Surface Water Assessment

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Report

Surface Water Baseline Conditions

Prepared for Tellus Holdings Ltd

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Revision History

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on behalf of	Beca Pty Ltd		

Executive Summary

This report details the surface water baseline conditions for the Proposal study area. The study area is located in the Finke River Basin within the Lake Eyre Drainage Division of the Northern Territory. The Finke and Hugh Rivers are the major drainage features within the Finke River Basin and for the purposes of the investigation frame the study area from their confluence westwards to the Central Australian Railway.

Desktop analysis reveals an arid climate with aeolian sand and alluvial deposits lying on a combination of rocky hills interspersed with low lying flood out and sand dunes. The community of Titjikala is located 25 kilometres to the north-east of the study area and exploration lease land is used for pastoral purposes by Maryvale Station. Dominant vegetation is grass and shrubland. This vegetation is spatially associated with dry drainage lines suggesting some reliance on surface waters as a water source. No aquatic vegetation / species are thought to be present in watercourses within the study area due to the unreliability of the quality and quantity of flows. Water quality data is limited but suggests a system characterised by low frequency / large magnitude floods causing turbidity and nutrient transfer and following this, retraction of waterholes during dry periods leading to harsh conditions of increasing temperature / salinity and decreasing dissolved oxygen.

Existing surface water information within the study area is limited so Tellus have initiated a baseline monitoring program to allow a more informed appraisal of hydrological, flood, water quality, geomorphology and erosion potential. Major watercourses in the study area are ephemeral for large periods of time but flow following characteristic heavy rainfall events. The Finke River is twice the catchment size of the Hugh River at the point they enter the study area with longer periods of flow but interestingly lower peak flows. Conditions in smaller drainage lines within the Proposal area are largely unknown but anecdotal evidence suggests a very flashy response during rainfall and dis-connectivity from the major drainage lines due to a combination of sandy deposits blocking the flow path, high evaporation and infiltration to the sub-soil system. Land inundation during flood events was scattered and minimal with bank overtopping considered a rare occurrence. At this point, no numerical flood modelling has been conducted. Instead, a conceptual hydrological model has been prepared. Beneficial water uses within the study area are restricted to aquatic ecosystem and livestock watering. A comparison of guideline values for these water uses against surface water quality data, however, indicated that surface water from dams and creeks / rivers exceeds these guidelines and is therefore not of sufficient quality to be fit-for-use. Sediment quality, however, is below guideline values and demonstrates that inherent water quality is driven by natural processes rather than contamination point sources. A rapid geomorphology assessment has characterised creek condition. In particular, thresholds for entrainment of channel bed material have been established and the implications of geomorphological functioning for instream habitat were assessed. A soil erosion hotspot model was generated to understand the relative potential risks of erosion within the study area. This tool found that 'high' and 'very high' cells coincided with headwater drainage lines but that most of the Proposal area was stable regarding water erosion. Finally, groundwater-surface water interaction was considered to be confined to recharge through wet river beds at small rates of 1mm per year. More information on this is provided in the separate groundwater technical report.

Contents

1 Introduction

Beca Pty Ltd (Beca) was engaged by Tellus Holdings Ltd (Tellus) to report baseline surface water conditions as part of the Environmental Impact Statement (EIS) for the Chandler Proposal (this incorporated the Apirnta Facility and the Chandler Facility).

1.1 The proposal

Tellus proposes to establish the Chandler Facility on the Maryvale pastoral lease (Northern Territory Portion 810) approximately 120 kilometres (km) south of Alice Springs.

The Proposal would comprise:

- Mining a high quality salt product at a depth of about 850 metres (m) below ground level.
- Providing for the permanent isolation of intractable hazardous waste or the temporary storage of materials in void spaces left from salt mining.
- Using mining and waste emplacement methods that will replicate current global best practice techniques.
- Haulage of salt and waste products via private haul roads.
- Transport of salt to port via rail.
- Delivery of waste predominantly by rail.
- Transport of workers via public and private roads.

The Proposal initially seeks approval over 29 years (4 year build, 25 year operation) but has capacity to operate well over 100 years. The development will start at 30,000 tonnes per annum, but has an overall design capacity of 400,000 tonnes per annum to accommodate for both steady state growth over 25 years and one off campaign style State Emergency Service infrastructure requirements (Tellus, 2016).

To support the export of salt and import of waste to the Facility transport will be mostly via rail to the Apirnta. Here the material will be offloaded onto road train and hauled 30 km south-east to the Chandler Facility along a dirt road on a regular basis.

Proposed surface infrastructure includes dry salt temporary storage facility and a 5 MW diesel fired power station supplemented by a 2MW solar power plant (Tellus, 2016). A surface plant for the hydraulic backfill emplacement of liquid and dry powdered wastes underground will also be present. Associated infrastructure including workshops, offices and 165 man accommodation camp, hardstand areas, car parks, weighbridges, vehicle wash down facility and sealed roads are planned.

1.2 Scope of the report

This section summarises baseline surface water baseline conditions that have been used to assess potential impacts of the Proposal. A review of the regional hydrological setting and defining assessment area (Section 2) and general catchment features (Section 3). The report also summarises the site investigation and assessment methodology (Section 4) and presents the results and analysis of surface water site observations and monitoring data which relates to:

- Baseline hydrology including flooding (Section 5);

- Water quality (Section 6);
- Geomorphology (Section 7);
- Soil erosion potential (Section 8); and
- Groundwater-surface water interaction (Section 9).

This report is presented as a technical appendix to the EIS and is intended to be read in conjunction with the water assessment presented in the main body of the EIS.

2 Regional-scale basin hydrology and definition of assessment area

Surface water in the Northern Territory (NT) is controlled mainly by climate (NT Government, 2016). The NT has humid and arid climatic zones. The Proposal is situated in the arid zone which has mean annual rainfall of 100 mm to 550 mm, streamflow of 0.2 megalitres per hectare each year and all streams flow inland (i.e. athalassic) rather than to the sea. The NT is covered by four drainage divisions based on rivers flowing into a particular sea or inland. Each drainage division has numerous river basins, which are the catchment areas of major rivers. There are 35 river basins in the NT. The study area is located in the Finke River Basin within the Lake Eyre Drainage Division.

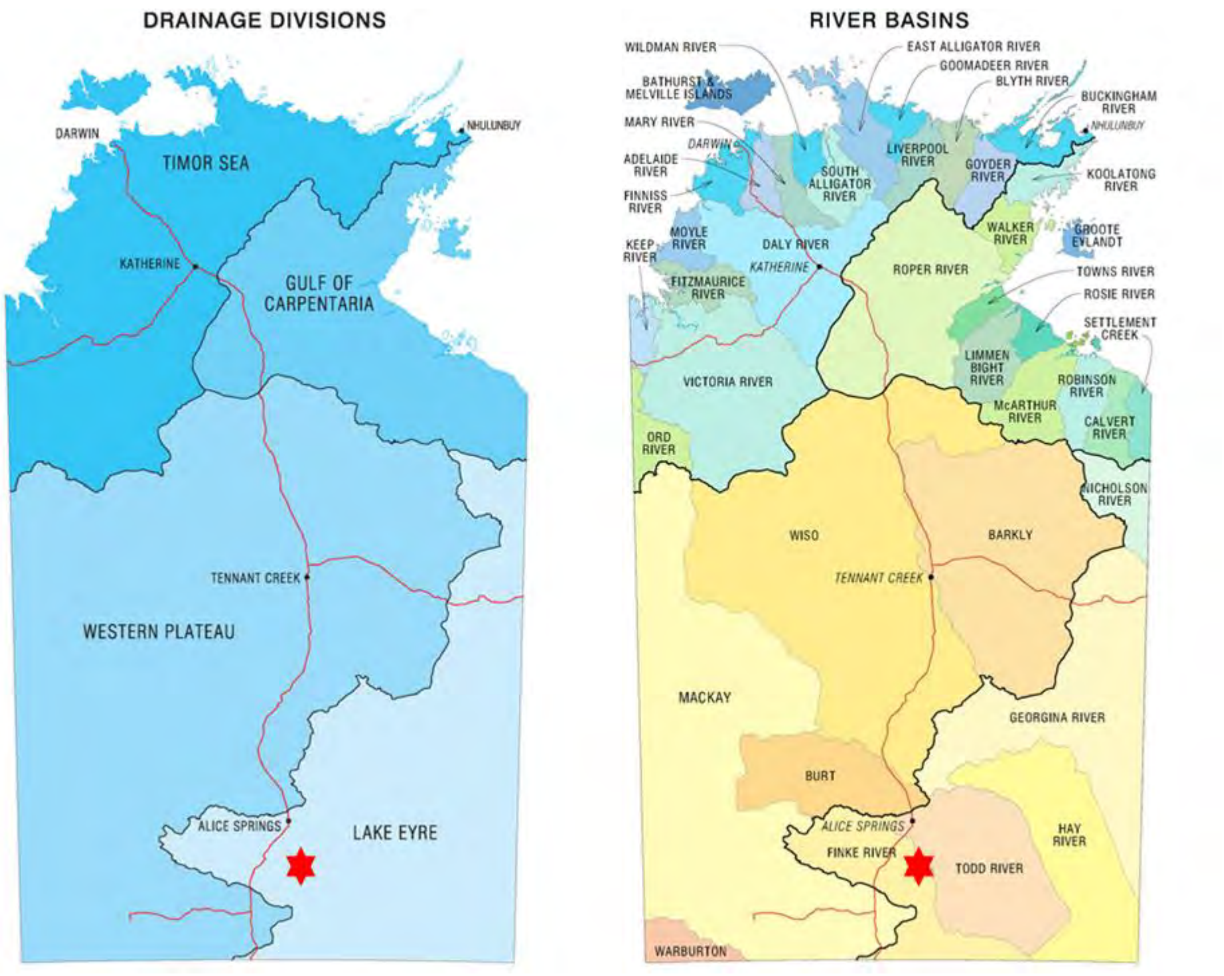

Figure 1 NT Drainage Divisions and River Basins

Approximate study area location; Source: NT Government, 2016

The study area also lies within the Lake Eyre Basin bioregion (Figure 2a). The Lake Eyre Basin bioregion covers an area of about 1.31 million square kilometres of central and north-eastern Australia, which is almost one-sixth of the country (Miles *et al*., 2015). It extends across parts of Queensland, South Australia, New South Wales and the Northern Territory and incorporates the whole of the Lake Eyre drainage basin. The Lake Eyre Basin bioregion includes four subregions: the Galilee, Cooper, Pedirka and Arckaringa subregions. The Pedirka sub-region lies approximately 100 km down-gradient from the study area (Figure 2b).

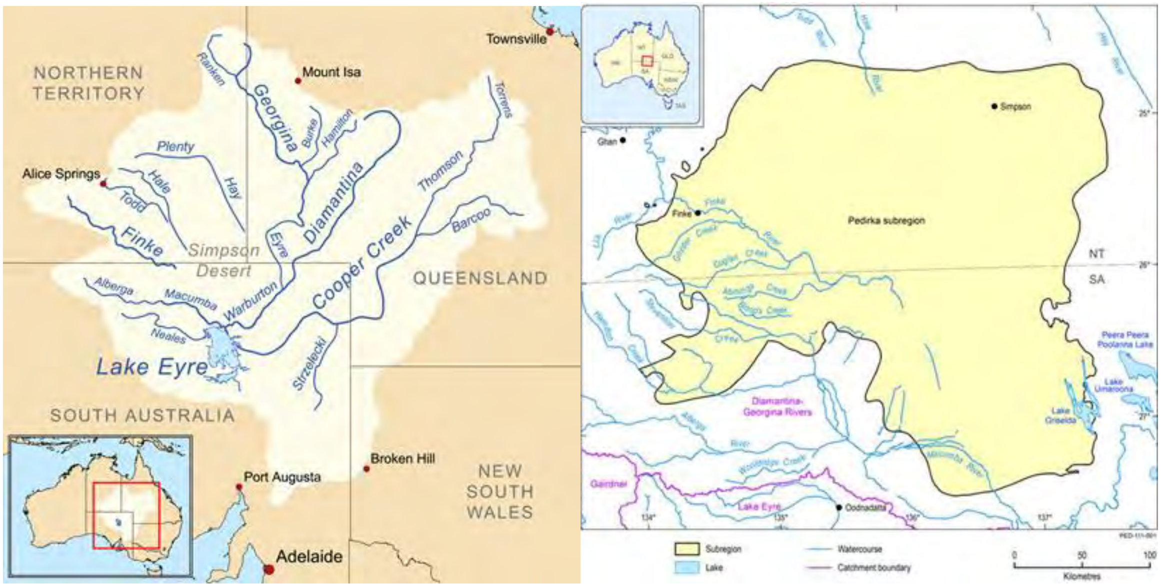

Figure 2 (a) Lake Eyre bioregion and (b) Pedirka subregion (Source: Miles *et al*., 2015)

The Finke and Hugh Rivers are the major ephemeral surface water features in the Finke River Basin which are potentially hydrologically connected to the Proposal area (Figure 3).

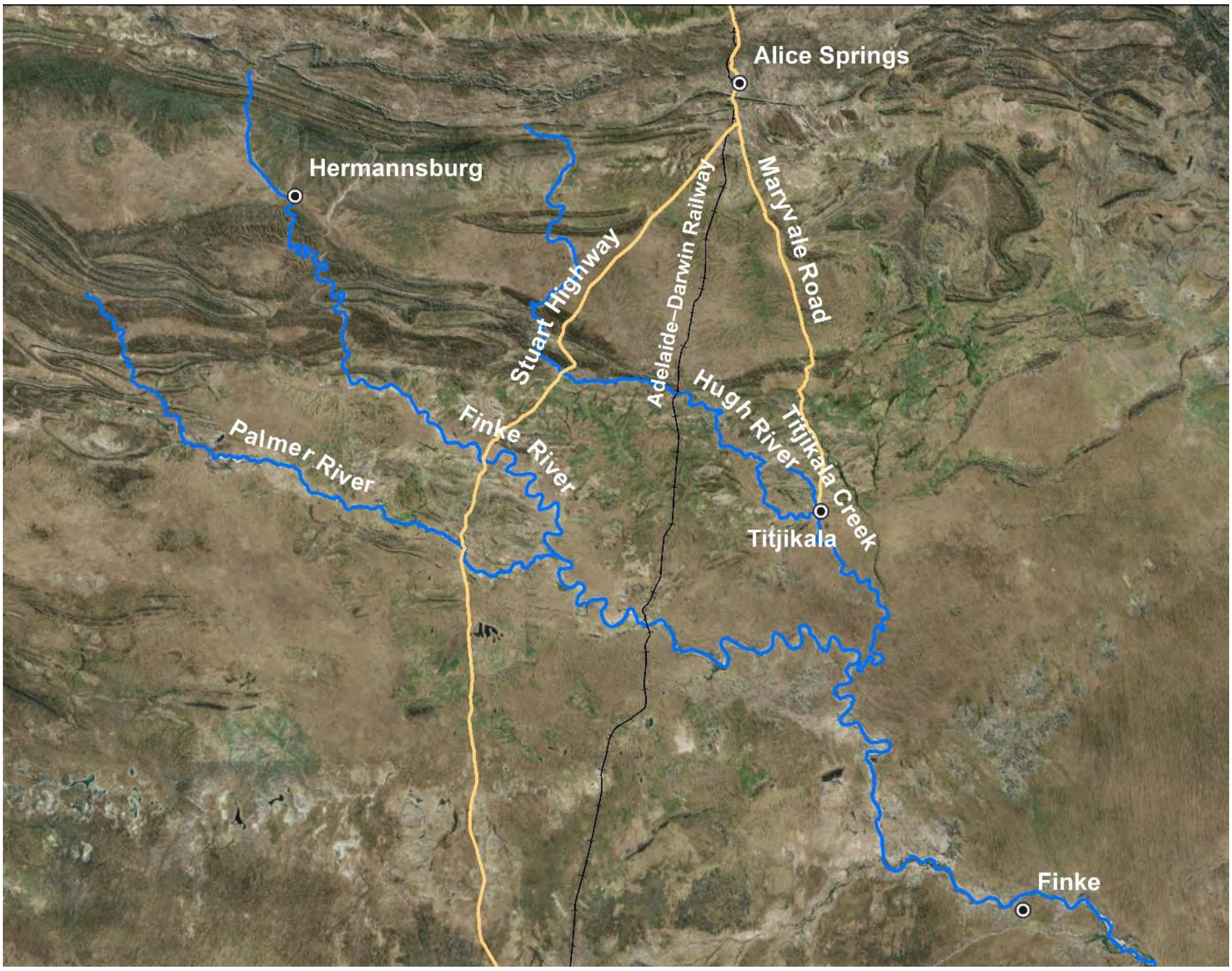

Figure 3: Major rivers surrounding the Proposal site. Aerial imagery sourced from ESRI partners

Both rivers originate at the foothills of the MacDonnell Ranges up to 200 km north-west of the Proposal area. The Hugh River is located to the north of the Proposal and flows south-easterly where it joins for Finke River approximately 30 km south-east of the Proposal. The Finke River flows in a south-easterly direction to the south of the Proposal. Several ephemeral drainage lines discharge to the Finke River and Hugh River along the reaches adjacent to the Proposal area. These are predominantly topographical controlled by various sand dunes, ranges and outcropping basement rock visible across the Proposal area.

For the purposes of this study, it was necessary to define the spatial extent of the assessment. A sub-catchment delineation map has been produced for the study area. The study area has been defined as potential surface water receptors defined as those watercourses that drain the Proposal area and / or could be impacted by the proposed activities downstream. By definition, the study area is therefore larger than the Proposal area.

To define the spatial scale of this assessment the potential connectivity from this sub-catchment delineation was used to identify the following water features which will be considered:

- All dams within or down-gradient from the Proposal area;
- All drainage lines within the Proposal area;
- The Finke River from the Stuart Highway Crossing to the confluence; and
- The Hugh River from the Rail Crossing to the confluence with the Finke River.

It should be noted that this sub-catchment delineation only refers to potential connectivity based on coarse-scale topography and has not been ground-truthed. In particular, anecdotal evidence suggests that the grey-shaded sub-catchment is not connected to the Hugh River (Figure 4). Observations suggest runoff from the Maryvale Hills flows in drainage lines westwards towards a flood-out zone. In this area, water is ponded with negligible flow and evaporation / infiltration into sub-soils gradually diminish the surface area. No breakthrough to the dune area to the north of the sub-catchment is observed, with water in this area locally-derived from runoff from the adjacent dune system. Furthermore, no connectivity between the dune area and the Hugh River to the north is anticipated. Furthermore, no assessment downstream from the confluence between the Hugh and the Finke is deemed necessary because the flow contribution from the Proposal area to flows below this point is considered to be insignificant.

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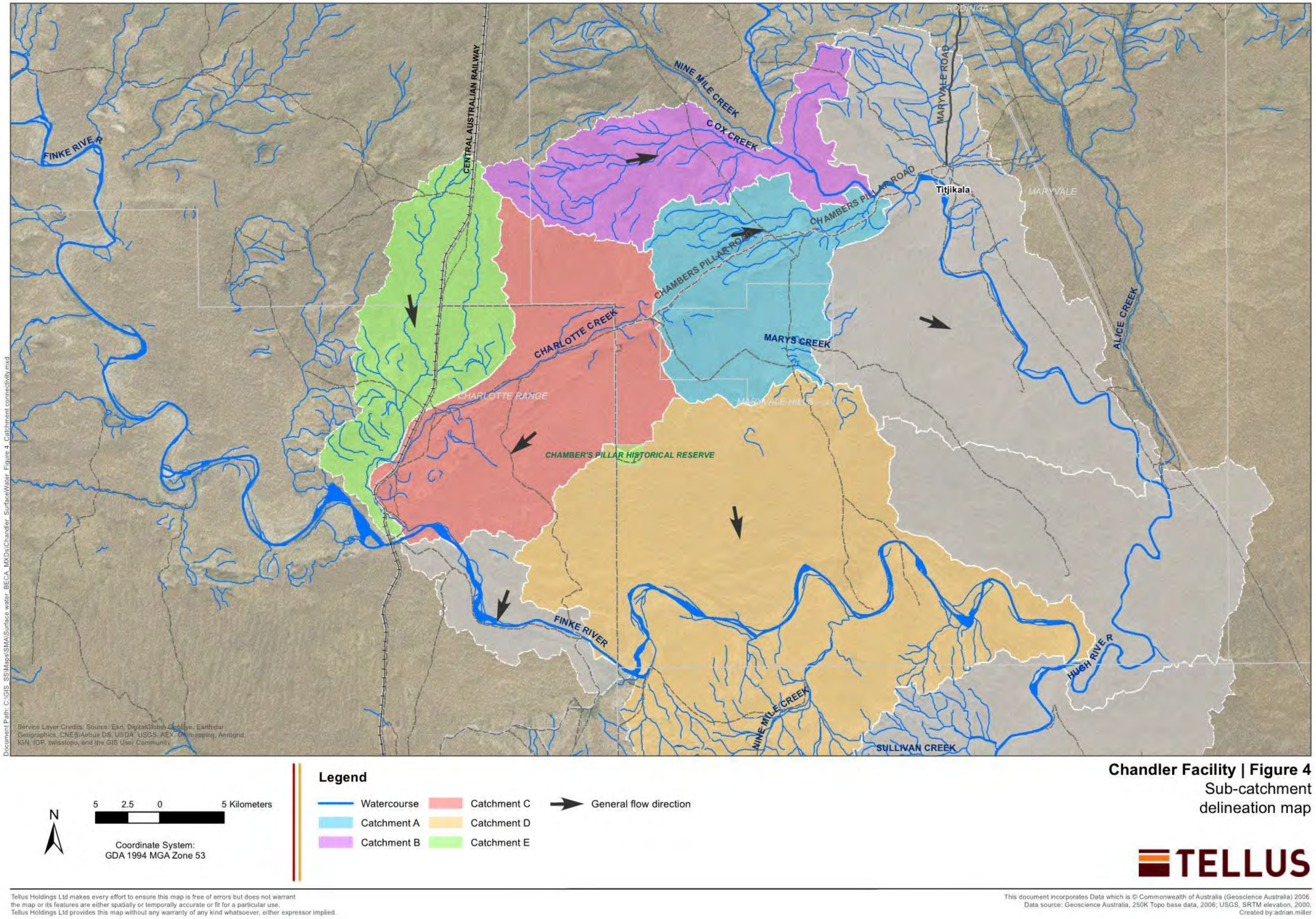

Figure 4 Sub-catchment delineation map

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3 Catchment features

This section summarises the physical characteristics of the region that the Proposal lies within. A more detailed description of site setting is given in Chapter 3 of the Proposal's EIS.

3.1 Location

The Proposal is located approximately 120 kilometres south of Alice Springs, Northern Territory and 25km south-west from the Titjikala indigenous community. The entire Proposal area lies within the Maryvale Station Pastoral Lease (30612). The study area for this report is larger than the Proposal area and is defined as the area receiving drainage from the Proposal area up to a nominal distance whereby no potential impacts on surface water are envisaged (Section 2).

3.2 Climate

Southern NT is characterised by a semi-arid to arid climate with hot dry summers and mild winters (EMM, 2016). The total annual rainfall recorded at the Alice Springs Airport weather station (BoM station # 015590) ranges from approximately 76 mm to 782 mm (over the 74 year monitoring period), with an annual mean of 278 mm. Rainfall is greatest over the summer months and is below the regional average during the winter months. The lowest measurements are typically between August and September. The annual average evaporation measured at the station is approximately 3,147 mm, exceeding the annual average rainfall by approximately 2,869 mm/yr. Overall monthly average evaporation exceeds monthly average rainfall. The greatest evaporation rates occur from October through to March, with evaporation significantly influenced by temperature and solar radiation over the summer period.

The low average rainfall and high evaporation in southern NT contributes to a lack of permanent watercourses and means most temporary watercourses are ephemeral with infrequent high flows during storm events. Watercourses originate where surface runoff discharges into defined channels, converging to form ephemeral rivers.

3.3 Geology and soils

Alluvial sediments and aeolian sand dominate low lying areas of the Proposal. Deposition of the alluvium is likely to have occurred in the early to mid-Cainozoic with the development of various fluvial systems, notably the Finke and Hugh Rivers. During the Tertiary, the persistence of continental conditions established a period of persistent aridity across Central Australia, prompting the development of extensive hard crusts. Ongoing aridity into the Quaternary lead to the development of sand dunes across the south-eastern extent of the basin and ultimately the modern day environment (Lloyd and Jacobson 1987). A more detailed treatise on soil conditions in the Proposal can be found in a previous Soils Investigation Report (Tellus, 2013). The implications of soil type to erosion potential and increased sediment loads in down-gradient watercourses is covered in Section 8.

3.4 Topography and land use

The southern region of the NT, where the Proposal is located, is characterised by rolling hills and dunes, and sand ridges. However, the general area of the Proposal is bisected by a number of orogenic mountain belts (i.e. created by tectonic activity) to the north, east and west. The James Ranges and the Oliffe Ranges, a series of west-east trending ridgelines, rise to 788 m Australian Height Datum (AHD) and 428 m AHD respectively to the north of the project area. These ridgelines lie at the southern edge of the Orange Creek Syncline and are predominantly composed of basement rock. To the east of the project area lies the Rodinga Ranges and the Pillar Range, a series of south-west to north-east trending ridgelines that rise to a maximum height of 350 m AHD. The Charlotte Range and the Maryvale Hills lie directly east of the Proposal and within the proposed surface infrastructure area. These topographic highs interrupt the low lying areas dominated by sand dunes and flood plain deposits. The low lying areas bounded by the surrounding mountain belts consist of series of rolling sand dunes, bisected by a number of large river systems (Figure 3). Figure 5 shows the low lying floodplain comprising alluvial and aeolian sediment and the distinguished Maryvale Hills and the Charlotte Range in the distance.

Figure 5 Vista from the Proposal, looking west, toward the Charlotte Range

The Proposal area is in the locality of the Titjikala settlement within the Rodinga ward of the MacDonnell Shire Council, which provides municipal services to the community. Titjikala is home to Arrernte, Luritja and Pitjantjatjara people with a population of 201 (ABS, 2011). Tellus holds exploration leases over the entire Proposal area, comprising the following exploration leases:

- EL29018;
- EL28900; and
- EL27972.

Adjacent land is associated with pastoral leases PPL1094 (Henbury), PPL1063 (Maryvale) and PPL1090 (Idracowra). Chambers Pillar Historical Reserve lies to the south-west of the Proposal area and a 50 m high sandstone pillar is the main feature (NT Government, 2016). Chambers Pillar and Titjikala attract approximately 6,500 tourists annually. Elsewhere, major land uses are recorded as cattle grazing and Aboriginal land management.

The Proposal area contains 17 different vegetation formations, including woodlands, shrublands, palmlands, grasslands, forblands and an inland salt lake. Forty two different vegetation types occur across the 17 vegetation formations (DLRM 2011). The dominant vegetation type across much of the Proposal area is Hard Spinifex (*Trioda basedowii*), Low Open Hummock Grassland with an open shrubland of Desert Cassia (*Senna artemisiodes* subsp. *filifolia*), Mulga (*Acacia aneura*), Witchetty Bush (*Acacia kempeana*), *Aristida holathera* and *Allocasuarina decaisneana* (DLRM, 2011) (Figure 6).

(a) Trioda basedowii *(b) Acacia aneura*

Figure 6 Proposal area dominant vegetation types

Several ephemeral creeks intersect the Proposal area and are lined by riparian woodlands, comprising:

- River Red Gum (*Eucalyptus camaldulensis* var. *obtusa*) Woodland, containing Coolabah (*Eucalyptus coolabah* subsp. *arida*) with an understorey of Couch (*Cynodon dactylon*), Silky Browntop (*Eulalia aurea*) and Spiny Sedge (*Cyperus gymnocaulos*); and
- Coolabah Woodland, with an understorey of Lignum (*Muehlenbeckia florulenta*), Mulga, Desert Cassia, Water Clover (*Marsiliea* spp.), Couch and Buffel Grass (*Cenchrus ciliaris*).

Given their proximity to waterways, and the presence of River Red Gum and Coolabah, it is likely that these vegetation communities could be partially dependent on the presence of shallow groundwater, derived from surface water infiltrating into the sub-surface zone following rainfall events. Environmental transects at the Tellus hydrographic stations have been completed to track changes in species composition. This information is contained within Chapter 7 of the EIS.

It should be noted that there are no protected aquatic species recorded in the study area (DLRM, 2011). Furthermore, no aquatic / semi-aquatic submersed, floating nor emergent macrophytes were observed during a June 2016 site walkover. Understanding the ecohydrology of ephemeral to intermittent arid-zone river systems is greatly hindered by the paucity of hydrological data describing both individual flow events and the long term flow regimes in particular rivers (Miles *et al*., 2015). It is believed that water quality (see Section 3.5) is a major driver in the compositional changes of many faunal groups and functional processes (Sheldon and Fellows, 2010).

3.5 Water quality

Extremely limited water quality data exists for Finke region in the scientific literature due to the unreliability of surface water flows and the remoteness of the area.

In general, cease-to-flow causes water to retract to a series of connected or disconnected waterholes where water quality is driven by processes such as evaporation, groundwater influence and the concentration or precipitation of compounds (Miles *et al*., 2015). Water quality conditions at a local scale include low dissolved oxygen levels, high temperatures, increasing salinities, hardness, alkalinity and cations (Sheldon and Fellows 2010).

Water quality during flooding flows is driven by the large volumes of catchment runoff. Flooding entrains organic carbon and nutrients from the productive floodplain areas into the river channels to support food webs (Miles *et al*., 2015). A unique feature of some Australian dryland rivers is their permanent high mineral turbidity, which is characteristic of the local geologies and land use (Sheldon and Fellows 2010). This leads to fine clays in suspension even under no-flow conditions (Bunn *et al.* 2006).

4 Field investigation programs

4.1 Existing baseline monitoring programs

Surface water is monitored in the NT, especially in areas of development where water extraction needs to be managed to prevent negative environmental impact. Currently there are around 160 operating gauging stations in the NT. Since the mid-1960s an additional 350 gauging stations were also operated, but these are no longer monitored. Data from current and historic water gauging sites on the DLRM's water data portal (NT Government, 2016). This monitoring network includes the following stations within the study area:

- Finke River South Railway Crossing (station # G0050116); rainfall, water level & stream discharge 1997-present; and
- Hugh River South Railway Crossing (station # G0050115); rainfall, water level & stream discharge 1972-present.

There are other government run open and closed stations on the Finke and Hugh Rivers up gradient of the Stuart Highway.

Tellus have been operating four surface water monitoring stations on Maryvale Station since late December 2013 to collect baseline hydrology information. The hydrographic stations include six automatic water samplers, maximum flow height gauges, cross-section traverses, environmental traverses and simple rain gauges. Site details are provided in Table 1 and locations are shown in Figure 7.

Table 1: Proposal hydrographic station details

Station code	Grid reference		Height (mAHD)	Waterbody type	Storm samples collected
	Easting	Northing			
CS005011	393587	7257170	422	Small creek	1 sample 23/12/2016 2 samples 01/01/2016 3 samples 22/01/2016
CS005012	393584	7257176	419	Small creek	No data
CS005013	393634	7257186	424	Small creek	1 sample 01/01/2016
CS005021	393284	7258550	413	Flood out	No data
CS005031	392436	7258387	408	Flood out	No data
CS005041	390218	7259782	398	Swale sheet flow	No data

In addition, an adhoc grab sample was collected from Chambers Pillar Road Creek and the Finke River on 23/12/2016 and 22/01/2016, respectively.

The samples collected have been analysed for major ions and a metals suite. Datasets on information collected from each station are to be prepared in separate standard hydrographic station reports following completion of additional fieldwork (land surveying and environmental surveys) and receipt of the latest series of laboratory water analyses, collation and assessment of the results of the water analyses and flow data (Ride Consultancy, 2016). At the time of writing this report, these station reports were not provided. It is understood that additional runoff events might have been captured by the stations but these data have not been supplied. Furthermore, it could not be ascertained at the time of writing this report if there is a standard list of analytes to be analysed for these storm event samples. For instance, no turbidity levels / suspended sediment concentrations, maximum flow heights or cross-section profiles have been provided in the hydrographic station dataset supplied.

It is understood that a regional hydrology technical note is in preparation by Ride Consulting with finalisation due upon completion of additional aerial photography commissioned to Ausurv (Ride Consultancy, 2016). This existing data would help to inform the geomorphological impact assessment by characterising cross-section morphology, measuring hydrological behaviour (especially rainfall-runoff dynamics) and quantifying sediment transport.

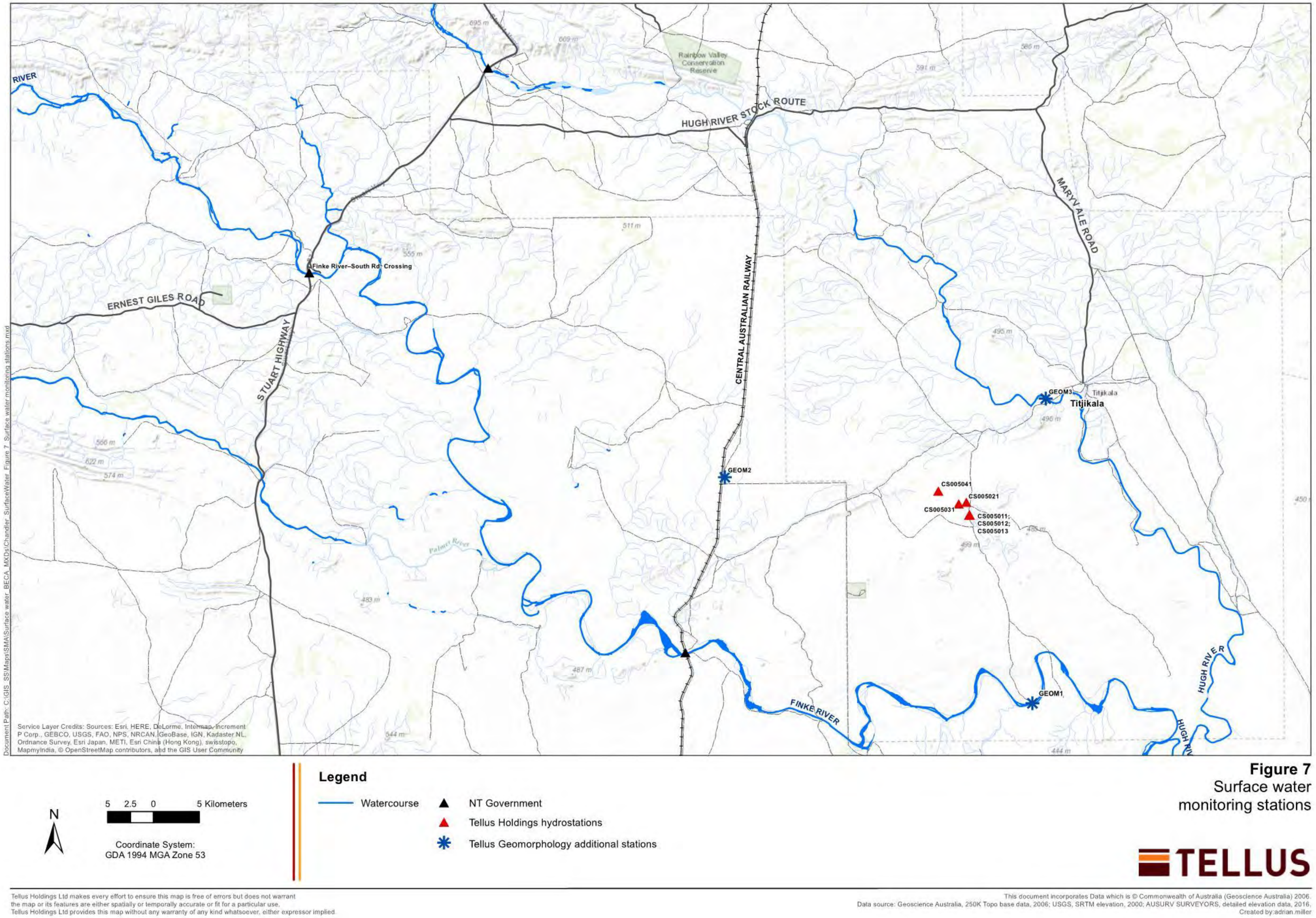

Figure 7 Tellus surface water monitoring stations

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4.2 Desktop gap analysis

Desktop gap analysis was completed in order to identify drainage channels and surface water features relevant to the Proposal prior to site visit and manipulate data collected during the site visit.

4.2.1 Desktop studies prior to site visit

The desktop assessment included the following:

- Review of available literature and data relating to climate / hydrology, geology / soils, geomorphology and vegetation;
- Review of current Proposal baseline monitoring program;
- Review of topographic data to gain an understanding of key watercourse characteristics including bed slope, sinuosity, meander bend characteristics, channel widths / depths; and
- Review of recent aerial photography to identify visible features relevant to watercourse geomorphology.

The findings of the desktop assessment informed the development of a watercourse geomorphology field survey (Section 4.3.1).

4.2.2 Desktop studies following site visit

Metal concentrations are generally higher in <0.063 mm fraction than the bulk sediment fraction. Normalisation is a procedure to correct or adjust contaminant concentrations for the influence of the natural variability in sediment composition; in particular for grain size. In this study, bulk sediment samples have been collected and analysed for metal concentrations and percentage <63 µm grain size. In this instance, a very simple form of normalisation was suitable whereby bulk sediment concentration data (expressed as mg/kg dry weight) was divided by the percentage '<63 µm % passing' (expressed as a decimal) (Simpson *et. al.*, 2013). Bulk metal concentrations for the current dataset can then be compared on a spatial basis in order to evaluate sediment enrichment, independent of differences in particle size in different creeks.

The ANZECC interim sediment quality guideline (ISQG) values for Aquatic Ecosystem Health (ANZECC, 2000) and Queensland guideline reference median range (RMR) values (DoE, 1998) were assessed against both the raw and normalised data. The latter dataset were used in the absence of any NT guidelines. (Table 2).

Table 2: Sediment guideline values to compare to raw and normalized chemical data

Parameter	Sediment guideline values (all mg/kg)			
	ANZECC 2000 ISQG Low	ANZECC 2000 ISQG High	QLD RMR-Low	QLD RMR-High
Antimony	2	25	NS	NS
Arsenic	20	70	NS	NS
Cadmium	1.5	10.0	0.5	1.5
Chromium	80	370	15	240
Copper	65	270	10	64
Lead	50	220	5	20
Mercury	0.15	1.00	NS	NS
Nickel	21	52	5	40
Silver	1.0	3.7	NS	NS
Uranium	300*	600*	NS	NS
Zinc	200	410	29	130

* Reported in Hardford *et. al.* (2013); NS = No standard

The trigger value that was the lower of the two for each parameter was applied when the ANZECC, Queensland guidelines differed. For antimony, arsenic, silver and mercury only ANZECC guidelines were found.

4.3 Additional May 2016 field investigation programs

Site locations for further geomorphological and sediment sampling were shown Figure 7. Sites were located on a representative range of creeks both within and down gradient from the Proposal area where land permissions could be obtained, access was relatively easy and conditions were suitable for sampling. Seven sites were selected where existing hydrographic stations were established (i.e. CS005013, CS005021, CS005031, CS005041) or where hydrographic stations are proposed in the near-future (i.e. GEOM01, GEOM2 and GEOM03).

4.3.1 Geomorphological conditions rapid walkover survey

A baseline geomorphology review was conducted at all seven sites to provide a snapshot of the current geomorphic conditions and capture the various channel types and characterise the main watercourses within the Proposal boundary. RiverStyles™ classification (Thompson et. al., 2005) was used to describe the main channel types identified in the assessment based on valley setting, channel continuity, river planform, geomorphic units and bed material texture.

4.3.2 Sediment testing

Bed sediment sampling was conducted on 16 and 17 May 2016. Antecedent hydrological conditions immediately prior to the sampling event were wet; 53 mm of precipitation was recorded in the Hugh catchment for the two weeks preceding the site visit (NT Gov, 2016). Bed sediment sub-samples were collected at 0, 20, 40, 60, 80 and 100 percentile width increments across the channel using a plastic scoop washed with deionized water to prevent cross-contamination. The six sub-samples were then combined into a composite sample by mixing, double-bagging and sent for the following analysis at a NATA accredited laboratory:

- Electrical conductivity (1:5 soil:water leach);
- Metals suite;
- Moisture content;
- Particle size distribution; and
- Total organic carbon.

Quality assurance / quality control analysis was conducted on these samples including blank testing, duplicate testing and spike recovery. No analysis for nutrients or organic compounds (e.g. hydrocarbons, pesticides) was conducted because no significant sources of these chemicals were anticipated within the surface catchments and the Proposal was not expected to affect baseline conditions.

5 Baseline hydrology

The following section will discuss existing hydrological information surrounding the Proposal, including rainfall and flow patterns, flood statistics and regional inundation observations. As information available on local lower-order channels is sparse, this examination focusses on major river flow records.

5.1 Gauging stations

Table 3 lists relevant stage, flow and rainfall gauging data available in the region surrounding the Proposal area, as provided by the NT Government[1]. Gauge station locations are plotted in Figure 8. Flow records are available for the Hugh River since 1972 and the Finke River since 2004. A gauge station on the Todd River at Alice Springs is included in Table 3 as it matches the duration and coverage of stage and flow records of the Hugh River station. Rainfall data is available for shorter periods, with the longest record (Hugh River) starting in 1994.

Table 3: Flow and rainfall data availability, as of August 2016

Site name	Catchment area	Data type	Availability	Completeness of record	Longest data gap (days)
G0050115 Hugh River at Stuart Highway crossing	3,140 km^2	Stage	May 1972 – current	99.99%	1
		Flow	May 1972 – current	99.99%	1
		Rainfall	Dec 1994 – current	97.9%	93
G0050116 - Finke River at Stuart Highway crossing	7,500 km^2	Stage	Nov 1997 – current	95.0%	308
		Flow	Feb 2004 – current	99.3%	33
		Rainfall	Nov 1997 – current	94.8%	308
G0050140 Finke River at rail crossing	15,100 km^2	Stage	Sep 1987 – current	94.8%	362
		Flow	Nov 2009 – current	99.96%	1
G0050117 Palmer River at Stuart Highway crossing	6,100 km^2	Stage	Sep 1997 – current	67.4%	5.5 years
		Flow	Apr 2010 – May 2016	37.8%	482
		Rainfall	Jun 2010 – current	100%	0
G0060009 Todd River at Anzac Oval (Alice Springs)	443 km^2	Stage	Jun 1972 – current	99.6%	48
		Flow	Jun 1972 – current	80.2%	591
		Rainfall	Jan 2002 – Dec 2010	100%	0

[1] https://nt.gov.au/environment/water/water-data-portal

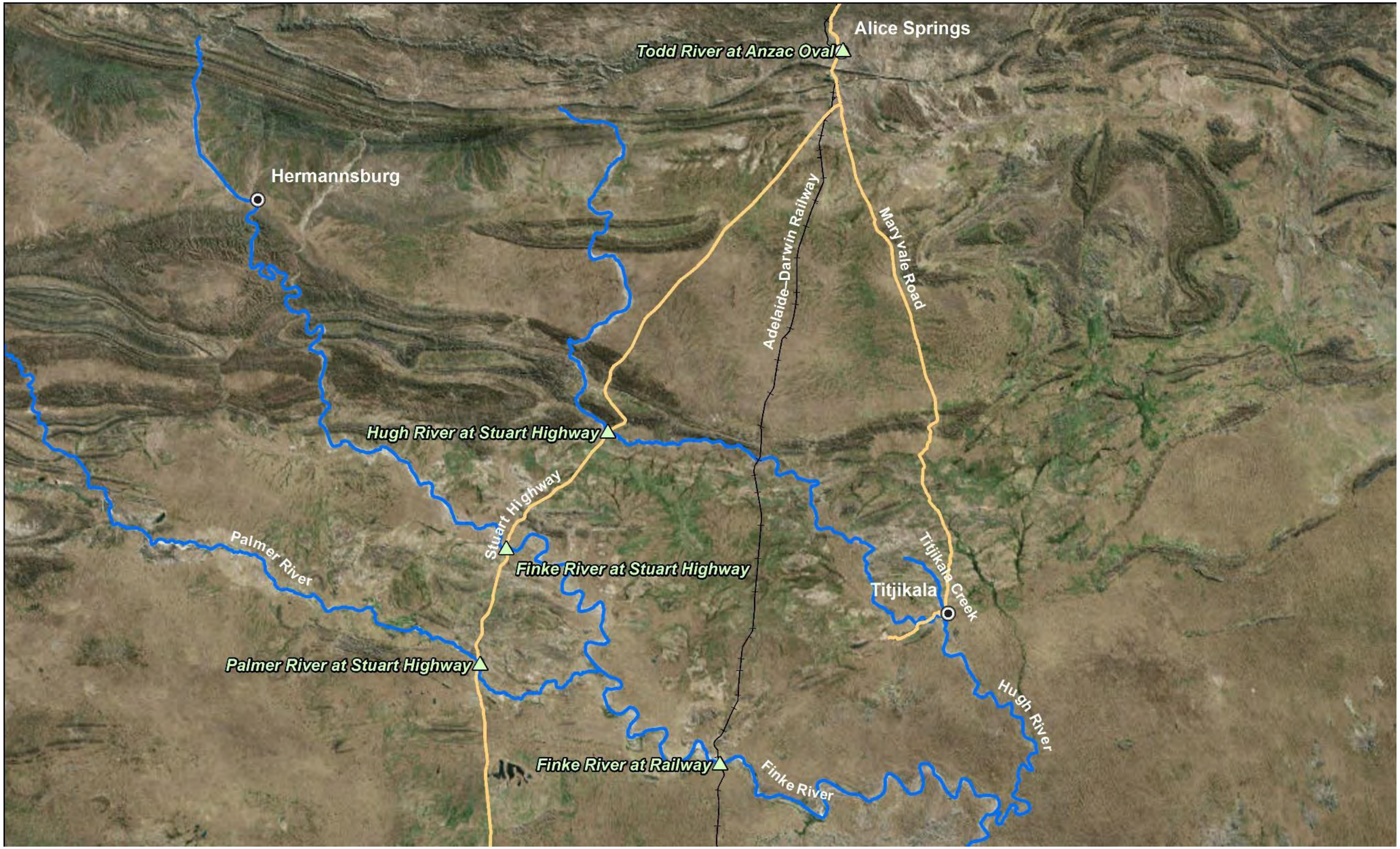

Figure 8: Location of gauging stations listed in Table 3. Aerial imagery sourced from ESRI partners

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5.2 Rainfall characteristics

Figure 9 plots mean monthly rainfall recorded at Alice Springs (BoM, 2016). A dry season spans from April to October, with September the driest month on average. A wet season spans November to March with February being the wettest month. On average rainfall only occurs 3.6 days per month, or 43 days per year. However, daily rainfall in storm events can exceed average monthly rainfall by more than a factor of two, indicating that weather patterns are highly irregular and erratic (Figure 10).

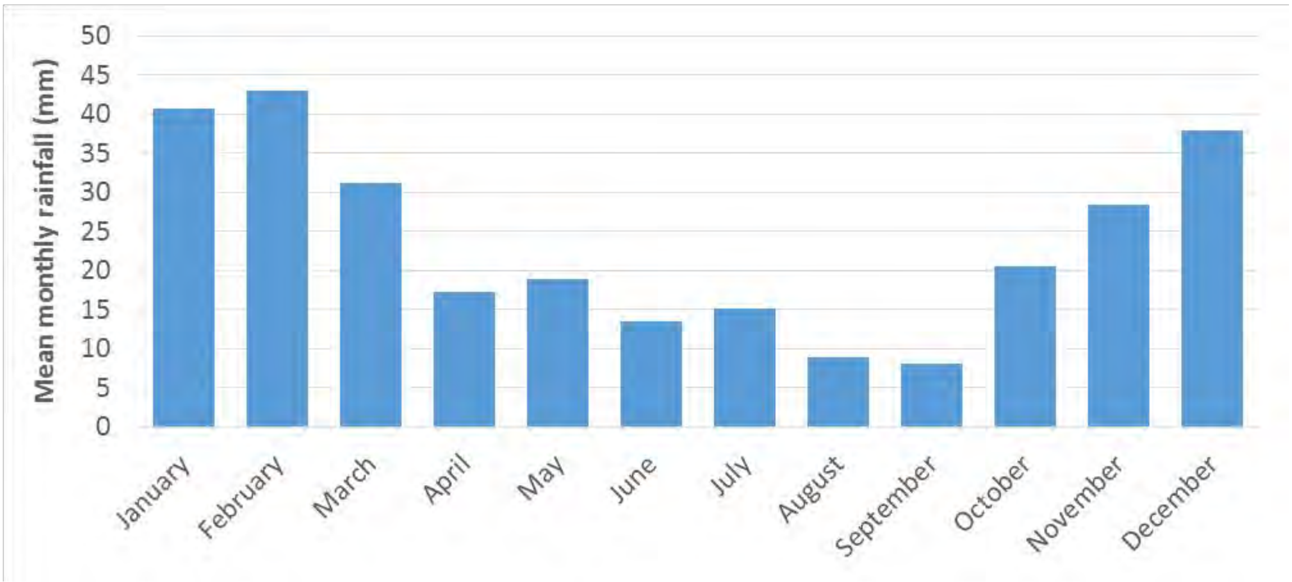

Figure 9: Mean monthly rainfall recorded at Alice Springs Airport

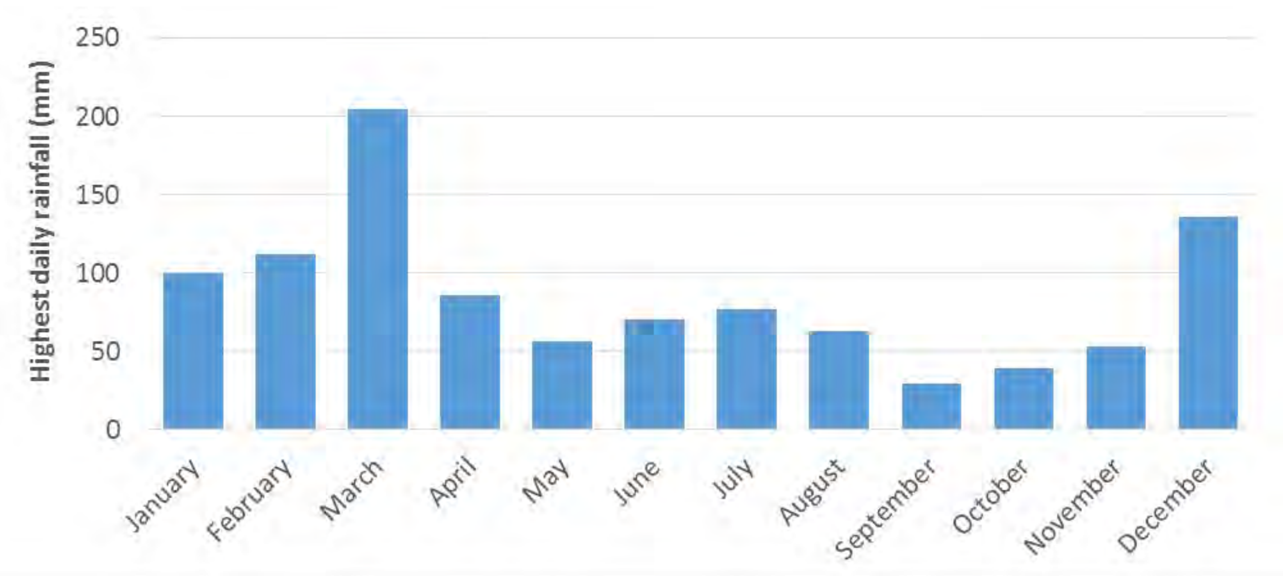

Figure 10: Highest daily rainfall recorded at Alice Springs Airport

5.3 Flow characteristics

Surface water flow is ephemeral in all watercourses in and around the Proposal area, with the Finke, Hugh and Palmer Rivers running dry for long periods of time. Flow events are generally driven by large rainfall systems associated with monsoonal rain depressions from northern Australia or extreme weather caused from cyclonic lows (NT Gov, 2012).

Small flow events occur with annual to bi-annual regularity, often only resulting in a section of each river flowing. This is reflected in flow duration curves (Figure 11), where a flow of 1 m^3/s is exceeded for only 10.4% of the Finke River record and 8.1% of the Hugh River record. No evidence of ongoing baseflow component can be seen in flow records, consistent with visual observations of dry river beds. A discussion of groundwater-surface water interaction is given in Section 9. Low or no-flow (LNF) conditions dominate for approximately 80% of the year on the Finke and Hugh Rivers, and 90% of the year on the Palmer River. *Note that measurement uncertainty at the Palmer and Hugh Rivers prevent identification of flows less than 1.4 and 0.3 m^3/s respectively*.

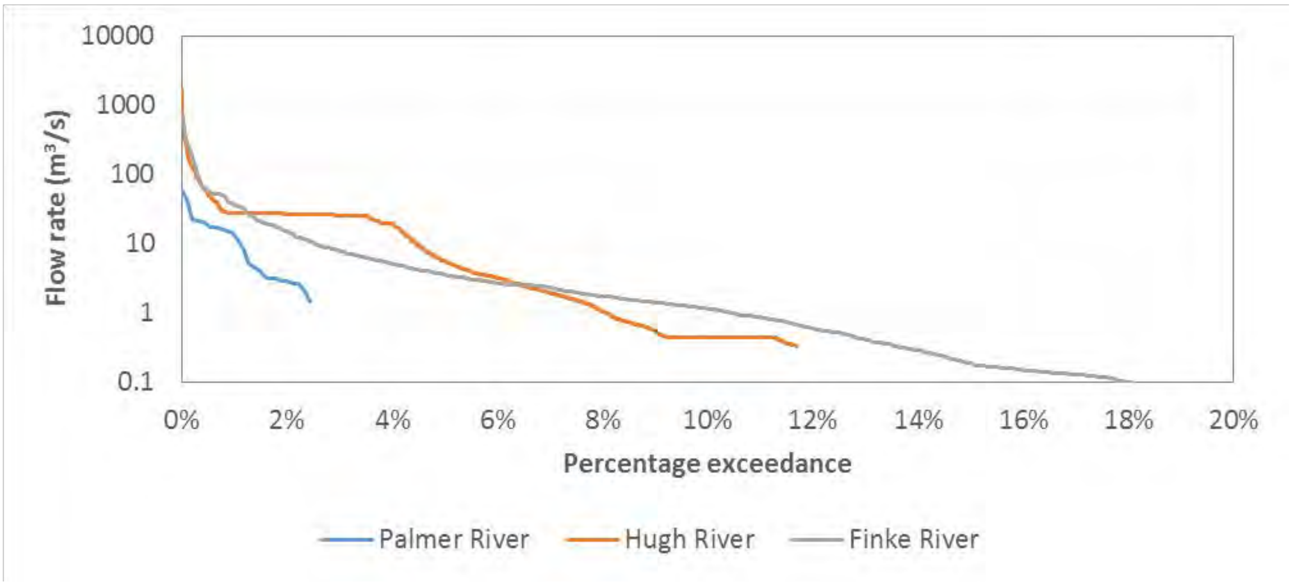

Figure 11: Percentage of flow record in which given average-daily flow rate is exceeded

Larger flow events (anecdotally known as those where a river flows simultaneously along its entire length (NT Gov, 2012)[2]) can result in rivers running for weeks as opposed to days. In February 2000, the Stuart Highway Bridge over the Finke River was submerged for approximately one week (DoIRD, 2003). A decision was made to replace this bridge after it had been submerged under floodwaters 13 times between 1969 and 2003.

Occasionally multiple larger events occur in the same year (such as recorded on the Finke River in 2010 or on the Hugh River in 2000). Table 4 lists flow rates of selected floods measured in flow gauging records for the Finke, Hugh and Palmer Rivers. Note that as these rivers are ephemeral, opportunity to assess rating curves is restricted and therefore large flood flow rates may be of limited accuracy.

The maximum water depth recorded on the Finke River at Stuart Highway was 9.7 m, while on the Hugh River was 6.7m (NT Government, 2016). Channel banks are approximately 5 m and 2 m high, respectively, at these locations. It follows that bank overtopping does occur but relevance to the sections of both rivers

[2] In the case of the Finke River, this refers to the region between its Hermannsburg headwaters through to the flood-out area at Andado, downstream of the Finke township (approximately 100km straight line distance down-gradient from the Proposal area).

closest to the Proposal area are unclear due to differences in bank heights, bed gradient and cross-sectional profile.

Table 4: Flow rate of significant floods, as measured at Stuart Highway gauging stations

River	Date and daily mean flow
Finke River (record starting 2004)	10 Jan 2010 – 755 m^3/s 1 Mar 2010 – 584 m^3/s
Hugh River (record starting 1972)	18 Mar 1983 – 640 m^3/s 31 Mar 1988 – 1,039 m^3/s 17 Jan 1995 – 629 m^3/s 12 Feb 2000 – 1,667 m^3/s 22 April 2000 – 592 m^3/s
Palmer River (record starting 2010)	22 Feb 2011 – 60 m^3/s 2 Mar 2012 – 42 m^3/s

The township of Titjikala is situated adjacent to Titjikala Creek, a tributary of Hugh River. While this creek is usually dry, it has been known to flood to a depth of one metre, effectively turning the town into an island (ABC, 2014). In 2015 a new sewage system was built in Titjikala to address health issues generated when such flooding caused residential septic tanks to overflow (LGANT, 2016).

5.4 Long-term hydrological trends

Figure 12 to Figure 15 plot daily flow hydrographs for the Hugh, Finke, Palmer and Todd Rivers, visually depicting high flow events and record completeness. The timing of many floods are reflected in all four records although the magnitude of response appears to be different in the recent flow record (i.e. last 5 years) between the Hugh River compared to the Finke and Palmer.

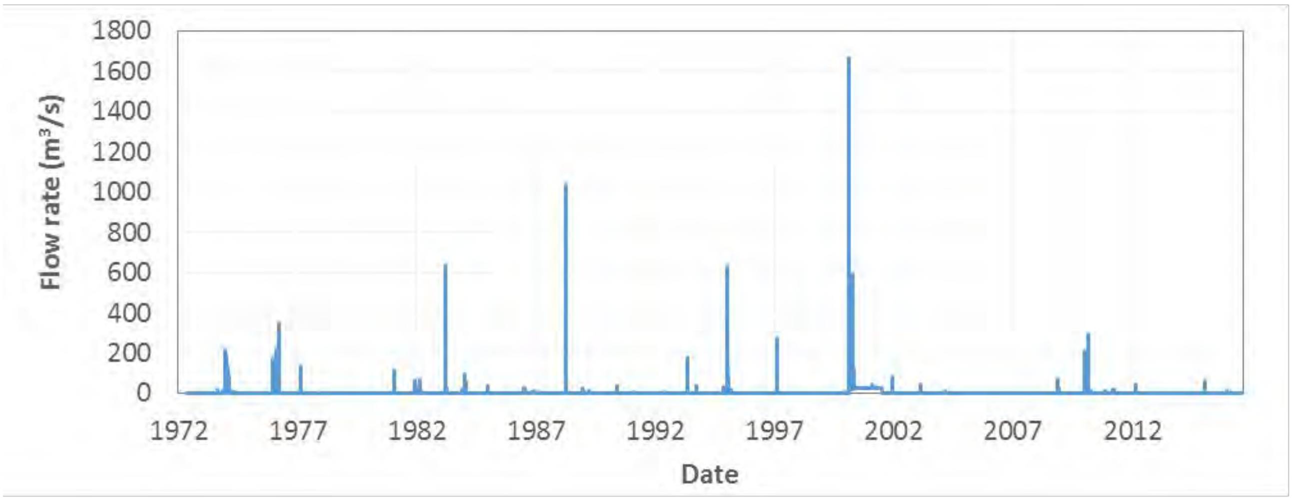

Figure 12: Average daily flow for Hugh River at Stuart Highway

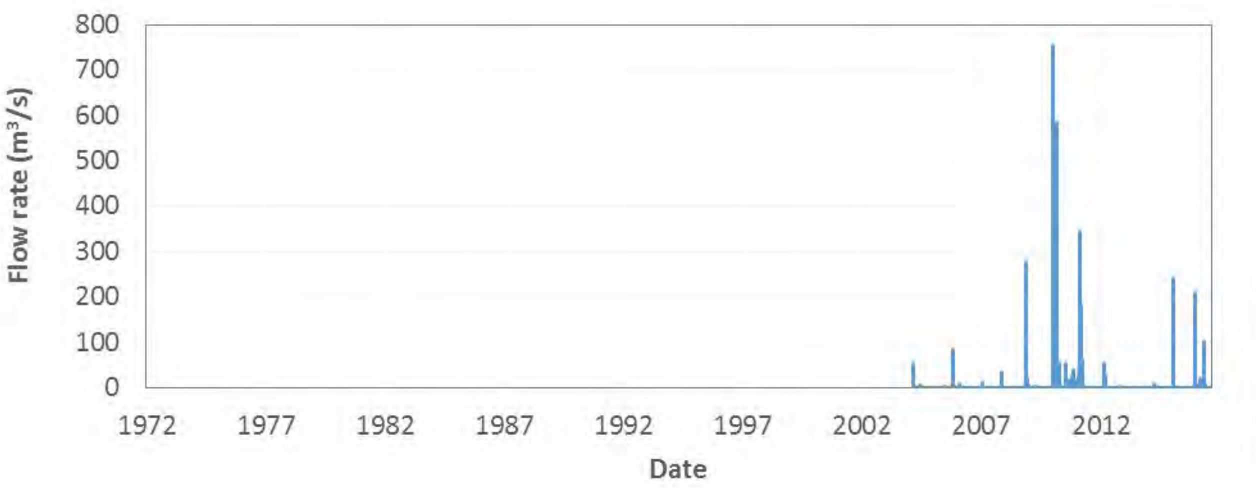

Figure 13: Average daily flow for Finke River at Stuart Highway

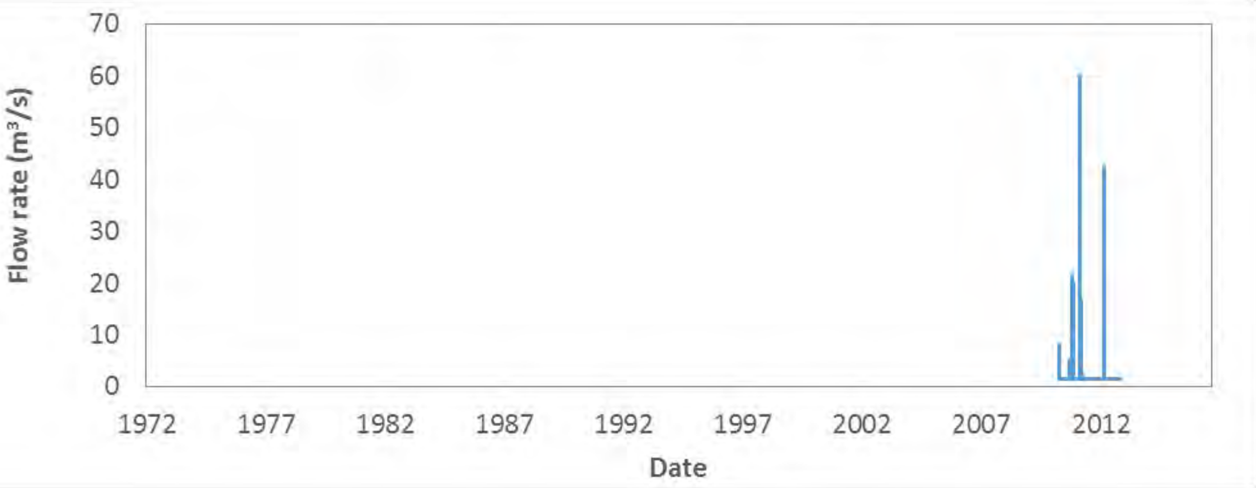

Figure 14: Average daily flow for Palmer River at Stuart Highway

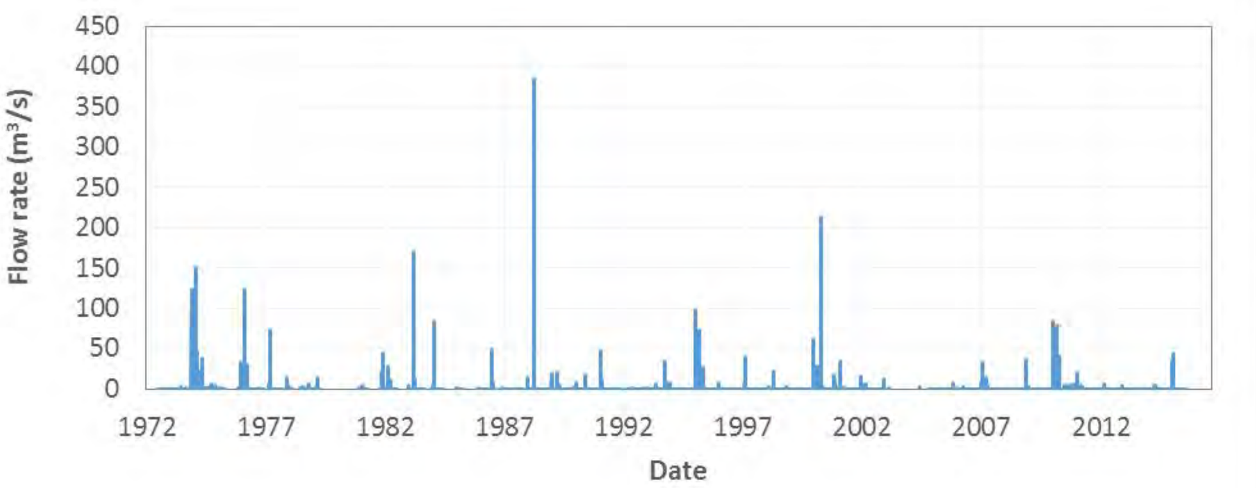

Figure 15: Average daily flow for Hugh River at Todd Oval (Alice Springs)

Annual maximum flood return periods are given in Figure 16 and Figure 17 for the Hugh and Finke Rivers, derived from flow gauging data. Estimated peak flow rates from a GEV distribution fit of this data are given in Table 5 for the Hugh and Finke Rivers.

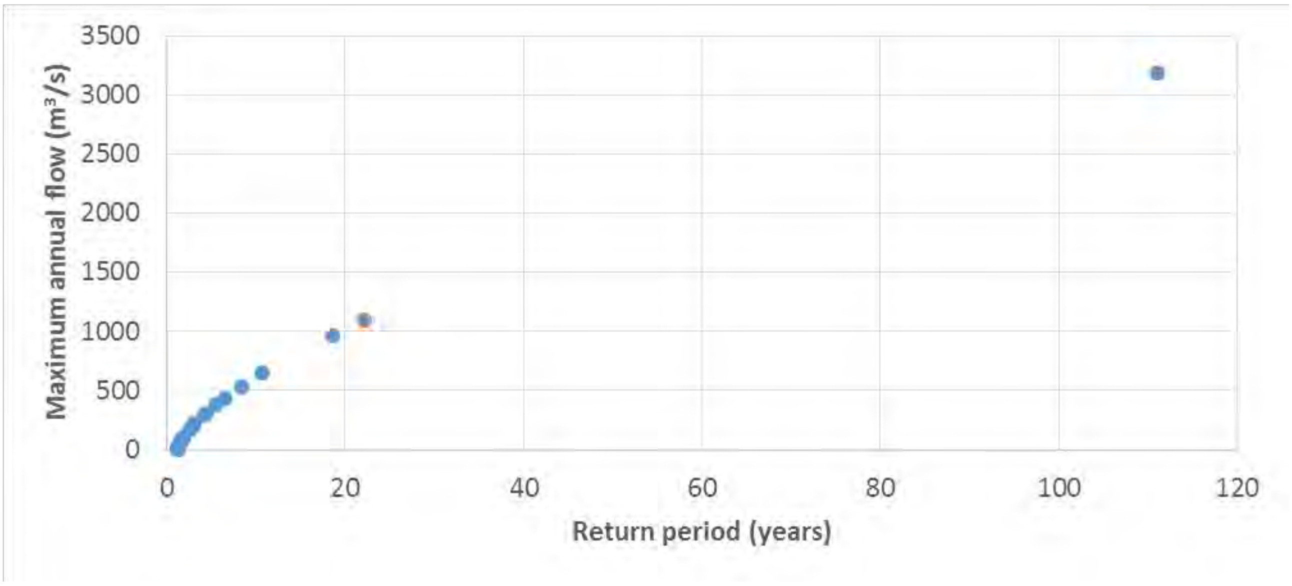

Figure 16: Annual maximum flood return periods for Hugh River at Stuart Highway record, determined using GEV fit

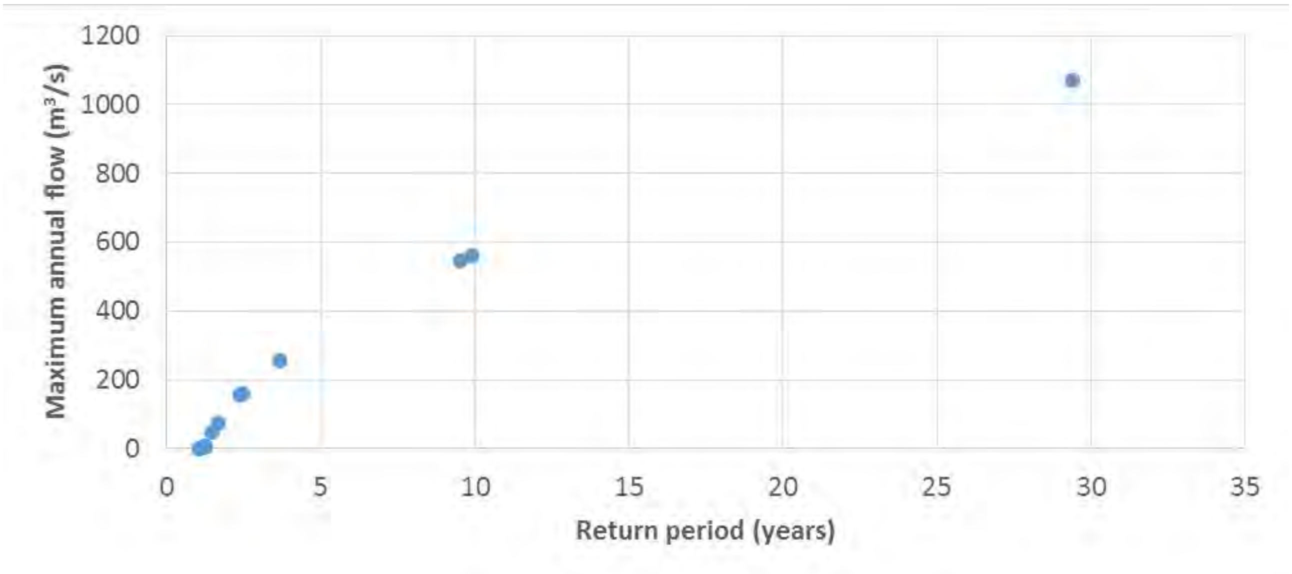

Figure 17: Annual maximum flood return periods for Finke River at Stuart Highway record, determined using GEV fit

Table 5: Estimated flood flow rates, based on GEV fit

Return Period (years)	Hugh River (m^3/s)	Finke River (m^3/s)
500	8140	--
100	2964	2039
50	1894	1430
10	616	565
5	346	340

5.5 Storm hydrographs

Figure 18 and Figure 19 plot storm hydrographs and hydrographs for large flood events on the Hugh and Finke Rivers, respectively. Here 15-minute data has been used instead of daily averages, so as to more clearly render temporal variability and resolve maximum peaks. In both cases, rainfall precedes flow peaks by 2 – 3 days, indicating the significant catchment areas (Table 3). Particularly high rainfall rates (up to 50 mm/hr) are seen in the Hugh River plot of Figure 18. Nevertheless it is expected that rainfall varied significantly across each catchment and therefore and rates measured at the Hugh and Finke gauging stations are not fully representative of the rainfall driving these runoff events.

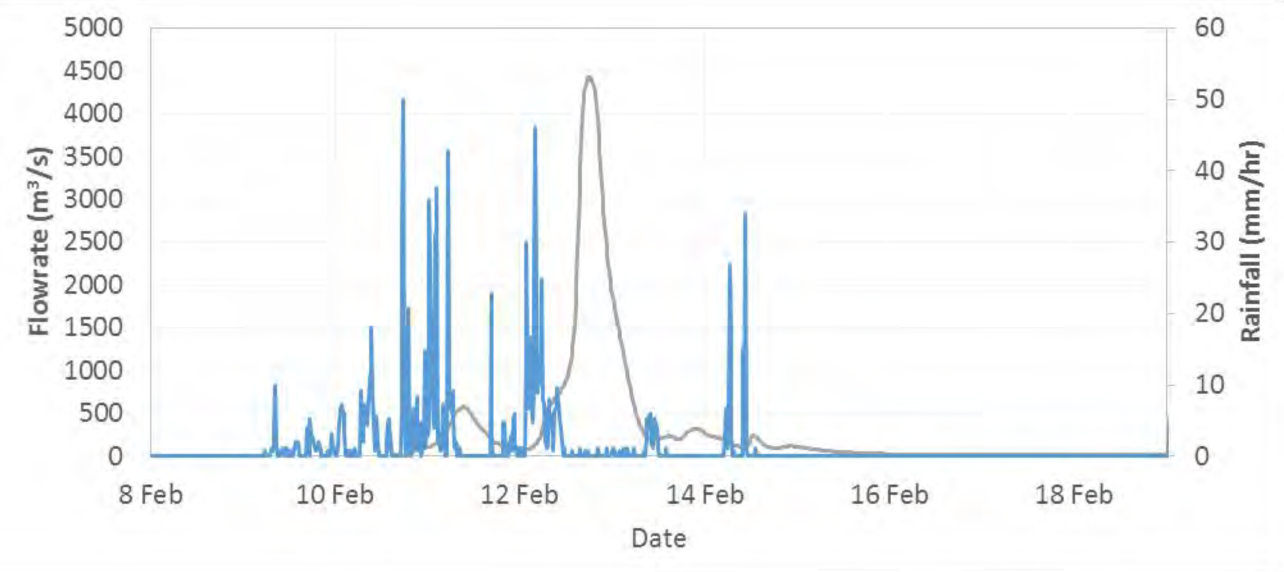

Figure 18: Largest flood event on Hugh River at Stuart Highway record, February 2000

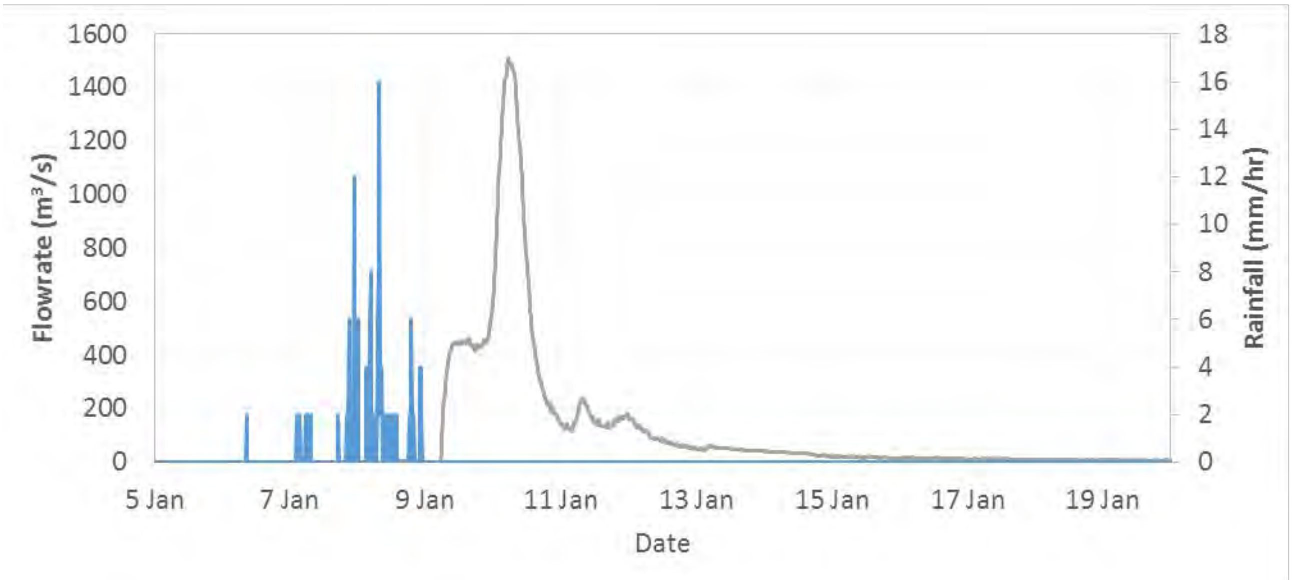

Figure 19: Largest flood event on Finke River at Stuart Highway record, January 2010. Note that flows above 610 m^3/s are based on a theoretical model

Further work on rainfall-runoff relationships is available in the Hydrology technical assessment (Beca, 2016).

5.6 Flood inundation

A method has been developed to estimate areas of standing water from data recorded by the Moderate Resolution Imaging Spectroradiometer (MODIS), an optical instrument on board the Terra and Aqua orbiting satellites (Guerschman *et al*., 2011). Figure 20 plots an average of annual maximum inundation plots from between 2000 and 2015, developed using this method. Brighter colours indicate a greater frequency of water observations. Whilst being of coarse resolution (cells of approximately 475 m by 475 m), this data identifies a number of endorheic basins / clay pans with no outflow where water has ponded for a period of time and equilibrate through evaporation. Within the Proposal area few distinct patterns can be seen, indicating both limited and spatially-varied ponding.

Geoscience Australia (2016) developed a similar dataset, at a higher resolution (25 m), a lower frequency but over a longer period. This data, derived from the Landsat 5 and Landsat 7 satellite imagery archive and known as *Water Observations from Space* (WOfS), presents the percentage of (good-quality) observations on which water was detected between 1987 and the present. It is aimed to better understand where water is usually present and where it is seldom observed. Figure 21 plots the WOfS dataset for the Proposal study area. The Finke River is clearly distinguished, with water detected between 2% and 50% of observations along its length. Higher-observation areas correspond roughly to refuge pools and waterholes. The Hugh River is narrower in width, and so harder to identify in the WOfS data. Water is detected between 1 and 5% in most sections, with occasional segments registering water in 20% of observations. This confirms both flow record interrogation and anecdotal observations that the Hugh River is dry for longer periods of time than the Finke. Water flowing in the Palmer River is generally below the spatial and / or temporal resolution of this dataset.

Scattered ponds in the order of 100 m – 500 m in diameter can be seen across Figure 21, particularly within the sand dune to the west of the Proposal area and the headwaters of Chambers Pillar Road Creek. The only ponding detected within the Proposal area is that of Halfway Dam.

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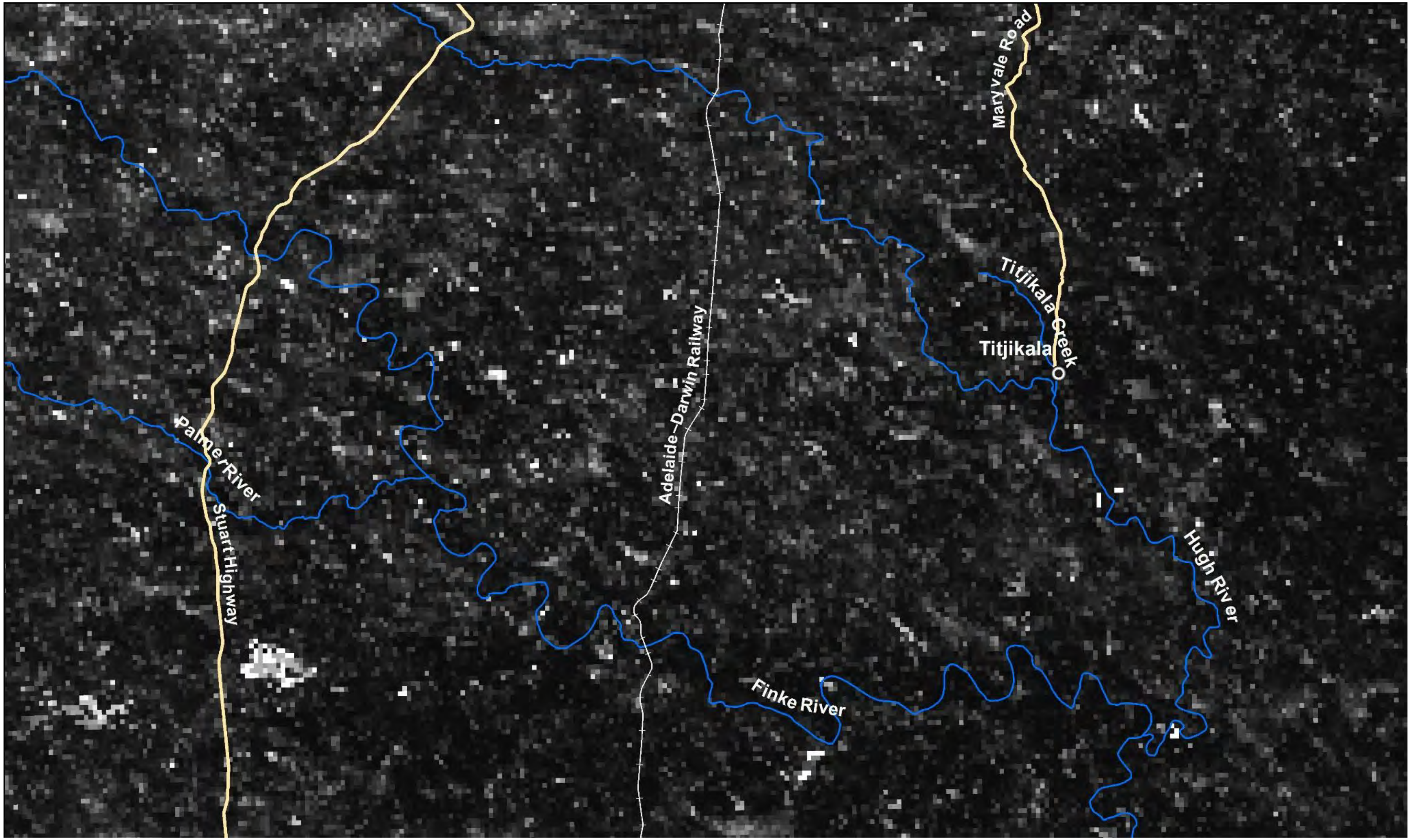

Figure 20: Average of annual maximum inundation from between 2000 and 2015 (ANU, 2016). Brighter colours indicate a greater frequency of water observations.

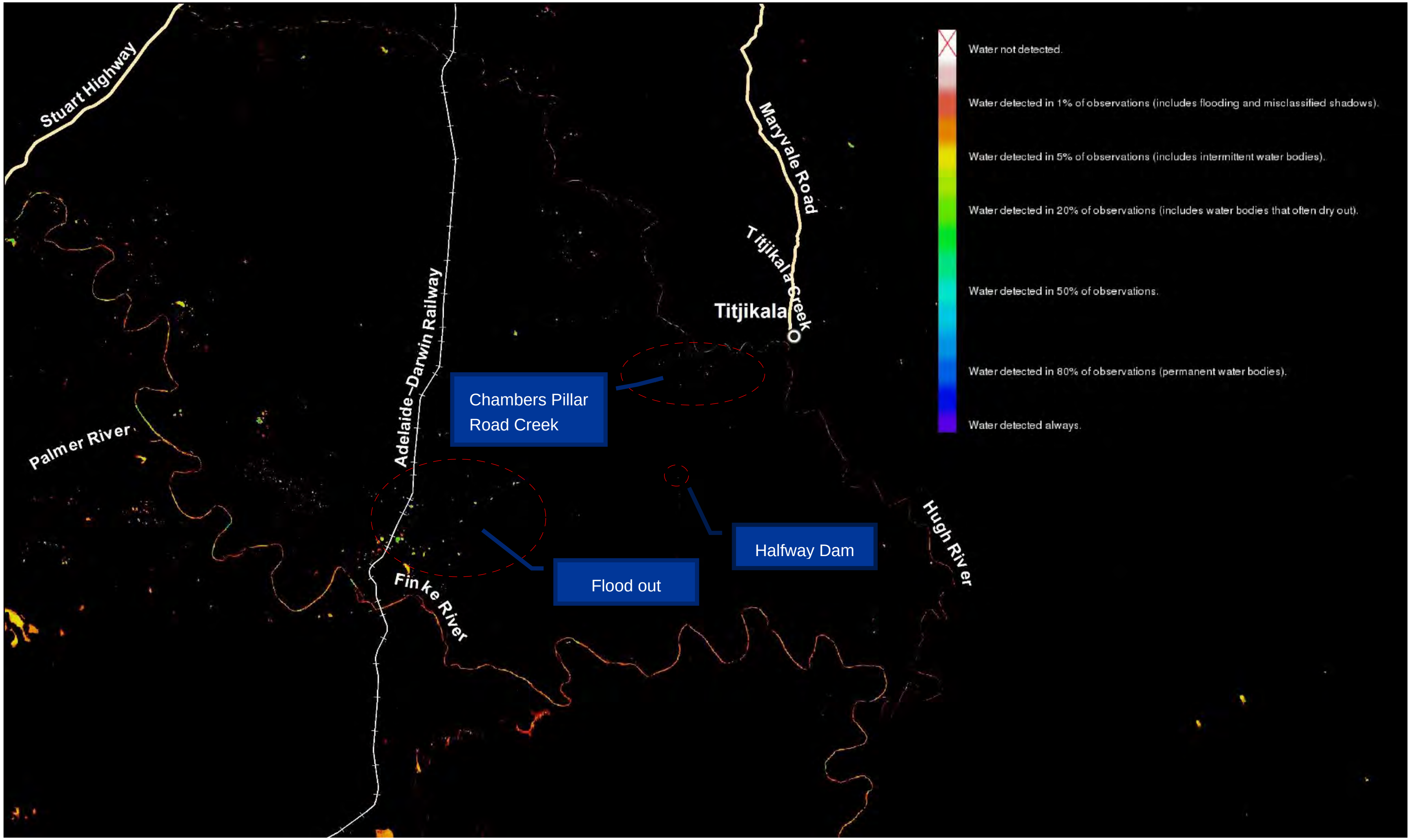

Figure 21: Percentage of good-quality satellite observations in which water was detected between 1987 and 2016. Image taken from GA (2016) Water Observations from Space dataset

5.7 Minor watercourses

Whilst the flow of major rivers surrounding the Proposal is relatively well monitored, local drainage lines immediate to the Proposal area are poorly understood owing to its remote location, temporary nature of the ephemeral waterbodies and lack of land use change over the last century. Channels range from the poorly defined and transitory to well established stream beds, such as those within escarpment valleys. Stream catchments surrounding the Proposal area are generally between 6 and 100 km^2, in contrast to catchment sizes between 3,100 and 7,500 km^2 for the Finke, Hugh and Palmer Rivers at Stuart Highway crossings (Table 3). As a consequence, the storm duration for the critical flow rate events will be shorter, and flooding will be more heavily driven by localised rainfall events.

As with rivers such as the Finke and Hugh, rainfall and evaporation patterns will cause local channels to be dry throughout a large part of the year. In various regions, channels drain across flood plains, providing increased opportunity for evaporation of flow due to the higher surface area to volume ratio. In these areas downstream connectivity is often unclear. Nevertheless, assuming flow patterns are analogous to those observed in river records, flood magnitudes in local channels are expected to be significant.

5.7.1 Watercourse types within the study area

There are six types of surface water present in the Proposal study area, classified according to wetland types after Duid, 2011:

- Major wooded watercourses (type WL2001) most are sandy channels fringed by River Redgum (*Eucalyptus camaldulensis*) and / or Coolabah (*Eucalyptus coolabah*). This includes the Finke and Hugh Rivers.
- Temporary generally dry waterholes (type WL1202) occur along the major Finke River. There is little survey or other data regarding how long individual waterholes last. Semi-permanent waterholes on the Finke River within the study area but outside of the Proposal area include the following:
  - Main Camp Waterhole;
  - Bankhole Waterhole;
  - Attalwaynimma Waterhole;
  - Oodratnamma Waterhole;
  - Arowie Waterhole;
  - Double Garden Waterhole; and
  - Junction Hole Waterhole.

  It is understood that these are not supported by groundwater but rather are refuge pools which slowly evaporate following rainfall events and upstream catchment water delivery. The Hugh River does not contain any waterholes and there are no small creeks, lagoons, or low lying areas within the Proposal area that contain water outside of rainfall event periods;
- Generally dry upland channels (type WU2201) which are ephemeral first-order drainage lines. More detail is provided in Sections 5.7.2 and 5.7.3.
- Small freshwater lakes and clay pans (type B1221). Notable examples include Mulga Claypan and Chambers Pillar Creek linear riverine lakes but it is expected that many more of these features exist in the study area. Clay pans are hard, bare, unproductive areas created from a loss of cover which exposes the soil surface to raindrop impact and erosion (Figure 22). This leads to surface sealing/crusting and water ponding following rainfall (Williams and Biggs, 2010).

Figure 22 Example clay-pan feature approximately 3km east from rail line crossing

- Shrubby / wooded flood prone flats (types F001 / F002) are flood outs receiving present in the Proposal area which are dry most of the time, but infrequent yet sometimes intense rainfall events cause up-gradient arid zone streams to flow for short periods and deliver sheet flow to these areas. They are not wet for sufficient periods to be regarded as a ‘swamp’ or ‘wetland’; and
- Dams across watercourses (type A1001) are man-made surface water held in artificial structures is present both within the Proposal area (Halfway Dam) and in the wider study area (Gypsum, Lookout, North East and Robinson Dams). More information on these features is provided in Section 5.7.4. There are no lakes, artificial swamps or sewage treatment ponds within the Proposal area.

These features are marked on Figure 23. There is no permanent or perennial surface water within the study area. There are no lakes, permanent waterholes, springs or swamps, supported by groundwater when there is little or no rain, present in the Proposal area.

A consequence of the short duration flow events and high evaporation of surface lay water in these headwater catchment is that it is difficult to monitor the events. In the absence of data, the following sub-sections detail anecdotal evidence on watercourse functioning for three specific watercourse features within the study area:

- Maryvale Hills drainage lines and flood out;
- In-line farm dams; and
- Apirnta Creek at rail crossing.

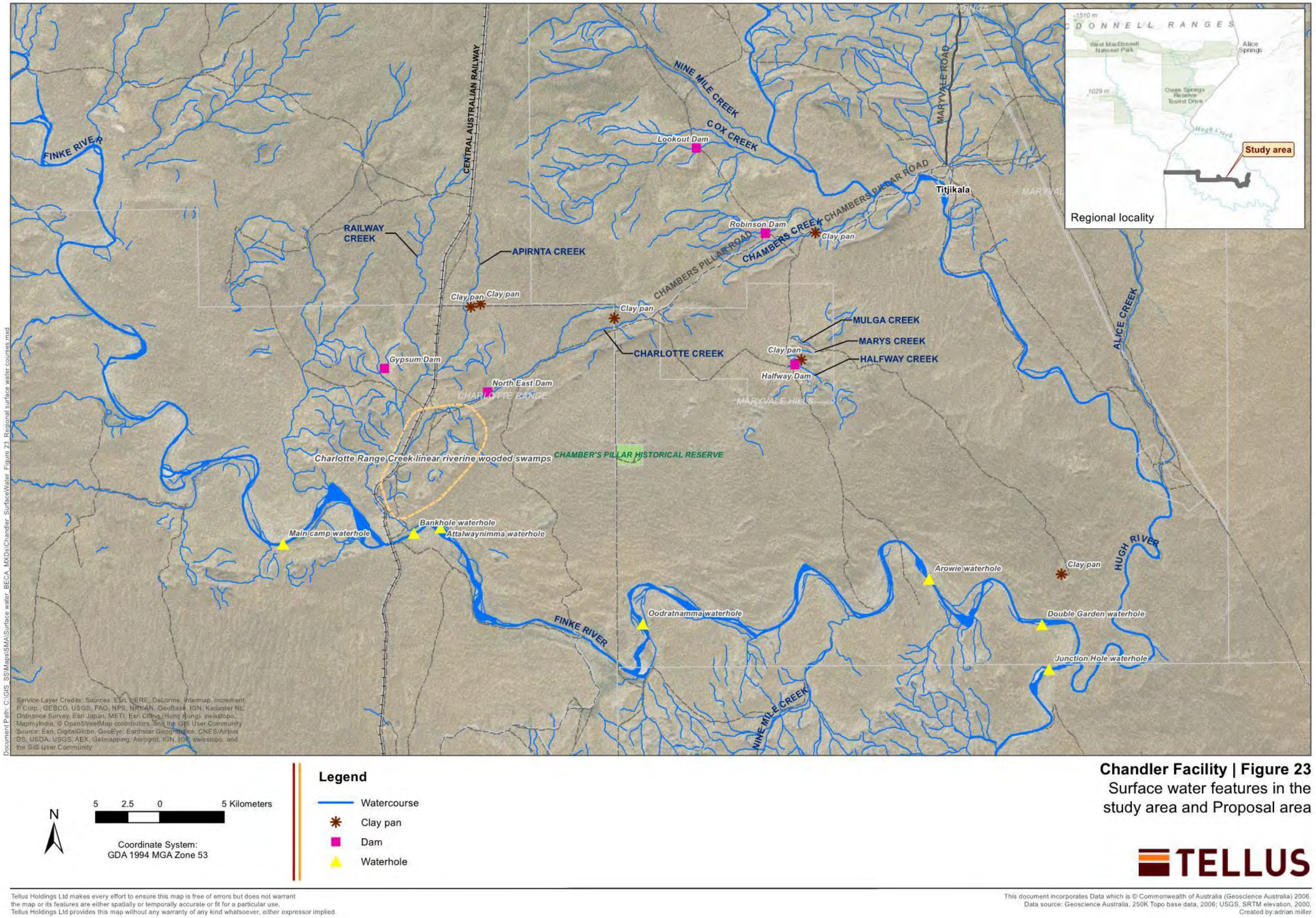

Figure 23 Surface water features in the study area and Proposal area

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5.7.2 Maryvale Hills drainage lines and flood out

The drainage lines coming off the Maryvale Hills to the east of the Chandler Facility are gully like features. They are deeply incised, capable of carrying small to medium angular to sub-angular rocks through the mid slopes and towards the lower slopes and sediment settlement zone. Rocks in the mid to lower slopes are typically 10 cm x 7 cm with some much larger than this. Riparian vegetation in the form of juvenile to mature Mulga, Mature Desert Oak, Salt bush, Cassia and Paper Daisy dominate the banks of the gullies.

Mary's Creek is the largest system of all the gullies followed by Oak Gully with Dingo, Ridey, Roo and Snake Gully all small by comparison and not consisting of a defined channel with banks. The drainage lines all flow westwards off the Maryvale Hills but the stock access road leading to Halfway Dam (and the Tellus camp site) acts as a barrier to westerly flows. Instead of flowing west towards the contiguous flood out zone as topography would have originally dictated, lower flows now tend to flow northeast along the road to an area of depression approximately 500 m northeast of Mary's Creek. A large clay pan lies between Halfway Creek and Roo Gully (refer to Figure 24).

Approximately 1 km beyond the flood out zone, in a north-westerly direction, lies a desert dune and swale system. The swales contain distinct plant community groups dominated by prostrate Daisy's and Millet Grass. The dunes probably act as a barrier to flows from the Maryvale Hill gullies and the plants instead rely heavily on locally sourced water from run-off out of the dunes. Conversely, the dune system also acts as a barrier to flows off the Charlotte Range (in the north-west). The Charlotte Range is located along the entire south section of Chambers Pillar Road. It too acts as a barrier to overland flows and acts as a barrier to flows between the Hugh River and the Chandler Facility.

A more detailed fluvial geomorphology treatise of Mary's Creek can be found in Section 7.1. A conceptual model for the drainage lines originating on the Maryvale Hills is provided in Figure 24.

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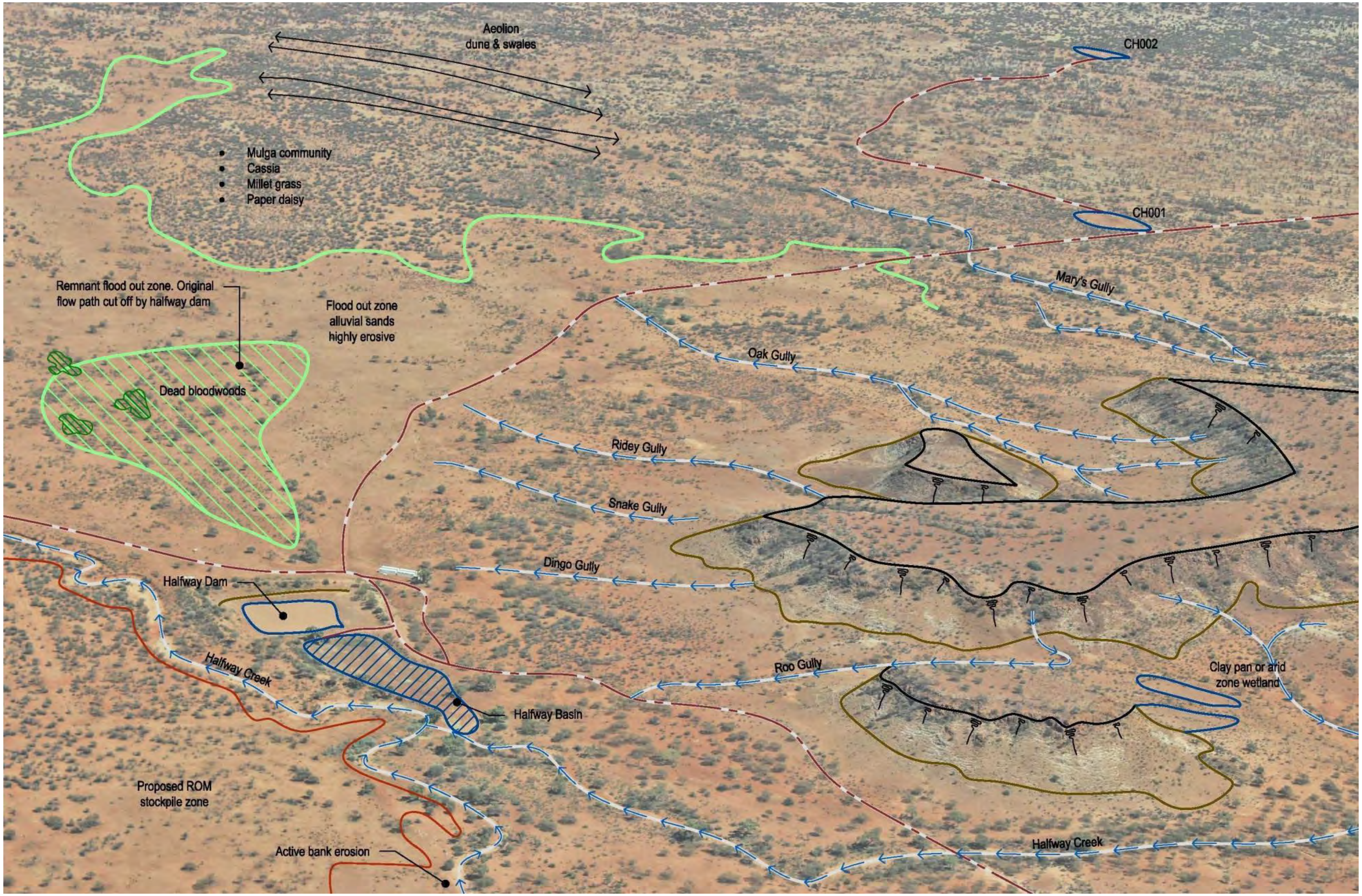

Figure 24 Conceptual model of hydrological functioning in at the Chandler Facility minor watercourses (Tellus, 2016)

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5.7.3 Apirnta Creek tributary rail crossing

Apirnta Creek provides a possible hydrological connection from the upstream catchment to the Finke River system. Apirnta Creek lies approximately 2 km to the east of the Central Australian Railway and drains across the existing access road (soon to be named Chandler Haul Road) at 10 km chainage from the upstream source. It flows towards a railway culvert at 16.5 km and continues in a westerly direction, joining another tributary at 17 km until it flows south and eventually towards the Finke River, some 35 km downstream at the Attalwaynimma Waterhole.

One of the tributaries of the Apirnta Creek flows along the east side of the rail line embankment and crosses the rail line under a 3.3 BRLEN deck culvert at rail chainage reference 1212.238 km (*pers comm.* Peter Taylor, Genesee & Wyoming Australia, 2016). It also receives inflow from the west side of the rail line via twin 700mm diameter circular culverts. This site has significant erosion issues (see GEOM02 Section 7.1). The history of the site is not clear but it appears that the rail embankment concentrates the flow line and an embankment has been placed across the original drainage course, diverting the flow under the rail line.

5.7.4 In-line farm dams

Five in-line drainage dams have been identified, one within the Proposal area (Halfway Dam) and four others in the study area (Gypsum, Lookout, North East and Robinson Dams). Schematics and a brief description of these dams are provided in Appendix A.

5.8 Data limitations and recommendations

It is recommended that flow monitoring sites are established on at least five representative creeks surrounding the Proposal area in order to redress the knowledge gap identified in Section 5.7 and determine hydrological behaviour of lower order drainage lines. In particular, flow monitoring on the following sites would be advantageous for stormwater management design for the Proposal area:

- Apirnta Creek tributary at rail crossing;
- Chambers Pillar Road Creek;
- Charlotte Range Creek;
- Halfway Creek draining west past Halfway Dam; and
- Mary’s Gully.

This information would be used to verify the hydrological and flood modelling provided as part of the EIS (Beca, 2016) regarding flow frequency, duration and magnitude. It would also support interpretation of water quality monitoring data. Anecdotal information on stream flooding extents or the filling, operation and reliability of Halfway Dam would also be helpful.

Available 2 m-resolution LiDAR elevation data currently only extends along the road alignment between the Chandler Facility and the railhead. However, this LiDAR does not extend along the road from the railhead to the Stuart Highway, so flood depths at the Finke River Crossing and other stream crossings cannot be reliably assessed. It is recommended that this data is collected at the next stage of the Proposal which is detailed design.

6 Surface water quality

The following section outlines the investigation into the surface water quality in watercourses within the defined study area and Proposal area (Section 2). This section identifies the uses of surface water and associated water quality objectives / guidelines and then evaluates surface water sampling data collected from both NT government water monitoring stations and Tellus monitoring stations against these guidelines.

There is currently insufficient resolution in any of the surface water quality datasets to discuss temporal trends or make judgements on the biological, chemical or physical drivers influencing water quality change in the study area. The processes governing water quality in similar arid-zone rivers in the region found in the scientific literature were summarised in Section 3.5.

Figure 25 outlines the location of the water quality monitoring stations in the study area and more detailed station details are summarised in Appendix B.

6.1 Beneficial water uses and protection guidelines

Surface water in the study area is minimal due to low rainfall. The watercourses within the study area were identified in Section 5.7.1. The Finke River has waterholes that retract during periods of dry weather but still support both aquatic life and terrestrial biota to some extent. Large floods trigger spectacular booms in biotic production but the periods of no flow are as critical in dictating the biotic assemblages that exist in arid environments. In-situ primary production by benthic algae was found to be the major source of energy supporting waterhole food webs in Cooper Creek during no-flow conditions (Bunn *et al.* 2006). Sustained high turbidity levels limit light availability in many of the dryland river systems.

Benthic algae can only grow where the waterhole bottom is shallow enough to receive at least 1% of the incoming light. Consequently, production is influenced by changes in water turbidity and interactions between water level changes and waterhole morphology. This has led to the ‘bath-tub hypothesis’, whereby highly productive bands of benthic filamentous algae grow around the perimeter of the waterhole in the photic zone.

Nine native fish species occur in the Finke but no surveys have been undertaken in the reaches within the study area. Piscivorous waterbirds have also been observed in the Finke floodout (Duguid, 2011). Finke waterholes provide refuge for terrestrial biota through drought periods including Plains Rat (*Pseudomys australis*), Thick-billed Grasswren (*Amytornis textilis*) and Mongolian Plover (*Charadrius mongolus*). Horses were observed drinking from the Finke during a July 2016 walkover survey (Appendix D).

Dams are used for livestock watering purposes and further information on their structure and functioning is provided in Section 5.7.3. Headwater Creeks are too temporary in nature to be relied upon for any water use. In clay pans, any vegetation that does grow never establishes due to limited water and/or a hostile (arid) soil environment, so the area remains bare (Williams and Biggs, 2010). No other surface water beneficial uses classified according to the NT Government Beneficial Use Categories (i.e. aquaculture, cultural (including recreation), industrial, agricultural irrigation, public water supply, recreation) were found in the area. Water control districts are areas where there is a need for improved management of water resources to avoid overusing groundwater reserves, river flows or wetlands (NT Government, 2016). Beneficial uses have been declared for the Alice Springs Water Control District, approximately 150 km north of the Proposal area.

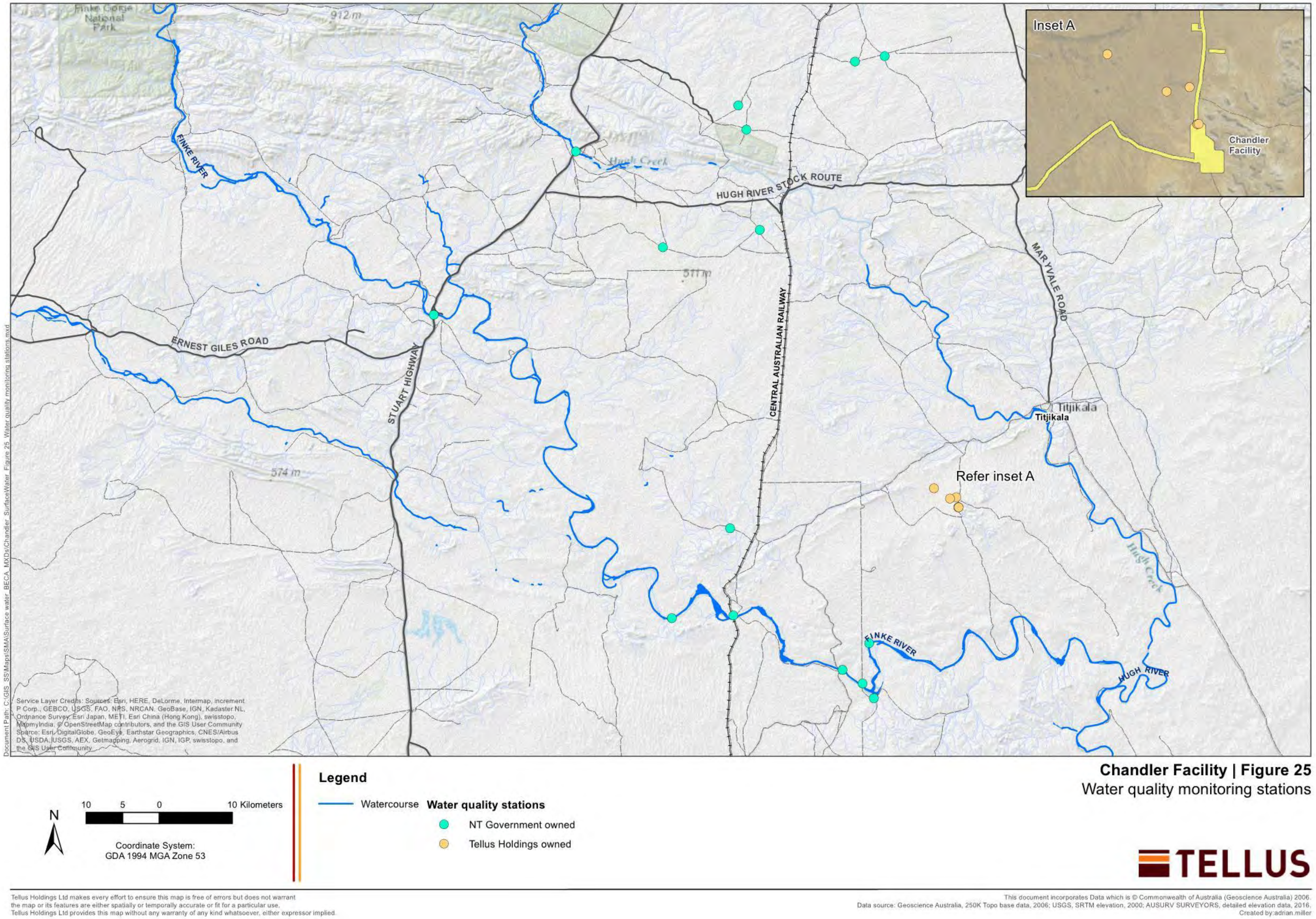

Figure 25 Water quality monitoring locations

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The most appropriate guideline values to compare water quality data against were therefore considered to be national guidelines outlined in ANZECC 2000 Water Quality Guidelines for 2 conditions:

- The 95 % freshwater aquatic ecosystem protection; and
- Primary industries livestock protection.

Adoption of the aquatic ecosystems guideline value was seen as a conservative approach, as the only possible aquatic systems supported in the study area were in the semi-permanent waterholes in the Finke River, which in turn has limited hydrological connectivity to the Proposal. The only sub-catchment linked to the Finke is the Apirnta Creek to the west of the study area. As the study area has a small degree of human activity, the study area ecosystem was classified as slightly to moderately disturbed. A 95 % statistically-based protection level is most commonly applied to these ecosystems, and represent the ‘no significant adverse effect’ guidelines. The objectives of the aquatic ecosystem 95 % protection are to maintain the key ecological processes and diversity as comparable as possible to that of the existing natural habitats within the area.

Chemical and physical indicators (or trigger values) for aquatic ecosystem 95 % protection guidelines are outlined in Table 6.

Table 6: Chemical and physical stressor trigger values for Aquatic ecosystem 95 % protection

Chemical/Physical stressor	Trigger Value
Aluminium (µg/L)	55
Ammonia (µg/L)	6
Arsenic (µg/L)	24
Boron (µg/L)	370
Cadmium* (µg/L)	0.2
Chromium* (µg/L)	1
Copper* (µg/L)	1.4
EC (µS/cm)	20 -250
Dissolved oxygen (%)	90-120
Manganese (µg/L)	1900
Lead* (µg/L)	3.4
Nickel* (µg/L)	11
Nitrate (µg/L)	700
Mercury (µg/L)	0.6
pH	6.0 – 7.5
Phosphate (µg/L)	5
Selenium (µg/L)	11
Silver (µg/L)	0.05
TSS (mg/L)	2-200
Turbidity (NTU)	2-15
Zinc* (µg/L)	8.0

* Site-specific HMTVs were applied to these selected metals based on a hardness correction factor

Good water quality is essential for the livestock production, where contaminates in drinking water can adversely affect animal production. The scope of the guidelines for livestock protection, include biological, chemical and radiological characteristics that may affect animal health. Chemical and physical trigger values for livestock protection are outlined in Table 7.

Table 7: Chemical and physical stressor trigger values for livestock protection

Chemical/Physical stressor	Trigger Value
Aluminium (mg/L)	5
Arsenic (mg/L)	0.5
Boron (mg/L)	5
Calcium (mg/L)	1000
Cadmium* (mg/L)	0.01
Cobalt (mg/L)	1
Chromium* (mg/L)	1
Copper* (mg/L)	1
Fluoride (mg/L)	2
Lead* (mg/L)	0.1
Mercury (mg/L)	0.002
Molybdenum (mg/L)	0.12
Nickel* (mg/L)	1
Nitrate (mg/L)	400
Selenium (mg/L)	0.02
Uranium (mg/L)	0.2
Sulfate (mg/L)	1000
TDS (mg/L)	4000-5000
Zinc* (mg/L)	20

* Site-specific HMTVs were applied to these selected metals based on a hardness correction factor

In Table 6 and Table 7, the bioavailability of cadmium, chromium, copper, lead, nickel and zinc is related to the hardness of the water. If the water found onsite was determined to be hard, hardness modified trigger values (HMTVs) will be developed, as outlined by the ANZECC guidelines, to better represent a site-specific trigger value. The hardness of the water quality data was evaluated against the ANZECC guidelines values outlined in Table 8.

Table 8: Hardness categories for ANZECC guidelines

Hardness Category	Values (mg/L)
Soft	0-59
Moderate	60-119
Hard	120-400

Water quality naturally changes temporally and spatially in dryland rivers. This makes developing and applying site-specific water quality guidelines and trigger levels very difficult for these rivers (Miles *et al*., 2015). One possible solution is to develop guidelines for both the no-flow and flowing phases. This could be done by collecting and interrogating monitoring data and developing conceptual, probabilistic and/or numerical models that incorporate flow, catchment and in-stream influences. Such an understanding would assist in guiding the sustainable use and management of watercourses in the Chandler Facility area, Apirnta area and wider study area. This site-specific system could be developed as part of the Water Management Plan once more data has been collected on site.

The ANZECC interim sediment quality guideline (ISQG) values for Aquatic Ecosystem Health (ANZECC, 2000) and Queensland guideline reference median range (RMR) values (DoE, 1998) were assessed against both the raw and normalised data. The latter dataset were used in the absence of any NT state guidelines.

Table 9 Sediment guideline values to compare to raw and normalized chemical data

Parameter	Sediment guideline values (all mg/kg)			
	ANZECC 2000 ISQG Low	ANZECC 2000 ISQG High	QLD RMR-Low	QLD RMR-High
Antimony	2	25	NS	NS
Arsenic	20	70	NS	NS
Cadmium	1.5	10.0	0.5	1.5
Chromium	80	370	15	240
Copper	65	270	10	64
Lead	50	220	5	20
Mercury	0.15	1.00	NS	NS
Nickel	21	52	5	40
Silver	1.0	3.7	NS	NS
Uranium	300*	600*	NS	NS
Zinc	200	410	29	130

* Reported in Hardford *et. al.* (2013)

The trigger value that was the lower of the two for each parameter was applied when the ANZECC, Queensland guidelines differed. For antimony, arsenic, silver and mercury only ANZECC guidelines were found.

6.2 NT Government water quality data

NT government has several water quality monitoring stations located within the study area. Appendix B outlines the location and details of each station, which are mapped in Figure 25. The water quality samples collected at each NT station were compared against the trigger levels for 95 % freshwater aquatic ecosystem protection (Appendix C, Table 13) and primary industries livestock protection (Appendix C, Table 14).

The following water features included in this analysis are not within the study area but were included to provide an indication of dam / tank water quality due to limited records within the Proposal area dams:

- Dead Bird Tank;
- Dead Horse Dam;
- Four Winds Tank;
- One Tree Hill Dam;
- River Tank; and
- Soakage Dam; and Top Soak Dam.

Water quality in these dams and tanks is likely to be similar to Charlotte Range, Lookout and Robinson Dams (Section 6.1).

6.3 Proposal water quality data

Proposal water quality stations are outlined in Appendix B, as mapped in Figure 25. The data collected from these station were compared against the trigger values for 95 % freshwater aquatic ecosystem protection (Appendix C, Table 15) and primary industries livestock protection (Appendix C, Table 16).

Due to the hardness of the water sample data, hardness modified trigger values (HMTVs) for cadmium, chromium, copper, lead, nickel and zinc were develop as outlined be the ANZECC guidelines. These HMTVs better represent the site-specific bioavailability of these metals in surface water onsite.

6.4 Proposal sediment quality data

The Proposal contaminant limits and triggers levels (Section 6.1) were compared for all five samples collected (Table 10).

Table 10: Comparison of sediment contaminant concentrations to guideline values

Sample code	Chemical concentrations (all mg/kg)										
	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Uranium	Zinc
CS005013	<7	<4	<0.4	4	1	2	<0.1	<1	<1	0.1	2
CS005021	<7	<4	<0.4	9	4	3	<0.1	2	<1	0.2	10
CS005041	<7	<4	<0.4	11	4	3	<0.1	2	<1	0.2	9
GEOM02	<7	<4	<0.4	9	3	3	<0.1	2	<1	0.2	5
GEOM03	<7	<4	<0.4	5	2	3	<0.1	2	<1	0.2	7

Key

< = Less than practical quantifiable limit

Below guideline value/s	Equal to guideline values	Exceeding guideline values

6.5 Water quality findings

At the NT stations, the comparison of the surface water samples with physical and chemical guidelines showed the following:

- For aquatic ecosystem 95 % protection, electrical conductivity exceeded the guideline values. The surface water was found to be hard and the pH samples was either equal to or greater than the pH trigger limits. The dissolved oxygen was only sampled once at station G0050116 and was below the guideline. Total dissolved solid (TDS) was below the trigger values, except at stations G0050119 and G00140 where samples taken exceeded the guideline. Total suspended solids (TSS) was measured once at station G0050115 and exceeded the guideline value. Similarly, turbidity was measure once at station G50050116 and was greater than the trigger values.

- For livestock protection, both calcium and fluoride was below the trigger values required to cause adverse effects in livestock protection. However, nitrate results were above the guidelines. Sulphate was below trigger values, accept where it exceeded the trigger value once at station G005119. The TDS was below the guideline except at sites G0055119 and G0055140.

The Proposal area surface water sample comparison showed the following:

- For aquatic ecosystem 95 % protection, electrical conductivity was below the guidelines at CS005011, CS005013 and CS005021, but exceed the trigger values at CS005060 and CS005071. The water was found to be hard, with pH and turbidity results exceeding the guideline values at stations CS005060 and C005071. TDS and TSS were below the guideline values at station CS005060 and CS005071.

Aluminium, chromium, copper, manganese and silver showed a split across the Chandler Facility water quality data, either exceeding or measuring below the guideline. Arsenic, boron, cadmium, mercury, nickel, nitrate, lead and selenium were lower than the guideline values. Zinc exceeded the guideline value, except at station CS005060 and CS005071. Ammonia was below the guideline value at sites CS005060 and CS005071. Phosphate was equal or greater than the trigger value at sites CS005071 and CS005060, respectively.

- For livestock protection, TDS was below the guideline values for livestock protection at station CS005060 and CS005071. Arsenic, boron, calcium, cadmium, cobalt mercury, nickel, nitrate, lead, selenium and uranium were lower than the guideline values. Aluminium, chromium, copper, manganese and silver showed a split across the Chandler Facility water quality data, either exceeding or measuring below the guideline. Molybdenum and zinc exceeded the guideline value, except at station CS005060 and CS005071. Ammonia was below the guideline value at sites CS005060 and CS005071. Fluoride was below the guideline value across each Proposal area site and sulphate was below the guideline value across all Proposal area sites, except CS005060. Phosphate was equal or greater than the trigger value at sites CS005071 and CS005060, respectively.

From the above results, NT monitoring sites would be suitable for aquatic ecosystem protection, but may have adverse effects for livestock production due to the level of nitrate at these stations. At the Proposal area stations, the results showed split results for several chemical and physical stressors across the station and may be due to the irregularity of the rainfall events in the region. Overall the results, suggest CS005060 and CS005071 would be suitable for aquatic ecosystem protection, but all sites within the area may not be suitable for livestock production, due to the levels of metals within the surface water.

Guideline sediment values were not exceeded for any of the metals tested at any site. Electrical conductivity (1:5 deionised water leach) were low at all sites, particularly CS005013 and CS0041, at 11 and 19 µS cm^{-1}, respectively. Total organic carbon in sediments were also low at CS005013, in addition to GEOM03, at 520 and 890 mg kg^{-1}, respectively. Presumably this was due to the high quartz content present in bed sediments at these two sites. The water management plan will define sediment quality trigger values which will prompt a further investigation into source / activity and mitigation and contaminant limits which should not be breached at any time. It is recommended that sampling be continued at all sites on a bi-annual frequency (i.e. dry and wet season) during construction and operation phases.

7 Fluvial geomorphology

The key objectives of this geomorphology assessment were identified as follows:

- Characterise geomorphological baseline conditions in existing channels;
- Sample and test sediments for physical characteristics; and
- Identify key habitat within the existing channels.

No historic aerial photography was available to compare to the current creek line in order to understand lateral channel migration. Available topographic data was coarse (30m^2) and higher resolution data derived from field surveys was not available at the time of writing this report.

This report summarises information captured during a two-day site visit and subsequent desk-based analysis to provide a robust and transparent approach to fluvial geomorphological impact assessment for the Proposal.

7.1 Geomorphological baseline conditions

Six sites were selected for the geomorphology study based on the following criteria:

- Major watercourses;
- Representative watercourses for the project in terms of type, catchment area and geographical spread;
- Within the likely sphere of influence of the Proposal; and
- Sites with existing data collection as part of the Proposal.

As a result sites CS005013, CS005021, CS005041 (see Table 1 for all three), GEOM1 (Finke River), GEOM2 (Railway Crossing Creek) and GEOM3 (Hugh River crossing near Titjikala) were nominated. The results from both the desktop and site work fluvial geomorphology baseline study are presented below.

The completed templates from the rapid geomorphological walkover assessment are contained in Appendix D.

7.1.1 Stream order

The Strahler stream classification system is a method of classifying waterways according to the number of tributaries associated with each waterway (Strahler 1957). Numbering begins at the top of a catchment where the headwaters of the system start. As the stream order increases the contributing catchment area and channel size also increase. Small tributaries at the top of the catchment are assigned as a first order streams. Where two first order streams join, the waterway downstream of the junction is referred to as a second order stream. Higher order streams are found in the lower parts of the catchment.

All drainage lines within the area surrounding the Chandler Facility are 1st order, with the exception of Halfway Creek (downstream from Halfway Dam), Chambers Pillar Road Creek downstream from Robinson Dam, Charlotte Range Creek downstream from bore # 14288 and Apirnta Creek downstream from the railway crossing which are all 2nd order. The major watercourses in the study area, Finke and Hugh Rivers are >5 order.

7.1.2 Long profile analysis

Gradient have been assessed to assist in the characterisation of major courses. No long profile analysis was possible for CS005041, Finke River, Hugh River and Railway Crossing Creek sites because contours were too coarse (50 m). The long profiles for sites CS005013, CS005021 and CS005031 (contour resolution 2 m) have been plotted for comparison in Figure 26.

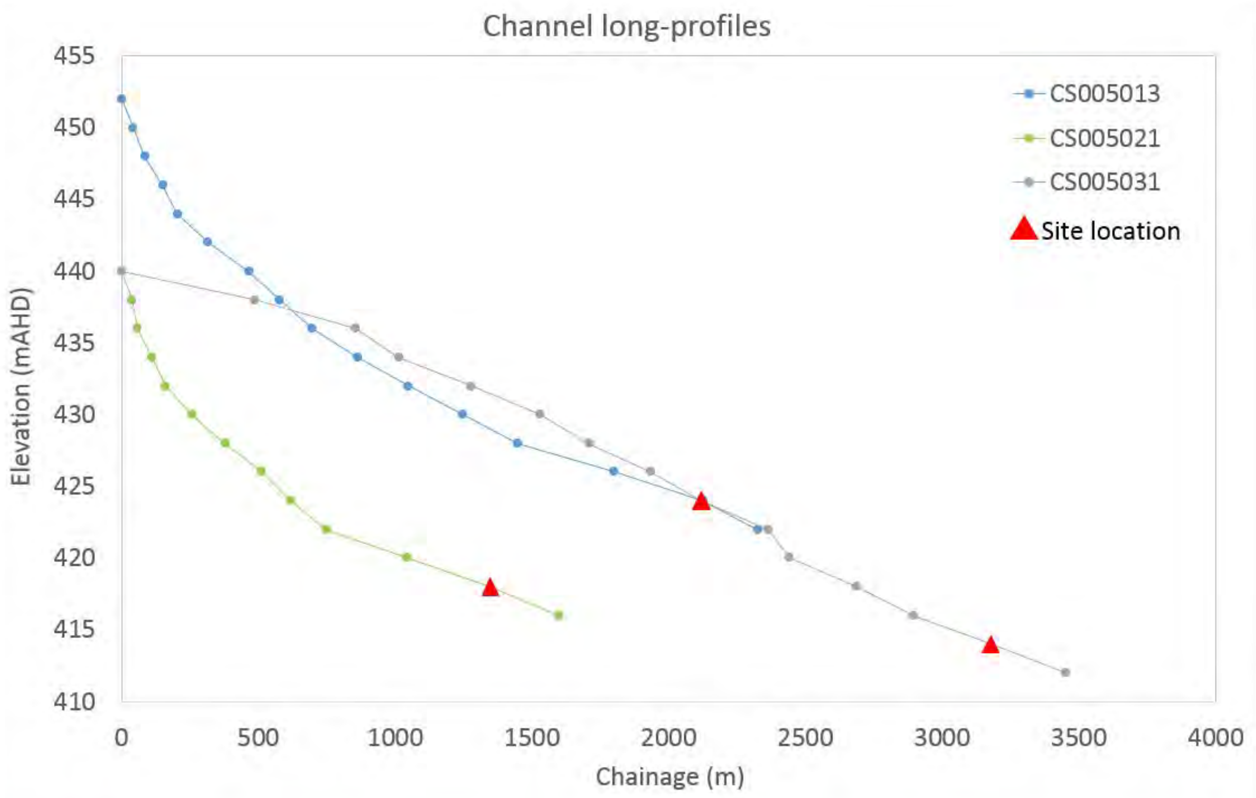

Figure 26: Long profiles of study channels

Typically erosion zones are likely to occur on steep / vertical down gradient sections and deposition zones will occur on flat reaches with little to no downfall. As such, it is clear from these long profiles that all sites would be characterised as depositional environments, although sites CS005013 and CS005021 do have significant up-gradient erosion potential indicated by high gradients in the headwaters.

7.1.3 Channel planform

Sinuosity has been assessed to assist in the characterisation of major courses. The sinuosity derivations have been provided below in Table 11.

Sinuosity is considered low if the degree of calculated sinuosity is between 1.06 and 1.30 and meandering between 1.31 and 3.0 (Brierly and Fryirs 2005). Open drainage lines within the alluvial floodplain show no defined or a discontinuous channel and low sinuosity. Finke River and Hugh River are considered meandering (high sinuosity).

As the majority of the study reaches are headwaters with low sinuosity, characterisation of meander bed characteristics (e.g. wavelength, amplitude, bend radius) was not relevant to this impact assessment.

Table 11: Sinuosity estimates for study reaches

Study reach	Blue line network length (m)	Straight line length (m)	Sinuosity	Description
CS005013	2,125	1,987	1.1	Low
CS005021	1,349	1,266	1.1	Low
CS005041	1,800	1,800	1.1	Low
GEOM01	96,256	42,172	2.3	Meandering
GEOM02	9,860	8,630	1.1	Low
GEOM03	58,805	40,815	1.4	Meandering

7.1.4 Channel cross-sections

Typical cross-sections for sites CS005013, CS005021, GEOM02 and GEOM03 are provided in Appendix D. The Finke River at GEOM01 was flowing at the time of the site visit so a cross-sectional survey was not possible due to health and safety reasons.

7.1.5 Sediment characteristics and transport

Variation in particle size for the five sampling sites are shown in Figure 27. Notable trends in particle size distribution were:

- GEOM02 and GEOM03 had largest particle size with a larger proportion of coarse sands and gravels than other sites. It is postulated that these two sites have higher flow velocities;
- CS005021 and CS005041 had the smallest particle size with the largest proportion of coarse silt and clay than other sites. It is postulated that these two sites have the lowest flow velocities as gradient in the flood out zones are lower and lack of channel form means flow is not constricted;
- No sites contained fine silts;
- Median particle size for CS005013, GEOM02 and GEOM03 was in the 0.15-0.3mm fine sand range; and
- Median particle size for CS005021 and CS005041 was in the 0.075 – 0.15 mm very fine sand range.

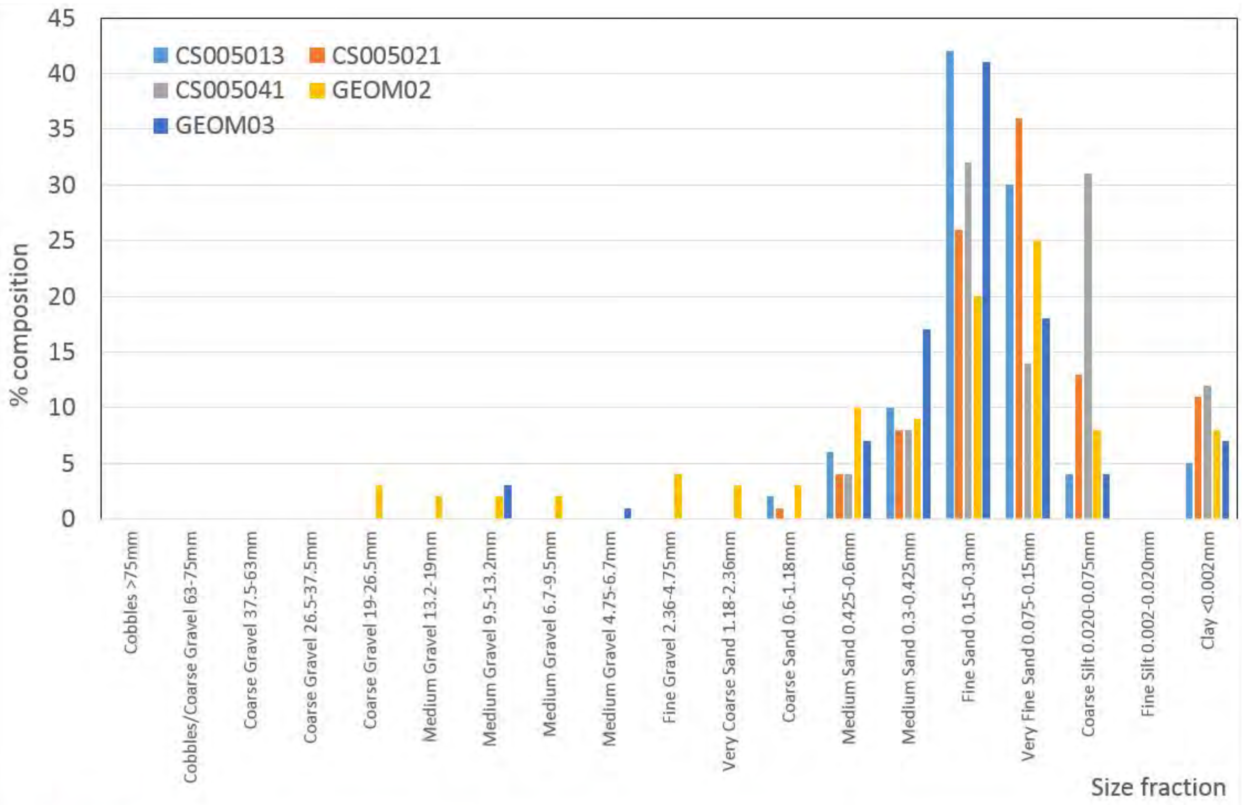

Figure 27: Particle size distributions

7.1.6 Sediment provenance and loads

At the time of writing this report, no flow nor suspended sediment concentration data has been provided for the nine storm samples collected from the surface water monitoring program (Section 4). As such, it is not possible to estimate sediment loads transported down-gradient during storm events.

Furthermore, it is not possible to establish the relationship between sediment size and the velocity regime causing erosion, transportation and deposition of channel material using a Hjulström curve as velocities have not been measured during storm events. What can be concluded from particle size data reported in Section 7.1.5 are the theoretical thresholds for motion of sediments of known sizing. As such, median sediment particle size determined by geomorphology field investigations have been compared in Table 12 to the known velocities (cm/s) controlling movement or deposition of sediments in the study channels.

It is evident that it would be most difficult to deposit and transport sediments at CS005013 and GEOM03 due to the calibre of sediments found here. However, it is easiest to erode sediments at these two sites, conversely, because of a lack of silt and clay content which performs a cohesive function against flow shear stress. It is hypothesised that sediment availability in the study channels is controlled by a combination of rainfall intensity, land cover and grazing pressure. Sediment transport is controlled by channel gradient and particle sizing.

Table 12: Thresholds for movement of study channel sediments

Study reach	Median particle size (mm)	Motion threshold (cm/s)		
		Deposition	Transport	Erosion
CS005013	0.3	<2	2	10
CS005021	0.15	<1	1	12
CS005031	0.075	<0.8	0.8	15
CS005041	0.15	<1	1	12
GEOM01	0.3	<2	2	10
GEOM02	0.3	<2	2	10
GEOM03	0.15	<1	1	12

7.2 Geomorphological classification of watercourses

A description of the River Styles™ types for each watercourse are listed below:

- CS0013 is a low-moderate sinuosity sand bed discontinuous channels. They feature chain of ponds with sand sheets and lateral bar features;
- CS005021 and CS005041 are both flood outs;
- GEOM01 is a fine-grained anabranching channel in an alluvial valley setting; and
- GEOM03 is a coarse-grained anabranching channel in an alluvial valley setting.

The implications of these channel types for surface water geomorphological functioning are that the discontinuous channel is a sediment supply systems in headwater catchments with rapid response to rainfall events. The alluvial valley setting channel at GEOM01 and GEOM03 will act as a sink for sediments, with gradual deposition and channel accretion over time. However, large storm events will move this material further downstream in stochastic ‘slugs’. The Finke and Hugh Rivers are anabranching: sections of the river channel split from the main channel and re-join further downstream. Characteristics of an anabranching river are flood dominated flows and erosion resistant banks (Nanson & Knighton, 1996). Some systems characterised by mechanisms to block or constrict channels trigger avulsion (Nanson & Knighton, 1996). For the Finke and Hugh Rivers the flow can diverge for a large distance before re-joining the main channel. Anabranching river channels are active and are thought to be more efficient at moving water and sediment than a single channel at the same flow discharge (Monroe, 2008). They are expected to have a lower velocity compared to single channels. Therefore, the Finke and Hugh Rivers have more periods of low flows and infrequent periods of high flows as a result of flood events.

7.3 Instream habitat

Geomorphic processes determine the character and distribution of channel form and introduce different ranges of habitat availability in different settings at different flow stages (Brierley and Fryirs 2005). Part of the function of a geomorphological assessment is to identify sensitive habitat that might require special protection from impact.

No refuge pools were observed during the site walkover and it is clear that waterbodies within the Proposal study area are ephemeral, rarely flowing except under extreme wet conditions. Instream habitat is not diverse, with a blanket of coarse sand observed at CS005013 thought to be due to high bedload transport during flow events. Flood out sites have compact sand beds, thought to be a result of deposition of fine sands during sheet flow and gradual evaporation / percolation of waters forming a pan. However, vegetation assemblages associated with the channels / flood-outs are apparent. Low salt tolerant species were observed along the channels, indicating a source of fresh water other than groundwater springs.

Finke River and Hugh River, however, have rich in-channel habitat diversity. The low-moderate sinuosity sand bed stretches will act as conveyance stretches, storing sediments in-between events and supplying them to downstream reaches during high flow conditions. They will probably not provide material in-situ as the channels here are relatively stable. Conversely, the meander bends will provide new material to the channel during high flow events, due to erosion on the apex of the curve facing highest water velocities. The secondary cut-off channels on both the Finke and Hugh Rivers perform an important function during high flow events and subsequent receding flows, providing additional storage capacity to reduce the likelihood of channel overtopping and acting as a fine sediment sink, respectively. Finally, the anabranching channels provide a complex geomorphological function, maximising bed sediment transport (work per unit area of the bed) under conditions where there is little opportunity to increase gradient. These features were located immediately downstream from the apex of meander bends (Appendix A), showing that the bends are a source of new material in the channel and that lower energy conditions downstream allowed subsequent deposition during flow recession forming the separating ridges. Major floods in the Finke and Hugh Rivers will form a laterally active short-lived anabranch.

Large woody debris was observed in the Finke and Hugh River channels, partly sourced from overhanging vegetation but also from further upstream. Bed or bank stabilisation by woody debris has been postulated in previous studies (Erskine *et al*., 2001). In the Finke and Hugh Rivers, formation of semi-permanent log steps did dissipate energy, store bed load. However, due to the non-cohesive nature of the bed sediment and the large velocities predicted during high flow events the presence of large woody debris only stabilised bed profiles on a temporary basis. In fact, scour and increased velocities (as reflected in increased particle size) was noted in the lee of logs and branches deposited within the channel due to creation of roughness.

8 Soil erosion potential

Soil erosion is one form of soil degradation. The erosion of soil is a naturally occurring process on all land. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. Excessive (or accelerated) erosion causes both "on-site" and "off-site" problems. As this is a surface water assessment, this sub-section focusses on the potential for water erosion driven effects to sedimentation of waterways.

8.1 Previous work

Most NT soil-landscapes are prone to water erosion if disturbed (Smith and Hill, 2011). Water erosion occurs when energy from the impact of rain or overland flow breaks up and transports soil. The erodability of a soil depends on inherent soil characteristics, such as structural stability and infiltration rate (Dilshad, 2007). The greater the structural stability of a soil, the greater is its resistance to being broken down by raindrop splash and overland flow. In addition, if it has a high infiltration rate, more water can percolate in the soil per unit time, which minimises shallow surface flow.

8.1.1 Soil mapping

The Northern Territory Natural Resources Map (NT Government, 2015) shows that the study area is dominated by two soil types: Aeolian sands (soil type code Qs) over the flood-out and dune areas and Alluvial Gravel, Sand and Silt (soil type code Qa) along drainage line and creek valleys (Figure 28). A small parcel of Conglomerate Sedimentary soil (soil type code Qc) is present on the northern fringe of the Charlotte Range.

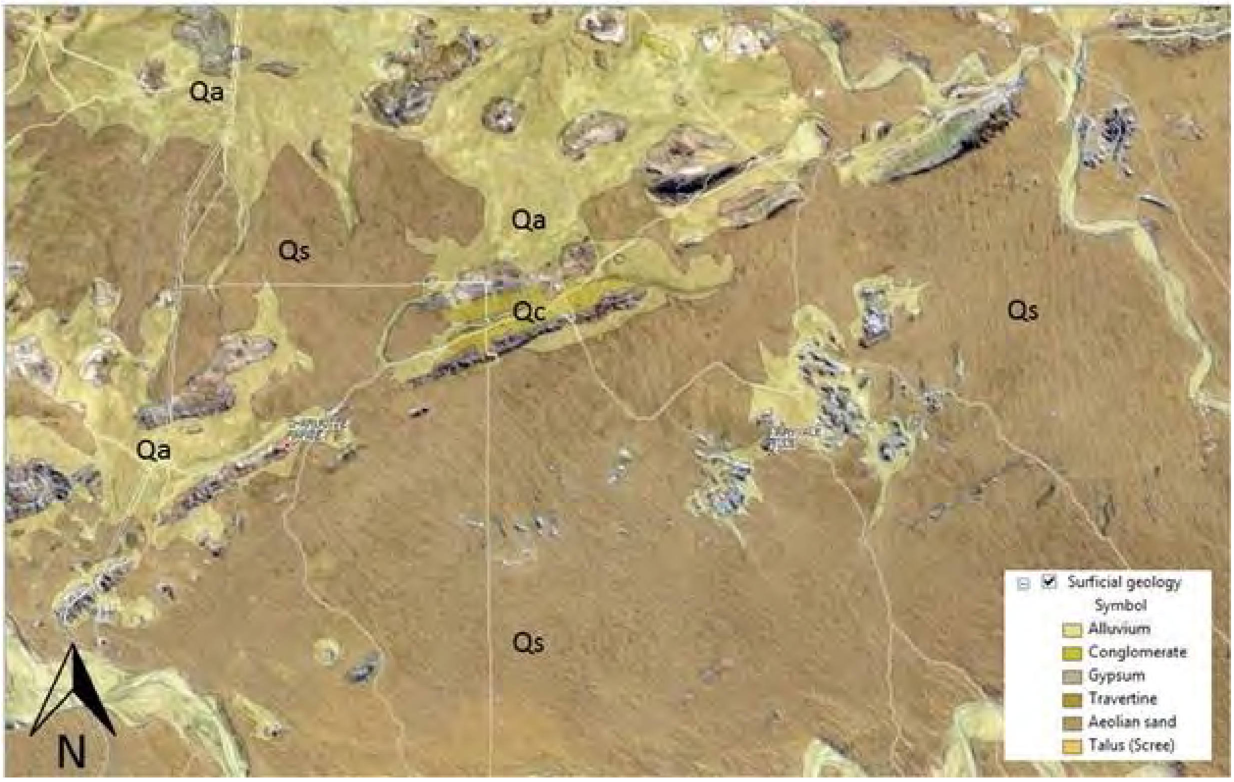

Figure 28 Surficial geology in the study area

8.1.2 Soil survey

A soil survey was undertaken in September 2013 (Low Ecological, 2013). The spatial extent of the survey was limited to eight locations within the EL29018 area to the west of the Maryvale Hills. This area is characterised by low gradients. The soils in the exploration lease EL29018 fall within soil classes B43 (Rudosols), Nb19 (Sodosols), Nb25 (Sodosols) and LD1 (Calcarosols). The site survey found that B43 dominates the investigation sites within project area EL29018. Localized water erosion was occurring at sites CNP03, S11-grasslands and S08 indicating a potential for further erosion with disturbance. Linear structures within the sand dunes and hill slopes which were present across EL29018 will have the potential to cause erosion. The drill site soils (CNP01, CNP02 and CNP03) have high rainsplash protection due to generally high soil cover (30-50%) with moderate below ground contributions (10-20%) from basal and canopy cover. The ground is also covered with more than 10% to 50% litter. S04, S08, S10, and S11 have less ground protection and would be more susceptible to erosional forces.

8.2 Erosion hotspot model

Previous work has not covered erosion risk over the entire study area in sufficient detail. To assess erosion potential for the entire study area, a bespoke Erosion Hotspot Model was created (adapted from Evans *et al*., 2006). More details on how this model were generated can be found in Appendix F. A raster layer map was produced in GIS platform to display these erosion risk classifications visually with different colours representing different erosion potentials within the study area (Figure 29).

The mapping shows that in general the east of the study area incorporating the Proposal area to the west of Maryvale Hills, Halfway Creek catchment, Chambers Pillar Road Creek have negligible, slight or low erosion potential. Conversely, the mapping shows that the west segment of the study area incorporating Apirnta Creek, Charlotte Creek and the rail line have low or intermediate erosion potential. Areas of high erosion potential are generally grouped along creek / river lines reflecting hydrological connectivity and increased risk of sedimentation issues. Very high erosion potential cells were in the upper catchments of these drainage lines, demonstrating the influence of lower ground cover and steeper slopes as well as hydrological connectivity.

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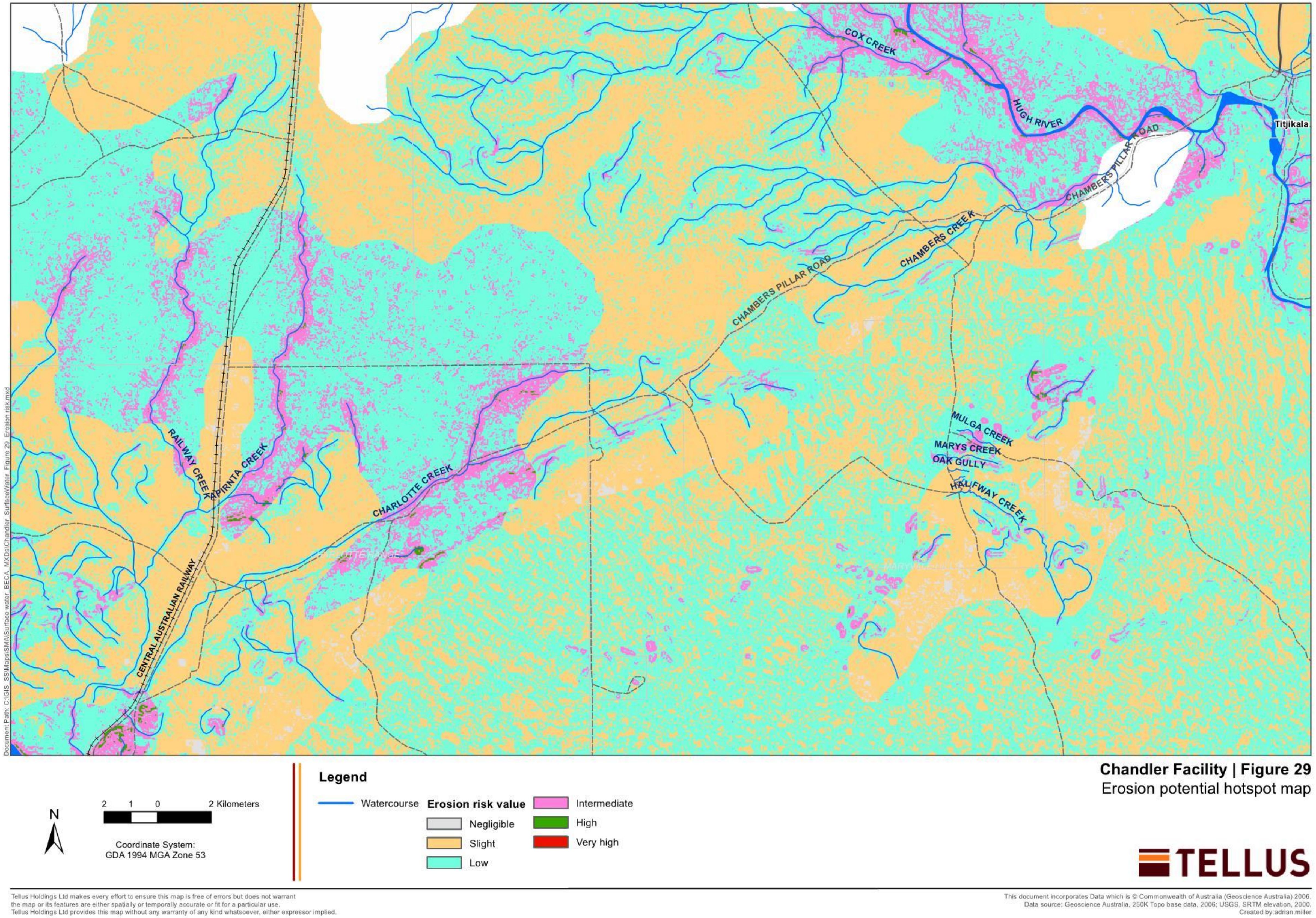

Figure 29 Erosion potential hotspot map

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9 Groundwater-surface water interactions

Surface water – groundwater interactions in the study area are most likely confined to ephemeral river recharge occurring 'in channel' through the base of the river bed and does not encompass any localised recharge that results from overbank flooding (Love *et al*., 2013). Although flow events in arid-zone rivers are often anecdotally referred to as 'floods', overbank flooding along the recharge reach of the Finke and Hugh Rivers are relatively rare due to the significant width and defined channel structure of the rivers.

The Finke River recharge zone has been recognised as commencing approximately 6 km west of the Finke Community and terminating 36 km downstream near the margin of the confining beds, covering an area of approximately 13 km^2 (Love *et al.*, 2013). This is approximately 100 km straight line distance down gradient from Titjikala. Observational evidence indicates that further connectivity between surface water and alluvial groundwater resources may occur throughout the length of the Finke River downstream of the recharge zone (Duguid, 2011).

Groundwater recharge rates previously estimated for the study area suggest very limited inflow of surface water into the groundwater system of 1mm/year (URS, 2012). Anecdotal evidence suggests that heavy rainfall in topographic highs within the Chandler Facility does result in sub-soil infiltration but that this water is expressed as return flow to existing gully/creek lines further down-gradient.

A detailed treatise of surface water-groundwater interaction is beyond the scope of this study and more information is provided in the groundwater baseline report.

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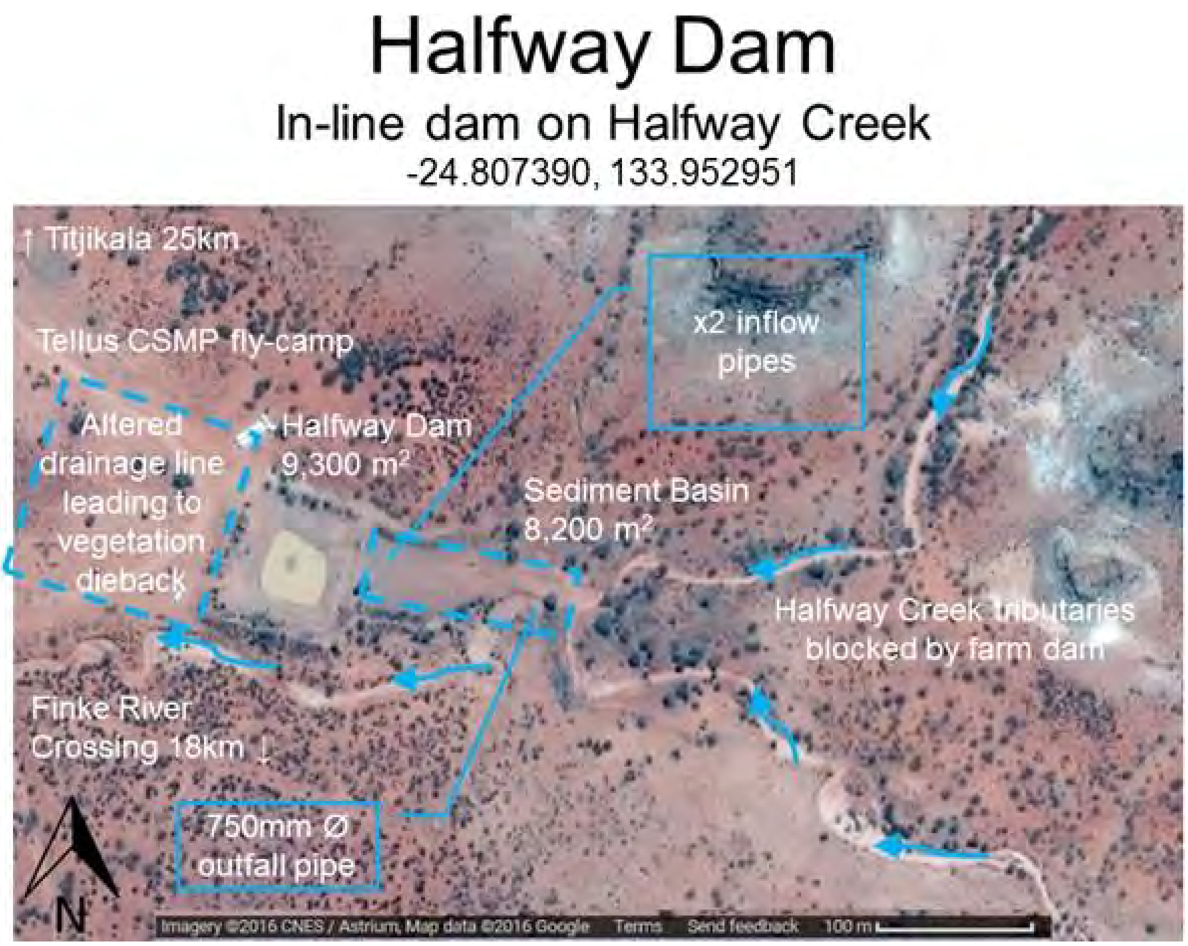
Appendices

Appendix A – Dam descriptions

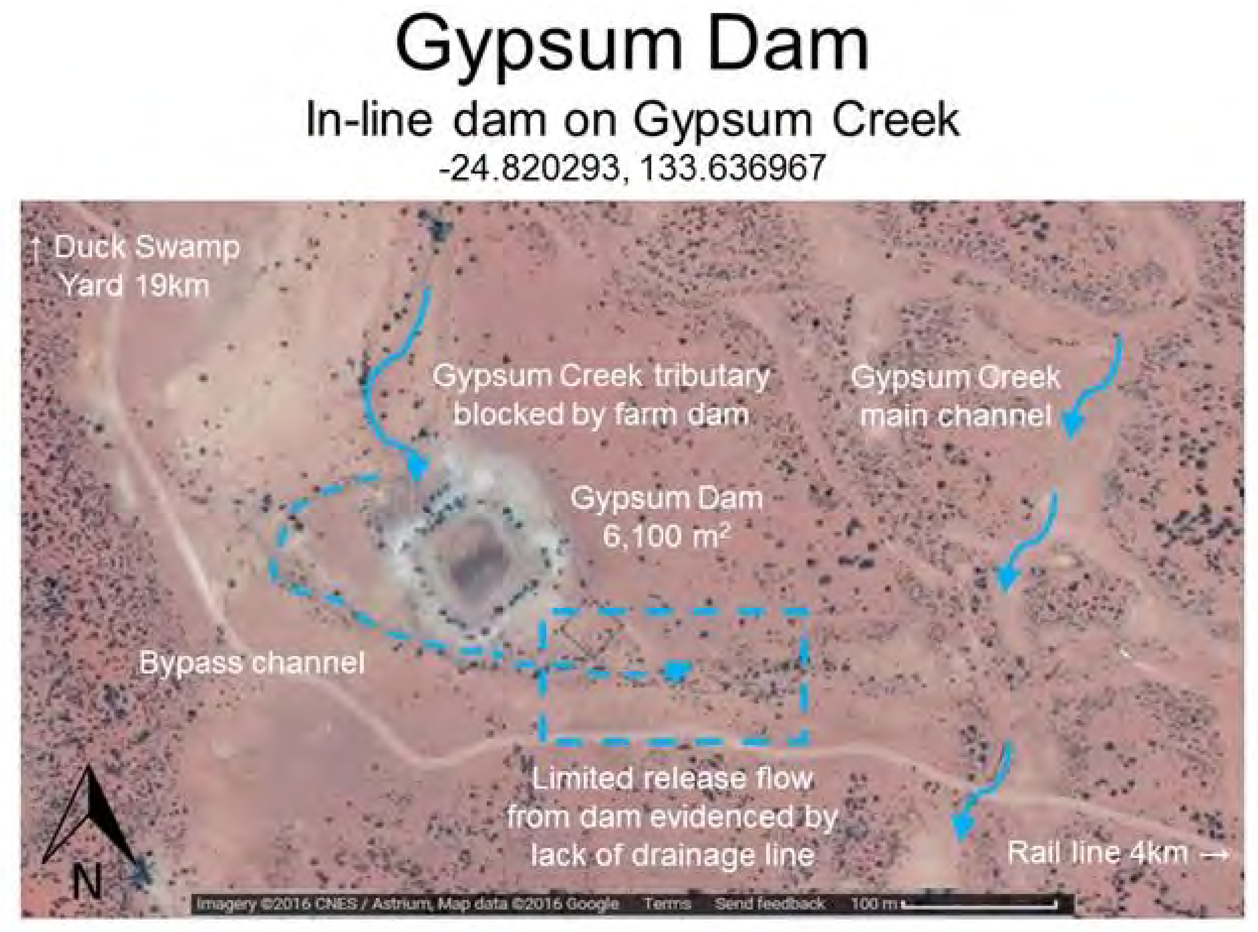
Appendix A.1 Halfway Dam

Halfway Creek's natural drainage course has been altered by the construction of Halfway Dam. This once flowed north and into a larger flood-out / sediment settlement zone as indicated in Figure 24. The same zone is meant to support indigenous groundcovers, shrubs and trees, some large tree species including Red Gums and Grey Box. However, these terrestrial plant communities have been adversely impacted by the location of Halfway Dam cutting off the natural (northward) flow of surface water. This is evident by the significant die back, or in some cases, mortality of large trees. A large sediment trap / basin has been artificially formed on the upstream side of Halfway Dam. When full, it recharges Halfway Dam. It also has an outlet through a constructed embankment. When the basin is full, water flows (south) through an outlet which is approximately 5 m above Halfway Creek. Halfway Creek at this point in the landscape is a relatively new surface water feature. The banks of Halfway Creek in this location are actively eroding, caused by livestock grazing.



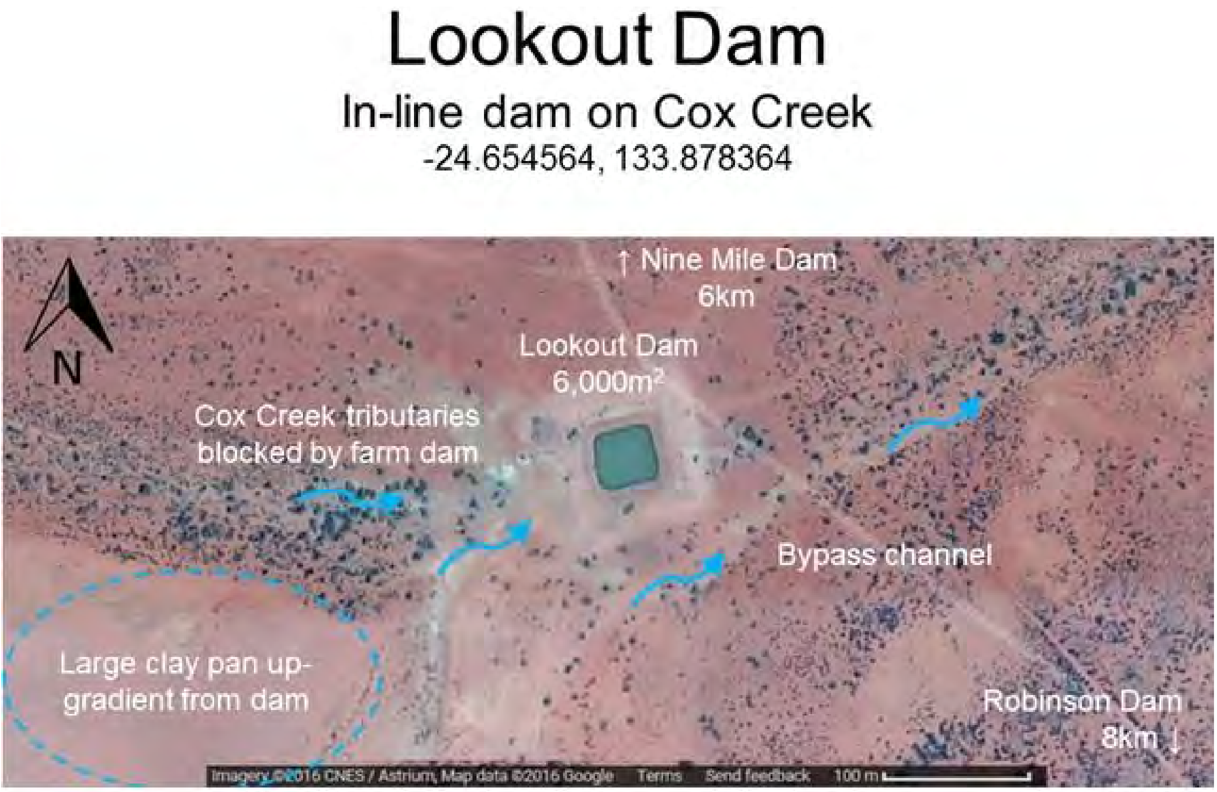
Appendix A.2. Gypsum Dam

Gypsum Dam is located approximately 4km to the west of the rail line and captures runoff from a tributary of Gypsum Creek. There is evidence of removal of flows downstream from the dam with absence of a constrained river channel but the bypass channel to the south of the dam has continued to support dependant vegetation assemblages downstream from the dam.



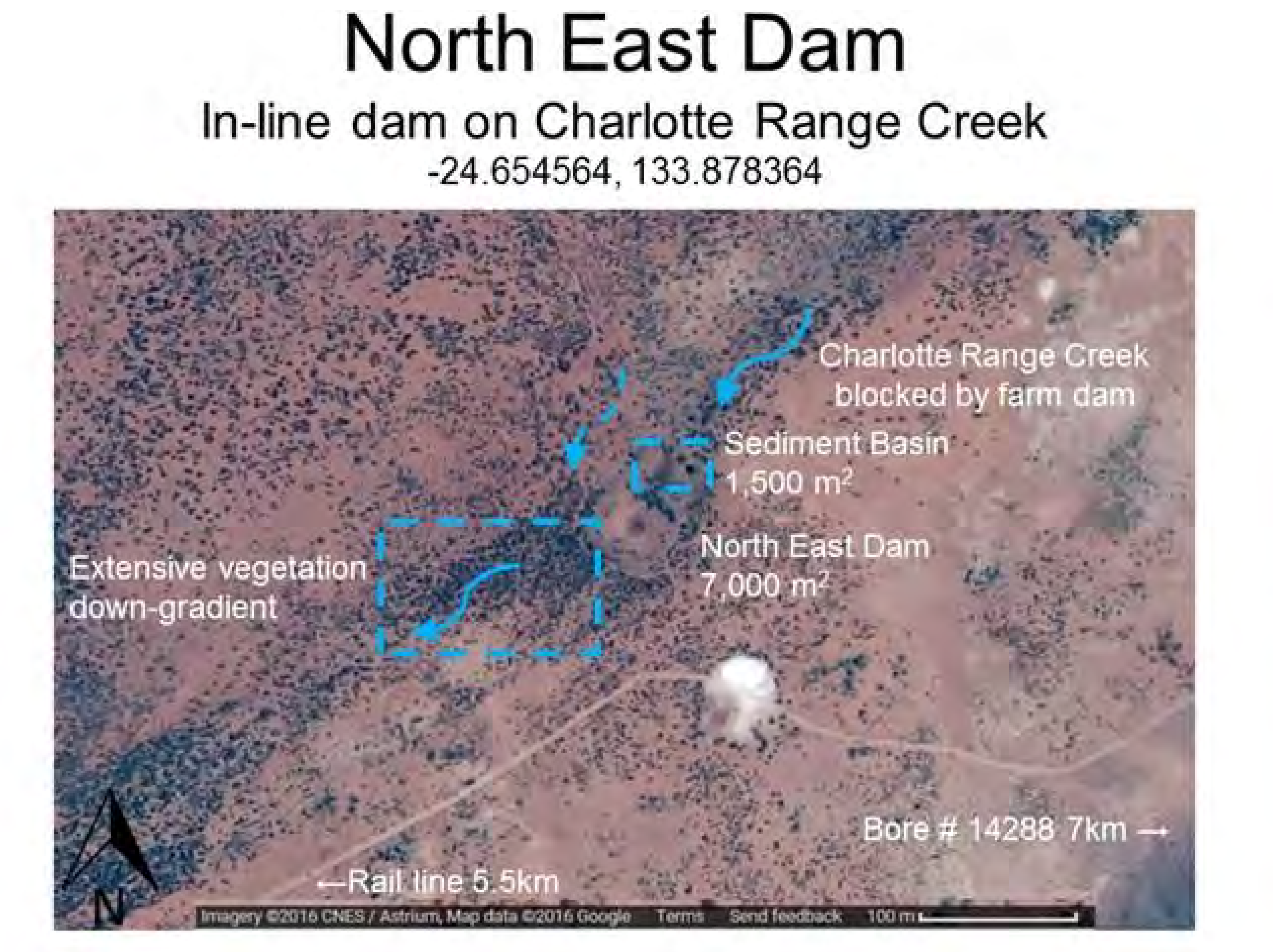
Appendix A.3. Lookout Dam

Lookout Dam is located equidistant between Nine Mile Dam and Robinson Dam and captures runoff from two tributaries of Cox Creek, which flows eastwards into the Hugh River near Mount Burrill. The two tributaries are sourced from a large clay pan circa 3km^2 up-gradient from the dam. It has not been established if an inflow pipe is present or if water simply overflows through the marked channel into the dam from the basin. A bypass channel to the south of the dam has continued to support dependant vegetation assemblages downstream from the dam. The dam has a surface area approximately two-thirds the size of halfway dam, suggesting inflow volumes are not as large.



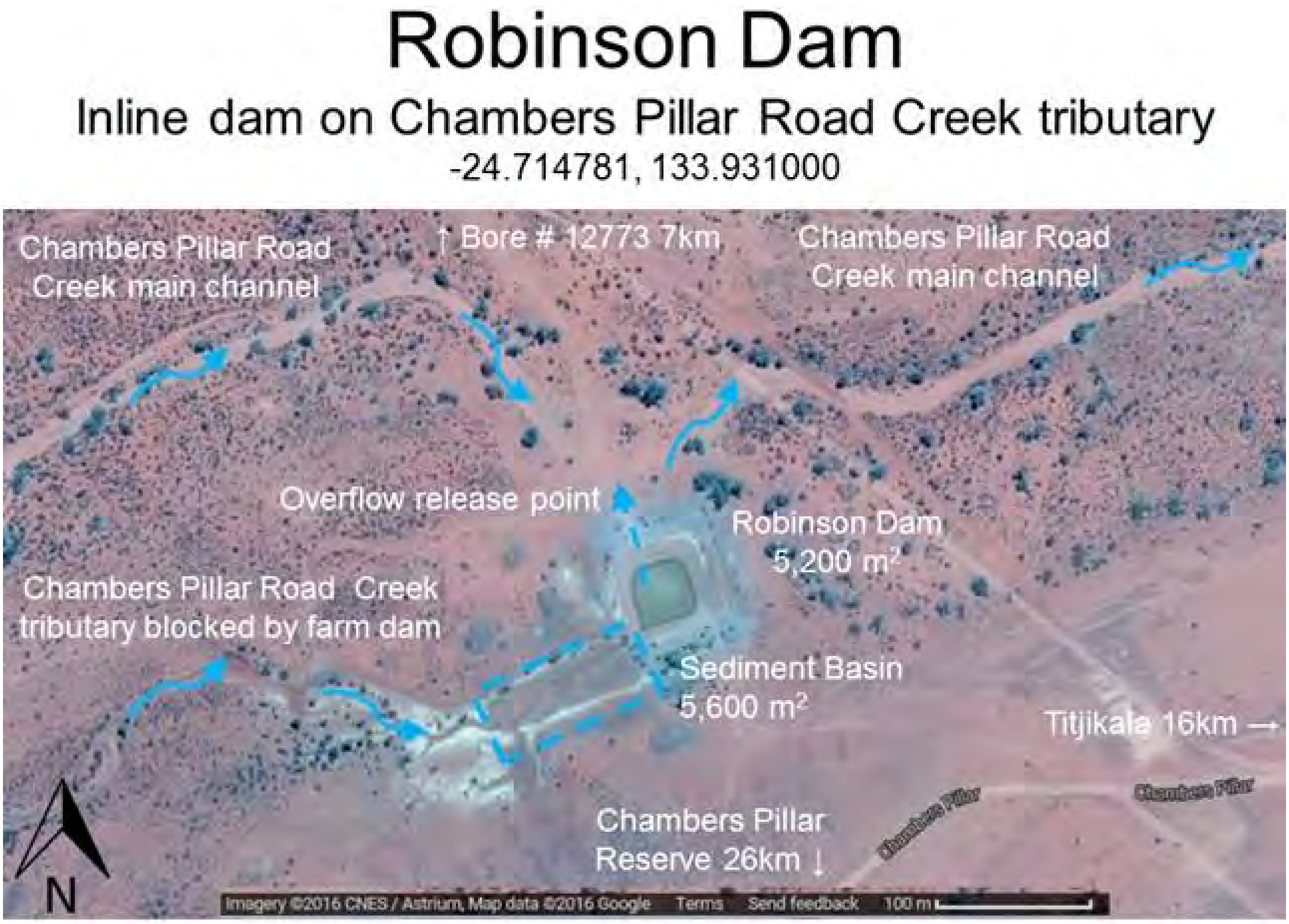
Appendix A.4. North East Dam

North East Dam is located just north of the Charlotte Range approximately 5.5km to the east of the rail line and captures runoff from the main channel of Charlotte Range Creek. A sediment basin up-gradient from the dam fills prior to the dam filling but has a small capacity compared to the main dam. The dam appears to be a simple downstream bund with no upstream flow control from the basin. The dam has a larger surface area than Gypsum, Lookout or Robinson dams, suggesting inflow volumes are larger.



Appendix A.5. Robinson Dam

Robinson Dam is located off Chambers Pillar Road approximately 16km to the west of Titjikala and captures runoff from a tributary of Chambers Pillar Road Creek. A sediment basin up-gradient from the dam fills prior to the dam filling. An overflow release point back to the main Chambers Pillar Road Creek channel can clearly be seen from aerial images. The dam has a surface area approximately two-thirds the size of halfway dam, suggesting inflow volumes are not as large.



Appendix B – Surface Water Quality Monitoring Locations

Water quality monitoring stations

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Finke River–South Rd. Crossing	G0050116	NT Government	321739.1 (E) 7283538.7 (N)	Alkalinity, calcium (soluble), chloride, dissolved oxygen concentration, dissolved oxygen saturation, EC, fluoride, hardness, iron (total), magnesium (soluble), pH, potassium, silicon, sodium (total), sulphate, TDS, temperature, turbidity	4 samples	Jun 2000 – Feb 2011
Hugh River–South Rd. Crossing	G0050115	NT Government	341210.8 (E) 7305873.9 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS, temperature, TSS	10 samples	Feb 1974 – Feb 2004
Top Soak Dam, Horseshoe Bend Station	G0055067	NT Government	381996.9 (E) 7231064.9 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, magnesium (soluble), pH, potassium, silicon, sodium, sulphate, TDS	2 samples	March 1999
Gypsum Dam, Idracowra Station	G0055073	NT Government	362313 (E) 7254305.8 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS	2 samples	June 1999
One Tree Hill Dam, Orange Creek Station	G0055091	NT Government	363427.9 (E) 7312170.6 N	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS, temperature	2 samples	August 1995
Dead Horse Dam, Orange Creek Station	G0055092	NT Government	353128 (E), 7292770.7 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS, temperature	2 samples	August 1995
Soakage Dam, Orange Creek Station	G0055095	NT Government	366395.9 (E) 7295150.7 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS, temperature	2 samples	August 1995

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Dead Bird Tank, Orange Creek Station	G0055097	NT Government	383489.8 (E) 7318905.6 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS, temperature	2 samples	August 1995
4 Winds Tank, Orange Creek Station	G0055098	NT Government	379432.9 (E) 7318184.6 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS, temperature	2 samples	August 1995
River Tank, Orange Creek Station	G0055099	NT Government	364559.9 (E) 7308842.6 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), pH, potassium, silicon, sodium, sulphate, TDS	2 samples	August 1995
Finke River - Railway Bridge 2	G0055119	NT Government	362773 (E) 7242380.8 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), pH, potassium, silicon, sodium, sulphate, TDS	4 samples	Aug 2000 – Oct 2000
Finke River - Main Camp Water Hole	G0055140	NT Government	354333 (E) 7242026.8 N	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), nitrate, pH, potassium, silicon, sodium, sulphate, TDS	2 samples	June 1998
Idracowra Homestead	G0055141	NT Government	377721.2 (E) 7234942.7 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), pH, potassium, silicon, sodium, sulphate, TDS	2 samples	August 2000
Kuringa C Junction, Idracowra / Horseshoe Bend Boundary	G0055142	NT Government	380474.1 (E) 7233056.6 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), pH, potassium, silicon, sodium, sulphate, TDS	2 samples	August 2000

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Pascoes Springs, Finke River - Maryvale	G0055143	NT Government	381345.5 (E) 7238598.7 (N)	Alkalinity, calcium (soluble), chloride, EC, fluoride, hardness, iron (total), magnesium (soluble), pH, potassium, silicon, sodium, sulphate, TDS	2 samples	August 2000
Tellus rising stage sampler	CS005011	Tellus Holdings	393587 (E) 7257170 (N)	Aluminium (total), antimony (total), arsenic (total), barium (total),beryllium (total), bismuth (total), boron (total), bromine (total), cadmium (total),caesium (total), calcium (total), cerium (total), chromium (total), cobalt (total), copper (total), dysprosium (total), EC, erbium (total), europium (total), gadolinium (total), gallium (total), gold (total), hafnium (total), holmium (total), indium (total), iodine (total), iron (total), lanthanum (total), lead (total), lithium (total), lutetium (total), magnesium (total), manganese (total), mercury (total), molybdenum (total), neodymium (total), nickel (total), niobium (total), osmium (total), palladium (total), potassium (total), praseodymium (total), rhenium (total), rubidium (total), samarium (total), scandium (total), selenium (total), silicon dioxide (total), silver (total), sodium (total), strontium (total), sulfate (total), tantalum (total), tellurium (total), terbium (total), thallium (total), thorium (total), thulium (total), tin (total), titanium (total), tungsten (total), uranium (total), vanadium (total), ytterbium (total), yttrium (total), zinc (total), zirconium (total)	8 samples	Dec 2015 – May 2016
Tellus rising stage sampler	CS005012	Tellus Holdings	393584 (E) 7257176 (N)	No data recorded at site.	N/A	N/A

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Tellus rising stage sampler	CS005013	Tellus Holdings	393634 (E) 7257186 (N)	Aluminium (total), antimony (total), arsenic (total), barium (total),beryllium (total), bismuth (total), boron (total), bromine (total), cadmium (total),caesium (total), calcium (total), cerium (total), chromium (total), cobalt (total), copper (total), dysprosium (total), EC, erbium (total), europium (total), gadolinium (total), gallium (total), gold (total), hafnium (total), holmium (total), indium (total), iodine (total), iron (total), lanthanum (total), lead (total), lithium (total), lutetium (total), magnesium (total), manganese (total), mercury (total), molybdenum (total), neodymium (total), nickel (total), niobium (total), osmium (total), palladium (total), potassium (total), praseodymium (total), rhenium (total), rubidium (total), samarium (total), scandium (total), selenium (total), silicon dioxide (total), silver (total), sodium (total), strontium (total), sulfate (total), tantalum (total), tellurium (total), terbium (total), thallium (total), thorium (total), thulium (total), tin (total), titanium (total), tungsten (total), uranium (total), vanadium (total), ytterbium (total), yttrium (total), zinc (total), zirconium (total)	2 samples	May 2016

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Tellus rising stage sampler	CS005021	Tellus Holdings	393284 (E) 7258550 (N)	Aluminium (total), antimony (total), arsenic (total), barium (total), beryllium (total), bismuth (total), boron (total), bromine (total), cadmium (total), caesium (total), calcium (total) cerium (total), chromium (total), cobalt (total), copper (total), dilution factor, dysprosium (total), EC, erbium (total), europium (total), gadolinium (total), gallium (total), gold (total), hafnium (total), holmium (total), indium (total), iodine (total), iron (total), lanthanum (total), lead (total), lithium (total), lutetium (total), magnesium (total), manganese (total), mercury (total), molybdenum (total), neodymium (total), nickel (total), niobium (total), osmium (total), palladium (total), potassium (total), praseodymium (total), rhenium (total), rubidium (total), samarium (total), scandium (total), selenium (total), silicon dioxide (total), silver (total), sodium (total), strontium (total), sulfate (total), tantalum (total), tellurium (total), terbium (total), thallium (total), thorium (total), thulium (total), tin (total), titanium (total), tungsten (total), uranium (total), vanadium (total), ytterbium (total), yttrium (total), zinc (total), zirconium (total)	1 sample	May 2016
Tellus rising stage sampler	CS005031	Tellus Holdings	392436 (E) 7258387 (N)	No data recorded at site.	N/A	N/A
Tellus rising stage sampler	CS005041	Tellus Holdings	390218 (E) 7259782 (N)	No data recorded at site.	N/A	N/A

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Finke River adjacent Magee Stock Bore	CS005060	Tellus Holdings	Unknown	Alkalinity, aluminium (total), ammonia, antimony (total), arsenic (total), barium (total), beryllium (total), bicarbonate, bismuth (total), boron (total), bromine (total), cadmium (total), caesium (total), calcium (total), calcium (total), carbonate, cerium (total), chlorine, chromium (total), cobalt (total), copper (total), dilution factor, dysprosium (total), EC, erbium (total), europium (total), fluorine, gadolinium (total), gallium (total), gold (total), hafnium (total), hardness, holmium (total), hydroxide, indium (total), iodine (total), iron (total), lanthanum (total), lead (total), lithium (total), lutetium (total), magnesium (total), magnesium (total), manganese (total), mercury (total), molybdenum (total), neodymium (total), nickel (total), niobium (total), nitrate, nitrite, osmium (total), palladium (total), pH, phosphate, potassium (total), potassium (total), praseodymium (total), rhenium (total), rubidium (total), samarium (total), scandium (total), selenium (total), silicon dioxide (total), silicon dioxide (total), silver (total), sodium (total), sodium (total), strontium (total), sulfate (total), tantalum (total), TDS, tellurium (total), terbium (total), thallium (total), thorium (total), thulium (total), tin (total), titanium (total), true colour, TSS, tungsten (total), turbidity, uranium (total), vanadium (total), ytterbium (total), yttrium (total), zinc (total), zirconium (total)	2 samples	Jan 2016 – June 2016

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Finke River Boundary Waterhole Henbury Southern Boundary	CS005071	Tellus Holdings	Unknown	Alkalinity, aluminium (total), ammonia, antimony (total), arsenic (total), barium (total), beryllium (total), bicarbonate, boron (total), bromine (total), calcium (total), calcium (total), carbonate, chlorine, chromium (total), copper (total), dilution factor, dysprosium (total), EC, erbium (total), europium (total), fluorine, gold (total), hardness, holmium (total), hydroxide, iodine (total), iron (total), lead (total), magnesium (total), manganese (total), mercury (total), molybdenum (total), nickel (total), nitrate, nitrite, pH, phosphate, potassium (total), samarium (total), scandium (total), selenium (total), silicon dioxide (total), silicon dioxide (total), silver (total), sodium (total), sulfate (total), TDS, thulium (total), tin (total), true colour, TSS, turbidity, uranium (total), zinc (total), zirconium (total)	1 sample	May 2016

Station name	Station code	Data owner	Grid reference	Data type	Data record details	Data record duration
Chambers Pillar Road Creek	RS005001	Tellus Holdings	Unknown	Aluminium (total), antimony (total), arsenic (total), barium (total), beryllium (total), bismuth (total), boron (total), bromine (total), cadmium (total), caesium (total), calcium (total), cerium (total), chromium (total), cobalt (total), copper (total), dysprosium (total), erbium (total), europium (total), gadolinium (total), gallium (total), gold (total), hafnium (total), holmium (total), indium (total), iodine (total), iron (total), lanthanum (total), lead (total), lithium (total), lutetium (total), magnesium (total), manganese (total), mercury (total), molybdenum (total), neodymium (total), nickel (total), niobium (total), osmium (total), palladium (total), potassium (total), praseodymium (total), rhenium (total), rubidium (total), samarium (total), scandium (total), selenium (total), silicon dioxide (total), silver (total), sodium (total), strontium (total), sulfate (total), tantalum (total), tellurium (total), terbium (total), thallium (total), thorium (total), thulium (total), tin (total), titanium (total), tungsten (total), uranium (total), vanadium (total), ytterbium (total), yttrium (total), zinc (total), zirconium (total)	1 sample	December 2015

Appendix C – Water quality data comparison against guideline values

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Appendix C.1. NT Government water quality data

Key for all tables

Trigger Values:	Not tested	Below guideline value/s	Equal to guideline values	Exceeding guideline values
Hardness Category:	Not tested	Soft (0-59 mg/L)	Moderate (60-119 mg/L)	Hard (120-400) mg/L

* Due to hard water, site-specific HMTVs were applied to these selected metals

Table 13: Comparison of NT government surface water samples against guideline values for physical and chemical stressors for aquatic ecosystem 95% protection levels

Site	Site Name	Date & Time	Dissolved Oxygen (%)	EC (µS/cm)	Hardness (mg/L)	pH	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)
G0055067	Top Soak Dam	8/03/1999 0:00		1457	243	7.0	846		
G0055073	Gypsum Dam	3/06/1999 0:00		1146	231	7.0	675		
G0055091	One Tree Hill Dam	17/08/1995 10:35		401	112	8.0	222		
G0055092	Dead Horse Dam	17/08/1995 11:35		289	114	8.0	166		
G0055095	Soakage Dam	18/08/1995 13:00		396	114	7.8	221		
G0055097	Dead Bird Tank	18/08/1995 9:00		1800	460	7.9	1100		
G0055098	Winds Tank	18/08/1995 8:30		1870	475	7.6	1110		
G0055099	Riverv.Tank	17/08/1995 16:30		1870	321		66		
G0050115	Hugh R S Xng	22/02/1974 19:59						2190	
G0050115	Hugh R S Xng	13/03/2000 12:23		452	160	7.7	271		
G0050115	Hugh R S Xng	13/03/2000 13:10		1492	330	8.0	865		
G0050115	Hugh R S Xng	14/03/2000 11:25		2222	384	7.2	1296		
G0050115	Hugh R S Xng	16/06/2000 11:05		600	191	8.4	344		
G0050116	Finke R S Xng	16/06/2000 10:25		2005	409	8.2	1140		
G0050116	Finke R S Xng	7/02/2011 13:25	79.8						717

Site	Site Name	Date & Time	Dissolved Oxygen (%)	EC (µS/cm)	Hardness (mg/L)	pH	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)
G0055119	Finke R Railway	23/08/2000 0:00		6770	1057	8.0	4095		
G0055119	Finke R Railway	27/10/2000 10:00		14040	2190	6.3	9440		
G0055140	Finke R Main Wh	17/06/1998 11:22		6890	1324	6.3	4452		
G0055141	Idracowra Hst2	25/08/2000 0:00		6040	904	8.1	3665		
G0055142	Kuringa C Junction	23/08/2000 0:00		2500	360	7.1	1358		
G0055143	Pascoes Sp	25/08/2000 0:00		6050	961	8.1	3630		

Table 14: Comparison of NT government surface water samples against guideline values for physical and chemical stressors for livestock protection

Site	Site Name	Date & Time	Calcium (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	TDS (mg/L)
G0050115	Hugh R S Xng	13/03/2000 12:23	46	0.2	2	22	271
G0050115	Hugh R S Xng	13/03/2000 13:10	81	0.3	7	124	865
G0050115	Hugh R S Xng	14/03/2000 11:25	98	0.2	4	211	1296
G0050115	Hugh R S Xng	16/06/2000 11:05	50	0.2		9	344
G0050116	Finke R S Xng	16/06/2000 10:25	88	0.3		196	1140
G0055067	Top Soak Dam	8/03/1999 0:00	58	1.0		210	846
G0055073	Gypsum Dam	3/06/1999 0:00	71	1.0	10	140	675
G0055091	One Tree Hill Dam	17/08/1995 10:35	30	0.2	4	23	222
G0055092	Dead Horse Dam	17/08/1995 11:35	34	0.1	2	13	166
G0055095	Soakage Dam	18/08/1995 13:00	31	0.2	5	21	221
G0055097	Dead Bird Tank	18/08/1995 9:00	79	0.7	2	270	1100
G0055098	Winds Tank	18/08/1995 8:30	80	0.7	1	210	1110
G0055099	Riverv.Tank	17/08/1995 16:30	113	0.1		32	66
G0055119	Finke R Railway	23/08/2000 0:00	208	0.3		773	4095
G0055119	Finke R Railway	27/10/2000 10:00	374	0.3		1724	9440
G0055140	Finke R Main Wh	17/06/1998 11:22	267	0.2	3	876	4452
G0055141	Idracowra Hst2	25/08/2000 0:00	181	0.3		651	3665
G0055142	Kuringa C Junction	23/08/2000 0:00	70	0.2		260	1358
G0055143	Pascoes Sp	25/08/2000 0:00	191	0.4		705	3630

Appendix C.2. Proposal water quality data

Key for all tables

Trigger Values:	Not tested	Below guideline value/s	Equal to guideline values	Exceeding guideline values
Hardness Category:	Not tested	Soft (0-59 mg/L)	Moderate (60-119 mg/L)	Hard (120-400) mg/L

* Due to hard water, site-specific HMTVs were applied to these selected metals

Table 15: Comparison of Proposal site surface water samples against guideline values for physical and chemical stressors for aquatic ecosystem 95% protection levels

Site	Site Name	Sample ID	Sample Depth	Date	Aluminum (mg/L)	Ammonia (mg/L)	Arsenic (µg/L)	Boron (µg/L)	Cadmium* (µg/L)	Chromium*(µg/L)	Copper (µg/L)	EC (µS/cm)
CS005011	CS005011	16063	B1	23/12/2015	103.0		5.65	59.0	0.50	112.0	99.7	
RS005001	Chambers Pillar Rd Creek	16064	Grab	23/12/2015	53.7		3.30	41.5	0.12	51.2	36.0	
CS005011	CS005011	16065	B1	1/01/2016	107.0		4.65	53.0	0.30	112.0	70.7	
CS005011	CS005011	16066	B3	1/01/2016	111.0		5.25	54.0	0.32	109.0	76.6	
CS005013	CS005013	16067	B2	1/01/2016	64.4		3.15	35.0	0.18	63.5	43.7	
CS005011	CS005011	16073	B1	22/01/2016	44.3		2.00	61.5	0.22	40.7	33.2	
CS005011	CS005011	16074	B2	22/01/2016			6.15	103.0	0.60	157.0	125.0	
CS005011	CS005011	16075	B3	22/01/2016	79.0		3.85	77.0	<0.20	68.9	46.5	
CS005060	Finke River	16079		22/01/2016	33.1		3.75	96.5	<0.40	26.0	21.5	7930
CS005071	Finke Bdy Henbury Stn	16087		1/06/2016	0.2	0.055	0.50	140.0	<0.20	<5	<10	1920
CS005060	Finke Rive Adj Magee Bore	16088		16/05/2016	10.3	0.115	1.00	40.0	<0.20	10.0	<10	361
CS005011	CS005011	16089		8/05/2016	54.8		4.00	118.0	<0.40	50.4	46.4	53
CS005011	CS005011	16090		8/05/2016	39.4		3.65	120.0	<0.40	36.0	30.6	41
CS005013	CS005013	16091		8/05/2016	59.8		3.30	104.0	<0.40	49.8	43.6	56

Site	Site Name	Sample ID	Sample Depth	Date	Aluminum (mg/L)	Ammonia (mg/L)	Arsenic (µg/L)	Boron (µg/L)	Cadmium* (µg/L)	Chromium*(µg/L)	Copper (µg/L)	EC (µS/cm)
CS005021	CS005021	16092		30/05/2016	188.0		1.70	106.0	<0.40	17.4	12.6	51

Table 15: Comparison of Proposal site surface water samples against guideline values for physical and chemical stressors for aquatic ecosystem 95% protection levels (continued)

Site	Site Name	Sample ID	Sample Depth	Date	Hardness* (mg/L)	Lead* (µg/L)	Manganese (µg/L)	Mercury (µg/L)	Nickel* (µg/L)
CS005011	CS005011	16063	B1	23/12/2015		55.8	2250	0.42	69.9
RS005001	Chambers Pillar Rd Creek	16064	Grab	23/12/2015		25.4	0	0.08	32.7
CS005011	CS005011	16065	B1	1/01/2016		51.1	1470	0.24	56.5
CS005011	CS005011	16066	B3	1/01/2016		50.5	1760	0.26	61
CS005013	CS005013	16067	B2	1/01/2016		32.5	0	0.16	33.4
CS005011	CS005011	16073	B1	22/01/2016		22.4	679	<0.20	24.8
CS005011	CS005011	16074	B2	22/01/2016		86.6	3010	0.54	95
CS005011	CS005011	16075	B3	22/01/2016		36.1	1030	<0.20	36.4
CS005060	Finke River	16079		22/01/2016		12.6	395	<0.40	18.2
CS005071	Finke Bdy Henbury Stn	16087		1/06/2016	270	<1	40000	<0.10	<2
CS005060	Finke Rive Adj Magee Bore	16088		16/05/2016	89	4.0		<0.10	6
CS005011	CS005011	16089		8/05/2016		28.6		<0.40	31.1
CS005011	CS005011	16090		8/05/2016		20.4		<0.40	21.6
CS005013	CS005013	16091		8/05/2016		26.8		<0.40	29.4
CS005021	CS005021	16092		30/05/2016		7.1		<0.40	9.09

Table 15: Comparison of Proposal site surface water samples against guideline values for physical and chemical stressors for aquatic ecosystem 95% protection levels (continued)

Site	Site Name	Sample ID	Sample Depth	Date	Nitrate (mg/L)	pH	Phosphate (mg/L)	Selenium (µg/L)	Silver (µg/L)	TSS (mg/L)	Turbidity (NTU)	Zinc (µg/L)
CS005011	CS005011	16063	B1	23/12/2015				1.2	<0.05			246.0
RS005001	Chambers Pillar Rd Creek	16064	Grab	23/12/2015				0.4	<0.05			104.0
CS005011	CS005011	16065	B1	1/01/2016				0.4	<0.05			184.0
CS005011	CS005011	16066	B3	1/01/2016				0.4	<0.05			201.0
CS005013	CS005013	16067	B2	1/01/2016				0.4	<0.05			116.0
CS005011	CS005011	16073	B1	22/01/2016				0.4	<0.5			95.5
CS005011	CS005011	16074	B2	22/01/2016				0.4	<0.5			297.0
CS005011	CS005011	16075	B3	22/01/2016				0.4	<0.5			124.0
CS005060	Finke River	16079		22/01/2016				0.4	<1			63.8
CS005071	Finke Bdy Henbury Stn	16087		1/06/2016	<0.02	8.5	<0.005	0.4	<10	<10	1	<10
CS005060	Finke Rive Adj Magee Bore	16088		16/05/2016	7.66	7.7	0.035	0.4	<10	40	240	20.0
CS005011	CS005011	16089		8/05/2016				0.4	<1			142.0
CS005011	CS005011	16090		8/05/2016				0.4	<1			78.4
CS005013	CS005013	16091		8/05/2016				0.4	<1			130.0
CS005021	CS005021	16092		30/05/2016				0.4	<1			111.0

Table 16: Comparison of Proposal site surface water samples against guideline values for physical and chemical stressors for livestock protection

Site	Site Name	Sample ID	Sample Depth	Date	Aluminum (mg/L)	Arsenic (µg/L)	Boron (µg/L)	Calcium (mg/L)	Cadmium* (µg/L)
CS005011	CS005011	16063	B1	23/12/2015	103.0	5.65	59.0	29.2	0.50
RS005001	Chambers Pillar Rd Creek	16064	Grab	23/12/2015	53.7	3.30	41.5	20.0	0.12
CS005011	CS005011	16065	B1	1/01/2016	107.0	4.65	53.0	19.2	0.30
CS005011	CS005011	16066	B3	1/01/2016	111.0	5.25	54.0	21.3	0.32
CS005013	CS005013	16067	B2	1/01/2016	64.4	3.15	35.0	12.6	0.18
CS005011	CS005011	16073	B1	22/01/2016	44.3	2.00	61.5	22.8	0.22
CS005011	CS005011	16074	B2	22/01/2016		6.15	103.0	34.4	0.60
CS005011	CS005011	16075	B3	22/01/2016	79.0	3.85	77.0	13.2	<0.20
CS005060	Finke River	16079		22/01/2016	33.1	3.75	96.5	31.5	<0.40
CS005071	Finke Bdy Henbury Stn	16087		1/06/2016	0.2	0.50	140.0	64.2	<0.20
CS005060	Finke Rive Adj Magee Bore	16088		16/05/2016	10.3	1.00	40.0	25.5	<0.20
CS005011	CS005011	16089		8/05/2016	54.8	4.00	118.0	13.2	<0.40
CS005011	CS005011	16090		8/05/2016	39.4	3.65	120.0	8.5	<0.40
CS005013	CS005013	16091		8/05/2016	59.8	3.30	104.0	12.5	<0.40
CS005021	CS005021	16092		30/05/2016	188.0	1.70	106.0	4.5	<0.40

Table 16: Comparison of Proposal site surface water samples against guideline values for physical and chemical stressors for livestock protection (continued)

Site	Site Name	Sample ID	Sample Depth	Date	Chromium* (µg/L)	Cobalt (µg/L)	Copper (µg/L)	Fluoride (mg/L)	Lead* (µg/L)	Mercury (µg/L)
CS005011	CS005011	16063	B1	23/12/2015	112.0	0.0	99.7		55.8	0.42
RS005001	Chambers Pillar Rd Creek	16064	Grab	23/12/2015	51.2	0.0	36.0		25.4	0.08
CS005011	CS005011	16065	B1	1/01/2016	112.0	0.0	70.7		51.1	0.24
CS005011	CS005011	16066	B3	1/01/2016	109.0	0.0	76.6		50.5	0.26
CS005013	CS005013	16067	B2	1/01/2016	63.5	0.0	43.7		32.5	0.16
CS005011	CS005011	16073	B1	22/01/2016	40.7	0.0	33.2		22.4	<0.20
CS005011	CS005011	16074	B2	22/01/2016	157.0	0.0	125.0		86.6	0.54
CS005011	CS005011	16075	B3	22/01/2016	68.9	0.0	46.5		36.1	<0.20
CS005060	Finke River	16079		22/01/2016	26.0	0.0	21.5		12.6	<0.40
CS005071	Finke Bdy Henbury Stn	16087		1/06/2016	<5		<10	0.3	<1	<0.10
CS005060	Finke Rive Adj Magee Bore	16088		16/05/2016	10.0		<10	0.2	4.0	<0.10
CS005011	CS005011	16089		8/05/2016	50.4	21.5	46.4		28.6	<0.40
CS005011	CS005011	16090		8/05/2016	36.0	14.9	30.6		20.4	<0.40
CS005013	CS005013	16091		8/05/2016	49.8	19.6	43.6		26.8	<0.40
CS005021	CS005021	16092		30/05/2016	17.4	6.1	12.6		7.1	<0.40

Table 16: Comparison of Proposal site surface water samples against guideline values for physical and chemical stressors for livestock protection (continued)

Site	Site Name	Sample ID	Sample Depth	Date	Molybdenum (µg/L)	Nickel (µg/L)	Selenium (µg/L)	Sulphate (mg/L)	TDS (mg/L)	Uranium (mg/L)
CS005011	CS005011	16063	B1	23/12/2015	0.20	69.9	1.2	5		4.050
RS005001	Chambers Pillar Rd Creek	16064	Grab	23/12/2015	0.20	32.7	0.4	2.9		1.450
CS005011	CS005011	16065	B1	1/01/2016	0.15	56.5	0.4	3.5		2.900
CS005011	CS005011	16066	B3	1/01/2016	0.15	61	0.4	3.8		3.290
CS005013	CS005013	16067	B2	1/01/2016	0.15	33.4	0.4	2.3		1.780
CS005011	CS005011	16073	B1	22/01/2016	<0.5	24.8	0.4	10.3		1.320
CS005011	CS005011	16074	B2	22/01/2016	<0.5	95	0.4	7.4		5.490
CS005011	CS005011	16075	B3	22/01/2016	<0.5	36.4	0.4	3.5		1.930
CS005060	Finke River	16079		22/01/2016	<1	18.2	0.4	1490		1.420
CS005071	Finke Bdy Henbury Stn	16087		1/06/2016	<5	<2	0.4	146	1100	2.760
CS005060	Finke Rive Adj Magee Bore	16088		16/05/2016	<5	6	0.4	25.2	100	0.910
CS005011	CS005011	16089		8/05/2016	<1	31.1	0.4	3.5		1.800
CS005011	CS005011	16090		8/05/2016	<1	21.6	0.4	1.9		1.150
CS005013	CS005013	16091		8/05/2016	<1	29.4	0.4	2.8		1.580
CS005021	CS005021	16092		30/05/2016	<1	9.09	0.4	3.3		0.311

Appendix D - Geomorphological baseline condition templates

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Project	Tellus Holdings CSMP				**Date**	16/05/2016
Surveyor	DE	**Reach name / code:** Un-named creek / CS005013			**Time**	12:30 hrs
Drainage channel ☒	**Creek** ☐	**River** ☐	**Flood-out** ☐	**Dam** ☐	**Wetland** ☐	**Lake** ☐
Weather conditions	Bright sunshine, mild		**Grid reference**		0393590; 7257170 (53 J UTM)	
Elevation (mAHD)	424		**Channel description**		Small incised drainage channel on alluvial plains draining east-west. Foot slopes of sandstone hills approximately 500m upstream and catchment extends a further 1.6km upstream onto steep rocky slopes.	

Watercourse attributes

Dimensions	**Max. width (m)**	4.44	**Max. depth (m)**	0.268	**Velocity (ms^{-1})**	n/a
Shape description		Rectangular	**Roughness Height (m)**	0.0	**Bank erosion**	None
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	None	**Bank vegetation** 10% cover Buffel Grass, Curly Windmill Grass & Saltbush	**Bench vegetation** 30% cover Salt-bush, Grey Mulga, Wildhop Bush, Wattle & Bloodwood		**Organic matter** Logs ☐ Twigs / Leaves ☒ Detritus ☐	

Flow type

Smooth surface flow ☐ [H1]	**Broken standing waves** ☐ [H2]	**Unbroken standing waves** ☐ [H3]	**Chute** ☐ [H4]	**Rippled** ☐ [H5]	**Scarcely perceptible flow** ☐ [H6]	**Upwelling** ☐ [H7]	**Standing water** ☐ [H8]	**Dry channel** ☒ [H9]

Channel Planform

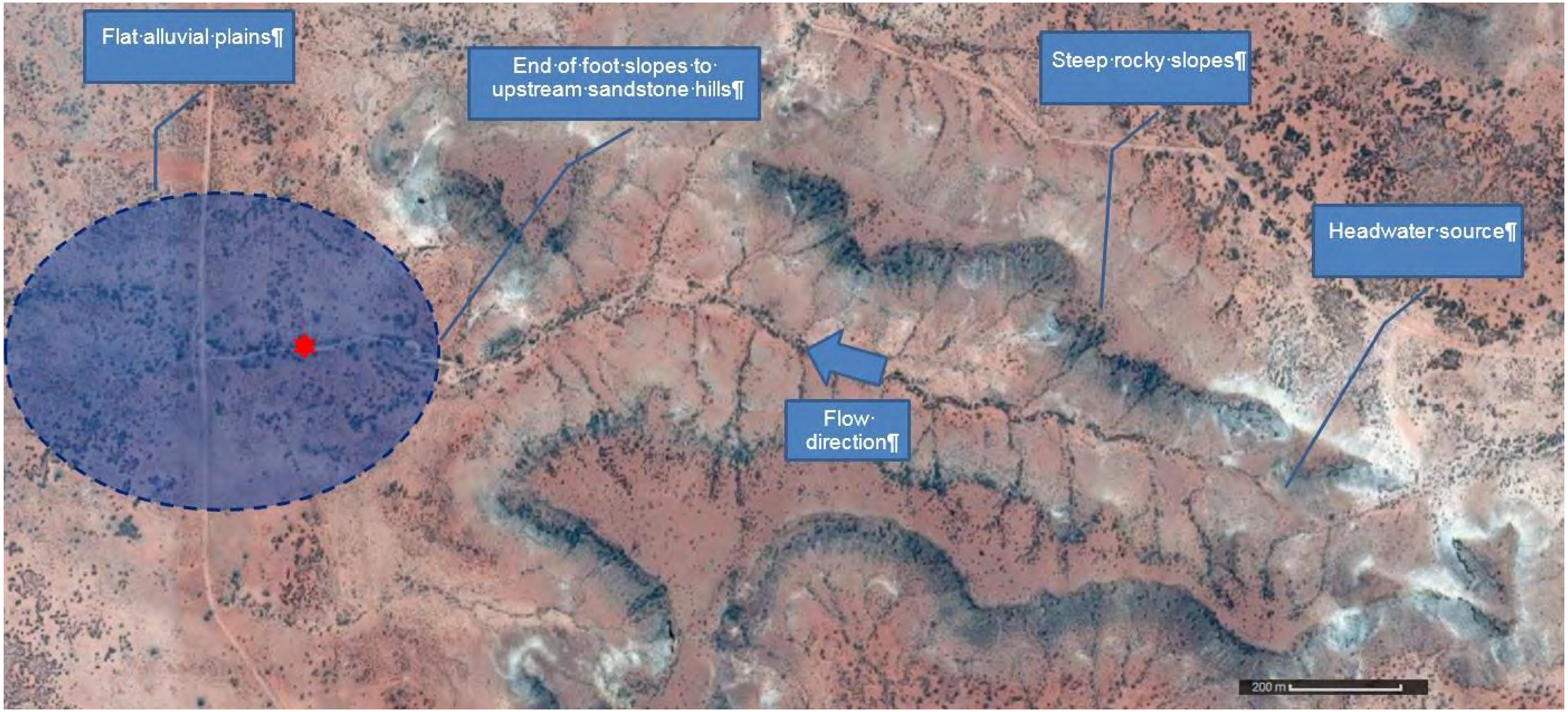
Sinuosity (straight, low, intermediate, high)	Straight	***Form***	Single ☒	Forked ☐	Braided ☐	Open ☐
Sand bars ☒	**Gravel bars** ☐		**Rock outcrops** ☐	**Riparian strip** ☐	**Floodplain connectivity**	Open with evidence of flood debris caught in trees at +0.5m
Floodplain land use	Natural vegetation cover attracting camels and donkeys in addition to cattle grazing				**Bank structure & angle**	Flat 90 degrees, 0.4m high

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
U-S			5	95		
D-S			0	80	20	
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Moderate packing of sand with bed ripples evident (regular spacing 0.2m)		**Supply** ☒	**Deposition** ☒	**Erosion** ☐	**Conveying** ☐

* RHB = Right hand bank, LHB = Left hand bank, U-S = Upstream location, D-S = Downstream location

Site CS005013 aerial catchment photograph



= Site CS005013 approximate location; Imagery source: CNES / Astrium 2016 (Google Earth, 2016)

Site CS005013 site photographs

Plate A.1.1 – Channel looking upstream towards water quality monitoring point

Plate A.1.2 – Floodplain view downstream from sandstone hills

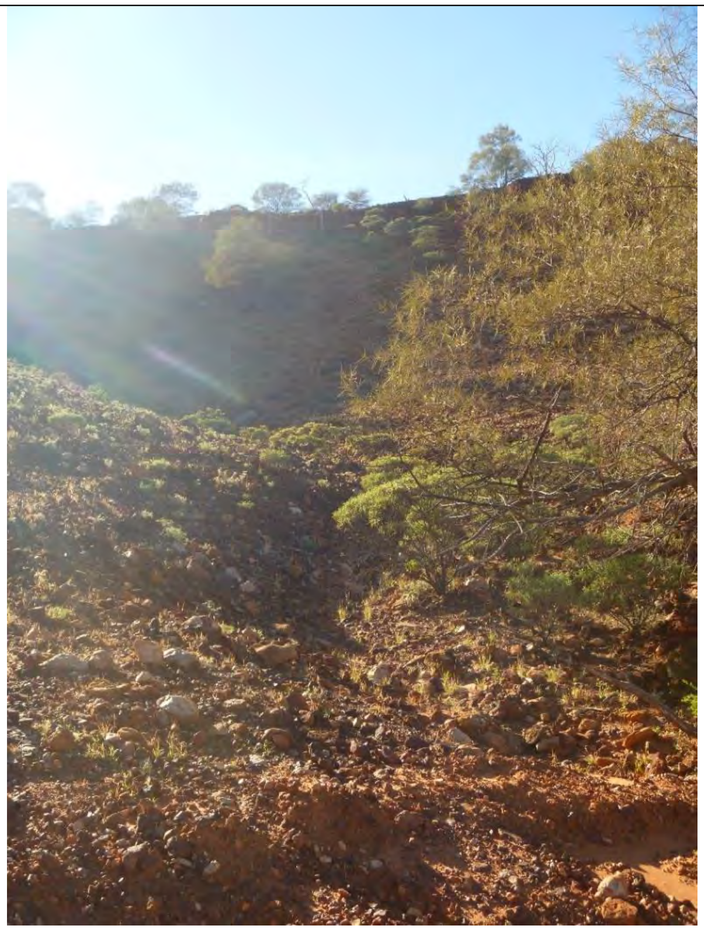
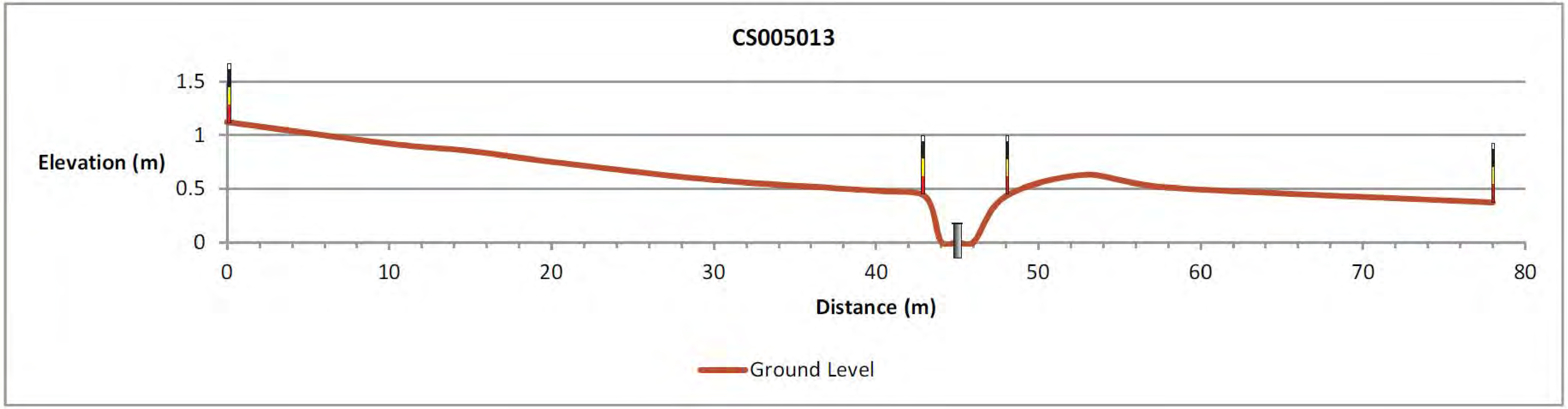


Plate A.1.3 – Typical steep rock scree slopes in upper catchment

Plate A.1.4 – Bed morphology showing chute with limited gravel deposits (left) and compacted riffle surface (right)

Typical cross-section



Source: Centreprise, 2014

Project	Tellus Holdings CSMP			**Date**	16/05/2016	
Surveyor	DE	**Reach name / code:** Un-named flood-out / CS005021		**Time**	13:30 hrs	
Drainage channel ☐	**Creek** ☐	**River** ☐	**Flood-out** ☒	**Dam** ☐	**Wetland** ☐	**Lake** ☐
Weather conditions	Bright sunshine, mild		**Grid reference**	0393288; 7258551 (53 J UTM)		
Elevation (mAHD)	413		**Channel description**	Relatively flat floodout receiving sheet drainage flows from small catchment lying on North-western Maryvale Hills.		

Watercourse attributes

Dimensions	**Max. width (m)**	20 (nominal based on environmental transect)	**Max. depth (m)**	N/A	**Velocity (ms^{-1})**	N/A
Shape description		N/A	**Roughness Height (m)**	0.3	**Bank erosion**	N/A

Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	N/A	**Bank vegetation** N/A	**Bench vegetation** 30% cover Spiniflex, native tomato, Salt-bush, Eremophilia	**Organic matter** Logs ☐ Twigs / Leaves ☒ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Standing water	Dry channel
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☒ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Straight	***Form***	Single ☐	Forked ☐	Braided ☐	Open ☒
Sand bars ☒	**Gravel bars** ☐	**Rock outcrops** ☐	**Riparian strip** ☐	**Floodplain connectivity**	No defined channel	
Floodplain land use	Natural vegetation cover attracting camels and donkeys in addition to cattle grazing. Older shrubs appear to be dead and have fire damage			**Bank structure & angle**	N/A	

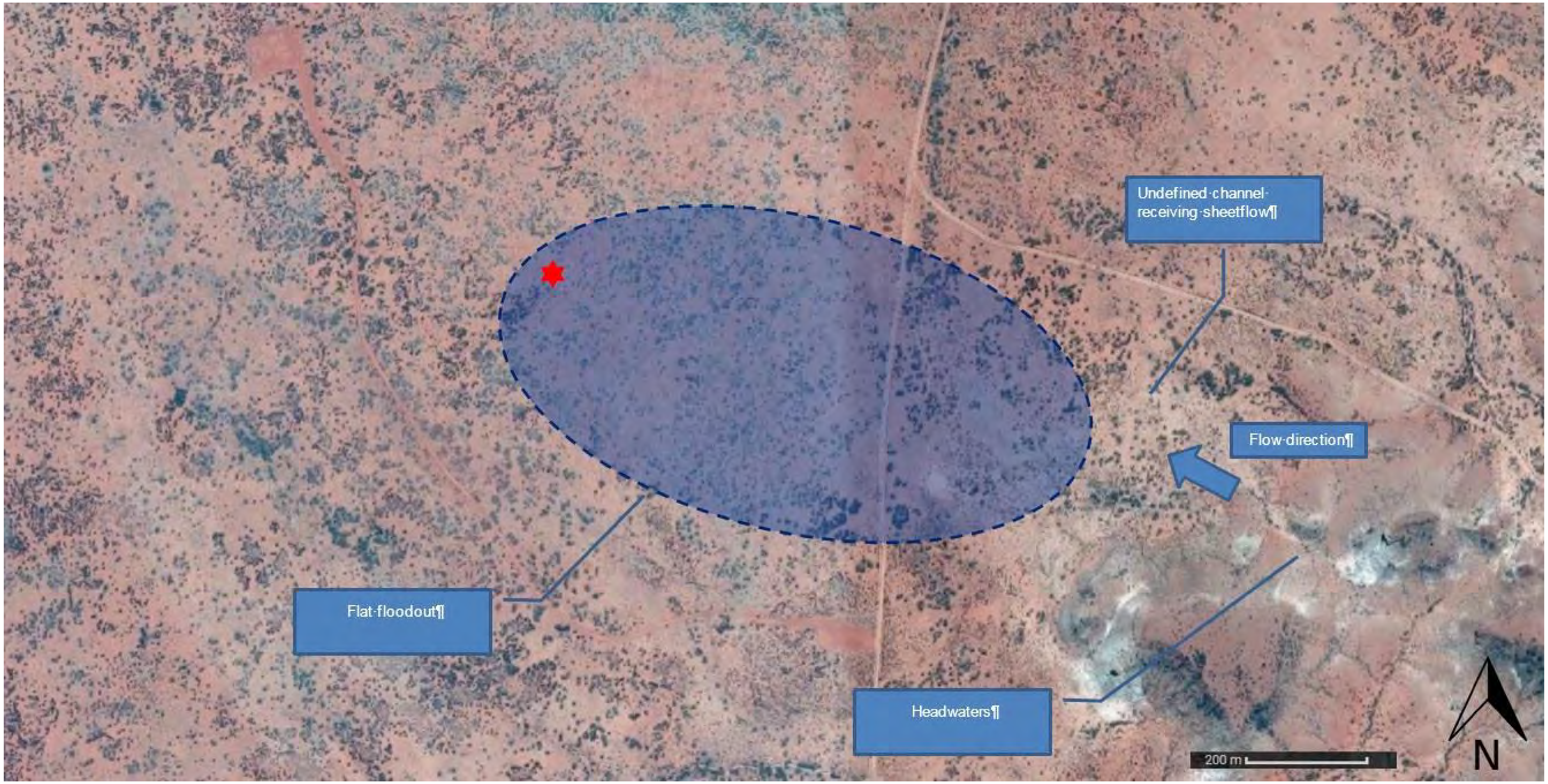
Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 95 D-S 80	U-S 5 D-S 10	U-S ☐ D-S 10

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Packed not armoured with cracks in surface indicating presence of water that has evaporated / drained into soils	**Supply** ☐	**Deposition** ☒	**Erosion** ☐	**Conveying** ☐

* RHB = Right hand bank, LHB = Left hand bank, U-S = Upstream location, D-S = Downstream location

Site CS005021 aerial catchment photograph

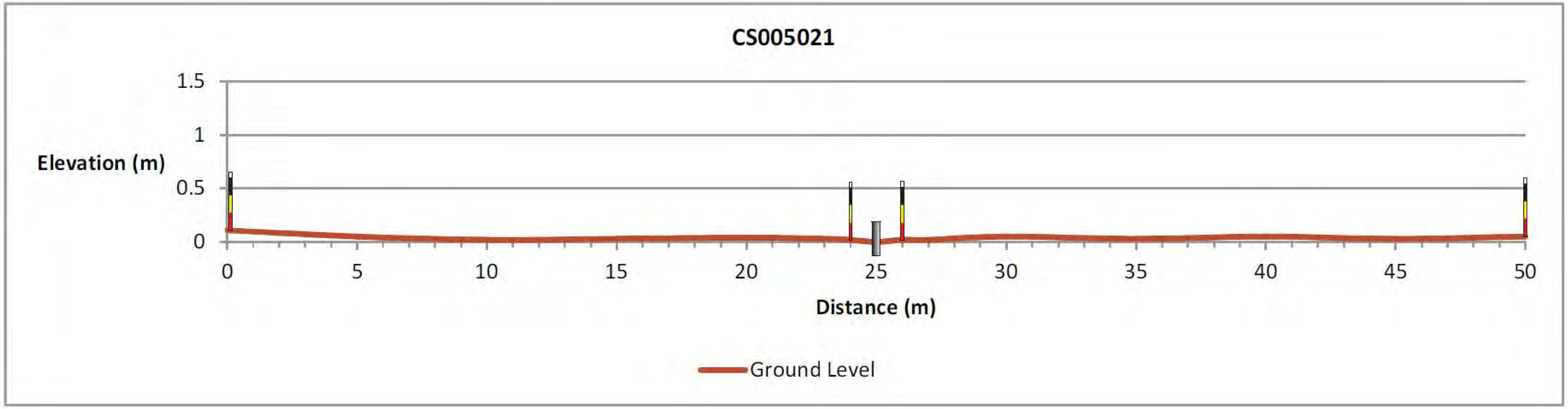


★ = Site CS005021 approximate location; Imagery source: CNES / Astrium 2016 (Google Earth, 2016)

Site CS005021 photographs

	
Plate A.1.5 – Flood-out looking east and up-gradient towards Maryvale hills	Plate A.1.6 – Flood out looking west towards water quality monitoring point
	
Plate A.1.7 – Bed morphology showing cracked surface silts and fine organic debris	Plate A.1.8 – Fire damage to Grey Mulga

Typical cross-section



Source: Centreprise, 2014

Project	Tellus Holdings CSMP				**Date**	16/05/2016
Surveyor	DE	**Reach name / code:** Finke River / GEOM01			**Time**	11:30 hrs
Drainage channel ☐	**Creek** ☐	**River** ☒	**Flood-out** ☐	**Dam** ☐	**Wetland** ☐	**Lake** ☐
Weather conditions	Warm, no wind		**Grid reference**		0402472; 7242245 (53 J UTM)	
Elevation (mAHD)	325		**Channel description**		Large channel which flows through deep incised meanders in a west-east direction. Complex multi-stage channel with lateral migration resulting in large meander bends.	

Watercourse attributes

Dimensions — **Max. width (m)**	330	**Max. depth (m)**	Unknown	**Velocity (ms^{-1})**	0.1
Shape description	Trapazoidal multi-stage channel with low flow channel and 3 high-low benches	**Roughness Height (m)**	0.2	**Bank erosion**	None visible

Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	None visible in highly turbid water	**Bank vegetation** 15% small bushes	**Bench vegetation** 80% coverage Gum trees LHB (low tolerance for saline water) and Box trees RHB (indicators of saline water)	**Organic matter** Logs ☒ Twigs / Leaves ☒ Detritus ☒

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Standing water	Dry channel
☒ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Intermediate	*Form*	Single ☐	Forked ☐	Braided ☒	Open ☐
Sand bars ☒	**Gravel bars** ☒ (D-S only)		**Rock outcrops** ☐	**Riparian strip** ☒	**Floodplain connectivity**	Constrained within 3-stage channel on LHB; open channel on RHB
Floodplain land use	Groundwater bore with old-fashioned pump linked to Kubota RK-80-1N tractor engine. Grazing possible on floodplain land. Horses drinking on RHB during site walkover.				**Bank structure & angle**	Straight, 30 degrees LHB; straight 10 degrees RHB

Bed character

% composition (based on secondary bench composition)	Boulder U-S ☐ D-S ☐	Cobble U-S ☐ D-S ☐	Gravel U-S ☐ D-S ☐	Sand U-S 10 D-S 10	Fine sand U-S 20 D-S 10	Silt / clay U-S 70 D-S 80
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Unknown, no access to channel bed			**Supply** ☒	**Deposition** ☒ **Erosion** ☐	**Conveying** ☒

* RHB = Right hand bank, LHB = Left hand bank, U-S = Upstream location, D-S = Downstream location

Site GEOM01 aerial catchment photograph

= Site GEOM01 approximate location Imagery source: CNES / Astrium 2016 (Google Earth, 2016)

Site GEOM01 photographs

Plate A.1.9 – Finke River looking east and downstream

Plate A.1.10 – Finke River looking west and upstream

Plate A.1.11 – Secondary flow exposed bench channel with deposited silts / clays

Plate A.1.12 – Secondary bench vegetation and floodplain slope towards channel

Typical cross-section

<<Access to the Finke River was not possible due to health and safety concerns during flow events>>

Project	Tellus Holdings CSMP			**Date**	16/05/2016	
Surveyor	DE	**Reach name / code:** Railway Crossing Creek @ / GEOM02		**Time**	15:30 hrs	
Drainage channel ☒	**Creek** ☐	**River** ☐	**Flood-out** ☐	**Dam** ☐	**Wetland** ☐	**Lake** ☐
Weather conditions	Warm, no wind		**Grid reference**	0366561; 7260744 (53 J UTM)		
Elevation (mAHD)	425		**Channel description**	Small creek amalgamated into the railway drainage system. Steep southerly approach then berm deflects flows at 90 degrees to the west through box culverts.		

Watercourse attributes							
Dimensions	**Max. width (m)**	13	**Max. depth (m)**	0.69	**Velocity (ms^{-1})**	N/A	
Shape description		V-shaped drainage channel running alongside railway line combines with open rectangular natural channel	**Roughness Height (m)**	0.3	**Bank erosion**	Consistent erosion over cross-section upstream. Erosion of concrete apron on both upstream and downstream sides of crossing. Large amounts of erosion downstream from culverts (both in-channel and banks)	
Instream vegetation ([% cover [emergent, floating, submerged, algae, moss])	40% cover emergent grasses	**Bank vegetation** None		**Bench vegetation** 20% cover Buffel Grass, Grey Mulga & Bloodwood		**Organic matter** Logs ☒ Twigs / Leaves ☒ Detritus ☒	

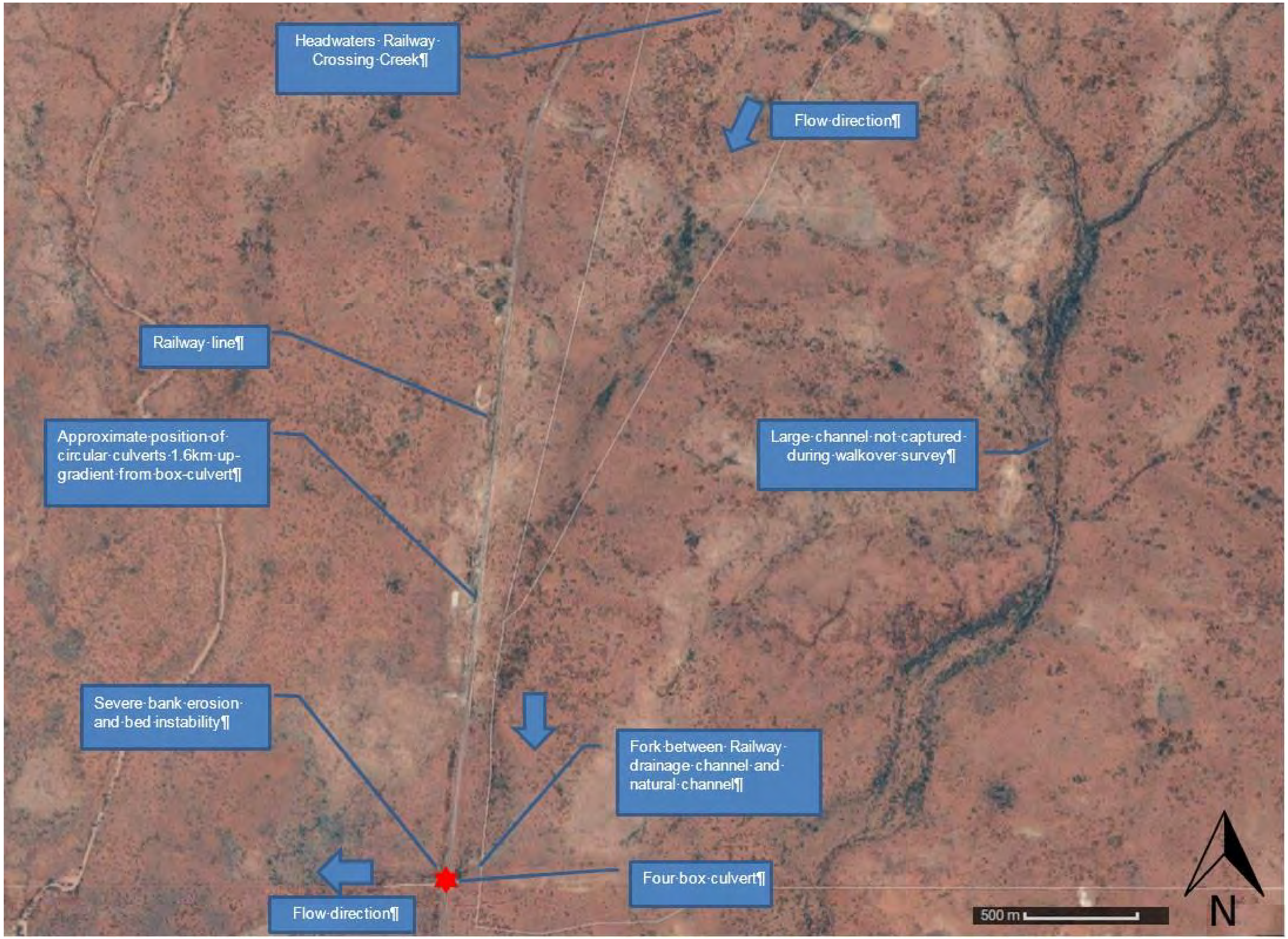
Flow type								
Smooth surface flow ☐ [H1]	**Broken standing waves** ☐ [H2]	**Unbroken standing waves** ☐ [H3]	**Chute** ☐ [H4]	**Rippled** ☐ [H5]	**Scarcely perceptible flow** ☐ [H6]	**Upwelling** ☐ [H7]	**Standing water** ☐ [H8]	**Dry channel** ☒ [H9]

Channel Planform						
Sinuosity (straight, low, intermediate, high)	Low	***Form***	Single ☐	Forked ☒	Braided ☐	Open ☐
Sand bars ☐	**Gravel bars** ☒ (D-S only)		**Rock outcrops** ☐	**Riparian strip** ☐	**Floodplain connectivity**	Open channel which could inundate track in storm conditions
Floodplain land use	Rail line & access track dominate land use. Grazing possible on land to both east & west of railway line but no livestock observed				**Bank structure & angle**	Straight, 45 degrees U-S; straight 90 degrees D-S RHB; straight 60 degrees D-S LHB

Bed character						
% composition	Boulder U-S ☐ D-S ☐	Cobble U-S ☐ D-S ☐	Gravel U-S 40 D-S 50	Sand U-S 50 D-S 40	Fine sand U-S 10 D-S 10	Silt / clay U-S ☐ D-S ☐
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Packed not armoured with elevated vegetated grass hummocks		**Supply** ☒	**Deposition** ☐	**Erosion** ☒	**Conveying** ☒

* RHB = Right hand bank, LHB = Left hand bank, U-S = Upstream location, D-S = Downstream location

Site GEOM02 aerial catchment photograph



= Site GEOM03 approximate location Imagery source: CNES / Astrium 2016 (Google Earth, 2016)

Site GEOM02 photographs

Plate A.1.13 – Four box culverts (3m width x 1.7m height) at railway crossing looking downstream

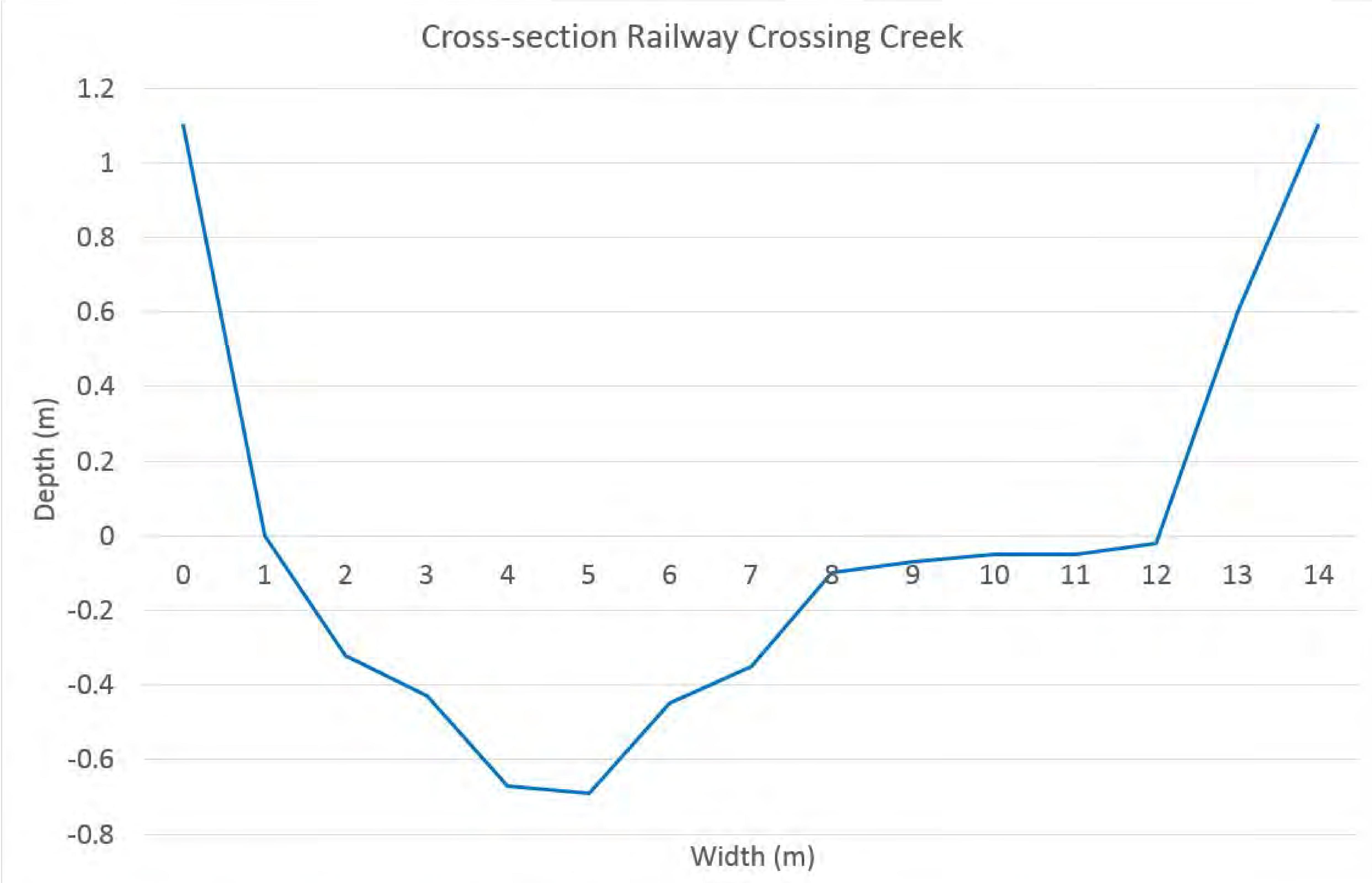
Plate A.1.14 – Four box arch culverts at railway crossing looking upstream showing under mimed concrete apron

Plate A.1.15 – Seven metre wide exposed soil bank caused by bank erosion during high flows

Plate A.1.16 – In-channel grass hummocks looking upstream from railway crossing point

	
Plate A.1.17 – Twin 0.7m Ø circular culverts (grid reference 0366716; 7262271) draining into Railway Creek Crossing drainage channel	Plate A.1.18 – Undermimed concrete apron on down-gradient side of twin circular culverts

Typical cross-section



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<tr><td>Surveyor</td><td>DE</td><td colspan="4">Reach name / code: Hugh River @ Titjikala Crossing / GEOM03</td><td>Time</td><td>08:30 hrs</td></tr>
<tr><td>Drainage channel
☐</td><td>Creek
☐</td><td>River
☒</td><td>Flood-out
☐</td><td>Dam
☐</td><td colspan="2">Wetland
☐</td><td>Lake
☐</td></tr>
<tr><td colspan="2">Weather conditions</td><td colspan="2">Mild, no wind</td><td>Grid reference</td><td colspan="3">0402472; 7269554 (53 J UTM)</td></tr>
<tr><td colspan="2">Elevation (mAHD)</td><td colspan="2">360</td><td>Channel description</td><td colspan="3">Well-defined large ephemeral channel with meandering planform and mixed sand/gravel/cobble bed. Flows west to east into the Finke River system approximately 75km downstream.</td></tr>
<tr><td colspan="8">Watercourse attributes</td></tr>
<tr><td>Dimensions</td><td>Max. width (m)</td><td colspan="2">168m</td><td>Max. depth (m)</td><td>2.6</td><td>Velocity (ms⁻¹)</td><td>N/A</td></tr>
<tr><td colspan="2">Shape description</td><td colspan="2">Trapezoidal with 3-stage channel with lateral sand bars, mid-channel gravel island, chute channels, rock outcrops & sand sheets</td><td>Roughness Height (m)</td><td>0.1</td><td>Bank erosion</td><td>Undercutting on both LHB & RHB approximately 30% coverage</td></tr>
<tr><td>Instream vegetation
(% cover [emergent, floating, submerged, algae, moss])</td><td>N/A</td><td colspan="2">Bank vegetation
None</td><td colspan="3">Bench vegetation
20% cover Gum Trees</td><td>Organic matter
Logs ☒ Twigs / Leaves ☒
Detritus ☒</td></tr>
<tr><td colspan="8">Flow type</td></tr>
<tr><td colspan="8">Smooth surface flow ☐ [H1] | Broken standing waves ☐ [H2] | Unbroken standing waves ☐ [H3] | Chute ☐ [H4] | Rippled ☐ [H5] | Scarcely perceptible flow ☐ [H6] | Upwelling ☐ [H7] | Standing water ☐ [H8] | Dry channel ☒ [H9]</td></tr>
<tr><td colspan="8">Channel Planform</td></tr>
<tr><td>Sinuosity
(straight, low, intermediate, high)</td><td>Intermediate</td><td>Form</td><td>Single
☐</td><td>Forked
☐</td><td colspan="2">Braided
☒</td><td>Open
☐</td></tr>
<tr><td>Sand bars
☒</td><td colspan="2">Gravel bars
☒</td><td colspan="2">Rock outcrops
☒</td><td>Riparian strip
☐</td><td>Floodplain connectivity</td><td>Constrained within 3-stage channel</td></tr>
<tr><td>Floodplain land use</td><td colspan="5">Gum tree line both banks. Vegetation on floodplain consists of Spiniflex Grass and sparse Grey Mulga</td><td>Bank structure & angle</td><td>Straight, 45 degrees</td></tr>
<tr><td colspan="8">Bed character</td></tr>
<tr><td>% composition</td><td>Boulder
U-S ☐ D-S ☐</td><td>Cobble
U-S 5 D-S 50</td><td>Gravel
U-S 10 D-S 20</td><td>Sand
U-S 20 D-S 30</td><td colspan="2">Fine sand
U-S 65 D-S 30</td><td>Silt / clay
U-S ☐ D-S ☐</td></tr>
<tr><td>Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)</td><td colspan="3">Packed and armoured with winnowing of fines evident in thawleg part of channel</td><td>Supply
☒</td><td>Deposition
☒</td><td>Erosion
☒</td><td>Conveying
☒</td></tr>
</table>

* RHB = Right hand bank, LHB = Left hand bank, U-S = Upstream location, D-S = Downstream location

Site GEOM03 aerial catchment photograph

= Site GEOM03 approximate location; Imagery source: CNES / Astrium 2016 (Google Earth, 2016)

Site GEOM03 photographs

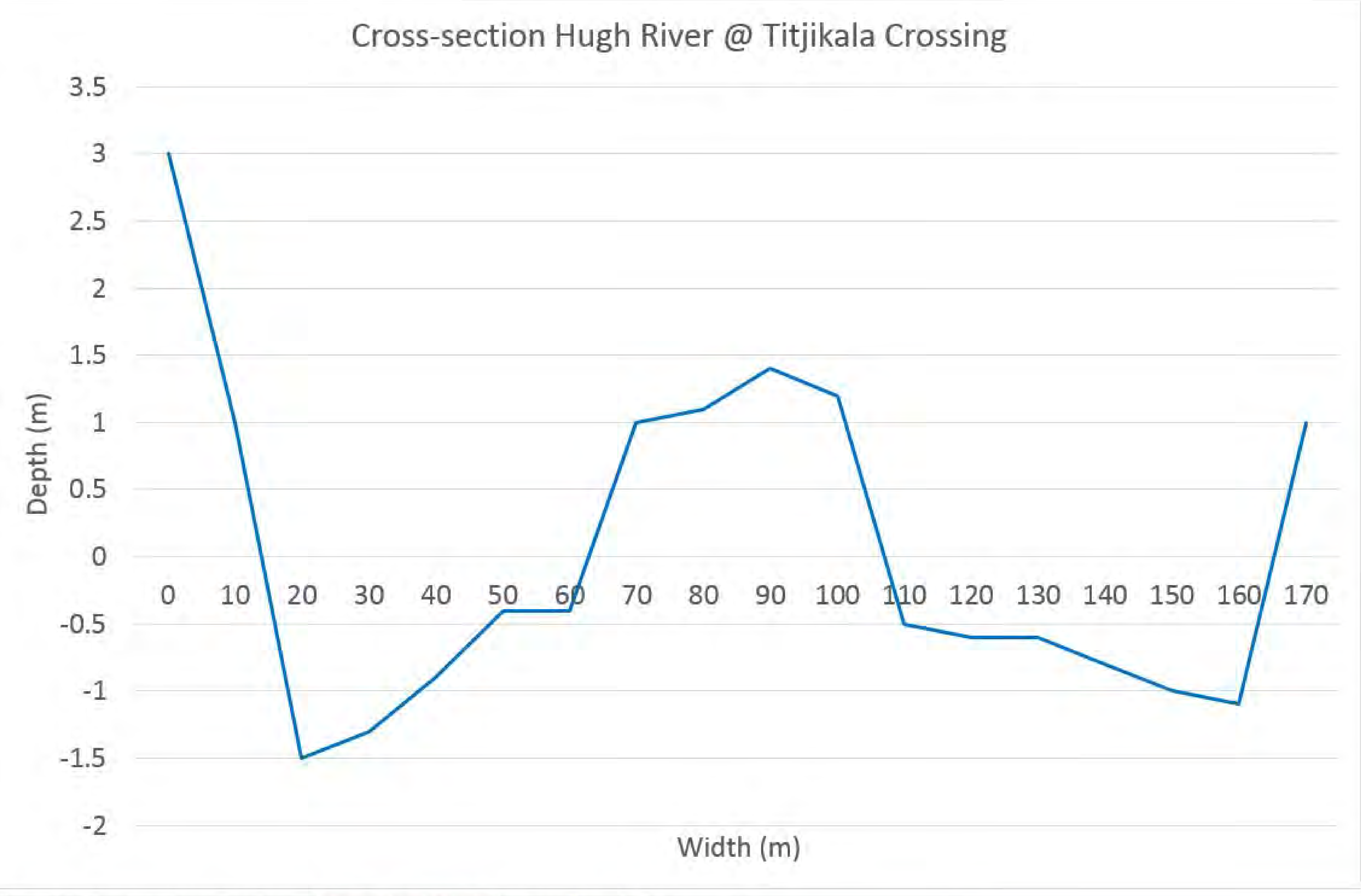
Plate A.1.19 – Hugh River South Branch looking upstream

Plate A.1.20 – Hugh River South Branch looking downstream

Plate A.1.21 – Vegetation stabilisation with coarse sediments in lee of plant

Plate A.1.22 – Rock outcrop across channel and debris load trapped on tree base / roots

Typical cross-section



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Appendix E - Soil erosion potential

An erosion hotspot model was generated for the study area following a procedure documented in Evans *et al*., 2006. The following attributes were incorporated as raster map layers in the model:

- Gradient derived from Tellus topographical data at 2-30m contour resolution;
- Hydrological connectivity derived from buffer rings to the nearest blue line drainage watercourse;
- Land cover derived from the National Dynamic Landcover dataset (Geoscience Australia, 2005);
- Rainfall intensity derived from the Tellus Automatic weather station; and
- Soil type / erodability derived from Department of Land Resource Management Natural Resources mapping.

These features were allocated a nominal ranking, based on the capacity to control erosion potential as follows:

Ranking	Gradient (%)	Hydrological connectivity (m)	Land cover	Rainfall intensity (mm hr^{-1})	Soil type / erodability
0	NS	NS	Salt Lakes	NS	NS
1	0 - 1.85	>1000	Closed Shrubs	0-20	Claystone / loamy content
2	1.86 - 4.01	251 – 1000	Open Hummock Grasses, Tussock Grasses or Trees	21-40	Crusty loamy soils
3	4.02 - 6.47	101 - 250	Sparse Hummock Grasses, Tussock Grasses, Shrubs, Chenopod Shrubs or Trees	41-60	Calcareous soils
4	6.48 - 9.86	51 - 100	Scattered Shrubs or Trees	61-80	Loamy soils
5	9.87 - 14.80	26 - 50	Rainfed Cropping	81-100	Red sands with clays
6	14.81 - 21.27	0 - 25	NS	>100	Red sands limited clay
7	21.28 - 29.29	NS	NS	NS	Red sands
8	29.30 - 40.08	NS	NS	NS	NS
9	40.09 - 78.30	NS	NS	NS	NS

NS = No score

Gradient rankings were nominally divided into 9 individual sub-categories based on the range of data recorded on site. Hydrological connectivity was scored according to the native buffer vegetation categories suggested in DLRM (2013) as follows:

- Native vegetation buffer 1st order streams = 6
- Native vegetation buffer intermittent streams = 5
- Native vegetation buffer creeks = 4
- Native vegetation buffer rivers = 3
- Native vegetation buffer Daly River = 2
- More than native vegetation buffer Daly River =1

Land cover rankings were allocated based on the density of vegetation classified in the National Dynamic Landcover dataset. Rainfall intensity was derived from the Tellus AWS station and a value of 61-80 mm hr^{-1} based on peak rainfall was applied to the whole site. The susceptibility of different soil types to erosion was based on a nominal scale based on professional experience and the clay content of the material.

This erosion hotspot tool is a relative comparison of erosion potential based on conditions in the study area only, and does not indicate an erosion risk potential that can be equated to other localities. No weighting factor was used to imply the relative importance of the five different attributes in controlling erosion potential. Combining rankings were summed to produce a maximum possible score range of 7 - 31. These combined rankings were then classified according to the following system:

- Negligible erosion risk – ranking range 7-10;
- Slight erosion risk – ranking range 11-14;
- Low erosion risk – ranking range 15-18;
- Intermediate erosion risk – ranking range 19-22;
- High erosion risk – ranking range 23-26; and
- Very high erosion risk – ranking range 27-31.

A raster map combining these layers was produced to provide a visual representation of erosion risk in the study area. It is envisaged that this can be used in the Water management Plan to identify areas of high erosion risk where infrastructure is planned in order to help prioritisation of mitigation measures.

Report

Chandler Facility- Flood and Hydrology Assessment

Prepared for Tellus Holdings Ltd

16 January 2017

www.beca.com

Revision History

Revision Nº	Prepared By	Description	Date
01	Michael Law	Draft for client review	14/09/2016
02	Michael Law	Draft final	28/09/2016
03	Michael Law	Final	13/01/2017

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Michael Law**		28/09/2016
Reviewed by	**Elliot Tuck**		28/09/2016
Approved by	**Dan Evans**		16/01/2017
on behalf of	**Beca Pty Ltd**		

Contents

Appendices

1 Introduction

1.1 Introduction

Beca Pty Ltd (hereafter referred to as 'Beca') was engaged by Tellus Holdings Ltd (hereafter referred to as 'Tellus') to assess potential surface water impacts from the construction and operation of the proposed Chandler dual business salt mine and waste storage and isolation project (hereafter referred to as the 'Proposal').

The Proposal is to develop a dual revenue business comprising of an underground rock salt mine for industrial and edible salt and using the voids resulting from mining for the secure storage and isolation of hazardous waste and the recovery of valuable materials using a best practice safety case (Tellus, 2016). The site is located approximately 120 km south of Alice Springs, Northern Territory (NT) and the Proposal has an estimated lifetime of 29 years (4 year build, 25 year operation).

The development will start at 30,000 tonnes of salt per annum, but has an overall design capacity of 400,000 tonnes per annum to accommodate for both steady state growth over 25 years and one off campaign style State Emergency Service infrastructure requirements (Tellus, 2016).

To support the export of salt and import of waste to the Facility transport will be mostly via rail to the Apirnta Facility. Here the material will be offloaded onto road train and hauled 30 km south-east to the Chandler Facility along a dirt road on a regular basis. Figure A.1 in Appendix A shows the location of the mine site, haul road and rail facility.

Proposed surface infrastructure includes dry salt processing facility and a 5 MW diesel fired power station supplemented by a 2MW solar power plant (Tellus, 2016). A surface plant for the hydraulic backfill emplacement of liquid and dry powdered wastes underground will also be present. Associated infrastructure including workshops, offices and 165 man accommodation camp, hardstand areas, car parks, weighbridges, vehicle wash down facility and sealed roads are planned.

1.2 Relevant guidelines and environmental objectives

The key environmental objective relating to water laid down by the NT EPA[1] for the Chandler Salt Mine is to:

> *"Ensure surface water and groundwater resources are protected both now and in the future, such that the ecological health and land uses, and the health, welfare and amenity of people are maintained."*[2]

In order to achieve this objective, risks need to be identified and assessed in an Environmental Impact Statement (EIS). The risk assessment should be at "an appropriate spatial scale as a result of the Project"[3].

[1] Northern Territory Environmental Protection Agency

[2] Paragraph 4.5.1, ***Draft Terms Of Reference For The Preparation Of An Environmental Impact Statement*** for the Chandler Salt Mine. NT EPA, August 2016

[3] Paragraph 4.5.2, NT EPA, August 2016

Of particular interest to surface water hydrology are potential changes to existing surface water quantity as a result of the Project, the impact of major and extreme weather events on water management and infrastructure, including flooding and the risks associated with proposed infrastructure and disturbance of soils that may alter the hydrology. Major weather events are considered those with an ARI[4] of up to 100-years and extreme events those with ARIs in excess of 100-years. These assessments will consider seasonality and the lifespan of the project.

1.3 Scope

It is not the intention of this report to duplicate information contained in the Baseline Report that included the acquisition and desktop review of the climate and hydrology of the region, with reference to long-term monitoring locations on the major watercourses, meteorology and elevation data.

The scope of this report is to identify, describe and assess the hydrological and flooding issues at a more local scale relating to the:

- Chandler Mine site;
- Haul road linking the mine site to the railhead at Apirnta, and westward to the Stuart Highway; and
- The Apirnta railhead site.

The objective of the report is to assess:

- The risks associate with any change in the hydrological regime on the receiving environment and local community as a result of the project. Of particular interest is whether the mine project will significantly alter the amount of water reaching the Hugh River in the vicinity of the Titjikala settlement; and
- Flood risk to the mine site, haul road and railhead. This will include the frequency, duration and extent of flooding, particularly at locations where the haul road crosses creek channels.

Sections 2 and 3 of this report addresses the assessment of flood risk to the project infrastructure (mine infrastructure area (MIA), haul road and railhead), while Section 4 addresses potential impacts to the hydrological regime.

[4] ARI: Average Recurrence Interval

2 Flood Flow Hydrographs

2.1 Approach

The mine site, haul road and railhead lie in the catchments of the Finke and Hugh Rivers. As noted in the Baseline Report (Beca, 2016), flows on both rivers are recorded at the Stuart Highway crossings (as is the Palmer, a tributary of the Finke) and the flows on the Finke are also recorded at the rail crossing. The haul road crosses the Finke River about 22.8 km east of the Stuart Highway, but west of the railhead. The topographic gradient suggests that water from the mine site would generally drain towards the Hugh River near Titjikala. However, site reconnaissance has shown that hydraulic connectivity between the mine site and the Hugh River is unlikely as reported in the EIS Surface Water Baseline Chapter.

Flood hydrographs have been defined for the catchments draining towards the project infrastructure (mine site, haul road and railhead) using the Australian Rainfall and Runoff (hereafter referred to as ARR87) guide to flood estimation and HEC-HMS hydrological modelling software. The resulting flood estimates have been verified with reference to the flood frequency of the major rivers.

The ARR87 approach requires:

- Catchment areas, lengths and slopes to be defined;
- Design rainfall;
- Storm depth;
- Aereal reduction;
- Profile;
- Losses; and
- Method of the transforming effective rainfall into a flow hydrograph. This includes calculating the Time of Concentration (Tc).

The input parameters for the hydrological modelling are listed in Tables B.1 to B.5 in Appendix B, and the calculated peak flows are in Table B.5 in Appendix B.

2.2 Catchment Delineation

This was done using a 30m grid digital elevation model (DEM), catchment delineation shape files from previous studies (though at a larger catchment scale) and aerial photographs. GIS files were produced showing the catchments draining to each low point along the haul road, and for those catchments discharging across the mine site, as shown in Figure 2.1 (a larger annotated version of Figure 2.1 is provided in Figure 3.3) and Figure A.2 in Appendix A. The limited DEM information was used to calculate average catchment slopes, which were in the range of 0.2% to 1.1%.

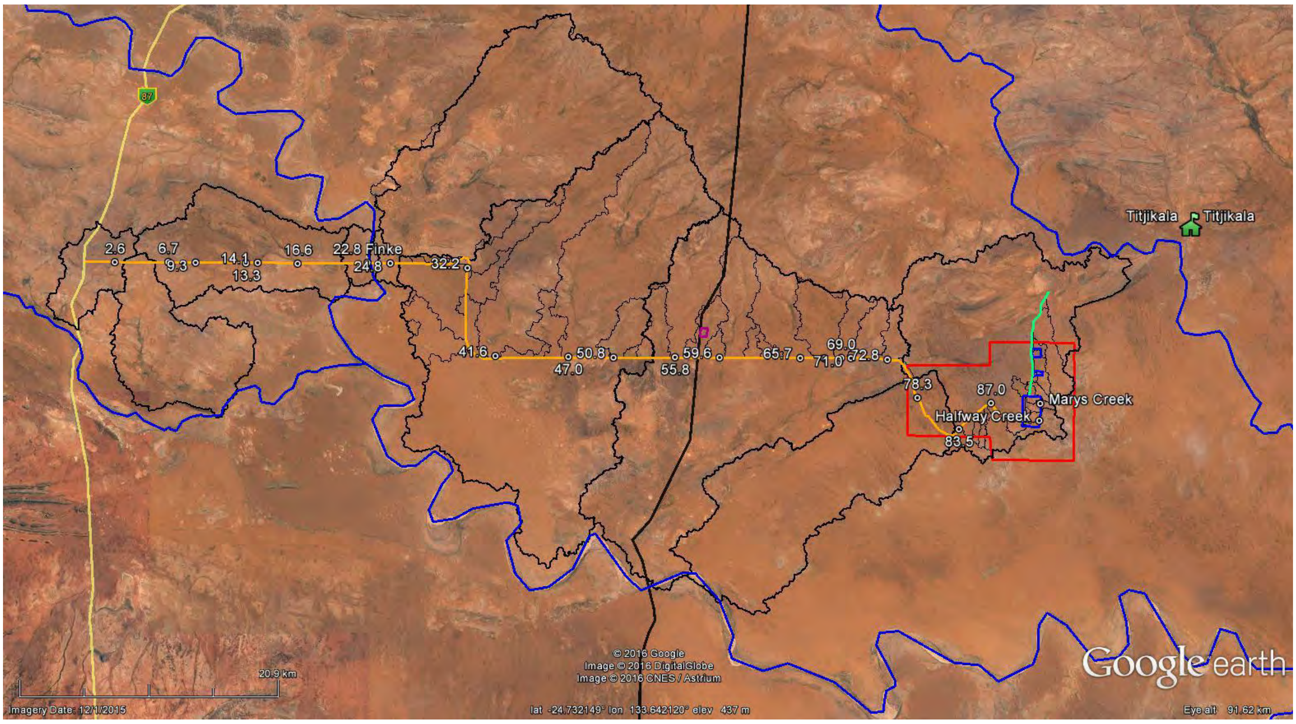

Figure 2.1 Catchment delineation (Project area in Red, Proposed mine sites in Blue)

The location where the watercourse (flow line) crossed the haul road was identified by its distance from the Stuart Highway. For example, the Finke River crossing is at 22.8 km. In the absence of named watercourses, this nomenclature has been retained throughout the report. The resulting derived catchment areas are shown in Table 2-1.

Table 2-1 - Derived sub-catchment areas for the Proposal

Catchment		Area km²
Finke at Rail		15,100
Finke at Stuart Hwy		7,500
Palmer at Stuart Hwy		6,100
Hugh at Stuart Hwy		3,140
Road crossing (kilometres from Stuart Highway)	6.0	6.0
	11.2	11.2
	18.7	18.7
	42.0	42.0
	62.7	62.7
	82.8	82.8
	8100	8100
	246.0	246.0
	25.0	25.0
	87.3	87.3
	123.0	123.0
	11.1	11.1
	46.0	46.0
	25.1	25.1
	24.0	24.0
	18.9	18.9
	7.7	7.7
	9.6	9.6
	6.0	6.0
	9.5	9.5
	3.8	3.8
	6.1	6.1
	1.6	1.6
Mine	3.5	3.5
	0.6	0.6

2.3 Design Rainfall

2.3.1 Storm depth

Rainfall depths for design storms up to the 100-year ARI event were taken from a Bureau of Meteorology Rainfall Intensity-Frequency-Duration (IFD) table generated for the railhead site (Figure 2.2). Values from the same table were used for all catchments relating to the project, as a comparison with IFD tables for the mine site and western end of the haul road (at the Stuart Highway) indicated that rainfall depths varied by less than 5% between the Stuart Highway and the mine site.

Intensity-Frequency-Duration Table

Location: 24.700S 133.425E NEAR.. Finke River Crossing Issued: 26/9/2016

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	40.4	54.4	79.2	95.4	116	144	167
6Mins	37.6	50.6	73.8	88.9	108	135	156
10Mins	31.1	41.8	60.9	73.3	89.0	111	128
20Mins	23.4	31.5	45.5	54.5	66.0	81.7	94.3
30Mins	19.3	25.9	37.3	44.6	53.9	66.7	76.8
1Hr	12.9	17.4	25.1	30.2	36.5	45.3	52.3
2Hrs	8.05	10.9	16.1	19.5	23.9	29.9	34.7
3Hrs	5.95	8.11	12.2	15.0	18.4	23.3	27.2
6Hrs	3.50	4.83	7.54	9.40	11.8	15.1	17.9
12Hrs	2.08	2.90	4.64	5.87	7.42	9.65	11.5
24Hrs	1.27	1.77	2.84	3.60	4.55	5.94	7.09
48Hrs	.763	1.06	1.68	2.11	2.67	3.46	4.12
72Hrs	.539	.750	1.19	1.50	1.90	2.46	2.93

(Raw data: 17.79, 2.91, 0.75, 45.64, 9.76, 2.46, skew=0.00, F2=3.83, F50=13.66) © Australian Government, Bureau of Meteorology

Figure 2.2 Bureau of Meteorology rainfall IFD table

2.3.2 Storm profiles

The critical storm durations for the catchments were initially defined by the calculation of the catchment Time of Concentration (Section 2.4) as being from 1.5 to 24 hours, depending on the catchment size and shape. The storm rainfall depths for these critical storm durations were distributed using the storm profiles for Zone 5 in ARR Table 3.2. Examples of the 1.5, 6, and 24 hour rainfall profiles for the 100-year ARI storm events are provided in Figures 2.3 to 2.5.

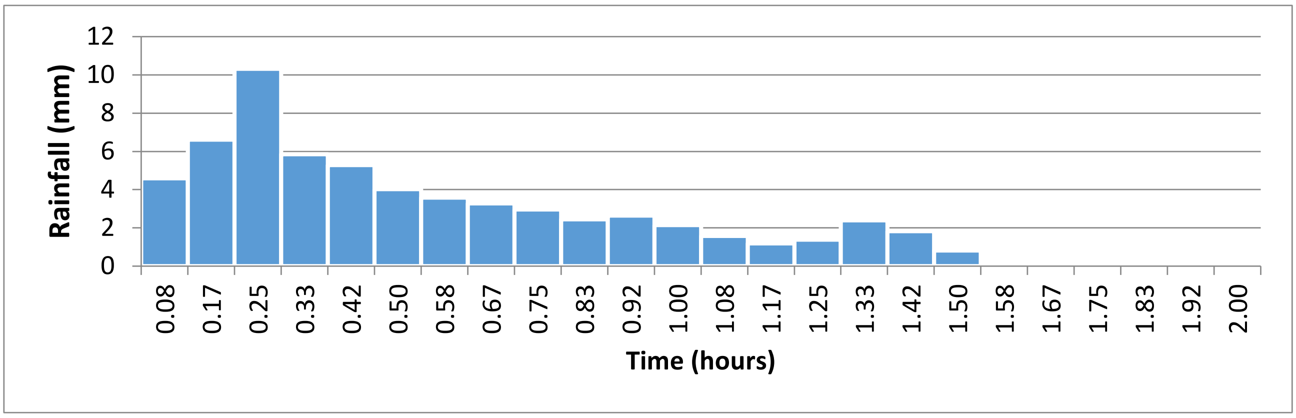

Figure 2.3 1.5 hour storm profile for 100-year ARI rainfall depth of 62.9 mm

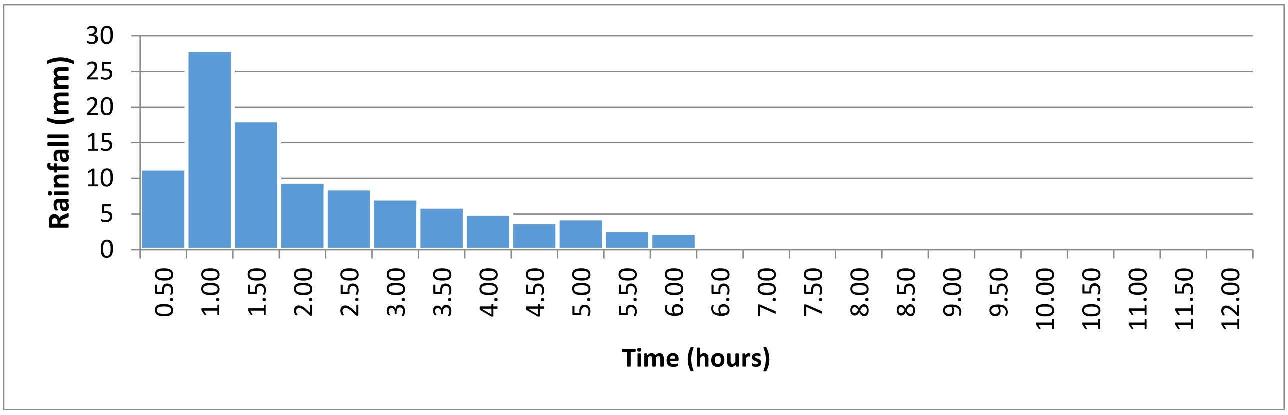

Figure 2.4 6 hour storm profile for 100-year ARI rainfall depth of 107.4 mm

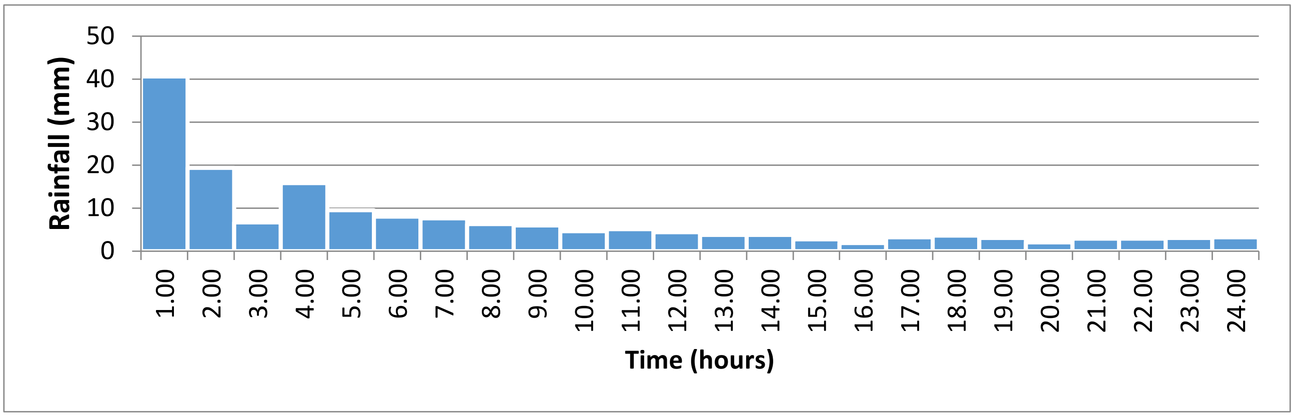

Figure 2.5 24 hour storm profile for 100-year ARI rainfall depth of 170.2 mm

However, subsequent modelling indicated that the losses (Section 0) applied to the rainfall resulted in little, or no, effective rainfall during short duration (<3 hours) rainfall events, and that the maximum peak flows for the majority of catchments affecting the mine infrastructure were generated by storms of 6-12 hours duration. For the 2-year ARI event, the 12 hour storm generated the highest peak flows. For the 10-year ARI event, there was little difference in peak flows generated by the 6, 9 or 12 hour storms. However, for the 100-year ARI event, the 6 and 9 hour storms generated the highest peak flows. The general relationship of the critical storm duration moving toward the catchment Time of Concentration as the magnitude of the event increases is expected, as the ratio of rainfall losses to total rainfall reduces.

2.3.3 Areal Reduction Factor

Design rainfall information for flood estimation is generally made available to designers in the form of point rainfall intensities. However, most flood estimates are required for catchments of significant size and will thus require a design estimate of the areal average rainfall intensity over the catchment. The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and annual exceedance probability (AEP), is called the areal reduction factor (ARF). It allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area (Engineers Australia, 2013).

Therefore, a factor is applied to the rainfall depth. The factor, which varies according to catchment size and the storm duration, was taken from ARR87 for IFD Zone 5. Figure 2.6 was used for determining the factors for the project infrastructure catchments (Table 2-1).

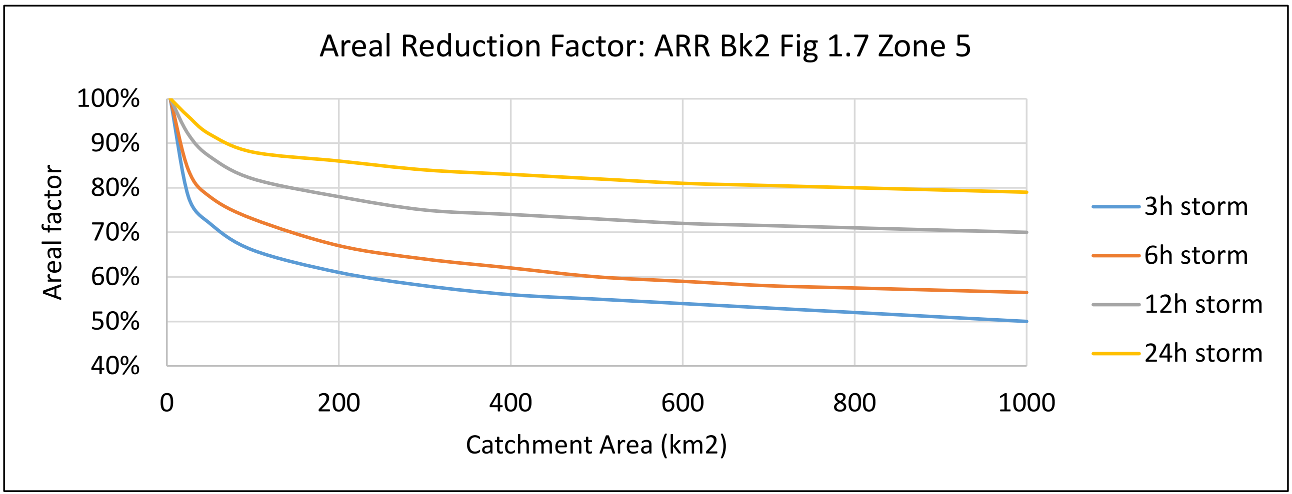

Figure 2.6 Rainfall areal reduction factor

The ARF's for the major rivers (Hugh, Palmer, and Finke) were between 0.70-0.75 for their respective catchment areas and times of concentration. The full set of ARF's are provided in Table B.2, Appendix B.

2.3.4 Rainfall losses

Not all of the rainfall that falls on the catchment will contribute to storm runoff. Depending on antecedent conditions, vegetation and other factors, some of the rain is intercepted by vegetation, some lost to infiltration into the ground, while more may be held in shallow depressions / clay plans.

ARR87 suggests that rainfall losses should be accounted for by applying an Initial Loss (Ia) to the rainfall and then an Ongoing Loss (OL) for the duration of the storm. For 'Central Australia' parts of the Northern Territory, Table 3.8 of ARR87 Book 2 directs the user to the losses for 'Arid Zone' parts of South Australia, which are given in Table 3.4 of ARR87 Book 2. Two combinations of Initial and Ongoing losses are provided; Initial Loss of 15 mm or 40 mm, and Ongoing Loss of 4 mm/h or 1-3 mm/h.

Storm runoff is sensitive to the choice of appropriate rainfall losses. Using an Initial Loss of 40 mm with the BoM IFD rainfall depths would result in no runoff for the majority of design events of 5 years ARI or less. While selecting a higher Ongoing Loss will result in no effective rainfall from much of the longer-duration storm profiles. Through a combination of professional judgement and verification against storm hydrographs for the Hugh and Finke rivers, the following rainfall losses have been used:

- Initial Loss: 20 mm; and
- Ongoing Loss: 1 mm/hr.

2.4 Rainfall-Flow Transformation

The Clark Unit Hydrograph (CUH) method has been used to transform the effective rainfall hyetographs for each catchment into flow hydrographs. The CUH method requires the Time of Concentration (Tc) and CUH Storage Coefficient (Sc) to be calculated using the following equations:

*Tc = 0.76*Area$^{0.38}$*	*where:*	*Tc = Time of Concentration (hours)*
		Area = Catchment area (km^2)
*Sc = Tc *ratio/(1-ration)*		*Sc = CUH Storage Coefficient (hours)*
		ratio = 0.65 for flat rural catchments

2.5 Flow results

Figure 2.7 shows the relationship (logarithmic scale) between peak flows and catchment area developed from the hydrological modelling of the catchments crossing the mine infrastructure, which range in size from 6 km² to 246 km² (Table 2-1). For the 10-year and 100-year ARI events there are good relationships that can be described by power equations. However, the relationship for the 2-year ARI event is less readily defined by a power equation, but a relationship is clear. This could reflect the greater relative effect of ongoing rainfall losses in reducing the effective rainfall in higher frequency events.

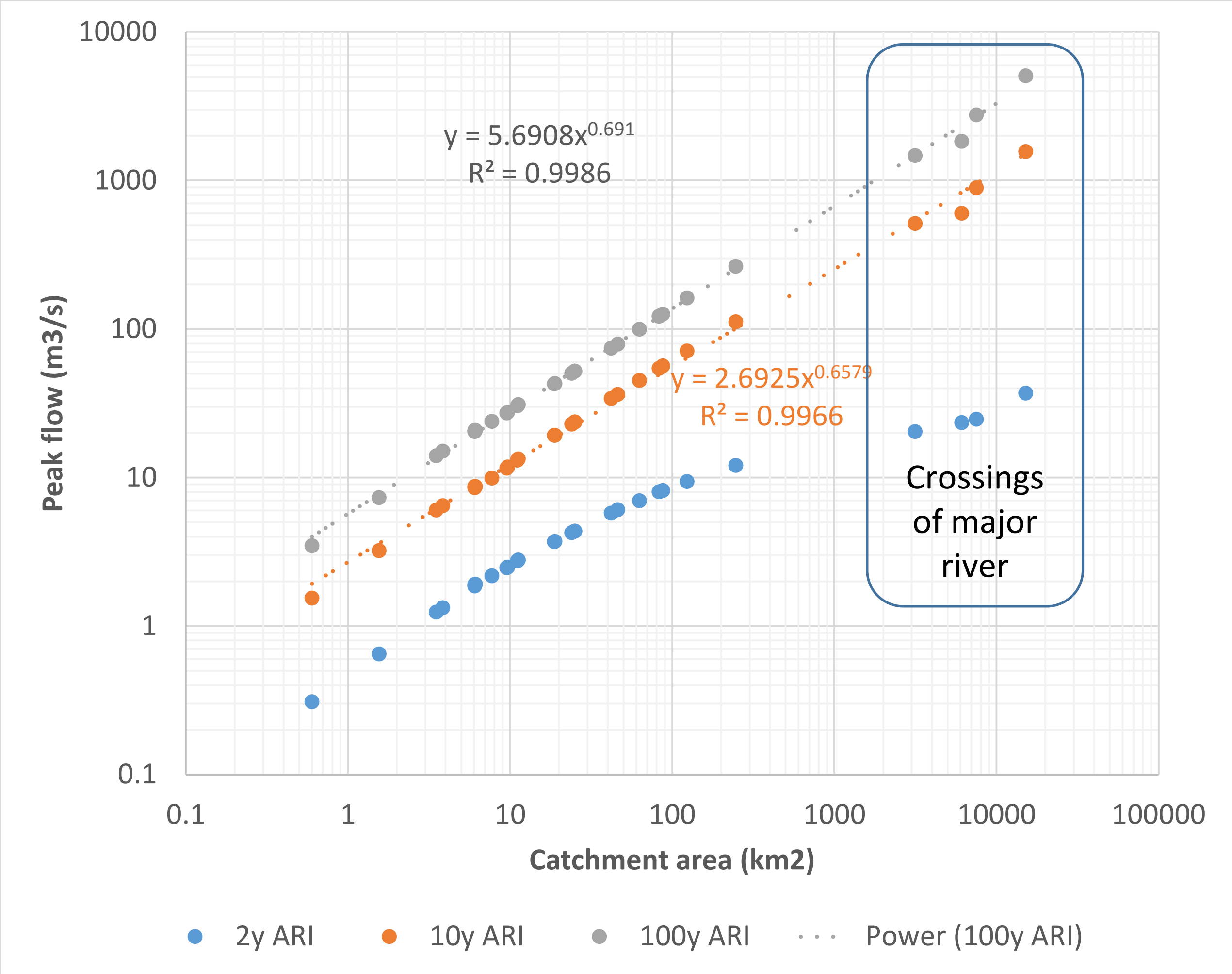

Figure 2.7 Catchment area – peak flow relationship

Figure 2.8 shows the peak flows per km² of catchment. As with Figure 2.7, the 10-year and 100-year ARI yields can be described by single power equations. The 2-year ARI relationship is more complex and has been split into two separate relationships; one representing catchments smaller than 60 km² and one for catchments greater than 60 km².

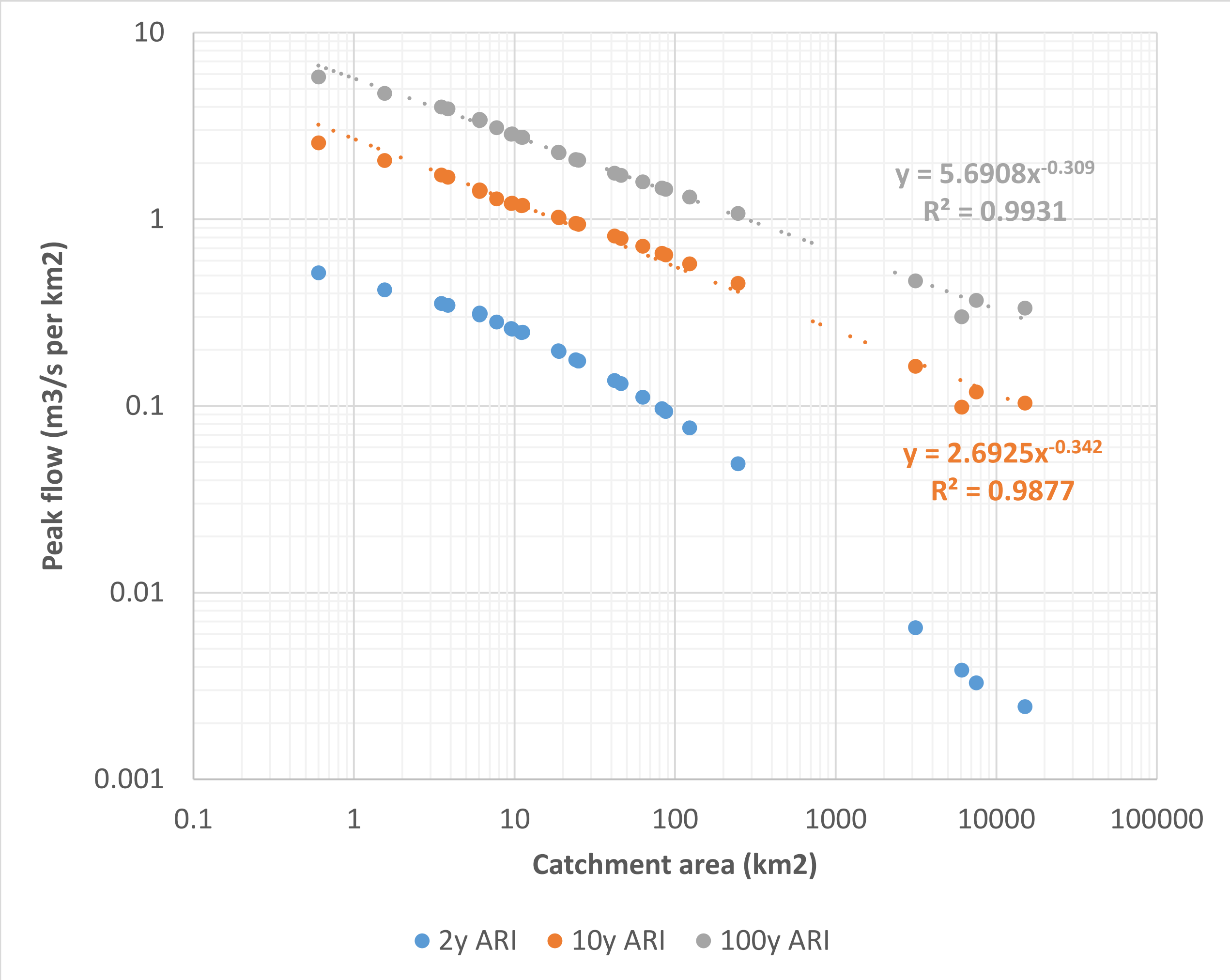

Figure 2.8 Peak flow per km^2

The calculated 100-year ARI peak flow for the Finke at the Stuart Highway (catchment area 92% of the Finke at the haul road crossing [22.8 km]) is 35% greater than the 100-year ARI flow calculated from limited recorded data. Further validation of calculated design flows (especially for the smaller sub-catchments reaching the site and crossing the haul road) would be desirable, but is dependent on the recording of water levels and flows on representative small catchments.

3 Flood Risk

3.1 Mine site

The mine site lies at the foot of an escarpment and a number of drainage lines and ephemeral creeks/gullies drain across the site and onto washout plains (Beca, 2016). At the mine site boundary, these range in size from about 0.03 to 3.5 km^2; the largest being the catchment that drains to Halfway Dam with a 100-year ARI peak flow of 11.7 m^3/s, and a 2-year ARI peak flow of 1.4 m^3/s. The total catchment area draining to the mine site is 4.1 km^2 (including the Halfway Dam catchment) which would generate the following peak flows:

- 2-year ARI 1.5 m^3/s
- 10-year ARI 6.7 m^3/s
- 100-year ARI 13.7 m^3/s

Drainage through or around the mine site will need to accommodate these peak flows. As noted in Section 2.5, short duration (<3 hours) rainfall does not generally result in significant runoff, as the majority of the rainfall is used to satisfy the initial rainfall loss. The peak flows are generally associated with longer duration rainfall that result in excess runoff. Under these conditions, it would be expected that the mine drainage network would have to manage flood flows for about 8 hours.

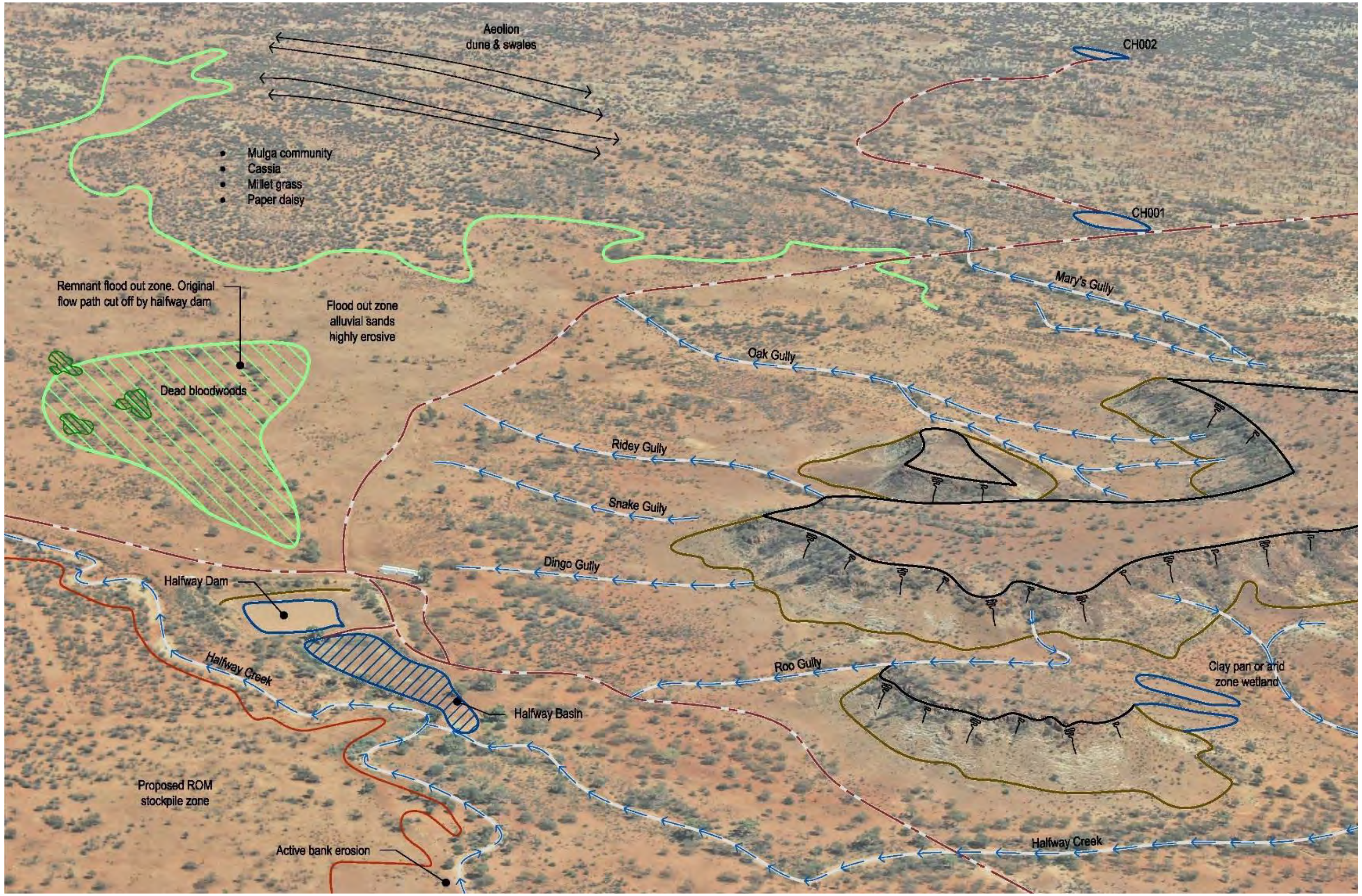

Figure 3.1 Hydrological features at the Chandler Mine Site (looking north)

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3.2 Road flooding

Peak flows and time-series hydrographs have been derived for each of the catchments (Figure 3.3) crossed by the access road and haul road between the mine site and the Stuart Highway. In total, the access and haul roads cross a significant watercourse or flow line 20 times over a total distance of 90 km. At each of these locations, there is the potential for the haul road to be flooded or to pond water (if the road is carried on an embankment across the floodway).

A detailed DEM of the road alignment between the mine site and the railhead allowed an assessment of the depth and duration of flooding, and the length of road affected. Between the railhead and Stuart Highway (proposed Henbury Access Road), a detailed assessment is not practical due to the absence of a high-resolution DEM, though an estimate of the flood risk at the Finke River crossing (22.8 km) has been made.

For the catchments between the Chandler Facility and railhead (Chandler Haul Road), the DEM was used to define the main channel and floodway cross-section, and the channel gradient. The Mannings flow formula (with a Mannings 'n' roughness of 0.04) was then used to calculate the:

- Depth of flooding over time;
- Velocity of water over time;
- Length of road flooded; and
- Duration of flooding.

The results are presented in Table 3.1 for the 100-year ARI storm of 24 hours duration. The results for the 24-hour storm are presented as these generate the highest peak flows for the larger road crossing sub-catchments. For the smaller sub-catchments, the 24-hour peak flows are within 10% of the shorter storm peak flows. Using this single storm duration provides comparability for flooded road lengths and durations.

Table 3.1 - Haul Road Flood Risk – 100-year ARI (24-hour storm)

Crossing (distance from Stuart Highway)	Peak Flow	Max. depth	Max. velocity	Flood hazard (Fig 3.2)	Length of road flooded		Duration of flooding	
					Water on road	>100mm flooding	Water on road	>100mm flooding
km	*m^3s^{-1}*	*m*	*ms^{-1}*		*m*	*m*	*hours*	*hours*
59.6	50.5	1.00	0.94	Medium	79	72	43	33
65.7	48.7	0.52	0.67	Medium	170	157	42	30
67.9	40.83	0.33	0.64	Low	169	127	43	25
69.0	20.5	0.30	0.50	Low	154	143	37	25
71.0	24.4	0.60	0.77	Medium	69	43	31	27
72.8	16.8	0.60	0.44	Medium	205	107	27	24
78.3	24.0	0.48	0.63	Medium	106	101	38	29
83.5	11.4	0.33	0.75	Low	33	24	25	11
87.0	17.1	0.37	0.57	Low	94	85	37	27
89.2	5.6	0.50	0.97	Medium	8	8	0	0

It is assumed that the road could be passable with shallow flooding (<100 mm). Therefore, the length of time that the maximum flood depth along the road exceeds 100 mm is also noted, as is the length of road affected by flooding of more than 100 mm.

Based on this assessment, peak water velocities are not high and are not the principal driver behind flood hazard at the crossings (Figure 3.2). Rather, the maximum depth of flooding puts some of the crossings into the medium hazard category, with the crossing at 59.6 km verging on the high category. The flood hazard categories represent the risk to life of entering the floodwaters, and are based on the matrix of flood depth and water velocity developed for Hamilton City Council (2012) based on local and international guidance.

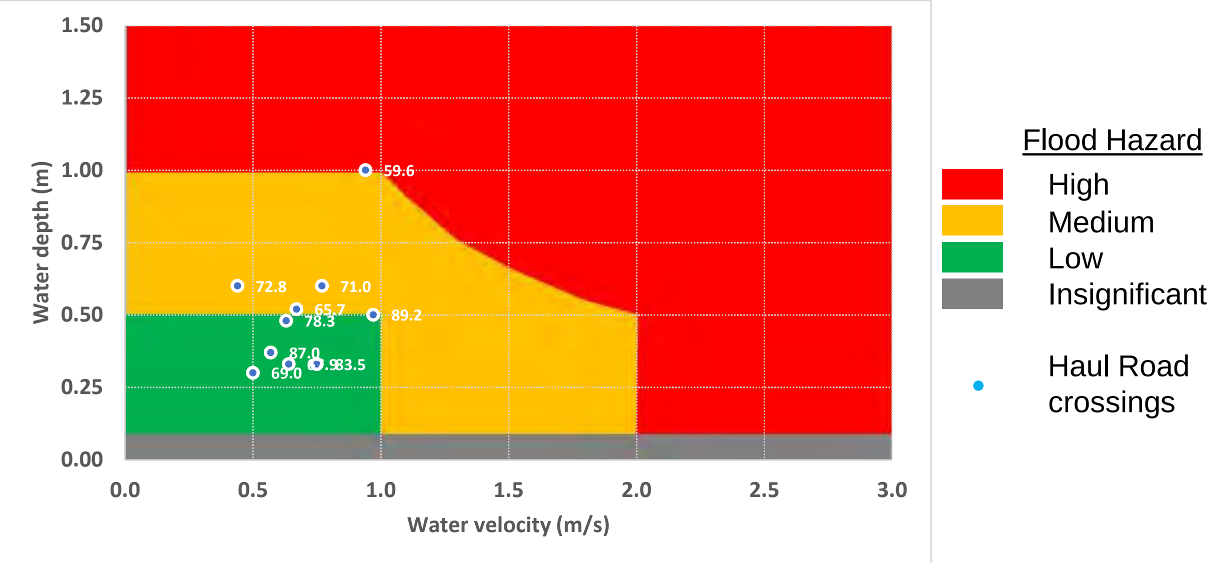

Figure 3.2 Flood Hazard at Haul Road crossings

While the assessment was limited to those crossings where high definition DEM data was available and a reasonably well-defined drainage line could be identified, it is assumed that the flow depths, velocities and lengths of road flooded are representative of all crossings along the haul road.

The modelling approach assumed that all of the flow passes over the road, and that the road is not raised above local ground level. As such, it is the worst case flooding scenario. The information will inform the road design, including options to mitigate flooding of the road, such as road raising and the use of culverts or bridges to pass flow. Such crossings would not be expected to interrupt natural stream flow and geomorphological processes. However, post-event maintenance may be required to ensure road usability.

In the absence of the DEM at the Finke River crossing, the width of the river channel was measured on Google Earth. It was assumed that the channel was well-defined, with the channel bed approximately 3-3.5 m below the top of the banks, as inferred from photographs of the Stuart Highway crossing of the Finke. Using the Mannings formula, the channel of the Finke has a bank-full capacity of about 1,300 m^3/s, which approximates to the 10-year ARI flow.

The approaches to the Finke River from the west and east would be lowered and a gravel based layer constructed on the river bed to allow floodwaters to pass over the road with the expectation that the road will be unpassable under such conditions, and would require maintenance following higher flow events.

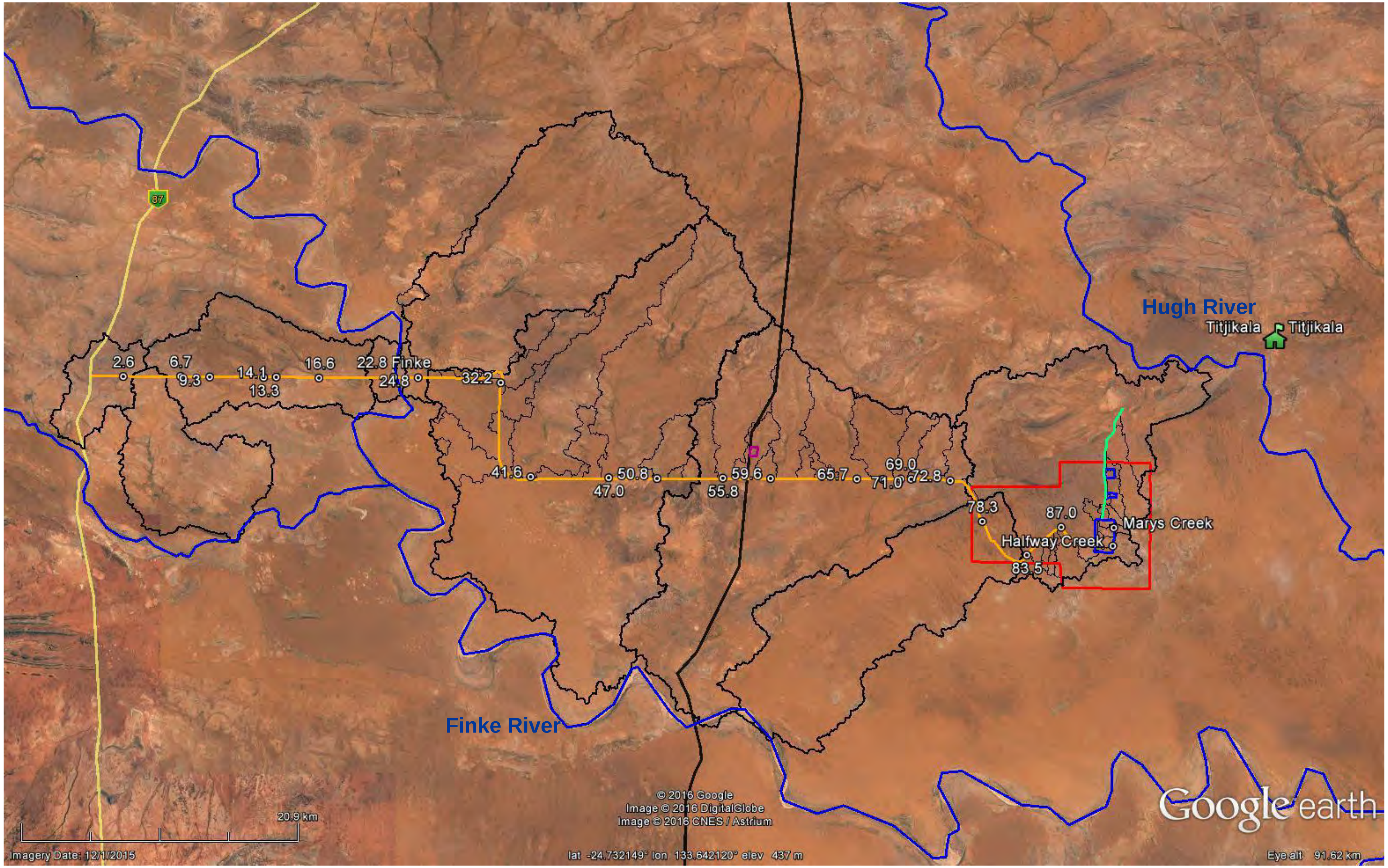

Figure 3.3 Haul Road catchments

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3.3 Apirnta Facility

The detailed DEM includes the Railhead loading site, which is about 2 km north of the existing rail crossing. The facility lies about halfway along an 8 km^2 catchment draining to the haul road. Figure 3.4 shows the location of the facility and contour lines that indicate that the facility intercepts the catchment drainage path, which has a slope of 0.4%. With an upstream catchment area of about 4 km^2, the peak 100-year flow will be about 13 m^3/s. This will need to be diverted around, or through, the site. For example, a 5 m wide channel with 4:1 side slopes and a roughness of n = 0.04, a flow of 13m^3/s would have a depth of 1.1 m and a velocity of 1.3 m/s.

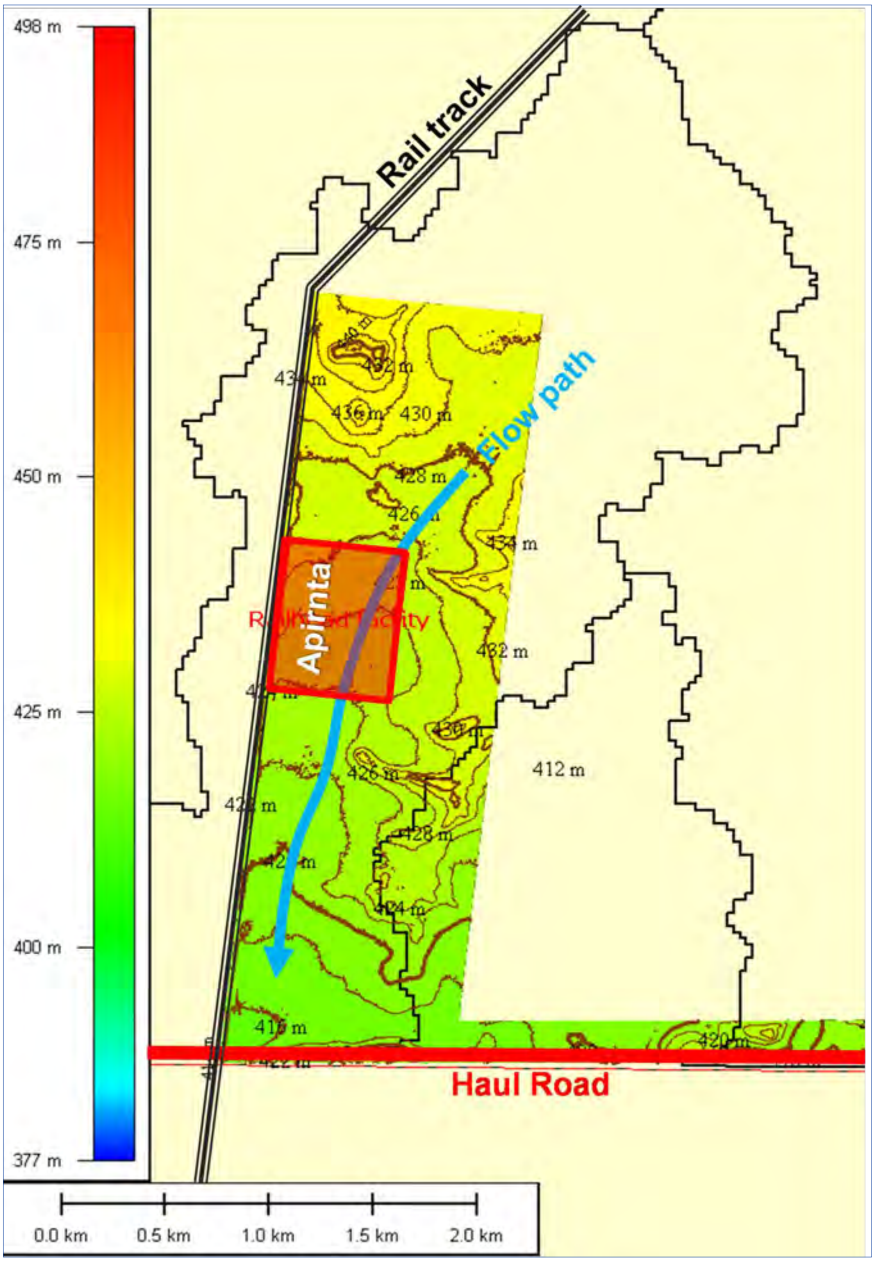

Figure 3.4 Railhead topography

The area shown as the railhead facility is about 0.4 km^2; which equates to 10 % of the catchment upstream of the railhead facility and 5 % of the catchment draining to the haul road.

Developing the railhead will result in an increase in impervious area, and potentially a corresponding increase in runoff from the site, though it is understood that the Project intention is to capture stormwater runoff from this site for reuse, such as dust suppression (Tellus, 2016). It is anticipated that this runoff will be intercepted for water quality treatment, which will have the additional benefit of attenuating flows and mitigating any increase in peak flows of volumes down to acceptable levels.

The storage capacity for capturing all stormwater could be significant for larger design events. The design requirements for this storage system are beyond the remit of this assessment and should be addressed in detailed design and later updated within the Proposal's Water Management Plan.

4 Hydrological effects

While the primary hydrological issue for the mine infrastructure is the risk from flooding, the potential impacts of the mine on the hydrological regime of the receiving environment must also be considered. In the case of the Chandler Facility and associated infrastructure, this includes potential effects on the Titjikala Community.

4.1 Mine site

The Chandler Facility (mine infrastructure area) is about 3.5 km^2, with an upstream catchment area of 4.1 km^2. The camp area is 3 km north of the mine site, which is an area of about 0.35 km^2. Under current proposals the remainder of the 100 km^2 mine lease site will not be developed. The majority of the lease area (including the mine site and camp) lies within an 84 km^2 catchment with topographic gradient orientated northeast through the Charlotte Ranges towards the Hugh River and Titjikala, as shown in Figure 4.1.

There are no signs that the drainage pathway from the MIA to the Hugh River is a permanent watercourse, and the Hugh River runs for less than 10% of the time. Water flowing through or from the mine site drains towards a flat washout (or ponding) area prior to passing towards the Charlotte Ranges, as shown on Figure 4.1. The detailed DEM only covers part of this washout area, but it is anticipated that the majority of the runoff will pond in this area, with significant to losses to evaporation and infiltration resulting in limited runoff reaching the Hugh River in all but the largest flood events. A conceptual drainage model for this area is detailed in the Surface Water Baseline Report (Beca, 2016).

The 84 km^2 catchment draining the mine lease area towards the Charlotte Range would generate about 5.5 million m^3 of runoff in the 100-year ARI 9-hour storm. This represents a runoff coefficient of about 54 %. The catchment topographical gradient lies towards the washout area before heading northeast towards the Hugh River and Titjikala. The washout area is about 12 km^2 (though difficult to define without detailed DEM) and will attenuate the flood.

The additional runoff from the mine site would represent an increase in water depth on the washout area of about 15 mm, if the area were totally ponded. However, while ponding in the washout area, floodwater will infiltrate into the ground and be subject to very high evaporation rates (greater than 3000 mm per annum) over a large area such that the effect of any additional runoff will be reduced further.

On this basis and as the mine site, camp, and catchments upstream of the mine only represent about 10 % of the catchment draining through the Charlotte Ranges, it is not anticipated that the change in hydrological regime due to the Chandler Facility would have a noticeable effect on the Hugh River near Titjikala.

At the south-eastern boundary of the mine site lies Halfway Dam, which captures runoff from a 3.5 km^2 catchment. An adverse impact on dependant vegetation was reported in the Surface Water Baseline chapter of the EIS relating to the historic diversion of the Halfway Creek to accommodate this dam and subsequent decrease in flows to the flood out area down-gradient from the dam. The current plan is to relocate Halfway Dam and utilise its current site as the salt stockpile (Tellus, 2016). Therefore, further investigation during detailed design is required to:

- Find a suitable location for a new dam;
- Assess the effect of any mine activity in the catchment upstream on flow yield / reliability; and
- Inform the dam location, intake structure (visible on Google Earth), and dam capacity.

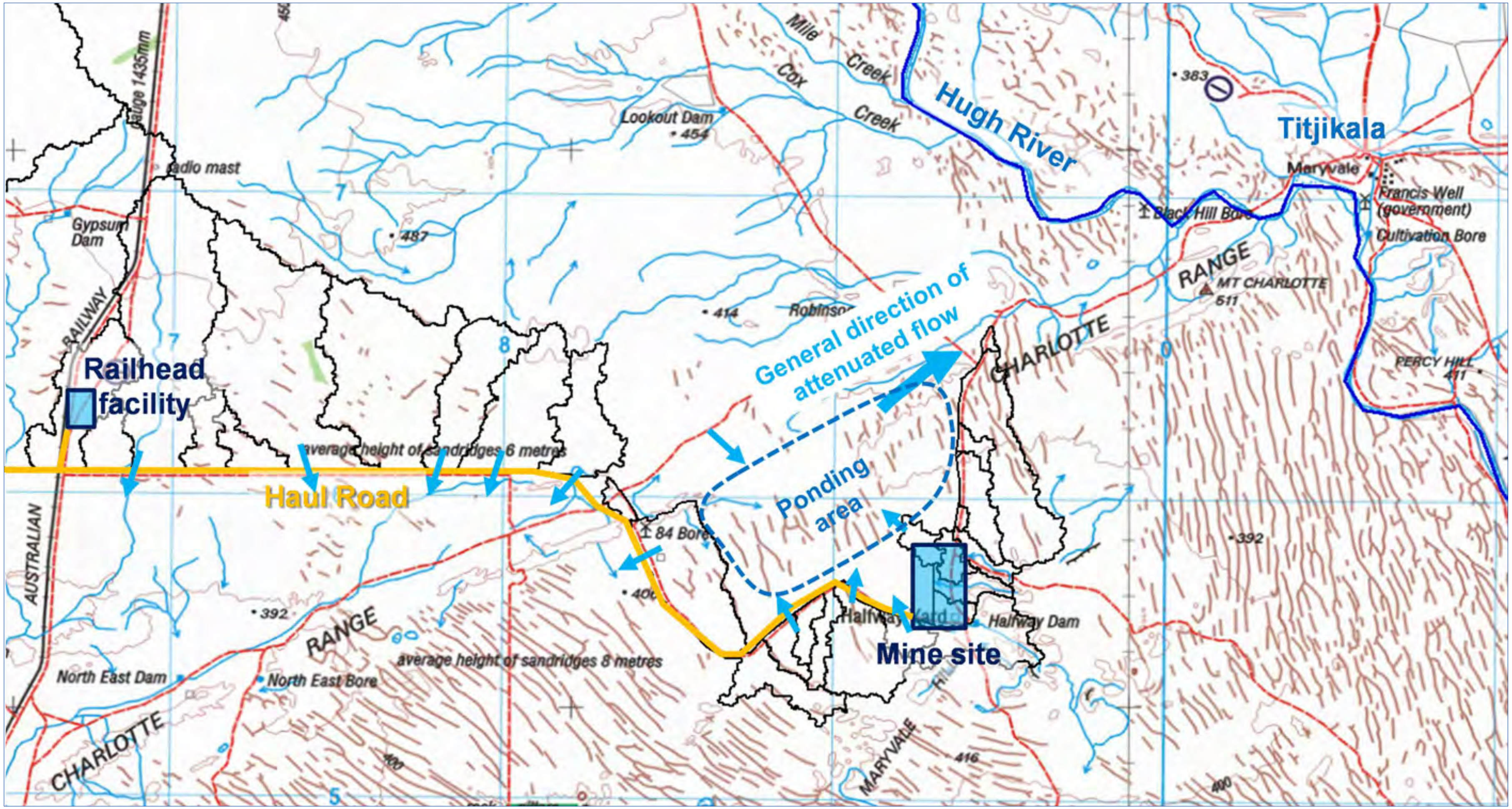

Figure 4.1 Topography and drainage lines

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4.2 Chandler Haul Road and Apirnta Facility

The drainage lines crossing the haul road and intercepted by the Apirnta railhead facility generally flow in a southerly direction towards a drainage line running south-westerly along the northern flank of the Charlotte Range, and hence to the Finke River. Between the Chandler Facility and the railhead, the river is about 19 km from south of the Chandler Haul Road.

The only infrastructure of note downstream of the Chandler Haul Road are the rail crossing of the Charlotte Creek drainage line along the northern flank of the Charlotte Range and North East Dam shown on the surface water bodies map in the Baseline report (Beca, 2016).

Though the upgraded Chandler Haul Road will be less pervious than the existing track, the area will be insignificant when compared to areas of contributing catchments. As such, it is not anticipated that the proposed Chandler Haul Road will increase the peak flood flow or volume at the rail crossing or dam. If the Chandler Haul Road is raised, there is the potential for storm runoff to be intercepted and ponded upstream of the road. If the effect of the road is to be neutral, then measures should be taken to minimise upstream ponding.

The Apirnta Facility occupies a site of about 0.4 km^2, in a catchment of about 8 km^2 draining south towards the proposed Chandler Haul Road. The flood modelling of this catchment shows a runoff coefficient of 72 % in the 100-year ARI 9-hour storm, generating 700,000 m^3 of runoff. Were the 0.4 km^2 of the Apirnta Facility to be 100% impervious, then runoff would increase by 13,000 m^3 or 1.9 %. It is assumed that site runoff would be collected for treatment, and so it is not anticipated that there would be an increase in peak flow 4 km downstream at the haul road crossing.

5 Mitigation measures and monitoring

5.1 Mitigation Measures

Table 5.1 summarises the measures that may be incorporated into the design of the Proposal's infrastructure to mitigate the effects of flooding and changes to the hydrological regime.

Table 5.1 - Mitigation measures

Issue	Mitigation measure
Management of floodwater draining towards the Chandler Facility from the Maryvale Hills upstream of the mine site.	▪ Formalise drainage channels through or around the site so that upstream runoff does not cause flooding of the site, and so that it is not contaminated by site runoff. ▪ Raise flood prone site infrastructure above surrounding ground level.
Development of the Chandler Facility and Apirnta Facility will increase impervious areas resulting in increased flood volumes and change the water quality of runoff.	▪ Treatment of runoff to improve water quality will result in an attenuation of flows, mitigating any increase in runoff peak flows or volumes.
Halfway Dam lies on the south-eastern boundary of the mine site.	▪ Investigate current and future use of the dam. ▪ Develop proposals to move or reconfigure the dam and intake.
Chandler Haul Road crossings of drainage lines	Mitigation measures will depend on the duration of road closure following flood events that is acceptable to the Proposal, but could include: ▪ Raising the road above surrounding ground level to prevent flooding. ▪ Culverts to pass flood flow and reduce / minimise upstream ponding. ▪ Causeways over which floodwaters in excess of the design event can pass, but that raise the road above frequent flood levels. *Combinations of above* Following flood events, it is anticipated that repairs to the haul road are likely to be required over the life of the Proposal.
Henbury Access Road at the River Finke crossing	▪ Raised road on the approaches to the river.

5.2 Additional Monitoring

The assessments described above have been undertaken with limited information. To improve certainty over the flood and hydrological modelling, and to allow mitigation measures to be progressed to design, additional monitoring, data collection and investigations are required. These include:

- Data collection:
  - Further interrogation of detailed DEM data during detailed design along the Henbury Access Road, particularly at the Finke River crossing;

  - DEM of the whole washout area downstream of the mine site to complement the existing DEM that covers much of this area; and
  - Anecdotal information on flood frequency, flood levels in the Finke and Hugh Rivers, as well as levels in the gullies and creeks surrounding the MIA and, halfway dam operation.
- Additional monitoring:
  - Level / flow measurement on Halfway Dam catchment and 3-4 catchments draining to the Haul Road or mine site, and including the catchment draining through the Apirnta Facility.
- Investigations (during detailed design)
  - Stormwater models of the Chandler Facility and Apirnta Facility, including the management of site runoff and the diversion / conveyance of floodwaters from upstream catchments around the sites;
  - 2-D modelling of flow paths and inundation in the mine lease area, including the 'washout area' to better understand the potential for floodwaters to reach the Hugh River near Titjikala. This investigation would include an assessment of infiltration and evaporation;
  - Modelling flood risk and scour protection at the Finke River crossing; and
  - Modelling flood risk of haul crossings (bridges, culverts, causeways) of drainage lines.
    The modelling would include an expanded suite of design events, including extreme events such as the Probable Maximum Flood.

6 Conclusions and recommendations

The Project is located in a remote, dry and sparsely populated part of the Northern Territory. Watercourses in the region are generally dry for the majority of the year. Rainfall is seasonal, with the potential to generate large flood events. Due to generally dry antecedent conditions, the first rain to fall is needed to satisfy the moisture demand of the surface layer, with runoff generated from rain later in the storm.

Without suitable mitigation, flooding has the potential to affect the mine site, Apirnta railhead facility and haul road. Mitigation will be required to divert / convey flood flows from upstream catchments past the mine site and Apirnta railhead facility, and to manage stormwater on both sites. Stormwater management will include water quality treatment (not considered in this report).

Where the access and haul road crosses drainage lines, the road could be closed for up to 24 hours following the 100-year ARI 9-hour storm unless mitigation measures (culverts or causeways) are incorporated into the road design. The crossing of the Finke River (between Apirnta and the Stuart Highway) could require a bridge, if the intention is to keep that section of road open at all times.

If managed correctly, the remote location of the Project limits the potential for the associated infrastructure to adversely affect other communities or environment. The changes in hydrological regime due to the mine site development are unlikely to be observed at the Titjikala community near the Hugh River, as the affected area is a small percentage of the contributing catchment and hydrological connectivity from the proposed mine site area through the washout zone and dunes to the Hugh River is unlikely.

It is acknowledged that the hydrological and flood investigations described in this report are not comprehensive, and that further monitoring and investigations are required to confirm the assessment undertaken to date and the reported conclusions.

7 References

- AR&R 1987 Australian rainfall and Runoff: A guide to flood estimation.
- Beca (2016) Surface Water Baseline Conditions. Prepared September 2016.
- EMM (2016) Water Assessment. Chandler Salt Mine Project. Prepared September 2016.
- Engineers Australia (2013) Collection and Review of Aereal Reduction Factors. Australian Rainfall and Runoff Revision Project 2. Final Report April 2013. Document reference P2/S2/012.
- Hamilton City Council (2012) Flood Hazard Report. October 2012. Available to download at: http://www.hamilton.govt.nz/our-council/council-publications/districtplans/flood/Pages/default.aspx
- NT EPA (2016) Final Guidelines for the Preparation of an Environmental Impact Statement. Chandler Salt Mine Project. Tellus Holdings Ltd. Northern Territory Environment Protection Authority. August 2016.
- NT Gov (2016) Water Data Portal.
- Tellus (2016) Chapter 3 Proposal Description. Draft Version, August 2016. Tellus Holdings Ltd.

Appendices

Appendix A – Study area maps and plans

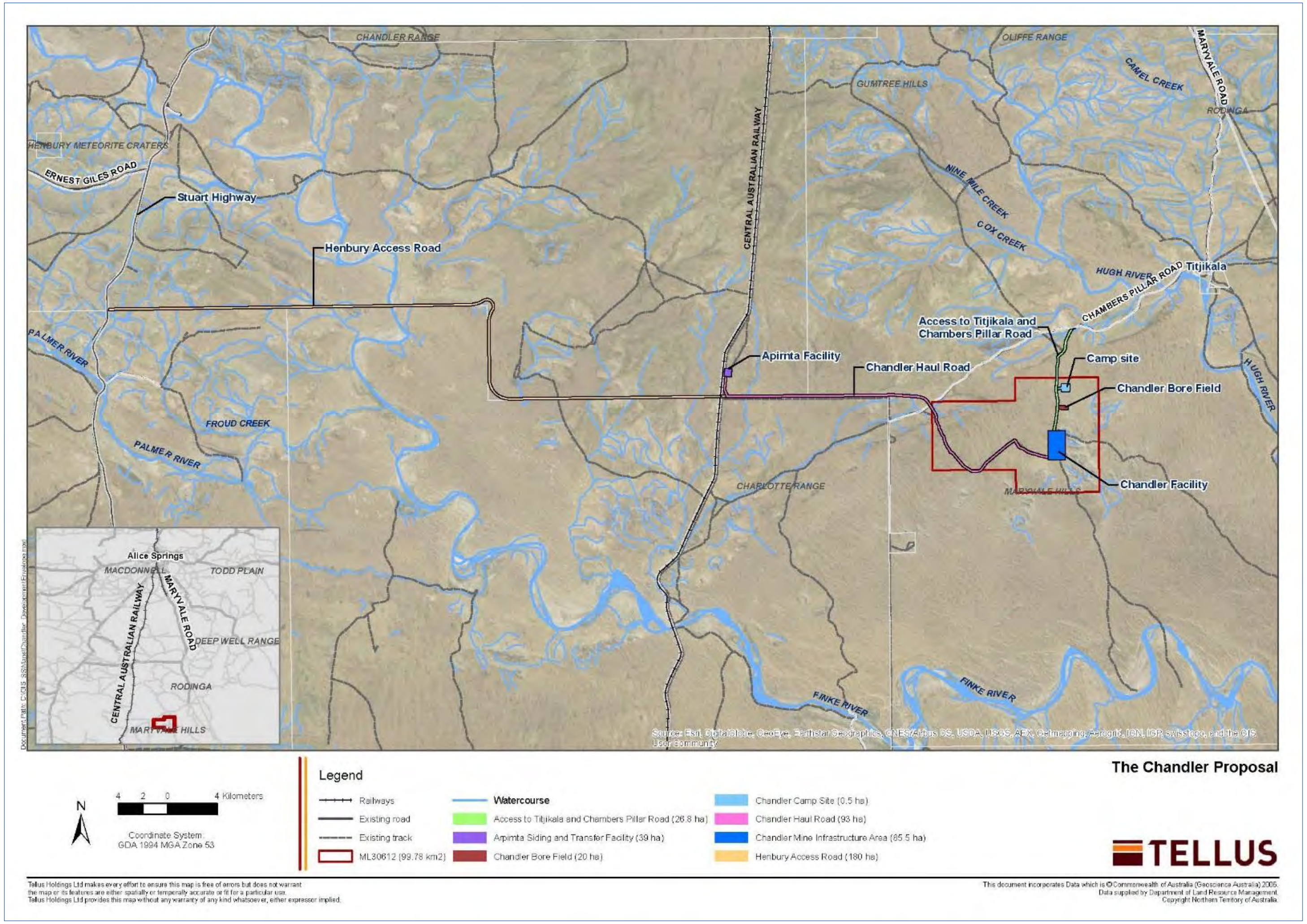

Figure A.1 Location map

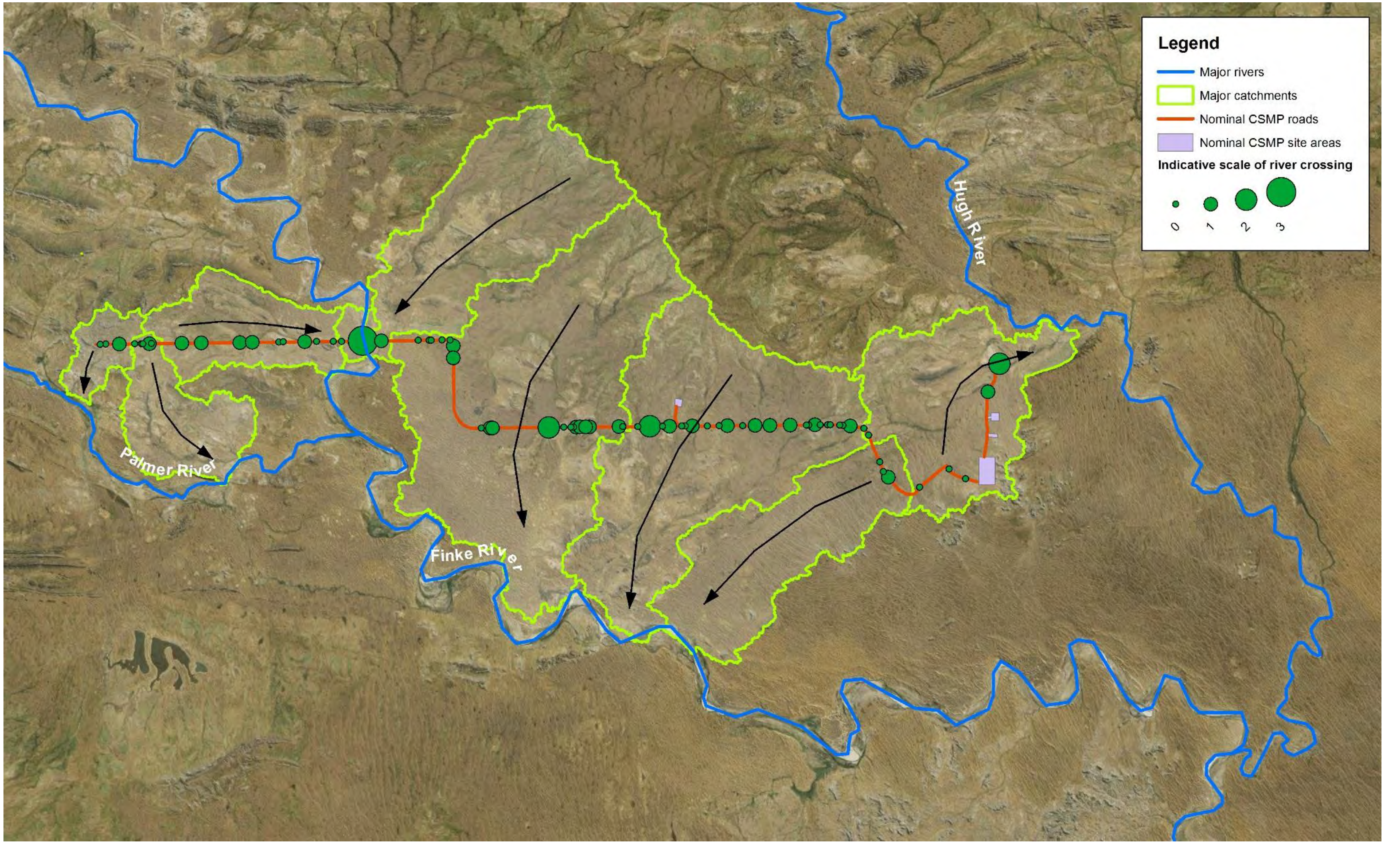

Figure A.2 Major catchments and crossing locations

Appendix B – Flood hydrograph modelling

Table B.1 Catchment inputs

Catchment		Area	Time of concentration (Tc)		Catchment slope	Clark UH storage coefficient	
		km²	*hours*	*minutes*		*Ratio*	*hours*
Finke at Rail		15100	29.4	1766	0.2%	0.65	54.15
Finke at Stuart Hwy		7500	22.6	1354	0.2%	0.65	41.50
Palmer at Stuart Hwy		6100	20.9	1251	0.2%	0.65	38.37
Hugh at Stuart Hwy		3140	16.2	972	0.2%	0.65	29.81
Road crossing (kilometres from Stuart Highway)	6.0	6.0	1.5	90	1.0%	0.64	2.67
	11.2	11.2	1.9	114	1.1%	0.64	3.37
	18.7	18.7	2.3	139	0.6%	0.64	4.19
	42.0	42.0	3.1	189	0.5%	0.64	5.71
	62.7	62.7	3.7	220	0.5%	0.65	6.66
	82.8	82.8	4.1	244	0.4%	0.65	7.44
	8100	8100	23.2	1394	0.2%	0.65	42.74
	246.0	246.0	6.2	369	0.3%	0.65	11.28
	25.0	25.0	2.6	155	0.5%	0.65	4.70
	87.3	87.3	4.2	249	0.4%	0.65	7.59
	123.0	123.0	4.7	284	0.3%	0.65	8.65
	11.1	11.1	1.9	114	0.8%	0.64	3.40
	46.0	46.0	3.3	195	0.5%	0.65	5.93
	25.1	25.1	2.6	155	0.5%	0.65	4.70
	24.0	24.0	2.5	153	0.3%	0.65	4.67
	18.9	18.9	2.3	139	0.4%	0.65	4.23
	7.7	7.7	1.7	99	0.4%	0.65	3.01
	9.6	9.6	1.8	108	0.5%	0.65	3.27
	6.0	6.0	1.5	90	0.4%	0.65	2.75
	9.5	9.5	1.8	107	0.2%	0.65	3.29
	3.8	3.8	1.3	76	1.0%	0.64	2.25
	6.1	6.1	1.5	91	1.0%	0.64	2.69
	1.6	1.6	0.9	54	1.2%	0.64	1.58
Mine	3.5	3.5	1.2	73	1.2%	0.64	2.16
	0.6	0.6	0.6	38	1.2%	0.64	1.10

Table B.2 Catchment rainfall areal reduction factors and Tc design rainfall

Catchment		Area	Areal reduction factor					Rainfall adjusted by areal reduction factor – Tc rainfall		
								2y ARI	10y ARI	100y ARI
		km^2	Tc	6h	9h	12 h	24h	mm	mm	mm
Finke at Rail		15100	70%	42%	50%	58%	70%	28.8	58.8	115.9
Finke at Stuart Hwy		7500	72%	45%	53%	61%	72%	29.7	60.7	119.7
Palmer at Stuart Hwy		6100	73%	46%	54%	62%	73%	30.0	61.3	120.8
Hugh at Stuart Hwy		3140	75%	50%	57%	65%	75%	30.9	63.2	124.5
Road crossing (kilometres from Stuart Highway)	2.6	6.0	92%	97%	98%	99%	100%	17.6	31.9	57.4
	6.7	11.2	86%	91%	93%	95%	97%	18.1	32.7	58.9
	9.3	18.7	80%	86%	89%	92%	95%	17.0	30.6	55.2
	13.3	42.0	74%	79%	83%	87%	92%	17.5	32.4	59.5
	14.1	62.7	70%	76%	80%	84%	90%	16.6	30.9	56.7
	16.6	82.8	71%	73%	78%	83%	89%	18.8	36.1	67.7
	22.8 Finke	8100	72%	45%	53%	61%	72%	29.6	60.5	119.2
	24.8	246.0	65%	65%	71%	77%	85%	18.3	35.9	68.6
	32.2	25.0	79%	83%	87%	90%	94%	18.6	34.5	63.4
	41.6	87.3	70%	73%	78%	83%	89%	18.7	35.8	67.3
	47	123.0	68%	70%	76%	81%	87%	18.0	34.5	64.7
	50.8	11.1	86%	91%	93%	95%	98%	18.2	32.8	59.0
	55.8	46.0	73%	78%	82%	86%	91%	17.3	32.1	58.9
	59.6	25.1	79%	83%	87%	90%	94%	18.6	34.5	63.4
	65.7	24.0	79%	84%	87%	90%	94%	18.7	34.7	63.7
	67.9	18.9	80%	86%	89%	92%	95%	17.0	30.6	55.1
	69	7.7	90%	95%	96%	97%	99%	19.0	34.3	61.8
	71	9.6	87%	92%	94%	96%	98%	18.5	33.3	60.0
	72.8	6.0	92%	97%	98%	99%	100%	17.6	31.9	57.4
	78.3	9.5	87%	92%	94%	96%	98%	18.5	33.4	60.1
	83.5	3.8	98%	100%	100%	100%	100%	18.7	33.9	60.9
	87	6.1	92%	97%	98%	99%	100%	17.6	31.9	57.3
	89.2	1.6	100%	100%	100%	100%	100%	16.8	29.7	52.0
Mine	Halfway Creek	3.5	99%	100%	100%	100%	100%	18.9	34.3	61.6
	Marys Creek	0.6	100%	100%	100%	100%	100%	16.8	29.7	52.0

Table B.3 Catchment 6 and 9 hour rainfall

Catchment		Area	Rainfall adjusted by areal reduction factor					
			6h rainfall			9h rainfall		
			2y ARI	10y ARI	100y ARI	2y ARI	10y ARI	100y ARI
		km^2	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*
Finke at Rail		15100	11.8	23.2	44.2	15.8	31.3	60.3
Finke at Stuart Hwy		7500	12.7	25.0	47.6	16.8	33.2	64.1
Palmer at Stuart Hwy		6100	13.0	25.5	48.7	17.1	33.8	65.2
Hugh at Stuart Hwy		3140	14.0	27.4	52.3	18.2	35.8	69.1
Road crossing (kilometres from Stuart Highway)	2.6	6.0	27.3	53.4	101.9	31.2	61.6	118.6
	6.7	11.2	25.5	50.0	95.4	29.6	58.4	112.4
	9.3	18.7	24.2	47.3	90.3	28.3	55.8	107.6
	13.3	42.0	22.2	43.4	82.8	26.4	52.1	100.3
	14.1	62.7	21.2	41.6	79.4	25.5	50.3	96.9
	16.6	82.8	20.6	40.4	77.1	24.9	49.1	94.6
	22.8 Finke	8100	12.6	24.7	47.2	16.7	33.0	63.6
	24.8	246.0	18.4	35.9	68.6	22.6	44.7	86.1
	32.2	25.0	23.4	45.9	87.5	27.6	54.4	104.9
	41.6	87.3	20.5	40.1	76.6	24.7	48.9	94.2
	47	123.0	19.8	38.7	73.9	24.0	47.4	91.4
	50.8	11.1	25.6	50.0	95.5	29.6	58.4	112.6
	55.8	46.0	22.0	43.0	82.0	26.2	51.7	99.5
	59.6	25.1	23.4	45.8	87.5	27.6	54.4	104.9
	65.7	24.0	23.5	46.1	87.9	27.7	54.6	105.3
	67.9	18.9	24.1	47.3	90.2	28.2	55.8	107.5
	69	7.7	26.6	52.0	99.2	30.5	60.3	116.1
	71	9.6	25.9	50.8	96.9	29.9	59.1	113.9
	72.8	6.0	27.3	53.4	101.9	31.2	61.6	118.6
	78.3	9.5	26.0	50.8	97.1	30.0	59.2	114.1
	83.5	3.8	28.1	55.0	105.0	31.8	62.8	121.0
	87	6.1	27.2	53.3	101.8	31.1	61.5	118.5
	89.2	1.6	28.1	55.0	105.0	31.8	62.8	121.0
Mine	Halfway Creek	3.5	28.1	55.0	105.0	31.8	62.8	121.0
	Marys Creek	0.6	28.1	55.0	105.0	31.8	62.8	121.0

Table B.4 Catchment 12 and 24 hour rainfall

Catchment		Area	Rainfall adjusted by areal reduction factor					
			12h rainfall			24h		
			2y ARI	10y ARI	100y ARI	2y ARI	10y ARI	100y ARI
		km²	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*
Finke at Rail		15100	19.5	39.7	77.9	28.8	58.8	115.9
Finke at Stuart Hwy		7500	20.5	41.6	81.8	29.7	60.7	119.6
Palmer at Stuart Hwy		6100	20.8	42.2	82.9	30.0	61.3	120.8
Hugh at Stuart Hwy		3140	21.8	44.2	86.8	30.9	63.2	124.5
Road crossing (kilometres from Stuart Highway)	2.6	6.0	33.4	67.8	133.3	41.0	83.8	165.1
	6.7	11.2	32.0	65.0	127.7	40.0	81.7	160.9
	9.3	18.7	30.9	62.8	123.3	39.0	79.8	157.2
	13.3	42.0	29.3	59.4	116.7	37.6	76.9	151.5
	14.1	62.7	28.5	57.8	113.5	36.9	75.5	148.8
	16.6	82.8	27.9	56.7	111.4	36.5	74.6	146.9
	22.8 Finke	8100	20.4	41.4	81.3	29.6	60.5	119.2
	24.8	246.0	25.9	52.6	103.3	34.7	70.9	139.8
	32.2	25.0	30.3	61.5	120.9	38.5	78.7	155.1
	41.6	87.3	27.8	56.5	111.0	36.4	74.4	146.5
	47	123.0	27.2	55.2	108.4	35.8	73.2	144.3
	50.8	11.1	32.1	65.1	127.9	40.0	81.7	161.0
	55.8	46.0	29.1	59.0	115.9	37.5	76.6	150.9
	59.6	25.1	30.3	61.5	120.9	38.5	78.7	155.1
	65.7	24.0	30.4	61.7	121.2	38.6	78.9	155.4
	67.9	18.9	30.9	62.7	123.2	39.0	79.7	157.1
	69	7.7	32.9	66.7	131.0	40.6	83.1	163.6
	71	9.6	32.4	65.7	129.1	40.2	82.2	162.0
	72.8	6.0	33.4	67.8	133.3	41.0	83.8	165.1
	78.3	9.5	32.4	65.7	129.2	40.3	82.3	162.1
	83.5	3.8	33.7	68.4	134.4	41.0	83.8	165.1
	87	6.1	33.4	67.8	133.2	41.0	83.8	165.1
	89.2	1.6	33.7	68.4	134.4	41.0	83.8	165.1
Mine	Halfway Creek	3.5	33.7	68.4	134.4	41.0	83.8	165.1
	Marys Creek	0.6	33.7	68.4	134.4	41.0	83.8	165.1

Table B.5 Peak flows

Catchment		Area	Peak flows (m3/s)														
			2-year ARI					10-year ARI					100-year ARI				
		km^2	Tc	6h	9h	12h	24h	Tc	6h	9h	12h	24h	Tc	6h	9h	12h	24h
Finke at Rail		15100	37.0	0.0	0.0	0.0	19.5	1567	138	516	840	1456	5053	1660	2610	3598	4809
Finke at Stuart Hwy		7500	24.7	0.0	0.0	0.0	20.9	894	92	311	492	874	2765	977	1504	2037	2724
Palmer at Stuart Hwy		6100	23.4	0.0	0.0	0.0	15.6	602	96.1	239	353	562	1837	705	1043	1378	1755
Hugh at Stuart Hwy		3140	6.1	0.0	0.0	0.0	20.4	437	17.0	123	222	513	1325	435	708	979	1473
Road crossing (kilometres from Stuart Highway)	2.6	6.0	0.0	1.3	1.6	1.5	1.9	4.7	8.7	8.5	8.2	8.3	15.5	20.7	19.5	17.7	17.0
	6.7	11.2	0.0	1.3	2.0	2.0	2.8	7.7	12.3	12.7	12.6	13.3	24.6	30.9	30.4	28.3	27.8
	9.3	18.7	0.0	1.1	2.1	2.3	3.7	8.4	16.0	17.2	17.5	19.2	30.1	42.1	42.8	40.8	40.7
	13.3	42.0	0.0	0.4	2.4	3.0	5.8	15.1	24.0	27.5	29.5	34.2	53.2	69.0	73.2	72.9	74.2
	14.1	62.7	0.0	0.2	2.4	3.1	7.0	16.8	28.9	34.3	37.8	45.1	64.2	87.3	95.7	96.3	99.6
	16.6	82.8	0.0	0.0	2.3	3.1	8.0	27.7	32.6	39.8	44.6	54.4	93.0	1021	1157	116	1226
	22.8 Finke	8100.0	19.4	0.0	0.0	0.0	19.4	860	68.7	280	460	860	2704	907	1426	1959	2705
	24.8	246.0	0.0	0.0	1.6	2.2	12.1	49.5	49.5	70.5	83.8	112	184	184	226	243	265
	32.2	25.0	0.0	0.9	2.2	2.6	4.4	12.7	18.5	20.4	21.1	23.6	41.0	50.3	51.9	50.4	50.5
	41.6	87.3	0.0	0.0	2.1	3.1	8.2	28.1	33.2	41.0	46.1	56.4	96	105	119	121	126
	47	123.0	0.0	0.0	1.8	3.0	9.4	31.8	38.4	49.3	56.6	71.0	114	127	148	1535	162
	50.8	11.1	0.0	1.3	1.9	2.0	2.7	7.3	12.1	12.4	12.4	13.1	23.7	30.4	29.9	27.8	27.3
	55.8	46.0	0.0	0.3	2.4	3.0	6.1	15.5	24.9	28.9	31.1	36.3	55.4	72.6	77.6	77.5	79.2
	59.6	25.1	0.0	0.9	2.2	2.6	4.4	12.7	18.4	20.4	21.1	23.6	41.1	50.3	52.0	50.4	50.5
	65.7	24.0	0.0	0.9	2.2	2.5	4.2	12.5	18.0	19.8	20.5	22.8	39.9	48.7	50.2	48.6	48.7
	67.9	18.9	0.0	1.1	2.1	2.4	3.7	8.4	16.0	17.2	17.6	19.3	30.1	42.2	43.0	41.0	40.8
	69	7.7	0.0	1.3	1.7	1.6	2.2	6.3	9.8	9.8	9.6	9.9	19.7	23.9	23.0	21.1	20.5
	71	9.6	0.0	1.3	1.8	1.8	2.5	6.9	11.1	11.3	11.2	11.8	21.9	27.6	27.0	25.0	24.4
	72.8	6.0	0.0	1.3	1.6	1.5	1.9	4.6	8.5	8.3	8.1	8.2	15.2	20.4	19.3	17.5	16.8
	78.3	9.5	0.0	1.3	1.8	1.8	2.5	6.7	10.9	11.1	11.0	11.6	21.4	27.2	26.6	24.6	24.0

Catchment		Area	Peak flows (m3/s)														
			2-year ARI					10-year ARI					100-year ARI				
		km²	Tc	6h	9h	12h	24h	Tc	6h	9h	12h	24h	Tc	6h	9h	12h	24h
	83.5	3.8	0.0	1.1	1.2	1.1	1.3	4.0	6.5	6.1	5.8	5.6	12.3	15.0	13.6	12.1	11.4
	87	6.1	0.0	1.3	1.6	1.5	1.9	4.8	8.7	8.5	8.3	8.3	15.6	20.8	19.6	17.8	17.1
	89.2	1.6	0.0	0.5	0.6	0.5	0.7	1.7	3.2	2.9	2.7	2.7	5.8	7.3	6.3	5.7	5.6
Mine	**Halfway Creek**	3.5	0.0	1.0	1.2	1.0	1.2	3.9	6.0	5.6	5.4	5.2	11.9	14.0	12.6	11.2	10.6
	Marys Creek	0.6	0.0	0.3	0.3	0.2	0.3	0.9	1.5	1.3	1.2	1.3	3.0	3.5	2.9	2.7	2.6

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Report

Chandler Facility – Erosion and Sediment Control Assessment

Prepared for Tellus Holdings Ltd

Revision History

Revision Nº	Prepared By	Description	Date
01	Natasha Webb	Draft for client review	06/10/2016
02	Natasha Webb	Draft final	21/10/2016
03	Dan Evans	Final	16/01/2017

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Natasha Webb**		20/10/2016
Reviewed by	**Dan Evans**		21/10/2016
Approved by	**Melody Valentine**		16/01/2017
on behalf of	**Beca Pty Ltd**		

Contents

1 Introduction

Beca Pty Ltd (Beca) was engaged by Tellus Holdings Ltd (Tellus) to assess erosion and sediment control as part of the Environmental Impact Statement (EIS) for the Chandler Proposal (this incorporated the Apirnta Facility and the Chandler Facility).

This report does not assess erosion and sediment control for the proposed (private) Henbury Access Road. At the time of preparing this report, negotiations between Tellus and land owners of Henbury Estate for the use of the private access road were ongoing. Should the access road become a viable alternative, further assessment of erosion and sediment control would be undertaken.

1.1 The Proposal

Tellus seeks planning approval to establish the Chandler Proposal on the Maryvale pastoral lease (Northern Territory (NT) Portion 810) and the Henbury pastoral lease (NT Portion 657) approximately 120 kilometres (km) south of Alice Springs.

The Proposal would comprise:

- Mining a high quality salt product at a depth of about 850 metres (m).
- Providing for the permanent isolation of intractable waste or the temporary storage of materials in void spaces left from salt mining.
- Using mining and waste emplacement methods that will replicate current global best practice techniques.
- Haulage of salt and waste products via private haul road (Chandler Haul Road).
- Transport of salt to port via rail.
- Delivery of waste predominantly by rail.
- Transport of workers via public (Maryvale Road) and a private road (Henbury Access Road).

The Proposal has an estimated lifetime of 29 years (4 year build, 25 year operation). The proposed development is seeking approval to store and / or permanently isolate up to 400,000 tonnes per annum over 25 years (Tellus, 2016).

To support the export of salt and import of waste to the Facility, transport will be mostly via rail to the Apirnta Facility. Here the material will be offloaded onto road train and hauled 30 km south-east to the Chandler Facility along a dirt road on a regular basis.

Proposed surface infrastructure includes dry salt temporary storage facility and a 5 MW diesel fired power station supplemented by a 2MW solar power plant (Tellus, 2016). A surface plant for the hydraulic backfill emplacement of liquid and dry powdered wastes underground will also be present. Associated infrastructure including workshops, offices and 165 man accommodation camp, hardstand areas, car parks, weighbridges, vehicle wash down facility and sealed roads are planned.

1.2 Scope of the report

Erosion and Sediment Control Plans (ESCPs) set out erosion and sediment control works for land development, such as subdivision or clearing of native vegetation. An ESCP is a standardised schematic plan based on the development site, showing the location and technical specifications for proposed erosion or sediment controls (NT Gov, 2015). The primary reasons for an ESCP for the Proposal are as follows:

- Asset Protection - disturbing vegetation and soils at the Chandler Facility, Haulage Roads and Apirnta Facility will create an erosion risk which, if not addressed, could lead to disruption of Proposal works, increased costs and delayed completion dates. Uncontrolled erosion could cause damage to the Proposal infrastructure, extra maintenance costs, reduced outbound mined salt transfer or reduced inbound waste transfer.
- Planning & control - an ESCP will enable landholders, Tellus and contractors to strategically plan erosion and sediment controls necessary to reduce the risk of erosion and sediment discharge during all phases of the Proposal. Forward planning facilitates integration of erosion and sediment control (ESC) and other site works, assists cost control and supports contract management.
- Approval - an ESCP provides landowners, Tellus and the NT EPA with a detailed and comprehensible plan of all proposed ESC works for the development. A clear and concise plan facilitates processing of applications and implementation.
- Implementation - an ESCP should be usable in the field as an instruction manual for contractors, providing clear directions and quick reference to methodology or standard drawings of erosion and sediment control structures. An ESCP clarifies roles and responsibilities for consultants, site managers and contractors.

An ESCP can be presented as one or more plans and diagrams, similar to technical drawings or building plans, showing the development site with the location of all temporary and permanent erosion controls identified and adequately labelled. ESCPs for rural sub-division and vegetation clearing generally have a different focus than those used for urban and civil construction sites (NT Gov, 2015).

The purpose of this Erosion and Sediment Control Assessment is to provide the context and framework for an ESCP at the detailed design phase. It is intended as a high-level document which assesses the risks to erosion and sediment transport and then recommends mitigation measures in terms of content for the ESCP. The report is structured according to Figure 1-1.

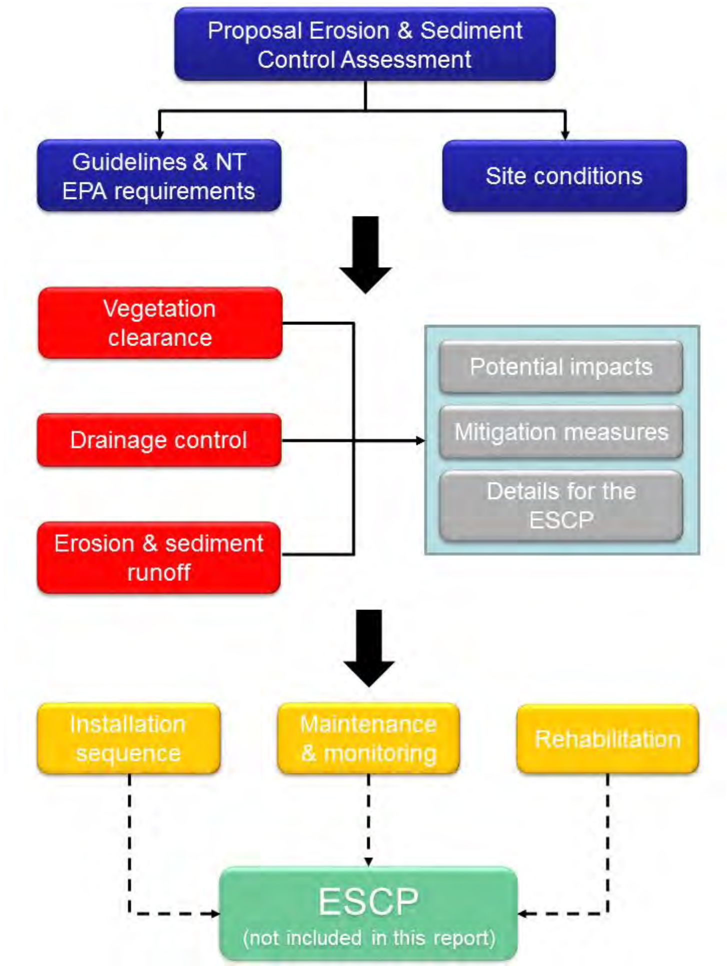

Figure 1-1 Structure for the erosion and sediment control assessment

The erosion and sediment control assessment is one of five surface water technical report for the Proposal EIS and should not be read in isolation. The other reports are as follows:

- Baseline surface water condition report;
- Flood and hydrology assessment;
- Geomorphology assessment; and
- Surface water quality assessment.

Although primarily focussed on the construction phase of the Proposal, some of the impacts and mitigation measures do address operational site issues.

2 Relevant Guidelines, Industry Standards and NT EPA Requirements

The following guidelines and industry best practice guides were used to inform this report:

- IECA (2008) Best Practice Erosion and Sediment Control. Australasia Chapter. International Erosion Control Association;
- NT Department of Land Resource Management (DLRM) have produced a comprehensive set of technical guidance notes for erosion and sediment control (DLRM, 2013);
- Pastoral Land Board (2010) Northern Territory Pastoral Land Clearing Guidelines (*Pastoral Land Act*); and
- Witheridge G (2012) Erosion & Sediment Control – A Field Guide for Construction Site Managers V5. Catchments & Creeks Pty Ltd.

In addition, Section 4.5.3 of the ToR for this Proposal cite compliance with an approved ESCP as a condition on a Development Permit i.e. preparation and subsequent implementation of an approved ESCP, to the satisfaction of the consent authority (NT EPA, 2016).

3 Site Conditions

3.1 Property details

The Proposal includes three sites (Apirnta Facility, Chandler Facility and Road Infrastructure) with characteristics summarised in Table 3-1.

Table 3-1 Site characteristics summary

Site name	Location	Site size	Site slope (average)	Upslope runoff	Soil type/s	Watercourses
Apirnta facility	Maryvale pastoral lease (Northern Territory Portion 810)	0.40 km^2	0.3 %	4 km^2 100-year ARI flow 13 m^3/s	Aeolian sand (soil type Qs)	Apirnta Creek east & west tributaries run alongside site
Chandler facility	Maryvale pastoral lease (Northern Territory Portion 810)	0.86 km^2	1.25 %	4.1 km^2 100-year ARI flow 14.9 m^3/s	Aeolian sand (soil type Qs)	Dingo Gully Halfway Creek Mary's Creek Mulga Creek Oak Gully Ridey Gully Roo Gully Snake Gully
Road infrastructure	Maryvale pastoral lease (Northern Territory Portion 810)	0.27 km^2	n/a	1.6 – 1,800 km^2 100-year ARI flow 5.8 – 2,704 m^3/s	Aeolian sand (soil type Qs) 57%; alluvial gravel, sand and silt (soil type Qa) 42%; conglomerate (soil type Qc) 1%	Multiple drainage channels including: Apirnta Creek Chambers Creek Charlotte Creek Finke River Hugh River

For the purposes of this Erosion and Sediment Control Assessment, the Chandler Facility refers to overground features only. A more detailed description of the three sites can be found in the Proposal Description (Tellus, 2016).

3.2 Site characteristics

The southern region of the NT, where the Proposal is located, is characterised by rolling hills and dunes, and sand ridges. The Charlotte Range and the Maryvale Hills lie directly east of the Proposal and within the proposed surface infrastructure area (Figure 3-1).

Figure 3-2 shows the typical ground condition at the proposed Apirnta Facility. Land is relatively flat with sparse vegetation. Figure 3-3 shows the low lying floodplain comprising alluvial and aeolian sediment where the Chandler Facility would be located and the distinguished Maryvale Hills in the distance. Figure 3-4 and Figure 3-5 show the typical landscape along the Haulage Road route. The proposed route is generally flat and vegetation has already been cleared for a significant proportion of the route corridor.

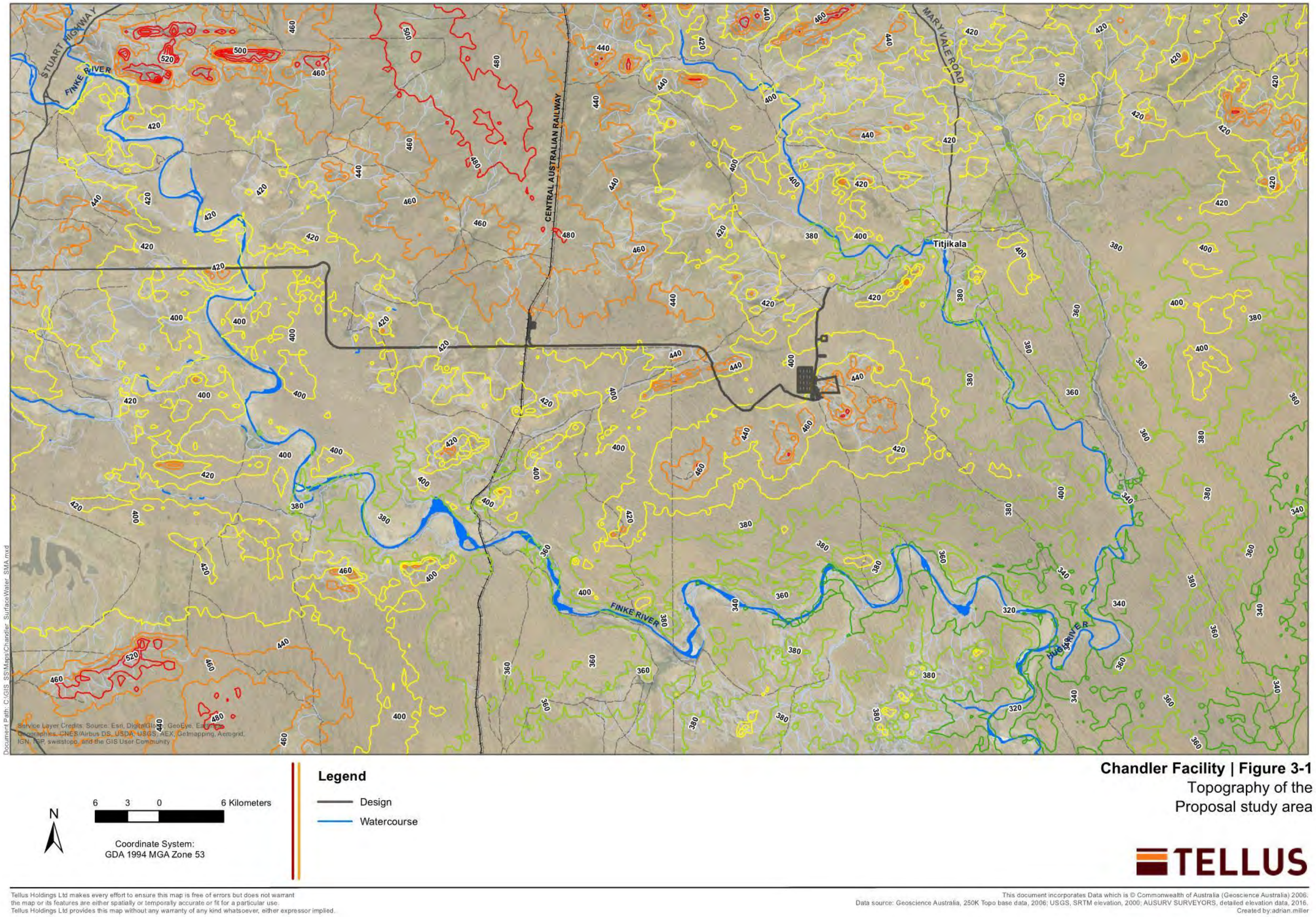

Figure 3-1 Topography of the Proposal study area

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Figure 3-2 Apirnta Facility

Figure 3-3 View east towards Maryvale Hills in general location of proposed Chandler Facility surface infrastructure

Figure 3-4 View north along Chandler Haul Road towards Chandler Facility

Figure 3-5 View west of Chandler Haul Road and Charlotte Range in the distance

Current stormwater directions for the three infrastructure sites are as follows:

- Apirnta Facility stormwater enters site from the north and will flow southwards into Apirnta Creek whose drainage channel eventually joins the Finke River near Attalwaynimma Waterhole. It is unknown if there is any 'true' hydrological connectivity between Apirnta Creek and the Finke River as the creek bed has always been dry during site visits;
- Chandler Facility stormwater enters site from the east and flows westwards into the flood out area where it is expected to pond and gradually evaporate / infiltrate into the soil; and
- Haulage Roads stormwater generally enters from a northerly direction and flows south towards the Finke River via the Charlotte Creek and Apirnta Creek drainage systems. It is unknown if there is any 'true' hydrological connectivity between Charlotte Creek / Apirnta Creek and the Finke River as the creek beds have always been dry during site visits. Access Roads stormwater generally enters from a westerly direction and flows eastwards via Chambers Creek towards the Hugh River approximately 5km upstream from Titjikala.

More details on expected existing flow conditions at the three sites are provided in the surface water baseline report and the Flood and Hydrology report sections of the Proposal EIS. Future stormwater flow conditions will not be established until final design stage.

A site plan that shows property boundaries and where stormwater surface flows enter and leave the site will be developed once detail design has been completed and will be updated in the outline ESCP.

4 Vegetation clearance

Clearing and grubbing of the Chandler Facility, Apirnta Facility and Haulage Roads will be necessary to carry out further site preparation activities as described in the Proposal Description of the EIS. This section reviews the potential impacts associated with vegetation clearance and the mitigation measures suggested to reduce the effects of this clearance. Finally, the content of an ESCP is recommended.

4.1 Potential impacts

Under the Northern Territory Planning Scheme Native Vegetation is defined as: 'terrestrial and inter-tidal flora indigenous to the Northern Territory, including grasses, shrubs and mangroves' (DLRM, 2013a). This means that clearing of any native vegetation for the Proposal requires consent, including vegetation cleared prior to the introduction of the native vegetation clearing controls. There are some general exceptions, which might apply to specific areas of the Proposal including clearing for:

- Fire breaks 5 m wide for properties <8 ha, or 10 m wide for properties >8 ha;
- Internal fence lines (up to 10 m wide) only on properties >8 ha; and
- Other exceptions as listed in the Northern Territory Planning Scheme.

The impacts of plant cover removal in the Proposal area include (DLRM, 2013a):

- Removal of filtering function for sediment and other pollutants from surface runoff by vegetation systems leading to a deterioration in water quality and associated loss of aquatic habitat;
- Decrease in shade and protection from wind and water erosion afforded by plants;
- Reduced infiltration and rise in salt water level;
- Decreased habitat quality surrounding the site, drainage lines and other sensitive areas;
- Increase in the speed of water runoff discharging creeks, exacerbating downstream flooding; and
- Increase in chemical spray drift, noise and dust.

The potential impacts of vegetation clearance thus include the unnecessary removal of valuable native vegetation with associated habitat loss and fragmentation. Removal of the filtering function of vegetation surrounding watercourses leading to increased sediment input into creeks during rainfall events is another potential impact. Exposure of topsoil to rainfall leading to exacerbated erosion impacts will need to be mitigated. The site-specific impacts related to vegetation clearance are covered in the Erosion and Sediment Runoff sub-section (Section 6).

4.2 Mitigation measures

Retained vegetation can have the dual purpose of not only assisting in the settling of sediment from overland flows, but also provide a refuge for flora and fauna (Figure 4-1). Generally, the wider the strip of retained vegetation, the more effective it will be (DLRM, 2013b).

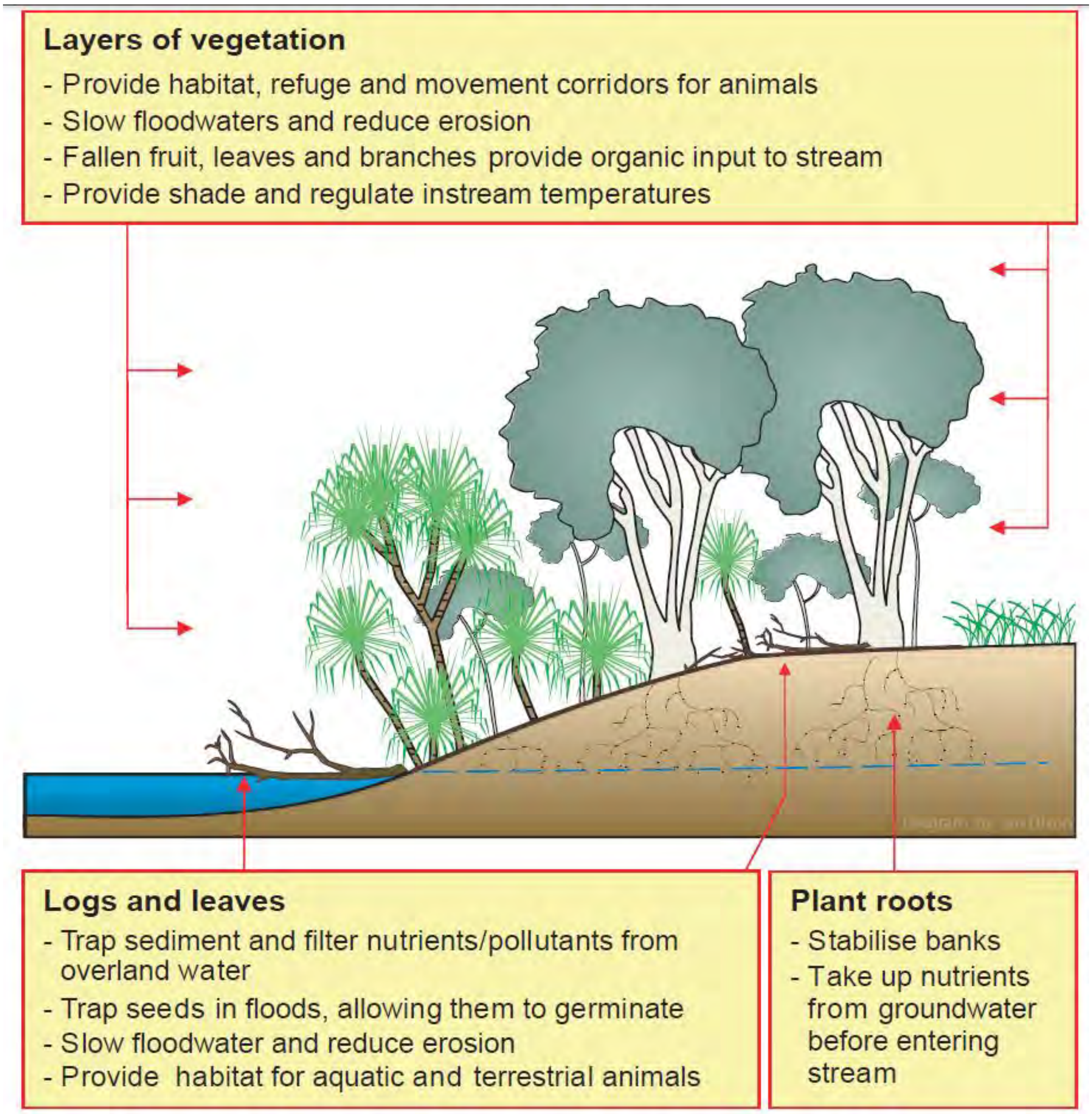

Figure 4-1 Benefits of riparian vegetation (DLRM, 2013a)

Management of groundcover and installation of temporary or permanent erosion control measures are essential considerations to mitigate against the impacts identified in Section 4.1.

Following completion of detailed design, a disturbance plan to retain or preserve as much of the existing vegetation as possible would be implemented, especially adjacent to drainage lines. Identification of any areas to be used as 'turn around' or laydown areas should be completed with an indication in the Construction Notes how cleared and NO-GO areas will be implemented e.g. GPS data provided to clearing contractors and areas flagged on the ground prior to any clearing activity.

DLRM Land Clearing Guidelines provide information on required buffer zones for watercourses (DLRM, 2013a and DLRM, 2013b). Areas of vegetation retention are commonly referred to as buffer zones or native vegetation corridors. They are areas of natural vegetation flagged prior to construction that will act as sediment traps. To be effective as a sediment control, the area for retention should contain at least 80% ground cover. The minimum width of a waterway buffer is based on stream order classification. Buffer zones for the Apirnta Facility, Chandler Facility, and Haulage Roads have been developed (Figure 4-2,

Figure 4-3 and Figure 4-4, respectively). The majority of waterways on the three sites, including all Chandler Facility and Apirnta Facility drainage channels, were intermittent first order requiring a buffer distance of at least 25 m. This distance is measured from the outer edge of riparian vegetation, where mapped, otherwise the primary bank of the outer stream channel where there is more than one channel or the stream is braided. The exception is the Chambers Creek on the access road crossing just south of Chambers Pillar road which is second order, requiring a buffer distance of at least 50 m.

It is unlikely that sinkholes are present on site and they have not been observed over four years of various field investigations. Once the final footprint has been confirmed, a walkover would be conducted by an appropriate specialist to confirm presence. If sinkholes are discovered, buffer widths of 50 m and 100 m are recommended for closed and open sinkholes, respectively (DLRM, 2013b). No rivers or wetlands will be affected by vegetation clearance nor will any developments occur directly adjacent to property boundaries. It is recommended that a wildlife corridor >200m wide should be maintained to the newly positioned Halfway Dam (Section 7).

Ensuring soil moisture conditions are optimal for clearing will reduce the need and cost of maintaining regrowth (DLRM, 2013b). Soil moisture can be a limiting factor. If soils are too wet, machinery will get bogged and track / wheel ruts will concentrate overland flows and cause gullying. Whereas if soils are too dry, trees are likely to snap off, leaving roots in the ground and promoting regrowth. Seasonal conditions are often unpredictable in the Proposal study area and the window of opportunity to clear, stick rake, windrow, burn, till and construct infrastructure in one season may not be long enough. Opportunities to stage clearing to avoid months that on record that are wetter than others should be investigated in the ESCP, to better manage costs and erosion potential.

It is recommended to leave felled vegetation in situ (where it falls) for as long as possible (ideally until the end of drier periods, just prior to planting) to minimise wind erosion. This would have the additional benefit of providing habitat as noted in the Proposal description chapter of the EIS. As clearing upslope progresses, diversions should be constructed as required to capture and direct runoff evenly through the retained vegetation. Flow must enter the retained vegetation as sheet flow and spread out over the width of the buffer. Runoff must be able to flow to and be dispersed through the area without concentrating water into rills and gullies. The vegetation must remain undisturbed while it is being used for trapping sediment. It should be noted that areas of retained vegetation are only capable of trapping course sediments. The fine silt will pass through this buffer during periods of heavy rainfall. The requirement for other types of sediment control devices in conjunction with the retained vegetation are reviewed in Section 6.2.2.

The stripped topsoil to be stockpiled on site for reuse on drain surfaces and other disturbed areas, should have adequate ESC measures as required (Section 6.1.2.2). Alternatively, schedule activity so that topsoil stripped from a new stage is immediately re-spread over a recently completed stage. This will also protect the viability of the seed bank in the soil. While topsoil will contain native species endemic to the area that will assist re-vegetation, weed seed spread must also be considered.

Details of re-vegetation for disturbed surfaces, for local climate and soil conditions, should be given (Section 9.4). Where dryland grass is to be established, a cover target of 70% at (development works) contract handover should be specified.

Any questions regarding location, extent or methods of installation should be referred to the responsible on-site supervisor or Natural Resource Officer (DLRM, 2013a). Requirements for a land clearance permit, separate from the Proposal Development Application, would be established with DLRM.

4.3 Details for the ESCP

Notes on methods and timing of clearing with an emphasis on avoiding or minimising formation of flow paths (e.g. placement of slash piles or wheel ruts) that can concentrate surface runoff and create potential for erosion should be provided. Areas of native vegetation not required to be cleared and buffer areas around watercourses should be identified in the ESCP and flagged on the ground as NO-GO areas. Retained native vegetation can limit the accessibility to a site for heavy machinery so the plan should consider entrance requirements.

Notes that indicate areas of identified weed infestation to be flagged and avoided, or machinery cleaning processes where this is not possible should be provided. Progressive site rehabilitation and re-vegetation should be included in the ESCP and not deferred to a landscape plan for later implementation.

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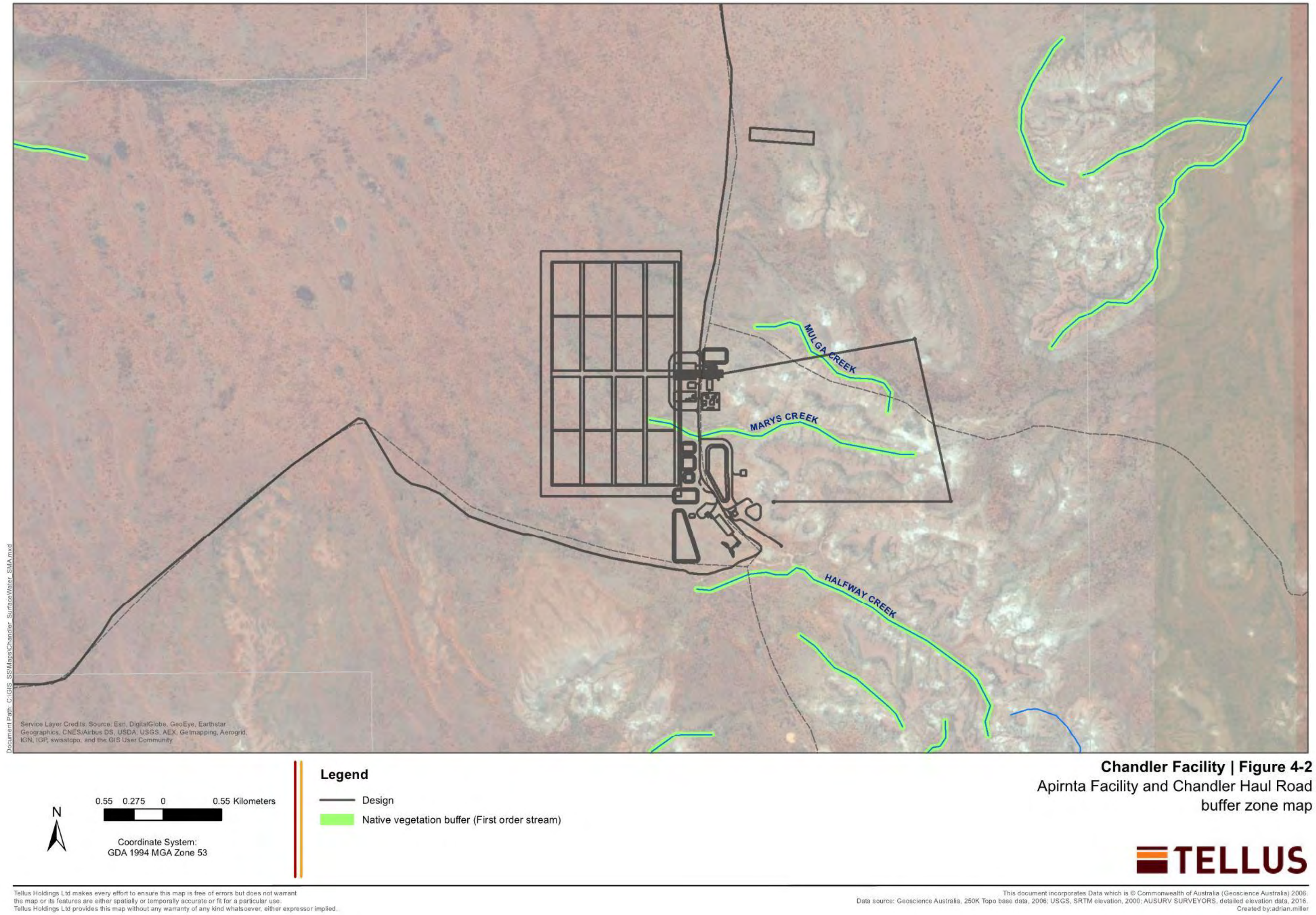

Figure 4-2 Apirnta Facility and Chandler Haul Road buffer zone map

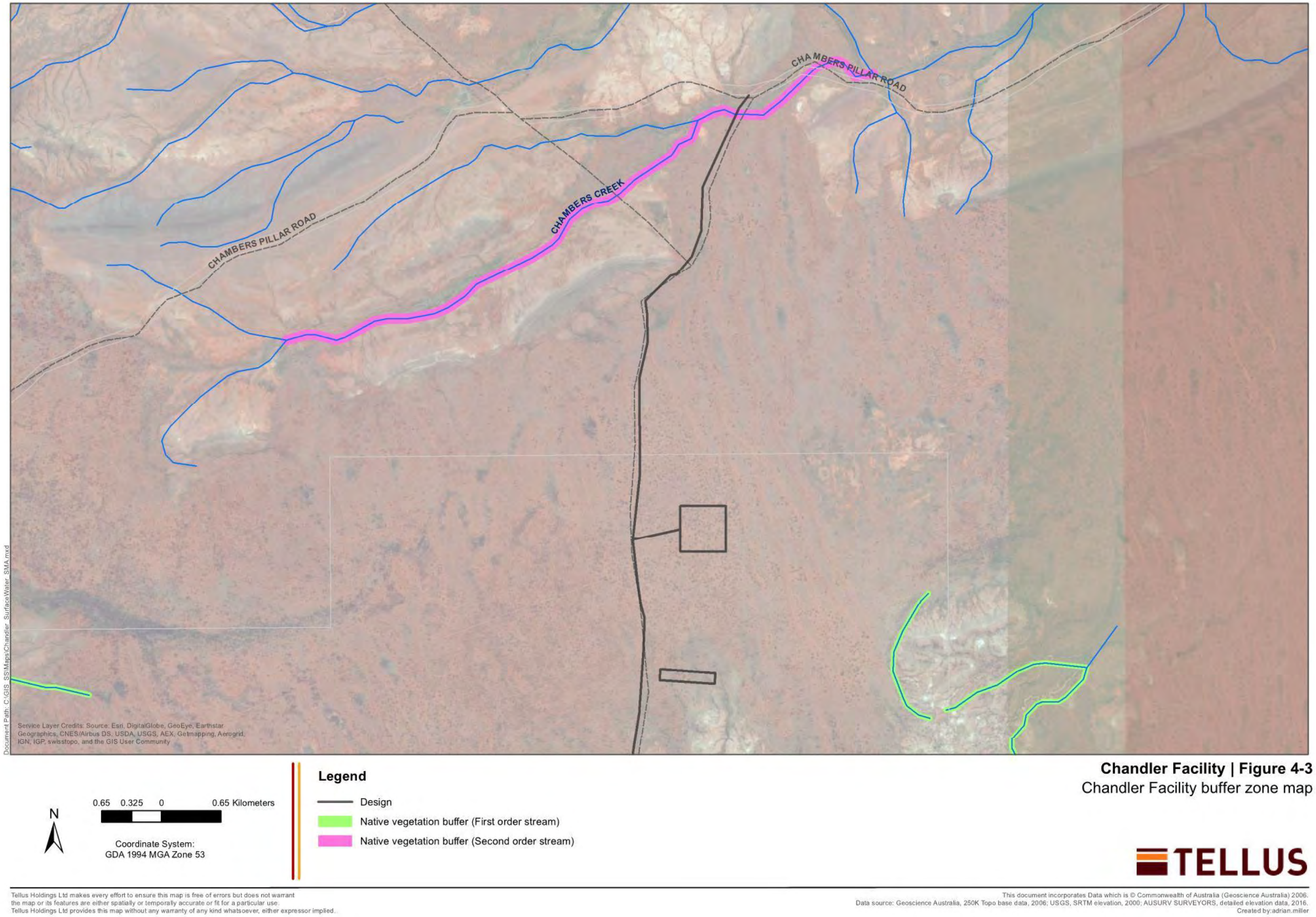

Figure 4-3 Chandler Facility buffer zone map

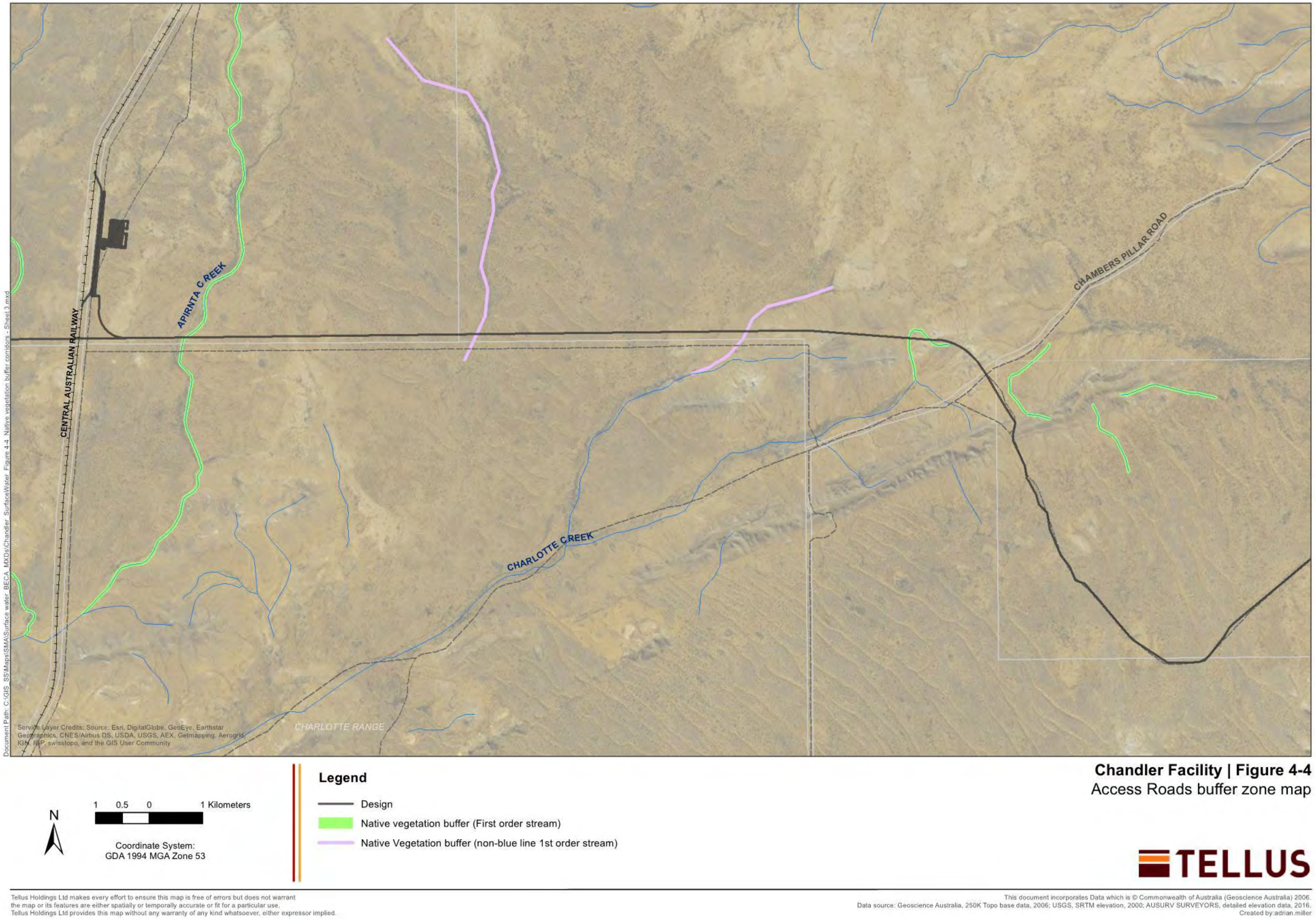

Figure 4-4 Access Roads buffer zone map

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5 Drainage Control

Water management is one of the most important factors affecting land use and management. The average annual rainfall in the Proposal area is low (278 mm per year at Alice Springs Airport). The rainfall intensity of actual storm events, however, is high (long term average 33 mm per day). Sudden, intense storms will generate excess surface water runoff (Smith and Hill, 2011). This section describes the potential impacts, mitigation measures and recommended content to include in an ESCP for both upslope and disturbed area stormwater.

5.1 Upslope stormwater

Upslope stormwater is defined as the surface water generated runoff from land that is up-gradient from the construction area which, without any controls, would flow through the construction area.

5.1.1 Potential impacts

Upslope stormwater will flow through the Apirnta Facility, Chandler Facility and Haulage Road sites. Free passage of upslope stormwater would lead to additional water volume to manage. Water might become ponded on the site or flood infrastructure causing access issues or damage to critical equipment. It would also mix with dirty / contaminated water and thus necessitate additional treatment treatments. The additional water could cause structural damage to soils, leading to increased erosion (Section 6.1.1).

5.1.2 Mitigation measures

Works should be planned to control the potential build-up of volume and velocity of surface water flows, and to limit the formation of concentrated flow (DLRM, 2013b). In broad acre situations such as this Proposal (i.e. sites greater than 1500 m^2, Table 3-1), this will involve interception of surface flows with graded banks or diversion banks where reasonable and practical (DLRM, 2013b). Surface flows entering the site from undisturbed areas upslope (‘clean’ water) should be separated from storm runoff arising from disturbed areas (‘dirty’ water). Diversion of upslope runoff around soil disturbances and unstable slopes will avoid or minimise soil erosion, and prevent ‘clean water’ adding to the volume of ‘dirty water’ to be managed. Controlling this upslope ‘clean’ water will reduce the volume of run-on to the Apirnta Facility, Chandler Facility and Haulage Road sites. Diversion channels should be designed according to best practice guidance including sizing and lining type (IECA, 2008). Estimates of water volumes generated during storm events at the three sites are given in the Flood and Hydrology Assessment for different return periods. These diversion channels will reduce the amount of “dirty water” requiring management, improve wet weather access to the sites and limit erosion and sediment mobilisation on the sites.

Apirnta Facility does not have any defined channel running through the site footprint but consideration to diverting flows along the swale created by the railway line berm should be made.

For the Chandler Facility Dingo, Oak, Ridey, Snake Gully and Halfway Creek will require diversion during both construction and operational phases of the Proposal. The provisional surface mine infrastructure footprint has been moved south by about 500m to avoid crossing the larger Mary’s and Mulga Creek systems.

Longitudinal drainage systems for the management of surface water runoff on the access and haulage roads will include swales and water quality basins. Crowning or box-type road designs should be considered to improve drainage and sediment retention (DLRM, 2013b). Whoa Boys or levels sills would be included in the design to improve drainage. There are a large number of drainage lines crossing the haulage and access roads. An assessment of flooding impacts to the road were completed as part of the Flood and Hydrology

Assessment report in the Proposal EIS. At this stage, it is considered that drainage at crossings will involve inverts with the finished surface at, or just below the level of the existing stream bed. Construction of inverts will require excavation of at least 300mm of soft, erodible topsoil material. Geotextile may be necessary as a base. Excavated material can then be replaced with compacted granular material to provide a trafficable surface. It is understood that there will be sacrificial periods when the roads are flooded and unpassable. Allowance of flood durations estimated in the Flood and Hydrology Assessment of the Proposal EIS would need to be factored into construction and operation.

Captured up-slope stormwater should be diverted through the site to a stable release point (e.g. through a temporary swale drain). Only this ‘clean’ stormwater should be discharged to surrounding land. ‘Dirty’ water from the disturbed site will be treated separately (Section 5.2).

5.1.3 Details for the ESCP

Direction of stormwater runoff flow though the site should be shown (both existing and proposed). Where catchment diversions are proposed, these locations should be shown on the plan, including any erosion and sediment controls, diversion works, e.g. rock protection and / or check dams. Inclusion of typical drawings (e.g. cross section of a swale drain to show dimensions and for erosion and sediment controls where required) in the ESCP are necessary.

5.2 Disturbed area stormwater

5.2.1 Potential impacts

In a disturbed environment, even a small amount of water can cause erosion. Whenever a raindrop hits bare soil it disturbs the soil aggregates and splashes soil particles into the air. Once the soil is disrupted it is easily eroded. More intense rainfall causes an increase in disruption to bare soil (DLRM, 2013b).

Most runoff on the Apirnta Facility and Haulage Road sites will occur as sheet flow. A film of water spreads across the soil surface, having low volume, velocity and energy. In undisturbed areas, this has low potential for erosion. However, if runoff is diverted or concentrated in sheet flow areas (e.g. along the eastern side of the railway track on the Apirnta Facility site or in channels crossing the Haulage road route), flow velocity and volume is increased. This leads to a higher risk of erosion.

At the Chandler Facility, degree of slope up-gradient will determine the amount of runoff energy on the site itself. The Maryvale Hills situated directly to the east are sufficiently sloping to create very rapid water flow. Rapid water flow can be very erosive and the length of slope will determine the speed and energy available to cause erosion. As such, the two drainage lines of most concern within the Chandler Facility footprint are the Mary’s Creek and Halfway Creek which are both >2 km in length, falling from 480 to 424 m AHD. Dingo, Oak, Ridey and Snake Gully’s’ by comparison are 0.5 km long, falling from 450 AHD to 424 m AHD. Sheet flow and concentrated flow at the Chandler Facility site eventually accumulates in low lying drainage lines or depression areas, flowing towards the flood out area downstream. This runoff will therefore impact down-slope habitat.

5.2.2 Mitigation measures

Stormwater from the disturbed area will not be discharged into down-gradient properties. To capture ‘dirty’ surface runoff, u-shaped earth banks would be constructed to pond water (DLRM, 2013b). This would have the additional benefits of improving soil conditions and enabling vegetation to establish. Ponding banks, are designed to be used on fairly gentle slopes, hold 10 cm of water and are relatively easy to construct using almost any type of earthmoving machinery. As such, the banks are a reasonable solution to surface water runoff capture at the Apirnta Facility and Haulage road sites. All banks need to be surveyed and banks should be constructed on the survey lines (DLRM, 2013b). They should be constructed with a single crest (double crested banks will catch water and increase the chance of tunnel erosion in the banks) avoiding sharp corners. Banks should only be constructed when soil is dry and an even height and width should be maintained. Maximum bank length should be 220-240 m as reaching will occur on longer banks (DLRM, 2013b). Ponding banks are not designed to be dams and they should never be constructed across major drainage lines. They would not be used on steep slopes because they are not designed to catch fast flowing surface runoff or intercept watercourses. As such, ponding banks are not deemed suitable for use at the Chandler Facility nor at the Haulage Road creek crossings.

The length of the slope should be reduced at the Chandler Facility site. Appropriately lined and sized catch and slope drains should be installed and the benefits of check dams to control velocity and provide some sediment settling facility should be considered. Appropriately sized sediment basins should be located down-slope from the construction works. The type of basin (i.e. Type 1, 2, F or D) will be assessed during detailed design. It is anticipated from particle size data collected from the Apirnta Facility and Chandler Facility as part of the Surface Water Baseline Assessment for the Proposal EIS that mobile sediments would generally be in the fine sand size range.

For the access and haulage roads, use of mitre drains or whoa-boys, changes in route direction and spilling water off on the corners or construction of ponding and diversion banks (these require exact surveying) to reduce slope length are recommended (DLRM, 2013b). Avoiding the route travelling in a direct up slope direction will be important. As an alternative, shortening the slope by either running the route parallel to the contour or zigzagging up the slope, or constructing diversion banks or drains to remove runoff from the road are recommended (DLRM, 2013b).

At the Haulage Road creek crossings and newly created Halfway Dam where implementation of the vegetated buffer zones discussed in Section 4.2 are not possible, stringent guidelines for working near watercourses would be investigated during detail design and, where appropriate, adhered to (DLRM, 2013b; IECA, 2008; Witheridge, 2011). The measures to be assessed include:

- Isolation of exposed soil sources from flow (e.g. cut-off drains, fence fabric, floating silt curtains, rubber/clay lined dams, sheet piling);
- Rehabilitation of exposed surfaces as soon as practical;
- Temporary erosion controls such as cut-off drains, rock emplacement at the toe of banks, control blankets and use of natural vegetation (Section 4.2); and
- Stabilisation of banks.

5.2.3 Details for the ESCP

Recording of drainage lines, both on the ground and on aerial photographs or satellite images would be made. Drainage lines can be identified by depressions, thick grass, greener grass, thick Mulga trees. The location and type of drainage controls such as temporary interception / diversion drains, channel form and stability, discharge points and stable outfalls would be recorded in the ESCP. Methods to achieve drainage outfall stability should be recommended (e.g. inlet pit with sediment control). Depending on length/slope of diversion, temporary velocity control measures such as rock-check dams may also be required.

5.3 Roof water

5.3.1 Potential impacts

Roof water draining freely from buildings / sheds onto the Apirnta Facility and Chandler Facility sites could cause erosion and soil wetness. This could be exacerbated in high traffic areas. It would also add unnecessarily to the volume of 'dirty' water requiring storage / treatment on site. In addition, ponding from roof water might lead to mosquito infestation.

5.3.2 Mitigation measures

The proposal plans to capture all roof drainage for beneficial re-use. All roof water drainage and storage will be designed and constructed according to best practice guidelines (Standards Australia, 2008). An estimate of volume potentially captured for different roof sizes based on the rainfall typical range at the Proposal site (long term median and maxima) are supplied in Table 5-1 (adapted from Arid, 2009).

Table 5-1 Maximum volume of harvested rain harvested (litres per year)

Annual rainfall (mm)	Roof area (m²)					
	50	100	150	200	250	300
76 (Alice Springs annual minima)*	3,230	6,460	9,690	12,920	16,150	19,380
100*	4,250	8,500	12,750	17,000	21,250	25,500
200*	8,500	17,000	25,500	34,000	42,500	51,000
300 (Alice Springs annual median)	12,750	25,500	38,250	51,000	63,750	76,500
400	17,000	34,000	51,000	68,000	85,000	102,000
500	21,250	42,500	63,750	85,000	106,250	127,500
600	25,500	51,000	76,500	102,000	127,500	153,000
700	29,750	59,500	89,250	119,000	148,750	178,500
800 (Alice Springs annual maxima)	34,000	68,000	102,000	136,000	170,000	204,000

*Data inferred from empirical relationship between annual rainfall and roof area

The anticipated roof water drainage volumes for the Apirnta Facility and Chandler Facility should be established once the final footprint is designed and total roof areas are known in order to correctly size storage.

Anti-mosquito measures should be adhered to for water storages, as described in RHAA (2011), including the following measures:

- Tanks must have mosquito proof screens (no larger than 1mm aperture mesh) on all outlets, overflows and other openings;
- All lids, covers and inlet downpipes must be fitted tightly to ensure mosquitoes cannot enter the tank;
- The water should be inspected at regular intervals; and
- All mosquito screening should be checked to ensure no signs of wear and tear.

Installation of temporary or permanent downpipes will be planned as soon as possible after the installation of roofing and guttering, especially if this is scheduled during periods when rain is expected. If roof water is not re-used because of site excess, it should either be stored in the site retention device or discharged away from the active work area and any disturbed soil surface.

It is not recommended that rain water is used for human consumption purposes unless a full drinking water safety assessment is conducted.

5.3.3 Details for the ESCP

Roof drainage controls are best described through the use of technical notes in the ESCP.

6 Erosion and Sediment Runoff

The main cause of natural and accelerated soil erosion in the NT is through water erosion. Water erosion occurs when energy from the impact of rain or overland flow breaks up and transports soil (Richards 1978) and can include raindrop, sheet, rill and chemically-induced erosion. Water erosion of soil progresses as soil particles detached by incident rainfall move by shallow flow to small channels or rills. Water may then move preferentially to depressions in the soil surface, such as wheel ruts. Rill erosion can then occur by soil detachment of the walls and floor of the rills by concentrated runoff (Lal, 1985). Erosion is exacerbated by increasing slope length and slope angle, and gullies may form that branch and extend upstream into their catchments (Richards 1978).

Wind erosion is the simple detachment and movement of surface soil from the action of wind (Smith and Hill, 2011). It is exacerbated by frequent wind conditions of sustained strength, flat land with few natural landscape interruptions and bare, non-vegetated soil. If wind velocity is high enough, soil particles are suspended in the air, forming dust clouds.

Sediment runoff is the entrainment and subsequent transport of eroded particulate matter of organic and inorganic composition. The conveyance capacity of stormwater to carry this sediment mixture either in suspension or as bedload (i.e. saltation) is related to the sediment particle size distribution / density and water depth / velocity, linked to shear stress (Evans *et al*., 2004). As such material can be preferentially sorted, with finer / lighter particles being transported more frequently and to greater distances than coarser / denser particles.

6.1 Disturbed areas erosion

6.1.1 Potential impacts

Impacts of erosion include dust generation which could cause visibility, plant smothering and breathing issues (Witheridge, 2012). Visibility would be a particular concern for transport routes, both rail and road. Excessive erosion on the disturbed sites may lead to land instability, rendering areas inaccessible or dangerous. Maintenance / rehabilitation of this land would be costly and may hinder successful re-establishment of native species if associated impacts such as soil nutrient loss, dryland salinity and surface instability is ongoing.

Alice Springs rural areas are highly susceptible to severe erosion due to soil types (i.e. fine texture powdery, saline and poorly structured) and land use (vegetation removal, earthworks and vehicle movement) (DLRM, 2014). During the late 1960's and the early 1970's Alice Springs region experienced many dust problems, which were serious enough to cause the closure of the airport. In response to the problem, a dust control project was initiated ('Alice Springs Erosion Hazard Area') with land rehabilitation works and Restricted Use Area implemented over 200 km². The DLRM Land Management Unit oversees the continued management of the area and reiterates that the area is still susceptible to soil erosion and that the restricted use declaration in this area still needs to be observed (DLRM, 2014). Although Alice Springs is approximately 150 km north of the Proposal, this issue highlights that ongoing erosion controls will be necessary on the Apirnta Facility, Chandler Facility and Haulage Road sites.

6.1.2 Mitigation measures

Since rain splash and water movement over the soil surface are the main agents of water erosion, mitigation activities are aimed at reducing the impact of these processes. According to Elliott *et al*. (2002) the basic principles for water erosion control involve:

- Preventing soil detachment by the energy from raindrop impact;
- Improving structural stability of the soil surface and improving its water retention by slowing surface flow and improving transmission properties, which provides more time for water to infiltrate; and
- Decreasing runoff rate and its velocity by providing appropriate surface drainage systems for safe conduct of water into pre-designed surface storage systems (Section 5).

Much of the above can be achieved by using reduced or no-till techniques in ground preparation, which retains vegetation (attached and non-attached) on the soil surface to reduce raindrop impact, while maintaining the structure of the soil, slowing surface flow and allowing more time for water to infiltrate. A strong relationship between attached vegetation cover and surface runoff with suspended sediment has been reported previously (Dilshad *et al*., 1994). Once attached vegetation cover fell below 40%, exposing the soil to significant rain splash, losses of soil in runoff increased rapidly. Litter on the soil surface (non-attached cover) was also important, but could be washed away in high intensity storms, reducing its effectiveness (van-Cuylenburg, 1989).

Where retention of existing vegetation groundcover is not possible (Section 4.2), appropriate erosion control measures should be employed to protect exposed soils to prevent or reduce erosion caused by raindrop impact and storm water flows should be completed. Examples include: re-grassing, mulch, geotextile, gravel or rock lining or the application of a soil binder. Loss of topsoil hampers re-vegetation and adversely affects the productive and amenity values of the site. Newly formed earth batters, such as fill slopes, should be covered with topsoil and mulched, vegetated or otherwise be stabilised as soon as practicable.

The extent and type of erosion control measures required will depend largely on the timing of works, i.e. if works are to commence and be completed during low rainfall months (May to September) significantly less erosion control measures are required than for works being undertaken during higher rainfall months. Where practicable, the site should have cover established as soon as construction activities are completed and a heavy mulch layer should be placed on exposed areas. Prompt stabilisation of the site will prevent or limit erosion damage to newly formed earthworks and reduce sediment creation at the source.

Dust suppression measures including mulching, soil binders, temporary seeding and water trucks can be considered (IECA, 2008). Water from the retention ponds on site can be pumped into a bowser and used to damp down the haulage roads and site compounds to prevent the generation of dust (Murdane, 2006). Care should be taken not to create clouds of vapour in order to prevent the possible spread of disease through inhalation of contaminated water. Silty or oily water should not be used for dust suppression purposes, because this will transfer pollutants to the haul roads or generate more dust.

While these general erosion control principles apply to the three sites, more focussed erosion controls may be site-specific. The following sub-sections details particular considerations for the Proposal sites.

6.1.2.1 Proposal erosion risk

Based on the Alice Springs case-study (Section 6.1.1) and the wide geographical spread of Proposal land (i.e. three sites including linear construction footprint), it was felt that an indication of priority areas for erosion control relevant to this Proposal were required. An erosion risk hotspot mapping tool was created – this is reported in the Surface Water Baseline Condition report of the Proposal EIS. Close-ups of erosion risk for the Apirnta Facility, Chandler Facility and selected portions of the Haulage Road are considered below.

The Apirnta Facility site and Haulage Road west section (Figure 6-1) is generally located on ‘low’ erosion potential land with ‘slight’ and ‘negligible’ erosion potential land to the south around the haulage road entry point and fence line. There are scattered cells in the general site vicinity with ‘intermediate’ erosion risk but these are not part of the Proposal footprint. Vehicle movement exclusion from these areas should be flagged in the ESCP. There are ‘intermediate’, ‘high’ and ‘very high’ erosion risk cells along the Apirnta Creek corridor. This highlights the benefit of establishing vegetated buffer zones along the watercourse to protect from excessive erosion (Section 4.2) and establishing stringent protocols for working near watercourses (Sections 5.2.2 and 6.1.2).

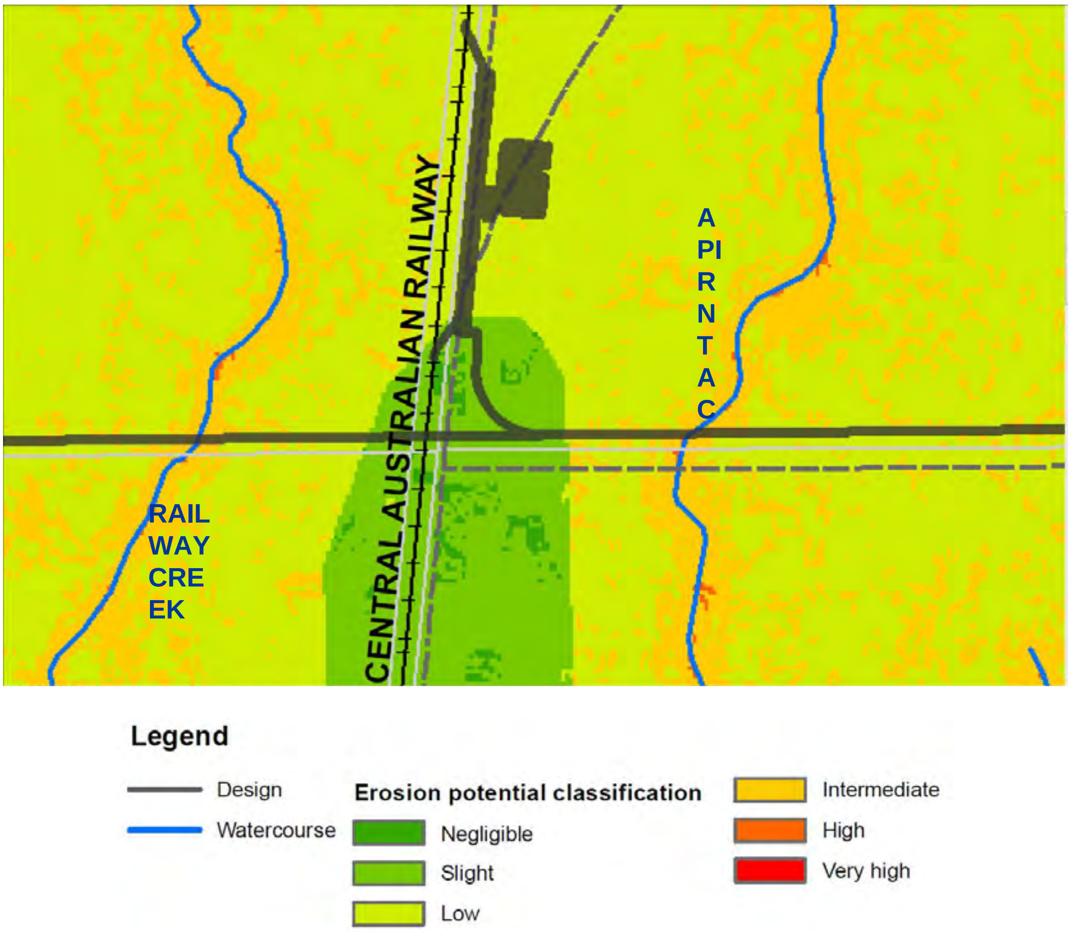

Figure 6-1 Apirnta Facility and Haulage Road west section erosion hotspot map

The Chandler Facility and Haulage Road east section are generally located on a combination of ‘slight’ or ‘low’ erosion potential land (Figure 6-2). There is no ‘negligible’ (dark green) erosion potential land in the footprint or adjacent to the sites. ‘Intermediate’ and ‘high’ erosion risk cells are concentrated along the Mulga Creek, Mary’s Creek and to a lesser extent Halfway Creek drainage lines. It should be particularly noted that a long corridor of ‘intermediate’ erosion risk land crosses the Proposal footprint along Mary’s Creek. Establishing vegetated buffer zones along the watercourse to protect from excessive erosion (Section 4.2) and establishing stringent protocols for working near watercourses are recommended here (Sections 5.2.2 and 6.1.2). Due to the high level of scrutiny afforded to the Chandler Facility, additional erosion control safeguards may be considered here and there would be an opportunity for added project value in the form of establishing a no-go habitat corridor in this area with wider buffers than the guidelines suggest.

Gully erosion is present on the lee-side of Maryvale Hills, due to concentration of runoff water, steep gradient and lack of vegetative cover. These gullies will likely transmit large sediment loads down-gradient into the Chandler facility drainage structures leading to lower capacity, possible flooding and increased maintenance requirements. The channels are also likely to migrate over time, possibly undermining critical infrastructure. Tellus could investigate whether stabilisation, such as gully fill, control of water flow, gully formalisation and subsequent monitoring, would be beneficial during detailed design as recommended in DLRM, 2013b. The impact would be lower and demonstrate added value by replacing some habitat lost from facility construction (i.e. biodiversity offsets). But this unvegetated headwater gully is a natural feature so what would we 'restore' to? Could be getting Tellus into difficult territory. Re-vegetation and drainage redesign is recommended to stabilise drainage lines directly up-gradient from the mine (). This may include.

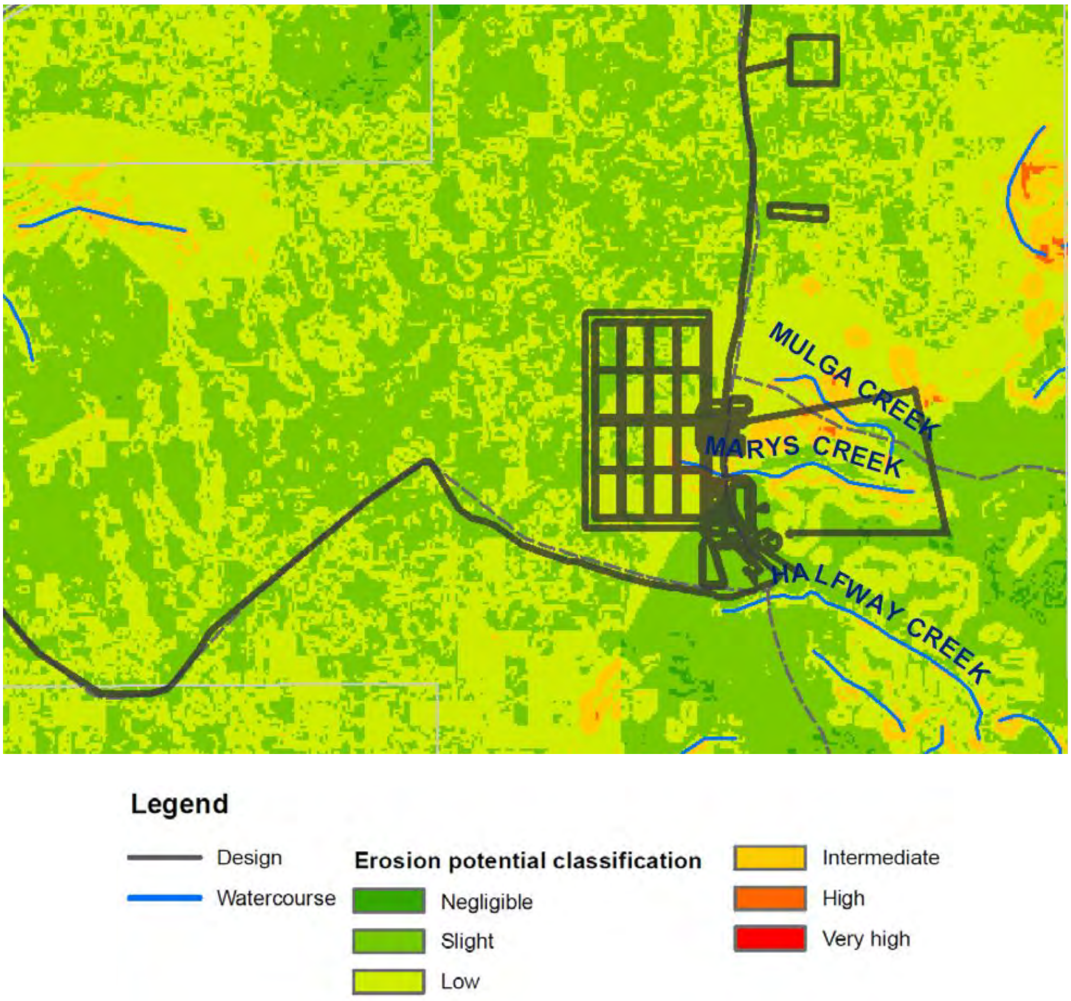

Figure 6-2 Chandler Facility and Haulage Road east section erosion hotspot map

The central section Haulage Road route runs through 'slight' or 'low' erosion potential land in the east sub-component and 'low' or 'intermediate' erosion potential land in the west sub-component (Figure 6-3). This marked change in classification is not related to a change in surficial geology nor topography, with aeolian sands dominating in both east and west sub-components and absolute gradient remaining similar, but is driven by a change in land cover, with sparser vegetation in the west sub-component, compared to the east. There is also a noticeable increase in the proportion of 'intermediate' erosion risk land associated with the northern branch headwaters of Charlotte Creek. Coincidentally, this land is on neighbouring property. As such, it is recommended that particular attention is paid to controlling the stormwater drainage down-gradient of the route in this section.

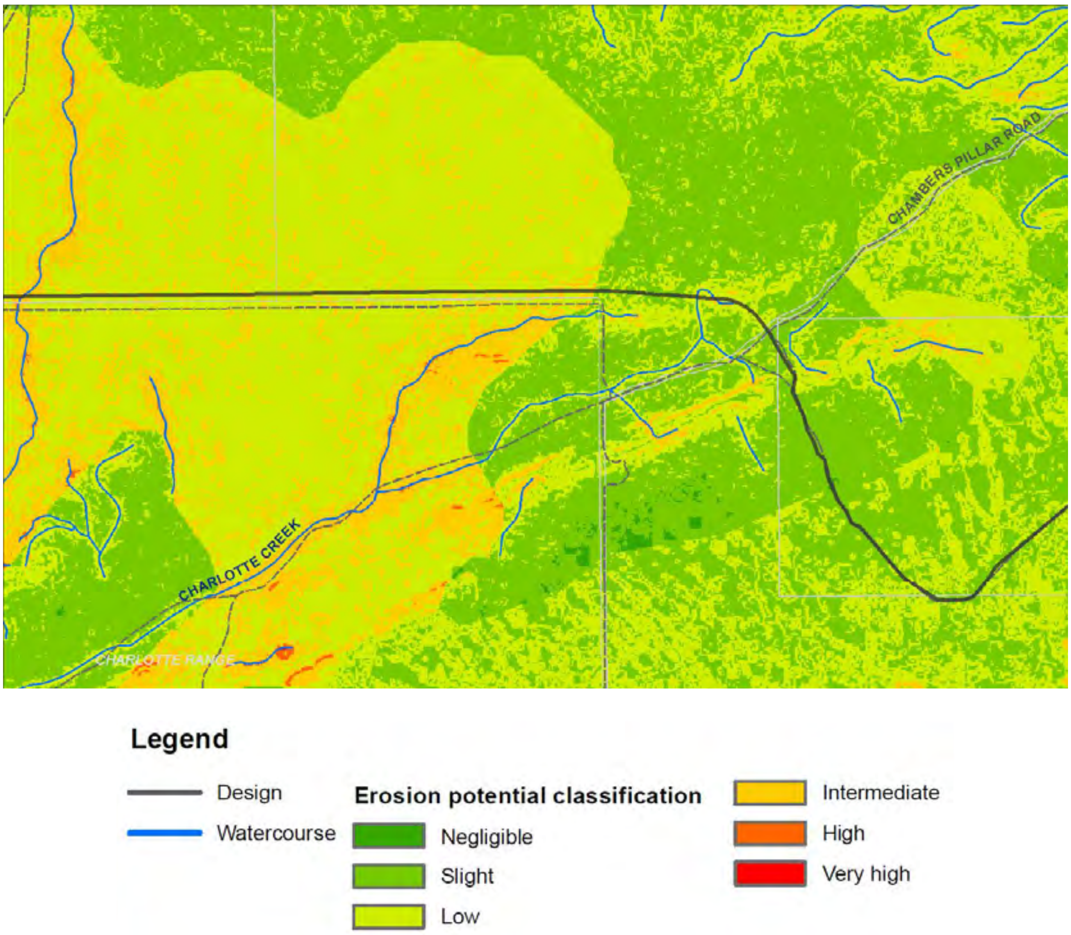

Figure 6-3 Haulage Road central section erosion hotspot map

6.1.2.2 Stabilised site entry / exit points and vehicle wash

The purpose of a stabilised construction access is to prevent sediment from being tracked off site and onto the road. It is recommended that one entry / exit point to the Apirnta Facility and Chandler Facility sites should be established. If the site slopes towards this entry / exit, drainage and sediment control devices should be installed so that all sediment laden runoff can be fully contained and treated on-site.

Unauthorised access should not occur across adjoining lots as erosion controls such as spray on soil binders may have been implemented and trafficking may incur considerable expense to re-establish binder.

Vehicles and construction equipment may require washing to prevent transfer and accumulation of mud on the haulage and access roads. Commercially available wheel-washes powered by a generator can remove silt and oils before recycling and discharging to the retention devices. Alternatively, manned jet washes or lance sprays could be used in a bunded area where the runoff can be contained and channelled to a treatment area, such as a settlement pond (Murdane *et al*., 2006). To prevent the possible spread of disease through inhalation of contaminated water, care should be taken not to create clouds of vapour. Runoff from wheel-washes and vehicle wash bays would not be allowed to enter the ‘clean’ stormwater system.

6.1.2.3 Stockpiles

Soil and sand stockpiles need to be located within the compound and upslope of a sediment control. Impervious covers, filter fences, mulch berms or sediment fences might be appropriate, depending on the size and content of the stockpile (IECA, 2008). Stockpiles of clay loam or other finely sized material may need to be covered, for dust and erosion control. All building waste materials should be placed in bins and disposed of appropriately.

6.1.3 Details for the ESCP

Erosion control methods and installations are best described through the use of technical notes on the ESCP. Down-slope perimeter sediment control would be specified as part of this documentation. Appropriate sediment control measures for all excavated sediment traps and inlets would be recorded. A note specifying that immediately after being constructed, all drop inlet pits and side entry pits will have temporary sediment controls installed. Notes on how disturbed areas will be progressively stabilised and / or re-vegetated as soon as possible following completion of works should be provided. The location of a stabilised construction access and stormwater runoff from entry / exit directed to sediment trap should be included on the drawing including a standard / typical drawing of the stabilised construction access. The location of stockpile/s should be nominated in the drawing. If not located immediately upslope of a boundary/perimeter sediment control, indicate a sediment control on the down slope side of stockpiles. Dust control measures should be detailed including method and application frequency.

6.2 Sediment runoff

6.2.1 Potential impacts

Sediment runoff can cause blockage of drainage systems, leading to increases in flood risk, maintenance costs for the stormwater infrastructure owner, road safety risks and mosquito issues. Sedimentation of waterways with coarse particulate matter could lead to increases in flood risk, channel instability, weed infestation and maintenance costs for stormwater asset owners as well as loss of essential aquatic habitat in Finke River waterholes. The release of fine sediments into waterways adjacent to the Proposal could increase the concentrations of particulate-bounds metals and nutrients, reduce light penetration and adversely affect the health of semi-aquatic life in temporary refuge pools.

6.2.2 Mitigation measures

Provision of a sediment trap, such as a mulch bank or a sediment fence, on the downslope boundaries of the Apirnta Facility, Chandler Facility and haulage roads is recommended. The mulch banks and sediment fencing should be positioned on the contour where possible (DLRM, 2013b). Sediment fencing or mulch banks running downslope require returns at more frequent intervals. Returns on mulch banks or sediment fences should be added at approximately 10 m intervals.

Onsite drop inlet pits and haulage road side entry pits should be protected prior to the commencement of works or as soon as constructed.

Buffer strips and vegetation filters should be employed, where practical, along the haulage road instead of sediment trapping structures (DLRM, 2013b). The Apirnta Facility and Chandler Facility sites may require additional sediment control measures, such as excavated sediment traps, especially if works are planned to be undertaken during months when rainfall within the area is traditionally higher. Works should be planned to intercept and retain sediment to prevent it spreading into Apirnta, Chambers, Charlotte, Halfway and Mary's Creeks.

6.2.3 Details for the ESCP

Sediment control methods and installations are best described through the use of technical notes on the ESCP. The location and typical drawing of perimeter sediment controls should be included on the drawing. Notes on dust control, e.g. cover or soil binder on exposed soils and stockpiles would be recorded.

7 Rehabilitation and landscaping

Rehabilitation is the treatment of the disturbed area to a pre-determined standard. It is required wherever there has been a change in the landscape or degradation is occurring. It is required in this Proposal case for construction areas that will no longer be required during site operations. The use of native plants indigenous to the area to re-vegetate disturbed areas and provide a buffer are recommended (DLRM, 2013b). This approach offers a number of advantages including:

- No need to purchase materials;
- Natural and effective measure to remove coarse sediment;
- Long term sediment control measure;
- Surrounding land impact is reduced;
- Refuge for existing indigenous vegetation and wildlife; and
- Where vegetation is retained on slopes greater than 1% the natural vegetation can provide good binding of the soils while still acting as a sediment filter for water entering from upslope.

Areas may require fencing, particularly during establishment periods. Species will be selected that are suited to local soil and climatic conditions. A mixture of perennial and annual pastures should be planted. This may also require a combination of other erosion control measures to assist in soil stabilisation (DLRM, 2013b). A separate Rehabilitation Closure Plan has been prepared as part of the EIS.

Under current design plans, the existing Halfway Dam will need to be decommissioned and a new dam constructed in an alternative location. Many of the problems encountered during earthworks construction will also be encountered during dam decommissioning. This includes the release of sediments, changes in water flow patterns and release of contaminated water. Extensive planning should be undertaken and protective measures implemented when decommissioning a dam to reduce the environmental impacts.

A new and appropriate location for Halfway Dam will be selected during detailed design. This would ideally make use of a similar gully or depression (due to storage to excavation ratio) off-line from an adjacent to a creek with similar catchment area nearby on gently sloping terrain (<15%). A site investigation and selection should optimise the sustainable use of available water within a dam's catchment. The size of the catchment, soil and vegetation characteristics and path of surface run-off water determines what water is available within a catchment. Contour maps should be used to predict the path of rainfall and irrigation run-off within the dam's catchment.

If the soil and sub soils that are excavated for the pond basin are suitable, they would be used to construct the dam. However, there must be sufficient clay content in the soil for the pond to hold water—20 percent clay content is the recommended minimum. Clay material excavated from the mine decline is expected to be suitable for dam building. The following steps are recommended for dam construction (NT Gov, 2015):

- Soil testing analysis of the dam wall, especially for the core, as any errors in that analysis can cause the dam wall to break;
- Soil and water testing of the sub-soil system to investigate salinity levels. When the dam is constructed it may tap into these sources of salt, creating stored water that is unusable and an environmental hazard.
- Detailed survey of the storage area to work out how much the dam will hold and the full supply level area of inundation;
- Hydrological report with a water balance study to meet the estimated demand;
- Detailed dam wall design with engineering drawings;
- Detailed spillway and outlet design with engineering drawings;
- Geotechnical report including the soil tests, the dam wall foundations and the ability of the dam to store water - outline any potential for leaks;

- Assessment of the downstream environment and vulnerability to flooding if the dam fails; and
- Aboriginal Areas Protection Authority clearance certificate.

A biodiversity survey was completed to assess the impact of moving the dam (Low Ecological, 2016).

To construct the new Halfway Dam, standard guidelines should be followed (e.g. Dept. Water, 2014; NRW, 2006). The sequence of construction work is generally:

- Prepare the site;
- Excavate and backfill cutoff;
- Install pipework (if necessary);
- Construct embankment;
- Excavate the bywash; and
- Protect vulnerable areas from erosion.

To reduce the potential damage caused by land clearing, only the minimum amount of vegetation necessary should be removed. This should match the footprint of the dam when full plus an allowance for dam protection linked to potential tree root intrusion. The benefits that vegetation surrounding the new Halfway Dam can provide should be considered. It should have appropriately constructed spillway and / or bypass channel to return water to the adjacent creek. These facilities should provide sufficient freeboard to prevent overtopping of the dam wall and reduce the risk of dam failure during periods of high or extended rainfall. They should be designed and constructed to reduce potential erosion and pressure on the dam wall. Dam storage freeboard should provide for at least a 1 per cent AEP (annual exceedance probability) storm event (Dept Water, 2014). The new Halfway Dam should be built during the dry season to allow construction without stormwater disturbing the earthworks. Soil embankments should have consistent low permeability soil characteristics, be moisture conditioned and compacted and have appropriate shape and dimensions, so they are sufficiently sturdy to prevent failure of the structure. Organic material in the dam wall, such as dead tree trunks, roots and plant matter, should be removed as the dam wall can weaken and fracture as the organic material decays (Dept Water, 2014).

8 Installation sequences

Subject to obtaining approval, it is anticipated that enabling works would run from January – June 2018, as described in the Proposal description chapter of the EIS. The majority of construction works would then occur over a three-year period with a year required for commissioning, in a 5-stage approach.

Flagging of ‘No-Go’ areas and establishment of site access should occur at the beginning of this period. Drainage diversion and sediment control measures would also be implemented prior to site disturbance. Following this, stockpile areas, avoid trench alignments, would be located. It is anticipated that construction of the permanent site facilities for Apirnta Facility and the Haulage Roads would begin in July 2018 and would be completed within approximately six months. Erosion controls and progressive rehabilitation would be programmed during this period. Final site rehabilitation / landscaping and removal of temporary ESC measures would occur at the end of the construction period. Work on the Chandler Facility would continue from a further two years.

9 Maintenance / monitoring

The ESCP will outline how the site works will be monitored and maintained, including repair of storm damage, until rehabilitation and re-vegetation is completed and specified contract handover conditions are met. A monitoring schedule and assigned personnel, indication of ESC materials to be held on site for emergency repair works and consideration of a site monitoring template form are recommended.

Buffer zones of retained vegetation can easily be disturbed or destroyed by poor on-site management. Retained vegetation buffers should be inspected after each rain event and checked for evidence of concentrated flow or bypassing flow (DLRM, 2013b). If necessary, the following steps should be followed to correct the passage of sheet flow through the area:

- Remove excessive accumulated sediment which may cause flow concentrations;
- If excessive sediment loads are apparent, investigate the source and resolve;
- Vehicular traffic and construction equipment must be kept off the retained vegetation buffer; and
- Where monitoring identifies problems in performance, additional installation of erosion and sediment control measures may be required upslope of the vegetation buffer.

Clearing of regrowth should be timed as recommended (Section 4.2), as a ‘clean’ pull will reduce the required frequency. Permanent vegetation buffers should have stock excluded (to promote dense groundcover) and be protected against the introduction of weeds, spreading crops, feral animals and destructive fire.

Weed control may be required to ensure the original vegetation make-up of the site is retained as much as possible and further weed spread does not occur. Vegetation regrowth cannot be cleared without a permit (DLRM, 2013a). Regrowth describes native vegetation recurring on an area of land that has previously been cleared. Regrowth can range from very small eucalypt and acacia suckers appearing on a recently cleared paddock to significant native vegetation communities with all the diversity and structural variability expected in any undisturbed bushland environment. Under the native vegetation clearing controls the definition of clearing of native vegetation does not include ‘native vegetation occurring on a site previously cleared in accordance with a permit issued under the Act’. This means that if an area has already been authorised by permit for clearing, a new permit is not required to re-clear any native vegetation regrowth on that site. If you have a permit to clear an area of land, you will be able to spell the area and allow it to return to native vegetation without having to reapply to clear it again. Other activities not included in the definition of clearing include:

- The removal or destruction of a declared weed within the meaning of the *Weed Management Act* or a plant removed under the *Plant Diseases Act*;
- The lopping of a tree;
- Incidentally through the grazing of livestock;
- In the course of traditional Aboriginal use;
- By fire;
- Harvesting of native vegetation planted for harvest; and
- For road access to the land or other land.

Livestock movement should be managed to prevent access during establishment periods and groundcover condition should be monitored with further fence-off areas when necessary.

The stability of the gullies up gradient from the Chandler Facility require monitoring (Section 6.1.2.1). A sequential combination of the following techniques, in accordance to NSW DPI (2008) and Wilkinson *et al*. (2013) methodology, is recommended:

- Visual observations of channel change and new gully initiation during / after rainfall events to see where water collects and flows, record damage to soils and assess impacts of changes in channel flow direction to down-gradient infrastructure;
- Take regular photographs once or twice a year (or following large rainfall events) of sites with particular reference features such as tree roots, fences etc. Date them and compare the new photographs with earlier versions. This will give a better idea than visual observation of the extent and rate of erosion; and
- Use markers such as a series of bottle tops pushed into the surface soil or erosion pegs to check if channels are eroding, what areas are most vulnerable to erosion, calculate gully length and quantify soil/ sediment loss.

Gullies not displaying any structural changes will be limited to bullet point 1 investigation with increased effort (bullet points 2 and 3) employed for more active networks close to critical infrastructure, if necessary.

Irrigation of new plant material may be required in order to assist in successful establishment and ongoing plant growth. Water bowser movements for dust suppression will need to be monitored as the application of too much water will generate runoff (Murdane, 2006).

10 Conclusions

Best practice ESC techniques should be implemented as part of normal site management to ensure that economic, social and environmental liabilities are minimised. ESC measures will also reduce repair/clean-up costs, public liability, extend site accessibility in wet conditions and improve the aesthetics and reputation of Tellus.

This assessment has identified the potential impacts of construction in terms of vegetation clearance (Section 4.1), drainage control (Sections 5.1.1, 5.2.1 and 5.3.1) and erosion and sediment runoff (Section 6.1.1 and 6.2.1). Associated mitigation measures have been recommended which should be detailed in an ESCP conducted by a suitably qualified professional. This should include technical notes to describe selected ESC methods and related maintenance requirements as detailed in Sections 4.3, 5.1.3, 5.2.3, 5.3.3, 6.1.3 and 6.2.3. Accompanying drawings and plans will provide helpful direction for contractors and site personnel responsible for implementing and maintaining ESC works.

During detailed design and following completion of detailed design, additional work requirements for the outline ESCP are recommended. These include:

- Detailed survey of the sites plotted to inform ESCP's;
- Dam evaluation as detailed in Section 7;
- Investigate whether a gully rehabilitation program on the Maryvale Hills up-gradient from the Chandler Facility is warranted, based upon ongoing monitoring (Section 9) and proximity of planned infrastructure;
- Roof water drainage volume estimation;
- Sinkhole inspections on the construction sites to verify buffer zones;
- Soil pits dug once excavation depths and known. Dispersion and soil characterisation testing should be performed for surficial and suitable depth increment samples for the Apirnta Facility, Chandler Facility and Haulage Road;
- Water monitoring plan for construction and operation;
- Wildlife corridor design for the newly created Halfway Dam.

The plan should be accompanied by Landscape Management Plan for operation and legacy of the site (Section 7).The sequencing of events and the maintenance / monitoring of the recommended control systems are crucial for successful implementation of the ESCP as detailed in Section 8 and 9.

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