.045			2.36	1.3	1	14.55	15581	15.58	50	75	1.9	1.8
		Nov	1071	376	0.045			2.36	1.3	1	51.96	55646	55.65	50	75	7.0	6.5
		Dec	1071	805	0.045			2.36	1.3	1	111.18	119079	119.08	50	75	14.9	13.9
Blunder Creek	Construction with ESC 'efficiency' (Monthly R value)	Jan	1071	1242	0.045			2.36	1.3	1	171.41	183582	183.58	50	75	22.9	21.4
		Feb	1071	1749	0.045			2.36	1.3	1	241.43	258567	258.57	50	75	32.3	30.2
		Mar	1071	1119	0.045			2.36	1.3	1	154.48	165444	165.44	50	75	20.7	19.3
		Apr	1071	309	0.045			2.36	1.3	1	42.73	45763	45.76	50	75	5.7	5.3
		May	1071	111	0.045			2.36	1.3	1	15.29	16378	16.38	50	75	2.0	1.9
		Jun	1071	74	0.045			2.36	1.3	1	10.27	11004	11.00	50	75	1.4	1.3
		Jul	1071	29	0.045			2.36	1.3	1	4.01	4299	4.30	50	75	0.5	0.5
		Aug	1071	18	0.045			2.36	1.3	1	2.45	2625	2.62	50	75	0.3	0.3
		Sep	1071	41	0.045			2.36	1.3	1	5.70	6109	6.11	50	75	0.8	0.7
		Oct	1071	182	0.045			2.36	1.3	1	25.18	26971	26.97	50	75	3.4	3.1
		Nov	1071	182	0.045			2.36	1.3	1	25.12	26900	26.90	50	75	3.4	3.1
		Dec	1071	584	0.045			2.36	1.3	1	80.69	86419	86.42	50	75	10.8	10.1
Chalumbin Pluvio	Construction with ESC 'efficiency' (Monthly R value)	Jan	1071	1805	0.045			2.36	1.3	1	249.25	266946	266.95	50	75	33.4	31.2
		Feb	1071	2527	0.045			2.36	1.3	1	348.85	373620	373.62	50	75	46.7	43.6
		Mar	1071	2018	0.045			2.36	1.3	1	278.58	298354	298.35	50	75	37.3	34.8
		Apr	1071	825	0.045			2.36	1.3	1	113.92	122003	122.00	50	75	15.3	14.2
		May	1071	326	0.045			2.36	1.3	1	45.02	48213	48.21	50	75	6.0	5.6
		Jun	1071	190	0.045			2.36	1.3	1	26.29	28154	28.15	50	75	3.5	3.3
		Jul	1071	142	0.045			2.36	1.3	1	19.60	20990	20.99	50	75	2.6	2.4
		Aug	1071	50	0.045			2.36	1.3	1	6.96	7454	7.45	50	75	0.9	0.9
		Sep	1071	80	0.045			2.36	1.3	1	11.10	11883	11.88	50	75	1.5	1.4
		Oct	1071	235	0.045			2.36	1.3	1	32.44	34742	34.74	50	75	4.3	4.1
		Nov	1071	257	0.045			2.36	1.3	1	35.49	38013	38.01	50	75	4.8	4.4
		Dec	1071	830	0.045			2.36	1.3	1	114.62	122755	122.75	50	75	15.3	14.3

Attachment B

Local Surface Water Flow Paths: Map Series



ARK ENERGY

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Chalumbin Wind Farm

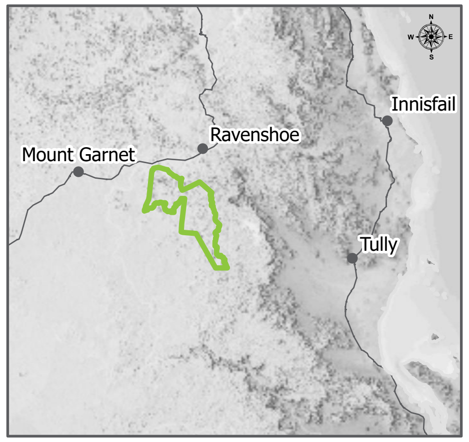
Estimated monthly soil loss during dry season construction (t/ha)

Sheet 1 of 4

Figure 2.2

- Project Area Boundary
- Project footprint Stages 1 & 2
- Watercourse
- Local surface water flow paths
- Turbine
- Met-mast
- Facilities
- Existing HV Transmission Line
- Lot Boundary
- Easement

Date: 11/10/2022 Author: TOD
Project: EPU-004 Reviewed: NOD



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Data Source(s):
Digital Cadastral Database - Department of Resources (2022)

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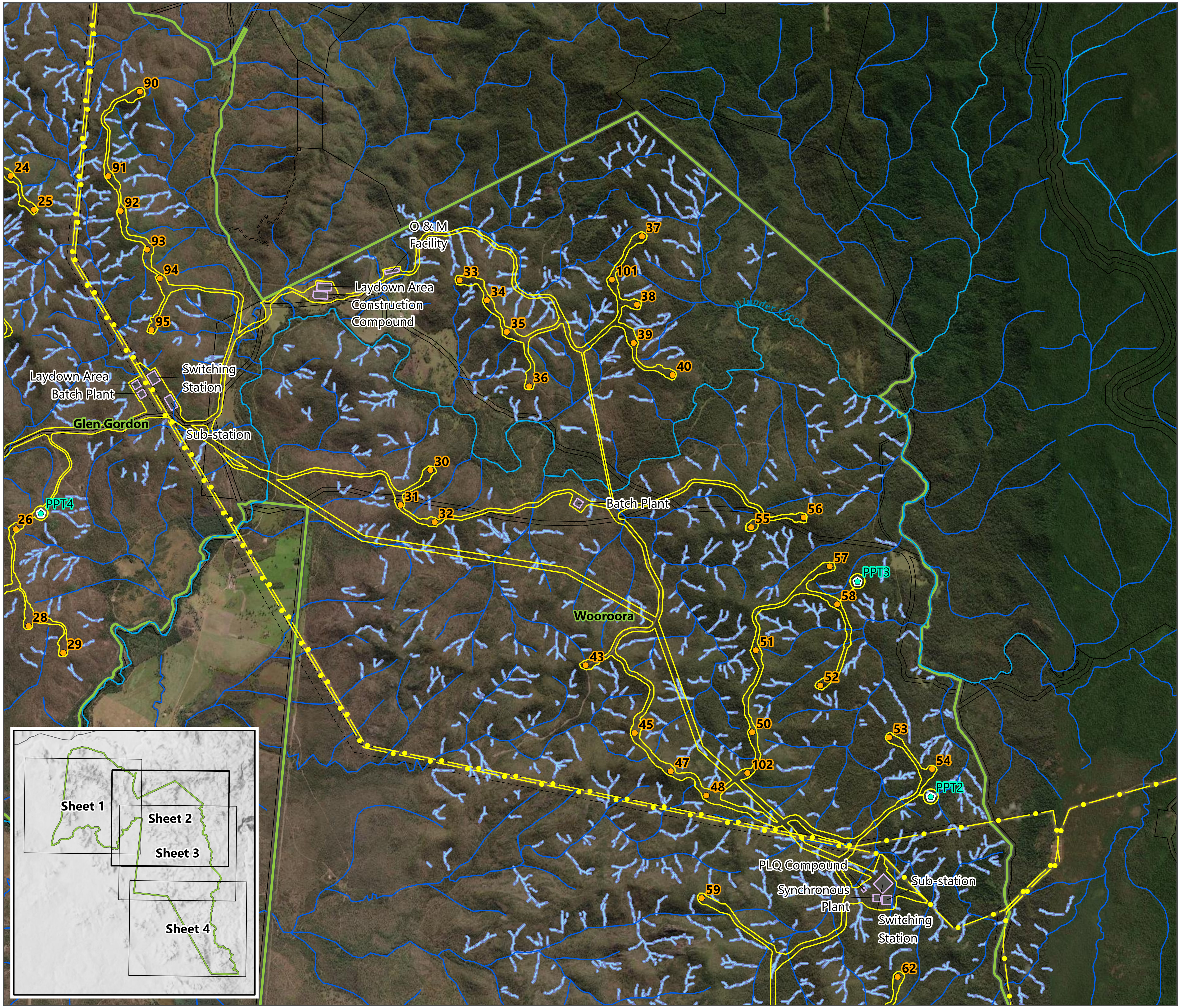

ARK ENERGY

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Chalumbin Wind Farm

Estimated monthly soil loss during dry season construction (t/ha)

Sheet 2 of 4

Figure 2.2

- Project Area Boundary
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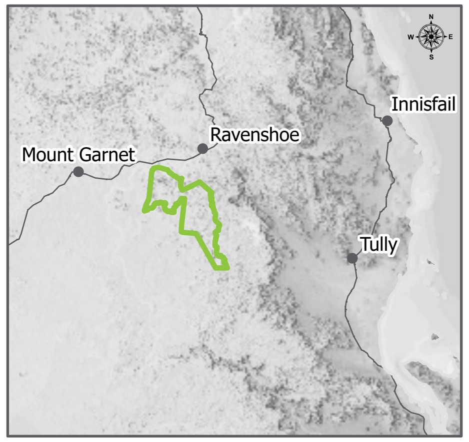

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Scale: 1:50,000@A3

Data Source(s):
Digital Cadastral Database - Department of Resources (2022)
Earthstar Geographics, © State of Queensland (Department of Resources) 2022

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