Recovery in land condition on Mitchell Grass Downs rangelands five years on from 2019 Flinders River flood

November 2024

Source: Queensland Country Life, 2019

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The report may be cited as

Koci, J., Hall, T., Milson, J., Tefera, A., Jarihani, B., Phelps, D., Nelson, P., Felderhof, C., Gardner, L., Wharton, P., Martinez, M. (2024) Recovery in land condition on Mitchell Grass Downs rangelands five years on from the 2019 Flinders River flood. Tropical North Queensland Drought Resilience Adoption and Innovation Hub, Townsville, Queensland.

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ACKNOWLEDGMENTS

Sincere thanks to all landholders who enabled field surveys to be conducted on their properties or on common land adjacent to their properties. Thank you to the Queensland Department of Agriculture and Fisheries and all people involved in the 2019 and 2020 land condition assessments. Thank you to Southern Gulf NRM for facilitating access with landholders and for facilitating extension and communication activities. This project was funded by the Tropical North Queensland Drought Resilience Adoption and Innovation Hub through the Australian Government's Future Drought Fund.

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EXECUTIVE SUMMARY

The 2019 Flinders River flood and associated wind chill event had a devastating impact on the grazing industry and local communities across north-west Queensland, with high stock mortality, infrastructure damage, and business disruption. Rangeland condition was also severely impacted by the flood. In some areas, severe erosion stripped away soil, nutrients, and seed bank, while in other areas, silt deposition smothered pasture plants. Prolonged floodwater inundation in low-lying areas also contributed to pasture death. The impacts of the flood were exacerbated by a prolonged drought which impacted the region in the six years prior to the flood, and in the three years following the flood.

This project sought to examine recovery in land condition on Mitchell Grass Downs rangelands five years on from the 2019 Flinders River flood. Soon after the floodwaters receded, on-ground land condition assessments were completed at 130 sites across the region. In August 2020, the land condition assessment was repeated at many sites surveyed in 2019. In September 2024, land condition assessments were repeated at 62 of the original sites.

Across the Mitchell Grass Downs, a wide range of flood impact and recovery responses on land condition are evident. In 2024, land condition: improved at least one condition score at 30 sites (48%); remained the same at 29 sites (47%); and declined at least one condition score at 3 sites (5%). The variation in response can be linked to interactions among: (i) historical grazing management; (ii) the impact of the preceding long-term drought, influenced by the grazing management imposed during this drought; (iii) the hydrodynamics of the flood water; (iv) grazing management following the flood; and (v) weather conditions following the flood.

Overall, it is clear that land that is managed to remain in good condition (A or B), is much more resilient to severe impacts associated with extreme weather events (both drought and flood) and recovers more quickly. The observed improvement in land condition at many sites was supported by strategic grazing land management and good rainfall in recent years. The Mitchell Grass Downs are some of the most resilient grazing lands in northern Australia, and Mitchell grass plants have a long survival period. These factors, along with strategic grazing land management, support the continued regeneration of these pastures to a more productive and stable state.

1 INTRODUCTION

Rangelands are the most extensive land-use type on Earth, covering approximately 40% of the global land surface (Briske, 2017). In Australia, rangelands cover over three quarters of the continent, contributing significantly to local and regional economies (Australian Government, 2024). In northern Australia, including parts of Western Australia, Northern Territory, and Queensland, rangelands cover approximately 1.2 million square kilometres (Russell-Smith & Sangha, 2018). These rangelands provide multiple important ecosystem services, including food production, cultural and recreational areas, habitat for wildlife, water and nutrient cycling, and carbon sequestration and storage (Brown & MacLeod, 2017). In northern Australia, as is the case globally, the health and function of rangelands are under increasing pressure from the combined effects of a changing climate and extreme weather events, invasive species, altered fire regimes, land use conversion and overgrazing (Boone et al., 2018; McKeon et al., 2004).

In northern Australia, the health and function of rangelands from a production perspective is commonly referred to as the 'grazing land condition'. Specifically, grazing land condition indicates the capacity of the land to efficiently capture energy, cycle nutrients, and respond to rainfall to produce useful forage (Karfs et al., 2009). Grazing land condition has two key interrelated components, including pasture condition and soil condition. Pasture condition refers to the capacity of pasture to capture solar energy and convert it into palatable green leaf, use rainfall efficiently, conserve soil condition, cycle nutrients and resist weed invasion. Soil condition refers to the capacity of the soil to absorb and store rainfall, store and cycle nutrients, provide habitat for seed germination and plant growth, and resist erosion. Land in good condition typically has a high proportion of perennial, productive, and palatable (3P) pasture species, few weeds present and minimal signs of erosion.

In northern Australia, rainfall is highly variable from year to year and extreme weather events (i.e., droughts and floods) are common. These climate and weather patterns present a major challenge for pastoralists in maintaining land in good condition (O'Reagain & Scanlan, 2013). There are several factors driving high rainfall variability, including the El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole, the Madden Julian Oscillation, and the northern monsoon (Cobon et al., 2021). The ENSO is perhaps the most important climatic driver in northern Australia. The ENSO is associated with a sustained period of warming (El Niño phase) or cooling (La Niña phase) in the central and eastern tropical Pacific Ocean. El Niño phases typically bring drier than average conditions to northern Australia, sometimes leading to drought, while La Niña phases typically bring wetter than average conditions, sometimes leading to flood (Eldridge & Beecham, 2018). The ENSO cycle typically operates over timescales of one to eight years.

Northern Australia's pastoralists are generally well-adapted to high interannual rainfall variability. The occurrence of extreme weather events often in succession, however, has contributed to several major land degradation 'episodes' throughout Australia's history (McKeon et al., 2004). In this region, it is common for periods of drought to be interspersed with, or 'broken' by, periods of prolonged and/or intense rain and flooding. In times of drought, the landscape is at its most vulnerable to severe impacts associated with intense rain and flooding. The increased vulnerability is associated with a reduction in vegetation cover and biomass arising from the combined effects of prolonged low rainfall and overgrazing during the drought.

Vegetation (including grass, shrubs and trees) plays a crucial role in controlling soil erosion during flood events (Bartley et al., 2006; Ludwig & Tongway, 2002; Osterkamp et al., 2012). Tree, shrub and grass roots increase soil cohesion, while surface biomass and debris reduce the energy of rain-drop impact which can dislodge soil particles. Vegetation also increases surface roughness (Stocking & Elwell, 1976; Thornes, 1990), moderating concentrated overland flow (Sidle et al., 2007) and effectively increasing the critical shear stress needed for erosion (Prosser et al., 1995). The breakdown of litter increases soil organic matter which improves soil structure and enhances infiltration (Feller & Beare, 1997). The creation of macropores has a similar effect through root development (Dunne et al., 1991).

Rangelands that are managed to remain in good condition during drought are typically more resilient to severe impacts associated with flood. If land degradation occurs during a flood, the land will become less resilient to future drought impacts. Few studies in northern Australia, or globally, however, have closely examined the interrelationships among grazing land management, the occurrence of droughts and floods, and land condition impact and recovery (Barendrecht et al., 2024). Globally, both dry and wet weather extremes are occurring more frequently and with increasing severity (Rodell & Li, 2023). These weather extremes are expected to become even more frequent and intense with ongoing changes in climate (IPCC, 2023; State of Queensland, 2019a). In

Northern Australia, predicted changes in climate will likely exacerbate existing pastoral management challenges. These challenges include declines in pasture productivity, reduced forage quality, livestock heat stress, greater problems with some pests and weeds, more frequent droughts, more intense rainfall events, and greater risks of soil erosion (Godde et al., 2019).

In the extensive Mitchell Grass Downs region of north-west Queensland, Australia, recent extreme weather events have had a devastating impact on the region's grazing industry and local communities (Phelps, 2019). The 2019 Flinders River flood was particularly significant. In late January and early February 2019, the Flinders River catchment had a period of 10 consecutive days of widespread heavy rainfall. Julia Creek for example, recorded 571 mm over the event, with a maximum daily total of 229 mm on the 5th of February. The rain event impacted an area that had been in drought for the previous six years. The rain event, unprecedented in recorded history, triggered broadscale flooding.

The extent of the 2019 flood, as mapped by the Queensland Government (State of Queensland, 2019c), was over 2.3 million ha. Some inundated areas spanned over 70 km east to west and over 400 km north to south (Figure 1). Importantly, this mapping was completed after the peak of the flood event due to extensive cloud cover during the event (Appendix 1). The mapped flood extent therefore likely greatly underestimates the full flood extent. AgForce Queensland (2019) produced a map that suggested a much larger flood extent of over 13.2 million ha (Figure 1). The Queensland Government also produced a map of flood duration (Appendix 2) which shows maximum inundation periods of over 14 days on the coastal plain between Karumba and east of Burketown, and across the central third of the inundation zone. Most of the inundated area experienced inundation of 3-4 days or more. Again, as the mapping was completed after the flood peak, the inundation duration periods are likely to be underestimated.

The flood event, coupled with an extreme wind chill event, resulted in the deaths of an estimated 457,000 head of cattle, 43,000 sheep, 710 horses and 3000 goats. In addition to livestock mortalities, about 22,000 km of fencing and 29,000 km of farm roads and tracks were destroyed or damaged, along with 2,320km of poly pipe and 1,350 tanks and troughs. Other losses included essential farm machinery and infrastructure such as dams and buildings (Phelps, 2019). The flood event also had severe impacts on land condition with widespread soil erosion, silt deposition and pasture death reported (Hall, 2020a, 2020b).

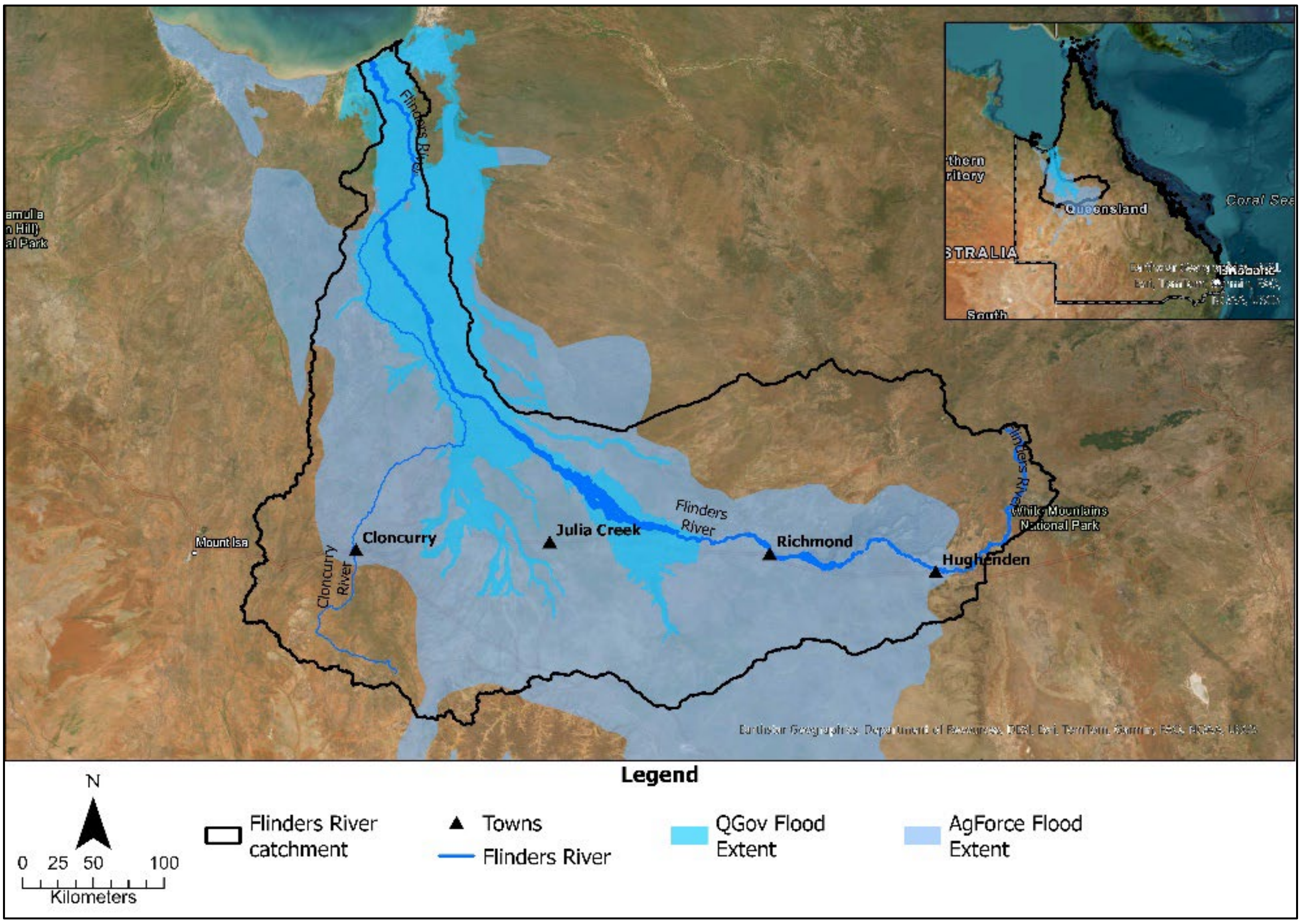


FIGURE 1. INUNDATION EXTENT OF THE 2019 FLINDERS RIVER FLOOD AS MAPPED BY THE STATE OF QUEENSLAND (2019C) AND AGFORCE QUEENSLAND (2019).

This study will assess recovery in land condition on Mitchell Grass Downs rangelands five years on from the 2019 Flinders River flood. To achieve this aim, on-ground land condition assessment data and observations collected in 2019 (soon after floodwaters had receded), 2020, and 2024, will be supplemented with satellite derived indices of ground cover and available rainfall data.

2 METHODOLOGY

2.1 STUDY AREA

The Flinders River catchment is in north-west Queensland, Australia, and covers approximately 109,000 km^2 (Figure 2). The Flinders River is the longest river in Queensland and sixth longest river in Australia. The Flinders Rivers initiates in the Great Dividing Range, 100 km north-east of Hughenden (Figure 3). From its headwaters, the river flows from north to south until Hughenden, where it tracks generally west across relatively flat plains toward Richmond. After Richmond, the Flinders River continues towards the north-west before flowing north and draining into the Gulf of Carpentaria, 25 km west of Karumba. The Flinders River has five major tributaries, including the Dutton River, Stawell River, Alick Creek, the Cloncurry River and the Saxby River. Large increases in catchment area occur where each of these major tributaries join the Flinders River. The dominant soils of the Flinders catchment are cracking clays (68%), derived from the fine-grained sedimentary rocks of the Great Artesian basin (Figure 4). There are 62 grazing land management land types within the Flinders River catchment (Figure 5).

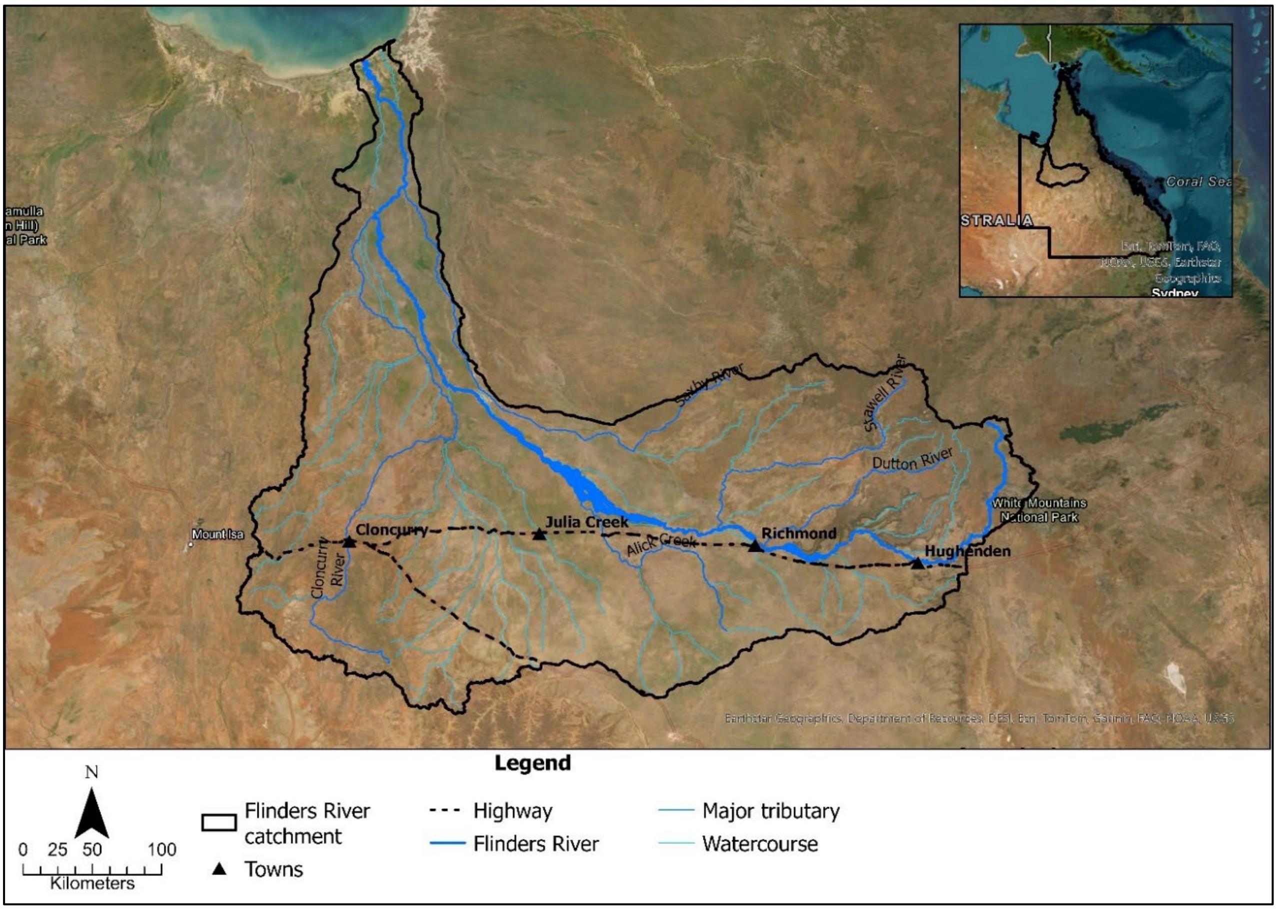


FIGURE 2. MAP OF THE FLINDERS RIVER CATCHMENT AND MAJOR TRIBUTARIES.

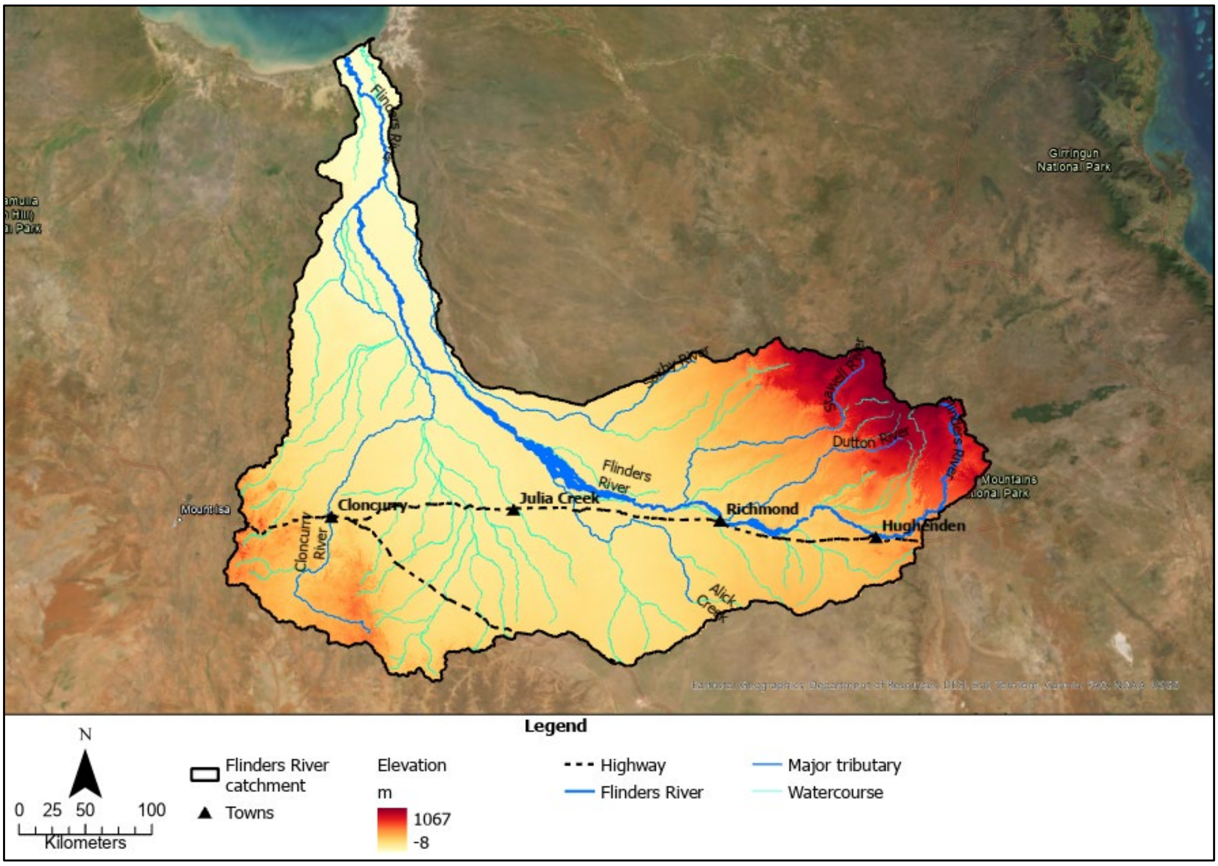


FIGURE 3. MAP OF ELEVATION WITHIN THE FLINDERS RIVER CATCHMENT.

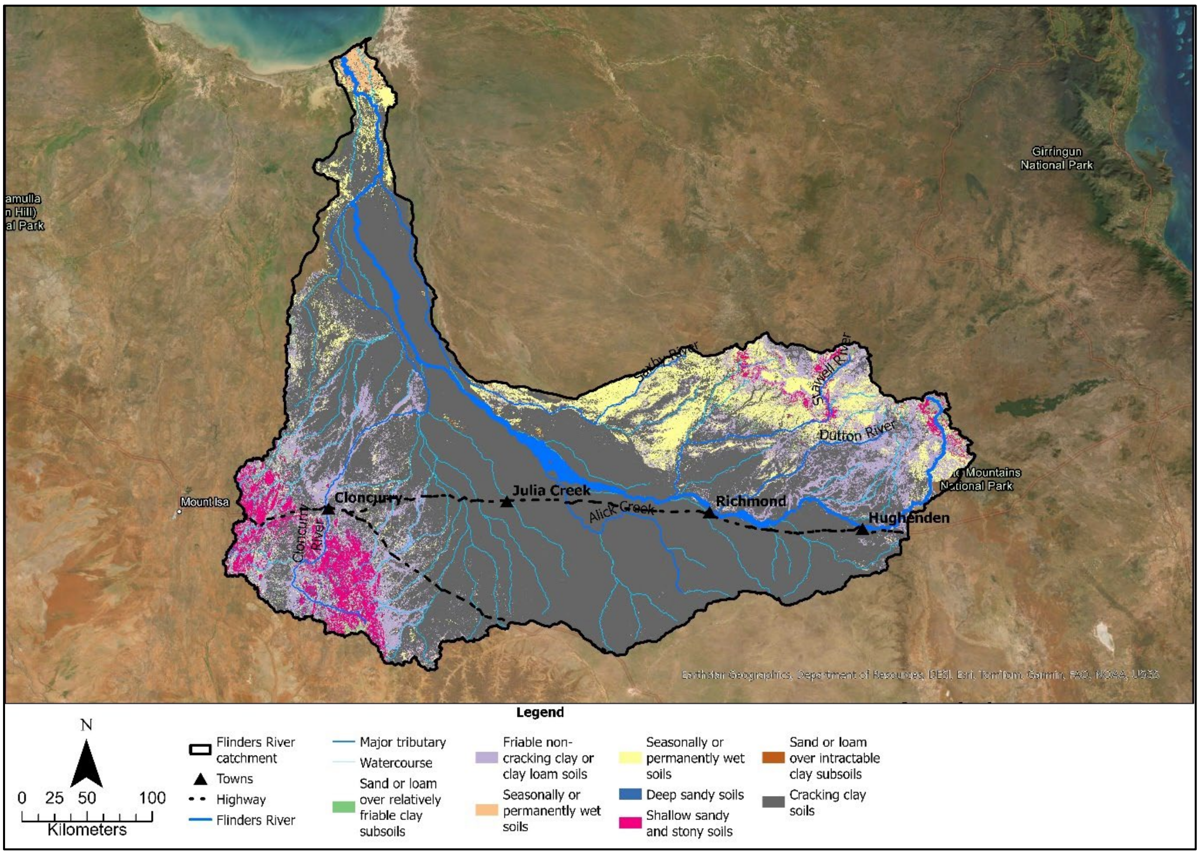


FIGURE 4. MAP OF SOIL GENERIC GROUP WITHIN THE FLINDERS RIVER CATCHMENT. DATA SOURCE: BARTLEY ET AL. (2013).

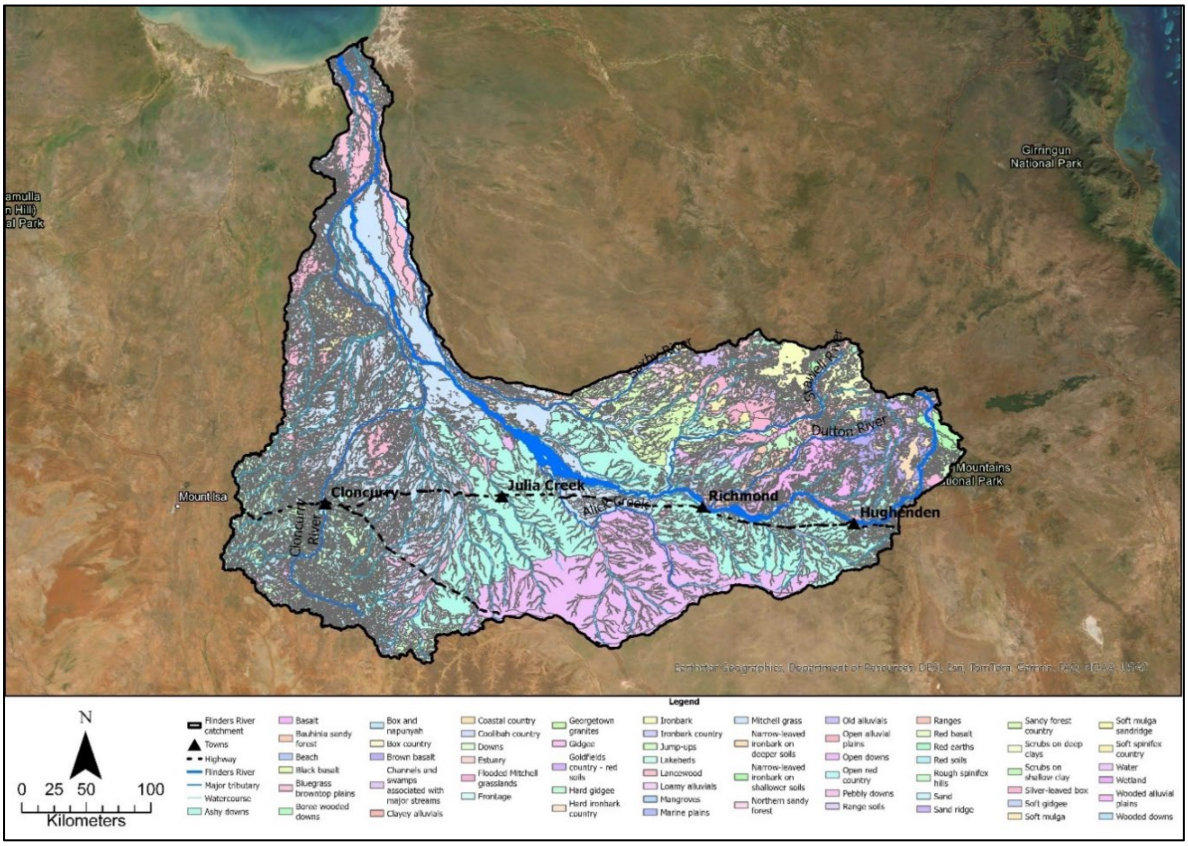


FIGURE 5. MAP OF LAND TYPES WITHIN THE FLINDERS RIVER CATCHMENT.

The Flinders River catchment has a hot and dry semi-arid climate, with high seasonality. Most of the rain falls during the wet season between December and March. On average, the catchment receives 492 mm of rain per year, 88% of which falls during the wet season (Petheram et al., 2013). Successive years of above and below average rainfall are common in the catchment (Figure 6). Spatially, mean annual rainfall varies from about 800 mm near the coast to about 350 mm in the south of the catchment. The mean annual potential evaporation is 1862 mm (1965 to 2011) (Petheram et al., 2013).

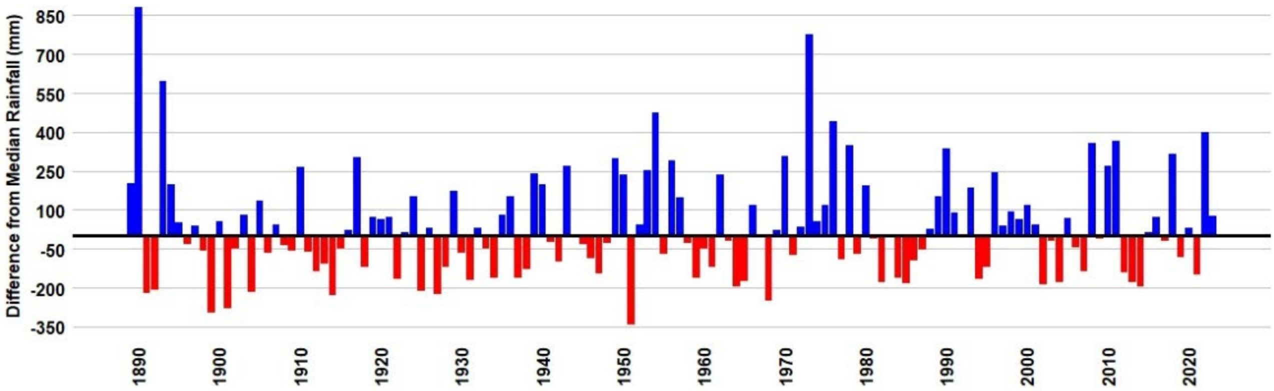


FIGURE 6. DIFFERENCE IN ANNUAL RAINFALL FROM THE LONG-TERM MEDIAN RAINFALL AT JULIA CREEK. BLUE BARS INDICATE ABOVE MEDIAN RAINFALL YEARS AND RED BARS INDICATE BELOW MEDIAN RAINFALL YEARS. DATA SOURCE: STATE OF QUEENSLAND (2024).

As with rainfall, runoff and streamflow in the Flinders River catchment are highly variable within years and between years. Approximately 95% of runoff in the Flinders River catchment occurs during the wet season (Petheram et al., 2013). The Flinders River has a mean and median annual flow at its most downstream gauge of 2543 GL and 1241 GL, respectively (Petheram et al., 2013).

The coastal floodplains regularly flood over very large areas, with flooding extending hundreds of kilometres inland (Petheram et al., 2013). The extent of flooding is in part due to the funnelling of several rivers draining large areas, into a relatively narrow (approximately 100 km wide) area around Canobie. The mid to lower reaches of the Flinders catchment are also very flat (less than 1:100,000) and as a result flood water drains slowly. Rainfall is also typically higher in the downstream floodplain area. Local floodwaters on the floodplain can cause upstream floodwaters to back-up. During large flood events water can cross between the Flinders River and Norman River catchments.

2.2 RAINFALL AND GROUND COVER ANALYSIS

Unless otherwise stated, rainfall data presented in this report are for the 'water year', defined as the period 1 July to 30 June. This allows each individual wet season to be counted in a single 12-month period. Gridded daily rainfall datasets for the Flinders River catchment were downloaded from the SILO website (State of Queensland, 2024). The daily rainfall data was aggregated into monthly and annual summaries at the towns of Richmond, Julia Creek, and Cloncurry, respectively, for the period of 2010/11 to 2023/2024. Spatially distributed maps of daily rainfall over the entire Flinders River catchment during the 2019 event (January 28 to February 10) were also derived from this dataset.

The seasonal fractional cover (Landsat JRSRP algorithm, version 1) dataset (Joint Remote Sensing Research Program, 2021) was downloaded for the Sep-Oct-Nov period of 2018, 2019, and 2020, and for the March-Apr-May period of 2019, and June-July-August period of 2024. The seasonal fractional cover product shows representative values for the proportion of bare, green and non-green cover across a season. It is a spatially explicit raster product, which predicts vegetation cover at medium resolution (30 m per-pixel) for each 3-month calendar season, using Landsat satellite imagery.

2.3 ON-GROUND PASTURE AND LAND CONDITION ASSESSMENT

Between the 20 February and 4 March 2019, staff from the Queensland Department of Agriculture and Fisheries (DAF) visited 130 sites and completed field land condition assessments at 111 sites (Figure 7) (Hall, 2020b). Sites were limited to land alongside a selection of major highways or secondary roads, on two broad land types: Mitchell Grass Downs and the Gulf Plains. Only roads that had been cleared of dead cattle, silt and debris were travelled. A formal recording system and pro forma was developed for assessing pastures and land condition (Appendix 3 and 4). All 3P (perennial, productive, palatable) grasses and seedlings were recorded, as well as annual grasses, legumes and other broad-leaved forbs and weeds. In August 2020, the land condition assessments were repeated at many of the sites surveyed in 2019, as well as at 35 new locations along repaired roads (Figure 7) (Hall, 2020a). In September 2024, 62 of the original sites were revisited and 14 new assessments were made (Figure 7). In 2024, most of the sites were located on the 'Mitchell grass' land type (29 sites) and the 'Ashy Downs' land type (20), with the remaining sites located on 'Flooded Mitchell grasslands', 'Bluegrass browntop plains', 'Frontage', 'Sandy Forest country', 'Bauhinia sandy forest', and 'Open downs' land types (Figure 8).

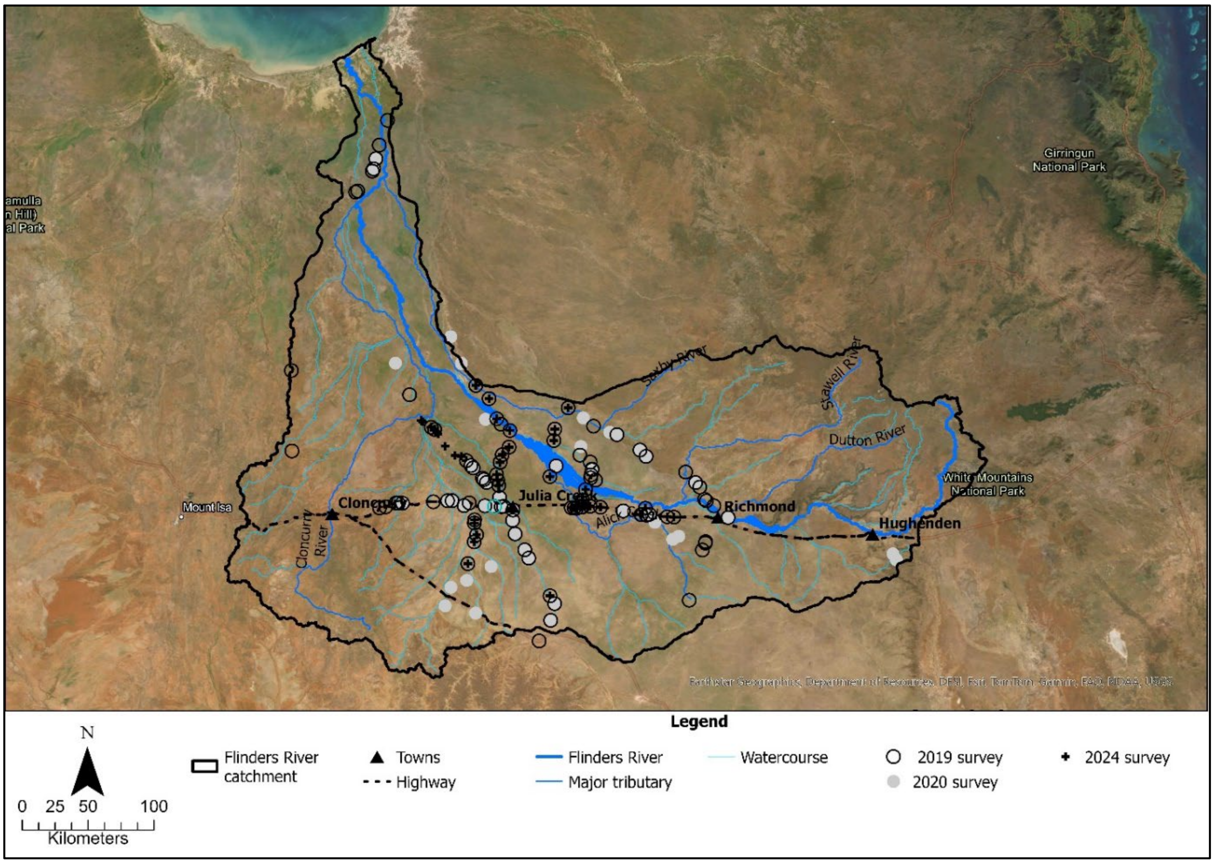


FIGURE 7. LOCATION OF SITES SURVEYED IN 2019, 2020 AND 2024.

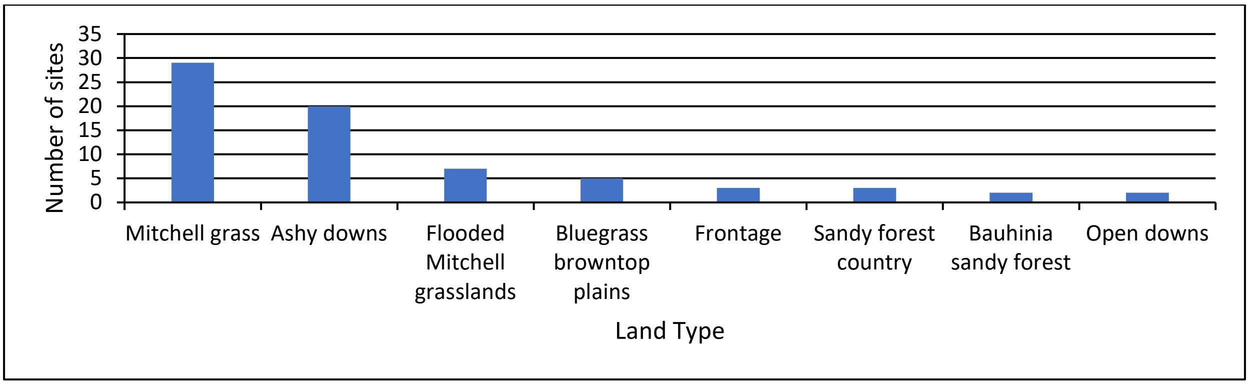


FIGURE 8. NUMBER OF SITES ASSESSED PER LAND TYPE IN 2024.

3 RESULTS

This section presents: (i) analysis of rainfall and satellite-based ground cover conditions before, during and after the 2019 event; and (ii) analysis and field observations from on-ground land condition assessments completed in 2019, 2020 and 2024.

3.1 RAINFALL AND GROUND COVER BEFORE, DURING AND AFTER THE 2019 FLOOD EVENT

In the six years prior to the 2019 flood event, much of the Flinders River catchment experienced average to below-average rainfall (Figure 9). The McKinlay Shire and Richmond Shire were drought declared. Some areas of the catchment did receive useful rainfall in late 2018. For example, Julia Creek received approximately 66 mm in November 2018. The consecutive years of below-average rainfall reduced ground cover levels across the region. In the September-November period of 2018, seasonal fractional ground cover across vast areas of the Flinders catchment were classified as either bare or a mix of bare and non-green vegetation (Figure 10 and 11).

In late January and early February 2019, the Flinders catchment had a period of 10 consecutive days of widespread heavy rainfall (Figure 12). Julia Creek Airport, for example, recorded 571 mm over the event, with a maximum daily total of 229 mm on the 5th of February (Figure 13). The rainfall occurred as two periods of heavy rainfall, the initial one in late January, and a second more intense burst of very heavy rainfall five days later. This resulted in two flood peaks. New flood records were recorded at numerous gauging stations along the length of the Flinders River and Cloncurry River (Appendix 5).

Once floodwaters had receded in March 2024, there was a significant increase in the extent of green vegetation across the Flinders catchment (Figure 10 and 11). In the months following the event, there was very little follow-up rain, with annual rainfall in 2019/20 well below average (Figure 9). The McKinlay Shire and Richmond Shire remained drought declared. In the September-November period of 2019, vast areas of the Flinders catchment were again classified as either bare or a mix of bare and non-green vegetation, and this persisted the following year (Figure 10 and 11). 2022/23 and 2023/24 were above-average rainfall years (Figure 9). The two consecutive years of good summer rainfall triggered widespread increases in ground cover across the catchment (Figure 10 and 11).

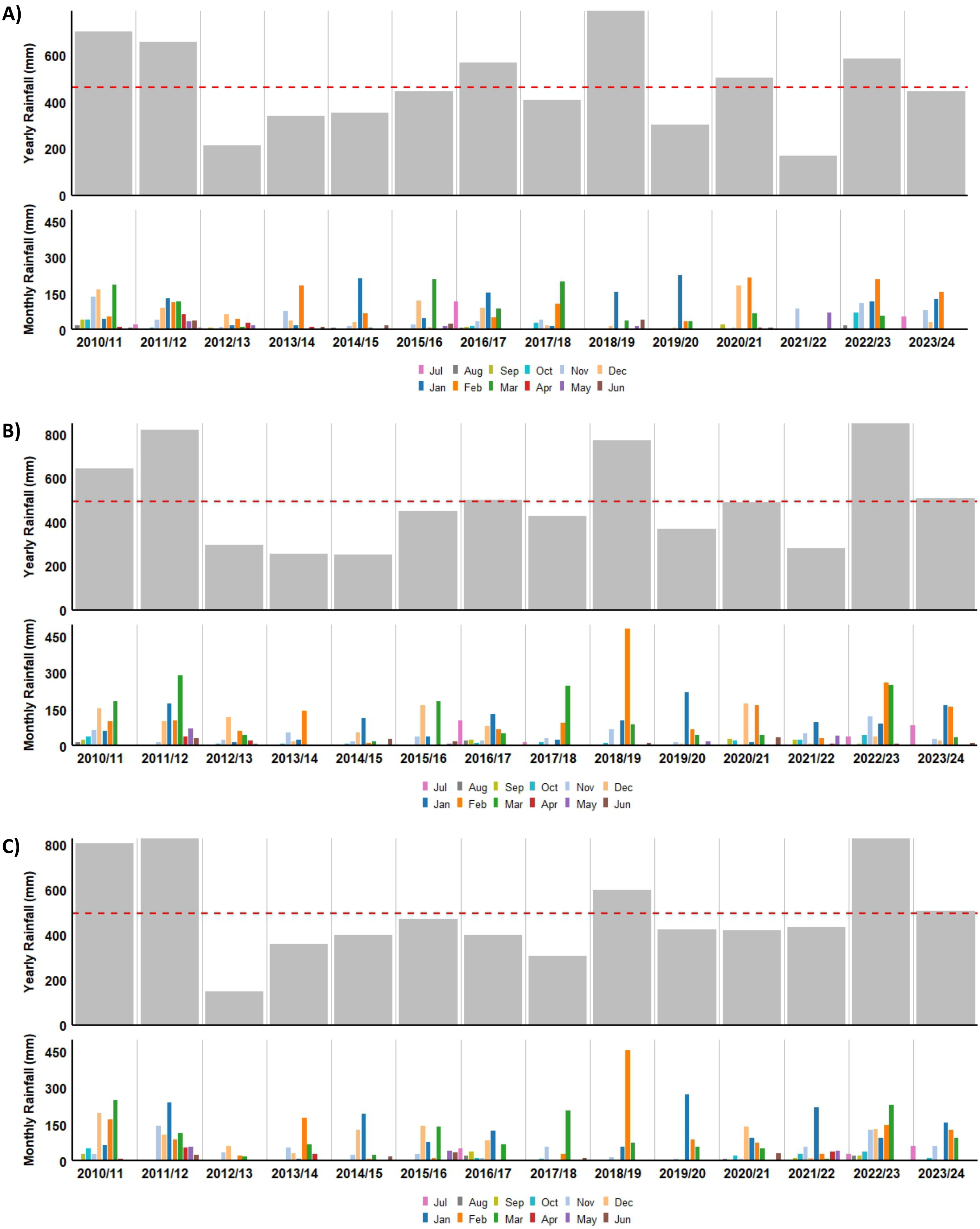


FIGURE 9. MONTHLY AND YEARLY RAINFALL AT: (A) RICHMOND; (B) JULIA CREEK; AND (C) CLONCURRY, BETWEEN 2010/11 AND 2023/24. THE RED DOTTED LINE SHOWS THE LONG-TERM (1888/89 – 2023/24) MEAN ANNUAL RAINFALL. DATA SOURCE: STATE OF QUEENSLAND (2024).

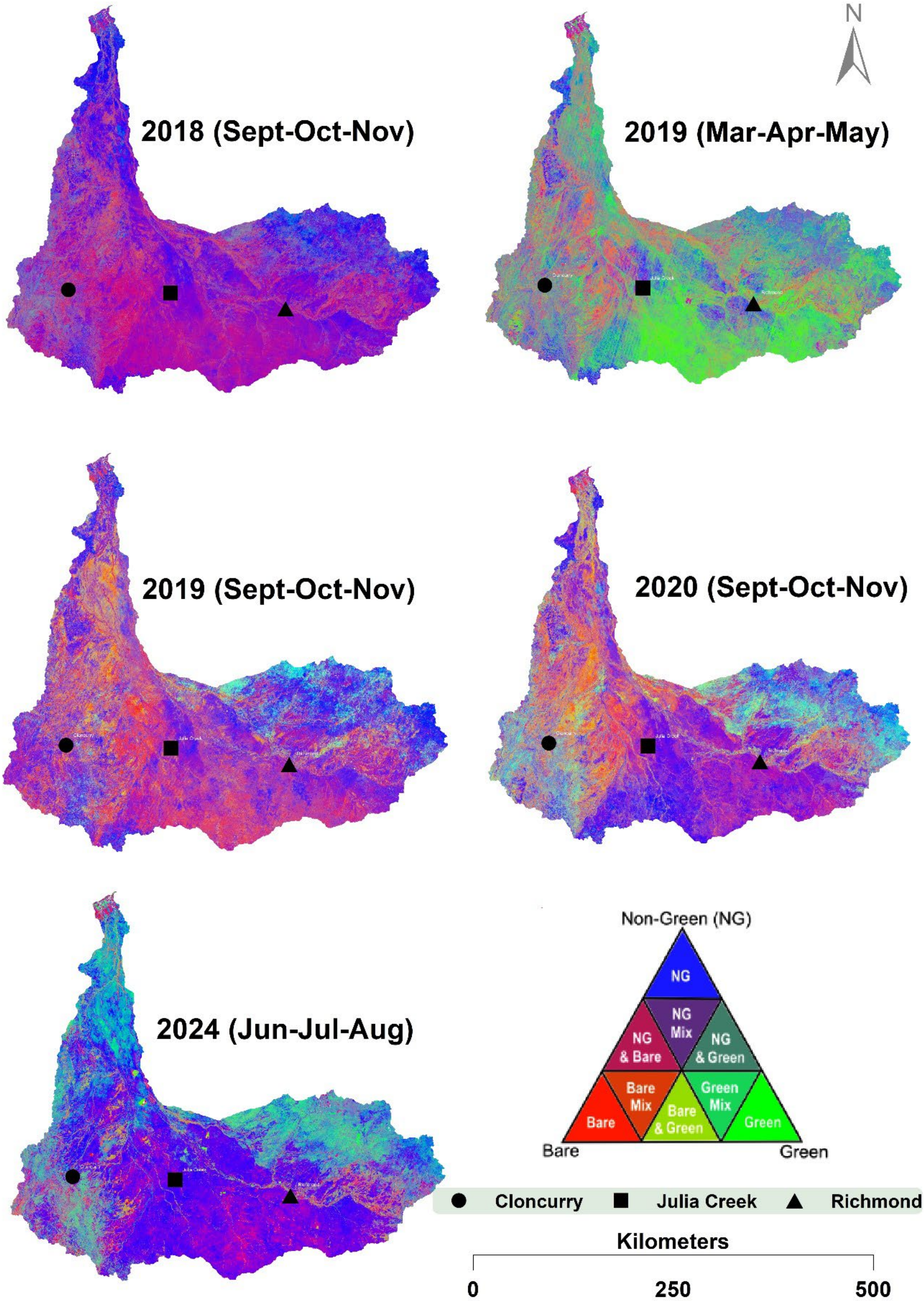
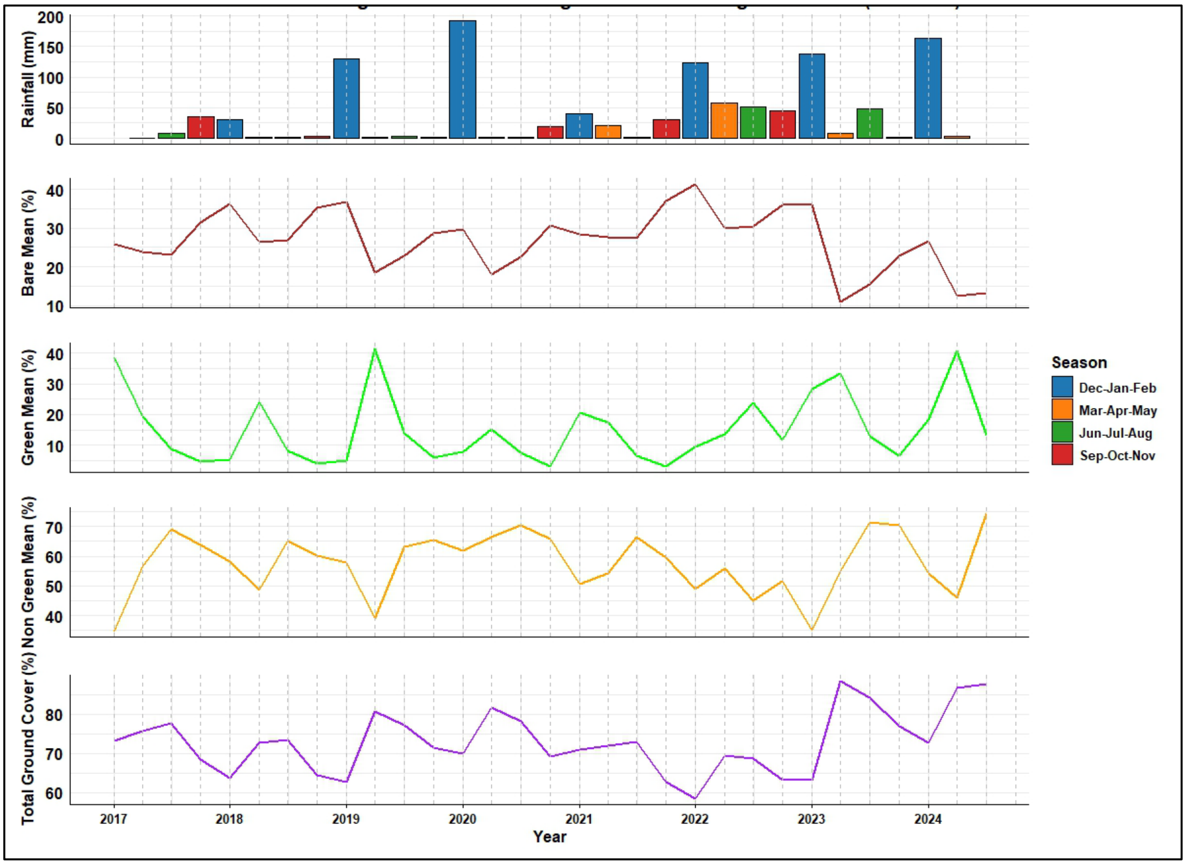


FIGURE 10. SEASONAL FRACTIONAL GROUND ACROSS THE FLINDERS CATCHMENT FOR: (A) SEPTEMBER-OCTOBER-NOVEMBER 2018; (B) MARCH-APRIL-MAY 2019, (C) SEPTEMBER-OCTOBER-NOVEMBER 2018; (D) SEPTEMBER-OCTOBER-NOVEMBER 2018, AND (E) JUNE-JULY-AUGUST 2024: DATA SOURCE: JOINT REMOTE SENSING RESEARCH PROGRAM (2021).

A)



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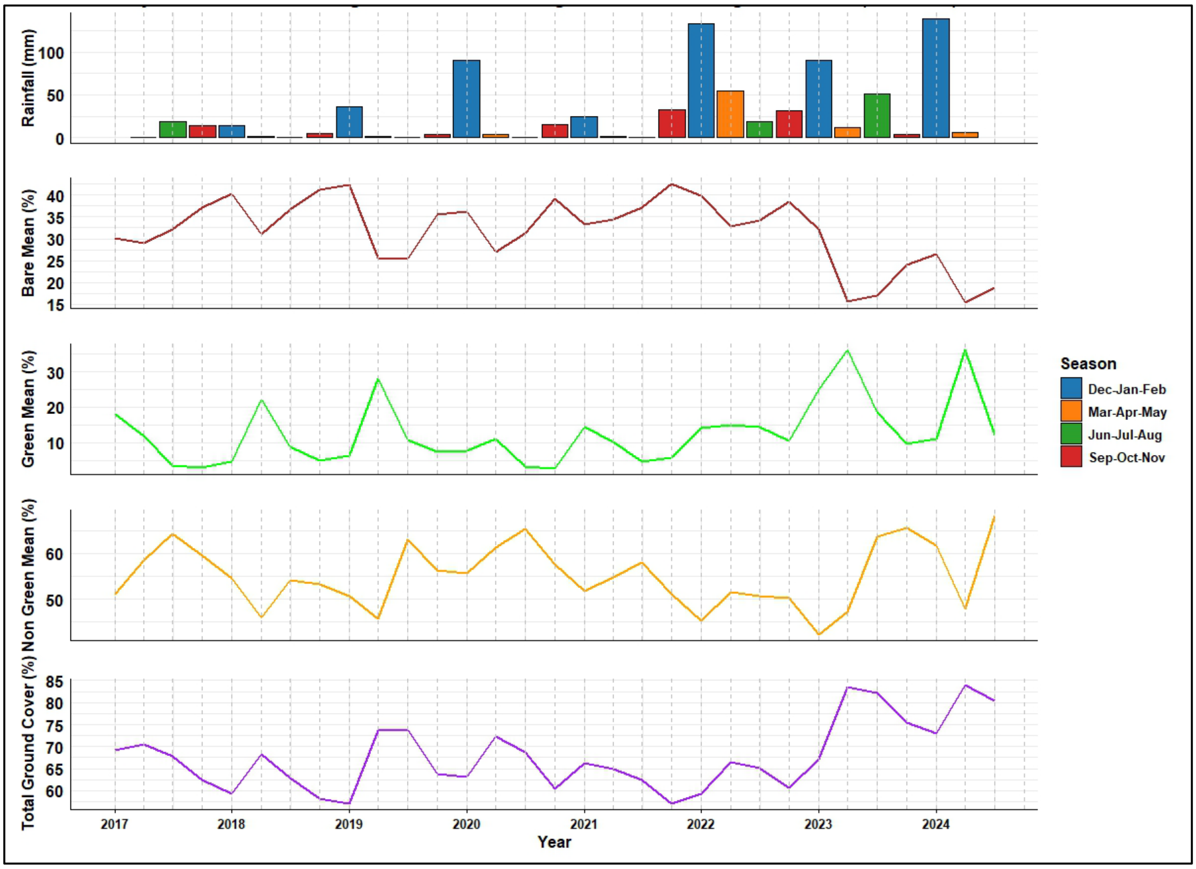

FIGURE 11. SEASONAL RAINFALL AND SEASONAL FRACTIONAL GROUND ACROSS THE: (A) RICHMOND SHIRE; AND (B) MCKINLAY SHIRE. DATA SOURCE: BEUTEL ET AL. (2019).

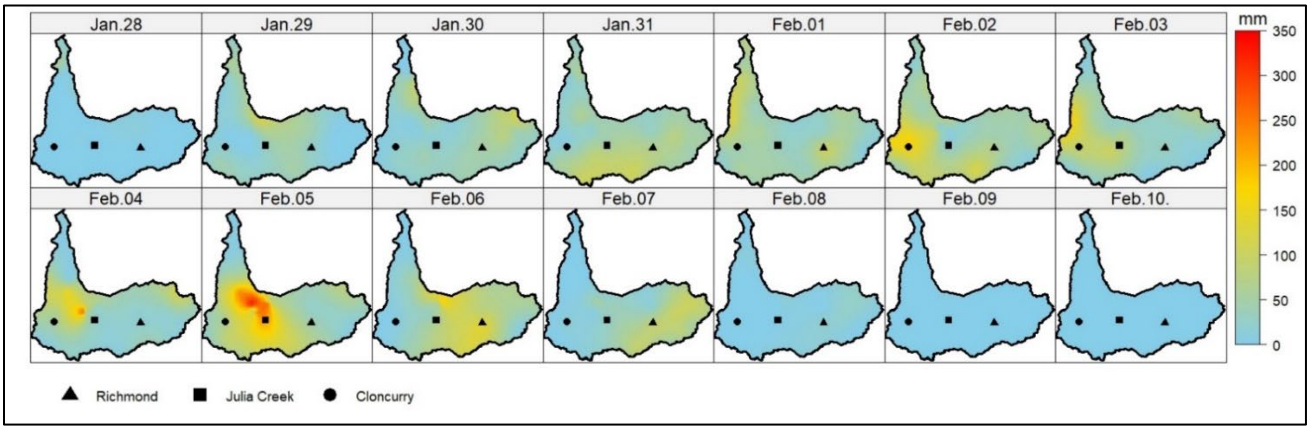

FIGURE 12. SPATIAL DISTRIBUTION OF DAILY RAINFALL WITHIN THE FLINDERS RIVER CATCHMENT DURING THE 2019 FLOOD. DATA SOURCE: STATE OF QUEENSLAND (2024).

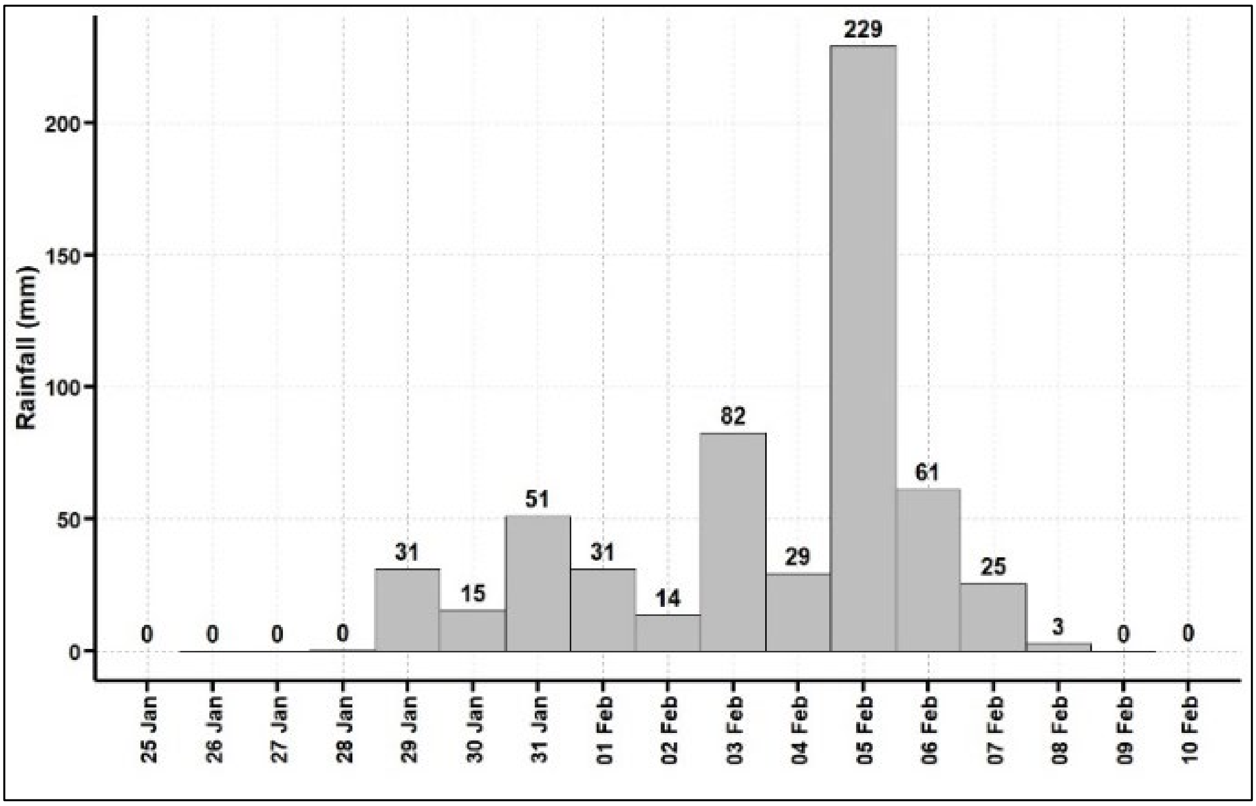

FIGURE 13. DAILY RAINFALL AT JULIA CREEK DURING THE 2019 FLOOD EVENT. DATA SOURCE: BOM (2024).

3.2 ON-GROUND LAND CONDITION ASSESSMENT

3.2.1 2019 LAND CONDITION ASSESSMENT

Full details of the 2019 on-ground land condition assessment are provided in Hall (2020b) and briefly summarised below. In February/March 2019, 1% of the 111 surveyed sites were in A condition, 22% of the sites were in B condition, 64% of the sites were in C condition, and 14% of the sites were in D condition (Figure 14 and 15).

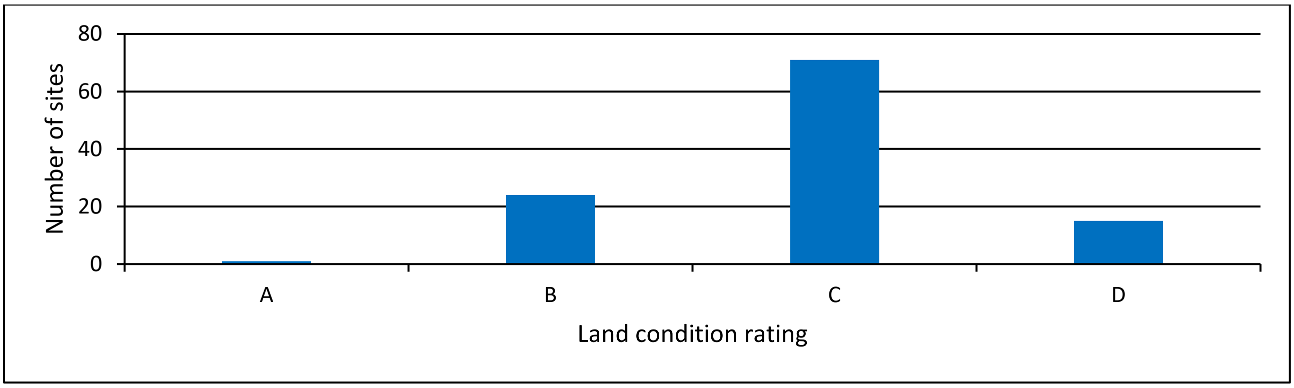

FIGURE 14. DISTRIBUTION OF LAND CONDITION RATINGS OF SITES SURVEYED IN 2019.

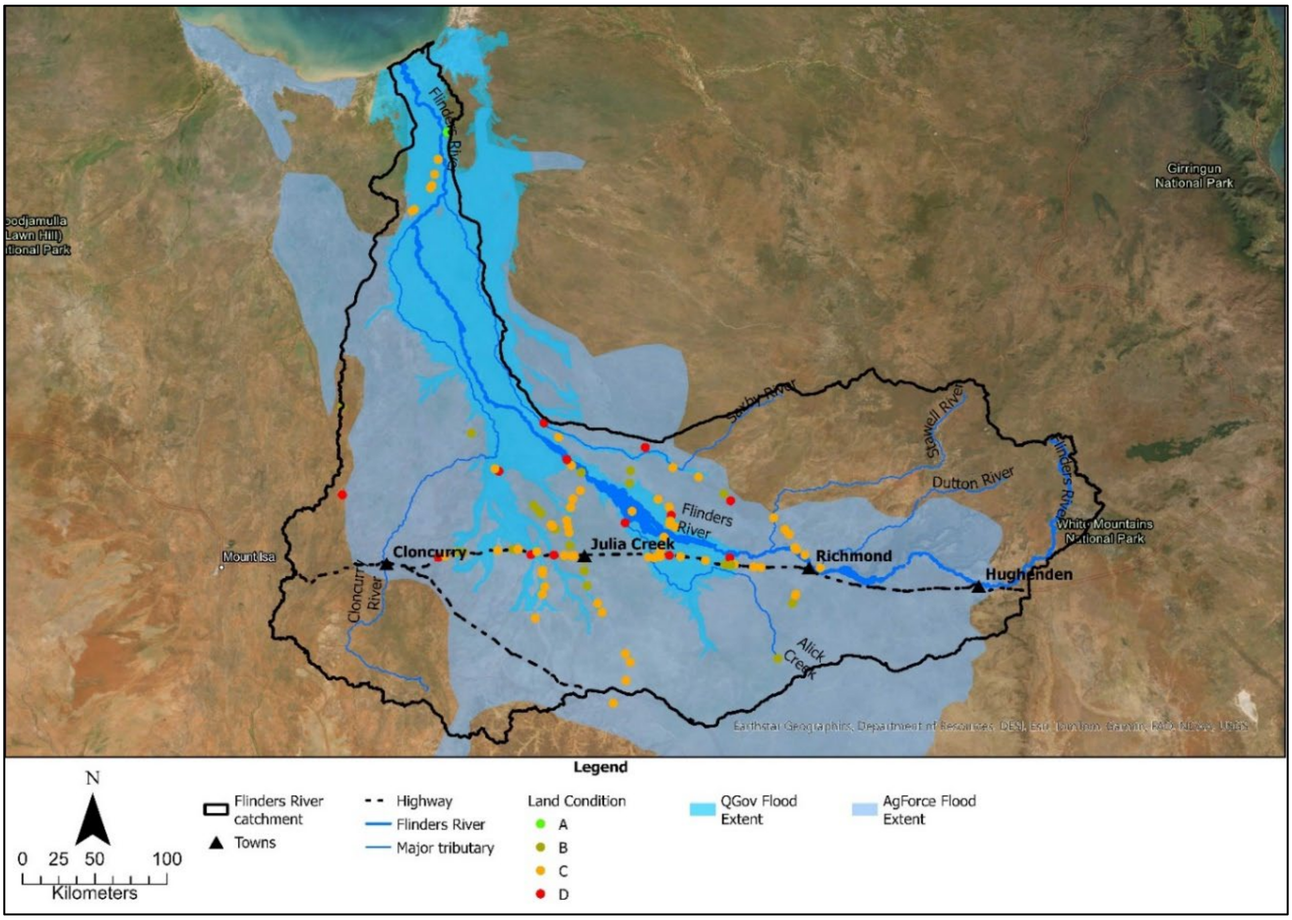

FIGURE 15. MAP SHOWING THE LAND CONDITION RATING OF SITES SURVEYED IN 2019.

Flooding effects were variable across the Mitchell Grass Downs due to the naturally undulating landscape. Most of the initial recovery was taking place on the rises, where water depth and time of inundations was less or where no inundation occurred. The variation in damage and recovery of tussocks is likely to have been affected by the water depth, flow strength, sediment load, light penetration, inundation period and water temperature, along with the available root reserve.

Major creeks and rivers sustained severe bank erosion. Severe sheet erosion occurred on floodplains close to channels, where tens of centimetres of topsoil were stripped, along with the perennial pastures (Figure 16). New gullies were formed, particularly in areas of flow concentration along drainage lines and often associated with compacted areas, such as roads, tracks and cattle pads (trails). At some locations (e.g., near the Flinders River north-east of Julia Creek), roads and tracks along fence lines were eroded to 2 m depth, 10 m wide and hundreds of metres long. Other areas, particularly low-lying ones, had silt deposits of 10–50 cm deep, and up to 1 m deep close to creek edges. Such severe erosion was more noticeable where two creeks meet.

A) **B)**

FIGURE 16. (A) SEVERE EROSION WITH ALL SURFACE SOIL LOST ADJACENT TO A WATERCOURSE. (B) PHOTO OF A NEWLY FORMED GULLY AND ADJACENT SEVERE SHEET EROSION ALONG A ROAD.

In many areas, well-established, drought-surviving tussocks had died, largely due to roots exposed by erosion and the period of inundation. Erosive effects around tussocks were most severe on the up-water flow direction. Silt deposits up to 30 cm deep were common, often on the down-water side of large tussocks, and often stretched 1-3 m. There were many areas with these parallel disturbances of erosion and silt deposition, where the plant was partially covered with silt on one side and the roots partially exposed on the other (Figure 17). The deposition of silt hindered plant recovery and regrowth.

A) B) C)

FIGURE 17. (A) DEAD MITCHELL GRASS TUSSOCKS IN A HEAVILY WASHED AREA; (B) PEDESTALLING OF MITCHELL GRASS TUSSOCKS; AND (C) SILT DEPOSITION AROUND TUSSOCKS.

In some areas, the original Mitchell grass tussocks were showing signs of surviving by producing new tillers from rhizomes (Figure 18). Often only 1-4 tillers were present. Exceptions were in places where destocking had occurred during the drought and tussocks still retained about 20 cm tall primary tillers (those growing direct from the basal) that promoted secondary tiller (i.e., tillers growing from nodes along existing primary tillers) development. Areas that received early summer rain prior to the flood were the most developed in terms of plant growth, starting to produce seed heads within four weeks of the water receding. Bull Mitchell grass areas were generally recovering better than Curly Mitchell areas. Recovery in smaller areas of Barley Mitchell were in between these two species in terms of regrowth of the original tussocks.

FIGURE 18. NEW TILLERS FROM AN OLD TUSSOCK.

Immediately following the flood there was widespread germination of Mitchell grass seedlings (Figure 19). The germination was aided by a week of no rain immediately following recession of floodwater and high (>40°C) temperatures. The seedlings were found where older plants were well established prior to the flood, and also in paddocks where there was no evidence of old tussocks, indicating the seed had remained viable in the soil for a very long period. Seedling populations of Mitchell grass were also recorded on some areas of severely eroded, silted hollows that had deep water for a longer period than the surrounding more elevated sites. This indicates that Mitchell grass seed in the soil can survive inundation for many days. The seedlings mostly had 2-4 leaves and were 5-15 cm high with only 2-4 roots. At the time of the 2019 assessment, these seedlings were healthy but starting to wilt on some of the lighter soils and some seedlings had already died in the west of the region by early March.

A) B)

FIGURE 19. GRASS TUSSOCK STEM COVERED IN SILT SURROUNDED BY NEW SEEDLINGS. (B) NEW SEEDLING.

Areas of silt deposition had hard-set surfaces 5-100 mm thick with the top 5-50 mm of soil curling upwards (Figure 20). This crusting made it impossible for new seedlings to emerge, so the seedlings observed are likely to have only been from the germination in the first one or two weeks after the floodwater receded. This mass germination event provided a rare opportunity to potentially regenerate the Mitchell grass pastures after the flood, providing pastures were rested, grazing management was restricted and follow-up rainfall was adequate.

FIGURE 20. NEW MITCHELL GRASS SEEDLINGS AMONGST CRUSTED SILT DEPOSITS

In addition to Mitchell grass seedlings, masses of other grass and forb seedlings had emerged to form a surface carpet and had grown to 5-20 cm high where soils were not severely eroded (see Appendix

6 for a full list of pasture species recorded). By the fourth and fifth weeks after the event, sesbania (*Sesbania brachycarpa*) was widespread and starting to flower as plants reached 30-50 cm in height.

Heavy grazing pressure and subsequent loss of perennial grass plants during the drought prior to the flood, had a negative impact on the regrowth of pastures. Where tussocks were grazed to the soil surface or only 10 cm of basal stem remained, there was often nil or very little tussock recovery in the weeks following the flood, but where there was 20-30 cm of Mitchell grass stem stubble left, the initial recovery was often high. Drought effects on tussocks were generally most severe in the south, for example Winton, Kynuna, McKinlay regions and less severe to the north on the Plains. There were strong exceptions on the plains where paddocks and some whole properties had higher grazing pressure than neighbouring areas for an extended period. There were distinct fence line effects of recovery versus no recovery of perennial grasses depending on levels of grazing prior to the flood event (Figure 21). It is possible some of this damage to the pasture community could have occurred many years prior to the recent drought, especially given that the Mitchell Grass Downs areas had experienced many droughts in the past. Soil type differences across the Mitchell Grass Downs also affected the establishment and survival of perennial tussocks. Against the general trend, some sites that had a recent history of conservative grazing still did not have a good perennial tussock population. These soils were more self-mulching, and probably 'ashy', and better supported annual grasses such as Flinders grass. Fence line effects of *Vachellia nilotica* (prickly acacia) management were obvious. Paddocks with no trees and a productive Mitchell grass pasture, sat beside their neighbours with a woodland of trees and much reduced pasture.

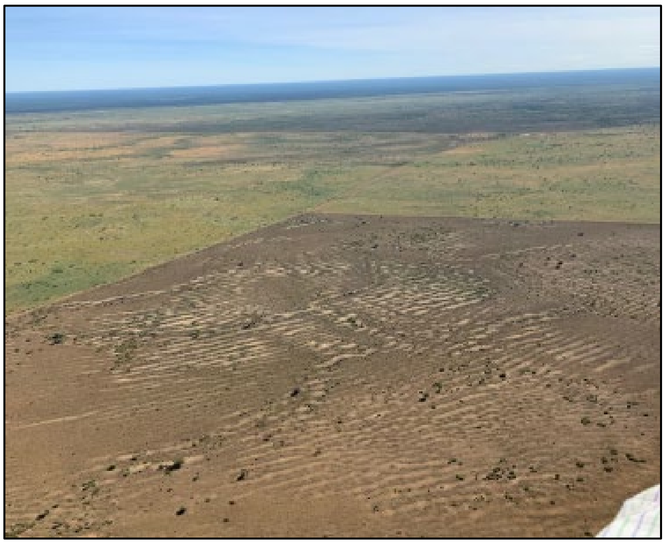

FIGURE 21. PADDOCK SCALE PRIOR GRAZING EFFECT ON PASTURES FROM FLOODING.

3.2.2 2020 Land condition assessment

Full details of the 2020 land condition assessment are provided in Hall (2020a) and briefly summarised below. In August/September 2020, 3% of the 63 surveyed sites were in A condition, 24% of the sites were in B condition, 57% of the sites were in C condition and 16% of the sites were in D condition (Figure 22 and 23).

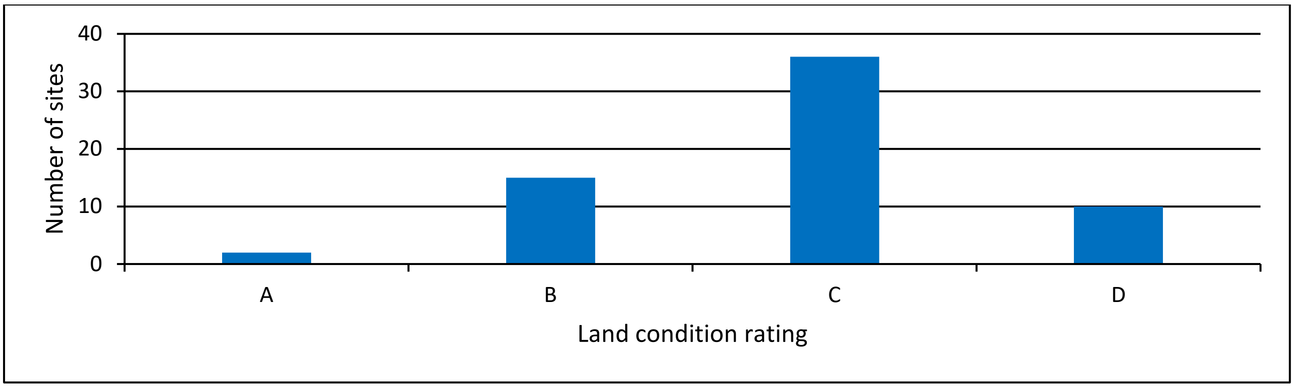

Figure 22. Distribution of land condition ratings of sites surveyed in 2020.

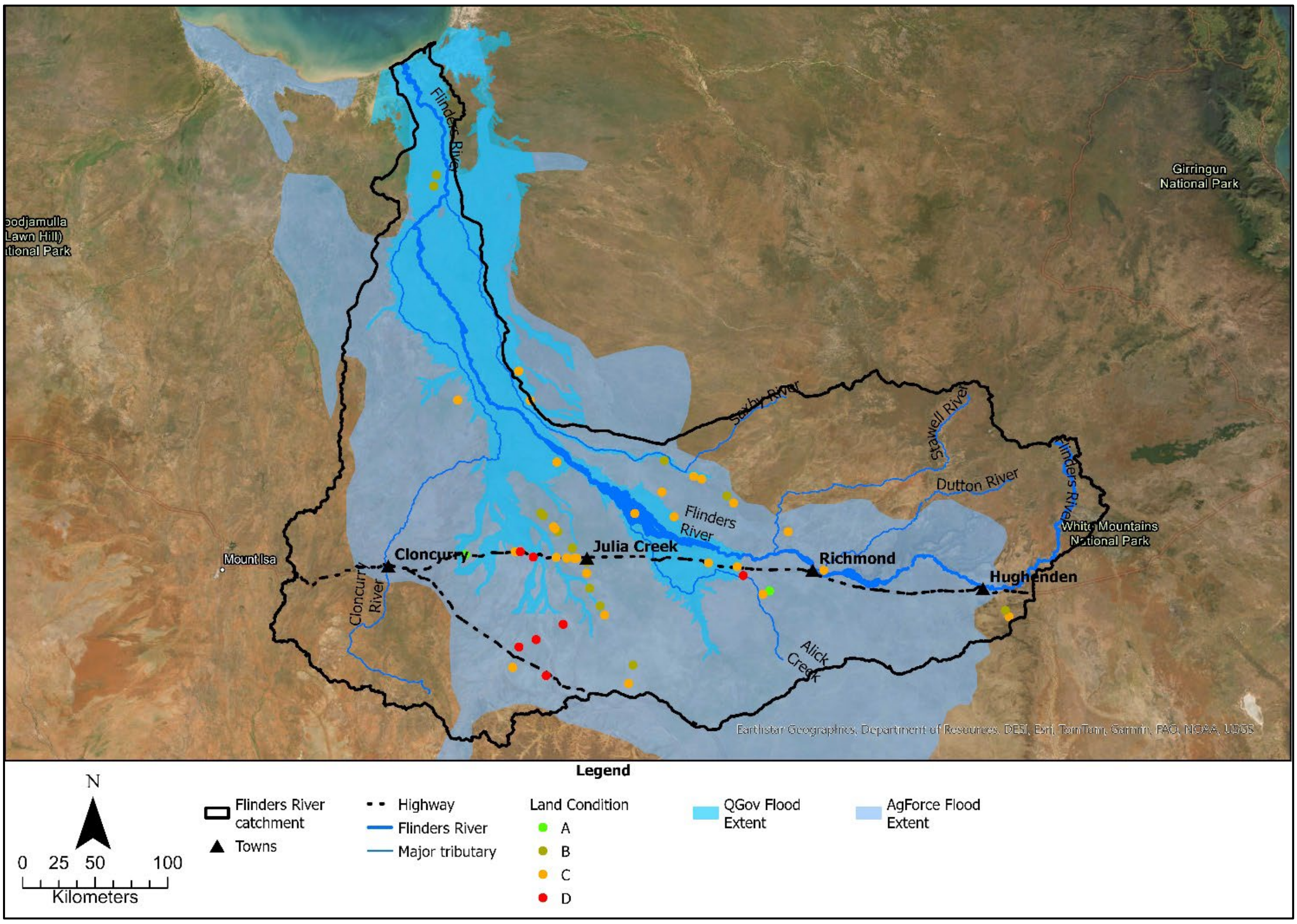

Figure 23. Map showing the land condition rating of sites surveyed in 2020.

The 2020 pasture responses on the Mitchell Grass Downs were parallel to those recorded immediately after the flood. There was a wide range of pasture and tussock response from the flood and poor follow-up rainfall on the different landscapes. Where there was some recovery within a month of the flood, there was also satisfactory tussock growth over 2019/20 summer relative to the summer rainfall. Conversely, where there was negligible or nil growth after the flood, there was generally no useful response in 2020. Grass growth responses on the Downs were naturally limited by the late and short rainfall season of 2019/2020 and often additionally by grazing after restocking.

Where there had been sufficient rain to initiate growth on Mitchell grass tussocks prior to the flood, (for example over 50 mm in late 2018), there was greater survival and a more rapid growth response when the flood receded. These sites were still in good condition in 2020, even after the poor summer rainfall and with grazing (Figure 24). The best grass response was from areas where the tussocks had not been grazed below 15-20 cm of stem height during the drought that preceded the 2019 flood event.

A) **B)**

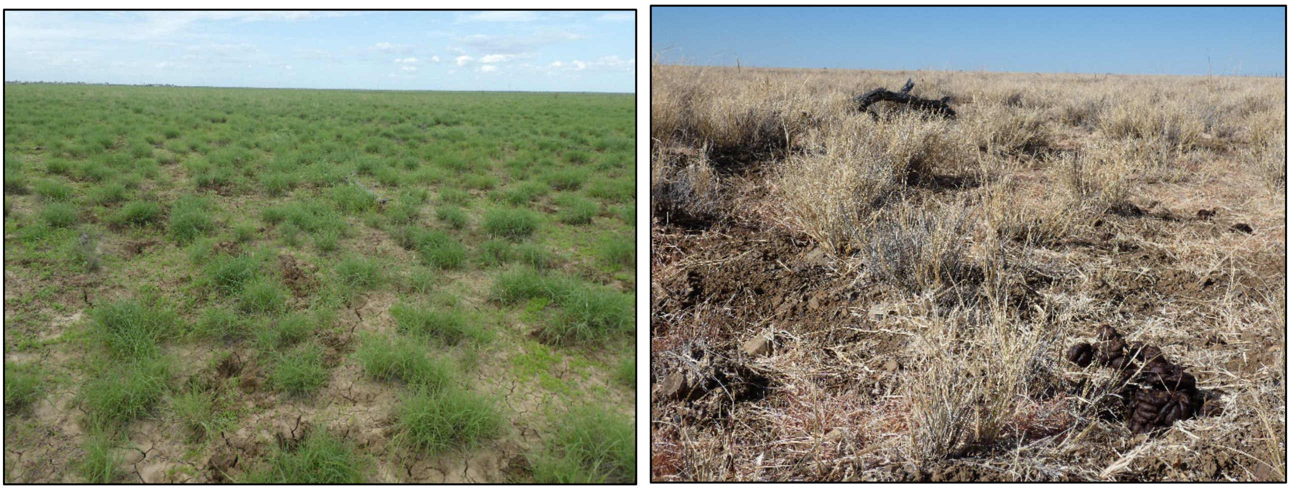

FIGURE 24. (A) GOOD MITCHELL GRASS TUSSOCK FLOOD SURVIVAL FROM EARLY SUMMER RAIN PRIOR TO THE FLOOD. (B) THE SAME SITE IN AUGUST 2020 AFTER GRAZING.

After the floodwaters receded, there was little or no follow-up rain to keep the Mitchell grass seedlings alive over most of the Downs, apart from some areas that received useful rain from Cyclone Trevor in late March 2019. This rain assisted a small percentage of seedlings to survive (Figure 25). However, in most areas all seedlings had died well before the 2019/2020 summer when useful rain was not received until late January 2020. The low rainfall also continued stress on the existing surviving tussocks.

FIGURE 25. A GRAZED SEEDLING IN 2020.

Surface soils eroded by the flood affected the survival of Mitchell grass tussocks by leaving the plants pedestalled and the rhizomes and fine roots drying out from sun exposure (Figure 26). There was a much higher rate of survival observed in pedestalled tussocks on the Gulf Plains than those on the Mitchell Grass Downs.

FIGURE 26. HEAVILY GRAZED TUSSOCKS WITH EXPOSED ROOTS AND RHIZOMES HAVE DIED ON THE DOWNS.

There was serious road and property infrastructure damage throughout the flooded zone in 2019. A typical example of gully erosion along a road and the current natural regeneration status of the new 'gully' after one summer is shown in Figure 27. The red surface colour after the flood was from sediment carried from red soils of the Cloncurry-Mt Isa uplands. This sediment had become incorporated into the soil surface over the next 18 months. At this site, the replacement road was moved upslope abandoning this location. Similar eroded effects occur along many creeks and will require a long period for natural regeneration and repair to occur.

A) B)

FIGURE 27. (A) A NEW GULLY AND SEVERE SHEET EROSION ALONG AN ORIGINAL ROAD IN 2019 (NOTE THE RED SOIL SURFACE SEDIMENT), AND (B) RECOVERY IN 2020. A NEW ROAD HAD BEEN GRADED UP-SLOPE. THE TREED CREEK IS DOWN-SLOPE TO THE RIGHT.

The reduced stock numbers and loss of infrastructure post-floods provided a management opportunity for recovery of the 3P grasses, especially the Mitchell grass species, across the Mitchell Grass Downs. It appeared that re-stocking occurred on some properties during the dry season of 2019 and continued into 2020, so plants in these areas did not get the opportunity to regenerate to their full extent. Delaying restocking followed by conservative stocking was recommended by DAF extension officers to provide tussocks with an opportunity to replenish reserves and produce a seed crop for future regeneration. Where restocking occurred during the dry season of 2019, it appeared that plants did not regenerate well on some properties, with pasture condition remaining in C condition through 2020.

3.2.3 2024 ASSESSMENT

In September 2024, 14% of the 72 surveyed sites were in A condition, 43% of the sites were in B condition, 40% of the sites were in C condition and 3% of the sites were in D condition (Figure 28).

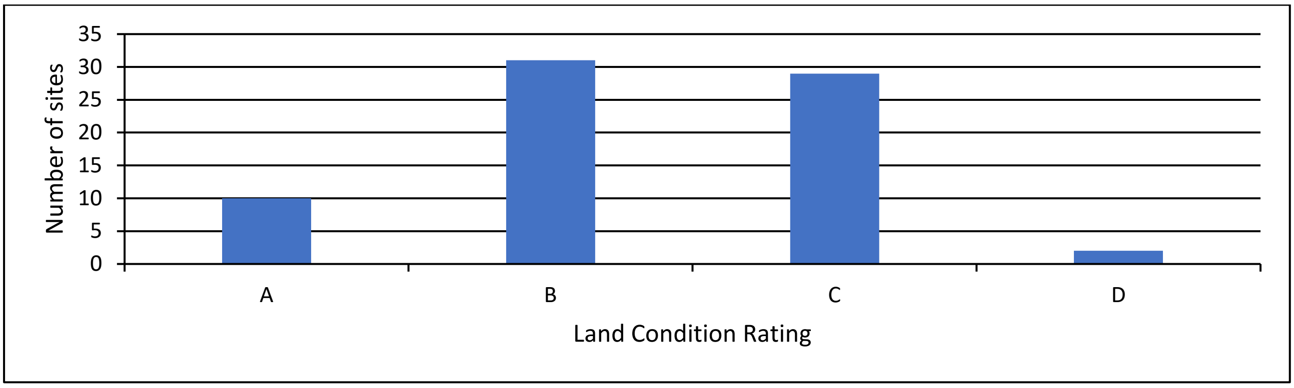

FIGURE 28. DISTRIBUTION OF LAND CONDITION RATING OF SITES SURVEYED IN 2024. NOTE THE 2024 SURVEY INCLUDED 10 SITES THAT WERE NOT SURVEYED IN 2019.

Out the 62 sites initially surveyed in 2019 and re-assessed in 2024, land condition improved at least one condition score at 30 sites (48%), remained at the same condition score at 29 sites (47%), and declined at least one condition score at 3 sites (5%) (Figure 29, Table 1 and 2).

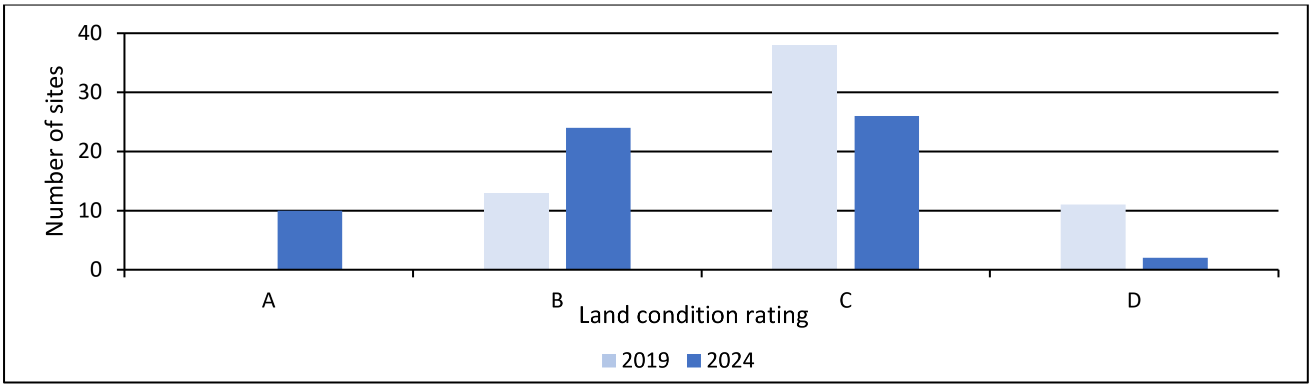

FIGURE 29. COMPARISON OF LAND CONDITION RATING OF SITES SURVEYED IN BOTH 2019 AND 2024.

TABLE 1. MATRIX SHOWING THE CHANGE IN LAND CONDITION RATING OF SITES ASSESSED IN 2019 AND 2024.

	2024					
	Class	**D**	**C**	**B**	**A**	**Total**
2019	**D**	1	3	7	0	11
	C	1	21	10	6	38
	B	0	2	7	4	13
	A	0	0	0	0	0
	Total	2	26	24	10	62

TABLE 2. MATRIX SHOWING THE CHANGE IN LAND CONDITION RATING OF SITES ASSESSED IN 2019 AND 2024 AS A PERCENTAGE.

	2024					
	Class	D	C	B	A	Total
2019	D	1.6	4.8	11.3	0.0	17.7
	C	1.6	33.9	16.1	9.7	61.3
	B	0.0	3.2	11.3	6.5	21.0
	A	0.0	0.0	0.0	0.0	0.0
	Total	3.2	41.9	38.7	16.1	100.0

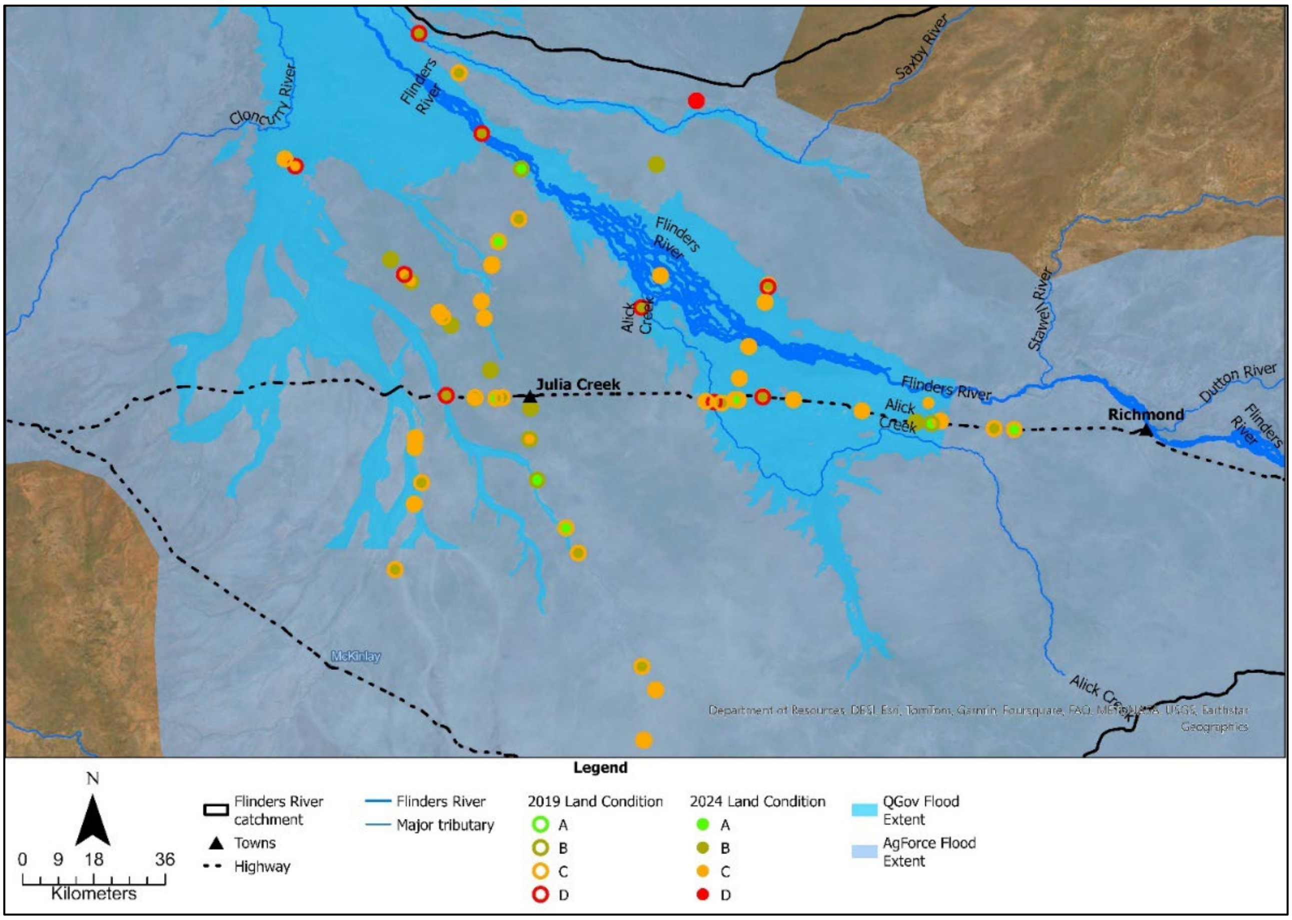

FIGURE 30. MAP SHOWING THE CHANGE IN LAND CONDITION RATING OF SITES SURVEYED IN BOTH 2019 AND 2024.

Across the surveyed Mitchell Grass Downs region, there are many areas that have improved in land condition (Figure 29, Table 1 and 2). The improvement in land condition is attributed to the implementation of strategic grazing land management supported by the occurrence of two recent years of above-average summer rainfall. There many examples of sites assessed to be in either C or D condition in 2019, improving to B condition in 2024 (Figure 31, 32, and 33). Despite considerable soil loss during the flood event, enough seed bank remained at these sites to stimulate pasture establishment.

FIGURE 31. DRONE IMAGE OF A SITE IN 2024 THAT IS IN A CONDITION. IN 2019, THE SITE WAS IN C CONDITION.

A) **B)**

FIGURE 32. ON-GROUND PHOTOS OF SITES IN B CONDITION IN 2024. THESE SITES WERE IN C CONDITION IN 2019.

A)

B)

FIGURE 33. (A) PHOTO OF A SITE THAT WAS IN D CONDITION IN 2019 WITH COMPLETE LOSS OF PASTURE COVER AND SERIOUS SCOURING. (B) IN 2024, THE SITE HAS RECOVERED TO B CONDITION WITH HIGH COVERAGE OF MITCHELL GRASS. NOTE THE 2024 PHOTO WAS TAKEN CLOSER TO THE TREE LINE THAT CAN BE SEEN IN THE 2019 PHOTO.

Despite receiving good summer rainfall over the past two years, some sites had not improved in condition and remained at C- or D condition (Figure 34). This suggests grazing has continued at levels above the carrying capacity of the land and/or that Mitchell grass germination and survival hasn't taken place for another reason (e.g., due to a lack of seed bank, soil chemical constraints inhibiting growth).

A)

B)

FIGURE 34. EXAMPLES OF SITES IN C- AND D CONDITION IN 2024.

After the flood, tussocks were exposed at many sites as a result of severe wash. In 2024, evidence of exposed tussocks still remains at most sites, although the tussocks seem to be in good health. At some sites, tussocks that were previously exposed are back to the level of the adjacent land. This is possibly due to the highly shrink/swell nature of the soils, coupled with cattle trampling and possibly small-scale (inter-tussock) runoff and sediment deposition dynamics. This was certainly not the case at all sites, with established tussocks remaining elevated several centimetres above the ground level (Figure 35). At some sites dead tussocks have remained pedestalled, indicating limited grazing since the flood, as cattle trampling would have broken off the old tussocks. There were some signs of new seedlings that germinated in 2024.

B)

FIGURE 35. PHOTO OF AN ALIVE TUSSOCK (LEFT) AND DEAD TUSSOCK (RIGHT) WITH RHIZOMES EXPOSED AS A RESULT OF SCOUR THAT LIKELY OCCURRED IN 2019.

The impact of the flood appeared to be more severe in lower parts of the naturally undulating landscape where flow depths, velocities and periods of inundation are likely to have been higher than on the more elevated parts. The flood impact also appeared to be more severe closer to the main drainage channels, creeks and the Flinders River. Evidence of severe erosion was still evident in places, particularly along fence lines (Figure 36), roads, and other compacted areas. It may take many years for these landscapes to recover naturally.

FIGURE 36. PHOTO OF A GULLY ALONG A FENCE LINE IN 2024.

The extent of Flinders grass coverage was highly variable. Some of the assessed paddocks had almost complete coverage of Flinders grass (Figure 37), other paddocks contained a mix of 3P grasses and Flinders grass, while other paddocks had none.

FIGURE 37. EXAMPLE OF A PADDOCK COMPLETELY COVERED IN FLINDERS GRASS.

Prickly Acacia (Figure 38) was common along drainage lines and in water holes including burrow pits. While providing shade for cattle, these areas are foci for the plant to grow and seeds to spread. Many areas had dead prickly acacia and some paddocks were completely clear, suggesting considerable effort has gone into control. Mimosa and Feathertop grass were scattered and sporadic in occurrence and neither appeared to be a major issue at present. A vast array of non-grasses and small herbaceous forbs were present throughout the region, particularly in degraded areas. The prevalence of these forbs was lower in areas with good coverage of 3P grasses.

FIGURE 38. PADDOCK WITH PRICKLY ACACIA.

Biocrusts were obvious on hard setting soils and in degraded areas (Figure 39). The occurrence of biocrusts was lower on softer self-mulching soil. Biocrusts provide several important functions including nitrogen cycling, improved infiltration capacity, and water retention properties.

FIGURE 39. CRYPTOGRAM IN AN INTER-TUSSOCK SPACE.

In late January 2024, the McKinlay and Kynuna area was impacted by a flood associated with the Cyclone Kirrily. The area received 400-live mm of rain in 48 hours, triggering widespread flooding. A detailed assessment of the impact of this flood on land condition was beyond the scope of this study, however a rapid assessment of land condition along the McKinlay-Gilliat road was completed. Piles of flood debris (mostly Sesbania) were evident in paddocks and on fence lines and the road was damaged in places (Figure 40). With the exception of main drainage lines, there did not appear to be widespread scouring, erosion or tussock death. It is likely the relatively good cover conditions prior to the event aided in minimising flood impacts.

A) B)

FIGURE 40. EVIDENCE OF 2024 FLOOD IN A DRAINAGE LINE (LEFT) AND FLOOD DEBRIS (RIGHT) IN THE MCKINLAY AREA.

4 DISCUSSION

4.1 INTERACTIONS AMONG DROUGHT, FLOOD AND GRAZING LAND MANAGEMENT

Across the Mitchell Grass Downs, a wide range of flood impact and recovery responses on land condition are evident as a result of the 2019 flood event. Sites closer to major drainage lines or in lower parts of the undulating landscape typically experienced more severe erosion, with considerable loss of topsoil and in some cases complete removal of established tussocks. In many areas, erosion around tussocks left roots exposed, contributing to plant death. There were also many areas where erosion occurred on one side of the tussock, while silt was deposited on the other side. Both erosion and silt deposition hindered plant growth. The 2019 flood event triggered a mass germination of Mitchell grass seedlings, however, after the floodwaters receded, there was little or no follow-up rain to keep the seedlings alive over most of the Downs. Leading into the flood event, where tussocks had been grazed to the soil surface or only 10 cm of basal stem remained, there was often nil or very little tussock recovery in 2019. However, where there was 20-30 cm of Mitchell grass stem stubble left, the initial recovery was often high. At some sites, land condition was poor (C or D) in 2019 and remained poor in 2024, while at other sites land condition improved one to two condition scores (Figure 41).

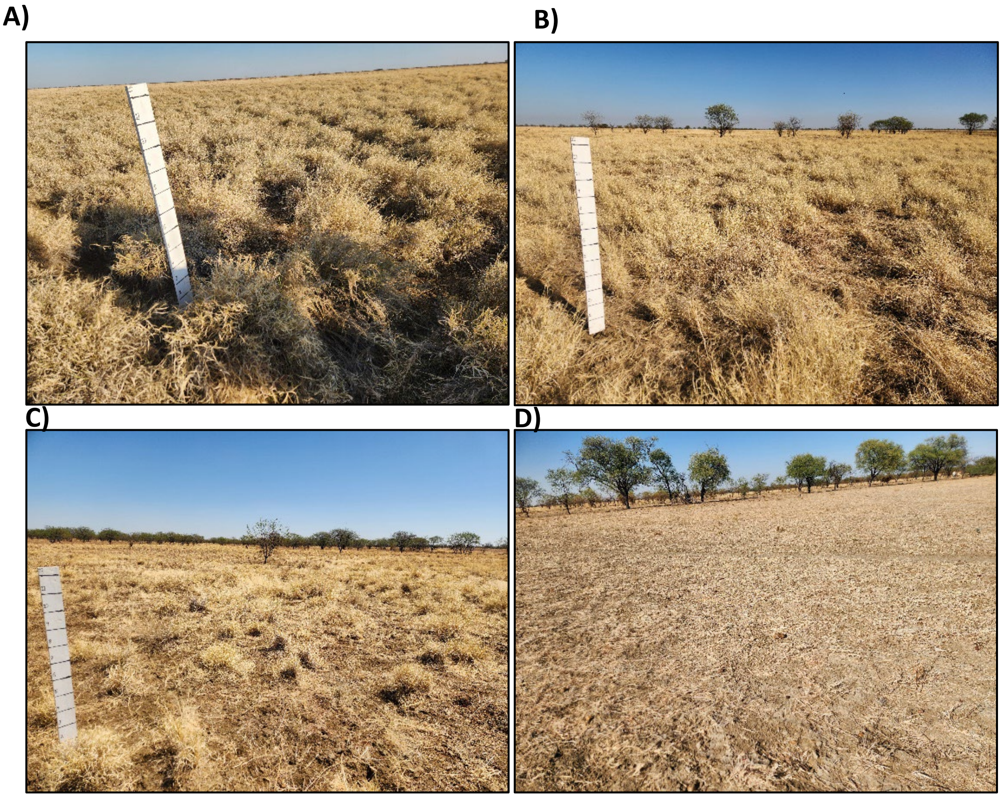

FIGURE 41. PHOTOS OF SITES IN 2024 ASSESSED TO BE IN: (A) A CONDITION; (B) B CONDITION; (C) C CONDITION; AND (D) D CONDITION.

Overall, the variable land condition impact and recovery observed across the Mitchell Grass Downs, can be linked to interactions among: (i) historical grazing management; (ii) the impact of the preceding long-term drought, combined with the influence of grazing management imposed during this drought; (iii) the hydrodynamics of the flood water; (iv) grazing management following the flood; and (v) climate conditions following the flood. Differences in soil type and related soil physical, chemical and biological properties, as well as available seed bank, are also likely to have affected the establishment and survival of perennial tussocks, however this was not evaluated in this study.

Hall (2020a) developed a simple conceptual model representing the interactions among drought, flood, grazing land management and land condition (Figure 42). Findings from the 2024 survey reinforce the basic principles behind the model. That is, land condition can be maintained and improved if supported by strategic grazing land management and reasonable rainfall during the summer growing season. Overgrazing coupled with a run of poor rainfall seasons can lead to a decline in grazing land condition. Land condition can, however, be improved, with careful grazing land management and good rainfall. If, however, overgrazing and/or poor rainfall continues, the land condition will continue to decline. It is at this point the land is at its most susceptible to severe impacts associated with flooding. If an extreme flood event occurs, the land may transition to a completely degraded state with high amounts of bare ground, annual grasses and weeds. It becomes increasingly difficult to return land to good condition once this state is reached. This conceptual model could be used to assist producers and land management extension staff to better understand the likely consequences of the interaction between management decisions and the climatic or seasonal conditions. This approach can be used in every paddock to determine why it is in its current condition state within the annual growth cycle, and what management is required to improve the condition of perennial grass tussocks and of the pasture as a whole.

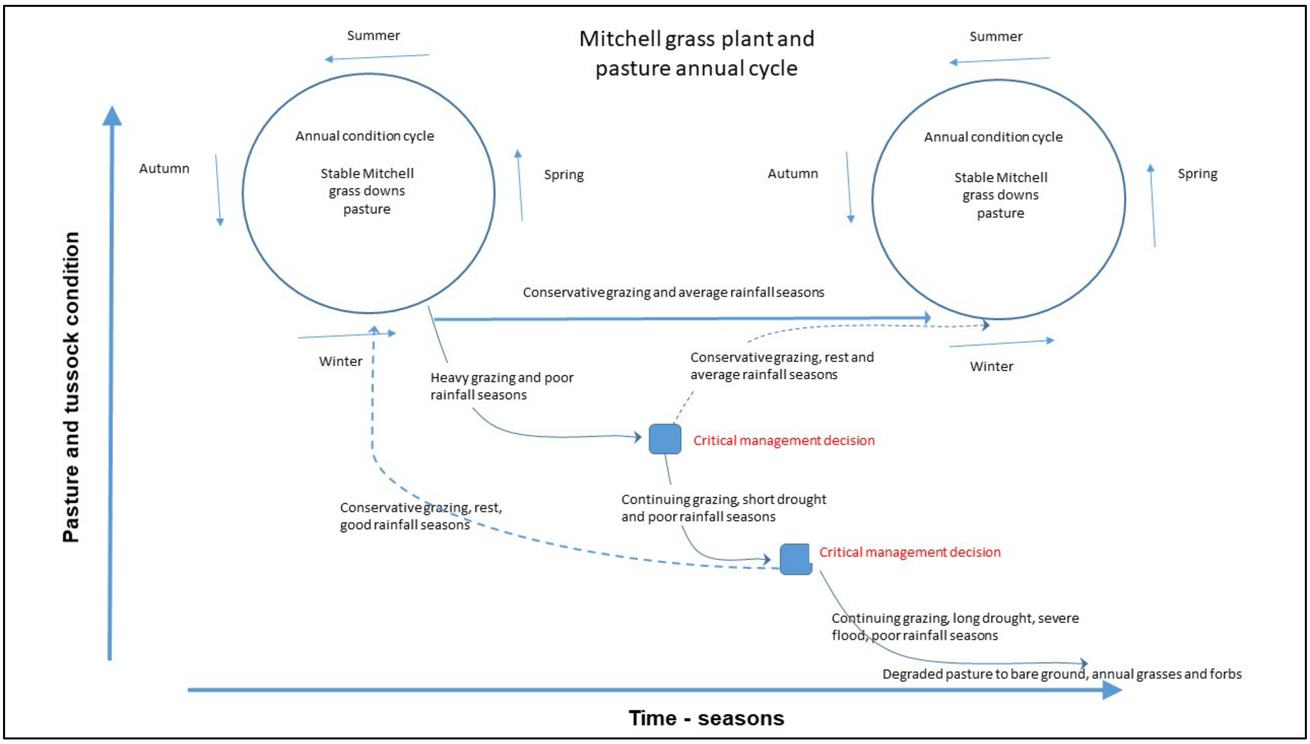

Figure 42. Mitchell Grass Downs pasture growth cycles model related to historical and current grazing pressure, resting, seasonal conditions, flooding, and critical management decision times to develop and maintain a stable and productive pasture. Source: Hall (2020a).

4.2 GENERAL MANAGEMENT ADVICE FOLLOWING FLOOD EVENTS

Results from this study indicate that land that is strategically managed to remain in good condition (A or B), is much more resilient to severe impacts associated with extreme weather events (both drought and floods) and recovers more quickly. A number of strategies can be implemented to achieve improved land condition before, during and after flood events (Future Beef, 2019; Phelps, 2012). Wet season spelling is important for pasture recovery especially after flood events; to be effective, stocking rates need to be carefully managed. For country that is badly damaged (e.g., has substantial erosion and tussock roots exposure), a full wet-season spell for successive years may be needed to allow existing tussock recovery and maximise seed setting to rebuild the soil seedbank. Grazing over the wet season should only be done in paddocks that have remained minimally effected during the flood. For country where tussocks are recovering, spell at least until the pasture is “ahead of the cattle”. In other words, when the grasses will hold their own when cattle are introduced. Manage and move livestock based on pasture availability. Establish pasture monitoring points that are easily accessible and monitor seedling and tussock development regularly. Undertake forage budgeting and understand short- and long-term carrying capacities. When stocking rates are too high, animal performance generally declines, and overall production is impacted. Leave a minimum of 15-20 cm residual grass stubble height at the end of the dry season for optimum plant health and to enable a quick response following rain. Severely degraded surfaces in D condition may require mechanical rehabilitation options with introduced pasture seed sowing.

4.3 FUTURE RESEARCH

The site data from the 2019, 2020 and 2024 surveys have been recorded and GPS locations identified. Continued monitoring at these and other sites into the future will enable a long-term assessment of pasture recovery following extreme weather events, and accounting for seasonal fluctuations in weather conditions. Further work is needed to better understand the role that soil type and related soil physical, chemical and biological properties, as well as available seed bank soil, has in influencing both the impact of flooding, and recovery after the event. Similarly, further work is also need to better model and understand the hydrodynamics of floodwater in low-gradient, multi-channel system such as the Flinders River catchment. In 2024, drone images were collected from each assessment site, providing high resolution orthophoto mosaics covering an area of 1-3 ha. These mosaics, in combination with on-ground land condition assessment data, could be used to ground-truth and validate satellite-based assessments of ground cover and land condition. It is critical that we continue to improve understanding of the linkages among drought, floods, grazing land management and land condition. This will assist producers to build resilience in their production systems to the occurrence of extreme weather events.

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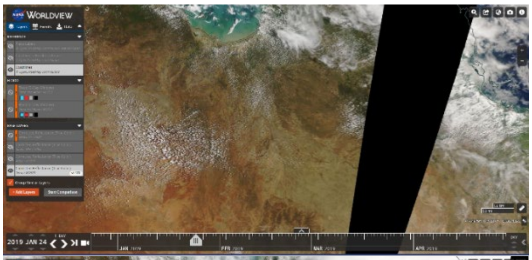
6 APPENDICES

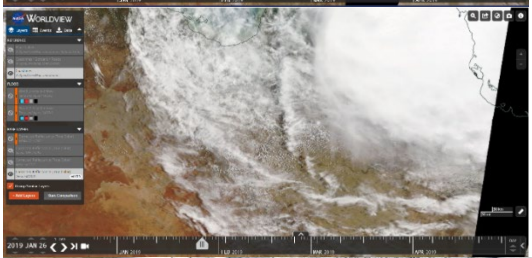
6.1 APPENDIX 1: TIMESERIES OF MODIS IMAGERY FROM THE 24 JANUARY TO THE 12 FEBRUARY 2019.

Source: NASA (2024).

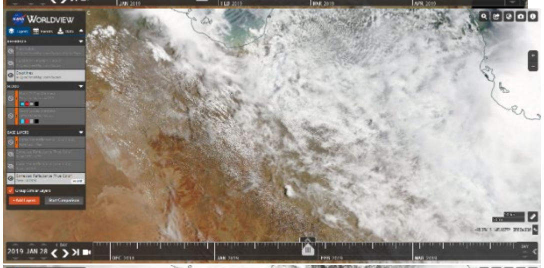
24 Jan



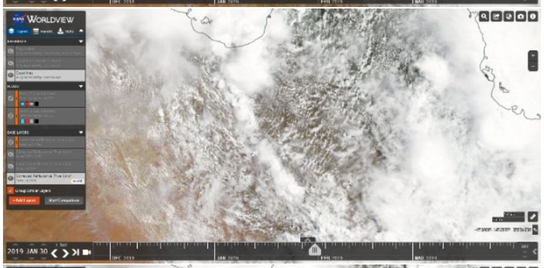
26 Jan



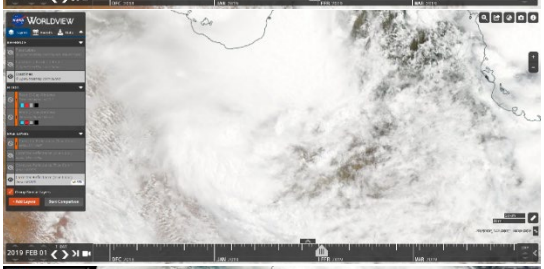
28 Jan



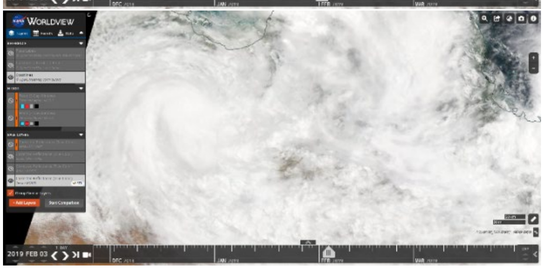
30 Jan



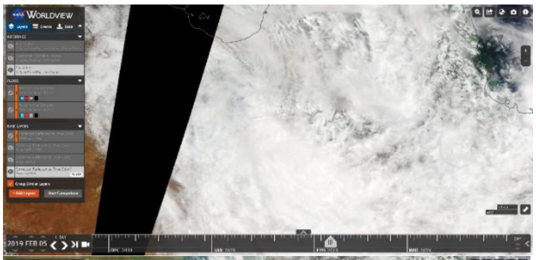
1 Feb



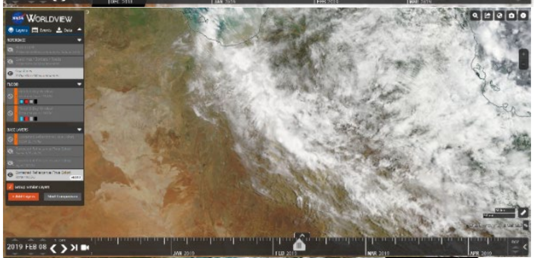
3 Feb



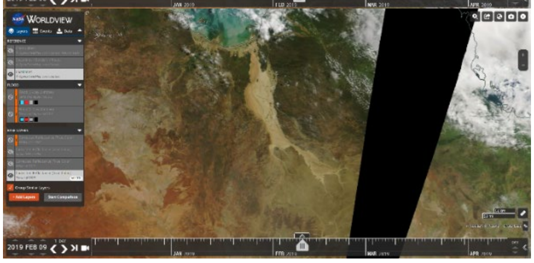
5 Feb



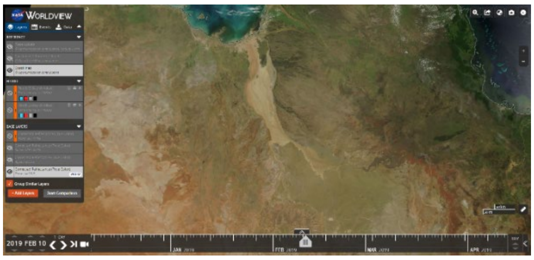
8 Feb



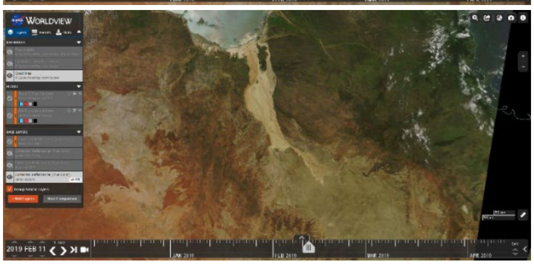
9 Feb



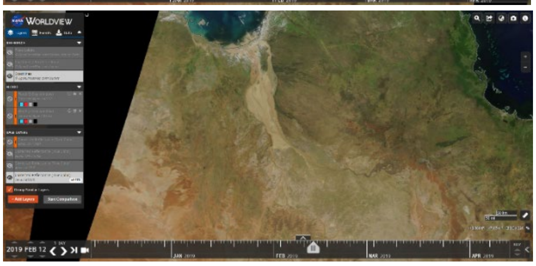
10 Feb



11 Feb

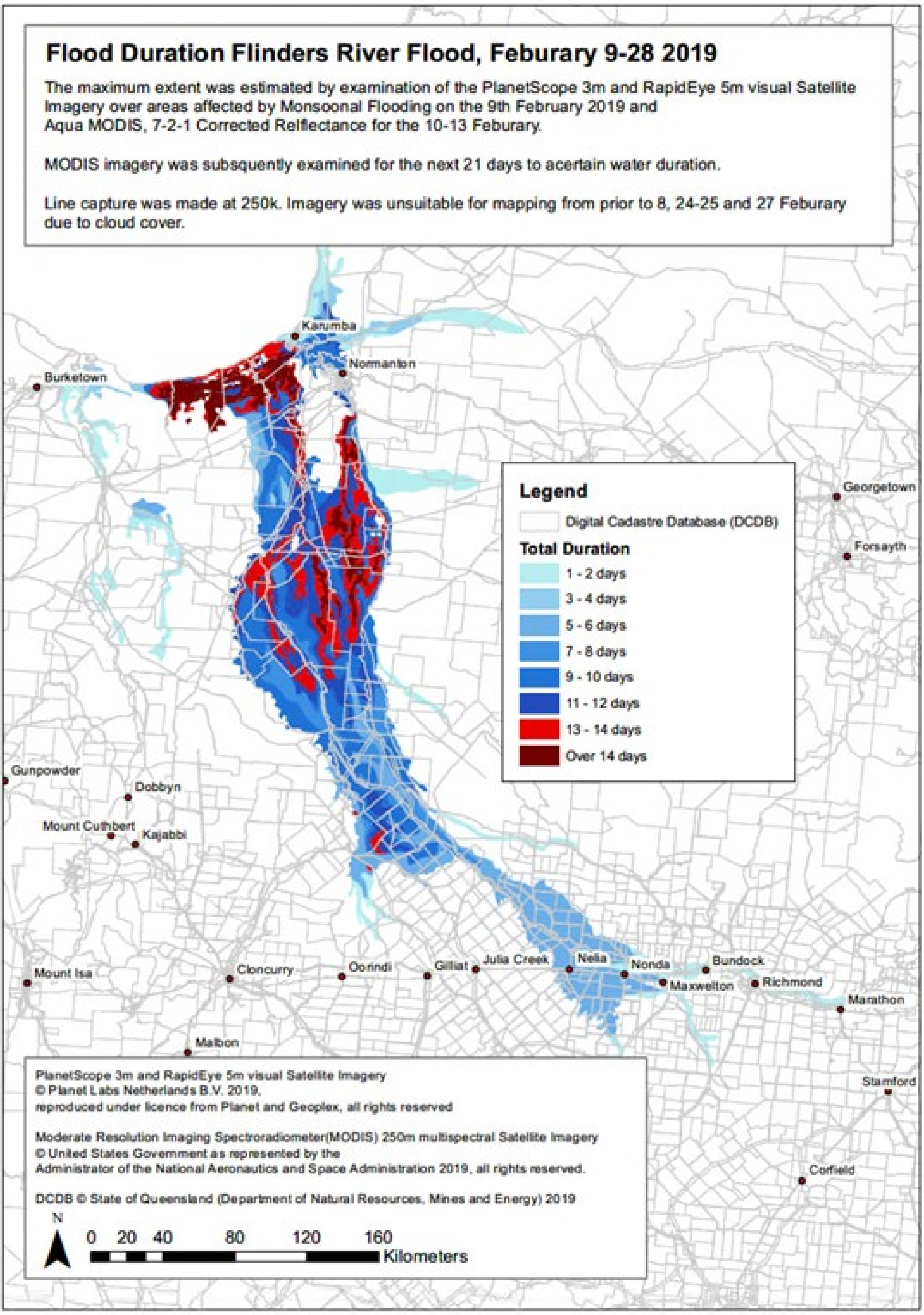


12 Feb



6.2 APPENDIX 2: FLOOD DURATION OF THE FLINDERS RIVER FLOOD, FEBRUARY 9-28, 2019.

Source: State of Queensland (2019b).



6.3 APPENDIX 3. FIELD PRO FORMA USED TO RECORD SITE DATA

Date: ________________ **Time:** ________ ***Operator(s)*:** ________________________ *Page No:*_______

Waypoint No: **GPS:** ^{0}*S* ^{0}*E*; **Elevation:** *m*

Site Location:

Property & Paddock:

Photo numbers: ☐ Landscape ☐ Into quadrat

Land condition: Rating: **+ A -- + B -- + C -- + D --** *(circle response)*

Soil condition: Rating: **1 2 3 4 5**

Ground cover (%): **Grass litter %:** **Tree litter %:** **Soil moisture depth:** *cm*

Soil surface/Erosion comments:

Pasture condition: Rating: **1 2 3 4 5**

***3P* tussocks responding:** 0% 1-10% 10-20% 20-50% 50-80% >80% (%)
0 1 2 3 4 5

Response - individual tussocks: weak moderate strong (%)
1 2 3

3P Tussock death %: **Stem height (grazed):** *cm*

DM yield (regrowth after event): *kg/ha* **Total DM Yield:** *kg/ha*

Dead stem %: *Dead leaf %:* *Green stem %:* *Green leaf %:*

Dominant pasture species (specify seedlings):

. . .
. . .

Other species:

. . .
. . .
. . .

Dominant seedlings:

. .
. .

3P seedlings species:

. . .

3P seedlings density: zero low medium high
0 1 2 3

Observations:

.
.
.
.

6.4 APPENDIX 4. LAND, PASTURE AND SOIL CONDITION RATING CRITERIA

OVERALL LAND CONDITION RATING CRITERIA

Category	A	B	C	D
3P grass (%)	>75	45-75	10-45	<10
Weeds	Basically none	Very few	Some	Obvious
Soil condition	Good	Some decline	Obvious erosion	Severe erosion
Productive capacity	100	75-85	45	20

PASTURE CONDITION RATING CRITERIA

Condition rating	**Condition indicators**				
	3P grasses		**Annual grass dry matter yield (%)**	**Undesirable pasture dry matter yield (%)**	**Weeds**
	% frequency	Healthy Mitchell grass tussock density			
1	>75	1 pace between tussocks (2-3 tussocks per m^2)	< 20	<20	None or very few
2	50-75	2-5 paces between tussocks (1 tussocks per 3-20 m^2)	20-40	20-30	Very few
3	10-50	>5-25 paces between tussocks (1 tussock per 20 – 500 m^2)	40-70	30-80	Some
4	<10	30-60 paces between tussocks (1 tussock per 900 – 3000 m^2)	>70	>80	Obvious
5	<1				

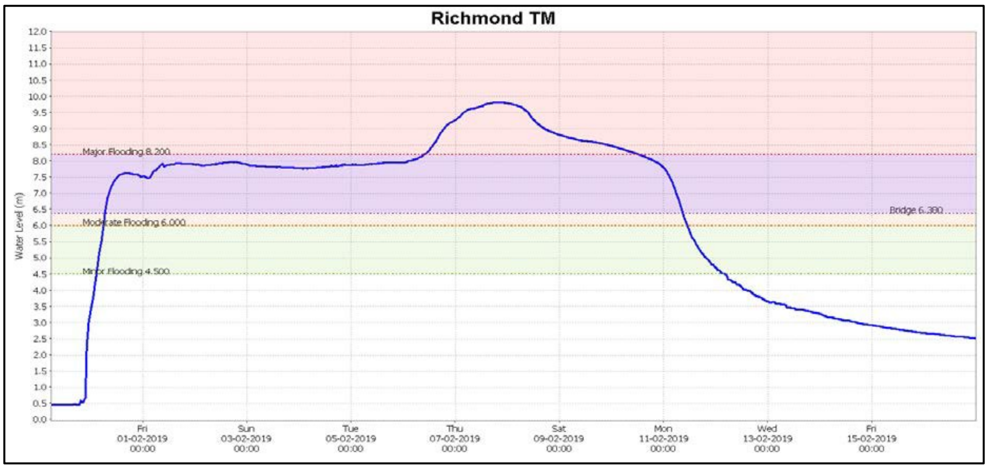
SOIL CONDITION RATING CRITERIA

Surface description	Rating
Stable	1
Slight disturbance	2
Moderate disturbance	3
Severe disturbance	4
Very sever disturbance	5

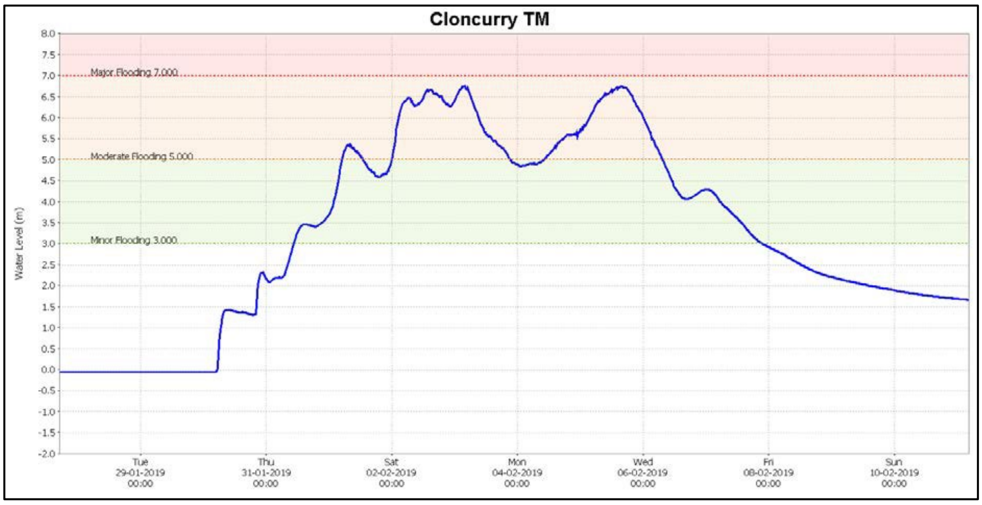
6.5 APPENDIX 5. HYDROGRAPH OF THE FLINDERS RIVER AT RICHMOND, JULIA CREEK, AND CLONCURRY

Source: BOM (2019).

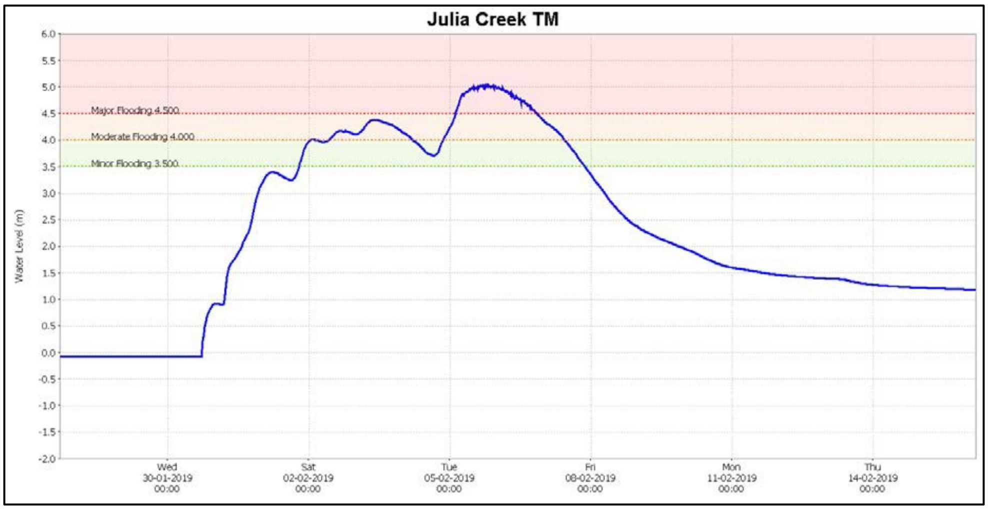
A)



B)



C)



6.6 APPENDIX 6. PASTURE AND FORB SPECIES RECORDED DURING THE 2019 LAND CONDITION ASSESSMENT

Source: Hall (2020b).

Dominant pasture species
Astrebla pectinata (Mitchell grass - barley)
Astrebla squarrosa (Mitchell grass - bull)
Astrebla lappacea (Mitchell grass - curly)
Astrebla elymoides (Mitchell grass - hoop)
Cenchrus ciliaris (buffel)
Cenchrus pennisetiformis (Cloncurry buffel)
Chrysopogon fallax (golden beard, ribbon grass)
Dichanthium fecundum (gulf bluegrass)
Eulalia aurea (silky browntop)
Other pasture / forb species
Acacia nilotica (prickly acacia)
Aerva javanica (kapok bush)
Alternanthera nana (joy weed)
*Alysicarpus rugosus (*chain pea)
Amaranthus mitchellii (boggabri)
Aristida latifolia (feathertop)
Aristida pruinosa (northern wiregrass)
Boerhavia paludosa (roly poly tar vine)
Boerhavia schomburgkiana (flat tar vine)
Bothriochloa bladhii (forest bluegrass)
Bothriochloa ewartiana (desert bluegrass)
Brachyachne convergens (native couch)
Brachiaria piligera
Bulbine sp. (native leek)
Calotropis procera (calotrope)
Cenchrus setiger (Birdwood)
Chenopodium auricomum (bluebush)
Chionachne hubbardiana (summer grass)
Chloris spp.
Cleome viscosa (tick weed)
Commelina sp. (wandering jew)
Convolvulaceae spp.
Corchorus pascuorum (native jute)
Crinum flaccidum (Murray Valley lily)
Crotalaria dissitiflora (grey rattlepod)
Crotalaria medicaginea (round-pod rattlepod)
Cucumis melo (native cucumber)
Cullen cinereum (native lucerne) (ex. *Psoralea*)
Cyperus spp. (nut grass -sedge) *C. gilesii*
Dactyloctenium radulans (button grass)
Desmodium spp. (native legume)
Digitaria brownii
Echinochloa colona
Eragrostis spp. (love grasses)
Eriochloa sp. (cup grass)
Euphorbia drummondii (caustic weed)
Fimbristylis spp. (sedge)
Flemingia pauciflora (native legume)

Other pasture / forb species (continued)
Glycine falcata (native legume)
Gomphrena conica
Goodenia falcata
Goodenia fascicularis
Hibiscus trionum
Indigastrum parviflora (indigofera)
Ipomoea polymorpha (cow vine - purple)
Ipomoea diamantinensis
Ipomoea lonchophylla (cow vine)
Iseilema sp. (Flinders grass)
Josephinia eugeniae (Josephinia burr)
Malvaceae spp.
Marsilea spp. (nardoo)
Merremia dissecta
Neptunia gracilis (low sensitive)
Neptunia monosperma (tall sensitive)
Ocimum tenuiflorum (native thyme)
Operculina aequisepala (paper rose)
*Oryza australiensis /Xerochloa imberbis (*rice grass)
Panicum decompositum (blow-away grass)
Pennisetum basedowii (asbestos grass)
Perotis rara (comet grass)
Phyllanthus maderaspatensis (spurge)
Polymeria longifolia
Portulaca oleracea (pigweed)
Ptilotus spicata
Pumalina sp.
Rhynchosia minima (native legume)
Rostellularia adscendens (purple pipe cleaner)
Sesbania brachycarpa (purple Sesbania pea)
Sida spp.
Solanum esuriale (potato bush)
Solanum nigrum
Sporobolus mitchellii (rat's tail couch)
Sporobolus actinocladus (katoora)
Streptoglossa adscendens (mint bush)
Stylosanthes spp. (Seca, Amiga, Verano)
Swainsona campylantha (gilgai Darling pea)
Tephrosia spp. (native legume)
Trianachne spp.
Trichodesma zeylanicum (blue flower)
Trianthema triquetra (red spinach)
Tribulus sp. (goat head burr)
Triodia pungens (soft spinifex)
Vigna spp. (native legume)
Xanthium occidentale(Noogoora burr)
Xerochloa imberbis (northern rice grass)