Expert witness statement provided to Melbourne Water in regard to:

- Amendment C207 to the Hume Planning Scheme – Sunbury South PSP
- Amendment C208 to the Hume Planning Scheme – Lancefield Road PSP

Statement prepared by Dr Dominic Blackham

August 2017

1. Witness details

I, Dr Dominic Blackham of Alluvium Consulting Australia Pty Ltd (Alluvium), 105 – 115 Dover Street, Cremorne, Victoria 3121, prepared this report. I hold the position of Principal Consultant. My qualifications and relevant professional experience are outlined below.

Qualifications
I hold the following qualifications:

- Bachelor of Science (First Class Honours) Physical Geography from the University of Leeds, 1996
- Master of Science (Engineering) Water Resources Technology and Management from the University of Birmingham, 1997
- Doctorate in Fluvial Geomorphology from the University of Melbourne, 2006

Related Experience
I have worked as a professional fluvial geomorphologist and urban water specialist for 20 years. During that time I have been involved in:

- More than 100 assessments of geomorphic form and processes across all the states and territories of Australia (apart from WA), the UK, New Zealand and Malaysia.
- The development of guidelines for waterway design and urban flow management to protect the physical form of waterways in urbanising areas.
- Geomorphic and flow assessments of the five major waterways in the Port Phillip and Westernport region, including Jacksons Creek, Emu Creek and many of their contributing tributaries.

My expert advice has been sought by both the private sector (e.g. urban developers) and the public sector (catchment management authorities, local government and state government agencies). I have presented at industry conferences and seminars, and trained more than 100 agency staff in the fundamentals of geomorphology and waterway management.

My qualifications, expertise and experience in fluvial geomorphology and urban water management qualifies me to make this report.

I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

2. Scope of evidence

Alluvium undertook studies that provide input to the design of Melbourne Water's development services scheme (DSS). Melbourne Water has used these studies to develop conceptual locations of waterways and drainage infrastructure within the study area.

I acted as Project Director for these studies. In this role I was responsible for overall project direction, technical review of the approaches and findings, and client liaison. The four studies are:

- Document 1: 'Final Assessment: Riparian vegetation and geomorphology in the Sunbury Growth Area' (October 2014)
- Document 2: 'Erosion Analysis Classification for Waterways around Sunbury' (February 2015)
- Document 3: 'Assessment of stormwater management challenges around Sunbury' (June 2015)
- Document 4: 'EPI and volumetric results, groups 1, 2 & 3 and additional reaches' (April to September 2015).

I have been requested to document the landscape factors that informed the design of the DSS in the study area, defined as the boundaries of the Sunbury South Precinct Structure Plan and the Lancefield Road Precinct Structure Plan. I have also been instructed to include the following in my evidence:

1. *A summary of the studies identified above, including the key findings and recommendations to Melbourne Water and your role in the studies.*

2. *Site specific assessments of the following waterways, likely to be the subject of submissions and evidence at the Panel hearing. From 'Erosion Analysis Classification for Waterways around Sunbury', GIS table 'Geomorphic_values.tab' OBJECTID: 16, 20, 39, 44, 71, 87, 99, 117, 118, 127, 129, 130, 147 and 150.*

3. *In relation to the site-specific assessments, visit the relevant waterways and undertake any ground-truthing work required to form an independent and up-to-date opinion on those waterways and any submissions relevant to those waterways, specifically waterways identified as 16, 44, 71, 87, 99, 127 and 150.*

3. Previous studies

Document 1: Final assessment: Riparian vegetation and geomorphology in the Sunbury Growth Area'

Melbourne Water commissioned Alluvium to deliver an assessment of the riparian vegetation, ecological habitat, cultural heritage and geomorphology of nominated waterways. Alluvium subcontracted Biosis Pty Ltd (Biosis) to deliver the vegetation, habitat and cultural heritage elements of the study.

The overall objectives of the geomorphic assessment component of the study were to:

- Identify the geomorphic condition, values and trajectory of the nominated waterways;
- Identify the sensitivity of the waterways to hydrological changes associated with urbanisation; and
- Determine the degree and type of management intervention required (if any) to maintain high value waterways, and adjust or increase resilience to changes in hydrology (where required).

The full scope of the geomorphic assessment was defined in the project brief issued by Melbourne Water. The relevant section of the brief is reproduced below.

Box 1. Scope of geomorphic survey

There are two overarching objectives for undertaking a geomorphic investigation when preparing a DSS. These are to determine if the existing drainage pattern (i.e. valley form where no waterway exists) or existing waterway can be retained, whether the existing waterway will need to be re-constructed or whether an entirely new waterway will need to be constructed.

Specifically, with these objectives in mind, the investigation is required to:

1. Determine the existing condition, values and trajectory of the waterway to inform:

   a. the sensitivity of the waterway to hydrological change caused by urbanisation and thus the need for management intervention:

      I. if management intervention not required for hydrological reasons, refer to b(I) below;

      II. if management intervention required for hydrological reasons, refer to b(II) below

   b. the degree and type of management intervention required to:

      I. achieve Melbourne Water's Healthy Waterway Strategy objectives and/or the 2030 Geomorphic Template (target) for the waterway;

      II. ensure channel form and processes can be adjusted to or made resilient to the urbanised hydrological regime

The below points are to be taken into consideration when determining the appropriate management response under b(II):

2. Determine, when combined with information from the suite of environmental investigations, whether:

   a. the existing waterway values, condition, form and processes are so significant that they need to be protected and/or enhanced;

   b. it is feasible, under the changed hydrological regime, to maintain the existing waterway with minimal management intervention, or if major works within the waterway would be triggered, whether an alternative management response will be required within the catchment to protect the waterway to avoid works in the waterway;

   c. the existing waterway values, condition and trajectory permit the re-construction of the waterway to facilitate development (i.e. the existing waterway is in poor condition, has no values of significance and is on a degradation trajectory). Flood mitigation and drainage outfall objectives can be achieved via major works within the waterway;

   d. the existing drainage pattern is not conducive to facilitate development, and a waterway will be required to be constructed, regardless of the existing condition and values of the valley form (i.e. existing values and condition are not significant enough to warrant an alternative drainage design response.

Spatial extent. The nominated waterways were identified by Melbourne Water, and comprised a total of more than 40 km of waterways within the Sunbury South PSP and Lancefield Road PSP.

Methods. The geomorphic assessment was a combination of field and desktop assessment. The assessment method was based on similar investigations Alluvium had undertaken elsewhere in the Port Phillip and Westernport region, which were reflected in the Melbourne Water project brief. More than 40 km of waterways were physically inspected by Karen White, a qualified and experienced geomorphologist from Alluvium.

The waterways were classified on the basis of their geomorphic condition and stream type. Four categories of geomorphic condition were used in the classification system: intact, good, moderate and poor. These categories were based on the criteria specified in the Melbourne Water project brief[1]. The stream types were classified using the River Styles® framework[2]. Examples of characteristic stream types in the study area are shown below (Figure 1).

An initial assessment of the risk of erosion of the waterways resulting from changes in hydrology after urban development was carried out as part of this study using the *stream erosion index* (SEI). The SEI approach is a simple, hydrologic method of assessing changes to the erosion potential in waterways following urban development. The SEI has been included in the Cooperative Research Centre for Water Sensitive Cities *Toolkit*[3].

The overall assessment of the geomorphology of the tributary waterways in the Sunbury Growth Area was that the steep, erodible nature of the landscape in the study area presents significant challenges to the design of a sustainable surface water drainage system that meets the objectives of Melbourne Water, the Victorian Planning Authority and other stakeholders.

Typical valley fill morphology with no clearly defined channel

Typical channelised fill with actively eroding channel

Typical chain of ponds in an unconfined valley setting

An example of a steep headwater reach

[1] Melbourne Water, 2014, Sunbury Growth Area: Riparian vegetation and geomorphic assessment, Assignment Brief April 2014

[2] Brierley, G.J. and Fryirs, K.A. 2005. Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publications, Oxford, UK. 398pp.

[3] https://watersensitivecities.org.au/solutions/water-sensitive-cities-toolkit accessed on 18 July 2017

An example of a gorge

An example of a confined reach with a discontinuous channel

Figure 1. Characteristic stream types from across the study area

The outputs from the desktop and field assessments were synthesised and interpreted to generate management recommendations. The suite of management recommendations was developed from the project brief issued by Melbourne Water[4].

Four groups of management actions were recommended by Alluvium for the waterways in the study area. The recommendations were based on options 2a, 2b, 2c and 2d in Box 1 (Table 1 and Figure 2):

Table 1. Summary of geomorphology-related management recommendations for the study area

Management recommendations	Actions
Protect high value waterway	Preserve high geomorphic and vegetation values as a priority by ensuring post development erosion potential is not increased beyond acceptable limits (as defined by the erosion potential index). Ensure adequate water corridor widths in accordance with Melbourne Water Waterway Corridor Guidelines. Improve ecological value and channel stability through revegetation of the waterway as part of Melbourne Water ongoing river health program.
Further investigation to determine options	Further investigations need to consider holistically the extent and cost to which riparian vegetation and/or geomorphic values are retained or disturbed. Undertake detailed hydrogeomorphic modelling to quantify erosion risk once further information on development patterns and WSUD is available. Modify drainage strategy if necessary to meet preferred waterway management option. Consider linkage with adjoining reaches during an investigation.
Maintain current form	Maintain form through flow management (e.g. through WSUD systems) and waterway corridor widths in accordance with the Melbourne Water Waterway Corridor Guidelines. Consider linkage with adjoining reaches. Advocate for urban design features that reduce stormwater generation to conserve vegetation that is dependent on ephemeral conditions.
Modify or reconstruct waterway taking into account vegetation	Modify waterway to mitigate existing erosion or provide sufficient flow capacity for post-development conditions using the Melbourne Water Constructed Waterway Design Manual. Design needs to take into account vegetation values and avoid vegetation where feasible.

[4] Sunbury Growth Area: riparian vegetation and geomorphic assessment: assignment brief, April 2014

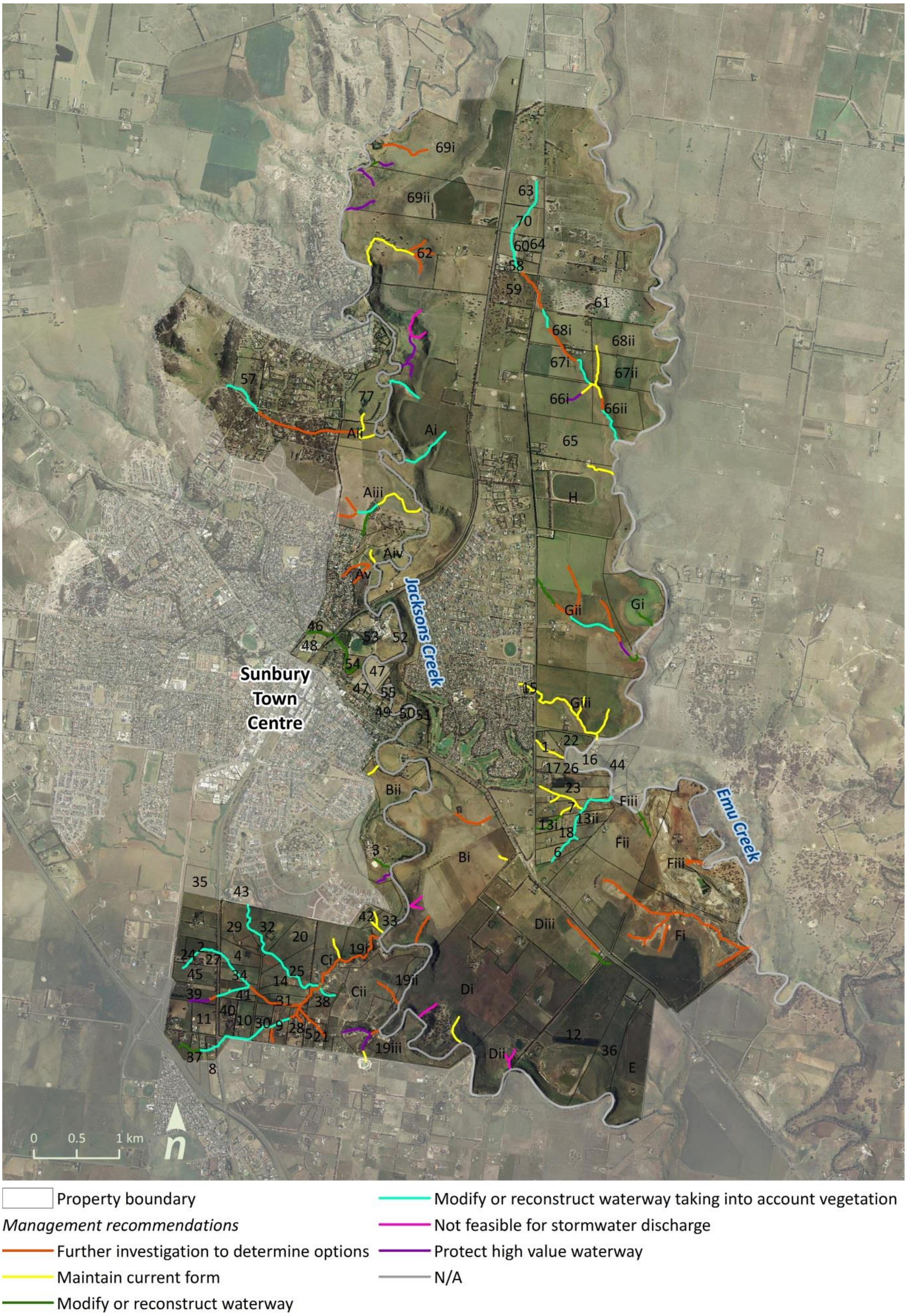


Figure 2. Summary of management interventions recommended for waterways in the riparian vegetation and geomorphology assessment

The riparian vegetation and geomorphology assessment established a baseline understanding of the geomorphic condition, values and trajectory of waterways throughout the Sunbury Growth Area. A series of subsequent studies were undertaken to identify the appropriate flow management analysis and management techniques to be employed to achieve Melbourne Water's management objectives.

Document 2: Erosion analysis classification for waterways around Sunbury

A number of reaches were identified in the riparian vegetation and geomorphology assessment (October 2014) as needing further investigation to determine the appropriate management intervention. Generally, this recommendation was made where it was not possible, within the scope of that study, to ascertain (with the information available at the time) the scale or feasibility of management intervention needed to achieve the management objective for that reach.

In particular, the scope of the riparian vegetation and geomorphology assessment was limited to identifying where flow management should be considered, but did not identify what sort of flow management analysis and design techniques should be used as an input to the design of the DSSs.

Two broad flow management analysis techniques were used in this study:

- Erosion potential index (EPI) analysis – a hydro-geomorphic assessment method that combines outputs from continuous simulation hydrologic models, field assessments of waterway erosion thresholds and hydraulic models that estimate long-term time series of shear stress on the channel boundary. The analysis—based on work by Bledsoe[5] and cited in recent Australian research—identifies drainage solutions that maintain current erosion potential on the waterway. It provides the highest degree of confidence that proposed drainage solutions will protect the integrity of receiving waterways, but is the most involved and complex. EPI analysis is not appropriate for drainage lines where fluvial erosion is not the dominant erosion process—for example, a steep, fractured rock face, where flow does not approximate uniform flow. The EPI and SEI approaches share a common basis of continuous simulation of flows under different land use scenarios, but the EPI approach explicitly takes into account the size, shape and erosion resistance of the waterway in question, and hence provides a higher degree of confidence in the outputs than SEI.
- Volumetric analysis – a hydrologic assessment method that uses output from continuous simulation MUSIC models to identify drainage solutions that match the current volume of flow in a waterway. This analysis is simpler and quicker than the EPI analysis, but provides a lower level of confidence that the integrity of the waterway will be preserved. The volumetric analysis method was developed to allow assessment of the large number of tributaries across the Sunbury Growth Area in the time available.

Both the EPI and volumetric analysis approaches allow the impacts of changes in hydrology to be assessed and potential mitigation measures to be designed.

The application of the EPI analysis across all waterways in the study area was not considered appropriate because of the time and cost associated with the application of this in-depth analysis, and because it is not appropriate for waterways where uniform flow conditions are not present.

To identify the appropriate flow management analysis method and inform DSS design for different reaches, Alluvium was commissioned by Melbourne Water to classify waterway reaches into the appropriate level of flow management analysis. A three step process was used for this:

- Define criteria for classifying reaches
- Apply criteria to reaches
- Map and report.

Two criteria were identified: geomorphic value and waterway slope. The categorisation of geomorphic values developed in the riparian vegetation and geomorphology assessment (October 2014) were used as the basis for the geomorphic value criterion in this investigation. The five classes

[5] Bledsoe BP, 2002, Stream Erosion Potential and Stormwater Management Strategies, Journal of Water Resources Planning and Management, Nov 2002.

of geomorphic value in the riparian vegetation and geomorphology assessment were simplified into two classes for this study (Table 2).

Table 2. Adaption of geomorphic values for use in the erosion analysis classification study

Riparian vegetation and geomorphology study criteria	Erosion analysis study classification criteria
Extreme	Significant
High	Significant
Moderate	Low
Low	Low
Insignificant	Low

Waterway slope was identified as the second criterion for classifying waterway reaches into different types of erosion analysis. The landscape in the study area is characterised by deeply dissected basaltic plains with many small, steep tributaries draining to either Jacksons or Emu Creeks. The steepness of the terrain places a significant constraint on the construction of waterways, and the long-term maintenance of drainage paths where existing tributaries are used as engineered stormwater discharge points from future urban development. For example, if stormwater is directed to a steep tributary, which is then destabilised and starts to erode, it will be difficult, expensive and potentially unsafe to access the tributary to stabilise and address the erosion.

A longitudinal (i.e. downstream) waterway slope threshold was used to identify waterways that are too steep to either be a constructed waterway or to convey additional flow, over and above the flow they currently convey under pre-development conditions. The threshold was selected on the basis of safe access for either construction or maintenance. A number of design guidelines set out maximum slopes for maintenance access around waterbodies, ranging between 1(V) in 10(H)[6] and 1 in 5[7]. A threshold of 1 in 8 was selected representing an approximate midpoint of the published ranges.

The geomorphic and waterway slope criteria were combined in six categories, each of which was assigned to either one of the two erosion analysis types, or identified as not needing erosion analysis (Table 3).

[6] Melbourne Water, 2005, WSUD engineering procedures: stormwater, CSIRO Publishing.
[7] Melbourne Water, Constructed Wetlands Design Manual, Draft.

Table 3. Waterway categories and erosion analysis requirements

Category			
Geomorphic or vegetation value	**Waterway slope**	**Erosion analysis requirement**	**Comment**
Significant value	>1 in 8	Volumetric analysis	EPI not applicable to very steep slopes. Volumetric analysis will provide some level of confidence that waterway integrity can be retained while using waterway as a discharge point.
Significant value	<1 in 8	EPI analysis	EPI analysis to ensure additional urban stormwater discharge does not cause loss of values.
Significant value	<1 in 8 with drops	EPI analysis	EPI analysis to ensure additional urban stormwater discharge does not cause loss of values.
Low value	>1 in 8	Volumetric analysis	Too steep for a constructed waterway. EPI not applicable to very steep slopes. Volumetric analysis will provide some level of confidence that waterway integrity can be retained while using waterway as a discharge point.
Low value	<1 in 8	None – constructed waterway	Assume constructed waterway will be designed to safely convey the hydrology from upstream catchment.
Low value	<1 in 8 with small drops	None – constructed waterway	Assume constructed waterway will be designed to safely convey the hydrology from upstream catchment.
Low value	<1 in 8 with large drops	Volumetric analysis	Topographic analysis indicates too steep for a constructed waterway. Volumetric analysis will provide some level of confidence that waterway integrity can be retained while using waterway as a discharge point.

The criteria were applied to spatially categorise waterways across the study area into the different types of erosion analysis.

Document 3: Assessment of stormwater management challenges around Sunbury

The challenges to the development of sustainable urban drainage systems presented by the landscape of the Sunbury Growth Area were established in the riparian vegetation and geomorphology assessment. Subsequently, EPI analysis was identified as the most appropriate method for assessing the impacts of changes in hydrology on the erosion of high value waterways.

To further understand the risk of increased erosion from changes in hydrology following urban development Alluvium produced a summary of the challenges and risks around the provision of sustainable stormwater drainage in new urban areas around Sunbury.

The summary identified the consequences of erosion of the dominant stream types in the study area and documented three case studies developed to examine the impact of changes in hydrology following urban development in the study area. The consequences of erosion following urban development are:

- Bank erosion and channel migration;
- Increased width of channels (through erosion of one or both banks) or channel deepening through incision
- Threats to natural and built assets (both public and private) in the vicinity of the eroding waterways, and potentially up and downstream reaches, including:
    - Roads, bridges, stormwater pipes, constructed wetlands, recreational infrastructure

- Private residences
- Destruction of valuable instream habitats (both vegetation and physical habitat)
- Increased sediment loads to receiving waterways downstream.

An example of a waterway in the study area that is the subject of erosion arising from increased flow is provided below (Figure 3).

The case studies were selected to:

- Provide representation of tributaries in both the Jacksons Creek and Emu Creek catchments
- Be representative of the waterway types found in the study area.

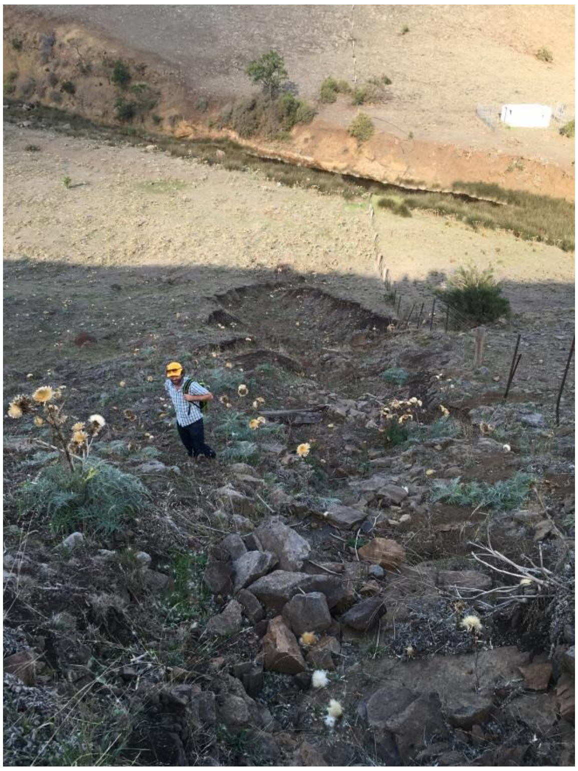



Figure 3. Looking up (left hand image) and downstream (right hand image) along eroding hillslope gully. Erosion of this waterway has been triggered by modification of the drainage on the basalt plateau immediately upstream of the hillslope.

The case studies used the EPI analysis approach (Bledsoe 2002) to assess the impact of changes in hydrology following urban development. The EPI is a measure of the change in excess shear stress or 'effective work' on a channel as a result of changes in catchment hydrology following (for example) urban development.

The EPI approach has three main inputs:

1. A continuous simulation hydrologic model that provides flow series at locations of interest throughout the study area for existing and post development conditions
2. A hydraulic model that converts the hydrographs into time series of shear stress for existing and developed conditions
3. A critical shear stress threshold below which significant sediment transport does not occur.

The long-term shear stress time series are analysed to calculate the time-integrated total effective work for each scenario. Effective work can be illustrated schematically for a single event (EPI curve Figure 4).

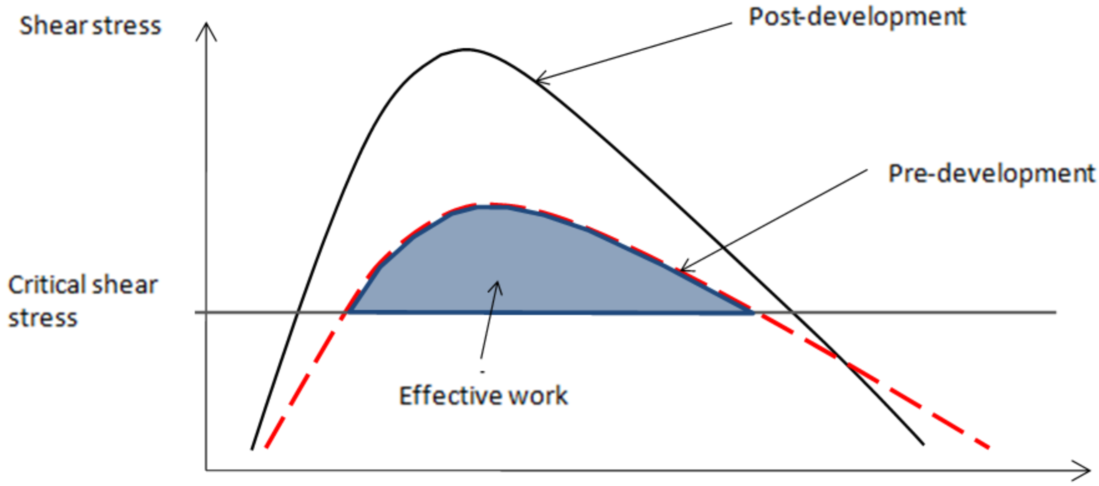


Figure 4. Difference in effective work for pre- and post-development scenarios for a single event

The area under the shear stress curve above the critical shear stress threshold is defined as the erosion potential for that flow scenario. The ratio between post- and pre-development erosion potential is the erosion potential index:

$$EPI = \frac{EP_{post-development}}{EP_{pre-development}}$$ Equation 1

Where:

1. EPI is erosion potential index.
2. $EP_{post\text{-}development}$ is erosion potential under post-development conditions.
3. $EP_{pre\text{-}development}$ is erosion potential under pre-development conditions.

If EPI is greater than 1.0 the analysis indicates erosion is likely to occur. An EPI of 1.0 indicates the stream will remain in equilibrium over a period of years, although there may be localised erosion and deposition at the flow event time scale.

Two scenarios for each case study location were analysed using the EPI approach:

1. Urban development with no stormwater management or treatment
2. Urban development with stormwater treatment to meet best practice pollutant reduction targets[8].

Each case study included:

- A brief description of the current form and erosion trajectory of the waterways (what is likely to happen under a 'do nothing' scenario with no further changes in land use)
- The predicted changes in erosion under future urban development (expressed by the results from the EPI analyses for the two scenarios outlined above).

The case studies showed that a business as usual drainage design approach that would meet current best practice treatment objectives would not manage flows sufficiently to protect waterway physical form and manage the risk to built and natural assets.

[8] Victorian Stormwater Committee, 1999, Best-Practice Environmental Management Guidelines, CSIRO Publishing

It was therefore recommended that a flow management strategy along with approximate waterway setbacks be developed to manage the increased risks of erosion following urban development in the growth areas around Sunbury.

Document 4: EPI and volumetric results

Alluvium was commissioned by the (then) Metropolitan Planning Authority to assess the erosion potential of waterways in the Sunbury Growth Area and develop design curves as an input to subsequent DSS design. This involved the development of options for flow management to preserve the physical integrity and manage the risk of large-scale erosion of waterways in the study area.

The central output from the erosion analysis was a series of drainage solutions for each waterway to meet the objectives. The solutions are combinations of storage volume (representing wetland/retarding basins) and bypass flows (representing either piped flows that bypass the waterways to prevent erosion or stormwater harvesting and reuse demand). For example, one solution would be no storage and a large pipe to divert all flows, or at the other end of the spectrum is a large storage and no bypass pipe. The range of solutions for each waterway was presented as a 'solution curve' (see example presented below (Figure 5)).

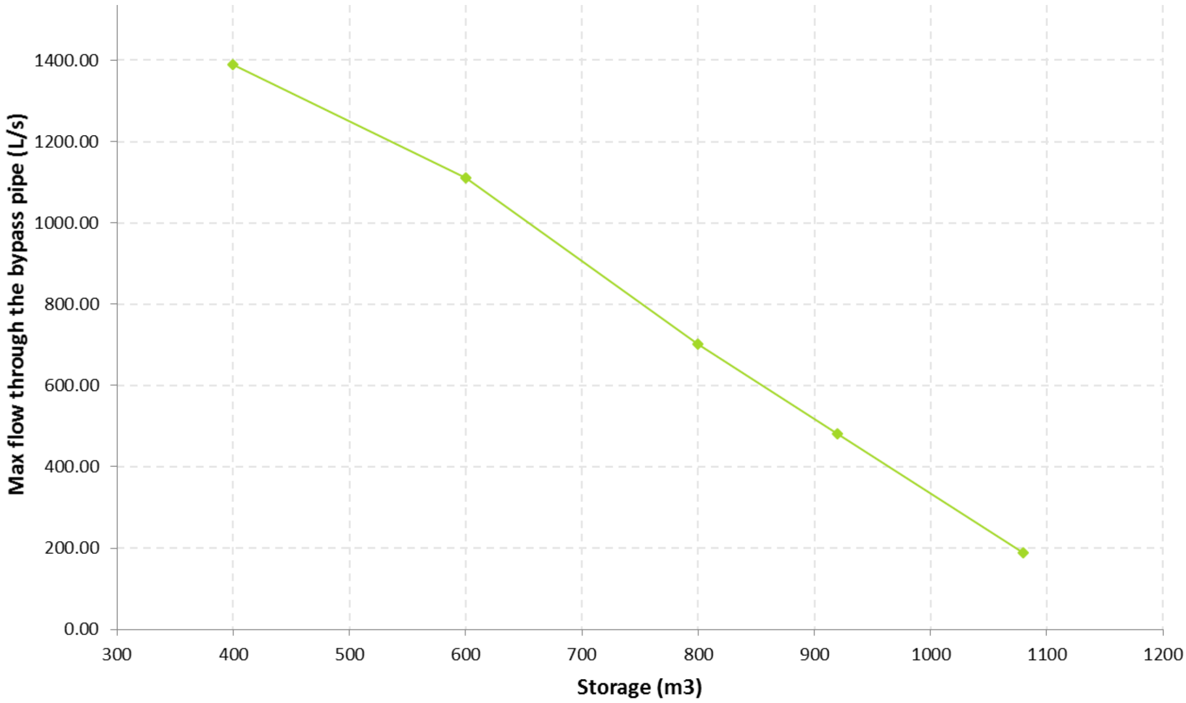


Figure 5. Example of conceptual drainage 'solution curve'. Note as storage increases the required capacity of bypass pipe or reuse demand is reduced.

The outputs from this study informed the subsequent DSS design.

4. Response to submissions

I have assessed the geomorphic condition and values of 13 specific reaches of waterway in the Sunbury Growth Area, that have been identified as the subject of submissions. Due to time constraints I have assessed six waterways in the field and carried out a desktop review of the information on the other seven. Also due to time constraints, waterway #39 was not assessed as part of this expert witness statement. The desktop review is primarily based on information provided in the report by Alluvium entitled Final Assessment: Riparian vegetation and geomorphology in the Sunbury Growth Area. Location of site specific waterways is provided below (Figure 6).

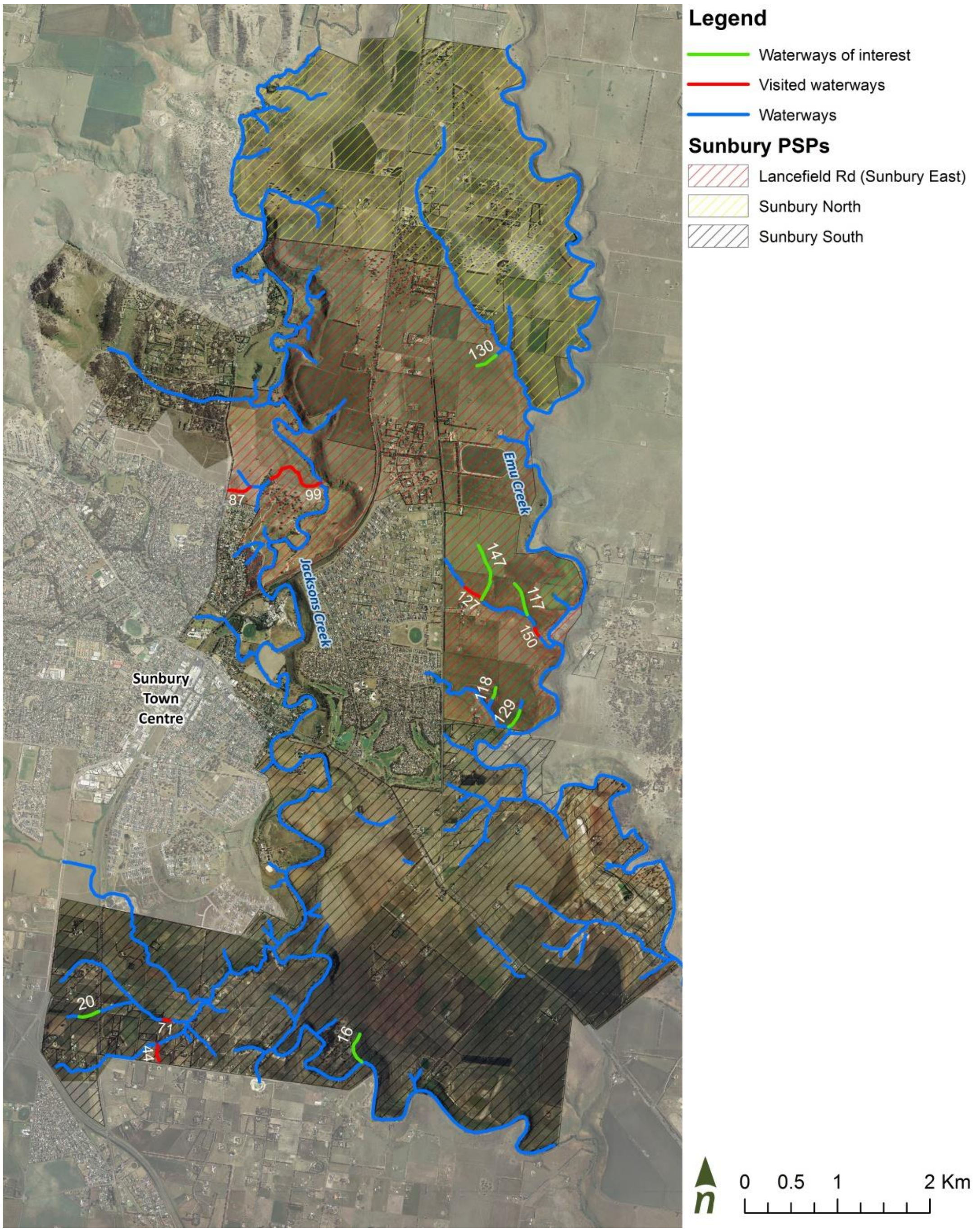


Figure 6. Location map showing waterways with site specific assessments

I assessed the geomorphic condition of the site specific waterways against four criteria, which were consistent with the criteria set out in the brief for the riparian vegetation and geomorphology assessment (October 2014):

- Stream type (based on River Style)
- Naturalness – how intact is the waterway in relation to its stream type
- Rarity – how frequently does the stream type occur
- Representativeness – how representative are stream types of the physiographic area or position in the catchment.

Using these criteria I classified each of the reaches into one of four geomorphic condition classes (Table 4).

Table 4. Geomorphic condition classes.

Geomorphic condition	Definition
Intact	Reach form in natural condition, presents all the typical features of the stream type, no evidence of erosion processes.
Good	Reach form in near natural condition, some limited impacts but most of the typical features of the stream type are retained.
Moderate	Reach form impacted by erosion or land use practices. Some features of the stream type may be retained but the majority of the features are highly modified.
Poor	Reach in a degraded condition due to extensive erosion or modified due to land use practices changing the form of the stream type.

My assessment of the geomorphic condition of the site specific reaches is presented below. The site numbers refer to the numbers on the map shown above (Figure 6).

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 44	Property 32 in the Sunbury South PSP	Alluvial discontinuous intact valley fill	Intact	Natural, with no visible modifications to geomorphology.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representativeness
Site 71	Property 30 in the Sunbury South PSP	Alluvial discontinuous intact valley fill	Intact	Natural, with no visible modifications to geomorphology.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 87	Property 2 in the Lancefield Road PSP	Alluvial discontinuous intact valley fill	Intact	Natural, with very minor erosion of tracks by stock.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 99	Property 2 in the Lancefield Road PSP	Alluvial discontinuous valley fill	Moderate	Area where valley fill was previously identified appears to have been extensively ploughed and planted with crops since the previous assessment. New farm tracks were also present. As a result the valley fill feature was very hard to discern.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 127	Property 23 in the Lancefield Road PSP	Alluvial discontinuous intact valley fill	Good	Natural physical form, but adjacent fields had been ploughed to the very edge of the waterway.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

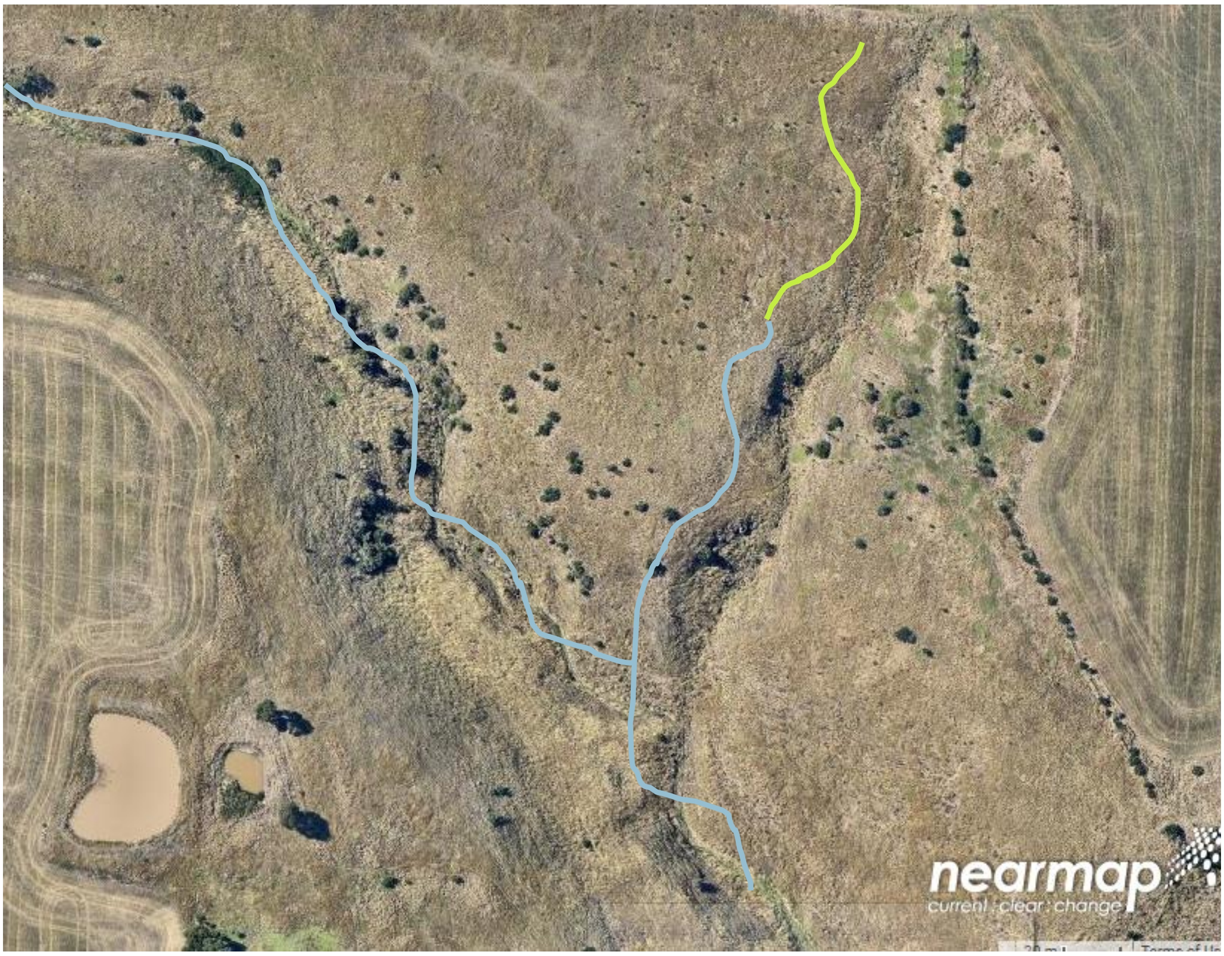
Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 150	Property 23 in the Lancefield Road PSP	Alluvial discontinuous intact valley fill	Intact	Natural, with no visible modifications to geomorphology.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.
		Chain of ponds	Good	Some evidence of erosion, but retain key elements of the geomorphology of this stream type.	Less than 0.5% of waterways in the Port Phillip and Westernport region are classified as chain of ponds, so they are extremely rare.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 16	Property 68 in the Sunbury South PSP	Alluvial discontinuous intact valley fill	Good	Natural, with no visible modifications to geomorphology.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 20	Property 12R in the Sunbury South PSP	Alluvial discontinuous intact valley fill	Intact	Natural, with no visible modifications to geomorphology.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 117	Property 23 in the Lancefield Road PSP	Confined discontinuous	Good	Natural, with minor impacts from agricultural activity.	Confined discontinuous channels are make up less than 5% of total waterway length in the Sunbury study area, so are considered rare. This site is representative of waterways of this type in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 118	Property 24 in the Lancefield Road PSP	Alluvial discontinuous intact valley fill	Good	Natural, with minor impacts from agricultural activity.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.



Legend
Site 118
Waterway

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 129	Property 24 in the Lancefield Road PSP	Confined discontinuous	Good	Natural, with minor impacts from agricultural activity.	Confined discontinuous channels are make up less than 5% of total waterway length in the Sunbury study area, so are considered rare. This site is representative of waterways of this type in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 130	Property 8 in the Lancefield Road PSP	Alluvial discontinuous intact valley fill	Intact	Natural, with no visible modifications to geomorphology.	Intact valley fills make up 5% of the total length of waterway in the Port Phillip and Westernport region, so they are considered rare. This site is representative of waterways in this region.

Site	Location	Stream type	Geomorphic condition	Naturalness	Rarity/representation
Site 147	Properties 19 and 23 in the Lancefield Road PSP	Confined discontinuous	Good	Natural, with minor impacts from agricultural activity.	Confined discontinuous channels are make up less than 5% of total waterway length in the Sunbury study area, so are considered rare. This site is representative of waterways of this type in this region.

5. Key findings

Waterway condition and value

- The landscape in the growth areas around Sunbury presents significant challenges to the development of sustainable urban drainage systems.
- The landscape factors that influence urban drainage are:
    - The steep and erodible nature of the existing drainage lines;
    - The presence of significant geomorphic values in some waterways; and
    - The active erosion occurring in some waterways
- The geomorphic condition of waterways across the study area is variable. There are several intact, natural and rare stream types in the study area, including alluvial valley fills, confined discontinuous waterways and chain of ponds stream types. These stream types generally have high to extremely high geomorphic value due to their condition (typically good to intact) and the rarity of the stream type.
- Many of the waterways in the study area are in a poor to moderate condition and consequently have low geomorphic values due to past and present land uses, most notably urban growth, grazing, cropping and on-line dams. The numerous on-line farm dams in the tributaries attenuate flow and interrupt sediment transport, limiting longitudinal connectivity of geomorphic processes.
- 13 site specific waterway assessments were undertaken to evaluate the geomorphic condition using criteria developed by Melbourne Water. The site specific assessments confirmed the geomorphic condition as previously assessed, with the exception of one waterway that appeared to have been significantly impacted by ploughing.

Risk of erosion and managing that risk

- If erosion is triggered or accelerated it is likely to impact natural and built assets, both onsite and downstream.
- The steepness of the landscape means many of the waterways are steep and inaccessible for maintenance and rehabilitation, so erosion that is triggered in these waterways is likely to be difficult and costly to remediate and manage.
- It is unlikely that standard best practice stormwater management will be sufficient to manage the risk of increased erosion from stormwater runoff in all tributary waterways following urban development.
- A flow management strategy is needed that explicitly recognises the risks of accelerated erosion following urbanisation and provides for its mitigation.
- The erosion potential and volumetric analysis methods are fit-for-purpose for quantifying the risk of erosion and informing the design of DSSs.