Lockyer Catchment Action Plan 2015 – 2018

July 2016

Resilient Rivers Initiative

Council of Mayors South East Queensland

Healthy Waterways ONE CLEAR VISION

Unitywater

Queensland Government

QUEENSLAND UrbanUtilities

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Acknowledgements

The input of the late Mayor Steve Jones to the development of this Lockyer Catchment Action Plan is acknowledged. Mayor Jones was a strong advocate for the Lockyer Valley community and was a guiding force behind the Resilient Rivers Initiative, consistently stressing practical on-ground management solutions.

Lockyer Valley
REGIONAL COUNCIL

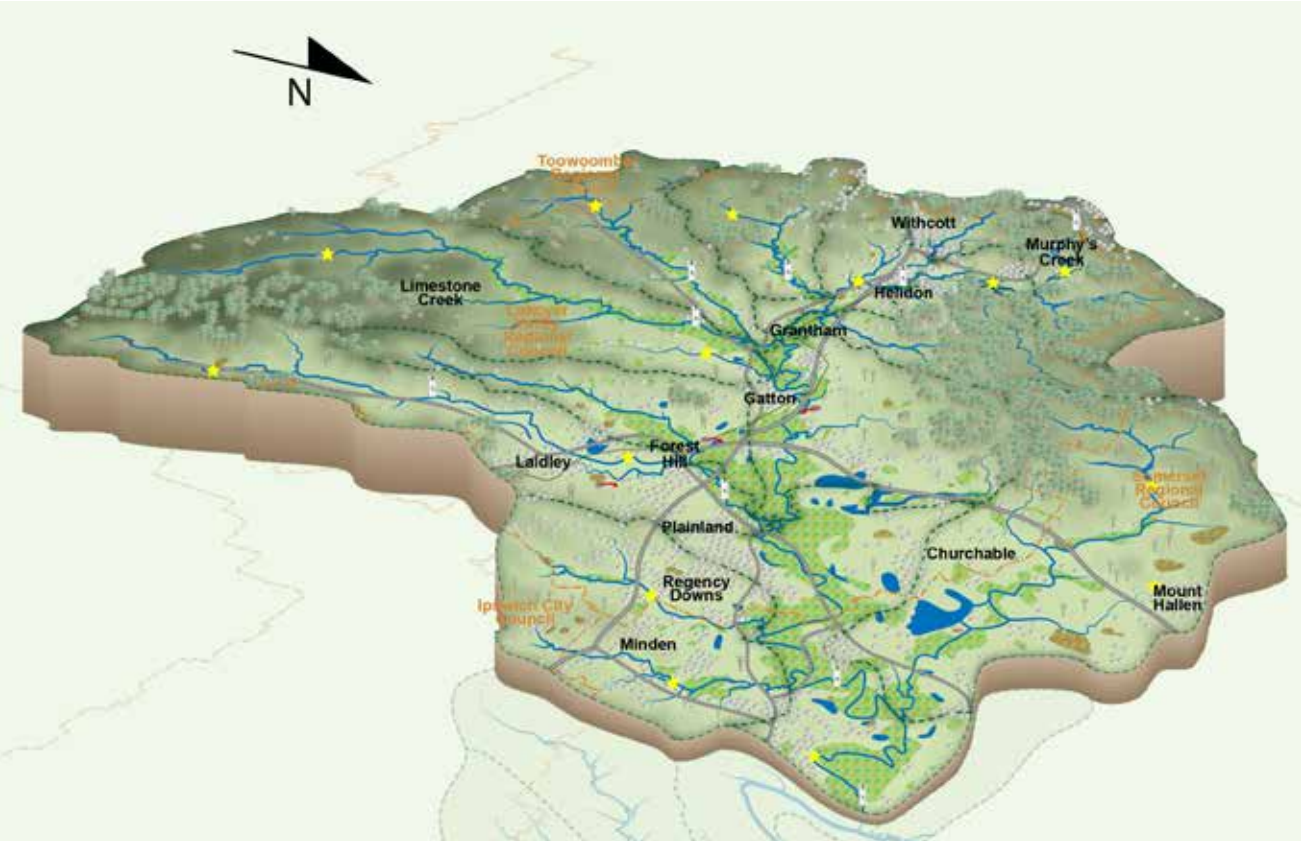
Executive Summary

The Resilient Rivers Initiative vision is: "By 2045, the catchments of South East Queensland will support a resilient, productive, liveable and growing region." This vision is documented in the Resilient Rivers Regional Strategy (2015-2025) which also has supporting goals and measures of success. The development of a Lockyer Catchment Action Plan has been identified as a priority area of work for this Strategy.

The primary focus of the Catchment Action Plan is addressing the very high risk of sediment movement from the catchment as identified in key State and Local Government and Seqwater investigations into the 2011 flood event and January 2013 weather event. The threat to the water supply of Brisbane arising from very high sediment loads in the Brisbane River in the 2013 event was identified as a matter of particular concern.

In addition to the impacts on the water supply of Brisbane, the loss of soil resources from the Lockyer Valley is a major concern in the context of the region producing 19 percent of Queensland's annual vegetable production and being a significant economic driver for the South East Queensland region with an annual production value of $260 million.

Keeping the soil on the land and out of the waterways will have benefits for the region's water supply with Mt Crosby Water Treatment Plant located downstream of the Lockyer catchment. The Brisbane River and Moreton Bay also will benefit from more effective catchment management in the Lockyer Valley.



Schematic of the Lockyer Creek catchment

A focus on agricultural water supply source protection is another important component of this Action Plan. Building the resilience of the groundwater irrigation sources requires attention to further protect and enhance the regionally significant Lockyer Valley horticultural industry. Actions include those which assist aquifer recharge through the protection of the recharge zones.

Recent devastating floods in the Valley have highlighted the importance of bridges, roads and railway lines for the Valley's economy as well as for a productive and healthy community.

The following table outlines the actions in the Lockyer Catchment Action Plan 2015-18 and the associated Measures of Success as identified in the Resilient Rivers Regional Strategy (2015 – 2025):

Lockyer Catchment On-Ground Actions	Regional-level Measures of Success
Targeted riparian management, including gully and creek bank stabilisation, with initial focus on Laidley, Sandy (Forest Hill), and Tenthill Creeks using an accepted and agreed reach and socio-economic methodology	Four on ground works completed Six industry best management practice projects implemented
Protect soil from damage where the hill-slope meets the floodplain	
Make use of The Big Flood Project outputs, strategically remove sediment slugs in main channel and some tributaries	
Improved grazing and horticultural practices via industry-led programs	
Coordinated fire, weed and vertebrate pest management so that soil is not exposed and riparian zones become stabilised	
Flood debris removal in strategic locations where causing bank erosion	
Tree planting program to manage salinity in Plain and Woolshed Creeks (recharge area) – link to Black Snake Creek in Mid-Brisbane catchment	
Infrastructure and community protection through soil stabilisation or re-siting of services and utilities	
Lockyer Catchment Policy Actions	**Measures of Success (to be determined as part of reporting framework)**
LVRC, ICC and SRC planning schemes recognise salinity issues in Lower Laidley, Sandy Creek, Tenthill, Plain and Woolshed Creeks	
Planning schemes / SEQ Regional Plan to recognise regionally significant groundwater recharge areas	
Resilience education for the local community	
Clarification of rights and responsibilities of landholders adjacent to creek reserves/riparian zones	
Coordinated assistance for small to medium landholders for riparian management in the tributaries	
Review of legislation to address potential site specific perverse outcomes (eg in stream vegetation removal where causing bank erosion; requirement to reinstate bank profile)	
Linking industry led best practice programs to leases and supply chain agreements	
Assess floodplain re-engagement management options (for soil deposition from channels)	
Western Corridor recycled treated water for catchment benefits (eg recharge) feasibility analysis (irrigation has been done)	
Undertake modelling of the Lockyer waterways, including individual creeks and confluences, to assist inform investments	
Investigate local/regional benefits and costs of flood mitigation in Laidley catchment (build on LVRC and State studies which assessed local and state benefits and costs respectively – not regional)	
Address knowledge gaps - sediment off hills, works costings and monitoring of effectiveness of works	

Contents

Warrego Highway, near Gatton, January 2013

About this action plan

Scope and purpose

The Lockyer Catchment Action Plan 2015 -18 has been prepared as part of the Resilient Rivers Initiative which has the following 30 year vision for the South East Queensland region:

"By 2045, the catchments of South East Queensland will support a resilient, productive, liveable and growing region."

This vision is documented in the Regional Strategy (2015–2025) which also has the following supporting goals:

- Keep soil on our land and out of our waterways to support agricultural productivity and improve water quality.
- Help protect our region's water security so it can support the current and future population of South East Queensland.
- Improve the climate resilience of our region.
- Promote partnerships with strong leadership to deliver a coordinated approach to catchment management in South East Queensland.

The priority for the Lockyer catchment is to address the very high risk of sediment movement from the catchment as identified in key State and Local government and Seqwater investigations into the 2011 flood and January (Australia Day) 2013 weather event.

This Catchment Action Plan:

1. Provides a commitment to enact change based on the "best of our knowledge and understanding" which reflects the values of the local community.
2. Identifies specific actions to mitigate risks in the catchment within the context of the Resilient Rivers Initiative.
3. Assists the preparation of a package of coordinated and consolidated investments based on agreed prioritised actions.

Location of the Lockyer Creek Catchment

Rationale for regional investment in the Lockyer catchment

The Lockyer catchment is a priority for the South East Queensland region under the Resilient Rivers Initiative due to its significant agricultural production value and its location upstream of the main water supply intake for the region. In addition, two pieces of regionally significant transport infrastructure traverse the catchment, the Warrego Highway and the railway line servicing Toowoomba and further west (the Darling Downs and mining areas).

The Lockyer catchment is an agricultural powerhouse for the region and Queensland with the highly fertile soils of the alluvial valley floor producing a range of vegetables worth over $260 million per annum. This equates to 19 percent of Queensland's annual vegetable production. The industry relies on irrigation mainly from groundwater. Floods and droughts impact on the groundwater supply and the integrity of the alluvial soil.

The 2011 and 2013 floods devastated the catchment and its community. The impact on infrastructure alone was extreme with greater than $12 million of repairs occurring in Tenthill Creek sub-catchment alone. Local infrastructure impacts caused significant disruption to the agricultural industry with flow-on effects to the regional economy.

Lockyer Creek enters the Brisbane River below Wivenhoe Dam and in high flow events it can impact downstream areas through flooding and siltation. Of significance is the potential impact on the Mt Crosby Weir and surrounding catchment, which is the main water supply intake for the region and provides drinking water for three million people in South East Queensland.

As the 2013 Australia Day weather event showed, the risk of siltation on the functioning of the water treatment plants, while of low frequency, is of potentially catastrophic consequences. Siltation caused the water treatment plants to shut down reducing the regional potable water supply availability to hours. As a general rule, any contaminants entering the 61km stretch of the Mid Brisbane River above the water treatment plants results in increased water treatment costs for the region's community and businesses. Taking action to reduce sediment movement from the Lockyer will also benefit downstream communities and users of Moreton Bay from the improved water quality within the Brisbane River.

The steep sided 'bowl shaped' catchment that is the Lockyer results from its unique underlying geology. This complexity provides particular challenges for on-ground resilience building actions. Traditional stream profiling for example, may not be effective in all reaches and consideration of infrastructure placement is part of the management options. A good understanding of how best to alleviate the impacts of climatic events and remediate the system will only be built through trial and error based on the best available knowledge of the underlying processes and management options. Into the future, a considered and concerted approach to maintaining knowledge and understanding of how the Lockyer catchment functions will have a significant benefit to the regional community.

Junction View, January 2013

Development of the Plan

The process for developing the Plan commenced in February 2015 and was overseen by a project team consisting of representatives from Lockyer Valley Regional Council (LVRC), Somerset Regional Council (SRC), Ipswich City Council (ICC), Brisbane City Council (BCC), Queensland Departments of Natural Resources and Mines, and Environment and Heritage Protection, Healthy Waterways Ltd, SEQ Catchments Ltd, Seqwater, Queensland Urban Utilities (QUU) and representatives of the Brisbane River Catchment Flood Study. The Resilient Rivers Taskforce reviewed aspects of the Plan as it proceeded. The Taskforce was supported by the executive level Catchment Action Plans Working Group which nominated the representatives for the project team. Council of Mayors (SEQ) provided the coordination and project management capacity on behalf of the project team. The Queensland Government's Wetlands Program provided invaluable data and conducted Step 1 to consolidate the current understanding of the catchment processes occurring at the landscape scale. A number of supporting factual publications have been prepared and are available on the Wetlands Program website.

Consultancies engaged were:

- Alluvium Consulting prepared a detailed Catchment Descriptions and Issues Report (Step 2) which included a stream type assessment for the major streams based on the RiverStyles® Framework. Desktop based assessments of RiverStyles® were undertaken using aerial imagery and available GIS spatial data, such as waterways, topography and infrastructure. Data from site inspections was used to supplement and refine the desktop assessments.
- ClimateRisk assisted the project team with the development of the catchment risk register (Step 3) using methodology developed for the region's water entities.
- Natural Decisions assisted the project team to conduct a cost benefit analysis based on the Investment Framework for Environmental Resources (INFFER) methodology. This analysis assisted with determining the priority actions within this Action Plan.
- Water Technology undertook a ground-truthed options assessment of Murphy's Creek and Tenthill Creek, to assist with prioritisation of short to medium term works within the Murphy's Creek and Tenthill Creek catchments. The geomorphic assessment, undertaken using a modified RiverStyles® framework technique which built on previous work, identified priorities for management from a geomorphic and river health perspective, to be used along with other prioritisation matrices to prioritise waterway works within each catchment.

A five step process was undertaken to develop the CAP:

Step 1: **Walking the Landscape** – gather information on the geology and hydrology of the catchment in a workshop setting

Step 2: **Catchment description and issues** – compile detailed data and prepare mapping products and a comprehensive analysis report; collate data gaps; community engagement

Step 3: **Risks, targets and preliminary actions** – identify key catchment issues and preferred management responses

Step 4: **Prioritisation of actions** – investigate the initial feasibility of actions and likelihood of success

Step 5: **Publishing** – finalise the action plan document and seek endorsement from collaborators

Prioritisation (Step 4) also involved consideration of key actions from previous planning and studies, feedback from community based knowledge experts involved in this Plan's development, and input from the catchment's political leadership.

Community engagement for this Catchment Action Plan was conducted by LVRC. The Catchment Action Plan has been endorsed by the relevant councils.

The following organisations provided funding towards the preparation of the Plan and assisted with the provision of venues for project team activities:

LVRC, SRC, BCC, Seqwater, QUU, Council of Mayors (SEQ), and the Australian Government Department of Environment (through SEQ Catchments Ltd).

A special thank you to the involvement of the community based knowledge experts at various points throughout the development of the Plan.

The catchment in context

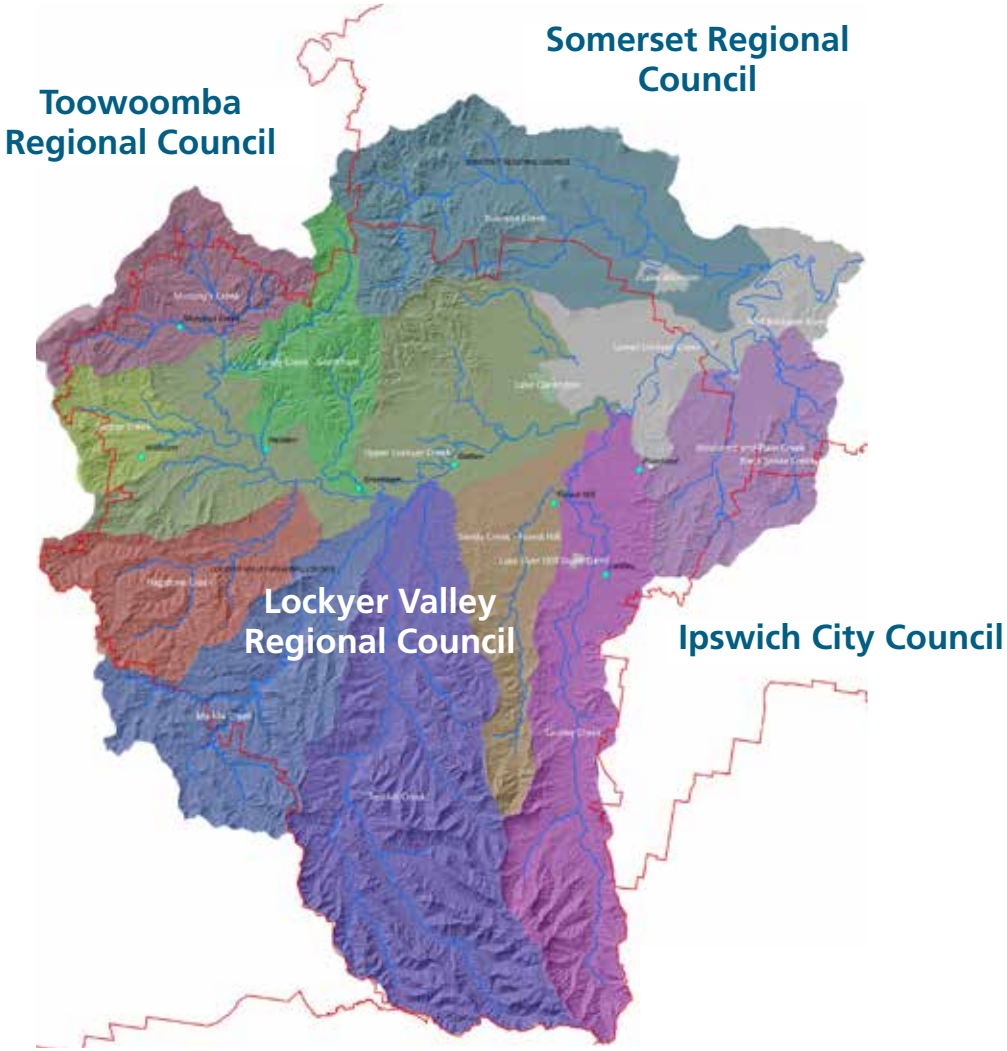
The Lockyer catchment

The base information for the Action Plan is drawn mainly from the comprehensive Lockyer – Description and Issues Report (Alluvium 2015) and is the primary reference source. Additional sources of information are referenced.

The Lockyer Creek catchment is located approximately 55 km west of Brisbane in South East Queensland and is a major tributary of the Brisbane River. It is predominantly located within the LVRC Local Government Area (LGA), with some sections within the Toowoomba Regional Council, SRC and ICC LGAs.

Lockyer Creek rises on the eastern slopes of the Great Dividing Range and flows in an easterly direction before joining the Brisbane River just below Wivenhoe Dam. The Creek and its tributaries form a bowl shaped catchment, with an area of approximately 3,000 km^2. Elevations range from up to 1100 m AHD on the Great Dividing Range to 24 m AHD on the broad alluvial plains at the confluence with the Brisbane River. For the purposes of this Action Plan, 12 sub-catchments have been defined and are described in more detail on the following pages.

Stream types throughout the catchment are highly variable, the upper catchment being bedrock confined, with narrow valleys following fault lines. Soils in the Lower Lockyer are alluvial with the main Lockyer Creek considered a 'macrochannel'. This is a deeply entrenched channel bounded by steep and resistant terraced banks which accommodates infrequent high magnitude floods and shows considerable structural resilience. However erosion of the bank can occur and structures within this zone are vulnerable. A rare extreme flood which overtops the banks can result in high velocity floodplain flow which may cause loss of farmland or the depositing of in-stream sediment on the floodplain. Lower flow events mobilise sediment in the creek which is then re-deposited further downstream.

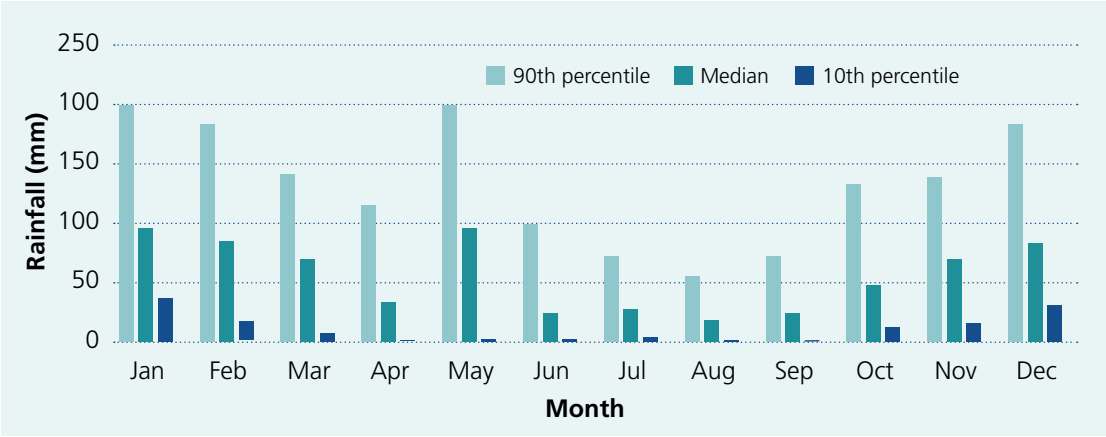


Council boundaries and sub-catchments of the Lockyer catchment

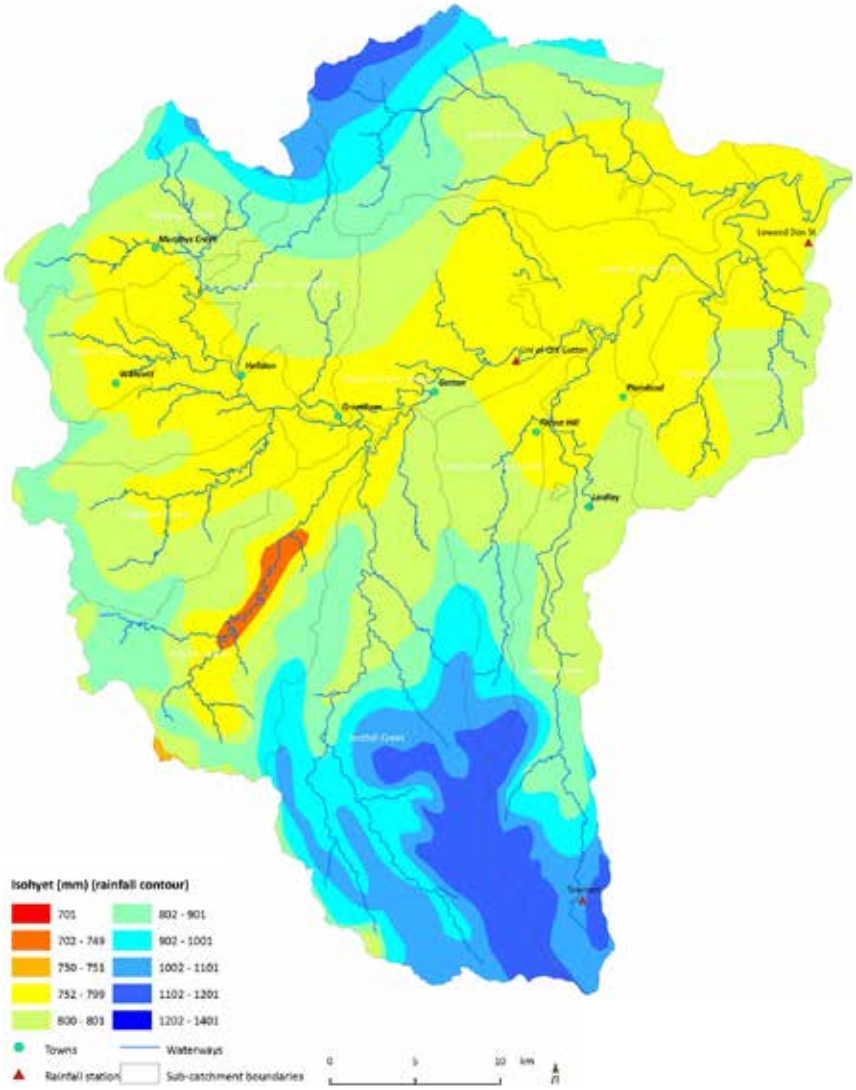
Climate

The Lockyer catchment is characterised by summer dominated rainfall with large inter and intra-annual variability. An old saying in the Laidley catchment confirms the variability: 'there isn't a month in the year that Laidley Creek hasn't broken its banks'. Rainfall also varies throughout the catchment, with high annual rainfall totals in the highlands (the upper Tenthill, Laidley and Buaraba sub-catchments) and relatively low annual rainfall in the lower catchment, such as the alluvial plains.

Inter-annual variability is strongly influenced by the El Niño-Southern Oscillation. The catchment experiences extreme climatic events such long-term droughts, very intense rainfall, flooding and flash flooding. The Millennium drought (2002-2009) saw six out of seven years recording below mean and median annual rainfall totals. This was followed by very intense rainfall, flooding and flash flooding during the December 2010, January 2011 and January 2013 flood events. Autumn and winter flood events related to East Coast Low weather systems can occur.



Rainfall data from University of Queensland Gatton gauge (40082) showing the variability in monthly rainfall within the Lockyer catchment (calculated using rainfall totals between 1899 and 2014)



The average distribution of rainfall within the Lockyer Catchment (50 year mean annual rainfall 1920 – 1969)

Sub-catchment descriptions

Laidley Creek

Key characteristics:

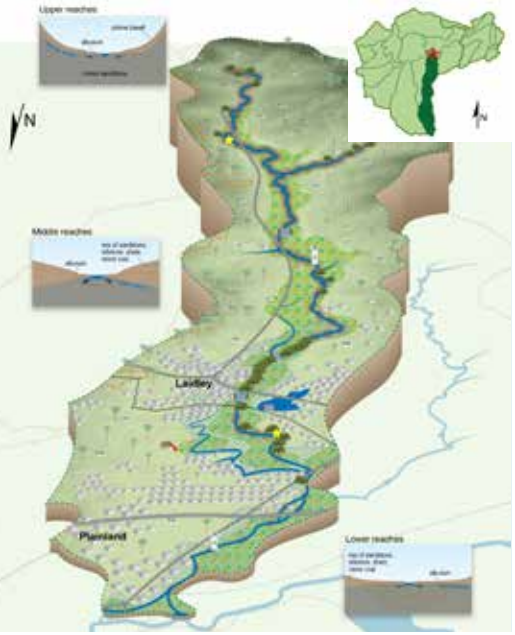
- Steep hillslopes with remnant vegetation
- High energy flows
- Channel adjustment
- Secondary channel activation
- Sediment transfer
- High quality agricultural land
- Grazing native vegetation
- Variable riparian vegetation
- Assets affected by flooding
- Dispersive soils
- Erosion and landslips
- Downstream surface salinity

The magnitude of flows in Laidley Creek are highly variable both during the year and between years and can result in catastrophic flooding such as in 2011 and 2013.

Upstream of Mulgowie Weir, Laidley Creek experienced major erosion during the 2011 and 2013 floods. The erosion resulted in loss of agricultural land as stream banks were washed away and floodplain soil lost. The unstable nature of the creek in this reach will continue to threaten high value horticultural land adjacent to the creek. Downstream of Mulgowie Weir significant flooding has occurred in the past and is likely to occur again in the future. The majority of the horticultural land and parts of Laidley town are within the flood risk zone.

The stream bank erosion is a major cause of high turbidity levels within the creek. Laidley Creek has been identified as a significant source of turbidity and nutrients to Lockyer Creek and subsequently the Brisbane River. Additionally, agricultural runoff, the Laidley Sewage Treatment Plant and on-site systems (such as septic tanks) may contribute to water quality issues within the creek.

Laidley Creek sub-catchment schematic >



Sandy Creek (Forest Hill)

Key characteristics:

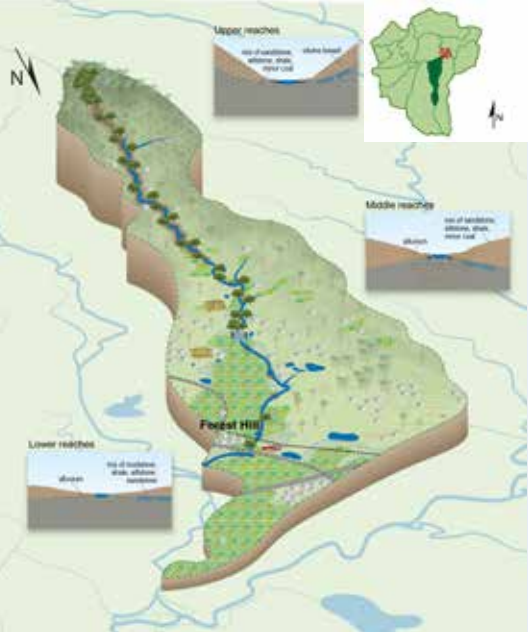
- Undulating hills partly cleared
- Minor to moderate channel instabilities
- Highly connected floodplain
- Groundwater salinity
- Grazing pastures
- High quality agricultural land
- Levees
- Surface salinity
- Dispersive soils
- Erosion and landslips
- Variable riparian vegetation
- Urban growth area

Flooding is a major issue within the sub-catchment particularly downstream of the Sandy Creek Recharge Weir with the floodplain often inundated, including the town of Forest Hill. Low flows are regulated by the Sandy Creek Recharge Weir, however the weir has limited impact upon higher flows.

Moderate instabilities have been identified in the upper reaches and woody riparian vegetation extent is variable. Ongoing channel erosion may contribute to high sediment loads exported from the sub-catchment. Within the lower reaches the channel is generally stable. Historical channel realignment and levee construction has occurred.

Groundwater levels in the sub-catchment are highly dependent on climate, streamflow and extractions. Water levels are rapidly recharged during wet periods (with assistance from the recharge weir), however high water levels are not maintained for long periods. High salinity levels are present in the groundwater, particularly bores overlaying Gatton Sandstone geology.

Sandy Creek (Forest Hill) sub-catchment schematic >



Tenthill Creek

Key characteristics:

- Steep hillslopes and valleys
- High energy flows
- Major channel instabilities
- High quality agricultural land
- Grazing native vegetation
- Residual flood damage
- Sediment transfer
- Dispersive soils
- Erosion and landslips
- Limited riparian vegetation
- Low floodplain resistance
- Infrastructure in creeks
- Main Range National Park

Tenthill Creek and its tributaries flow intermittently with baseflow provided by groundwater sources. Low flows within the sub-catchment are regulated by the presence of two weirs. The weirs have limited impacts on high flows and the catchment experienced significant flooding in 2011 and 2013.

Major instabilities have been identified within the majority of creeks in the sub-catchment. Major floodplain and stream bank erosion and channel adjustment occurred during the January 2011 and 2013 flood events. The erosion resulted in the loss of agricultural land as stream banks and floodplains were washed away. The unstable nature of the creek and limited riparian vegetation will continue to threaten the high value horticultural land adjacent to the creek and export sediment downstream.

Surface water and groundwater salinity is typically low to moderate except in bores adjacent to Wonga Creek and Deep Gully Creek, where salinity levels are extreme.

Tenthill Creek sub-catchment schematic >

Ma Ma Creek

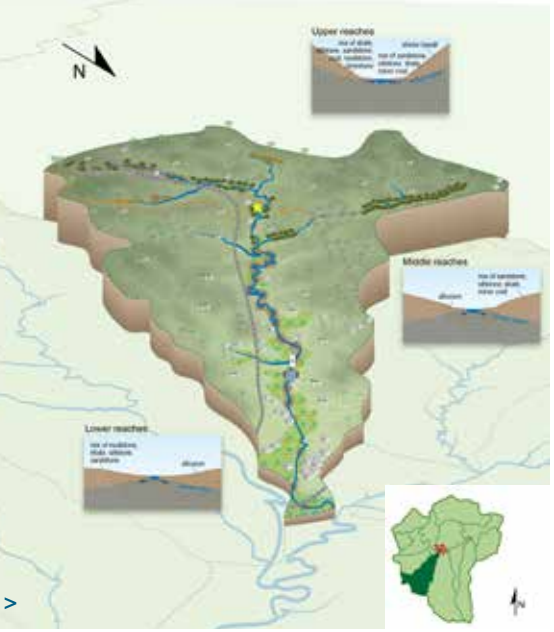
Key characteristics:

- Steep hillslopes and valleys
- High energy flows
- Minor to moderate channel instabilities
- Grazing native vegetation
- Groundwater salinity
- Limited riparian vegetation
- Shallow stony soils and hardsetting duplex soils
- Reduced infiltration
- Erosion and landslips
- Downstream surface salinity

Surface water experiences high salinity, which is likely related to the underlying sandstone geology. Above the Ma Ma Creek Weir flood extents are confined to a narrow band adjacent to the creek, below the weir the flood extent widens across the floodplain and flows merge with those from Tenthill Creek. Low flows within Ma Ma Creek are impacted by the weir, however the weir has minimal effect during higher flows.

The upper reaches of Ma Ma Creek are confined by the valley margins and are stable. The upper reaches of Silky Oak Creek experience bank instabilities, during recent floods significant erosion occurred in these reaches. Below the confluence of Ma Ma and Silky Oak Creeks the creek is relatively stable, with minor instabilities identified, however riparian vegetation extent is low, which may contribute to minor ongoing instabilities. Fine grained sediments mobilised within the channel can be deposited behind the weir, resulting in a build-up of sediment. This build up reduces the potential of the weir to recharge groundwater due to a reduction in the permeability of the channel.

Ma Ma Creek sub-catchment schematic >



Flagstone Creek

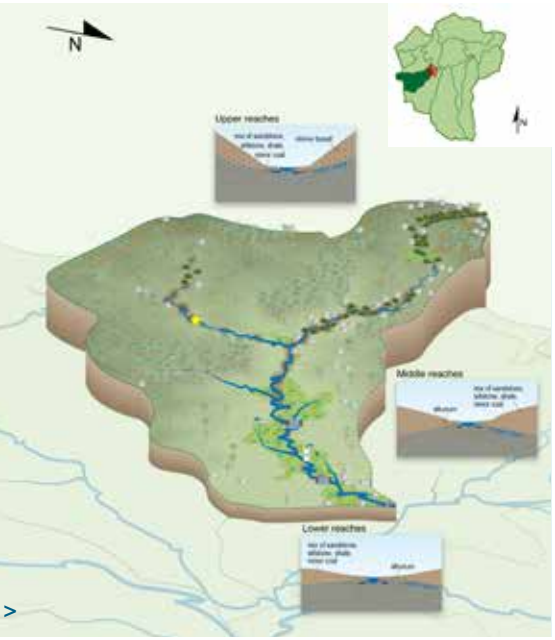
Key characteristics:

- Steep hillslopes and valleys
- High energy flows
- Minor to moderate channel instabilities
- Grazing native vegetation
- Groundwater salinity
- Limited riparian vegetation
- Shallow stony soils and hardsetting duplex soils
- Reduced infiltration
- Erosion and landslips
- Downstream surface salinity

Flagstone Creek's bed and banks are relatively stable, often flowing adjacent to hard, erosion resistant terraces. However, in some locations, particularly in the lower sub-catchment, the creek flows through erodible floodplains with poor riparian vegetation coverage. This may increase rates of stream bank erosion and threaten the high value horticultural land adjacent to the creek as well as increase sediment loads in Flagstone and Lockyer Creeks.

Flooding can be as a result of high flows within the sub-catchment and also backwater flooding from Lockyer Creek.

Salinity within the creek is slightly elevated above the water quality objectives, however is suitable for irrigation of moderately sensitive crops.



Flagstone Creek sub-catchment schematic >

Gatton Creek

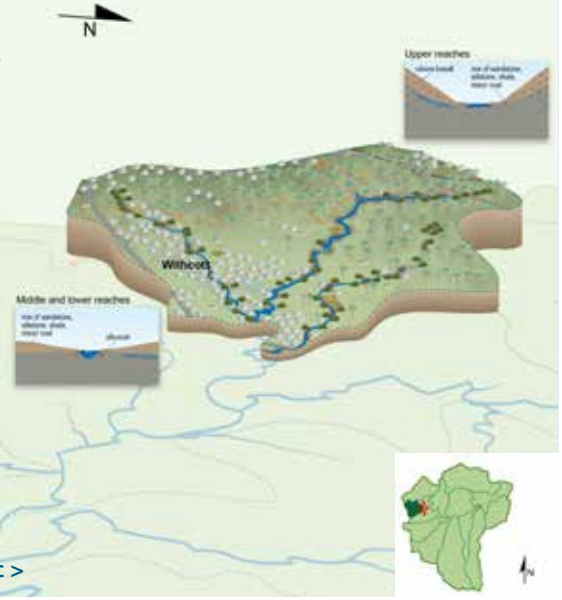
Key characteristics:

- Steep slopes with remnant vegetation
- Minor to moderate channel instabilities
- Channel adjustment
- Gullying and landslips
- Grazing native vegetation
- Urban growth area
- Toowoomba Second Range Crossing construction
- Assets affected by flooding
- Variable riparian vegetation
- Sediment and debris transfer
- Shallow aquifer

The majority of Gatton Creek and Six Mile Creek contain minor instabilities, whilst the majority of Rocky Creek contains moderate instabilities. Within the reach with moderate instabilities the coverage of woody riparian vegetation is low. During recent flood events significant channel erosion occurred, which resulted in stripping of vegetation and sediment from the channel and floodplain and subsequent delivery of material to downstream reaches and Lockyer Creek.

The steep nature of the sub-catchment results in a 'flashy' flooding where the levels in the creek rise and fall quickly.

In the lower reaches, in and around Withcott, flooding occurred in the recent flood events. The flood risk is constrained to a narrow zone within the floodplain, however private and public infrastructure is located within this zone.



Gatton Creek sub-catchment schematic >

Murphy's Creek

Key characteristics:

- Steep slopes and valleys with remnant vegetation
- High energy flows
- Moderate to high riparian vegetation
- Minor channel instabilities
- Grazing native vegetation
- Erosion and landslips
- Channel erosion to bedrock
- Debris transfer
- Hardsetting duplex soils with sandy surface, dispersive clay subsurface and gravel layers
- Lockyer National Park

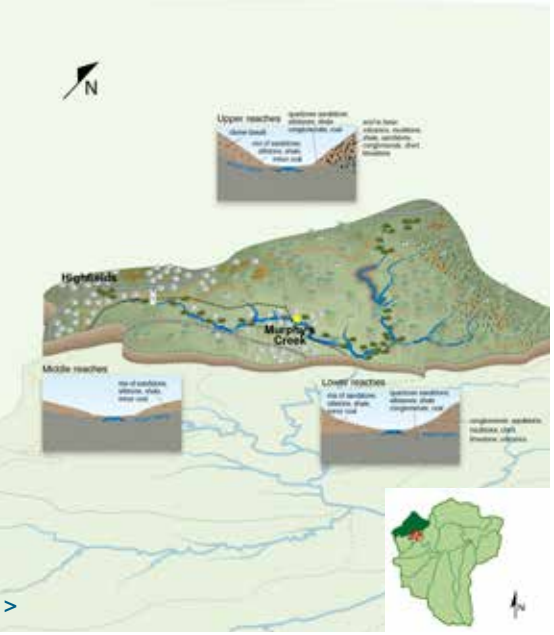
Murphy's Creek is relatively stable. During the recent floods there was minimal lateral movement, however significant stripping of vegetation and sediment occurred within the channel. Fifteen Mile Creek is predominantly stable, with the exception of the middle reaches, where severe bank erosion occurred during recent flooding.

The steep nature of the sub-catchment results in 'flashy' flooding where the levels in the creek rise and fall quickly.

Given the relatively limited extent of floodplain development, alluvial aquifers are likely to be relatively shallow and responsive to climate conditions. Groundwater and surface water salinity levels are typically low. Additionally, agricultural runoff and on-site systems (such as septic tanks) may contribute to water quality issues within the creek.

The Helidon Hills within the sub-catchment have been identified as a significant recharge area for the alluvial aquifers of the upper Lockyer Valley and are recognised as areas of very high nature conservation significance. Lockyer National Park forms part of this area.

Murphy's Creek sub-catchment schematic >



Sandy Creek (Grantham)

Key characteristics:

- Steep slopes and valleys with remnant vegetation
- High energy flows
- High riparian vegetation
- Minor channel instabilities, except in riverine mining areas
- Grazing native vegetation
- Shallow soils over parent rock
- Sandstone extraction
- Lockyer National Park
- Flooding from Lockyer Creek backflow

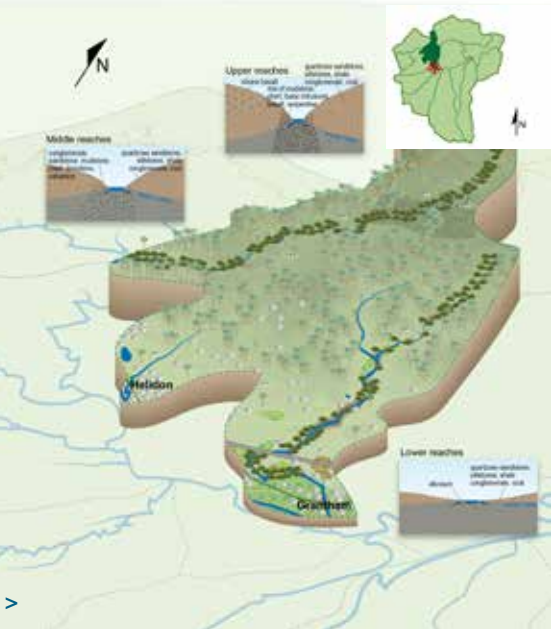
Due to the steep nature of Alice and Sandy Creeks, the flows in the creeks are fast, flashy and generate high stream powers. For example, during the January 2011 floods the flows were sufficient to completely strip vegetation and mobilise cobbles and boulders. Despite this the streams are stable for the majority of the length due to the bedrock upon which they sit. Where Sandy Creek flows through the floodplain there are some sections where the stream contains major instabilities and may be prone to erosion in future flood events.

Floods within the catchment are predominantly due to flooding in Lockyer Creek, from both water backing up the creek and also water breaking the banks of Lockyer Creek and flowing across the floodplain.

Water quality within the creeks is typically good, with low salinity levels and most likely low turbidity levels on account of the well vegetation sub-catchment.

The Helidon Hills within the sub-catchment have been identified as a significant recharge area for the alluvial aquifers of the upper Lockyer Valley and are recognised as areas of very high nature conservation significance. Lockyer National Park forms part of this area.

Sandy Creek (Grantham) sub-catchment schematic >



Upper Lockyer Creek

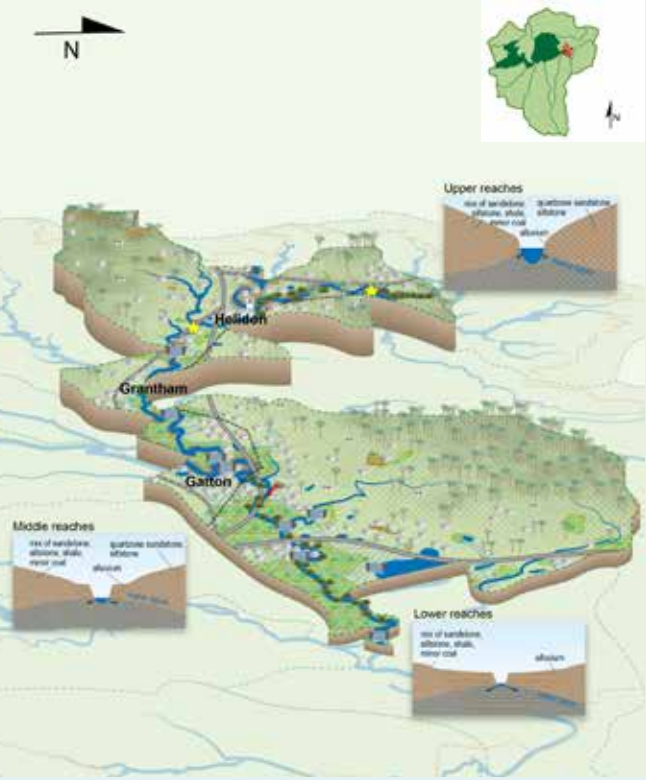
Key characteristics:

- Six major sub-catchments
- Stream flow regulated by weirs
- Macrochannel with levees
- Minor channel instabilities
- Expansion and contraction reaches
- High energy stream
- High velocity breakouts
- Floodplain erosion and accretion
- Low channel and floodplain resistance
- Low to moderate riparian and in-stream vegetation
- Channel erosion via mass failures
- Extensive alluvial flats
- High quality agricultural land
- Grazing native vegetation
- Gullying and landslips
- Assets affected by flooding
- Upper catchment salt affected
- Urban growth area
- Toowoomba Second Range Crossing construction
- Lockyer National Park

Low flows within Upper Lockyer Creek are impacted by the presence of a series of groundwater recharge weirs however these have limited impact upon flood events.

Significant flooding occurred within the Upper Lockyer catchment during the 2011 flood event leading to widespread damage and destruction. Lockyer Creek has a deep and narrow channel. In some areas floodwaters are contained within the creek, however where the creek narrows significant floodplain flows occur, leading to both floodplain scour/erosion in some areas and sediment deposition in other areas.

The banks of upper Lockyer Creek are relatively stable and are unlikely to experience major erosion and bank retreat. However, within the channel a lack of in-stream vegetation means that significant sediment deposits are constantly mobilised and deposited, contributing to high sediment loads within the creek. Additionally, agricultural runoff, the Gatton and Helidon Sewage Treatment Plants and on-site systems (such as septic tanks) may contribute to water quality issues within the creek.



Upper Lockyer Creek sub-catchment schematic >

Buaraba Creek

Key characteristics:

- Steep slopes partly cleared
- Hills and flats mostly cleared
- Minor to moderate channel instabilities
- Laterally active gravel/ cobble bed stream
- Channel widening
- Low channel and floodplain resistance
- Low to moderate riparian vegetation
- Grazing and animal farming
- Instream sand and gravel extraction
- Dispersive soils
- Erosion
- Sediment and debris transfer
- National Parks

Low flows in Buaraba Creek are regulated by the presence of the Buaraba Creek Regulator Weir, which diverts streamflow to Atkinson Dam, which is part of the Lower Lockyer irrigation system. Flooding occurs within the lower sub-catchment inundating the floodplain.

Moderate instabilities have been identified within Buaraba Creek. Significant stream bed and bank erosion occurred during the January 2011 and January 2013 flood events, particularly in the vicinity of sand and gravel extraction operations. Ongoing channel erosion may contribute to high sediment loads exported from the sub-catchment and threaten agricultural land.

Groundwater and surface water salinity levels are low as the aquifers of the Woogaroo Subgroup are predominantly very low in salts. Surface water quality is likely to be impacted by diffuse agricultural pollutants and a high number of on-site sewerage systems.

Buaraba Creek sub-catchment schematic >

Woolshed and Plain Creeks

Key characteristics:

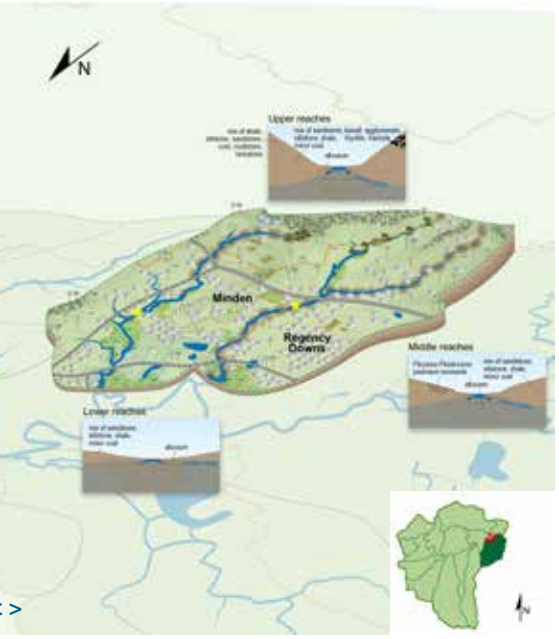
- Cleared for grazing
- Shallow poorly drained alluvium
- Minor to moderate channel instabilities
- Highly connected floodplain
- Low riparian vegetation
- Unconfined creeks
- Acid sulphate soils
- High salinity in creeks, groundwater and soil
- Sodic and dispersive soils
- High siltation of creeks
- Severe erosion
- Assets affected by salinity and flooding

Flooding occurs within the Woolshed and Plain Creeks sub-catchment, however it is generally within the lower sub-catchment, which is sparsely populated and predominantly used for grazing.

The waterways are typically unconfined by valley margins and historically were most likely swampy discontinuous watercourses. These waterways have been extensively modified with works including channelisation and in-stream impoundments. These works have instigated channel instabilities in the upper reaches of Woolshed and Plain Creeks.

Salinity levels in groundwater are high to extreme, predominantly due to the underlying sandstone geology. The high salinity of the groundwater also contributes to very high salinity in the waterways, particularly Plain Creek. As a result there are a relatively high number of farm dams within the sub-catchment.

The relatively high number of rural residential lots and hence on-site sewerage systems may be contributing pollutants to the waterways.



Woolshed and Plain Creeks sub-catchment schematic >

Lower Lockyer Creek

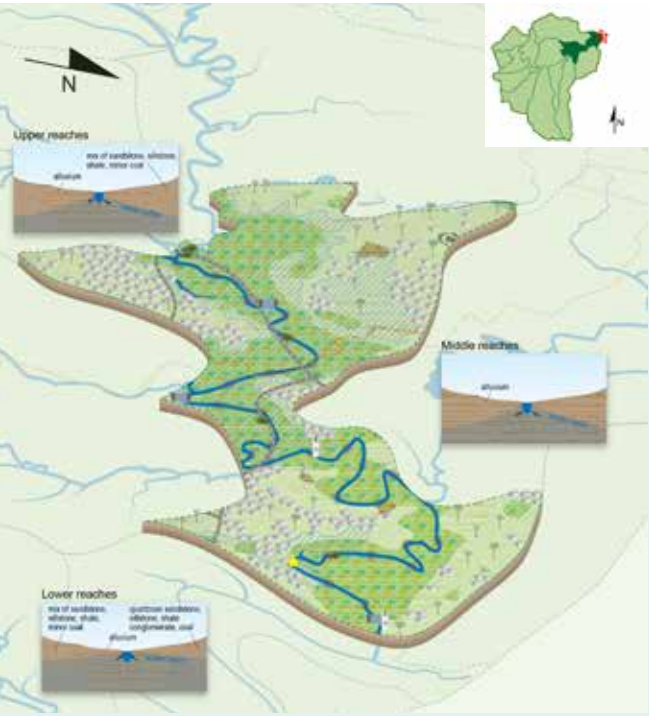
Key characteristics:

- Three major sub-catchments
- Stream flow regulated by weirs
- Large capacity macrochannel with levees
- Extensive terrace and floodplain deposits 1.5-7 km wide
- Net sediment deposition zone in large floods (ie floodplain deposition exceeds floodplain stripping)
- In-channel erosion via wet flow mass failures in large floods
- Channel breakout at constriction below Gatton
- Sediment export in moderate flows (ie less than bank full) due to increased stream power
- Cleared for irrigated horticulture
- High quality agricultural land
- Minor channel instabilities
- Low riparian and in-stream vegetation
- High energy stream
- Low channel and floodplain resistance
- Grazing and animal farming
- Salinity issues adjacent to Woolshed Creek catchment
- Assets affected by flooding

Flows within the Lower Lockyer Creek are predominantly determined by inflow from upper Lockyer Creek. The lower reaches are also impacted by backwater from the Brisbane River when it is in flood.

A network of weirs has been constructed to assist in the storage of creek water and recharge to the adjacent groundwater aquifers. Backwater effects of each weir extend almost if not entirely to the next weir upstream, benefitting most areas of the Lower Lockyer valley plains.

The Lower Lockyer Creek channel is relatively stable and unlikely to experience bank retreat and lateral adjustment. However, within the channel a lack of in-stream vegetation means that significant erosion of deposits within the channel which are constantly mobilised and deposited, contributing to high sediment loads within the creek.



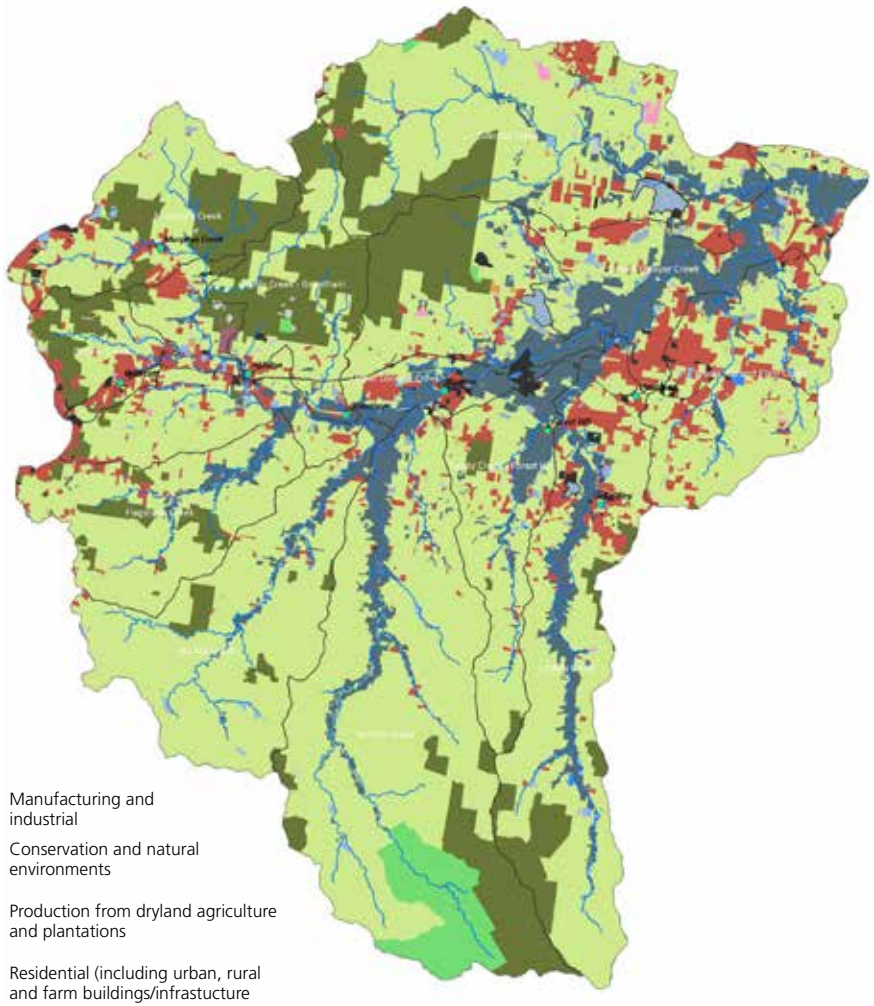
Lower Lockyer Creek sub-catchment schematic >

Land use and infrastructure

Land uses within the catchment are dominated by agriculture. The Lockyer Valley features some of the most valued and diversified agricultural land in Australia, supported by highly fertile soils on the valley floor. The alluvial valley floor adjacent to Lockyer Creek and its southern tributaries has been predominantly cleared for agricultural purposes. This area covers approximately 9 percent of the catchment and is used primarily for irrigated horticulture with an annual value of $260 million.

The largest land use (63 percent) within the catchment is "grazing native vegetation", which is classified by Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) as areas where there has been limited or no deliberate attempt at pasture modification and typically occurs in open woodland or grasslands where greater than 50 percent of the dominant species are native. The annual value of "slaughtered cattle and calves" in the catchment is $9.4 million. Approximately 13 percent of the catchment is classified as "conservation and natural environments".

Residential land uses cover approximately 8 percent of the catchment. The largest majority of residential land uses is rural living, which encompasses properties that are rural residential in nature, are generally greater than 0.2 ha that undertake some agricultural activities however this is unlikely to be the major source of income for the property. There are two small residential areas within the catchment located near the towns of Gatton and Plainland which have been identified as Growth Areas in the 2009-31 South East Queensland Regional Plan. The councils' Planning Schemes guide specific land use in the catchment.



Land use within the catchment (2012)

The location of key infrastructure in the Lockyer catchment is shown in the following table. There is a high concentration of culverts, bridges, roads and weirs in the lower catchment, along the alluvial plains and near the towns. The nationally significant Warrego Highway traverses the catchment in an east-west direction, crossing many waterways including the main Lockyer Creek several times. The Warrego Highway is the state's vital east-west freight artery that transports people and freight from western and southern Queensland, New South Wales and the Northern Territory. The Western Rail Line also traverses the catchment.

Key infrastructure locations within the Lockyer catchment

Sub-catchment	Culverts	Bridges	Weirs	Dams	Roads (km)
Laidley Creek	459	6	3	1	440
Sandy Creek (Forest Hill)	279	1	1	0	249
Tenthill Creek	247	5	2	0	556
Ma Ma Creek	86	0	1	0	304
Flagstone Creek	145	3	2	0	226
Gatton Creek	79	3	0	0	155
Murphy's Creek	64	2	0	0	256
Sandy Creek (Grantham)	45	1	0	0	266
Upper Lockyer Creek	432	13	7	0	785
Buaraba Creek	227	6	1	1	429
Woolshed and Plain Creek	559	4	0	0	350
Lower Lockyer Creek	321	5	3	1	285

Infrastructure in the catchment is highly vulnerable to damage from natural disasters as shown during the January 2011 and January 2013 flood events. This in turn has severe social and economic impacts. During the 2011 event, 40 of the Lockyer Valley's 48 bridges were damaged. In addition to bridge damage:

- Significant damage to the railway tracks resulted in the shutdown of the rail line for several months disrupting the movement of Queensland coal to the Port of Brisbane
- Damage to the Warrego Highway, in particular below Toowoomba, caused major disruption to the freight transport industry, affecting western Queensland and produce movement from the Lockyer Valley
- 1,080km or 77 percent of LVRC road infrastructure was damaged
- 174 (of 2,500) culverts required major repair or replacement within the LVRC LGA
- Community infrastructure damage included halls and parks and recreation facilities.

Population within the catchment is expected to increase by approximately 30,000 people by 2031. As population increases, infrastructure requirements, such as roads and drains also increase. The following table outlines the projected increase in the sewered population, which will require an increase in sewerage drainage and water treatment facility upgrades. Additionally, increases in population will place more pressure on existing infrastructure such as the Warrego Highway, which is already over capacity.

Queensland Urban Utilities sewered population growth forecasts

Region	LVRC – Sewered Population Projections			
STP Name	**Forest Hill**	**Gatton**	**Helidon Region**	**Laidley – Plainland**
Current estimated population	667	6,219	310	3,048
Projected 2031 estimated population	500	21,400	2,200	13.000
Scaled Increase	0.75	3.44	7.11	4.27
Percentage Decrease/Increase	**-75%**	**+344%**	**+711%**	**+427%**

Seqwater maintains a network of weirs in the catchment to assist in the storage of creek water and subsequent recharge to the adjacent groundwater aquifers. These are described in further detail in the preceding section (Sub-catchment descriptions).

Policy and management context

The organisations with a primary policy and management interest in the Lockyer Catchment include four councils (Lockyer, Somerset, Ipswich and Toowoomba), the Queensland Government, Queensland Urban Utilities, and Seqwater. The majority of land is in private ownership and so the interests of land managers are an important consideration within the management context.

Councils

As previously outlined, the councils have a role in land use planning. They also invest in local infrastructure asset management and recreational area management. Councils have some devolved responsibilities such as local laws relating to on-site sewerage facilities. Councils have an interest in protecting the community and economy of the valley, which includes improving resilience in public and private property, assets and infrastructure.

Queensland Government

The Department of Environment and Heritage Protection (EHP) has involvement in regulatory, policy and catchment management roles. EHP regulates Environmentally Relevant Activities, such as STPs and sand and gravel extraction under the Environmental Protection Act 1994.

At a policy level, EHP sets Water Quality Objectives (WQO) and Environmental Values (EVs) under the Environmental Planning Policy 2009 (EPP) to ensure the water is usable for the purposes defined in the EVs

(eg drinking water, stock water, irrigation, recreation, aquatic ecosystems).

The EPP also establishes requirements for consultation with key stakeholders in deriving the WQO. EHP's catchment management interest focuses on reducing the source of pollutants entering waterways through research, capacity building, policy development, on-ground investments and industry partnerships for improving land management.

The Department of Natural Resources and Mine's role is to regulate instream work to maintain the physical integrity of the watercourses and manage the take of water for irrigation and other purposes. It works closely with Seqwater which holds a Resource Operations Licence for water storages.

The Department of Transport and Main Roads has a key role in the design, construction and maintenance of key roads and associated infrastructure including the Warrego Highway and the Toowoomba Range crossings.

Queensland Urban Utilities (QUU)

QUU operates under the South-East Queensland Water (Distribution and Retail Restructuring) Act 2009, Water Supply (Safety and Reliability) Act 2008, Environmental Protection Act 1994, and the Water EPP 2009. These prescribe standards for the operation of wastewater systems including licensed discharge criteria for protection of waterway environmental values.

More recently, QUU has been investigating the State's 2014 "Flexible options for managing point source water emissions: A voluntary market-based mechanism for nutrient management" Policy. This Policy is a mechanism for protecting downstream water quality (for example, receiving water quality at a STP discharge) by mitigating upstream rural diffuse pollution sources. In a practical sense for QUU, this means targeting investments to mitigate significant sediment pollution sources (containing relatively low levels of nutrients).

Seqwater

Seqwater is the bulk water authority for South East Queensland and works collaboratively with stakeholders, customers and community to deliver safe, secure and cost-effective water and catchment services to more than three million people. On behalf of the community, the organisation manages water supply assets including dams, weirs, water treatment plants, reservoir, pumps and pipelines as well as climate resilient water sources.

In 2015, Seqwater completed their first Water Security Program – starting the development of a 30 year plan to meet SEQ's water supply needs. Seqwater adheres to the Australian Drinking Water Guidelines 2011.

The guidelines contain six principles which highlight the importance of understanding the nature of the source water, the risks and hazards involved in sourcing water from catchments, and how to manage these issues and mitigate risks.

Seqwater owns and operates a number of water storages and weirs in the Lockyer Catchment which supply water to the Central Lockyer irrigation scheme, supporting local producers. The water storages include Lake Atkinson, Lake Clarendon and Lake Dyer (Bill Gunn Dam), which provide various forms of recreational opportunities for visitors.

Private landowners

A landowner will have lifestyle and/or business goals as well as land and water use rights and responsibilities to consider. Goals and circumstances may change over time.

Extension services

Extension service providers influence and facilitate the management of land and water within the catchment. Some examples of such service providers are the Queensland Department of Agriculture and Fisheries, Agforce, Growcom, SEQ Catchments Ltd, Healthy Waterways Ltd, and agricultural service businesses.

Issues analysis

Based on the information gathered through the development of this Action Plan the following high level issues have been identified:

Asset/value	Threat or pressure	Impacts on: Infrastructure	Environment	Finances and people
• High agricultural value alluvial soils	• Increased stream power from land clearing, residual flood damage, levees etc • Disturbance of banks and reduction in riparian vegetation of the Lockyer Creek macrochannel and major tributaries • Erosion and landslips	• Loss of agricultural infrastructure (eg pumping equipment, sheds, fences etc) in the riparian zone	• Vegetation and soil stripping • Loss of high value agricultural land through erosion • Reduction in the physical stability of waterways resulting in bank collapse and/or scouring • Change in flood behaviour and distribution of flood flows • Waterholes filled in with silt and gravel, and increased siltation of creeks	• Decreased resilience to future flooding resulting in reduced productivity • Decreased business profitability and local employment • Increased indirect economic impacts on the supply chain (packaging, processing, transport, machinery manufacture, irrigation equipment supplies etc)
• Key transport infrastructure critical for maintaining the agricultural economy of the region • Key community infrastructure	• Flooding of and associated damage to infrastructure • Standard infrastructure designs which don't account for local conditions	• Railway line and Warrego Highway out of action disrupting freight movement from and through the Valley to the west (Darling Downs) and east (Greater Brisbane) • Loss of key services (roads, communications, electricity, water and sewerage) located in creek reserves • Houses and other buildings in the inundation area damaged, impacting on the local and regional economy • Fences along creeks damaged and maintenance of creek banks not occurring • Key bridges in the Valley unable to be used	• Decreased water quality due to debris from damage and subsequent erosion where infrastructure has been washed out • Damage to riparian vegetation from debris, resulting in a snowball effect of increasing debris	• Risk to life and injury • High cost to community (local, state and national) for infrastructure repair • Associated public health impacts • Reduced regional economic productivity due to direct and indirect impacts on the agriculture supply chains (primary producers, packing, transport etc) • Reduced access to places of employment, education, emergency services etc • Increased social issues (financial hardship, mental and physical health etc)

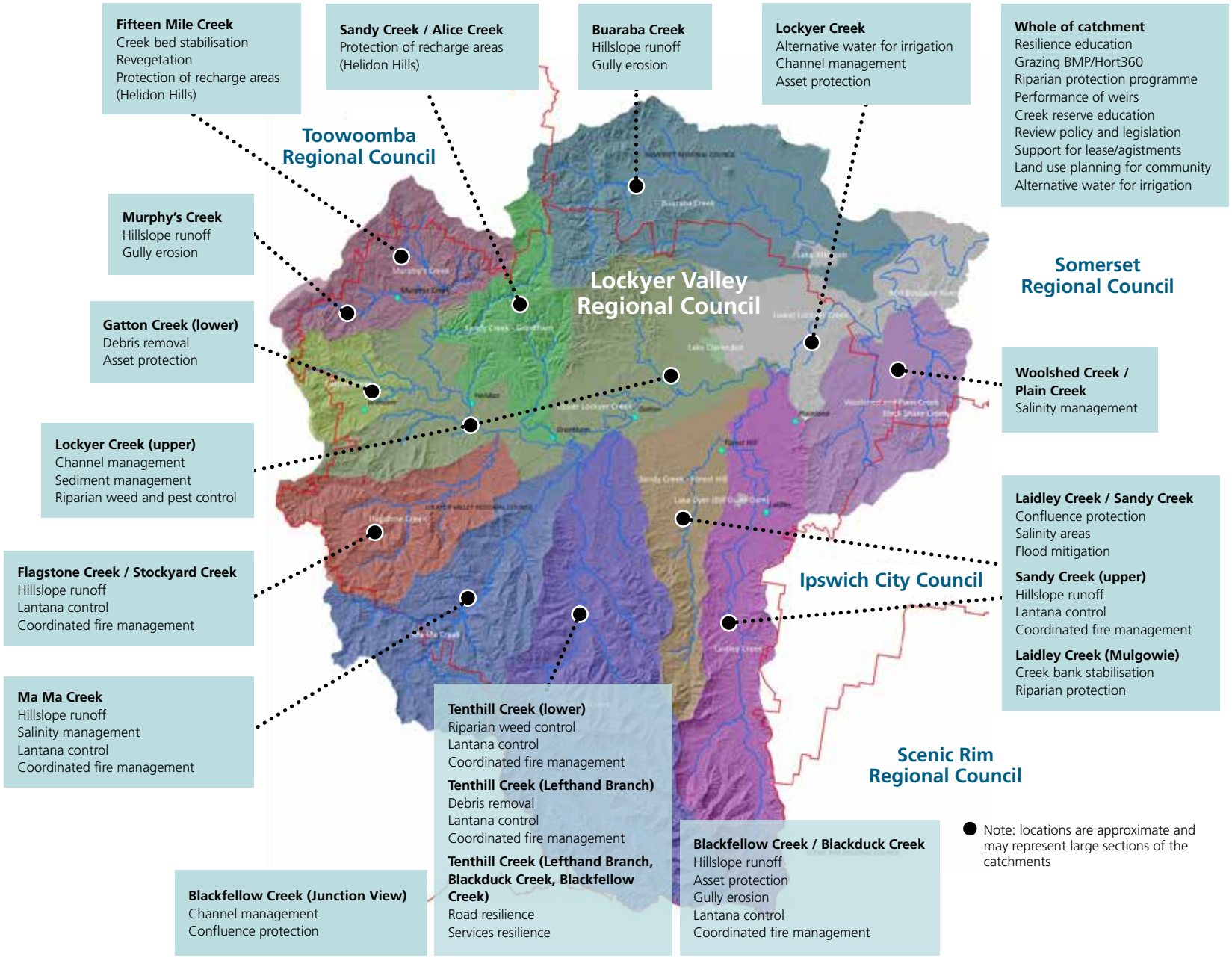
Asset/value	Threat or pressure	Impacts on: Infrastructure	Environment	Finances and people
• Groundwater	• Extreme climatic impacts from drought, floods and higher temperatures • Extraction of groundwater resources in excess of recharge	• Reduced vegetation cover, resulting in increased volume of rain runoff and increased erosion of high quality soils • Reduced groundwater infiltration in upper catchments and reduced groundwater availability for irrigation • Increased volume of runoff and greater risk of downstream flooding • Altered fire regimes, resulting in uncontrolled bushfire	• Variable groundwater • Erosion of high quality soils, resulting in less land available for crops and grazing • Increased siltation of creeks, resulting in decreased groundwater recharge from creek channels • Increased infestation of weeds, impacting remnant vegetation, riparian vegetation, agriculture and grazing • Increased salinity of groundwater, surface water and soil	• Decreased crop yield, due to variable water supply and increased salinity • Reduced surface water quality resulting in increased water treatment costs due to mobilisation and transport of sediment • Decreased amenity and loss of tourism revenue • Increased costs of catchment management
• Downstream regional water supply catchment, Brisbane River, Moreton Bay	• Increased salinity seepage in Plain and Woolshed Creek catchments when water table is high • Sediment movement from the catchment during medium to large rain events	• Brackish surface waters resulting in ecosystem change • Waterway eutrophication due to decreased organic matter decomposition in saline water • Decreased efficiency of water treatment plants and increased risk of shut-down	• Loss of native vegetation and increased erosion due to saline seepage in the landscape • Loss or change in agricultural production due to salt effected land and the use of saline water for irrigation	• Reduced surface water quality resulting in increased water treatment costs due to mobilisation and transport of sediment • Decreased crop / grazing yield

Action Plan

Overview

Regional investment drivers	To protect the water supply of the region; to keep soil on the land and out of our waterways for water quality purposes; to improve the climate resilience of the region; to promote partnerships with strong leadership to deliver a coordinated approach to catchment management in South East Queensland
Assets at risk	High agricultural value alluvial soils; groundwater; key transport infrastructure critical for maintaining the agricultural economy of the region; downstream regional water supply catchment, Brisbane River and Moreton Bay; key community infrastructure at risk from inundation
Outcomes sought	Protection of horticultural production areas; protection of infrastructure from erosion; protection of infrastructure from flooding; improvement in the integrity of the riparian zone of the Lockyer Creek macrochannel and priority tributaries; reduction of sediment and salinity entering the Mid Brisbane River to reduce drinking water treatment costs
Actions summary	Targeted gully and creek bank stabilisation with initial focus on Laidley, Sandy/ Tenthill Creeks using an accepted and agreed reach and socio-economic methodology Infrastructure and community protection through soil stabilisation or re-siting of services and utilities Protect soil from damage where the hill-slope meets the floodplain Make use of The Big Flood Project outputs, strategically remove sediment slugs in main channel and some tributaries Flood debris removal in strategic locations where causing bank erosion Improved grazing and horticultural practices via industry-led programs Coordinated assistance for small to medium landholders for riparian management in the tributaries Coordinated fire, weed and pest management so that soil is not exposed and riparian zones become stabilised Resilience education for the local community Tree planting program to manage salinity in Plain and Woolshed Creeks (recharge area) – link to Black Snake Creek in Mid-Brisbane catchment Council planning schemes recognise salinity issues in Lower Laidley, Sandy Creek/ Tenthill, Plain and Woolshed Creeks Planning schemes/Regional Plan to recognise regionally significant groundwater recharge areas Clarification of rights and responsibilities of landholders adjacent to creek reserves and riparian zones Review of legislation to address potential site specific perverse outcomes (eg in stream vegetation removal where causing bank erosion; requirement to reinstate bank profile). Linking industry led best practice programs to leases and supply chain agreements Assess floodplain re-engagement management options (for soil deposition from channels) Western Corridor recycled treated water for catchment benefits (eg recharge) feasibility analysis (in addition to irrigation) Investigate local/regional benefits and costs of flood mitigation in Laidley catchment Address knowledge gaps - sediment off hills, works costings and monitoring of effectiveness of works Undertake modelling of the Lockyer waterways, including individual streams and confluences, to assist inform investments.

Lockyer Catchment Action Plan: Key investment issues



Management action hierarchy

To maintain the long-term resilience of the catchment and its community, a holistic approach to catchment management is essential. There are complex interactions between catchment flows, water quality, channel morphology, land use, riparian vegetation and aquatic ecology. These interactions also impact on human health and wellbeing, assets, infrastructure, property, recreation, economy, tourism, amenity and natural resources.

Managing only one element of a catchment is unlikely to address all of the relevant aspects. Catchment management should consider the hydrological, geomorphological, ecological, soil, land use and cultural characteristics of a catchment and its stream network. If the interactions are not recognised, there is the potential for well-intended management techniques to have an adverse environmental impact.

The relative importance of catchment characteristics vary within and between catchments. It may be necessary to compromise between the priorities at any particular site to achieve a balanced outcome that maximises overall environmental, social and economic benefits. However, given that catchment runoff volumes and forces cause many social, economic and environmental impacts, managing these specific runoff characteristics is imperative.

There are numerous techniques for prioritising actions, however a hierarchy which prioritises actions which address: (1) the causes of the catchment issues (eg land clearing which increases runoff volume and force), (2) the symptoms of the catchment issues (such as unstable creek banks and erosion), and (3) the consequences of the symptoms (eg damage to assets), is the first step to determining priorities. This approach is consistent with Soil Conservation Guidelines for Queensland 3rd edition (Carey et al 2015), which advocates understanding the 'big picture' and addressing runoff and land management before drilling down to property level then finally specific problem locations.

It is logical to first address, where possible, the sources of catchment issues. If a new bridge is required where creek flows are excessively powerful as a consequence of upstream land management, it makes sense to address the land management to slow the water down. Then if a new bridge is still necessary, it may have lower load requirements which means it will have a lower construction cost. The total investment will not only address road resilience and access, it will also potentially provide environmental and socio-economic benefits through improved land management.

On this basis, a management action hierarchy can be identified:

1: Sources: protect, restore and manage

Reasons or causes of WHY the catchment is being impacted, for example:

- Climatic event (eg flooding)
- Decreased permeability of surfaces, particularly hillslopes, resulting in increased runoff volume and increased runoff force (eg cleared land)
- Variations in soil and geology types, which affect runoff and infiltration

2: Symptoms: alleviate and treat

Indicators of catchment issues, particularly unexpected geomorphological features and behaviour, such as:

- Unstable creeks
- Erosion and siltation
- Significant creek incision and widening
- Poor water quality
- Increased salinity in soil and groundwater

3: Consequences: mitigate and increase resilience

Direct and indirect impacts on assets, infrastructure, utilities, property, natural resources, community and economy

Based on the information gathered through the development of this Action Plan the following high level issues have been identified:

Hierarchy	Description	On Ground Actions	Policy Actions
Level 1: **Sources: protect, restore and manage**	Reasons or causes of WHY the catchment is being impacted, for example: • Climatic event (eg flooding) • Decreased permeability of surfaces, particularly hillslopes, resulting in increased runoff volume and increased runoff force (eg cleared land) • Variations in soil and geology types, which affect runoff and infiltration	Revegetation and the encouragement of managed regeneration on steep slopes and gullies together with active ground cover management through the industry led best practice programs in appropriate locations, to slow down runoff and reduce the volume of runoff Revegetation in appropriate locations to manage salinity and sodic soils (maintain groundcover and soil structure integrity) Support for weed (eg lantana) control in upper catchment areas (particularly those which are grazed) to reduce the need for annual controlled burns Coordinated approach to controlled burns in upper catchment areas, including education, fire breaks, property fire management plans, review of permit system	Planning Schemes and Regional Plan to identify areas which should not be cleared / developed and take measures to prevent clearing / development, including: • Areas with soil / groundwater salinity issues • Recharge areas of regional significance Support for lease / agistment and supply chain agreements to link to industry led best practice programs for horticulture and grazing - to protect soil and keep soil on the land

Hierarchy	Description	On Ground Actions	Policy Actions
Level 2: Symptoms: alleviate and treat	Indicators of catchment issues, particularly unexpected geomorphological features and behaviour, such as: • Unstable creeks • Significant creek incision and widening • Erosion • Siltation / aggradation • Poor water quality • Increased salinity in soil and groundwater	Protect soil from damage where the hill-slope meets the floodplain and high stream power causes damage Measures to prevent damage at creek confluences Use findings of Lockyer Creek: Big Flood Project to identify Lockyer Creek reaches at risk (avulsions, braiding etc) and appropriate management actions In other sub-catchments undertake fluvial geomorphology / RiverStyles analysis to identify reaches at risk, as per Lockyer Creek, and implement measures as appropriate Use the findings of the Big Flood Project and other geomorphological analysis to assess the impacts of excess sediment within creeks, and implement measures to reduce the future inputs of sediment to the system and manage the excess sediment as appropriate Assess floodplain re-engagement management options for soil deposition from channels Targeted riparian management including bank stabilisation and gully erosion stabilisation Riparian revegetation in appropriate locations Riparian weed control program - labour, machinery, chemicals etc - with follow up management plan including options relevant to landholder	Investigate performance of weirs (efficiency of aquifer recharge) and identify potential options for performance improvements (de-silting, ripping, low level chutes, inverted weirs etc) Rights and responsibilities of landholders adjacent to creek reserve and riparian zones - education / awareness program Review key policy and legislation with a view to identify and rectify decisions and requirements which are potentially having perverse outcomes

Hierarchy	Description	On Ground Actions	Policy Actions
Level 3: Consequences: mitigate and increase resilience	Direct and indirect impacts on assets, infrastructure, utilities, property, natural resources, community and economy	Infrastructure and community protection through stabilisation or re-siting of road reserves Infrastructure and community protection through stabilisation or re-siting of services and utilities Resilience education for local community Coordinated rural support program to source alternative markets, marketing opportunities, grants and other funding opportunities, assistance with applications, low rate loans for more efficient equipment, centralised administration / human resources etc - so that growers can have time and resources to manage their riparian zone Flood debris removal and prevention program - identify flood debris at risk of diverting flows and remove as appropriate, and implement measures to prevent loose objects from becoming flood debris	Future-proofing community safety through land use planning and identification of alternative sites for key community facilities at risk of damage from climatic events (flood, bushfire etc) Western Corridor recycled treated water for catchment benefits: construct recycled water pipeline to Laidley Creek for irrigation and/or aquifer recharge Investigate local/regional benefits and costs of flood mitigation in Laidley catchment (build on LVRC and State studies which assessed local and state benefits and costs respectively but not regional)

Lockyer Catchment Action Plan – detailed action and location list

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG1 Infrastructure and community protection through stabilisation or re-siting of road reserves	Improved / alternative access for communities in areas at risk of isolation due to extreme climatic events, to improve safety and reduce economic impacts (direct and indirect on supply chain) Improved resilience of public assets and infrastructure, to reduce costs of repair and/or replacement	Planning legacy of road reserves located in creek reserves and inappropriate design of access crossings for people in remote areas: • Debris and sediment caught behind / under mid-height crossings cause damage to crossings and washouts in creeks • Crossings deflect water into creek banks and cause erosion • Creek banks cut for low crossings can cause flow up onto the roads • Towns, assets and infrastructure at risk of flooding and inundation • Increased risks of isolation during climatic events (emergency access etc)	Level 3: Consequence	Priority catchment: • Tenthill Creek Other locations to be determined by mapping analysis
OG2 Infrastructure and community protection through stabilisation or re-siting of services and utilities	Improved resilience and safety for communities at risk of isolation due to extreme climatic events (eg communication during emergencies, potable water availability, health risks of failed sewerage infrastructure etc)	• Services and utilities are often installed in road reserves • Where roads are located in creek reserves, services and utilities are at risk of flooding and inundation • Health and safety risks increase when services are not available	Level 3: Consequence	As per OG1
OG3 Resilience education for local community	Education program for new residents living in remote areas, to help them understand the potential risks (eg isolation due to road failure, bushfire, floods etc) and measures to reduce risks to safety	• Community resilience and awareness • Safety • Risks associated with emergencies and disasters, including no services, emergency contact etc	Level 3: Consequence	New residents living in remote areas (eg upper catchment areas) 'Remote' may include likelihood of isolation due to flood, fire etc

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG4 Grazing BMP program	Grazing Best Management Practice (BMP) will promote activities which maximise ground cover to minimise soil loss, such as: • Stocking rates • Pasture management • Grazing distributions and practices etc	Flood risks: • Erosion and landslips • Sediment, nutrient and pollutant export to creeks • Damage from high stream power • Weed dispersal Drought risks: • Groundwater supply • Groundwater quality (salinity etc) • Groundcover Financial: • Business profitability	Level 1: Source	Target high priority sub catchments with largest grazing areas (in order): • Tenthill Creek (351 km^2) • Buaraba Creek (254 km^2) • Ma Ma Creek (231 km^2) • Laidley Creek (203 km^2) • Upper Lockyer Creek (193 km^2)
OG5 Horticulture BMP program - Hort360	Horticulture Best Management Practice (BMP) will promote activities which improve climate resilience and financial viability, and minimise soil and other pollutant loads to creeks, such as: • Ccover crops • Irrigation techniques • Buffer strips / inter-row cover • Tillage • Sediment traps • Green manure crops etc	Flood risks: • Lloss of topsoil • Sediment, nutrient and pollutant export to creeks • Loss of creek banks/fields • Damage to infrastructure • Weed dispersal Drought risks: • Groundwater supply • Groundwater quality (salinity etc) Financial: • Business profitability	Level 1: Source	As determined by Growcom's program OR Target high priority sub catchments with large irrigated horticulture areas: • Lower Lockyer Creek (66 km^2) • Laidley Creek (40 km^2) • Upper Lockyer Creek (40 km^2) • Tenthill Creek (35k m^2) • Sandy Creek (Forest Hill) (25 km^2)

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG6 Soil protection from damage in those instances where hill slope meets floodplain and high stream power causes damage	Measures to dissipate stream energy at the transition between steep slopes and alluvial plain to prevent damage to soil. This occurs in some areas, not all, and requires investigation. Assets impacted may include: • soil / cropping land • infrastructure such as roads and crossings, and associated services • infrastructure within creeks such as weirs	• Erosion of valuable cropping fields • Sediment export to creeks • Climate resilience • Damage to infrastructure • Weed dispersal	Level 2: Symptom	To be determined by mapping analysis and local knowledge (eg which areas were heavily impacted during the recent flood events) Known locations (examples): • Laidley Creek (Mulgowie) • Blackfellow Creek (Junction View)
OG7 Revegetation and the encouragement of managed regeneration on steep slopes and gullies together with active ground cover management through the Grazing BMP in appropriate locations to slow down runoff and reduce the volume of runoff	Measures undertaken in strategic locations that do not limit grazing opportunities will reduce the speed and volume of runoff, improve groundwater infiltration and aquifer recharge, and mitigate downstream salinity	• Increased stream power and water velocity as a consequence of historical land clearing and residual damage from floods, which results in increased damage during rain events • Groundwater recharge is reduced where vegetation cover is limited • Limited vegetation increases salinity issues and erosion	Level 1: Source	To be determined by mapping analysis, focussing on steep slopes in upper catchment areas where it would be beneficial to slow down runoff to minimise downstream impacts Known locations: • Sandy Creek (Forest Hill) catchment eg Blenheim
OG8 Coordinated rural support program to source alternative markets, marketing opportunities, grants and other funding opportunities, assistance with applications, low rate loans for more efficient equipment, centralised administration / HR etc - so that growers can have time / resources to manage their riparian zone	The program will target small and medium sized growers to reduce market pressures which are presently limiting opportunities to manage adjoining riparian areas and undertake works to protect their cultivated areas or accommodate lateral creek movement	Residual flood damage (eg vegetation stripping, creeks overgrown with weeds, damaged stock fences etc), combined with limitations on resources (landholder time and funds), results in creek banks in poor condition, leading to: • Ccreeks overgrown with weeds • Pest harbourage (eg rabbits, wild dogs, feral pigs etc) • Creek bank instability • Erosion and water quality impacts	Level 3: Consequence	To be determined by mapping analysis and ABN data (or similar) Areas of cultivated alluvium throughout the Lockyer Creek catchment, owned by small to medium sized businesses

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG9 Lockyer Creek: Big Flood Project - use findings to identify reaches at risk (avulsions, braiding etc) and appropriate management actions for protection of assets (eg stabilisation, reinforcement, revegetation, structure of revegetation, sediment extraction, vegetation (tree) removal in creek beds, bed ripping, increasing channel roughness, reinstatement of waterholes / billabongs etc) Other sub-catchments: undertake fluvial geomorphology / RiverStyles analysis to identify reaches at risk, as per Lockyer Creek, and implement measures as appropriate	To ensure that the funds and resources for significant engineering and creek stabilisation works are targeted at specific sites to protect high quality reaches 'self-repair' is unlikely to occur within a reasonable period of time	Creek reaches have been straightened and roughness has been reduced, resulting in higher stream power and water velocity, leading to • Erosion • Damage to crops / soil / property / infrastructure • Reduced groundwater recharge • Reduced channel capacity • Uncontrolled breakouts of flood water • Flash flooding • Extreme turbidity in large rain events • Increased use of levees Erosion due to land clearing and drought, along with loss of environmental flows in creeks, resulting in excess sediment deposited in creek beds	Level 2: Symptom	Review results from Big Flood Project (after July 2016) Review results from further geomorphological studies on other sub-catchments
OG10 Bank stabilisation program - identify assets at risk (dwellings, infrastructure, alluvial cropping soil etc) as a priority	Identify where slumping has or is likely to occur together with significant scarping or risk of avulsion that threatens important infrastructure or assets (to be considered with the findings of the Big Flood Project and the Risk Assessment process) and to initiate a program of education and awareness but most importantly on-ground action	Historical land clearing combined with residual flood damage (eg vegetation and floodplain stripping) results in higher runoff velocity and volume, and therefore increased stream power, which causes: • Unstable creek banks • High power flows diverted into creek banks • Creek bank erosion / slumping • Creek widening • Erosion of alluvial soil • Loss of productive land • Damage to crops • Damage to assets and infrastructure	Level 2: Symptom	Assets identified through the mapping and in consultation with the Big Flood Project / Technical Report / other creek stability assessments

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG11 Gully erosion and landslip stabilisation in key locations	The erosion of gullies and hill-slope slumps are significant contributors to the sediment loads of creeks and streams and limit upland grazing opportunities	Historical land clearing combined with residual flood damage (eg vegetation and floodplain stripping) results in higher runoff velocity and volume, and therefore increased stream power, which causes: • Landslips on hillslopes • Creek bank erosion / slumping • Creek widening • Erosion of alluvial soil • Loss of productive land • Damage to crops • Damage to assets and infrastructure	Level 2: Symptom	Review of mapping and ground-truthing to identify existing and 'at risk' gully erosion and hill-slope slumps
OG12 Riparian revegetation in appropriate locations	Revegetation of creek banks has been shown to increase in-stream roughness and reduce flow speeds, however, works should be strategically located to maximise efficacy and avoid conflicts with adjoining land uses in particular horticulture on alluvial soils. In most cases, improvement in vegetation composition can be obtained with minimal impact on crops	Residual flood damage (eg vegetation stripping, creeks overgrown with weeds, damaged stock fences etc), combined with limitations on resources (landholder time and funds), results in creek banks in poor condition, leading to: • Ccreeks overgrown with weeds • Pest harbourage (eg rabbits, wild dogs, feral pigs etc) • Creek bank instability • Erosion and water quality impacts	Level 2: Symptom	Revegetation opportunities identified from geomorphological analysis of creeks and participating landholders
OG13 Use the findings of the Big Flood Project and other geomorphological analysis to assess the impacts of excess sediment within creeks, and implement measures to reduce the future inputs of sediment to the system and manage the excess sediment as appropriate	Sediment slugs are typically essential for the self-repair of creek banks and beds, however, in a highly modified catchment the presence of sediment slugs (where they are over-sized or not expected) is not always beneficial and these may be considered for modification or extraction. The causes of the unexpected sediment slugs should be identified and measures implemented to minimise future sediment input	Combinations of unsuitable vegetation in creeks, loss of environmental flows in creeks, land clearing and unstable soils (eg sodic) result in excess sediment transfer and deposition downstream, which exacerbates or causes: • Erosion • Water quality impacts • Ecological impacts • Reduced groundwater recharge	Level 2: Symptom	Review results from Big Flood Project (after July 2016)

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG14 Flood debris removal and prevention program: • Identify flood debris at risk of diverting flows and causing impact damage • Remove as appropriate • Implement measures to prevent loose objects from becoming flood debris	Log jams and build-ups of instream detritus can add to localised flooding risk, threaten infrastructure and increase erosion	Loose objects (eg containers, water tanks, vehicles, old power poles, log jams not removed after floods etc), can be picked up by flood water, causing: • Damage to property and infrastructure, which causes additional debris (snowball effect) • High costs for repair/replacement of property and infrastructure	Level 3: Consequence	Identify via: • Consultation with community members and stakeholders • Review of mapping • Results of geomorphology studies Notified debris piles to be assessed: • Gatton Creek (lower) • Tenthill Creek (upper) • Laidley Creek (Forest Hill)
OG15 Measures to prevent damage at creek confluences	The high energy zones at the confluence of creeks are at risk of heightened erosion and impact upon infrastructure and assets	Historical land clearing combined with residual flood damage (eg vegetation and floodplain stripping) results in higher runoff velocity and volume, and therefore increased stream power. When two high power creeks converge, the combined forces cause: • Creek bank erosion / slumping • Creek widening • Erosion of alluvial soil • Loss of productive land • Damage to crops • Damage to assets and infrastructure	Level 2: Symptom	Confluences of: • Laidley Creek and Sandy Creek (Forest Hill) • Blackfellow Creek and Blackduck Creek (Junction View) • Use mapping and geomorphological analysis to identify others

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG16 Revegetation in appropriate locations to manage salinity and sodic soils (to maintain groundcover and soil structure integrity)	Sandstone geologies naturally contain salt. Trees keep groundwater below surface soil, but when trees are cleared the groundwater can rise and bring salt to the surface. Salinity is of particular concern in Plain and Woolshed catchments but also prevalent in other catchments where ground water is in contact with sandstone Recharge of alluvial aquifers from surrounding naturally saline aquifers affects the quality of water for irrigation Water users, particularly those in salt affected areas, capture surface runoff, but this reduces runoff to creeks and subsequent infiltration to the aquifer, resulting in reduced recharge - cyclic problem Naturally sodic soils present in the catchment exacerbate the problems when exposed (eg by erosion, vegetation clearing etc) Areas of high salinity are difficult to rehabilitate but the cost to downstream users (including large city buildings with conventional air conditioning) are significant. Salinity may also affect horticultural production by limiting the crops that can be grown and impacting soil. Salinity problems are difficult to halt and reverse, therefore prevention is vital	Buildup of salt in soil causes: • Damage to infrastructure • Reduced vegetation, which increases erosion and decreases water quality • Reduced soil productivity • Crops limited to salt tolerant varieties • Land can eventually become unusable / barren • Soil erosion (dispersive soils and/or limited groundcover) • Salt seeps will continue to bring salt to the surface and the problem will spread • Owners may wish to subdivide / develop salt affected non-productive land to minimise losses, but this will exacerbate the salinity problem further	Level 1: Source	Salt affected areas in the following catchments: • Woolshed and Plain Creeks • Laidley Creek • Sandy Creek (Forest Hill) • Ma Ma Creek • Flagstone Creek • Upper Lockyer Creek Catchments with sodic / dispersive soils: • Woolshed and Plain Creeks • Laidley Creek • Sandy Creek (Forest Hill) • Tenthill Creek • Murphy's Creek • Buaraba Creek Catchments with saline groundwater: • Woolshed and Plain Creeks • Sandy Creek (Forest Hill) • Ma Ma Creek • Flagstone Creek All aquifer recharge areas, particularly in upper catchment areas

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG17 Riparian weed control program. Potential provision of: • Labour, machinery, chemicals etc • Follow up management plan with options relevant to landholder • Management of weed hygiene (eg seed spread via wheels of vehicles, imported soil/gravel etc)	While weeds can provide some in-stream roughness they can be lifted by storm flows and subsequently clog culverts and bridges. Most importantly, poorly managed creek banks create harbourage for pest animals including rabbits, pigs and dogs which, in turn, threaten agricultural productivity and management measures such as burning and ripping increase instability of creek banks. In addition, there is a perception that adjoining landholders are restricted from management activities in the creeks and that the responsibility for their maintenance lies with the government	Residual flood damage (eg vegetation stripping, creeks overgrown with weeds, damaged stock fences etc), combined with assumptions about management responsibilities of creeks, results in creek banks in poor condition, leading to: • Creeks overgrown with weeds • Pest harbourage (eg rabbits, wild dogs, feral pigs etc) • Creek bank instability • Erosion and water quality impacts	Level 2: Symptom	Lockyer Creek catchment - start in upper catchment areas of all sub-catchments
OG18 Support for coordinated lantana control in upper catchment areas (particularly those which are grazed) to reduce the need for annual controlled burns, including: • Education about techniques for lantana removal and prevention • Provision of labour, heavy machinery, chemicals etc for lantana removal	Lantana is a perennial problem on grazing properties by reducing available fodder. Traditionally it has been managed by regular burning – a technique that is quick and cost effective, however, it does not permanently remove lantana and can have adverse impacts on other vegetation and soil, resulting in erosion and water quality issues. Techniques such as helicopter spraying have shown success in lantana reduction, however this has the potential to poison surrounding vegetation or drift onto neighbouring crops The application of situation specific techniques can 'permanently' remove lantana and dramatically increase grass cover within paddocks	Coordinated control of lantana will: • Slow the spread of lantana • Reduce competition for water, nutrients and sunlight, resulting in improved grazing and stocking rates • Allow regeneration of native vegetation which will assist with long term lantana control, management of runoff (decrease velocity and increase infiltration) and improve soil condition	Level 1: Source	Catchments with largest grazing areas (in order): • Tenthill Creek (351 km^2) • Buaraba Creek (254 km^2) • Ma Ma Creek (231 km^2) • Laidley Creek (203 km^2) • Upper Lockyer Creek (193 km^2)

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
OG19 Coordinated approach to controlled burns in upper catchment areas, including education, fire breaks, property fire management plans, review of permit system	Fire management remains a significant issue for catchment management. Over frequent burning and too infrequent burning leading to hot, intense wild fires will reduce ground cover leading to loss of soil and its ultimate movement into watercourses. Deeply entrenched views about restricting fire or defaulting to customary practice are often at the centre of poor fire management practices. There is a need to match fire regime to vegetation community ecological requirements. These practices can be improved through education and the development of property management plans	Coordinated approach to fire, pest and weed management will mitigate risks of over-burning and under-burning: Over-burning: • No vegetation regeneration as seedlings are destroyed by burns • Weeds are only suppressed not eradicated • Soil more susceptible to erosion and landslips • Increased stormwater runoff, resulting in downstream impacts and reduced groundwater infiltration Under-burning: • High fuel loads which increase the risk of uncontrolled bushfire and burn hot, destroying all vegetation and topsoil, and increasing risks to life and injury, damage to infrastructure and property and community impacts	Level 1: Source	Lockyer Creek catchment - start in upper catchment areas of all sub-catchments
P1 Investigate performance of weirs (efficiency of aquifer recharge) and identify potential options for performance improvements (de-silting, ripping, low level chutes, inverted weirs etc)	It is unclear how the weirs within the Lockyer catchment are achieving their primary purpose of facilitating groundwater re-charge, due to sediment capture and potential barriers such as impermeable detritus layers. De-silting can encourage further erosion through increasing reach gradient and decisions should be made in the light of dependable research and investigation. Furthermore, advances have been made in the technology of enhancing groundwater re-charge including inverted weirs. These, too, should be investigated	• Reduced water storage capacity • Reduced infiltration potential, affecting baseflow and groundwater levels • Reduced flow attenuation, resulting in no dampening of stream power • Reduced channel capacity, resulting in increased uncontrolled breakouts of high power flows • Potential for mass sediment transfer in significant rain events	Level 2: Symptom	All weirs

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
P2 Planning - identify areas which definitely should not be cleared / developed and take measures to prevent clearing / development, including: • Areas with soil / groundwater salinity issues • Recharge areas of significance	To date, the emphasis of limiting clearing of vegetation has been to achieve biodiversity outcomes. The importance of extant vegetation in positively affecting catchment and aquifer management is well understood but requires further work to ensure that clearing does not negatively affect surface and groundwater issues	• Reduced groundwater recharge • Reduced groundwater availability for irrigation • Increased runoff volume and velocity, resulting in increased flooding, erosion and water quality impacts • Increasing salt affected areas	Level 1: Source	Lockyer Creek catchment
P3 Planning scheme/Regional Plan to recognise regionally significant recharge areas	As above, future iterations of both the Planning Scheme and the Regional Plan should reflect the importance of retaining vegetation in recharge areas	• Uncontrolled clearing of areas which are important for groundwater recharge and prevention of downstream salinity issues	Level 1: Source	Lockyer Creek catchment
P4 Rights and responsibilities of landholders adjacent to creek reserve /riparian zones - education / awareness program	The Land Act and the Water Act identify the rights and responsibilities of landholders in regard to the management of creeks however, over time, community perceptions have developed and resulted in poorly managed creek banks. There is clearly a need to address these perceptions and to encourage improved management activities. Similarly, legislation and policy can result in unintended outcomes and these issues should be highlighted to legislators and policy makers	• Waterways not maintained due to uncertainty and fear of prosecution or fines	Level 2: Symptom	Lockyer Creek catchment
P5 Review key policy and legislation with a view to identify and rectify decisions and requirements which are potentially having perverse outcomes	The development of legislation and policy can result in unintended outcomes with regard to the management of waterways and these issues should be highlighted to legislators and policy makers	• Perpetuation of perverse outcomes from unintended consequences of legislation	Level 2: Symptom	n/a

Actions	Reasons	Risks Addressed	Hierarchy Level	Locations (where known)
P6 Support for lease / agistment and supply chain agreements for horticulture / grazing to link to industry best practice programs - to protect soil and keep soil on the land	There is potential for an imbalance of power and access to advice and resources between the lessor and lessee of land. This can result in unsatisfactory land management practices which threaten the sustainability of lessors land	• Inappropriate land management practices on leased properties resulting in degradation of land and waterways	Level 1: Source	Lockyer Creek catchment
P7 Future-proofing community safety through land use planning and identification of alternative sites for key community facilities at risk of damage from climatic events (flood, bushfire etc)	Community facilities (such as hospitals, aged care homes, schools, emergency services, government service centres etc), which are located in areas at risk from climatic events such as bushfires and floods, have the potential to cause direct and indirect impacts on the local community. In the event of a disaster, these facilities need to be accessible and functional to support and protect the community	• Loss of community facilities due to climatic events, with adverse impacts on members of the community (particularly those who are vulnerable)	Level 3: Consequence	To be determined by mapping analysis
P8 Western Corridor recycled treated water and/or stormwater harvesting for catchment benefits: construct recycled water / stormwater harvesting pipeline to Laidley Creek catchment for irrigation and/or aquifer recharge	Water security for irrigation and drought resilience Reduced demand on aquifers for irrigation water Potential restoration of 'natural' flows to Laidley Creek, to manage sediment build up (to reduce sediment export and increase flow capacity of the channel in rain events), restore resilience to the creek and increase amenity for the community	• Environmental issues associated with extraction of groundwater for irrigation • Drought resilience • Socio-economic impacts of agricultural downturn due to water supply issues	Level 3: Consequence	Pipeline to Laidley Creek Reaches: Mid 1 and Mid 2
P9 Investigate local/regional benefits and costs of flood mitigation in Laidley catchment (build on LVRC and State studies which assessed local and state benefits and costs respectively – not regional)	The private and public property and infrastructure within Laidley is at risk from the impact of floods. Calculations in regard to future investment in flood mitigation measures should consider the likely cost of damage to Laidley through flooding	• Flood impacts, including risk to life and injury and damage to property and infrastructure	Level 3: Consequence	Laidley Creek catchment

Review

Information gaps and emerging studies

This Action Plan and supporting documents will be updated by June 2018 with any relevant information arising as described below.

Key data gaps identified during the study include detailed knowledge of waterway stability, erosion potential and sediment transport quantities and transport rates for the tributaries of Lockyer Creek. A high-level qualitative channel stability assessment over the major tributaries within the catchment has identified areas that may be at risk from erosion, however detailed geomorphic assessments are required in these areas to determine the extent and level of risk. Additionally, minor tributaries and gully lines were not assessed for stability and may represent significant sources of sediment. This is of critical importance to the goals of the Resilient Rivers Initiative as erosion of the channel network has been identified as a major source of sediment within the region.

The current extent of erosion from hills within the catchment requires quantification. This information is crucial to understanding the quantity of soil and sediment moving through the catchment. Related to the limited understanding of waterway stability, there is limited quantification of infrastructure assets under threat. A high-level qualitative assessment identified potential assets under threat, however this assessment was limited to the main tributaries. Further data gaps identified included limited surface water quality monitoring throughout the catchment, limited groundwater extraction volume metering and limited research surrounding the social, tourism and recreational values within the catchment. Collection of the aforementioned data would allow for the development of a catchment model, which could be used to help inform future decision making and monitoring.

Other studies or investigations that should be reviewed for the next update include:

- Outputs of the Big Flood Project. The Big Flood Project is an Australian Research Council project (LP120200093) looking at the geomorphic effects of extreme flood events in South East Queensland led by A/Professor Jacky Croke, University of Queensland. The project has three Chief Investigators, five PhD students and two honours students. Project partners include Seqwater, LVRC and the Department of Science, Information Technology and Innovation.
- Recommendations of sub-catchment studies (Tenthill and Murphy's) prepared by Water Technology for LVRC.
- Outcomes of the Port of Brisbane on-ground works and monitoring study in Laidley Creek.
- The Central Lockyer Water Supply Scheme regulation amendments. This Action Plan has not addressed irrigation water use efficiency as allocation is a topic under review within the Valley.

The South East Queensland Regional Plan will be reviewed in 2016-17 and may inform a future review of this action plan.

Monitoring and evaluation

Progress on action implementation will be monitored through the reporting framework established under the Resilient Rivers Initiative, including an evaluation to be conducted in 2018.

The Big Flood Project recommends that investment in on-going catchment LiDAR capture is essential to understand sediment movement over time and so enable appropriate management plans to be developed and monitored for adaptation.

References

Alluvium (2015) Lockyer Catchment Action Plan: Technical Report: Catchment descriptions and issues, Report P415020_R04 by Alluvium Consulting Australia for the Council of Mayors South East Queensland

Carey BW, Stone B, Norman PL, Shilton P (2015). Soil conservation guidelines for Queensland, 3rd edition, Department of Science, Information Technology and Innovation, Brisbane. Available at: https://publications.qld.gov.au/dataset/soil-conservation-guidelines

Queensland Wetlands Program (2016) Walking the Landscape – Lockyer Catchment Summary. Department of Environment and Heritage Protection, Brisbane.

Appendix

Water erosion – a summary

Overview

The following is extracted from the Soil Conservation Guidelines for Queensland (3rd edition) and provides a summary of likely erosion processes within the Lockyer catchment. For up-to-date information, check the Queensland Government website.

The greatest land degradation threat to rural Queensland is water erosion. Well-structured soils are less prone to break up, and the impact of raindrops is minimised if the soil surface is protected by plant or litter cover. The vulnerability of soils to water erosion depends on:

- rainfall intensity (erosivity)—high intensity rainfall creates serious risk as heavy drops on bare soil causes the soil surface to seal
- nature of the soil (erodibility)—clay soils vary in their ability to withstand raindrop impact
- slope length—if a slope is long, water running down the slope becomes deeper and moves faster, taking more soil with it
- slope steepness—the speed of runoff increases on steep slopes, which increases the power of water to break off and carry soil particles.

Water moving over a soil's surface will remove the lighter, smaller soil particles first (such as clay and silt), leaving fine and coarse sand behind. A combination of large amounts of fine sand and small amounts of clay at the surface means the soil tends to seal and set hard, which limits infiltration (water entering the soil).

Water erosion can be controlled by applying the three principles:

- using land according to its capability
- providing soil surface cover
- controlling runoff.

Types of water erosion

Gully erosion

Gullying can occur on any soil types (but those with dispersive subsoils are the most vulnerable) and often in a natural drainage line as runoff flows from the most remote part of a catchment to its outlet. Any management practice or infrastructure that concentrates runoff has the potential to cause a gully in any place in the landscape. Gully development may be triggered by:

- cultivation or grazing on soils susceptible to gully erosion
- increased runoff from land use changes such as tree clearing in a catchment or construction of new residential areas
- runoff concentration caused by furrows, contour banks, waterways, dam bywashes, stock pads, fences, tracks or roads
- improper design, construction or maintenance of waterways in cropping areas
- poor vegetation cover that may be caused by overgrazing, fires or salinity problems
- low flows or seepage flows over a long period
- 'down cutting' in a creek that causes gullies to advance up the drainage lines flowing into it
- diversion of a drainage line to an area of high erosion risk, such as a steep creek bank or soil that is highly prone to erosion.

Stream erosion

Stream erosion comprises a number of different processes that can occur singly or in combination. These processes include:

- overbank erosion
- bed erosion
- bank scouring (fluvial erosion)
- bank collapse/slumping (mass failure)
- channel widening
- channel avulsion (the development of a new or additional course for a stream)
- soil cracking and crumbling during dry periods.

The major cause of stream bank erosion is the destruction of vegetation on river banks (generally by clearing, overgrazing, cultivation, vehicle traffic up and down banks, or fire) and the removal of sand and gravel from the stream bed. Stream bank erosion can also be accelerated by factors such as:

- stream bed lowering or infill
- inundation of bank soils followed by rapid drops in flow after flooding
- saturation of banks from off-stream sources
- redirection and acceleration of flow around infrastructure, obstructions, debris or vegetation within the stream
- soil characteristics such as poor drainage or seams of readily erodible material within the bank profile
- intense rainfall events.

Sheet and rill erosion

Hill slopes are prone to sheet erosion and rill erosion. The amount of hill slope erosion largely depends on how the land is used. Sheet erosion occurs when a thin layer of topsoil is removed over a whole hillside paddock—and may not be readily noticed. Rill erosion occurs when runoff water forms small channels as it concentrates down a slope. These rills can be up to 0.3m deep. If they become any deeper than 0.3m they are referred to as gully erosion.

Scalding

Scalding can occur when water erosion removes the top soil and exposes saline or sodic soils.

Tunnel erosion

Tunnel erosion is the removal of subsoil. When water penetrates through a soil crack or a hole where a root has decayed, the soil disperses and is carried away with the flow to leave a small tunnel which with every flow, becomes larger and the soil may eventually collapse and form a gully. The whole process speeds up significantly if an outlet is provided (such as an existing gully or cutting in a roadside) as this allows free flow of subsurface drainage water.

Soils vulnerable to tunnel erosion have dispersible subsoils with naturally high levels of sodium. Such soils are referred to as being sodic and are called Sodosols.

Erosion on floodplains

Some of Queensland's best agricultural land is on floodplains because of the high fertility soils and availability of water for irrigation. These areas are subjected to high velocity floods that erode soils with insufficient surface cover. This erosive flooding can remove the entire layer of cultivated topsoil exposing compacted subsoils. It is common for such areas to be stripped of 0.1 to 0.15m of topsoil.

The risk of erosion on floodplains depends on flood velocities—the bigger the flood, the higher the velocities - and the orientation of crop rows and the amount of protective cover provided by crops or stubble when flooding occurs. Problems can also occur at the end of a flood event when slow moving water flows over saturated soils.

Mass movement

Mass movement occurs on cleared slopes in coastal areas. Gravity moves earth, rock and soil material downslope both slowly (millimetres per year) and suddenly (eg rock falls).

During periods of prolonged and heavy rainfall, water entering permeable soils can be stopped by a barrier such as bedrock or a clay-rich soil horizon. The heavy weight of this saturated soil can slide downslope if it is sitting on a rock surface loosened by the build-up of water in the soil. As excessive water intake is the most common trigger of landslip retain deep rooted trees and avoid obstructions such as dams or cross-slope drains.

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