Ground Cover Under Pressure: Case Study Analysis on the Effects of Ground Cover on Soil Loss During Extreme Flood Conditions in Queensland

Prepared by the Queensland Department of Science, Information Technology, Innovation and the Arts for the Australian Government Caring for our Country

Final Project Report

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Executive Summary

This report examines the impact of landscape and ground cover (the vegetation, living and dead, biological crusts and stone in contact with the soil surface) on soil loss under the extreme pressures of the floods experienced in Queensland during the period of December 2010 to January 2011. During this time of natural disasters, more than 90% of the state was declared disaster affected by prolonged rainfall, intense storms through Southwest, Southeast, and central Queensland, while severe Tropical Cyclones Anthony (in January) followed by Yasi (in February) delivered category 5 rated winds crossing the coastline between Innisfail and Cardwell and extending as a Category 3 to Georgetown.

This information was gathered through a series of related landscape studies that assessed the extent and severity of soil degradation that occurred during the January 2011 floods. It combined data from land resource information, fluvial geomorphology, sediment tracing measurements, remote sensing data and applied modelling technology to assess the damage. Indicators of resilience/vulnerability included tree and ground cover, the extent of water inundation, the level of carbon in the soil and other indicators of soil health, monitoring of land use and land management practices. Other indicators of impact from flooding included the inspection of coastal wetland areas known to comprise acid sulfate soils, loss of terrestrial habitats and loss of biodiversity, the downstream impacts of flooding and sediment movement such as the destruction of aquatic habitats, wetlands, mangroves and the smothering of seagrasses, however these were beyond the scope of this report.

Prior to the floods, the level of ground cover, in addition to existing land use and land management, influenced the degree of damage experienced during the floods. Areas with low levels of surface ground cover tended to be associated with higher levels of soil loss and damage to paddocks and stream channels by water flow.

The Queensland Government is continuing to compile comprehensive information on the environmental, economic, social and physical impacts and the recovery of catchments and habitats following the floods and cyclones through the Queensland Reconstruction Authority (see: http://www.qldreconstruction.org.au). This information, analysis of technical studies and fact sheets will help inform land management decisions to remediate lands that have suffered damage and also assist planning decisions to help avoid problems that could result from future floods.

This report focuses on the role of ground cover in providing erosion protection through two selected case studies for more detailed investigation. The case studies focus on the Lockyer Valley catchment in South East Queensland with a dominance of grazing land management, and the Condamine River catchment in the South West where grain cropping is practised. Some supplementary information is also drawn from state-wide assessments of ground cover which provide wider context for the observations and recommendations.

Key findings:
Analysis of remote sensed imagery showed that the levels of ground cover prior to the flooding were high to very high in both the Lockyer and Condamine catchments, with ground cover levels ranging from 60-80%. This was consistent with many parts of the State where ground cover was high and follows a general upward trend in the ground cover levels in recent years across the state after the shift from El Nino to a strong La Nina weather pattern. For the case study areas, the data also showed that the mean ground cover was higher in 2010 than the 20-year long-term mean of 54 per cent.

These high levels of ground cover observed prior to the January 2010 flood afforded the Lockyer Valley hillslopes substantial protection from sheet and rill erosion. This
is consistent with the established relationships between ground cover and hillslope erosion.

However the high levels of ground cover did not protect the Lockyer Valley from accelerated landslips. Landslips were visible on many steeper slopes, and in most cases involved a number of parallel slips at one location. In the majority of cases these landslips did not appear to be directly connected to the stream channel and therefore may not have contributed to the sediment loads. Preliminary analysis has shown that the majority of landslips mapped with the upper beds of the Marburg geological formation, steeper slopes (>5%), and on land that was generally cleared of remnant native vegetation. Visual comparisons also suggested that many of the landslips resulting from the recent rainfall events coincided with, or were extensions of, past landslips mapped from a previous study (Wilmott, 1984) where the occurrences shared common mapping.

On-ground assessment showed severe erosion of channel banks and beds in the upper reaches of the Lockyer Valley (for example, Upper Lockyer and Murphy's Creek). Where the valley floor widens, this has been accompanied by soil erosion of the adjacent floodplain. Areas of soil deposition were also identified where the widening of the floodplain resulted in a lowering of the flow velocity. In the lower reaches of the extensive alluvial plain, accelerated bank slumping occurred in certain places, particularly in reaches where bank slumping has occurred previously. The presence of isolated trees on banks was commonly associated with accelerated erosion of the banks, although more mixed riparian vegetation (trees, shrubs and grass) afforded the channel more protection from stream bank erosion. This in part may be attributed to the denser vegetation in combination with the geometry of the channel and streambank that reduced the velocity of the water flow, and therefore reduced amount of soil erosion. Future measurements of the changes in channel and streambank geometry, in combination with analysis of ground cover from remote sensing imagery, would provide valuable information to better understand these dynamic processes.

Aerial surveys of the Lockyer Creek and its tributaries also revealed extensive channel erosion (including incision, scouring and bank slump) occurred as a result of the flooding. At a number of sites throughout the Lockyer Catchment there was evidence of significant channel widening and the formation of flood chutes. Evidence of flood plain erosion, deposition and infrastructure damage due to the flood water breaking the banks of the channel was visible in some areas. Where overland flow was minimal, the damage to cropping lands even with low levels of ground cover was not severe. Some evidence of gully activity was visible from the plane, although it was not possible to determine if these were pre-existing or new gullies initiated by the flood events.

In the Condamine catchment, no significant damage to soil conservation structures was observed. Soil conservation banks in the upland areas remained stable compared to similar intensity events in the past, where banks were commonly overtopped and eroded. This is attributed to better vegetation cover (grass and crops) and the uptake of improved crop management practices that retain higher level of residue during periods of fallow.

Most waterways were extensively damaged and scoured unless the banks were well battered (gently sloping) and had high levels of grass cover. There was relatively little silt deposition on roads, except in floodplain areas. However failure of hillslope dams was common at the interface of the uplands with the floodplains.

On the floodplains there was extensive damage to levees and banks and scouring out of floodplains where upland tributaries discharged to the floodplains. In addition, extensive scouring was common along the main watercourses where the vegetation had been removed by the flooding and the banks were undercut by the high velocity
flows. There was damage to irrigation infrastructure such as pumps and irrigators, and erosive flooding was worse where strip-crop farming had not been implemented (for example, controlled traffic down slopes). Erosion tended to be more extensive on properties held by newer landholders where they may not have been exposed to previous land planning and extension information.

Application of remote sensing imagery:
Remote sensing provided a valuable tool for assessing landscapes under pressure from flooding. The access and analysis of Landsat and MODIS imagery allowed the following products to be derived for this study:
- Pre- and post-flood ground cover
- Location and extent of landslips
- Location and change in riparian vegetation cover

The value and accuracy of the remote sensing imagery depended on availability and sequence in relation to the flood event, cloud contamination, availability of pre-flood imagery, extent of ground-truthing soon after the event, and available resources. The accuracy of the satellite imagery products continues to be tested, and further work is required to validate the existing products and provide recommendations for improved methods to map floods more effectively in the future.

Recommendations
Specific recommendations are listed below in relation to hillslopes, footslopes, alluvial plains and channels. Although they are connected as a landscape and may have some issues in common (e.g. maintenance of ground cover), all have degradation challenges specific to their landscape position. It is also important to acknowledge that in some cases it is not possible to protect all elements of the landscape from extreme flooding events.

Recommendations for Hillslopes and Footslopes
- Maintain ground cover at a minimum of 50 per cent through the use of best land management practices.
- Ground cover should be maximised during the wet season, particularly from December to February when the risk of high intensity rainfall and storm events is much greater.
- Access information available through existing government programs on land management and land use planning, e.g. Delbessie Rural Leasehold Lands Strategy, Paddock to Reef, Reef Water Quality and Water Quality Improvement Plans.
- Identify landscapes at risk of landslip (Figures 1 and 2), hillslope and gully erosion (Figures 3 and 4), and dam failure, particularly on footslopes (Figure 5).
- Monitor the status and rate of change in ground cover using existing ground cover index mapping.

5 Strip cropping is the land management practice of growing crops in rotation in a systematic arrangement of parallel strips at right angles to the direction of water flow. It is generally used on lands of low slope (< 1 per cent) to reduce the velocity of flows and spread water in order to minimise soil erosion.
Figure 1. Landslips in the Lockyer Valley 2011.
(a) Pre-flood aerial photography. (b) Post-flood aerial photography. (c) Post-flood aerial photography with landslip mapping shown in blue outline.

Figure 2. Landslips from aerial inspection 2011.
(a) Lockyer Valley. (b) Brisbane Valley

Figure 3. Fitzroy River catchment aerial photos of sloping grazing lands 2011.
(a) Gullying of drainage line in hillslope landscape. (b) Vulnerable hillslope landscape with severe gully erosion.
Figure 4. Fitzroy River catchment aerial photos of sloping cropping lands 2011.
(a) Low ground cover experienced sheet and gully erosion. (b) High ground cover and contour banks have stabilised hillslopes.

Figure 5. Lockyer Valley - gully formed below collapsed dam wall 2011

**Recommendations for Alluvial Plains**

- Maintain ground cover at a minimum of 50 per cent through the use of best land management practices.
- Maintain ground cover through existing programs e.g. Delbessie Rural Leasehold Land Strategy, Paddock to Reef, Reef Water Quality, Land and Water Management Plans.
- Identify landscapes at risk of erosive flooding and siltation (Figures 6, 7 and 8), gully erosion and dam failure through existing programs.
- Monitor ground cover using existing ground cover index mapping.
- Identify the extent of past floodplain activity using fluvial geomorphology and sediment dating techniques.
Figure 6. Erosive flooding and siltation on the Condamine floodplain 2011

(a) Major gully erosion. (b) Severe erosive flooding.

Figure 7. Lower Condamine floodplain 2011.
(a) Major gully erosion. (b) Severe erosive flooding.
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Figure 8. Ground cover contrast catchment 2012.
(a) Condamine River extensive groundcover has protected land from erosion. (b) Lockyer Creek floodplain erosive flooding removed 50–70cm of topsoil (Note plough marks in subsoil material).

Recommendations for Stream Channels

- Improve the extent of natural and restored riparian vegetation and natural channel debris to slow flood velocity and increase the level of stream bank and channel protection.
- Identify channels at risk of stream bank erosion (Figures 9, 10 and 11) and gully initiation through existing programs. Apply fluvial geomorphology and sediment tracing techniques to determine the extent and severity of stream bank erosion and areas of sediment deposition arising from past extreme flood events.
- Identify the landscape position of townships at risk from catastrophic flooding if subjected to January 2011 type flood events (Figure 9).
- Apply best practice guidelines to sustainably manage stream channels (see p.52)
- Monitor ground cover and riparian vegetation using existing ground cover index and vegetation mapping programs
- Examine the potential to improve design of weirs, road and bridge infrastructure to avoid debris build up, minimise concentrated runoff and turbulence downstream and reduce flood damage (Figures 12, 13 and 14).

Figure 9. Towns and houses at risk from January 2011 floods.
(a) Lockyer Valley (b) Brisbane Valley.

Figure 10. Lockyer Siding floodplain post-flood, February 2011.
Note the extensive sand deposition across the valley floor and the coincidence with valley widening.

Figure 11. Lockyer Creek before and after the January 2011 flood.

Figure 12. Creek slumping at Wilsons Weir, Lockyer Creek 2012.
Figure 13. Close up of bank slumping at Wilsons Weir, Lockyer Creek 2012.

(a)  (b)

Figure 14. Condamine River catchment. (a) Severe slumping of creek below road crossing. (b) Stable waterway with battered banks and 100% tall grass ground cover below road crossing.
1. Introduction

The storms and flooding events in Queensland over the 2010-2011 wet season have scoured hill slopes to remove top soil and nutrients, created and expanded gullies and landslips, and reformed waterways, channels and floodplains.

The transported soil has either deposited across infrastructure, habitats and floodplains, or been transported by streams to the estuarine and near-shore ecosystems to form sediment plumes. Essentially, the extreme flooding event has connected the terrestrial, riparian, riverine, estuarine and marine systems.

Ground cover is defined as the vegetation, living and dead, biological crusts and stone that is in contact with the soil surface. By protecting the surface, ground cover plays an important role in reducing the loss of topsoil by storm rainfall and surface runoff. The amount and type of protective ground cover will vary across time and space due to the physical features of the soils, the climate and land use, in concert with the economic and social influences of the type of land management practices being employed by the landowner. As a result, the level of ground cover prior to storm events may range from high to bare ground. Under the conditions of storm rainfall, it is expected that high levels of surface and ground cover will reduce the amount of soil erosion from hillslopes. However, to what extent does this model of sustainable management remain when the landscape is subjected to extreme rainfall and flooding events which have a statistical recurrence frequency greater than 1 in 100 years?

The recent flood and storm conditions in Queensland provide an opportunity to examine the effect of ground cover under extreme circumstances. Between November 2010 and January 2011, catchments in the Southwest, Darling Downs, South East Queensland and in the Burnett, Fitzroy, Mackay catchments in Central Queensland, experienced well above average rainfalls leading to widespread flooding causing damage to property, farm infrastructure, and the loss of lives in the Lockyer catchment.

The conditions following the storm and flooding events provide an opportunity to study the impacts of land management and land cover when subjected to the extreme pressures of a natural disaster. Outcomes from this investigation can then be used to communicate key messages on the role that good ground cover management can provide in reducing the risk of soil loss, even under extreme conditions.

1.1 Objectives

The purpose of this report is to examine the nature and effect of ground cover on soil loss under the extreme conditions of prolonged rainfall and extensive flooding.

Specifically, this report is designed to provide new knowledge and insights through an analysis of case studies on the impacts of ground cover and land use (cropping and grazing) and land management practices on soil erosion under extreme rainfall and flood conditions.

The report also provides illustrative evidence on the role that ground cover management can provide in reducing the risk of soil loss for different landscapes in Queensland. These examples can be used in subsequent factsheets, brochures and other communication products to extend the knowledge and further influence the move towards improved land management practices in cropping and grazing lands.
1.2 Case study catchments

The case study areas include the Lockyer Valley (Figure 15a) and the Condamine River catchment (Figure 15b).

Figure 15. Case study areas for ground cover assessment in the (a) Lockyer Valley and (b) the Condamine River catchments.

To provide advice on how to recover from this damage and how to better manage landscapes in the future, a state-wide overview assessment of the severity and extent of soil degradation was conducted. More detailed assessments were also undertaken in the selected case study catchments.
2. Data sources and assessment methods

Information on ground cover and landscape impacts were assembled from a number of sources. A brief description follows.

2.1 Ground cover

A pre-flood assessment of ground cover levels was undertaken using the Ground Cover Index (GCI). The GCI is a remote sensing product derived from medium-resolution Landsat TM and ETM+ satellite imagery (30 metre pixel resolution) using a multiple linear regression approach (Scarth et al., 2006). It is an image based product with groundcover values estimated for each 30mx30m pixel. The GCI is not estimated in areas of woodland and forests (with foliage projective cover >15%), areas affected by cloud at the time of acquisition of the image, or areas covered by open water.

The Landsat images used to produce the GCI were the best available taken from the Remote Sensing Centre (RSC) image archive or downloaded from the United States Geological Survey (USGS). For the pre-flood GCI, image selection attempted to obtain Landsat scenes that were as near as possible to the end of 2010, and those which had the least cloud-affected areas. Imagery for previous years was generally, late dry season imagery acquired for the Statewide Landcover and Trees Study (SLATS).

For each image selected for 2010, the GCI was estimated and summarised for major catchments. The relative level of ground cover pre-flood was also assessed by comparing the mean GCI for 2009 to the GCI for preceding years to 1987. This was only completed to 2009 because missing data (due to cloud or image availability) in 2010 meant that the entire state was not represented. This comparison is useful for showing the general trend in state-wide ground cover levels, particularly in the years immediately preceding the flooding events. A final analysis was undertaken which compared the pre-flood (2010) mean GCI to the mean GCI calculated from a time-series from 1988-2010 and summarised for each major catchment. This analysis provides useful information about the levels of ground cover present in each catchment just prior to the flooding events compared to the long-term mean of the ground cover for each catchment.

2.2 Flood extent and inundation mapping

A rapid regional-scale mapping of approximate maximum inundation extent was conducted in the case study catchments. Although not directly related to soil erosion, this mapping can inform the assessment of flood impacts and inform recovery efforts at a regional scale. In both regions, the accuracy of the mapping was limited by the availability of cloud-free imagery and available imagery that corresponded with the timing of the maximum extent of inundation. The delineation of flood extent was informed by land resource mapping, particularly the mapping of alluvial soils and floodplains. These mapping products are being verified in collaboration with local council authorities.

An approximation of inundation extent was visually interpreted and manually digitised using a selection of Landsat 5 TM imagery between December 2010 and January 2011. Interpretation in some cases was based on the maximum visible extent of standing water. However, for most areas imagery was not available during the peak of the flood. The best available post-flood imagery was used and areas that appeared to have changed during the floods, possibly as a result of sediment
deposition, scouring or changes to ground cover, were delineated as the likely flood footprint. An example of this is provided in Figure 18. The mapping was undertaken at an approximate scale of 1:100 000. Inundated areas were captured in raster format for each Landsat scene, then mosaiced and converted to vector format.

A threshold water index approach was chosen to map standing water across the catchments between December 2010 and January 2011. Water index rasters were generated from Landsat 5 TM using a method developed by DSITIA and described by Danaher and Collett (2006). Thresholds were manually selected for each individual Landsat 5 scene. These thresholds maximised the identification of water pixels and minimised cloud, cloud shadow and other distortions. The resulting threshold–based images were checked for errors and manually edited, where necessary, to remove obvious errors of commission (primarily cloud and cloud shadow). The images were then aggregated to create a mosaic, filtered to remove speckle, and converted to vector format.

Figure 16. Example of post-flood Landsat imagery and interpretation of flood footprint
3. Results

3.1 State-wide Ground Cover

Mean state-wide ground cover in 2009 was approximately 57%, as shown in Figure 17. As previously mentioned, due to an incomplete state-wide coverage of Landsat imagery for 2010, the mean ground cover for that year is not presented here. However, given the generally wet conditions across the state over the past two years due to the strong La Nina weather pattern, and based on the upward trend in mean ground cover for the past 6-7 years, it could be reasonably assumed that mean state-wide ground cover levels in 2010 were at least that of 2009, if not slightly greater.

![Graph of state-wide ground cover 1986-2009.](image)

Figure 17. Mean state-wide ground cover 1986-2009.
Note the general upward trend in cover levels in recent years following the drought as the weather shifted due to the presence of a strong La Nina cycle.

Figure 18 shows the ground cover levels pre-flood in 2010, where Landsat imagery was available. There was generally high cover in those areas that were significantly flood-affected however the cropping regions of the Central Highlands and Darling Downs showed lower levels of cover. This is likely to be due to the timing of the imagery for those areas (late winter to early spring) when there are increased areas of bare and fallow soil following harvesting of winter crops and tillage for summer crops. Further analysis of the actual cover levels at the time of the flooding impact is required but is limited by available and cloud-free imagery.
In all regions across the state pre-flood, (that is, mid to late 2010) ground cover levels were high to very high. This followed a general upward trend in the ground cover levels in recent years across the state after the shift from El Nino to a strong La Nina weather pattern. For the case study areas (see Sections 4 – 6), the data also showed that the mean ground cover was higher in 2010 than the long-term mean. This suggests that the impacts of the high rainfall and flooding events of 2010-11 on hill slope erosion processes may have been minimised due to the high ground cover present at the time. The impact of erosive flooding on the alluvial plains was also generally minimised by the high levels of ground cover preceding the flood events. If this flood event occurred following a drought or a drier period with low ground cover,

Figure 18. State-wide ground cover for (pre-flood) 2010. Darker browns indicate high levels of cover, lighter browns low levels. Note areas of woodland and forests are not included in the analysis and large areas have been omitted due to cloud contamination or unavailability of imagery. Note: FPC is the Foliage Projective Cover beneath tree canopies.
across the state, for example in 2004, the erosion levels would have been significantly higher. As a result, the losses in productivity would have been much greater as well as the negative impacts on biodiversity and water quality. Through modelling, estimations of the erosion levels for the state based on: (i) the actual conditions with high ground cover prior to the floods; and (ii) ground cover levels for a drier period, for example at 2004, are being investigated further.

In some of the more intensively cropped areas where land management and cropping practices result in extended periods of low cover or bare (fallow) soil (for example, the Condamine Plain), there may have been a greater impact of erosive flooding, particularly on topsoil. See Section 6 Condamine River catchment case study.

### 3.2 Flood extent SEQ and Condamine-Balonne catchments

The rapid flood mapping for the SEQ and Condamine-Balonne and Border Rivers catchments showed that flood waters affected most of the catchments (Figure 19), the exceptions being the Baffle, Boyne, Maroochy, Noosa, South Coast and Dumaresq catchments.

Estimates of the areas inundated for these catchments are provided in Table 1. Based on the mapping undertaken, the catchments with the greatest areas of flood inundation included the Fitzroy, Mackenzie, Comet, Balonne, Macintyre, Condamine, Bremer, Lockyer and Moonie. It is important to recognise that the figures in Table 1 are estimates only and, due to time constraints, no validation has been undertaken. As a result, a description of the accuracy of the mapping is not available. The limitations encountered included the lack of imagery available during the peak of the floods, the presence of cloud and cloud shadow that covered areas of interest, and reliance on visual interpretation without accompanying validation data.

Figure 19 also shows the extent of (open water) inundation mapping for the Bulloo, Paroo, Warrego and Cooper Creek catchments. As described in the methods, the mapping captured the extent of water in the imagery. As the imagery was often captured after the floods, the extent of actual inundation could be considerably larger than shown in the mapping. Therefore we did not consider it appropriate to provide estimates of the areas flooded for these catchments based on this approach.

### 3.3 Discussion and observations

Long periods of inundation can have negative impacts on pasture growth. For example, the 2009 floods in the Northern Gulf left extensive grazing paddocks bare. It appeared that the inundation affected the seed bank with limited growth of pasture species for some time following the flood. Eventually ‘exceptional circumstances’ assistance was granted to landholders affected. Having produced a pre-flood ground cover snapshot for Queensland, future studies of ground cover post floods that are possible include the assessment of the impacts in areas that had longer inundation periods and monitoring of recovery over time.
Figure 19. Inundation mapping based on rapid processing and assessment of Landsat imagery.

Table 1. Flood inundation by catchment

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Catchment Area (ha)</th>
<th>Mapped flood area (ha)</th>
<th>Percentage of catchment mapped as flooded</th>
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<td>176540</td>
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<td>148389</td>
<td>731</td>
<td>0</td>
</tr>
<tr>
<td>South Coast</td>
<td>130404</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>40050817</strong></td>
<td><strong>2992160</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

Examples of the fractional ground cover product showed some potential benefits over the standard ground cover product (i.e. the GCI) for assessing pre- and post-flood effects of inundation and flood movement. The additional information provided by the fractional ground cover product about the ‘photosynthetic state’ of the ground cover has demonstrated in this study some promise for comparing changes in ground cover.
pre- and post-landscape degradation events (such as the recent floods and Cyclone Yasi). Once the algorithm and products are fully tested and validated, the data generated may also assist with ongoing assessments and recovery monitoring; providing surrogate information for pasture health, cropping cycles and possibly for ground cover species composition. This information will be also be further improved by incorporating a denser time-series of imagery into the analysis to better understand seasonal changes.

Future work is planned by DSITIA to continue to monitor recovery of flood- and cyclone-affected areas using the fractional ground cover algorithm applied to seasonal Landsat imagery. This information will be critical to future land management recommendations and disaster response. It will also provide contextual and quantitative information to inform key government programs and policies that are reliant on ground cover data to characterise and understand landscape trends and condition (for example, Delbessie, Reef Plan Programs), particularly if they are to account for the impacts of natural disasters.

The rapid, regional scale flood mapping undertaken by DSITIA has demonstrated that remote sensing can be used to map flood extent. The accuracy of the products has not yet been tested. However, from the mapping, it is clear that large areas of the state were affected by inundation and flooding during 2010-11 flood events, particularly the Fitzroy River Basin and Condamine-Balonne river systems.

The ability to map flood extent was limited by available imagery, cloud contamination and available resources. Further work is required to validate the existing products and to provide recommendations for improved methods to map floods and inundation more effectively in future. This may include incorporating multi-resolution optical and radar imagery, and developing systems for rapidly acquiring and processing the imagery to produce flood mapping products. Such products could include, for example: maximum inundation extents; near real-time mapping of flood water movement; and, water residence time.

The flood mapping undertaken by DSITIA was done at short notice and involved a redirection of resources from current programs. The spatial data generated was not validated nor assessed for accuracy. This information was provided to the Queensland Reconstruction Authority to inform assessment of flood relief claims and to assist with recovery efforts. There is a clear need for a program that develops operational flood (and other disaster) mapping capability using remote sensing. The information produced by any such program should be subject to scientific rigour and peer review. The program should also formalise and improve existing collaborative arrangements with state and federal agencies responsible for emergency response (for example, Department of Community Services and Geoscience Australia).
4. Lockyer Valley case study

4.1 Methods
The methods for assessing ground cover and aerial surveys described below also applied to the Fitzroy River and Condamine River catchment case study areas (Sections 5 and 6 respectively).

4.1.1 Ground cover
The pre-flood ground cover levels were assessed for sub-catchments within each of the case study areas using the GCI (refer to Section 2.1 for details). Statistics calculated included the mean GCI for 2010 and the long-term mean GCI for the period 1986 to 2010.

The DSITIA Remote Sensing Centre (RSC) has been developing a new method that uses remote sensing to estimate what is referred to as fractional ground cover. Fractional ground cover is the (sub-pixel) photosynthetic cover, non-photosynthetic cover and bare ground components (or fractions) that, when summed, constitute the total estimate of ground cover (and bare ground). The fractional cover product is currently undergoing validation and has been included in this study to provide an example of its potential for future applications. Fractional ground cover may be useful for comparing pre- and post-flood ground cover conditions. It may be used to show where ground was bare prior to flooding or where extended periods of inundation or areas of erosive flooding affected the ground cover through removal or deterioration of healthy live, green (photosynthetic) cover.

The fractional ground cover algorithm developed by the RSC was applied to pre- and post-flood Landsat 5 TM imagery for two areas selected from the Lockyer and the Darling Downs. Image dates are given for the two locations in Table 2.

Table 2. Image dates and locations for pre- and post-flood fractional cover examples in the Lockyer Valley and Condamine River catchment case study areas

<table>
<thead>
<tr>
<th>Location</th>
<th>Pre-flood image date</th>
<th>Post-flood image date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lockyer Valley</td>
<td>20/1/2010</td>
<td>23/1/2011</td>
</tr>
<tr>
<td>Condamine River catchment</td>
<td>16/8/2010</td>
<td>23/1/2011</td>
</tr>
</tbody>
</table>

An additional step was undertaken for the Lockyer Valley. A two-date change detection was applied to the green (photosynthetic) fractional cover for the pre- and post-flood dates over an area where landslips had been mapped (see Section 4.2.3).

4.1.2 Aerial surveys
Aerial surveys were undertaken for the two case study areas. The surveys were conducted in the first week of February when conditions presented a safe opportunity for flying. Staff involved had experience in remote sensing, landscape processes and a regional expert from DNR&M and DAFF. All photos were geo-coded.

Global Positioning System (GPS) tracking was used to record the routes taken during the aerial survey. Flying heights ranged from approximately 150m to 800m depending on conditions and controls over airspace. Conventional digital photography was used to photograph features of interest from the windows of the aircraft. These features included flood-affected areas, evidence of recent erosion, and areas that were flood-affected but showed little or no signs of degradation.
Post-processing of the digital photography geo-linked individual photographs to their approximate location, based on time-based synchronisation between when the photograph was taken (as recorded by the camera) and the GPS track-log time record. The photos were then converted to thumbnails, geo-linked with the aerial survey routes and converted to .kmz format for display in Google™ Earth.

4.1.3 Landslip mapping and assessment

Landslip mapping was undertaken for approximately 66,000ha of the Lockyer Valley (approximately 20% of Lockyer catchment). The area of ground surface visibly affected by landslips was delineated using visual comparison and manual digitisation of ortho-rectified colour aerial photography acquired pre- and post-flood. Details of the aerial photography are given in Table 3.

Table 3. Aerial photography specifications for Lockyer Valley landslips mapping

<table>
<thead>
<tr>
<th>Date of capture</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>50cm</td>
</tr>
<tr>
<td>2011</td>
<td>15cm</td>
</tr>
</tbody>
</table>

A preliminary assessment of the landslip mapping was undertaken to characterise the landscapes in which landslips were most prevalent by analysing biophysical features including: vegetation cover and structure; geology and soil type; and topographic features such as slope, aspect and distance to watercourse.

Historical landslip mapping was undertaken for part of the Lockyer Valley by Wilmott (1984) and for the entire catchment by Shaw (1979). The maps produced by the current study were acquired in digital format. There were only small areas that matched the historical mapping with the current mapping. This precluded any meaningful statistical comparisons between the historical and current landslip mapping. However, for those areas that did coincide, visual comparisons were able to be made between the location of landslips resulting from the recent rainfall event and those mapped by Wilmott (1984) from historical events.

4.1.4 Channel and floodplain erosion assessment

Data relating to channel and floodplain erosion were collected for the Lockyer Valley and the Condamine River catchment. The Lockyer Valley was analysed in three main stages:

**Stage 1: Pre-Flood Assessment.**
A detailed analysis of pre-flood channel metrics (geometry) and the extent of channel erosion features have been undertaken based on pre-flood high resolution digital elevation data using Light Detection and Ranging imagery (LiDAR) acquired in 2010.

**Stage 2. Field data.**
Field data collection was undertaken during May 2011 at approximately 60 sites throughout the main stem of the Lockyer Valley ranging in elevation from Spring Bluff (~700m) through to the confluence of Lockyer Creek with the mid-Brisbane River (Fig. 20). Each site consisted of ~10 transects which assessed the nature and degree of erosion both of the channel banks and the surrounding floodplain. In addition, the stratigraphy and soil profile development at 30 sites were described in detail and ~110 samples were taken for Optically Stimulated Luminescence (OSL) dating to determine the recurrence interval of previous floods of this magnitude.
Figure 20. Location of field data sites throughout the Lockyer Valley. Each site included ~10 cross-channel transects. The grey-shaded area represents the spatial coverage of pre-flood lidar data. Sites were assessed beyond this area for completion.

**Stage 3. Assessment of Post-Flood Lidar Imagery.**

Post flood imagery has recently been acquired and will provide an estimate of the extent of channel erosion post the January flood. This data will be compared to that obtained during Stage 1 to provide a measure of landscape change and the net erosion or deposition of sediments.

**4.2 Results**

**4.2.1 Aerial survey**

Figure 21 shows the aerial survey route taken for the Lockyer Valley on 1 February, 2011. The aerial survey showed that there was extensive channel erosion (including incision, scouring and bank slumps) in the Lockyer Creek and its tributaries, particularly Alice Creek, Buaraba Creek, Murphy's Creek, Ma Ma Creek, Black Duck Creek, Blackfellow's Creek and Tenthill Creek. At a number of sites throughout the Lockyer Catchment there was evidence of significant channel widening and the formation of flood chutes. Evidence of flood plain erosion, deposition and infrastructure damage due to the flood water breaking the banks of the channel was visible in some areas (see section on Erosive Flooding). There was comparatively little evidence of floodplain erosion due to overland flow. The majority of the cropping lands were fallow and looked relatively intact. Some evidence of gully activation was visible from the plane.

Landslips were visible on many steeper slopes, and in most cases involved a number of parallel slips at one location. In the majority of cases these landslips did not appear to be directly connected to the channel.
Figure 21. Map of Lockyer Valley showing aerial survey route and locations of field-based assessments
4.2.2 Ground cover

Pre-flood (2010) mean ground cover levels were very high (>80%) for all sub-catchments in the Lockyer Valley (Fig. 22). Ground cover levels pre-flood also exceeded the long-term mean for all sub-catchments.

![Ground Cover Pre-flood and Long-term Mean](image)

Figure 22. Mean pre-flood (2010) (green) and long-term mean (blue) ground cover levels of sub-catchments of the Lockyer Valley.

4.2.3 Fractional ground cover

Figure 23 is an example of a pre- and post-flood change detection applied to the fractional cover product. This highlights areas of significant change between fractional ground cover states and may be useful for detecting and monitoring change and landscape recovery over time.
Figure 23. Example of the change detection in the Lockyer Valley based on the green (photosynthetic) cover fraction. Landslip mapping is shown in blue. a) Pre-flood aerial photography b) Post-flood aerial photography c) Pre-flood Landsat image (RGB 3 2 1) d) Post-flood Landsat image – note bare ground areas where landslips occurred. e) Result of change detection. Red areas show significant change in the green (photosynthetic) cover fraction.

4.2.4 Landslip mapping and assessment

For the approximately 66,000ha of the Lockyer Valley assessed for landslips, approximately 110ha of land was affected by over 1000 individual landslips (Fig. 24).
Figure 25 is a detailed view of the landslip mapping using pre- and post-flood aerial photography.

Figure 24. Landslip mapping for the Lockyer catchment
4.2.5 Channel and floodplain erosion

Severe erosion damage was largely associated with stream channels. The baseline data for comparison with the post flood lidar and field data has been summarised, however due to the late acquisition of the post-flood lidar, there has been insufficient time to accurately quantify the volume of material removed through post-flood channel and floodplain erosion for this report. The following results are based, therefore, on the observations and measurements recorded during the field data period in May 2011.

Extent of Channel Bank Erosion

The range of sites covered in the field data phase of this project is sufficiently representative of a range of geomorphic settings from narrow creek flats confined by uplands (Spring Bluff, Murphy’s Creek) through to the wider alluvial plains of the lower Lockyer Valley.

Each of the 60 sites (~500 transects) showed some degree of change in the geometry of the channel; either widening through bank erosion/collapse or deepening through changes in the elevation of the bed. At a number of sites, the upper reaches of the Lockyer and Murphy’s Creek are now characterised by a complete transformation of the channel. In many confined reaches, the alluvial banks have been stripped away and the channel now occupies the entire valley floor (Fig. 26a). These sites will undergo a progressive adjustment to these new dimensions and with smaller runoff events, alluvial infilling will occur over time.
In the middle to lower reaches of the main valley, the dominant form of channel bank erosion appears to be mass failure, that is, bank slumping (see Fig. 26b). The likely cause of this slumping is both a combination of the shear stresses occurring during the flood but equally and importantly, water seepage from banks immediately post the flood event. The highly saturated banks, with fast flowing return floodwaters, are likely to have contributed to the high incidence of bank slumping.

There appears to be some indication from the preliminary analysis that slumping is re-activated at sites which showed evidence of mass failure in previous imagery. This suggests some sites are now inherently susceptible to mass failure.

A detailed analysis is now underway to identify the characteristics and likely causes of the most significantly eroded sites.

**Erosive Flooding**

This term is taken to indicate erosion of the alluvial surface adjacent to the channel banks and would indicate net loss of soil from the floodplain areas. The full extent of this throughout the study area has not yet been evaluated from the lidar data. However, several sites show visible evidence of floodplain erosion (Fig. 27). These sites are located in the upper, steeper parts of the catchment and throughout the middle and lower segments of our survey. At this preliminary stage of analysis, there appears to be a correlation between erosive flooding and changes from confined to unconfined parts of the valley. The example shown at Lockyer Siding (Fig. 28) reflects the change from a confined upper reach to a wider, more unconfined valley downstream. In such transitions, the flood waters had space to spread out across the floodplain, reducing the stream power of the flow and allowing sediments to deposit. In examples observed further downstream, similar occurrences are related to channel confinement in more erosion-resistant material, forcing the channel to cut-across floodplain surfaces and leading to net soil loss. Overall, however, field observations would indicate that such occurrences are relatively isolated and the large dimensions of the Lockyer Creek channel has managed to contain large volumes of flood waters.

![Figure 27. Floodplain erosion at a downstream site on the Lockyer. Flows came across the floodplain surface removing approximately 50-70cm of topsoil at this site. Note plough marks in subsoil material.](image)
4.2.6 Sediment tracing

Sampling for this project will be undertaken in two stages. In the first stage samples were collected from 18 sites on the Lower Brisbane River floodplain (Figure 29) in February 2011. Sites were located between the Mt Crosby Water Treatment Plant and Luggage Point in areas where sediment drapes were identified (Figure 30). The second stage of sampling is to collect four five metre cores from Moreton Bay. The cores will be taken at sites previously sampled by Heggie et al. (1999) from the area containing the largest fine-grained sediment (mud) deposits in the Bay, each site possibly representing different long-term deposition histories.

Floodplain sediment deposit samples are being analysed for particle size distribution. Radio-nuclide analysis using gamma spectrometry and major and trace element analysis are being conducted on relevant size fractions.
Moreton Bay cores will be sectioned into depth intervals based on core stratigraphy. These samples will then be dated using Optically Stimulated Luminescence (OSL) and the major and trace element concentrations will be determined.

Figure 30. Sediment drapes deposited on the Brisbane River floodplain during the January 2011 flood were sampled at 18 sites between the Mt Crosby Weir and Luggage Point. Sites sampled included (Clockwise from top left) Hamilton, Indooroopilly, Kangaroo Point, and Oxley.

4.3 Conclusions

The high levels of ground cover observed on hillslopes prior to the January 2010 flood afforded the Lockyer Valley substantial protection from sheet and rill erosion. For the case study areas, the mean ground cover exceeded 80 per cent and was higher in 2010 than the 20-year long-term mean of 54 per cent. This assessment is consistent with the established relationships between ground cover and hillslope erosion.

However the high levels of cover did not protect it from accelerated landslip formation. Preliminary analysis shows that the majority of landslips occurred on the same geology (mainly the upper beds of the Marburg Formation), steeper slopes (>5%), and on land that was generally cleared of remnant native vegetation. Visual comparisons also showed that where the study area shared common ground with that of Wilmott’s study (Wilmott, 1984), landslips that were the result of the recent rainfall events did coincide with those mapped for previous rainfall events. Future work will include an assessment of vegetation structure, and possible quantification of sediment movement based on analysis of LiDAR data. An investigation of the proximity to watercourses to understand the sediment transport paths from the landslips is also planned.

Preliminary assessment shows severe erosion of channel banks and beds in the upper reaches of the Lockyer Valley (e.g. Upper Lockyer, Murphy’s Creek). Where the valley floor widens, this has been accompanied by erosive flooding of the
adjacent floodplain. In the lower reaches of the extensive alluvial plain, accelerated bank slumping occurred in certain places, particularly in reaches where bank slumping has occurred previously.

The presence of infrastructure (e.g. road crossings, bridges and weirs) or isolated trees on banks was commonly associated with accelerated erosion of the banks, although more mixed riparian vegetation (trees, shrubs and grass) afforded the channel more protection from stream bank erosion. Particular attention should be given to the role of vegetation in the remediation of these sites.
5. Condamine River Catchment case study

5.1 Methods

See sections 4.1.1 and 4.1.2 for details of aerial survey and ground cover assessment.

5.1.1 Field assessment

The Condamine River catchment was assessed in the field in February 2011. A number of sub-catchments were assessed for evidence of damage caused by the floods which occurred over the period of December 2010 and January 2011. The main aim was to visually assess soil loss and attempt to identify relationships with land use and management practices.

Sub catchments assessed within the Condamine catchment were Swan and Emu Creek, Glengallan Creek, Dalrymple Creek, Kings Creek, Hodgson Creek, Ashall Creek, Oakey Creek, Myall Creek, Charleys Creek, Lower Condamine River, Condamine Rover and Upper Condamine River (Fig. 31).

Six teams of two people were assigned various sub catchments and involved local volunteers supported by the Condamine Alliance. A site description sheet based on a modified DSITIA site description was devised so that completed sheets could be entered onto the DSITIA SALI (Soil and Land Information) system. This system is not only a data storage system but allows for interrogation of the data. Sites were generally located on drainage lines on roadsides and roadside paddocks, where damage was observed (Table 4).

Information collected at each site included Site number and geographic location using GPS, vegetation characteristics such as type and cover percentage (%), land characteristics including local geology, slope and relief, erosion type within a 40 metre radius, land use management practices employed, if any, and land use via the ALUM (Australian Land Use and Management classification) version 7 (Australian Government 2010). This system emphasises the level of intervention or potential impact on the natural landscape. It has a 3 level hierarchical structure with six primary classes. Primary and secondary levels relate to land use. The tertiary level includes data on commodities or vegetation (e.g. crops such as cereals and oil seeds).
Table 4. Distribution of field assessment sites in the Condamine River catchment.

<table>
<thead>
<tr>
<th>Sub-catchment</th>
<th>Sites on drainage lines</th>
<th>Sites on paddocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swan and Emu Creek</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Glengallan Creek</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Dalrymple Creek</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Kings Creek</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Hodgson Creek</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Ashall Creek</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Oakey Creek</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Myall Creek</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Charleys Creek</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Lower Condamine River</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>Condamine River</td>
<td>6</td>
<td>28</td>
</tr>
<tr>
<td>Upper Condamine</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>72</strong></td>
<td><strong>129</strong></td>
</tr>
</tbody>
</table>
Figure 31. Sub-catchments of the Condamine River catchment and field site locations
5.2 Results

5.2.1 Aerial survey

Figure 32 shows the aerial survey route taken on 1st February, 2011. The aerial survey showed that the catchment did not suffer widespread hillslope erosion, although some gullies were observed. The Sites experiencing most damage were located either in stream channels or on the floodplains. Many streams were observed to have bank erosion and slumping. Floodplains were extensively eroded or aggraded in places, particularly where ground cover was absent (Fig. 31).

Figure 32. Map of Condamine River catchment showing aerial survey route and locations of field-based assessments

5.2.2 Ground cover assessment

Pre-flood (2010) mean ground cover levels were high (>60%) for all sub-catchments in the Darling Downs (Fig. 33). Ground cover levels pre-flood also exceeded the long-term mean for all sub-catchments with the exception of Undalla Creek which was about equal to its long term mean. Mean ground cover levels in the Darling Downs appear to be generally lower than the Lockyer Valley because of the low levels of cover in the intensive cropping areas. This is related to cropping cycles and land management practices. Upland areas of the Darling Downs were observed to have generally very high cover pre- and post-flood.
5.2.3 Fractional ground cover example

Pre- and post-flood examples of the fractional ground cover product are shown in Figure 34 for an area over the Condamine River floodplain. The pre-flood image on the left was captured in August 2010. It shows a large amount of bare, cultivated land (red to pink colours) with some active crops at the bottom of the image (green colours). It also shows vegetative cover, both photosynthetic and non-photosynthetic (blue and green colours), along the main river channel. The image on the right was captured in January 2011. There is an obvious pattern of change from photosynthetic and non-photosynthetic ground cover pre-flood, to bare ground post-flood, over the main river channel areas where erosive flooding was at its most powerful. However, this should be viewed with caution, as the fractional cover product classifies water as bare ground and it is possible that a significant component of the bare fraction shown in that image is flood waters. Further validation and development of the product is required to account for these issues.
Figure 34. (a) Pre-flood and (b) Post-flood fractional cover for Condamine River floodplain. Red colours indicate bare ground fractions, blue colours indicate non-photosynthetic cover fractions and green colours indicate photosynthetic cover fractions. Note the change from vegetated ground cover along the main river channels in the pre-flood image, to an increase in bare ground in the image on the right. Note that water can also be 'misclassified' with bare ground fractions. There is also a significant increase in vegetation cover fractions in areas surrounding the river in the post-flood image. This includes summer crops and pastures.

5.2.4 Field assessment

A total of 201 sites were assessed across the study area. Within each catchment, sites varied between drainage lines and paddocks. Site data and photos are held in the SALI database as described in Appendix 1. The level of damage is summarised in Table 5, while major characteristics in each sub-catchment, based on the field assessment, is provided in Table 6.

Table 5. Summary of field erosion status in Condamine River catchment.

<table>
<thead>
<tr>
<th>Sub-catchment</th>
<th>Number of sites</th>
<th>% of sites - stable</th>
<th>% of sites - partly stable</th>
<th>% of sites - active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swan and Emu Creek</td>
<td>15</td>
<td>33</td>
<td>53</td>
<td>13</td>
</tr>
<tr>
<td>Glengallan Creek</td>
<td>6</td>
<td>16</td>
<td>50</td>
<td>33</td>
</tr>
<tr>
<td>Dalrymple Creek</td>
<td>11</td>
<td>18</td>
<td>55</td>
<td>27</td>
</tr>
<tr>
<td>Kings Creek</td>
<td>21</td>
<td>33</td>
<td>38</td>
<td>29</td>
</tr>
<tr>
<td>Hodgson Creek</td>
<td>12</td>
<td>17</td>
<td>25</td>
<td>58</td>
</tr>
<tr>
<td>Ashall Creek</td>
<td>14</td>
<td>0</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>Oakey Creek</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Myall Creek</td>
<td>12</td>
<td>17</td>
<td>50</td>
<td>33</td>
</tr>
<tr>
<td>Charleys Creek</td>
<td>9</td>
<td>56</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Lower Condamine River</td>
<td>42</td>
<td>34</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>Condamine River</td>
<td>34</td>
<td>20</td>
<td>24</td>
<td>56</td>
</tr>
<tr>
<td>Upper Condamine</td>
<td>5</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL Sites / Average %</strong></td>
<td><strong>201</strong></td>
<td><strong>30</strong></td>
<td><strong>36</strong></td>
<td><strong>34</strong></td>
</tr>
</tbody>
</table>
Table 6. Description and major damage of sub-catchment

<table>
<thead>
<tr>
<th>Sub-catchment</th>
<th>Description of land form, land use and major erosion damage</th>
</tr>
</thead>
</table>
| Swan and Emu Creeks | 15 sites mostly on paddocks  
Undulating low hills, rolling low hills and gently undulating plains on Mulgildie and Walloon Coal Measures  
Ground cover - 10 to 100%  
Slopes 3 to 8%  
Land use - cropping and grazing  
Minor to moderate rill/sheet erosion, minor to severe gullying and stream bank erosion  
Erosion status – 33% stable, 53% partly stable and 13% active  
Land management – contour banks and pasture |
| Glengallan Creek | 6 sites on drainage lines  
Undulating low hills and gently undulating plains on Mulgildie and Walloon Coal Measures and Quaternary Alluvium  
Ground cover 80 to 100%  
Slopes 1 to 4%  
Land use - cropping and grazing  
Minor to moderate rill/sheet, gully and stream bank erosion  
Erosion status – 16 % stable, 50% partly stable, 33% active  
Land management stubble retention and pasture |
| Dalrymple Creek | 11 sites, 7 on drainage lines and 4 on paddocks  
Rolling rises and gently undulating plains of Tertiary Volcanics (mainly basalt) and Evergreen and Marburg Formation sandstones at lower end  
Ground cover 70 to 100%  
Slopes 1 to 3%  
Land Use – cropping and grazing  
Minor to moderate rill/sheet, gully and stream bank erosion  
Erosion status – 18%stable, 55% partly stable and 27% active  
Land management contour banks and pasture |
| Kings Creek | 21 sites –12 on drainage lines and 9 on paddocks  
Rolling rises and gently undulating plains on Tertiary Volcanics (mainly basalt) and Quaternary Alluvium  
Ground cover 30 to 100%  
Slopes 1 to 3%  
Land use – grazing and cropping  
Minor rill/sheet erosion and minor to severe gully and stream bank erosion  
Erosion status - 33% stable, 38% partly stable and 29% active  
Land management – contour banks, stubble retention and pasture |
| Hodgson Creek | 12 sites mostly on paddocks  
Rolling Rises  
Ground cover 50 to 100%  
Slopes 1 to 7%  
Land use - cropping lower slopes and grazing upper slopes on Tertiary Volcanics (mainly basalt) and Quaternary Alluvium  
Minor to moderate rill/sheet and gully erosion  
Erosion status – 17% stable, 25% partly stable and 58% active  
Land management – contour banks, contour planting, stubble retention, minimum till and pasture |
### Ashall Creek
- **14 sites** – 11 on drainage lines and 3 on paddocks
- Rolling rises and gentle plains on Tertiary Volcanics (mainly basalt) and Quaternary Alluvium
- **Ground cover** - 50 to 70%
- Slopes 0 to 2%
- Land use – cropping and grazing
- Minor to moderate rill/sheet, gully and stream bank erosion
- Erosion status – 0% stable, 43% partly stable and 57% active
- Land management – contour banks, contour planting, stubble retention, minimum till

### Oakey Creek
- **20 sites** – 12 on drainage lines and 8 on paddocks
- Rolling rises and level terraced plains on Tertiary Volcanics (mainly basalt) and Quaternary Alluvium
- **Ground cover** - 10 to 100%
- Slopes 1 to 3%
- Land use cropping and grazing
- Minor rill/sheet and minor to moderate gully and stream bank erosion
- Erosion status – 40% stable, 20% partly stable and 40% active
- Land management – some contour banks, pasture

### Myall Creek
- **12 sites** – 10 on drainage lines and 2 on paddocks
- Rolling low hills, rolling rises and level terrace plains on Bundamba Sandstones and Quaternary Alluvium
- **Ground cover** - 50 to 100%
- Slopes - 0 to 1%
- Land use - cropping and grazing
- Minor to moderate rill/sheet, gully and stream bank erosion
- Erosion status – 17% stable, 50% partly stable and 33% active
- Land management - Strip cropping, stubble retention, pasture

### Charleys Creek
- **9 sites** – mostly on paddocks
- Gently undulating plains on Quaternary Alluvium and Pliocene/Pleistocene Sediments
- **Ground cover** – 5-25%
- Slopes – 1 to 3%
- Land use – cropping cotton and some grazing
- Minor to severe rill/sheet erosion
- Erosion status – 56% stable, 22% partly stable and 22% active
- Land management – minimum till, stubble retention, pasture

### Lower Condamine River
- **42 sites** - mostly on paddocks
- Gently undulating plains on Quaternary Alluvium
- **Ground cover** - 10 to 50%
- Slopes - 0 to 1%
- Land use – cropping and some grazing
- Minor to severe rill/sheet, gully and stream bank erosion
- Erosion status – 34% stable, 26% partly stable and 56% active
- Land management – stubble retention, pasture
### Condamine River

<table>
<thead>
<tr>
<th>Ground Cover Under Pressure</th>
<th>34 sites- mostly on paddocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gently undulating plains on Quaternary Alluvium</td>
<td>Ground cover – 10 to 80%</td>
</tr>
<tr>
<td>Slopes – 0 to 1%</td>
<td>Land use – cropping and some grazing</td>
</tr>
<tr>
<td>Minor to severe rill/sheet, gully and stream bank erosion</td>
<td>Erosion status – 20% stable, 24% partly stable and 56% active</td>
</tr>
<tr>
<td>Land management – stubble retention and minimum till</td>
<td></td>
</tr>
</tbody>
</table>

### Upper Condamine

<table>
<thead>
<tr>
<th>Ground Cover Under Pressure</th>
<th>5 sites – all on paddocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulating and rolling low hills on sandstones of the Walloon Coal Measures and Marburg Formation</td>
<td>Ground cover – 80 to 100%</td>
</tr>
<tr>
<td>Slopes – 1 to 5%</td>
<td>Land use - Mostly grazing</td>
</tr>
<tr>
<td>Limited erosion</td>
<td>Erosion status – 80% stable and 20% partly stable</td>
</tr>
<tr>
<td>Land management – pasture some old contours</td>
<td></td>
</tr>
</tbody>
</table>

Although roads of all classes on the floodplains were severely impacted, there appeared to be less silt on the roads after this flood than from previous storm events. The lower levels of silt were associated with the higher levels of ground cover across the catchment, which minimised the impact of the severe flooding events (Fig. 35a). There appears to be limited hill erosion damage to the uplands and damage is mainly confined to the drainage lines and channels which in some cases were severely eroded (Fig. 35b). Eroded gully lines and significant mass movement (slumping) of creek and river banks were also observed during the field assessments, particularly downslope of road and rail crossings and culverts.

![Figure 35](image1.jpg)

(a) Extensive groundcover has protected land from erosion.
(b) Severe slumping of creek below road crossing.

Severe gully and sheet erosion was also observed to occur along the major creeks and the Condamine River (Fig. 36) and there was a severe impact on unbunded irrigation infrastructure adjacent to the main water courses and on the open floodplains subject to overland flows (Fig. 37).
A number of dams failed, mainly at the interface of the uplands with the plains where the velocity of the overland flow exiting onto the plains was at its greatest. Some crops on the Upper Condamine had in the words of one grower "been decimated, with severe disruption on fence lines along the rivers and tributaries".

Specific sites where there has been severe erosion include the Linthorpe Creek below the Toowoomba Cecil Plains Road, the Ashall Creek on the Evanslea Road, Pipeline Road in the Ashall Creek, River Road and Coggans Road in the old Millmerran Shire and Nangwee Road north of the Branchview Hall. Generally, there had been some significant diversions of overland flow from its natural path as a result of the blocking of natural flowpaths with irrigation.
infrastructure. Extensive irrigation development has taken place since the last regional flood in 1996.

5.4 Conclusions and Future Directions
There were no significant impacts on soil conservation banks in upland areas and slopes of the Condamine catchment as compared to similar intensity events in the past, probably due to better vegetation cover (grass and crops). Downstream of road crossings, many waterways were extensively damaged and scoured unless the banks were well battered and had high levels of ground cover (Fig. 38). There was relatively little silt deposition on roads, except in floodplain areas. However, failure of hillslope dams was common at the interface of the uplands with the plains.

Figure 38. Stable water in Condamine River catchment with battered banks and 100% tall grass ground cover.

On the floodplains there was extensive damage to levees and banks and scouring out of floodplains where upland tributaries discharge to floodplains. In addition, extensive scouring was common along main watercourses due to removal of vegetation and undercutting of banks. There was damage to irrigation infrastructure such as pumps and irrigators, and erosive flooding was worse where strip-cropping\(^6\) was not implemented (e.g. controlled traffic down slopes). A proportion of floodplain farmers had never experienced a flood before and it was observed by experienced regional officers that these newer landholders are more likely to be in strife because they have not been exposed to previous planning and extension.

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\(^6\) Strip cropping is the land management practice of growing crops in rotation in a systematic arrangement of parallel strips at right angles to the direction of water flow. It is generally used on lands of low slope (< 1 per cent) to reduce the velocity of flows and spread water in order to minimise soil erosion.
6. Sources of land management information to assist the flood recovery

6.1 Introduction

This section provides a brief description of land management practices required to overcome land degradation processes that occur after significant rainfall events as experienced in the summer months in Queensland in 2010-11. It includes sources of technical information that will be of interest to a range of government, industry and community sectors, and steps that can minimise land degradation associated with flood events. These forms of land degradation include the management of hillslopes, gullies, stream banks and landslips. The degrading processes have not only damaged farmlands and waterways but also transported large volumes of sediments and nutrients into dams and estuaries.

It also outlines topics for which there are information deficiencies. It is recognised that for landholders to adopt these practices we need to do far more than just provide information. An overview is also provided of some of the issues involved in getting these practices adopted.

6.2 Hillslope erosion

The principles of controlling hillslope erosion are to:

- use land according to its capability
- protect the soil surface with some form of cover
- manage runoff before it develops into an erosive force.


Using land according to its land capability

Soil type and land slope determine how vulnerable land will be to erosion. For most agricultural areas in Queensland, information about soil types and their management is available from the Land Management Field manuals. These manuals were prepared in the 1980s and 1990s for all the major cropping regions in Queensland. They describe the soil types that occur in these regions, their land use potential and issues to consider in their management. Broad scale maps are provided to give landholders an indication of the soil types that might occur on their properties.

Information sources on hillslope erosion

Fact sheets

- L1 Understanding soils

Other publications

Land Management Field Manuals and Guidelines for Agricultural Land Evaluation in Queensland are available by accessing the following web page.


Surface cover

Adequate surface cover is a major factor in controlling erosion because it reduces the erosive effect of raindrops falling onto bare soils and slows runoff. Once soil cover levels are greater than 30-40%, there is a significant reduction in the risk of erosion but higher levels of cover should be aimed for. Cover levels of 100% are achievable for many grazing and cropping systems.
In grazing lands, animals need to be managed to ensure that there is always an adequate amount of pasture on the soil surface. The ideal stocking rate is flexible, matching stock numbers to available feed. As droughts develop this means that there is a need to reduce stock numbers.

A wide range of crops are grown on the 2% of Queensland (approximately 3 million ha) that is regularly used for cropping. These crops vary in the amount of cover they provide depending on the crop type and how the fallow period is managed.

The value of leaving crop stubbles on the soil surface is now widely recognised. This has required the use of modified machinery including planters that can plant crops into standing stubble. The use of herbicides has allowed farmers to practice minimum or zero tillage by controlling weeds and eliminating or greatly reducing the number of tillage operations.

**Information sources on surface cover**

*Managing Grazing Lands in Queensland* is a 30 page guide to managing the grazing lands of Queensland – a resource that covers around 80% of the state. It is expected to be made available as a PDF file on the DNR&M web site at [http://www.derm.qld.gov.au/land/state/rural_leasehold/strategy.html](http://www.derm.qld.gov.au/land/state/rural_leasehold/strategy.html) in July 2012. It draws on, and refers to over 50 other information sources – web sites, computer programs, CD's, books, brochures, fact sheets and training packages.

**Fact sheets**

- **Erosion control in grazing lands - L91**
- **Erosion control in cropping lands - L13**

*Managing Surface Water Runoff*

As runoff flows downslope, it concentrates and has the potential to cause erosion. If the concentration occurs on bare soils, the risk of erosion becomes very high.

In extensively cropped lands on hillslopes, runoff is managed by using contour banks and grassed waterways. In horticultural areas a variety of structures are used —including mounds for crops like bananas and papaws and raised beds for fruit and vegetable crops.

When implementing runoff control measures the coordination of runoff within catchments needs to be considered. Runoff may pass through several properties and cross several roads (sometimes railway lines) as it passes from the most remote part of a catchment to a major drainage line or creek. The *Soil Conservation Act 1986* provides a basis for ensuring the coordination of run-off measures.

**Information sources on managing runoff**

- **Soil conservation planning in cropping lands - L83**
- **Runoff control measures for erosion control in cropping land - L35**
- **Maintaining contour banks L202**
- **Contour bank specifications L205**
- **Soil conservation waterways - Planning and design**
- **Soil conservation waterways - Construction and management**
- **Soil conservation waterways - Plants for stabilisation**

*Manuals*

The publication *Soil conservation measures – a Design manual for Queensland* has chapters on the following topics

- **Runoff processes**
- **Peak discharge estimation**
Controlled traffic farming and tramlining

Controlled traffic farming (CTF) is a system where all traffic in a paddock is restricted to permanent wheel tracks referred to as traffic lanes or tramlines. CTF has many advantages including less compaction and more efficient farming operations.

It is now a widely accepted practice for farmers to work their paddocks parallel to a fence line which means going over broad-based contour banks,—a practice referred to as ‘tramlining’ and which may or may not be part of a CTF system. While this technique greatly improves efficiencies, in extreme rainfall events it may also create ‘hotspots’ in paddocks where runoff concentrates and causes erosion. If these problems cannot be overcome, farmers may have to revert to working paddocks between contour banks or strip cropping (on the contour) on floodplains. Further information on controlled traffic is provided in the following fact sheet.

Information sources on controlled traffic farming
Fact sheets
- L146 Controlled traffic farming – soil conservation considerations.
• Avoid cutting or directing floodplain drains directly into streams (especially through the natural levees that exist on many stream banks)

A range of treatment options for gullies are described below. It is important to establish the cause of the gully before selecting a treatment option. It should be noted that it is generally impractical to apply gully erosion control techniques to large areas of highly erodible, marginal grazing lands with extensive gully erosion.

**Gully fencing** – In many cases this may be the only practical option for gully management. The removal of grazing animals allows vegetation to establish with the expectation that nature will eventually find a solution to the problem. This approach is not likely to control a rapidly advancing gully head but it should provide stability to gully walls and sides and help to minimise movement of sediment downstream.

**Diversion** – Diversion banks divert run-off from the gully head to a stable outlet. Unfortunately, such outlets can be difficult to find and often the instability may simply be transferred from one area to another.

**Chutes** – Chutes are formed by battering gully heads to an acceptable slope. Their role is to convey run-off safely to a lower level. Chutes are lined with erosion-resistant materials such as stoloniferous grasses, reinforced turf, erosion control mats, rock, rock mattresses, concrete, rubber or PVC sheeting.

**Drop structures** – Drop structures allow run-off to drop vertically to a lower level, where the energy is dissipated before flowing down the watercourse. They can be made of formed concrete, concrete blocks, gabions, timber or steel plate. Gabions and rock mattresses have an advantage of being flexible and permeable.

**Dams** – Gully control dams are situated so that they 'drown' the gully head when the spillway is operating. Run-off is returned to the watercourse at a safer location or allowed to spread into a grassed area via a diversion bank. The success of these dams depends on a stable by wash and outlet which can be difficult to obtain in erosion prone soils. A PVC pipe can be used to direct some of the water stored in the dam to the bottom of the gully below the dam wall.

**Gully floor stabilisation**

The long-term success of gully stabilisation work depends on establishing a good vegetative cover on the gully floor which prevents further gullying and allows the gully floor to gradually silt up reducing the fall over the gully head.

A series of small weirs made from wire netting, logs or concrete can trap sediment which encourages vegetative growth. Vegetative weirs can be established using species with erect growth forms such as vetiver grass and lomandra.

Branches of dead shrubs or trees can play a useful role in stabilising a gully floor by restricting access by grazing animals. They also retard run-off flow which encourages further deposition of sediment.

**Gully reshaping and filling**
The practicability of reshaping a gully depends on its size and the amount of fill needed to restore the gully to its desired shape. Steep gully sides can be reshaped. Topsoil should be stockpiled and respread over exposed areas to ensure the rapid establishment of vegetation. Annual crops such as millet (summer), oats or barley (winter) can be sown to provide a quick cover. It may be possible to temporarily divert water from the battered gully while grass is establishing. Gullies in cultivation can be filled when constructing contour banks. The banks must have sufficient capacity where they cross old gully lines as this is a common site for contour bank failure.

Old car bodies and similar objects are not recommended for gully stabilisation. They divert flows against the sides of the gully which leads to further erosion.

Information sources on gully erosion
Fact sheets
- Gully erosion - L81
- Catchments and Creeks Pty Ltd has a large number of detailed fact sheets on gully control that are available free of charge.

- Gully erosion - an introduction
- Gully erosion - How gullies develop
- Gully erosion - Prevention and control
- Gully erosion control - Filling or shaping
- Gully erosion control - Chute design and construction
- Gully erosion control - Hard faced chutes
- Gully erosion control - Grass chutes
- Gully erosion control - Bed stabilisation
- Gully erosion control - Dams with drop inlets

6.4 Stream bank erosion

Much of the following material is sourced from the Rehabilitation Manual for Australian Streams by Rutherford, Jerie and Marsh (2000).

Stream bank erosion is a dynamic and natural process but human interference can accelerate the rate of bank erosion, sometimes to unacceptable levels. Rapid bank erosion leads to loss of valuable land, and can damage infrastructure such as roads, bridges and buildings. Stream bank erosion is the dominant source of sediment in many river systems, and sediment loads in Australian streams have generally increased by 10 to 15 times in comparison with pre-European loads in intensively used river basins (National Land and Water Resources Audit 2002).

High stream banks are exposed to great forces when a flood occurs and as a result, stream bank erosion can be the most difficult land degradation issue to deal with. In the last summer, stream bank erosion occurred on a massive scale.

Before attempting any reclamation project, an understanding of the stream processes that led to the problem needs to be obtained. Without proper understanding of the fluvial system, even projects intended to rehabilitate streams can cause severe instability. There
are three main processes that cause bank erosion (scour, mass failure and slumping), and it is essential to determine which are operating at any particular site because the management required to slow or prevent them may differ. The relative importance of the three erosion processes often varies with position in the catchment. An understanding of the natural recovery processes in streams in order is also needed to help set priorities for stream rehabilitation.

Under natural circumstances most streams have a mix of vegetation – trees, shrubs and ground cover plants growing on the soil surface. Ground cover plants provide protection from raindrop impact as well as from floods. Trees and shrubs help to reduce the velocity of flood flows and their deeper roots help to provide stability by reinforcing stream banks. Maintaining healthy vegetative cover on the bank itself, and along the top of it, is one of the cheapest ways of slowing the rate of bank erosion, but sites with a high risk of erosion and high stream power may require in-stream works to, for example, protect the toe of the bank.

Given the importance of vegetation in slowing bank erosion, control of grazing animals is often the first step to improved management. Fencing riparian areas and encouraging natural regeneration has advantages in protecting the river frontage from erosion but it is not likely to be very effective in controlling well advanced stream bank erosion.

Human-made obstacles (car bodies, tanks etc) should be removed from creeks but careful consideration should be given towards moving other objects such as fallen trees and natural debris. Infrastructure such as roads, weirs, culverts and tracks can concentrate flow or create turbulence leading to erosion problems and modifications may need to be made to allow for a stream to become stable.

Many attempts have been made to remediate stream bank erosion, but few of them have been adequately monitored, evaluated and reported on to assess their effectiveness e.g. Brooks and Lake (2007) have collated and synthesized data on river restoration projects in Victoria, Australia. Of the 2,247 Victorian cases examined, only 14 percent appeared to include monitoring or evaluation but information was inadequate for determining whether monitoring was being carried out to check that construction projects remained intact and that planted vegetation had survived. It was also not clear from the information recorded if monitoring data was used to evaluate the success of the project in achieving the restoration goals. Monitoring and evaluation should be an essential component of all projects that target remediation of stream bank erosion. The success of improvements to vegetation, hydrology, hydraulics and stream morphology should be self-sustaining, meaning that the stream should not need continual intervention to retain the improved condition (Rutherford, Jerie and Marsh 2000).

It is important to emphasise that rehabilitation does not imply absolute stability. On the contrary, in their natural state, stream systems rely on a certain level of disturbance by flooding, erosion and variable water quality, to reach their natural equilibrium and maintain their diversity.

Information sources on stream bank erosion

The following fact sheets are on the DNR&M website, dated 2006.

How healthy is your watercourse? - R34
- Managing stock in and around waterways - R33
- Stream bank planting guidelines and hints - R31
• **Stream bank vegetation is valuable** - R30
• **What causes bank erosion?** - R2 -
• **What causes stream bed erosion?** - R20

A useful range of publications and fact sheets are also available from the web site of the *Australian River Restoration Centre*.

**Manuals and guidelines**  

[http://www.riverstyles.com/outline.php](http://www.riverstyles.com/outline.php) River Styles® is a geomorphic approach for examining river character, behaviour, condition and recovery potential. This provides a physical template for river management.


**6.5 Erosive flooding**

Some of our best agricultural land is found on floodplains because of the high quality soils and availability of water for irrigation. However they are subject to erosive flooding when high velocity flows inundate soils with insufficient ground cover. Erosive flooding can remove the entire layer of cultivated topsoil exposing compacted subsoils. It would be common for such areas to be stripped of 10 to 15 cm of topsoil.

Damage to fencing is a major cost in any flood prone area. Fences collect stubble and grass carried by floodwaters. This creates considerable resistance to flow resulting in damage to or destruction of the fence.

Floodplains that are regularly exposed to erosive flooding should have a land use that is suitable for these circumstances. Permanent pastures provide far better protection than cropping.

On parts of the Darling Downs floodplain subject to erosive flooding, strip cropping is used for erosion control. With this measure, alternating strips of summer and winter crops are grown on the contour (at right angles to the flood flow). Prior to last summer no erosive flooding had occurred in the catchment since 1996 and many farmers had become complacent about the practice.

Strip cropping is most suitable for large areas on floodplains. It is not practical to use it on the narrow flood plains of coastal streams or inland tributary streams.

An important component of managing a flood plain is to avoid practices that concentrate flood flows. By allowing floods to spread, their depth and velocity will be reduced thus minimising the loss of topsoil and damage to fencing.

In general, the community has a desire for roads to be above flood height. However, roads may be more likely to concentrate and divert flood flows if there is insufficient capacity in the culverts under the road. On the Darling Downs floodplain many roads have been lowered to allow floods to pass freely over them to reduce erosion problems. This means that people using the road may suffer some inconvenience when a flood occurs.
6.6 Landslip

Landslip occurrence during the 2010-2011 wet season has been the most extensive since 1974 (the year of the previous major Brisbane River flood). Landslips are often associated with land clearing on steep hillslopes of susceptible rock types but they can also be a natural occurrence after extreme rainfall events. They most commonly occur in Queensland on the escarpments and steep eastern flanks of the Great Dividing Range (Environmental Protection Agency, 2003). This is exactly what was observed after the recent heavy rainfall events.

Prevention of landslips (also referred to as landslides or mass movement) is far preferable to subsequent rehabilitation which is expensive, time-consuming and may only be partially effective.

Trees should not be cleared from susceptible locations, and on cleared areas locally adapted, deep-rooted, fast-growing trees should be planted or allowed to naturally regenerate. Destocking and the control of shallow-rooted weeds (e.g. lantana) will enhance the re-establishment of trees in vulnerable areas. Excessive water intake is the most common trigger of landslip. Obstructions to the downslope flow of water such as dams or cross-slope drains should be avoided in areas prone to mass movement.

Information sources on landslip

Fact sheets
Landslide risk in Queensland – a publication prepared by Geological Society of Australia (Qld division)

Reports

6.7 Achieving the adoption of land management practices to overcome land degradation problems

Most landholders are concerned about land degradation on their property especially when it is visible and they can see that it is affecting their economic viability.

Some land degradation problems are relatively easy to overcome and the required practices are often widely adopted. For example, erosion in cropping lands removes valuable topsoil and creates gullies which can greatly hinder farming operations. It can be controlled by good stubble management and the construction of contour banks and
Grassed waterways. In grazing lands, good stock management is the key to avoiding soil erosion by maintaining adequate levels of surface cover. Good stock management also significantly reduces the impact of droughts.

However many land degradation problems are difficult to overcome for the following reasons:

- They may require considerable outlay in both investment and time for little or no economic benefit to the landholder.
- There may be no readily apparent solution to the problem. In identifying possible solutions experts with knowledge of the local area should be consulted in regard to cost-effectiveness and long term resilience to future flood events.
- Solutions to a problem may work in some soil, climate and land use regimes. However, more widespread use of the ‘solution’ may not be applicable and may create even larger problems.
- In many cases there can be no guarantee that the chosen strategy will be successful.

Examples of land degradation issues that are difficult to deal with include:

- There are large areas of highly erodible, marginal grazing lands with extensive gully erosion. Reclamation of individual, multi-branched gullies in such a system is impractical. In these cases the only option may be to fence off the area and withdraw stock in the hope that nature will eventually find a solution to the problem.
- Treatment of eroded stream banks by using engineering structures is very costly and can be technically difficult. More simple measures such as the strategic use of vegetation may provide some benefits in the long term but landholders need sound advice on what to plant and where to plant it.
- Landslip occurs on steep slopes that may be inaccessible. There may be treatment options for some situations but most cases of landslip will go untreated. It is advisable to seek experts with knowledge of the local area in regard to cost-effectiveness.
- There are some areas of grazing land that have lost most of their topsoil. While there are some management practices that can rehabilitate this land to halt the rate of degradation, it is almost impossible to return these soils to their former productivity and original level of ground cover.
References


