BACK TO NATURE – CAN REVEGETATION OF RIPARIAN ZONES BENEFIT FLOOD RISK MANAGEMENT?

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Introduction

Revegetation of riparian zones has long been promoted as a method to enhance water quality, waterway health and amenity. However, little has been documented on the potential flood risk benefit that riparian vegetation can offer. A more common topic of discussion is how riparian vegetation can exacerbate local flood risk. However riparian vegetation can offer flood risk benefits, in particular on downstream floodplains. This concept is explored further within this paper, and potential flood risk benefits are quantified for the Caboolture River catchment in South East Queensland.

The term 'riparian' relates to the bank of a river. How riparian land is defined often depends on what it is being defined for (Tubman and Price, 1999). For the purposes of this paper, the riparian zone is simply defined as a strip of land running alongside a creek.

Ecological and morphological functioning

With surface and sub-surface flow of water through creeks, and the associated sediment transport processes, proximate land has greater water availability and nutrient exchange than more distant terrestrial habitats. The wetter and richer soils provide a conducive environment for fauna and flora.

Riparian zones are susceptible to natural disturbances of varying degree of intensity and rarity. Extreme floods can generate morphological features that exist for centuries, while more regular flood events create more transient morphological features. Flooding regimes within riparian zones can affect seedling germination and the survival of saplings and adult vegetation. Riparian vegetation species have adapted over time to cope with these disturbances. The cooler and shadier environment also provides an important habitat for some fauna.

Vegetation has been found to increase bed and bank stability both directly and indirectly. The direct affect is due to the roots of vegetation helping to reinforce the soil it grows in (Smith, 1976; Andrews, 1984). The indirect effect is through the vegetation's' effect on the hydraulics. When water flows through anchored vegetation, the vegetation resists the flow by causing a loss of energy through turbulence and by exerting additional drag forces on the moving fluid (Bakry et al., 1992). The flow resistance offered by vegetation depends on its density, maturity, distribution and type. The drag forces on the vegetation increases the overall resistance of the channel, but due to force equilibrium the resistance offered by vegetation will have the added effect of reducing bed shear. The reduced bed shear decreases the probability of erosion, and therefore effectively stabilises the bed material.

The net result of these riparian zone interactions is a complex and active mosaic of landforms and ecological diversity (Gregory et al., 1991), and, by virtue, ecological value. This has long been recognised in the scientific community, and maintaining or increasing the extent of indigenous riparian vegetation has been recommended for the biodiversity and genetic integrity of an area (Howell et al., 1994).

Anthropogenic disturbances

Farming activities have led to degradation of riparian zones (Tubman and Price, 1999). The primary disturbance has been through removal of riparian vegetation. This has disrupted waterway habitats and led to increased bank scour. Continuation of agriculture to stream banks has increased sediment and nutrient supply into streams. Riparian zones in urban areas have also been cleared to make way for urban development.

Clearing of riparian vegetation reduces resistance to flow through the creek. In addition, increased bank scour can result in wider channels. The increased capacity to convey water can exacerbate flooding to downstream communities. Rehabilitation of riparian zones may, therefore, serve a dual purpose; improve waterway health and flood risk to downstream communities.

This paper does not investigate the extent of riparian vegetation clearance across Australia. The work discussed herein has been undertaken on the premise that opportunities to revegetate upper catchment riparian zones do exist, and seeks to understand and quantify the potential for reduced flood risk through revegetation.

Flood risk and riparian zone vegetation

Riparian vegetation is often viewed as incompatible with flood risk management. This is especially so in urban areas. Human impact to riparian zones in urban settings is often a direct result of engineered structural measures to manage flood risk. This includes: channel modifications such as channel lining, straightening and altering the channel profile and gradient; filling in the floodplain; flow alteration such as constructing diversion channels and storage basins. While reversing this development is often financially prohibitive, it may also be seen as undesirable from a flood risk management perspective. Rehabilitating the riparian zone can lead to locally increased flood levels, which would impact adversely on surrounding development.

Despite this, rehabilitation of riparian zones in urban areas has been implemented on the grounds of ecological and social benefits. There is also a sense of social justice in returning hard engineering environments back to their more natural states.

While revegetation of riparian zones can be contradictory to flood risk management, it can also be complementary. The increased resistance to flow caused by riparian vegetation causes an increase in flood levels and reduction in flow. This results in an increase in flood storage in the riparian zone, which can reduce flood levels to downstream communities. Although flood levels increase in the vicinity of the rehabilitated riparian zone, there may be situations where this is beneficial to the communities in the catchment as a whole.

Test case: Caboolture River catchment

The Moreton Bay Regional Council (MBRC) is currently undertaking a study, called the Regional Floodplain Database (RFD), for which a 2D hydraulic model of the Caboolture River Catchment has been developed using TUFLOW. This provided an opportunity to use the Caboolture River catchment, facilitated by the TUFLOW model, as a test case. The TUFLOW model comprised a 10m computation grid with topography based on Light Detection and Ranging (LiDAR) data.

The Caboolture River catchment is located in South East Queensland. The catchment encompasses an area of 380km^2 and a stream network length of 515km. The dominant land uses in the catchment are: native bush, grazing, rural residential, urban, poultry farms, strawberry and pineapple farms. The mid and upper catchment is characterised mostly by agricultural and rural residential areas (source: Healthy Waterways Website).

The Caboolture River flows through the town of Caboolture, the northern most urban area of the greater Brisbane metropolitan, in its mid to lower reaches. Issues affecting the catchment include: channel erosion and sedimentation; riparian zone degradation, including weed invasion and vegetation disturbance; nutrients and other contaminants entering waterways; vegetation clearing and habitat fragmentation (Caboolture Shire Council, 2007). Parts of the upper catchment are protected by the D'Aguilar National Park.

The following cases were modelled:

1. Base case – the TUFLOW model in its current form representing the catchment as it exists today.
2. Revegetated case – This hypothetical case was based on dense revegetation of the riparian zone in the upper catchment.

The layout of the catchment is illustrated in Figure 1.The upper catchment, where revegetation of the riparian zone has been tested, covers an area of 202km^2 or 53% of the total catchment area.

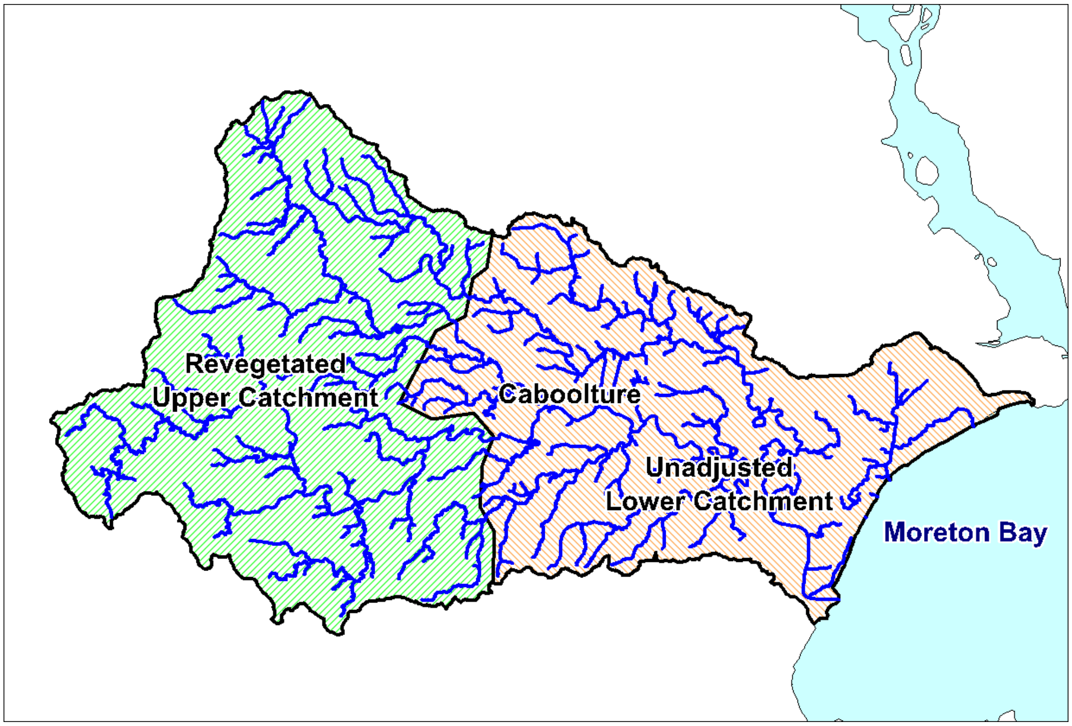

Figure 1: Layout of Caboolture River catchment

To develop the revegetated case, a number of assumptions in relation to defining the riparian zone and vegetation roughness have been made:

1. Mapped areas of existing dense vegetation were included in the base case and revegetated case, using a constant Manning's *n* of 0.15.
2. In both the base case and revegetated cases a clear channel width of 20m has been assumed with a Manning's *n* of 0.08.
3. The lateral extent (or width) of the revegetation zone was assumed to be 20m wide on either side of the clear channel. In reality the riparian zone width varies according to the river morphology. In the upper reaches of the catchment the creek channels are relatively incised. The flood extents and riparian zones are therefore relatively narrow and the assumed riparian zone width tended to extend beyond the flood extent.
4. The longitudinal extent (or length) of the revegetation zone was determined by inspection of cadastre and aerial photos. Revegetation was assumed to extend from the top of the creek systems to the start of areas of concentrated urban development.
5. For the flow resistance model, a simplistic approach was adopted for this study. A constant Manning's *n* of 0.15 was employed; which corresponds to the suggested maximum roughness coefficient for natural channels with heavy stands of timber and underbrush in Chow (1959). It is recognised that this approach can be improved – discussed in more detail later in this paper.

These assumptions resulted in a 255km stream length being defined as riparian zone in the upper catchment, of which 135km (53%) was already densely vegetated in the base case. Thus the revegetated riparian zone stream length is 120km. The Manning's *n* for existing dense vegetation and revegetated riparian zones was the same. Therefore, only areas within the riparian zone which do not have existing dense vegetation were roughened.

The cases were simulated for the 100 year ARI flood event using a 3 hour storm duration. The 100 year ARI flood event was selected as this flood magnitude is typically used for defining flood planning levels in Australia. The critical storm duration through Caboolture ranges from 3 hours to 12 hours depending on the location.

Flood risk benefit in Caboolture

Figure 2 shows the difference between the revegetated peak water levels and base case peak water levels in the vicinity of Caboolture. The results indicate that there is a general decrease in water levels downstream of the revegetated zone. Through Caboolture, the decrease in flood levels is generally between 100mm and 200mm. Further downstream flood levels decrease by less than 50mm.

In contrast, flood levels in the revegetated portion of the catchment have increased. These increases are, in some areas, more pronounced than the flood level reductions in Caboolture.

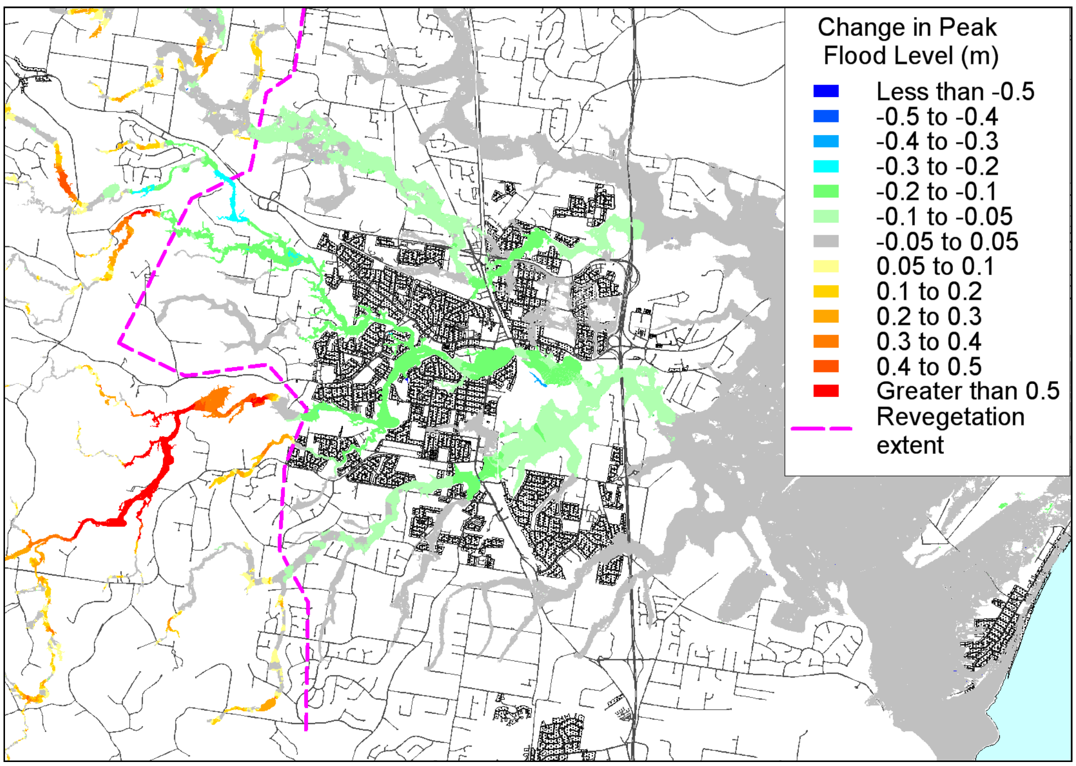

Figure 2: Flood level impact map

Figure 3 shows the location of selected points within Caboolture where stage hydrographs have been extracted. Figures 4 to 8 compare the base case and revegetated case hydrographs for these points.

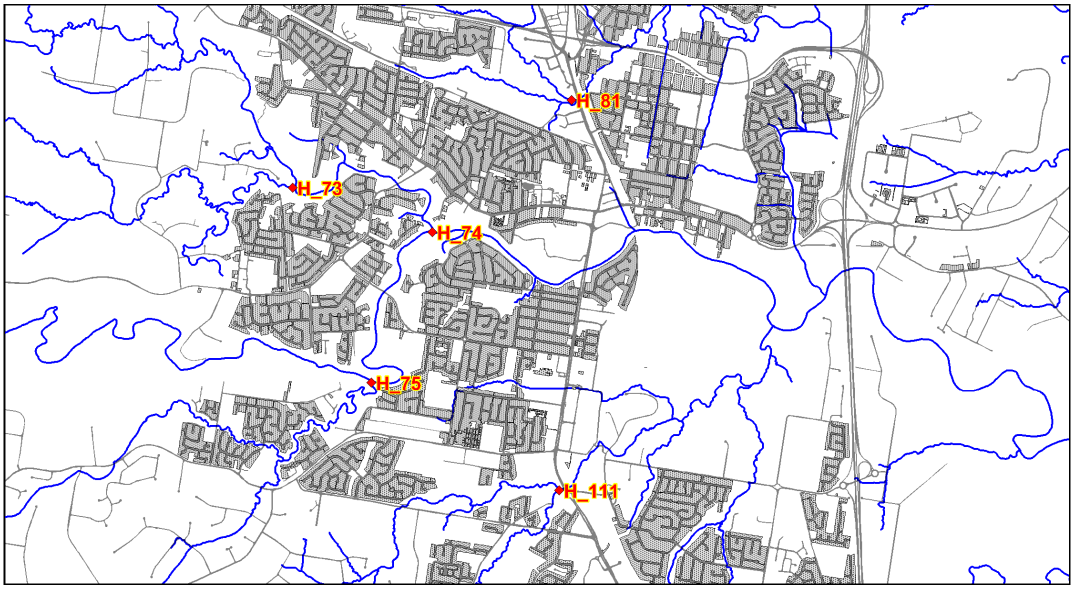

Figure 3: Location of query points in Caboolture

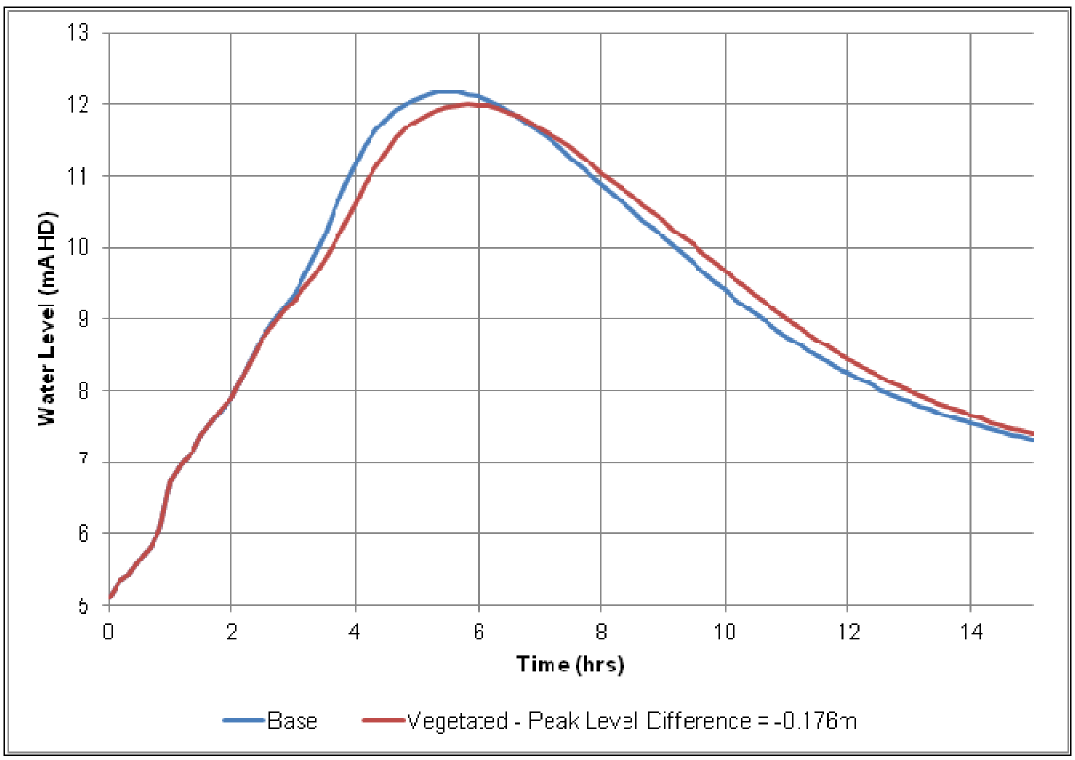

Figure 4: Stage hydrograph at point H_73

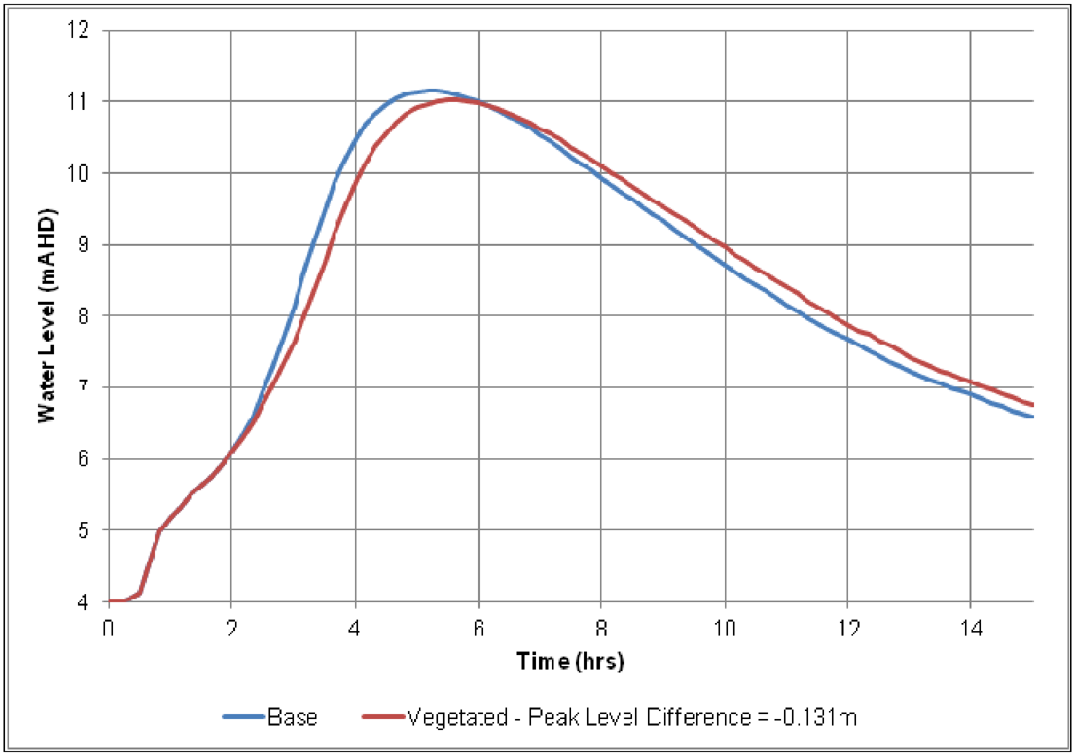

Figure 5: Stage hydrograph at point H_74

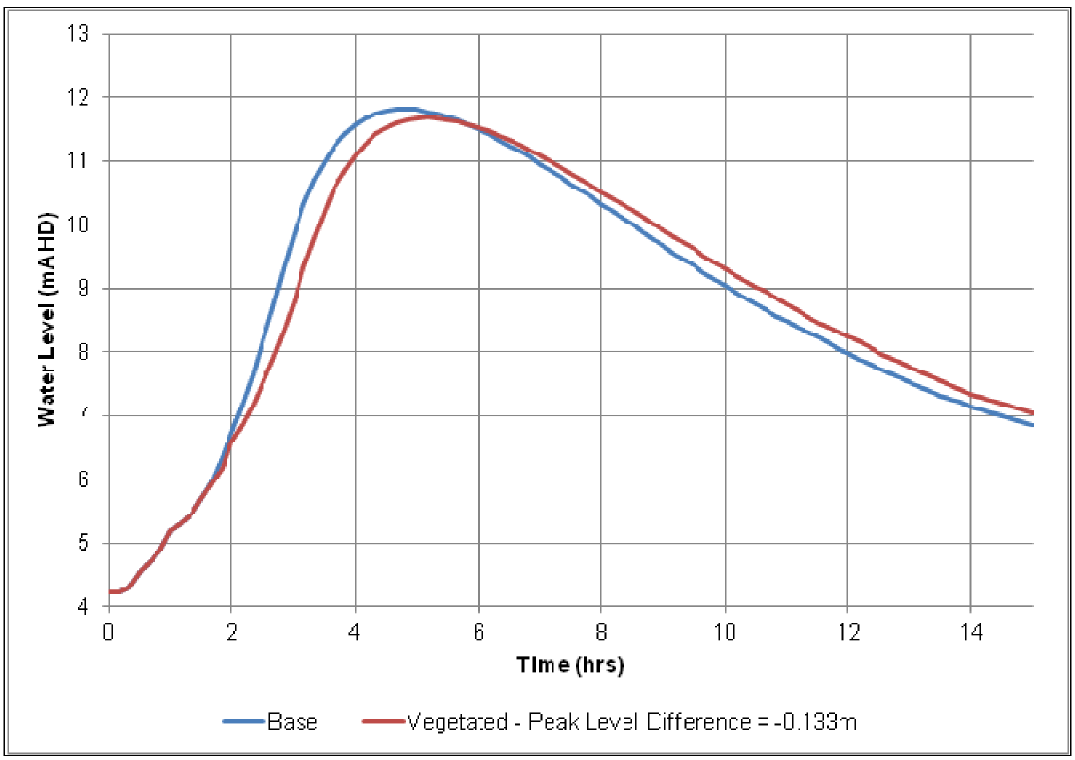

Figure 6: Stage hydrograph at point H_75

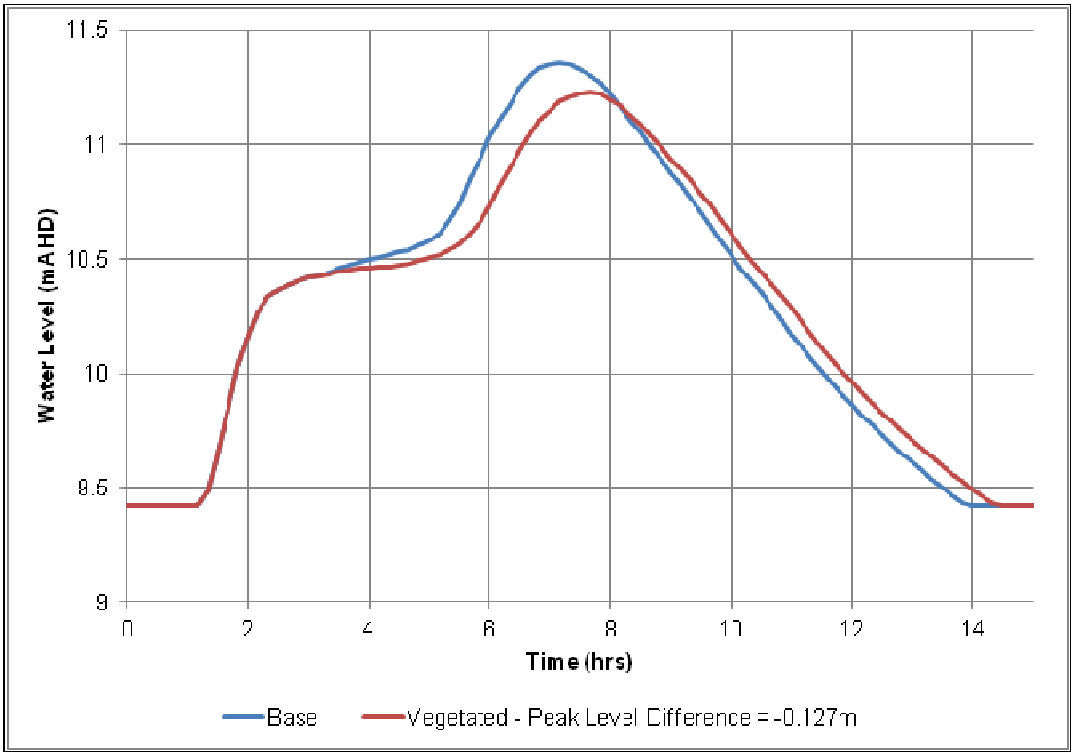

Figure 7: Stage hydrograph at point H_81

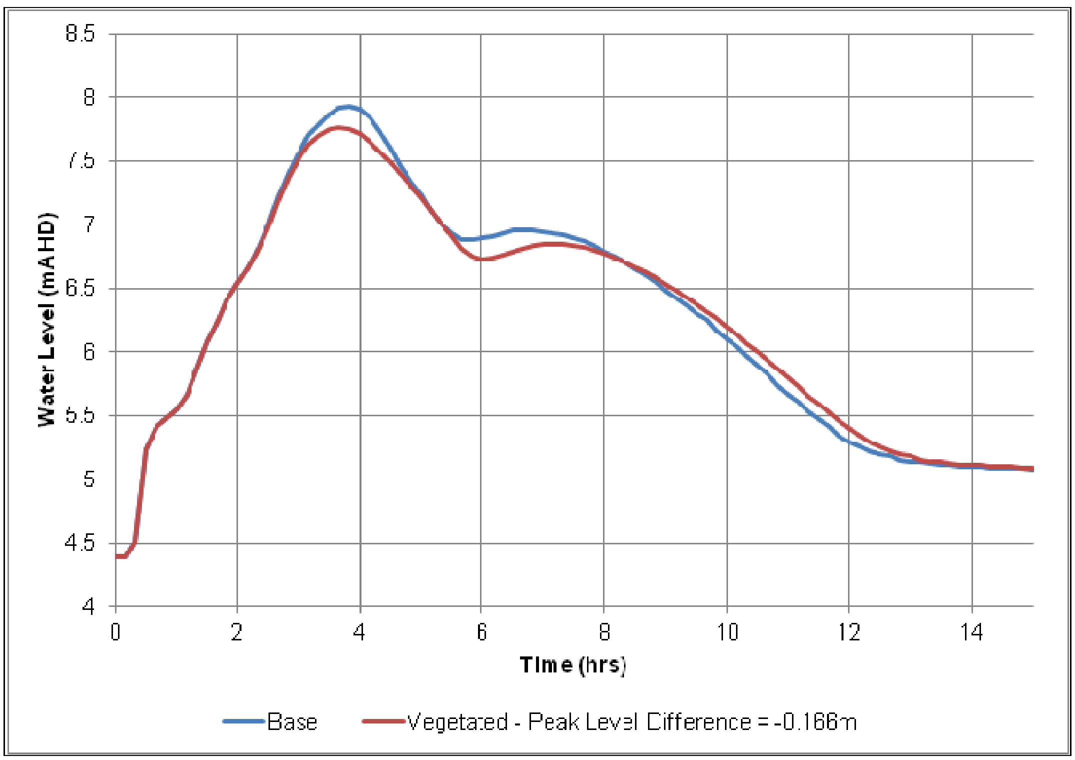

Figure 8: Stage hydrograph at point H_111

The presented stage hydrographs indicate that by revegetating the upper catchment riparian zone, peak flood levels in Caboolture have reduced by approximately 130mm to 180mm in some locations and there is a short lag in the timing of the peak. Peak flows were reduced by up to 9% through Caboolture.

Sensitivity of flood levels to Manning's *n*

The sensitivity of the flood level changes to the assumptions of Manning's *n* values has been tested by adopting a Manning's *n* value of 0.2 (33% increase) for the revegetated riparian zones. One of the key differences in the sensitivity case is that the Manning's *n* in the 7% of the riparian zone covered by dense vegetation was also increased. Therefore, in comparison to the base case, the entire riparian zone has been roughened to some degree, whereas previously only areas with no existing dense vegetation were roughened.

The resulting peak water levels at the locations shown in Figure 3 are listed in Table 1.

Table 1: Peak flood level reductions

Point ID	Revegetated Case (mm)	Sensitivity Case (mm)	Difference (mm)
H_73	176	403	227
H_74	131	351	220
H_75	133	284	151
H_81	127	527	400
H_111	166	31	-135

There has been a large change in flood levels for the sensitivity case. Peak flood levels have decrease by up to 530mm in Caboolture and peak flows by up to 12%. From these results it can be concluded that the flood levels are sensitive to the Manning's *n* assumptions, and there may be significant flood risk benefits from revegetating upper riparian zones.

Discussion on assumptions

A key component to the conveyance of flow through channels with densely vegetated banks is the clear channel width. Research has shown that the flow through bank vegetation is negligible compared to the flow through the clear channel. (Hirschowitz and James, 2009). Due to the relatively coarse computational grid cell size, a 20m clear channel width has been assumed. However it is likely that much of the upper catchment creeks will have a clear channel width closer to 5m. In addition, ephemeral creeks may have a significant amount of in-channel vegetation and debris. The clear channel assumptions made in this paper may, therefore, lead to an underestimation of the upper catchment attenuation of flow and potential flood risk benefits in Caboolture.

In terms of the flow resistance assumptions within dense riparian vegetation, it is anticipated that low flow through dense undergrowth could be significantly more restrictive than assumed. Also, flow resistance through vegetation is known to vary considerably with flow depth. For regular rigid emergent vegetation, Manning's *n* tends to increase linearly with depth (James et al, 2004). In reality, the depth versus Manning's *n* model would be more complex to allow for transitions from dense undergrowth, to tree trunks, to tree canopies and above the tree canopy. A simplistic method has been adopted in this study; constant Manning's *n* value.

Another consideration regarding the conveyance of flow through the riparian zone is the physical obstruction caused by the vegetation foliage. The vegetation foliage obstructs and reduces the flow area and reduces the volume available for flood storage in the riparian zone. For flow through dense emergent vegetation, the volume of vegetation foliage can be a significant proportion of the flow volume.

To improve the work undertaken in this paper it is recommended that a finer grid size is used so that a better representation of the clear channel width can be resolved. It is also recommended that a more representative depth varying Manning's *n* model is used to simulate the flow resistance through riparian vegetation. Depth varying Manning's *n* values can be used in TUFLOW. Also, a new TUFLOW feature has recently been developed which will enable reduced flow conveyance and storage due to the physical presence of vegetation foliage to be accounted for.

Conclusion and recommendations

The potential flood management benefit of revegetation of upper riparian zones has been investigated using the Caboolture River catchment as a test case. Flood levels in lower catchment urban areas were found to decrease significantly. It is therefore concluded that, in addition to improving waterway health and amenity, rehabilitation of riparian zones can reduce downstream flood risk.

In terms of application of this concept, it is noted that there are constraints. Current planning instruments tend to focus on ensuring no worsening of flood levels in the catchment. Since upper catchment flood levels increase, revegetation of riparian zones is in conflict with this philosophy. The author has personally experienced revegetation being discouraged for this reason. However, disregarding revegetation on this basis may be a lost opportunity to reduce flood risk to downstream communities along with the other benefits. One avenue for application of this concept may be through high level studies which consider the whole catchment at a strategic level, such as Floodplain Risk Management Studies. These studies can accommodate limited flood level increases for the greater benefit of the communities in the catchment. It is recommended that opportunities to improve waterway health, amenity and flood risk by revegetating riparian zones are explored during such studies.

References

Andrews, E. D. (1984). Bed material entrainment and hydraulic geometry of gravel bed rivers in Colorado. *Geological Society of America Bulletin*, 95, 371-378.

Bakry M.F., Gates T.K. & Khattab A.F. (1992). Field measured hydraulic resistance characterisitcs in vegetation infested canals. *Journal of Irrigation and Drainage Engineering*. 118, p256-274.

Gregory, S.V., Swanson, F.J., McKee, W.A. & Cummins, K.W. (1991). An ecosystem perspective of riparian zones. *BioScience* 4, 540-552.

Caboolture Shire Council. (2007). *Caboolture River Brochure – Care for our catchment series*. Version 1, February 2007.

Chow V.T. (1959). *Open Channel Hydraulics*. McGraw Hill, New York.

Healthy Waterways Website. (Accessed on 4th December 2011).
http://www.healthywaterways.org/EcosystemHealthMonitoringProgram/2008ReportCar

dResults/CatchmentResults/MoretonBayCatchments/CabooltureRiverCatchmentandEstuary.aspx,

Hirschowitz, P.M. & James, C.S. (2009). Conveyance estimation in channels with emergent bank vegetation. *Water SA*, Vol 35 No.5, October 2009.

Howell, J., Benson, D. & McDougall, L. (1994). Developing a strategy for rehabilitating riparian vegetation of the Hawkesbury-Nepean River, Sydney, Australia. *Pacific Conservation Biology* 1, 257-271.

James C.S., Birkhead A.L., Jordanova A.A. & O'Sullivan J. (2004). Flow resistance of emergent vegetation. *Journal of. Hydraulic. Research.* 42 (4) 390-398.

Tubman, W. & Price, P. (1999). The significance and status of riparian land. In Lovett, S. & Price, P. (Eds), *Riparian Land Management Technical Guidelines. Volume One: Principles of Sound Management. Land and Water Resources Research and Development Corporation*. Canberra, 1-8.

Smith, D.G. (1976). Effects of vegetation on lateral migration of anastomised channels of a glacier meltwater river. *Bulletin of the Geological Society of America* 87, 857-860.