Pasture recovery, land condition and some other observations after the monsoon flooding, chill event in north-west Queensland in Jan-Mar 2019

Cattle survivors on the Balbirini Plains, 'Magoura', south of Normanton

Report prepared by Trevor J Hall
with field recording assistance by Jenny Milson and Cristine Hall

Department of Agriculture and Fisheries

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This publication has been compiled by Trevor Hall of the Queensland Department of Agriculture and Fisheries with field recording assistance from Jenny Milson of the Queensland Department of Agriculture and Fisheries and Cristine Hall.

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Executive Summary

Monsoonal flooding rains to 800 mm across north-west Queensland during late January and early February 2019 resulted in the inundation of hundreds of thousands of hectares of grazing land. Pastures of the Mitchell Grass Downs and the Gulf Plains that support cattle production were impacted by the rain event, and particularly so, because the land had just suffered a prolonged drought of 5-7 years. An area of some 13M hectares were affected and an estimated 0.5M head of cattle were lost from cold, wet wind exposure and flooding. The immediate post-flood assessment, of pasture reported in this document, is a record that informs agricultural practices and forms an historical baseline, for future research of ways to better understand and implement best management practices, in the tropical landscape of north-west Queensland in northern Australia.

Selected field sites (130) were inspected within the first three weeks after the floodwaters had receded. This pasture and soil surface survey was limited to sites along highways and main formed inter-property roads or tracks in the Winton, Kynuna, Cloncurry, Normanton, Julia Creek and Richmond regions. Recording was in late February and early March of 2019. These regions are on three broad land types; Mitchell Grass Downs, Southern Gulf Plains and the Northern Gulf Plains (Balbirini land system). These GPS located sites can be used for future assessment of grass tussock regeneration and seedling establishment, across the various degrees of flood impact over the Downs and Plains.

The flood had a wide range of effects on the land surface and pastures. The impact on land surfaces was generally detrimental in the short-term. However, the effects on the pastures will be generally beneficial to a droughted landscape, albeit with highly uneven responses, mainly due to the undulating landscape and the subsequent various depths and periods of inundation. Properties with prolonged and deep flooding will take some years to recover reasonable pasture condition. Most of the floodwaters flowed from south to north with variation of cross-flow from east to west away from major rivers. Thus, topsoils in some locations were eroded over 1.5 m deep, and elsewhere silt and debris were deposited in various directions to 1 m deep near water course systems. At some sites, the water remained in hollows for prolonged periods of over 14 days, killing all grass tussocks.

The impact of the rain and flood on pasture recovery across the Mitchell Grass Downs, covered the full range from; (i) no original pasture plants left to regrow; (ii) dead plants with no sign of recovery; (iii) slight recovery from a small percentage of tussocks with a few new tillers and seedlings emerging; and (iv) all tussocks remaining alive and producing a full crop of tillers going to seed. The widespread Mitchell grass seedling emergence, a rare event, has the potential to produce good Mitchell grass pastures in the next couple of years, providing there are suitable follow-up climatic conditions and landholders conduct recommended, conservative, grazing management practices. Delaying grazing for the remainder of the 2019 summer and lenient future grazing will be required over the next year or longer to achieve this potential. Curly Mitchell (*Astrebla lappacea*) seedlings were most widespread, with significant areas having bull Mitchell (*A. squarrosa*) seedlings. Other areas, particularly in the north of the Downs and on the Gulf Plains, hoop Mitchell (*A. elymoides*) and some barley Mitchell (*A. pectinata*) grass seedlings were present. This may be a once in a several decade's opportunity to get these Mitchell grass pastures back into their known productive capacity.

The flood impact on the Gulf Plains pastures was initially severe and surface sheet erosion between tussocks was widespread. However, the 3P grasses that dominate these pastures when in good condition are more able to tolerate short-term inundation than pasture species on the Downs, and they will recover well with normal seasons over the next couple of years. Also with the proviso that appropriate conservative grazing management is applied during this early tussock recovery phase, and future rainfall is adequate.

The main species to monitor for recovery on these plains are Gulf bluegrass (*Dichanthium fecundum*), silky browntop (*Eulalia aurea*), bull and hoop Mitchell grasses, and ribbon or golden beard grass (*Chrysopogon fallax*). Spread or increase of undesirable grasses such as feathertop (*Aristida latifolia*) or asbestos grass (*Pennisetum basedowii*) is of concern for long-term productivity of the Plains. Forb weeds will be more prevalent throughout the flood zone this year, and probably for the next couple of years, and undesirable tree seed spread from the flood, will require treatment in the first few years to prevent further expansion of the woody weed populations that has occurred across the Gulf Plains over the last four decades.

The main grazing management recommendation for both the Mitchell Grass Downs and the Gulf Plains is to delay restocking until the new seedlings become established and surviving tussocks have produced new tillers and starting to set seed. Then continue conservative grazing into the next one or two summers. Forage budgeting and monitoring, both the condition of the cattle and pastures to retain at least 20 cm of basal stem height, will produce best long-term results. However, to achieve long-term pasture benefits, short-term financial pressures for landholders may need to be managed effectively. For some producers, financial viability may be a critical issue in the short-term and land/pasture management may not take into full consideration the requirements of the new Mitchell grass seedlings and the new tillers on old tussocks. To achieve long-term optimal pasture benefits, such short-term financial pressures will need to be managed.

The DAF pastures teams at Longreach, Charters Towers and Mareeba are well-positioned to provide advice on the timing and level of grazing management of the re-establishing flooded pastures, advisors are available also for financial management advice. The factsheet on the management of Mitchell Grass Downs after this flood and the abnormal rainfall event has been prepared and is available on the DAF FutureBeef web site. The aim of land and pasture management, is to allow the new grass seedlings and tillers to develop and produce long-term productive pastures with their full potential for the environment.

Climatic conditions

Mitchell Grass Downs near Julia Creek started the summer with useful rainfall events from October to December (82 mm), which started new growth on Mitchell grass tussocks that retained some 20 cm of basal stem. This early summer rainfall was not universal, but was followed by 102 mm in the last three days of January and 482 mm in the first week of February (***Table 1***).

Table 1. *Rainfall (mm) at Julia Creek airport between 1 October 2018 and 23 March 2019*

Julia Creek Rainfall	
Month	mm
Oct-2018	11
Nov-2018	66
Dec-2018	5
Jan-2019	105
Feb-2019	482
Mar-2019	0
Total	669

This extended wet period, which included four days of abnormally strong and cold winds with continuous rain, caused huge stock and native animal losses through exposure, across the southern and central flood zone. The droughted pastures did not allow the cattle to build up condition before the rain commenced, so the poor-conditioned cattle could not withstand the wet, cold and bogging conditions across the open clay soil Downs. One property reported that they had been feeding grass hay and cottonseed to some of their herd prior to the rain and that these Brahman cross cattle, including pregnant cows, survived much better than un-supplemented growing white Brahman cattle in a nearby paddock. The rain prior to the flood rains near Julia Creek produced new tussock growth, and these properties had rapid recovery of their Mitchell grass pastures. Plants were a healthy deep green colour and were producing seed heads by the start of March.

The duration of flooding has been mapped in periods of four days, up to 20 days, inundation by the Queensland Departments of Natural Resources, Mines and Energy/Environment and Science. Most of the area between Winton, Hughenden and Cloncurry received from 1-4 days flooding. The longer periods of flooding occurred from Nelia-Nonda along the Flinders River to the Gulf of Carpentaria. Some of the coastal marine plains received up to 20 days inundation and in early March, were still covered in water at the time of our visit. The pastures around the perimeter of the flood zone benefited from the monsoon event, by receiving well above average rainfall without the damaging flooding. Cattle losses from exposure still occurred in some areas well outside the flood zone.

Land condition and pasture assessment

Recording sites and locations

Field pasture inspections at 130 sites were completed over a period of 16 days, between 20 February and 4 March 2019. 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, the Gulf Plains are overseen by the Northern Gulf and Southern Gulf Natural Resource Management groups. Only roads that had been cleared of dead cattle, silt and debris were travelled. Checking country between the road systems was not possible by surface travel. A map of the land management regions of north-west Queensland are shown in ***Figure 1*** and the main roads traversed are shown in ***Figure 2***. Inter-property road sides inspected are not depicted.

Figure 1. *Mitchell Grass Downs, Southern Gulf and Northern Gulf land management areas in north-west Queensland impacted by the 2019 monsoon flood event.*

The landscapes inspected were near roads from:

- Winton to Kynuna to Julia Creek;
- Gilliat to McKinlay to Kynuna;
- Julia Creek to Burke and Wills to Normanton to Karumba;
- Burke and Wills to Cloncurry;
- Cloncurry to Julia Creek;
- North from Julia Creek along Taldora road to Millungera Station;
- Julia Creek along the Punchbowl road to Debella Station;
- Julia Creek to Richmond;
- Richmond to Cambridge crossing;
- Maxwelton to Bunda Bunda Station to Nelia;
- Richmond to Hughenden; and
- Hughenden to Muttaburra.

These roads are mainly in the land systems of the Mitchell Grass Downs in the south and across the Gulf Plains in the north. These Plains south of Normanton, sometimes known as the Wondoola Plains of the Balbirini Land System, received deep and unprecedented flooding. At Walkers Bend of the Flinders River the flood was about 1m higher than the 1974 flood, however, that flood was more extensive in this northern area and it caused more damage in the forests of the Mayvale land system to the north-east. This region generally was not affected seriously by this monsoon system. The survey area crossed five Local Government Shires of Queensland: McKinlay, Cloncurry, Carpentaria, Richmond and Hughenden.

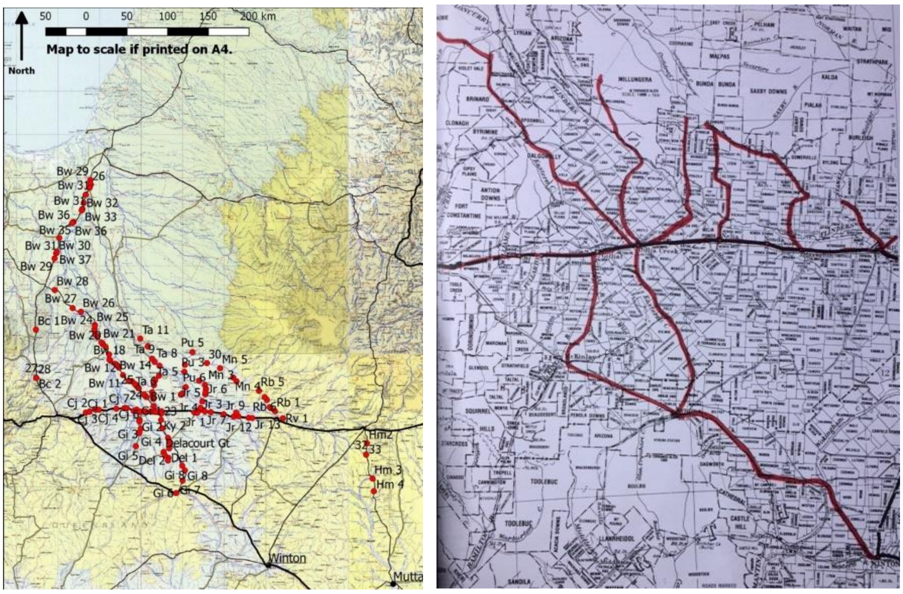

Figure 2a, 2b. *(a) Location and identification number of pasture recording sites, and (b) Map of main roads inspected in the Julia Creek and Richmond 2019 flood zone. Other roads inspected include: Cloncurry to Burke & Wills to Normanton to Karumba highways.*

The extent of the flood zone was from Winton to Hughenden to Cloncurry and north to Normanton and the Karumba marine plains and is shown on a satellite image pair: before flooding, 7 January 2019, and after flooding, 10 February 2019, ***(Figure 3).***

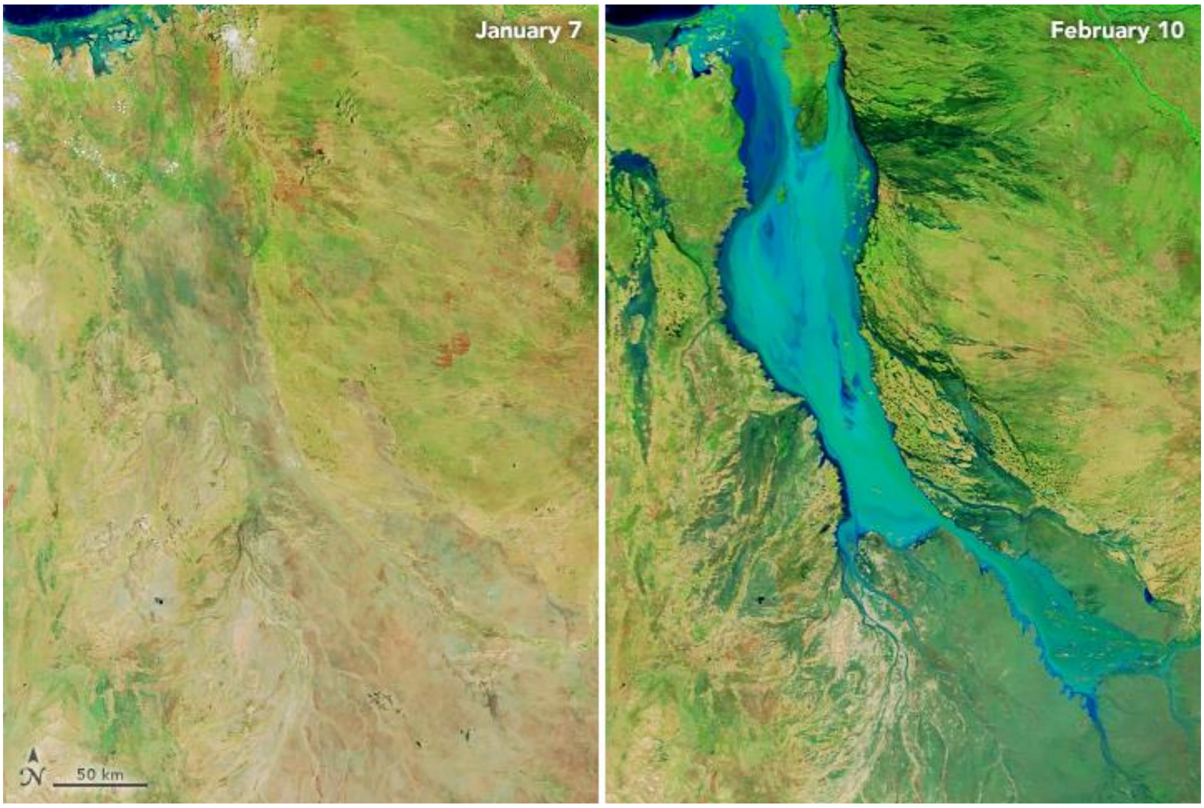

Figure 3a, 3b. *Images of the flood zone in NW Queensland (a) before on January 7, and (b) after the monsoon trough rain event on February 10 2019 (from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite).*

A satellite image of the main monsoon flood zone, including the deep water damaged areas and the high rainfall affected surrounding areas, was published by AgForce on 10 February 2019 ***(Figure 4).*** This image shows the approximate 13 250 000 hectare extent of these zones affected by the monsoon rain event.

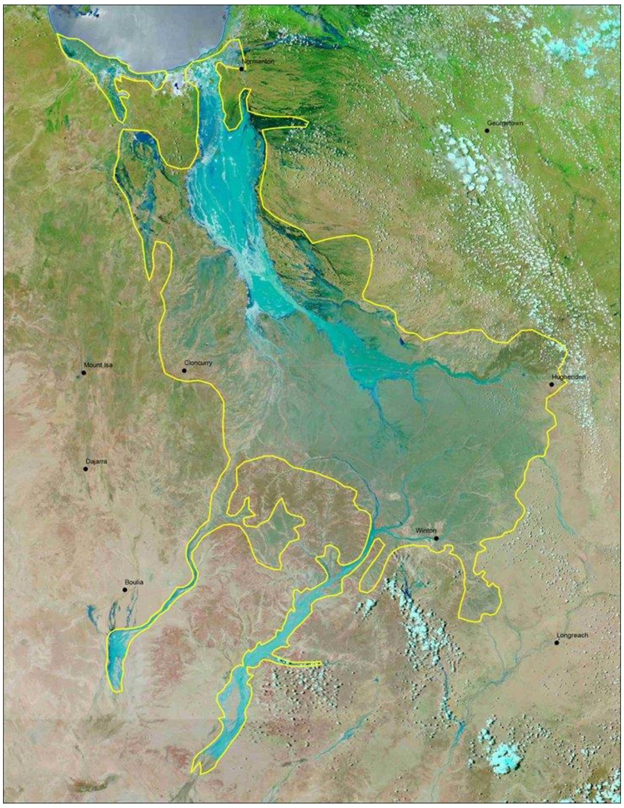

Figure 4. *An image of the extent of the flood and high rainfall affected areas of 13M hectares (AgForce 10 Feb. 2019).*

A detailed assessment of the land between the roads traversed will require satellite imagery analysis and at this time will require helicopter travel to check the most affected areas indicated from the imagery. Personnel from the Australian Army conducted aerial filming of transects along the main highways, which gives some indication of initial vegetation recovery and soil cover, as well as the extent of infrastructure damage and cattle losses ***(Figure 5)***. I was advised that the Army staff photographed the flooded landscape whilst flying helicopters across the region delivering hay to stranded cattle. However, these photographs have not been available to DAF. A photograph selection is included in this report (Appendix 2) and other photos are included in a DAF directory specifically for flood zone photographs. Photographs were taken at all detailed sites recorded and at most minor sites inspected.

Figure 5. *Example of Army imagery showing infrastructure damage, pasture cover and cattle deaths (Richmond to Winton road, Feb. 2019).*

This abnormal cyclonic monsoonal rain event and flooding occurred after six to seven years of severe drought that had decimated much of the pastures in the southern areas of the survey zone. At the time of inspection, the floodwaters had largely receded except in original swamps and across the marine plains. These still had vast expanses of shallow water supporting huge flocks of water birds, including pelican flocks. All major rivers and creeks were still flowing and bridges became passable as the inspection time passed, and the highway east of Julia Creek was re-opened near the end of the inspection time. The flood waters washed across the Downs between creek lines, at times, at right angles to the normal flow along the creek lines ***(Figure 6)***.

Figure 6. *Surface erosion across the Downs at right angles to the local creek line.*

Cattle deaths from exposure

As the flood waters receded and monsoon conditions abated, the first observations, very depressing for all concerned, were of the dead cattle spread across the landscape as well as literally in piles on fence lines and in fence corners. The locals said there was four days of exceptionally cold and severe winds with constant rain during the monsoonal period. A Chill Index Map produced by the Department of Environment and Science following the event offers insight to not only the extent of the chill event but also its severity, centred on the flood affected area ***(Figure 7)***. This extended exposure to rain and cold winds, was the cause of the cattle deaths across the Downs ***(Figure 8)***. Cattle body condition was low from the drought and the usual end of the dry season meant the bogging in the clay soils also sapped any energy reserves, exacerbating the effects of the strong cold wet winds. However, even in open woodlands, on harder red earth soil country, many cattle also died from exposure during this time. It is estimated that about half a million head of cattle were lost in the flood and chill event in addition to significant losses of sheep. The impact on native wildlife was not quantified, but the numbers are thought to be much more than the losses suffered in livestock.

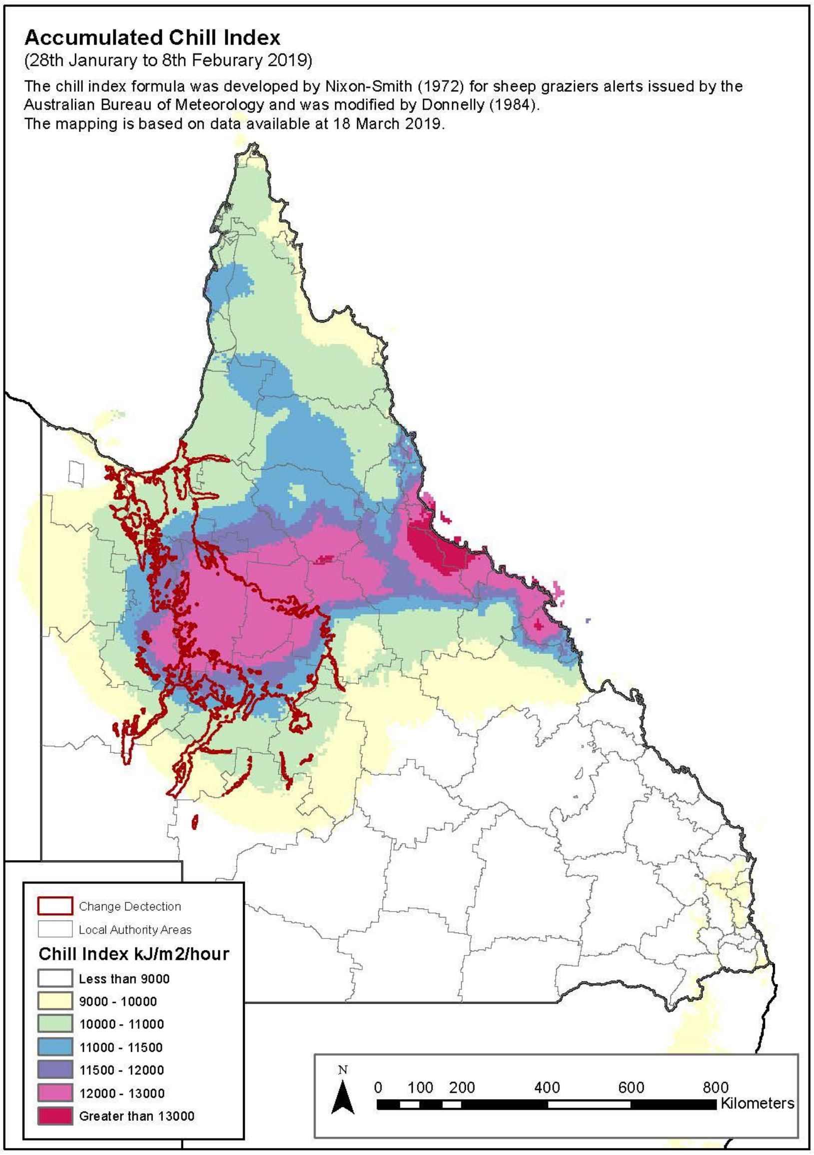

Figure 7. *Accumulated Chill Index for Northwest Queensland over the period 28 January to 8 February 2019. Source Department of Environment and Science, Queensland Government.*

Figure 8. *Typical example of white Brahman cattle deaths from exposure across the Downs.*

There was no escaping from the cold wind and rain and cattle and native animals moved to the highest ground, including onto the banks of dams and turkey nests, and around sheds, both inside and outside, and in fence corners ***(Figure 9)***, but there was no escaping the effects of exposure.

Figure 9a, 9b. *Cattle died of exposure across the landscape (a) Cattle accumulated on dam and turkey nest banks to escape flood waters, and (b) mobs accumulated along fences and in fence corners, but still died in such locations.*

Site recording system

Initially, the recordings were descriptive notes of different flood effects with the aim of covering as many land types along as many roads as practical. A GPS point location was recorded at some of these sites. As the pasture established and grew over the weeks, a more formal selected-site recording system was developed, based on a drought recovery recording approach used at Longreach. Extra parameters were added, definitions refined, and a recording sheet of land, pasture and soil conditions, plant/tussock regrowth, seedlings, other species and proportions of regrowth components was incorporated. The common grass and herbaceous species recorded across all sites are shown in ***Table 2***.

Table 2. Pasture and forb species recorded during the flood recovery inspections

Dominant pasture species	**Other pasture / forb species (continued)**
Astrebla pectinata (Mitchell grass - barley)	*Glycine falcata* (native legume)
Astrebla squarrosa (Mitchell grass - bull)	*Gomphrena conica*
Astrebla lappacea (Mitchell grass - curly)	*Goodenia fascicularis/falcata*
Astrebla elymoides (Mitchell grass - hoop)	*Hibiscus trionum*
Cenchrus ciliaris/pennisetiformis (buffel)	*Indigastrum parviflora* (indigofera)
Chrysopogon fallax (golden beard, ribbon grass)	*Ipomoea* sp. (cow vine - purple)
Dichanthium fecundum (gulf bluegrass)	*Ipomoea diamantinensis*
Eulalia aurea (silky browntop)	*Ipomoea lonchophylla* (cow vine)
Other pasture / forb species	*Iseilema* sp. (Flinders grass)
Acacia nilotica (prickly acacia)	*Josephinia eugeniae* (Josephinia burr)
Aerva javanica (kapok bush)	*Malvaceae* spp.
Alternanthera nana (joy weed)	*Marsilea* spp. (nardoo)

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)
Merremia dissecta
Neptunia gracilis (low sensitive)
Neptunia monosperma (tall sensitive)
Ocimum oleiofolium (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 pungens (Noogoora burr)
Xerochloa imberbis (northern rice grass)

The recording sheet was used, at selected sites, where there were obvious changes in the pasture recovery or there was no recovery across variable soil types. This land and pasture recording form is shown in ***Table 3***.

Assessment criteria and details of the rating system used at these main sites are shown in ***Table 4***. Because this system evolved and was not developed specifically for recording this flooded country condition and recovery, it did not fully capture the observed changes in the landscape, particularly that of soil surface condition where the landscapes experienced both erosion losses and silt deposits. Any future designed recording for post-flood pasture recovery will need to have additional categories of soil erosion loss ratings and descriptions, and also ratings for soil and sediment deposition and their descriptions. Specific definitions, to better describe soil damage and recovering pastures on flooded surfaces could be included.

Table 3. *Land, pasture and soils recording sheet for main inspection sites.*

North-West Queensland Flood Response Pasture Observations March, 2019 *Page No:*

Date: ______________ ***Operator***(*s*): ______________

Waypoint No: **GPS:** ⁰*S* ⁰*E*; **Elevation:** *m*

Site Location:

Property & Paddock (where relevant)**:**

Photo numbers: ☐ Landscape ☐ Into quadrat

Land condition: Rating: **+ A - + B - + C - + D -** *circle responses*

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

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

Soil surface/Erosion:

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

***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:

Table 4. *Criteria used for land, soil surface and pasture condition, and plants/tussocks responses at main recording sites.*

a. Land condition

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

b. Soil surface condition

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

c. Pasture condition

Condition rating	Condition Indicators				
	3P Grasses Frequency %	Healthy Mg tussock density	Annual grass % DM Yield	Undesirables % DM Yield	Weeds
1	> 75%	1 pace/tsk (2-3 tussocks per m²)	< 20%	<20%	None or very few
2	50 – 75%	2-5 paces/tsk (1 tsk per 3-20 m²)	20 – 40%	20 – 30%	very few
3	10 – 50%	>5-25 paces/tsk (1 tsk per 20-500 m²)	40 – 70%	30 – 80%	some
4	< 10%	30-60 paces/tsk (1 tsk per 900-3000 paces)	>70%	>80%	obvious
5	< 1%				

d. Tussocks (%) (1) responding and (2) level of response after flooding

1. Rating	% Tussocks responding
0	0%
1	1-10%
2	10-20%
3	20-50%
4	50-80%
5	> 80%

2. Rating	Tussock response
0	nil
1	weak
2	moderate
3	strong

Logistics and operational issues

Fieldwork logistics and operations in post-flood recovery was similar to mainstream pasture field work situations. Similar equipment was used and the usual field safety precautions were actioned. Field equipment included the field recording sheets, GPS unit, height post, soil moisture depth probe, and a camera. A programmed palmtop computer could have increased efficiency but was not available. A four-wheel drive vehicle was required, which was equipped with the remote travel safety items, such as a UHF radio, water tank, spotlights. Mobile telephone coverage was limited and a satellite telephone for safety could be useful in these regions. Personal protection equipment was necessary for a tropical outdoor environment with dead animals in summer (face masks and mud boots), and on this occasion, a fly veil became more essential as the days passed.

Access to an office location with a printer and a desk for working on a laptop computer was necessary for updating and printing recording sheets, input and safety of accumulated data, and labelling and organising the daily sets of photographs. On this occasion, property maps and good road maps were needed. Maps from the Avenza app were downloaded to a mobile phone and were valuable in locating minor roads throughout the region. The Terrance Alick pastoral stations atlas maps were useful for property locations, but unsuitable for many road locations.

General effects across the landscape

There was a wide range of effects from the flood and high rainfall event, on the different landscapes. Some included:

- Severe river and creek bank erosion – a normal process for such a flood event, but more damaging than from average floods; large trees on banks fell into the rivers.
- Severe erosion near major rivers and creeks on existing floodplains, both new gullying, extensive sheet erosion removing all pasture and surface soil, and grass tussock pedestalling occurred extensively.
- New and severe soil erosion to the extent of new gullies near water courses, washing perennial tussocks away leaving bare, hard-set subsoil with deep indentations, some greater than 50 cm.
- Eroded roads and tracks across paddocks and along fence lines – some new wash to 2 m deep by 10 m wide by hundreds of metres long; e.g. near Flinders River NE of Julia Creek,
- Eroded pastures leaving perennial grass tussocks pedestalled to over 30 cm, and exposed roots where plants then died.
- Eroded surfaces with pedestalled tussocks, eroded and roots exposed on the upstream side while there were deep silt deposits on the down-water flow side, immediately behind and often within the tussock.
- Silt deposited areas completely covering the pasture or with some tussock tops still emerged.
- Tussocks stems covered in silt; there was negligible leaf on remaining stems (***Figure 10***).

Figure 10. *Grass tussock stems covered with silt amongst new seedling establishment.*

- Pastures that had endured varying depths of water carrying sediment loads and for varying periods were in stages of recovery from dead plants with nil new growth, to one tiller emerging, to a full tiller crop.
- Deep crusting of surfaces now cracking and curling up. Some crusts were 10 cm thick of new silt and the hard-set crust prevented seedlings from emerging. Only seedlings that emerged in the first one to two weeks, while the surface remained moist, were present (***Figure 11***).

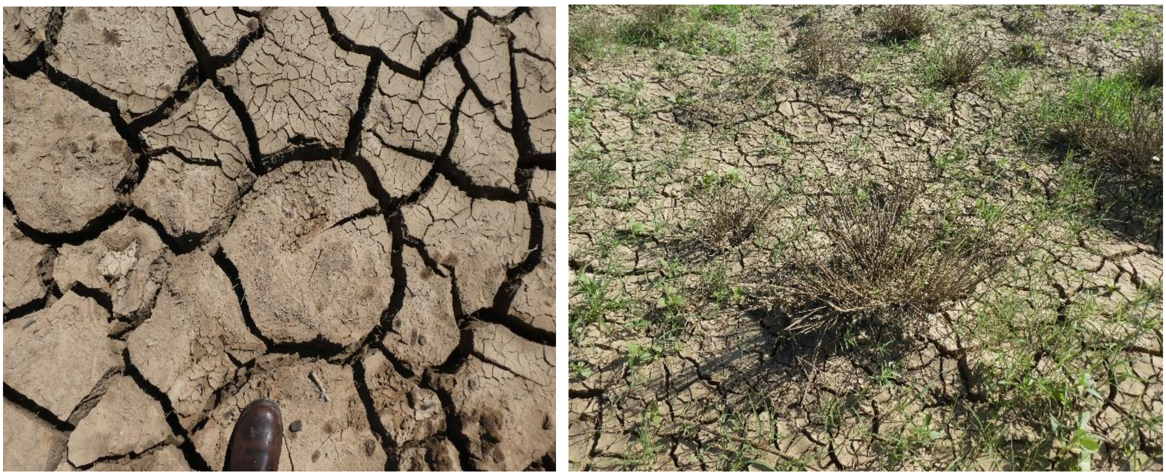

Figure 11a, 11b. *Large deep crusting of (a) bare surfaces, and (b) amongst old tussocks*

- Cloncurry buffel grass, on upland red soil country, to the west of the region has benefitted from the rain event; plant deaths occurred in the lower parts of water courses, creeks and rivers.
- Deep erosion of over 50 cm soil loss on the upstream side of trees and shrubs near rivers ***(Figures 12 and 13)***.
- Extensive damage to fencing, roads and other property infrastructure such as dam by-washes.

Figure 12. A new gully and severe sheet erosion along an original road. Note the treed creek line is down-slope to the right.

Figure 13a, 13b. *Typical examples of perennial grass (a) pedestalling, and (b) silt deposition across the Mitchell grasslands.*

Mitchell Grass Downs

Land condition and pasture assessment

Overall, the Mitchell Grass Downs was on average between C- and B+ land condition on the ABCD land condition scale (refer ***Table 4***). However, there were eroded areas damaged to D condition, which will not revegetate naturally within a reasonable time frame. South of Julia Creek, areas that had been lightly grazed or destocked, and received early summer rain in November-December 2018, were classified as B+ condition ***(Figure 14)***. The widely variable land conditions after the flood resulted from the prior impact of the long-term drought, combined with the grazing management imposed, and probably the supplementary feeding programs added further pressure on tussocks.

Figure 14a, 14b. *Mitchell Grass Downs regrowth in areas with different levels of flooding South of Julia Creek (a) shallow negligible erosion, and (b) deeper floodwater with erosion and silt deposition.*

A major concern for recovering stable Mitchell grass pastures was the deaths of well-established, drought-surviving tussocks, largely due to roots exposed by erosion and the period of inundation. Erosive effects of soil loss around tussocks were most severe on the up-water flow direction. Silt deposits up to 30 cm deep often on the down-water side of large tussocks stretching 1-3 m was common. There were many areas with these parallel disturbances of erosion and silt deposit, where the plant was partially covered with silt and the roots partially exposed. These plants are susceptible to death from lack of moisture or dying by grazing the few emerging tillers and using up any remaining root reserves. This is of particular concern in areas where some grass pedestals reach 20-30 cm high ***(Figure 15)***.

Figure 15a, 15b*. Dead Mitchell grass tussocks (a) in a washed area with silt deposits, and (b) downs with extensive silt deposits now crusting.*

Generally, there was a high population of Mitchell grass seedlings, certainly of a number to produce a productive pasture, of one or more of all four *Astrebla* species across many sites. Mitchell grass seedlings were widespread in high populations, mostly with 2-4 leaves and 5-15 cm high with only 2-4 roots ***(Figure 16)***. These seedlings were healthy but starting to wilt on some of the lighter soils. Some seedlings had already died in the west of the region by early March. This seedling event provides a rare opportunity, perhaps once in decades, to regenerate these Downs pastures.

Figure 16a, 16b. *(a) A typical bull Mitchell grass seedling, and (b) new tillers from an old tussock, on flooded Downs in late February 2019.*

At some sites, Mitchell grass seedlings were germinating despite the lack of surviving tussocks. There was no evidence of tussocks being present in recent years, likely due to prior heavy grazing and drought. The germinating seeds must have survived in the soil for many years, as they were less likely to be brought in floodwaters. Some such seedling populations were on slopes that only received overland water flow from further up the rises, for example west of Gilliat. At other similar tussock-less sites, no Mitchell grass seedlings were evident, only a mass population of forbs had germinated. Seedling populations of Mitchell grass were 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 survives inundation for many days.

Areas near major creeks and rivers sustained the highest levels of water erosion damage from flooding ***(Figure 17)***. Other pasture areas had silt deposits of 10–50 cm deep. Silt was up to 1 m deep close to creek edges, more notably where two creeks meet. River bank erosion was obvious at most crossings leaving large Eucalypt and Melaleuca trees falling into the running water.

Figure 17a, 17b. *Severe erosion with all surface soil lost across Mitchell Grass Downs, and (b) upslope adjacent to a water course.*

Litter accumulation and damage to fences

Litter collections by the flood waters, caused damage to unknown thousands of kilometres of barbwire fences throughout the flood zone ***(Figure 18)***. The washed over fences will need to be completely replaced with new posts and wire. By the end of the recording period some properties had started accumulating fencing materials and were using large loaders to push up the damaged fences, all wire and posts all included, into large piles in preparation for burying in the future.

Figure 18a, 18b. *Litter accumulation on fences and fences washed over throughout the flood zone.*

Patches of tree and grass litter 5-25 cm deep were seen near creek lines and one litter patch covered some five hectares along the slope up from a creek line ***(Figure 19)***.

Figure 19. *Grass and tree litter accumulation areas along the side of slopes.*

In the first few weeks after the flood there was no rain and high temperatures, with over a week of >40^{0}C temperatures. These weather conditions helped the initial germinating seedlings to grow, but then the soil surface dried out to a depth of 5-10 cm and opened up extensive cracking. The silt surfaces had hard-set surfaces 5-100 mm thick with the top 5-50 mm of soil curling up. This crusting made it impossible for new seedlings to emerge, so the populations were only from the germination in the first one or two weeks after the flood receded. Tussocks needed rain to wash the silt off stems and seedlings needed follow-up rain to get their roots down to the receding soil moisture, which was 65-115 cm deep over both Mitchell grass downs and the Gulf Plains. In this time, masses of forb seedlings, producing a surface carpet, had emerged and grown to 5-20 cm high, where not severely eroded. By the 4-5th week sesbania (*Sesbania brachycarpa*), which occurred almost everywhere was starting to flower at 30-50 cm high. The common grass and forb species recorded at inspection sites across the flood zone were referred to previously in ***Table 2***.

Bull Mitchell grass areas generally recovered better than Curly Mitchell areas. Recovery in smaller areas of Barley Mitchell were in between these two species in regrowth of original tussocks. Hoop Mitchel grass was more common in the Gulf Plains and had less time to recover, but there were signs that it would respond over the next few weeks. Seedlings of all Mitchell grass species were found where the older plants were well established prior to the flood, also in paddocks where there was no evidence of old tussocks. In extensive areas the whole tops of the plants had died, leaving silt covered stems, and there had been no rain to wash the silt off. Silt hinders plant recovery and regrowth. However, in most areas, the original Mitchell grass tussocks were showing signs of surviving by producing new tillers from rhizomes. Often only 1-4 tillers were present. Exceptions were, where destocking had occurred, when tussocks still retained about 20 cm of basal stems that allowed faster tiller 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.

The increased 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 everywhere. Slow recovery was still evident in areas showing signs of tussock regeneration. Drought effects on tussocks were generally most severe in the south, for example Winton, Kynuna, McKinlay region and less severe to the north on the Plains. There were strong exceptions where paddocks and probably properties had higher grazing pressure for an extended period, beyond that of their neighbours. There were distinct fence line effects of recovery of perennial grasses due to this prior heavy grazing. It is possible some of this damage to the pasture community could have occurred many years prior to this current drought ***(Figure 20)***. The Downs had a history of sheep grazing and has experienced many droughts in the past. Fence line effects of *Acacia nilotica* management were obvious as well. Paddocks with no trees and a productive Mitchell grass pasture, sat beside their neighbours with a woodland of trees and much reduced pasture.

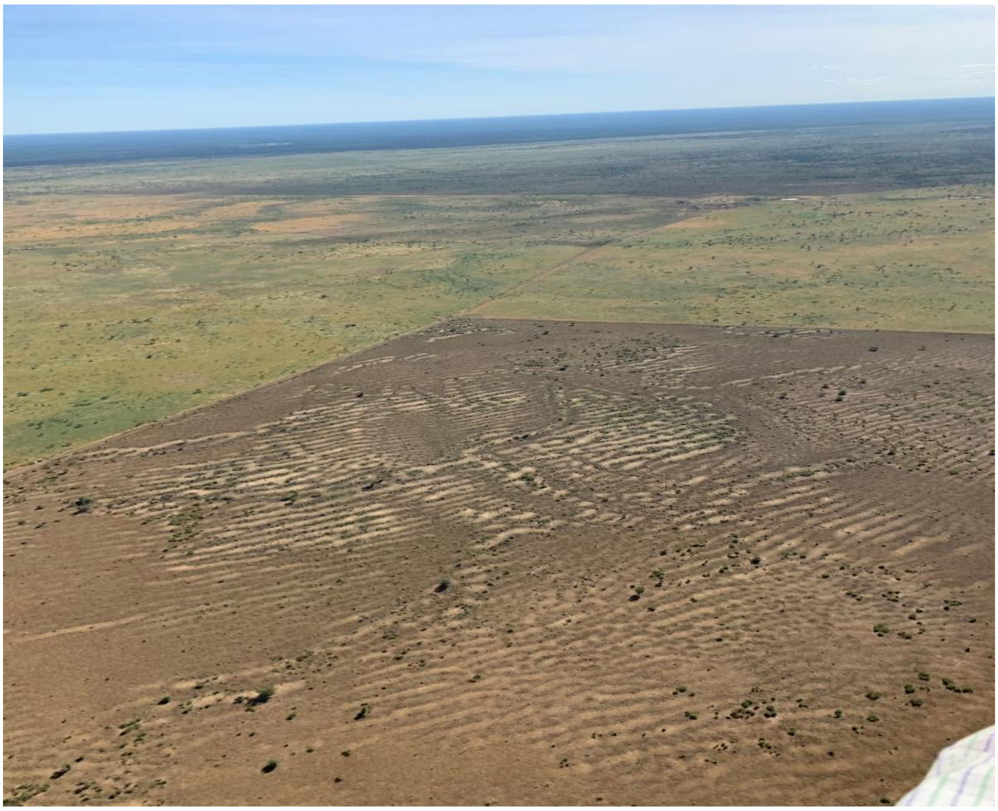

Figure 20. *Paddock scale prior grazing effect on pastures from flooding.*

Mitchell grass downs country is largely undulating, so flooding effects were variable. Most of the initial recovery was taking place on the rises, where water depth and time of inundations was less or no inundation occurred. The variation in damage and recovery of tussocks would have been affected by the water depth, flow strength, sediment load, light penetration, inundation period and water temperature when shallow, along with the root reserve remaining after the extended drought of some 6-7 years.

Mitchell Grass Downs pasture recovery

With follow-up rain, conservative grazing and long rest periods, the Mitchell Grass Downs has the potential to have a good recovery in most areas after this flooding event, from the surviving grass tussocks and the populations of seedlings. Often large populations of Mitchell grass seedlings were growing in paddocks that had no surviving tussocks from previous drought and grazing conditions. All grass plants have to compete with the mass forb species establishment. With optimal management and seasons, the Mitchell grass seedlings have the potential to become a full population of tussocks over the next few years, converting previously bare paddocks, back into an original Mitchell grass pasture. Following the grazing management recommendations in the DAF Fact Sheet (see Appendix 1) will help to achieve this potential.

The grass seedlings were water-stressed and needing several follow up rainfall events to occur soon, for them to have a good chance of survival. If such rain occurred, a strong Mitchell grass recovery over most of the flooded area is expected. The exceptions to good growth are near main creeks and some rivers where severe surface erosion has occurred. For example, the Flinders River north of Julia Creek has extensive eroded country and silt deposits that will take several years to regain a grass cover ***(Figure 21)***.

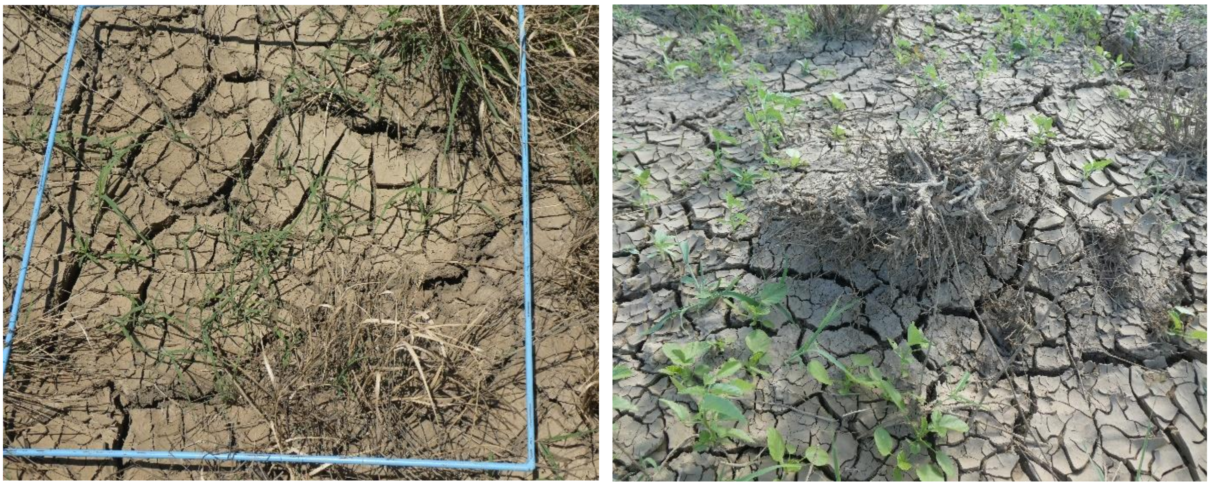

Figure 21a, 21b. *Examples of (a) Mitchell grass seedlings in a 50 cm * 50 cm quadrat and (b) forb seedlings with dead Mitchell grass tussocks that emerged prior to strong crusting of the surface soil.*

The rain and flooding were limited to a large area of NW Queensland, from Mt Isa Uplands to within 100 km south of Hughenden towards Muttaburra, where drought continued with little pasture cover. There are whole paddocks of almost bare soil. The country around the perimeter of the flood zone that received high rainfall but no flooding, is recovering well with strong Mitchell grass on the Downs and Cloncurry buffel grass on the red country to the west. Tussocks in these areas are producing new tillers and going to seed in early March. Within the 'flood zone', this type of pasture was present between Richmond and Hughenden, especially in the higher areas of the undulating Downs. Although some of this country received flooding of expansive hollows, the elevated country received high rainfall, with reports of 500 – 800 mm across the region, producing a full soil moisture profile that will produce high dry matter yields and a good seed crop. These grass dominant pastures still have a high population of forbs, especially cow vine, tick weed and sesbania during the early stage of recovery, before the grasses grow to their potential. Almost everywhere in this eastern highway strip, the buffel grass was still alive, which is a good indicator of negligible or short-term flooding of less than five days. In small areas only, between the highway and railway line, where water was dammed-up for longer periods, were the buffel grass tussocks dead. This contrasts to the west of Julia Creek where the buffel grass has died for kilometres along the highway table drains, from longer-term inundation and deep flooding ***(Figure 22)***.

Figure 22a, 22b. *Alive and dead buffel grass tussocks from inundation. (a) Buffel grass dead in table drains of the highway across the Downs, and (b) dead Buffel grass tussocks up the side of a hill showing the flood line in Bauhinia trees, north of Julia Creek.*

Birdwood grass (*Cenchrus setiger*) occurred along the roadside well north of Julia Creek. Some plants had partially died from inundation and others appeared to be suffering the same symptoms as pasture dieback in eastern Queensland, such as reddish-purple leaves and deaths of whole plants. The healthy Birdwood plants were seeding.

Grazing history affected pasture recovery

Perennial grass recovery of the 3P species post-flood appeared correlated strongly with prior grazing history, and an interaction with the preceding drought. Where tussocks were grazed to the surface or only 10 cm of basal stem remained, there was often nil or very little tussock recovery, but where there were 20-30 cm of Mitchell grass stem stubble left, the initial recovery was often high. 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 species. The paddocks now have a coverage of forbs and patchy areas of small Flinders grass seedlings. These will also need follow-up rain to produce a productive Flinders grass pasture.

Where Mitchell grass tussocks were showing signs of life, it was new tillers growing from rhizomes. The tillers usually occurred around the perimeter of the old plants. All old stems of tussocks were dead across the more seriously flooded pastures. There may only be 1-4 new tillers to 20-30 cm high. In areas where flooding was of a shorter duration or did not occur, full tussocks of new tillers were recorded. These strong plants were putting up seed heads within the first 3-4 weeks. For example, south of Julia Creek for 35 km the Curly Mitchell grass plants have had almost 100% survival and were producing a full tussock of new tillers and going to seed by early March. Their colour was a deep healthy green indicating the release of nitrogen from decaying plants and roots during the drought: a typical Birch effect. However, over 50 km south of Julia Creek there has been negligible tiller regrowth where the plants had been grazed heavily and affected by the drought prior to flooding. The depth of flooding was over fence height throughout this area and probably over 3 m deep in the hollows.

Gulf Plains – Balbirini land system

Overall, the Gulf Plains, commonly known as the Gulf bluegrass-browntop plains or the Balbirini land system, was in C+ to C- condition after the flood. Sheet erosion and tussock pedestalling were obvious, but not as serious as the most damaged areas on the Mitchell Grass Downs ***(Figure 23)***. The tops of grass tussocks of all P3 species, including Gulf bluegrass, silky browntop, hoop and bull Mitchell and golden beard grasses, were killed by inundation across extensive areas. However, within three to four weeks there were signs of new tillers on a high proportion of old plants in many areas. These plants will return to productive tussocks during this year with follow-up rain. There were no annual grasses present and generally fewer forbs in the inter-tussock spaces than appeared on the Mitchell grass Downs to the south. These pastures are resilient to short-term flooding and most areas will recover well within 1-3 years, depending on grazing pressure and rainfall next summer.

Figure 23a, 23b. *(a) Inundation across the Plains has killed the tops of tussock grasses, including bluegrass, browntop, hoop and bull Mitchell and golden beard grasses, 50 cm * 50 cm quadrat shown, and (b) Erosion scouring and pedestalling are obvious across extensive areas. Note: New tillers on some old plants.*

Seed of multiple species of forb weeds, as well as of trees, will likely be spread across the Plains. After previous flooding across these Plains in 1974, trees appeared well away from the major rivers and water-courses. Both *Eucalyptus* species and guttapercha (*Excoecaria parviflora*) have grown and spread across the heavy clay soils, onto previously treeless plains from the Bang Bang Jump-up range to Karumba on the coast. These trees have continued to spread, with the introduction of high-grade Brahman cattle and more intensive grazing management, including supplementary feeding along with improved infrastructure including fencing, water supplies and bitumen roads. This type of management has also encouraged the extensive spread of prickly acacia (*A. nilotica*) into previously clean areas. Whitewood (*Atalaya hemiglauca*) trees have also spread further over this time.

That 1974 flood event caused the spread of asbestos grass (*P. basedowii*) away from around the perimeter of wet hollows. The continued spread of this almost unpalatable grass has created problems for cattle grazing on some properties on the Plains. This flood may cause the grass seed to spread further and there are no easy management options to contain this grass weed. The water height, on the Plains at Walkers Bend crossing of the Flinders River, was about 16.75 m about 1 m higher than the previous 1974 flood record level, which gives an indication of the potential damage that could be caused by the spread of asbestos grass and other undesirable plant seeds.

Gulf Plains pasture recovery

The Gulf plains has a strong potential for recovery of the desirable grasses, Gulf bluegrass, silky browntop, Bull and Hoop Mitchell and ribbon grass. There were seedlings at most sites inspected, except the obviously more seriously eroded or silted areas (land condition D). The dead buffel grass (*Cenchrus* spp.) on light soil rises, on the Plains, were not recovering within two weeks of the flood receding. The initial signs of recovery on the Plains were behind the rate of recovery on the Downs, due to the later flooding stage. However, these pastures will likely recover more quickly, except in low areas still under water ***(Figure 24)***.

Surviving cattle on the Plains are in good condition with access to regrowth of green hoop Mitchell and golden beard grasses ***(Figure 25)***. The old dead stems of grass tussocks occur across the flooded Plains.

Figure 24a, 24b. Pastures *on the Balbirini Plains south of Normanton (a) Pasture recovery and Sesbania in an area that was flooded but not damaged by inundation, and (b) Flood damaged pastures, fencing and lost animals.*

Figure 25a, 25b*. Brahman cattle survivors after flooding across the Balbirini Plains with access to grass regrowth and dead stems from prior to the flood event.*

The sown legume Milgarra butterfly pea (*Clitoria ternatea*), growing up Mimosa bushes survived flooding, while another sown legume of the *Desmanthus* genus was killed by a long period of inundation ***(Figure 26)***.

Figure 26a, 26b. *(a) cv. Milgarra Butterfly pea growing on Mimosa bushes survived, while (b) the tops of old Desmanthus plants were killed by inundation and extended flooding.*

Rubber vine (*Cryptostegia grandiflora*), a potentially toxic plant, has spread along major rivers and onto the plains and was not damaged by the flooding ***(Figure 27)***.


Figure 27a, 27b. *Rubber vine along the Flinders River near Walkers Bend survived flooding and is flowering by late February.*

Isa Uplands

The Cloncurry buffel grass (*Cenchrus pennisetiformis*) along rivers and frontages has benefitted from the flooding and monsoonal rainfall, except inside the river banks where tussocks have died. These will be replaced with buffel seedlings during this summer and be back to a dominant pasture within 2-3 years. Some of these river systems supporting good buffel grass stands include the Cloncurry, Corella, and Dougal Rivers, and their associated creeks such as Cattle, Bony, Capsize and Tommy creeks. On these red soil frontages, buffel grass has already responded to the rainfall with new healthy leaf growth, and plants are producing seed heads. There are still long-term scalds present on these frontages, with a small population of pigweed (*Portulaca* spp.), tar vine (*Boerhavia* spp.) and *Sporobolus* spp. Mimosa (*A. farnesiana*) and prickly acacia (*A. nilotica*) have spread onto these frontages in recent decades, especially north of Cloncurry, to the extent that they need to be controlled ***(Figure 28)***.

Unusual observations

Observations of the landscape included unusual observations that may have an impact on pasture recovery. These observations included:

- There was no grass or tree leaf litter on the pasture surface after the flooding, except in specific accumulation areas left as the waters receded or caught in barbwire fences and Mimosa bushes.


Figure 28a, 28b. *Grass litter accumulated in (a) Mimosa bushes and (b) 4 m up in gutta-percha trees. Note: the eroded and bare soil surfaces.*

- Huge amounts of silt and debris was moved over the landscape. One example of silt movement was some 40 km NE of Julia Creek where it was reported by the land owner that an area 2 km long and up to 1 km wide of red soil silt, was deposited over black soil Mitchell grass country. There is no red country anywhere near this property, and may have come from 'upstream 100 km away' ***(Figure 29)***.

Figure 29. *Flood deposited red silt from up to '100 km' away onto black Mitchell Grass Downs country north of Julia Creek.*

- Noogooa burr (*Xanthium pungens*) seedlings 12 cm high with a population of millions have created a carpet of leaves on banks of the Flinders River, especially near Richmond. Before the release of the Noogoora burr rust it grew 2 m tall along the Flinders River and was so thick cattle could not get down the banks to water. Spreading the rust into these new areas before the plants seed, will be advantageous in reducing future burr growth.
- Plains turkeys appeared to survive the flooding, or returned soon after, and were plentiful in the Kynuna to Julia Creek area, living under prickly acacia trees and Mimosa bushes. Brolgas re-appeared to the north of the flood zone in late February ***(Figure 30)***.

Figure 30a, 30b. *The large ground dwelling native birds re-appeared in mid-February. (a) Plains turkeys (bustards) were plentiful under Mimosa bushes near Kynuna in the southern flood zone, and (b) Brolgas reappeared in the northern flood zone.*

- There were no kangaroos; they died of exposure along with the cattle, nor any emus, until about a month after the flood when an occasional red kangaroo and a few emus were seen ***(Figure 31)***.

Figure 31a, 31b. *Native animals died along with cattle from cold, rain and wind. (a) kangaroo mob died behind a shed, and (b) died in paddocks.*

- Flies were not obvious on the carcasses in the first few weeks but appeared in the millions as the pastures regrew after about three weeks.
- Kite hawks and crows were not present on the carcasses for the first month, and then hundreds of kite hawks appeared together on three occasions in flocks, circling in rising air currents. It was rare to see them near a carcass ***(Figure 32)***.

Figure 32. *Kite hawks appeared about a month after the flood with hundreds circling on thermals.*

- The carcasses dried out and decreased in size by over 50% over the first 3-4 weeks, especially in the >40^{0}C temperature week, with no hide openings as there were no animals feeding on them to cause new openings to the bodies ***(Figure 33)***. Locally it was called, bodies 'melting' with thick black liquid running down-slope.

Figure 33. *Cattle died of exposure in open woodlands on hard soil surfaces and their bodies dried out within weeks of >40^{0}C heat, even with no attacks from animals or birds.*

- There were fresh water crocodiles in floodwaters at both crossings, of the Saxby River on Punchbowl (1 seen) and Taldora (3 observed) roads north of Julia Creek.

NW Qld long-term pasture recovery

The full range of species that usually occur across the Mitchell Grass Downs and Gulf Plains was recorded, but in different proportions to what is present in normal seasons. This differentiation may impact on the long-term recovery of the pasture. The dominant 3P grasses, including the four Mitchell grass species (*Astrebla spp*.), Gulf bluegrass (*D. fecundum*), silky browntop (*E. aurea*) and ribbon grass (*C. fallax)* were all previously present across the flood zone. All 3P species present had seedlings, especially at the locations that had been less severely flooded and suffered less surface soil damage. The annual species, Flinders grass, was only present as small clusters of seedlings in very localised favourable sites and also occurring in its previous range. Button grass (*Dactyloctenium radulans*) and native couch (*Brachyachne convergens*) were widespread annual grasses. There was a much higher proportion of broadleaf forbs present than would be expected in a non-flood season. All forbs were seedlings and their dry matter yield was often higher than that of the grasses. The main forb species widespread across the flood zone include: sesbania (*Sesbania spp*.), tick weed (*Cleome viscosa*), cow vine (*Ipomoea* spp.), wandering jew (*Commelina* spp.), neptunia (*Neptunia gracilis*) and native jute (*Corchorus pascuorum*). A list of species recorded was previously shown in ***Table 2***, and their presence at the main recording sites is shown in the accompanying Excel spreadsheet to this report (as Appendix 3).

The reduced stock numbers and loss of infrastructure post-flood, provides an ideal management opportunity to recover the 3P species on properties across both the Mitchell Grass Downs and the Gulf Plains. This could occur with follow-up rain and a good season next summer, providing restocking is delayed and grazing pressure is managed conservatively when restocking does occur. The extended drought with continued grazing pre-flood has caused serious damage to vast areas of the Downs, particularly south of the rail line, and stress on surviving tussocks, will greatly increase if grazing continues now recovery is possible. These management issues of restocking numbers and timing, and the real carrying capacity of the recovering pastures, are an area where DAF extension staff can have an input and influence future grazing decisions to consider the pastures' health and composition. A DAF FutureBeef Fact Sheet has been prepared on the optimum management of the recovering Mitchell grass pastures (also refer to Appendix 1).

Delayed restocking and conservative stocking, will allow for a future long-term production benefit. Early restocking will damage the pasture recovery rate and reduce long-term profitability, for a short-term gain. Although the pastures look totally green, where recovery is happening, much of the initial vegetation is annual or short-lived perennial herbage/forb species, with some areas having regenerating grass tussocks. The pressure from droughted southern Queensland properties to take on agistment on recovering pastures, if accepted, will delay the 3P grass recovery in flood damaged pastures. There are areas within and around its perimeter of the flood zone, where the original tussocks are already healthy and growing a full crop of new tillers, that are ready to graze, but these areas are the exception.

In previous droughts, I had been informed about producers flying in forage hybrid sorghum seed, onto bare paddocks, in an effort to provide early feed and perhaps to protect the Mitchell grass seedlings. Some of these actions were successful and when followed by conservative grazing they had produced dense Mitchell grass pastures, again within a few years after the end of the drought. I did not hear of any producers attempting this seeding approach, before or after the flood this year, but it may have been of value in some soil surfaces and in pastures that were originally in A, B or C condition.

Rehabilitation options of D condition surfaces

Severely degraded surfaces, now in D condition, could benefit from mechanical rehabilitation options with introduced pasture seed sowing. There is currently not a reliable native pasture, grass or legume, seed industry to supply significant seed supplies for a native species rehabilitation program in north-west Queensland. However, this may be an option for entrepreneurial producers in the Mitchell grass zone where seed is produced, during the current growing season in preparation for sowing, before the next wet season. There are limited sown exotic pasture species options for rehabilitation of the Mitchell Grass Downs in the southern half of flood affected zone, where curly Mitchell grass and native legumes should eventually regenerate. These native legumes include *Rhynchosia minima*, *Glycine* spp., Vigna spp. and *Desmodium* spp. and their presence fluctuates with seasonal conditions.

In the higher rainfall northern flood zone, especially on the infertile, heavy grey clay soils of the bluegrass-browntop plains closer to Normanton (Balbirini land system), mechanical treatments such as ripping, chisel ploughing, discing or crocodile seeding of D condition land and sowing exotic legumes has potential to regenerate the degraded grass pastures. Perennial species to evaluate include cv. Milgarra butterfly pea (*Clitoria ternatea*), *Desmanthus* spp. cultivars such as Progardes, Marc and newer shrubby selections, and Caatinga stylo cultivars, Primar and Unica. Alternative annual forage species such as the legume Lablab or forage hybrid sorghums, such as silk types could also be tested. These options could also be evaluated in pastures with the invasive asbestos grass (*Pennisetum basedowii*) to help curtail its spread. There are tropical exotic grasses that could grow in this environment, with adequate attention to their nutrition on infertile clays. These grasses have not had sufficient evaluation to be recommended for rehabilitation of the degraded landscapes on these soils.

Additional issues that may impact on pasture management

Strategic pasture management is essential for good pasture recovery. However, in these regions, several additional issues emerged that may impact on how the pastures are managed, both short and long-term.

In early post-flood event action, the local Councils in conjunction with DAF staff had phoned owners or managers of every property in the flood-affected areas, to assess their immediate needs, health risks and wellbeing. This data was used by the Councils and Army to prioritise assistance, and what actions were needed to eliminate immediate human health risks. The Army has taken photos of the flooding extent during this process. These photos would show why the original local reports were of totally destroyed and silt covered pastures, over some 500 000 ha. After several weeks this assessment may have been revised down or could be checked with access to their imagery. The Army from Townsville also flew the main roads and took strip photos of both sides of the road to assess infrastructure damage and where there were carcasses requiring burial. Some of these strip images were made available to DAF, to help check the status of the pastures and to be used to assess recovery over the coming months. The cameras used varying formats and were able to be analysed for Normalised Difference Vegetation Index (NDVI), but the more sophisticated imagery was not available to us to check the pastures and their recovery, however, Queensland Government staff in DES are able to produce similar imagery and have mapped the extent and duration of flooding.

Cattle and hay management

From the available information gathered, representatives from DAF, Councils and the Australian Army were able to coordinate and distribute hay to cattle stranded during the flood and to other herds as the waters receded ***(Figure 34)***. Dropping hay to stranded cattle on the heavy clay country was not successful. The cattle became bogged, so hay drops had to be on hard surfaces, such as on gravel ridges as they dried out sufficiently and on bitumen roads. The potential for spreading new weed species from these hay drops should not be underestimated and sites need to be monitored into the future, during and after the next few seasons. Some old hay patches were burnt to reduce this problem.

Figure 34. *A hay distribution centre on Bang Bang Range for feeding flood stranded cattle on the Balbirini Plains, south of Normanton. The potential introduction of new weed species is a concern.*

Carcase disposal

DAF biosecurity staff, the Australian Army and local Shire Councils developed a carcass disposal strategy to reduce the risks to human health in the present and later to animal health, such as from botulism. When this plan was formally released, the carcass disposal grants of $5,000 per property became available. By this time many properties had started their own disposal process of carcass removal and burial. Deep burying was recommended, preferably with up to about 2 m of soil on top, but with the saturated subsoil this proved impossible for heavy machinery in the first few weeks. As a result, many single animals were covered with soil where they lay across the paddocks or had been pushed off roads. At one site, landholders had attempted to burn carcasses after about three weeks using only fuel, but this method failed as mainly surface hair was burnt. This method was not part of the recommended disposal practices. From UK experience, burning carcases effectively requires a significant tonnage of wood and it releases excessive pollution into the atmosphere.

The Councils were heavily involved in clearing main roads and roadside carcass removal, initially and later, their burial using large loaders including some from private contractors, as the soil profile dried sufficiently. Many cattle died on the top of Council roads as these were the highest and hardest strips of land. The saturated black soil downs became so boggy cattle often bogged to their knees. Large numbers of cattle, and native animals, died of exposure during a four-day period that was cold and wet with extremely strong winds, following days of rain. Council road grids were often the site of tens of dead cattle clustered together on the hard road surface ***(Figure 35)***.

At this time, it was too early for an accurate assessment of stock losses other than estimates of how many were in particular paddocks, or properties and now were not present. An initial estimate of cattle losses was some 500 000 across the flooded regions. Some may turn up many properties away when first round musters take place. DAF biosecurity staff, may be called upon, to assist in identifying and relocating surviving cattle that have been carried by the floodwaters, onto properties further downstream. This process will become a higher priority during the muster rounds early this year. Reduced cattle numbers and subsequent reduced grazing pressure may contribute positively to long-term pasture recovery.

Figure 35a, 35b. *Cattle died by exposure and bogging in the heavy clay soils, (a) often in fence corners, and (b) an attempt to burn cattle carcases at a grid where they died by exposure on the hard road surface.*

A stock routes manager reported pressure from southern cattle producers, still in drought, to get approval to bring their cattle into the McKinlay Shire. There was resistance, as the pastures needed a long rest after the drought and the grass component was in an early stage of recovery. The stock routes had masses of forb seedlings providing a carpet of short vegetation that would look attractive to a producer with bare paddocks and still in severe drought. I suggested resisting this pressure for the sake of the pastures in the stock routes into the future. Grazing in the coming winter will do much less long-term pasture damage.

Council and rail infrastructure damage

There was extensive destruction of infrastructure maintained by the local Councils, particularly the main roads that were severely washed out, often leaving deep gullies. These roads are now a severe gully erosion hazard and some were still holding water and impassable ***(Figure 36)***.

Figure 36a, 36b. *Washed out Council maintained main roads (a) Punchbowl to Nelia road NE of Julia Creek, and (b) Gilliat to McKinlay road SW of Julia Creek.*

Deep silt deposition across Council roads, causeways and bridges to depths of 3 m was a problem immediately after the flood receded and required urgent action by the Councils staff and their equipment as road surfaces dried out ***(Figure 37)***.

Figure 37a, 37b. Deep silt deposition on Council maintained main roads, causeways and bridges north of Julia Creek.

Similarly, the railway line across the Mitchell Grass Downs was washed out in multiple places and for long distances. Some bridges were washed out as well as the ballast along extensive strips, where the floodwaters washed over the built-up line. One train tipped over after the ballast washed away ***(Figure 38)***. This caused the loss off some 600t of lead and zinc in semi-processed forms that may have been possible to wash across the grass pastures. The derailment of this lead and zinc train at Nelia, continued to be of great concern to the local landowners, who have had their properties flooded. They are not confident that the Queensland railways and National Pacific, who were running the train, are providing enough information or any details of soil testing to know where the metals have finished up. The contaminated soil surface, at least in the immediate vicinity of the carriages, will have to be removed at some stage. The concern is if their cattle get increased lead levels from grazing pastures and ingesting soil particles in dry times, then their properties may have restrictions placed on them. One affected property owner was asking for more input from DAF.

Figure 38a, 38b. *Railway line damage near Julia Creek and a train carrying lead and zinc from Mt Isa to Townsville rolled over after erosion of the line ballast at Nelia.*

Property infrastructure damage

In some undulating country, there was less wash damage to Mitchell grass tussocks, but there was serious damage to property roads and water infrastructure, such as dams. There were examples of property tracks being washed out over 50 cm deep by 4+ m wide for hundreds of metres up a slope.

The by-washes of dams have been severely eroded, even where only affected by the high rainfall and not flooding, and these require truckloads of stone to restabilise, but they are on black soil downs country without stone or gravel. Some dam walls were damaged and broken through as well ***(Figure 39)***.

Figure 39a, 39b. *(a) Dam bank and by-wash destroyed by flood waters, and (b) a property road washed out with a new adjacent track graded on the Downs south of Julia Creek.*

The time taken to rebuild fencing infrastructure will hinder cattle management for some months after the flood, but this delay will assist in reducing grazing pressure on establishing grass seedlings and on the recovering pastures.

Social issues

Most owners were dealing with multiple stresses after experiencing the preceding extended drought, the monsoon period, the flood, and then assessing the subsequent stock losses and property infrastructure damage. However, community resilience was also evident. Across all affected Shires, counsellors of social, mental health and financial issues were available for contact, by any person affected in any way by the flood event. These conversations gave some indications of the mental health of many respondents. The Councils were determined that their annual social events would still occur to show support for their local communities and to attract the much-needed tourists back to the area. The intense publicity of the infrastructure damage concerned the Councils that it may deter tourists from visiting the north-west.

Neighbours were assisting each other early after the flood receded, by clearing roads into homesteads and clearing carcasses from near homesteads and water sources. Native animals including kangaroos died from the flooding and exposure, some perished in and around sheds, and had to be buried as well. Not all properties had their own loaders, the most useful piece of machinery for the initial clean-up, so property owners, managers or contractors with such machinery helped their neighbours.

Charity and farm assistance organisations were preparing to offer household items/materials and labour help as the land dried out. For example, by late February Drought Angels were on-hand with semi-trailer loads of household materials sent to Burke and Wills Roadhouse, halfway between Julia Creek and Normanton, for property distribution ***(Figure 40)***. Although this household products aid was much appreciated by the receivers, there was an opinion from business owners that they would prefer external support assistance in the form of cash or local business vouchers, so the whole community was supported. This applied also to rural businesses that wished to supply materials such as fencing and building supplies for the recovery. The charity Blaze Aid was preparing to support volunteers to assist in basic farm repairs, including pulling-up washed away fences that had been covered in litter. This form of aid supports the local landholders and communities directly. I saw some property owners bulldozing the washed-away fencing material into piles for later burial and preparing to build totally new fences using this volunteer labour along with their own staff.

Figure 40. *Pallets of aid materials delivered to Burke and Wills for local distribution by Drought Angels.*

A strong local opinion was that the high land prices and their continuing increase in value with no relation to the earning capacity, has encouraged producers into managing with increasingly higher stocking rates. The extra stock numbers combined with supplementary feeding programs and retaining cattle, long into a drought after it may have become economically viable to do so, had caused further pasture damage. This type of management was suggested as one cause of the obvious land degradation prior to the flood and remained a problem for delaying pasture recovery after the flood. Another local comment was that bank loan repayment pressure during this extended drought has caused an increase in grazing pressure beyond the capacity of the pasture to respond to the reduced rainfall. Counsellors advised that financial pressures will inevitably lead to mental health stresses in many cases.

The financial grants offered for flood damage recovery ($75 000) and carcass disposal ($5000) appeared slow to be taken up by landholders initially. In the first few weeks until the surface dried out, travel around properties to assess the damage and stock losses was difficult. In the early stage of land recovery, the long-term, low interest loans (e.g. to $250 000 at 1.37% interest) were not being considered by producers, but are more likely to be taken up as the fences and infrastructure are rebuilt and restocking becomes an option. I understand this loan was later increased to $400 000. Several producers said they already had uncomfortable debt levels and would take time to consider adding new debt, even at low interest rates. Cattle prices were declining in southern Queensland due to the continuing drought (February 2019), but these producers were not in a position to capitalise, and their pastures needed to be rested for grass recovery in any case. If it rains in southern and central Queensland before properties are ready to restock, an automatic increase in prices will make it more difficult to rebuild herds.

Future use of the site data

The data recorded during these site inspections can be used in the future, to re-check the pasture recovery at various sites and relate this recovery to the management conditions and grazing pressure imposed over time. The GPS locations and species notes will provide a long-term record of how the site came out of the flood event and how it subsequently developed. There is a range of conditions recorded from almost bare sites, through seriously damaged sites showing early stages of recovery, to well established perennial grass tussocks producing a full crop of tillers and going to seed. To contrast these flooded sites, there is currently an opportunity to establish paired recording sites, in paddocks that are still in complete drought, from bare paddocks with no sign of perennial grass, to paddocks that were destocked early in the drought leaving tussocks with 30 cm of dry stems, now appearing grey and dead. Such sites can be found in the Muttaburra region at present ***(Figure 41)***.

Figure 41a, 41b. *The extensive Queensland drought is still occurring in the Muttaburra to Hughenden area of the eastern Mitchell Grass Downs.*

Comparing the future recovery of these currently bare sites, when the drought breaks, with some of the flooded sites that are starting to recover now, will give a good dataset to analyse the climatic and management requirements to convert heavily grazed and droughted Mitchell Grass Downs in a range of condition states, into a productive pasture. Linking the management with the climatic conditions and pasture responses will show what management needs to be implemented, under various situations and can help refine current DAF advice on Mitchell grass grazing, recovery from drought, and management for long-term sustainability.

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I thank the Animal Science management of Queensland Department of Agriculture and Fisheries for supporting this pasture recovery investigation in the immediate aftermath of the monsoon flood event in NW Qld. I appreciate the property owners discussing their experiences with cattle, soil and pasture responses to the flood event. The McKinlay Shire Council CEO, Mayor and administration staff were of great assistance providing office space and printing facilities. Captain Vehlow was our contact with the Australian Army and supplied imagery of main roads showing infrastructure damage and early pasture responses. David Phelps, DAF Longreach, provided the initial site-recording format that matched earlier work on Mitchell grass drought recovery, Jed Somerfield, DAF Charleville, produced the recording site map, and Cameron Mosch, DAF Longreach, assisted with transport for three days surveying out of Julia Creek. I thank Chris Gardiner (cg), JCU Townsville, for providing aerial images of flood effects on the landscape; and I especially thank Jenny Milson, DAF Longreach and Cristine Hall for their detailed pasture recording in the field surveys and for data entry. Without their assistance, under trying field conditions, this data would not be as comprehensive. I also express thanks to staff at the Queensland Department of Environment and Science for providing timely maps and information to better understand the impact and extent of this extreme event.

APPENDICES

Appendix 1. Balancing restocking and pasture management following north-western Queensland monsoon floods – DAF FutureBeef Fact Sheet.

DAF pasture staff have developed guidelines for the future restocking of regenerating pastures and the grazing management best suited to produce successful Mitchell grass recovery. These guidelines provide management required for pastures in various states of damage and stages of regeneration. The widespread germination of Mitchell grass seedlings and soil profiles, with some 65-115 cm of moisture, provides a rare opportunity to allow the pastures to regenerate back to their productive potential. The timing and intensity of grazing, of these seedlings and new tillers of surviving tussocks, requires careful and monitored management to achieve the former Mitchell Grass Downs pasture productive capacity. These management guidelines are on the DAF FutureBeef web site.

FutureBeef Web site: https://futurebeef.com.au/after-the-north-west-queensland-floods/

A summary of the main management recommendations to recover Mitchell pastures and to restore long-term land condition and productivity is:

- Defer re-stocking as long as possible, conservative grazing pressure this dry season, and wet-season spelling over the future summers.
- Allow Mitchell grass seedlings to grow to mid-winter 2019.
- Allow weak tussocks and seedlings to become firmly established through delayed re-stocking or low stocking rates.
- Avoid high-impact grazing to prevent over-grazing and trample damage to seedlings and weak tussocks.
- Monitor seedling establishment and tussock development every month and manage grazing according to the pasture recovery requirements.
- Review pasture recovery and adjust stock numbers in winter-spring 2019 and into the next summer (wet season).
- Feed budget to manage stocking rates to leave Mitchell grass stubble at least 20 cm high by the start of the next summer.

Appendix 2. Photographs of the flood effects on pastures, cattle and locations after the monsoon rain event of 2019 (Photos TJ Hall Feb-Mar 2019).

Figure a. *1. Flood and erosion damage to soil surfaces, tussocks and pastures: 2. Sediment deposition downstream from tussocks; 3. Cracking surfaces and dead tussocks; 4. Sheet erosion leaving tussocks pedestalled; 5. Cryptogam surface cracking; 6. Recording flooded Gulf Plains with new tillers emerging from dead plant tops* – note: *10-20 cm sheet erosion between tussocks.*

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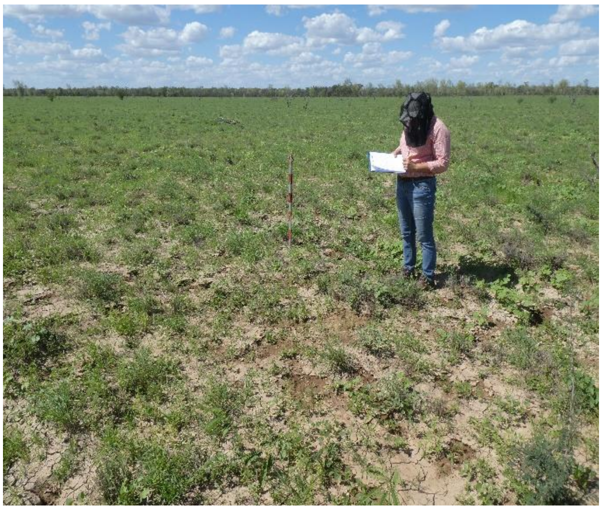

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Figure b. 1. *Horses in the dam for fly protection; 2. Dead buffel grass from inundation; 3. Weaner pulling grass seedlings out of the ground; 4. Weaner cattle that survived the flooding and exposure north of Julia Creek; 5. Surface silt washed across flat Downs country to the edge of a formed road; 6. Recording soil surfaces, moisture depth and pasture recovery including grass and forb seedlings (note: the essential fly veil).*

Appendix 3. Excel spreadsheet of data recorded at the detailed recording sites and at the rapid assessment sites (GPS locations are included).

See separate Excel file of sites where pastures and soil surface conditions were recorded across the flood zone.

Native animals return to recovering pastures of annual button grass near Julia Creek (early March 2019)

New calves from cows that survived the monsoon rain event, south of Julia Creek (late February 2019)

Weaners – survivors of the flood - the future of a herd in the NW Qld flood zone

Flowering *Clitoria ternatea* cv. Milgarra butterfly pea survived flooding on a Mimosa (*Acacia farnesiana*) bush, Balbirini Plains south of Normanton (February 2019)