PRIMARY GOLD

Appendix R - Water Quality Improvement Plan

CDM Smith

cdmsmith.com

Initial water quality improvement plan for the lower Mary River based on the water management plan for the redevelopment of the Rustler's Roost mine and the Quest 29 mining precinct.

Surface Water & Erosion Solutions

29 August 2022

DOCUMENT CONTROL RECORD

Job number	
Client	Hanking Mining
Author (s)	Ken Evans
Date	02/08/2022
Document ID	

DOCUMENT HISTORY

Rev	Reviewed by	Certified by	Issued to	Date
1				
Final				

ACRONYMS & ABBREVIATIONS

AEP	Annual Exceedance Probability
ARR-DH	Australian Rainfall and Runoff Data Hub
BOM	Bureau of Meteorology
CPEng	Chartered Professional Engineer
CPESC	Certified Professional in Erosion and Sediment Control
DEM	Digital Elevation Model
DITT	Department of Industry, Tourism and Trade (NT)
ESCP	Erosion and Sediment Control Plan
IECA	International Erosion Control Association
IFD	Intensity Frequency Duration
LOM	Life of Mine
LP3	Log Pearson 3 statistical distribution
ML	Mineral Lease
MMP	Mining Management Plan
NSE	Nash-Sutcliffe model efficiency coefficient
NT	Northern Territory
NVIS	National Vegetation Information System
PGO	Primary Gold Limited
Q29	Quest 29 Project Area
RPC	Representative Concentration Pathway
RRPA	Rustler’s Roost Project Area
SILO	Scientific Information for Landowners
SoCS	Site of Conservation Significance
TSF	Tailing Storage Facility
WRD	Waste rock dump

TABLE OF CONTENTS

Tables

Figures

1 INTRODUCTION

As a result of review of the draft EIS for Rustler's Roost (RR) and Quest 29 (Q29) mines, the comments and additional information requirements in Table 1 were received.

Table 1-1. Specific comments on Draft EIS

Cumulative impact assessment	Whole of environment considerations	**Comment** The EIS and the modelling work presented in Appendix H suggests around 5,800 ML/annum (or 78%) of the water produced on site will accumulate and require storage, or treatment and disposal. With the location of Toms Gully and other mining activity downstream of Rustlers Roost and Quest 29, there is a potential for successive, incremental, and combined impacts to sensitive receptors in the Mary River catchment. **Additional Information Required** 1. Conduct a cumulative impact assessment of potential significant environmental impacts to environmental values and beneficial uses of the Mary River system because of both controlled and uncontrolled discharges from mine sites (Rustlers Roost, Quest 29, and Toms Gully). 2. The assessment should focus on maintaining or improving catchment sediment and water quality consistent with the **National Water Quality Management Strategy.**

This report continues from the whole-of-catchment hydrologic analysis and water quality modelling (dot point 1 above) and addresses maintaining or improving catchment sediment and water quality (dot point 2 above).

2 BACKGROUND TO LOWER MARY RIVER WATER QUALITY IMPROVEMENT PLAN

This water quality improvement plan (WQIP) for the lower Mary River is directly related to the water management plan (WMP) for the Rustlers Roost-Quest 29 redevelopment project (Project Area) (Appendix Q of the Draft EIS). It is established to develop a whole-of-catchment assessment of the Mary River. Environmental values of the catchments upstream of Charles Creek (Quest 29) and Mt Bundey Creek (Rustlers Roost) are not discussed in detail as the plan is water-focused and the main receptor of the Project Area is the lower Mary River.

The WMP outlines water quality values that have been approved for discharge from Charles Creek and Mt Bundey Creek. These are the baselines for water quality management on the project area. Site specific trigger values (SSTV) have been established for these discharges and water quality modelling for uncontrolled releases indicate that the water quality in the lower Mary River does not exceed ANZG trigger values.

This report compiles baseline environmental data based on desktop studies, proposes environmental values, and discusses proposed monitoring.

2.1 Integrated Catchment Management Plan 1998, 2001

An integrated catchment management plan (ICMP) was developed for the Mary River and released in 1998 (Anonymous, 1998) and revised in 2001 (Mary River Catchment Advisory Committee., 2001). The plan was developed because of the increased economic production, including live cattle shipping, tourism, recreational pursuits, and mining, as well as long-term climatic change and sea level rise. It was considered that left untreated, saltwater intrusion and weeds have the capacity to destroy a large part of the Mary River catchment. ICMP considered aquatic habitat protection to be of high priority. Threats include fire, grazing, pastures, clearing, water quality, erosion, and feral animals. The main goal of the plan was ecologically sustainable multiple use of the Mary River catchment. The actions to achieve the goal were listed as:

1. Maintenance or enhancement of soil, vegetation, and water quality
2. Maintenance of biodiversity
3. Maintenance of resource productivity
4. Optimisation of net financial and social benefits.

Detailed responses to the threats above are listed in the ICMP.

2.2 Integrated Assessment of Wetland Services and Values

De Groot et. al. (2008) conducted an analysis of wetland services and values of the Mary River. The main services were identified as:

1. Provisioning services:
    a. Carrier functions: agriculture (cattle, buffalo, horticulture, aquaculture) and mining
    b. Production functions: harvesting natural resources, commercial and subsistence fishing, raw materials, and ornamental resources.
2. Supporting services: important habitat wildlife and soil formation and retention.
3. Regulating services: the critical role of ecological and biophysical processes such as climate change, water supply, regulating runoff, erosion control, disturbance prevention, nutrient regulation, waste treatment, and biological control.

4. Cultural and amenity services: aesthetics, recreation and tourism, spiritual and holistic information, cultural and artistic information, and science and education.

The seasonally inundated wetlands are of national importance (de Groot, Finlayson, Verschuuren, Ypma, & Zylstra, 2008) providing essential habitat for rare and endemic species and seasonal habitat for migratory species.

In the 2008 report the economic benefits provided by the main ecosystem services was A$50.7 million; however, not all ecosystem services were considered. The four most economically important services are carbon sequestration, water use, agriculture/horticulture, and tourism.

2.3 Mt Bundey Ck, Charles Ck, and Lower Mary River Water Quality Improvement Plan

This report addresses the lower floodplain areas of the Mary River downstream of Charles Creek and Mt Bundey Creek. The report collates existing environmental data relative to the lower floodplains, which can be used as a baseline to assess changes that may or may not occur because of mining activity in the project area. The main aim is to maintain the current environmental values (EV) of the lower Mary River and where possible improve these values. This report draws heavily on the water management plan (WMP) for the project area, Appendix Q, of the draft EIS and should be read in conjunction with that report.

This plan covers the geographical area of the lower Mary River. It is in the Darwin Administrative Region, the Alligator administrative sub-region, and the unincorporated (Marrakai-Douglas Daly) Area (Figure 1-1). Aboriginal Land is administered by the Northern Land Council.

The WMP is the benchmark of this WQIP. The focus is to maintain/improve the water quality leaving the project site in accordance with the WMP and approved water quality values. The WMP has a detailed monitoring program and a list of commitments relative to the project area.

The WPM makes the following commitments:

2.3.1 Commitment Summary

In addition to the surface and mine affected water, groundwater, sediment, and biological monitoring the following commitments relevant to this Water Management Plan are made.

Commitment 1.

Primary Gold Ltd (PGO) will complete the detailed design for the relevant Water Storage Infrastructure and provide it to the Department of Industry, Tourism and Trade (DITT) for review and approval prior to construction.

Commitment 2

The tailings management strategy (including the tailings storage facility (TSF) expansion) will be completed and provided to DITT for review and approval prior to modification and use.

Commitment 3

Review of the groundwater monitoring network will be undertaken to inform locations of additional monitoring bores to provide effective coverage throughout the life of mine and beyond closure.

Commitment 4

Installation of flow meters and water storage gauges to validate the water balance model. Weekly readings will be collected on all transfers across site and storage levels.

Commitment 6

A water treatment plan will be established and provided for review as part of the Waste Discharge Licence Application and Mining Management Plan.

2.3.2 Stakeholder Engagement

Section 3 of the Draft EIS has a detailed Stakeholder Engagement Plan. The WMP, and this WQIP, will be guided by the results of those engagements.

2.4 Aim of lower Mary River WQIP

The principle aim of this WQIP is to understand water quality at a mid-point of the lower Mary River reach or have sufficient monitoring data to detect a change and therefore commence investigations. A change does not mean it is from the project area as there are many and diverse uses of the lower Mary River of which the project area is a very small percentage.

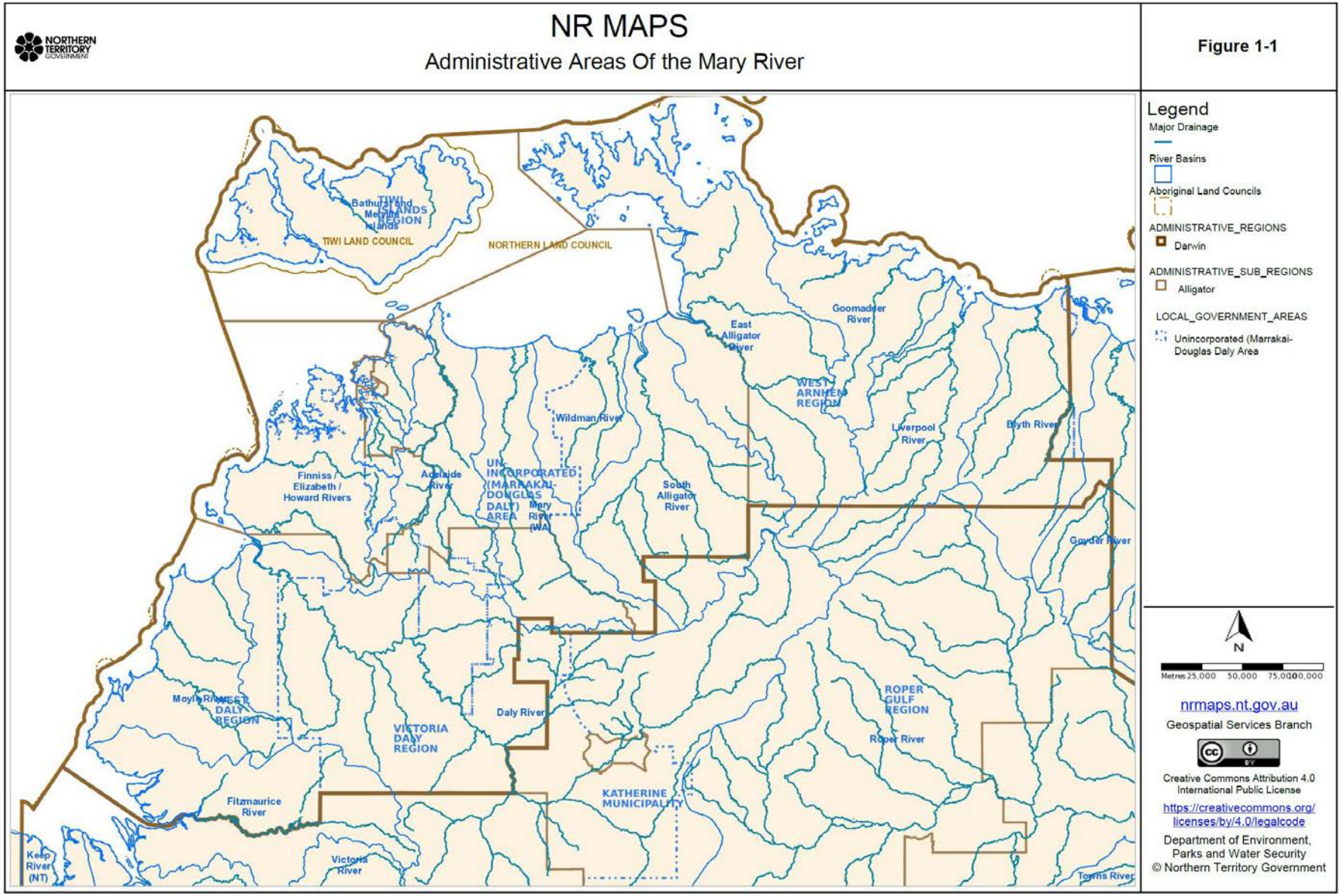


Figure 2-1 Administrative regions of the Mary River catchment.

3 WATER AND CATCHMENTS OF CONCERN

3.1 The lower Mary River Basin

The Mary River has a drainage area of approximately 7899 km^2 including the McKinlay River, its major left-bank tributary. For this analysis, the Mary River has been split into the upper catchment containing the McKinlay River and the "upper" Mary River. The "lower" Mary River receives flow from Mt Bundey Creek and Charles Creek, as well as the upper Mary River (Appendix A). The term "upper" and "lower" are not official terms but are used in this report to separate the two channel systems. Discharge from Charles Creek flows for a short distance through the upper Mary River before entering the lower Mary River. This water quality improvement plan (WQIP) focuses on the lower Mary River. The Mary River is 297 km along its thalweg from sandstone plateaus in the south to the outlet into Van Diemen Gulf (Figure 3-1).

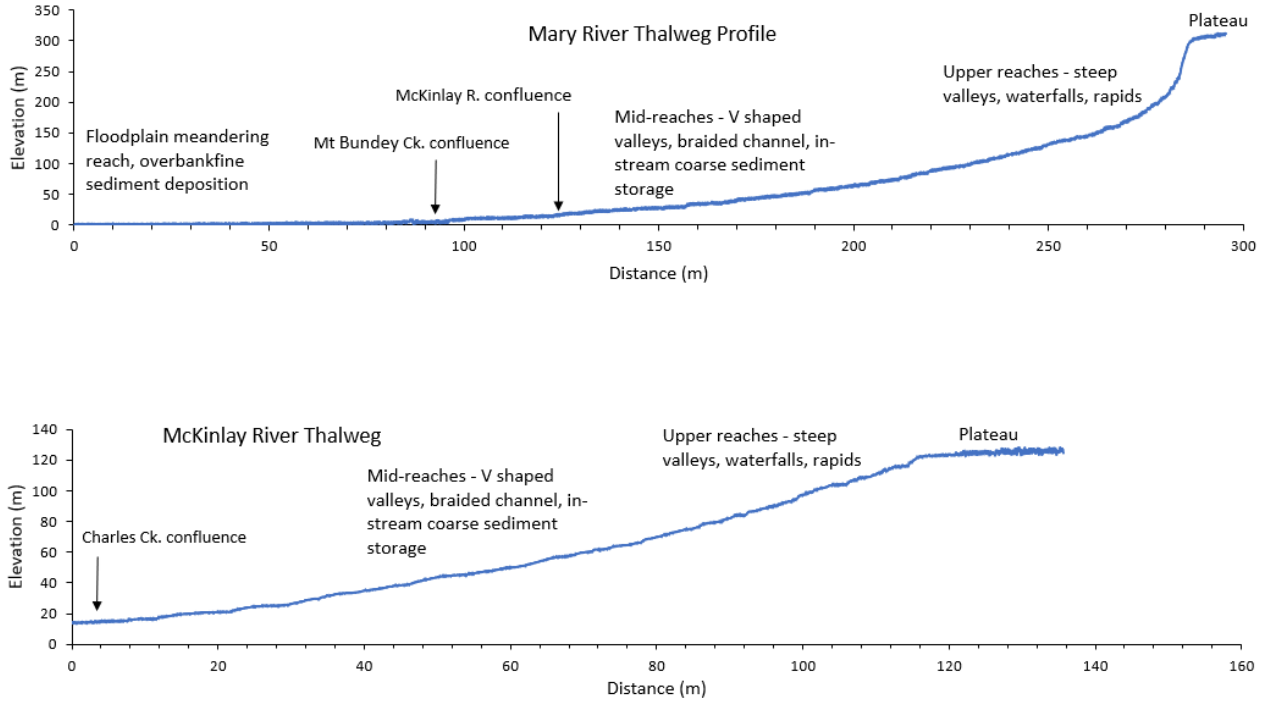


Figure 3-1 Top: The Mary River thalweg profile shows the confluence of the McKinlay River and Mt Bundey Creek. Bottom: McKinlay River thalweg profile showing the confluence with Charles Creek.

This report collates environmental data for the lower Mary River and discusses initial environmental values. The main aim of the plan is to maintain the current level of environmental conditions during and post mining operations.

The upper Mary River has a catchment area of 3838 km^2 and the McKinlay River has a catchment area of 1840 km^2. The McKinlay River is 136 km^2 along its thalweg from where it rises to its confluence with the Mary River (Figure 3-1), including Charles Creek. The average annual flow from hydrologic modelling for the combined rivers is 3102 GL.

Mt Bundey Ck, containing Rustler's Roost, Quest 29 north and Tom's Gully mines, has a catchment area of 200.4 km^2 and is a major left-bank tributary of the Mary River.

Charles Creek has a catchment area of 80.3 km^2 and contains the Quest 29 south mining precinct.

The lower Mary River has a catchment area of 2017.5 km^2. The thalweg from the lower Mary River to the outlet is approximately 119 km long passing through meandering channels and extensive floodplains to where it debouches into Van Diemen Gulf.

3.2 Van Diemen Gulf

The Mary River discharges directly into Van Diemen Gulf (Appendix A), a semi-enclosed marine embayment that is poorly flushed with a tidal range of 3–4 m (Department of the Environment, Water Heritage and the Arts, 2007). It is bounded by the Tiwi Islands, Coburg Peninsular, and the mainland (Appendix A). Large river catchments, including the Mary River, contribute large volumes of sediment, nutrient, and freshwater during the monsoon season. A sand barrier in the centre of the basin traps freshwater inflows leading to low salinity and high turbidity.

3.3 Biophysical risk

The Mary River is in the wet-dry tropics and has steep near-coastal topography. Most of the lower Mary River is wetlands, estuarine tidal areas, and seasonally inundated floodplains. Research has found that there is a risk conversion of native vegetation to dense para grass or gamba communities, which could lead to a substantial loss of plant and animal diversity and reduction in the size of animal populations (Beggs, 2010).

Other management problems in the lower Mary River include saltwater intrusion and wetlands weeds invasion of *Mimosa Pigra* (Anonymous, 1998). There are also the concerns of long-term climate change and sea level rise, as well as fire, grazing, pastures, clearing, water quality, erosion, and feral animals.

3.4 Climate

The catchment is situated within the wet-dry tropics and experiences two distinct seasons: the dry season from May–September and the hot and humid wet season from October–April.

Bureau of Meteorology (BOM) daily rainfall records are available for station 014278 Marrakai. This station is near the centroid of the lower Mary River catchment. The average annual rainfall is 1577 mm with the greatest average monthly rainfall occurring during January (398 mm). Cyclones and monsoons can occur during the wet season. Little rain falls during the dry season (Figure 3-2).

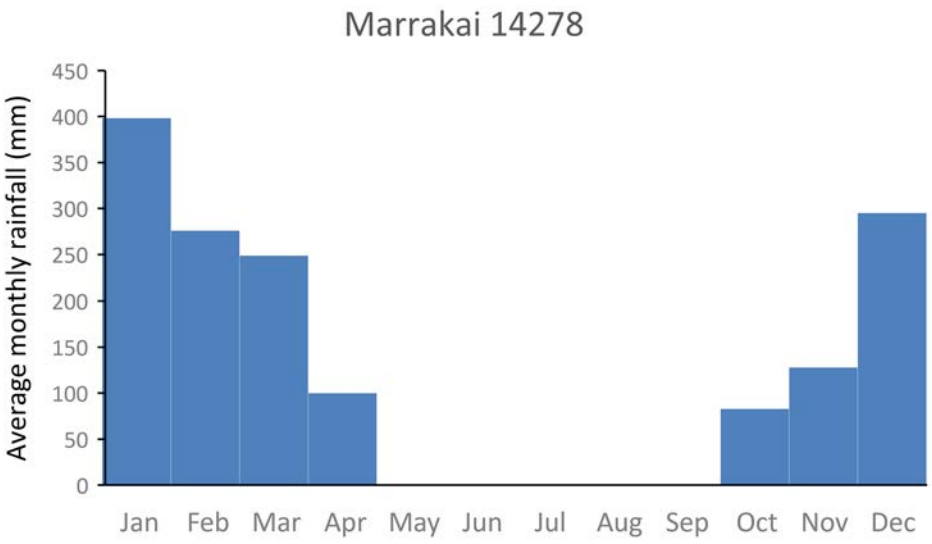


Figure 3-2 Mean monthly rainfall for BOM station 014278 Marrakai.

3.5 Land Use

Sixteen land uses have been classified in the lower Mary River (Table 3-1). Area-wise the largest uses are grazing of native vegetation and esturine/coatal waters (Appendix C).

The top two land uses comprise almost 94% of the catchment area, indicating a sub-catchment with low impact uses apart from grazing on native pastures.

Table 3-1 Land uses in the lower Mary River.

Land Use	Area (ha)	% of total area
Grazing native vegetation	6157	49
Estuary/coastal waters	5563	45
River	349	3
Residential and farm infrastructure	106	0.8
Irrigated land in transition	70	0.6
Lake	51	0.4
Marsh/wetland	39	0.3
Land in transition	36	0.3
Services	31	0.2
Nature conservation	23	0.2
Marsh/wetland	22	0.2
Other minimal use	21	0.2
Cropping	8	0.1
Lake	5	0.04
Mining	5	0.04
Transport and communication	0.6	0.005

3.6 Mary River Floodplain System and National Park

The Mary River National Park is located downstream of the Project area, approximately 6.5 km east of Quest 29 at its closest. The Mary River Floodplain System is protected within the Mary River National Park and is defined as a Site of Conservation Significance (SoCS). The Mary River National Park is managed under a Joint Management Plan between the Limilngan and Uwynmil Traditional Owners of the park (PWCNT 2015). The park contains biodiversity values of national and international significance, as it provides a complex mosaic of wet and dry habitats that supports a diverse population of waterbirds (PWCNT 2015). The park also has cultural, natural, recreational, and historical significance for tourism in the Top End.

The Mary River floodplain is a major tourist and recreational fishing attraction for the region. Recreational fishing locations downstream within the Mary River system includes Hardies Creek (approximately 10 km downstream from the Arnhem Highway crossing), Corroboree Billabong (approximately 20 km downstream), and Shady Camp (approximately 60 km downstream).

4 ENVIRONMENTAL VALUES

Environmental values for Mt Bundey Creek and Charles Creek have been described in the Draft EIS 2021 (https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/rustlers-roost-and-quest-29-open-cut-mine-redevelopment).

They are expanded here for the lower Mary River.

Data were accessed from the Department of Environment, Parks, and Water Security (DEPWS) online mapping database (NR Maps) (Northen Territory Government, 2022) for a desktop assessment.

4.1 Terrestrial

This section describes terrestrial environmental values, including land systems, soil types, and land units, in the lower Mary River.

4.1.1 Land systems

The lower Mary River is in the Pine Creek and Darwin Coastal bioregions. Land systems of the lower Mary River, as well as descriptions, are given in Table 4-1 and the spatial distribution is shown in Appendix C.

4.1.2 Soils

Overview

Detailed information on soil association, soil description, and landforms are provided in Table 4-1. The spatial distribution of soil is shown in Appendix D.

Acid Sulphate Soils

There are 22 km^2 of tidal mudflats comprising saline muds and grey cracking clay and 902 km^2 of seasonally flooded coastal plains comprising black cracking clay. These units have potential to contain acid sulphate soils and cautioning specialist planning is required if disturbed (Appendix D).

4.1.3 Erosion

Erosion risk at the Rustlers Roost and Quest 29 Project area has been associated with land clearing, pastoral activities, existing disturbed soils from mining activities, and the surface slopes gradient of the disturbed areas. A detailed erosion and sediment control plan has been prepared (Appendix L of the EIS). High annual erosion rates that may occur on steep-sloped portions of the mines will be managed through the ESCP and sediment basins.

Long-term whole-of-catchment erosion rates can be determined using a denudation rate. Recent work determined a regional denudation rate of 0.075 mm/y (Wasson, Saynor, & Lowry, 2021), which applied to the catchment area gives an erosion rate of ≈8.3 T/y/ha. This applies to the whole catchment, but it must be considered in the knowledge that the lower Mary River floodplain is mostly a deposition zone where over bank fine sediments are deposited during floods. The CSIRO RUSLE mapping of soil erosion give rates of 0.5 to 2 T/ha on the floodplain (Teng, et al., 2016).

4.1.4 Land Units

There is only partial coverage available for land units of the lower Mary River.

Table 4-1 Land systems of the lower Mary River.

Land System	Geozone	Class	Class Description	Landform	Soil Description	Soil Association	Vegetation	Acis Sulphate Soil
Bend	Darwin Coastal & Pine Creek	sandstone plains and rises	plains, rises and plateaux on mostly on sandstone, siltstone, claystone, shale, and some limestone; commonly shallow soils with surface stone and rock outcrop	Undulating low strike ridges and rises on folded Burrels Creek greywacke, sandstone, and siltstone	Skeletal soils and shallow gravelly loams	Shallow Yellow and Brown Kandosols and Leptic Rudosols	Mid-high woodland of C. latifolia, C. foelscheana, E. polysciadia, E. tectifica, Erythrophleum chlorostachys over tropical tall grass (Sorghum spp, Heteropogon spp, Chrysopogon spp)	No occurrence of acid sulphate soils
Copeman	Darwin Coastal	coastal floodplains	seasonally flooded coastal floodplains; inundated 3-6 months; poorly drained clay soils	Low swampy coastal floodplains	Black cracking clays over gleyed muds	Aquic Vertosols over gleyed muds	Mid-high closed grassland of Pseudoraphis spinescens, Fimbristylis spp, Cyperus spp (herbaceous swamps)	Common occurrence of acid sulphate soils on tidal flats, coastal floodplains, and some coastal sandplains
Cyperus	Darwin Coastal	coastal floodplains	seasonally flooded coastal floodplains; inundated 3-6 months; poorly drained clay soils	Seasonally flooded coastal floodplains	Black cracking clays over mainly calcic estuarine muds	Aquic Vertosols over mainly calcic estuarine muds	Mid-high closed grassland of Dichanthium sericeum, Germania grandiflora, Eleocharis spiralis	Common occurrence of acid sulphate soils on tidal flats, coastal floodplains, and some coastal sandplains
Effington	Darwin Coastal	alluvial floodplains	alluvial floodplains, swamps, drainage depressions and alluvial fans; sandy, silty and clay soils	Level to gently undulating alluvial floodplains of	Uniform gradational and texture contrast sandy soils	Kandosolic, Tenosolic and Chromosolic Redoxic Hydrosols	Mid-high woodland of Melaleuca viridiflora, C. polycarpa, Melaleuca nervosa, E. bigalerita, C. latifolia over Chrysopogon	No occurrence of acid sulphate soils

Land System	Geozone	Class	Class Description	Landform	Soil Description	Soil Association	Vegetation	Acis Sulphate Soil
			on Quaternary alluvium	dominantly sandy alluvium			fallax, Pseudopogonatherum spinescens, Eriachne triseta.	
Kay	Darwin Coastal	lateritic plains and rises	plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products; sandy and earth soils	Level to gently undulating plains on deeply weathered rocks	Lateritic red and yellow earths	Ferric Red, Brown, and Yellow Kandosols	Tall open woodland of C. bleeseri, Erythrophleum chlorostachys, E. tetrodonta, E. miniata, E. tectifica over Sorghum spp, Chrysopogon fallax, Eriachne spp	No occurrence of acid sulphate soils
Littoral 1	Darwin Coastal	tidal flats	tidal mudflats and coastal floodplains with channels and estuaries; subject to tidal inundation; poorly drained clays and muds	Level tidal flats with channels and estuaries and minor dunes	Saline muds and grey cracking clays	Supratidal and Intertidal Hydrosols	Samphire, sedgeland, or mangrove low closed forest	Common occurrence of acid sulphate soils on tidal flats, coastal floodplains, and some coastal sandplains
Pinwinkle	Darwin Coastal	coastal floodplains	seasonally flooded coastal floodplains; inundated 3-6 months; poorly drained clay soils	Low swampy coastal floodplains and depressions	Black cracking clays overlying marine alluvium	Aquic Vertosols overlying marine alluvium	Tall open forest of Melaleuca cajuputi, M. leucadendra, M. viridiflora, Acacia auriculiformis over Eleocharis spp, Cyperus spp, Pseudoraphis spinescens	Common occurrence of acid sulphate soils on tidal flats, coastal floodplains, and some coastal sandplains

Land System	Geozone	Class	Class Description	Landform	Soil Description	Soil Association	Vegetation	Acis Sulphate Soil
Queue	Darwin Coastal	lateritic plains and rises	plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products; sandy and earth soils	Gently undulating sandplains	Deep red earthy sands	Red-Orthic Tenosols	Mid-high woodland of E. tetrodonta, E. miniata, C. bleeseri, Callitris intratropica over tall tropical grass (Heteropogon triticeus, Chrysopogon fallax, Sorghum spp)	No occurrence of acid sulphate soils
Baker	Pine Creek	sandstone hills	low hills, hills and stony plateaux on sandstone, siltstone, quartzite, and conglomerate (deeply weathered in places); outcrop with shallow stony soils	Rugged hills and strike ridges with intervening narrow valleys and short lower slopes on folded Burrels Creek greywacke, sandstone, and siltstone	Skeletal soils and outcrop with minor sandy red and yellow gradational soils	Leptic Rudosols, shallow Yellow and Brown Kandosols	Mid-high woodland of C. dichromophloia, E. miniata, C. bleeseri, E. tectifica and C. terminalis over Sorghum spp, Themeda triandra and Chrysopogon spp	No occurrence of acid sulphate soils
Cully	Pine Creek	granite plains and rises	gently undulating to undulating plains with rises and low hills on granite, schist, gneiss (deeply weathered in places); coarse grained sandy, earthy and texture contrast soils	Gently undulating to undulating plains and rises on weathered granite	Coarse textured stony and gravely yellow-red sandy earth soils	Orthic Tenosols and Yellow Kandosols	Mid-high open woodland of C. polycarpa, C. foelscheana, E. tetrodonta, Erythrophleum chlorostachys, C. dichromophloia over tropical tall grass (Heteropgon triticeus, Chrysopogon fallax, Sorghum spp)	No occurrence of acid sulphate soils

Land System	Geozone	Class	Class Description	Landform	Soil Description	Soil Association	Vegetation	Acis Sulphate Soil
Currency	Pine Creek	granite hills	low hills and hills mostly on granite, gneiss, rhyolite, and some schist; common rock outcrop and surface stone with shallow gritty or stony soils	Rolling to steep low hills and undulating rises on granite	Skeletal soils and minor coarse sandy yellow soils	Leptic Rudosols, some shallow Red, Yellow and Brown Kandosols	Mid-high open woodland of E. tetrodonta, E. tectifica, C. latifolia, Erythrophleum chlorostachys, E. miniata over tropical tall grass (Heteropgon triticeus, Chrysopogon fallax, Sorghum spp)	No occurrence of acid sulphate soils
Flatwood	Pine Creek	alluvial floodplains	alluvial floodplains, swamps, drainage depressions and alluvial fans; sandy, silty and clay soils on Quaternary alluvium	Level to gently undulating alluvial floodplains of dominantly silty alluvium	Mottled yellow earths and duplex soils	Kandosolic and Chromosolic Hydrosols	Mid-high open woodland of Melaleuca viridiflora C. polycarpa, Melaleuca nervosa, C. latifolia, C. grandifolia over Chrysopogon fallax, Pseudopogonatherum spinescens, Eriachne spp	No occurrence of acid sulphate soils
McKinlay	Pine Creek	alluvial floodplains	alluvial floodplains, swamps, drainage depressions and alluvial fans; sandy, silty and clay soils on Quaternary alluvium	Alluvial floodplains and channels	Siliceous sands, silty brown and yellow earths, yellow podzolics	Kandosolic, Chromosolic and Tenosolic Redoxic Hydrosols	Mid-high grassland of Chrysopogon spp, Themada triandra, Cyperus spp with minor areas of woodland (C. papuana, C. polycarpa, Pandanus sp, Melaleuca spp, E. apodophylla)	No occurrence of acid sulphate soils
Rumwaggon	Pine Creek	sandstone plains and rises	plains, rises and plateaux on mostly on sandstone, siltstone, claystone, shale, and some limestone;	Low rounded hills and low gravelly ridges with intervening alluvial flats	Lithosols on rises, yellow podzolics on alluvial areas	Leptic Rudosols on rises, Chromosolic Redoxic	Mid-high open woodland of E. polysciadia, C. ferruginea, C. foelscheana, E. tectifica, Xanthostemon paradoxus over Chrysopogon spp,	No occurrence of acid sulphate soils

Land System	Geozone	Class	Class Description	Landform	Soil Description	Soil Association	Vegetation	Acis Sulphate Soil
			commonly shallow soils with surface stone and rock outcrop			Hydrosols on alluvial areas	Sorghum spp, Eriachne triseta	

4.2 Terrestrial Ecosystems

4.2.1 Vegetation

In accordance with the National Vegetation Information System (NVIS), the surrounding vegetation within the region is generally classified as Eucalyptus woodland on undulating rises and plains extending onto low hills (DEPWS 2021). Areas along the alluvial floodplains of the Mary River generally consist of Oryza tall, closed tussock grassland and around the mouth of the river there is 11.5 ha of mangrove community comprising closed mangrove forest, open mangrove forest and samphire/salt flats (Appendix E). Tussock grassland transitions to dominating eucalypt open forest in the mid-reaches of the floodplain to the catchment boundaries. The regional vegetation outside of the primary drainage lines and floodplains transitions from Eucalyptus woodland to Eucalyptus open forest on undulating low plateaux, peneplains and rises, and upper slopes of ridges. Remnants of rainforest can be found in the riparian zone along the mid-reaches. Table 4-1 lists vegetation descriptions relative to land system class.

There are 2424 recorded occurrences of weeds in the lower Mary River (Appendix E). The dominant weed species is *mimosa pigra* on the floodplains followed by gamba grass in Eucalyptus open forest in the east of the catchments (NR Maps 2022).

4.2.2 Fauna

Detailed surveys of fauna presence in the lower Mary River have been conducted and the results are available on NR Maps.

There are 23 threatened species in the region. The distributions of observations are shown in Figure 4-1.

See Section 7.5.1 of the draft EIS for a detailed discussion of threatened species on the project area.

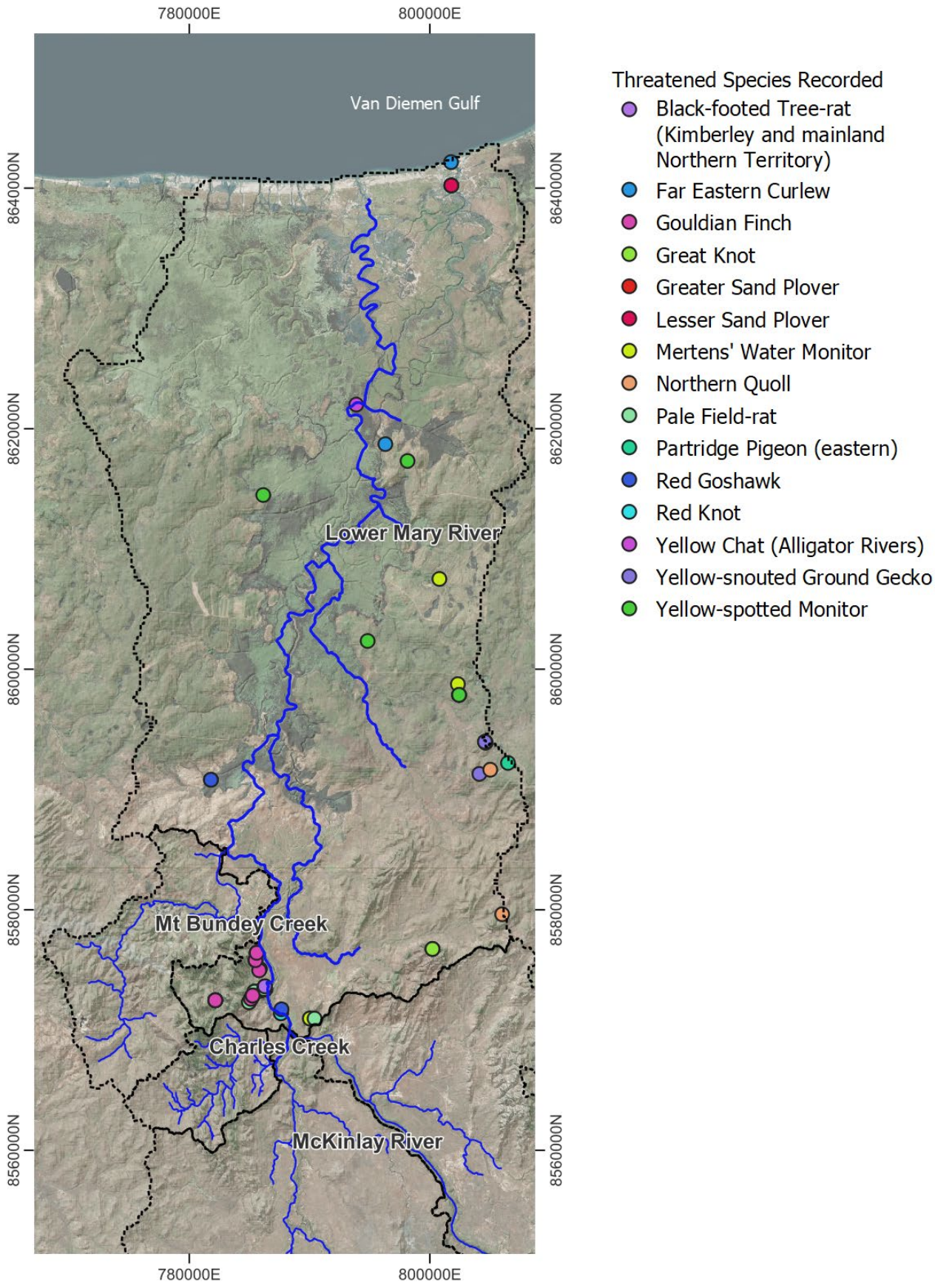


Figure 4-1 Recorded locations of threatened species

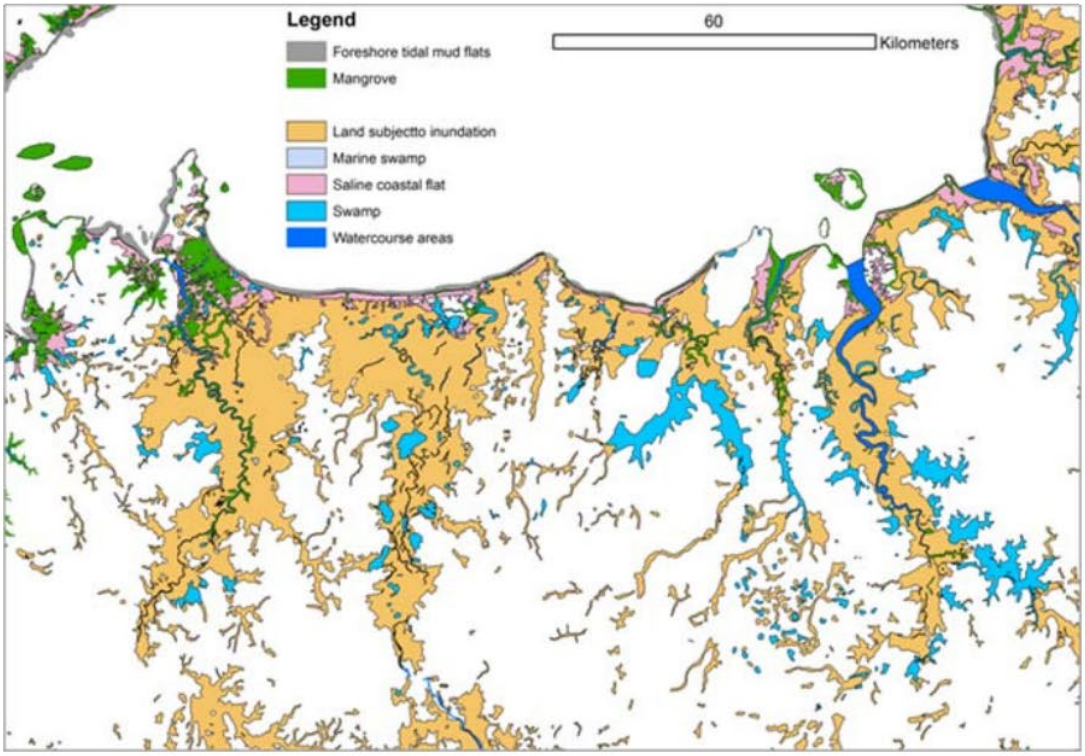
Aquatic Ecosystems

The main aquatic ecosystems in the lower Mary River are riverine and associated riparian zones, estuarine, palustrine or seasonally inundated floodplains, and lacustrine (often referred to as billabongs) in paleochannels. The distribution of low-lying coastal habitats and aquatic ecosystem types are shown in Figure 42 (Bayliss, Kennard, Bartolo, & Close, 2011).

The lower Mary River has been subjected to pastoral development and its hydrology and aquatic systems have been altered by barrages in order to mitigate saltwater intrusion (de Groot, Finlayson, Verschuuren, Ypma, & Zylstra, 2008).

Mary River wetland systems have been associated with a number of significant and threatened species. The *Environmental Protection and Biodiversity Conservation Act 1999* protected matters search relevant to aquatic ecosystems for species or species habitat likely to occur within the Project area and a 25 km buffer zone listed two vulnerable fish species (Freshwater Sawfish and Northern River Shark), nine migratory wetland species with two of them listed as critically endangered (Curlew Sandpiper and Eastern Curlew), and two reptile species (Freshwater and Salt-water crocodiles). More detail is available in Table 7-55 of the Draft EIS.

(a) Low-lying coastal habitats



(b) Aquatic ecosystem types

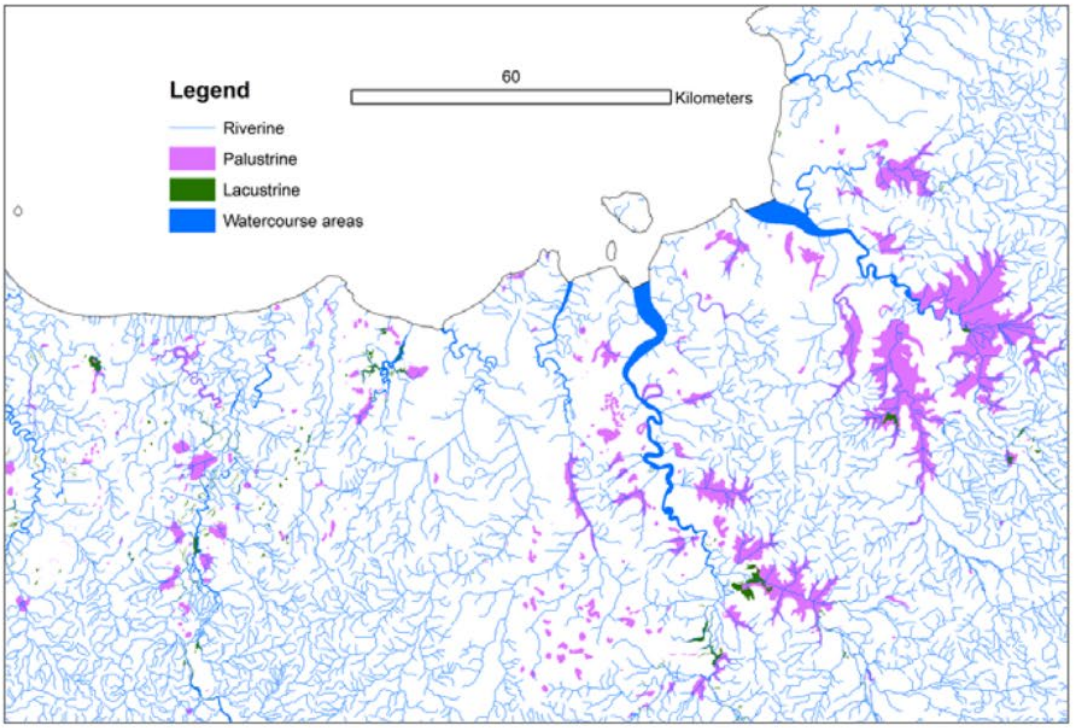


Figure 4-2 (a) Low-lying habitats and (b) aquatic ecosystems of the Lower Mary River (from Bayliss, Kennard, Bartolo, & Close (2011)). The Mary River is left centre of the figures.

4.3 Hydrological Process

4.3.1 Surface Water

Surface water types in the lower Mary River are shown in Appendix A. The main water type is land subject to seasonal inundation (881 km^2). Lakes have the next highest surface area (20 km^2).

Monitoring

There are 16 NTG river discharge gauges in the lower Mary River (Appendix F). Of these only 4 are active and the rest inactive (Table 4-2).

Inundation and Flood Occurrence

Long-term hydrologic modelling was conducted to assess the effects of mine redevelopment on the Mary River. Two simulations for the period 1 October 2030–30 September 2121 were run for the catchments with inputs from the mining areas in their present condition before the redevelopment and in the post-redevelopment condition. A climate change component using the RCP 4.5 model (Surface Water & Erosion Solutions, 2021b) was applied to both scenarios. The HEC-HMS model used in previous reports in these catchments was used with the same parameter values for rainfall losses, catchment lag, and channel lag derived as described in the previous reports (Surface Water and Erosion Solutions, 2021a). The results are given in Table 4-3. There is only minor difference in peak discharge, total discharge, and annual average discharge for the pre- and post-development conditions.

To assess the time of inundation, the long-term simulated flows at J3 (Figure 4-4) were used to conduct a flood frequency analysis using an LP3 distribution (Figure 4-3). A bank-full discharge commonly occurs during a 50% AEP flood event, which was determined as 869 m^3/s from the LP3 distribution. Floods with peak discharges greater than 869 m^3/s result in inundation.

The 50% AEP discharge was plotted on the long-term discharge trace (Figure 4-4). Flow above 869 m^3/s occurs 1.9% of the time. During the events when flow exceeds the bank-full discharge, floodplain inundation can occur from several days to a few weeks. For example, there are 11 events within the simulated long-term flow that peak above the 10% AEP discharge (1728 m^3/s). During these events, flow is overbank (i.e., greater than 869 m^3/s) for a median duration of 14 days (ranging between 11–34 days).

Beneficial Uses

Declared beneficial uses under the Water Act 1992 are environment, riparian, and cultural. These uses rely on the maintenance of stream flows and good water quality.

Surface Water Users

Flows in watercourses or permanent waterholes downstream of the mine sites may be accessed by stock and fauna. Water is also used for irrigation in some areas. Recreational fishing is also a water use.

Table 4-2 NTG river gauges with discharge records in the lower Mary River.

Location	Location	Monitoring	Latitude	Longitude
G8180035	Mary River - Mount Bundey	Inactive	-12.90613	131.6466
G8180055	Adcm - Second Chenier	Inactive	-12.27963	131.7515
G8180056	Top of Barramundie Crk Adcm Site	Inactive	-12.33233	131.7411
G8180057	Tarpon Crk between Sampan and Tommycut Cks	Inactive	-12.3894	131.7168
G8180058	Mary River - D/S Shady Camp Barrage	Inactive	-12.4831	131.726
G8180059	Mary River - U/S Shady Camp Barrage	Inactive	-12.48463	131.7247
G8180061	Sampan Crk D/S of the S - Bends	Inactive	-12.3908	131.7391
G8180065	Opium Crk - Old Point Stuart Road Xng	Inactive	-12.5435	131.7658
G8180066	Sampan Crk U/S of the Narrows	Inactive	-12.46059	131.7209
G8180071	Jimmys Crk - Point Stuart Road Xng	Inactive	-12.5819	131.7679
G8180080	Tommycut Crk U/S of Crabbers Camp	Inactive	-12.31827	131.7168
G8180082	Mary River - Alligator Head	Inactive	-12.48713	131.674
G8180084	Mary River - U/S Tyrell's Barrage	Active	-12.47816	131.7146
G8180084.01	Mary River - D/S Tyrell's Barrage	Active	-12.47816	131.7146
G8180085	Mary River - U/S Bobbies Barrage	Active	-12.45159	131.7
G8180085.01	Mary River - D/S Bobbies Barrage	Active	-12.45159	131.7

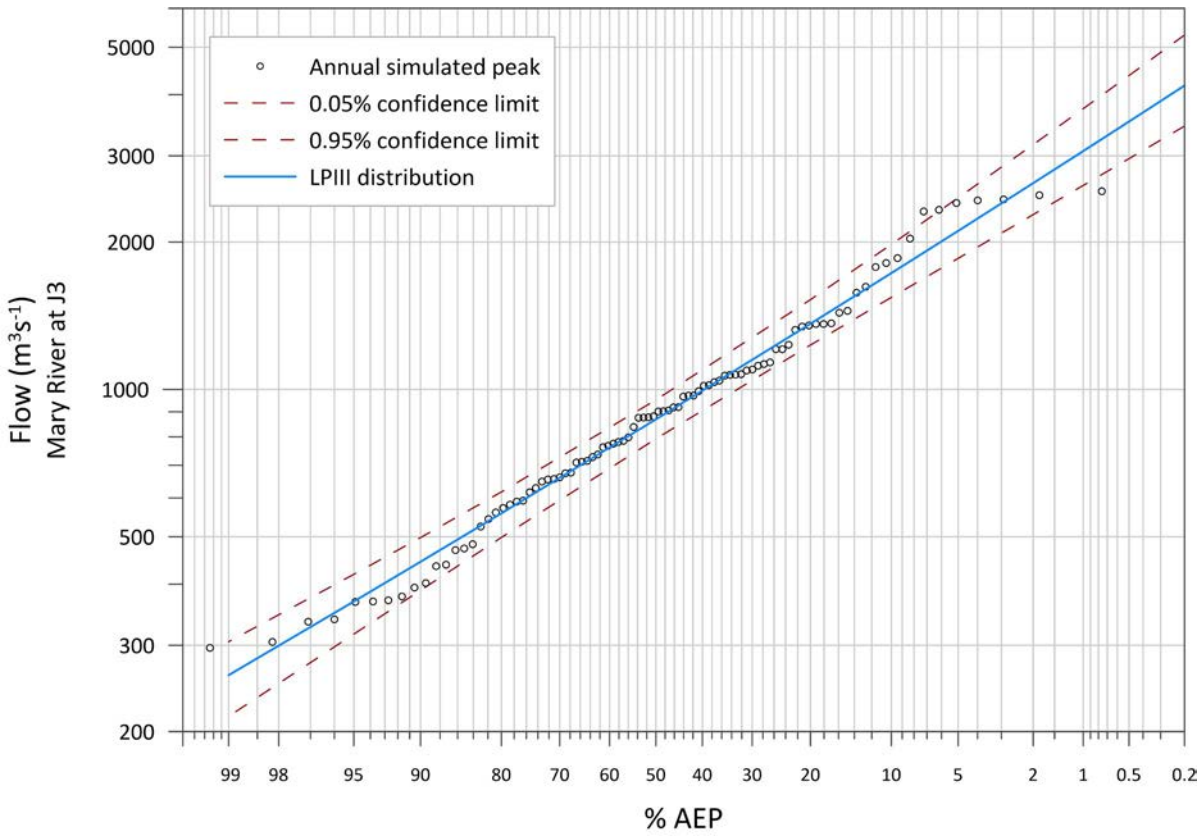


Figure 4-3 The LP3 distribution of annual peak discharges simulated at J3.

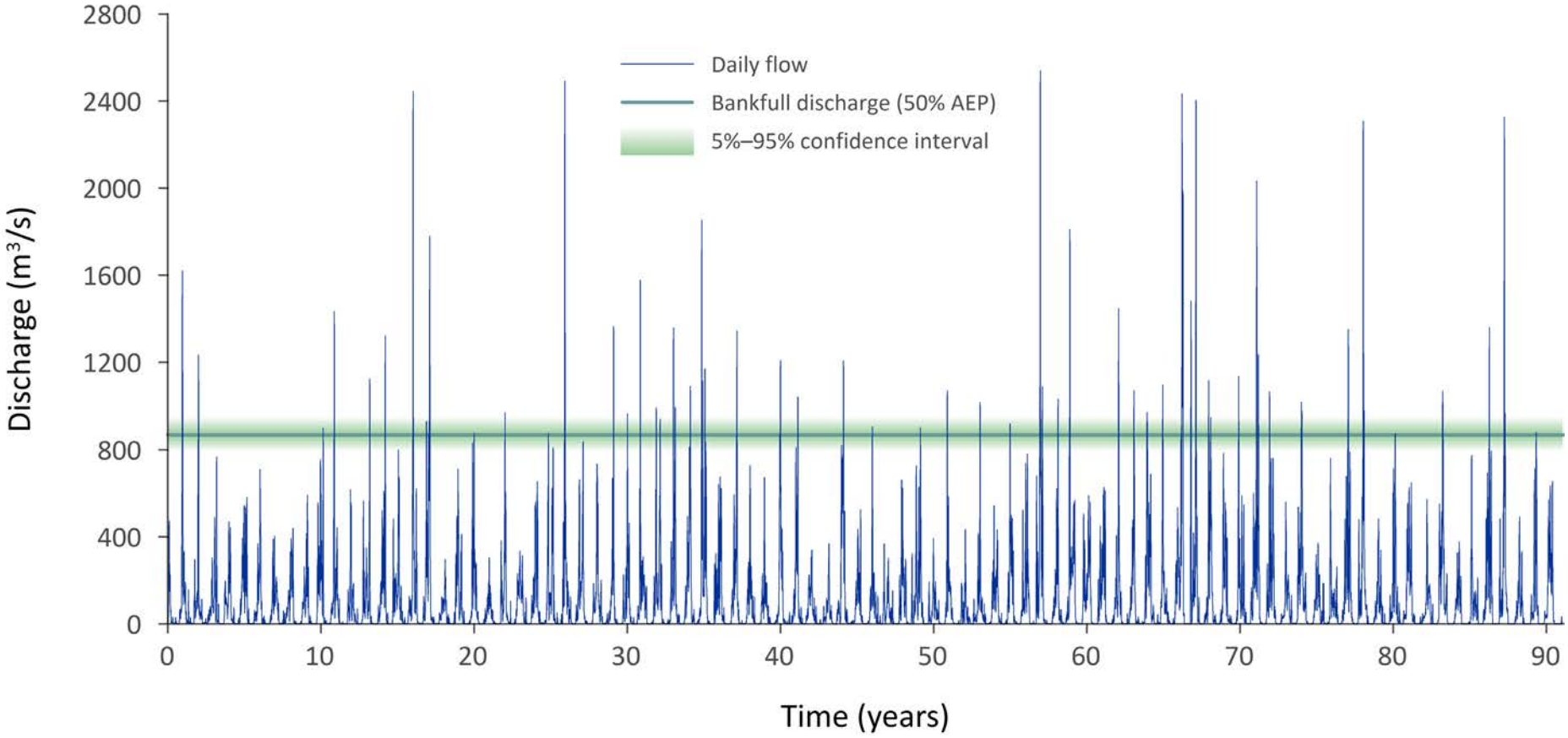


Figure 4-4 Simulated long-term flow at J3 showing the bank full discharge (869 m^3/s).

Table 4-3 Comparison of pre- and post-redevelopment long-term hydrology (2030–2121) in the Lower Mary River

Junction	Pre-redevelopment			Post-redevelopment			Nash-Sutcliffe statistic	Total Discharge Difference (%)
	Peak discharge (m^3/s)	Total discharge (TL)	Average annual discharge (TL)	Peak discharge (m^3/s)	Total discharge (TL)	Average annual discharge (TL)		
McKinlay-Mary River confluence	2527.9	279.3	3.07	2529.1	279.1	3.07	1	-0.04
Mt Bundy-Mary River confluence	2496.3	292.0	3.21	2496.0	292.0	3.21	1	-0.02
Mary River outlet	2584.0	354.0	3.89	2584.0	353.9	3.89	1	-0.01

4.3.2 Groundwater

There are 79 current groundwater bores in the lower Mary River catchment (Appendix F). Of these 49% have a risk class 1 (Figure 3-4), 29% are class 2, 8% are class 3, 10% are class 4, and 4% are undefined. No bores are shown to have a risk of running dry even though 12 bores are in the yield class of 0–1 L/s.

The bores have electric conductivities (EC) ranging from 18 µS/cm in the south to 74000 µS/cm in the estuarine zone in the north. Values of pH range between 3.7–8.3 (Table 4-4, Appendix G).

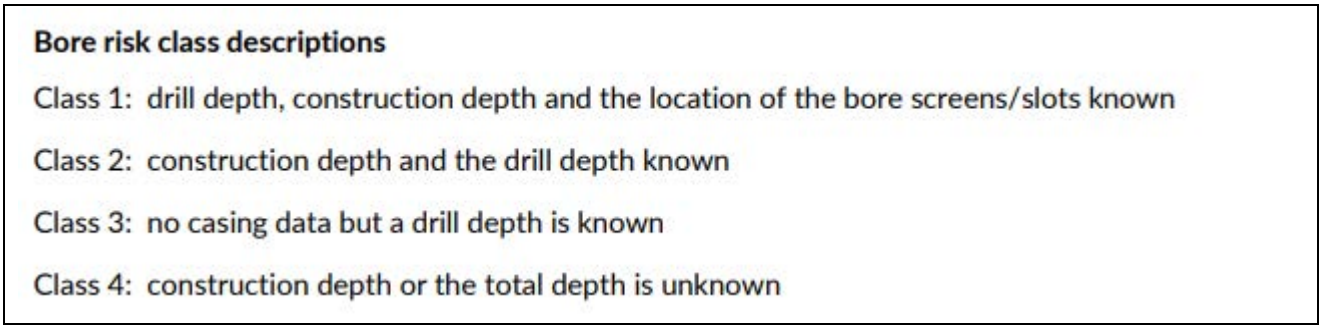


Figure 4-5 Bore risk class descriptions (https://depws.nt.gov.au/__data/assets/pdf_file/0020/705071/bores-with-dry-risk-assessment.pdf)

Beneficial Use

Around the edges of the catchment, away from the floodplain, the declared beneficial uses are environmental, riparian, and agriculture.

Table 4-4 Current average bore water quality (NR Maps 2022)

Bore No.	EC	pH	Total Alkloids	Hardness	TDS	Na	K	Ca	MG	Chloride	HCO_3	SO_4	NO3
RN001611	348	8	173	165	203	8	1	33	20	13	209	6	1
RN005883	29200	6	12	7200	26059	0	0	0	0	12900	7	0	0
RN006561	330	8	176	162	190	4	2	42	10	4	215	2	2
RN007742	162	6	81	81	97	2	1	17	9	4	96	3	2
RN007837	57222	1	14	1325	0	0	0	0	0	3300	17	0	0
RN008126	485	8	255	237	270	3	2	53	31	5	311	8	2
RN020518	45	5	1	3	47	4	1	1	1	9	1	8	1
RN020519	0	7	33	67	0	0	0	0	0	12	40	0	0
RN020520	3570	7	0	758	1710	390	13	90	130	640	694	156	1
RN020521	25400	7	165	3240	0	0	0	0	0	7801	201	0	0
RN020522	30	6	2	1	20	1	1	1	1	7	3	1	1
RN020523	30	5	2	1	20	1	1	1	1	9	3	1	1
RN020524	170	5	1	19	140	16	1	1	4	40	1	1	1
RN020525	1490	5	4	629	1070	48	16	68	112	22	5	700	1
RN020526	2790	8	140	0	1759	258	3	118	67	664	171	90	1
RN021211	390	7	195	195	250	5	2	40	23	10	238	9	1
RN021212	388	7	223	192	200	5	2	38	22	12	223	5	1
RN021213	160	7	48	35	85	10	7	11	1	8	58	9	2
RN021214	45	6	7	4	30	5	1	1	1	6	9	2	1
RN023439	480	8	240	220	300	18	1	42	28	8	293	23	1
RN023440	80	7	17	19	75	6	1	1	4	10	21	9	1
RN023641	130	5	1	34	60	7	2	5	5	36	1	3	1

Bore No.	EC	pH	Total Alkloids	Hardness	TDS	Na	K	Ca	MG	Chloride	HCO_3	SO_4	NO3
RN023917	52	5	16	17	39	3	1	4	2	4	19	1	1
RN024380	90	7	36	29	95	3	9	3	5	6	44	4	1
RN024410	165	8	76	79	120	4	2	11	13	9	92	4	1
RN024599	356	7	168	187	205	4	1	39	22	16	205	5	1
RN024645	4735	7	21	976	2493	574	7	228	100	1468	26	149	1
RN025235	74000	4	1	12500	0	0	0	0	0	30870	1	0	0
RN025649	325	7	167	175	0	0	0	0	0	6	203	0	0
RN025804	12730	4	1	2631	7359	1640	20	521	324	4220	1	337	1
RN025907	70	7	30	27	50	2	1	6	3	3	36	3	1
RN027329	175	7	80	77	110	4	1	19	7	6	98	2	1
RN028360	36800	7	460	4270	23400	7120	116	447	765	13300	561	1040	6
RN028361	26600	8	57	3350	16100	4560	124	411	565	9940	69	51	7
RN028362	23950	7	377	3255	14300	4130	85	272	627	8440	459	127	26
RN028363	23500	8	207	3220	14400	4040	87	417	529	8340	252	162	7
RN028364	2510	8	135	370	1300	326	39	41	64	689	164	33	1
RN028365	52	7	7	7	44	5	2	3	1	9	8	5	4
RN028366	2050	7	35	422	1170	245	5	75	57	446	43	286	1
RN028823	232	7	116	114	138	6	4	31	9	5	141	7	1
RN030082	18	8	6	3	37	2	2	1	1	3	8	3	1
RN030672	284	8	188	182	195	2	1	30	26	5	229	8	1
RN030754	382	7	210	182	220	13	1	40	20	6	256	12	1
RN031348	178	6	87	53	121	14	6	8	8	3	107	6	1

5 WATER QUALITY ISSUES, POLLUTANTS OF CONCERN, WATER QUALITY OBJECTIVES

Water quality in the region has been influenced by previous land uses such as pastoral uses and mining activities with legacy related water quality issues on the project area arising from pit lakes, waste rock dumps, and heap leach pads and ponds. Potential impacts related to these land uses include:

- deterioration of aquatic ecosystem structure and function
- erosion of natural waterways
- increased bioavailability of metals due to pH changes
- toxicity of salinity, sulphate, acid/alkaline solutions, and metals/metalloids.

Activities on the mining area must not adversely affect the Declared Beneficial Uses and Objectives and Sites of Conservation Significance (identified in Section 2.6 above). To ensure this happens, monitoring data are collected and assessed against the site-specific trigger values (SSTV) for surface water leaving the site and ANZG livestock trigger values for groundwater.

5.1 Surface Water

As part of the licence conditions for activities in the mining area, water monitoring at set compliance points around the site are undertaken in accordance with a monitoring schedule. Rules are set for any exceedances of a trigger value. Table 5-1 is a list of the parameters measured as part of a sampling program and the associated SSTV, based on 90% species protection for freshwater ecosystems, compared to ANZG (2018) trigger values for physical and chemical stressors in tropical Australia in slightly disturbed ecosystems, based on 95% species protection for freshwater ecosystems.

Monitoring data collected around the Rustler's Roost, Quest 29, and Tom's Gully mining areas between 2011–2022 indicate that there are some key pollutants of concern. Concentrations of these pollutants regularly exceed the ANZG (2018) trigger values at the monitoring sites. The high concentration of some parameters indicates that influences on water quality are likely to come from a range of sources including storm events, natural geology, previous mining activities, as well as current pastoral land use. The pollutants of concern are similar for both surface water and groundwater.

Table 5-1 ANZG trigger values for parameters measured as part of a sampling program. Pollutants of concern are shaded.

Parameter	SSTV	Trigger value (ANZG (2018))
Physical parameters		
pH	5.8–8	6–8
Electrical conductivity (µS/cm)	41	20–250
Dissolved Oxygen (%sat)		85–120
Turbidity (NTU)	87	15
Metals (µg/L)		
Aluminium	295	55
Arsenic	42	13
Cadmium	0.4	0.2
Chromium	6	1.0

Cobalt		1.4
Copper	1.8	1.4
Iron	2700	300
Lead	5.6	3.4
Manganese	2500	1900
Molybdenum	34	34
Nickel	13	11
Selenium		11
Tin		3
Uranium		0.5
Zinc	15	8
Other (µg/L)		
Chloride		3
Cyanide		7
Nutrients (µg/L)		
Total Nitrogen		200–300
Total Phosphorous		10

Surface water quality modelling was used to assess contaminant dispersion from hypothetical releases from mine pits in the Quest 29, Rustler's Roost, and Tom's Gully mining areas during a high-magnitude rainfall event. The conservative modelling showed that during a 1% annual exceedance probability (AEP) rainfall event, almost all the metal pollutants of concern identified in Table 5-1 have concentrations that exceed the trigger values at key water quality monitoring points along Mt Bundey and Charles creeks (Table 5-2). All these concentrations are likely to be diluted to below the trigger values once flow from these creeks enters the Mary River and reaches the key monitoring site at J3.

Aluminium and Cadmium were identified as the two metal pollutants of greatest concern in this modelling study. Concentrations of these pollutants may still exceed the trigger value in the Mary River during a high-magnitude rainfall event; however, concentrations should be diluted below trigger values within only a few kilometres downstream of entering the Mary River (and well upstream of J3).

The management aim is that points of significance in the lower Mary River flood plain (Figure 5-1) do not exceed water quality guidelines. Water quality at SWQ8 and SWTG3 should be managed in accordance with the WMP (Appendix Q).

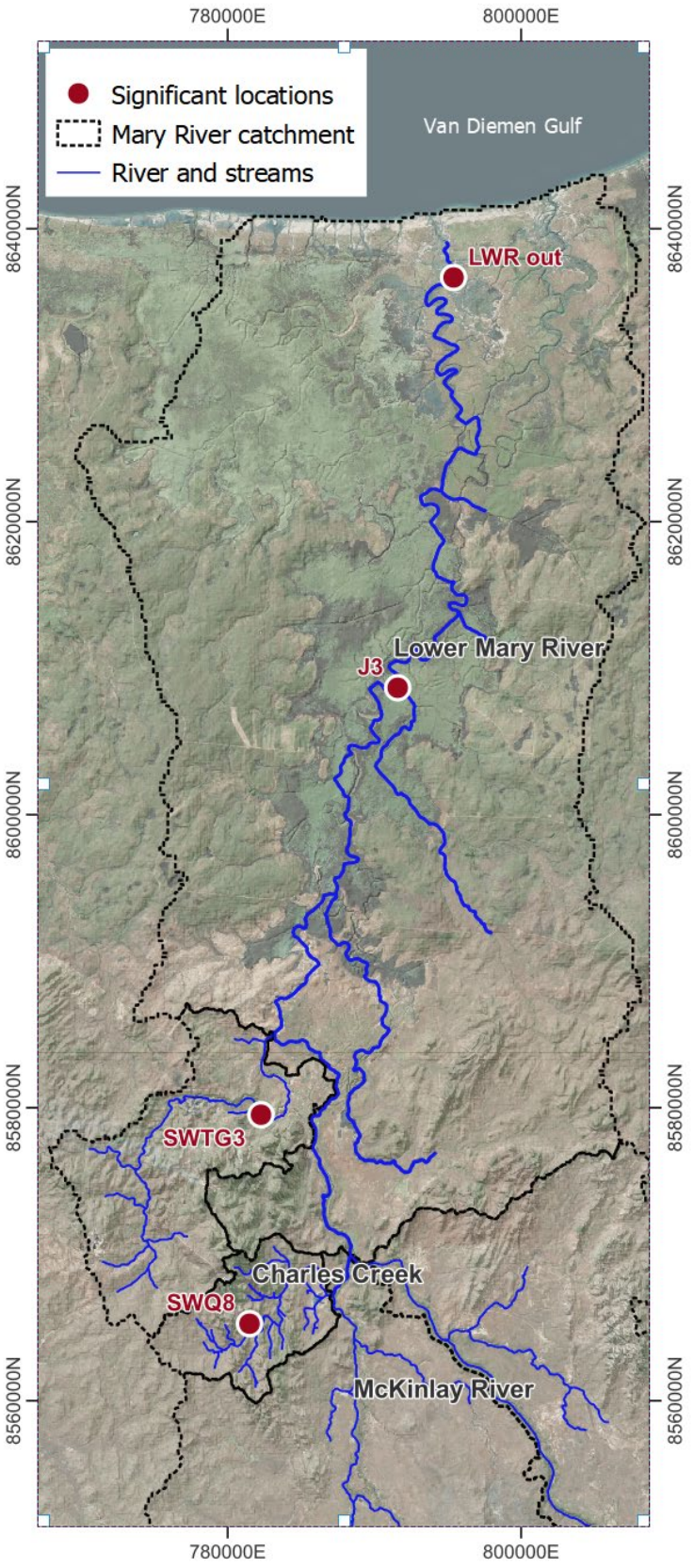


Figure 5-1 Locations of significance for the lower Mary River water quality improvement plan.

Table 5-2 Metal parameters of concern and the estimated peak concentrations at locations of significance during conservative modelling of a 1% AEP rainfall event. Pollutants above the trigger value are shaded.

Parameter	Trigger value (ANZG (2018))	SSTV	Mt Bundey Creek (SWTG3)	Charles Creek (SWQ8)	Mary River (J3)
Aluminium	55	295	160	1175	19
Arsenic	13	42	5	224	0.8
Cadmium	0.2	0.4	0.6	<0.1	<0.1
Chromium	1.0	6	0.5	4.3	<0.1
Copper	1.4	1.8	0.7	7.4	<0.1
Iron	300	2700	470	1560	48
Lead	3.4	5.6	0.6	18	0.1
Nickel	11	13	2	6	<0.1
Zinc	8	15	6	74	0.8

5.2 Groundwater

Most of the surrounding land use comprises pastoral leases used for cattle farming with the likely future land use the continuation of pastoral activities. PGO acknowledges good water quality is essential for successful livestock production with poor water quality likely to reduce animal production and impair fertility. High contaminant loads may produce residues within animal products and adversely affect saleability and/or create human health risks (ANZG 2018). Therefore, as a minimum, the ANZG Stock water trigger values have been adopted to assess groundwater quality.

A summary of groundwater assessment guideline values is provided in Table 5-3.

Table 5-3 Groundwater Assessment Guideline Values

Analytes	Units	ANZG Livestock Trigger Values
pH	pH	6.0–8.0
Electrical Conductivity	µS/cm	3,000
Total Suspended Solids	mg/L	5,000
Sulphate	mg/L	1,000
Calcium	mg/L	1,000
Aluminium	µg/L	5,000
Arsenic (total)	µg/L	500
Cadmium	µg/L	10
Chromium	µg/L	1,000
Cobalt	µg/L	1,000*
Copper	µg/L	1,000
Iron	µg/L	NA
Lead	µg/L	100

Manganese	µg/L	NA
Molybdenum	µg/L	150
Nickel	µg/L	1,000
Uranium	µg/L	200
Zinc	µg/L	20,000

6 RIVER FLOW OBJECTIVES

There are no long-term river flow data available on which to set objectives. Long-term modelling has been completed and flow objectives can be based on those results determined as part of the EIS process. A climate change factor for the RCP 4.5 model was applied and simulations conducted for the pre- and post-redevelopment condition of the project area.

Table 4-3 shows there is only minor difference between pre- and post-development flows in the Mary River.

Currently, the modelling results will be suitable for flow objectives at the Mary River outlet and the mid-reaches. (Figure 6-1, Figure 6-2).

Modelling showed that it is unlikely that the project area will impact river flows.

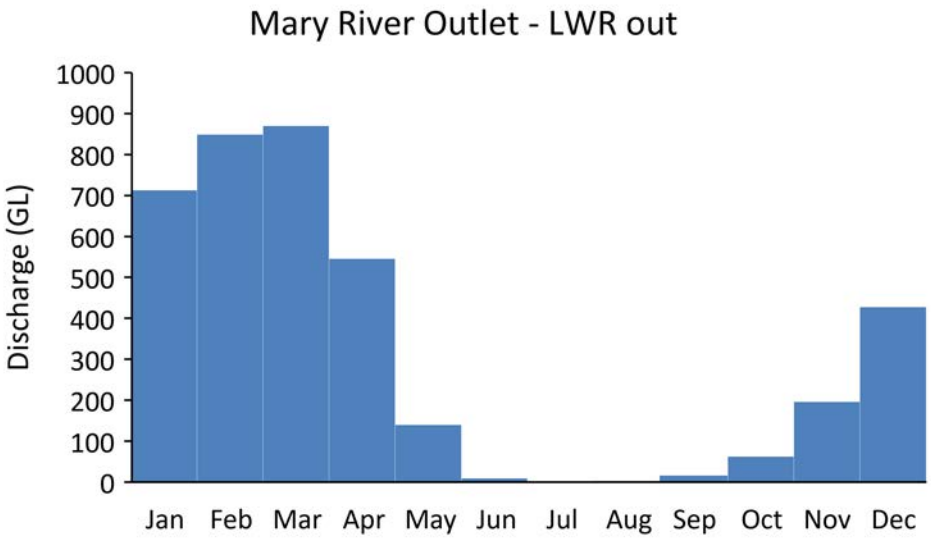


Figure 6-1 Average monthly discharges at the Mary River outlet to van Diemen Gulf based on 91-year simulation with a climate change factor RCP 4.5 applied.

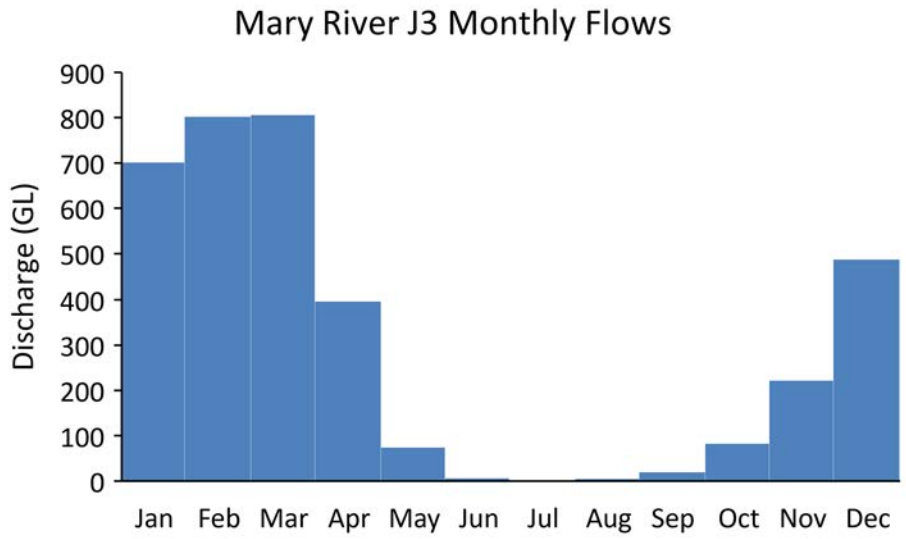


Figure 6-2 Average monthly discharges based on long-term simulation at junction J3 downstream of Mt Bundey Creek confluence (i.e., also reflecting changes in Charles Creek).

7 MONITORING AND REPORTING

A detailed monitoring program for the project area is provided in Appendix Q of the Draft EIS. For this plan it is recommended that one further location be added to the plan for surface water sampling with samples taken at monthly intervals when project area samples are taken using the methods outlined in Appendix Q. The proposed sampling location is J3 in Figure 5-1. The most suitable location should be confirmed by field inspection.

The assessment guidelines are those given in Table 5-1.

A measured water quality value above a trigger value at J3 does not indicate it is poor water quality from the project area, but should the parameter remain elevated, responses in accordance with trigger levels should be implemented.

8 COMMUNITY AND STAKEHOLDER CONSULTATION PROGRAM

The following consultation program establishes the activities to be undertaken and key project milestones. All consultation activities undertaken for the Project are provided in the register located in Appendix A of the Draft EIS.

Table 8-1 Consultation Phases

Stage	Description	Who	Activities	Progress
Pre-EIS Site Investigation and Survey Stage	▪ Initial regulatory engagement to outline the project and confirm necessary inclusions in the assessment; and ▪ Early engagement with pastoral leaseholders regarding proposal.	▪ Pastoral Stations/Lease Owners ▪ Northern Territory Government Agencies	▪ Communication via email, phone etc. ▪ One-on-one meetings	Complete
Draft EIS Development Stage	▪ Activities to improve general stakeholder awareness of the project and avenues for providing input; ▪ Targeted engagement and communications specific to stakeholder groups; ▪ Targeted engagement and communication activities designed to gain specific feedback to inform the Draft EIS.	▪ Pastoral Stations/Lease Owners ▪ Indigenous Stakeholder and Traditional Owners ▪ Northern Territory Government Agencies ▪ Local and Regional Community ▪ Territory and Federal Politicians ▪ Federal Government ▪ Neighbouring Commercial Businesses and Local Operators ▪ Interest group(s) (AFANT)	▪ Communication via email, phone etc. ▪ One-on-one meetings ▪ Technical meetings and briefings ▪ Website (General)	Complete
Post-Draft EIS Stage (Supplement Stage)	▪ Update the Stakeholder Engagement Plan as necessary; and ▪ Undertake additional targeted consultation as necessary to address specific issues raised in comments on the Draft EIS.	▪ Pastoral Stations/Lease Owners ▪ Indigenous Stakeholder and Traditional Owners ▪ Northern Territory Government Agencies ▪ Local and Regional Community ▪ Territory and Federal Politicians ▪ Federal Government ▪ Neighbouring Commercial Businesses and Local Operators ▪ Interest group(s) (AFANT)	▪ Communication via email, phone etc. ▪ One-on-one meetings ▪ Technical meetings and briefings ▪ Website (General)	Pending

Notification of Approval and Conditions	▪ Update the Stakeholder Engagement Plan as necessary; ▪ Undertake activities to inform stakeholders of the approval and conditions; and ▪ Provide information to stakeholders on the next steps and project schedule.	▪ Pastoral Stations/Lease Owners ▪ Indigenous Stakeholder and Traditional Owners ▪ Northern Territory Government Agencies ▪ Local and Regional Community ▪ Territory and Federal Politicians ▪ Federal Government ▪ Neighbouring Commercial Businesses and Local Operators ▪ Interest group(s) (AFANT) ▪ Local and Regional Supplier and Business Organisations ▪ Public	▪ Communication via email, phone etc. ▪ Website (General)	Pending
Construction Stage	▪ Update the Stakeholder Engagement Plan as necessary; and ▪ Early notification to key potentially affected stakeholders (e.g., local community) of project construction commencement and actions being implemented to manage risks; and ▪ Undertake stakeholder and community engagement as required to satisfy approval conditions and achieve compliance with statutory obligations for construction. ▪ Provide general awareness of the avenues for stakeholder complaints.	▪ Pastoral Stations/Lease Owners ▪ Indigenous Stakeholder and Traditional Owners ▪ Northern Territory Government Agencies ▪ Local and Regional Community	▪ Communication via email, phone etc. ▪ One-on-one meetings ▪ Website (General)	Pending
Operational Stage	▪ Update the Stakeholder Engagement Plan as necessary; and ▪ Undertake stakeholder and community engagement as required to satisfy approval conditions and achieve compliance with statutory obligations for the operation; ▪ Undertake activities to maintain community and stakeholder awareness regarding avenues for project information and complaints.	▪ Pastoral Stations/Lease Owners ▪ Indigenous Stakeholder and Traditional Owners ▪ Northern Territory Government Agencies ▪ Local and Regional Community	▪ Communication via email, phone etc. ▪ One-on-one meetings Website (General)	Pending
Decommissioning	▪ Update the Stakeholder Engagement Plan as necessary; and	▪ Pastoral Stations/Lease Owners ▪ Indigenous Stakeholder and Traditional Owners	▪ Communication via email, phone etc. ▪ One-on-one meetings	Pending

	▪ Notification of closure of the facility to relevant stakeholders; ▪ Inform local and regional community of ongoing site management following closure.	▪ Northern Territory Government Agencies ▪ Local and Regional Community	▪ Website (General)	

9 REVISIONS

The WQIP should include an adaptive management strategy for the life of the WQIP with regular and predictable reviews of management practices and control actions based on:

- additional information obtained from monitoring, including improved understanding of the effectiveness of different management actions;
- improvements in predictive modelling capacity;
- revised water quality objectives, load targets, or environmental flow objectives and regimes resulting from monitoring; and
- concerns raised during community consultation.

Initially, the WQIP should be reviewed and updated triennially.

10 REFERENCES

Anonymous. (1998). *Integrated catchment management plan: Mary River Northern Territory.* Darwin: Northern Territory Government.

Ball, J., Babister, M., Nathan, R., Weeks, W., Weinmann, E., Retallick, M., & Testoni, I. (2019). *Australian Rainfall and Runoff: A Guide to Flood Estimation.* Commonwealth of Australia (Geoscience Australia).

Bayliss, P., Kennard, M., Bartolo, R., & Close, P. (2011). *An assesment of risks to aquatic ecosystems in morthern Australia from development and sea level rise threats. Final report NAWFA - Chapter 4.* Brisbane: CSIRO Marine & Atmoshperic Research.

Beggs, K. E. (2010). *Effects of pasture grasses on biodiversity of the Mary River Catchment, Northern Territory.* PhD Thesis. Charle Darwin University.

Coombes, P., & Roso, S. (2019). *Rainfall Estimation, Book 2 in Australian Rainfall and Runoff - A Guide to Flood Estimation.* Commonwealth of Australia (Geoscience Australia).

de Groot, R., Finlayson, M., Verschuuren, B., Ypma, O., & Zylstra, M. (2008). *Integrated assessment of wetland services and values as a tool to analyse policy trade-offs and management options: A case study in the Daly and Mary River catchments, northern Australia.* (Vol. Supervising Scientist Report 198). Darwin, NT: Supervising Scientist.

Department of the Environment, Water Heritage and the Arts. (2007). *Characterisation of the marine environment of the north marine region. Ouctomes of an expert workshop. Darwin, Northern Territory, 2-3 April 2007.* Darwin: Australia Government.

Jeffery, S. J., Carter, J. O., Moodie, K. B., & Beswick, A. R. (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling and Software*, 309-330. doi:10.1016/S1364-8152(01)00008-1

Kroon, F. J. (2008). *Draft Tully Water Quality Improvement Plan.* CSIRO: Water for a Healthy Country National Research Flagship.

Manning, R. (1891). On the flow of water in open channels and pipes. *Transactions of the Institution of Civil Engineers of Ireland, 20*, 161-207.

Mary River Catchment Advisory Committee. (2001). *Revised integrated catchment management plan: Mary River.* Darwin: Department of Lands Planning and Environment,.

Moliere, D. R., Saynor, M. J., & Evans, K. G. (2005). Suspended sediment concentrtion-turbidity relationships for Ngarradj - season stream in the wet-dry tropics. *Australian Journal of Water Resources, 9*(1), 37-48.

Northen Territory Government. (2022). *NR Maps*. Retrieved from https://nrmaps.nt.gov.au/

Surface Water & Erosion Solutions. (2019). *Appendix 2 & 3: Supplementary Information, Tom's Gully Underground Project Closure Plan. Inland water environmental quality: Potential release of mine-affected water after closure.* Retrieved from https://ntepa.nt.gov.au/__data/assets/pdf_file/0003/797016/further_info_toms_gully_underground_project.PDF

Surface Water & Erosion Solutions. (2021b). *Quest 29 Open-Cut Mine Redevelopment. Catchment Hydrology and Flood Risk.* Perth: Primary Gold.

Surface Water and Erosion Solutions. (2021a). *Rustler's Roost Open-Cut Mine Redevelopment. Catchment Hydrology & Flood Risk Assessment.* Perth: Primary Gold.

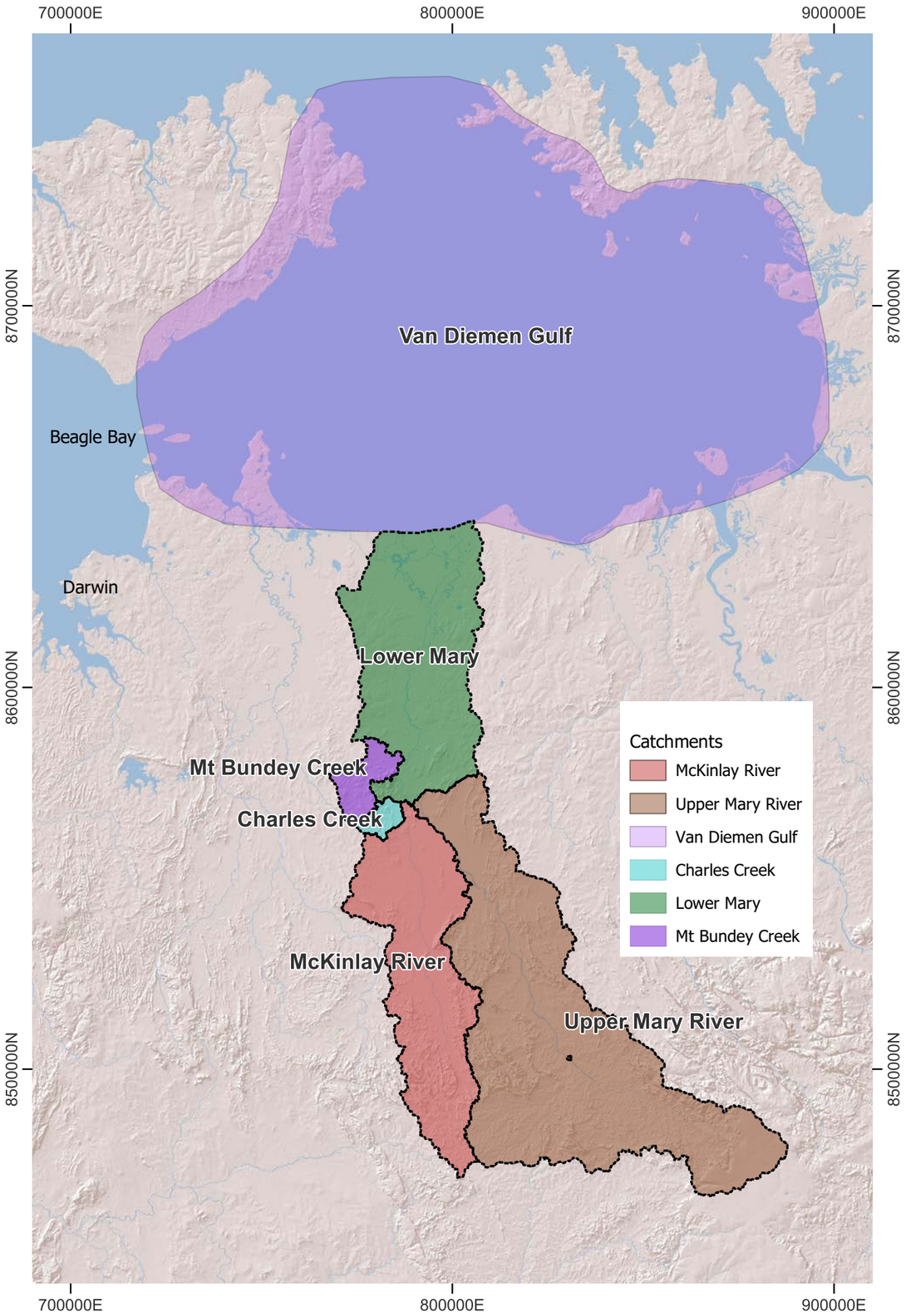
SWES. (2022). *Assessment of broader catchment surface water impacts of redevelopment of the Rustler's Roost mine and the Quest 29 mining precinct.* Darwin: Surface Water & Erosion Solutions.

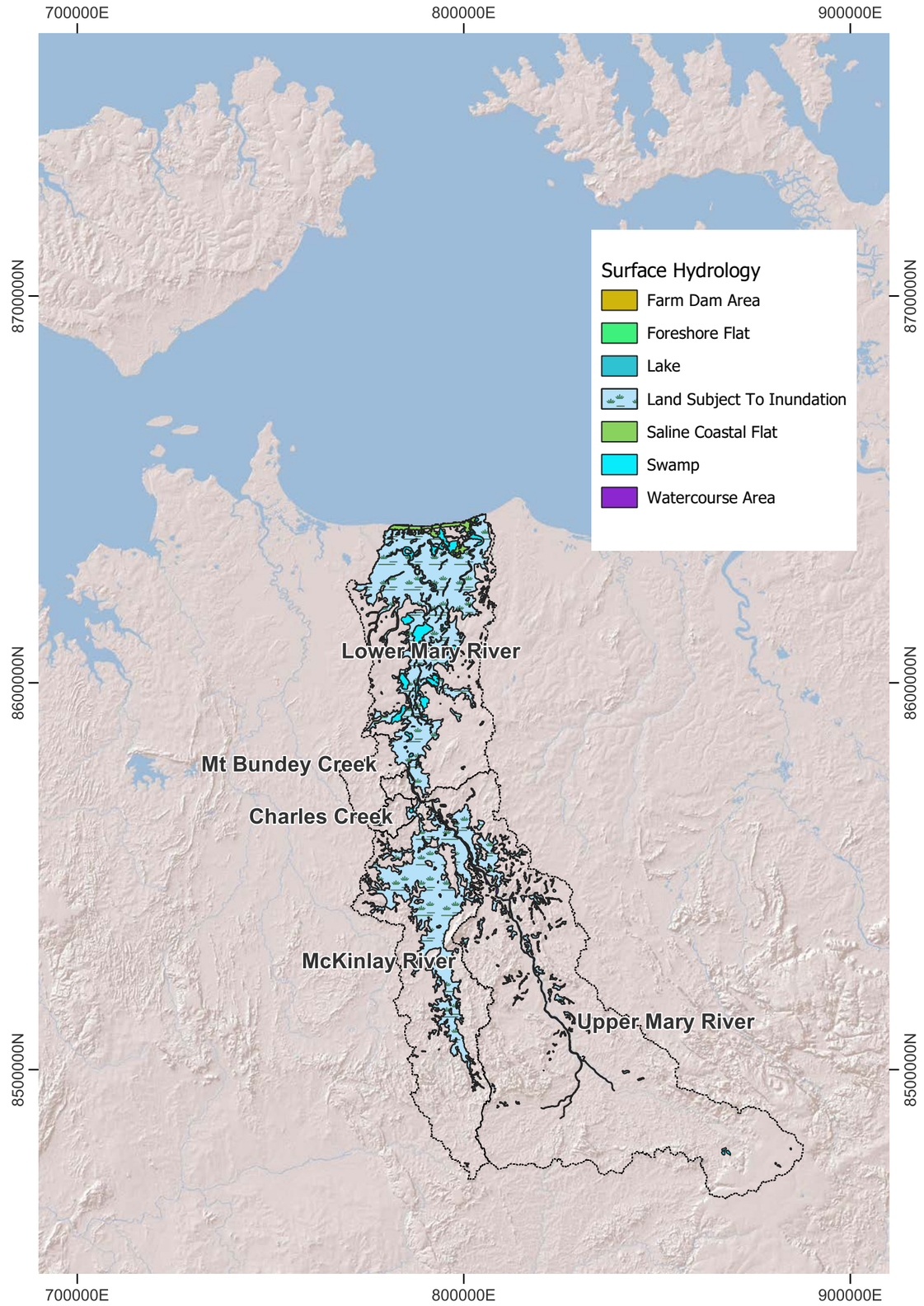
Teng, H., Viscara Rossel, R. A., Shi, Z., Behrens, T., Chappell, A., & Bui, E. (2016). Assimilating satellite imagery and visible–near infrared spectroscopy to model and map soil loss by water erosion in Australia. *Environmental Modelling & Software, 77*, 156-167.

Wasson, R. J., Saynor, M. J., & Lowry, J. (2021). The natural denudation rate of the lowlands near the Ranger mine, Australia: A target for mine site rehabilitation. *Geomorphology*.

11 APPENDICES

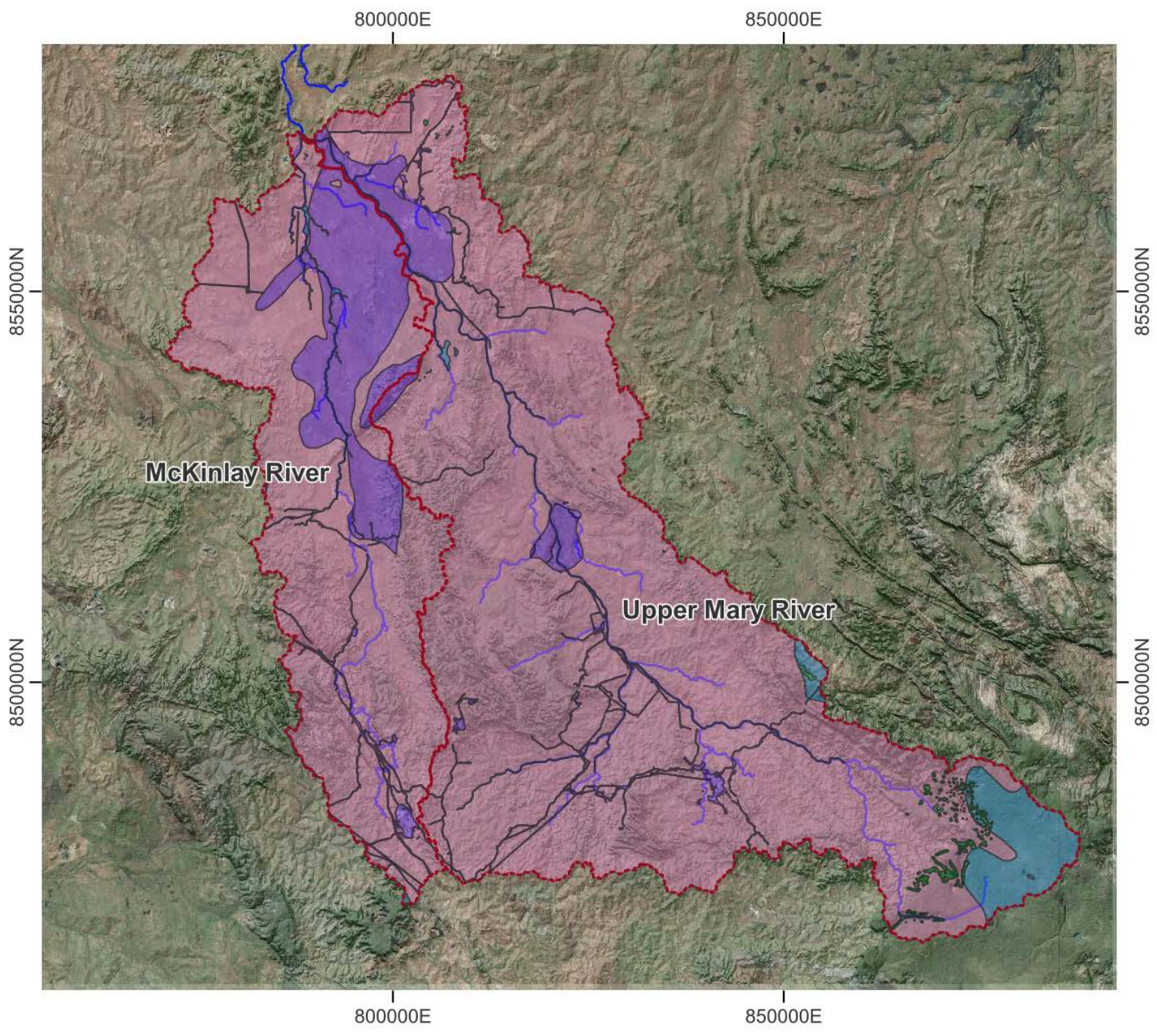
Appendix A Catchments of the Mary River and Water Types

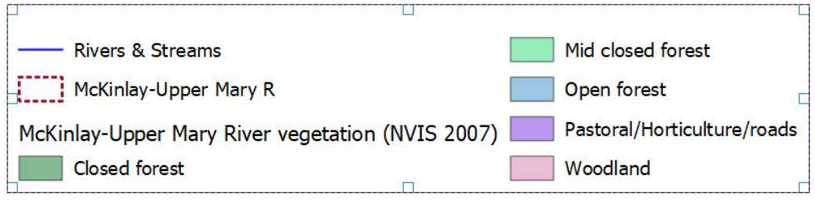




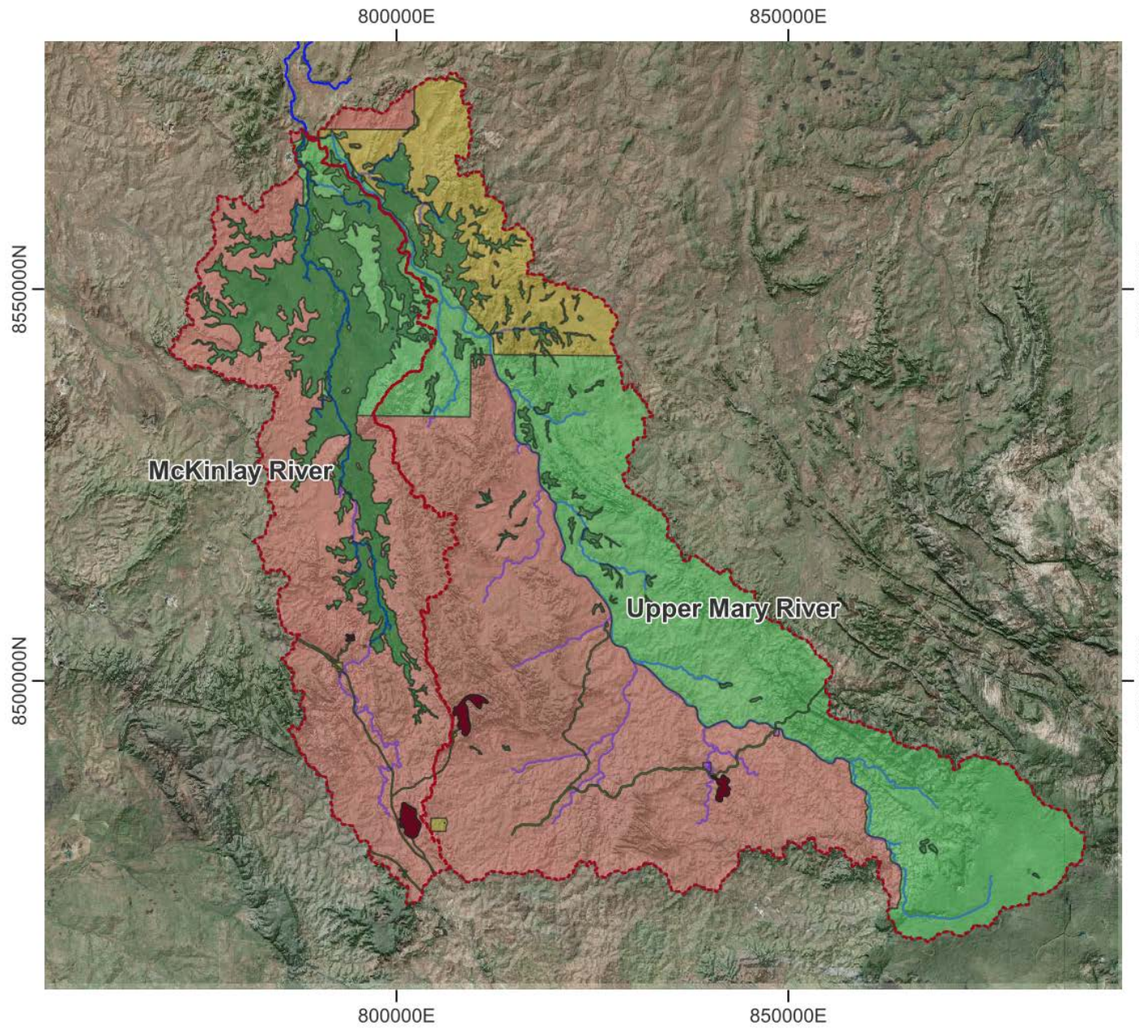
Appendix A	SURFACE WATER & EROSION SOLUTIONS	PRIMARY GOLD	Project: Lower Mary River Water Qaulity	Title: Catchments of the Mary River and Water types.	Designed: KGE; Drawn: KGE; Checked: DRM; Sheet size: A3; Date: 19/8/2022; Sheet No. 1; Sheet of 10

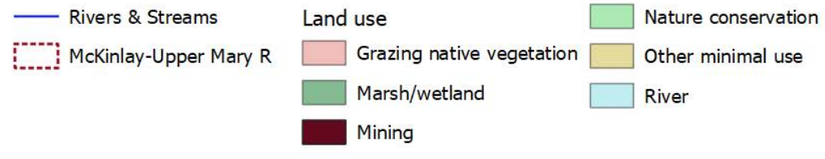
Appendix B Vegetation and land use of the upper Mary River





Above: McKinlay-Upper Mary River vegetation (NVIS 2007).

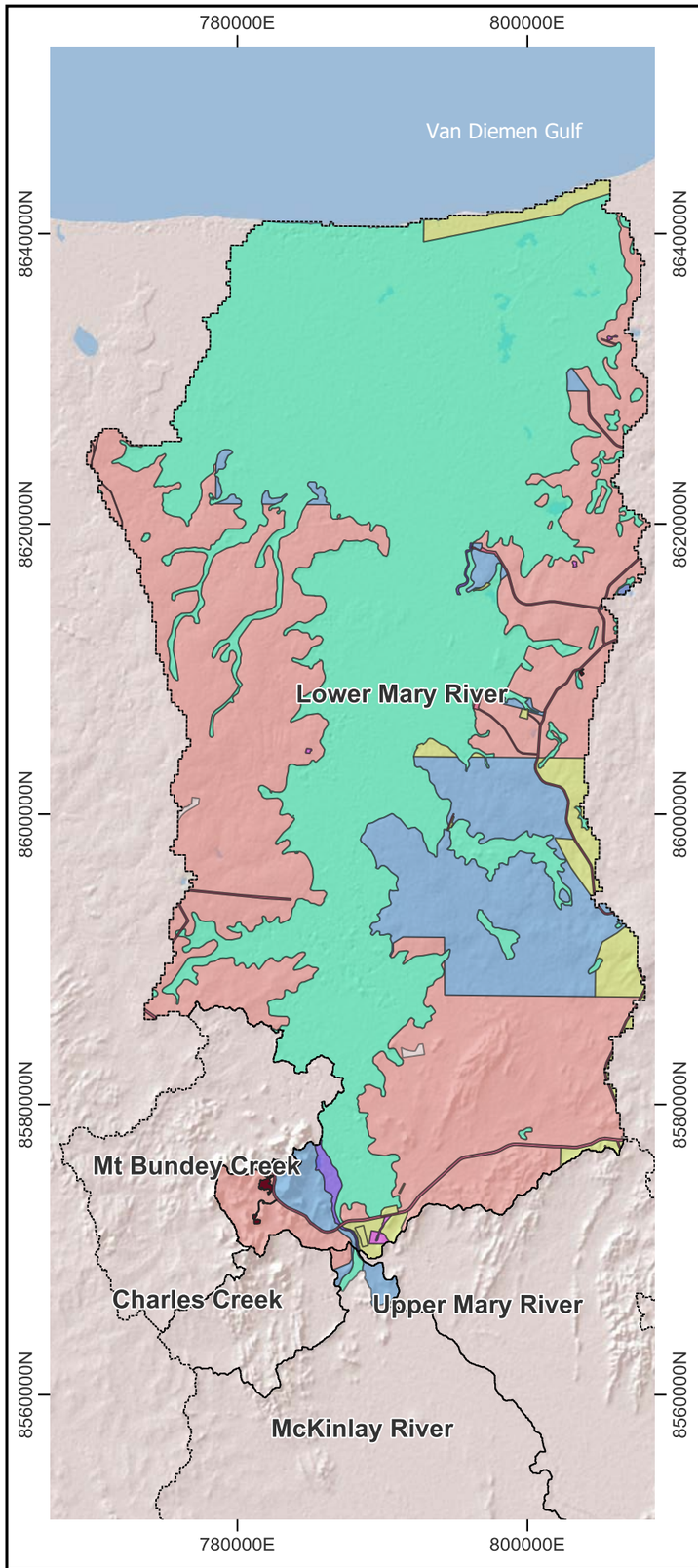




Above: McKinlay-Upper Mary River land use (NR Maps 2022).

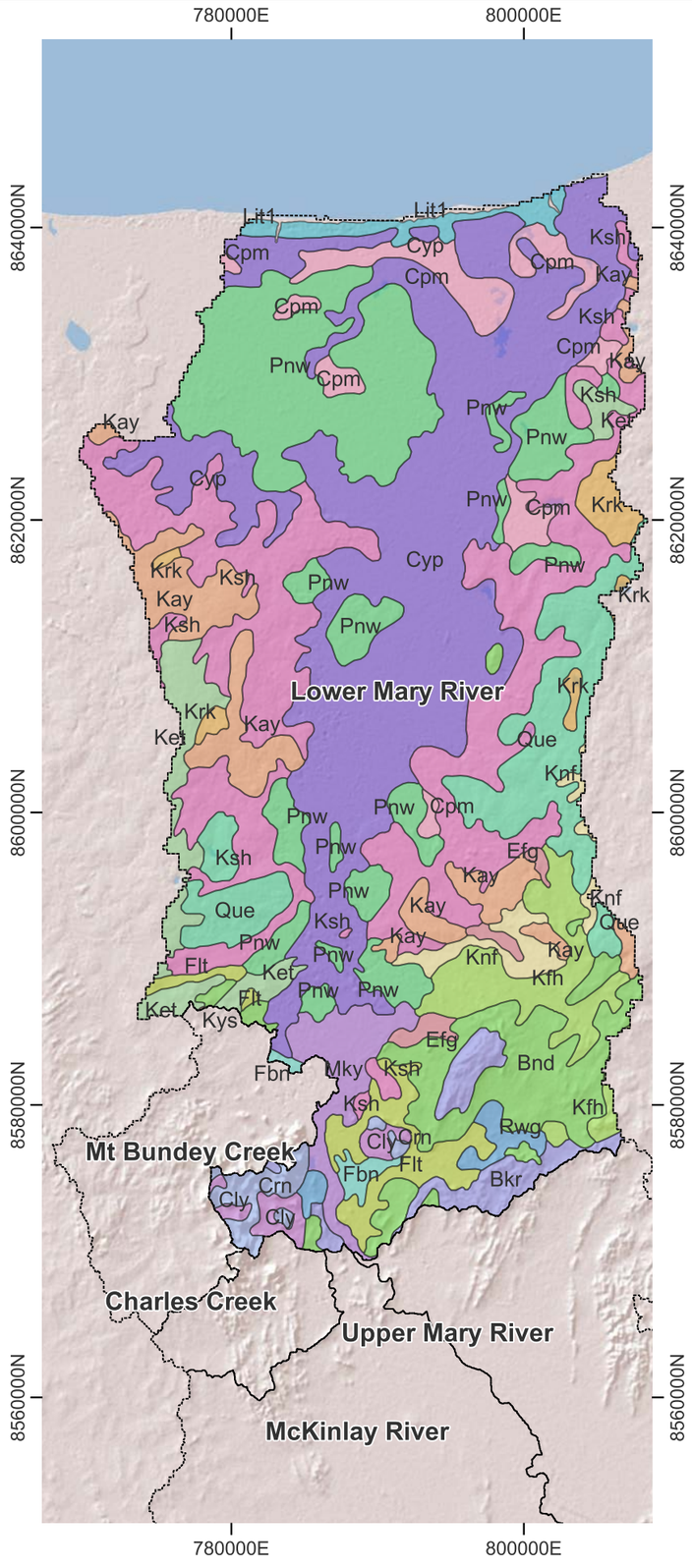
Appendix B	SURFACE WATER & EROSION SOLUTIONS	PRIMARY GOLD	Project: Lower Mary River Water Quality	Title: Vegetation and land use of the upper Mary River	Designed: KGE	Drawn: KGE	Checked: DRM / Sheet size: A3
					Date: 19/8/2022		Sheet No.: Sheet of

Appendix C Land use and Land Systems of the Lower Mary River



Land Use

- Cropping
- Grazing modified pastures
- Grazing native vegetation
- Irrigated perennial horticulture
- Land in transition
- Estuarine/coastal waters
- Mining
- Nature conservation
- Reservoir/dam
- Residential and farm infrastructure
- Receation and culture
- Transport and communication
- Utilities

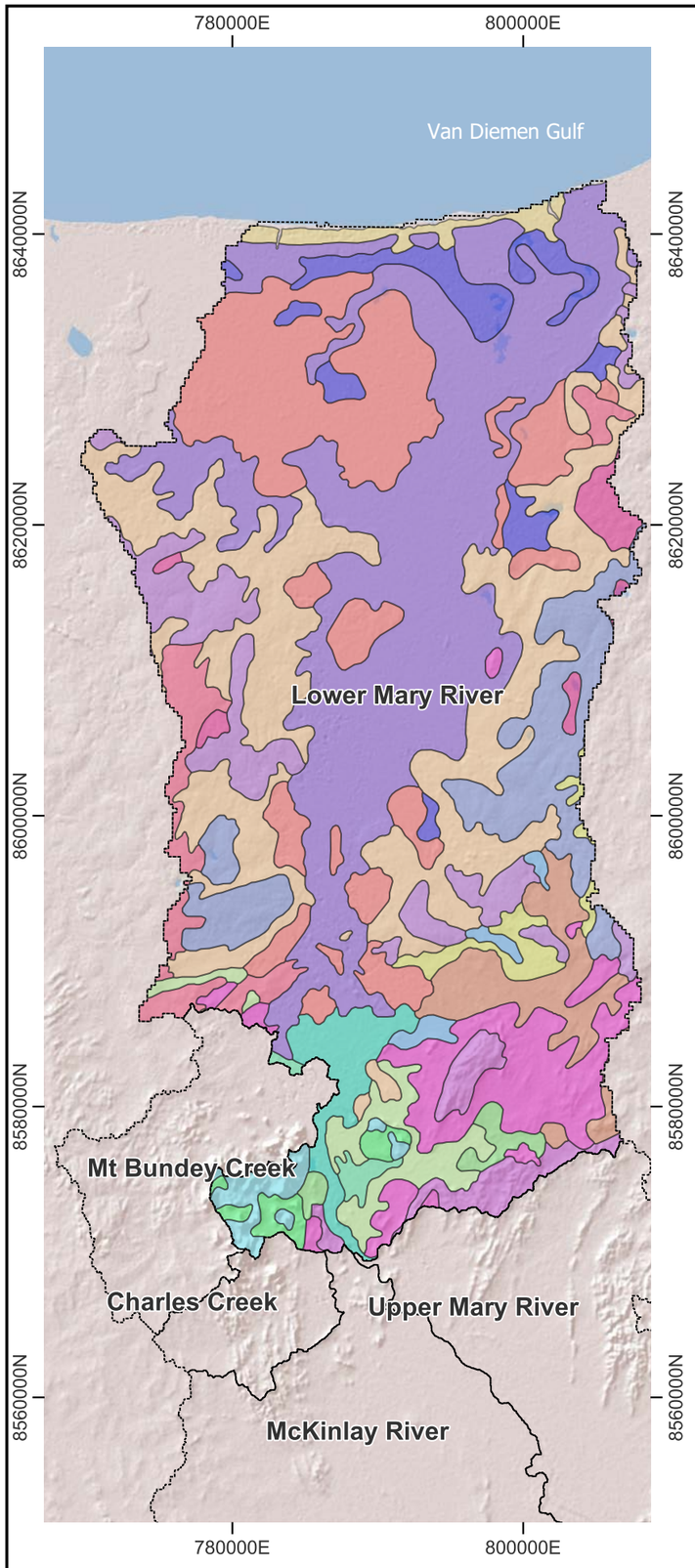


Land Systems

- Baker
- Bend
- Copeman
- Cully
- Currency
- Cyperus
- Effington
- Fabian
- Flatwood
- Kay
- Keating
- Keefers Hut
- Knifehandle
- Kosher
- Krokane
- Kysto
- Littoral 1
- McKinlay
- Pinwinkle
- Queue
- Rumwaggon

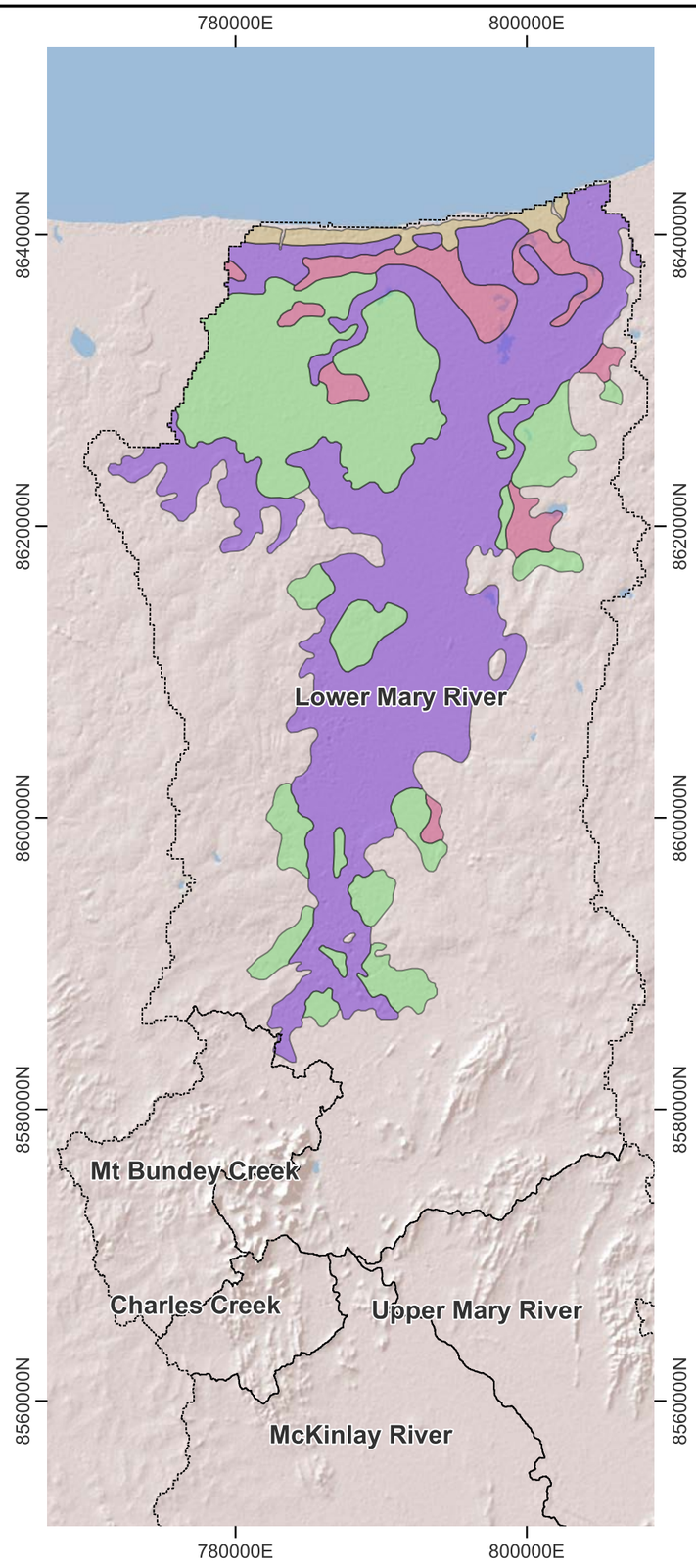
Appendix C	SURFACE WATER & EROSION SOLUTIONS	PRIMARY GOLD	Project: Lower Mary River Water Quality	Title: Land use and Land Systems of the Lower Mary River	Designed: KGE; Drawn: KGE; Checked: DRM; Sheet size: A3; Date: 19/8/2022; Sheet No.: Sheet of

Appendix D Soil associations and Acid Sulphate Soil Risk Areas



Lower Mary River Soil Associations

- Aquic Vertosols over gleyed muds
- Aquic Vertosols over mainly calcic estuarine muds
- Aquic Vertosols overlying marine alluvium
- Brown and Yellow Kandosols, some Orthic Tenosols
- Chromosolic and Kandosolic Redoxic Hydrosols
- Ferric Red, Brown and Yellow Kandosols
- Kandosolic and Chromosolic Hydrosols
- Kandosolic, Chromosolic and Tenosolic Redoxic Hydrosols
- Kandosolic, Tenosolic and Chromosolic Redoxic Hydrosols
- Leptic Rudosols on rises, Chromosolic Redoxic Hydrosols on alluvial areas
- Leptic Rudosols, shallow Yellow and Brown Kandosols
- Leptic Rudosols, some shallow Red, Yellow and Brown Kandosols
- Orthic and Leptic Tenosols and Leptic Rudosols
- Orthic Tenosols and Yellow Kandosols
- Red and Yellow Kandosols, Orthic Tenosols
- Red-Orthic Tenosols
- Redoxic Hydrosols in drainage areas, Red and Yellow Kandosols and Orthic Tenosols on upland areas
- Shallow Yellow and Brown Kandosols and Leptic Rudosols
- Supratidal and Intertidal Hydrosols
- Yellow and Brown Kandosols



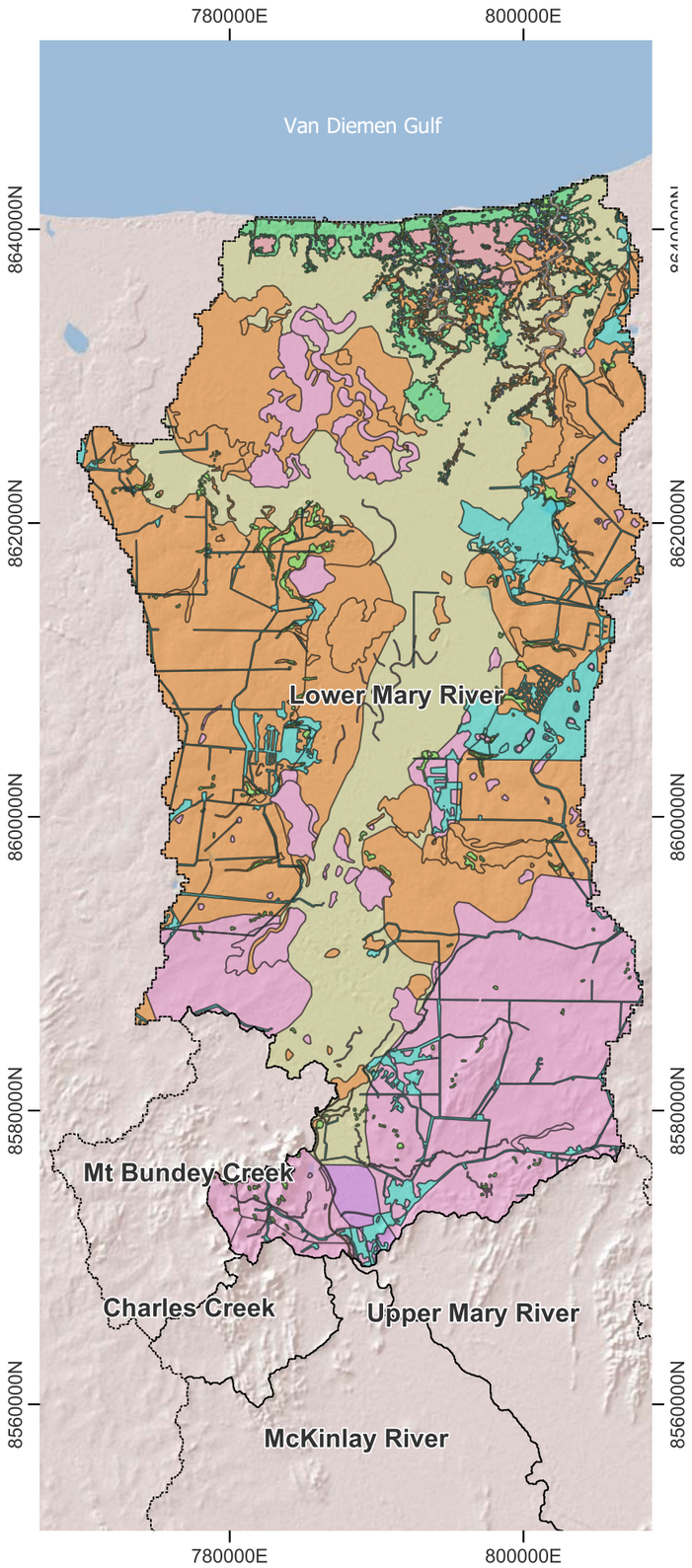
Areas of acid sulphate soil risk

- Black cracking clays over gleyed muds
- Black cracking clays over mainly calcic estuarine muds
- Black cracking clays overlying marine alluvium
- Saline muds and grey cracking clays

Appendix D	SURFACE WATER & EROSION SOLUTIONS	PRIMARY GOLD	Project: Lower Mary River Water Quality Improvement Plan	Title: Soil associations and Acid Sulphate Soil Risk Areas

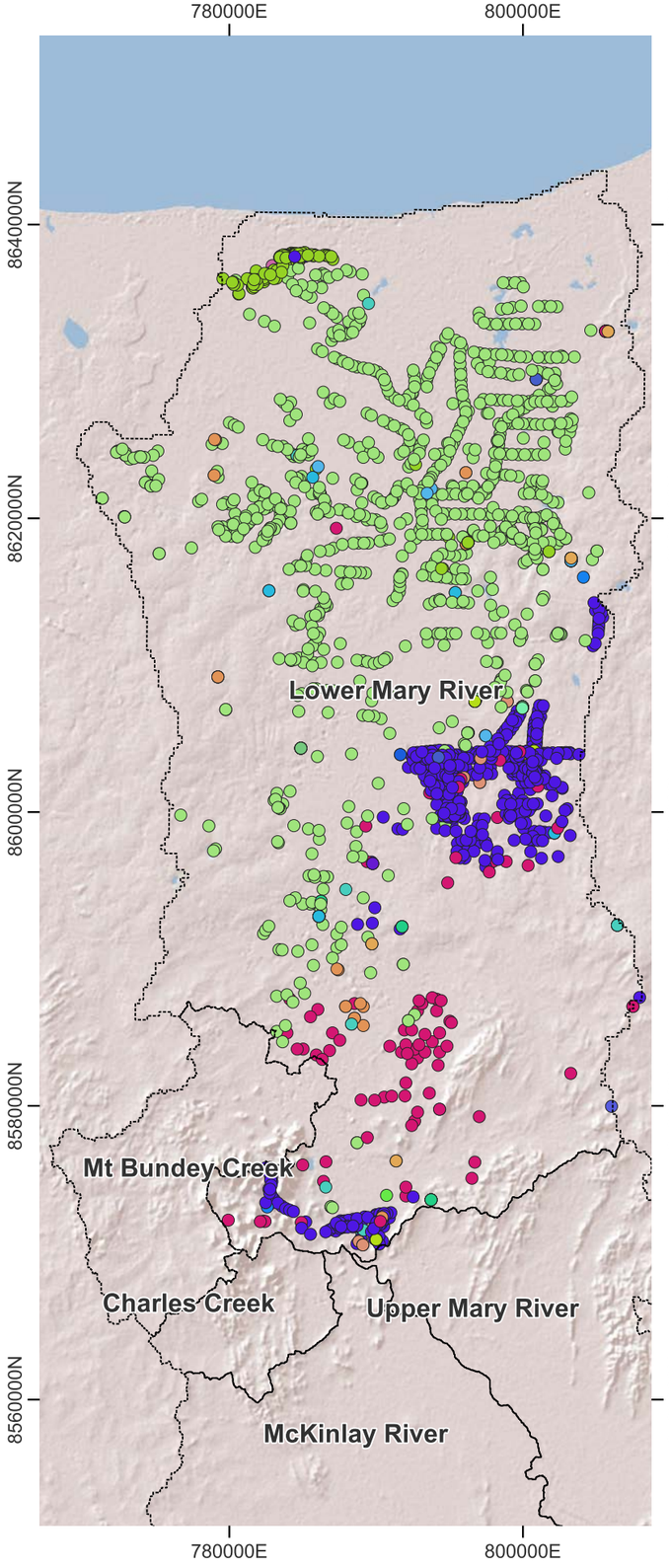
Designed	Drawn	Checked	Sheet size
KGE	KGE	DRM	A3
Date		Sheet No.	
19/8/2022		Sheet of	

Appendix E Vegetation and weeds distribution



NVIS 2007 lower Mary River

- Closed forest
- Closed tussock grassland
- Mid closed forest
- Open forest
- Open woodland
- Pastoral/Horticulture/roads
- Sparse samphire shrubland
- Tussock grassland
- Woodland



Lower Mary River Weed Distribution

- African mahogany
- Barnyard grass - colona
- Billy goat weed
- Calopo
- Cavalcade
- Centro
- Coffee bush
- Couch grass
- Crab grass - bicornis
- Crab grass - Summer grass
- Crab grass - violascens
- Crotalaria - Gambia pea
- Gamba grass
- Golden rain tree
- Hyptis
- Mimosa
- Mission grass - annual
- Morning glory - triloba
- Neem
- Olive hymenachne
- Poinciana
- Rats tail grass sp
- Red natal grass
- Senna - Coffee
- Senna - Sicklepod
- Senna - tora
- Sesame
- Sida - Flannel weed
- Sida - Paddys lucerne
- Sida - Spiny head
- Snake weed - cayennensis
- Stylo - caribbean
- Stylo - townsville
- Stylo shrubby - scabra
- Stylo shrubby - viscosa
- Urochloa - Para grass
- Urochloa - Tully grass
- Wynn cassia

Appendix F

SURFACE WATER & EROSION SOLUTIONS

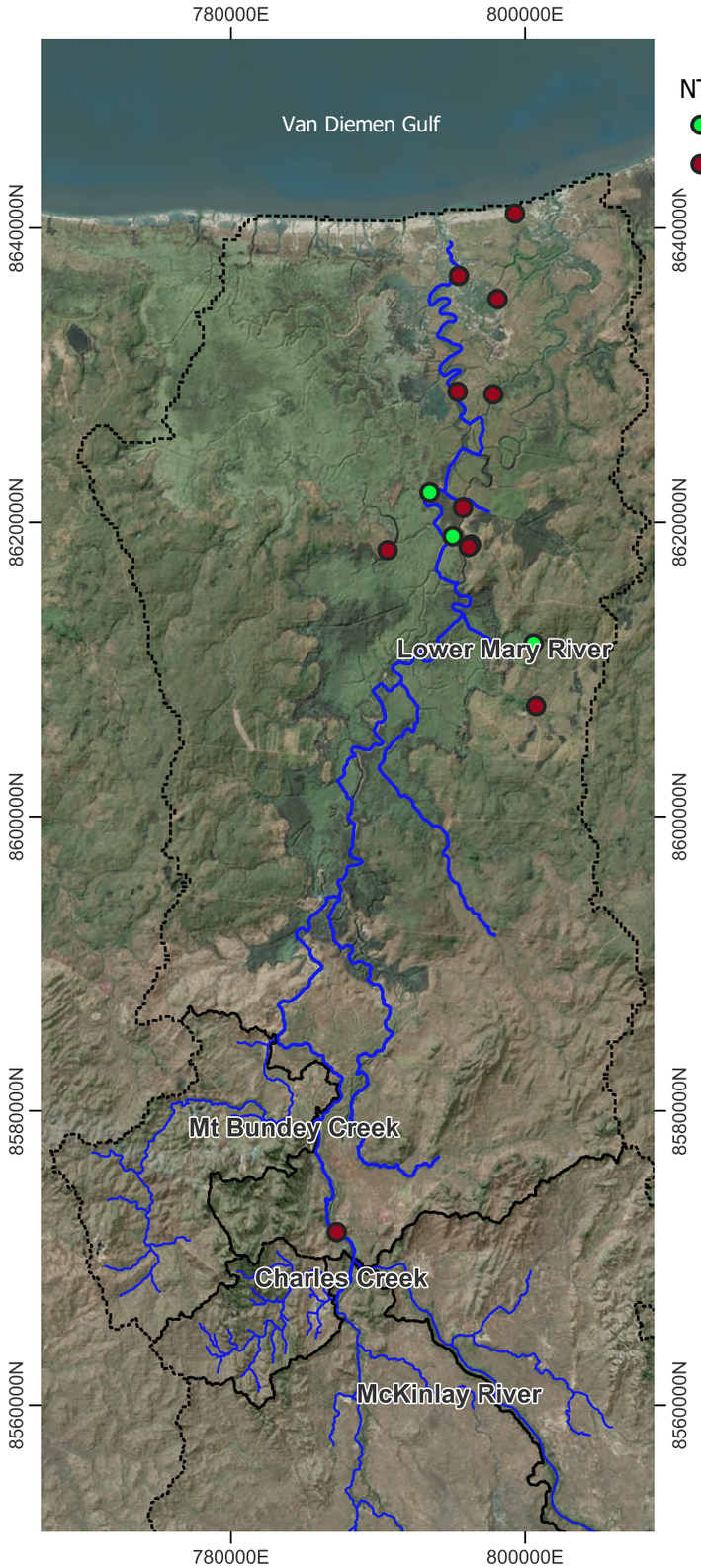
PRIMARY GOLD

Project: Lower Mary River Water Quality Improvement Plan

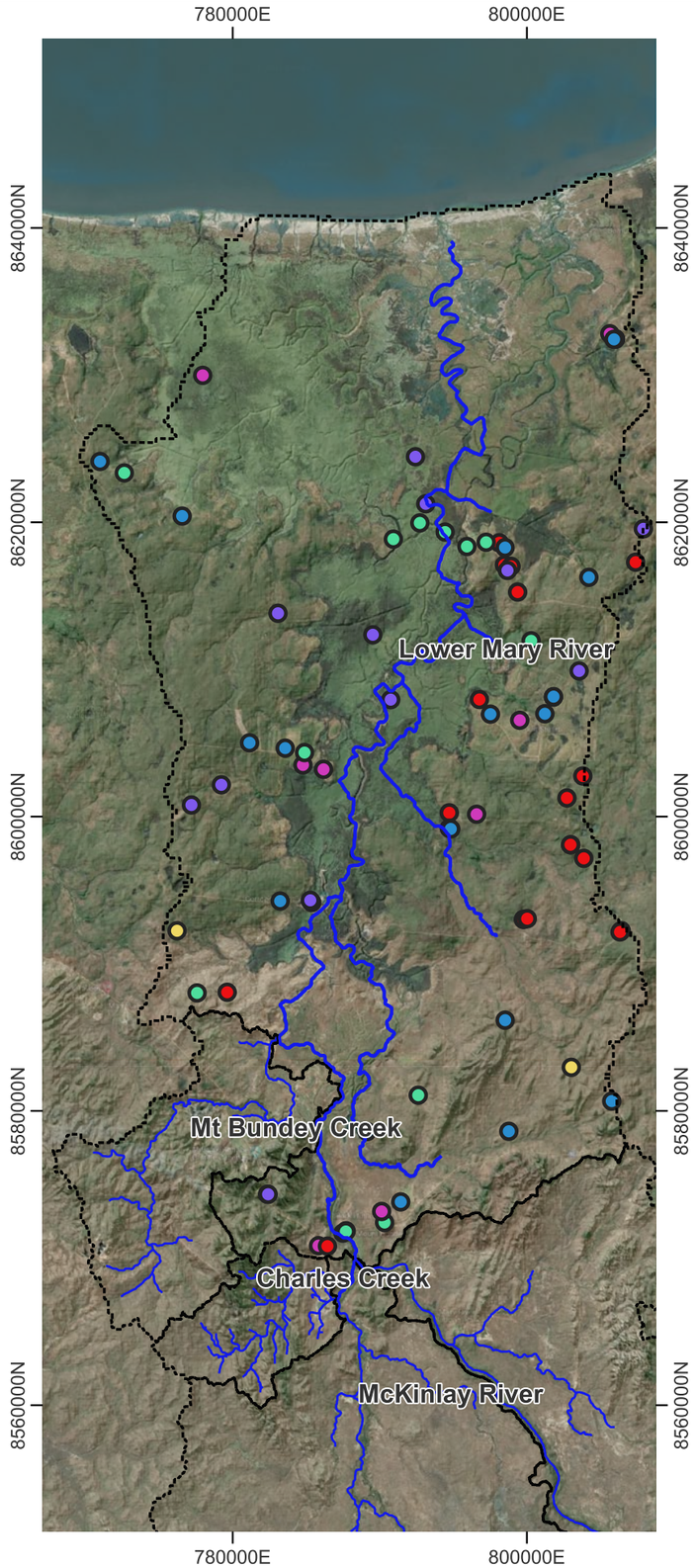
Title: Vegetation and weeds distribution

Designed	Drawn	Checked	Sheet size
KGE	KGE	DRM	A3
Date		Sheet No.	
19/8/2022		Sheet of	

Appendix F NTG River Flow Gauges and Current Bores



NTG river gauges in the LMR
- Active
- In Active



LMR current bores yield class
- >0.0 - 1.0 L/s
- >1.0 - 2.0 L/s
- >2.0 - 5.0 L/s
- >5.0 - 10.0 L/s
- >10 L/s

Appendix F

SURFACE WATER & EROSION SOLUTIONS

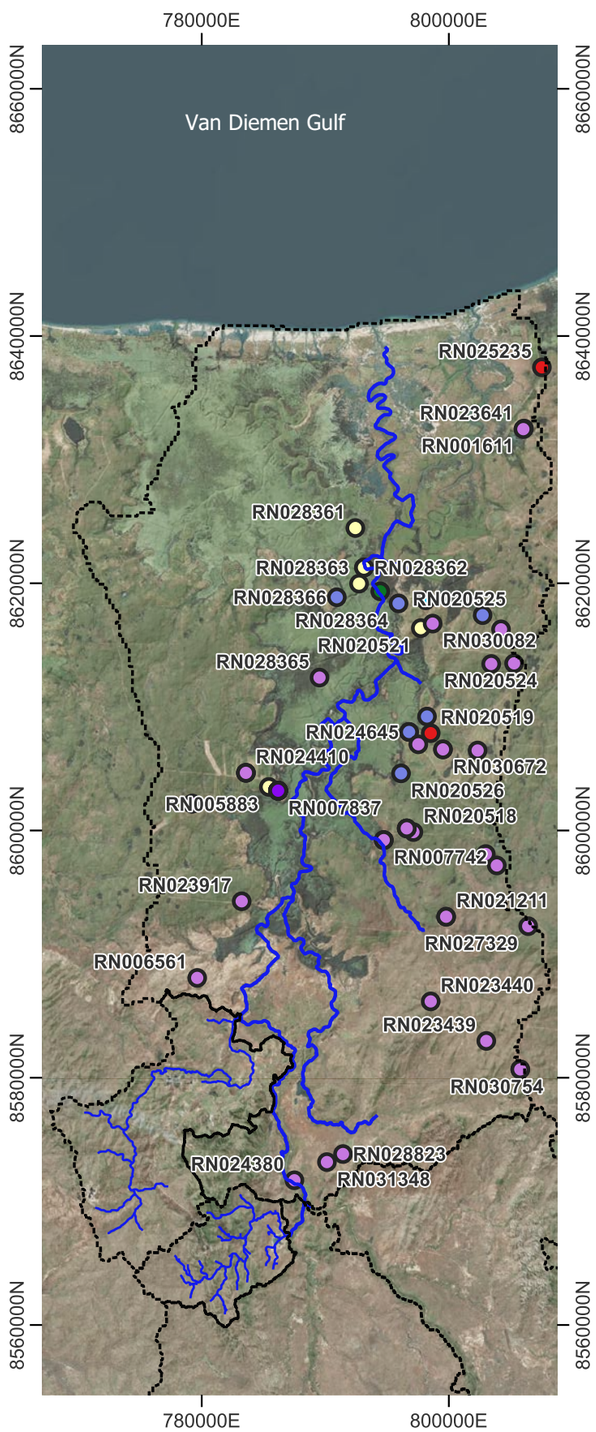
PRIMARY GOLD

Project: Lower Mary River Water Quality Improvement Plan

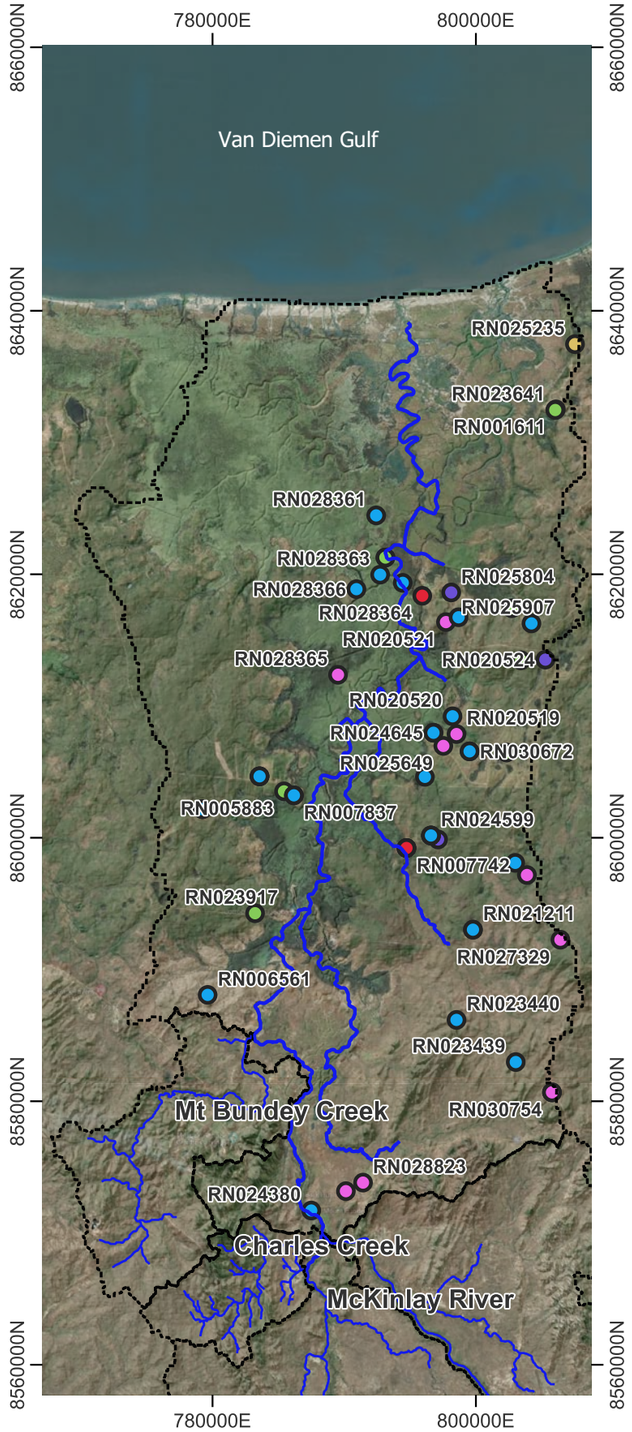
Title: NTG River Flow Gauges and Current Bores

Designed	Drawn	Checked	Sheet size
KGE	KGE	DRM	A3
Date			Sheet No.
19/8/2022			Sheet of

Appendix G NTG Current Bores - EC and pH Range.



Bore EC (μS/cm)
- 0 - <1000
- 0 - <5000
- 10000 -<20000
- 20000 -<30000
- 30000 -<40000
- 50000 -<60000
- Mary River
- Catchments



Bores pH Range
- 3 - <4
- 4 - <5
- 5 - <6
- 6 - <7
- 7 - <8
- 8 - <8.3
- Mary River
- Catchments

Appendix G	SURFACE WATER & EROSION SOLUTIONS	PRIMARY GOLD	Project: Lower Mary River Water Quality Improvement Plan	Title: NTG Current Bores - EC and pH Range.

Designed	Drawn	Checked	Sheet size
KGE	KGE	DRM	A3
Date		Sheet No.	
19/8/2022		Sheet of	