



TURNER RIVER SOLAR HUB SOIL AND LANDFORM ASSESSMENT

Fortescue Limited
December 2024



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1 INTRODUCTION

1.1 Project overview

Pilbara Energy (Generation) Pty Ltd (PEG), a wholly owned subsidiary of Fortescue Limited (Fortescue), is proposing to develop the Turner River Solar Hub Project (the Project).

The Project comprises solar panel arrays, associated infrastructure and 220kV transmission line connecting to the Fortescue Integrated Power Network, located adjacent to the Roy Hill rail line, in the East Pilbara region of Western Australia. The Project is situated approximately 120km south-east of Port Hedland and 25km west of Fortescue’s Iron Bridge project (Figure 1).

The Project area is 1,403ha in size, comprised of the northern Wodgina section (379ha) and the southern NSJ West section (1,024ha). Associated tenements are outlined in Table 1.

Table 1: Tenure associated with the Project.

Tenure	Status	Holder
L 45/692	Live	Pilbara Energy (Generation) Pty Ltd
L 45/693	Live	Pilbara Energy (Generation) Pty Ltd
L 45/694	Live	Pilbara Energy (Generation) Pty Ltd
L 45/293	Live	Fortescue Magnetite Pty Ltd
L 45/294	Live	Fortescue Magnetite Pty Ltd

The Project includes the installation of solar panel arrays, construction of substation/s (including transformer/s), transmission lines and inverter stations with future capability for battery storage. Supporting infrastructure and access roads will also be required. The Project will supply renewable energy for use by Fortescue and is expected to contribute to powering the Iron Bridge mine.

Fortescue is developing an Environmental Impact Assessment (EIA) to accompany a referral to the Environmental Protection Authority (EPA) under Section 38 of the *Environmental Protection Act 1986* (the EP Act). Fortescue is required to thoroughly understand the environmental factors that may be impacted by its developments. The size and scale of these impacts need to be fully understood to allow for a high-quality environmental impact assessment. To meet this requirement, Fortescue undertakes a range of surveys and studies to better understand the environment.

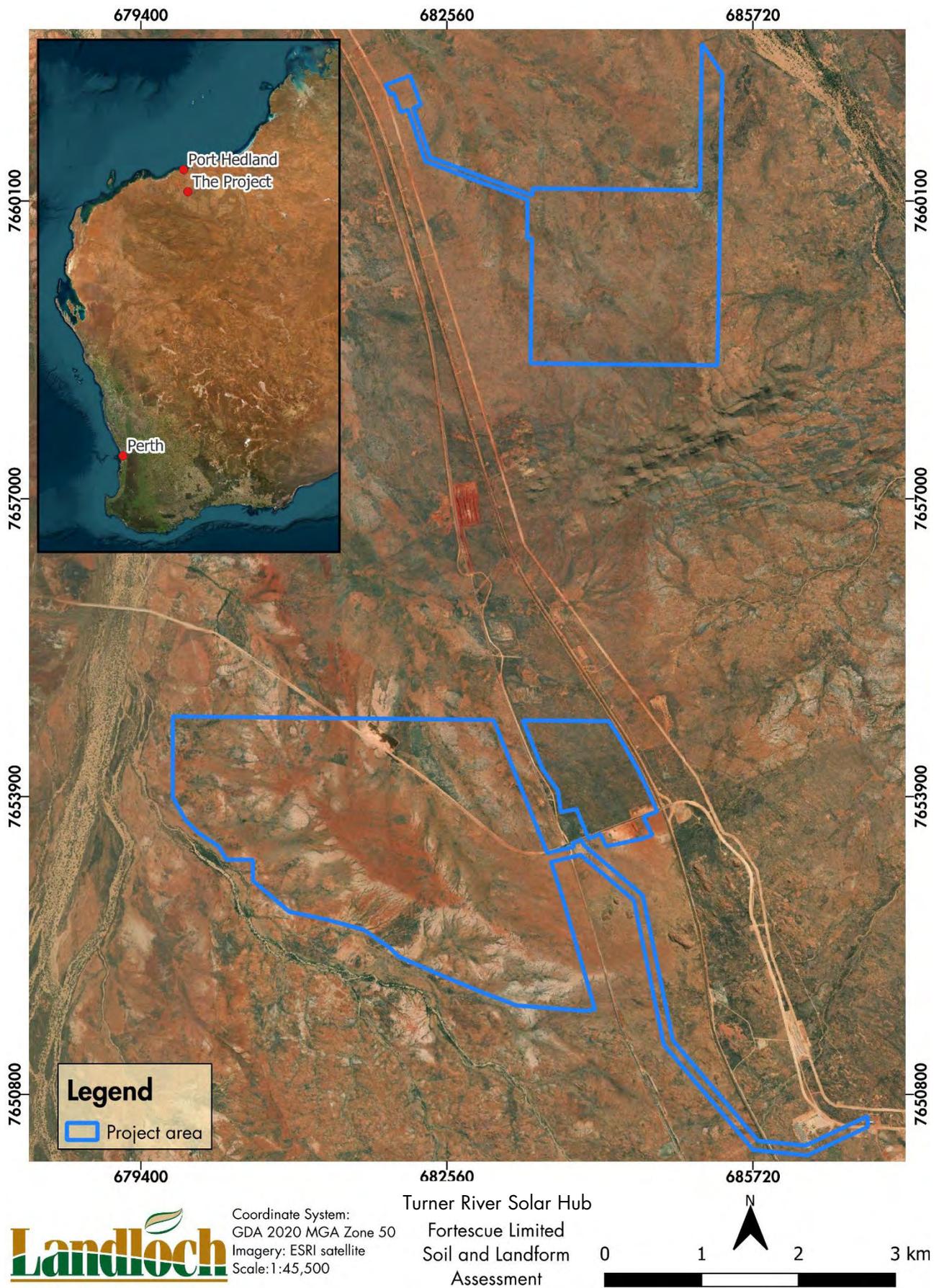


Figure 1: Project area overview.

1.2 Scope of work

Landloch Pty Ltd (Landloch) were engaged by Fortescue to complete a soil and landform assessment for the Project. The aim of the assessment was to characterise the existing surface soils within the Project area, to identify any potentially problematic characteristics, and to identify any landforms of potential significance. Included in this was an assessment of Acid Sulfate Soils (ASS). As part of the soil and landform assessment, the following activities have been completed:

- Review of relevant site information, land systems, and regional soil information;
- Description of surface soil profile;
- Desktop analysis of the landforms present within the Project area and assessment of their potential significance;
- Mapping of landform type based on desktop information and supplemented by in-field observations;
- Description of soil physical and chemical characteristics;
- Development of soil mapping units and mapping of these units across the Project area;
- Assessment of potential ASS; and
- Development of soil management recommendations for topsoil stripping, handling and placement as a rehabilitation resources.

1.3 Guidance documents

To complete the soil and landform assessment, a number of guidance documents have been used to form the basis of the field methodology, laboratory analysis, and data interpretation. The following documents were used by Landloch to guide the project:

- *Environmental Factor Guideline: Terrestrial Environmental Quality* (EPA 2016).
- *Environmental Factor Guideline: Landforms* (EPA 2018).
- *Identification and investigation of acid sulfate soils and acidic landscapes* (DER 2015).
- *Draft guidance Material Characterisation Baseline Data Requirements for Mining Proposals* (DMP 2016).
- *Interpreting Soil Test Results, what do all the numbers mean?* (Hazelton and Murphy 2016).
- *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al.* 2008).
- *Australian Soil and Land Survey Handbook* (NCST 2009).

2 REVIEW OF REGULATORY REQUIREMENTS

2.1 EIA assessment

The EPA requirements to be addressed for the Project include two Environmental Factors:

- Terrestrial Environmental Quality (EPA 2016); and
- Landforms (EPA 2018).

The Terrestrial Environmental Quality factor was identified as potentially being impacted by the Project. For a comprehensive assessment, Fortescue also require a high-level review of the landform factor to ensure no significant impacts to significant landforms are expected.

2.1.1 Terrestrial environmental quality

The EPA’s environmental objective for the Terrestrial Environmental Quality factor is, “to maintain the quality of land and soils so that environmental values are protected”.

The Terrestrial Environmental Quality factor is aimed at understanding the existing environmental values and potential impacts to these values as a result of the proposed activity.

The focus of this project is to address the soil quality component of this factor; specifically, how changes to soil quality impact environmental values. The broad requirements include collection of baseline (pre-disturbance) information on soil quality, and using this data, if required, to determine the mitigation, management, and rehabilitation practices to be adopted at a local scale.

2.1.2 Landforms

To address the landform component, a review of existing information was completed to assess if any of the six criteria are likely to be present within the Project area. As part of the field investigation, photographs of the surrounding landscape at each sampling location were taken.

Table 2: Criteria for determining whether a landform is significant (EPA 2018).

Criteria	Determination
Variety	The landform is a particularly good or important example of its type. The landform is not well represented over the local, regional or national scale or differs from other examples at these scales, either naturally or as a result of cumulative impacts from existing and reasonably foreseeable activities, developments and land uses.
Integrity	The landform is intact, being largely complete or whole and in good condition.
Ecological importance	The landform has a distinctive or exclusive role in maintaining the existing ecological and physical processes; for example, by providing a unique microclimate, source of water flow, or shade. The landform supports endemic or highly restrictive plants or animals.
Scientific importance	The landform provides evidence of past ecological processes or is an important geomorphological or geological site. The landform is of recognised scientific interest as a reference site or an example of where important natural processes are operating.
Rarity	The landform is rare or relatively rare, being one of the few of its type at a national, regional or local level.
Social importance	The landform supports significant amenity, cultural or heritage values linked to its defining physical features.

2.2 Acid sulfate soils

Acid Sulfate Soils (ASS) are soils or sediments containing iron sulfides. These iron sulfides form naturally in the soil under waterlogged conditions. When exposed to air by draining, lowering of the water table, or excavation, the oxidation of the sulfides creates sulfuric acid which can have a range of deleterious effects.

The term ASS includes both sulfate materials (i.e. materials that, when oxidised will produce acid) and sulfuric materials (i.e. materials that have undergone some degree of oxidation), referred to by the following terms:

- Potential Acid Sulphate Soils (PASS) are soils or sediments that contain iron sulphides and/or other sulfidic minerals that have not been oxidised. The field pH of these materials in their undisturbed state is more than pH 4 and is commonly neutral to alkaline. These materials are fully saturated; the waterlogged layer may be peat, clay, loam, silt or sand, and is usually dark grey and soft, but may also be dark brown, or pale grey to white.
- Actual Acid Sulphate Soils (AASS) are soils or sediments that contain iron sulphides and/or other sulfidic minerals that have undergone some oxidation. This results in low pH (i.e. pH <4) and often a yellow and/or red mottling (jarosite/iron oxide) in the soil profile. AASS also commonly contain residual un-oxidised sulphide minerals (i.e. potential acidity) as well as existing acidity.

The first step is to review ASS risk maps to determine if the proposed works are in an area where there is a known ASS risk. If risks are identified, the next step is to complete a preliminary desktop assessment and site inspection, which involves:

- Desktop review including site description based on landscape properties, and a review of geomorphic and geological maps; and
- Site inspection to conduct preliminary ASS testing; and
- Summarisation of the results.

Fortescue requested that a preliminary investigation of ASS be conducted as part of an additional level of due diligence, despite the low likelihood of ASS presence within the Project area. The approach adopted for this project is to include preliminary ASS testing as part of the field investigation, in line with the DER guideline (2015).

3 DATA REVIEW

3.1 Geology

The type of tectonic unit present at a local level plays a significant role in the overarching geological features that will be present. Bedrock geological mapping (1:100,000) indicate there are three units present within the Project area:

- Split Rock Supersuite;
- Cleland Supersuite; and
- Sisters Supersuite (Geoscience Australia 2024).

The Split Rock Supersuite comprises multiple intrusions of highly fractionated monzogranites that were emplaced in a broad north-west-trending linear belt. Dating of the Split Rock Supersuite indicates that it might have been emplaced at 2,800Ma.

In the East Pilbara Terrane, the Cleland Supersuite comprises numerous granitic intrusions with crystallisation ages between 3,257–3,223 Ma. Most intrusions of the Cleland Supersuite are comprised of monzogranite, although granodiorite and synogranite are also locally present. Felsic magmas for the Cleland Supersuite were mostly derived from melting of older granitic crust.

The Sisters Supersuite was initially intruded into the Mallina Basin. Geochronology has established that from 2,954–2,919Ma, magmatic activity migrated into the east Pilbara Craton, where intrusions were mainly composed of high potassium monzogranite derived from partial melting of older basement rock.

The Split Rock Supersuite is present over a majority of the Project area (90%) and is comprised of the Numbana Mozogranite formation. The Cleland Supersuite is present in the northern extent of the Project, comprising a minor proportion of the project area (8%). Although no specific formation is noted, the lithology is comprised of Monzogranites. The Sisters Supersuite accounts for 2% of the Project area, and is comprised of the Pincunah Monzogranite formation.

Overall, the surface lithologies present across the Project area are dominated by monzogranites. A summary of the surface geology is presented in Table 3 and illustrated in Figure 3.

Table 3: Bedrock geology within the Project area (Geoscience Australia 2024).

Parent unit	Formation	Lithology type	Lithology description	Estimated Proportion of Survey Area (%)
Split Rock Supersuite	Numbana Monzogranite	Biotite monzogranite Pegmatite	Intrusion comprised of weakly foliated to non-foliated porphyritic to even-gained biotite monzogranite. Associated with pegmatite veins and sheets when in contact with Wodgina greenstone belt.	90
Cleland Supersuite	-	Diorite Tonalite Monzogranite, Syenogranite Dolerite.	Extremely variable composition of diorite, tonalite, monzogranites and syenogranites. Can also include dolerite. Granitic rocks are typically massive or contain only weakly developed tectonic foliations.	8
Sisters Supersuite	Pincunah Monzogranite	Monzogranite Granodiorite	Medium grained feldspar porphyritic biotite monzogranite and granodiorites.	2

Regolith geological mapping (1:50,000) has a similar pattern to the surface geological mapping. Residual regolith comprises the majority of the Project area (59%), with exposed bedrock also comprising an appreciable proportion (29%). Sheetwash (7%) and colluvial (5%) surfaces comprise the remaining 11%. The regolith across the Survey area is dominated by residual units and exposed bedrock, comprised of monzogranites. The surface regolith is summarised in Table 4 and shown in Figure 4.

Table 4: Surface regolith within the Project area (Geoscience Australia 2024).

Regolith	Description	Estimated Proportion of Project Area (%)
Residual/relict	Residual or relict unit.	59%
Exposed	Exposed rock, saprolite and saprock.	29%
Sheetwash	Clay, silt, and sand sheetwash, local pisoliths and gravels.	7%
Colluvial	Slope deposits including colluvium.	5%

3.2 Topography

Topography has a strong influence on the development of soils. Eroded material from hills and ridges is transported down the slope resulting in the development of varying soil profiles. Drainage lines transport this material into depositional plains.

The topography of the Project area is relatively consistent. Turner River West runs 600m to the west of the Project area, and is a major tributary that flows towards the north to Port Hedland. Turner River is located approximately 3.3km east of the Project area, running parallel to Turner River West, and also flows north to Port Hedland. There is also a significant stream that intersects Turner River approximately 3.5km east of the Project area.

Contour data provided by Fortescue at a 0.5m resolution was combined with DEM data sourced from the publicly available NASA DEM elevation dataset (1-arc-second resolution) and is illustrated in Figure 5. The southern section has low relief and very gently-sloping land gradients, with land sloping downwards from south-east to north-west (Figure 6) at an average gradient of $<1^\circ$. The northern section has similar characteristics, sloping from south-east to north-west at an average gradient of $<1^\circ$, and is located slightly lower in the landscape. The highest elevation in the landscape is 196m in the south-east, and lowest elevation is 154m in the north-west.

A slope analysis conducted over the Project area during the desktop review (Figures 6 and 7) found that the majority of the Project area is comprised of surfaces with a gradient of $0-5^\circ$ (~89% or 1,250ha of the Project area), with a minor proportion comprised of gradients of $5-10^\circ$ (~11% or 153ha). There are very isolated locations across the Project area with gradients $>10^\circ$ which are associated with exposed bedrock, drainage line channels, and existing disturbed features ($<0.1\%$ or 1ha).

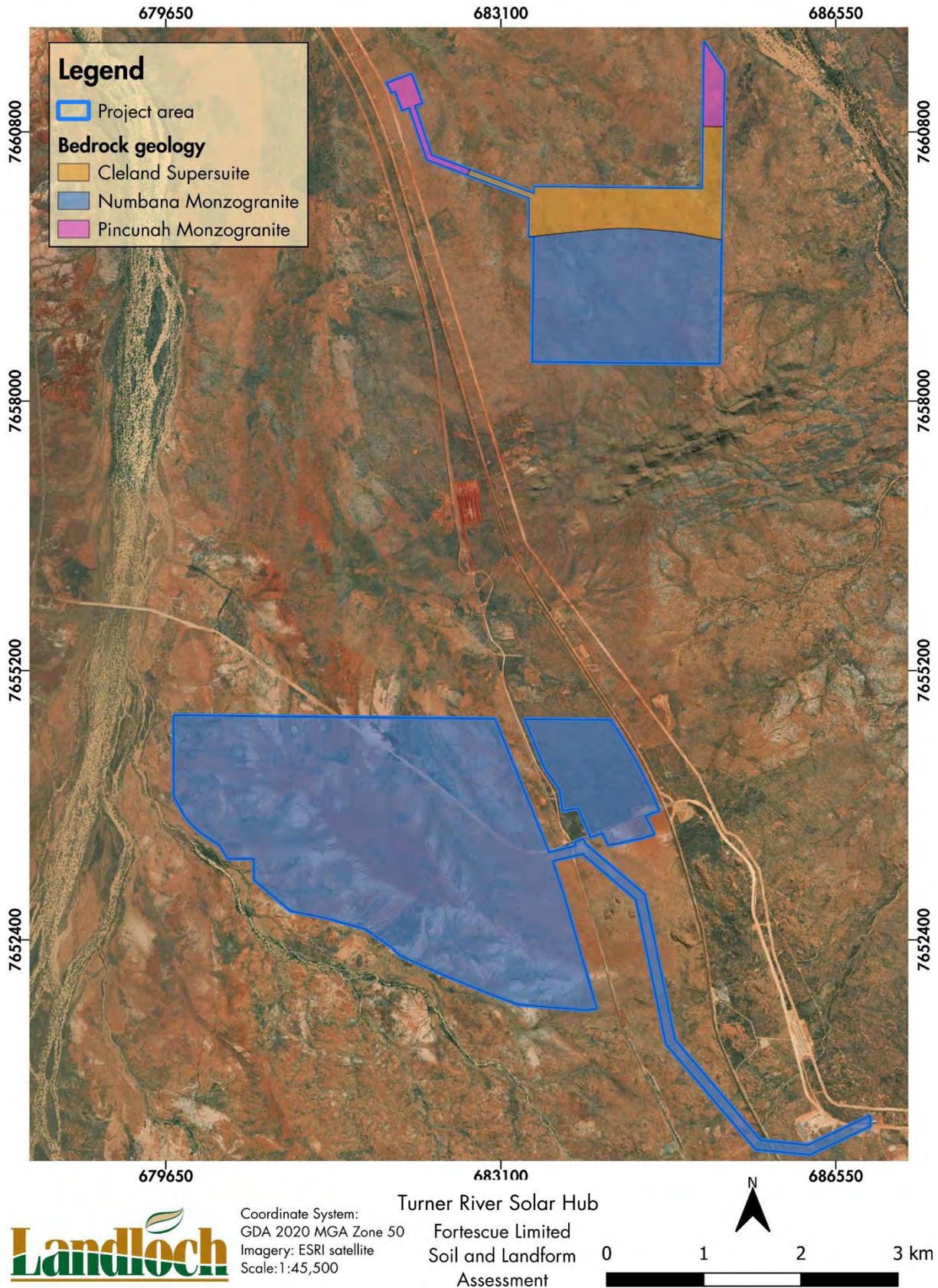


Figure 3: Bedrock geology of the Project area (Geoscience Australia 2024).

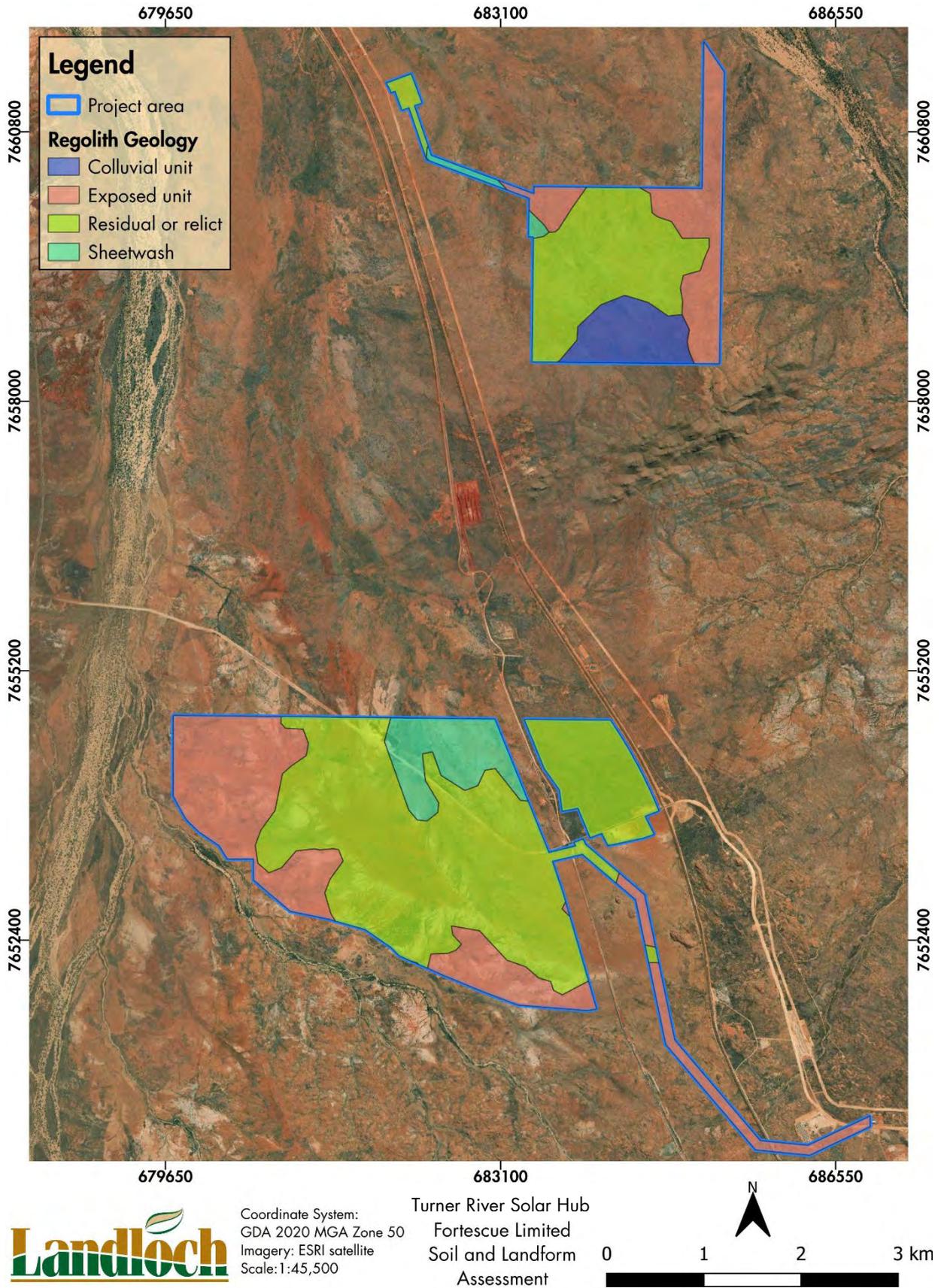


Figure 4: Regolith of the Project area (Geoscience Australia 2024).

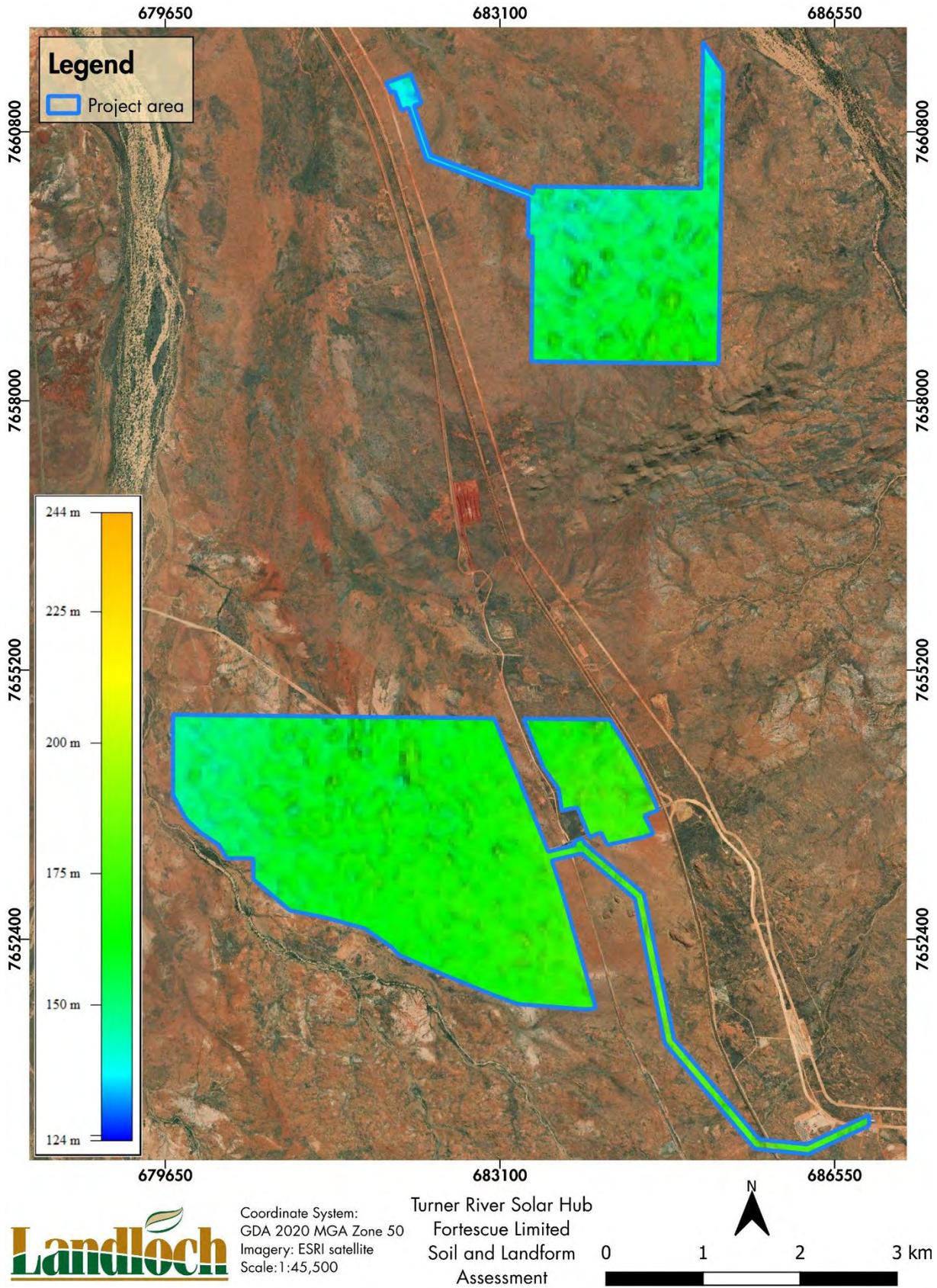


Figure 5: Digital elevation model of the Project area (Source: Fortescue).

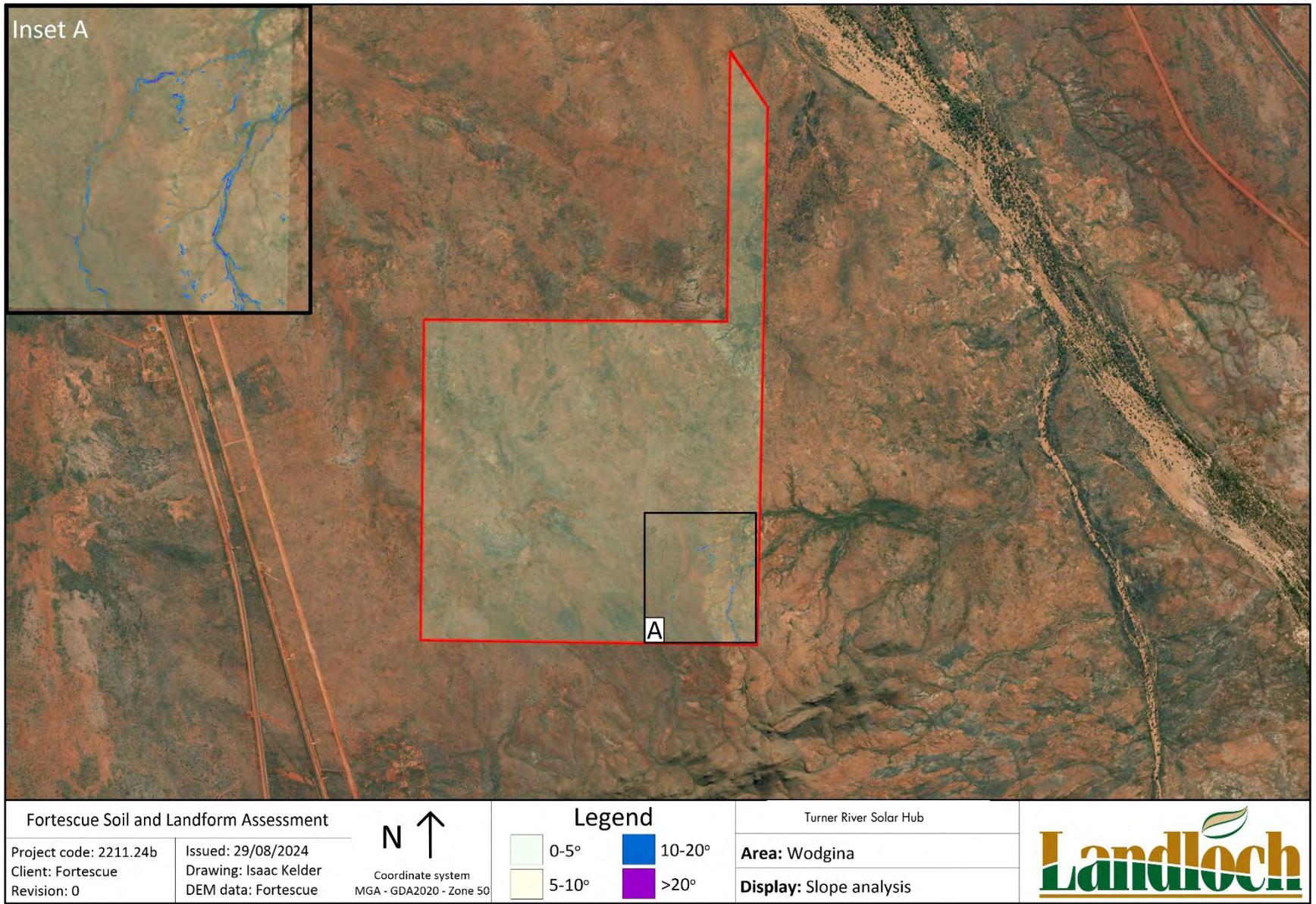


Figure 6: Slope analysis of north section (Wodgina)

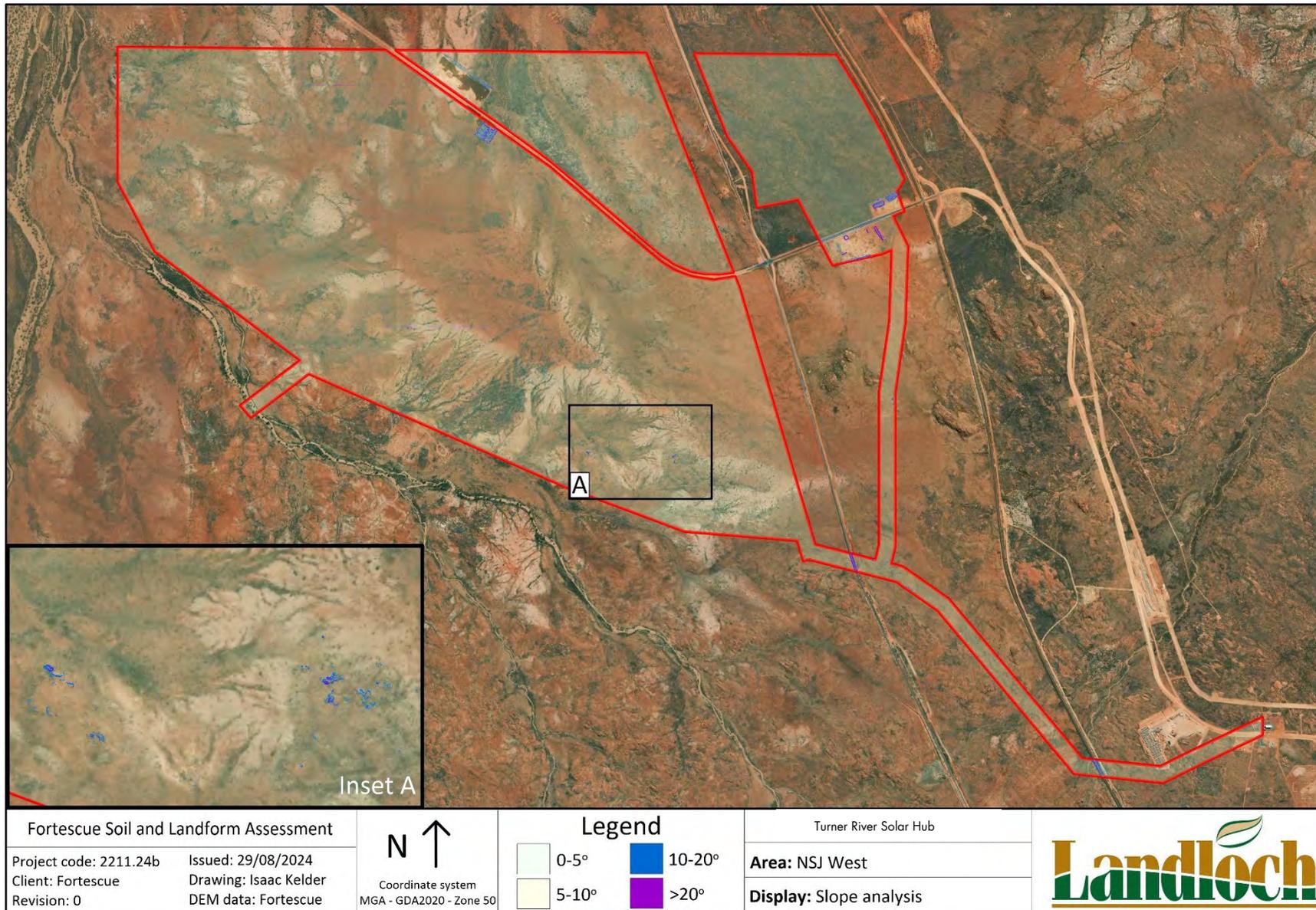


Figure 7: Slope analysis of south section (NSJ West)

3.3 Vegetation

At the broad scale, one vegetation system occurs over the Project area, defined as Abydos Plain Chichester 93. It is comprised of hummock grassland with scattered shrubs or mallee *Triodia* spp., *Acacia* spp., *Grevillea* spp., and *Eucalyptus* spp.

Detailed flora and vegetation surveys were conducted for the northern section (360 Environmental 2024) and the southern section SLR (2023) that cover the project area.

Vegetation units for the southern area (NSJ West) are summarised in Table 5, and the northern area (Wodgina) summarised in Table 6.

Table 5: Detailed vegetation units of the southern area (SLR 2023).

Vegetation unit and description	Local landform	Area	Vegetation condition
AoTe: <i>Acacia orthocarpa</i> (<i>A. ancistrocarpa</i>) mid to tall open shrubland over <i>Triodia epactia</i> and <i>T. lanigera</i> low open hummock grassland	Plains	450ha (66%)	Excellent
ChAbTc: <i>Corymbia hamersleyana</i> low isolated trees over <i>Acacia bivenosa</i> sparse shrubland over <i>Triodia chichesterensis</i> and <i>T. wiseana</i> low open hummock grassland	Plains with minor exposed calcrete	96ha (14%)	Excellent
AancTl: <i>Acacia ancistrocarpa</i> (<i>A. orthocarpa</i> , <i>A. tumida</i> var. <i>pilbarensis</i>) mid to tall shrubland over <i>Triodia lanigera</i> (<i>T. epactia</i>) low open hummock grassland	Plains	43ha (6%)	Excellent
AsTl: <i>Acacia stellaticeps</i> and <i>Pluchea ferdinandi-muelleri</i> low open shrubland over <i>Triodia lanigera</i> (<i>T. epactia</i>) low hummock grassland	Plains with minor sheet flow	26ha (4%)	Very good to excellent
ChAacrTs: <i>Corymbia hamersleyana</i> low isolated trees over <i>Acacia acradenia</i> tall, isolated shrubs over <i>Triodia schinzii</i> low hummock grassland	Plains with minor sheet flow	21ha (3%)	Excellent
Cleared	Existing rail, roads and infrastructure	20ha (3%)	Completely degraded
Tlo: <i>Triodia longiceps</i> low hummock grassland	Plains with minor sheet flow	9ha (1%)	Excellent
AeTe: <i>Acacia eriopoda</i> and <i>A. tumida</i> var. <i>pilbarensis</i> tall sparse shrubland over <i>Triodia epactia</i> and <i>T. lanigera</i> low open hummock grassland	Minor granite outcroppings	7ha (1%)	Excellent
AacrTw: <i>Acacia acradenia</i> (<i>A. bivenosa</i> , <i>Grevillea wickhamii</i> subsp. <i>hispidula</i>) mid to tall shrubland over <i>Triodia wiseana</i> (<i>T. epactia</i>) low hummock grassland	Plains	5ha (<1%)	Excellent
AtTe: <i>Acacia trachycarpa</i> (<i>Acacia tumida</i> var. <i>pilbarensis</i> , <i>Cullen leucanthum</i>) tall open shrubland over <i>Triodia epactia</i> and <i>Triodia longiceps</i> low open hummock grassland over low open mixed herbs and grasses	Minor drainage channels within granites and plains	<1ha (<1%)	Very good to excellent

Table 6: Detailed vegetation units of the northern section (360 Environmental 2024).

Vegetation unit and description	Local landform	Area	Vegetation condition
AiAbTw: <i>Acacia inaequilatera</i> tall sparse shrublands over <i>Acacia bivenosa</i> mid sparse shrubland over <i>Triodia wiseana</i> low hummock to open hummock grassland.	Plains	12ha (3%)	Excellent
AoAsTw: <i>Acacia orthocarpa</i> tall shrubland over <i>A. maitlandii</i> mid isolated shrubs over <i>A. stellaticeps</i> low isolated shrubs over <i>Triodia wiseana</i> (<i>T. epactia</i>) low hummock grassland.	Low granite rocky rises and shallow granite	44ha (12%)	Excellent to very good
ChAaTc: <i>Corymbia hamersleyana</i> low isolated trees over <i>Acacia acradenia</i> , <i>Petalostylis labicheoides</i> , and <i>Grevillea wickhamii</i> (<i>A. inaequilatera</i>) tall sparse shrublands over <i>Triodia chichesterensis</i> and <i>Triodia wiseana</i> low hummock grassland	Low rocky rises	7ha (2%)	Excellent to very good
ChAspTla: <i>Corymbia hamersleyana</i> low isolated trees over <i>Acacia inaequilatera</i> (<i>Grevillea wickhamii</i> subsp. <i>Hispidula</i>) tall, isolated shrubs over a mosaic of <i>Acacia ancistrocarpa</i> , <i>A. acradenia</i> , and <i>Petalostylis labicheoides</i> mid open shrubland over <i>Triodia lanigera</i> and <i>T. epactia</i> (<i>T. longiceps</i> , <i>T. wiseana</i>) low hummock grassland.	Gently undulating plains	252ha (67%)	Excellent to very good
ChAtpTrf: <i>Corymbia hamersleyana</i> low isolated trees over <i>Acacia tumida</i> var. <i>pilbarensis</i> , <i>A. acradenia</i> and <i>Petalostylis labicheoides</i> tall shrubland over <i>Tephrosia rosea</i> var. <i>clementii</i> and <i>Corchorus parviflorus</i> low open shrubland over <i>Triodia epactia</i> (<i>Triodia spp.</i>) low sparse hummock grassland.	Drainage thicket	1ha (<1%)	Excellent to very good.
CplmTs: <i>Cajanus pubescens</i> mid isolated shrubs over <i>Indigofera monophylla</i> low isolated shrubs over <i>Triodia epactia</i> and <i>T. schinzii</i> low hummock grassland.	Sandy plains	31ha (8%)	Excellent
PfTlo: <i>Pluchea ferinandi-muelleri</i> (<i>Acacia stellaticeps</i>) low open shrubland over <i>Triodia longiceps</i> (<i>T. epactia</i>) low open hummock grassland.	Sandy plains	32ha (8%)	Excellent

3.4 Land resource mapping

Land resource mapping has been conducted across Western Australia at varying levels of intensity. The collation of this information has resulted in the development of soil-landscape mapping for the whole of Western Australia. The scale of mapping varies across the state, with areas split into regions depending on the level of data available at the time of compilation. Mapping is compiled at different intensities depending on the region. Land systems mapping is available for the Project area, based on Tille (2006) and van Vreeswyk *et al.* (2004). This mapping was conducted at level 4 (land systems) with a corresponding scale of 1:250,000. There are three land systems present across the Project area (Figure 8):

- Macroy (79% of Project area);
- Uaroo (20% of Project area); and
- Boolaloo (1% of Project area).

Each land system is comprised of several landform elements, consisting of upper erosional landscapes and lower depositional landscapes. A detailed breakdown of the landform elements present in each land system, their abundance within the land system, and their associated vegetation are provided for Tables 7–9 for Boolaloo, Macroy, and Uaroo, respectively (van Vreeswyk *et al.* 2004).

The Boolaloo land system is comprised of erosional surfaces and typically occurs at a higher relief than the Macroy and Uaroo land systems. Granite hills with boulder-strewn slopes are coupled with tor heaps and bare domes. These are surrounded by stony and sandy plains, with widely spaced tributary drainage patterns with narrow drainage floors and channels. Soils include stony soils, red shallow loams and red deep sands.

The Macroy land system is comprised of erosional surfaces, with gently undulating stony plains and interfluves with quartz surface mantles the dominant feature. These landforms result in soils that vary from red shallow sands and loams, to red sandy earths, to red shallow sandy duplex soils. The land system also includes sandy-surfaced plains, minor calcrete plains, and closely spaced tributary drainage lines in upper parts of the system that become much wider downslope. Granite hills, tor fields and quartz ridges comprise a small portion of the landforms present.

The Uaroo land system is comprised of depositional surfaces, with level sandy plains up to 10km (or more in some places) in extent with little organised through drainage. Pebbly surfaced plains and plains with calcrete and a shallow depth are also present, with some broad unchanneled tracts receiving concentrated sheet flow. There are minor occurrences of low stony hills and rises. Soils present on these plains include red sandy earths, red deep sands, and red loamy earths.

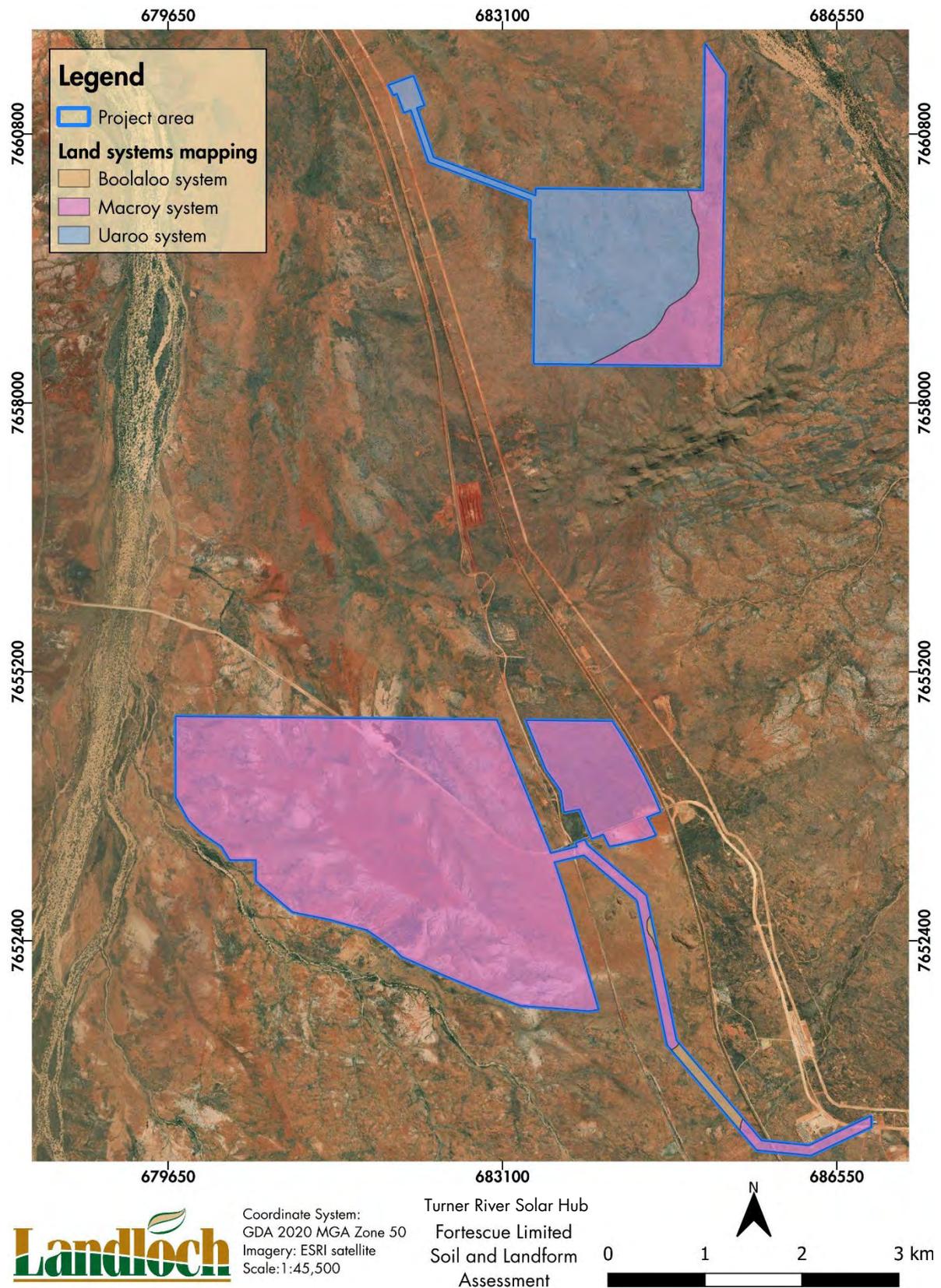


Figure 8: Land systems of the Project area.

Table 7: Characteristics of the Boolaloo system.

Landform element	% land system	Description	Vegetation
Hill, tor heaps and hill slopes	70%	Rounded hill crests with gently inclined to steep stone and boulder strewn slopes, bare domes and tor heaps. Relief mostly <50m, occasionally higher.	Scattered hummocks of <i>Triodia pungens</i> (soft spinifex) with isolated <i>Acacia spp.</i> and other shrubs, occasionally <i>Terminalia canescens</i> trees.
Sandy plains	10%	Level to very gently inclined sandy plains between hills and tor heaps.	Hummock grasslands of <i>Triodia sp.</i> (hard spinifex) with scattered <i>Acacia spp.</i> and other shrubs. Occasionally <i>T. pungens</i> (Soft spinifex).
Stony plains	13%	Level to undulating plains with gritty surfaces and mantles of variable density granitic or quartz pebbles and cobbles, occasional granite outcrops.	Hummock grasslands of <i>T. wiseana</i> , <i>T. brizoides</i> (hard spinifex) or <i>T. pungens</i> (soft spinifex) with very scattered shrubs such as <i>Acacia orthocarpa</i> , <i>A. maitlandii</i> .
Tracts receiving run-on	5%	Level tracts receiving run-on, usually unchanneled but may have a few rills and gutters.	Hummock grasslands of <i>T. pungens</i> with scattered <i>Acacia spp.</i> and other shrubs.
Narrow drainage floor and channels	2%	Level drainages floors up to 200m wide, channel up to 50m wide and 3m deep.	Scattered shrublands or hummock grasslands with <i>Acacia spp.</i> and <i>Triodia spp.</i> (soft and hard spinifex). Larger channels have fringing woodlands of eucalypts and melaleucas.

Table 8: Characteristics of the Macroy system.

Landform element	% land system	Description	Vegetation
Low hills and ridges	5%	Isolated hills and tor heaps up to 500m in extent or ridges up to several kilometres long, moderately inclined to very steep slopes, surface mantles of abundant to very abundant cobbles, stones, and boulders of granite, quartz and other rocks; relief up to 25m	Patchy hummock grasses <i>Triodia pungens</i> (soft spinifex) or <i>T. spp</i> (hard spinifex) with isolated or very scattered shrubs.
Stony plains and interfluves	70%	Level to gently undulating plains and interfluves extending up to 4km between drainage lines in lower parts but much narrower between small drainage lines in upper parts; surface mantles of few to very abundant grit and pebbles of quartz and granite, occasional outcrops of granite.	Hummock grasslands of <i>Triodia wiseana</i> , <i>T. lanigera</i> (hard spinifex) or <i>T. pungens</i> (soft spinifex) in about equal proportions; isolated to scattered <i>Acacia inaequilatera</i> (kanji) and other <i>Acacia spp.</i> shrubs.
Sandy plains	10%	Level sandy surfaces plains extending up to 2km as inclusions within the stony plains and interfluves, surface mantles absent or as few pebbles of quartz.	Hummock grasslands of <i>Triodia pungens</i> , <i>T. lanigera</i> (soft or hard spinifex) with very scattered to scattered shrubs <i>Acacia inaequilatera</i> , <i>A. stellaticeps</i> (poverty bush).

Landform element	% land system	Description	Vegetation
Calcrete plains	3%	Level plains restricted to 300-400m in extent associated with lower parts of low hills or drainage floors, sometimes raised 3-4m above surrounding plains. Includes surface mantles of common to many pebbles of calcrete and quartz, also calcrete outcrop.	Hummock grasslands of <i>Triodia wiseana</i> or <i>T. pluinervata</i> (hard spinifex) with isolated <i>Acacia spp.</i> shrubs or <i>Corymbia hamersleyana</i> (hamersley bloodwood) trees.
Drainage floors and channels	12%	Level to gently inclined linear drainage tracts up to 500m wide as slight depressions within stony plains and interflues becoming much narrower and more incised.	Hummock grasslands of <i>Triodia spp.</i> (hard or soft spinifex) with isolated to scattered <i>Acacia spp.</i> shrubs and occasional eucalypt trees. Also tussock grasslands or shrublands/woodlands with tussock grass understoey with <i>Chrysopogon fallax</i> (ribbon grass), occasionally <i>Cenchrus ciliaris</i> (buffel grass).

Table 9: Characteristics of the Uaroo system.

Landform element	% land system	Description	Vegetation
Low hills	<1%	Isolated hills and ridges up to 1km long, gently inclined to steep stony footslopes, relief up to 30m above surrounding plains.	Hummock grasslands or <i>Triodia wiseana</i> , <i>T. spp.</i> (hard spinifex) with isolated or very scattered shrubs.
Low rises	3%	Gently undulating raised surfaces up to 1.5km in extent, surface mantle of variable abundance grit and pebbles of quartz and granite, occasional outcrops of granite or other parent rock.	Hummock grasslands of <i>Triodia pungens</i> , <i>T. epactia</i> (soft spinifex), with very scattered to scattered <i>Acacia spp.</i> shrubs. Less frequently with <i>Triodia spp.</i> (hard spinifex).
Pebbly plains	8%	Level plains up to 3km in extent, marginal to or as patches within sandy plains. Surface mantles of many to abundant pebbles of quartz and/or ironstone.	Hummock grasslands of <i>Triodia langera</i> , <i>T. plurinervata</i> , <i>T. wiseana</i> (hard spinifex) with isolated to scattered shrubs such as <i>Acacia inaequalatera</i> (kanji) and <i>A. ancistrocarpa</i> (shiny leaf wattle). Less frequently with <i>Triodia pungens</i> (soft spinifex).
Sandy/loamy plains	82%	Level plains up to 10km or more in extent, microrelief often mounded on more sandy sites, no surface mantles.	Hummock grasslands or shrubby hummock grasslands of <i>Triodia pungens</i> , <i>T. epactia</i> , <i>T. schinzii</i> (soft spinifex) or <i>T. lanigera</i> , <i>T. spp.</i> (hard spinifex) with isolated to scattered shrubs
Calcrete plains	1%	Level surfaces associated with sandy/loamy plains up to 1km in extent, surface mantles of abundant calcareous gravel.	Hummock grasslands of <i>Triodia wiseana</i> , <i>T. lanigera</i> (hard spinifex) with isolated to scattered <i>Acacia spp.</i> shrubs.
Tracts receiving sheet flow	6%	Level tracts up to 2km wide, slightly lower and extending downslope through sandy/loamy plains for many kilometres, unchanneled or occasionally with narrow creeklines, scour lines and scalds.	Hummock grasslands of <i>Triodia pungens</i> or <i>T. spp.</i> (soft or hard spinifex) with isolated to very scattered <i>Acacia spp. shrubs.</i> Also scattered tall shrublands/woodlands with <i>Acacia</i> and <i>Eucalyptus spp.</i> and hummock and tussock grass understories.

3.5 Atlas of Australian soils

The Atlas of Australian Soils (Northcote *et al.*, 1960-1968) was compiled by CSIRO in the 1960s to provide a consistent national description of Australia's soils. It comprises a series of ten maps and associated explanatory notes. The maps are published at a scale of 1:2,000,000, but the original compilation was at scales ranging from 1:250,000 to 1:500,000. Mapped units within the Atlas are soil landscapes usually comprising several soil types.

An assessment of the Atlas mapping over the Project area indicates the presence of one soil landscape – Oc62. The Oc62 soil landscape is described as very gently undulating pediplains with low granite outcrops and tors, with occasional basic dykes occurring as long elongated ridges. The chief soils in this landscape are hard alkaline red soils with coarse textured A (surface) horizons.

3.6 Acid sulfate soils

DER (2015) recommends that the following criteria are considered to determine if ASS are likely to be present:

- Sediments of recent geological age;
- Marine or estuarine sediments or tidal lakes;
- Coastal wetlands or back swamp areas;
- Waterlogged or scalded areas;
- Interdune swales or coastal sand dunes;
- Areas where dominant vegetation is water based;
- Areas with geology associated with sulfide bearing minerals; and
- Deep older estuarine sediments.

National ASS mapping has been completed at a variable scale that provides an indication of the potential presence of ASS (Fitzpartrick *et al.* 2011). For the Project area, risk mapping indicates that there is a low probability (6-70% of mapping unit) of PASS occurring (Figure 9). The soils associated with PASS are Sodosols, Chromosols, and Dermosols, with ASS (where present) occurring in the upper 1m of the soil profile. The confidence level of this mapping is noted as *'No necessary analytical data are available, and classifier has little knowledge or experience with ASS, hence classification is provisional'*.

The underlying geology are comprised of lithologies from the Archean era. The associated lithologies (Monzogranites) are typically not associated with sulfide bearing minerals and as such do not indicate the presence of ASS. The Project area does not contain any marine or estuarine sediments or tidal lakes. This is evident by the distance of the site from the nearest coastal area (~100km). There are also no interdune swales or coastal sand dunes present, and no waterlogged areas visible from aerial imagery. Lastly, there is no indication that the dominant vegetation is comprised of mangroves, reeds, rushes, or other vegetation associated with areas of shallow water tables. Based on the desktop review, it was considered unlikely that ASS is present within the Project area. However, given that ASS trigger mapping indicates that there is a reasonable possibility (6–70% probability), a preliminary assessment of ASS was completed as part of the field survey.

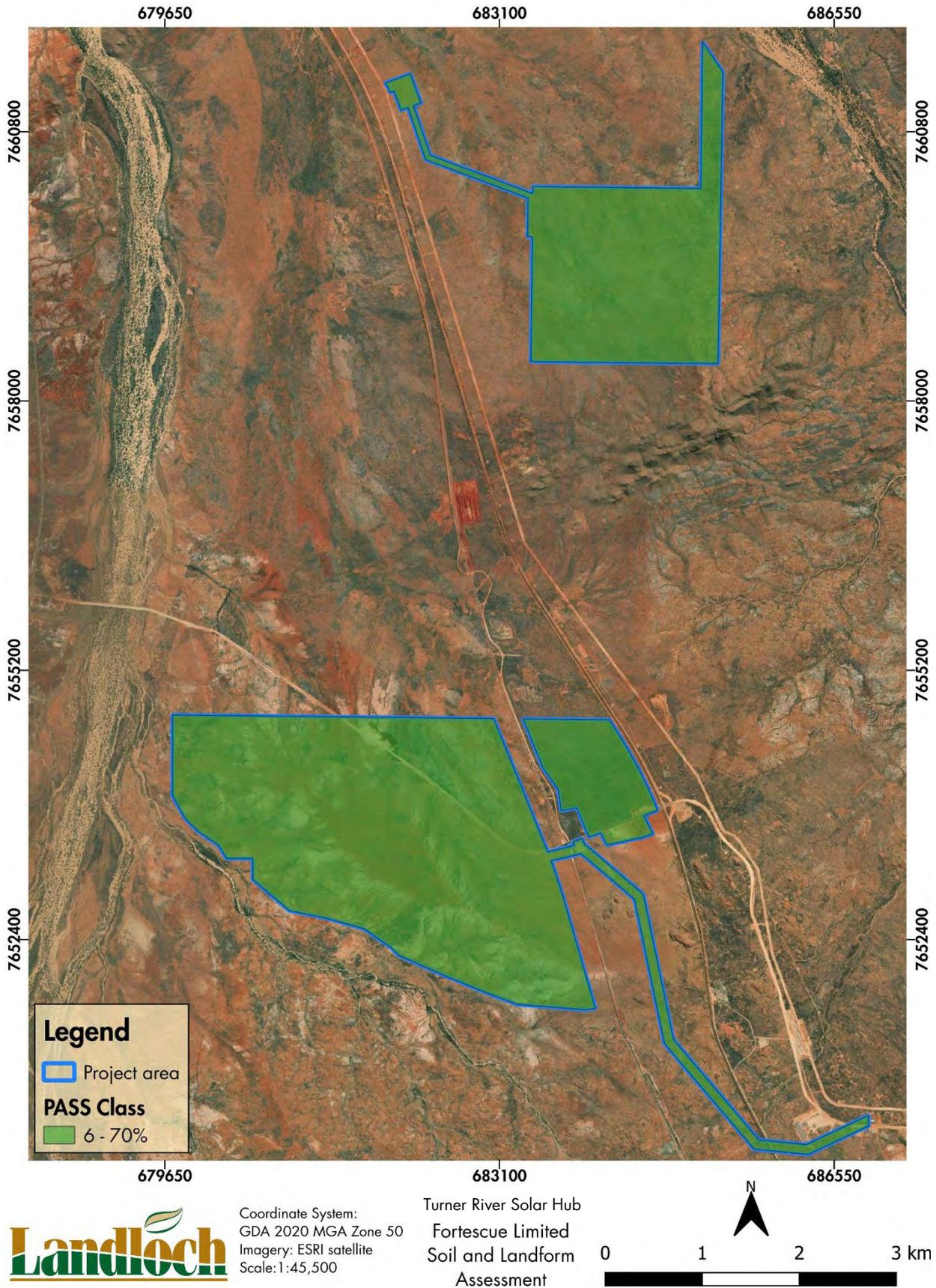


Figure 9: ASS risk mapping over the Project area.

4 FIELD INVESTIGATION

4.1 Mapping scale and sample density

The required scale of soil mapping and the size of the proposed Project area dictates the density and number of soil inspection sites required. The inspection site density defined in the *Australian Guidelines for Soil and Land Resources* (McKenzie *et al.* 2008).

The size of the Project area is 1,417ha, and includes the southern area (1,016ha) and the northern area (401ha). For the objective of assessing moderately intense land uses for a semi-detailed project, an inspection site every 20–100ha is consistent with a medium ‘semi-detailed’ intensity assessment, with a publication scale of 1:50,000. Based on this scale, the number of sample sites to meet this intensity is between 15 and 72. Landloch investigated 22 sites, which is equivalent to a density of 1 site per ~64ha. The sites were split across the two areas as follows:

- 15 sites within the southern area (SP01–SP15); and
- 7 sites within the northern area (OP01–OP07).

The field investigation was conducted on 11–14 June 2024. The coordinates of the samples are given in Table 10, and their locations are shown in Figure 10.

Table 10: Proposed sampling location coordinates (GDA2020, Zone 50).

Site ID	Easting (m)	Northing (m)	Site ID	Easting (m)	Northing (m)
SP01	681,115	7,654,051	SP12	683,391	7,652,898
SP02	681,377	7,653,428	SP13	683,503	7,652,178
SP03	681,268	7,654,278	SP14	682,994	7,653,594
SP04	681,013	7,653,726	SP15	684,438	7,653,733
SP05	681,325	7,653,726	OP01	685,256	7,660,533
SP06	681,467	7,653,174	OP02	683,924	7,660,111
SP07	682,251	7,653,726	OP03	685,046	7,659,774
SP08	682,091	7,653,174	OP04	684,773	7,659,305
SP09	681,984	7,652,621	OP05	683,985	7,658,933
SP10	682,885	7,652,253	OP06	684,432	7,658,510
SP11	682,922	7,652,621	OP07	685,285	7,658,650

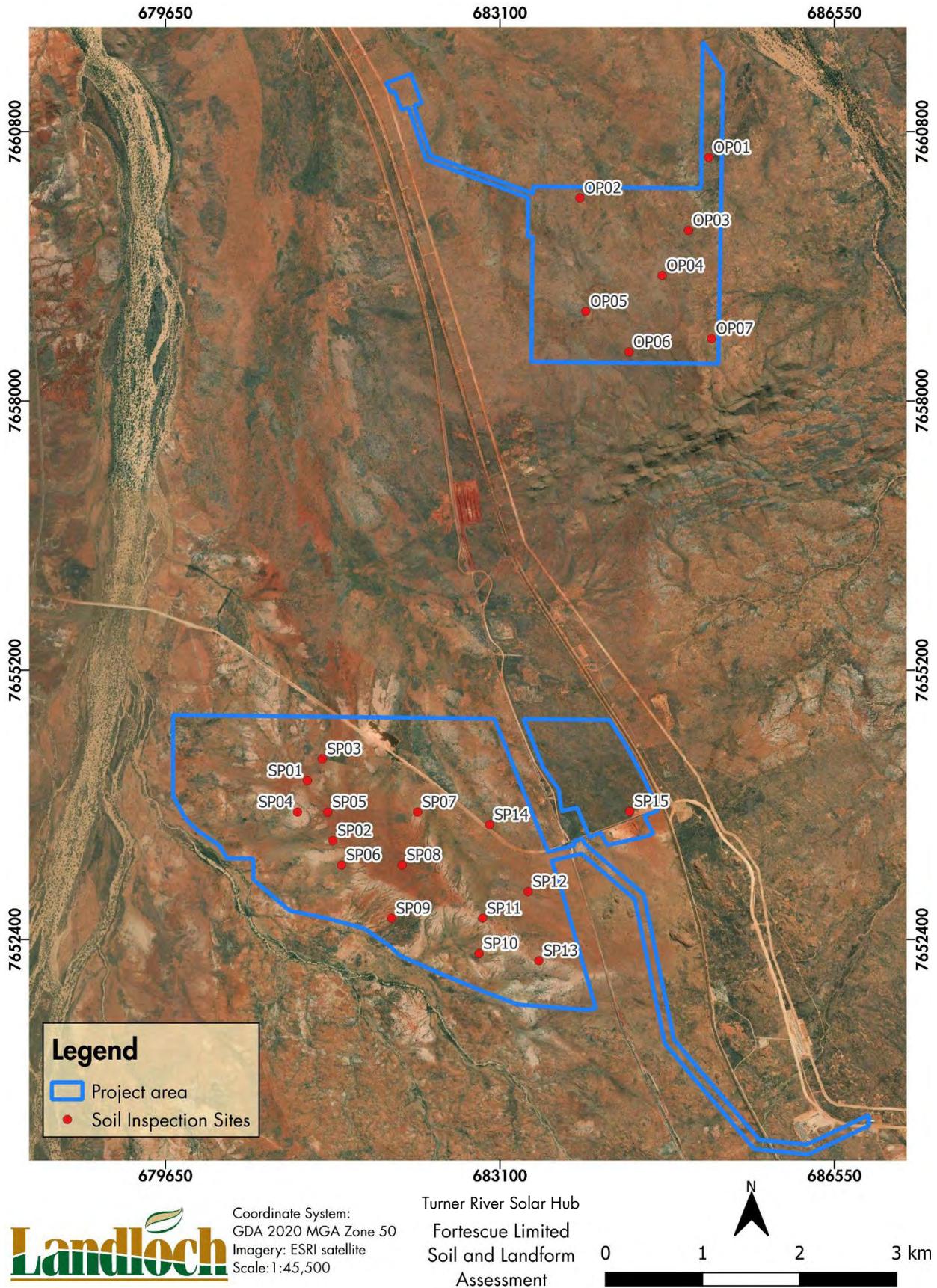


Figure 10: Location of soil inspection sites within the Project area.

4.2 Site descriptions

Site information, soil profile descriptions, and baseline soils data were recorded at each of the soil inspection sites. At each location, a hole was dug using hand tools to a depth of 0.3. Images of the landscape, vegetation, soil surface, and soil profile were taken. Observations of the location, landform, vegetation, land surface, and soil profile were recorded for each site.

Location, landform, vegetation and land surfaces observations included:

- Assessment date;
- GPS coordinates;
- Current land use;
- Dominant vegetation forms;
- Vegetation cover percentages;
- Land surface aspect and microrelief;
- Surface coarse fragments;
- Rock outcrop abundance; and
- Erosion state, type and extent.

The following information was recorded for each soil horizon observed within an assessed soil profile:

- Horizons (including depth and boundary type);
- Field texture;
- Colour; and
- Coarse fragment abundance and size.

4.3 Soil sampling

Soil samples were collected from typically two depths at each inspection site (topsoil and subsoil). The number of samples taken at each site varied based on the depth of the soil hole. Generally, one soil sample was taken from the topsoil (A) horizon, and one from the diagnostic (B) horizon. A total of 44 samples were collected from the 22 inspection sites.

4.4 Soil testing

Landloch completed in-field testing for ASS at southern area sampling locations (SP01–SP15) following the methodology outlined by DER (2015). This testing was not conducted at northern area locations due to time constraints. At each site the following was recorded:

- pH_F – field pH;
- pH_{FOX} – oxidised pH;
- Reaction type; and
- ΔpH – change in pH.

All soil samples collected were freighted to Landloch’s facility in Bibra Lake and assessed for the screening parameters listed in Table 11. Samples were then submitted to an external laboratory for more detailed analysis. The suite of laboratory analyses was split into a topsoil characterisation suite and subsoil characterisation suite (Table 12) in line with the relevant guidelines (DMP 2016).

Table 11: Screening analyses (all samples collected).

	Analysis
Fine/coarse fraction percent	pH _w (1:5 soil: deionised water)
Emerson dispersion class	EC _{1:5} (1:5 soil: deionised water)

Table 12: Detailed soil laboratory analysis (not yet received)

Laboratory Suite	Target samples	Analysis
Topsoil Suite	A horizon (topsoil fertility) generally between 0-100mm depth.	pH _w EC _{1:5} Soluble Cl
	Analyses include soil fertility as this is the ‘growth media’ depth of the soil profile and is a major factor in determining a soil’s nutrient status. This will also include one sample from the subsoil for baseline comparison.	Exchangeable cations (K ⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ & Al ³⁺) Effective cation exchange capacity (ECEC) Exchangeable sodium percentage (ESP) Water repellence Particle size distribution of the fine fraction (coarse sand, fine sand, silt, clay) Organic C Total N & Total P Available P and K (Colwell) Available S (KCl) Trace elements (Cu, Zn, Mn & Fe)
Subsoil Suite	All other horizons below the topsoil (>100mm).	pH _w EC _{1:5} Soluble Cl
	Analyses focus on chemical and physical properties of the soil.	Exchangeable cations (K ⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ & Al ³⁺) Effective cation exchange capacity (ECEC) Exchangeable sodium percentage (ESP) Particle size distribution of the fine fraction (coarse sand, fine sand, silt, clay)

5 DATA INTERPRETATION SCHEME

To assist with the interpretation of soils data, Landloch developed a scheme to define their suitability. It establishes a baseline of properties for soils that support vegetation (to varying degrees). The defined values are specific to this Project area.

5.1 Soil pH_w

Soil pH was measured using a solution containing 1-part solids to 5-parts deionised water (pH_w). A general classification of soil pH_w values is given in Table 12 (Hazelton and Murphy 2016). This classification allows for pH values to be expressed in qualitative terms but does not provide guidance on the suitability of a given pH value for vegetation establishment.

The range of pH_w values of the topsoils from inspection sites supporting mid-dense foliar cover levels (30–90%) ranged from 5.0 to 9.0. This is a range from a strongly acid to moderately alkaline pH_w (Table 13). A pH_w range of 5.0–9.0 (strongly acid to moderately alkaline) was used in this report to define pH values that will not adversely affect vegetation growth or establishment. Soils with pH_w values greater than 9.0 or less than 5.0 will be defined as soils that may not be suited to establishment and growth of the more prevalent species of vegetation and may require an alternative approach if used in rehabilitation (i.e. adoption of alternative vegetation species that are suited to the pH conditions).

Table 13: General soil pH_w classification.

pH _w (pH units)	Classification
<4.0	Very strongly acid
4.0–5.5	Strongly acid
5.5–6.0	Moderately acid
6.0–7.0	Slightly acid
7.0–8.0	Slightly alkaline
8.0–9.0	Moderately alkaline
9.0–10.0	Strongly alkaline
>10.0	Very strongly alkaline

5.2 Salinity (EC_{1:5})

Salinity is often measured using the electrical conductivity of a solution containing 1 part solids to 5 parts deionised water (EC_{1:5}). Most published salinity suitability ranking systems assume agricultural vegetation, and application of these ranking systems have little relevance for plant species used in rangeland rehabilitation.

Van Vreeswyk *et al.* (2004) provide a range of salinity values and an associated classification scheme as part of the reporting of a land inventory and condition survey for the Pilbara region (Table 14). The classes are based on field measurements taken throughout the dominant landscape types found in the Pilbara.

Table 14: Topsoils and subsoil EC_{1:5} classes for the Pilbara region.

Classification	EC _{1:5} (dS/m)
Low (non-saline)	0.01-0.40
Moderate (saline)	0.41-0.80
High (highly saline)	>0.80

Soils with $EC_{1.5} < 0.4 \text{dS/m}$ were considered a growth media that poses minimal potential adverse impacts to plant growth. Soils with $EC_{1.5}$ between $0.4\text{--}0.8 \text{dS/m}$ were considered moderately saline and likely to still be able to support vegetation, but the growth of salt sensitive species may be limited. Highly saline soils ($EC_{1.5} > 0.8 \text{dS/m}$) will likely adversely impact salt sensitive and moderately tolerant species, though highly salt tolerant species would likely still grow. The density of vegetation in extremely saline soils may also be reduced.

5.3 Fertility

Suitable fertility values were defined as those of soils that support mid-dense foliar cover levels (30–90%), accounting for some losses due to removal of standing biomass. The resulting fertility values are summarised in Table 15 and represent values that are not expected to limit vegetation growth or establishment.

These parameter values could be used in the future to determine whether soil handling during operations (stripping, stockpiling, mixing with subsoils etc.) has caused a reduction in fertility. They could be used in the future to determine fertiliser requirements of stockpiled soils, and fertiliser requirements for subsoils if they are to be used as alternative topsoils.

Table 15: Suitable nutrient values based on measured values from the topsoils.

Nutrient	Unit	Value
Total nitrogen	mg/kg	>300
Total phosphorus	mg/kg	>100
Organic carbon	%	>0.2
Available phosphorus (Colwell)	mg/kg	>10
Available potassium (Colwell)	mg/kg	>80

5.4 Structural stability

Structure is the arrangement of primary particles into secondary units or peds. The secondary units are characterised on the basis of size, shape, and grade. A structurally unstable soil is one that tends to have minor or reduced particle arrangement.

It is important to note that structural stability as used in this report is different to geotechnical stability.

Structurally unstable soils may be prone to:

- Tunnel erosion;
- Increased bulk density and hardsetting surfaces;
- Increased runoff and erosion potential;
- Reduced water holding capacity and infiltration capacity; and
- Reduced root penetrability.

A soil's potential to have an unstable structure is dependent on both its chemical and physical characteristics. These are considered in a number of ways.

The proportion of exchangeable Na held on the soil's exchange complex in relation to other exchangeable cations is important. This is referred to as the Exchangeable Sodium Percentage (ESP). McKenzie *et al.* (2004) considers the measurement of ESP as suitable for assessing the potential for clay dispersion when a soil's Effective Cation Exchange Capacity (ECEC) is $>3\text{meq}/100\text{g}$ and exchangeable Na $>0.3\text{meq}/100\text{g}$. Further, clay dispersion risk is greatest in soils with loam or clay textures (clay fraction $>10\%$). Sand dominated wastes are not prone to structural instability even if they have high ESP.

Clay dispersion potential for a soil is also influenced by interactions between clay content, ESP, and $\text{EC}_{1.5}$. The Electrochemical Stability Index (ESI) is a way of considering the relationship between ESP and $\text{EC}_{1.5}$ for loam and clay-textured soils (clay fraction $>10\%$). A tentative critical ESI value is 0.05 (McKenzie 1998), with $\text{ESI} < 0.05$ and clay content $>10\%$ indicating a soil that is prone to structural instability due to clay dispersion.

Magnesian soils can also be prone to clay dispersion. This is assessed using a combination of the Exchangeable Magnesium Percentage (EMP), exchangeable Ca:Mg ratio, ESP, and clay content. Where $\text{EMP} > 30\%$, clay dispersion may occur when the Ca:Mg ratio is < 1 , and ESP is $> 4\%$ or when $(\text{ESP} + \text{EMP}/10)$ is $> 6\%$, assuming they also have $> 10\%$ clay (Fenton and Conyers 2002).

Soils with a high combined proportion of fine sand, silt, and clay (particles $\leq 0.2\text{mm}$) are prone to structural instability, even if their clay fractions are not chemically dispersive. This is because these smaller particles can mobilise within the coarse sand matrix. For this reason, soils with a combined fine sand, silt, and clay fraction $> 70\%$ are considered to be at increased risk of structural instability (Vacher *et al.* 2004).

It is noted that a soil can have a fine fraction that is prone to structural instability, but if the proportion of unstable fines is small, the soil as a whole may be structurally stable. Typically, a binary mixture with $> 30\text{-}40\%$ fines and $< 60\text{-}70\%$ coarse fraction could be considered a fines-dominated material with some coarse fraction; a binary mixture with $< 30\text{-}40\%$ fines and $> 60\text{-}70\%$ coarse fraction could be considered a coarse-dominated material with some fines. Based on this, a fines fraction cut-off of $> 40\%$ seems reasonable, with soils that contain $> 40\%$ fines being at risk of structural instability if the fine fraction meets one or more of the other criteria outlined above. A soil with $< 40\%$ fines is classified not prone to instability even if the fine fraction is prone to instability.

To capture interactions between physical and chemical properties and their effect on structural stability, the samples were assessed against these four criteria. If any of these criteria are met, that soil was classified as being prone to structural instability. The criteria are detailed in Table 16.

Table 16: Structural stability criteria

ESP criteria	EMP criteria
<ul style="list-style-type: none"> Clay content >10% of fines, and Fines >40%, and ECEC >3meq/100g, and Ex. Na >0.3meq/100g, and ESP >6%. 	<ul style="list-style-type: none"> Clay content >10% of fines, and Fines >40%, and ECEC >3meq/100g, and EMP >30%, Ca:Mg <1, & ESP >4%, or EMP >30%, Ca:Mg <1, & (ESP + (EMP/10) >6%
ESI criteria	PSD criteria
<ul style="list-style-type: none"> Clay content >10% of fines, and Fines >40%, and ESI <0.05. 	<ul style="list-style-type: none"> Fines >40%, and Fine sand + silt + clay >70% of fine fraction.

5.5 Coarse fraction

In addition to its influence on structural stability, the abundance and size of the coarse fraction also has a significant bearing on a soil's erosion potential. In semi-arid environments where vegetation does not effectively control surface erosion rates, the condition of the surface (in particular the rockiness) is a key determinant of erosion potential (along with surface treatments such as tree debris and landform shape). Surfaces with more abundant, durable coarse fragments are more likely to be erosion-resistant than surfaces with a lower abundance of durable coarse fragments.

For the purpose of this report, soils with a coarse fragment abundance >50% and coarse fragment sizes >20mm will be considered to have a high resistance to erosion.

5.6 Acid sulfate soils (ASS)

The interpretation of ASS field test results is based on the guideline provided by DER (2015). The key characteristics include the pH_F and pH_{FOX} values, the difference between these values (ΔpH), and the severity of reaction that occurs (Table 17).

For a soil to be considered ASS, a pH_F of <4 must be recorded. For a soil to be considered PASS, the soil pH_F must be >4 and the soil pH_{FOX} <3. Additionally, there must be a reaction type that is 'volcanic' (i.e. test-tube bubbles over in an intense reaction that looks similar to a volcanic eruption), and a ΔpH >1 unit.

A soil classed as ASS may have additional sulfides that have not yet oxidised. In this scenario, a soil can be considered as both ASS and PASS if it meets both sets of criteria.

Table 17: PASS and ASS classification.

Characteristics	PASS	ASS
Soil pH_F	>4	<4
Soil pH_{FOX}	<3	-
Reaction type	Volcanic	-
ΔpH	>1	-

6 LANDFORM ASSESSMENT

6.1 Assessment of landforms

To determine potential landform type present over the Project area, the landform elements associated with land systems were used as a starting point. The three land systems present over the Project area are:

- Macroy (79% or 1,121ha of Project area);
- Uaroo (20% or 284ha of Project area); and
- Boolaloo (1% or 12ha of Project area).

The Macroy and Uaroo land systems comprise 99% of the Project area, and are two of the six most prevalent land systems within the Pilbara region. Across the Pilbara, the Macroy land system covers an area of 1,309,500ha and the Uaroo land system cover 768,100ha. Any landform elements present within these two land systems can be expected to occur extensively across the Pilbara region. The Boolaloo land system (comprising 1% of the Project area) covers an area of 150,200ha within the broader Pilbara area. Although it is not a dominant land system, it is still present extensively over the Pilbara region.

For the three land systems present over the Project area, there are 16 associated landform elements. Each landform element is split by their percentage of abundance within a given land system. As the Project area can be split by the percentage of each land system present, the probability or abundance of each landform element can be broadly estimated. In this way, an estimate of the likely landform elements present within the Project area can be determined.

Based on this assessment, there are six landform elements that are most likely to be present within the Project area (Table 18). It is noted that all 16 landform elements may be present, and this provides only an indication of the most likely landform elements that will be encountered.

In addition to this, a slope analysis of elevation data and high-resolution aerial imagery was used to assess potential landform types present. This was combined with observations collected at each sampling location during the field investigation, along with imagery of the surrounding landscape.

Table 18: Summary of landform elements and their associated slopes.

Landform element	Modal slope	Slope gradients (%)
Stony plains and interfluves	Level to moderately inclined	<1-32
Sandy/loamy plains*	Level	<1
Pebbly plains	Level	<1
Drainage floors and channels	Level to gently inclined	<1-10
Low hills and ridges	Gently inclined to very steep	1-100
Calcrete plains	Level	<1

*Sandy/loamy plains and Sandy plains landform elements were combined due to their similarities.

6.2 Landform mapping

Landforms encountered within the Project area generally aligned with those present within the land systems mapping (Table 17). The exception to this were Calcrete plains which were not encountered within the Project area, and/or were present with characteristics that were closer aligned with other 'plains' landform element. Additionally, the low hills and ridges landform element encompasses various landform types, including Tor heaps.

The broad landforms present over the Project area have been mapped using a combination of all available data. Six landform types have been identified and mapped:

- Stony plains and interfluves (535ha);
- Sandy/loamy plains (787ha)
- Pebbly plains (31ha);
- Drainage floors and channels (22ha);
- Low hills and ridges (7ha); and
- Tor heaps (3ha).

Disturbed areas (e.g. roads and rail) were removed from the assessment. Details on each landform type are provided below, with landform mapping give in Figures 11 and 12.

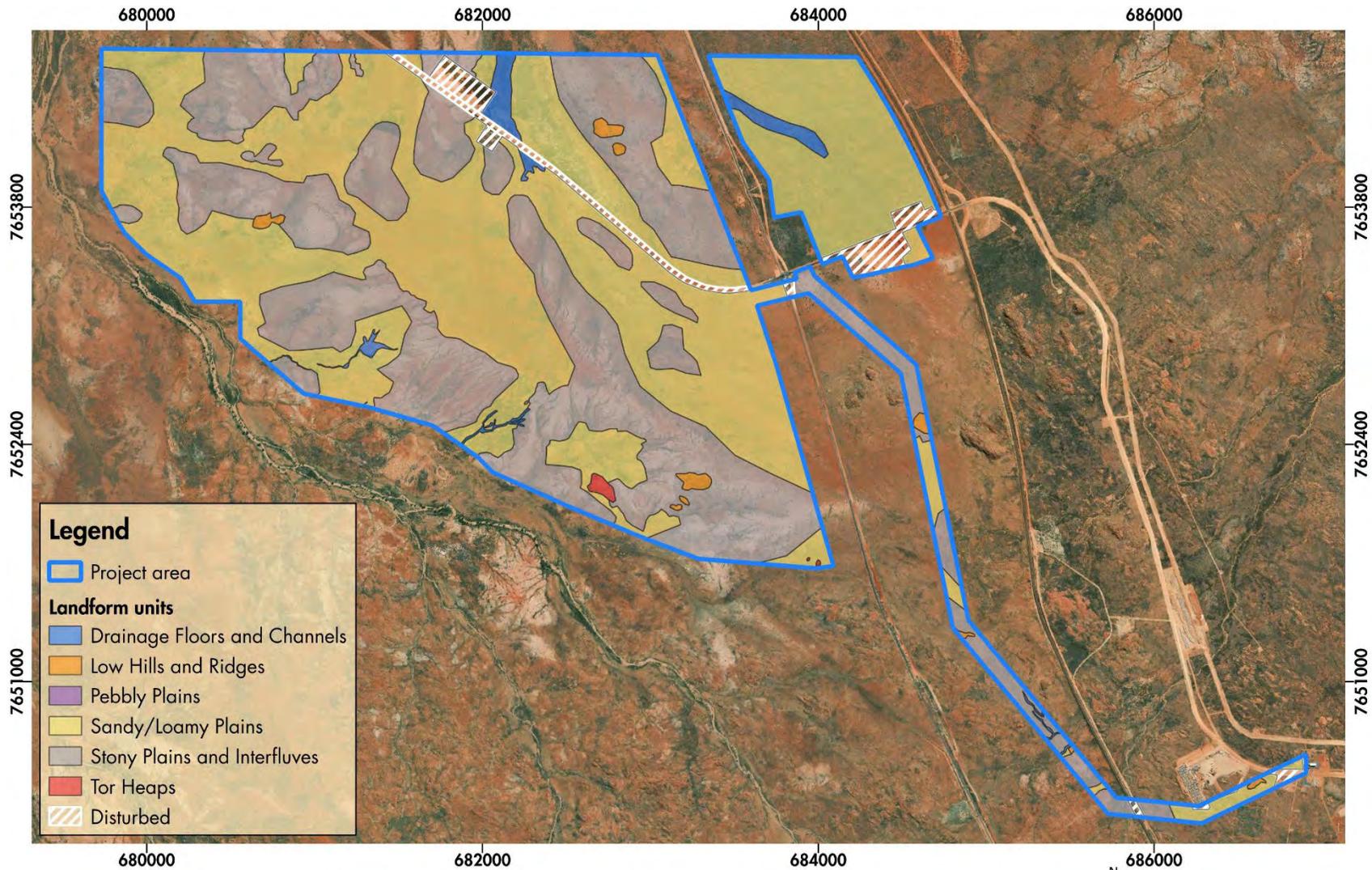


Figure 11: Landforms of the Project area (southern section)

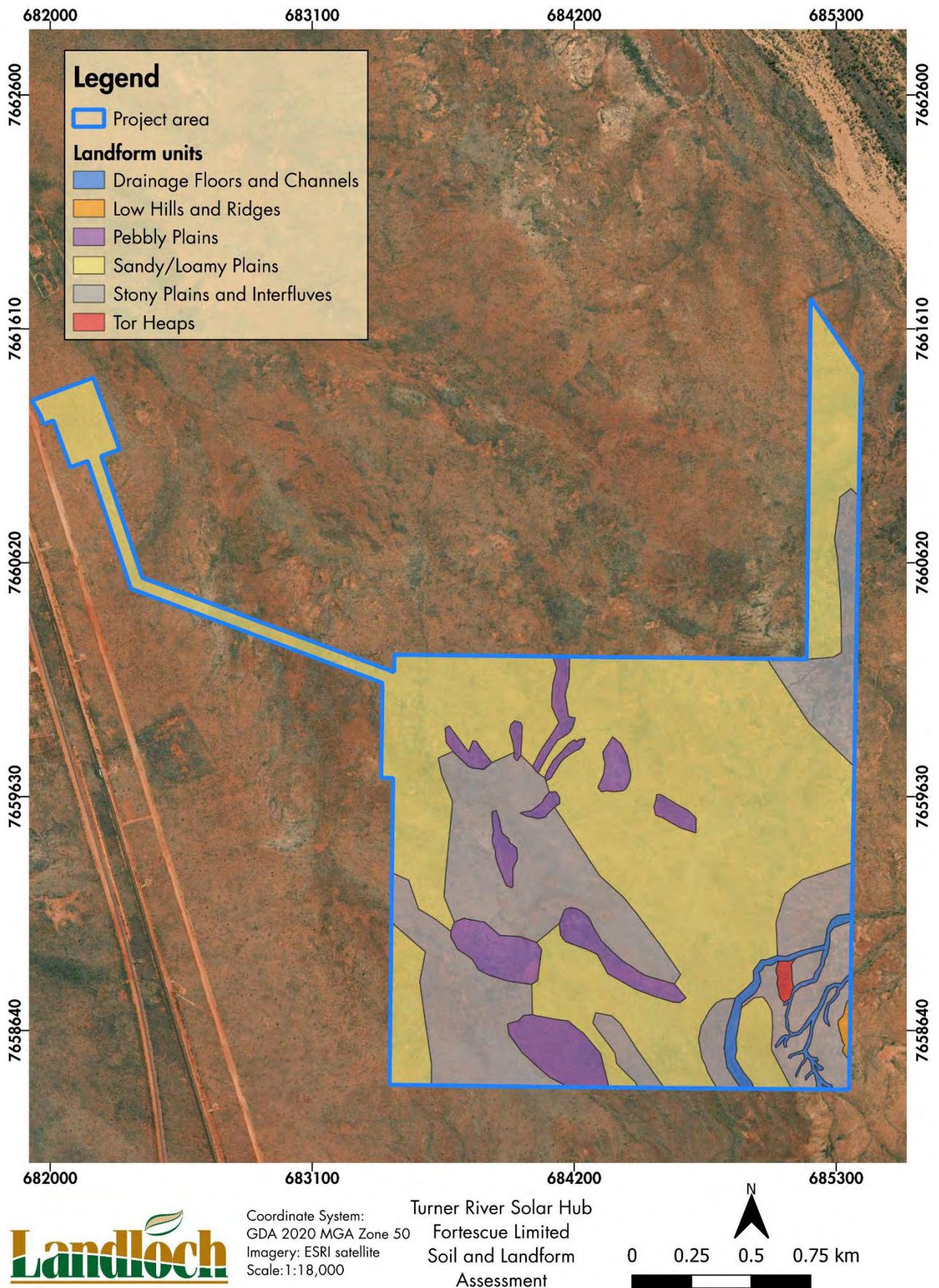


Figure 12: Landforms of the Project area (northern section).

6.2.1 Stony plains and interfluves

The stony plains and interfluves are comprised of level to undulating plains with a gritty surface and mantles of variable rock cover. The surface is typically comprised of few to very abundant grit and pebbles of quartz and granite with occasional outcrops of granite. Interfluves extend throughout the landform in between major drainage lines.

As a depositional landform, the majority of surface material is transported from larger flood events. Interfluves are commonly present throughout, with these ephemeral drainage lines becoming active only under significant rainfall. As a result, these areas receive fast moving flows resulting in the deposition of coarse sediment.

Interspersed throughout the Project area, the stony plains and interfluves form a dominant part of the landscape, comprising 535ha (or 37.8%) of the overall Project area. They often occur adjacent to drainage floors and channels and the sandy/loamy plains. The key characteristic of this landform is the abundance of coarse fragments on the surface, with larger rock fragments typically present, and exposed bedrock often located nearby (Figure 13).



Figure 13: Typical surface cover of the Stony plains and interfluves landform.

6.2.2 Sandy/loamy plains

The Sandy/loamy plains are level to very gently inclined sandy and loamy plains that extend throughout and in between the stony plains and interfluves. Surface mantles are typically absent or with few coarse fragments only.

As a depositional landform, the majority of surface material is comprised of alluvial deposits. Coarse sediments are deposited within the stony plains and interfluves, with finer sediments depositing into the sandy/loamy plain landform. As a result, the surface of this landform is typically devoid of coarse material.

Interspersed throughout the Project area, the sandy/loamy plains are the most common landform present, comprising 788ha (or 55.6%) of the Project area. They often occur adjacent to the stony plains and interfluves. The key characteristic of this landform is the lack of coarse fragments on the surface, and sandy texture of the topsoil (Figure 14).



Figure 14: Sandy surface of the sandy/loamy plains landform.

6.2.3 Pebbly plains

The Pebbly plains are level plains that occur as patches within the sandy/loamy plains. The surface of the pebbly plains includes many to abundant pebbles of quartz and ironstone. The inclusion of ironstone gives the surface a distinct black appearance. The forces that derive this landform are similar to those of the sandy/loamy plains and the stony plains with interfluves. The key difference is the presence of ironstone that has been deposited on the surface.

The Pebbly plains are a relatively minor landform located in the northern section of the Project area in separated patches; it comprises 31ha (or 2.2%) of the overall area. This landform can be distinguished by the presence of a black rocky mantle (Figure 15).



Figure 15: Top image illustrating the black rocky mantle of the Pebbly plains, and bottom image showing the general appearance of this landform.

6.2.4 Drainage floors and channels

Drainage floors and channels are level to gently inclined linear drainage tracts that are locally 5–10m wide and 1–3m deep. This landform is typically located within the stony plains and interfluvies as the wider drainage pathways become narrower and more incised. Vegetation is typically dense within these drainage channels as water concentrates within these areas.

The depth and width of this landform varies depending on the source of the received drainage water. In some areas, the channels are very narrow (1–2m wide) and shallow (0.5m depth) and in other areas can extend out to 10m at depths of 3–4m, with bedrock underpinning some sections.

The drainage floors and channels are a relatively minor landform located across the Project area, but at a higher density within the northern section, comprising 21ha (or 1.5%) of the overall area. No imagery of this landform was captured during the field investigation. An aerial image of the typical appearance of the drainage floors and channels is provided in Figure 16.

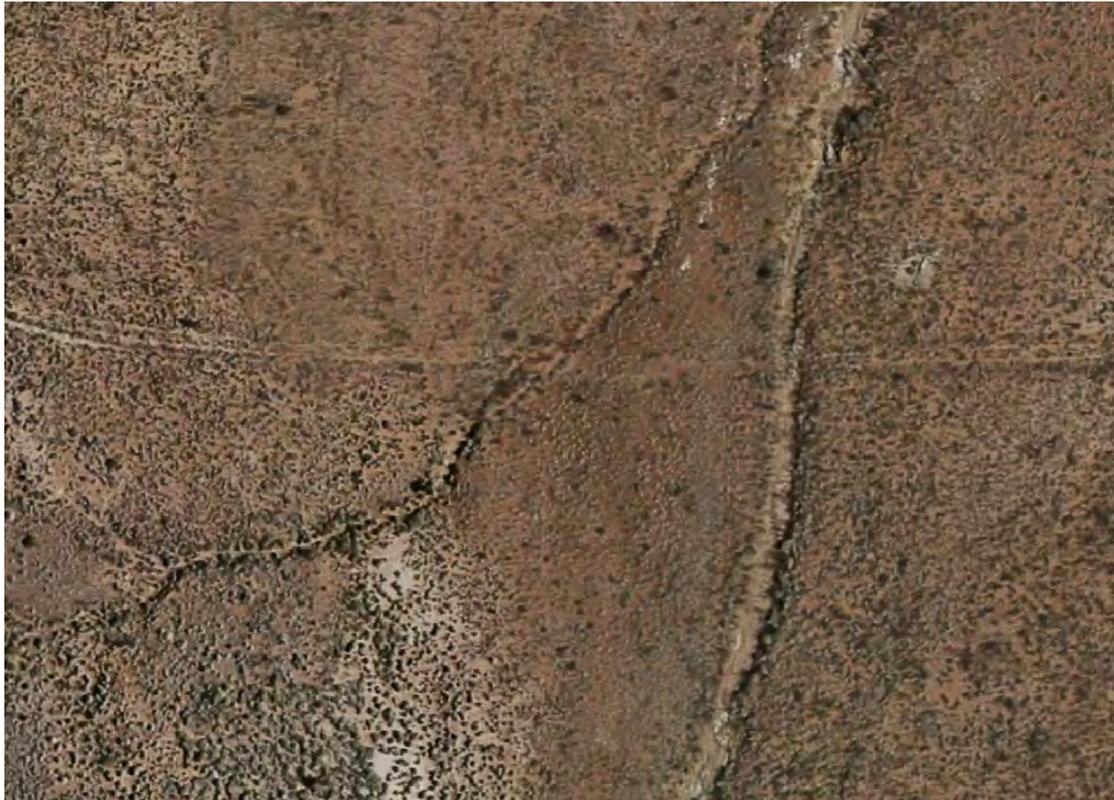


Figure 16: Typical appearance of the drainage floor and channels landform within the Project area, with a major channel running from north-south (image from the northern section of the Project area).

6.2.5 Low hills and ridges

The low hills and ridges are an isolated landform within the Project area. These are typically very low hills comprised of exposed bedrock with gently inclined slopes. Surface mantles are comprised of abundant to very abundant cobbles, stones, and boulders of granite, quartz and other rocks, with relief up to 5m.

The lower slopes of the low hills and ridges are an erosional landform surrounded by surfaces that contain a rocky mantle. Granitic outcrops are common on the surface, with the pattern of these outcrops typically broader than the Tor heaps.

Present primarily in the southern section of the Project area, the low hills and ridges are an isolated landform, comprising 7ha (or 0.5%) of the overall area. They often occur adjacent to the stony plains and interfluves.

No images of the low hills and ridges were captured during the field investigation, as the intent of the survey was to sample the soils of the Project area and these rocky features cannot be excavated. An example of the low hills and ridges located on the southern section of the Project area is provided in Figure 17.



Figure 17: Typical appearance of the low hills and ridges, surrounded by stony plains and interfluves.

6.2.6 Tor heaps

Tor heaps are steep to precipitous hillocks that are typically convex in shape with a surface cover comprised of bare rock. This rock is either singular or is comprised of multiple subangular to rounded large boulders separated by open fissures. Erosion of these rocks is driven by sheet wash or water-aided mass movement, and results in a broken appearance. At the local level, these landforms are typically 10–20m in extent and can be up to 5m in height.

The Tor heaps present within the Project area are typically extremely weathered and in poor condition. They are isolated to a few discrete sections of the southern Project area comprising 3ha (or 0.2%) of the overall Project area. No images of these landforms were captured during the field investigation. However, an example from aerial imagery is provided in Figure 18.



Figure 18: Tor heaps (highlighted with red circle) within southern Project area.

7 SOIL MAPPING UNITS

Soil Mapping Units (SMUs) are the basic geographic component of a soils map and can be associated with a single or multiple soil types with definable characteristics. SMUs are developed based on recurring landscape and soil attributes, with minor variations in soil properties allowable within each SMU. The purpose of SMUs is to group soils by their management requirements, such as depth, salinity, sodicity, and coarse fragments. For the purpose of this project, SMUs were used as the basis for defining the quality and volume of the potential topsoil and subsoil resource.

Development of SMUs allows for consideration of the soil-disturbing actions in light of the end use of the soils; that is rehabilitation of the land disturbed by mining. As such, this report focuses on the development and mapping of SMUs for the determination of stripping depths, potential for re-use during mining rehabilitation, and management of the soil resource during the life of the mine.

SMUs are typically based on full soil profile descriptions, which are not available for this Project. However, SMUs can be developed based on the known morphology of the surface soils. The soil inspection sites were grouped into SMUs based on their management requirements, particularly their morphological properties, chemical data, particle size distributions, and coarse fragment abundance. Three SMUs were identified:

- SMU1: Loamy/clayey soils. Soils that have loamy or clayey textures within the topsoil or subsoil layers. The defining feature of this soil is the higher abundance of clay compared to other soil types, with clay content increasing with depth. These soils occur within the sandy/loamy plains and are likely to be present within the drainage floors and channels.
- SMU2: Rocky soils. Soils with a high abundance of coarse fragments on the surface and within the soil profile, with a rocky mantle typically present. The defining feature of this SMU is the abundance of coarse fragments, typically on the surface and within the topsoil, but can extend to the subsoil. These soils typically occur within the stony plains and interfluvial landform, but also include those associated with the pebbly plains, and low hills and ridges (very rocky soils).
- SMU3: Sandy soils. Soils that are sandy throughout the observed profile with little to no change in texture. These soils are defined by a very low abundance of clay throughout the observed profile. They are typically associated with the sandy/loamy plains.

A summary of the SMUs and the soil inspection sites associated with each is provided in Table 19.

Table 19: Soil Mapping Units within the Project area.

Soil Mapping Unit	Description	Sites
SMU1: Loamy/clayey soils	Soils dominated by loamy/clayey textures in the topsoil and subsoil.	SP01, SP03, SP05, SP07, SP08, SP12, SP15, OP02, OP03, OP04
SMU2: Rocky soils	Soils with a high abundance of coarse fragments on the surface and/or in the soil profile.	SP02, SP04, SP09, SP11, SP13, OP05, OP06, OP07
SMU3: Sandy soils	Soils that are sandy throughout with few to no coarse fragments.	SP06, SP10, SP14, OP01

7.1 Common attributes

There are many attributes that are common for the soils across the Project area and as such, are not a differentiating factor for the development of SMUs.

Values for pH vary across the sites, but ultimately the variation is not considered to be a key factor in re-use of these soils (Figure 19). Across all sites, the median pH is 6.8, ranging from 5.9–9.5 (moderately acidic to strongly alkaline). SMU1 (Loamy/clayey soils) had a median pH of 6.5 (5.9–8.9), SMU2 (Rocky soils) a median pH of 8.9 (6.0–9.5) and SMU3 (Sandy soils) a median pH of 6.8 (6.2–7.9). The soils of SMU2 (Rocky soils) are typically more alkaline than the other two SMUs, however this is not considered a differentiating factor between the mapping units.

Salinity was low across the Project area (Figure 20). The median $EC_{1:5}$ values across all sites is 0.02dS/m, ranging from 0.01–0.24dS/m. SMU1 (Loamy/clayey soils) has a median $EC_{1:5}$ value of 0.02dS/m (0.01–0.24dS/m), SMU2 (Rocky soils) a median $EC_{1:5}$ value of 0.06dS/m (0.01–0.12dS/m), and SMU3 (Sandy soils) a median $EC_{1:5}$ value of 0.01dS/m (0.01–0.03dS/m). Overall, salinity is not a differentiating factor between the mapping units.

From a structural stability perspective, the majority of sites are prone to structural instability when disturbed due to their ESI values; these sites occur across all SMUs. Three sites were prone to structural instability due to elevated magnesium and/or their particle size distribution. All sites were considered non-sodic.

Vegetation cover varied across the sites but was typically sparse (10–30% cover) with *Triodia spp.* noted as the dominant species type present. The northern section (Wodgina) typically had denser vegetation cover (30–70%) compared to the southern section (NSJ West). Bushes and shrubs were common, with trees occasionally present and at a very low density.

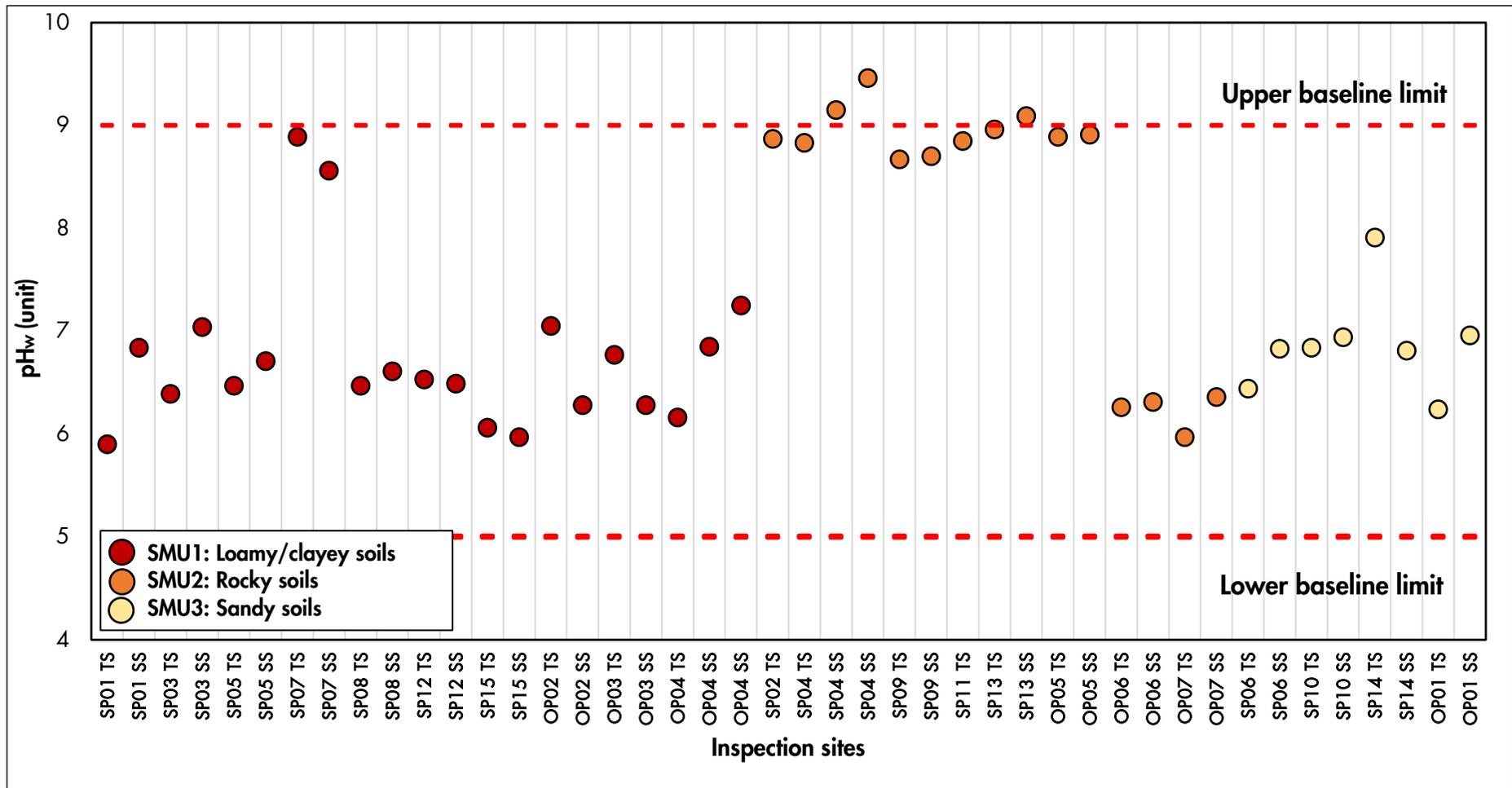


Figure 19: Summary of pH across all sites, grouped by SMU.

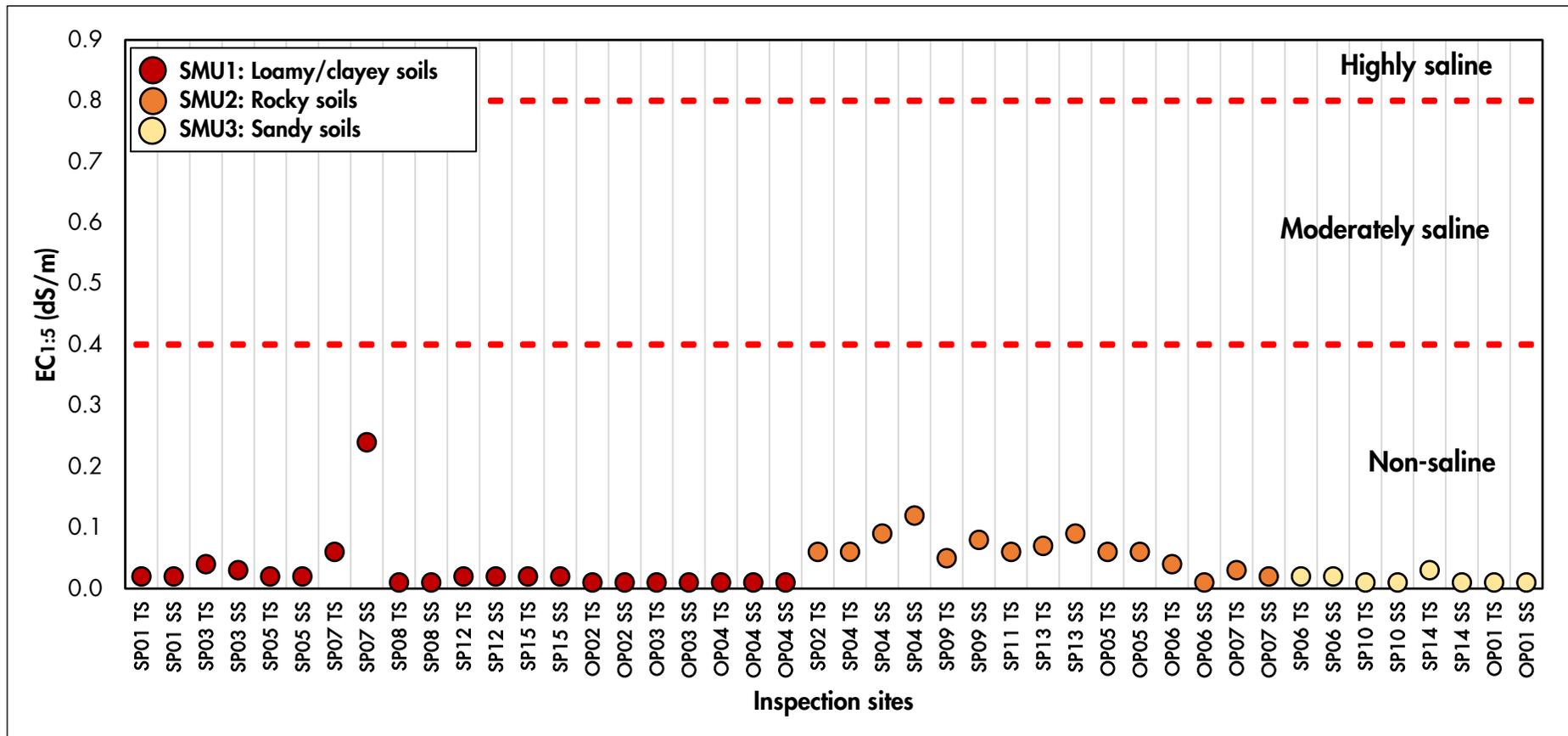


Figure 20: Summary of EC_{1:5} across all sites, grouped by SMU.

7.2 Differentiating attributes

The key differentiating attributes of the SMUs are:

- Coarse fragment abundance;
- Soil texture; and
- Landform position.

7.2.1 Coarse fragment abundance

The median abundance of coarse fragments across all sites is 12%, ranging from 2–71% (Figure 21). SMU2 (Rocky soils) recorded a median coarse fragment percentage of 45% (12–71%), which is significantly higher than both SMU1 (Loamy/clayey soils) with a median of 11% (2–50%), and SMU3 (Sandy soils) with a median of 4% (2–7%). This highlights the characteristic trait of the Rocky soils (SMU2), which are defined by the presence of coarse fragments in the soil profile.

For SMU2 (Rocky soils), coarse fragments are typically higher in the topsoil (median of 49%) than in the subsoil (median of 43%). This trend is reversed in SMU1 (Loamy/clayey soils), with topsoils (median of 5%) typically lower than subsoils (median of 16%). SMU3 (Sandy soils) exhibited a similar trend to SMU1, with topsoils (median of 2%) lower than the subsoils (median of 5%).

Given the abundance of coarse fragments within SMU2 (Rocky soil), it can be expected that these soils will have an increased resistance to water erosion compared to the other two SMUs. SMU1 (Loamy/clayey soils) and SMU3 (Sandy soils) both are expected to be potentially prone to water erosion due to their lower abundance of coarse fragments.

7.2.2 Soil texture

SMU1 (Loamy/clayey soils) and SMU3 (Sandy soils) are both defined by their soil texture, for which clay content can be used as an indicator. SMU3 (Sandy soils) have a median clay content of 10% (6–18%), indicative of their high proportion of sand (Figure 22). Soil textures varied from loamy sand to sandy loams (Figure 23). SMU1 (Loamy/clayey soils) had a median clay content of 20% (10–41%). Soil textures varied from loamy sand to loams and clay loams.

SMU1 (Loamy/clayey soils) typically have a higher abundance of clay in the subsoils, with a median clay content of 17% in the topsoils, and 23% in the subsoils. The Sandy soils had topsoils with a median clay content of 8%, and subsoils with 15%.

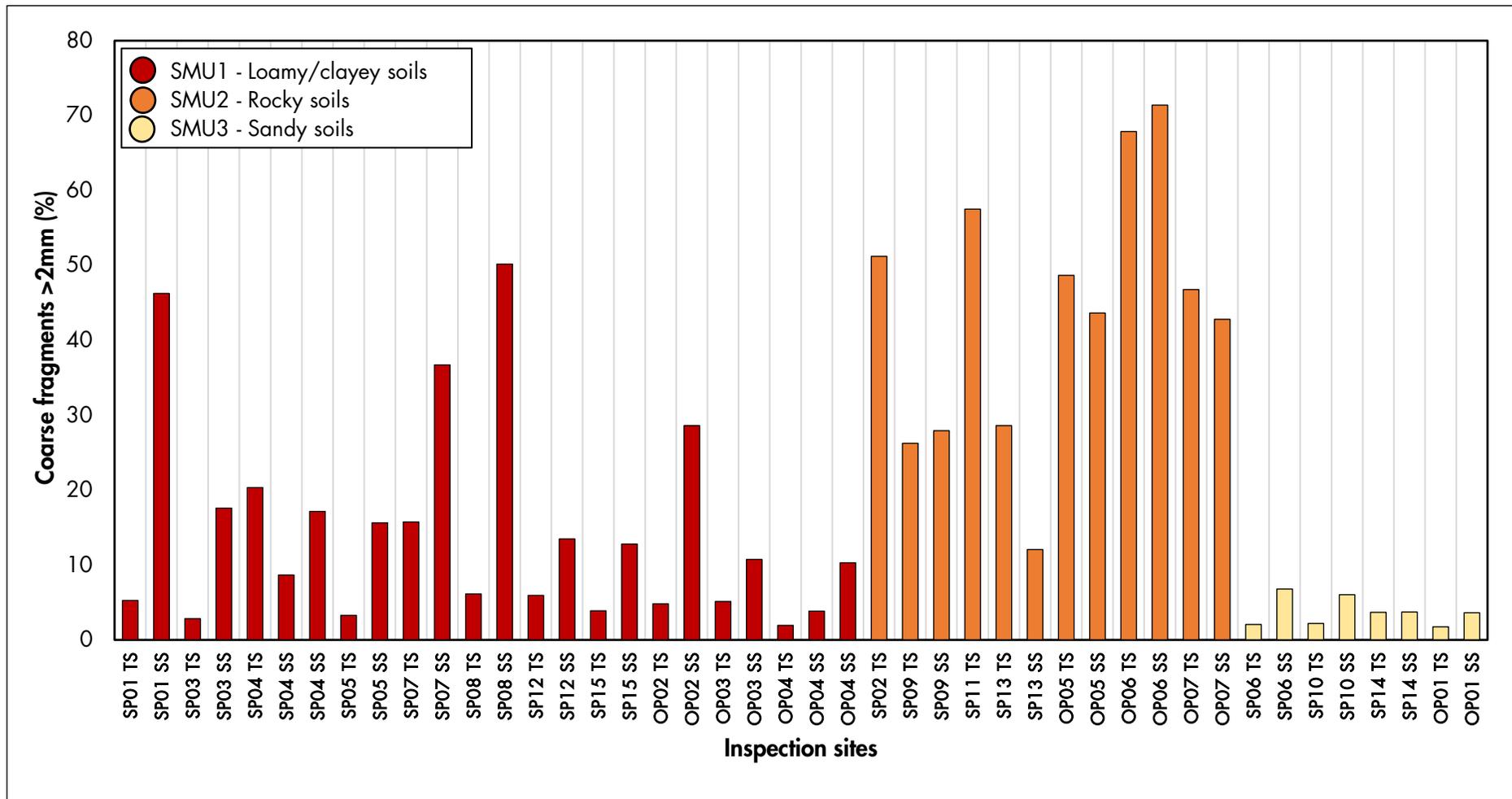


Figure 21: Coarse fragment percentage (>2mm) across all soil inspection sites.

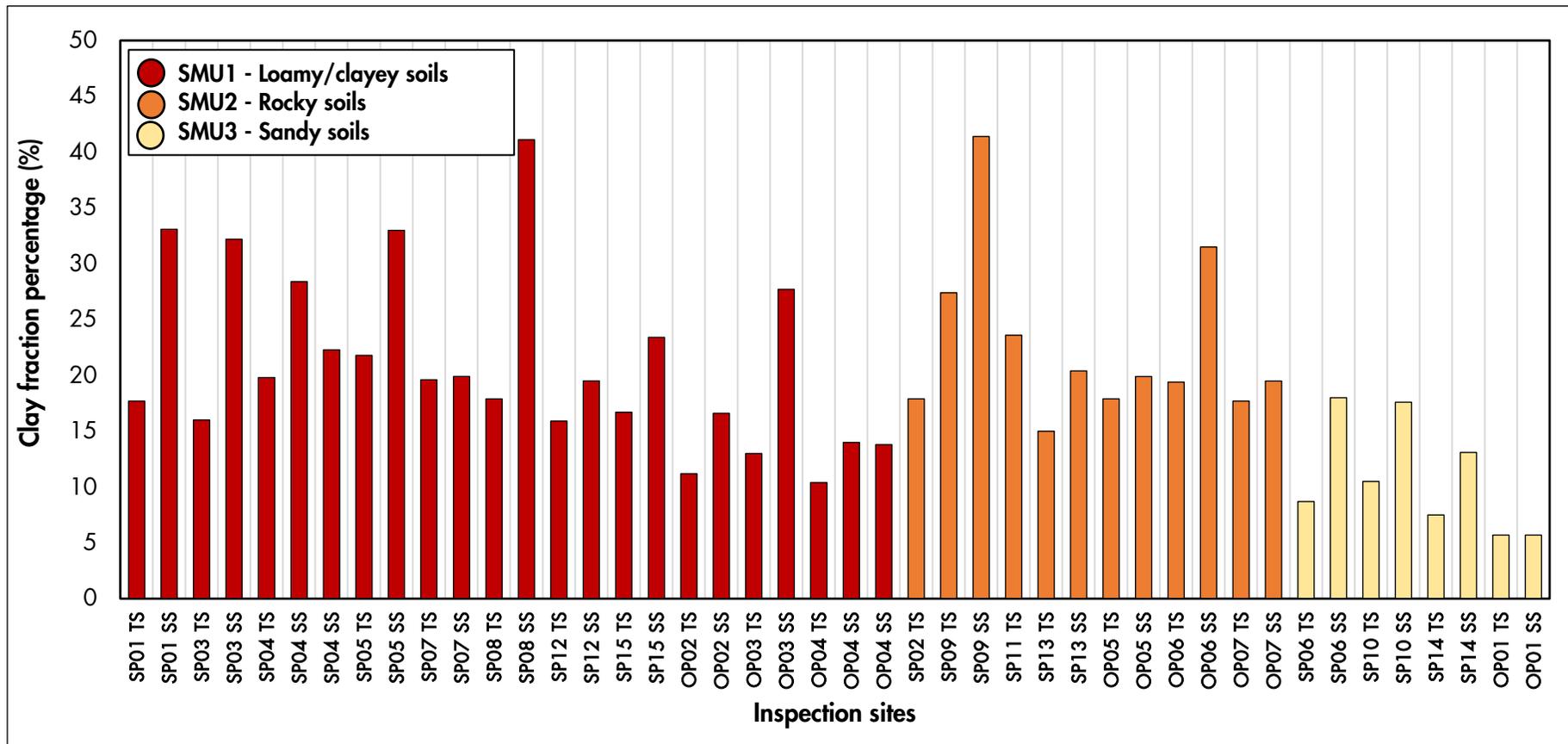


Figure 22: Percentage of clay across all soil inspection sites.

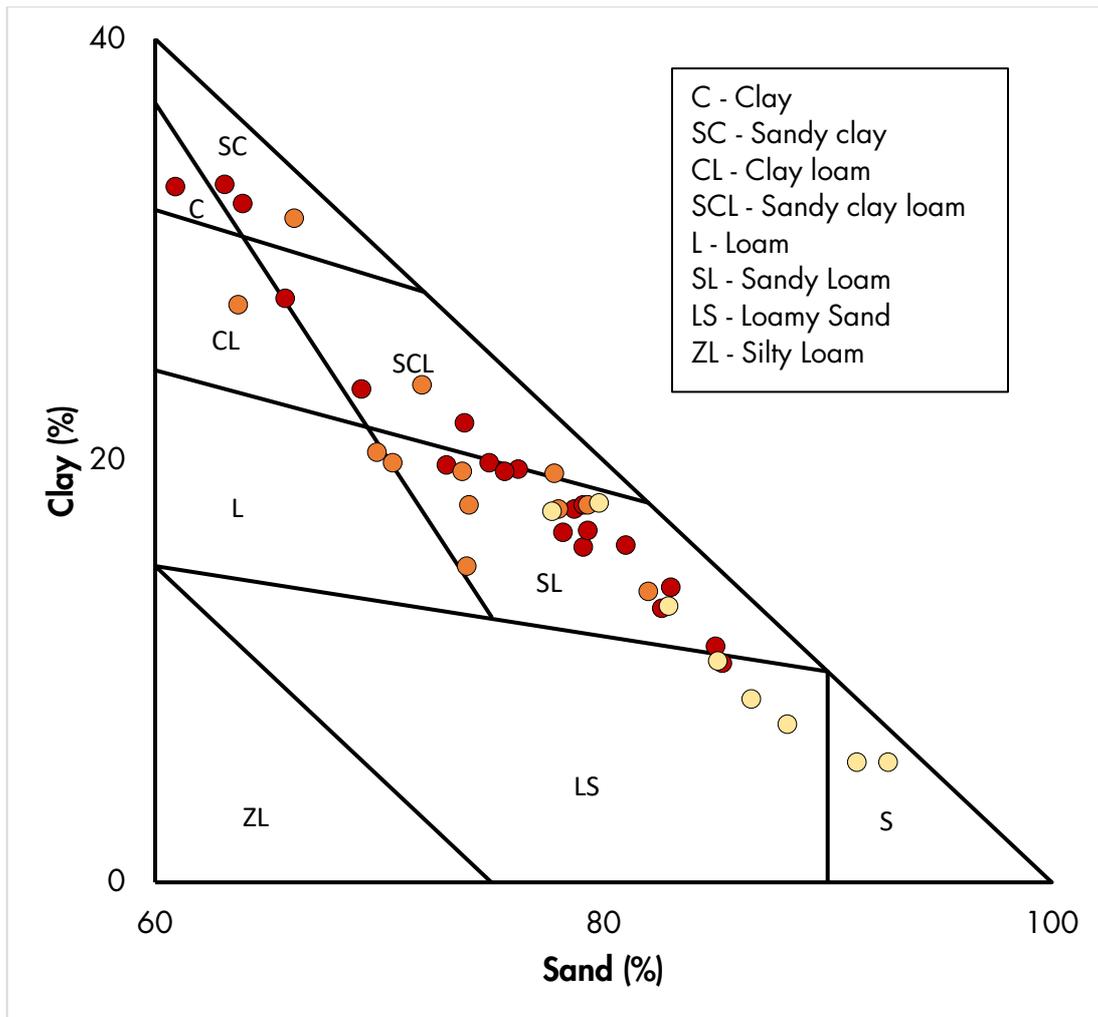


Figure 23: Texture plot with Rocky soil sites shown in dark red, Loamy/clayey soils in orange, and Sandy soils in yellow.

7.3 SMU size and proportion

The size and proportion of each SMU within the Project area is given in Table 20 (with disturbed areas excluded) and illustrated in Figures 24 and 25. The process of delineating SMUs includes a level of uncertainty, relating to the variability of the soils and the degree of uniformity of the landscape and the scale of the survey.

Table 20: Area of each SMU within the Project area.

SMU	Size and Proportion Within Project Area	
	Size (ha)	Proportion (%)
SMU1: Loamy/clayey soils	707	51
SMU2: Rocky soils	560	40
SMU3: Sandy soils	123	9

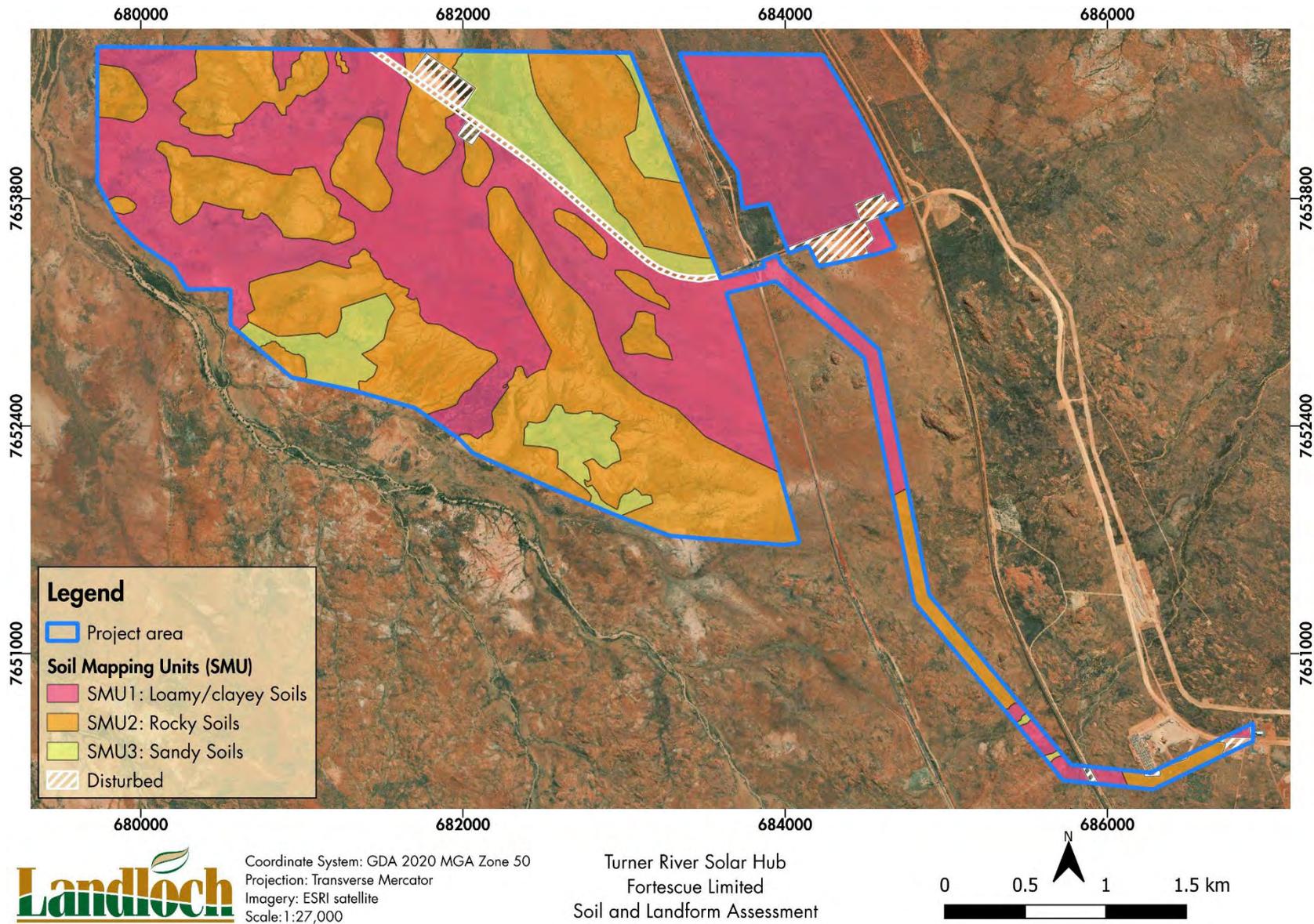


Figure 24: SMU mapping southern section (NSJ West).

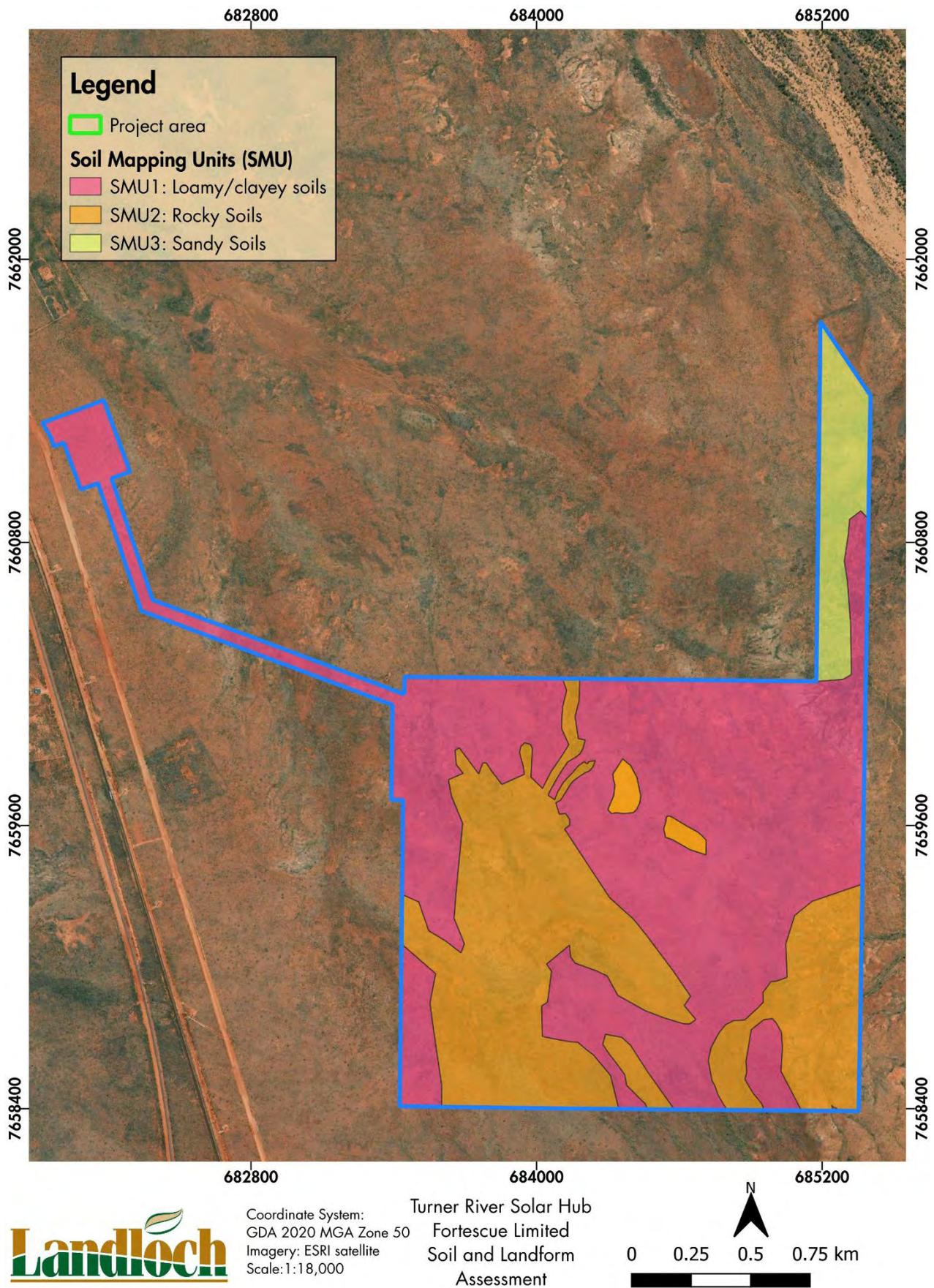


Figure 25: SMU mapping northern section (Wodgina).

7.4 SMU1: Loamy/clayey soils

The Loamy/clayey soils are the most abundant SMU within the Project area, comprising 51% of the soils present. This SMU is typically present within the sandy/loamy plains and the drainage floors and channels.

In general, soils have a sandy or loam texture in the topsoil that increases in clay content to loam or clay in the subsoils. An example of two soil profiles is provided in Figure 26, with SP08 comprised of clayey sand over clay loam, and SP09 clay loam over light clay. No evidence of soil structure was observed, and these soils typically have a very low abundance of coarse fragments.

Median salinity ($EC_{1:5}$) for the topsoils and subsoils were 0.02dS/m (for both), indicating that the soils of this SMU are typically non-saline. Both the topsoils and the subsoils are slightly acidic (median of 6.5 and 6.8, respectively). There are no major chemical limitations for establishment of vegetation in these soils.

From a fertility perspective, the loamy/clayey soils are typically within the ranges defined in Section 5, with reasonable total N, total P, available P, available K and organic C. These soils are not considered to be highly deficient in macro-nutrients.

Almost all soils from this SMU are prone to structural instability due to ESI (ratio between ESP and $EC_{1:5}$). The subsoils from one site (SP04) are further prone to instability due to EMP and PSD. As a whole, these soils are considered to be at risk of structural instability when disturbed and may be prone to water erosion.

Table 21 summarises the median properties of the loamy/clayey soils against the threshold values present in Section 5. Laboratory results are provided in Table 22. The physical and morphological attributes of the soil horizons of a representative soil profile for the SMU is given in Table 23.

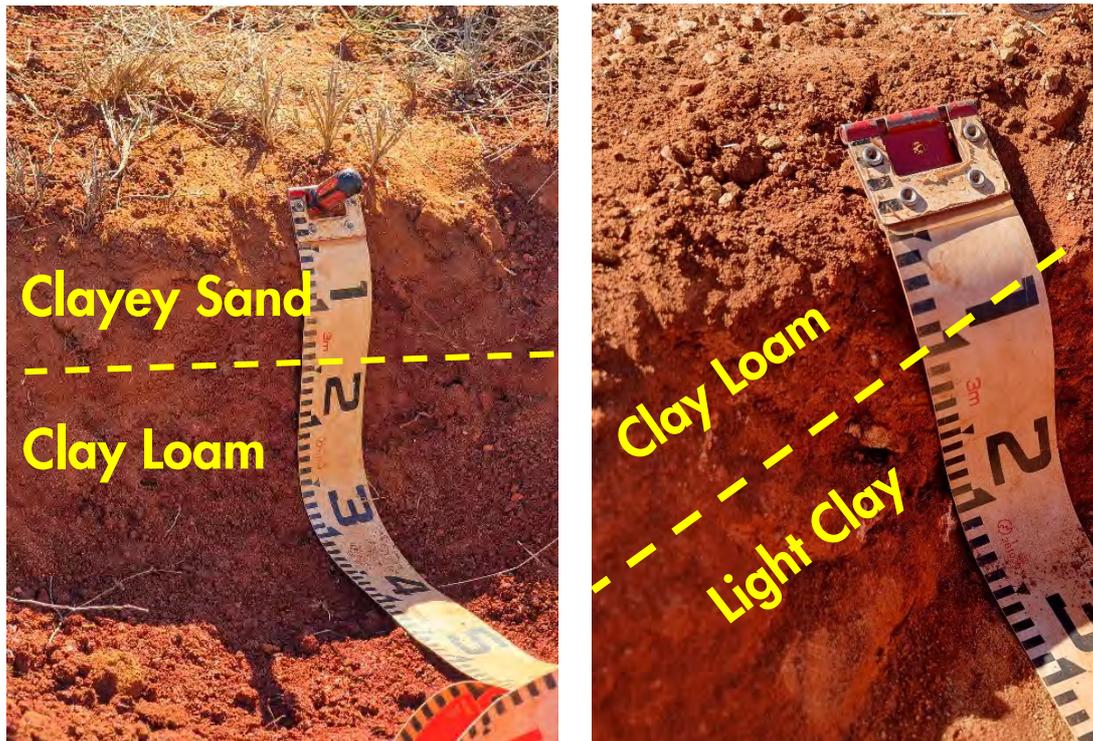


Figure 26: Differences in soil texture, with SP08 (left image) clayey sand topsoils into clay loam subsoils, and SP09 (right image) clay loam topsoils into light clay subsoils.

Table 21: Summary of Loamy/clayey soil properties (median values) against data interpretation scheme thresholds.

Parameter	Unit	Threshold	Topsoil
Soil chemical properties			
Soil pH	-	5.0–9.0	6.5
Soil salinity	dS/m	<0.40	0.02
Soil fertility			
Total nitrogen	mg/kg	>300	411
Total phosphorus	mg/kg	>100	13
Organic carbon	%	0.2	0.2
Avail. phosphorus	mg/kg	>10	13
Avail. potassium	mg/kg	>80	173
Structural stability			
Structural stability	-	ESI/EMP ESP/PSD	ESI
Soil physical properties			
Coarse fraction	%	50%, >20mm	2-10%, 2–6mm

Table 22: Laboratory results for SMU1: Loamy/clayey soils.

Analysis	Unit	NSJW01	NSJW02	NSJW04	NSJW05	NSJW09	NSJW10	NSJW13	NSJW14	NSJW15	NSJW16	
		SP01	SP01	SP03	SP03	SP05	SP05	SP07	SP07	SP08	SP08	
Depth	mm	0-100	100-250	0-100	200-300	0-100	200-300	0-50	150-200	0-100	200-300	
pH - Water	pH units	5.9	6.8	6.4	7.0	6.5	6.7	8.9	8.6	6.5	6.6	
Electrical Conductivity	dS/m	0.02	0.02	0.04	0.03	0.02	0.02	0.06	0.24	0.01	0.01	
Chloride	mg/kg	≤5.00	8	≤5.00	≤5.00	≤5.00	11	≤5.00	244	≤5.00	≤5.00	
Total Nitrogen	mg/kg	884	-	-	148	338	-	560	-	483	-	
Total Phosphorus	mg/kg	84	-	-	69	89	-	84	-	86	-	
Available Phosphorus (Colwell)	mg/kg	9.8	-	-	9.1	30.8	-	15.3	-	8.7	-	
Potassium (Colwell)	mg/kg	160	-	-	237	198	-	190	-	158	-	
Sulphur (KCl)	mg/kg	7	-	-	5	7	-	5	-	4	-	
Organic Carbon	%	0.0	-	-	0.0	0.2	-	0.2	-	0.3	-	
Trace Elements	Copper	mg/kg	0.3	-	-	0.7	0.3	-	0.4	-	0.4	-
	Iron	mg/kg	5.4	-	-	5.0	5.6	-	3.0	-	5.9	-
	Manganese	mg/kg	4.5	-	-	3.6	4.7	-	1.7	-	5.1	-
	Zinc	mg/kg	0.3	-	-	0.3	0.3	-	0.4	-	0.4	-
	Boron	mg/kg	0.6	-	-	0.7	0.6	-	0.7	-	0.6	-
Exchangeable Cations	ECEC	meq/100g	3.1	4.7	4.1	4.7	3.0	3.3	5.4	5.5	3.3	4.4
	Ex Sodium Percent	%	2.7	2.2	2.8	1.7	3.2	2.0	0.9	2.7	3.1	2.6
	Ex Magnesium Percent	%	44.0	38.0	31.6	25.8	38.2	30.0	13.2	14.4	30.8	32.2
	Exchangeable Calcium	meq/100g	1.40	2.45	2.34	3.05	1.51	1.96	4.44	4.46	1.93	2.55
	Exchangeable Magnesium	meq/100g	1.38	1.80	1.30	1.21	1.13	0.98	0.71	0.79	1.01	1.43
	Exchangeable Potassium	meq/100g	0.19	0.33	0.24	0.26	0.20	0.25	0.14	0.10	0.17	0.28
	Exchangeable Sodium	meq/100g	0.08	0.10	0.12	0.08	0.10	0.07	0.05	0.15	0.10	0.11
C:N Ratio	-	-	-	-	-	5.9	-	4.3	-	6.0	-	
ESI	-	0.007	0.009	0.014	0.018	0.006	0.010	0.067	0.089	0.003	0.004	
Average coarse fragment size (range)	mm	2 - 6	-	2 - 6	-	2 - 6	-	2 - 6	-	2 - 6	-	
Coarse Fraction >2mm	%	5.3	46.3	2.8	17.6	3.3	15.6	15.8	36.7	6.1	50.2	
Particle Size Distribution of Fine Fraction	Coarse Sand (0.2-2.0mm)	%	58.5	49.3	62.6	50.8	58.0	50.1	59.3	57.6	40.4	
	Fine Sand (0.02-0.2mm)	%	20.2	13.8	18.4	13.1	15.8	10.8	16.9	17.0	21.5	
	Silt (0.002-0.02mm)	%	1.8	1.9	1.8	1.8	3.7	3.7	3.6	3.7	1.8	
	Clay (<0.002mm)	%	17.7	33.1	16.0	32.2	21.8	33.0	19.6	19.9	17.9	

Table 22: Laboratory results for SMU1: Loamy/clayey soils (continued).

Analysis	Unit	NSJW22	NSJW23	NSJW28	NSJW29	NSJW32	NSJW33	NSJW34	NSJW35	NSJW36	NSJW37	NSJW38
		SP12	SP12	SP15	SP15	OP02	OP02	OP03	OP03	OP04	OP04	OP04
Depth	mm	0-50	250-350	0-100	200-300	0-100	200-300	0-100	250-350	0-100	200-300	400-500
pH - Water	pH units	6.5	6.5	6.1	6.0	7.1	6.3	6.8	6.3	6.2	6.9	7.3
Electrical Conductivity	dS/m	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chloride	mg/kg	≤5.00	≤5.00	≤5.00	7	≤5.00	≤5.00	≤5.00	≤5.00	≤5.00	9	9
Total Nitrogen	mg/kg	792	-	629	-	164	-	240	-	288	-	-
Total Phosphorus	mg/kg	95	-	84	-	96	-	74	-	72	-	-
Available Phosphorus (Colwell)	mg/kg	7.3	-	16.2	-	11.6	-	16.3	-	19.3	-	-
Potassium (Colwell)	mg/kg	190	-	185	-	155	-	142	-	148	-	-
Sulphur (KCl)	mg/kg	5	-	5	-	4	-	4	-	4	-	-
Organic Carbon	%	≤0.2	-	0.2	-	0.2	-	0.2	-	≤0.2	-	-
Trace Elements	Copper	mg/kg	0.3	-	0.3	-	0.3	-	0.3	-	1.7	-
	Iron	mg/kg	6.0	-	6.7	-	6.1	-	5.8	-	62.8	-
	Manganese	mg/kg	3.6	-	5.7	-	4.1	-	3.0	-	69.8	-
	Zinc	mg/kg	0.3	-	0.4	-	0.4	-	0.4	-	6.3	-
	Boron	mg/kg	0.5	-	0.6	-	0.6	-	0.5	-	0.6	-
Exchangeable Cations	ECEC	meq/100g	3.2	2.8	2.8	3.3	2.7	3.1	2.9	6.0	2.1	2.4
	Ex Sodium Percent	%	2.3	2.7	4.7	2.6	2.7	2.8	2.7	1.5	2.6	2.7
	Ex Magnesium Percent	%	33.3	33.8	33.4	34.8	31.6	31.3	38.2	23.0	29.8	26.8
	Exchangeable Calcium	meq/100g	1.77	1.58	1.50	1.77	1.56	1.66	1.51	4.35	1.22	1.48
	Exchangeable Magnesium	meq/100g	1.05	0.95	0.94	1.15	0.84	0.97	1.09	1.38	0.63	0.63
	Exchangeable Potassium	meq/100g	0.21	0.19	0.22	0.23	0.16	0.20	0.15	0.17	0.13	0.11
	Exchangeable Sodium	meq/100g	0.07	0.08	0.13	0.09	0.07	0.08	0.08	0.09	0.06	0.06
C:N Ratio	-	-	-	3.5	-	14.0	-	9.6	-	-	-	
ESI	-	0.009	0.007	0.004	0.008	0.004	-	0.004	0.007	0.004	0.004	
Average coarse fragment size (range)	mm	2 - 6	-	2 - 6	-	-	-	-	-	-	-	
Coarse Fraction >2mm	%	5.9	13.5	3.9	12.8	4.8	28.6	5.1	10.8	1.9	3.8	
Particle Size Distribution of Fine Fraction	Coarse Sand (0.2-2.0mm)	%	57.1	59.1	56.0	55.7	65.3	63.8	64.4	53.7	66.4	
	Fine Sand (0.02-0.2mm)	%	22.0	16.5	23.3	13.5	19.7	14.4	18.2	12.1	18.9	
	Silt (0.002-0.02mm)	%	3.6	3.6	2.9	4.6	2.9	2.9	2.9	4.8	2.9	
	Clay (<0.002mm)	%	15.9	19.5	16.7	23.4	11.2	16.6	13.0	27.7	10.4	

Table 23: Representative inspection site of the Loamy/clayey soils

Representative Site No: SP01 Landform: Open depression. Micro-relief: N/A Surface condition: Soft		Dominant Vegetation: Non-woody Surface cover: Sparse (10-30%) Site Drainage: Moderately well-drained		General comments: Vegetation is notably smaller in size than surrounding areas. Very light scattering of surface rock cover, 2-10% with sizes of 6-20mm on average.						
Landscape Photos		Profile Photo		Horizon (mm)	Moist Colour	Texture	Structure	Consistence	Roots	pH _w & EC _{1:5}
				A1 (0-100)	2.5YR 3/4 (light red)	Sandy Clay Loam	Single grain	Weak (dry)	Few (1-10) Fine (2-5mm)	pH: 5.9 EC: 0.02 dS/m
				B (100-250)	2.5YR 3/6 (light reddish brown)	Clay loam, sandy	Single grain	Weak (dry)	None recorded	pH: 6.8 EC: 0.02 dS/m

7.5 SMU2: Rocky soils

The Rocky soils are the second dominant SMU within the Project area, comprising 40% of the soils present. This SMU is typically present within the stony plains and interfluvial landform, but also occurs within the pebbly plains, low hills and ridges, and Tor heaps.

In general, these soils have variable textures in both the topsoils and subsoils, ranging from sands to clay loams. The abundance of coarse fragments on the surface and within the soil profile are the key determinant of this SMU. Median coarse fraction percentage (>2mm) in the topsoils is 49%, and 43% in the subsoils. A rocky mantle with ~50% surface cover and typical sizes of 20–60mm is common. An example of two soil profiles from this SMU is provided in Figure 27.

Median salinity ($EC_{1:5}$) for the topsoils and subsoils were 0.06dS/m (for both), indicating that the soils are typically non-saline. Both the topsoils and the subsoils are moderately alkaline (median of 8.9 and 8.7, respectively). There are no major chemical limitations for establishment of vegetation in these soils.

From a fertility perspective, the Rocky soils are typically within the ranges defined in Section 5, with the exception of total N. These soils are not considered to be highly deficient in macro-nutrients, however the lack of N may impact vegetation establishment.

As a whole, these soils are potentially at risk of structural instability, but due to the abundance of coarse fragments and are likely to have some inherent resistance to water erosion. This is despite have a fine fraction that is prone to instability.

Table 24 summarises the median properties of the Rocky soils against the threshold values present in Section 5. Laboratory results are provided in Table 25 The physical and morphological attributes of the soil horizons of a representative soil profile for the SMU is given in Table 26.

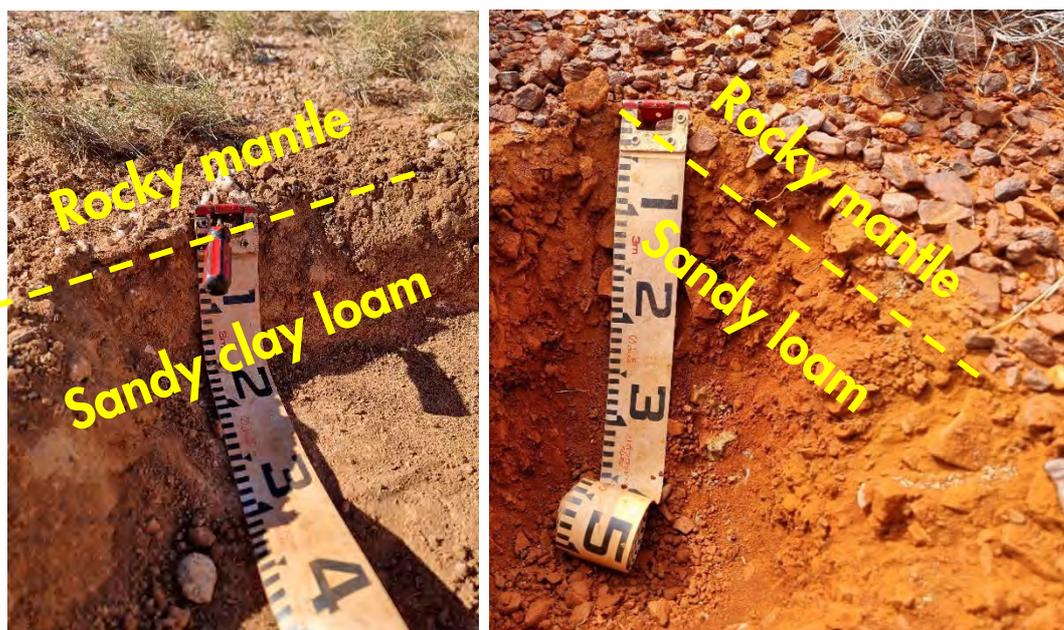


Figure 27: Rocky mantles with SP13 (left image) showing a rocky mantle with sandy clay loam texture underneath, OP06 (right image) comprised of ironstone.

Table 24: Summary of Rocky soil properties (median values) against data interpretation scheme thresholds.

Parameter	Unit	Threshold	Topsoil
Soil chemical properties			
Soil pH	-	5.0 – 9.0	8.8
Soil salinity	dS/m	<0.40	0.06
Soil fertility			
Total nitrogen	mg/kg	>300	177
Total phosphorus	mg/kg	>80	87
Organic carbon	%	0.2	0.4
Avail. phosphorus	mg/kg	>10	11
Avail. potassium	mg/kg	>80	180
Structural stability			
Structural stability	-	ESI/EMP ESP/PSD	ESI
Soil physical properties			
Coarse fraction	%	50% >20mm	50-90% 20–60mm

Table 25: Laboratory results for SMU2: Rocky soils.

Analysis	Unit	NSJW03	NSJW06	NSJW07	NSJW08	NSJW17	NSJW18	NSJW21	NSJW24	NSJW25	NSJW39	NSJW40	NSJW41	NSJW42	NSJW43	NSJW44	
		S02	SP04	SP04	SP04	SP09	SP09	SP11	SP13	SP13	OP05	OP05	OP06	OP06	OP07	OP07	
Depth	mm	0-100	0-100	150-250	300-400	0-50	100-200	0-100	0-50	100-150	0-100	200-250	0-100	200-300	0-100	200-300	
pH - Water	pH units	8.9	8.8	9.2	9.5	8.7	8.7	8.9	9.0	9.1	8.9	8.9	6.3	6.3	6.0	6.4	
Electrical Conductivity	dS/m	0.06	0.06	0.09	0.12	0.05	0.08	0.06	0.07	0.09	0.06	0.06	0.04	0.01	0.03	0.02	
Chloride	mg/kg	7	7	≤5.00	25	7	14	≤5.00	≤5.00	6	6	≤5	≤5	≤5	14	11	
Total Nitrogen	mg/kg	211	-	-	-	527	-	305	159	-	177	-	121	-	67	-	
Total Phosphorus	mg/kg	74	-	-	-	125	-	89	102	-	130	-	147	-	87	-	
Available Phosphorus (Colwell)	mg/kg	11.1	-	-	-	7.8	-	5.4	5.8	-	17.8	-	17.9	-	70.0	-	
Potassium (Colwell)	mg/kg	188	-	-	-	196	-	165	180	-	202	-	160	-	146	-	
Sulphur (KCl)	mg/kg	4	-	-	-	4	-	4	5	-	4	-	6	-	9	-	
Organic Carbon	%	0.4	-	-	-	≤0.2	-	0.5	0.7	-	0.4	-	0.2	-	≤0.2	-	
Trace Elements	Copper	mg/kg	0.3	-	-	0.4	-	0.4	2.3	-	0.3	-	0.5	-	0.3	-	
	Iron	mg/kg	3.2	-	-	3.0	-	2.9	2.9	-	2.9	-	6.6	-	5.2	-	
	Manganese	mg/kg	1.6	-	-	2.0	-	1.5	2.0	-	1.9	-	11.0	-	9.7	-	
	Zinc	mg/kg	0.4	-	-	0.4	-	0.3	2.3	-	0.4	-	0.4	-	0.4	-	
	Boron	mg/kg	0.7	-	-	0.7	-	0.6	0.8	-	0.7	-	0.5	-	0.5	-	
Exchangeable Cations	ECEC	meq/100g	21.6	4.8	5.3	9.0	5.5	6.4	5.9	5.0	5.1	6.7	4.7	2.9	3.7	2.7	3.5
	Ex Sodium Percent	%	0.4	0.9	1.0	3.4	1.7	1.6	1.1	1.4	5.1	0.7	0.9	2.9	2.8	6.9	6.8
	Ex Magnesium Percent	%	3.7	31.4	63.6	71.8	6.4	5.1	6.2	11.4	18.1	4.7	4.0	36.7	40.4	42.8	45.7
	Exchangeable Calcium	meq/100g	20.40	3.18	1.83	2.15	4.84	5.70	5.25	4.24	3.78	6.11	4.35	1.45	1.89	1.20	1.50
	Exchangeable Magnesium	meq/100g	0.81	1.50	3.37	6.43	0.35	0.33	0.37	0.57	0.92	0.32	0.19	1.08	1.50	1.17	1.61
	Exchangeable Potassium	meq/100g	0.22	0.03	0.03	0.05	0.15	0.22	0.15	0.13	0.10	0.19	0.10	0.16	0.20	0.16	0.11
	Exchangeable Sodium	meq/100g	0.09	0.04	0.05	0.30	0.09	0.10	0.06	0.07	0.26	0.05	0.04	0.08	0.10	0.19	0.24
C:N Ratio	-	20.4	-	-	-	-	-	15.4	42.1	-	20.3	-	19.0	-	-	-	
ESI	-	0.140	0.066	0.091	0.036	0.030	0.052	0.055	0.050	0.018	0.086	0.065	0.014	0.004	0.004	0.003	
Average coarse fragment size (range)	mm	6 - 20	6 - 20	-	-	2 - 6	-	6 - 20	6 - 20	-	-	-	-	-	-	-	
Coarse Fraction >2mm	%	51.2	20.3	8.7	17.2	26.3	27.9	57.5	28.6	12.1	48.7	43.6	67.9	71.4	46.8	42.8	
Particle Size Distribution of Fine Fraction	Coarse Sand (0.2-2.0mm)	%	58.2	49.4	37.9	29.2	39.2	37.0	53.1	52.8	52.4	40.9	43.1	46.2	44.0	52.2	53.5
	Fine Sand (0.02-0.2mm)	%	21.1	23.6	19.9	19.6	24.5	17.3	18.8	21.1	17.5	33.1	27.5	31.6	22.2	25.8	20.2
	Silt (0.002-0.02mm)	%	1.8	5.5	13.4	28.5	7.4	3.8	3.7	10.3	8.4	6.6	8.5	1.1	1.1	2.9	4.7
	Clay (<0.002mm)	%	17.9	19.8	28.4	22.3	27.4	41.4	23.6	15.0	20.4	17.9	19.9	19.4	31.5	17.7	19.5

Table 26: Representative inspection site of the Rocky soils

Representative Site No: SP13 Landform: Simple slope Micro-relief: N/A Surface condition: Soft	Dominant Vegetation: Non-woody Surface cover: Sparse (10-30%) Site Drainage: Moderately well-drained	General comments: Surface cover of ~30%, with 20-60mm coarse fragments on the surface. Most the surface rocks are quartz. Profile included smaller coarse fragments in the topsoil (20-50%, 6-20mm, decreasing in size and abundance in the subsoil (10-20%, 2-6mm).						
Landscape Photos	Profile Photo	Horizon (mm)	Moist Colour	Texture	Structure	Consistence	Roots	pH _w & EC _{1:5}
		A1 (0-50)	5YR 3/3	Sandy Clay Loam	Weak polyhedral	Firm (dry)	Few (1-10) Fine (2-5mm)	pH: 9.0 EC: 0.07 dS/m
		B (50-150)	5YR 6/6	Sandy Clay Loam	Weak polyhedral	Firm (dry)	None recorded	pH: 9.1 EC: 0.09 dS/m

7.6 SMU3: Sandy soils

The Sandy soils are a minor SMU within the Project area, comprising 9% of the soils present. This SMU is typically present within the sandy/loamy plains.

In general, this SMU consists of a sandy texture in the topsoil and subsoils. An example of two soil profiles is provided in Figure 28. No evidence of soil structure was observed, and these soils typically have a very low abundance of coarse fragments.

Median salinity ($EC_{1.5}$) for the topsoils and subsoils were 0.02dS/m and 0.01dS/m respectively, indicating that the soils of this SMU are typically non-saline. Both the topsoils and the subsoils are slightly acidic to circum-neutral (median of 6.6 and 6.9, respectively). There are no major chemical limitations for establishment of vegetation.

From a fertility perspective, the sandy soils are below the ranges defined in Section 5 for available P, and total P. As such, these soils are likely to be deficient in P which may limit vegetation establishment.

Almost all soils from this SMU are prone to structural instability due to ESI (ratio between ESP and $EC_{1.5}$). As a whole, these soils are considered to be at risk of structural instability and may be prone to water erosion.

Table 27 summarises the median properties of the sandy soils against the threshold values present in Section 5. Laboratory results are provided in Table 28. The physical and morphological attributes of the soil horizons of a representative soil profile for the SMU is given in Table 29.

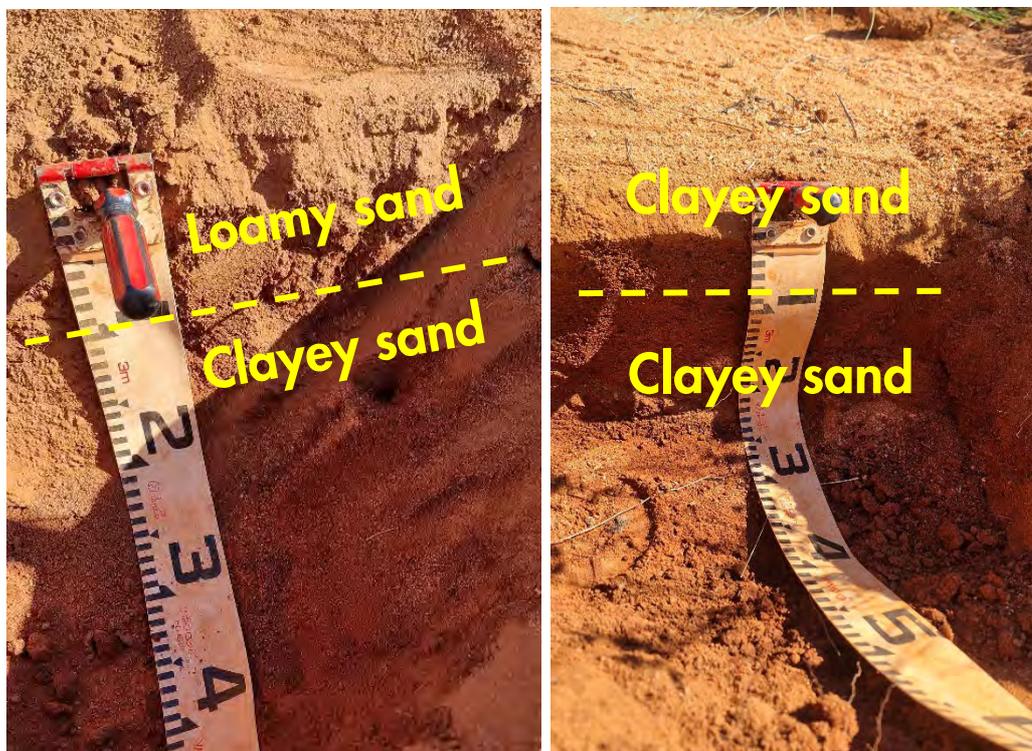


Figure 28: Sandy profiles with SP03 (left image) and SP10 (right image) showing the homogeneity in texture.

Table 27: Summary of Sandy soil properties (median values) against data interpretation scheme thresholds.

Parameter	Unit	Threshold	Topsoil
Soil chemical properties			
Soil pH	-	5.0 – 9.0	6.8
Soil salinity	dS/m	<0.40	0.01
Soil fertility			
Total Nitrogen	mg/kg	>300	356
Total Phosphorus	mg/kg	>80	67
Organic Carbon	%	0.2	0.2
Avail. Phosphorus	mg/kg	>10	8
Avail. Potassium	mg/kg	>80	91
Structural stability			
Structural stability	-	ESI/EMP ESP/PSD	ESI
Soil physical properties			
Coarse fraction	%	50% >20mm	None

Table 28: Laboratory results for SMU3: Sandy soils.

Analysis	Unit	NSJW11	NSJW12	NSJW26	NSJW27	NSJW30	NSJW31	NSJW19	NSJW20
		SP06	SP06	SP14	SP14	OP01	OP01	SP10	SP10
Depth	mm	0-50	150-250	0-50	150-200	0-100	300-400	0-50	150-250
pH - Water	pH units	6.4	6.8	7.9	6.8	6.2	7.0	6.8	6.9
Electrical Conductivity	dS/m	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01
Chloride	mg/kg	5	≤5.00	≤5.00	≤5.00	≤5.00	≤5.00	≤5.00	≤5.00
Total Nitrogen	mg/kg	335	-	681	-	91	-	377	-
Total Phosphorus	mg/kg	60	-	73	-	51	-	76	-
Available Phosphorus (Colwell)	mg/kg	24.8	-	6.9	-	7.3	-	7.7	-
Potassium (Colwell)	mg/kg	158	-	130	-	91	-	150	-
Sulphur (KCl)	mg/kg	5	-	4	-	4	-	4	-
Organic Carbon	%	0.3	-	0.3	-	≤0.2	-	0.2	-
Trace Elements	Copper	mg/kg	0.4	-	0.3	-	0.2	-	0.3
	Iron	mg/kg	5.3	-	4.7	-	5.3	-	4.6
	Manganese	mg/kg	5.1	-	2.4	-	2.1	-	2.8
	Zinc	mg/kg	0.4	-	0.4	-	0.3	-	0.3
	Boron	mg/kg	0.6	-	0.6	-	0.5	-	0.6
Exchangeable Cations	ECEC	meq/100g	3.1	3.8	1.6	2.5	1.8	1.4	3.6
	Ex Sodium Percent	%	2.6	2.0	4.7	3.0	5.4	10.0	2.3
	Ex Magnesium Percent	%	27.1	22.8	14.7	29.9	37.6	58.3	25.2
	Exchangeable Calcium	meq/100g	1.93	2.68	1.17	1.44	0.90	0.35	2.46
	Exchangeable Magnesium	meq/100g	0.83	0.87	0.24	0.75	0.67	0.82	0.92
	Exchangeable Potassium	meq/100g	0.15	0.13	0.08	0.17	0.09	0.06	0.15
	Exchangeable Sodium	meq/100g	0.08	0.07	0.08	0.07	0.10	0.14	0.08
C:N Ratio	-	7.8	-	4.4	-	-	-	6.4	-
ESI	-	0.008	0.010	0.006	0.003	0.002	0.001	0.004	0.006
Average coarse fragment size (range)	mm	6 - 20	-	2 - 6	-	-	-	2 - 6	-
Coarse Fraction >2mm	%	2.1	6.8	3.7	3.7	1.8	3.6	2.2	6.0
Particle Size Distribution of Fine Fraction	Coarse Sand (0.2-2.0mm)	%	64.9	58.8	67.8	64.8	73.6	70.3	68.6
	Fine Sand (0.02-0.2mm)	%	21.7	21.0	20.4	18.1	19.1	21.0	16.5
	Silt (0.002-0.02mm)	%	3.6	1.8	2.9	2.9	1.1	1.1	3.6
	Clay (<0.002mm)	%	8.7	18.0	7.5	13.1	5.7	5.7	10.5

Table 29: Representative inspection site of the Sandy soils

Representative Site No: SP10 Landform: Simple slope Micro-relief: N/A Surface condition: Firm	Dominant Vegetation: Non-woody Surface cover: Sparse (10-30%) Site Drainage: Imperfectly drained.	General comments: Evidence of past running water. Negligible surface rock cover.						
Landscape Photos	Profile Photo	Horizon (mm)	Moist Colour	Texture	Structure	Consistence	Roots	pH _w & EC _{1:5}
		A (0-100)	2.5YR 3/3	Clayey sand	Single grain	Firm (dry)	None recorded	pH: 6.8 EC: 0.01dS/m
		B (100-250)	2.5YR 4/6	Clayey sand	Single grain	Firm (dry)	None recorded	pH: 6.9 EC: 0.01dS/m

7.7 Non-SMU Mapping Units

In addition to the SMUs described above, a separate mapping unit was mapped within the Project area, associated with currently existing disturbance. This unit accounts for ~30ha of the Project area. Soils in this SMU were not described or sampled.

7.8 Landform position

An association between the soils and their landform type (relief and gradient) was observed. These soil-landform associations were typically characterised as follows:

- SMU1: Loamy/clayey soils. Typically present on the sandy/loamy plains and within drainage floors and channels. These lower lying areas receive deposited materials from the surrounding landscape, typically comprised of finer material.
- SMU2: Rocky soils. Present on the stony plains and interfluves, pebbly plains, low hills and ridges, and tor heaps. The stony plains and interfluves and the pebbly plains occur adjacent to the sandy/loamy plains, and characterised by a high abundance of coarse fragments on the surface. The low hills and ridges and tor heaps are erosional landforms and are typically comprised of large rocks and boulders.
- SMU3: Sandy soils. Present on the sandy/loamy plains. As the sandy/loamy plains are comprised of both sand and loam soils, the areas that are dominated by sand are associated with this SMU. SMU3 (Sandy soils) typically occur within or adjacent to SMU2 (Rocky soils).

8 ASSESSMENT OF ASS

Results from the in-field ASS testing (Table 30) indicate that none of the soils tested were considered to be ASS or PASS:

- The field pH values were above the required threshold to be considered ASS and as such are not considered to be actively generating acid.
- The pH oxidation values were all above the required thresholds, and as such are not considered to have potential to generate acid.
- Although reactions were often strong or volcanic, results of the fizz test indicate that this is likely a result of carbonaceous material and/or organic matter reacting with the acid, rather than a direct reaction with potentially sulfidic materials.

Based on these results, further testing of ASS is not required at this stage, and the risk associated with ASS is considered to be very low. It is noted that ASS testing was unable to be performed on the northern sites in the Project area due to time constraints. As such, we are unable to comment on the likelihood of ASS presence within that area.

Table 30: In-field ASS testing results.

Sample	Analyses							
	Depth (mm)	pH _F	pH _{FOX}	Δ pH	Reaction	Fizz test	PASS	ASS
SP01	100	6.4	5.5	0.9	Strong	No	No	No
	200	6.3	5.5	0.8	Strong	No	No	No
SP02	50	8.1	7.6	0.5	Strong	Yes	No	No
	250	7.1	7.7	-0.6	Strong	No	No	No
SP03	100	6.7	6.3	0.4	Strong	No	No	No
	150	6.6	5.8	0.8	Strong	Yes	No	No
SP04	150	8.3	7.4	0.9	Limited	Yes	No	No
	300	8.2	8.2	0.0	Limited	Yes	No	No
SP05	150	5.8	5.4	0.4	Strong	No	No	No
	300	5.6	4.8	0.8	Strong	No	No	No
SP06	100	6.1	5.2	0.9	Strong	No	No	No
	200	6.4	4.9	1.5	Strong	No	No	No
SP07	50	6.9	7.5	-0.6	Strong	Yes	No	No
	150	6.2	7.0	-0.8	Strong	Yes	No	No
SP08	150	5.8	5.0	0.8	Volcanic	No	No	No
	250	5.6	4.4	1.2	Volcanic	No	No	No
SP09	100	7.7	8.0	-0.3	Volcanic	Yes	No	No
	200	7.7	8.1	-0.4	Volcanic	Yes	No	No
SP10	50	6.6	5.4	1.2	Very strong	No	No	No
	200	6.4	5.2	1.2	Strong	Yes	No	No
SP11	50	7.9	7.8	0.1	Volcanic	Yes	No	No
SP12	100	6.3	6.4	-0.1	Strong	No	No	No
	300	6.4	5.7	0.7	Strong	No	No	No
SP13	50	6.8	7.4	-0.6	Very strong	No	No	No
	100	8.2	8.1	0.1	Strong	Yes	No	No
SP14	100	6.6	5.1	1.5	Very strong	No	No	No
	200	6.4	4.5	1.9	Very strong	Yes	No	No
SP15	150	5.7	5.1	0.6	Strong	No	No	No
	250	5.9	4.5	1.4	Strong	No	No	No

9 DISCUSSION

9.1 Assessment on significance of landforms

Based on the landform mapping, an assessment of the significance was conducted for the six landform types present over the Project area. This assessment is outlined in Table 31. It is noted that the designation of a landform as being potentially significant forms part of the feedback provided by the EPA as part of the EIA process. Ultimately, the EPA is the final authority on defining a landform as significant, and the assessment completed by Landloch is provided from a guidance perspective only.

Of the six landforms present within the Project area, it is Landloch's view that no landforms present are considered significant under the criteria set out by the EPA guidelines. The drainage floors and channels have local significance from a cultural perspective and will be addressed as part of cultural heritage but lack unique features that would indicate they are significant from a region/state perspective.

From a variety perspective, only the tor heaps represent a landform that may differ from other examples, but it is noted that their condition on site is poor. Ecologically, the stony plains and interfluves, and the sandy/loamy plains both recorded a single sighting of significant fauna. However, both landforms are common throughout the Pilbara region.

From a scientific and rarity perspective, the tor heaps are a potential example of a highly eroded version of this landform type, which may have some interest from a geological and geomorphological perspective. It is also noted that tor heaps, whilst occurring within four land systems within the Pilbara, are a relatively rare landform type. The low hills and ridges are highly eroded and are unlikely to be of interest from a scientific perspective. From a social importance perspective, the drainage floors and channels have been identified as culturally sensitive and are delineated as high risk zones.

Landloch's interpretation is based on the information available at the time of the assessment and is primarily based on desktop information supplemented by in-field observations. No detailed in-field assessment of landform type has been conducted, as the desktop assessment did not identify any significant landforms.

Table 31: Assessment of landform significance.

Criteria	Stony plains and interfluves	Sandy/loamy plains	Pebbly plains	Drainage floors and channels	Low hills and ridges	Tor heaps
Variety	The stony plains and interfluves are well represented locally, regionally and nationally. Within the Macroy land system alone, this landform is estimated to cover an area of 916,650ha.	Sandy/loamy plains occur across the Pilbara. Within the Uaroo land system alone this landform is estimated to cover an area of 629,842ha.	Less common landform associated only with the Uaroo land system. It is estimated that this landform comprises an area of 61,448ha.	Varieties of drainage floors and channels occur throughout the Pilbara. Within the Macroy land system, this landform is estimated to cover an area of 157,140ha.	The low hills and ridges are well represented locally, regionally and nationally. Within the Macroy land system alone, this landform is estimated to cover an area of 61,448ha.	Tor heaps occur across four land systems within the Pilbara region. However, they are typically not separated out as a single landform, but rather form part of other landform types. In the nearby area (within ~10km of the Project area), examples of Tor heaps can be seen.
Integrity	This landform is intact and in good condition at the local level.	This landform is intact and in good condition at the local level.	This landform is intact and is in good condition at the local level.	This landform is intact and is in good condition at the local level.	This landform is highly weathered and in a generally poor condition.	Highly weathered, fractured and broken. Tor heaps present on site are in a poor condition compared to other local examples.
Ecological importance	One observation of a brush-tailed Mulgara was noted within this landform at the northern section of the site.	One observation of Magpie-lark was recorded in the southern section of the site.	Flora and fauna surveys of the Project area did not identify any rare or unique species present within this landform.	Fauna surveys indicate that several species make use of drainage channels in general (Northern Quoll, Ghost Bat, Pilbara Olive Python etc.)	Fauna surveys note that the Northern Quoll prefers granitic outcrops as a denning habitat, but none were encountered within the survey area. Preferred transient roost for Ghost Bats, and shelter for Pilbara Olive Python.	Fauna surveys note that the Northern Quoll prefers granitic outcrops as a denning habitat, but none were encountered within the survey area. Preferred shelter for Pilbara Olive Python.
Scientific importance	Depositional landform, as such there is little evidence of past ecological processes.	Depositional landform, as such there is little evidence of past ecological processes.	Depositional landform, as such there is little evidence of past ecological processes.	Depositional landform, as such there is little evidence of past ecological processes.	An erosional landform, and as such may provide some insight into past geological processes.	Given the extent of weathering that has occurred on these Tor heaps, there may be some scientific interest from a geomorphological and geological perspective, however unlikely.
Rarity	Described as 'commonly occurring in the Pilbara' by van Vreeswyk et al. (2004).	Comprises ~4% of the Pilbara (van Vreeswyk <i>et al.</i> 2004).	Comprises 31ha of the Project area, estimated to comprise 61,448ha of the Pilbara.	Present in over 10 other land systems within the Pilbara region. Common landform that occurs extensively.	Present within three other land systems within the Pilbara region. Common landform that occurs extensively.	While Tor heaps form part of four land systems within the Pilbara, they are not a common feature and can be considered rare.
Social importance	Potential use for grinding patches.	Potential use for grinding patches.	Potential use for grinding patches.	Major drainage lines are considered culturally sensitive.	Potential use for grinding patches.	Potential use for grinding patches.
Significance	Unlikely to be significant.	Unlikely to be significant.	Unlikely to be significant.	Unlikely to be significant.	Unlikely to be significant.	Unlikely to be significant.

9.2 Assessment on terrestrial environmental quality

From a Terrestrial Environment Quality perspective, the soils encountered across the Project area exhibit characteristics that are typical for Pilbara soils.

SMU1: Loamy/clayey soils

The loamy/clayey soils are a typical sandy/loamy soil that grades to clay at depth. The soil is typically unstructured, with a very low abundance of coarse fragments. From a chemistry perspective, these soils are non-saline and slightly acidic, which are unlikely to impact their capacity to establish vegetation. Fertility values are reasonable but low, which is typical of the rangeland soils present in the Pilbara.

SMU2: Rocky soils

In general, these soils have variable textures in both the topsoils and subsoils, ranging from sands to clay loams. With an appreciable proportion of coarse fragments present on both the surface and within the soil profile, these soils have properties that are similar to rocky soils present across the Pilbara.

The topsoils and subsoils non-saline and moderately alkaline, there are no major chemical limitations present. Fertility levels are typical for rangeland soils, although nitrogen levels are lower than other soil types.

SMU3: Sandy soils

Soils that are dominated by sands with no soil structure, and a very low abundance of coarse fragments. The Sandy soils are non-saline and slightly acidic, with fertility values that indicate low phosphorus levels. These soils are prone to erosion, with surface water flows in high intensity storm events likely to result in movement of topsoil to other parts of the landscape.

Disturbance of the three soil types identified in the Project area are unlikely to result in significant degradation of soil quality. These soils have properties that are typical of rangeland soils, with generally low fertility and benign chemical properties. The disturbance of soils through compaction, stripping and stockpiling results in the destruction of soil structure, and the removal of plant matter that reduces their fertility. However, as these soils have no structure, and their fertility is already low, any disturbance is unlikely to have a significant impact on their quality.

10 SUMMARY

10.1 Landforms

The broad landforms present over the Project area have been mapped using a combination of all available data. Six landform types have been identified and mapped:

- Stony plains and interfluves;
- Sandy/loamy plains;
- Pebbly plains;
- Drainage floors and channels;
- Low hills and ridges; and
- Tor heaps.

Based on the landform mapping, an assessment of the significance was conducted for the six landform types present over the Project area.

Of the six landforms present within the Project area, it is Landloch's view that no landforms present are considered significant under the criteria set out by the EPA guidelines. The drainage floors and channels have local significance from a cultural perspective and will be addressed as part of cultural heritage but lack unique features that would indicate they are significant from a region/state perspective.

10.2 Soils

The soils of the Project area have been split into three Soil Mapping Units (SMUs):

- SMU1: Loamy/clayey soils. Soils that have loamy or clayey textures within the topsoil or subsoil layers. The defining feature of this soil is the higher abundance of clay compared to other soil types, with clay content increasing with depth. These soils occur within the sandy/loamy plains and are likely to be present within the drainage floors and channels.
- SMU2: Rocky soils. Soils with a high abundance of coarse fragments on the surface and within the soil profile, with a rocky mantle typically present. The defining feature of this SMU is the abundance of coarse fragments, typically on the surface and within the topsoil, but can extend to the subsoil. These soils typically occur within the stony plains and interfluves landform, but also include those associated with the pebbly plains, and low hills and ridges (very rocky soils).
- SMU3: Sandy soils. Soils that are sandy throughout the observed profile with little to no change in texture. These soils are defined by a very low abundance of clay throughout the observed profile. They are typically associated with the sandy/loamy plains.

Disturbance of the three soil types identified in the Project area are unlikely to result in significant degradation of soil quality. These soils have properties that are typical of rangeland soils, with generally low fertility and benign chemical properties. The disturbance of soils through compaction, stripping and stockpiling results in the destruction of soil structure, and the removal of plant matter that reduces their fertility. However, as these soils have no structure, and their fertility is already low, any disturbance is unlikely to have a significant impact on their quality.

10.3 ASS

Results from the in-field ASS testing indicate that none of the soils tested were ASS or PASS:

- The field pH values were above the required threshold to be considered ASS and as such are not considered to be actively generating acid.
- The pH oxidation values were all above the required thresholds, and as such are not considered to have potential to generate acid.
- Although reactions were often strong or volcanic, results of the fizz test indicate that this is likely a result of carbonaceous material and/or organic matter reacting with the acid, rather than a direct reaction with potentially sulfidic materials.

Based on these results, further testing of ASS is not required at this stage, and the risk associated with ASS is considered to be very low.

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Appendix 1: Turner River Solar Hub Soil and Landform Assessment