THE BIG FLOOD: WILL IT HAPPEN AGAIN?

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UNDERSTANDING PREDICTING MANAGING

Final report

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Macquarie University Sydney · Australia
University of Lincoln
Lockyer Valley
Australian Government Australian Research Council
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Contents

Introduction

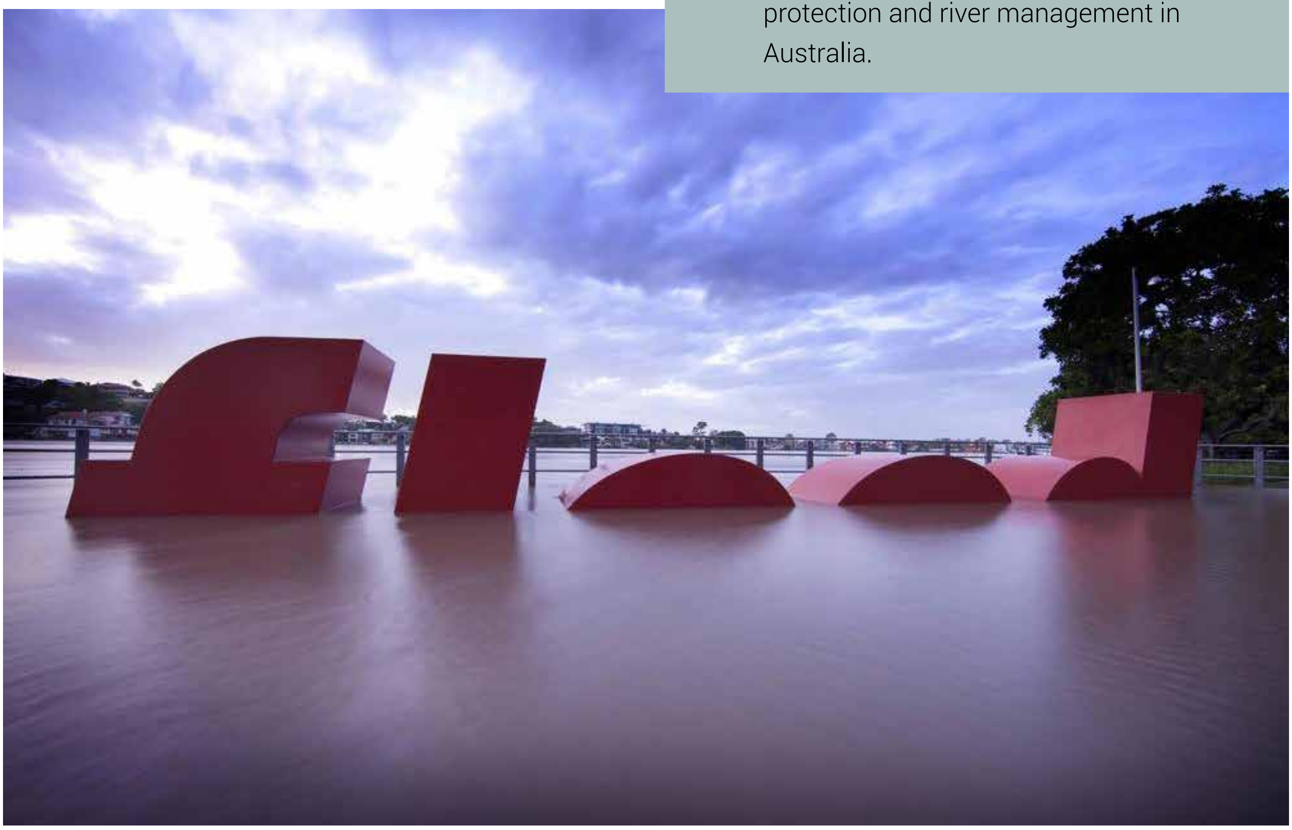
The urgency to understand and predict the magnitude and timing of floods in Eastern Australia reached a critical point following widespread flooding across large parts of Queensland, NSW and Victoria in January 2011. Twenty-two lives were lost in the Lockyer Creek floods in southeast Queensland (SEQ) in the summer of 2011. The total damage to public infrastructure as a result of this flood was estimated at about $2 billion.

Whilst the hydrological characteristics of the Lockyer Creek 2011 event have now been evaluated through Coronial Enquiries, there remains concern about the timing of the next 'big-event' and how other populated settlements in similar settings may be affected. River discharge records are too short to determine the likely recurrence intervals of these extreme flood events with any certainty. Climate change predictions for Australia also indicate increased incidences of extreme flood events with some areas being at greater risk than others.

Understanding the frequency and causes of extreme flood events is crucial for social and economic planning and environmental protection. SEQ has one of the fastest growing populations in Australia; currently around 2.8 million people, and expected to increase to ~4.4 million by 2031. The associated expenditure on infrastructure is expected to exceed $100 billion. This overall goal of this project was to contribute to the improved understanding, prediction and management of extreme flood events in the Lockyer Valley and broader SEQ region.

Major aims of the project

- Reconstruct a time series of major flood events for Lockyer Creek extending back more than 1000 years.
- Predict river channel and floodplain geomorphic susceptibility to floods in the Lockyer Valley and locate areas of high risk.
- Incorporate research findings into climate change predictions, water quality protection and river management in Australia.



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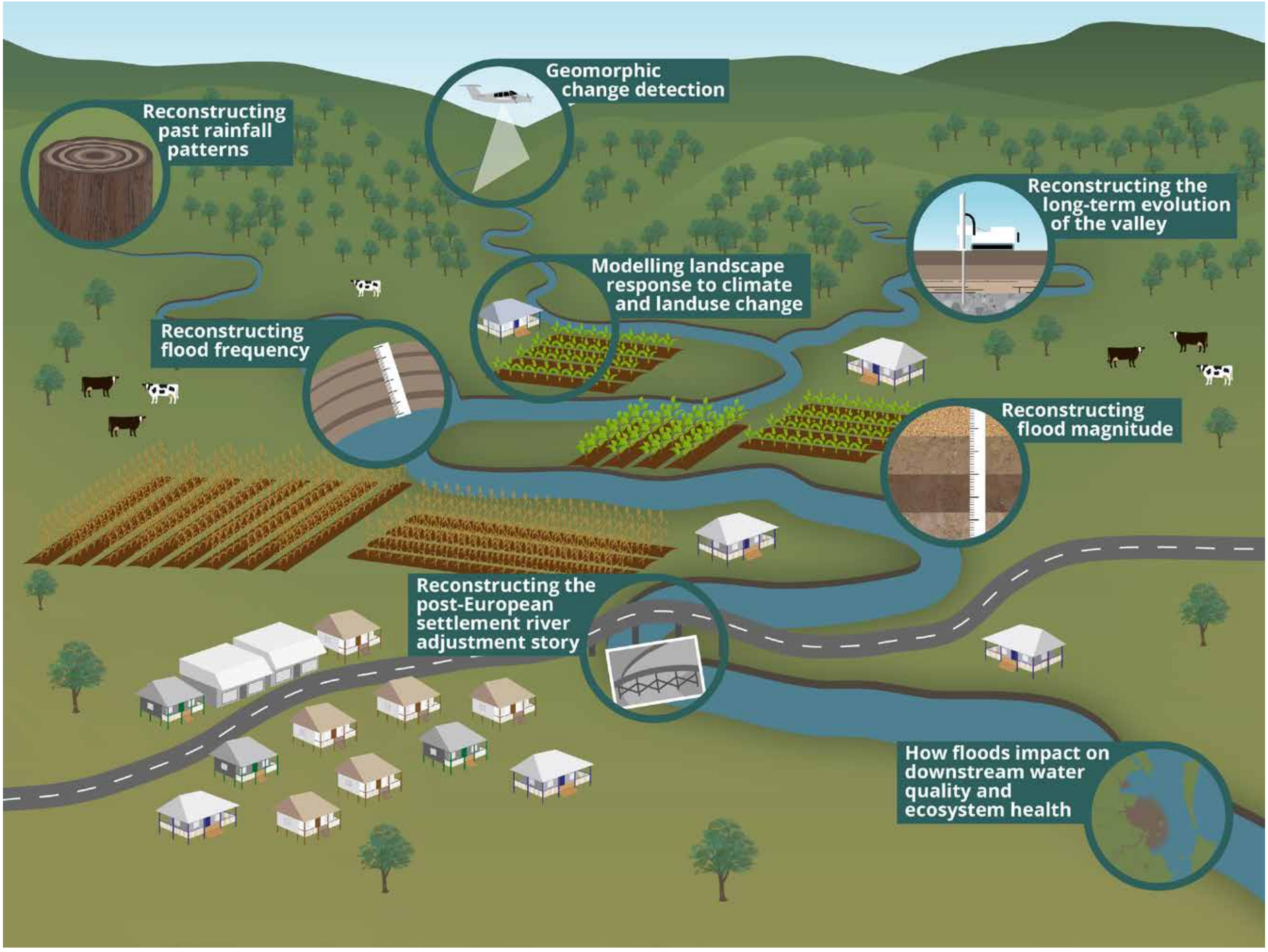
Approach

A range of innovative methods and approaches were used to answer the project questions. Collectively these tools allowed us to develop a source-to-sink framework for assessing the impacts of floods on our rivers and receiving waters.



Geomorphic change detection

Geomorphic change detection (GCD) using high resolution LiDAR digital elevation models from different time periods (pre- post-flood) was used to determine the extent and magnitude of change following a flood (Figure 1). The application used in the Lockyer was the largest scale this approach has been applied and gave very accurate estimates of erosion, deposition and sediment redistribution [3].

Figure 1. Pre-flood, post-flood and DEM of difference

Approach

Reconstructing the long-term evolution of the valley?

To put the present river channel of Lockyer Creek into perspective, we investigated the long-term evolution of the valley over several time periods; Pleistocene (~ 250, 000 years ago); Holocene (last 10,000 years) and Historic (~ 200 years ago). Old river features such as river terraces were mapped in the Lockyer valley.

We used DSITI's Geoprobe drill rig (Figure 2) to obtain samples of the deep alluvium stored in the Lockyer's floodplain. We sampled sediments from 30m deep in the floodplain. A total of 6944 bore records for the Lockyer catchment were extracted from the Queensland groundwater database with 2330 records having a record of depth to bedrock. These were used to construct the bedrock palaeovalley [20].

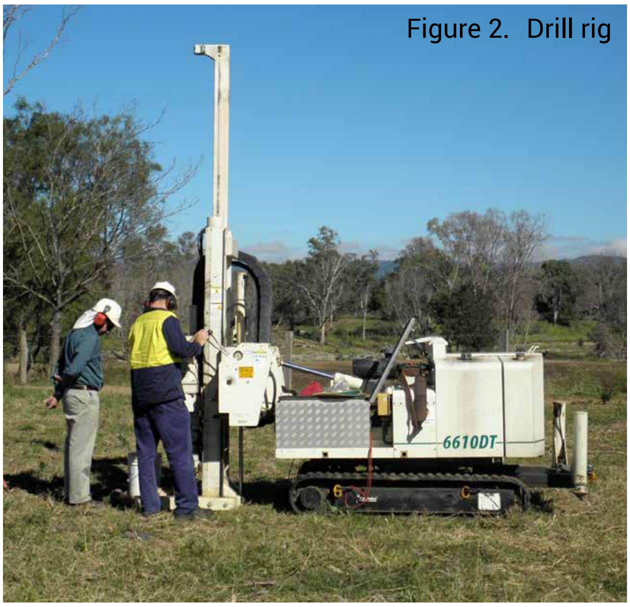


Figure 2. Drill rig

Reconstructing the post-European settlement river adjustment story reconstructed?

Time was spent at the State Library of Queensland and the State Archives at Runcorn searching for the following types of information:

- Explorers' journals often have descriptions of the landscape, vegetation and rivers they encountered.
- Old on-ground photographs of the landscape, rivers, old bridges (Figure 4) to establish what the landscape was like at the time of the photographs being taken.
- Parish maps that contain information on channel planform and sometimes floodplain vegetation descriptions.
- Bridge surveys to determine any changes in channel capacity.
- Old photographs at bridges that can be rephotographed in the field (Figure 3).
- One of the most useful forms of information is the historical air photograph record (Figure 5). All the air photos are orthorectified in ArcGIS and analysed for recognisable geomorphic adjustments between timeslices. Changes in channel position, width, and a range of other geomorphic adjustments can be detected. In the Lockyer Valley the first set of air photographs were flown in 1933. The most complete set of parish maps is from the 1890s. Google Earth can also be used to detect more recent changes [9].

Figure 3. Helidon (Drover's Crossing), 1890s and 2014.

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Figure 4. Gatton O'Connors Bridge ca 1924

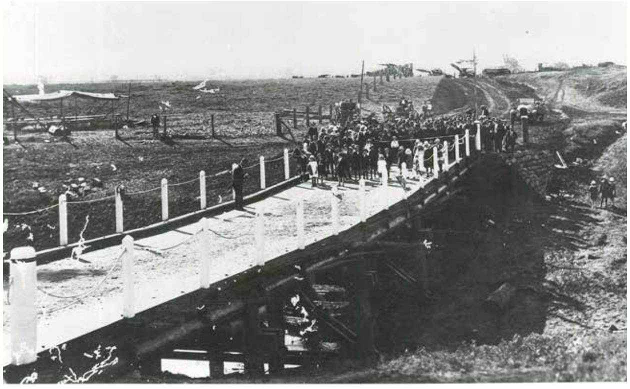

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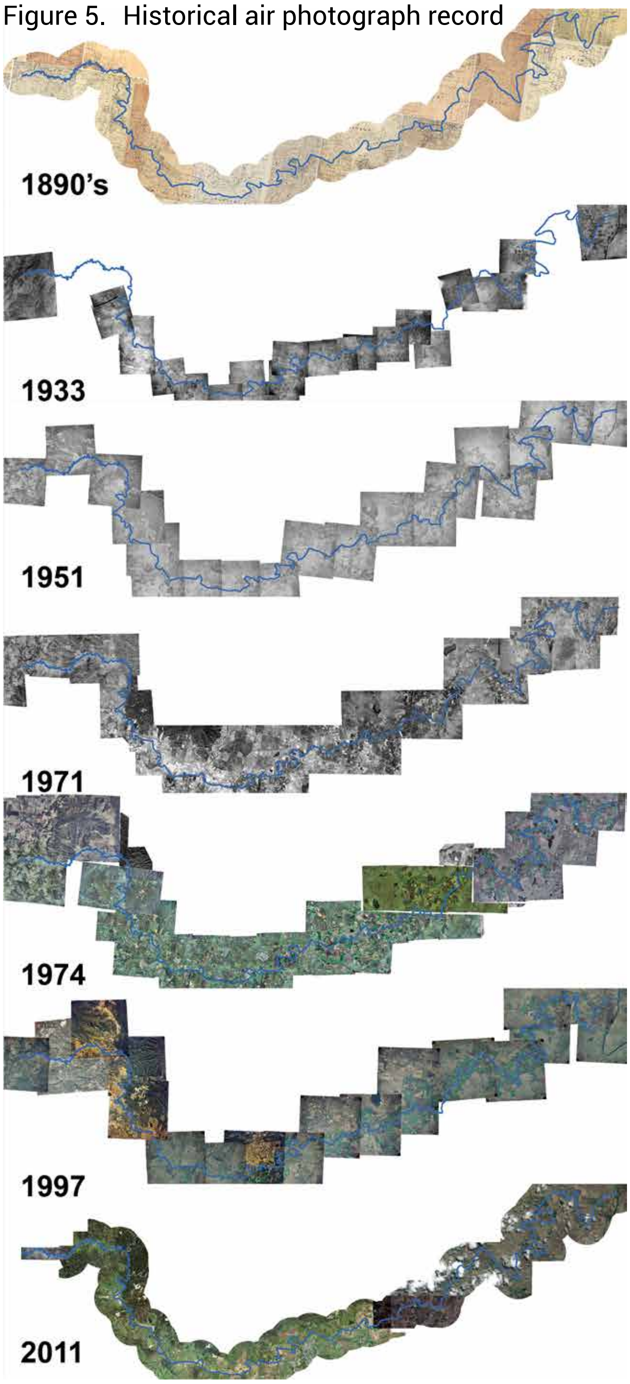
Figure 5. Historical air photograph record



Reconstructing flood frequency

Floods often leave a layer of overbank sediment which can build up over time to provide a record of past flood events.

These were located in the bank profiles exposed during the flood. They are horizontal and can range in thickness from 10cm to nearly 1m (Figure 6).

We sampled 41 sites down the length of the main Lockyer Creek.

Sediments were taken in the field and taken back to the laboratory for dating using Optically Stimulated Luminescence (OSL) dating. OSL can measure the last time each grain of sand was exposed to sunlight, allowing us to determine a burial age for each flood unit. OSL is one of the most accurate ways to date the age of river sediment. A data base of over ~ 180 OSL ages have been compiled through this project [19].

Figure 6. Flood unit sampling

Approach

Reconstructing flood magnitude

Slack-water deposits (Figure 7 and Figure 8) are flood-sediments deposited in slow flow or backwater zones generally on the margins of bedrock or laterally stable channels and are protected from subsequent erosion.

The timing of the flood is determined by OSL dating and the magnitude of the flood is reconstructed based on the minimum stage height of flow required to inundate the slack-water deposit. A calibrated hydraulic model is built based on topographic surveys and/or LiDAR DEMs and is used to estimate paleoflood magnitude.

Paleoflood reconstructions based on slack-water deposits have been reconstructed from six sites across Southeast Queensland and the Wide Bay-Burnett [24].

Figure 7. Slack water deposits

Reconstructing past rainfall patterns

Records of past rainfall in the region are relatively short- only ~ 100 or so and patchy in coverage throughout SEQ.

One way of reconstructing past rainfall patterns is dendrochronology- the study of tree ring growth (Figure 9).

Several species of trees were sampled in the region to reconstruct their growth rate [11].

Figure 8. Slack water deposits

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Figure 9. Tree rings can be assessed to reconstructed past rainfall patterns

Approach

Modelling landscape response to climate and landuse change

To evaluate potential future channel response to climate and land use change, a river evolution model (REM) is developed to examine movement of sediment through the system. The interaction of two factors (1) changing hydrological regime and (2) riparian vegetation are examined based on scenario modelling.

A cellular automata model called CAESAR-Lisflood is used to develop a Lockyer Valley REM (Figure 10) which is calibrated using floodplain deposition rates derived from OSL dating and geomorphic change measured after the 2011 and 2013 flood events. The Lockyer Valley REM identifies possible trajectories of channel response over the next 100 to 500 years.

How floods impact on downstream water quality and ecosystem health?

To evaluate the impact of the 2011 flood on delivering muddy sediments to Moreton Bay four cores were collected from the bay for particle size analysis (PSA) and dating with Optically Stimulated Luminescence (OSL) for determining deposition rates over time and estimating the volume of sediment delivered to Moreton Bay by the flood.

To evaluate the impact of the 2011 flood on delivering metal contaminants (Lead, Zinc and Copper) to Moreton Bay, 22 sediment samples were collected for geochemical analysis with inductively coupled plasma optical emission spectrometry (ICP-OES) [8].

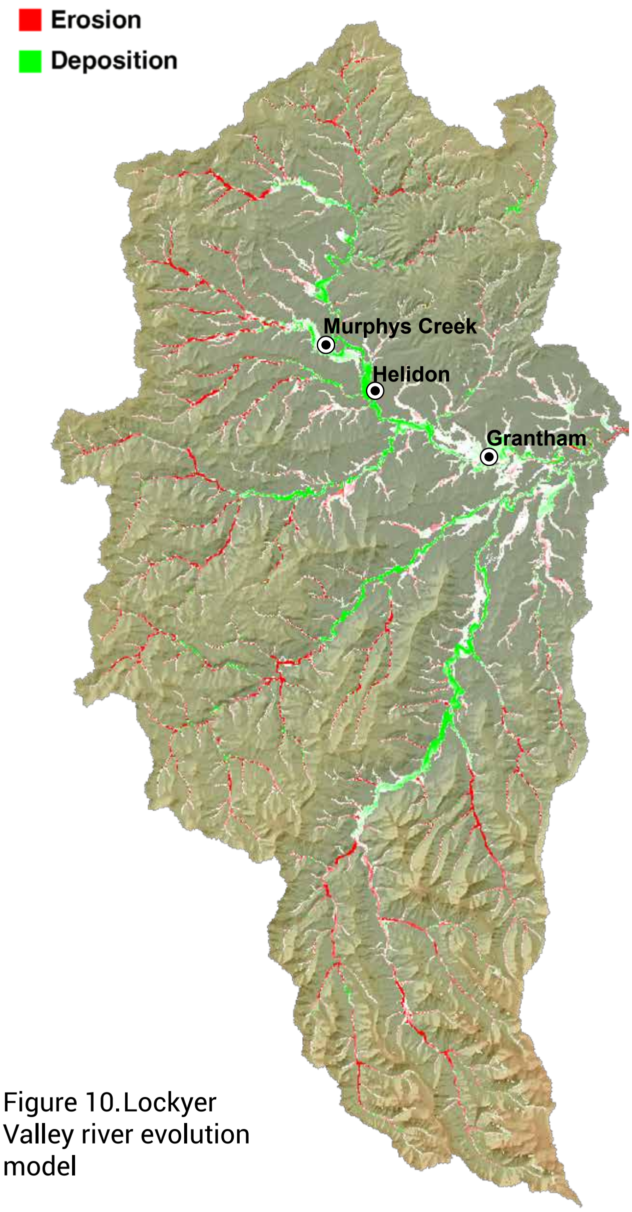


Figure 10. Lockyer Valley river evolution model

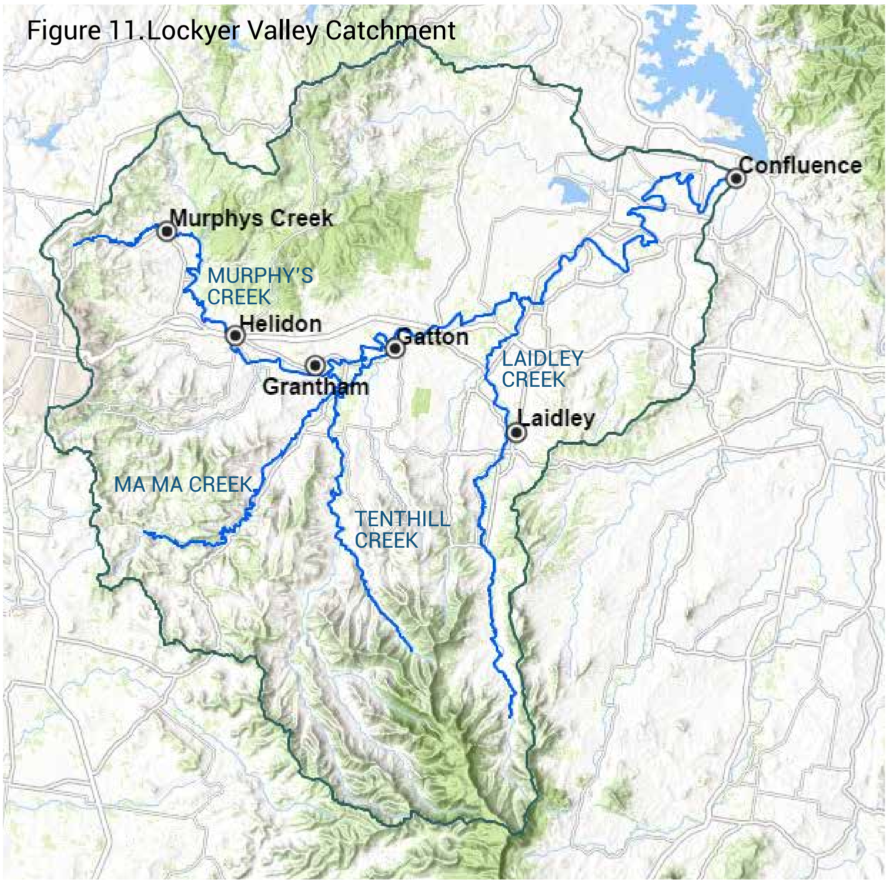
THE CONVERSATION

The Lockyer Valley

Located in South East Queensland

The Great Dividing Range forms the western boundary of the Lockyer Creek catchment (~3000 km^2). The Creek flows east with numerous tributaries joining (including Murphy's Creek, Ma Ma Creek, Tenthill Creek and Laidley Creek) before it's confluence with the Mid Brisbane River just downstream of Lake Wivenhoe (Figure 11).

Figure 11.Lockyer Valley Catchment



Climate

The climate of the Lockyer Valley is sub-humid, subtropical and strongly seasonal, with 65-70% of total rainfall occurring between October and March, in part due to higher precipitation intensities associated with summer storms generated by sub-tropical lows (Figure 12).

The area experiences highly variable multi-year rainfall regimes and decadal trends of above- and below-average rainfall. Hydrologically, this manifests in high streamflow variability.

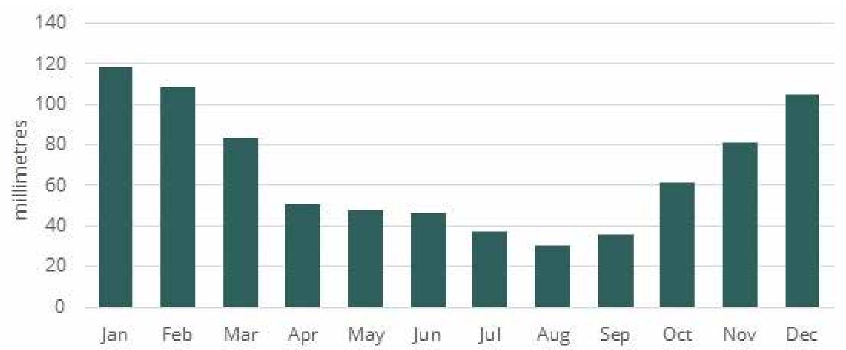


Figure 12.Average monthly rainfall for Helidon (1870-2015)

The Lockyer Valley

Geology

The catchment geology comprises Main Range Volcanics (Olivine basalt) on the divide. The headwaters have incised down to, and flow across, the Marburg subgroup (Jurassic sandstones, siltstones, shale).

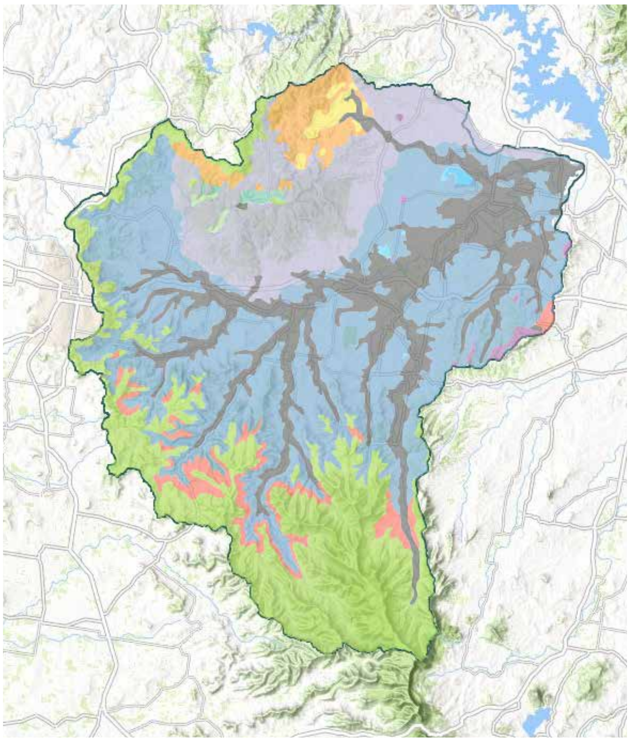
Quaternary terrace and floodplain alluvium deposits commence near Helidon along the main channel down to the mid-Brisbane River confluence (Figure 13).

Soils

The soils in the Lockyer Valley are some of the most productive in Australia and support an important agricultural industry in the region.

European settlement

European settlement and exploration of the Lockyer Valley began in 1823. The explorer's notes of Allan Cunningham during his 1829 excursion depict the Lockyer Creek basin as having mixed forests with variable density along with abundant grassland plains and pastures in close proximity to Lockyer Creek (Steele, 1972). Through the early and mid-1800's the Lockyer Valley region was used by squatters to manage sheep. Widespread vegetation clearance from floodplains occurred when established farming began in the late 1800's, producing corn, alfalfa, potatoes, pumpkins, citrus fruits and dairy products.



Walloon subgroup	MG-PTRg
Marbug subgroup	Helidon Sandstone
Main Range volcanics	Water body
MG-Tv	MG-CPm
Cressbrook Creek Group	Quaternary Alluvium

Figure 13. Geology of the Lockyer Catchment

Based on or contains data provided by the State of Queensland (Department of Natural Resources and Mines) 2012

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The Lockyer Valley

Today's landuse

Since European settlement, two-thirds of native vegetation has been cleared for agricultural purposes (Apan et al., 2002). Riparian vegetation is highly variable through the 20th century, but there is a noticeable increase in within-macrochannel vegetation density since 1974.

Widespread irrigation of farmland developed through the early and mid-1900's. The latter part of the 20th century saw the reduction of dairy production to accommodate expanding crop farming, along with the establishment of large-scale beef production.

Today, land use in the region is dominated by pasture (47%), followed by woody vegetation (41%) and crops (11%) (Figure 14).

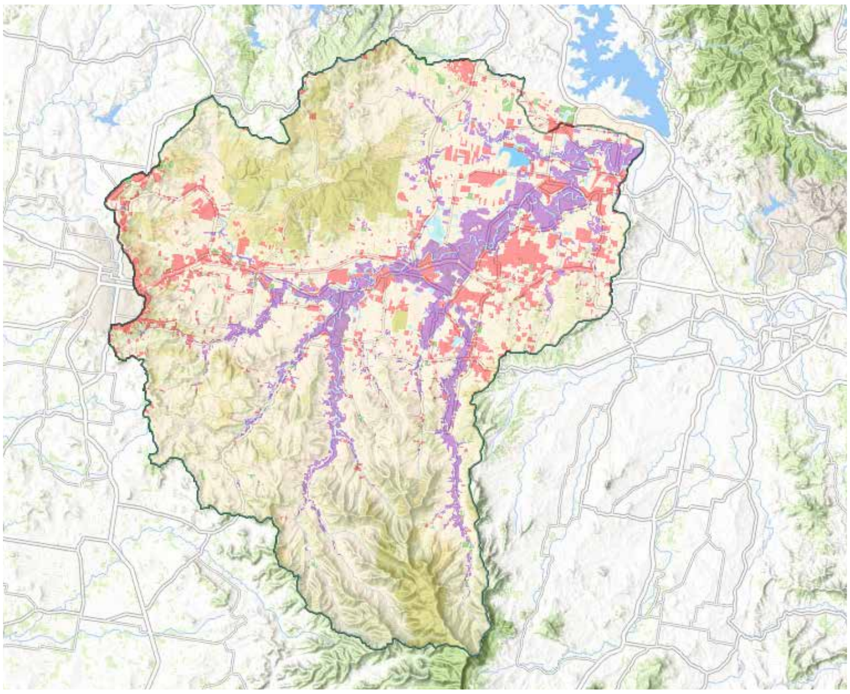
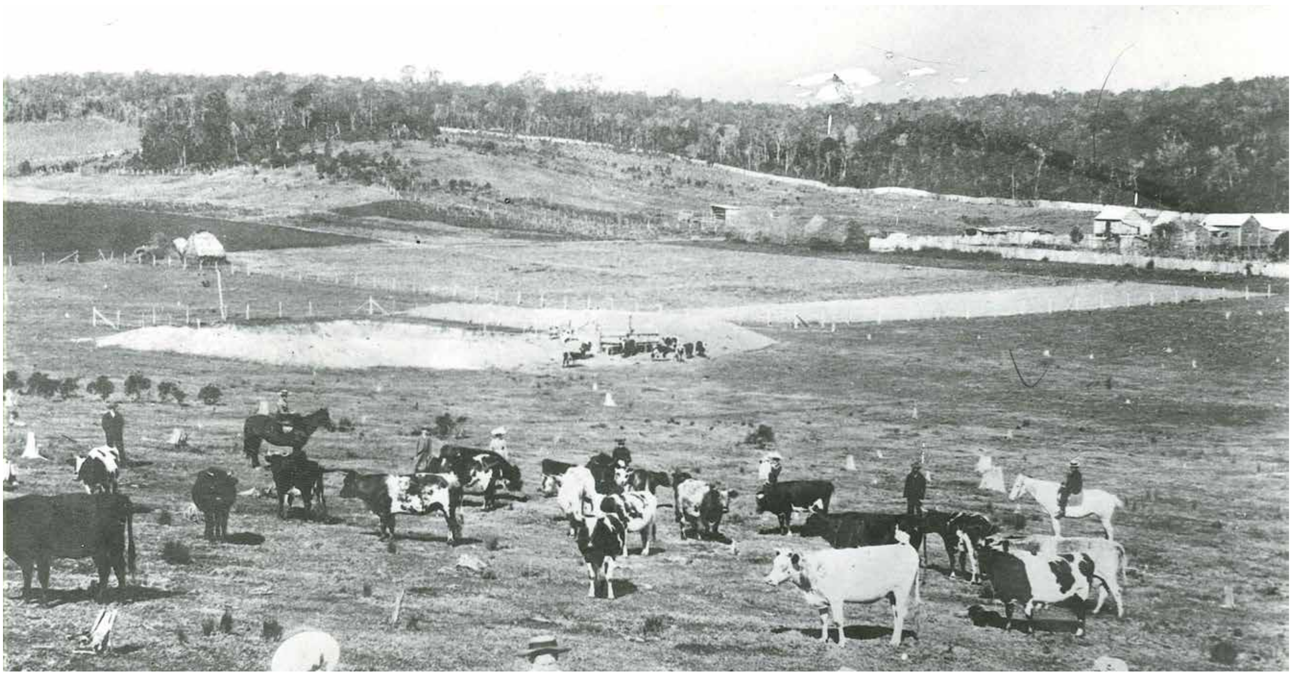


Figure 14. Today's land use

Based on or contains data provided by the State of Queensland (Department of Natural Resources and Mines) 2012

- Intensive uses
- Production from dryland agriculture and plantations
- Conservation and natural environments
- Production from irrigated agriculture and plantations
- Water
- Production from relatively natural environments
- Other



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WHAT HAPPENED?
The Flood

Wettest year on record

2010-2011 was the wettest year on record for the state of Queensland, and the wettest year since 1974 for SEQ. The second half of 2010 and early 2011 was characterized by one of the four strongest La Niña events since 1900. Strong La Niña events are often associated with extreme rainfall and widespread flooding in eastern Australia. The extremely heavy rain in early January 2011 (Figure 15) fell on the near-saturated catchments of the Brisbane River causing it to overtop its banks, resulting in an area of inundation equivalent to the total land area of France and Germany combined (Figure 16).

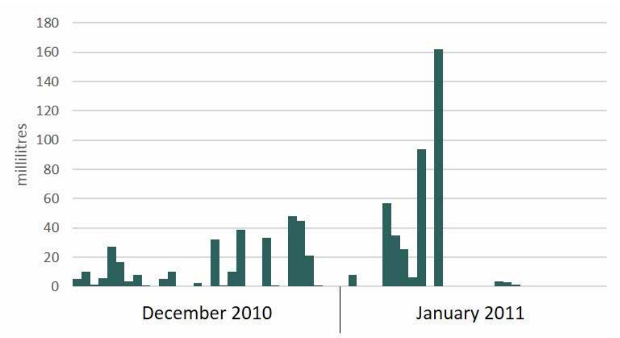
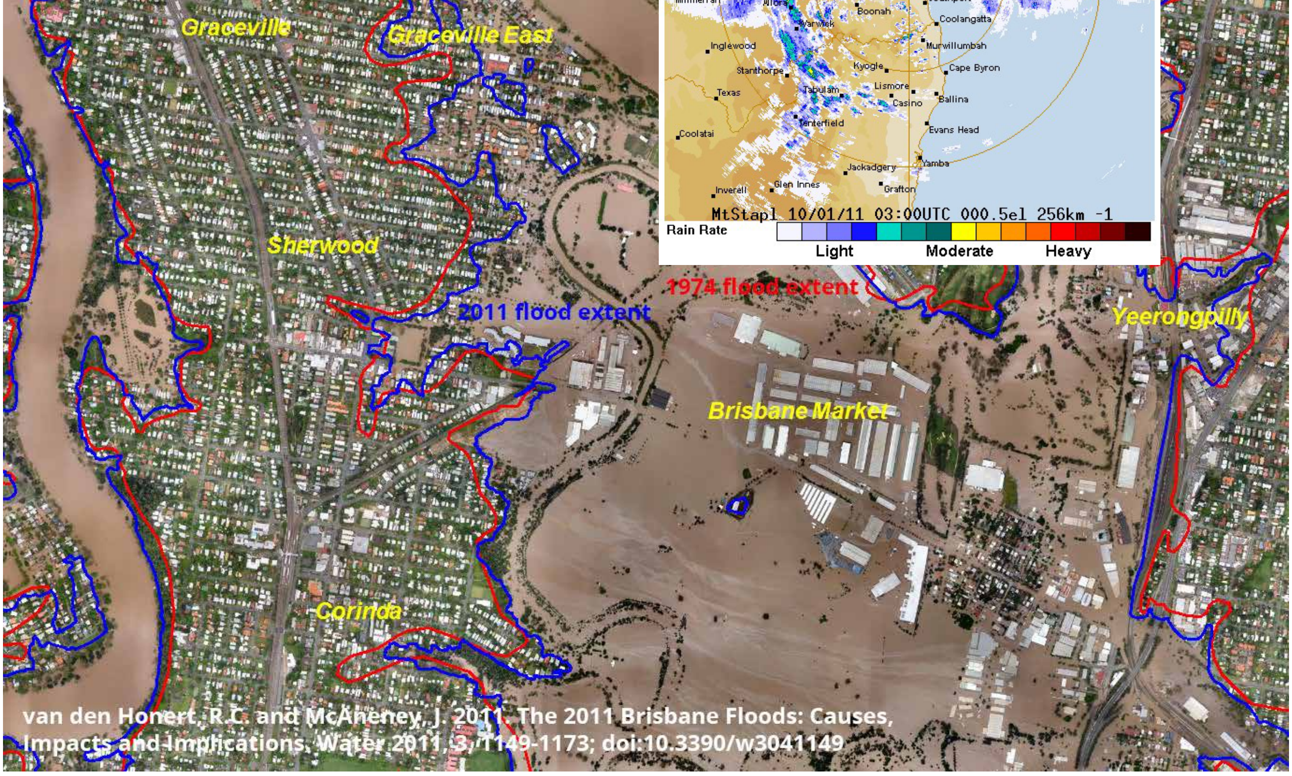


Figure 15. December 2010-January 2011 rainfall at Helidon

Figure 16. Flood inundation extent in Brisbane



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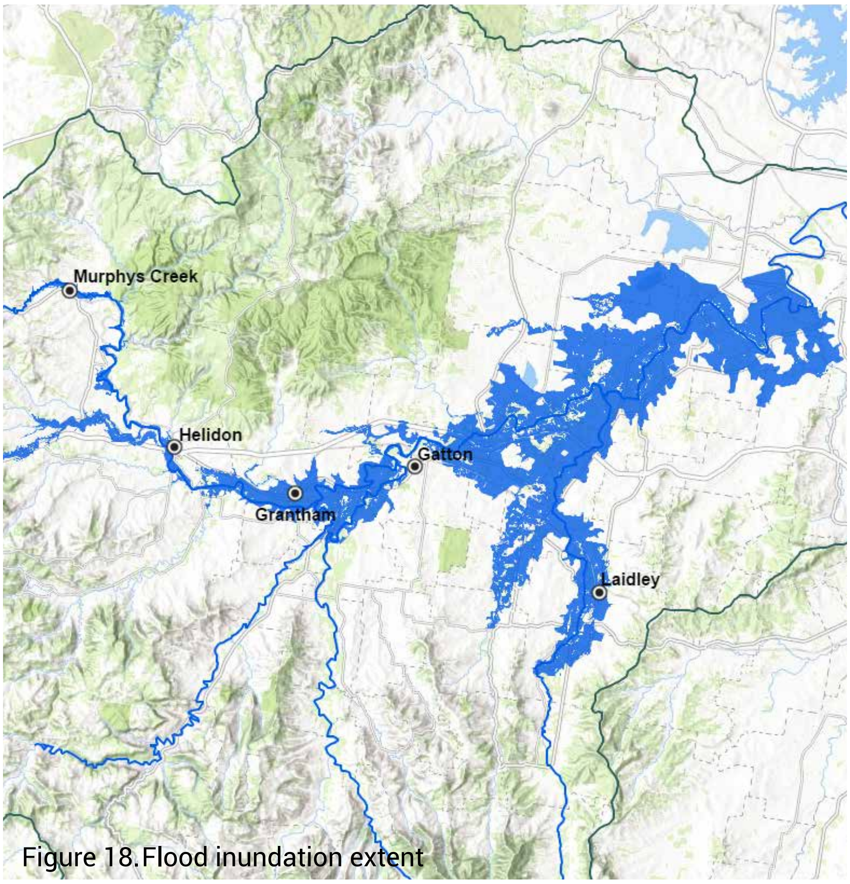
Low pressure system moves in

In 1974 the heaviest rains in south east Queensland occurred close to the coast, whereas in 2011 the heaviest rainfalls spread further inland, particularly on the western fringe of the Brisbane River catchment and on the Great Dividing Range. On 10 January, a low-pressure system moved inland over the catchment (Figure 17), colliding with upper level and monsoon troughs and intensified in the north and west of the Lockyer Valley. Rainfall intensities on 10 January ranged from 58 mm in 1 hour at Toowoomba on the catchment divide, 90 mm in 1 hour on the escarpment near Spring Bluff to an estimated 150 mm in 2 hours over Fifteen Mile and Alice Creek subcatchments. Helidon and Gatton received ≤ 11 mm. On the 11 January rainfall persisted for 12 hours over the central and southern catchments resulting in higher rainfall totals than the 10 January event but at lower rainfall intensities.

Figure 17. Rain radar from January 10, 2011

Flooding varied across the catchment

In spite of the significant magnitude of the January 2011 flood event, flood inundation varied significantly downstream (Figure 18).

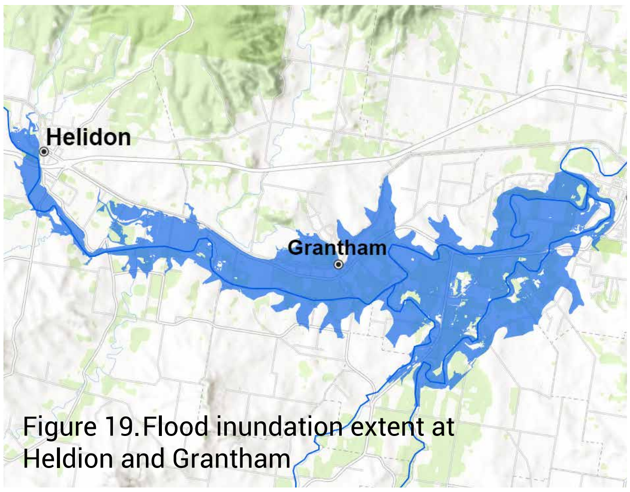


SKM, 2012

Figure 18. Flood inundation extent

Flooding occupied the whole valley in Murphy's Creek which has a steep, narrow channel close to the valley sides. The valley widens as the channel meanders past the town of Murphy's Creek.

The flood waters throughout the bedrock channel of lower Murphys Creek- upper Lockyer Creek were fully contained in the channel and were rapidly conveyed towards Helidon. A relatively large channel conveyed flood waters at high speed past Helidon towards Grantham (Figure 19). We refer to this as a macrochannel, a channel which is capable of containing large discharges and contains a number of inset surfaces.



SKM, 2012

Figure 19. Flood inundation extent at Heldion and Grantham

A reduction in the size of the channel past Grantham resulted in floodwaters spilling out across the entire floodplain at high velocities. At Gatton the channel increased in size around the large bend which could convey the majority of the flood waters limiting floodplain inundation.

Below Gatton the channel size decreases and natural levees are present along the channel. Floodwaters breached the natural levees at low points and flowed out across the floodplain generally following the path of older channels.

The natural levee ceases over the lower 16 km of Lockyer Creek leading to the confluence of the Brisbane River, and the channel size increases. As flood waters approached the confluence, they were backed up by flow in the Brisbane River causing valley wide inundation for many days [2].

Sediment movement

Once rainfall and overland flow discharges exceed the resistance offered by the soil and vegetation, erosion occurs. Once detached, sediments can be transported throughout the catchment. The 2011 flood caused large amounts of sediment to be moved from both the hillslopes and the channel (Figure 20). Some sources of sediment connected to the channel, while others remained disconnected.

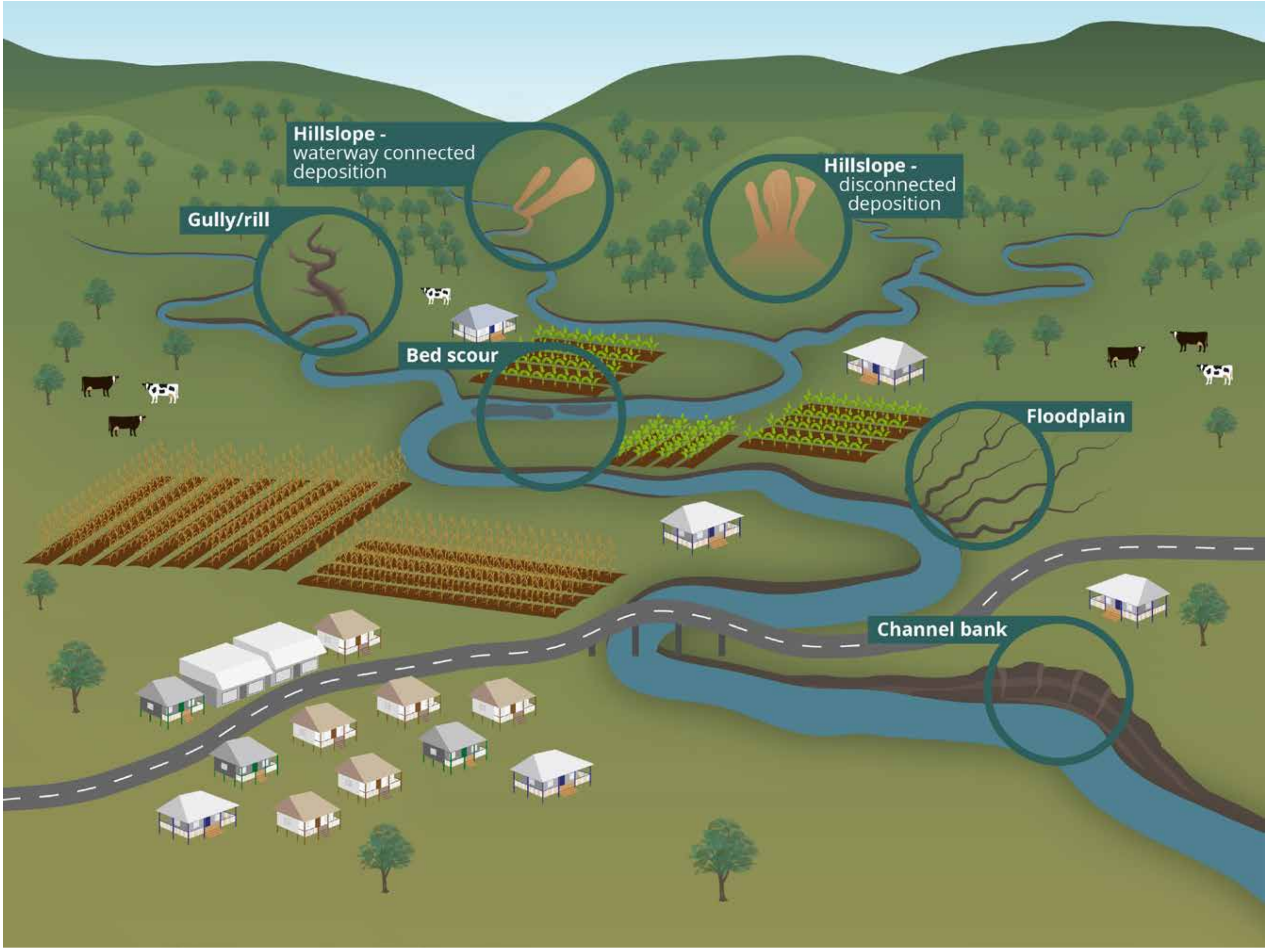


Figure 20. Large amounts of sediment were moved from hillslopes and channels in the catchment

Sediment movement

Hillslope erosion

During the storm numerous landslides (Figure 21) occurred on the Koukandowie formation (Figure 22) and on both cleared and forested hillslopes. The majority of the material eroded was deposited across the lower slopes and did not connect with Lockyer Creek.

In the confined headwater channels such as 15 Mile Creek, Paradise Creek and Alice Creek where steep hillslopes bound the channel, rock fall and debris flows provided coarse sediment supply to Lockyer Creek.

Figure 21. Hillslope erosion

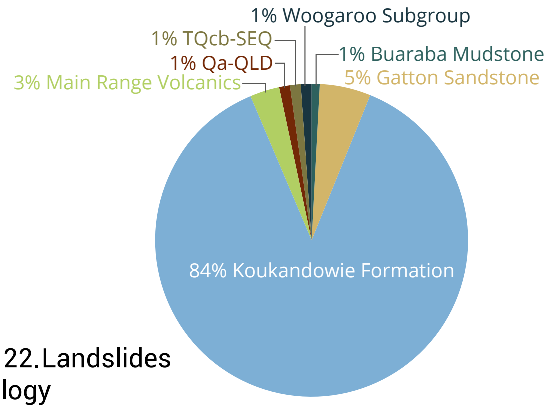


Figure 22. Landslides by geology

Floodplain erosion

Erosion of floodplain sediments occurs due to both hillslope runoff and overland flowing into the channel. The 2011 flood resulted in minimal erosion of floodplain sediments. This was due in part to the fine-grained cohesive nature of the thick floodplain sediments along Lockyer Creek (Figure 23). In contrast, the thin (< 1m), less cohesive floodplain sediments of the upper tributaries of Tenthill Creek and Laidley Creek were more easily eroded and were significant sediment sources during the event.

Channel erosion

Erosion from within the main boundary of the macrochannel of Lockyer Creek (Figure 24) was the dominant source of sediment during the 2011 flood. Two erosion processes dominated and varied depending on the location in the catchment and the type of channel (Figure 25).

Figure 24. Macrochannel

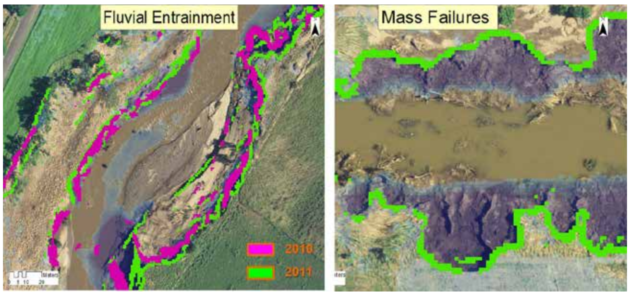


Figure 25. Bank erosion processes

Figure 23. Thick, fine-grained and resistant floodplaing sediments

Sediment movement

Fluvial entrainment

Fluvial entrainment is the process of the flood's velocity, depth and density (stream power or shear stress) exceeding the sediments resistance (cohesive forces, weight, bedform resistance).

The confined bedrock gorge has the steepest stream gradient (Figure 26) giving it high stream power and the flood along these upper reaches carried very high concentrations of sediment and woody debris along these upper reaches. As a result, sediment within the bedrock gorge was stripped back down to bedrock.

In the silty-sandy alluvial reaches of the main channel, fluvial entrainment caused bank undercutting and retreat of the inner-channel bank. This lead to the removal of the within-channel benches. In total an estimated 692,362 m^3 of sediment was eroded along the channel via this process [10].

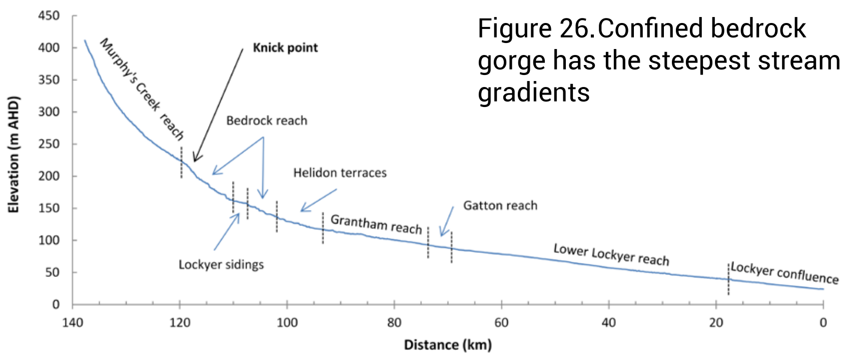


Figure 26. Confined bedrock gorge has the steepest stream gradients

Sediment movement

Wet-flow bank mass failures

The second process contributing to bank erosion during the 2011 event was Wet-flow Bank Mass Failures (WBMF) which was dominant along the lower Lockyer (Figure 27).

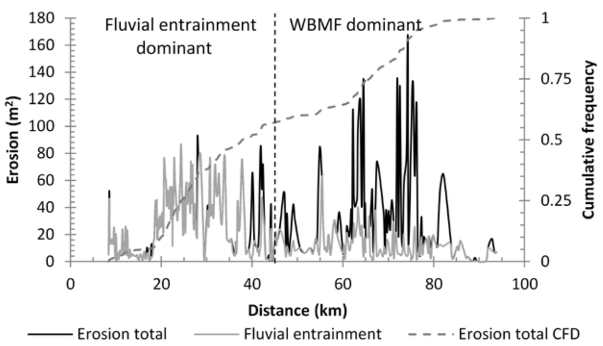


Figure 27.Wet-flow bank mass failure and fluvial entrainment down Lockyer Creek

These features were the most worrying from the point of public safety and loss of land. They are characterised by scalloped- shaped head walls which did not extend past the natural levee top and they contributed 695,394 m^3 of sediment as a result of the flood and are on average 676 m^2 in area.

Their formation (Figure 28) was a result of a combination of factors;

1. the alternating sand and loam layers in the channel banks. Subsurface water flows fast through sand layers and slower through finer loam layers
2. the wet bank moisture conditions due to the very wet summer prior to the flood
3. flood stage height and receding waters. High stage height forced more water into the already saturated banks (positive water pressure). As flood waters receded, floodplain and bank stored water flowed through sand layers back into the stream (exfiltration due to negative pore water pressure). As a result, the saturated bank sediments were removed in liquid form from the bank profile. Similar process observed post dam release in Washington State, USA

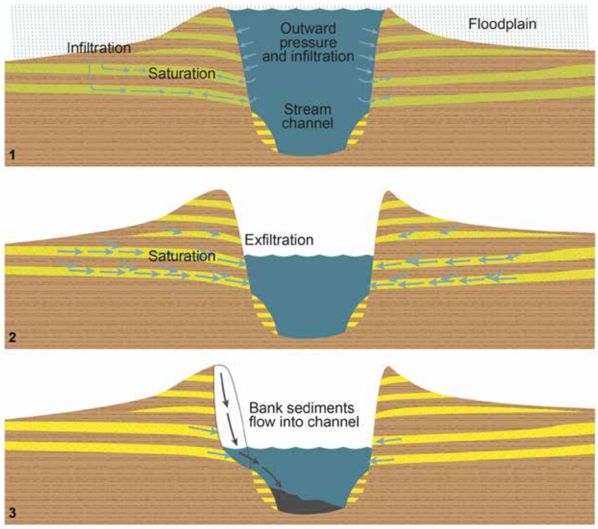


Figure 28.Wet-flow bank mass failure formation

These features also occurred during past floods but their density and spacing increased considerably in the 2011 flood event (Figure 29).

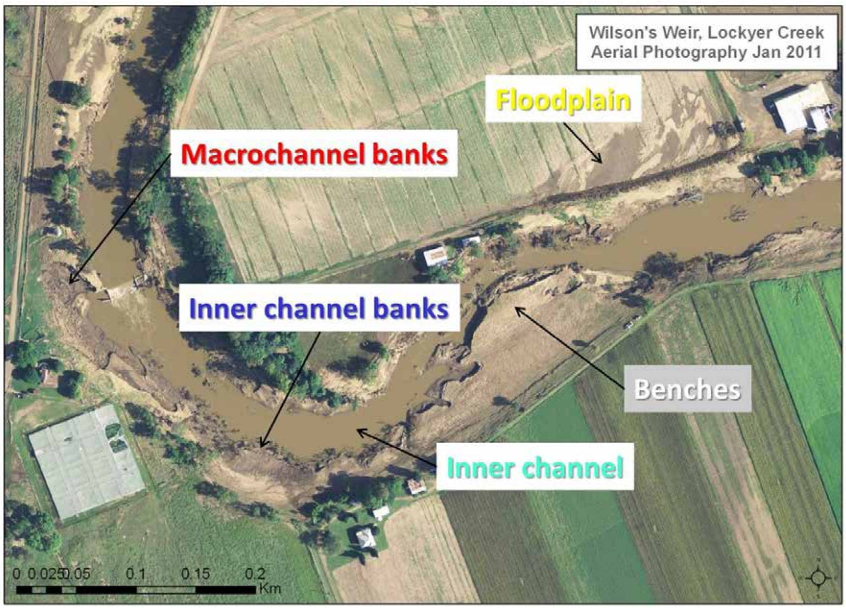
Based on the mapping extent of the pre-existing (n= 234) and 2011 wet-flow bank mass failures (n = 437), only 17% overlapped or reoccurred at the same location, the rest occurring in banks without previous failures [10].

Figure 29. Wet-flow bank mass failure density and spacing increased considerably in 2011 flood event

Where did the sediment go?

Sediment supplied to the channel from the hillslopes, floodplains, channel banks and bed was transported variable distances (Figure 30). Eroded sediment can be moved very short or long distances both within the catchment and further downstream to Moreton Bay. How far the sediment moved varies depending on its size, and whether erosion occurred before, at, or after, the flood peak.

Figure 30. Channel components



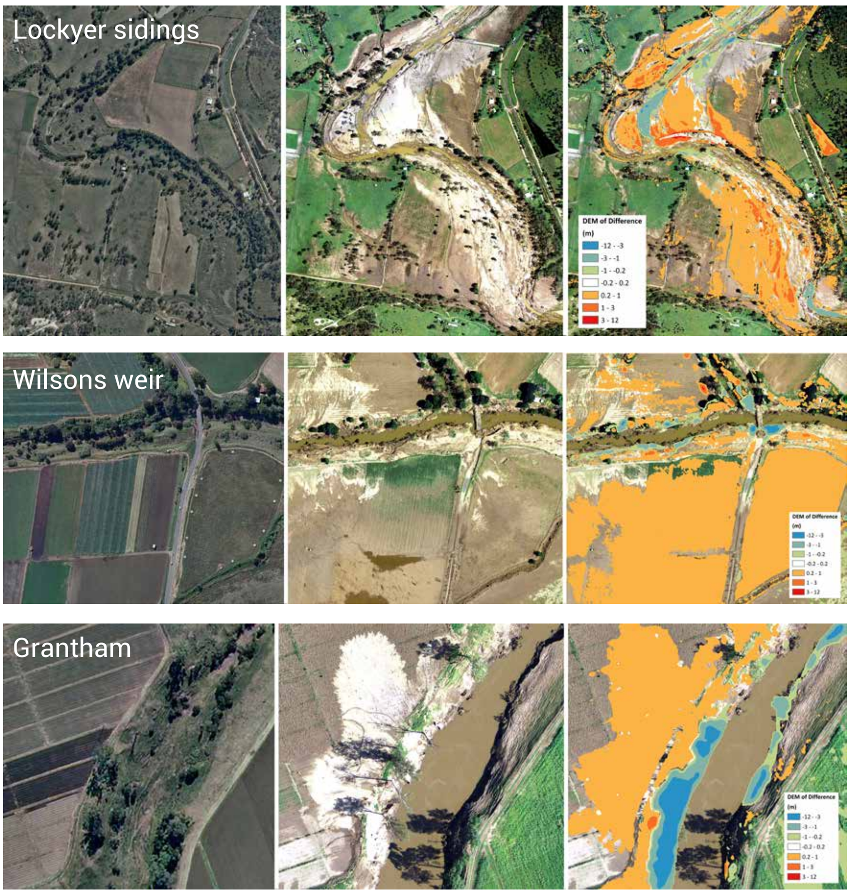


Figure 31. Pre-flood, post-flood and DEM of difference for selected sites on Lockyer Creek

Sediment stores

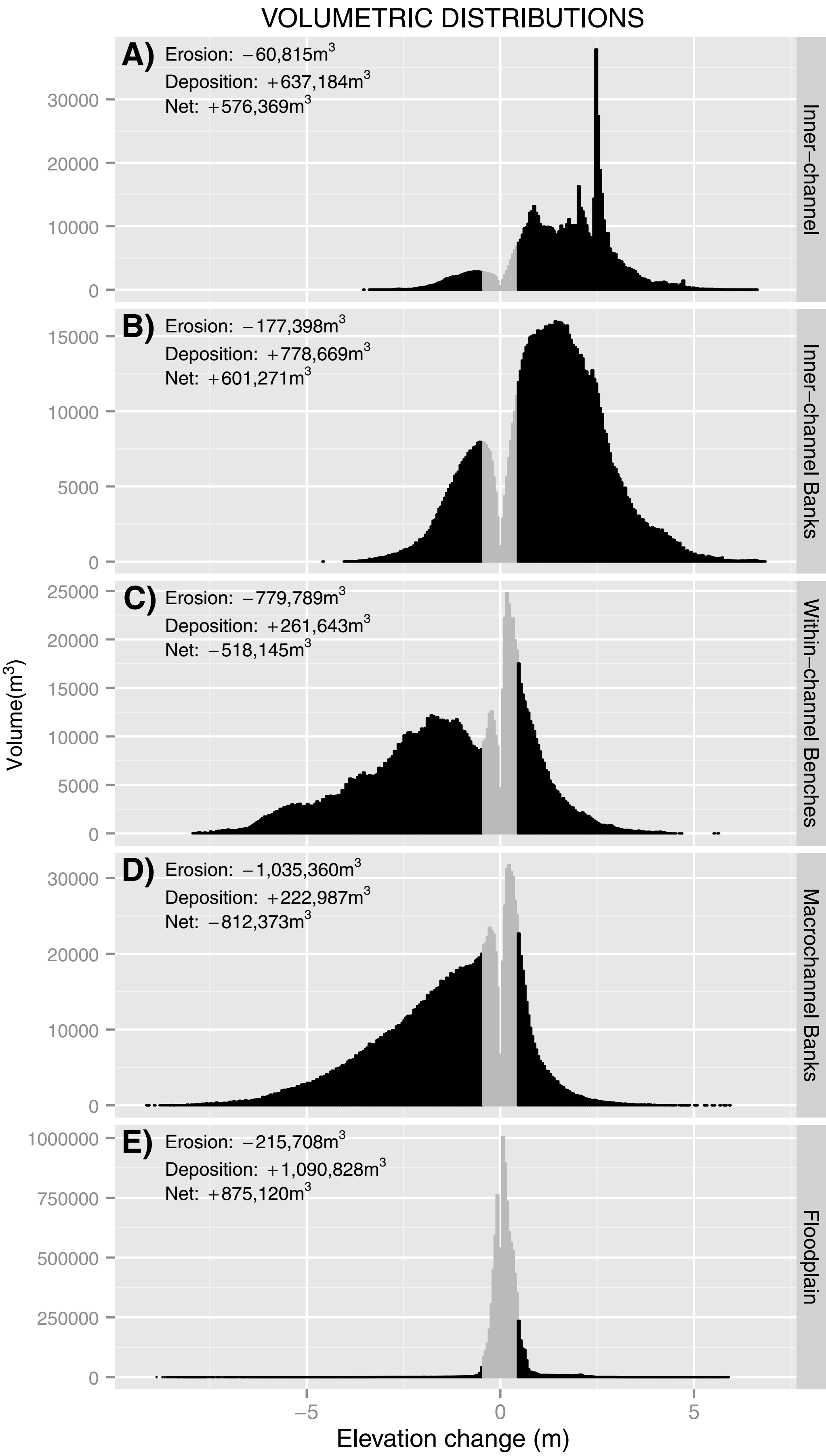
There are two major stores for the sediment eroded during the flood (Figure 31).

Within-channel features received sediment from upstream channel erosion sources. Over the study extent 266,000 m^3 was deposited on benches, and 223,000 m^3 was deposited across the macrochannel banks and infilled pre-existing bank mass failure holes.

Floodplains are effective stores for sediment eroded in the catchment. Following the 2011 event, approximately 1,605,312 m^3 of the eroded material was deposited on a floodplain. In the lower Lockyer, for example, flood waters extended right out across the valley floor and left a deposit, almost 20-30cm thick (Figure 32) [3].

Where did the sediment go?

Figure 32. Graph of net volume change between geomorphic features. From Croke et al., 2013 a



What was the impact on Moreton Bay?

The 2011 flood inundated agricultural land, heavy industry, sewage treatment plants, commercial and residential land (Figure 33). The flood also scoured the tidal reaches of the lower Brisbane River entraining fine sediments and attached contaminants, transporting the load to the shallow estuarine embayment of Moreton Bay.

Fine sediment pollution

An estimated 5 – 10 million tonnes of mud (clay and silt) was delivered to Moreton Bay [8].

Metal pollution

Shallow estuarine embayments receive contaminants from developed catchments. A significant increase in concentrations of Lead (Pb), Zinc (Zn) Copper (Cu) and other major elements were found in sediments in the Bay after the 2011 flood (Figure 34). These metal contaminants originate from a range of sources including urban impervious surfaces and industrial waste. Prior to the wet La Nina event from 2009-2012, the region was experiencing severe drought (the millennium drought). Low freshwater flows the decades prior to this intense wet period resulted in a build-up of metal contaminants in the drainage network, including the estuary. These contaminants were then rapidly delivered to the coast in a single flooding event. This highlights the importance of intermittent high magnitude floods in the subtropics in controlling contaminants export to coastal environments [7].

Figure 33. The 2011 flood inundated agricultural land, heavy industry, sewage treatment plants, commercial and residential land

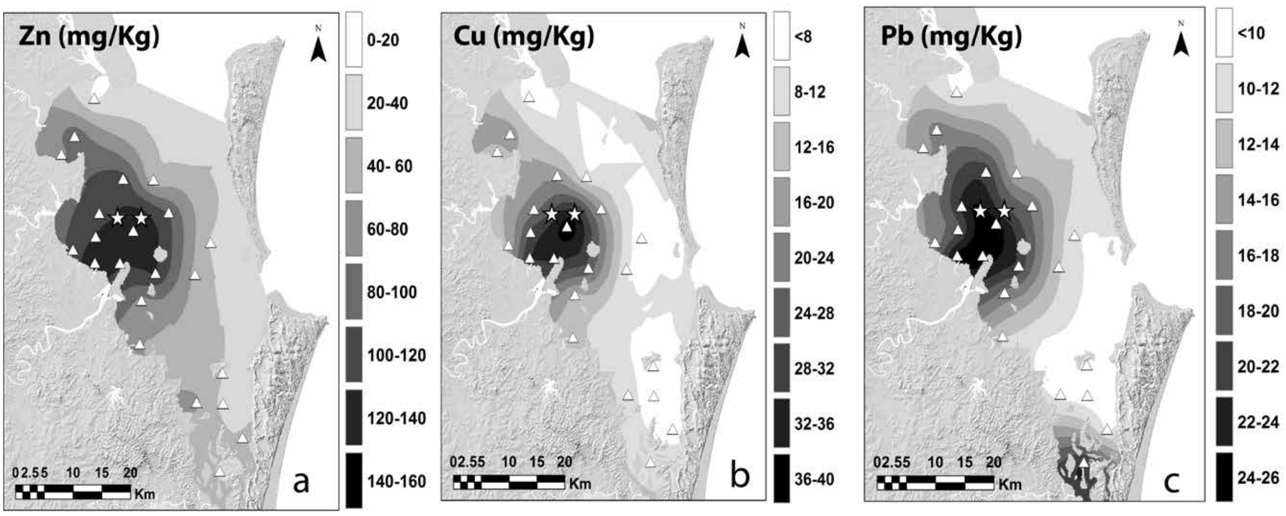


Figure 34. Distribution of heavy metals in Moreton Bay after the floods. From Coates-Marnane et al., 2016b

Valley evolution

The way Lockyer Creek responds to floods today is dependent on how the macrochannel and its floodplains have evolved over the past. Reconstructing past channel development provides an insight into how Lockyer Creek may respond in the future.

Reconstructing valley history

Deep sediment cores collected along the Lockyer floodplain indicate 3 major channel-floodplain types. These reflect how the river has responded to major changes in climate and sea level change over past glacial-interglacial cycles.

What was it like 230,000 – 140,000 years ago?

During this period the Lockyer Creek channel was a wide braided system constrained within an older bedrock valley (Figure 35). Coarse sediment of sand, gravel and cobbles remains on the floor of the valley providing the aquifer for much of today's irrigation. Later river flows could not remove this material and the present Lockyer Creek now sits on top of these older deposits.

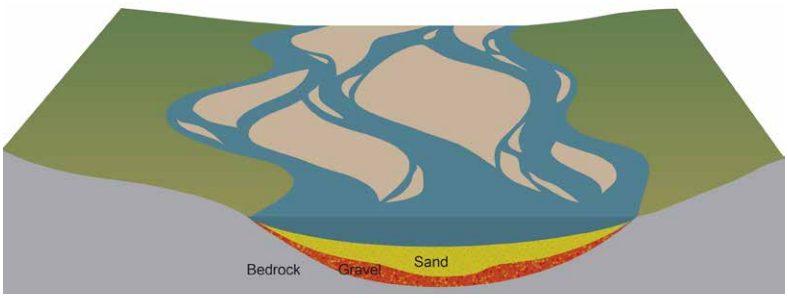


Figure 35.Channel form 230,000-140,000 years ago

What was happening 100,000 to 7,000 years ago?

By 100,000 years ago the channel changed from a wide braided system into a single channel system transporting fine-grained sediment (Figure 36). This fine-grained sands and silty loams provide the rich productive soils used in the valley today. The effect of this period of fine-grained floodplain building is that the present Lockyer Creek cannot now move freely across the valley floor. It has to move across the floor via a process of channel avulsion, where the channel relocates often rapidly from one location to another. This occurred several times throughout this period, mostly during times when sea level was falling and the channel bed was forced to adjust its bed level.

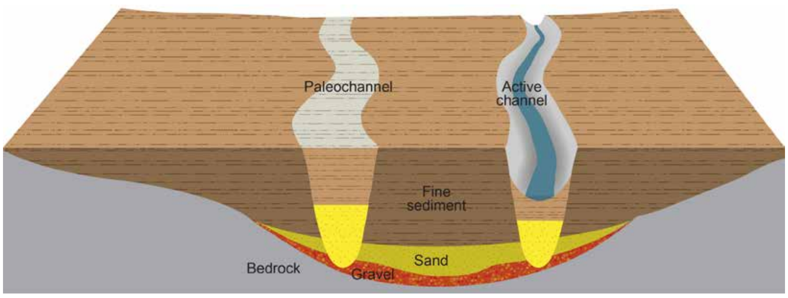


Figure 36.Channel form 100,000 to 7,000 years ago

What has been happening over the last 2,000 years?

The Lockyer channel has remained a single channel but about 2000 years ago it started transporting a coarser, mixed-load and started to build up its surrounding levees (Figure 37). This levee is now building up quite rapidly, creating a steep backslope on the adjacent floodplain (Figure 38). When the height of the levee reaches a critical elevation, channel avulsion will occur again.

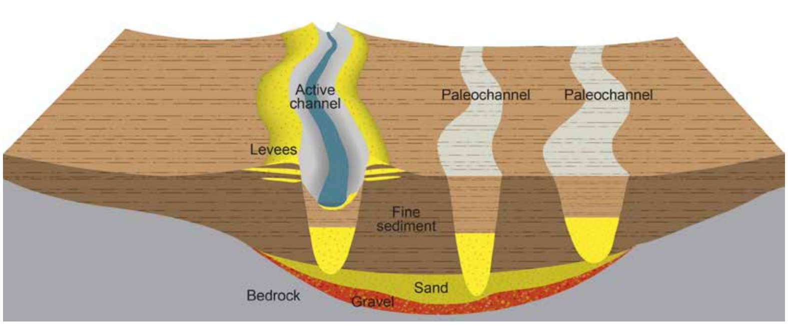


Figure 37.Channel form over the last 2,000 years

How does this affect the Lockyer?

These past phases of valley evolution have conditioned the current Lockyer to operate in a set way during floods. For example, alluvial rivers can often adjust their size by both channel widening and changing bed elevation. The current Lockyer is now locked in place both by remnants of older resistant material and the underlying bedrock valley. At some locations, Lockyer Creek bed is sitting on bedrock preventing incision or channel slope adjustment. At other locations, it abuts the edge of the bedrock valley which prevents lateral migration (Figure 39). This often limits the ability of the present channel to adjust to large flows during floods [20].

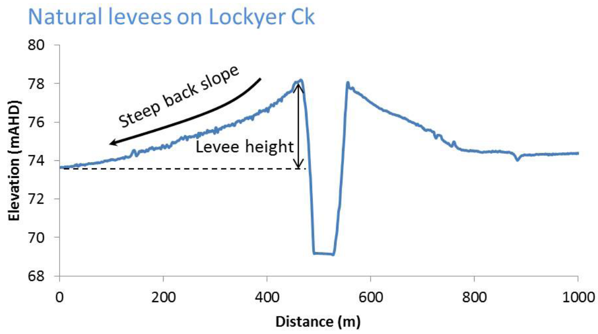
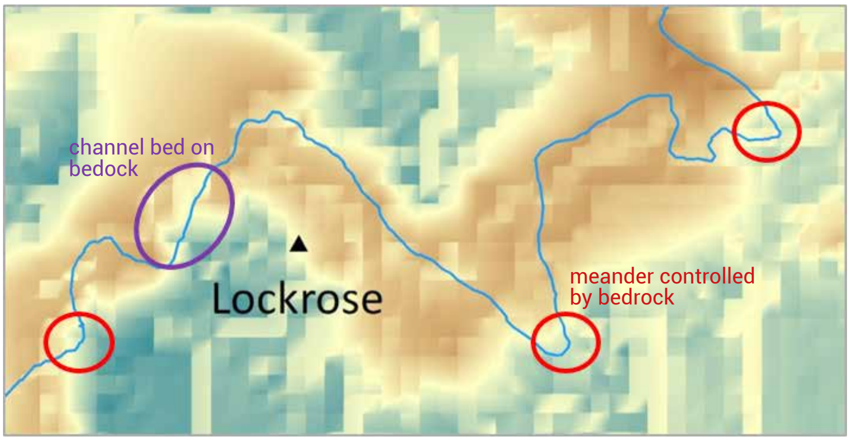


Figure 38. Natural levees creates a steep backslope on the adjacent floodplain

Figure 39. Depth of bedrock in the catchment.
Based on or contains data provided by the State of Queensland (Department of Natural Resources and Mines) 2012



Channel and floodplain characteristics

The present channel and floodplain of Lockyer Creek now reflects these past stages of valley evolution. The size and shape of the channel, and its downstream gradient largely control the amount of flood water conveyed within the channel, and therefore overbank flooding.

Macrochannel

The main channel of Lockyer Creek displays a compound channel-in-channel which is characterized by a small inner channel and associated benches set within a much larger channel that operates as a conduit for high magnitude floods (Figure 40).

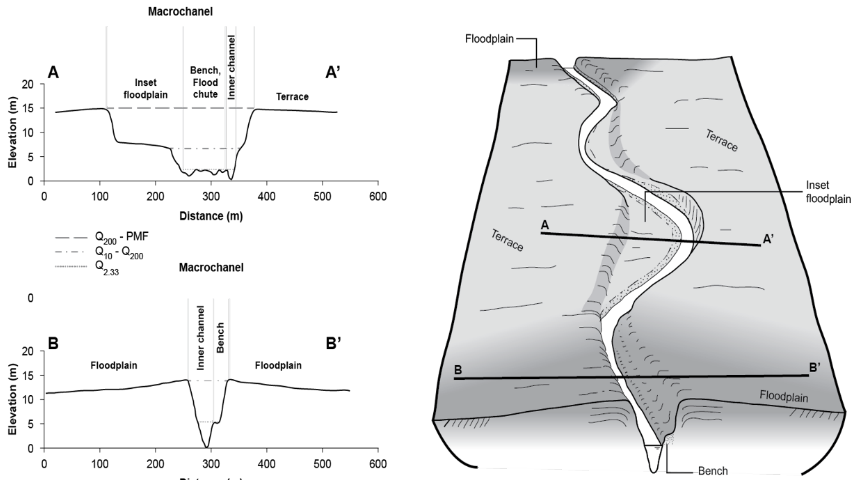


Figure 40. Channel form

The relative size of the macrochannel varies considerably along its length (Figure 41). It was the dramatic reduction in channel size which resulted in widespread overbank flooding at Grantham [5].

Where flood waters were contained in the macrochannel, these reaches are referred to as contraction zones. One example occurs on Lockyer Creek at Helidon. Here the channel is disconnected from its floodplain and limited opportunity for deposition occurs. Where flood waters spill onto the adjacent floodplains, these locations are referred to as expansion zones. One example is Lockyer Creek near Grantham.

Most of the sediment was derived from contraction reaches which had higher stream powers while most of the deposition occurred within expansion reaches (Figure 42) [5].

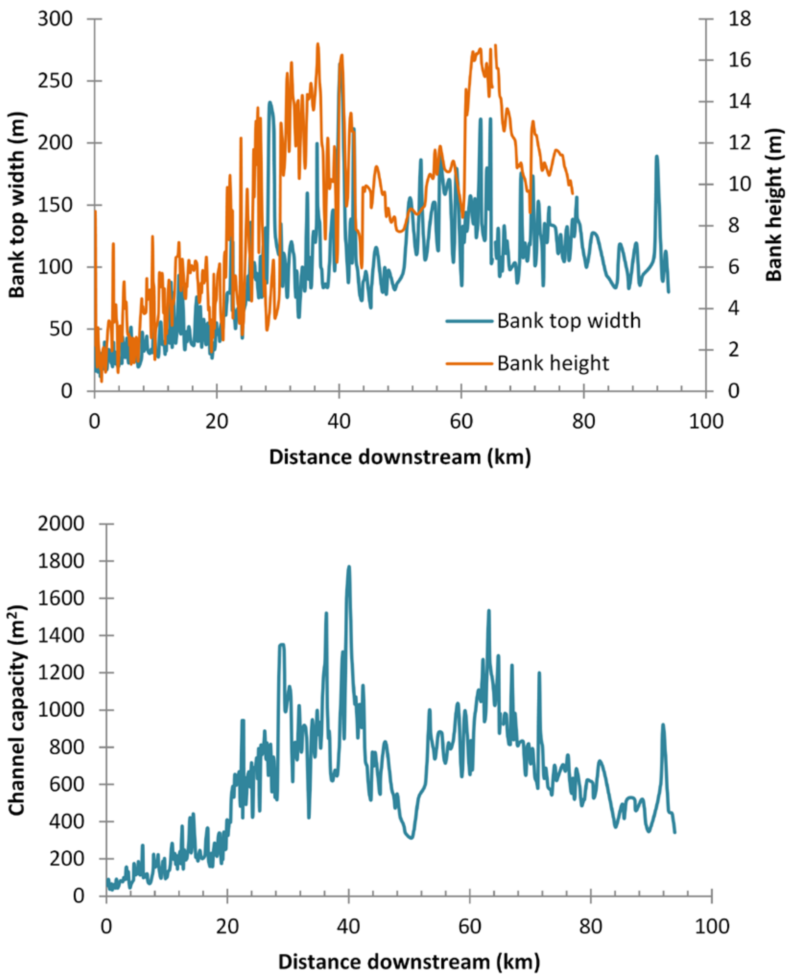


Figure 41. Downstream macrochannel size

Channel and floodplain characteristics

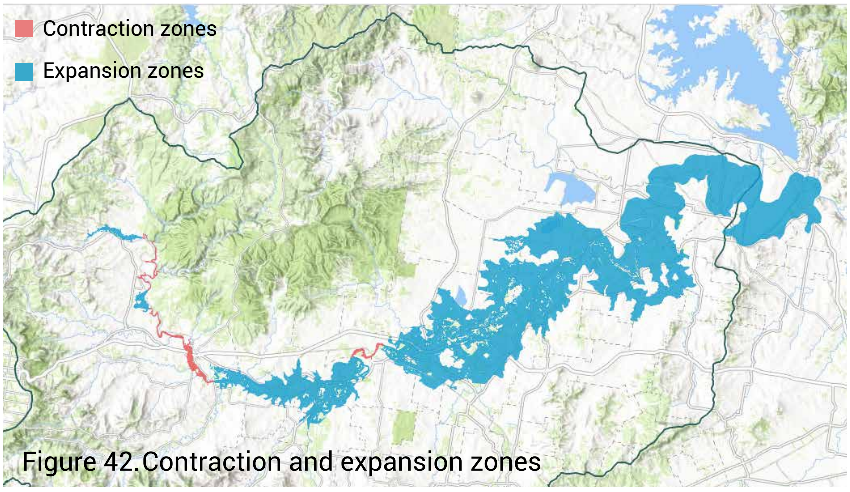


Figure 42. Contraction and expansion zones

The next surface is the ***Hydraulic floodplain*** which gets inundated during larger floods with recurrence intervals of between 20 to 200 years. These floodplains are generally located adjacent to the relatively large contraction zone channels.

The next highest surface is called a ***Terrace*** which is common in the mid Lockyer around Helidon. These were formed between 7000 – 10000 years ago. Today floods with return intervals up to the Probable Maximum Flood (PMF) are required to inundate these surfaces.

A critical area is the **Spill Out Zone (SOZ)** which are floodplains that receive high velocity overbank flooding. Spill out zones are located:

1. Where the channel size rapidly reduces relative to upstream;
2. At channel bends which often force floodwaters to one valleyside causing it to spill out;
3. At low points in the floodplain which forces water along old channels or depressions [6].

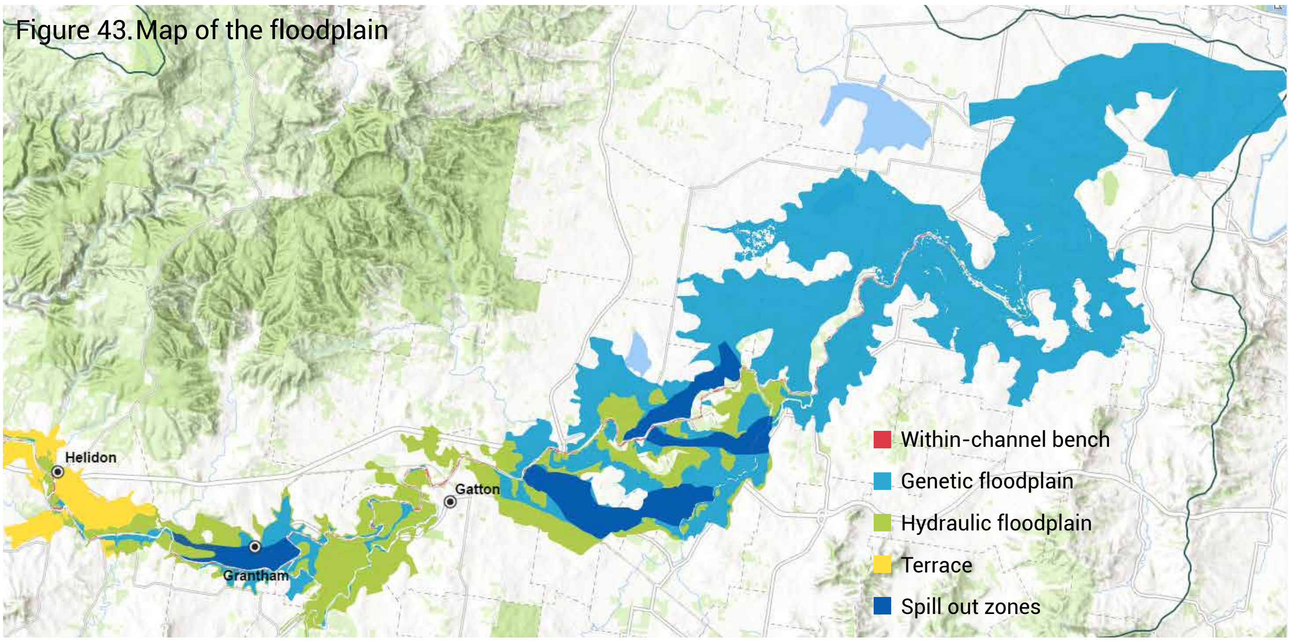
Defining the floodplain

The floodplain in the Lockyer Valley appears like a single surface which is inundated equally. However, there is no single floodplain with a common inundation frequency. Hydraulic modelling identified at least three different inundation surfaces in the valley (Figure 43).

The lowest surface is the ***Within-channel bench***- which occurs within the main boundary of the macrochannel and is inundated during the 2.5 year recurrence flood.

The next surface is the ***Genetic floodplain*** which has formed over the past 2000 years and gets inundated during the10 to 20 year recurrence interval flood.

Figure 43. Map of the floodplain



Historical channel adjustment

Channel adjustment since European settlement in the region (1860s to present) differed considerably between the main channel (Lockyer Creek) and the tributaries (Figure 44).

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Figure 44. Railway contruction site at Helidon ca 1865.

Lockyer Creek main channel adjustment

Lockyer Creek has not experienced catastrophic geomorphic adjustment in the period since European settlement, certainly compared to other rivers in eastern Australia (Figure 45). Along Lockyer Creek, only 26% of the channel has experienced some geomorphic adjustment since the time of the first parish maps in 1886. No wholesale river change in the form of lateral migration or avulsion has occurred.

Types of adjustment

Twelve different types of geomorphic adjustment have occurred along the Lockyer trunk stream since European settlement. These fall into three categories; erosional, depositional, and reorganizational. Erosional forms of adjustment include; removal of geomorphic units, channel widening, bank failure, bend extension, chute channel erosion, scour of low flow channel, incision of channel bed. Depositional forms of adjustment include; formation of a new geomorphic units, accretion on an existing geomorphic unit, and deposition of floodplain sediment sheets. Reorganisational forms of adjustment include; change in geomorphic unit assemblage and inset channel realignment.

There has been very little change to macrochannel width since European settlement (Figure 46).

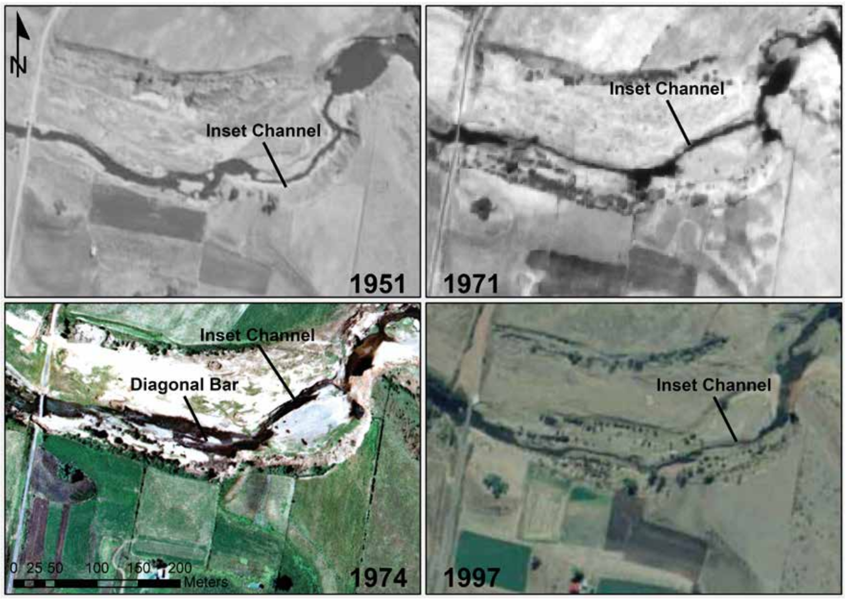
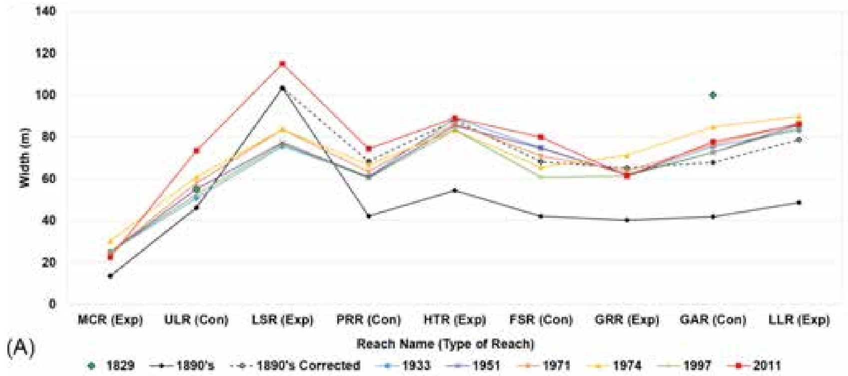


Figure 45. Lockyer Creek has not experienced catastrophic geomorphic adjustment since European settlement

Figure 46. Change in macrochannel width over time



Re-visiting bridges

Historical photographs taken at bridges along Murphy's Creek, at Helidon, and at Gatton were used to reconstruct the macrochannel size and morphology since European settlement (Figure 47). At all these locations there has been very little change in macrochannel size and shape since at least the 1860's.

The most changes in the Lockyer have occurred upstream of Gatton and mainly after 1974 and in 2011 (Figure 48). Most of the adjustments upstream of Postman's ridge have been erosional with some within-channel deposition. Downstream of Postman's Ridge geomorphic changes are dominated by reorganisation and erosional forms of adjustment within the macrochannel and the deposition of floodplain sediment sheets [9].

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Figure 47. Historical photos taken at bridges

Upper Murphy's Creek

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Lockyer Creek at Gatton Railway Bridge

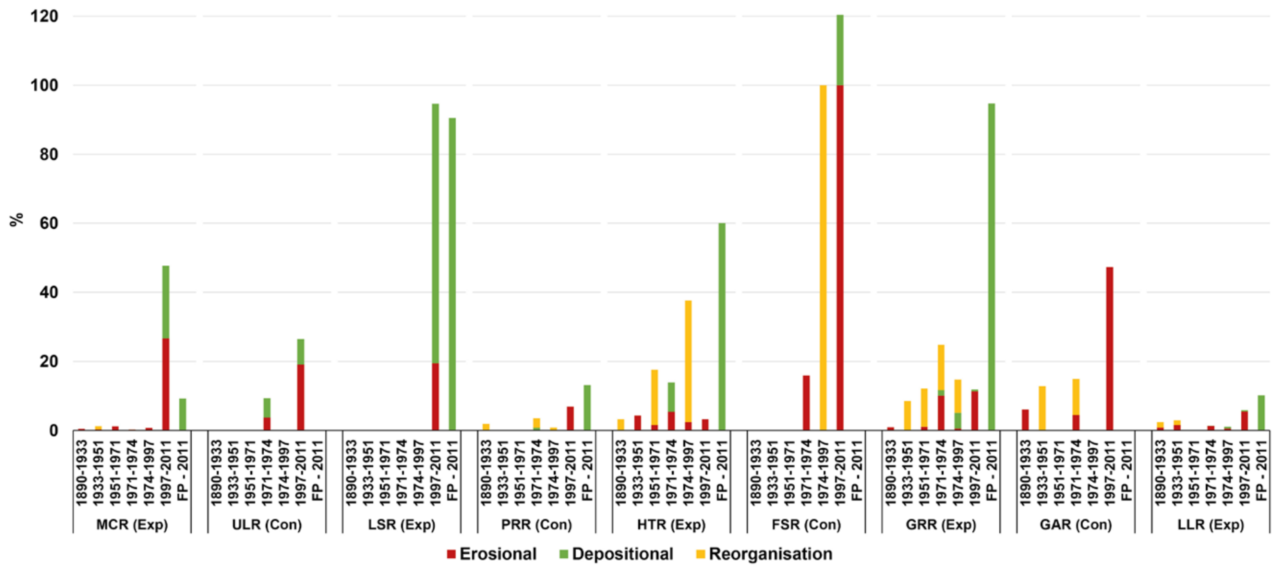


Figure 48. Historical changes in types of adjustment

Historical channel adjustment

Tributary adjustments

The majority of geomorphic adjustments that have occurred since European settlement have generally been concentrated in the wide, shallow, gravel-bed mid-reaches of each tributary.

Blackfellows-Tenthill Creek begins upstream in steep, narrow, bedrock confined valleys and has very coarse sediment (gravels and boulders).

Laidley Creek also has very coarse sediment (gravels and boulders) and forms a distributary with two channels entering Lockyer Creek which is indicative of a past incomplete channel avulsion.

The headwaters of Buaraba Creek begin in steep, narrow, bedrock confined valleys and has very coarse sediment.

Forms of adjustment

Historically, the dominant forms of adjustment have been avulsions, channel stripping, or bed adjustment.

Over the last 130 years, 93 adjustments were mapped in Laidley Creek with lateral expansion, bend adjustment and channel avulsion being the most common (Figure 49).

Along Blackfellows Creek, a tributary of Tenthill Creek, 157 adjustments were mapped with channel avulsion, lateral expansion and bend adjustment being the most common (Figure 50).

Along Buaraba Creek, 61 adjustments were mapped with channel avulsion, bend adjustment and lateral expansion being the most common.

Key controls on tributary adjustments

The tributary systems have much more capacity to adjust and are more sensitive than Lockyer Creek macrochannel. Most geomorphic adjustment occurs in the mid-reaches where drainage areas are between 10% and 60% of the total drainage area, where the channel is wide and shallow (Width:Depth ratio > 12, locally exceeding 50) and have low unit stream power (< ~200 Wm^{-2}).

Overall, Blackfellows/Tenthill Creek is the most sensitive tributary system based on the number and density of channel adjustments [13].

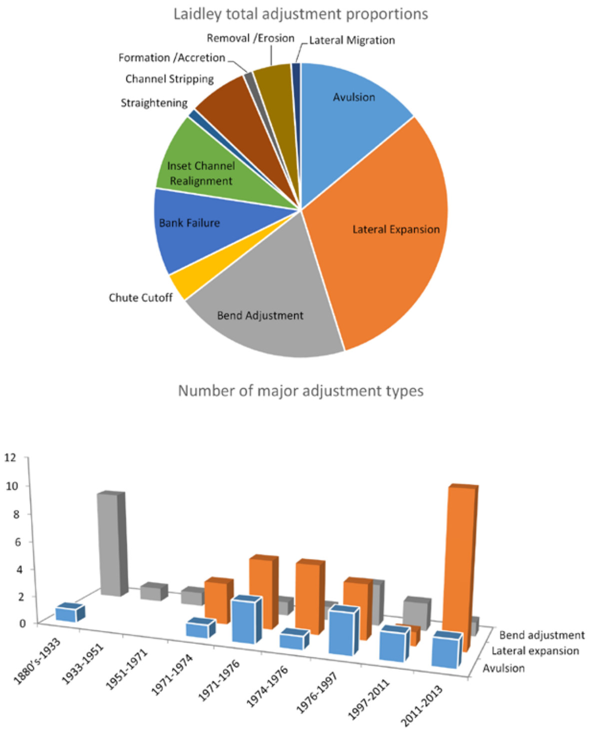


Figure 49. Types of adjustment along Laidley Creek

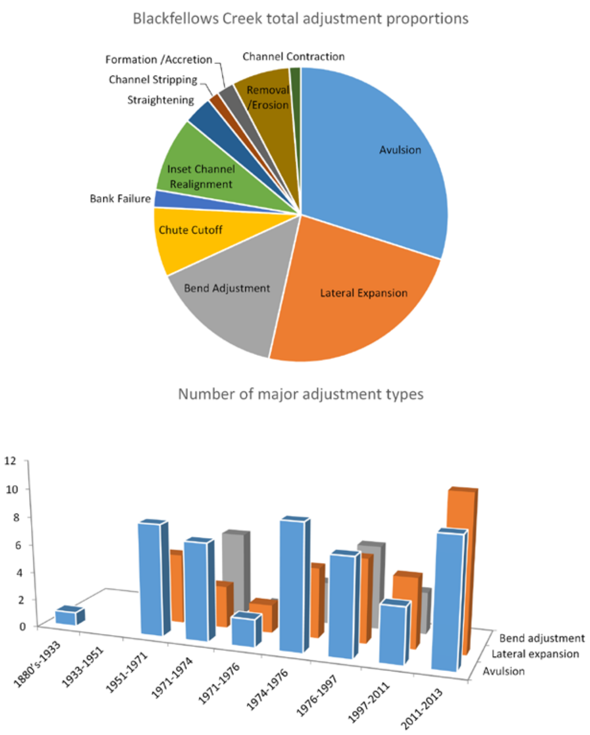


Figure 50. Types of adjustment along Blackfellows Creek

Flood energy and stream power

Flood energy is controlled in part by the nature of the channel and floodplain types. Channel size, slope and shape are key factors influencing flood energy for which stream power is an approximation.

What is stream power?

Stream power is the conversion of gravitational potential energy through the downslope flow of water into kinetic energy. This transformed energy is then made available to erode channel beds or transport sediments

Stream power is often calculated from Discharge (*Q*), energy gradient (*s*) often approximated by water surface slope or channel gradient, density of the fluid (σ) and gravity (*g*).

$$\Omega = \rho g Q s \ (\mathrm{W\ m^{-1}})$$

s=slope

Q=discharge ($m^3 s^{-1}$)

ρ=density of water (kg m^{-3})

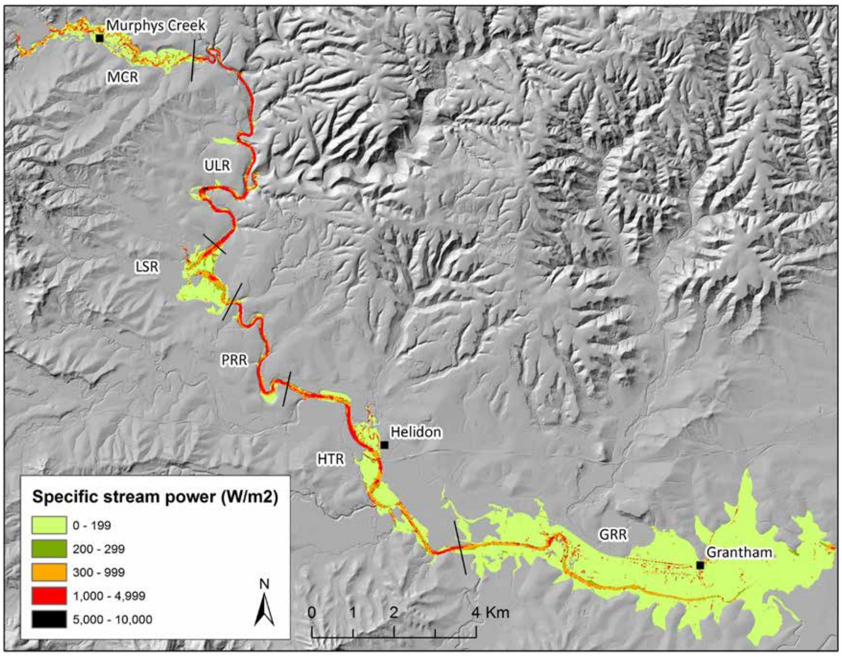
g=gravity (m s^{-2})

How did stream power vary downstream during the 2011 flood?

The 2011 flood generated such a large volume of discharge which combined with the local valley slope caused extremely high specific stream power values which correlated with zones of high fluvial entrainment (Figure 51) [14].

Total stream power, the sum of specific stream power over the duration of the event, peaked in the upper catchment and along the bedrock gorge. In contrast, it was low mid valley because of the rapid conveyance of flood waters. It increased again along the lower Lockyer due to the long duration of the flood which may explain the high fluvial entrainment relative to lower flood peak specific stream power (Figure 52) [21].

Figure 51. Specific stream power along Lockyer Creek



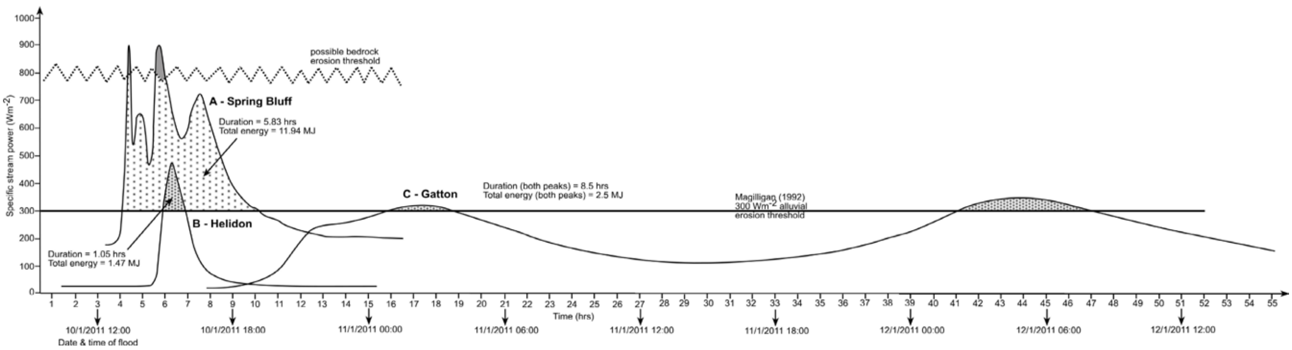


Figure 52. Specific stream power along Lockyer Creek

Predicting flood frequency

Our ability to predict whether a flood event will occur again is limited by several key factors. Firstly, there is no consistent definition applied to what constitutes an extreme event. Secondly, gauge record length is very short in Australia and this limits statistical analysis of the 'extremes'. Thirdly, climate is known to have varied at both decadal and centennial scales and this can also affect flood frequency predictions.

Definition of an extreme flood

Based on the IPCC, an extreme flood event has been defined as equivalent to, or of greater magnitude, than the 90th quantile of the largest recorded floods (Figure 53). The World Envelope Curve (WEC) encapsulates the world's largest rainfall-runoff flood events. However, the world's largest floods greatly exceed flood magnitude of the Australian Envelope Curve (AEC). An extreme event has been defined as ≥ 90th quantile of the Australian Envelope Curve and delineates the presently known upper limit of flood magnitude in Australia

The 2011 event lies below this upper limit in both the Australian and global data sets suggesting that while large, events of higher magnitude can, and do, occur [12].

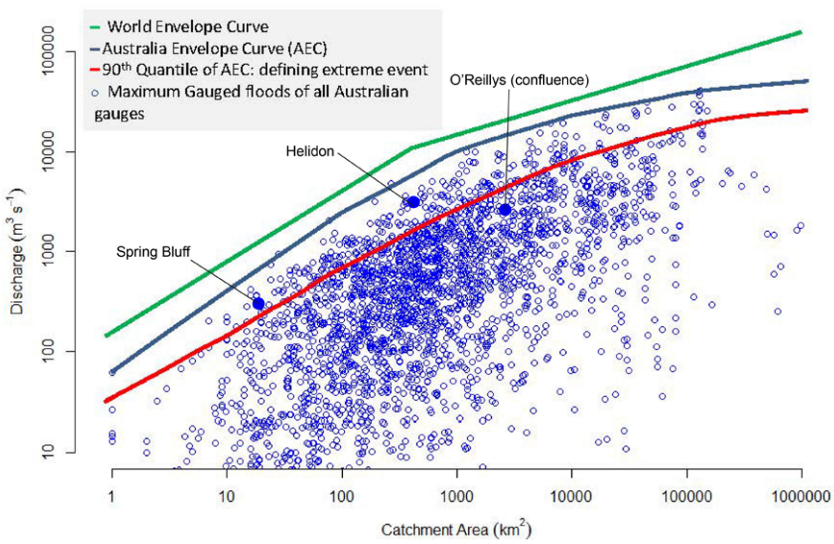


Figure 53. Extreme flood evens as defined by IPCC

Flood record length

SEQs longest record is the Brisbane Port-City gauge commencing in 1841 (Figure 54). It records extreme events in 1840s and 1890s which were much larger than any flood events recorded since 1900.

The majority of gauging stations in the region have very short record length (30-40 years). This means using a very short sample window to predict a rare event. In addition, more than half of the stations have not recorded an extreme event to guide the upper tail of the statistical distribution.

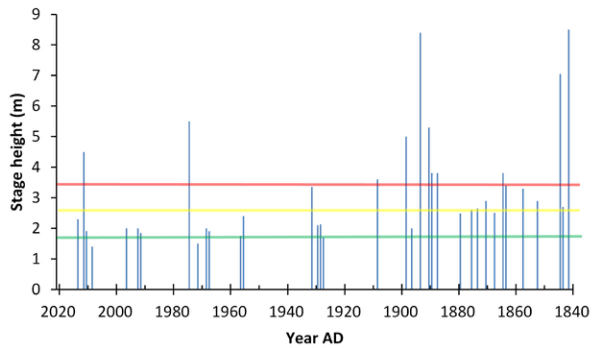


Figure 54. Brisbane gauge record

Too many extreme events

Some gauging stations have too many extreme flood events. This was well illustrated after 2011 when the gauge record in the Lockyer Valley then included two extreme events (2011 and 2013). The Spring Bluff gauge in the headwaters of Lockyer Creek had 31 years of flood record prior to the 2011 flood. Based on this record, the 2011 flood is predicted to have an ARI of >> 2000 years. With the inclusion of 2011 (32 year record), this reduced to 75 years. Today this gauge has a record length of 36 years and the 2011 flood has a predicted recurrence interval of 90 years (Figure 55). This alone highlights the sensitivity of flood prediction to record length [24].

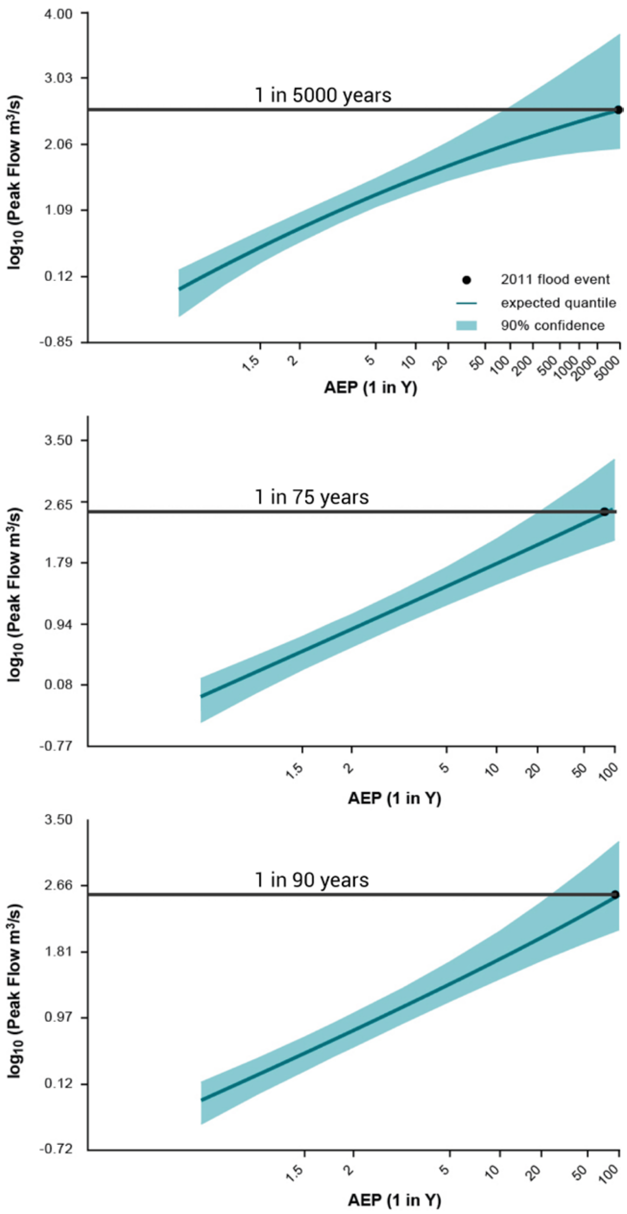


Figure 55. Changes in predicted ARI for Spring Bluff Gauge with the addition of 2011 and 2013 floods

Decadal and centennial-scale climate variability

Cyclical changes in climate which significantly influence or change the likelihood of floods are known to occur. These include variations in ENSO and La Nina events and the Interdecadal Pacific Oscillation (IPO) which modulates ENSO. La Nina events occurring during negative IPO phases have significantly higher likelihood of above average rainfall and flood events.

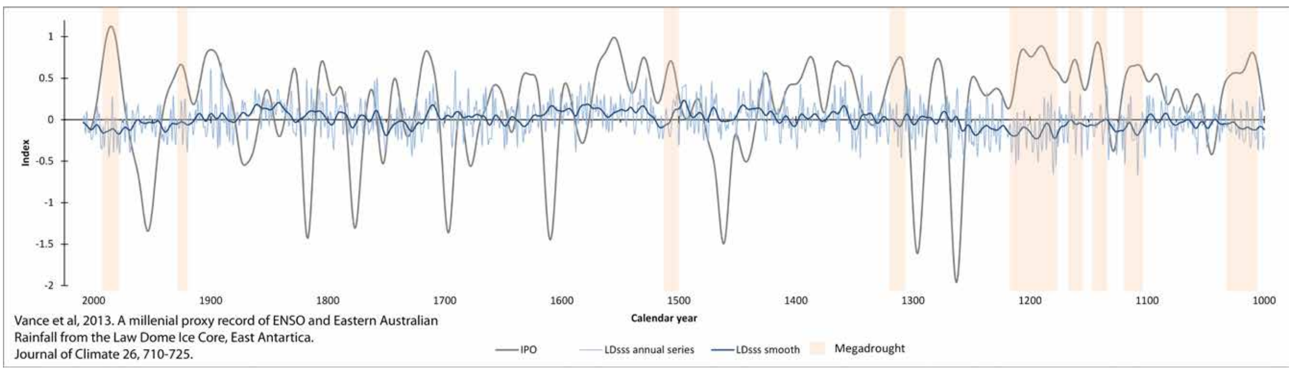
If short gauging records capture either a drought-dominated or flood-dominated period, then predictions of flood frequency will be biased by these variations. Likewise, longer-term changes in rainfall and temperature are also known to have occurred.

Climate proxies

Longer term oscillations are often reconstructed using climate proxies from throughout the SEQ region and elsewhere. One of the highest resolution climate proxies for SEQ is derived from the summer sea salt concentrations in ice cores from Law Dome (LDsss), Antarctica (Figure 56). These have been found to be highly correlated to subtropical Queensland annual rainfall due to atmospheric teleconnections.

This proxy indicates a period of below average rainfall between Cal year 1000 to 1260 including evidence of megadroughts, droughts which extend over > 5 years. Between 1260 to 1860 is generally above average rainfall and coincides with numerous negative IPO phases. From 1920 until 2009 the rainfall proxy is below the 1000 year average. This most recent time period coincides with the majority of gauging records and illustrates the potential bias in flood frequency predictions caused by reduced rainfall during this period.

Figure 56. Summer sea salt concentrations in ice cores from the Law Dome in Antarctica



Extending the flood record

One of the key challenges for SEQ, is to extend the current gauging record length to better represent these climate fluctuations. A number of different approaches have been applied in this project.

Probabilistic regional envelope curve

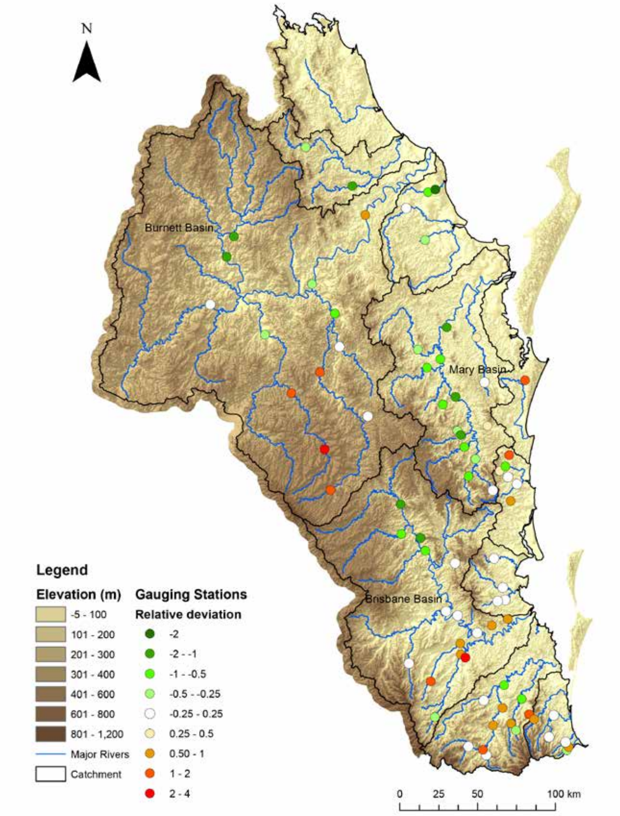
One solution to short gauging station records is to combine flood records from regions with similar characteristics. This method is called a Probabilistic Regional Envelope Curve (PREC) which is then combined with traditional Flood Frequency analysis (FFA) on the combined longer record gauging data (Figure 57). This was undertaken for SEQ and results showed considerable variability in the predicted recurrence interval between the traditional FFA and the PREC-FFA methods, especially with gauging record lengths less than 60 years (Figure 58). Where gauge record length equalled 60 years or more, there was no significant change in the predicted recurrence interval using the combined PREC-FFA.

Historical flood data

Historical flood information often shown by flood marks on old buildings, in newspaper reports, and photos and from oral history, can also supplement gauging station records to improve flood prediction.

However, in localities where European settlement occurred relatively recently, historical flood information is often limited or non-existent. For example, historical flood information from the early gold mining town of Gympie on the Mary River can only extend the record back to the 1870s (Figure 59) [12].

Figure 57. Gauging stations



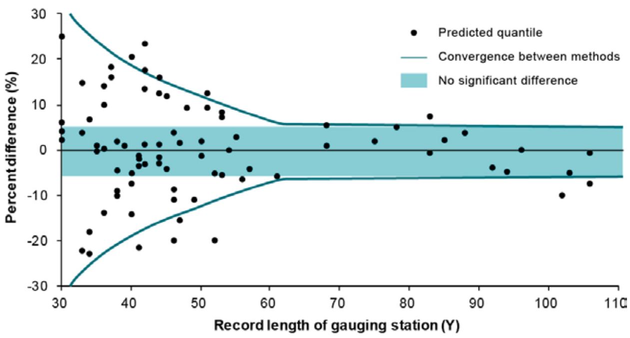


Figure 58. Record length of gauging station

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Rockhampton 1918

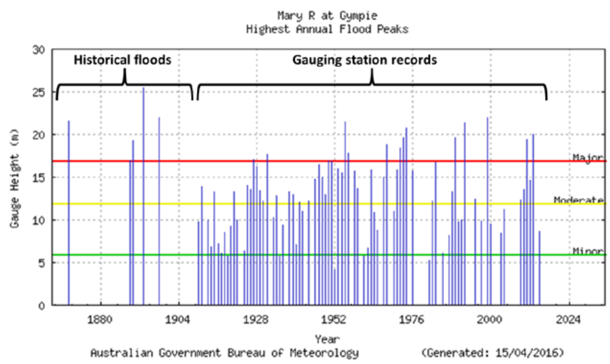


Figure 59. Gympie flood record

Extending the flood record

Paleoflood record for the Lockyer Valley

Nature also records a history of past flood events stored within the floodplain sediments (Figure 60). Overbank flood deposits along Lockyer Creek (Figure 61) were dated to obtain a long-term record of past flood events. The reconstructed flood history shows multiple periods or 'modes' of past flood activity over the past 2000 years. Peaks in flood activity occurred in 0500, 1300 and 1700's, well before historical and gauging station information was available (Figure 62). More recent peaks in flood activity in 1890s and 1970s correlate with the historical and gauging record.

This period of high flood activity during the 1700's was also evident in the rate of deposition on the floodplain (Figure 63), which was very high during this period and has not reached this magnitude since [19].

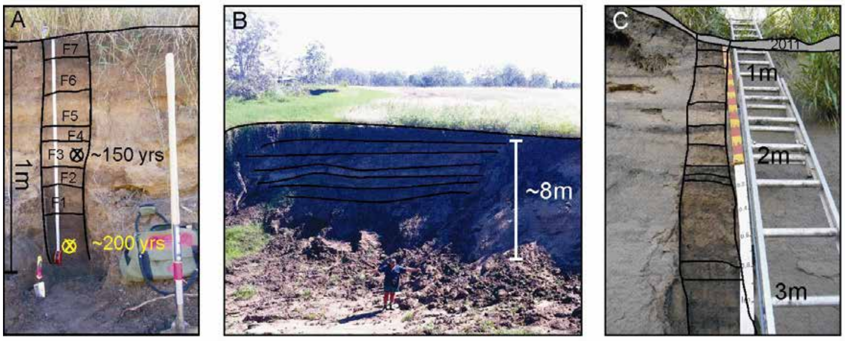


Figure 60.Preserved flood units in Lockyer Creek floodplain.

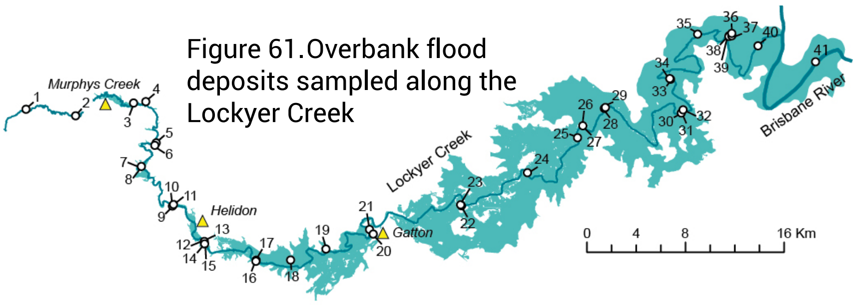
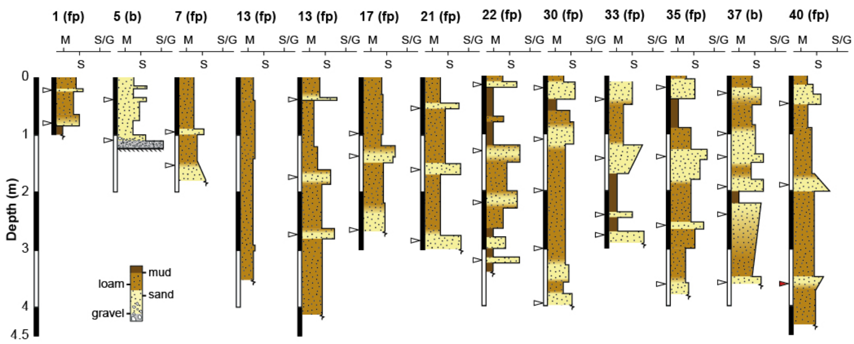


Figure 61.Overbank flood deposits sampled along the Lockyer Creek



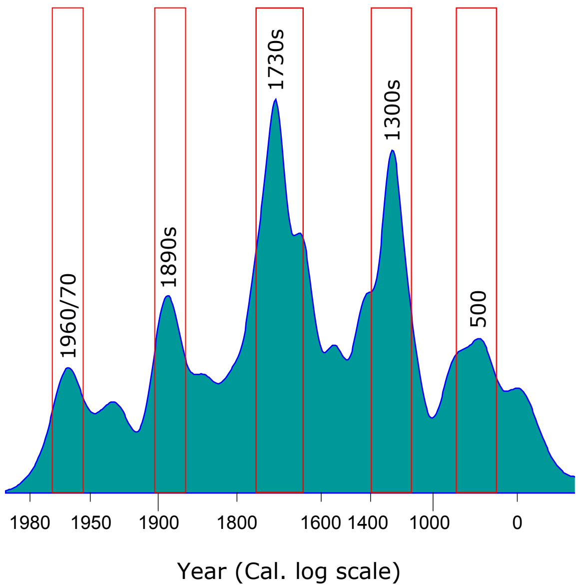


Figure 62.Past flood activity showing peaks

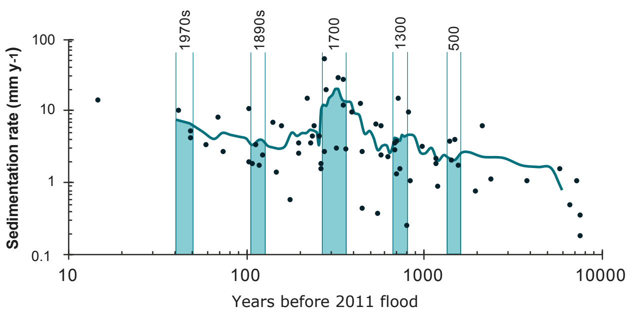


Figure 63.Rate of deposition on the floodplain

Integrating paleoflood data

Large datasets of paleoflood records have been compiled in Europe and North America, and to a lesser extent here in Australia. Until recently there has been limited application of paleoflood records to flood frequency analysis because of a lack of a consistent methodology. The recent development of the Peak-Over Threshold (POT) methods and Bayesian models are starting to address this limitation.

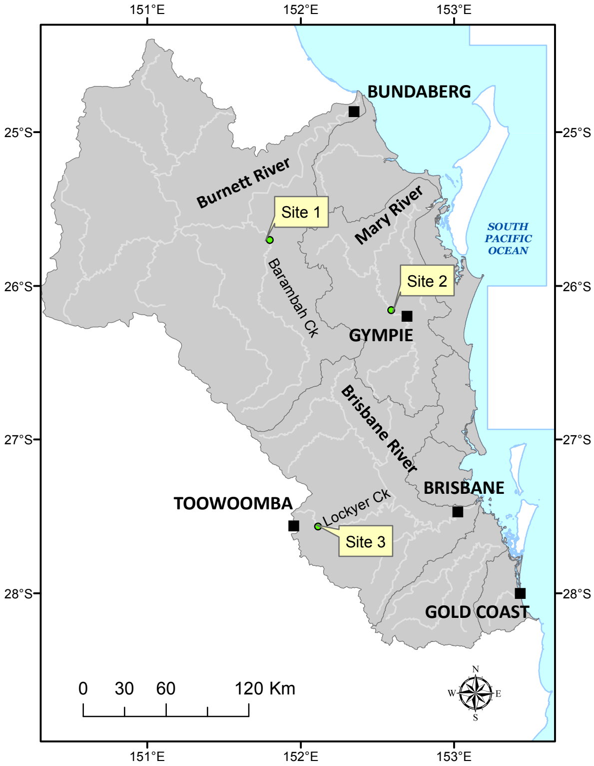


Figure 64. Paleoflood sites

A method to integrate paleoflood data

Paleoflood data was integrated with Annual Maximum Series (AMS) for FFA using a Bayesian inference method in the FLIKE software (http://flike.tuflow.com). The method allows the integration of records outside the gauge period and data to be censored using of minimum/maximum thresholds.

The apporach was tested in 3 paleoflood sites across south-eastern Queensland: Barambah Creek in the Burnett catchment, the Mary River near Gympie and Lockyer Creek near Helidon (Figure 64). Findings indicate that the inclusion of paleoflood records in at-a-station FFA significantly decreases the uncertainty (90 % confidence Interval) and adjusts the expected quantile estimate for rare events (Figure 65).

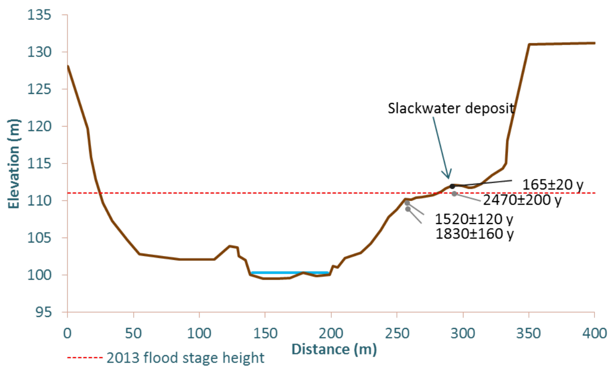


Figure 66. Slackwater deposit 1m above biggest flood of record

Higher flood magnitudes

The reconstruction of paleoflood magnitude from slackwater deposits in the region has indicated the occurrence of larger flood events over the past 1000 years. For example, slackwater deposits from Barambah Creek at Ban Ban where more than 1m higher than largest flood of record on the near-by gauge (Figure 66) [24].

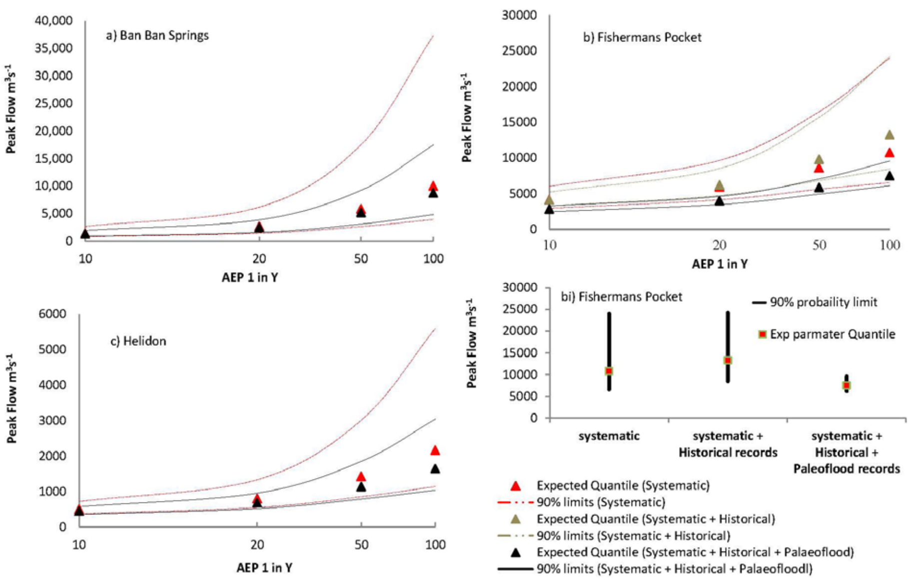
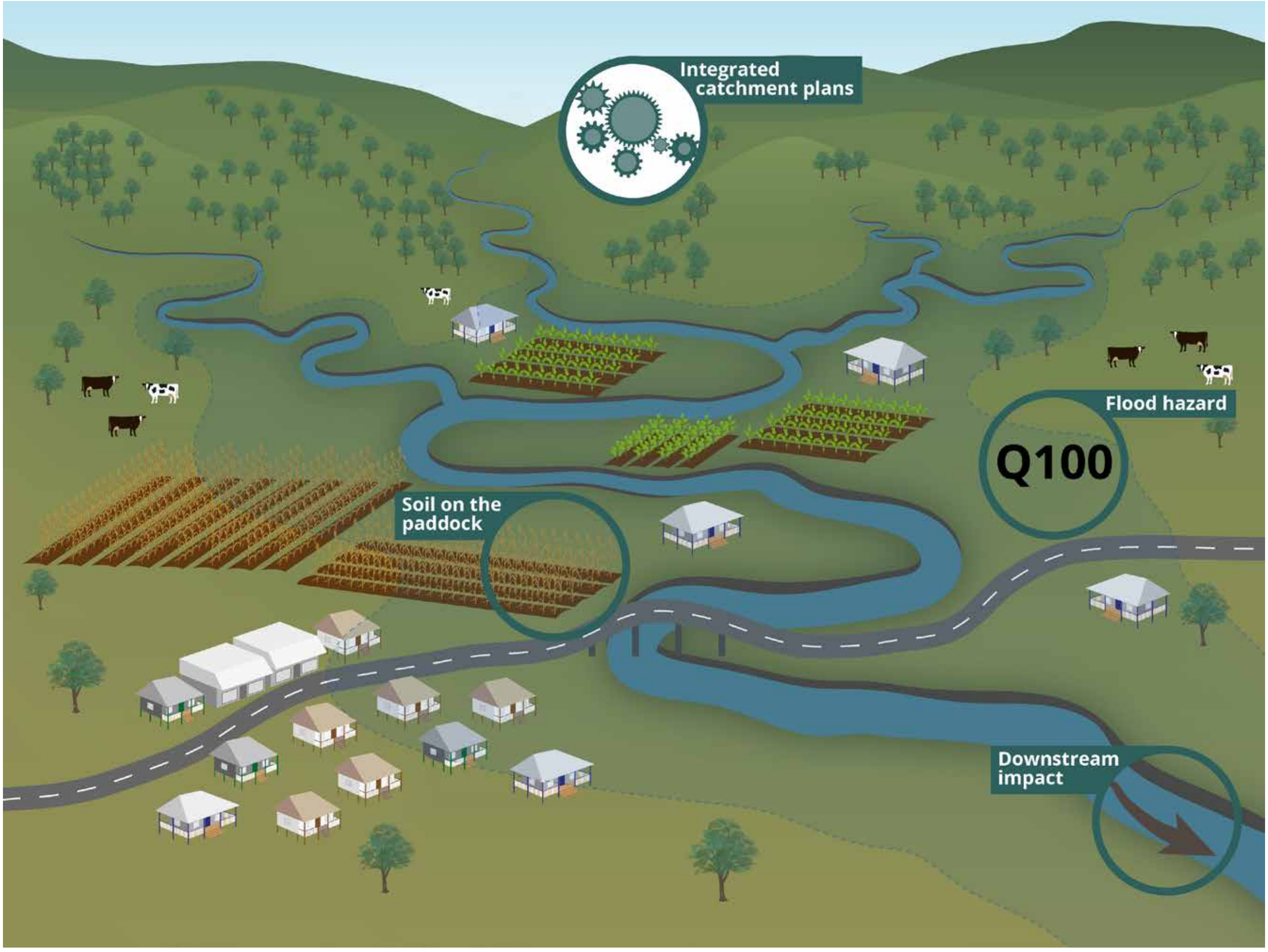


Figure 65. Inclusion of paleoflood records in at-a-station FFA significantly decreases the uncertainty and adjusts the expected quantile estimate for rare events

MANAGING FUTURE FLOODS
Key findings

Findings from this project make a significant contribution to the future management of floods in the region. Specifically we identify actions that can be undertaken to meet the future objectives of (a) improved flood hazard mapping (b) 'keeping soil on the paddock' through appropriate catchment action plans and (c) reducing end-of-catchment sediment yields.



Flood risk management is an essential responsibility of state governments and local councils to ensure the protection of people residing on floodplains. The traditional approach of empirical flood frequency analysis continues to be primarily engineering-based and relatively inaccurate with short gauging records. This project has delivered the understanding and methods to improve flood hazard prediction in SEQ.

Extending the flood record with paleoflood data

Findings from this project present compelling evidence to support the inclusion of historical and paleoflood data into future flood frequency analysis. Estimates of improved certainty in flood prediction of between 50 -75% have been reported with as little as 3 extra paleoflood events (Figure 67). Following the 2011 food event in SEQ, the Queensland Flood Commission of Inquiry advocated that all sub-catchments in the Brisbane River should undertake a paleolfood analysis for inclusion in future flood predictions. To date, this has not been undertaken and yet, as this project illustrates, it provides the most accurate and cost effective solution to the improved prediction of flood frequency and magnitude in these catchments.

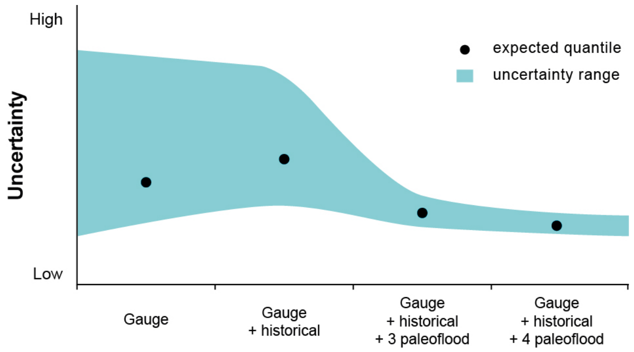


Figure 67. Uncertainty is reduced when including paleoflood records

Mapping the floodplain

Considerable effort has been undertaken in the mapping of the design flood (e.g. Q100). However, findings from this project point to the complexity of different floodplain surfaces in these hydrologically-variable settings (Figure 68). While it is generally assumed based on at-site hydraulic geometry relations that inundation occurs simultaneously across floodplains, this is rarely the case. The mapping of different floodplain 'types' across SEQ can add considerable value to better prediction of flood inundation. It will also assist in the recognition of floodplains at risk from erosion and remobilisation during extreme events [6].

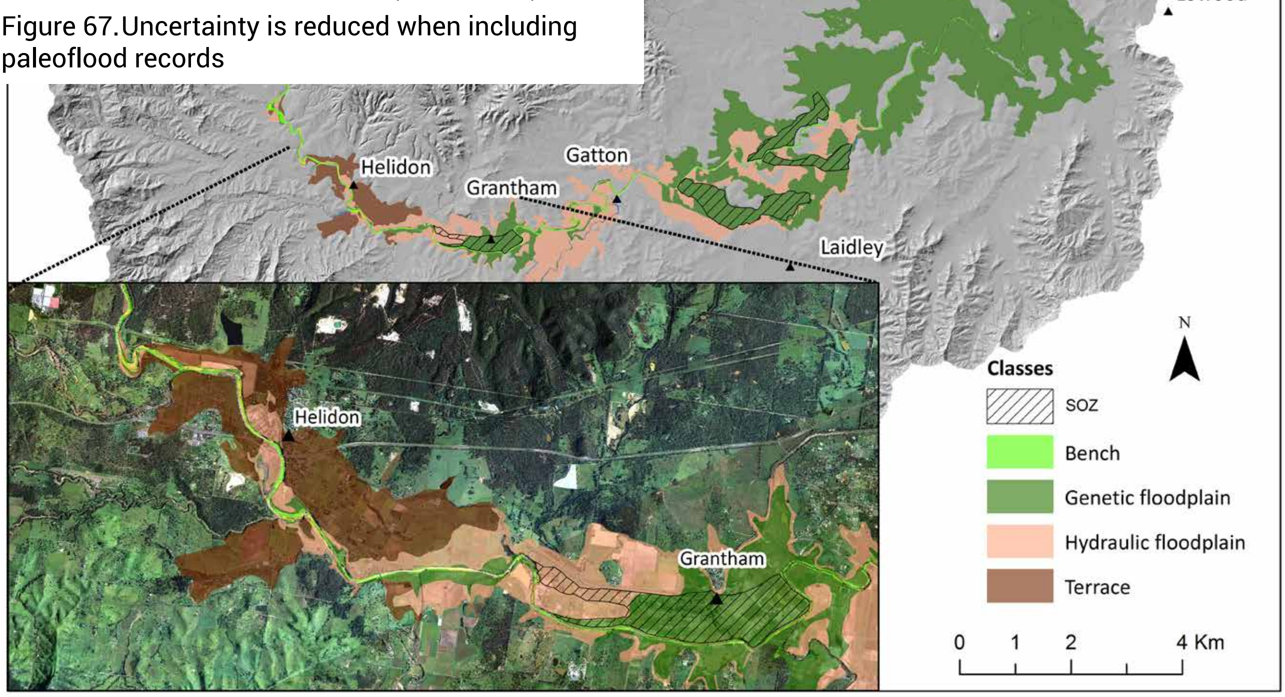


Figure 68. Complex floodplain surfaces

Flood hazard

Mapping spill out zones

This project identified an area referred to as a Spill Out Zone (SOZ) which occurs in settings where upstream channel capacity is larger than downstream, often due to the presence of more resistant boundary material in terraces or direct bedrock confinement. Current flood risk procedures do not evaluate downstream changes in channel capacity and associated changes in flood conveyance. At present such Spill-Out Zones are not mapped and yet they can form one of the highest risks to both people and public property. Flow velocity and depth conditions at Grantham led to wholesale removal of masonry dwellings and the devastating loss of lives in the 2011 flood event. An additional example of a SOZ is illustrated for the Burnett River as it flows through the City of Bundaberg (population 100, 000) where flood waters during an extreme flood event in January 2013 spill-out across the lower floodplain (Figure 69).

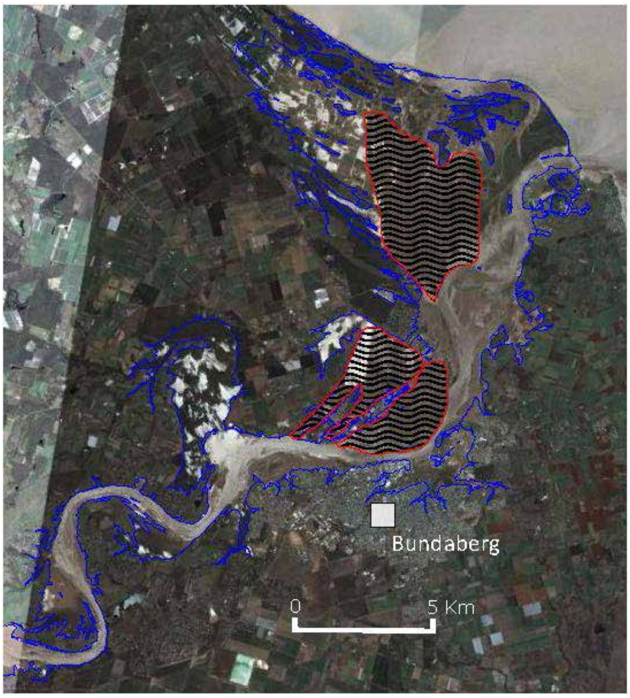


Figure 69. Spill out zone at the Burnett River in Bundaberg

Mapping stream power distributions

As the floods of 2011 and 2013 illustrated, it is not just flood inundation that causes damage and loss of lives, but the force of the flood waters also needs to be considered. Both erosion and channel adjustment are strongly correlated with values of high stream power. Stream power maps can identify where zones of high flood energy occur and can provide a useful tool to identify flood risk (Figure 70). Given the widespread availability of digital technology to map channel slope and discharge, these sorts of analyses should be incorporated into regional assessments of flood risk.

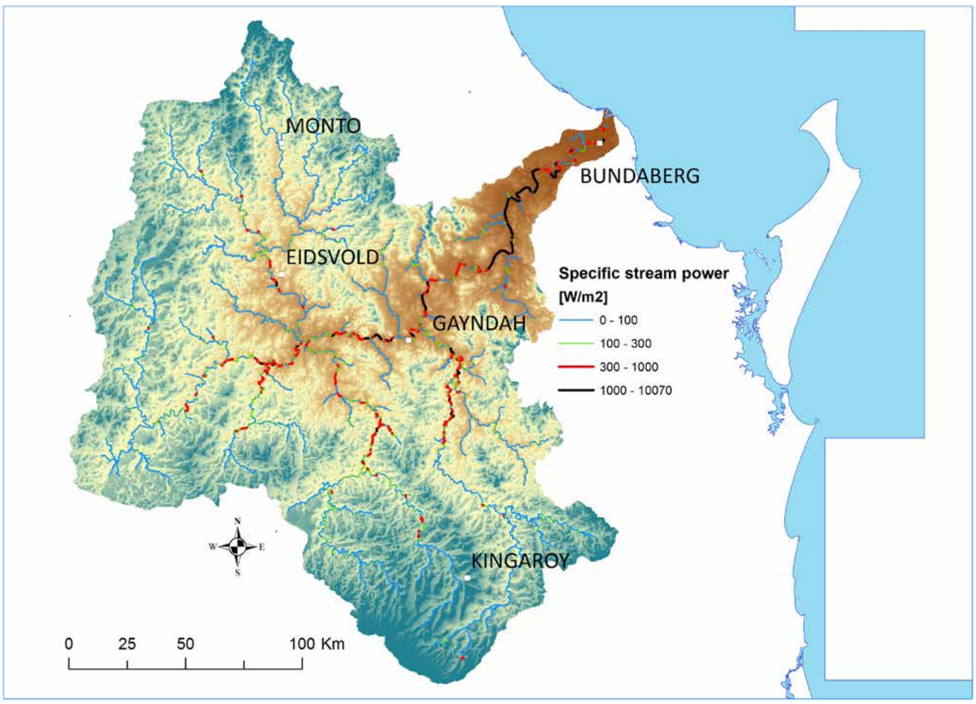


Figure 70. Stream power map

Soil on the paddock

Many local stakeholders and regional bodies are concerned about the extent of soil loss during flood events, and yet many management practices currently prohibit the deposition of valuable soils on downstream floodplains. This occurs primarily because many management practices actually act to speed up flood flows, reducing opportunities for deposition both in-channel and on adjacent floodplains.

Artificial levee construction

Natural levees are a common feature along these laterally-stable channels in SEQ. Poorly planned and executed artificial levee construction (Figure 71) can limit floodplain deposition can significantly increase flow velocity, banktop discharges and associated stream powers, producing a higher likelihood of channel change such as channel avulsion (Figure 72). Research suggests that the lower Lockyer is at, or already exceeds, many of the recognised critical setup conditions for channel avulsion. In precautionary river management practice, such as those where 'erodible corridor' programs are becoming more popular, floodplain surfaces are allowed to inundate where possible and store sediment, thereby minimising the risk to life and property during extreme floods [31].

Cease channel cleaning-out post floods

Traditionally after extreme floods there is widespread community and local government support for the 'cleaning out' of channels to ensure more effective downstream flood water conveyance. Within-channel benches and associated vegetation are often removed to meet this aim (Figure 73). However, numerous studies now point to the significance of these within-channel features in terms of both reducing downstream sediment yields and channel-bank stabilisation.

Project findings support a non-intervention approach to the management of within-channel surfaces for flood management. Efforts should be focused on within-channel re-vegetation to increase roughness, reduce velocities and promote sediment deposition within-channel.

Figure 71. Artificial levee

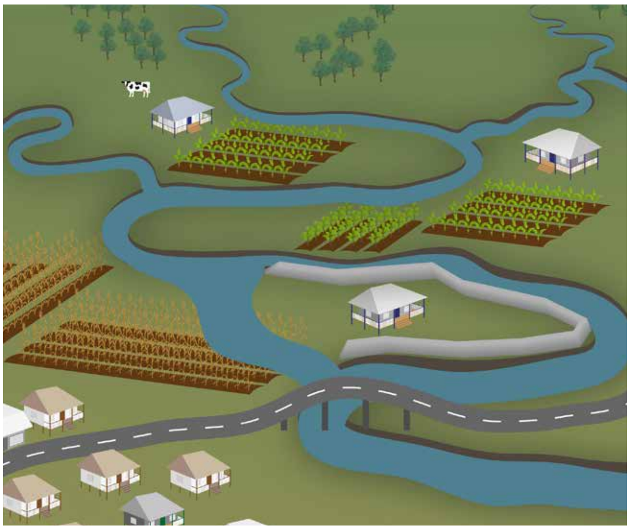


Figure 72. Poorly planned artificial levees can increase likelihood of channel avulsion

PROF JON OLLEY, ARI

Figure 73. Channel cleaning out is often called for immediately following a flood

Downstream impacts

Extreme floods contribute disproportionately to the amount of sediment delivered to downstream ecosystems such as Moreton Bay. This is because floods produce high stream power, increased erosion and transport capacity. Identifying where erosion processes are highest can help reduce downstream yields.

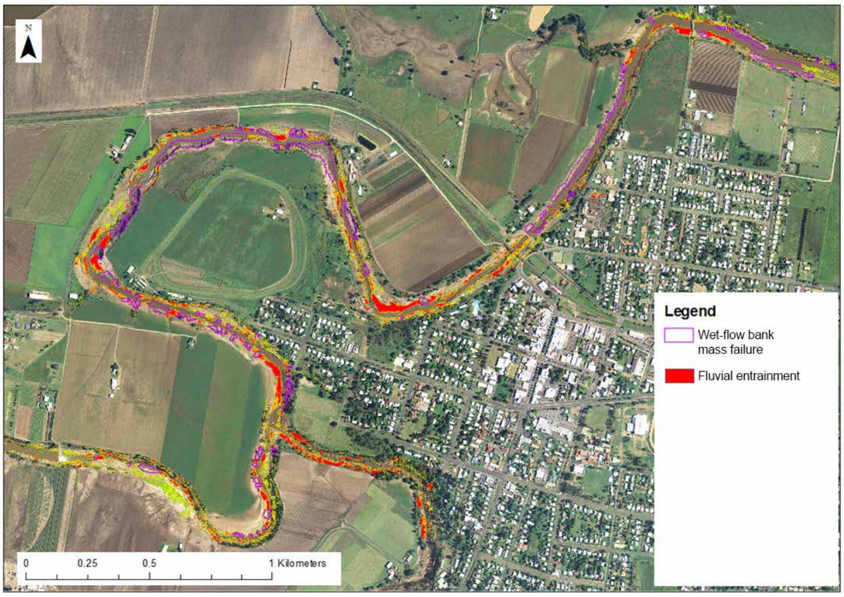
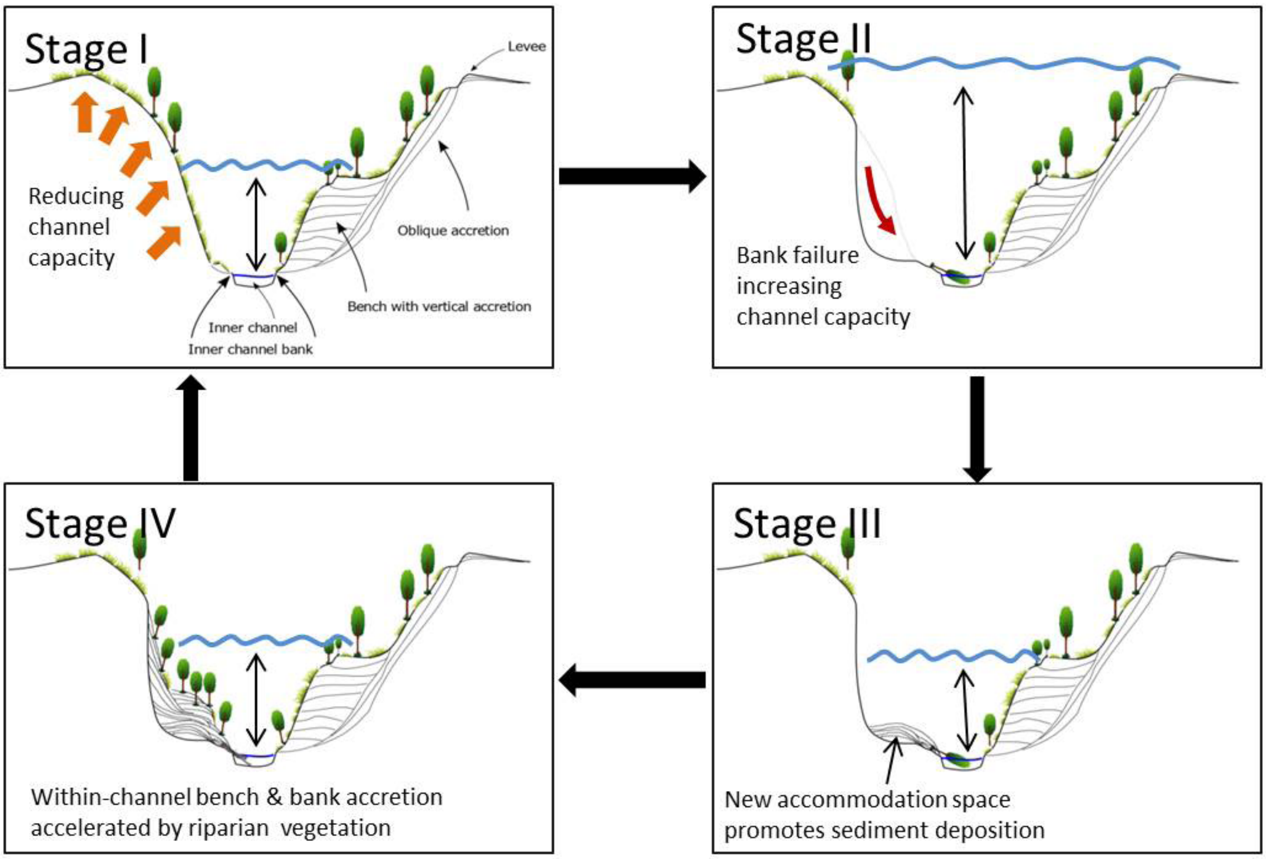


Figure 74. Identifying where erosion processes dominate

Managing bank erosion

Understanding patterns and processes of bank failure is important in order to inform river hazard assessments, stream management and restoration options. Certain bank erosion processes occur due to bank profile saturation and are difficult to rehabilitate and manage. Others, such as those associated with fluvial entrainment can be more readily engineered. Identifying where each process is dominant in the catchment (Figure 74), and the stage of channel evolution (Figure 75), is a priority. For example, some reaches will self-repair with a non-intervention approach to river management [22].

Figure 75. Channel evolution stages. From Thompson et al., 2016



Downstream impacts

Placement of riparian vegetation

Riparian vegetation is well known to help control bank stability and limit erosion. Two key issues often confound the success of strategic re-vegetation plans in SEQ; (1) identifying the active channel bank and bank top and (2) determining where riparian vegetation could contribute most to reducing flood velocities and trapping sediment. An example of riparian vegetation prioritisation has been undertaken for the Lockyer Creek catchment and shows the potential to align sediment trapping with inundation frequency and erosion potential (Figure 76). This approach recognises that revegetating everywhere is not necessary or cost effective. The 'sweet spot' for investment involves prioritising areas such as within-channel benches and Spill Out Zones on genetic floodplains (Figure 77).

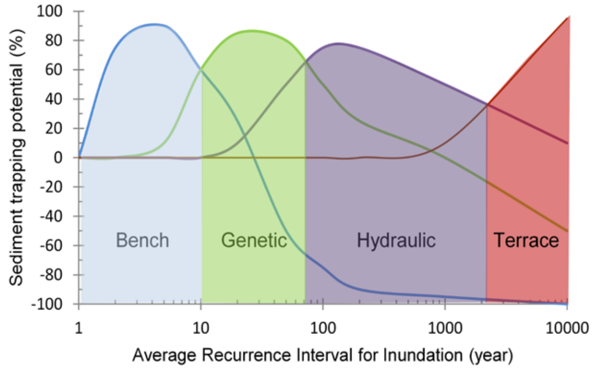
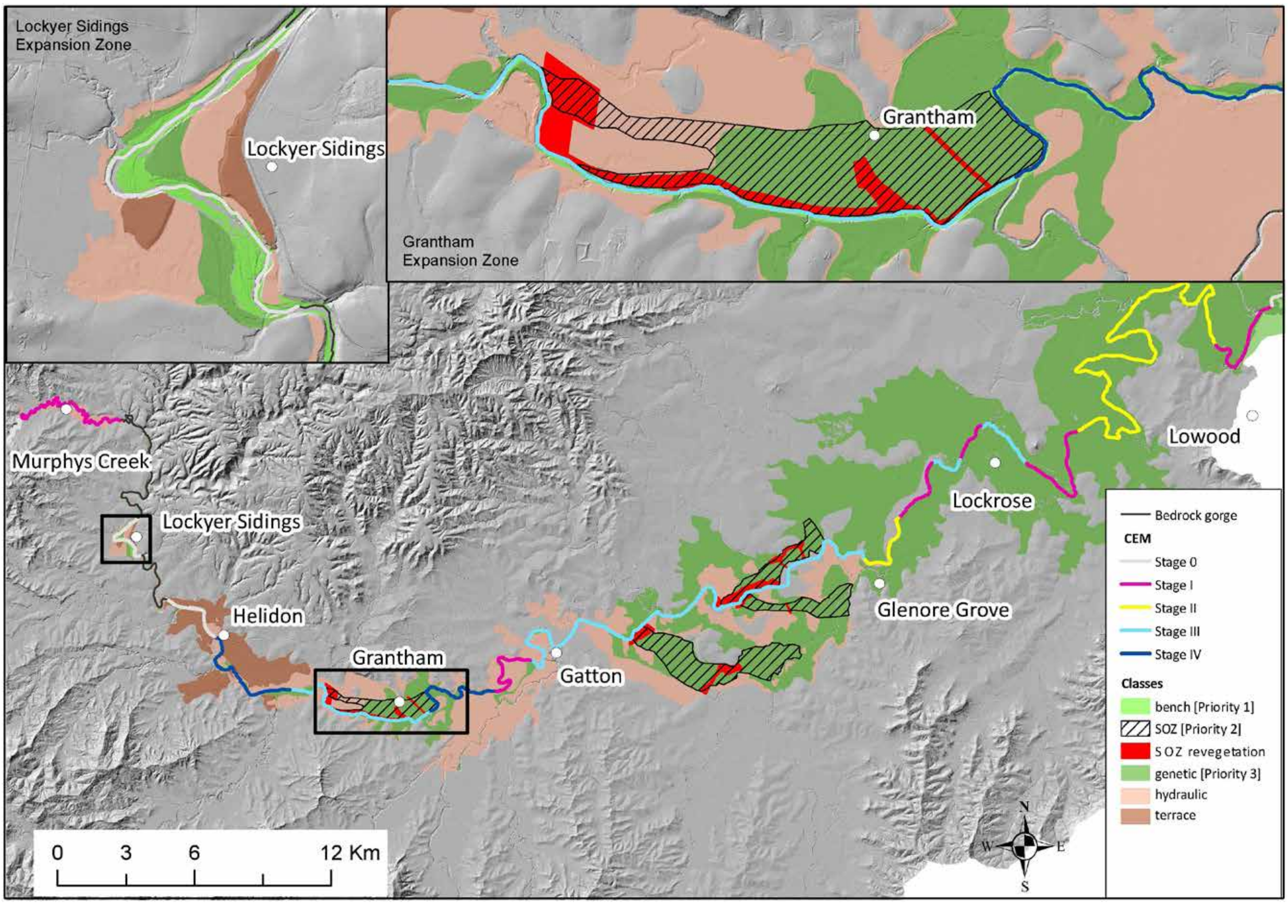


Figure 76. Sediment trapping potential for each surface based on inundation frequency and timescales of re-working. Croke et al., in review

Figure 77. Prioritisation of riprarin vegetation placement in the Lockyer Valley based on inundation frequency and surface area. Croke et al., in review



Future trajectories

Future trajectories of change in both Lockyer Creek and its tributaries will depend on the interaction of two factors (1) hydrological regime and (2) riparian vegetation management.

Model scenarios

CAESAR-Lisflood, a reduced complexity landscape evolution model, is used to simulate future (next 100 years) channel response based on two projected climate change scenarios and rainfall projections based on Representative Future Climate partitions from SILOs Consistent Climate Change Scenario (CCS) https://www.longpaddock.qld.gov.au/silo/

1. warm and wet using composite of Global Climate Models HI, and
2. warm and dry using Global Climate Model HADCM3.

These are run in conjunction with two riparian vegetation management scenarios

1. no change in riparian vegetation density and
2. reforestation of within channel vegetation.

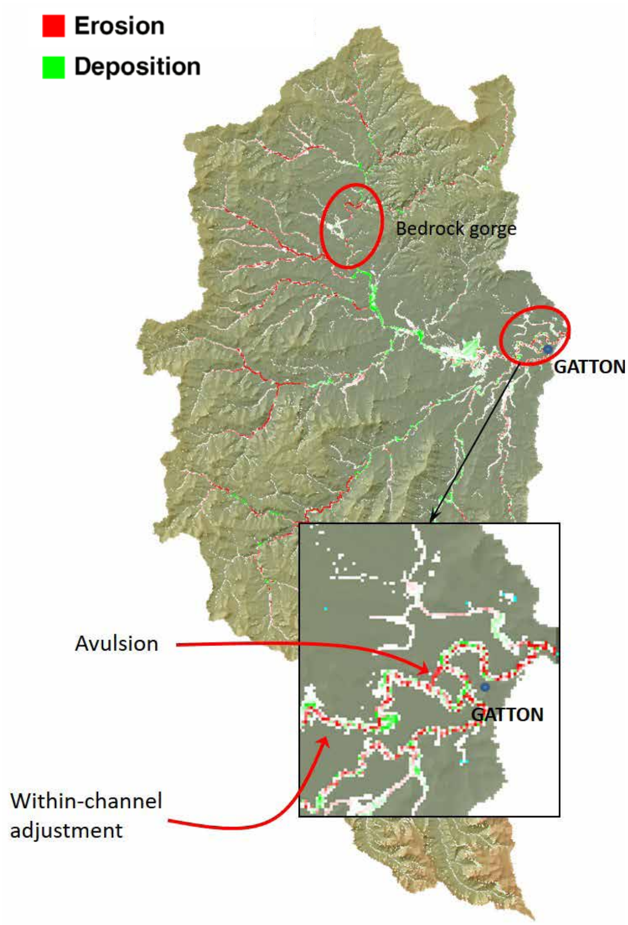


Figure 78. Main channel erosion

Model results

Initial model results for the upper Lockyer Creek catchment based on Climate scenario 1 and current riparian condition (Figure 78) show erosion occurs along the mid-reaches while deposition dominates along the lower tributary reaches, particularly in Tenthill Creek.

Along the main channel, an alternating pattern of deposition and erosion occurs. The main deposition locations are the upper bedrock gorge reach, Helidon terraces reach and the floodplain at Grantham which is the largest sink of sediment.

Main channel erosion occurs along the lower bedrock gorge and near Gatton where two processes are observed. Here, channel avulsion has commenced with the cutting off of the meander bend containing the confluence of Tenthill Creek. The second process occurring in the macrochannel is the within-channel reworking of benches and minor re-alignments of the active channel bed.

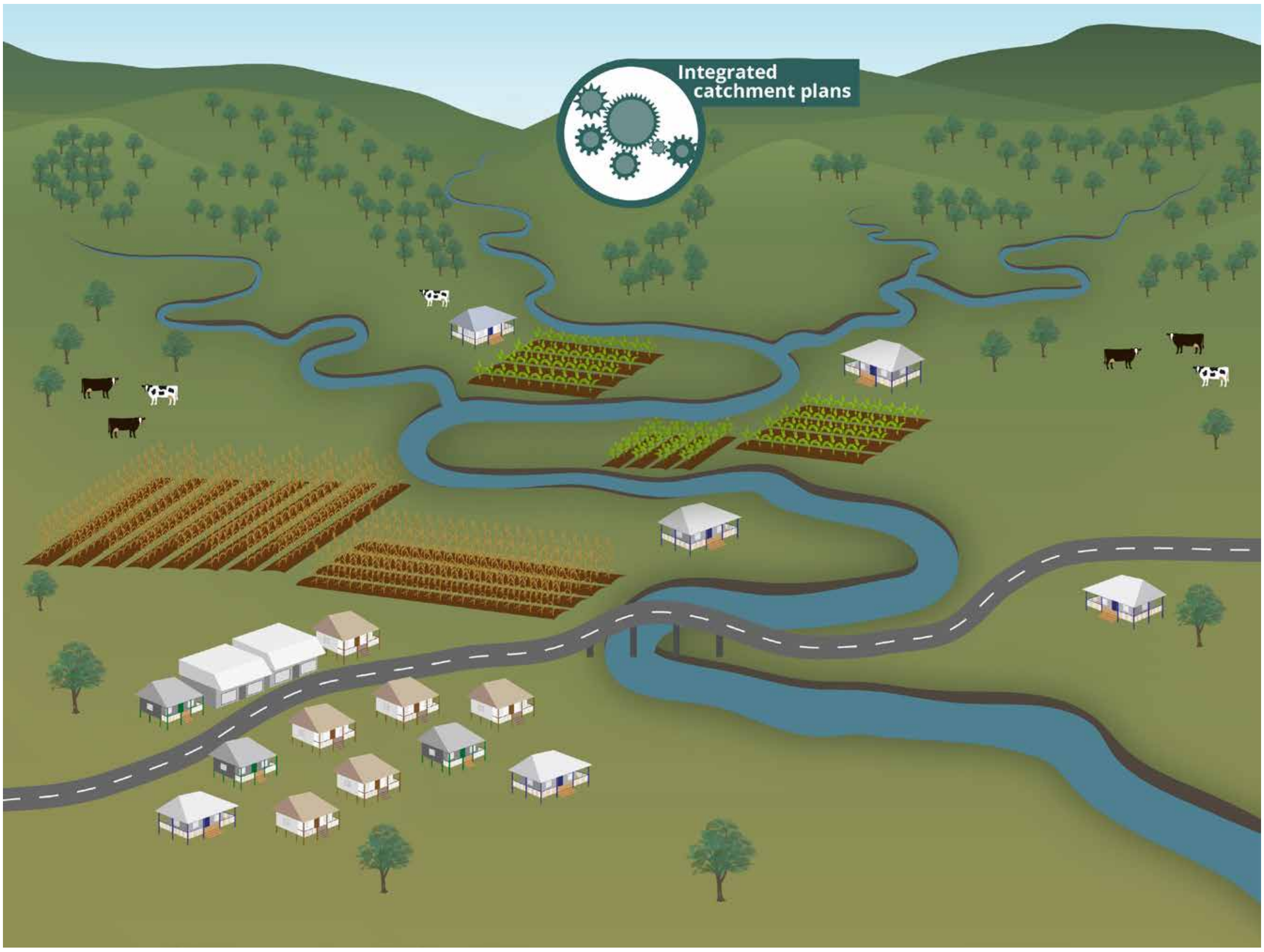
These initial model results highlight two important processes for which strategic riparian vegetation management can play an important role. Within-macrochannel benches near Gatton and the floodplain along the avulsion pathway should be a priority for riparian revegetation. Results also highlight the tributary reaches most susceptible to adjustment enabling a more targeted approach to river rehabilitation.

Integrated catchment action plans

Following recent extreme flood events, local and federal governments invested heavily in building flood resilience programs. The state government initiated the Brisbane River Catchment Flood Studies (BRCFS) with additional investments in associated programs such as River Resilience Trust. However, the absence of a coordinated strategic approach, is a missed opportunity to integrate flood risk mitigation with other elements of catchment management.

Building on this data

Findings produced in this project offer the opportunity for state governments and councils to open a new dialogue on future changes to flood management. Resources such as Fact Sheets, over 30 scientific peer-reviewed papers, and the final report now form a sound basis for future change. Opportunities for revised approaches, definitions and methods now exist. Consistently defining floodplain types, spill out zones, locations of high stream power and aligning management actions with the right erosion process will take SEQ a long way to better flood hazard management and downstream water quality protection.



References

Published Papers in International Journals

1. Baggs Sargood M, Cohen TJ, Thompson CJ, Croke JC. 2015. Hitting rock bottom: morphological responses of bedrock-confined streams to a catastrophic flood. Earth Surface Dynamics 3(2): 265-279
2. Croke JC, Fryirs KA, Thompson CJ. 2013a. Channel-floodplain connectivity during an extreme flood event: Implications for sediment erosion, deposition, and delivery. Earth Surface Processes and Landforms 38: 1444–1456
3. Croke JC, Todd P, Thompson CJ, Watson F, Denham R, Khanal, G. 2013b. The use of multi temporal LiDAR to assess basin-scale erosion and deposition following the catastrophic January 2011 Lockyer flood. Geomorphology 184: 111-126
4. Croke JC, Denham R, Thompson CJ, Grove JR. 2015 Evidence of self-organized criticality in riverbank mass failures: a matter of perspective? Earth Surface Processes and Landforms 40(7): 953-964
5. Croke JC, Reinfelds I, Thompson CJ, Roper E. 2014. Macrochannels and their significance for flood-risk minimisation: examples from southeast Queensland and New South Wales, Australia. Stochastic Environmental Research and Risk Assessment 28(1): 99-112
6. Croke JC, Fryirs KA, Thompson CJ. 2016. Defining the floodplain in hydrologically-variable settings: implications for flood risk management. Earth Surface Processes and Landforms
7. Coates-Marnane J, Olley JM, Burton J, Grinham A. 2016a. The impact of a high magnitude flood on metal pollution in a shallow subtropical estuarine embayment. Science of the Total Environment 569-570: 716-731
8. Coates-Marnane J, Olley JM, Burton J, Sharma A. 2016b. Catchment clearing accelerates the infilling of a shallow subtropical bay in east coast Australia. Estuarine, Coastal and Shelf Science 174: 27-40
9. Fryirs KA, Lisenby P, Croke JC. 2015. Morphological and historical resilience to catastrophic flooding: The case of Lockyer Creek, SE Queensland, Australia. Geomorphology
10. Grove JR, Croke JC, Thompon CJ. 2013. Quantifying different riverbank erosion processes during an extreme flood event. Earth Surface Processes and Landforms 38(12): 1393-1406
11. Haines HA, Olley JM, Kemp J, English NB. 2016. Progress in Australian dendroclimatology: Identifying growth limiting factors in four climate zones. Science of the Total Environment 572: 412-421
12. Lam D, Thompson CJ, Croke JC. 2016. Improving at-site flood frequency analysis with additional spatial information: a probabilistic regional envelope curve approach. Stochastic Environmental Research and Risk Assessment 1-21
13. Lisenby PE, Fryirs KA. 2016. Catchment- and reach-scale controls on the distribution and expectation of geomorphic channel adjustment. Water Resources Research 52(5): 3408–3427
14. Thompson CJ, Croke JC. 2013. Geomorphic effects, flood power and channel competence of a catastrophic flood in confined and unconfined reaches of the upper Lockyer valley, south east Queensland, Australia. Geomorphology 197: 156-169
15. Thompson CJ, Croke JC, Grove JR, Khanal, G. 2013. Spatio-temporal changes in riverbank mass failures in the Lockyer valley, Queensland, Australia. Geomorphology 191: 129-141
16. Thompson, C. J., Fryirs, KA. and Croke, J. 2016. The Disconnected Sediment Conveyor Belt: Patterns of Longitudinal and Lateral Erosion and Deposition During a Catastrophic Flood in the Lockyer Valley, South East Queensland, Australia. River Research and Applications 32(4): 540-551.
17. Thompson CJ, Croke JC, Fryirs KA, Grove JR. 2016 A channel evolution model for subtropical macrochannel systems. Catena 139: 199-213

Accepted

18. Daley JS, Croke JC, Thompson CJ, Cohen TJ, Macklin M, Sharma A. 2016. Late Quaternary channel and floodplain formation in a partly confined subtropical river, eastern Australia. Journal of Quaternary Science
19. Croke JC, Thompson CJ, Denham R, Haines HA, Sharma A, Pietsch T. Submitted. Reconstructing a millennial-scale record of flooding in a single valley setting: the 2011 flood-affected Lockyer Valley, SEQ, Australia. Journal of Quaternary Science

References

Papers In Review

20. Croke JC, Thompson CJ, Larsen A, Sharma A. Submitted. The nature and timing of fluvial response to changing base-level and climate over the last glacial -interglacial cycle in sub-tropical Australia. Quaternary Science Reviews

21. Croke JC, Thompson CJ, Fryirs KA. Submitted. Using estimates of stream power to predict channel erosion during an extreme flood event. Water Resources Research

22. Croke JC, Thompson CJ, Fryirs KA. Submitted. Prioritising the placement of riparian vegetation to reduce flood risk and end-of-catchment sediment yields: Important considerations in hydrologically-variable regions. Journal of Environmental Management

23. Haines HA, Olley JM. Submitted. The implications of regional variations in rainfall for reconstructing rainfall patterns using tree rings. Hydrological Processes

24. Lam, D, Thompson CJ, Croke JC, Sharma A, Macklin M. Submitted. Reducing uncertainty with flood frequency analysis: the contribution of palaeo- and historical flood information. Water Resources Research

25. Lisenby PE, Fryirs KA. Submitted. Sedimentologically Significant Tributaries: Catchment-Scale Controls on Sediment (Dis)Connectivity in the Lockyer Valley, SEQ, Australia. Earth Surface Processes and Landforms

26. Lisenby PE, Fryirs KA. Submitted. 'Out with the Old?' Why Coarse Spatial Datasets are Still Useful for Catchment-Scale Investigations of Sediment (Dis)Connectivity. Earth Surface Processes and Landforms

27. Lisenby PE, Croke JC, Fryirs KA. Submitted. Geomorphic Effectiveness: A Linear Concept in a Non-Linear World. Earth Surface Processes and Landforms

Conference proceedings

28. Thompson CJ, Croke JC, Pietsch T. 2012. Geomorphic impact of the January 2011 flood on Murphys Creek, southeast Queensland. In: Proceedings of the 6th Australian Stream Management Conference: Managing for Extremes. Canberra, ACT, Australia. pp 23-30.

29. Croke JC, Watson F, Thompson CJ, Todd P. 2012. Erosion and deposition during the January 2011 Lockyer flood, Southeast Queensland. In: Proceedings of the 6th Australian Stream Management Conference: Managing for Extremes. Canberra, ACT, Australia. pp 14-22.

30. Grove JR, Croke JC, Thompson CJ. 2014. Making a difference: using multiple event based LiDAR datasets to guide river management decisions following extreme floods. In: Proceedings of the 7th Australian Stream Management Conference. Townsville, QLD, Australia. pp 232-239

31. Thompson CJ, Croke JC, Dent C. 2014. Potential Impacts of levee in construction in the Lockyer Valley. In: Proceedings of the 7th Australian Stream Management Conference. Townsville, QLD, Australia. pp 109-115

32. Lisenby PE, Fryirs KA. 2016. Sedimentologically Significant Tributaries: Characterizing Sediment Connectivity in the Lockyer Valley, SEQ. In: Vietz GJ, Flatley AJ, Rutherfurd ID. Proceedings of the 8th Australian Stream Management Conference. Leura, NSW, Australia. pp 435-443

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