Melbourne Water

GEOMORPHOLOGIC ASSESSMENT

LITTLE STRINGYBARK CREEK

EarthTech

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Acknowledgements

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- Sharyn Rossrakesh and Rob Ferguson from Melbourne Water for fieldwork assistance and report review
- James Grove, Tony Ladson and Chris Walsh from Monash University for technical input and report review

1. Introduction

Earth Tech Engineering (Earth Tech) has been commissioned by Melbourne Water to undertake a geomorphic assessment of Little Stringybark Creek in Mt Evelyn, Victoria. This report details the approach to and outcomes of that assessment.

1.1 BACKGROUND

Little Stringybark Creek, a tributary of the Yarra River, is located in Mt Evelyn, one of the outer eastern suburbs of the Melbourne metropolitan area. Much of the 450ha catchment has been cleared. Past land uses have included agriculture. While most of the catchment remains rural, a significant portion of the upper catchment has been developed for urban housing.

Figure 1-1 Location of Mt Evelyn and the Little Stringybark Creek catchment in relation to Melbourne, Victoria (Source: http://www.street-directory.com.au/sd_new/mapsearch.cgi, accessed 21 April, 2006)

The creek consists of a single continuous channel. However there is some evidence to suggest that this single channel form is the result of channel incision post European settlement.

There is growing body of evidence on the impacts of urbanisation on stream systems. These impacts can be both direct, such as litter, channelisation, pollutant runoff and more indirect, associated with changes in the hydrologic regime. Changes in the hydrologic regime can have an adverse impact on stream ecology and geomorphology. The impacts on stream ecology have been linked to the degree of connectivity between impervious surfaces (roads, driveways and roof area) and the waterway. Whilst not yet investigated, it is believed that a similar relationship may exist between connectivity and geomorphic condition.

Water sensitive urban design (WSUD) is being promoted in Melbourne and elsewhere as a means of improving runoff quality from urban areas. A number of WSUD techniques involve the disconnection of impervious surfaces from creek systems. Monash University, propose to retrofit WSUD based disconnection of impervious urban surfaces from Little Stringybark Creek and monitor changes to the instream ecology. This experiment is proposed as a means of testing the hypothesis that the introduction of WSUD can have a positive impact on instream ecology in this catchment.

This geomorphic investigation, the subject of this report, has been commissioned by Melbourne Water to complement the Monash University experiment by identifying the geomorphic change that is likely to be associated with the proposed introduction of WSUD. The geomorphic investigation has been undertaken in three stages comprising data collection, analysis and recommendations.

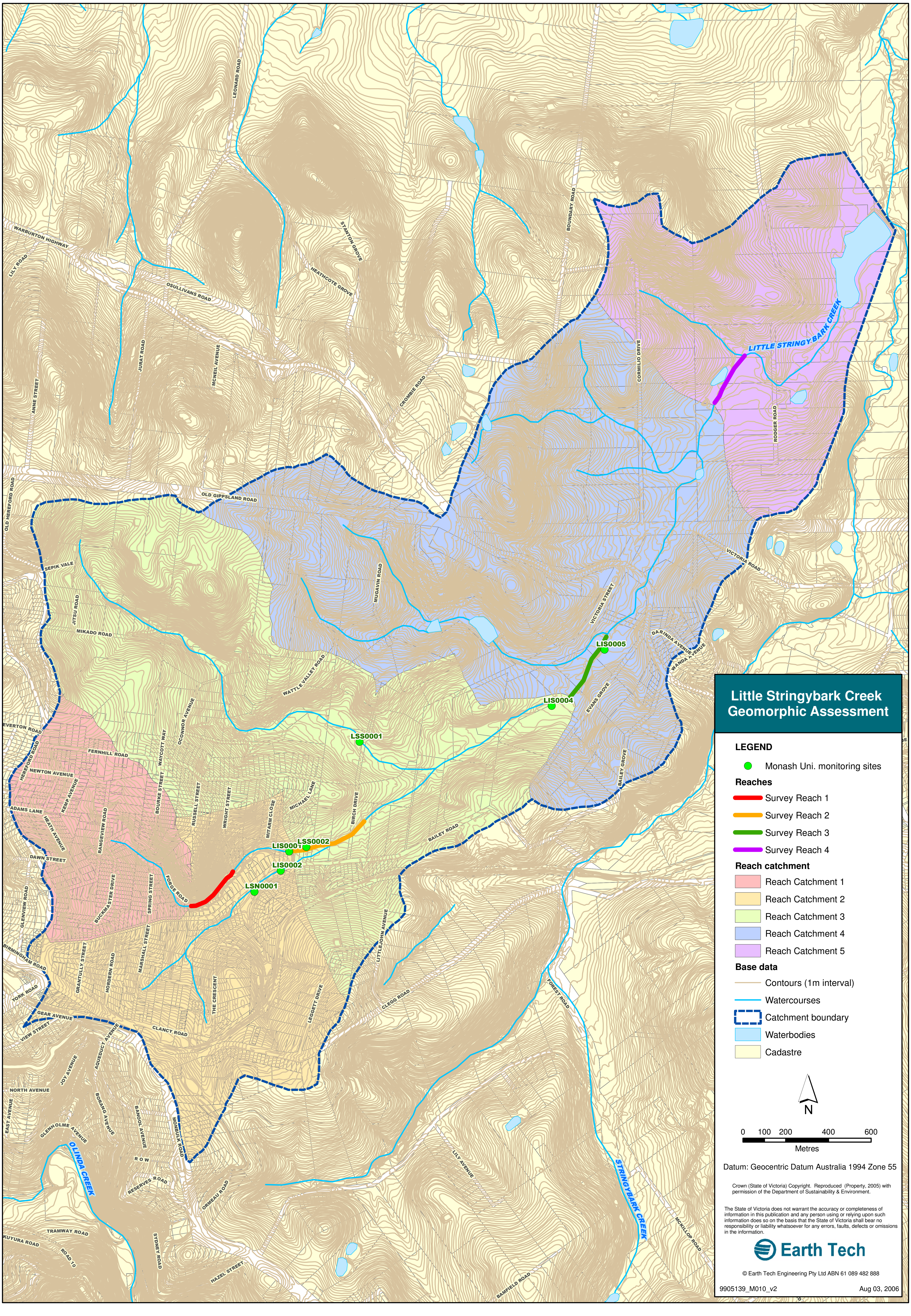
1.2 GEOGRAPHIC EXTENT OF INVESTIGATIONS

This investigation includes Little Stringybark Creek from Mt Evelyn to Stringybark Creek. The Little Stringybark Creek and the catchment and study area are shown in Figure 1-2

1.3 STUDY OBJECTIVES

The investigations have been based on addressing the following questions:

- Have the changes to inflows that have arisen as a result of urbanisation of the Little Stringybark Creek catchment significantly altered the channel from its original, pre-European form?
- Will retrofitting the catchment with WSUD have an impact on the current channel morphology?
- Will the physical stream processes impact on the ecological experiment and monitoring?
- Is the energy expenditure approach to assessment of the impact of urbanisation on channel form a valid analysis technique for catchments in Melbourne?
- What monitoring techniques are recommended for assessing geomorphic change in Little Stringybark Creek?



Little Stringybark Creek Geomorphic Assessment

LEGEND

● Monash Uni. monitoring sites

Reaches

- Survey Reach 1
- Survey Reach 2
- Survey Reach 3
- Survey Reach 4

Reach catchment

- 🟥 Reach Catchment 1
- 🟧 Reach Catchment 2
- 🟩 Reach Catchment 3
- 🟦 Reach Catchment 4
- 🟪 Reach Catchment 5

Base data

- Contours (1m interval)
- Watercourses
- Catchment boundary
- Waterbodies
- Cadastre

Datum: Geocentric Datum Australia 1994 Zone 55

Earth Tech

9905139_M010_v2 Aug 03, 2006

1.4 SCOPE

Following discussion with Melbourne Water's nominated project manager the project scope included the following:

- Characterise the catchment geology, landuse change, vegetation, terrain, rainfall, catchment area
- Characterise channel morphology pre and post catchment disturbance channel shape, size, vegetation, slopes, meander patterns, floodplain characteristics and substrate composition
- Describe channel forming processes pre and post catchment disturbance
- Describe the influence of different land uses on the physical form of the channel e.g. rural land-use stressors such as stock access and degraded riparian vegetation versus urban impacts in headwaters of the catchment.
- Characterise the stream hydrology – using real and/or modelled flows and diversion impacts
- Document channel modifications and erosion control works that have occurred in the past and an indication of their success
- Conduct hydraulic analysis to assess shear stress, stream power and bank-full discharges
- If the stream condition and trajectory is identified as not favourable, recommend works along the waterway to aid the recovery process (but will not conflict with the retrofit monitoring).

1.5 APPROACH

The approach adopted for addressing the study objectives has included the following:

Literature Review

A literature review was undertaken to identify and report on national and international research on the impact of urbanisation on channel morphology. This was undertaken to gain a broad context and understanding of the potential processes occurring in Little Stringybark Creek.

In addition, literature on the catchment geology soils and vegetation, and the historic development of the catchment was identified and reviewed. This information included historic literature, local government data, mapping and aerial photography.

Field Inspection

A 2-day field inspection was undertaken using Thorne's stream reconnaissance surveys (Thorne, 1998). Observations of channel width, depth, bed and bank material, connection with floodplain and points of incision were identified for the entire length of stream. Summary outcomes of the field inspection are provided in this report. Detailed field sheets can be found in Appendix D.

Map Overlays

Maps and aerial photography of the stream, spanning a period of approximately 100 years, have been reviewed. A defined stream course has been identified from these and the length of defined stream compared.

Survey

Stream bed longitudinal and cross sectional survey has been undertaken. Project limitations and vegetation densities prevented the complete survey of the streambed longitudinal profile. Survey has been limited to one representative site for each of four stream reaches

Hydraulic Model and Analysis

A hydraulic model has been developed for each representative site based on the stream survey. The hydraulic model has been used to assess the relative stability of the system and as input to the Energy Expenditure Analysis (refer below)

MUSIC Hydrologic model

A MUSIC hydrologic model has been developed for the catchment by Monash University. This model was reviewed, simplified and extended to enable creation of flow regimes for a range of catchment development scenarios. These are used as input to the Energy Expenditure analysis.

Total and Excess Energy Expenditure Analysis

A total and excess energy expenditure analysis was undertaken to provide a quantitative measure of hydraulic/geomorphic change due to altered hydrologic conditions. For the purpose of this investigation three development scenarios were assessed:

1. Current flow conditions
2. Pre-development flow conditions
3. WSUD flow conditions

The Energy Expenditure Analysis approach is based on combining the hydrologic regimes for each development scenario with an hydraulic analysis of the subject reach of stream to identify the occurrence and duration of events that have the capacity to do “work” on the channel bed and banks. The term work refers to the capacity of the flowing water to erode or transport sediment.

In this instance the analysis has been undertaken to identify whether, and the extent to which, any changes in the hydrologic regime caused by urbanisation and potentially the WSUD, have the capacity to change the work done on the channel bed and banks. Such an analysis can assist to identify whether changes in the catchment hydrology can increase or decrease the rates of erosion and or sediment deposition in the reach and thereby whether such changes are likely to impact on stream shape and form.

Details of this approach can be found in Appendix A.

1.6 REPORT STRUCTURE

This report details the findings of all three stages of the investigation, and is structured as follows:

Section 1 Introduction and Study Objectives and Approach

Section 2 Results of Investigations

Outlines the results of the investigations undertaken for this project

Section 3 Past and Present Stream Conditions and Trajectory

This section includes a narrative description of past and present stream conditions and the likely trajectory for the stream under current management and with the introduction of the proposed WSUD experiment .

Section 4 Conclusions and Management Implications

Conclusions and management implications respond to the study objective questions.

Appendices

Detailed review and analyses can be found in the Appendices:

Appendix A	Excess Energy Expenditure
Appendix B	Assessment of Impervious Areas
Appendix C	Longitudinal Sections of Study Reaches
Appendix D	Field Inspection Sheets

2. Results of Investigations

2.1 REVIEW OF LITERATURE ON CHANNEL CHANGE

In order to understand the consequences of retrofitting a catchment to change its hydrological regime, the mechanics of how the river erodes and aggrades must first be understood. The effect of urbanisation on these processes must then be considered so that stormwater influences can be placed in context with current day processes.

Riverbank Erosion Processes

Most stream channels are in a state of dynamic equilibrium. Natural channels erode and aggrade, however, in a reach that has attained dynamic equilibrium, there is unlikely to be any substantial change in average channel dimensions unless there is a change in the discharge or sediment budget.

Thorne (1993) describes three states the riverbank may be in based on the condition of the bank toe. Thorne considered whether the bank is aggrading, in dynamic equilibrium, or eroding:

1. **Impeded Removal**

Inputs of sediment, from stream and bank, are higher than the volume being removed. Net accumulation results, which lowers the bank angle and height.

2. **Unimpeded Removal**

Inputs of sediment are balanced with outputs of sediment. This is therefore a state of equilibrium. The bank may retreat by parallel retreat if the sediment load at the bank base is zero.

3. **Excess Basal Capacity**

Inputs of sediment are lower than the outputs. Basal retreat and lowering occurs, increasing the bank angle and height. The retreat results in increased bank erosion due to instabilities.

The erosion and aggradation mechanisms that contribute to these three states are outlined in the following section.

Erosion

There are 3 main forms of erosion in a channel:

1. **Sub-aerial Erosion and Preparation**

These processes take place without the direct input of the stream water and therefore may dominate when the river is at low flow as there is greater surface area of sediment available. The preparation processes in place on the sediment may reduce its shear strength and make it more erodible. These preparation processes may also directly erode the bank material. The main forms of riverbank erosion may be classed as Sub-aerial Erosion and Preparation:

- Cryergic Processes: including needle ice growth; ice lens growth; thermo-erosional niching and snow melt;

- Processes associated with pore water, including desiccation; slaking; piping and sapping; and gravel lens washout;
- Rainsplash processes: including raindrop impact; rilling; and gullying.

2. Fluvial Entrainment

The assumption or simplification often made in literature is that riverbanks erode solely by scour (otherwise termed fluvial entrainment). Fluvial entrainment is the direct removal/detachment of the sediment from the bank by the shear applied to the surface. The shear stress applied by the fluid needs to exceed the shear strength of the bank material. In the case of non-cohesive banks, empirical relationships have been derived to calculate the shear stress needed to mobilize the sediment. It is difficult to define a shear strength for cohesive material. Differing clay, organic, vegetation roots, and stream water chemistry all produce variability in the material strength. Experimental results for cohesive material of different shear strengths are shown in Figure 2-1.

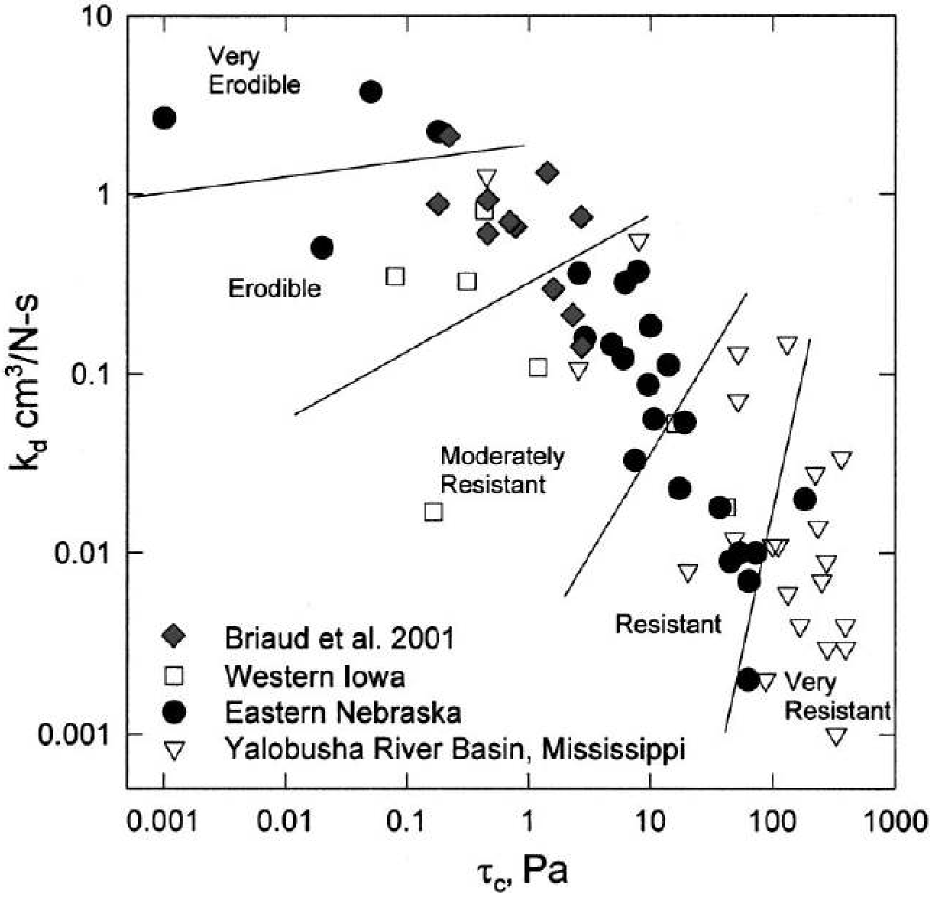


Figure 2-1 Experimentally derived relationship between shear stress (τ_c, x-axis) and the erodibility co-efficient of bed material (k_d, y-axis), from cohesive streambed tests (Hanson and Simon, 2001).

Cohesive sediments, usually clay sized material (i.e. a particle diameter of <0.004mm), have electromechanical forces that bind the particles together. When subjected to a stress, such as from boundary fluid forces, the particles may not be removed individually but as aggregates. These particle clusters will have a proportion of void space within their structure, making them less dense than a single unit of quartz. This results in a lower force being needed to lift them off the bed/bank than a solid particle of the same dimensions (Richards, 1982; Lawler et al., 1997). The past conditions that the sediment has been subjected to will alter the degree of cohesion, which makes exact prediction of shear stresses needed for entrainment difficult. According to Grissinger, (1982, p.276) the stability of the cohesive sediment may be affected by:

- Mean particle size;
- Clay and organic matter content;
- Type of clay;
- Bulk density or void ratio;
- Solution phase/exchangeable ionic strength and composition.

3. Mass Failure

The downslope movement of a unit of sediment (or rock) due to the internal strength becoming lower than gravitationally induced stresses is known as mass movement/failure/wasting. The failures are not directly caused by ice, water and air but are frequently aided by these variables (Selby, 1982). Internal shear strengths of the sediment are usually related to the cohesion and friction of the sediment. Undercutting of the bank toe, seepage, and high pore water pressures will all reduce the soil strength.

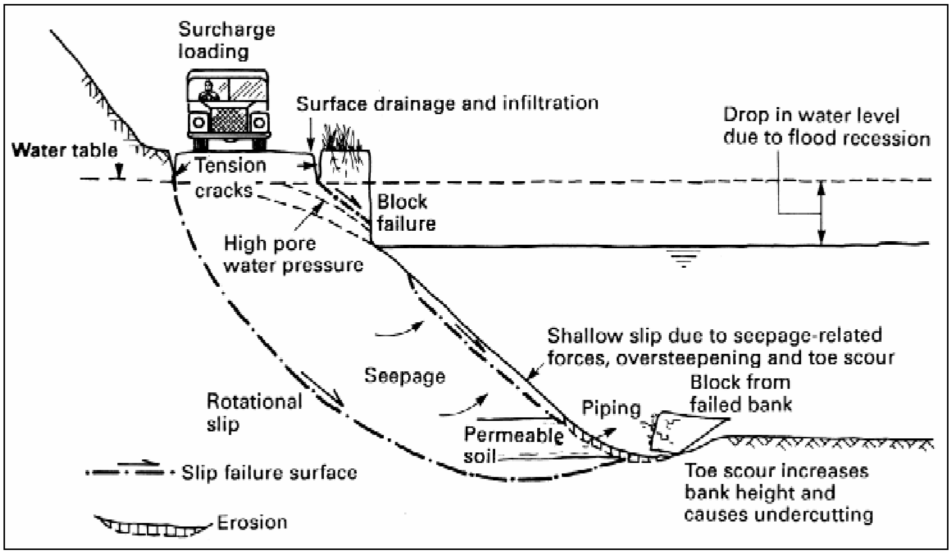


Figure 2-2 Channel cross-section illustrating processes responsible for mass failure (Hemphill and Bramley, 1989, p. 27).

Cantilever Failures

The undercutting of a riverbank by the removal of basal material can lead to instabilities in the upper bank profile. The mechanism often cited is the removal of basal gravel by entrainment, leaving an unsupported cohesive sediment layer (Thorne and Lewin, 1979; Rinaldi and Casagli, 1999). The upper layer of sediment may be more resistant to erosion because of a higher shear strength, due to the cohesion of fine sediment or the root strength from vegetation (Sidle, 1991). Lower non-cohesive sediment may lose strength by winnowing of interstitial material, reducing the angle of internal friction (Carson, 1971). The potential for entrainment may also be higher in the basal area due to the increased number of flows that encroach on the lower bank, relative to the upper bank (Thorne and Tovey, 1981; Hickin and Nanson, 1984).

The bank does not necessarily need to be composite in nature for cantilever development. Abam (1997) found that in the Niger Delta the differing moisture regimes in the bank profile produced heterogeneity in homogenous sediment. The wetting and drying sequence of lower layers increased pore water pressures and allowed desiccation processes to occur at depth, whilst on the surface the vegetation bound the soil.

Planar Failures

A planar failure plane is often found in steep (>60^o) relatively low banks (Osman and Thorne, 1988) (Figure 2-3).

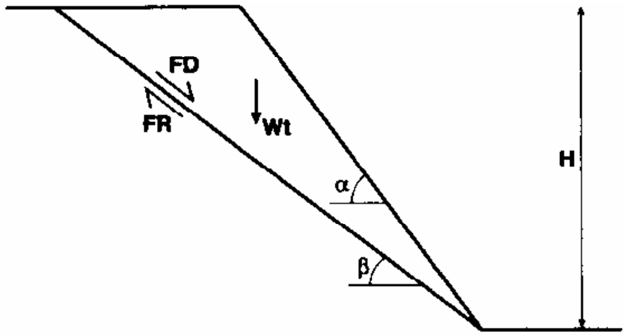


Figure 2-3 Idealised bank profile used in simplified bank stability analyses. Symbols: β = failure plane angle, α = uneroded bank angle, W_t = weight of failure block, FD = driving force, FR = resisting force, H = total bank height (Darby et al., 2000).

Pop-out or Drawdown Failures

Seepage concentrated at the base of a steep bank may result in a failure plane at the bank base. Rather than removing individual particles of sediment a block, or blocks, of material are eroded. The increased cohesion of the upper bank sediment, basal position of a single sandy preferential flow path, or elevated seepage potential due to a higher bank and/or rapidly receding hydrograph falling limb, may all cause a mass failure as opposed to piping or sapping.

An alcove shaped cavity remains in the bank after the failure has occurred, which is a distinctive means of identification (Thorne, 1993). The upper soil is then left overhanging, probably due to the greater shearing strength provided by the root zone. This unsupported material then has the potential to fail as a cantilever failure.

Rotational Failures

Physically a rotational failure can often be identified in the field by the deep seated, curved failure scars; back-tilted towards the intact bank failure blocks; and arcuate shape of the intact bank line behind the failure mass (Thorne, 1993). High, gently angled (<60^o) slopes are needed in a cohesive material in order to attain the shear stresses need to initiate the failure. Cohesive materials, such as clay, have increasing shear stresses with depth that can become higher than the shear strength. The frictional forces in non-cohesive sediment increase with depth, and so limit the ability for a failure plane to develop.

Sediment Flows

There is a paucity of work identifying sediment flows as a mechanism of bank erosion. This may be because they form near larger failures, such as rotational failures, which are more prominent.

There are three different flow typologies:

1. debris flow;
2. earth flow, and;
3. mud flow.

These categories correspond to the liquefaction of coarse debris, fine grained soil, and silt and clay respectively (Selby, 1982). The loss of coherence of the soil to cause the flow may be facilitated by:

- Soils remoulded after landslide disturbance;
- Presence of clays with high liquid limits in regions of high rainfall;
- Presence of clays with low liquid limits in regions of low rainfall;
- Soils with relatively open fabrics, due to flocculation during deposition or thawing of soil ice;
- Collapse of material at the head or sides of the failure, loading sediment beneath and creating high pore pressures.

Aggradation

In a meandering river system the erosion takes place on the outer bend of the meander where shear stresses are highest, and deposition of material takes place on the inner bend, the point bar.

Geomorphic Effects of Urbanisation

Initial work by Wolman (1967) described the geomorphic effects of urbanisation. The model he produced of the channel response to urban areas may be summarized as:

- Construction work on urban areas increases the sediment supply to the channel, this is a response to the removal of vegetation and bare soil left open for long periods to rainfall;
- The rapid increase in sediment causes aggradation in the channel, making it inefficient to carry its discharge load;
- With an increase in impervious area the sediment budget of the catchment changes, more flow enters the channel due to reduced evapotranspiration and increased runoff. The availability of sediment decreases from the urban areas, and so the flow becomes more erosive;
- The channel widens to accommodate the increased discharges, and then incises.

Unknown in the model suggested by Wolman (Figure 2-4) is whether the channel then attains a new dynamic equilibrium state, and if so how long it takes to reach it. The time that the channel takes to respond to the changes sediment and discharge are also not clearly articulated.

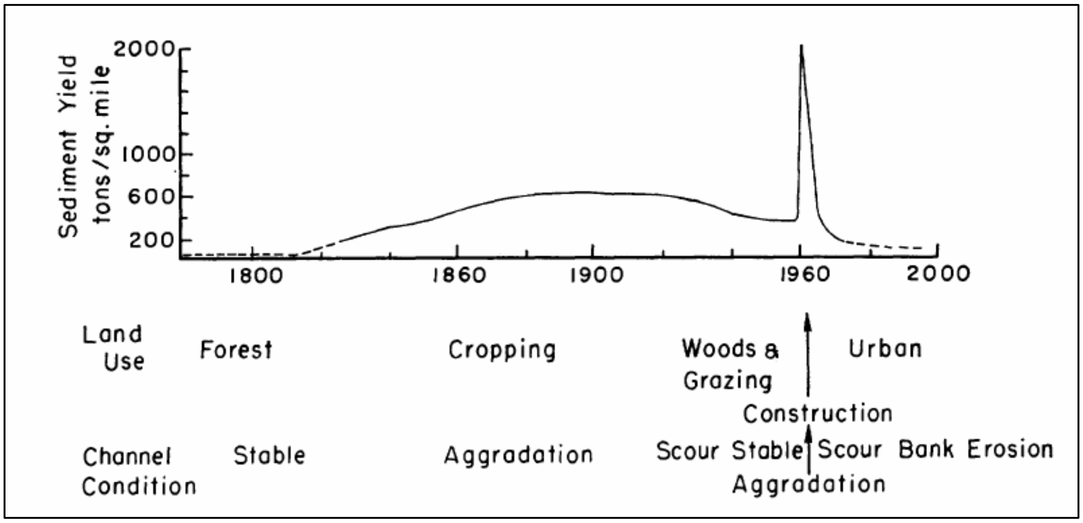


Figure 2-4 Sediment yield and channel conditions associated with catchment development (Wolman, 1967)

Other work has identified changes in the characteristics of the catchment and channel. Most of these changes are a consequence of the anthropogenic desire to remove water as quickly as possible from a natural area to reduce flooding risks.

1. Increasing urbanisation often decreases the drainage density as a consequence of piping and drainage works. The drainage works often result in faster velocities and greater shear stress in the channel;
2. Baseflow may decrease in the channel due to less groundwater recharge in urban areas and a greater amount of surface runoff-piped flow. Conversely the baseflow may increase with more imported water coming into the catchment. Watering gardens and pipe leakage may increase the groundwater recharge and elevate the baseflow.
3. Channels are often straightened and instream large wood removed. This reduces the lag time on the hydrograph, and increases the peak stage. Keller (1976) describes the modifications as:
    a. Widening, deepening and straightening;
    b. Clearing and snagging;
    c. Diking;
    d. Bank stabilisation
4. Increased shear stresses on the bed lead to greater competency to entrain sediment, the incision caused may reduce bedform diversity, resulting in a plane bed.
5. Keller (1976) states that manmade channels tend to have more riffle environments and high pool velocities;
6. Flood management, to manage the risk, the stream can be channelised with artificial levees, reducing the flood storage on the floodplain.
7. Hammer (1972) found that effect of impervious areas associated with detached houses was small unless the gutter downspouts connect directly with the storm

sewers. The effect of street and sidewalk area is large if the streets are sewered but is small otherwise.

8. Henshaw and Booth (2000) found that the density of urbanisation was more important at predicting change than the amount of impervious areas.
9. Morisawa (1982) concluded that there was a delayed response to development and increased runoff until 25% of the area of the watershed has more than 5% impermeability. The initial impact of increased runoff from urbanisation is increased velocity. When the velocity is increased enough for the stream power to overcome the resistance of the bed/banks enlargement takes place.
10. Keller (1976) hypothesizes that channel recovery is likely to be faster geomorphologically than biologically.

There is general agreement in the literature that urbanisation results in an increase in channel dimension. The enlargement ratio from pre-development to current conditions can be used to assess the impact of urbanisation. The enlargement ratio for Southern California is shown in Figure 2-5.

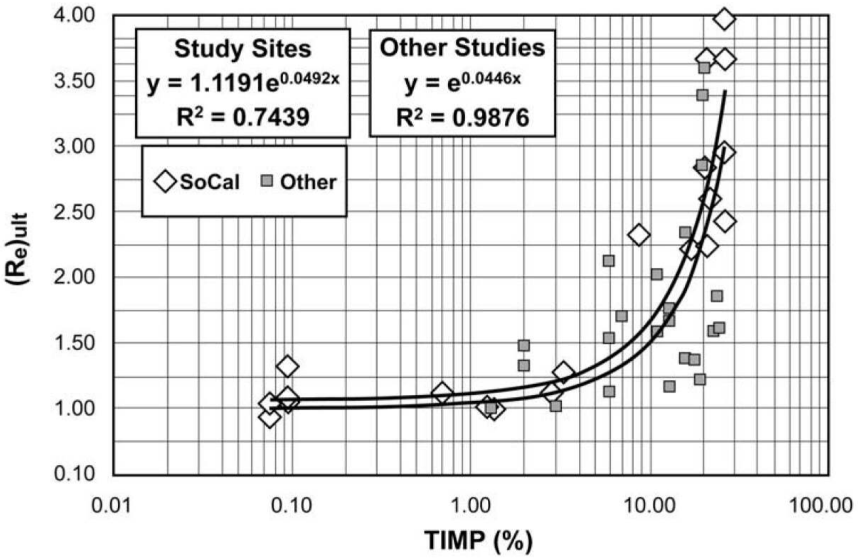


Figure 2-5 Enlargement Curve for Southern California (SoCal). Upper curve and data points are for southern Californian channels. Lower curve is based on data from other locations in Northern America. (Re)ult = Enlargement ratio; TIMP (%) = Total Impervious Area as a percentage of the whole area. (Coleman et al., 2005)

The degree of urbanisation in a catchment can be represented by the degree of effective impervious area within the catchment. Walsh et al (2005) class an effective impervious area as any area that drains, via a stormwater pipe, into the stream. Given the geomorphic consequences of urbanisation as detailed above, the proportion of effective impervious area in a catchment is closely related to, and may therefore be used to predict, the degree of geomorphic change following urbanisation. Whilst a useful indicator of likely geomorphic change, solely using the measure of effectiveness impervious area incorporates, but does not highlight, the effect that the processes of decreased infiltration, increased surface runoff and increased flow stages may have on channel morphology and sediment budget.

MacRae and Rowney (1992) (in MacRae, 1996) demonstrate that under urban conditions the absolute maximum on the effective work curve increased in magnitude and shifted to flows of ½ year ARI to 1½ year ARI. This means that rather than the traditional 1½ year ARI to 2 year ARI bankfull flow being the geomorphically dominant flow there is a more frequent set of flows that are competent enough to mobilise bed and bank sediment.

These studies by McRae found that channel change and enlargement resulting from catchment urbanisation can be attributed to an increase in the duration and occurrence of events that have the capacity to “do work” on the weakest of the bed and bank material. The work of McRae and others has lead to the development and implementation of controls on urban development in a number of regions of North America that seek to prevent an increase in the occurrence and duration of events that have the capacity to “do work” on bed and bank material. These regions include the Santa Clara Valley and Washington State in the USA and Ontario in Canada. For the purpose of this report, this approach to the analysis and management of the hydrologic regime is known as a excess energy expenditure assessment. The controls on urban development and the target flow range within which the hydrologic regime should not be modified are discussed in Earth Tech 2006.

Fundamental to the approach are the analyses of pre and post urban development hydrology and the identification of the critical shear stress for the mobilisation of streambed and bank sediment.

Ecological Impact of Urbanisation

Work by Walsh et al (2005) has suggested that increasing the connection of impervious surfaces, such as rooftops and roads, to stream channels (i.e. an increase in effective impervious area) will result in a reduction in the ecological health of the stream (measured using SIGNAL Scores (Chessman, 1995)). Figure 2-6 shows the decreasing SIGNAL score with increasing connectivity, with a stronger relationship between Effective Imperviousness and the number of pipe connections to the stream than the Total Imperviousness.

The ecological impact of urbanisation integrates both the physical and chemical changes within the catchment.

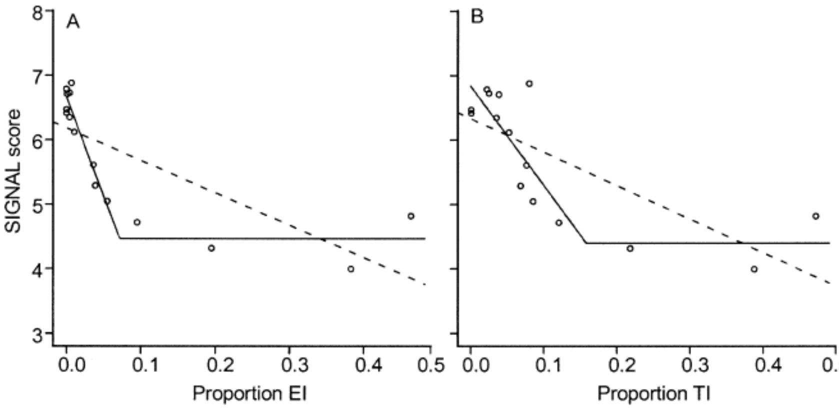


Figure 2-6 SIGNAL score for macroinvertebrates in edge habitats plotted against effective imperviousness (EI) (A) and total imperviousness (TI) as an illustration of the 4 models assessed for goodness of fit. Solid lines are piecewise regressions and dashed lines are linear regressions. (Walsh, 2005, p. 698)

2.2 REVIEW OF CATCHMENT LITERATURE

Geology

The upstream part of the Little Stringybark Creek catchment is comprised of Mt Evelyn Rhyodacite (Figure 2-7). This deposit was formed by pyroclastic flows (Nicholls, 1988) and little lava was deposited within the unit as it was originally deposited as magma fragments (pumice), country rock (lithic fragments), and volcanic glass (shards). This mass of material was welded and deformed under heat and pressure. In the lower catchment the exposure contains two thin rhyolitic ignimbrite units, a rhyodacite lava and lenses of bedded siltstone and sandstones, presumably lake deposits.

Downstream of the Mt Evelyn Rhyodacite, Little Stringybark Creek flows along the junction between Lower Devonian Siltstone, which contains some Sandstone layers and local limestone lenses, and the Upper Devonian Coldstream Rhyodacite. The Lilydale Hills Syncline controls the stratigraphy. The lower valley is confined between two outcrops of Coldstream Rhyodacite. This has led to the sharp eastward meander of the creek near Roger Rd. The geology of the area is shown in Figure 2-7.

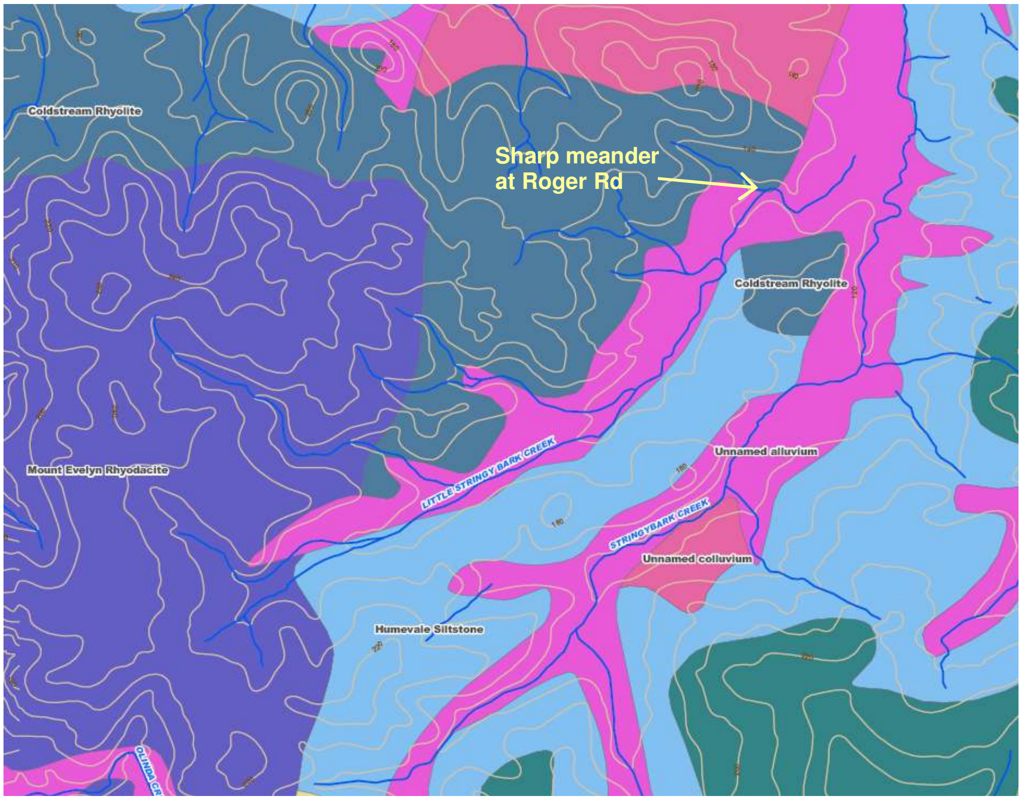


Figure 2-7 Geology of Little Stringybark Creek (source: Geoscience Australia, www.ga.gov.au, not to scale)

The geological structure has resulted in a relatively steep catchment. The overall stream pattern is controlled by the boundaries between the different geological structures. The igneous flows have resulted in a wide valley cross-section with little confinement and wide floodplain, apart from in the very headwaters of the catchment.

Soils

Most of the soils of the Mt Evelyn area have developed on the rhyodacite. This light grey loam is friable and poor in nutrients. Another soil type in the region is alluvial and restricted to areas near the watercourse. This dark grey to brown loam has deep organic rich material and a tendency to be clayey. The red loam (mountain soil) is found generally in the eastern and south-eastern parts of Mt. Evelyn and derives from the old basalt lava flows. It is well-structured and high in organic material (Newton et al., 1997, G. Hoxley, 1988).

Runoff from the catchment will contribute a mix of sand, silt and clay derived from the loam and clay soils to the stream channel. The relatively wide shallow floodplain for most of the catchment, will result in poor connection of the hillslopes to the channel, with most of the sediment eroded by surficial flow being redeposited further downstream. This will result in the finer fraction clay being the dominant sediment to enter the channel.

Vegetation

The Ecological Vegetation Class (EVC) produced by the Department of Sustainability and Environment (http://www.affa.gov.au/content/output.cfm?ObjectID=D2C48F86-BA1A-11A1-A2200060B0A02732, accessed 19/04/06) provides information on the vegetation that may existed before European settlement in the 1750's. The database also has a current map of the vegetation classes across Victoria.

For the 1750's data the EVC uses a model to predict the distribution of different vegetation types that is based on:

- aspect, elevation, gradient, geology (eg. age and type-limestone, sandstone, granodiorite etc. and composition);
- soils (eg. origin, clay content, depth, organic content and drainage characteristics, hard pans);
- landform;
- rainfall (eg. total rainfall, effective rainfall, seasonality of rainfall);
- water relations (eg. level and frequency of inundation, depth to water table);
- salinity (eg. saline, brackish, freshwater); and
- broad climatic zone (eg. maritime, continental, warm temperate, cool temperate, montane, sub-alpine);

The details for the pre-1750's EVC map for Little Stringybark creek are shown in Table 2-1.

Table 2-1 The position of different EVC types throughout the Little Stringybark riparian zone from the pre1750's mapping.

Position in Catchment	EVC		EVC Sub-group	EVC Name	Group Name
Upper	159	▨	16.2	Clay Heathland/Wet Heathland/Riparian Scrub Mosaic	Heathland (Not well drained)
Mid-Upper	59	▨	8.1	Riparian Thicket	Riparian Scrubs or Swampy Scrubs and Woodlands
Mid	126	▦	8.1	Swampy Riparian Complex	Riparian Scrubs or Swampy Scrubs and Woodlands
Mid-Lower	18	■	8.2	Riparian Forest	Riparian Scrubs or Swampy Scrubs and Woodlands
Tributaries	17	▩	8.1	Riparian Scrub/Swampy Riparian Woodland Complex	Riparian Scrubs or Swampy Scrubs and Woodlands

The current and pre-European EVC state of the catchment is shown in Figure 2-8.

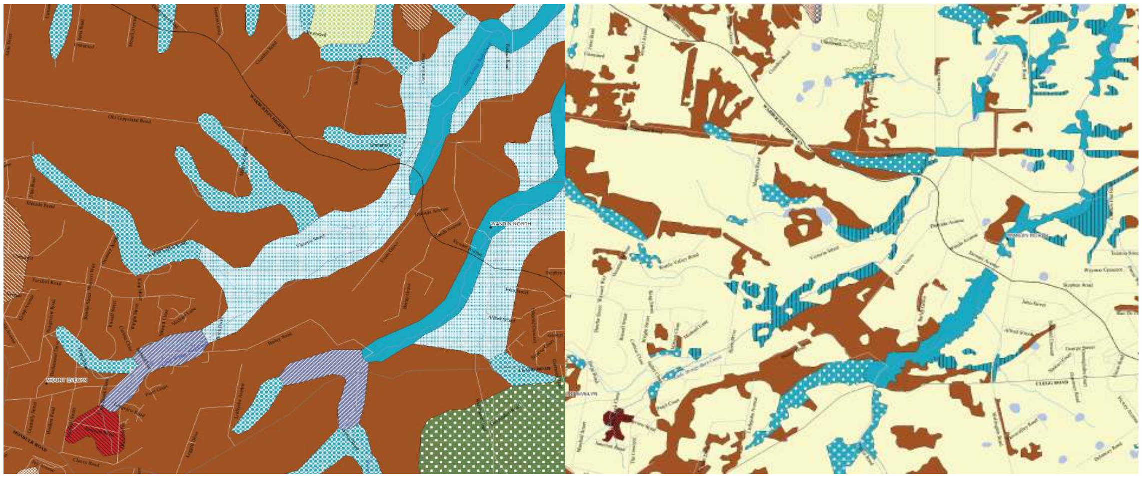


Figure 2-8 Pre 1750s (left) and current (right) EVC extent for Little Stringybark Creek. The key to EVC shadings is shown below.

	EVC	EVC Name		EVC	EVC Name
▨	159	Clay Heathland/ Wet Heathland / Riparian Scrub Mosaic	▩	8	Wet Heathland
▨	59	Riparian Thicket	■	191	Riparian Scrub
▦	126	Swampy Riparian Complex	▥	937	Swampy Woodland
▩	17	Riparian Scrub/Swampy Riparian Woodland Complex	■	18	Riparian Forest
■	16	Lowland Forest	▩	23	Herb-rich Foothill Forest
▨	128	Grassy Forest	■	47	Valley Grassy Forest
▩	22	Grassy Dry Forest			

The current catchment is very patchy with scarce patches of EVC subgroup 8.1 (Table 2-1) along the main trunk of the stream, and a small area of heathland (EVC subgroup 16.2) in the upper catchment.

The two EVC maps indicates a change from a pre-1750's heath-swamp type environment to a more defined current day channel. The pre-1750's environment is unlikely to have been a large and continuous wetland, rather sections of wetland in local low gradient areas connected by more defined channels. This vegetation structure change is largely a consequence of the landuse changes within the catchment since European Settlement and may also have been influenced by a change in climate.

Landscape Change

Little historical information is directly available for Little Stringybark Creek. However land use history has been well documented for the Dandenong region as a whole, as has the urbanisation of Mt Evelyn in the upstream part of the catchment.

The 8 stages of human occupation for the region, described by Winzenried (1993), are:

1. Aboriginal Occupation (to ~1850);

Early descriptions of the area include 'very scrubby stringybark ranges', 'very barren, scrubby, heavily wooded forest', 'barren densely wooded range', 'barren stringybark forest ranges'. Barren probably denoted the lack of gold, pasture and luxuriant ferns (Newton et al., 1997). Periodic burns would have taken place both naturally and by aboriginal intervention.

2. Grazing (~1840-1920);

"Cattle, however, ran free. They were simply let loose to roam at will and mustered perhaps only twice a year for branding, checking or sale. In the higher regions such free-ranging was the only method of grazing until wholesale clearing some years later had produced extensive hill pastures." (Wizenreid, 1993, p. 77)

3. Timber getting (~1840-1940);

Mt Evelyn sawmill was active from around 1856. Once first class timber had been removed, the fellers moved on leaving the way open for more agricultural pursuits. "The attitude of settlers who followed reflected the typical nineteenth century notions of nature being subservient to human needs." (Wizenried, 1993, p. 110)

Bushfires increased in frequency and, with more material on the floor of the forest after the timber fellers had been through, increased in intensity. One of the more devastating ones in this period occurred in 1898, its outbreak almost certainly attributable to clearing then being carried out by Village Settlers.

The area of Mt Evelyn was renamed several times, originally it was probably called Olinda Vale but it was also called Valinda. The name was changed to Evelyn in around 1907 and finally to Mount Evelyn in 1920.

4. Gold (~1850-1860);

No information regarding this period was found during this investigation for the Mt Evelyn area. There is no record of gold mining in the area.

5. Tourism (~1870- to date);

"The 1920's began the most lively period in Mt. Evelyn's history. It was a period when the community became more defined as the two small nucleus communities of McKillop and Mt. Evelyn grew together, the latter becoming dominant owing to its proximity to the railway station. From an area focusing on woodcutting and small fruit farms, it grew into a base for the Silvan Dam labour force and a bush holiday destination for many" (Newton et al., 1997, p.49).

In 1923-24 land was acquired for a sanitary depot on Bailey Road. Domestic water was from tanks and the creek, or pumped water from O'Shannassy aqueduct for the well off.

"To the north, Mt Evelyn developed in much the same way after the railway reached there in 1902. Population in the upper hills rose almost 50 % between 1898 and 1911 so that by the latter year some 3,613 people lived in the district which is now principally covered by the Shire of Sherborooke." (Victorian Municipal Directory, 1911, p. 816)

That English grass should replace the natural ground cover, and that progress should be measured in land replanted in introduced types, exemplifies the attitude of hill settlers.

"Falling trees presented problems but trees could be felled. More serious were the almost imperceptible changes occurring as a direct result of the altered land use. Almost immediately a number of blocks on the northern slopes of Mount Dandenong were cleared landslides began to occur. With slopes as steep as 1 in 15 on a number of blocks in the Mooroolbark village, this was not surprising once the original vegetation was removed. Some blocks lost all their topsoil in this manner. Others lost theirs as a result of erosion"

6. Small Farming (nurseries, berries) (~1870 – to date);

"In the higher hills, land clearing was continuing with a larger number of settlers moving onto the cheaper land. Berry growing introduced around the 1870s was found to be highly suitable to the region. Large sections of the hills unsuitable for grazing and large scale farming (both of which had dominated agriculture in the regions beforehand) were turned into small holdings and planted in berry crops or fruit trees"(Wizenreid, 1993, p. 109)

7. Weekenders (~1920-1950);

Blocks were sold to city dwellers who came to the area periodically for holidays, some only for their annual holidays once or twice a year. The new occupants had little knowledge of rural living and built temporary shacks with no consideration for environmental pollution.

"Sewerage was disposed of generally via pans, though by the 1940's septic systems were being introduced. Thus seepage could occur without any controls on pollution. Food waste was usually buried and may thus have had little detrimental effect but storm water was simply run off the roofs into drains which took it on the shortest route down hill out of the property. This frequently led to erosion problems on a number of the steeper properties." (Wizenreid, 1993, p. 232)

8. Permanent Housing (~1940- to date).

The Dandenong Ranges National Park Management Plan (1991) identified six major impacts of individual properties, these include soil erosion and effluent discharge. Vegetational invasion by garden plants and fire prevention needs are also highlighted.

The effects of urbanisation that would have taken place during the Permanent House phase can be better understood by looking at the consequence of population change over time. Figure 2-9 shows the population of the Mt Evelyn area from 1911 to 1980 (Winzenried 1993). Population growth has been fairly steady over time, and has nearly doubled over the 69 year period.

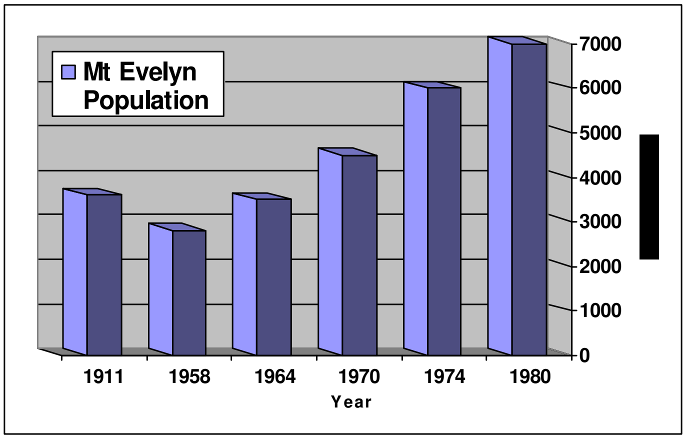


Figure 2-9 Population of Mt Evelyn from 1911 to 1980

The consequences of this increasing population are a greater impervious area from, both roads and roofs, causing more surface runoff than would occur naturally.

Drainage Development

The consequences of this increasing population are a greater impervious area from, both roads and roofs, causing more surface runoff than would occur naturally. The work of Walsh et al. (2005) indicates that there is a correlation between the amount of stormwater pipes that drain into the stream and the ecological health of the stream. The council data shows that the length (Figure 2-10) and diameters (Figure 2-11) of the different pipes constructed in the region. This may be used as a surrogate for the increase in impervious area, and reveals a peak on pipe construction in the early 1970's, tailing off until the present day.

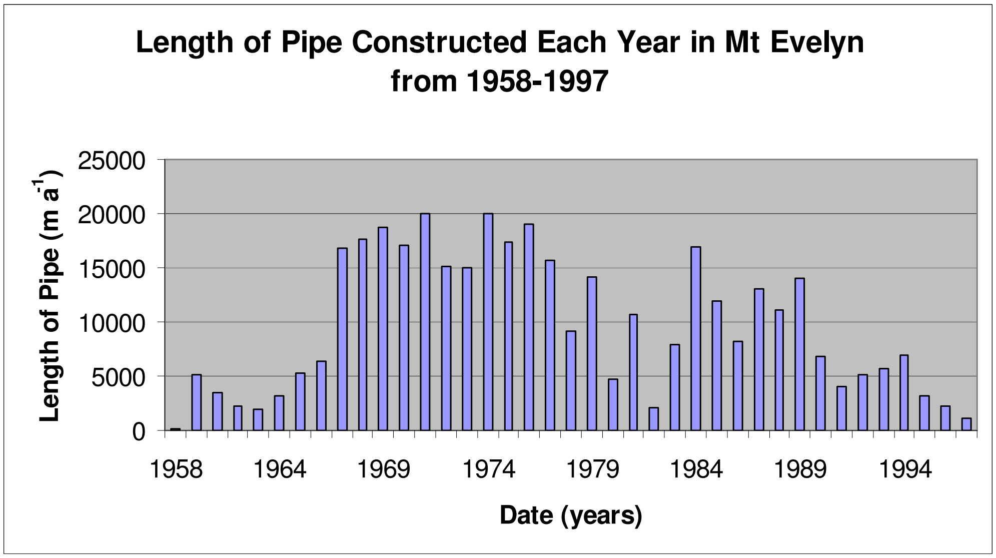


Figure 2-10 Length of pipe constructed in Mt Evelyn from 1958 to 1997

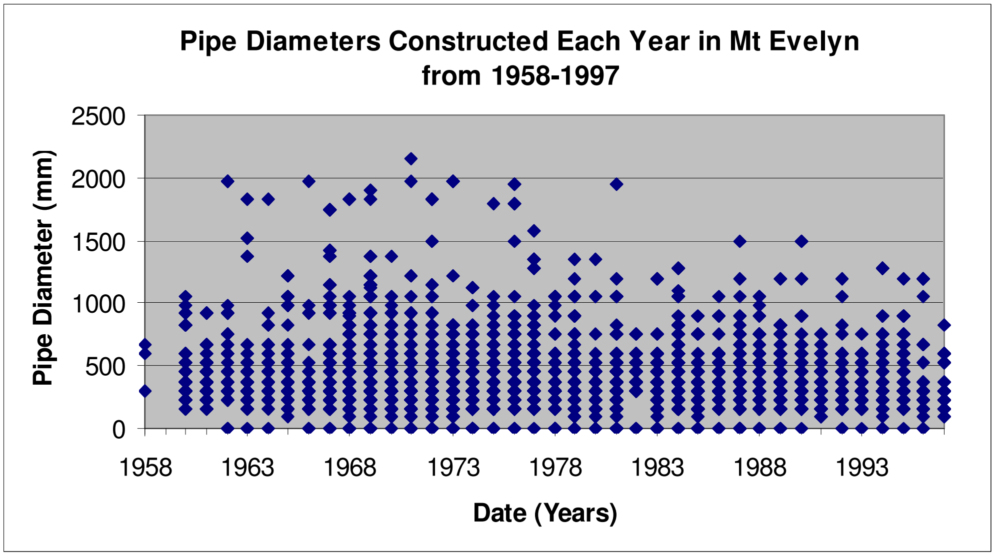


Figure 2-11 Pipe diameters constructed in Mt Evelyn from 1958 to 1997. The graph indicates the range of pipe diameters constructed in each year, showing a decline in recent decades in the number of pipes constructed with a diameter of >1500mm.

Work by Horton (2004) calculated the impervious area in the upper catchment (451.3 ha), where the town of Mt Evelyn is situated (Figure 2-12).

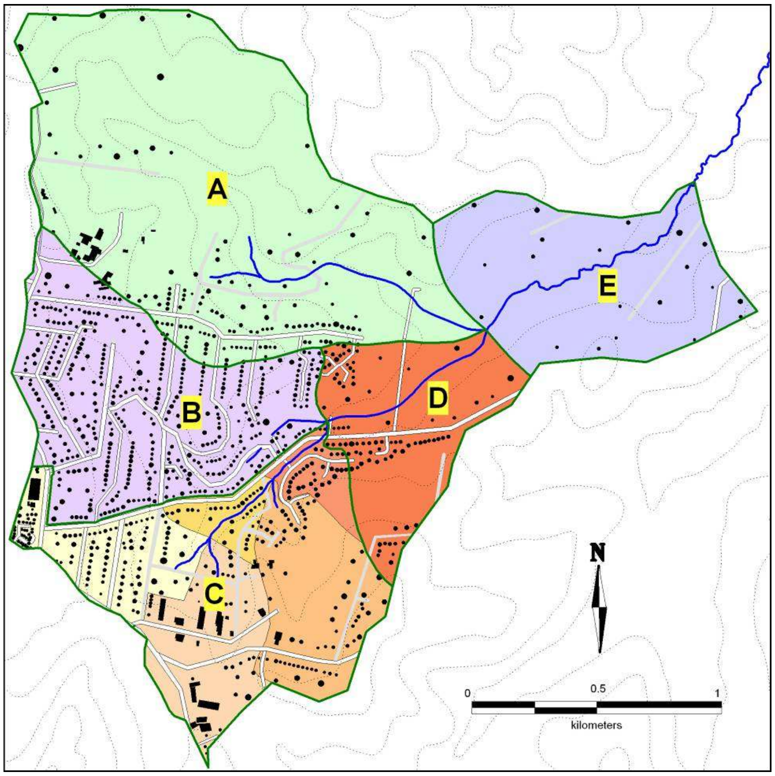


Figure 2-12 The Mt Evelyn catchment area used by Horton (2004). The five sub-catchments (A-E) used by Horton in developing the MUSIC model are bounded by green and shaded various colours. Buildings are shown in black.

Based on the work of Horton the impervious and effective impervious areas have been identified for the Little Stringybark Creek catchment. The total effective impervious area areas were calculated by adding only the connected impervious areas together. The connected impervious areas were only those that were identified on the GIS to be highly likely of being connected and to be possibly connected but were found to be connected following field investigations. These areas are shown in Table 2-2.

Table 2-2 Little Stringybark Creek impervious and effective impervious areas

Reach	Catchment area	Impervious area	Effective Impervious area
1	451ha	38.6 ha (8.6%)	24.7 ha (5.5%)
4	860 ha	38.6 ha (4.5%)	24.7 ha (2.9%)

Proposed WSUD Retrofit

In order to test the theory that Effective Imperviousness influences the ecological condition of a stream, there is a proposal by Monash University to retrofit the Little Stringybark catchment. The aim of the retrofit is to stop the direct connection of impervious surfaces with the stream. The catchment has been modelled in detail with the MUSIC model (Horton, 2004) with Ladson et al. (2006) recommending several different strategies for disconnection of impervious areas (Table 2-3). Treatments included: house block/streetscape infiltration systems; dual purpose rainwater tanks; bio-filtration basins; swale and bio-filtration systems along waterways; swales along roads, and a downstream wetland.

Table 2-3 Summary of retrofit scenarios. Treatment measures used (•) (Ladson et al., 2006)

	Scenario				
	No treatment	1	2	3	4
Dual-purpose rainwater tanks on all properties	-	●	●	-	-
Grassed swales along some section of roads and waterway	-	●	●	●	-
Streetscape infiltration system	-	●	-	●	-
Biofiltration basins near stream	-	●	●	●	-
Downstream wetland system	-	-	-	-	●

The aim is to maximise infiltration of the rainfall by slow seepage from WSUD. The result of this should be to elevate baseflow, reduce the number of mid channel level flows, but keep the large flows about the same. The treatments were optimised for a range of variables to give a proposed WSUD retrofit that achieved the desired level of hydrologic change for the least cost.

2.3 FIELD INSPECTION

A field inspection was undertaken along Little Stringybark Creek. Based on the field inspection the reach has been divided into 4 reaches (Figure 2-17, Figure 2-20, Figure 2-23, Figure 2-28). The observations from the field inspection are provided below, divided into discussion on each of the four study reaches. The most upstream reach is referred to as reach 1 with the most downstream reach within the project scope referred to as reach 4.

Summary information is provided for the four reaches in Table 2-4.

Table 2-4 Reach summary information. Each reach was split into several sub-reaches each with a relatively constant grade. The range of average sub-reach grades are provided.

Reach	Catchment area	Sub-reach grade range	Land use	Piping of stream?	Stream crossings	Riparian vegetation condition
1	63 ha	0.024 – 0.032	Urban	Yes	Constructed stream crossings at sealed roads	Highly modified
2	201 ha	0.009 - 0.013	Large urban lots	No	Mix of formal and informal stream crossings to private properties	Modified
3	432 ha	0.007 – 0.0100	Small rural lots	No	Mix of formal and informal stream crossings to private properties	Highly modified
4	726 ha	0.003 – 0.007 -	Larger rural lots	No	Majority of crossings informal private access	Highly modified

Reach One – Urban (Mt Evelyn to Birch Drive)

- Confined valley section
- Urbanised reach.
- Catchment area approximately 63 ha.
- Representative site located 300m upstream of Forge Rd crossing (Figure 2-17).

The channel within this reach alternates between low flow piped sections with an artificial floodplain, and un-piped sections where the channel is a slot approximately 1 m deep and 0.7 m wide. The banks of the stream are mainly silty clay and the bed fines downstream from coarse gravel in the headwaters to silty-clay. The coarse bed material is probably a product of an artificial valley fill that was emplaced when the low flow pipes were installed (Figure 2-13).

Figure 2-13 Exposed broken low flow pipe (looking upstream)

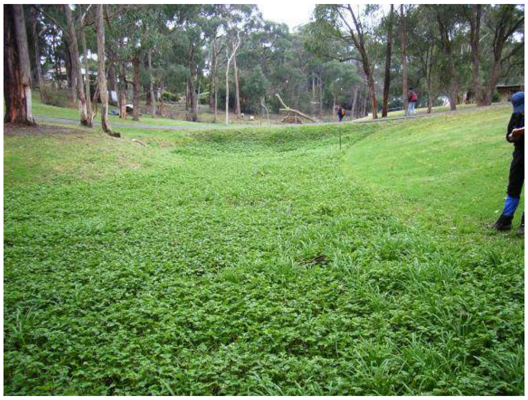


Figure 2-14 Grassed floodplain with underground pipe (looking downstream)

The valley is not very confined with a small artificial floodplain surface (Figure 2-14). Downstream of Forge Rd, the channel becomes more incised, up to 2 m deep in places. This may be a function of the stormwater inputs that enter the stream during this segment. Willows are present both on the banks and instream (Figure 2-15). Their roots have an impact on the channel with increased resistance provided by the roots leading to channel confinement. Downstream of the roots the channelised flow is more erosive and has created plunge pools. The banks of this section are vertical with some undercutting at low flow levels (Figure 2-16).

Figure 2-15 Willow root mat in the bed (looking upstream)

Figure 2-16 Near vertical banks of the confined upper reach (looking downstream)

Earth Tech

N

0 12.5 25 50

Metres

Datum: GDA94 Zone 55

LEGEND

- ● Monash Uni. monitoring sites
- ● Reach start/end points
- — Survey data
- ▭ Cadastre

Little Stringybark Creek Geomorphic Assessment

Reach 1

Aug 03, 2006

9905139_M011

Reach Two – Semi Urban - Birch Drive to Upstream of Evan Grove Road

- Characterised by denser vegetation cover and boggy conditions.
- Catchment area approximately 201 ha.
- Representative site located immediately downstream of the end of the low flow pipe section, through to Birch Drive.

The channel has a non-compound form and has silty clay bed and banks. There is little bed morphological diversity, apart from the occasional fine gravel deposit and invasion of instream vegetation. The culvert sections show signs of erosion, both around the structure and the creation of pools downstream. Sections of the stream have been overgrown with blackberries, providing little erosion protection for the banks.

Erosion control works have been installed over sections of this reach. Downstream of a culvert (Figure 2-18) there is massive erosion. Further downstream (Figure 2-19) the channel has tortuous meanders, good riparian vegetation cover, and instream woody debris. This channel is narrower and has more bed variability.

Figure 2-18 Erosion downstream of culvert (looking downstream)

Figure 2-19 Meandering channel upstream of Evan Grove Rd (looking downstream)

Earth Tech

N

0 15 30 60

Metres

Datum: GDA94 Zone 55

LEGEND

● Monash Uni. monitoring sites

● Reach start/end points

— Survey data

☐ Cadastre

Little Stringybark Creek Geomorphic Assessment

Reach 2

Aug 03, 2006

9905139_M011

Reach Three – Semi Rural- Upstream of Evans Grove Road to the Warburton Highway

- Catchment area approximately 432 ha.
- Representative site located 400m reach upstream of Monash University monitoring site.

The channel becomes less well defined and more swampy (Figure 2-21) just upstream of a private access culvert. This may be due to a decrease in slope, combined with a more open floodplain. The channel downstream of the culvert shows localised erosion (Figure 2-22) and whilst there is an offline wetland downstream, localised erosion also occurs around the pipes before the next tributary confluence. More widespread incision appears to have occurred in the system and it is expected that these culverts are holding incision heads from passing up through the system. Although the channel in this section looks incised and straighter than should occur (probably attributed to artificial straightening to drain the marshy land) a secondary phase of incision is not likely given the frequency of stream crossings.

Figure 2-21 Marshy area upstream of private road crossing (upstream of Warburton highway, looking downstream)

Figure 2-22 erosion downstream of stream crossing (looking upstream)

Downstream of an unnamed tributary the channel has been rocked and there are willows on the right bank. The tributary has two online storages that have probably changed the hydrology of the tributary.

Earth Tech

N

0 12.5 25 50

Metres

Datum: GDA94 Zone 55

LEGEND

- ● Monash Uni. monitoring sites
- ● Reach start/end points
- — Survey data
- ☐ Cadastre

Little Stringybark Creek Geomorphic Assessment

Reach 3

Aug 03, 2006

9905139_M011

Reach Four – Rural - Downstream of Warburton Highway to confluence with Stringybark Creek

- This reach includes both sinuous and artificially straightened stream channel.
- Catchment area approximately 726 ha.
- Representative site is located 400m upstream of the confluence with un-named tributary.

Between the Highway and Victoria Rd there is a gravel bed with bars. Willows have altered the bed, creating hard points and erosion on the opposite banks or the bed downstream (Figure 2-24). The channel is around 4 m wide and 1.5 m deep. Blackberries have invaded this reach. Downstream of Victoria Road the channel is fenced but has little riparian vegetation despite restricted grazing access. The channel is straightened and the intermittent willows again create hard points with the root systems stretching across the channel. In the area of willows the channel is shallow and narrow followed by a deeper wider sections downstream.

Figure 2-24 Willows lining the creek downstream of the Warburton Highway (looking downstream)

Figure 2-25 Bed and bank rock protection upstream of most upstream rock chute (looking downstream).

Downstream of the willows, the channel has been rocked and replanted (by Melbourne Water) in response to increased erosion triggered from the large February 2005 storm event (Figure 2-25).

Downstream of the rock chutes the channel enters a system of tortuous meanders with lots of woody debris and undercut banks. This section is followed by another straight section of channel that is ~5-6 m wide and 2.5 m deep and has a clay bed. After this the channel again meanders through a property grazed by cattle, the bed has some sandy deposits.

The next section is made distinct by the dense natural riparian vegetation and tortuous meanders (Figure 2-26). Undercut banks and overhanging, trailing, vegetation are present. Plenty of large woody debris means that there are debris dams and plenty of flow/bed variability. The channel is approximately 2 m wide and 0.8 m deep.

Outside the densely vegetated section the stream continues to meander but it is not as sinuous (Figure 2-27). Grazing is up to the stream edge and the channel is much narrower with sections of around 0.4 m in width. Just upstream of the reservoir there is a marshy area where the flow backs up during flood events.

Figure 2-26 Meandering, heavily vegetated section of the creek (looking downstream)

Figure 2-27 Straightened section of creek (looking downstream)

Earth Tech

N

0 10 20 40

Metres

Datum: GDA94 Zone 55

LEGEND

●	Monash Uni. monitoring sites
●	Reach start/end points
—	Survey data
▭	Cadastre

Little Stringybark Creek Geomorphic Assessment

Reach 4

Aug 03, 2006

9905139_M011

Sites of Localised Erosion

Substantial scour was observed immediately downstream from a number of culverts. An example of this scour is shown in Figure 2-29.

Figure 2-29 Instability downstream of channel crossings. Photo taken between reach 2 and 3 (looking upstream).

This erosion is likely to be associated with one or a combination of:

- High velocity of flow over and through the culverts resulting in localised scour,
- Concentration of otherwise dispersed flow through the culverts,
- Headward incision having moved up through the stream system and now being held at or near the culverts.

2.4 MAPPING AND AERIAL PHOTOGRAPH INTERPRETATION

Historical maps are available from the early Parish Plans at around 1900 (Figure 2-30) and a 1922 map sheet of the Ringwood region (Figure 2-31). Aerial photography of the catchment is available for 1946 and 2005 (Figure 2-32 and Figure 2-33). Gross changes in the channel planform may be observed by using historical maps and aerial photos.

The stream network has been identified in each plan and from the aerial photographs. These networks have been traced and compared. The traced stream lines appear to show a much smaller channel network in the Parish Plan dated at around 1900 (Figure 2-30) than the contemporary stream network (Figure 2-33). This suggests that the stream network has increased in length, and that the upper stream reaches may have consisted of undefined or discontinuous stream type such as a swampy marsh.

This mapping evidence alone may not be sufficient to confirm the intact form of the creek. Other reasons why there may be a change in the defined stream length could be:

- Drier conditions during this earlier period;
- A poor resolution of mapping, possibly a result of denser vegetation;
- A combination of the above.

The 1922 map (Figure 2-31) shows a much greater network of streams across the catchment. The 1940's aerial photo (Figure 2-32) is difficult to interpret. Wet road surfaces, and other reflective linear features, could be misconstrued as the stream. Vegetation near the stream channel also make identification of stream patterns less accurate. The overall picture appears to be of much the same stream pattern in the lower catchment, but a less dense stream network in the upper catchment. Initial channel development since major clearance may have halted, resulting in revegetation of sections, and the reduced visibility of some of the channels.

The current aerial photography (Figure 2-33) shows a stream network that extends up into the upper catchment but with less extensive tributaries than the 1922, and 1940's images. This may be a result of contemporary urban drainage systems replacing much of the incised streams in the upper catchments.

Interpretation of the historic mapping, aerial photography and EVC layers of Little Stringybark Creek suggests that the stream network was once a discontinuous channel connected through swampy marsh areas. The permanent watercourse evident today is expected to have been a result of processes occurring prior to 1922 and therefore, prior to the influence of urbanisation on catchment hydrology.

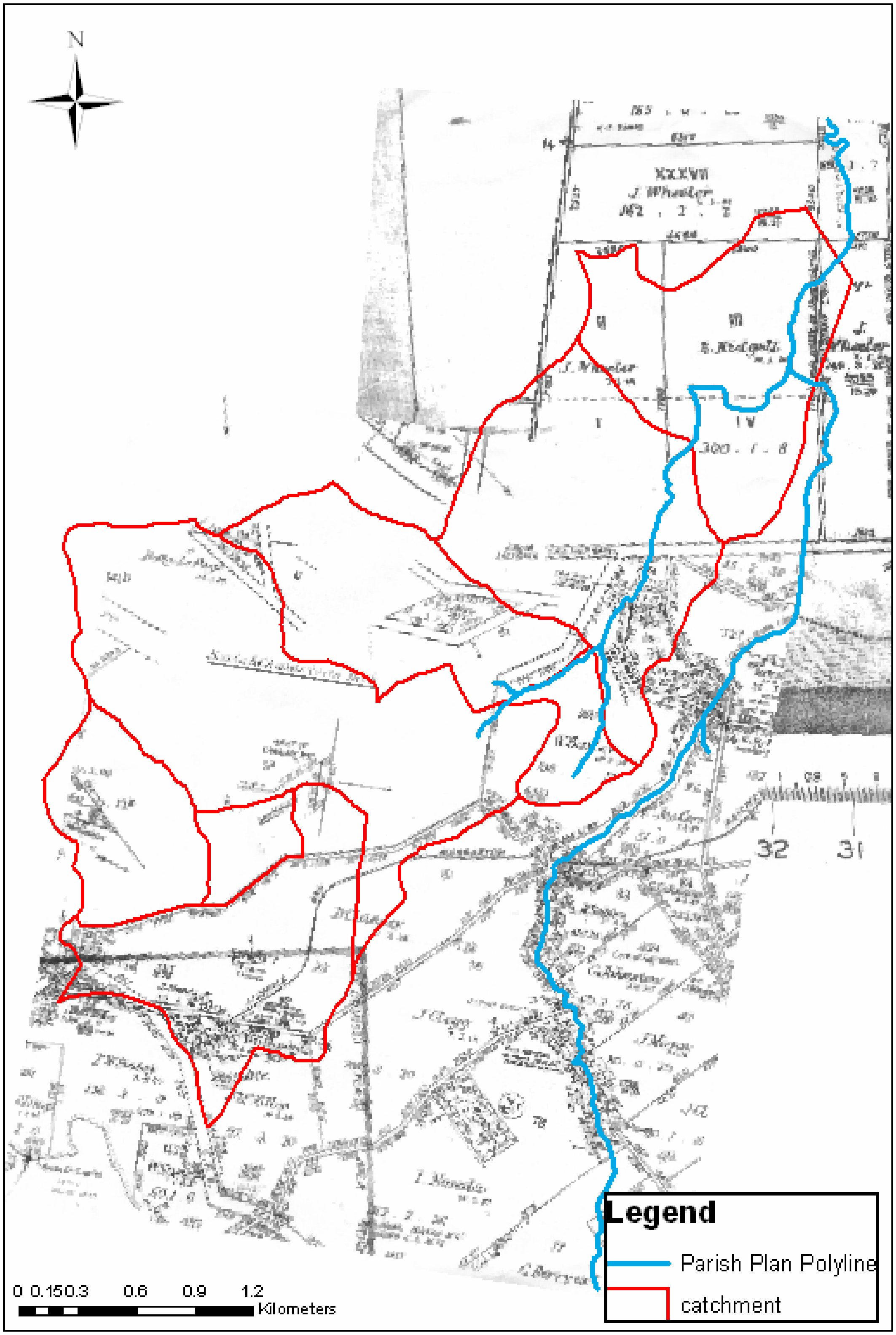


Figure 2-30 Stream line from Parish Plan circa 1900

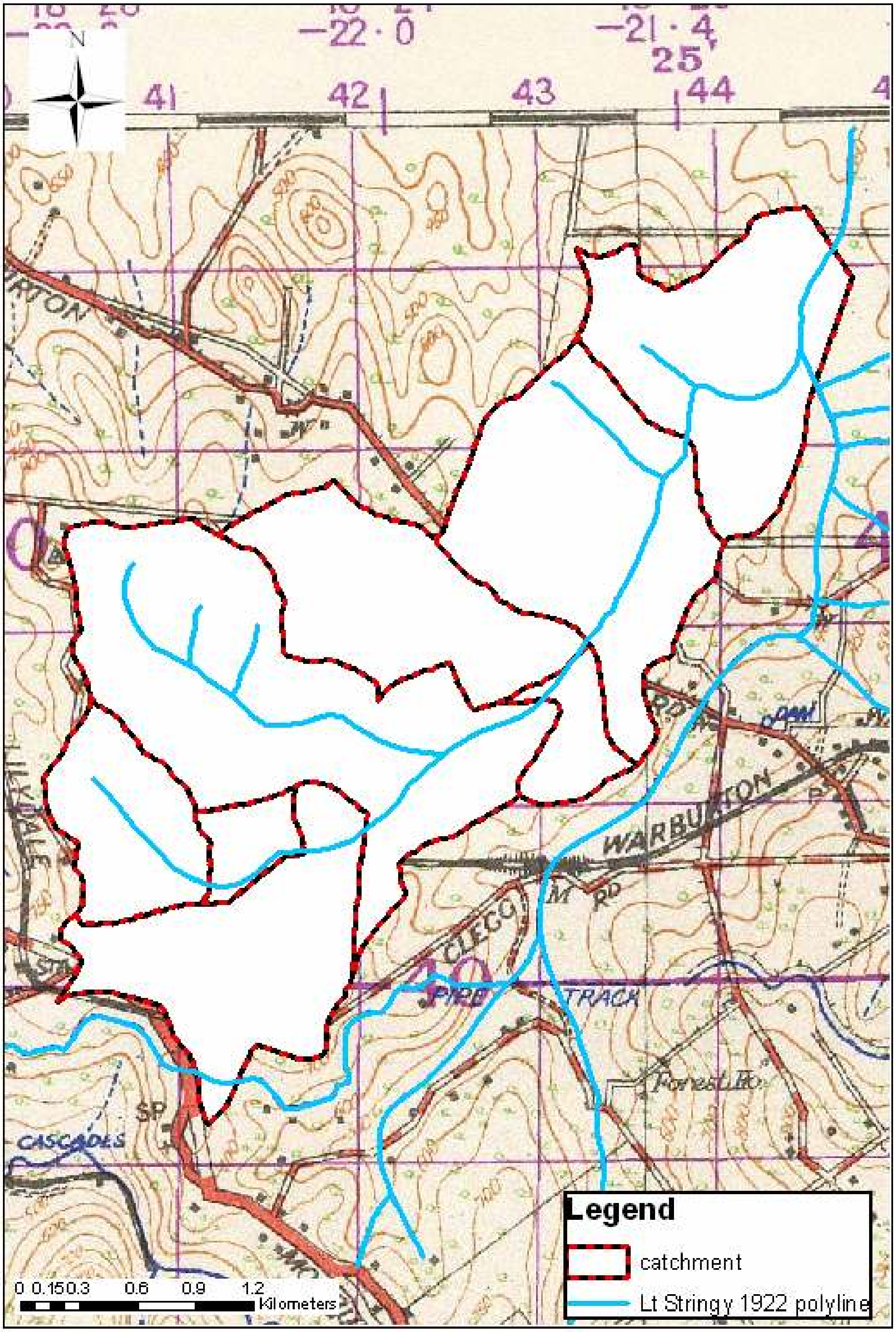


Figure 2-31 Stream line from 1922 map

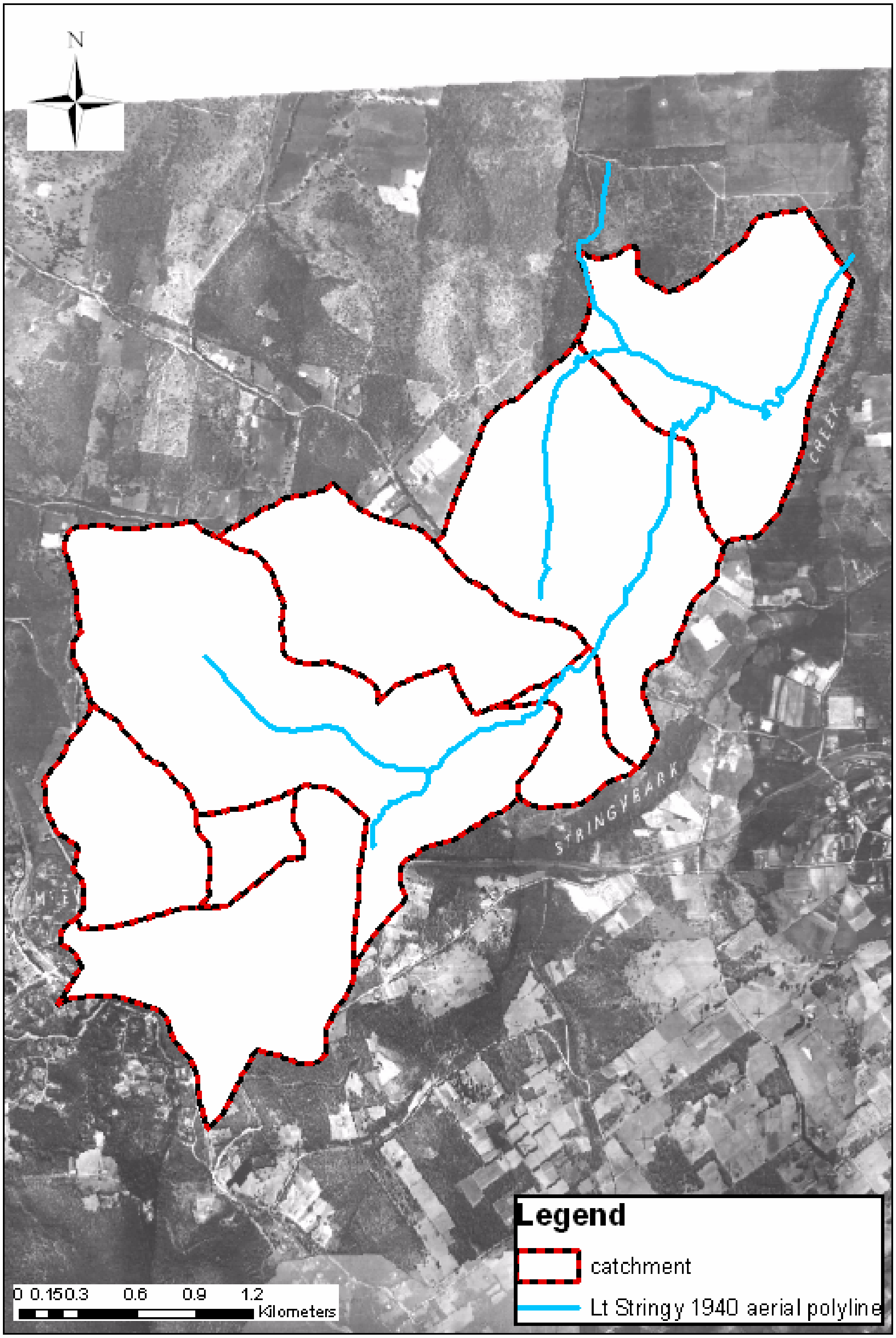


Figure 2-32 Stream line from 1940's aerial photograph

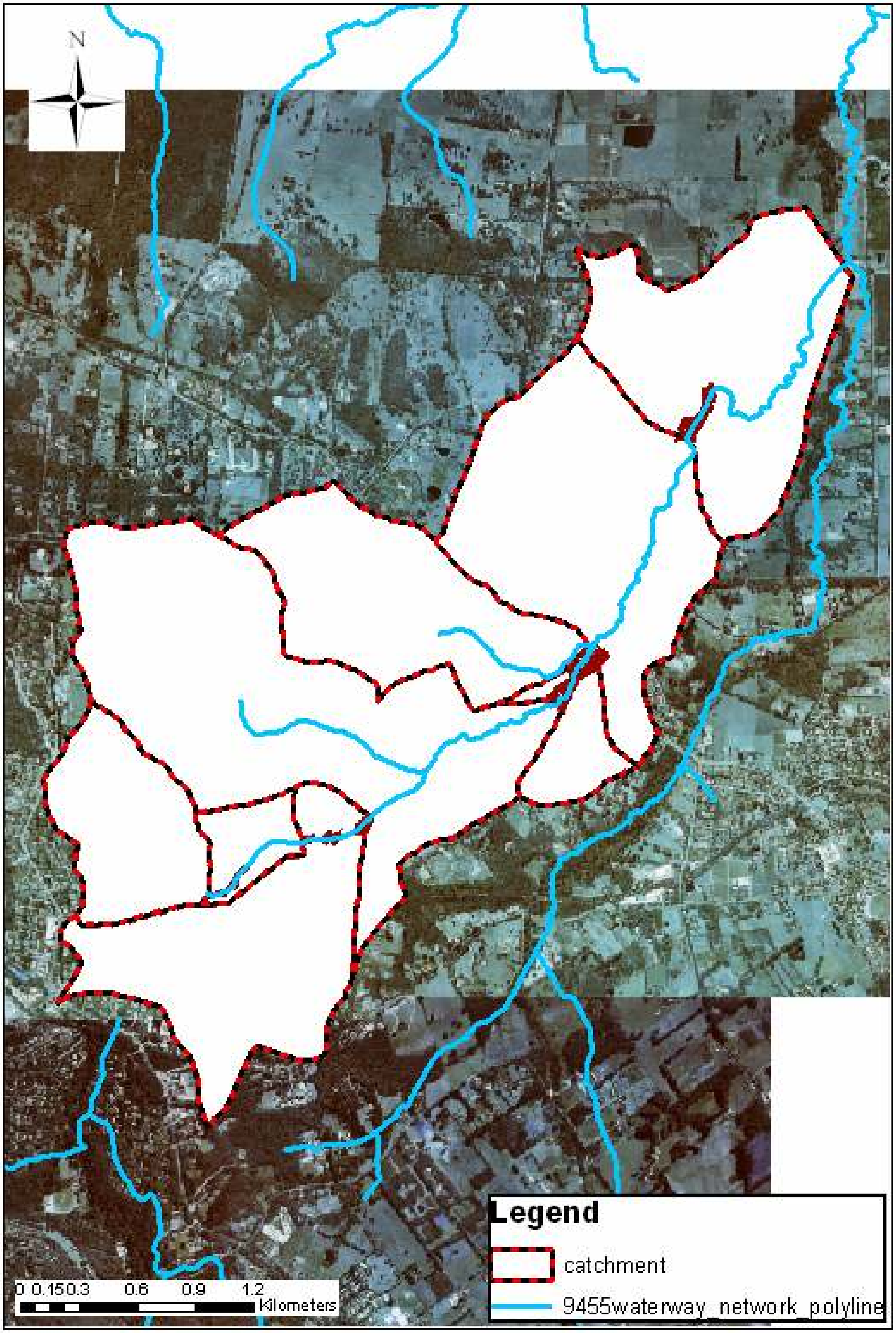


Figure 2-33 Stream line from 2005 aerial photograph

2.5 SURVEY

A stream bed longitudinal and cross sectional survey has been undertaken for this investigation. The survey has been undertaken at four sites, representing each of the four reaches(refer to Appendix C for longitudinal sections).

A full longitudinal profile survey of the entire reach would have enabled identification of bed grades, nick points, and zones of sediment accumulation and deepening. However project constraints and the density of vegetation prevented such survey from being undertaken.

Historic cross section data suitable for comparative analysis against the survey commissioned for this project was not identified during the literature review. As a consequence no comparative analyses have been undertaken for this investigation.

The survey data has been used for the development of hydraulic models (using HEC RAS). The results of modelling are provided in the following sections of this report.

2.6 HYDROLOGIC ANALYSIS

A hydrologic model has been developed to estimate flows in Little Stringybark Creek for current and modified conditions using MUSIC (Model for Urban Stormwater Improvement Conceptualisation). This model was used largely because of its ability to model WSUD features such as wetlands, swales and bioretention systems.

The model originally developed by Monash University (Horton, 2004) was simplified for the purposes of this study to enable rapid review of development scenarios (Figure 5-3). The hydrologic output of the simplified model was compared with the original model and was found to be sufficiently similar to adopt the simplified version.

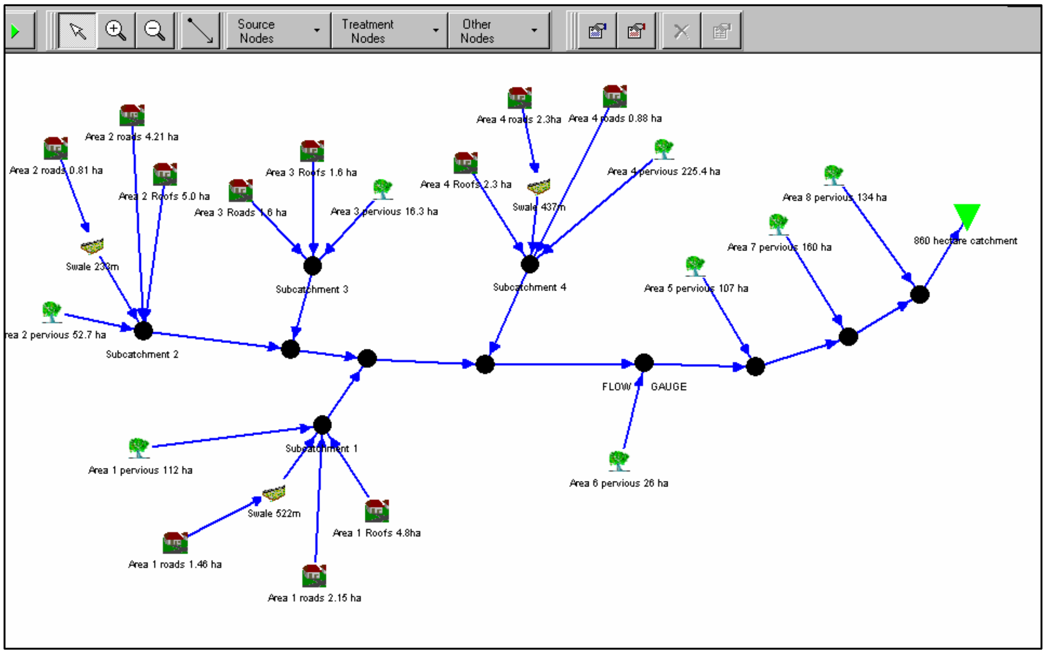


Figure 2-34 Simplified MUSIC model used in this study

Models were developed for three catchment development scenarios:

- Undeveloped catchment - all of the catchment areas are modelled as pervious catchment areas;
- Current development - include the roof and road areas of the urban areas. A number of swale drains are also included in these cases based on the original MUSIC model, which reflect the fact that not all the sealed areas are piped directly to the creek;
- Current development with WSUD - same as the current development but with the addition of treatment nodes following the impervious areas without swales. The treatment nodes adopted are bioretention systems sized at 2% of the upstream urban catchment area.

Efforts were made to calibrate the MUSIC model to provide some confidence that the modelled flows are similar to the actual creek flows. A confident calibration was not able to be achieved for all development scenarios as the parameters that matched well for the current and WSUD scenarios produced very small flows in the undeveloped catchment scenario. It was therefore decided to adopt default parameters for Melbourne for the purposes of this study.

Refer to Appendix A for further information.

Flood Frequency analysis

A flood frequency analysis was undertaken using the Rational Method to determine the current 2 year and 50 year average recurrence interval (ARI) in each reach (Table 2-5).

Table 2-5 Current flood frequency of study reaches in Little Stringybark Creek

	2 year ARI (m^3/s)	50 year ARI (m^3/s)
Reach 1	0.28	1.04
Reach 2	0.71	2.55
Reach 3	1.29	4.58
Reach 4	1.93	6.77

2.7 HYDRAULIC ANALYSIS

The hydraulic modelling software package HEC RAS was used to generate data for a range of flow events for further analyses. Modelled bankfull flows for each reach (Table 2-6) suggest that the 5 year ARI event is contained within the channel for all reaches. This demonstrates the incised nature of the channel in each of the surveyed sites. This is typical for much of Little Stringybark Creek, however there are some isolated swampy areas (not surveyed) in reaches 3 and 4 that are not incised. In particular reach 2 is substantially incised and contains all flows up to the 20 year event.

Table 2-6 Range of bankfull flows for study reaches in Little Stringybark Creek

	Flow at which channel begins to overtop (m^3/s)	Flow at which all cross sections overtop (m^3/s)
Reach 1	5 year ARI (0.4 m^3/s)	20-50 year ARI (0.9 m^3/s)
Reach 2	20 year ARI(2 m^3/s)	>100 year ARI(5 m^3/s)
Reach 3	5 year ARI (2 m^3/s)	50-100 year ARI (5 m^3/s)
Reach 4	5 year ARI (3 m^3/s)	>20 year ARI (>5 m^3/s)

A unit stream power analysis was undertaken to provide an indication of the relative stability of the study reaches. The analysis was undertaken using the HEC RAS models of the representative sites for each reach. The results have been compared with the unit stream power for naturally incised stream reaches in central Queensland, not subject to erosional adjustments (Hardie, 2004). While the central Queensland data set had different bed material and sediment supply, the data is useful for comparative purposes. The results for all reaches are shown in Figure 2-35.

The results show that the stream power for the reach 1 representative site are typically lower than that for other stream reaches. The modelling results are consistent with field observations which noted no active incision of the wide, shallow grassed channel at the representative site. All cross sections analysed for the representative site in reach 1 were found stream power below the thresholds found for non eroding, incised streams of central Queensland.

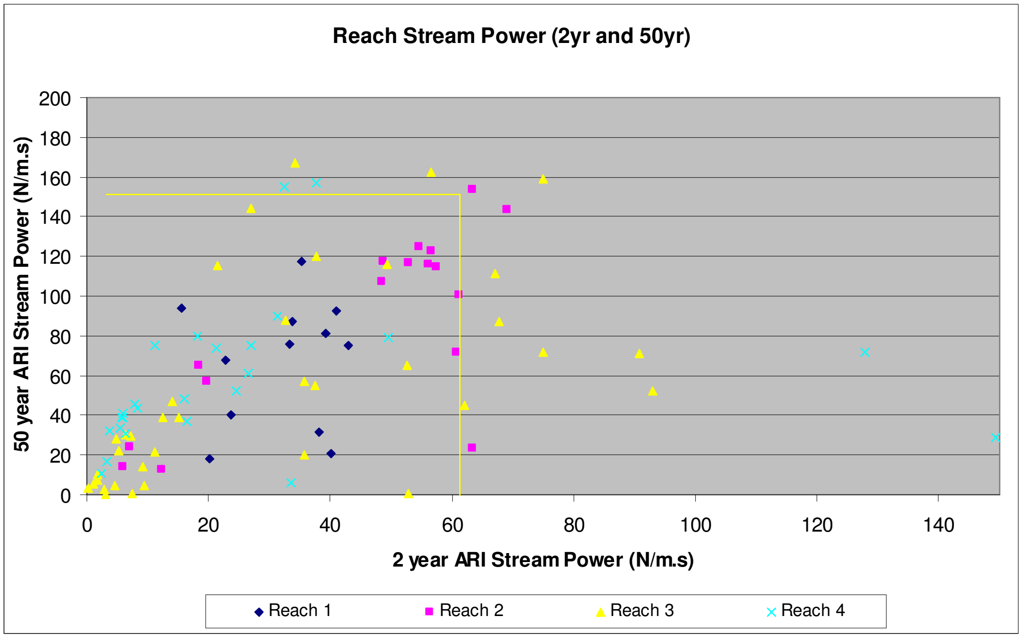


Figure 2-35 2 year and 50 year ARI Stream Power in all study reaches. The yellow lines indicate the highest unit stream powers identified in non eroding, incised streams of central Queensland (all systems with unit stream powers above these values were eroding).

Analysis of the stream power for reaches 2, 3 and 4 found it to be higher than that for reach 1, with many cross sections exceeding the unit stream power found for non eroding incised stream reaches in central Queensland. Field observations of these downstream reaches revealed localised instability at and downstream of channel crossings. Without intervention, Little Stringybark Creek will continue to experience instability around channel crossings.

Analysis of the results suggests that the representative sites within reaches 2, 3 and 4, may be subject to ongoing erosional adjustments.

2.8 ENERGY EXPENDITURE ANALYSIS

A cumulative excess energy expenditure analysis (an adaptation of an effective discharge analysis) has been undertaken to identify the extent to which changes in the hydrology associated with urbanisation may have and may continue to have an impact on stream shape and form. The analysis was based on the method detailed in Appendix A.

A total energy assessment identifies the change in total energy expenditure, whereas an excess energy analysis seeks to identify the change in energy associated with those events that have the capacity to “do work” on the channel. The excess energy analysis is reliant on the identification of a criteria and threshold above which stream flow has the capacity to mobilise and transport sediment. For non-cohesive bed and bank material, shear stress is often used as this criteria. While threshold or critical shear stress values are available for non-cohesive materials, data for cohesive materials has a broad and variable range of values. An analysis of critical shear stress values for cohesive material is provided in Appendix A. The difficulty in assigning a critical shear stress for this catchment has limited the applicability of the excess energy assessment.

This approach included the use of the MUSIC software package to derive flow regimes for the intact and urbanised catchment conditions.

Please note – survey data of the current channel form was used to assess all three development scenarios. While it is recognised that pre and post development channel geometry is not likely to be the same, the current survey was used in the absence of pre-development survey .

Total Energy Expenditure

In all study reaches, the introduction of urbanisation resulted in a marked increase in the total energy expenditure energy over that found for the forested/ cleared catchment scenario (for the 40 year hydrologic record). The greatest relative difference in energy expenditure occurs in the upper reaches of the creek and at low flows. The results for reach 2 are shown in Figure 2-36.

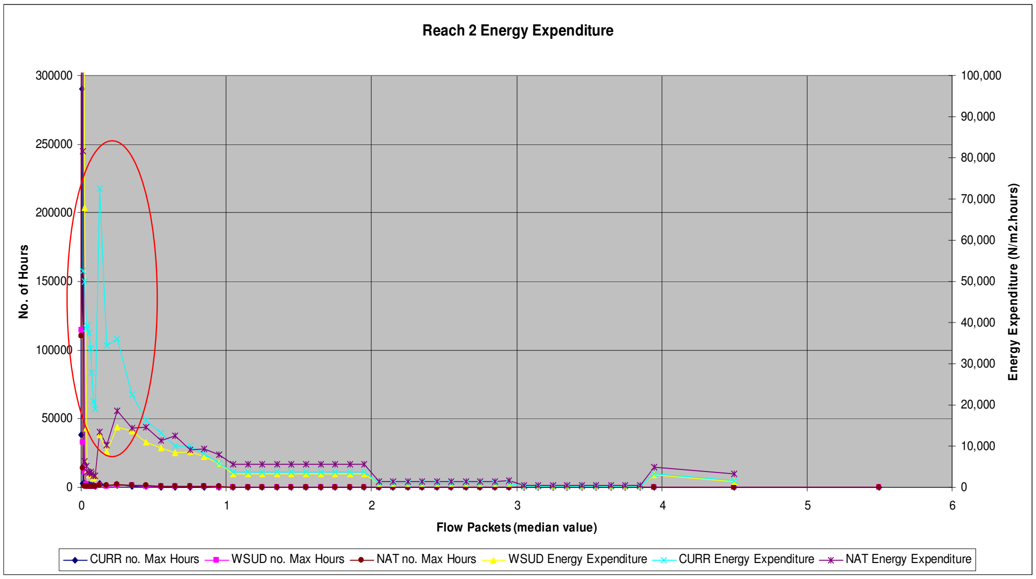


Figure 2-36 Reach 2 Energy Expenditure

Analysis of the total energy expenditure results suggests that a change in the flow regime associated with urbanisation may have the capacity to create channel change. The results also show that the introduction of WSUD can return the flow regime to something that approximates the intact flow regime.

In all reach scenarios, the introduction of the proposed WSUD reduced the peak in the energy expenditure curve to a level that closely aligns with the natural energy expenditure. The range of flow events and relative change does however, vary with proximity to urbanisation in the catchment.

In reach 1, the urbanised upper catchment, WSUD influences the energy expenditure for flow events less than 1m^3/s (Figure 2-37). This range of flow events decreases as the distance from urbanisation increases, with reach 4 only depicting a reduction in energy expenditure for flows up to approximately 0.4m^3/s (Figure 2-38).

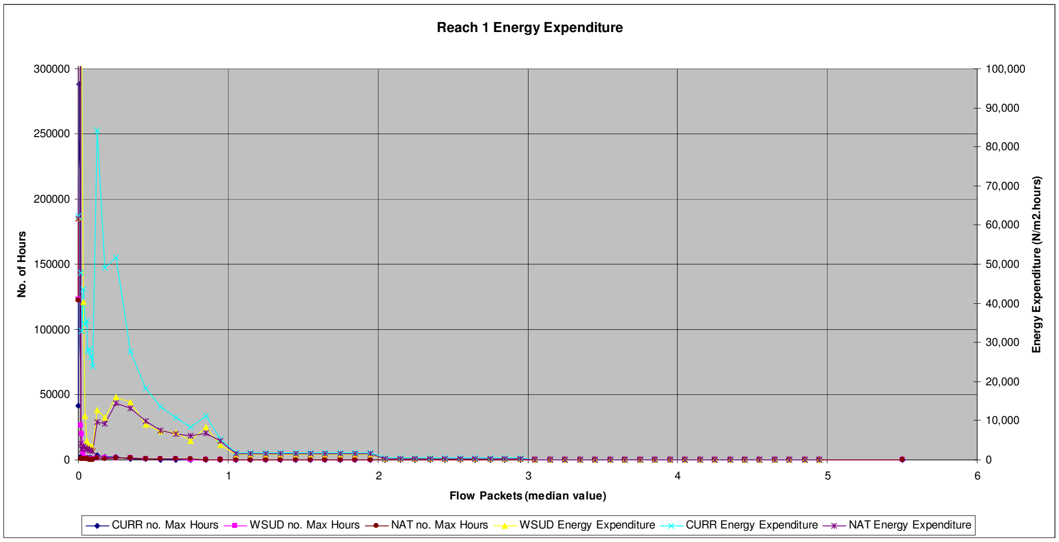


Figure 2-37 Reach 1 Energy Expenditure

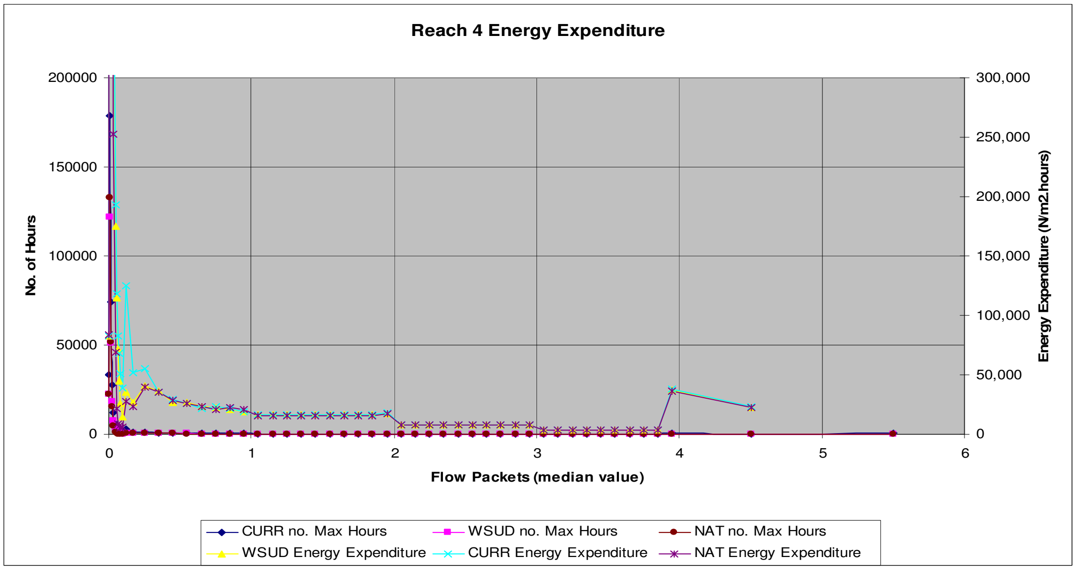


Figure 2-38 Reach Four Energy Expenditure

Similarly, there is a greater percentage reduction in current to WSUD energy expended in the upper reaches than the lower reaches of the creek. Both of these changes highlights the localised influence of WSUD on the hydraulic conditions of the channel.

Excess Energy Assessment

The excess energy expenditure assessment was reliant on the identification of a suitable critical shear stress for the bed and bank material. The critical shear stress for the weakest of the bed and bank material is often adopted for this purpose. However much of the bed and bank material in Little Stringybark Creek is comprised of clay for which only limited, suitable critical shear stress data exists (refer to Appendix A for further information on critical shear stress).

The cumulative excess energy expenditure (area under the excess energy expenditure curve) has been estimated for each reach and each flow regime (natural, current and WSUD). The assessment has been based on adoption of a critical shear stress of 20 N/m^2 (refer to Appendix A). The results of the assessment for current and WSUD development scenarios are summarised in Table 2-7.

Table 2-7 Excess energy expenditure of study reaches (critical shear 20 N/m^2)

		Total Excess Energy Expenditure (N.days/m^2)	**Relative Change – Current to WSUD**
Reach 1	WSUD	180,496	65% reduction
	Current	522,423	
Reach 2	WSUD	161,165	61% reduction
	Current	417,600	
Reach 3	WSUD	18,079,562	2% reduction
	Current	18,354,816	
Reach 4	WSUD	7,904,851	2% reduction
	Current	8,036,340	

As there is uncertainty on the critical shear stress for Little Stringybark Creek, the impact of retrofitting WSUD to the catchment is difficult to define. However based on the analysis undertaken for this assessment, the results suggest that the greatest change in excess energy expenditure, associated with the retrofitting of the WSUD will occur in reaches 1 and 2.

The results suggest that it may be difficult to detect the geomorphic impact of the WSUD in reaches 3 and 4. However in reaches 1 and 2 some geomorphic change may arise as a result of the introduction of WSUD. These potential changes are discussed in the next section of this report.

Please note: the above results are based on a predicted critical shear stress. Field tests of bed and bank material may be required to confirm the threshold of motion for all study reaches in Little Stringybark Creek.

3. Past and Present Stream Condition and Trajectory

3.1 PRE EUROPEAN SETTLEMENT

There is a body of evidence collated for this investigation that supports an argument that prior to European settlement, Little Stringybark Creek consisted of poorly defined swampy reaches, connected by more defined creek segments. This body of evidence includes.

- Site inspection of intact reaches of stream
- Modelled EVC data for the system
- Historic stream mapping
- Presence of excavated drainage channels on the main creek path

The geological structure of the catchment has produced a relatively steep channel grade. The overall stream pattern has been controlled by the boundaries between the different geological structures. Igneous flows have resulted in a wide valley cross-section with little confinement and wide floodplain, apart from in the headwaters of the catchment.

Runoff from the intact catchment would contribute a mix of sand, silt and clay derived from the loam and clay soils, to the stream channel. The relatively wide shallow floodplain for most of the catchment results in poor connection of the hillslopes to the channel, with most of the sediment eroded by surficial flow being redeposited further downstream. This has resulted in the finer fraction clay being the dominant sediment to enter the channel.

Mapping of expected Ecological Vegetation Classes (EVCs) prior to European settlement indicates that Little Stringybark Creek was most likely a swampy environment (Swampy Riparian Complex consisting of Riparian Scrubs or Swampy Scrubs and Woodlands). Field inspections noted a number of heavily modified swampy, marsh-like areas predominantly located mid-catchment (Figure 2-21).

These swampy areas would act to slow high flow events, with flows from large rainfall events dissipated over wide areas.

Also observed during field inspection was a section of highly sinuous, densely vegetated, narrow channel (Figure 2-26). Located in the lower reaches of the catchment, this area appears to be the most intact reference condition. Channelised sections such as this may have been present in between sections of swampy marsh.

3.2 PROCESS OF CHANNEL CHANGE

The analysis of the body of evidence collated for this investigation suggests that Little Stringybark Creek has been subject to an historic and contemporary incision process.

This process was most likely initiated by one or a combination of:

- Channelisation of the creek course
- Catchment clearing and related hydrologic change
- Grazing pressure and the loss of instream vegetation.
- Removal of instream timber

Further, the body of evidence suggests that the incision processes commenced prior to the urbanisation of the catchment, and as a consequence, that urbanisation was not the cause of the incision.

However this is not to suggest that urbanisation has not had an impact on the stream. Urbanisation has had both direct and indirect impacts on the catchment and the stream form, and may be contributing to ongoing instabilities in the system.

The energy expenditure analysis revealed that urbanisation may have significantly increased the energy expenditure in the creek and as a consequence may be contributing to ongoing and accelerated rates of erosion. Further the partial urbanisation of the catchment and works to limit further headward erosion have limited the bed load sediment supply to the incised reaches, limiting the rate of channel recovery in the incised reaches.

Research on channel incision has identified that the incision and recovery process occurs in several distinct stages. An example of the types of models developed to explain the process of channel incision and recovery is shown in Figure 3-1.

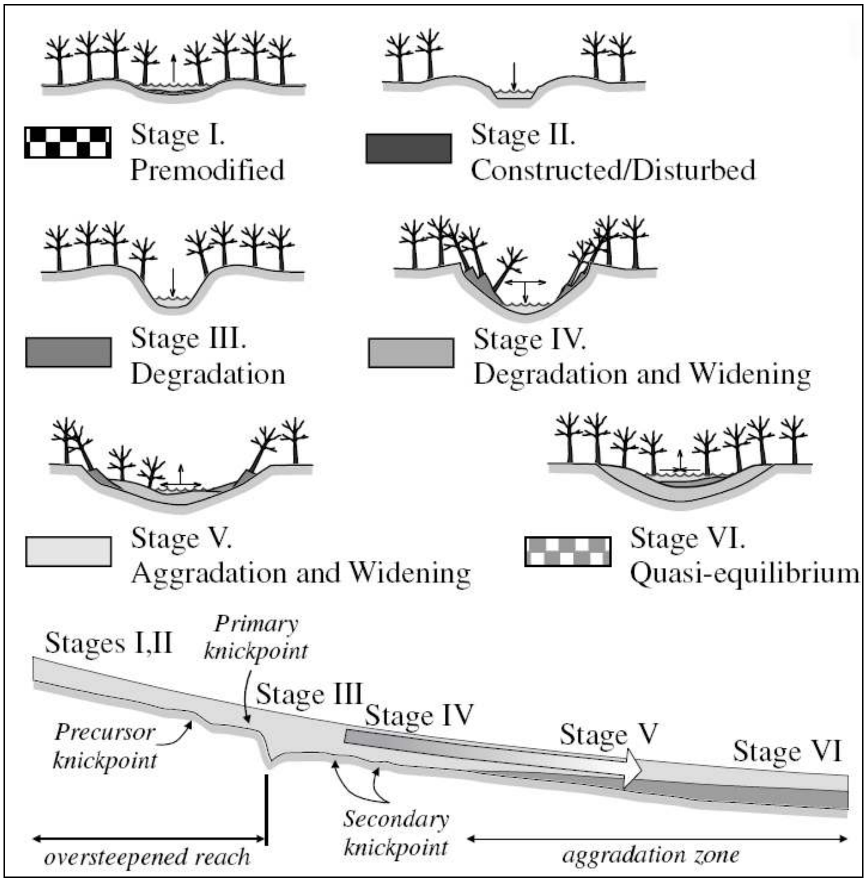


Figure 3-1 Process of channel incision and recovery (Simon, 1989)

The results of the investigation suggest that urbanisation may be contributing to ongoing instabilities in the system, but were not the cause of the channel incision.

The upper sections of the stream, in and around Mt Evelyn, appear to be the most geomorphically modified. The low flow pipe and artificial floodplain are combined with stormwater inputs and highly modified (from natural) vegetation. In the rest of the catchment the creek has probably increased in cross-sectional area, mostly by incision, from its natural condition. Whilst it is expected that the stream should have near vertical banks in this silty clay substrate the straight sections with little bed diversity are not thought to be the natural state. More bed diversity both in sediment size and woody debris are expected, and can be seen to some extent in the areas with greater native riparian cover.

The current condition of each reach and the trajectory for the reaches of Little Stringybark Creek under current catchment management and under a proposed management arrangement that includes the proposed Monash University WSUD experiment are provided below.

3.3 REACH 1

Present stream condition and processes

- The upper sections of the stream, in and around Mt Evelyn, appear to be the most geomorphically modified (ie. low flow pipe, modified floodplain and vegetation, stormwater inflows).
- Stream power analyses and field observations indicate that this reach is relatively stable despite the modified channel form.
- There is a limited sediment supply to the reach.

Trajectory under current conditions

Under current levels of development, the condition of reach 1 is not expected to change noticeably from the current form. The previous incision process is largely complete and halted, however, as there is a limited sediment supply to the stream, aggradation is not expected to follow this process.

The continued stable form of reach 1 is subject to the management of incision processes downstream.

Trajectory under WSUD

Modelling suggests that there would be a significant decrease in the total energy expended in the channel under the proposed WSUD conditions. However, as the channel has only limited erosion, a noticeable change in erosion rates is not expected.

The WSUD will trap and reduce the small, suspended sediments being delivered to the system. As the system already has a limited sediment supply, it is not expected that there will be an increased rate of channel recovery through sediment deposition.

However some accelerated rate of vegetation encroachment could occur. The extent of vegetative channel encroachment will be a function of the level of maintenance undertaken by adjoining landholders. With high levels of maintenance, no change would be observed.

3.4 REACH 2

Present stream condition and processes

- Appears to be substantially modified with some ongoing erosion at channel crossings.
- Stream power analyses and field observations indicate that this reach is experiencing some instabilities.
- There is a limited sediment supply to the reach.

Trajectory under current conditions

Ongoing instability in the areas downstream of channel crossings is expected in this reach of Little Stringybark Creek. These headcuts are controlled by the crossings themselves and are not expected to move upstream (assuming that the crossings remain intact).

Trajectory under WSUD

Similar to the reach upstream, modelling suggests that there would be a significant decrease in the total and excess energy expended in the channel under the proposed WSUD conditions. This may potentially reduce the rate of erosion in the reach.

3.5 REACH 3

Present stream condition and processes

- Ongoing erosion and instability evident downstream of channel crossings.
- Stream power analyses and field observations indicate that this reach is experiencing some instability.
- Monash University ecological monitoring site is located in this reach.

Trajectory under current conditions

Ongoing instability in the areas downstream of channel crossings is expected to continue in reach 3. Headcuts controlled by the crossings themselves are not expected to move upstream (assuming that the crossing remains intact).

Trajectory under WSUD

No significant impact is expected under the WSUD development scenario. It is anticipated that ongoing erosional adjustments will continue to persist in this reach.

3.6 REACH 4

Present stream condition and processes

- Ongoing erosion and instability evident downstream of channel crossings (to a lesser degree than upstream reaches).
- Stream power analyses and field observations indicate that this reach is experiencing some instability.
- Sections of artificially straightened channel present.
- Intact section present in this reach that could be used as a reference condition.

Trajectory under current conditions

Ongoing instability in the areas downstream of channel crossings is expected to continue in reach 4. Headcuts controlled by the crossings themselves are not expected to move upstream (assuming that the crossings remain intact).

Trajectory under WSUD

No significant impact is expected under the WSUD development scenario.

3.7 SUMMARY

The extent of ongoing channel change in Little Stringybark Creek is limited. Only isolated erosion is currently present. A full longitudinal profile survey would help to confirm the extent of incision. However, the most visible erosion appears to be associated with channel crossings. This could be related to two issues

1. Headcuts being held at these structures, and/or
2. Poorly designed nature of the crossing results in downstream scour

Without intervention, the form of the channel is not expected to change greatly. The current channel form is not thought to be actively eroding and the incision process is believed to have been largely halted. Typically following the incision process, the system would begin infilling. However there appears to be no significant ongoing sediment sources. Without a supply of sediment to the system channel aggradation will not occur and the channel form will generally remain the same as that at present.

4. Conclusions and Management Implications

4.1 ONGOING CHANNEL PROCESSES

The analyses for this project has revealed that the current incised form of Little Stringybark Creek is most likely due to catchment and stream responses to drainage, vegetation clearing and agriculture in the area prior to catchment urbanisation. Urbanisation is an additional process on top of the pre-existing incision, and is contributing to ongoing instabilities in the system. Some limited ongoing adjustments (widening and deepening) is expected under the current level of development and management, however not much downstream infilling is expected due to the low rate of sediment supply in the catchment.

Current Trajectory

Ongoing processes will be most evident in reaches 2, 3 and 4. The scour is associated with road crossings and some ongoing evolution and recovery of the incised channel. Channel widening is part of the process of channel recovery.

WSUD

Implementing WSUD in the catchment will reduce the energy expended in the channel (primarily in the urban upper reaches, reaches 1 and 2). This will result in some reduction in the rate and occurrence of erosional adjustments to that equivalent to a rural incised system.

When and where the deepening process has finished, incised streams typically undergo a phase of widening and bed aggradation (deposition). Sediment for such deposition is derived from ongoing upstream incision. Most of the incision in the stream has now been halted and there is limited sediment being produced for downstream deposition. Under WSUD conditions the sediment supply is expected to reduce further from the current scenario. Therefore, infilling processes are unlikely to occur, slowing the channel recovery process.

4.2 GEOMORPHIC IMPACTS ON ECOLOGIAL EXPERIMENT

The existing ecological monitoring site is in reach 3. Baseline monitoring of the ecological condition of Little Stringybark Creek, prior to the implementation of WSUD, has commenced and is ongoing. The ecological experiment seeks to identify the impact of WSUD on instream ecology. Beneficial impacts on instream ecology could be the result of improved hydrology, improved water quality and reduced channel instability.

Current Trajectory

Some ongoing erosional instability is expected upstream of the ecological monitoring site. The rate of erosional adjustments is greater than for a natural system in dynamic equilibrium and these adjustments are likely to continue. Therefore the adjustments have potential to alter the bed form at the monitoring site significantly more than would be expected under natural equilibrium conditions.

Management intervention measures such as grade control may be required to prevent these ongoing geomorphic processes swamping the ecological monitoring experiment. However such work may also bias the results of the ecological experiment.

WSUD

Some minor and ongoing geomorphic change is expected under the current trajectory. However, this investigation has found that the proposed WSUD retrofit is not likely to influence the ongoing processes in the reach. As a consequence, any changes to the ecological condition of Little Stringybark Creek following the implementation of WSUD would not likely be a result of changes to retrofit induced geomorphic processes.

Baseline ecological monitoring has been undertaken within reach 3 under current levels of urban development and with existing instream instabilities. There may be some value implementing works to prevent ongoing processes swamping the results of the ecological experiment. However, such works have the potential to bias the results of the ecological experiment if they were to be undertaken in parallel with the proposed WSUD. In this instance, it would be difficult to discriminate changes in ecological condition arising from the implementation of WSUD, from changes arising from works to reduce accelerated rates of scour and deposition.

4.3 MONITORING OF GEOMORPHIC CHANGE

There are 2 monitoring options applicable for the project:

- **Monitor the geomorphic change in the system attributed to WSUD.**

  Urbanisation has created changes in the stream hydrology that are additional to other large scale pre-existing changes in stream condition and processes. Further, the scale of the existing urban development in Little Stringybark Creek is on the cusp of where the literature suggests that urbanisation has an impact on channel form. Large scale changes in physical form and ongoing processes are not expected as a result of the implementation of WSUD.

  As a consequence it will be difficult to detect and isolate the influence of WSUD on stream form in Little Stringybark Creek. While a monitoring program could be developed to detect and isolate the impacts of WSUD, this is likely to be an expensive and resource intensive task. Alternate means of identifying the stream physical form changes due to WSUD should be explored prior to committing resources to such a monitoring program.

- **Monitor the ongoing processes in Little Stringybark Creek.**

  It is possible that ongoing geomorphic processes will have some impact on the ecological monitoring site and the results of the ecological monitoring program. There would be value in undertaking a geomorphic monitoring program of the Little Stringybark Creek system to assist identify the occurrences when the ecological monitoring program results may be impacted by these ongoing geomorphic processes.

  Geomorphic monitoring should focus on identifying rates of channel change. Methods for such monitoring have been reviewed by Lawler (1993) and include repeat longitudinal and cross sectional surveys, comparative photo analysis using fixed photo points, and erosion pins.

4.4 CONCLUSIONS REGARDING ANALYSIS TECHNIQUES

There is evidence in the literature that urbanisation of a catchment results in changes to the stream physical condition and geomorphic processes. These changes include channel incision and/or enlargement. Literature indicates that channel changes can be the result of an increase in the occurrence and duration of flow events that exceed the threshold of motion of the bed and bank material.

In a number of regions in North America, effort is going into the protection of the geomorphic form of stream systems by implementing urban developments that protect certain components of the hydrologic regime. These regions include, but may not be limited to, the Santa Clara Valley and Washington State in USA and Ontario in Canada.

Key to the analyses and management of urban runoff will be the establishment of a modelling package that can be used to assess the range of proposed management alternatives and the identification of the threshold of motion or critical shear stress for the bed and bank material. These both proved challenging exercises for this Little Stringybark Creek investigation:

Use of MUSIC as a hydrologic tool. The proposed WSUD treatments for Little Stringybark Creek were assessed and developed by Monash University using the MUSIC software package. This package was subsequently used by Earth Tech for the analysis of the hydrologic implications of the proposed WSUD. MUSIC is one of a number of hydrologic modelling tools currently available to assess small time step, long term hydrologic processes. However MUSIC is the only one of these packages that has been specifically designed for the analysis of WSUD and related urban stormwater quality treatments.

Calibration and modelling of a ‘natural’ scenario in Little Stringybark Creek with no (or very low) impervious surface area for the purpose of comparison with current and proposed WSUD conditions proved difficult, time consuming and ultimately fruitless. Wider industry adoption of this package for the analysis of hydrologic implications of WSUD on geomorphic form would be difficult if each assessment required calibration and analysis of the rural and/or forested (pre-development) catchment condition. Development and industry acceptance of default parameters for a range of soil and geological characteristics of the Melbourne region would assist adoption of the package for this purpose.

Furthermore, short time steps were adopted for the analysis to reflect the short time of concentration of storm events in Little Stringybark Creek. This was necessary to adequately identify the occurrence of short duration events capable of “doing work” on the stream. The adoption of hourly time steps and a 40 year data set resulted in extremely large files and lengthy computational time. The establishment of visual basic routines assisted the handling and data analyses. However only increased computing memory and speed could assist the computational time issue. Establishment of routines for MUSIC to enable handling of large data sets would assist wider adoption of the package for the purpose of this type of analysis.

Threshold of motion for clay based streams. There is extensive information in the literature on critical shear stress for stream bed and back material. This information provides a broad range of possible critical shear values for cohesive soils such as that found in the bed and banks of Little Stringybark Creek. However there is limited information that can assist the narrowing of this range for the purpose of identifying the occurrence and duration of events that exceed this threshold. As a consequence the identification of a critical shear stress and excess energy expenditure for Little Stringybark Creek proved difficult.

Widespread adoption of this excess energy approach, as applied to Little Stringybark Creek, to the analysis and management of the impacts of urbanisation on stream physical form will require development and acceptance of agreed thresholds of motion for bed and bank material in the Melbourne region.

To simplify the application of this approach, a number of regions in North America have removed the determination of the critical shear stress from the analysis. In the Santa Clara Valley and Washington State controls are placed on urban developments to prevent erosional adjustments to stream systems. While the basis of the controls is in preventing an increase in excess energy expenditure, the control and the analysis are based on limiting change to a target range of flows that do most of the work on the stream. Rather than use the critical shear stress for the bed and bank material present, the lower limit of this target flow range is expressed as a fixed percentage of the 2 year ARI. The fixed percentage of the 2 year ARI was based on investigations into critical shear stress for streams in those regions and the subsequent adoption of a uniform criteria to cover the range of stream types and material present.

The issue of the range of flows over which some control should be placed to limit geomorphic change to stream systems is related to, but beyond, the scope of this investigation. The issue was the subject of an investigation by Earth Tech for the NSW EPA Stormwater Management Program (Earth Tech 2006).

4.5 RECOMMENDATIONS

Based on the findings of this investigation a number of recommendations can be made:

Little Stringybark Creek Management

There are ongoing instabilities in Little Stringybark Creek, however these do not appear to warrant major capital investment. Furthermore, and depending on the location and timing, such an investment may compromise the results of the ecological monitoring program. Much of the instability in the system is now associated with small scale private access tracks holding headcuts and/ or creating localised downstream scour.

Recommendation No. 1

It is recommended that existing private access crossings over Little Stringybark Creek that show signs of instability be removed and replaced with more appropriate and longer term structures. Alternatively, these existing crossings could be protected with rock armouring. This work could be undertaken on an ‘as needs’ basis with landholder participation as a component of the ongoing Melbourne Water Stream Frontage Management Program.

Geomorphic monitoring of Little Stringybark Creek

Ongoing stream instabilities have the potential to impact on the results of the Monash University ecological monitoring site on Little Stringybark Creek.

Recommendation No. 2

It is recommended that a monitoring and evaluation program be implemented to assess ongoing changes in the Little Stringybark Creek system, in particular to identify and record the physical impact of ongoing channel change at and on the ecological monitoring site established by Monash University in reach 3.

This monitoring and evaluation program should include repeat longitudinal and cross sectional surveys, repeat photography using photo points, visual inspection and site notes. The monitoring program could also include establishment of erosion pins. Objectives, methods, communication, data collection, evaluation, storage and retrieval should be detailed prior to commencement.

It will be very difficult to detect and isolate the impact of WSUD on stream geomorphic form from other ongoing processes.

Recommendation No. 3

It is recommended that alternative means of assessing the implications of WSUD on stream form be explored prior to Melbourne Water developing and committing resources to the monitoring and evaluation of geomorphic change in Little Stringybark Creek arising from the proposed retrofit of WSUD to this catchment.

Excess Energy approach to assessing hydrologic impacts of urbanisation on stream form.

Urbanisation has been found to have an adverse impact on stream shape and form. One such impact is urbanisation induced changes to the hydrologic regime, increasing the occurrence and duration of events with the capacity to “do work” on the stream bed and banks.

Review of the literature indicates that there is a movement toward, and a strong theoretical basis for, the adoption of an excess energy approach to modelling the effect of management scenarios on the hydrologic regime from urbanised catchments.

Recommendation No. 4

It is recommended that the excess energy approach to the analysis and management of urban development to protect stream form be the subject of further investigation and development by Melbourne Water. This should include a review of the extent of stream forms in the Melbourne Region likely to be impacted by catchment urbanisation.

An agreed means of analysing the pre and post urban development catchment hydrology, in a manner that is compatible with both the application of WSUD, and an excess energy assessment has not been established. Some difficulties exist with the use of the MUSIC hydrologic modelling software for this purpose.

Recommendation No. 5

It is recommended that the application of the MUSIC and other software packages be investigated for the purpose of undertaking hydrologic analysis of proposed urban developments and excess energy assessments. This should also include the identification of appropriate computational routines as necessary to simplify the handling of large data sets.

The development and application of an excess energy approach to the management of urban hydrology for the protection of stream geomorphic form will require the identification of the target flow range to be managed. The lower limit of this flow range should be related to the critical shear stress for the subject stream.

Recommendation No. 6

It is recommended that Melbourne Water undertake an investigation into the establishment of the target flow range to be managed to protect streams against the adverse impacts of urbanisation. The lower limit of this target flow range should be related to the critical shear stress. This will require an investigation into and development of critical shear stress parameters for the range of bed and bank materials in the Melbourne Region. However for the purpose of developing a method that can be readily applied to new developments and the retrofit of WSUD to existing developments, this lower limit of the target flow range could be simplified to a hydrologic criteria based on the research into critical shear stress for streams in the Melbourne Region.

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Appendix A Excess Energy Expenditure Analyses

5.1 OVERVIEW

One method of predicting channel change and establishing geomorphic understanding is through an ‘energy expenditure’ analysis. This can provide a quantitative measure of hydraulic/geomorphic change due to altered hydrologic conditions. Such an approach allows for the analysis of alternate catchment conditions. For the purpose of this investigation three development scenarios have been assessed:

1. Current flow conditions
2. Pre-development flow conditions
3. WSUD flow conditions

The approach is based on combining the hydrologic regimes for each development scenario with an hydraulic analysis of the subject reach of stream to identify the occurrence and duration of events that have the capacity to do “work” on the channel bed and banks. The term work refers to the capacity of the flowing water to erode, mobilise or transport sediment. In this instance the analysis has been undertaken to identify whether, and the extent to which, any changes in the hydrologic regime caused by urbanisation and potentially the WSUD, have the capacity to change the work done on the channel bed and banks. Such an analysis can assist to identify whether changes in the catchment hydrology can increase or decrease the rates of erosion and or sediment deposition in the reach and thereby whether such change are likely to impact on stream shape and form.

The two key inputs to an energy expenditure analysis are the hydraulic and hydrologic conditions of the study reach. Hydrologic conditions are represented by flow packets, which are the number of flow events within a range of flow magnitudes (ie, in the 0.2m^3/s to 0.3m^3/s flow packets, 156 events occur in this range over the whole flow record). Hydraulic conditions are represented by the hydraulic parameters such as shear stress or stream power, in the study reach at a range of flows (defined as the median value of each of the flow packets).

The energy expended in the channel can then be measured by multiplying the number of events in each nominated flow packet by the shear stress/stream power in the reach for that event, i.e.,

Energy Expended = No. of Events in Flow Packet x Shear Stress or Stream Power

This can be plotted, with the volume below the curve representing the energy expended in the study reach. It is recognised that not all energy expended has the ability to move sediment and change channel form. Therefore, the ‘excess energy expenditure’ is defined as the energy expended that occurs above the threshold of motion of the bed material.

A flow chart of the excess energy expenditure approach outlined above is depicted in Figure 5-1.

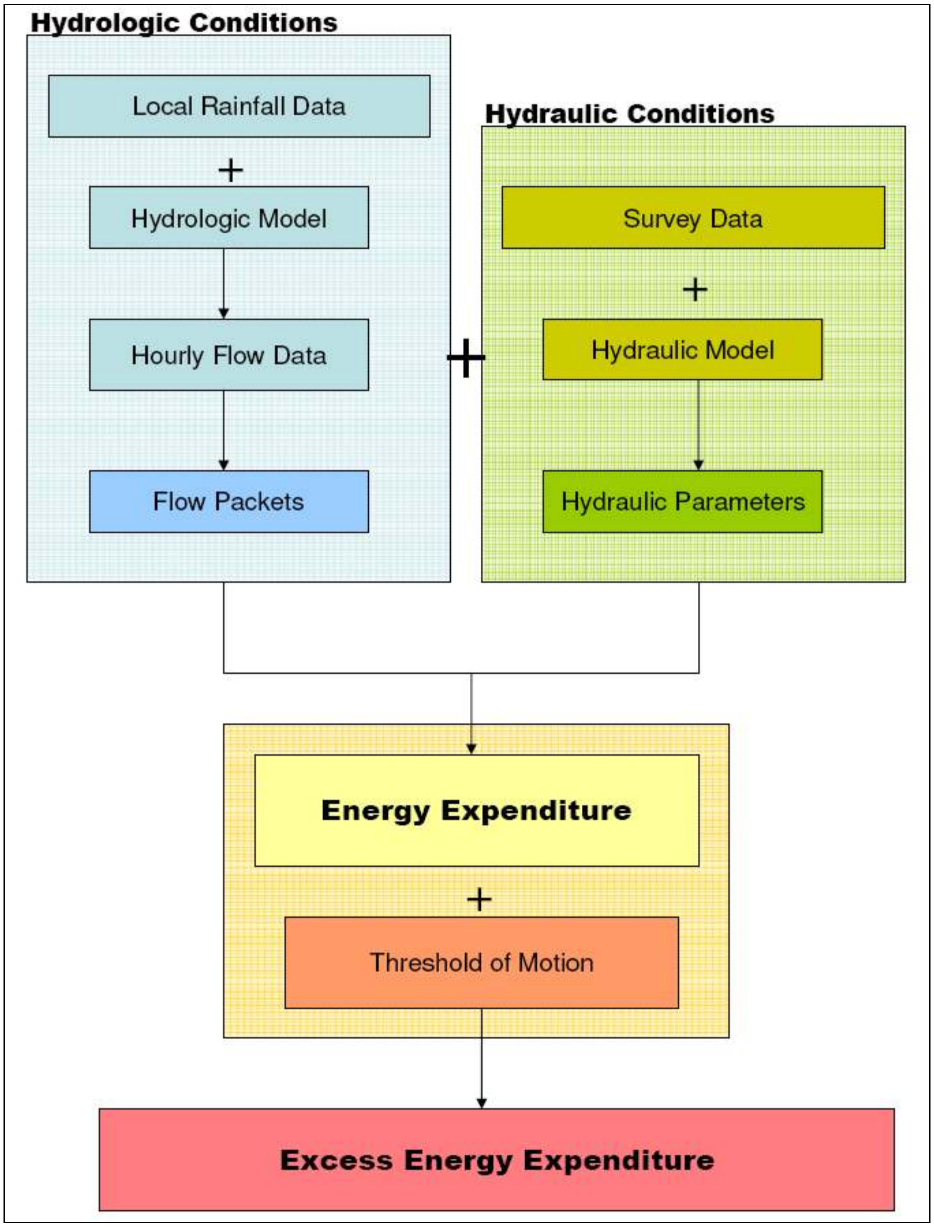


Figure 5-1 Approach to Excess Energy Expenditure analysis

5.2 HYDROLOGIC CONDITIONS

Local Rainfall Data

The most complete rainfall record for the area recording six-minute interval rainfall data is recorded at the Croydon (Council Depot) rainfall gauge (Table 5-1). This rainfall data has been used as the rainfall template in the Monash University MUSIC model that investigates retrofitting scenarios for the catchment. The 40-year record of rainfall data is sufficient for the purposes of this investigation, however gaps in the rainfall record may need to be excluded to gain a more complete record of rainfall.

Table 5-1 Number of days recorded for rainfall record at Croydon Council Depot gauge (source: Bureau of Meteorology)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1965				28	31	30	31	31	30	31	30	31	**273**
1966	31	28	31	30	30	30	30	30	30	31	27	15	**343**
1967	30	28	31	30	31	30	31	31	29	31	28	29	**359**
1968	31	28	30	29	30	28	30	28	30	31	30	31	**356**
1969	28	27	30	29	31	29	28	30	28	29	29	31	**349**
1970	31	28	31	30	30	29	30	30	30	31	30	31	**361**
1971	30	28	31	30	31	30	29	31	30	31	29	30	**360**
1972	30	29	28	29	30	30	30	30	30	29	28	30	**353**
1973	29	28	31	29	30	30	30	29	30	31	29	31	**357**
1974	30	28	31	26	27	24	28	30	29	29	28	28	**338**
1975	31	28	31	26	29	29	28	28	27	30	28	31	**346**
1976													**0**
1977													**0**
1978													**0**
1979							27	28	27	28	24	24	**158**
1980	19	25	23	29	30	29	25	27	25	26	26	25	**309**
1981	29	25	26	23	25	27	28	26	28	28	28	27	**320**
1982	30	27	29	26	26	26	26	28	26	27	27	31	**329**
1983	29	27	24	25	24	22	22	28	26	28	29	29	**313**
1984	26	28	29	26	31	28	30	23	28	29	28	27	**333**
1985	25	28	25	28	26	28	30	26	24	30	29	31	**330**
1986	30	27	30	26	30	25	24	27	28	29	28	30	**334**
1987	29	27	28	29	29	27	24	23	26	29	14	31	**316**
1988	30	28	30	29	29	23	28	31				31	**259**
1989	29	28	31	26	27	29	29	31	22	29	29	31	**341**
1990	30	24	29	24	25	21	25	28	28	29	27	29	**319**
1991	29	28	31	25	28	29	24	30	28	20			**272**
1992	26	26	25	28	25	27	29	31	25	29	29	29	**329**
1993	30	22	29	28	27	26	26	29	27	28	27	29	**328**
1994	30	26	30	28	24	28	27	28	25	30	29	30	**335**
1995	28	27	28	26	21	21	27	26	24	28	26	28	**310**
1996	30	29	31	28	29	18	22	26	25	27			**265**
1997													**0**
1998				30	31	30	31	31	30	31	30	31	**275**
1999	31	28	31	30	31	30		31	30	31	30	31	**334**
2000	31	24	31	30	31	30	31	31	30	31	30	31	**361**
2001	31	28	31	30	1	28	31	31		31	30	31	**303**
2002	31	28	31	30	31	30	31	31	30	31	30	31	**365**
2003	31	28	31	30	31	30	31	31	30	31	30	31	**365**
2004	31	29	31	30	31	30	31	31	30	31	30	31	**366**
2005	31	28	31	30	31	30							**181**

Rainfall Runoff Model

Hydrological modelling was undertaken to estimate flows in Little Stringybark Creek for current and modified conditions.

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) was used as the hydrological model largely because of its ability to model WSUD features such as wetlands, swales and bioretention systems. Models were developed for three main scenarios of catchment development; being an undeveloped catchment, current development and cases with WSUD features added.

Set Up of MUSIC Models

MUSIC represents stormwater systems with source nodes for the catchment areas, water quality treatment nodes and links representing flow paths. MUSIC generates runoff from the 6-minute interval rainfall data supplied by the Bureau of Meteorology.

The Little Stringybark Creek MUSIC model provided by Monash University focuses on the upper, urbanised catchment (Figure 5-2). This model includes an extensive breakdown of the urban areas into a large number of model nodes as shown.

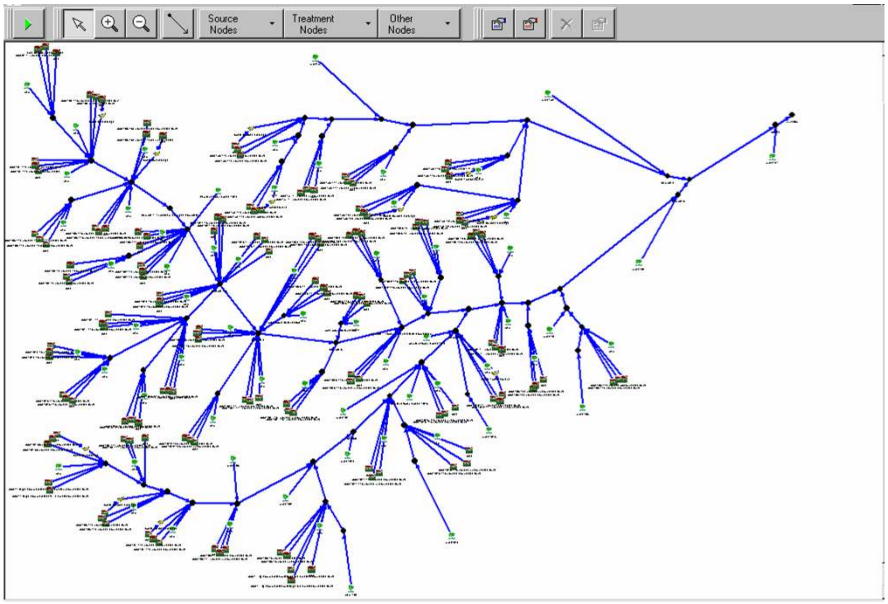


Figure 5-2 MUSIC models developed by Monash University (Pascal Horton)

For the purposes of this study, a number of changes were made to the layout of the original Monash University MUSIC model.

The model was extended to include the lower catchment of Little Stringybark Creek, which is mostly undeveloped land.

The large number of source nodes in the original MUSIC model proved time consuming in the calibration process. Therefore, the model was simplified by combining the source nodes of the same types within sub-catchments. The three main types of source nodes represent house roof areas, road areas (both totally impervious) and the remaining impervious areas. Sub-catchments were modelled to correspond with the areas draining to the creek reaches that had been selected for this geomorphic investigation.

The simplified MUSIC model for the Little Stringybark Creek is shown in (Figure 5-3). The hydrologic output of the simplified model was compared with the original model and was found to be sufficiently similar to adopt the simplified version.

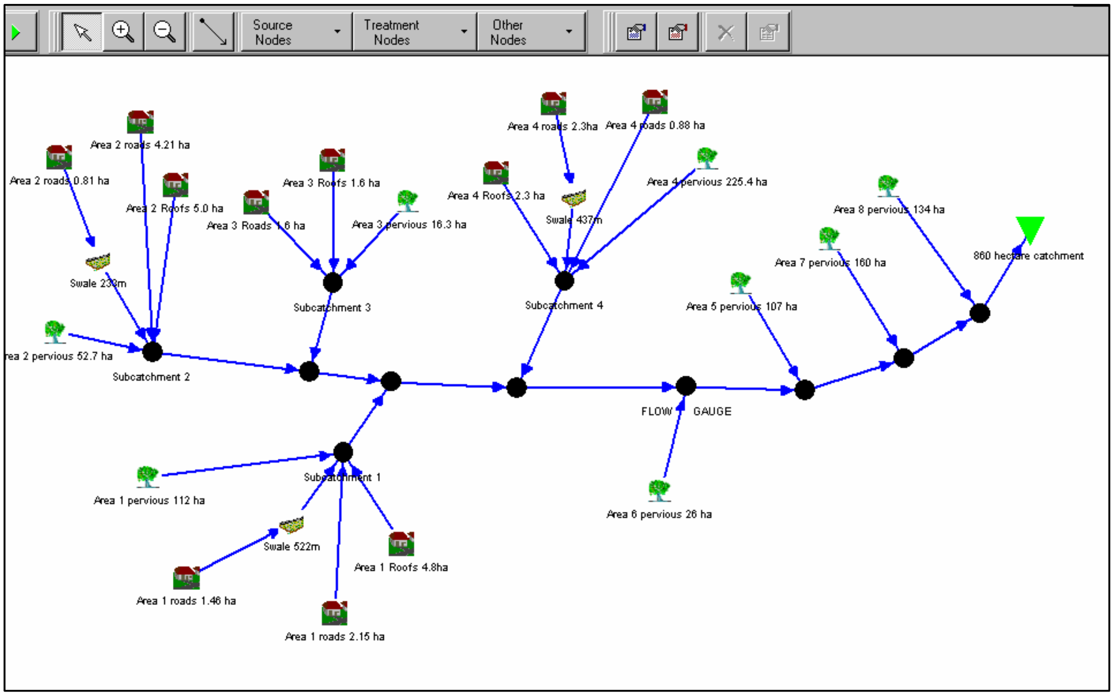


Figure 5-3 Simplified MUSIC model used in this study

5.3 CALIBRATION OF THE MUSIC MODEL

Efforts were made to calibrate the MUSIC model to provide some confidence that the modelled flows are similar to the actual creek flows.

A depth gauge was installed in Little Stringybark Creek in conjunction with the CRC Freshwater Ecology monitoring site downstream of reach 3. Creek flows were estimated from the water depth records by Ladson (2005). It needs to be recognised that no hydrographic rating curve has been established for this gauge and so there is some uncertainty in the derived flows.

The Little Stringybark Creek catchment is largely undeveloped and so is dominated by impervious areas. Therefore, the flows modelled from MUSIC are sensitive to the soil parameters adopted for these impervious areas. Soil parameters that were adjusted in MUSIC were the soil storage capacity, field capacity and the daily baseflow rate. Modelled flows from the impervious areas are most sensitive to the soil storage capacity values adopted.

Adjustments were also made to the links or flow paths in the MUSIC models. Flow attenuation was included in the links that represent the main creek lengths. The Muskingum-Cunge routing option was selected in the MUSIC models for these links. The translation time was estimated from the reach lengths and an attenuation factor (theta) of 0.25 was adopted.

The following Figure 5-4 provides an example of a calibration trial that compares the modelled flows with the flows derived from the gauge. This model case includes soil storage capacity of 300 mm, field capacity of 200 mm and base flow rate of 3%.

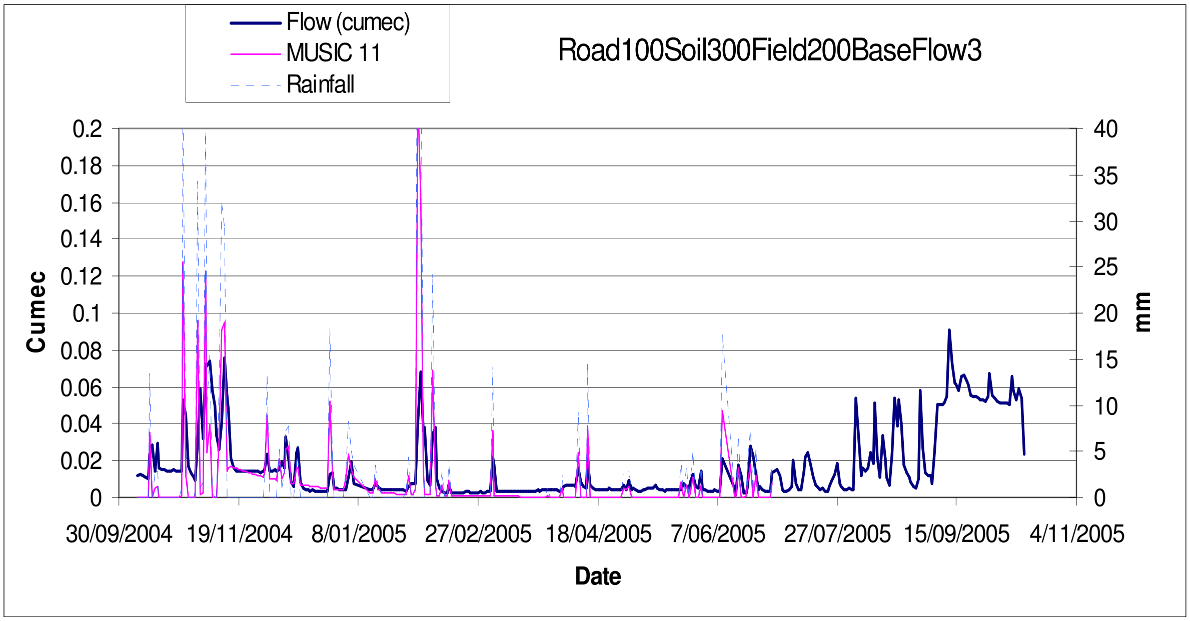


Figure 5-4 Example of calibration trial adopting a soil store of 300mm and field capacity 200mm

The example above shows a reasonable match between the shapes of the two hydrographs. However, parameters that matched well for the current development scenario produced very small flows in the undeveloped catchment scenario.

Other cases were analysed to compare high and low flow peaks, hydrograph shapes, base flow periods and totalled flow volumes. Unfortunately, a confident calibration was not able to be achieved in this study. It was decided to adopt a value of 30 mm for the most sensitive parameter of soil storage capacity, with a corresponding value of 20 mm for the soil field capacity.

5.4 MUSIC MODEL CASES

Models were developed using 6-minute rainfall data from the Croydon weather station for the period from April 1965 to June 2005. However there are two lengthy periods with missing data. The resulting period of mostly complete rainfall records comprises 35 years of data.

A 6-minute time step was adopted in the MUSIC models. This small time step is appropriate to the scale of the WSUD elements (bioretention systems and swales) included in the models and the time for water to flow through them.

Three main scenarios were modelled in MUSIC and these are:

- Undeveloped catchment. All of the catchment areas are modelled as pervious catchment areas.
- Current development of the catchment. These cases include the roof and road areas of the urban areas. A number of swale drains are also included in these cases based on the original MUSIC model, which reflect the fact that not all the sealed areas are piped directly to the creek.
- Current development with WSUD. These model cases are the same as the current development but with the addition of treatment nodes following the impervious areas

without swales. The treatment nodes adopted are bioretention systems sized at 2% of the upstream urban catchment area.

Model Flow Outputs

Modelled flows were extracted from the MUSIC models at a number of nodes corresponding to the reaches of interest in Little Stringybark Creek. From the full modelled period, there are about 40 years of flow values at 6-minute time steps (over 3.5 million data values). Flows were extracted from the model nodes representing four reaches for each of the three model scenarios.

Flows were analysed by determining the maximum flow modelled for each hourly period. These flows were then grouped into appropriate ‘flow packets’ for further hydraulic analysis. The ‘flow packets’ record the number of hourly flows in each range from the full modelling period. The flow packets used in this analysis are listed below in Table 5-2.

Table 5-2 Flow packets used in energy expenditure analysis

Flow Packets (m3/s)
0 - 0.00001
>0.00001 – 0.01
>0.01 - 0.02
>0.02 – 0.03
>0.03 – 0.04
>0.04 - 0.05
>0.05 – 0.06
>0.06 – 0.07
>0.07 – 0.08
>0.08 – 0.09
>0.09 – 0.1
>0.1 – 0.2
>0.2 – 0.3
>0.3 – 0.4
>0.4 – 0.5
>0.5 – 0.6
>0.6 – 0.7
>0.7 – 0.8
>0.8 – 0.9
>0.9 – 1
>1 - 2
>2 – 3
>3 – 4
>4 – 5
>5 – 6

5.5 HYDRAULIC CONDITIONS

Survey Data

The intent of survey recommended for this study is for use in modelling the creek hydraulics. This modelling will be undertaken to determine:

a. the processes occurring in the catchment, and

b. the response of the creek if the catchment characteristics are varied.

Therefore, it is important to focus the survey in areas of channel change and of channel stability. Four survey reaches were identified as representative of the creek in the area and show both instability and stability. These four reaches are:

1. **Urban** – 300m upstream of Forge Rd crossing. Confined valley section in heavily urbanised section.
2. **Semi-Urban** – immediately downstream of the end of the low flow pipe section, through to Birch Drive. Characterised by denser vegetation cover and boggy conditions.
3. **Mid Catchment** – 400m reach upstream of Monash University monitoring site.
4. **Lower Catchment** – 400m upstream of the confluence with un-named tributary. This reach will encompass some sinuosity and also a portion of artificially straightened channel.

Feature survey was undertaken for each reach.

Hydraulic Model

The digital terrain modelling software, 12D, was used to interpret the survey of the representative sites and generate topographic data into a format suitable for input to and creation of a hydraulic model.

The hydraulic modelling software package HEC RAS was used to generate hydraulic data for a range of flow events for analysis (Figure 5-5).

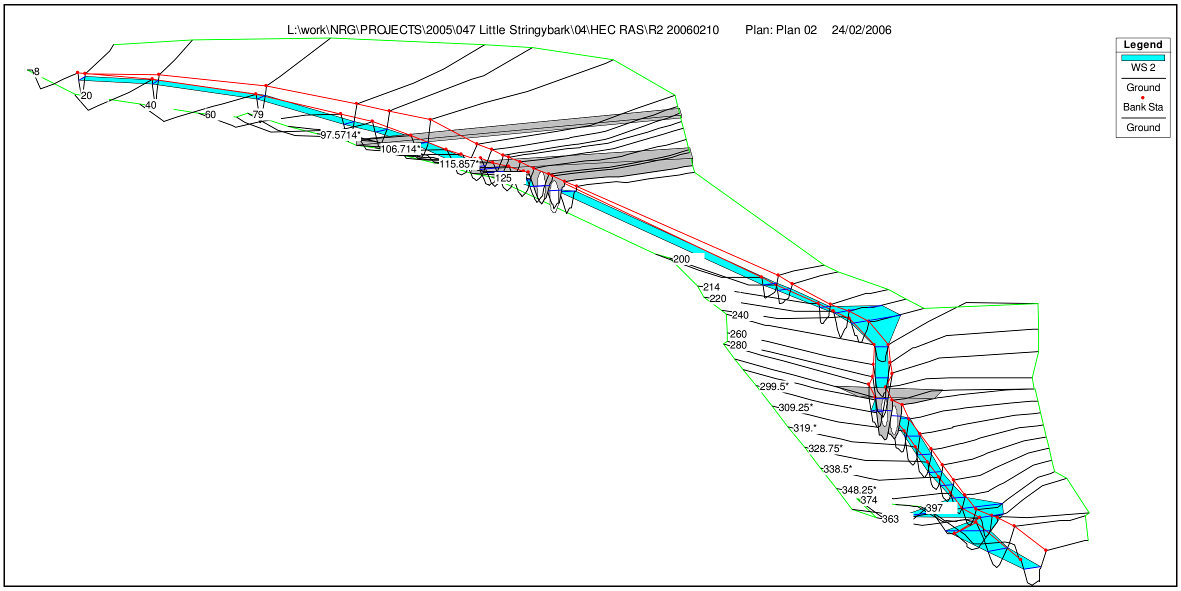


Figure 5-5 HEC RAS model of Reach 2 – Semi Urban (at 2 m^3/s discharge)

Cross sections for use in the hydraulic assessment were then located at nominated points of change in the reach.

The maximum shear stress in the reach for each flow event was adopted as the hydraulic input into the energy expenditure analysis. This parameter describes the force exerted on the channel for nominated flow events.

5.6 ENERGY EXPENDITURE ANALYSIS

The energy expended for each flow packet was plotted for each reach and development scenario.

5.7 CRITICAL SHEAR STRESS IN LITTLE STRINGYBARK CREEK

The critical shear stress (or threshold of motion) was determined through a review of previous studies undertaken on channels of similar bed material. This provides an indication of the flow event that begins to do 'work' on the channel.

There is a significant range in the literature values for the critical shear in clay based streams, from 1N/m^2 to 100 N/m^2. Without undertaking extensive field and laboratory testing of the materials of the Little Stringybark Creek channel, and in the absence of literature values, a critical shear stress is not able to be defined with any level of confidence.

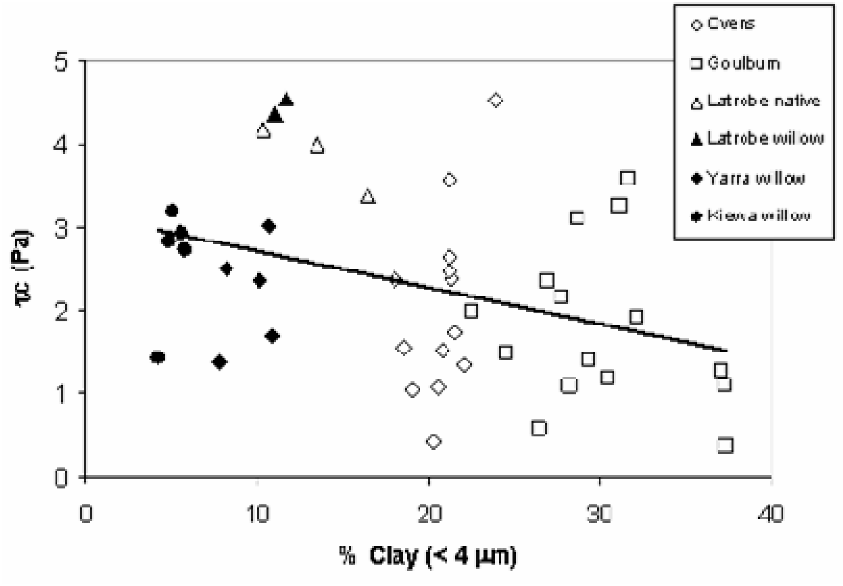


Figure 5-6 Critical shear stress for clay streams in Victoria (Rutherfurd and Bailey)

For the purposes of this investigation, a value for critical shear stress of 20 N/m^2 was adopted. This allows for some assessment of excess energy expenditure to occur.

Points on the curve relating to events below the critical shear stress were disregarded. It is assumed that no 'work' is being done on the channel in the events below the threshold of motion.

5.8 ENERGY EXPENDITURE RESULTS

The areas under the excess energy expenditure curves (Figure 5-7, Figure 5-8, Figure 5-9 and Figure 5-10) were compared and the relative change in energy expended in each development scenario determined (Table 5-3).

Table 5-3 Excess Energy Expenditure – Little Stringybark Creek

		Total Excess Energy Expenditure (N/m^2)	Relative Change – Current to WSUD
Reach 1	WSUD	180,496	65% reduction
	Current	522,423	
	Natural	126,772	
Reach 2	WSUD	161,165	61% reduction
	Current	417,600	
	Natural	216,238	
Reach 3	WSUD	18,079,562	2% reduction
	Current	18,354,816	
	Natural	17,505,545	
Reach 4	WSUD	7,904,851	2% reduction
	Current	8,036,340	
	Natural	7,644,686	

As it is uncertain what the critical shear stress to be adopted is, the impact of retrofitting WSUD to the catchment is also unable to be defined. The excess energy expenditure does however indicate that the greatest influence would be in reaches 1 and 2.

A reduction in the energy expended in these reaches would decrease the rate of bed and bank material movement in the system. With a sufficient sediment supply, the bed of the channel may increase in diversity. This is not likely as the sediment supply to the catchment is currently limited (and will be more limited under WSUD).

Therefore, under WSUD conditions, it is expected that the rate of localised erosion and instability will reduce. Ongoing stream processes, such as instability around channel crossings, will however still influence the physical form of the channel under WSUD conditions as this process is not dependent on low flow conditions.

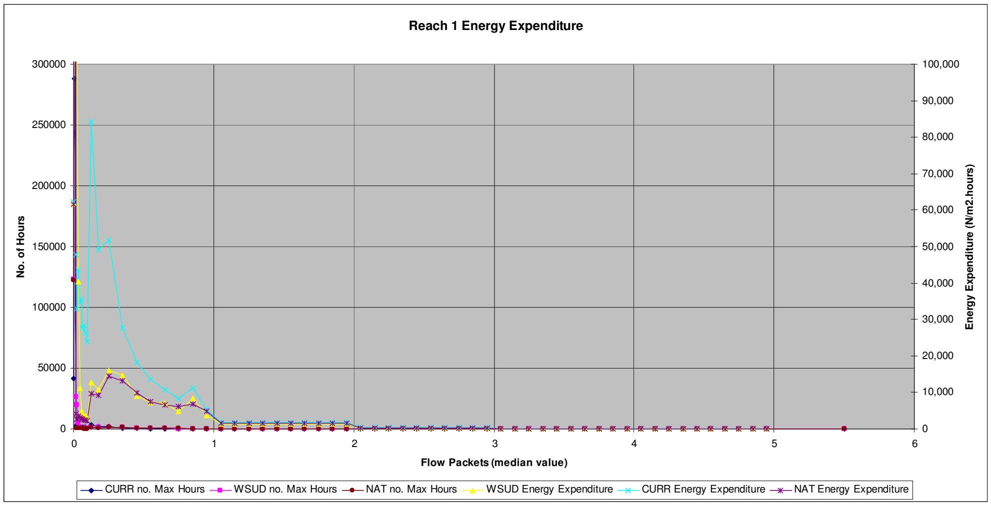


Figure 5-7 Reach One Energy Expenditure

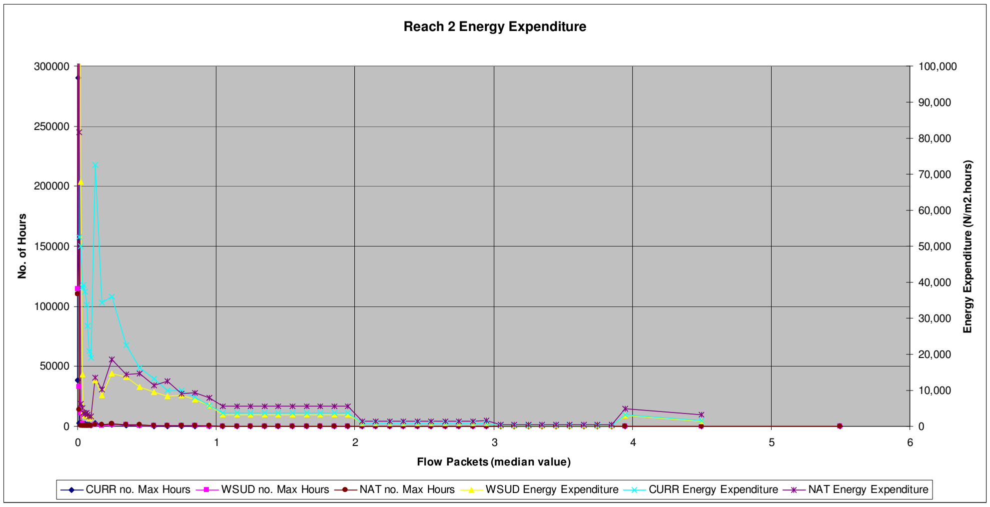


Figure 5-8 Reach Two Energy Expenditure

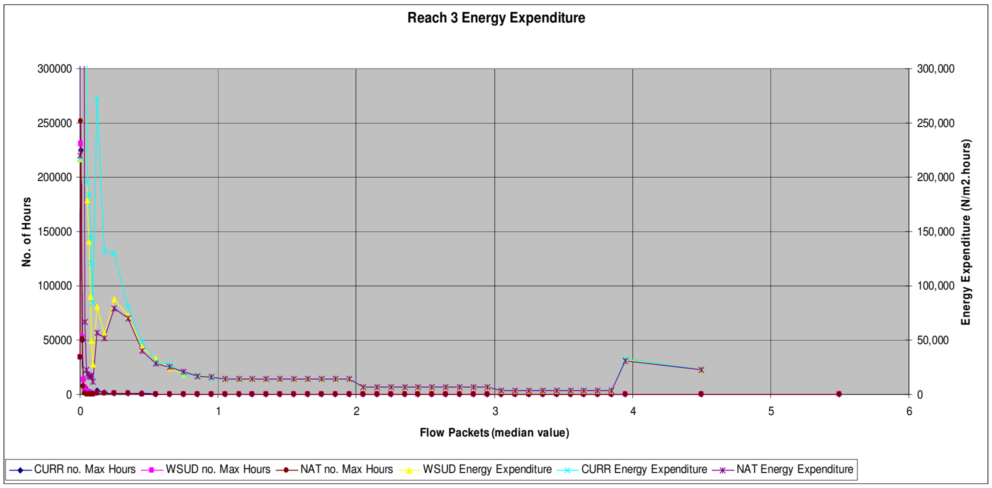


Figure 5-9 Reach Three Energy Expenditure

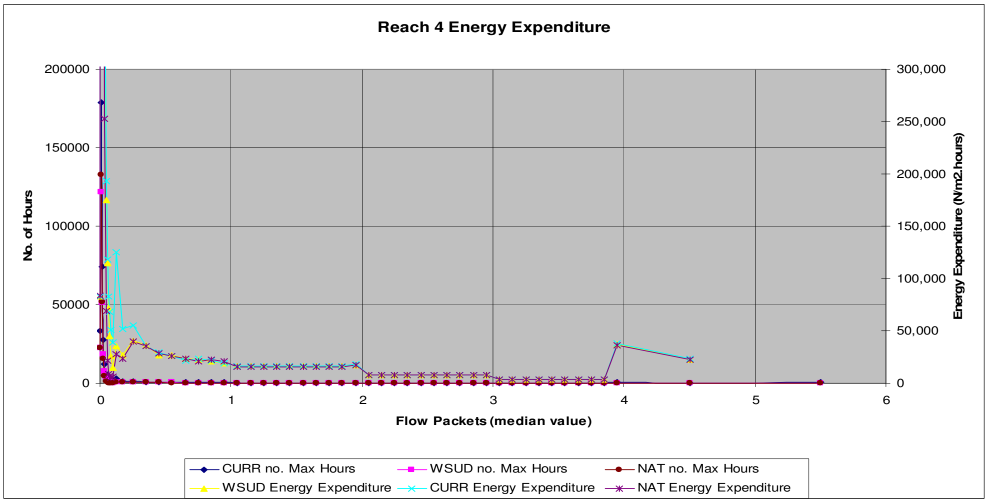


Figure 5-10 Reach Four Energy Expenditure

Appendix B Catchment Impervious Area Assessment

5.9 ESTIMATION OF CATCHMENT IMPERVIOUS AREAS

Work by Horton (2004) calculated the impervious area in the upper catchment (451.3 ha), where the town of Mt Evelyn is situated (Figure 5-11).

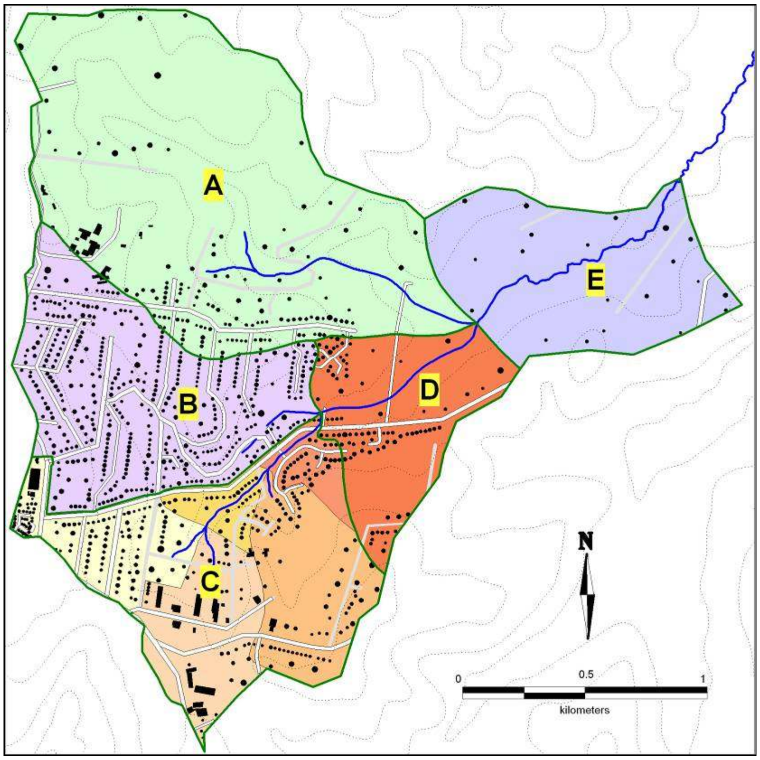


Figure 5-11 The Mt Evelyn catchment area used by Horton (2004)

The present catchment imperviousness was calculated as follows (Horton, 2004):

Roads:

Table 5-4 Road area in the catchment (calculated)

	sealed roads	unsealed roads
total	112,507 m^2	28,201 m^2
connected	67,854 m^2	
unconnected	44,653 m^2	

Buildings:

Table 5-5 Building area in the catchment (calculated)

	roofs	garages	roofs + garages
total	176,559 m^2	26,484 m^2	203,043 m^2
connected	115,559 m^2	17,334 m^2	132,893 m^2
unconnected	61,000 m^2	9,150 m^2	70,150 m^2

Table 5-6 Private driveway area in the catchment (calculated)

	sealed driveways	unsealed driveways
total	70,624 m^2	70,624 m^2

connected	46,224 m^2	46,224 m^2
unconnected	24,400 m^2	24,400 m^2

Unsealed roads were not considered Horton's study, and roofs and garages were considered together under the same in-lot technique.

Total roof area: 203,000 m^2

Connected total roof area: 132,900 m^2

Unconnected total roof area: 70,200 m^2

Unsealed roads and driveways: 98,800 m^2

Sealed roads and driveways: 183,100 m^2 (112,500 m^2 of roads and 70,600 m^2 of driveways)

connected sealed roads: 114,000 m^2

unconnected sealed roads: 69,100 m^2

➔ **Total imperviousness** = 38.6 ha / 451.3 ha = **8.56 %**

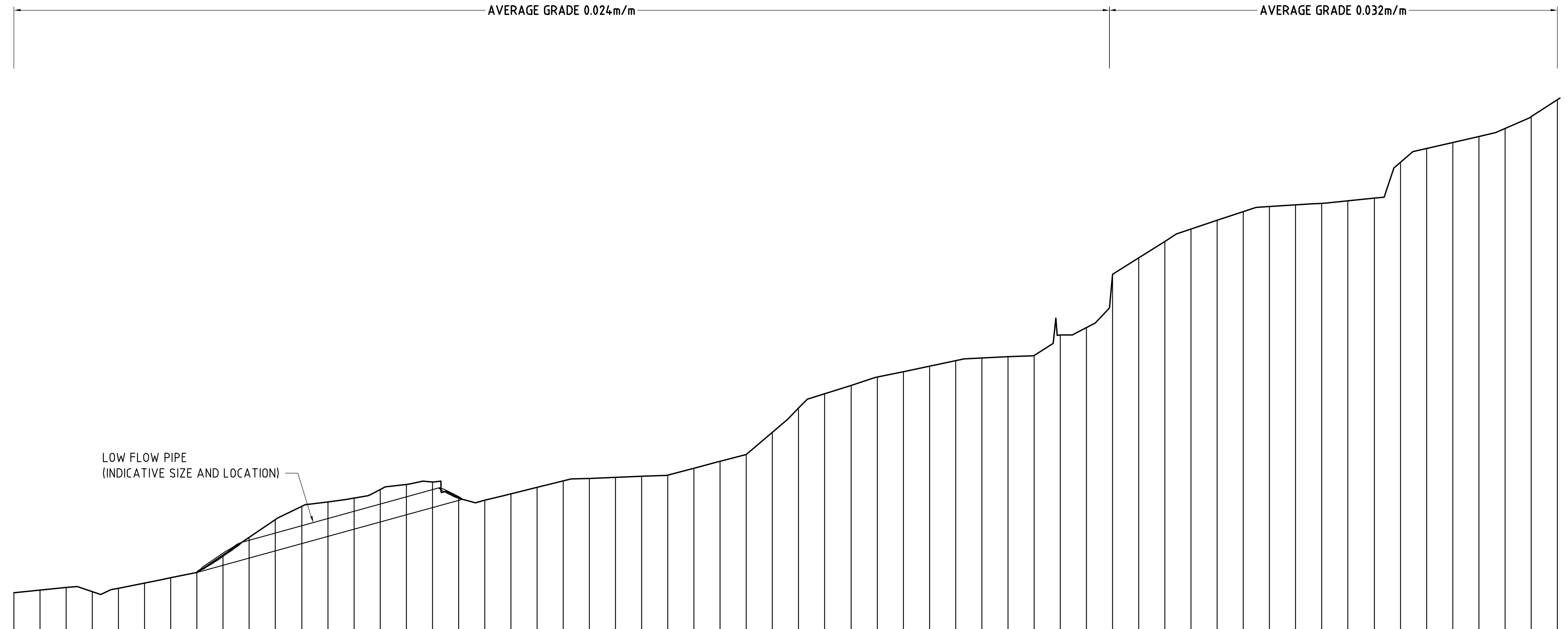
➔ **Effective imperviousness** = 24.7 ha / 451.3 ha = **5.47 %**

The total catchment area of Little Stringybark Creek, up to the confluence with Stringybark Creek, is 860.3 ha. The downstream part of the catchment has very little urban development and is sparsely populated. If imperviousness is considered negligible in the lower catchment then Little Stringybark Creek as a whole would have the following Impervious areas:

➔ **Total imperviousness** = 38.6 ha / 860.3 ha = **4.49 %**

➔ **Effective imperviousness** = 24.7 ha / 860.3 ha = **2.87 %**

Appendix C Longitudinal Sections of Study Reaches



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EXISTING SURFACE	166.75	166.80	166.86	166.78	166.84	166.94	167.04	167.14	167.48	167.81	168.15	168.40	168.49	168.56	168.73	168.82	168.87	168.57	168.52	168.64
CHAINAGE	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0

EXISTING SURFACE	168.77	168.89	168.94	168.96	168.98	169.00	169.14	169.27	169.40	169.82	170.28	170.56	170.72	170.88	170.98	171.08	171.19	171.24	171.26	171.29
CHAINAGE	100.0	105.0	110.0	115.0	120.0	125.0	130.0	135.0	140.0	145.0	150.0	155.0	160.0	165.0	170.0	175.0	180.0	185.0	190.0	195.0

EXISTING SURFACE	171.68	171.83	172.84	173.16	173.47	173.70	173.87	174.04	174.14	174.17	174.20	174.25	174.30	174.98	175.25	175.36	175.48	175.63	175.85	176.18
CHAINAGE	200.0	205.0	210.0	215.0	220.0	225.0	230.0	235.0	240.0	245.0	250.0	255.0	260.0	265.0	270.0	275.0	280.0	285.0	290.0	295.0

HORIZONTAL SCALE 1:500 (A1)

VERTICAL SCALE 1:50 (A1)

		Issue	16.6.06	
REV	ZONE	REVISION	DATE	APP'D

DRAWN	D.FRANCIS	PLAN REFERENCE	
DESIGNED		MELWAY REFERENCE	
CHECKED		THE WATER COMPANY OFFER No.	

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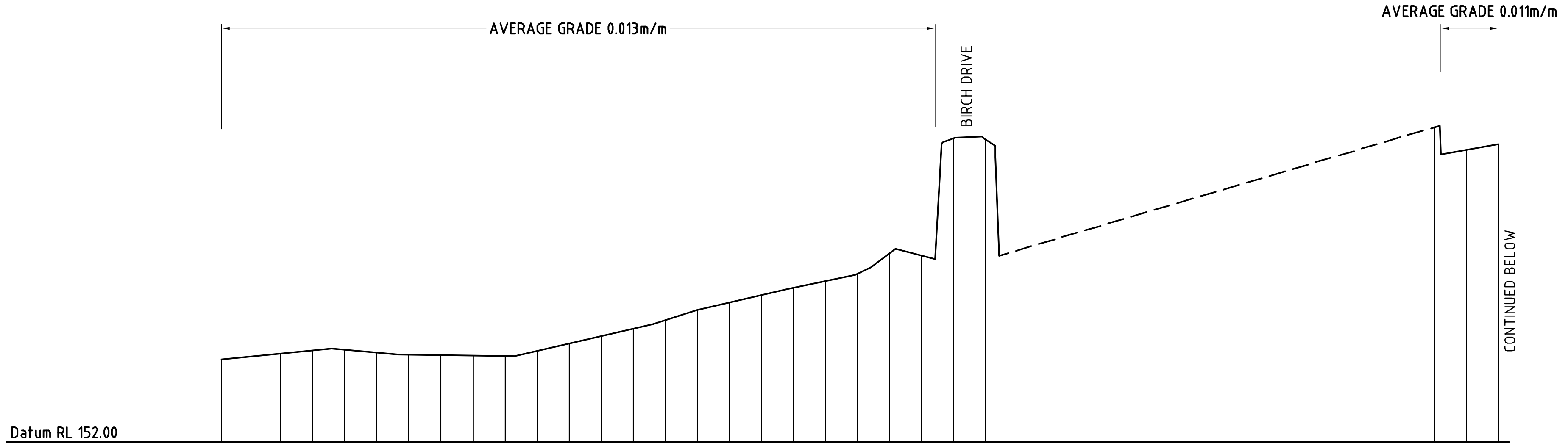
Natural Resource Group - Melbourne
T 8517 9200 F 8517 9455
71 Queens Road, Melbourne 3004 - GPO Box 5175AA Melbourne 3001
R1.dwg 6005047

MELBOURNE WATER

LITTLE STRINGYBARK CREEK
GEOMORPHOLOGIC ASSESSMENT
REACH 1 LONGITUDINAL SECTION

16 June 2006
SHEET 1 OF 4
DRAWING No.
R1

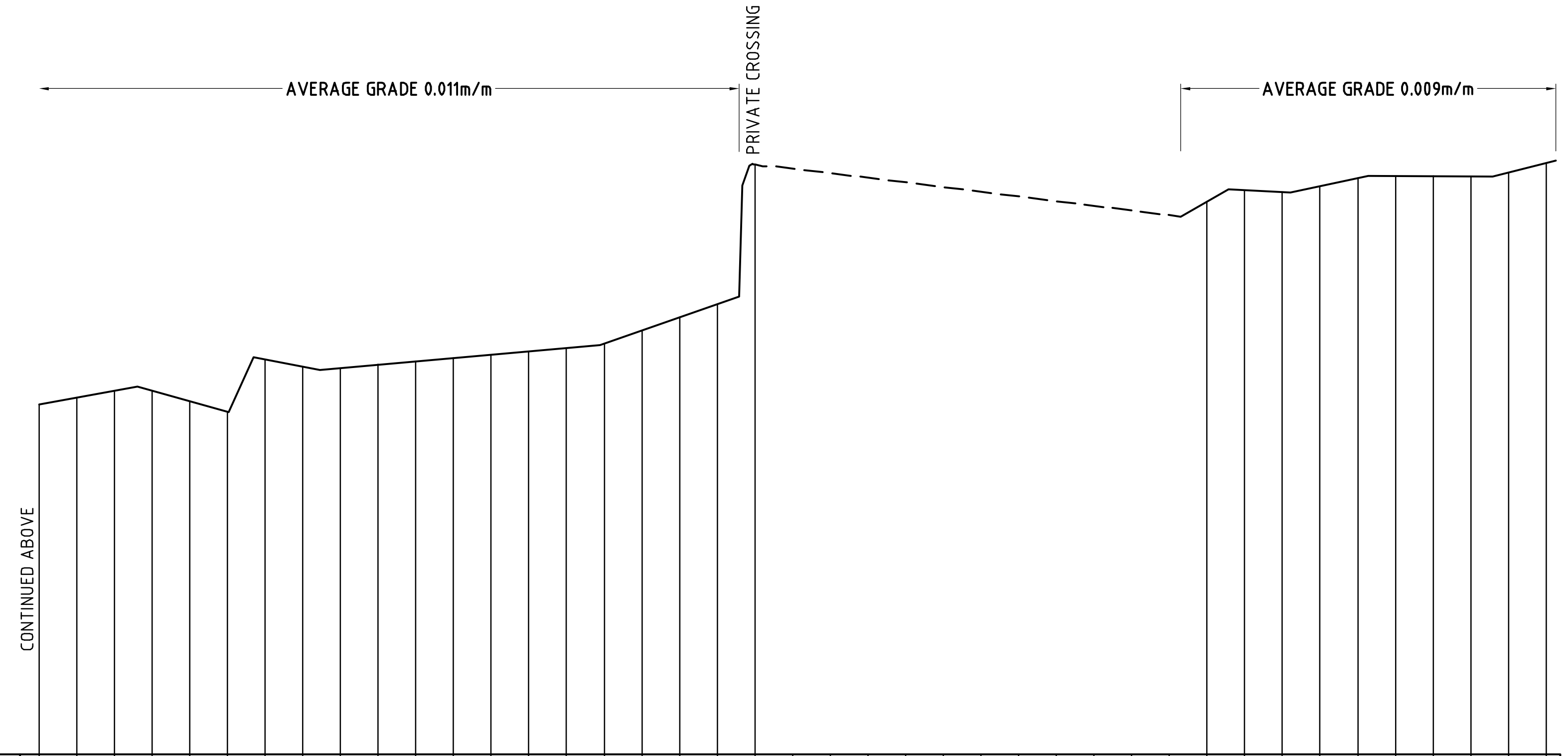


Datum RL 152.00

EXISTING SURFACE	153.28	153.37	153.42	153.43	153.39	153.36	153.35	153.34	153.33	153.41	153.53	153.65	153.77
CHAINAGE	0.0	9.2	14.2	19.2	24.2	29.2	34.2	39.2	44.2	49.2	54.2	59.2	64.2

EXISTING SURFACE	153.90	154.06	154.17	154.29	154.40	154.50	154.62	154.94	154.90	156.74	156.72		
CHAINAGE	69.2	74.2	79.2	84.2	89.2	94.2	99.2	104.2	109.2	114.2	119.2	124.2	129.2

EXISTING SURFACE													156.56	156.64
CHAINAGE	134.2	139.2	144.2	149.2	154.2	159.2	164.2	169.2	174.2	179.2	184.2	189.2	194.2	199.2



Datum RL 152.00

EXISTING SURFACE	156.64	156.73	156.82	156.82	156.68	156.54	157.24	157.15	157.13	157.17	157.22	157.26	157.30
CHAINAGE	199.2	204.2	209.2	214.2	219.2	224.2	229.2	234.2	239.2	244.2	249.2	254.2	259.2

EXISTING SURFACE	157.35	157.39	157.45	157.62	157.80	157.98	159.82						
CHAINAGE	264.2	269.2	274.2	279.2	284.2	289.2	294.2	299.2	304.2	309.2	314.2	319.2	324.2

EXISTING SURFACE						159.33	159.48	159.46	159.54	159.65	159.67	159.67	159.67	159.72	159.85
CHAINAGE	329.2	334.2	339.2	344.2	349.2	354.2	359.2	364.2	369.2	374.2	379.2	384.2	389.2	394.2	399.2

LEGEND

— — — GAP IN SURVEY INFORMATION

HORIZONTAL SCALE 1:500 (A1)

VERTICAL SCALE 1:50 (A1)

REV	ZONE	REVISION	DATE	APP'D
		Issue	16.6.06	

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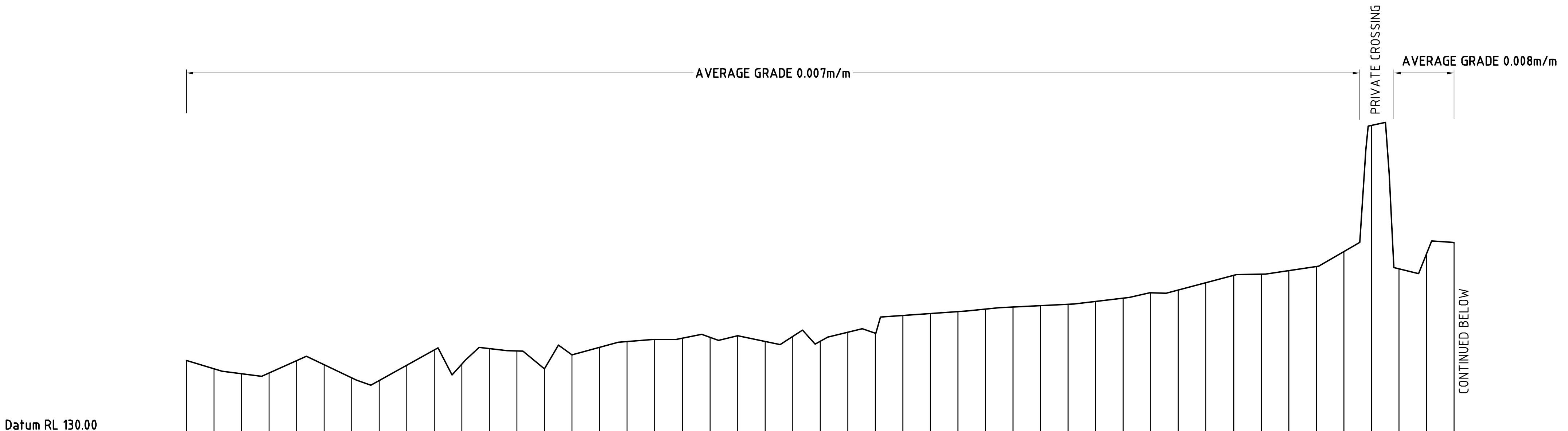
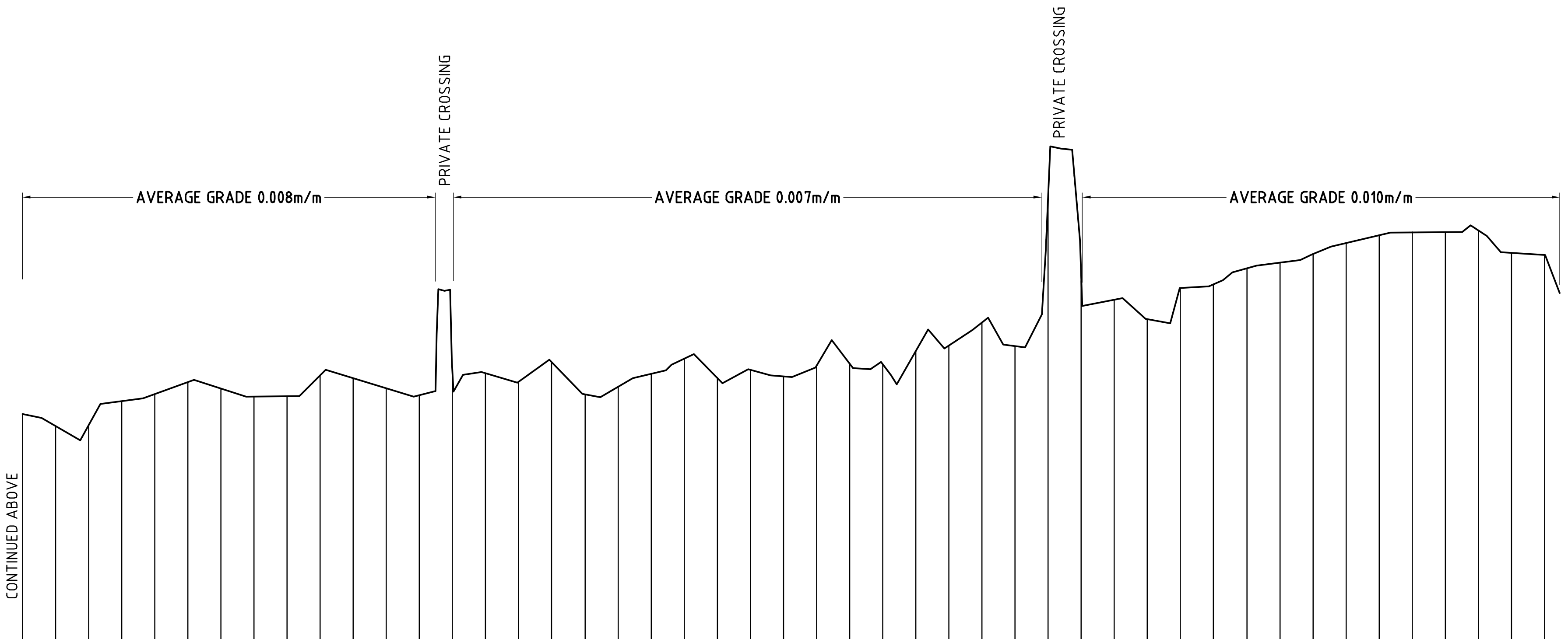
MELBOURNE WATER

LITTLE STRINGYBARK CREEK
GEOMORPHOLOGIC ASSESSMENT
REACH 2 LONGITUDINAL SECTION

16 June 2006
SHEET 2 OF 4
DRAWING No.
R2



EXISTING SURFACE	131.32	131.16	131.07	131.08	131.31	131.23	131.00	130.95	131.23	131.51	131.25	131.53
CHAINAGE	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0
EXISTING SURFACE	131.48	131.16	131.42	131.55	131.65	131.69	131.72	131.73	131.76	131.66	131.75	131.66
CHAINAGE	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0	105.0	110.0	115.0
EXISTING SURFACE	131.83	131.80	132.13	132.17	132.20	132.24	132.28	132.30	132.33	132.38	132.44	132.54
CHAINAGE	120.0	125.0	130.0	135.0	140.0	145.0	150.0	155.0	160.0	165.0	170.0	175.0
EXISTING SURFACE	132.59	132.72	132.86	132.88	132.94	133.02	133.29	135.57	132.98	133.24	133.45	
CHAINAGE	180.0	185.0	190.0	195.0	200.0	205.0	210.0	215.0	220.0	225.0	230.0	



EXISTING SURFACE	133.45	133.27	133.28	133.64	133.74	133.93	133.83	133.71	133.71	134.03	133.99	133.84
CHAINAGE	230.0	235.0	240.0	245.0	250.0	255.0	260.0	265.0	270.0	275.0	280.0	285.0
EXISTING SURFACE	133.73	134.06	134.06	133.93	134.22	133.75	133.86	134.06	134.28	134.00	134.12	134.01
CHAINAGE	290.0	295.0	300.0	305.0	310.0	315.0	320.0	325.0	330.0	335.0	340.0	345.0
EXISTING SURFACE	134.18	134.21	134.20	134.40	134.48	134.83	134.47	136.78	135.46	135.17	134.88	135.35
CHAINAGE	350.0	355.0	360.0	365.0	370.0	375.0	380.0	385.0	390.0	395.0	400.0	405.0
EXISTING SURFACE	135.41	135.64	135.73	135.86	136.03	136.15	136.19	136.20	136.22	135.88	135.85	
CHAINAGE	410.0	415.0	420.0	425.0	430.0	435.0	440.0	445.0	450.0	455.0	460.0	

HORIZONTAL SCALE 1:500 (A1)

VERTICAL SCALE 1:50 (A1)

REV	ZONE	REVISION	DATE	APP'D
		Issue	16.6.06	

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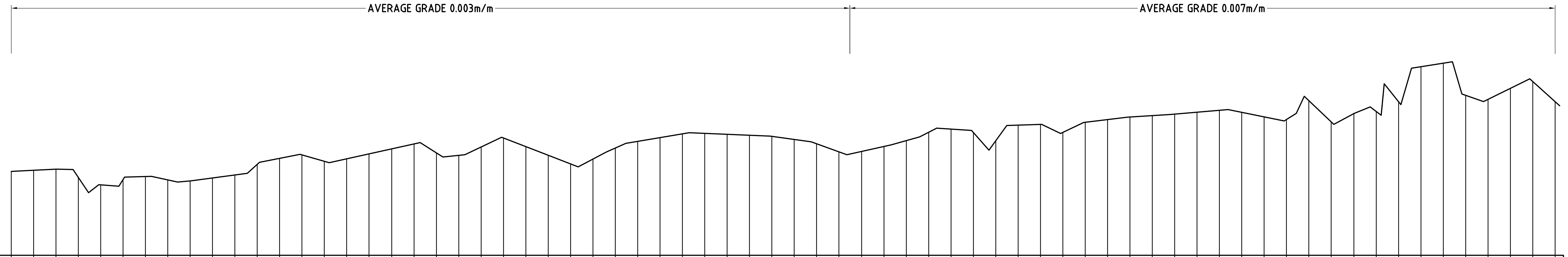
MELBOURNE WATER

LITTLE STRINGYBARK CREEK
GEOMORPHOLOGIC ASSESSMENT
REACH 3 LONGITUDINAL SECTION

16 June 2006
SHEET 3 OF 4
DRAWING No.
R3



Datum RL 115.00

EXISTING SURFACE	116.87	116.90	116.92	116.74	116.57	116.69	116.76	116.69	116.66	116.73	116.79	117.03	117.16	117.24
CHAINAGE	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0

EXISTING SURFACE	117.10	117.16	117.27	117.37	117.48	117.28	117.23	117.42	117.62	117.43	117.23	117.04	117.15	117.39
CHAINAGE	70.0	75.0	80.0	85.0	90.0	95.0	100.0	105.0	110.0	115.0	120.0	125.0	130.0	135.0

EXISTING SURFACE	117.54	117.63	117.71	117.72	117.70	117.68	117.65	117.59	117.49	117.31	117.32	117.43	117.56	117.74
CHAINAGE	140.0	145.0	150.0	155.0	160.0	165.0	170.0	175.0	180.0	185.0	190.0	195.0	200.0	205.0

EXISTING SURFACE	117.82	117.74	117.56	117.91	117.92	117.75	117.97	118.03	118.08	118.12	118.15	118.19	118.23	118.19
CHAINAGE	210.0	215.0	220.0	225.0	230.0	235.0	240.0	245.0	250.0	255.0	260.0	265.0	270.0	275.0

EXISTING SURFACE	118.09	118.03	118.45	117.98	118.16	118.21	118.43	119.21	119.29	118.57	118.48	118.73	118.88	118.43
CHAINAGE	280.0	285.0	290.0	295.0	300.0	305.0	310.0	315.0	320.0	325.0	330.0	335.0	340.0	345.0

HORIZONTAL SCALE 1:500 (A1)

VERTICAL SCALE 1:50 (A1)

REV	ZONE	REVISION	DATE	APP'D
		Issue	16.6.06	

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MELBOURNE WATER

LITTLE STRINGYBARK CREEK
GEOMORPHOLOGIC ASSESSMENT
REACH 4 LONGITUDINAL SECTION

16 June 2006
SHEET 4 OF 4
DRAWING No.
R4

Appendix D Field Inspection Sheets

No 1

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:- To understand the current condition of Little Stringybark creek in order to understand the consequences of WSUD.

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Little Stringybark

LOCATION u/s Forge Rd. bridge crossing.

DATE

PROJECT

STUDY REACH From To

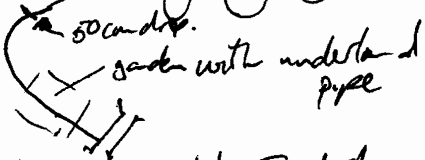
SHEET COMPLETED BY JRG

RIVER STAGE Low

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:- u/s of bridge piped sections – low flow → ~1m deep slot x ·7m width
erosion on outer meander bend – undercutting but not looking very dynamic.



+ steep drop – plunge pool at manhole cover
u/s 0·2 deep channel.
Two pipe structures u/s with manhole covers – incised 1.2m – narrow slot. Eroded u/s with scour and drop of channel from surface flow into [illegible]
Clay banks. – bed getting more gravelly u/s
Further u/s pipe with rocks covering → gravel bed d/s slope wash from some properties pipe underneath and floodplain/stream. Builders fill variable so different sediment into system.
New building with culvert added.
At u/s of Forge Rd (maybe sponge) culvert + drop structure.

SECTION 2 - REGION AND VALLEY DESCRIPTION

[illegible] ROUND RIVER VALLEY
- Mountains ☐
- Uplands ☐
- Hills ☑
- Plains ☐
- Lowlands ☐

- Dendritic ☑
- Parallel ☐
- Trellis ☐
- Rectangular ☐
- Radial ☐
- Annular ☐
- Multi-Basin ☐
- Contorted ☐

Surface Geology
- Weathered Soils ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial ☐
- Lake Deposits ☐
- Wind blown (loess) ☐

Rock Type
- Metamorphic ☐
- Igneous ☑
- [illegible] ☐

Specific Rock Types (if known)

Land Use
- Managed ☐
- Cultivated ☐
- Urban ☑
- Suburban ☐

Vegetation
- Temperate Forest ☐
- Boreal Forest ☐
- Wetland ☐
- Savanna ☐
- Temperate grassland ☐
- Desert scrub ☐
- Extreme Desert ☐
- Tundra or Alpine ☐
- Agricultural land ☐

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
- In Valley ☑
- On Alluvial Fan ☐
- On Alluvial Plain ☐
- In a Delta ☐
- In Old Lake Bed ☐

Valley Shape
- Symmetrical ☑
- Asymmetrical ☐

Height
- < 5 m ☐
- 5 - 10 m ☑
- 10 - 30 m ☐
- 30 - 60 m ☐
- 60 - 100 m ☐
- > 100 m ☐

Side Slope Angle
- < 5degrees ☐
- 5-10 degrees ☐
- 10-20 degrees ☐
- 20-50 degrees ☑
- >50 degrees ☐

Valley Side
- None ☑
- Occasional ☐
- Frequent ☐

Failure Locations
- None ☐
- Away from river ☐
- Along river (Undercut) ☐

Interpretative Observations

Material Type
- *Soils* ☐
- *Loose debris* ☐

Failure Type
(see Sketches in Manual)

Severity of Problem
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☑

Valley Floor Data
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- 5-10 river widths ☑
- >10 river widths ☐

Flow Resistance*
- Left Overbank Manning n value ___
- Right Overbank Manning n value ___ (* note: n value for channel is recorded in Part 6)

Surface Geology
- Bed rock ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial: Alluvium ☐
- Fluvial: Backswamp ☐
- Lake Deposits ☐
- Wind Blown (Loess) ☐

Land Use
- Natural ☐
- Managed ☑
- Cultivated ☐
- Urban ☐
- Suburban ☑
- Industrial ☐

Vegetation
- None ☐
- Unimproved Grass ☐
- Improved Pasture ☐
- Orchards ☐
- Arable Crops ☐
- Shrubs ☐
- Deciduous Forest ☐
- Coniferous Forest ☐
- Mixed Forest ☐

Riparian Buffer Strip
- None ☐
- Indefinite ☐
- Fragmentary ☑
- Continuous ☐

Strip Width
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☑
- > 5 river widths ☐

Notes and Comments:- Housing close to river in places.

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
- None ☑
- Indefinate ☐
- Fragmentary ☐
- Continuous ☐
- Number of Terraces ___

Trash Lines
- Absent ☑
- Present ☐
- Height above flood plain (m) ___

Overbank Deposits
- None ☑
- Silt ☐
- Fine sand ☐
- Medium sand ☐
- Coarse sand ☐
- Gravel ☐
- Boulders ☐

Levees
- None ☑
- Natural ☐
- Constructed ☐

Levee Description
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☐
- Left Bank ☐
- Right Bank ☐
- Both Banks ☐

Levee Data
- Height (m) ☐
- Side Slope (o) ☐

Levee Condition
- None ☐
- Intact ☐
- Local Failures ☐
- Frequent failures ☐

Interpretative Observations

Present Status
- *Adjusted* ☐
- *Incised* ☑
- *Aggraded* ☐

Instability Status
- *Stable* ☐
- *Degrading* ☑
- *Aggrading* ☐

Problem Severity
- *Insignificant* ☐
- *Moderate* ☑
- *Serious* ☐

Problem Extent
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach scale* ☐
- *System wide* ☑
- *Regional* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80 90] 100 %

Notes and Comments:- Flows in and out of piped

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
- Straight ☑
- Sinuous ☐
- Irregular ☐
- Regular meanders ☐
- Irregular meanders ☐
- Tortuous meanders ☐
- Braided ☐
- Anastomosed ☐

Planform Data
- Bend Radius ___
- Meander belt width ___
- Wavelength ___
- Meander Sinuosity ___

Location in Valley
- Left ☐
- Middle ☐
- Right ☐

Lateral Activity
- None ☑
- Meander progression ☐
- Increasing amplitude ☐
- Progression+cut-offs ☐
- Irregular erosion ☐
- Avulsion ☐
- Braiding ☐

Floodplain Features
- None ☑
- Meander scars ☐
- Scroll bars+sloughs ☐
- Oxbow lakes ☐
- Irregular terrain ☐
- Abandoned channel ☐
- Braided Deposits ☐

Interpretative Observations

Present Status
- *Adjusted* ☐
- *Over wide* ☑
- *Too narrow* ☐

Instability Status
- *Stable* ☐ ?
- *Widening* ☑
- *Narrowing* ☐

Problem Severity
- *Insignificant* ☐
- *Moderate* ☐
- *Serious* ☐

Problem Extent
- *None* ☐
- *Local* ☐
- *General* ☑
- *Reach scale* ☐
- *System wide* ☐
- *Regional* ☐

Level of Confidence in percent (Circle one)
0 10 20 30 40 50 [✓ 60] 70 80 90 100 %

Notes and Comments:-

SECTION 3 - CHANNEL DESCRIPTION

PART 6: CHANNEL DESCRIPTION

Dimensions
Av. top bank width (m) 0·7
Av. channel depth (m) 1
Av. water width (m) __
Av. water depth (m) __
Reach slope __
Mean velocity (m/s) __
Manning's n value __

Flow Type
None ☐
Uniform/Tranquil ☑
Uniform/Rapid ☐
Pool+Riffle ☐
Steep + Tumbling ☐
Steep + Step/pool ☐
(Note: Flow type on day of observation)

Bed Controls
None ☑
Occasional ☑
Frequent ☐
Confined ☐
Number of controls __

Control Types
None ☐
Solid Bedrock ☐
Weathered Bedrock ☐
Boulders ☐
Gravel armor ☐
Cohesive Materials ☐
Bridge protection ☑
Grade control structures ☐

Width Controls
None ☐
Occasional ☑
Frequent ☐
Confined ☐
Number of controls __

Control Types
None ☐
Bedrock ☐
Boulders ☐
Gravel armor ☐
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☑
Dykes or groynes ☐

Notes and Comments:-

PART 7: BED SEDIMENT DESCRIPTION

Bed Material
Clay ☑
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☑
cobbles + boulders ☐
boulders + bedrock ☐
Bed rock ☐

Bed Armour
None ☑
Static-armour ☐
Mobile-armour ☐

Sediment Depth
Depth of loose Sediment (cm) __

Surface Size Data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Substrate Size Data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Bed Forms (Sand)
Flat bed (None) ☐
Ripples ☐
Dunes ☐
Bed form height (m) __

Island or Bars
None ☐
Occasional ☐
Frequent ☐

Bar Types
None ☑
Pools and riffles ☐
Alternate bars ☐
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Bar Substrate data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Notes and Comments:-

Channel Sketch Map

Map Symbols

Study reach limits
Cross-section
Bank profile

North point
flow direction
impinging flow

Cut bank
exposed island/bar
structure

Photo point
Sediment sampling point
Significant vegetation

Representative Cross-section

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☑
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☑
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

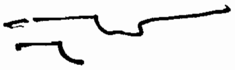
Bank Materials
Silt/clay ☑
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) 0·7

Ave. Bank Slope
angle (degrees) ___

Bank Profile Shape
(see sketches in manual)



Tension Cracks
None ☑
Occasional ☐
Frequent ☐
Crack Depth
Proportion of
bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	**Material Type 2**	**Material Type 3**	**Material Type 4**
Toe ☐	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☐	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef. ___

Notes and Comments:-

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐
Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐
Tree species
(if known)

Density + Spacing
None ☐
Sparse/clumps ☑
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐
Roots
Normal ☐
Exposed ☑
Adventitious ☐

Location
Whole bank ☐
Upper bank ☑
Mid-bank ☐
Lower bank ☐
Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☑
Dead ☐
Age
Imature ☐
Mature ☑
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___
Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Bank Top Edge	Failed debris	Engineered Structure
Bank Toe	Attached bar	Significant vegetation
Water's Edge	Undercutting	Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
General ☐
Outside Meander ☑
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☑
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ____

Rate of Advance
m/yr (if applicable and known) ____

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☑
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☑
General ☐
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☐
Impinging flow ☑
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☑
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 [✓ 90] 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks
None ☐
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☑
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species (if known)
____
____

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☐
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
Average angle (o) ___

Bank Profile Shape
(see sketches in manual)
☐

Tension Cracks
None ☐
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	**Material Type 2**	**Material Type 3**	**Material Type 4**
Toe ☐	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☐	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef. ___

Notes and Comments:-

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐

Tree species
(if known)
☐
☐
☐

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Profile Symbols

Bank Top Edge
Bank Toe
Water's Edge

Failed debris
Attached bar
Undercutting

Engineered Structure
Significant vegetation
Vegetation Limit

PART 15: RIGHT BANK EROSION

Erosion Location
- General ☐
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☐
- Eroding:dormant ☐
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Processes
- *Parallel flow* ☐
- *Impinging flow* ☐
- *Piping* ☐
- *Freeze/thaw* ☐
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1		***Process 2***	
Toe (undercut)	☐	*Toe (undercut)*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐
Process 3		***Process 4***	
Toe (undercut)	☐	*Toe (undercut)*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location
- General ☐
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☐
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☐

Failure Scars+Blocks
- None ☐
- Old ☐
- Recent ☐
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☐
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1		***Mode 2***	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐
Mode 3		***Mode 4***	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☐
- Individual grains ☐
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☐
- Boulders ☐

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species (if known)
☐
☐

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☐
- *Concave upward* ☐
- *Convex upward* ☐

Sediment Balance
- *Accumulating* ☐
- *Steady State* ☐
- *Undercutting* ☐
- *Unknown* ☐

Present Debris Storage
- *No bank debris* ☐
- *Little bank debris* ☐
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

No 1

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
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SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:- To understand the current condition of Little Stringybark creek in order to understand the consequences of WSUD.

Purpose of Stream Reconnaissance:-

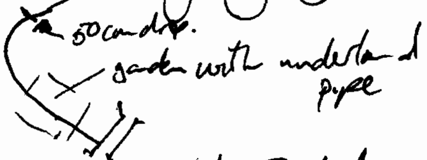
Logistics of Reconnaissance Trip:-

RIVER Little Stringybark
LOCATION u/s Forge Rd. bridge crossing.
DATE
PROJECT
STUDY REACH From To
SHEET COMPLETED BY JRG
RIVER STAGE Low
TIME: START
TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

u/s of bridge piped sections – low flow ✱ a 1m deep slot x ·7m width
erosion on outer meander bed – under-cutting but not looking very dynamic.

+ Steep drop – plunge pool at manhole cover



u/s 0·2 deep channel.

Two pipe structures u/s with manhole covers – incised 1·2m – narrow slot. Eroded u/s with scour and drop of channel from surface flow into manhole
Clay banks. – bed getting more gravelly u/s
Further u/s pipe with rocks covering → gravel bed d/s slope wash from some properties pipe underneath and floodplain/stream. Builders fill variable so different sediment into system.
New building with culvert added.
At u/s of Forger Rd (maybe spronger) culvert + drop structure.

SECTION 2 - REGION AND VALLEY DESCRIPTION

ROUND RIVER VALLEY
- Mountains ☐
- Uplands ☐
- Hills ☑
- Plains ☐
- Lowlands ☐

- Dendritic ☑
- Parallel ☐
- Trellis ☐
- Rectangular ☐
- Radial ☐
- Annular ☐
- Multi-Basin ☐
- Contorted ☐

Surface Geology
- Weathered Soils ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial ☐
- Lake Deposits ☐
- Wind blown (loess) ☐

Rock Type
- Metamorphic ☐
- Igneous ☑
- [illegible] ☐

Specific Rock Types (if known)

Land Use
- Managed ☐
- Cultivated ☐
- Urban ☑
- Suburban ☐

Vegetation
- Temperate forest ☐
- Boreal forest ☐
- Wetland ☐
- Savanna ☐
- Temperate grassland ☐
- Desert scrub ☐
- Extreme Desert ☐
- Tundra or Alpine ☐
- **Agricultural land** ☐

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
- In Valley ☑
- On Alluvial Fan ☐
- On Alluvial Plain ☐
- In a Delta ☐
- In Old Lake Bed ☐

Valley Shape
- Symmetrical ☑
- Asymmetrical ☐

Height
- < 5 m ☐
- 5 - 10 m ☑
- 10 - 30 m ☐
- 30 - 60 m ☐
- 60 - 100 m ☐
- > 100 m ☐

Side Slope Angle
- < 5degrees ☐
- 5-10 degrees ☐
- 10-20 degrees ☐
- 20-50 degrees ☑
- >50 degrees ☐

Valley Side
- None ☑
- Occasional ☐
- Frequent ☐

Failure Locations
- None ☐
- Away from river ☐
- Along river (Undercut) ☐

Interpretative Observations

Material Type
- *Soils* ☐
- *Loose debris* ☐

Failure Type
(see Sketches in Manual)

Severity of Problem
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☑

Valley Floor Data
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- 5-10 river widths ☑
- >10 river widths ☐

Flow Resistance*
Left Overbank Manning n value ___
Right Overbank Manning n value ___ (* note: n value for channel is recorded in Part 6)

Surface Geology
- Bed rock ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial: Alluvium ☐
- Fluvial: Backswamp ☐
- Lake Deposits ☐
- Wind Blown (Loess) ☐

Land Use
- Natural ☐
- Managed ☑
- Cultivated ☐
- Urban ☐
- Suburban ☑
- Industrial ☐

Vegetation
- None ☐
- Unimproved Grass ☐
- Improved Pasture ☐
- Orchards ☐
- Arable Crops ☐
- Shrubs ☐
- Deciduous Forest ☐
- Coniferous Forest ☐
- Mixed Forest ☐

Riparian Buffer Strip
- None ☐
- Indefinite ☐
- Fragmentary ☑
- Continuous ☐

Strip Width
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☑
- > 5 river widths ☐

Notes and Comments:- Housing close to river in places-

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
- None ☑
- Indefinate ☐
- Fragmentary ☐
- Continuous ☐

Number of Terraces ___

Trash Lines
- Absent ☑
- Present ☐

Height above flood plain (m) ___

Overbank Deposits
- None ☑
- Silt ☐
- Fine sand ☐
- Medium sand ☐
- Coarse sand ☐
- Gravel ☐
- Boulders ☐

Levees
- None ☑
- Natural ☐
- Constructed ☐

Levee Description
- None ☑
- Indefinite ☐
- Fragmentary ☐
- Continuous ☐
- Left Bank ☐
- Right Bank ☐
- Both Banks ☐

Levee Data
- Height (m) ☐
- Side Slope (o) ☐

Levee Condition
- None ☐
- Intact ☐
- Local Failures ☐
- Frequent failures ☐

Interpretative Observations

Present Status
- *Adjusted* ☐
- *Incised* ☑
- *Aggraded* ☐

Instability Status
- *Stable* ☐
- *Degrading* ☑
- *Aggrading* ☐

Problem Severity
- *Insignificant* ☐
- *Moderate* ☑
- *Serious* ☐

Problem Extent
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach scale* ☐
- *System wide* ☑
- *Regional* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80 90] 100 %

Notes and Comments:- Flows in and out of piped

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
- Straight ☑
- Sinuous ☐
- Irregular ☐
- Regular meanders ☐
- Irregular meanders ☐
- Tortuous meanders ☐
- Braided ☐
- Anastomosed ☐

Planform Data
Bend Radius ___
Meander belt width ___
Wavelength ___
Meander Sinuosity ___

Location in Valley
- Left ☐
- Middle ☐
- Right ☐

Lateral Activity
- None ☑
- Meander progression ☐
- Increasing amplitude ☐
- Progression+cut-offs ☐
- Irregular erosion ☐
- Avulsion ☐
- Braiding ☐

Floodplain Features
- None ☑
- Meander scars ☐
- Scroll bars+sloughs ☐
- Oxbow lakes ☐
- Irregular terrain ☐
- Abandoned channel ☐
- Braided Deposits ☐

Interpretative Observations

Present Status
- *Adjusted* ☐
- *Over wide* ☑
- *Too narrow* ☐

Instability Status
- *Stable* ☐ ?
- *Widening* ☑
- *Narrowing* ☐

Problem Severity
- *Insignificant* ☐
- *Moderate* ☐
- *Serious* ☐

Problem Extent
- *None* ☐
- *Local* ☐
- *General* ☑
- *Reach scale* ☐
- *System wide* ☐
- *Regional* ☐

Level of Confidence in percent (Circle one)
0 10 20 30 40 50 [✓ 60] 70 80 90 100 %

Notes and Comments:-

SECTION 3 - CHANNEL DESCRIPTION

PART 6: CHANNEL DESCRIPTION

		Bed Controls	**Control Types**	**Width Controls**	**Control Types**
Dimensions	**Flow Type**	None ☒	None ☐	None ☐	None ☐
Av. top bank width (m) 0.7	None ☐	Occasional ☑	Solid Bedrock ☐	Occasional ☑	Bedrock ☐
Av. channel depth (m) 1	Uniform/Tranquil ☑	Frequent ☐	Weathered Bedrock ☐	Frequent ☐	Boulders ☐
Av. water width (m) ___	Uniform/Rapid ☐	Confined ☐	Boulders ☐	Confined ☐	Gravel armor ☐
Av. water depth (m) ___	Pool+Riffle ☐	Number of controls ___	Gravel armor ☐	Number of controls ___	Revetments ☐
Reach slope ___	Steep + Tumbling ☐		Cohesive Materials ☐		Cohesive Materials ☐
Mean velocity (m/s) ___	Steep + Step/pool ☐		Bridge protection ☑		Bridge abutments ☑
Manning's n value ___	(Note: Flow type on day of observation)		Grade control structures ☐		Dykes or groynes ☐

Notes and Comments:-

PART 7: BED SEDIMENT DESCRIPTION

Bed Material	**Bed Armour**	**Surface Size Data**	**Bed Forms (Sand)**	**Bar Types**	**Bar Surface data**
Clay ☑	None ☑	D50 (mm) ___	Flat bed (None) ☐	None ☑	D50 (mm) ___
Silt ☐	Static-armour ☐	D84 (mm) ___	Ripples ☐	Pools and riffles ☐	D84 (mm) ___
Sand ☐	Mobile-armour ☐	D16 (mm) ___	Dunes ☐	Alternate bars ☐	D16 (mm) ___
Sand and gravel ☐			Bed form height (m) ___	Point bars ☐	
gravel and cobbles ☑	**Sediment Depth**	**Substrate Size Data**	**Island or Bars**	Mid-channel bars ☐	**Bar Substrate data**
cobbles + boulders ☐	Depth of loose	D50 (mm) ___	None ☐	Diagonal bars ☐	D50 (mm) ___
boulders + bedrock ☐	Sediment (cm) ___	D84 (mm) ___	Occasional ☐	Junction bars ☐	D84 (mm) ___
Bed rock ☐		D16 (mm) ___	Frequent ☐	Sand waves + dunes ☐	D16 (mm) ___

Notes and Comments:-

Channel Sketch Map

Map Symbols

Study reach limits
Cross-section
Bank profile

North point
flow direction
impinging flow

Cut bank
exposed island/bar
structure

Photo point
Sediment sampling point
Significant vegetation

Representative Cross-section

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☑
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☑
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

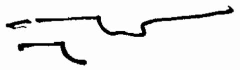
Bank Materials
Silt/clay ☑
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) 0·7

Ave. Bank slope angle (degrees) ___

Bank Profile Shape
(see sketches in manual)



Tension Cracks
None ☑
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe ☐	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☐	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef. ___

Notes and Comments:-

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐

Tree species
(if known)

Density + Spacing
None ☐
Sparse/clumps ☑
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☑
Adventitious ☐

Location
Whole bank ☐
Upper bank ☑
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☑
Dead ☐

Age
Imature ☐
Mature ☑
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Bank Top Edge	Failed debris	Engineered Structure
Bank Toe	Attached bar	Significant vegetation
Water's Edge	Undercutting	Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
General ☐
Outside Meander ☑
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☑
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☑
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☑
General ☐
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☐
Impinging flow ☑
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☑
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 [✓ 90] 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks
None ☐
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☑
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)
☐
☐

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☐
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
Average angle (o) ___

Bank Profile Shape
(see sketches in manual)
☐

Tension Cracks
None ☐
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	**Material Type 2**	**Material Type 3**	**Material Type 4**
Toe ☐	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☐	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef. ___

Notes and Comments:-

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐

Tree species
(if known)
☐
☐
☐

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Profile Symbols

Bank Top Edge	Failed debris	Engineered Structure
Bank Toe	Attached bar	Significant vegetation
Water's Edge	Undercutting	Vegetation Limit

PART 15: RIGHT BANK EROSION

Erosion Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☐
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☐
Impinging flow ☐
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks
None ☐
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☐
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)
☐
☐

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

No. 2

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
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SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Gt Struggy Beck

LOCATION D/S of Forge Bridge

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

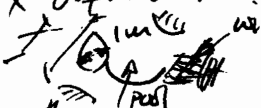
TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

Infilled roadwash / gravels with small bits of channel incision – looks artificially made channel with veg ~ 20yrs old veg on margins.
At next rd crossing pipe falls/steep drop the older flood drain + rd. landscaped above surface channel.
D/s ~~bridge~~ road erosion at pipe with infill

Next Rd crossing → d/s stormwater pipe inputs – lrger channel ≠ 3m wide 2m deep. Clay bed + banks – high instream veg. looks steep slope just d/s of rd.
Then narrows ~ 700m d/s into 1m wide × 0.7m deep.
Next track crossing culvert pool eroded



throughflow be? + entrain in LB.

Incised channel, 1m wide × 2m deep.
Willow making bed elevation change pools below willows.
Scoured clay – white clay on bed. bare roots on bank – fairly recent – 5yrs erosion
Willow removal – may lead to problems.

SECTION 2 - REGION AND VALLEY DESCRIPTION

PART 1: AREA AROUND RIVER VALLEY

Mountains ☐
Uplands ☐
Hills ☒
Plains ☐
Lowlands ☐

Dendritic ☒
Parallel ☐
Trellis ☐
Rectangular ☐
Radial ☐
Annular ☐
Multi-Basin ☐
Contorted ☐

Surface Geology
Weathered Soils ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
☐
Lake Deposits ☐
Wind blown (loess) ☐

Rock Type
Metamorphic ☐
Igneous ☒
None ☐

Specific Rock Types (if known)

Land Use
Managed ☐
Cultivated ☐
Urban ☒
Suburban ☐

Vegetation
Temperate forest ☐
Boreal forest ☐
Woodland ☐
Savanna ☐
Temperate grassland ☐
Desert scrub ☐
Extreme Desert ☐
Tundra or Alpine ☐
Agricultural land ☐

As No. 1

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
In Valley ☒
On Alluvial Fan ☐
On Alluvial Plain ☐
In a Delta ☐
In Old Lake Bed ☐
Valley Shape
Symmetrical ☒
Asymmetrical ☐

Height
☐
5 - 10 m ☒
10 - 30 m ☐
30 - 60 m ☐
60 - 100 m ☐
> 100 m ☐

Side
< 5 degrees ☐
5-10 degrees ☐
10-20 degrees ☐
20-50 degrees ☐
>50 degrees ☐

Valley Side
None ☐
Occasional ☐
Frequent ☐
Failure Locations
None ☐
Away from river ☐
Along river (Undercut) ☐

Interpretative Observations
Material Type
Soils ☐
Loose debris ☐
Failure Type
(see Sketches in Manual)

Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-
As No. 1

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☐

Valley Floor Data
None ☐
< 1 river width ☐
1 - 5 river widths ☐
5-10 river widths ☐
>10 river widths ☐
Flow Resistance*
Left Overbank Manning n value ___
Right Overbank Manning n value ___ (* note: n value for channel is recorded in Part 6)

Surface Geology
Bed rock ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
Fluvial: Alluvium ☐
Fluvial: Backswamp ☐
Lake Deposits ☐
Wind Blown (Loess) ☐

Land Use
Natural ☐
Managed ☐
Cultivated ☐
Urban ☐
Suburban ☐
Industrial ☐

Vegetation
None ☐
Unimproved Grass ☐
Improved Pasture ☐
Orchards ☐
Arable Crops ☐
Shrubs ☐
Deciduous Forest ☐
Coniferous Forest ☐
Mixed Forest ☐

Riparian Buffer Strip
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☐
Strip Width
None ☐
< 1 river width ☐
1 - 5 river widths ☐
> 5 river widths ☐

Notes and Comments:-
As No. 1

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
None ☐
Indefinate ☐
Fragmentary ☐
Continuous ☐
Number of Terraces ___
Trash Lines
Absent ☐
Present ☐
Height above flood plain (m) ___

Overbank Deposits
None ☐
Silt ☐
Fine sand ☐
Medium sand ☐
Coarse sand ☐
Gravel ☐
Boulders ☐

Levees
None ☐
Natural ☐
Constructed ☐
Levee Description
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☐
Left Bank ☐
Right Bank ☐
Both Banks ☐

Levee Data
Height (m) ☐
Side Slope (o) ☐
Levee Condition
None ☐
Intact ☐
Local Failures ☐
Frequent failures ☐

Interpretative Observations
Present Status
Adjusted ☐
Incised ☐
Aggraded ☐
Instability Status
Stable ☐
Degrading ☐
Aggrading ☐

Problem Severity
Insignificant ☐
Moderate ☐
Serious ☐
Problem Extent
None ☐
Local ☐
General ☐
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-
As No. 1

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
Straight ☒
Sinuous ☐
Irregular ☐
Regular meanders ☐
Irregular meanders ☐
Tortuous meanders ☐
Braided ☐
Anastomosed ☐

Planform Data
Bend Radius ___
Meander belt width ___
Wavelength ___
Meander Sinuosity ___
Location in Valley
Left ☐
Middle ☐
Right ☐

Lateral Activity
None ☐
Meander progression ☐
Increasing amplitude ☐
Progression+cut-offs ☐
Irregular erosion ☐
Avulsion ☐
Braiding ☐

Floodplain Features
None ☐
Meander scars ☐
Scroll bars+sloughs ☐
Oxbow lakes ☐
Irregular terrain ☐
Abandoned channel ☐
Braided Deposits ☐

Interpretative Observations
Present Status
Adjusted ☐
Over wide ☐
Too narrow ☐
Instability Status
Stable ☐
Widening ☐
Narrowing ☐

Problem Severity
Insignificant ☐
Moderate ☐
Serious ☐
Problem Extent
None ☐
Local ☐
General ☐
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in percent (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:- Buried pipes making change in channel flows

SECTION 3 - CHANNEL DESCRIPTION

PART 6: CHANNEL DESCRIPTION

Dimensions

Av. top bank width (m) 1
Av. channel depth (m) 2
Av. water width (m) ___
Av. water depth (m) ___
Reach slope ___
Mean velocity (m/s) ___
Manning's n value ___

Flow Type

None ☐
Uniform/Tranquil ☐
Uniform/Rapid ☐
Pool+Riffle ☑
Steep + Tumbling ☐
Steep + Step/pool ☐
(Note: Flow type on day of observation)

Bed Controls

None ☐
Occasional ☑
Frequent ☐
Confined ☐
Number of controls ___

Control Types

None ☐
Solid Bedrock ☐
Weathered Bedrock ☐
Boulders ☐
Gravel armor ☐
Cohesive Materials ☐
Bridge protection ☑
Grade control structures ☐

Width Controls

None ☐
Occasional ☑
Frequent ☐
Confined ☐
Number of controls ___

Control Types

None ☐
Bedrock ☐
Boulders ☐
Gravel armor ☐
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☑
Dykes or groynes ☐

Notes and Comments:- Pool + riffle based around willow roots.

PART 7: BED SEDIMENT DESCRIPTION

Bed Material

Clay ☑
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☑
cobbles + boulders ☐
boulders + bedrock ☐
Bed rock ☐

Bed Armour

None ☑
Static-armour ☐
Mobile-armour ☐

Sediment Depth

Depth of loose Sediment (cm) ___

Surface Size Data

D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Substrate Size Data

D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bed Forms (Sand)

Flat bed (None) ☑
Ripples ☐
Dunes ☐
Bed form height (m) ___

Island or Bars

None ☑
Occasional ☐
Frequent ☐

Bar Types

None ☐
Pools and riffles ☐
Alternate bars ☑
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data

D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bar Substrate data

D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Notes and Comments:-

Channel Sketch Map

Map Symbols

Study reach limits
Cross-section
Bank profile

North point
flow direction
impinging flow

Cut bank
exposed island/bar
structure

Photo point
Sediment sampling point
Significant vegetation

Representative Cross-section

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☑
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☑
Sand/silt/clay ☐
Silt/sand ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
angle (degrees) ___

Bank Profile Shape
(see sketches in manual) ☐

Tension Cracks
None ☑
Occasional ☐
Frequent ☐
Crack Depth
Proportion of
bank height

Distribution and Description of Bank Materials in Bank Profile

Material Type 1		**Material Type 2**		**Material Type 3**		**Material Type 4**	
Toe	☐	Toe	☐	Toe	☐	Toe	☐
Mid-Bank	☐	Mid-Bank	☐	Mid-Bank	☐	Mid-Bank	☐
Upper Bank	☐	Upper Bank	☐	Upper Bank	☐	Upper Bank	☐
Whole Bank	☐	Whole Bank	☐	Whole Bank	☐	Whole Bank	☐
D50 (mm)	___	D50 (mm)	___	D50 (mm)	___	D50 (mm)	___
sorting coefficient	___	sorting coefficient	___	sorting coefficient	___	sorting coef.	___

Notes and Comments:-

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐
Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐
Tree species
(if known)

Density + Spacing
None ☐
Sparse/clumped ☐
dense/clumps ☑
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☑
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☑
Climax-vegetation ☐

Health
Healthy ☑
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☑
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☑
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Bank Top Edge
Bank Toe
Water's Edge
Failed debris
Attached bar
Undercutting
Engineered Structure
Significant vegetation
Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
- General ☑
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☐
- Eroding:dormant ☐
- Eroding:active ☑
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ____

Rate of Advance
m/yr (if applicable and known) ____

Interpretative Observations

Severity of Erosion
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☑
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☐
- *Local* ☐
- *General* ☑
- *Reach Scale* ☐
- *System Wide* ☐

Processes
- *Parallel flow* ☑
- *Impinging flow* ☑
- *Piping* ☐
- *Freeze/thaw* ☐
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1		***Process 2***	
Toe (undercut)	☑	*Toe (undercut)*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐
Process 3		***Process 4***	
Toe (undercut)	☐	*Toe (undercut)*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
- General ☑
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☐
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☑

Failure Scars+Blocks
- None ☐
- Old ☐
- Recent ☑
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☑
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☐
- *Local* ☐
- *General* ☑
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☑
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1		***Mode 2***	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☑	*Whole bank*	☐
Mode 3		***Mode 4***	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☑
- Individual grains ☐
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☐
- Boulders ☐

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species
(if known) ____

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☐
- *Concave upward* ☐
- *Convex upward* ☐

Present Debris Storage
- *No bank debris* ☐
- *Little bank debris* ☐
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Sediment Balance
- *Accumulating* ☐
- *Steady State* ☐
- *Undercutting* ☐
- *Unknown* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
Non-cohesive ☐
Cohesive ☐
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
Average angle (o) ___

Bank Profile Shape (see manual)
☐

Tension Cracks
None ☐
Occasional ☐
Frequent ☐
Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 2
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 3
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 4
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coef. ___

Notes and Comments:-

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐
Orientation ___
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐
Tree species (if known)
___

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Profile Symbols

Bank Top Edge
Bank Toe
Water's Edge

Failed debris
Attached bar
Undercutting

Engineered Structure
Significant vegetation
Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
General ☑
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☑
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☐
Significant ☑
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☐
General ☑
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☑
Impinging flow ☑
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☑
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
General ☑
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☑

Failure Scars+Blocks
None ☐
Old ☐
Recent ☑
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☑
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☑
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☑
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☑

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☑
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 15: RIGHT BANK EROSION

Erosion Location
- General ☐
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☐
- Eroding:dormant ☐
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Processes
- *Parallel flow* ☐
- *Impinging flow* ☐
- *Piping* ☐
- *Freeze/thaw* ☐
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 2
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 3
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 4
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location
- General ☐
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☐
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☐

Failure Scars+Blocks
- None ☐
- Old ☐
- Recent ☐
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☐
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☐
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 2
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 3
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 4
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☐
- Individual grains ☐
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☐
- Boulders ☐

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species
(if known) ___

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☐
- *Concave upward* ☐
- *Convex upward* ☐

Present Debris Storage
- *No bank debris* ☐
- *Little bank debris* ☐
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Sediment Balance
- *Accumulating* ☐
- *Steady State* ☐
- *Undercutting* ☐
- *Unknown* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

No 1

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
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SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:- To understand the current condition of Little Stringybark creek in order to understand the consequences of WSUD.

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Little Stringybark

LOCATION u/s Forge Rd. bridge crossing.

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY JRG

RIVER STAGE Low

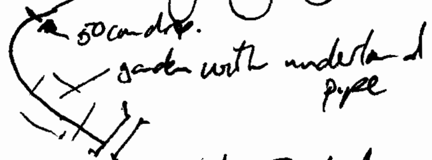
TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:- u/s of bridge piped sections – low flow → ~1m deep slot x ·7m width

erosion on outer meander bed – undercutting but not looking very dynamic.

+ Steep drop - plunge pool at manhole cover



u/s 0·2 deep channel.

Two pipe structures u/s with manhole covers – incised 1·2m – narrow slot. Eroded u/s with scour and drop of channel from surface flow into incision

Clay banks. – bed getting more gravelly u/s

Further u/s pipe with rocks covering → gravel bed d/s slope wash from some properties pipe underneath and floodplain/stream. Builders fill variable so different sediment into system.

New building with culvert added.

At u/s of Forger Rd (maybe sponge) culvert + drop structure.

SECTION 2 - REGION AND VALLEY DESCRIPTION

ROUND RIVER VALLEY
Mountains ☐
Uplands ☐
Hills ☒
Plains ☐
Lowlands ☐

Dendritic ☒
Parallel ☐
Trellis ☐
Rectangular ☐
Radial ☐
Annular ☐
Multi-Basin ☐
Contorted ☐

Surface Geology
Weathered Soils ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
Fluvial ☐
Lake Deposits ☐
Wind blown (loess) ☐

Roc
Metamorphic ☐
Igneous ☒
N ☐

Specific Rock Types (if known)
☐
☐
☐

Land Use
Managed ☐
Cultivated ☐
Urban ☒
Suburban ☐

Vegetation
Temperate forest ☐
Boreal forest ☐
Wetland ☐
Savanna ☐
Temperate grassland ☐
Desert scrub ☐
Extreme Desert ☐
Tundra or Alpine ☐
Agricultural land ☐

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
In Valley ☒
On Alluvial Fan ☐
On Alluvial Plain ☐
In a Delta ☐
In Old Lake Bed ☐
Valley Shape
Symmetrical ☒
Asymmetrical ☐

Height
< 5 m ☐
5 - 10 m ☒
10 - 30 m ☐
30 - 60 m ☐
60 - 100 m ☐
> 100 m ☐

Side
Slope Angle
< 5degrees ☐
5-10 degrees ☐
10-20 degrees ☐
20-50 degrees ☒
>50 degrees ☐

Valley Side
None ☒
Occasional ☐
Frequent ☐
Failure Locations
None ☐
Away from river ☐
Along river (Undercut) ☐

Interpretative Observations
Material Type
Soils ☐
Loose debris ☐
Failure Type
(see Sketches in Manual) ☐

Severity of Probl.
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☒

Valley Floor Data
None ☐
< 1 river width ☐
1 - 5 river widths ☐
5-10 river widths ☒
>10 river widths ☐
Flow Resistance*
Left Overbank Manning n value ___
Right Overbank Manning n value ___ (* note: n value for channel is recorded in Part 6)

Surface Geology
Bed rock ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
Fluvial: Alluvium ☐
Fluvial: Backswamp ☐
Lake Deposits ☐
Wind Blown (Loess) ☐

Land Use
Natural ☐
Managed ☒
Cultivated ☐
Urban ☒
Suburban ☒
Industrial ☐

Vegetation
None ☐
Unimproved Grass ☐
Improved Pasture ☐
Orchards ☐
Arable Crops ☐
Shrubs ☐
Deciduous Forest ☐
Coniferous Forest ☐
Mixed Forest ☐

Riparian Buffer Strip
None ☐
Indefinite ☐
Fragmentary ☒
Continuous ☐
Strip Width
None ☐
< 1 river width ☐
1 - 5 river widths ☒
> 5 river widths ☐

Notes and Comments:- Housing close to river in places.

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
None ☒
Indefinate ☐
Fragmentary ☐
Continuous ☐
Number of Terraces ___
Trash Lines
Absent ☒
Present ☐
Height above flood plain (m) ___

Overbank Deposits
None ☒
Silt ☐
Fine sand ☐
Medium sand ☐
Coarse sand ☐
Gravel ☐
Boulders ☐

Levees
None ☒
Natural ☐
Constructed ☐
Levee Description
None ☒
Indefinite ☐
Fragmentary ☐
Continuous ☐
Left Bank ☐
Right Bank ☐
Both Banks ☐

Levee Data
Height (m) ☐
Side Slope (o) ☐
Levee Condition
None ☐
Intact ☐
Local Failures ☐
Frequent failures ☐

Interpretative Observations
Present Status
Adjusted ☐
Incised ☒
Aggraded ☐
Instability Status
Stable ☐
Degrading ☒
Aggrading ☐

Problem Severity
Insignificant ☐
Moderate ☒
Serious ☐
Problem Extent
None ☐
Local ☐
General ☐
Reach scale ☐
System wide ☒
Regional ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80 90] 100 %

Notes and Comments:- Flows in and out of piped

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
Straight ☒
Sinuous ☐
Irregular ☐
Regular meanders ☐
Irregular meanders ☐
Tortuous meanders ☐
Braided ☐
Anastomosed ☐

Planform Data
Bend Radius ___
Meander belt width ___
Wavelength ___
Meander Sinuosity ___
Location in Valley
Left ☐
Middle ☐
Right ☐

Lateral Activity
None ☒
Meander progression ☐
Increasing amplitude ☐
Progression+cut-offs ☐
Irregular erosion ☐
Avulsion ☐
Braiding ☐

Floodplain Features
None ☒
Meander scars ☐
Scroll bars+sloughs ☐
Oxbow lakes ☐
Irregular terrain ☐
Abandoned channel ☐
Braided Deposits ☐

Interpretative Observations
Present Status
Adjusted ☐
Over wide ☒
Too narrow ☐
Instability Status
Stable ☐ ?
Widening ☒
Narrowing ☐

Problem Severity
Insignificant ☐
Moderate ☐
Serious ☐
Problem Extent
None ☐
Local ☐
General ☒
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in percent (Circle one)
0 10 20 30 40 50 [✓ 60] 70 80 90 100 %

Notes and Comments:-

SECTION 3 - CHANNEL DESCRIPTION

PART 6: CHANNEL DESCRIPTION

Dimensions
Av. top bank width (m) 0·7
Av. channel depth (m) 1
Av. water width (m) __
Av. water depth (m) __
Reach slope __
Mean velocity (m/s) __
Manning's n value __

Flow Type
None ☐
Uniform/Tranquil ☑
Uniform/Rapid ☐
Pool+Riffle ☐
Steep + Tumbling ☐
Steep + Step/pool ☐
(Note: Flow type on day of observation)

Bed Controls
None ☒
Occasional ☑
Frequent ☐
Confined ☐
Number of controls __

Control Types
None ☐
Solid Bedrock ☐
Weathered Bedrock ☐
Boulders ☐
Gravel armor ☐
Cohesive Materials ☐
Bridge protection ☑
Grade control structures ☐

Width Controls
None ☐
Occasional ☑
Frequent ☐
Confined ☐
Number of controls __

Control Types
None ☐
Bedrock ☐
Boulders ☐
Gravel armor ☐
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☑
Dykes or groynes ☐

Notes and Comments:-

PART 7: BED SEDIMENT DESCRIPTION

Bed Material
Clay ☑
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☑
cobbles + boulders ☐
boulders + bedrock ☐
Bed rock ☐

Bed Armour
None ☑
Static-armour ☐
Mobile-armour ☐

Sediment Depth
Depth of loose Sediment (cm) __

Surface Size Data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Substrate Size Data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Bed Forms (Sand)
Flat bed (None) ☐
Ripples ☐
Dunes ☐
Bed form height (m) __

Island or Bars
None ☐
Occasional ☐
Frequent ☐

Bar Types
None ☑
Pools and riffles ☐
Alternate bars ☐
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Bar Substrate data
D50 (mm) __
D84 (mm) __
D16 (mm) __

Notes and Comments:-

Channel Sketch Map

Map Symbols

Study reach limits
Cross-section
Bank profile

North point
flow direction
impinging flow

Cut bank
exposed island/bar
structure

Photo point
Sediment sampling point
Significant vegetation

Representative Cross-section

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive ☐
- Cohesive ☑
- Composite ☐
- Layered ☐
- Even Layers ☐
- Thick+thin layers ☐
- Number of layers ___

Protection Status
- Unprotected ☑
- Hard points ☐
- Toe protection ☐
- Revetments ☐
- Dyke Fields ☐

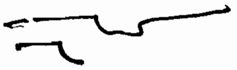
Bank Materials
- Silt/clay ☑
- Sand/silt/clay ☐
- Sand/silt ☐
- Sand ☐
- Sand/gravel ☐
- Gravel ☐
- Gravel/cobbles ☐
- Cobbles ☐
- Cobbles/boulders ☐
- Boulders/bedrock ☐

Layer Thickness
- Material 1 (m) ___
- Material 2 (m) ___
- Material 3 (m) ___
- Material 4 (m) ___

Ave. Bank Height
- Average height (m) 0·7

Ave. Bank slope
- angle (degrees) ___

Bank Profile Shape
(see sketches in manual)



Tension Cracks
- None ☑
- Occasional ☐
- Frequent ☐

Crack Depth
- Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe ☐	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☐	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef. ___

Notes and Comments:-

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Orientation

Angle of leaning (o)

Tree Types
- None ☐
- Deciduous ☐
- Coniferous ☐
- Mixed ☐

Tree species
(if known)

Density + Spacing
- None ☐
- Sparse/clumps ☑
- dense/clumps ☐
- Sparce/continuous ☐
- Dense/continuous ☐

Roots
- Normal ☐
- Exposed ☑
- Adventitious ☐

Location
- Whole bank ☐
- Upper bank ☑
- Mid-bank ☐
- Lower bank ☐

Diversity
- Mono-stand ☐
- Mixed stand ☐
- Climax-vegetation ☐

Health
- Healthy ☐
- Fair ☐
- Poor ☑
- Dead ☐

Age
- Imature ☐
- Mature ☑
- Old ☐

Height
- Short ☐
- Medium ☐
- Tall ☐
- Height (m) ___

Lateral Extent
- Wide belt ☐
- Narrow belt ☐
- Single row ☐

Notes and Comments:-

Bank Profile Sketches

Bank Top Edge	Failed debris	Engineered Structure
Bank Toe	Attached bar	Significant vegetation
Water's Edge	Undercutting	Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
General ☐
Outside Meander ☑
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☑
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ____

Rate of Advance
m/yr (if applicable and known) ____

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☑
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☑
General ☐
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☐
Impinging flow ☑
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☑
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 [✓ 90] 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks
None ☐
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☑
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)
☐
☐

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☐
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
Average angle (o) ___

Bank Profile Shape
(see sketches in manual)
☐

Tension Cracks
None ☐
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 2
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 3
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 4
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coef. ___

Notes and Comments:-

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐

Tree species
(if known)
☐
☐
☐

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Profile Symbols

Bank Top Edge
Bank Toe
Water's Edge

Failed debris
Attached bar
Undercutting

Engineered Structure
Significant vegetation
Vegetation Limit

PART 15: RIGHT BANK EROSION

Erosion Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☐
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☐
Impinging flow ☐
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location
General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks
None ☐
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☐
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)
☐
☐

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

No. 2

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Lt Stringybark

LOCATION D/s of Forge Bride

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

Infilled roadwash/gravels with small bits of channel incision – looks artificially made channel with veg ~ 20yrs old veg on margins.

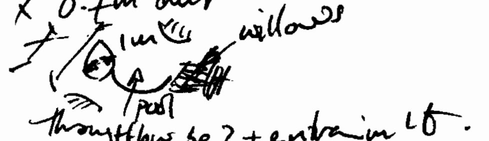
At next rd crossing pipe falls/steep drop then under flood ~~drain~~ + rd.

D/s ~~bridge~~ road erosion at pipe with infill – landscaped above surface channel.

Next Rd crossing → d/s stormwater pipe inputs – lrger channel & 3m wide 2m deep. Clay bed + banks – high instream veg. looks steep slope just d/s of rd.

Then narrows ~ 700m d/s into 1m wide x 0.7m deep.

Next track crossing culvert pool eroded



throughflow be? + entrain LO.

Incised channel, 1m wide x 2m deep.
Willow making bed elevation change pools below willows.

Scoured clay – white clay on bed. bare roots on bank – fairly recent – 5yrs erosion

Willow removal – may lead to problems.

SECTION 2 - REGION AND VALLEY DESCRIPTION

PART 1: AREA AROUND RIVER VALLEY

Mountains ☐
Uplands ☐
Hills ☑
Plains ☐
Lowlands ☐

Dendritic ☑
Parallel ☐
Trellis ☐
Rectangular ☐
Radial ☐
Annular ☐
Multi-Basin ☐
Contorted ☐

Surface Geology
Weathered S... ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
☐
Lake Deposits ☐
Wind blown (loess) ☐

Rock Type
Metamorphic ☐
Igneous ☑
None ☐

Specific Rock Types (if known)
___
___
___

Land Use
Managed ☐
Cultivated ☐
Urban ☑
Suburban ☐

Vegetation
Temperate forest ☐
Boreal forest ☐
Woodland ☐
Savanna ☐
Temperate grassland ☐
Desert scrub ☐
Extreme Desert ☐
Tundra or Alpine ☐
Agricultural land ☐

As No. 1

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
In Valley ☑
On Alluvial Fan ☐
On Alluvial Plain ☐
In a Delta ☐
In Old Lake Bed ☐
Valley Shape
Symmetrical ☑
Asymmetrical ☐

Height
☐
5 - 10 m ☑
10 - 30 m ☐
30 - 60 m ☐
60 - 100 m ☐
> 100 m ☐

Side
< 5 degrees ☐
5-10 degrees ☐
10-20 degrees ☐
20-50 degrees ☐
>50 degrees ☐

Valley Side
None ☐
Occasional ☐
Frequent ☐
Failure Locations
None ☐
Away from river ☐
Along river (Undercut) ☐

Interpretative Observations
Material Type
Soils ☐
Loose debris ☐
Failure Type
(see Sketches in Manual) ___

Severity
Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-
As No. 1

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☐

Valley Floor Data
None ☐
< 1 river width ☐
1 - 5 river widths ☐
5-10 river widths ☐
>10 river widths ☐
Flow Resistance*
Left Overbank Manning n value ___
Right Overbank Manning n value ___ (* note: n value for channel is recorded in Part 6)

Surface Geology
Bed rock ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
Fluvial: Alluvium ☐
Fluvial: Backswamp ☐
Lake Deposits ☐
Wind Blown (Loess) ☐

Land Use
Natural ☐
Managed ☐
Cultivated ☐
Urban ☐
Suburban ☐
Industrial ☐

Vegetation
None ☐
Unimproved Grass ☐
Improved Pasture ☐
Orchards ☐
Arable Crops ☐
Shrubs ☐
Deciduous Forest ☐
Coniferous Forest ☐
Mixed Forest ☐

Riparian Buffer Strip
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☐
Strip Width
None ☐
< 1 river width ☐
1 - 5 river widths ☐
> 5 river widths ☐

Notes and Comments:-
As No. 1

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
None ☐
Indefinate ☐
Fragmentary ☐
Continuous ☐
Number of Terraces ___
Trash Lines
Absent ☐
Present ☐
Height above flood plain (m) ___

Overbank Deposits
None ☐
Silt ☐
Fine sand ☐
Medium sand ☐
Coarse sand ☐
Gravel ☐
Boulders ☐

Levees
None ☐
Natural ☐
Constructed ☐
Levee Description
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☐
Left Bank ☐
Right Bank ☐
Both Banks ☐

Levee Data
Height (m) ☐
Side Slope (o) ☐
Levee Condition
None ☐
Intact ☐
Local Failures ☐
Frequent failures ☐

Interpretative Observations
Present Status
Adjusted ☐
Incised ☐
Aggraded ☐
Instability Status
Stable ☐
Degrading ☐
Aggrading ☐

Problem Severity
Insignificant ☐
Moderate ☐
Serious ☐
Problem Extent
None ☐
Local ☐
General ☐
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-
As No. 1

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
Straight ☑
Sinuous ☐
Irregular ☐
Regular meanders ☐
Irregular meanders ☐
Tortuous meanders ☐
Braided ☐
Anastomosed ☐

Planform Data
Bend Radius ___
Meander belt width ___
Wavelength ___
Meander Sinuosity ___
Location in Valley
Left ☐
Middle ☐
Right ☐

Lateral Activity
None ☐
Meander progression ☐
Increasing amplitude ☐
Progression+cut-offs ☐
Irregular erosion ☐
Avulsion ☐
Braiding ☐

Floodplain Features
None ☐
Meander scars ☐
Scroll bars+sloughs ☐
Oxbow lakes ☐
Irregular terrain ☐
Abandoned channel ☐
Braided Deposits ☐

Interpretative Observations
Present Status
Adjusted ☐
Over wide ☐
Too narrow ☐
Instability Status
Stable ☐
Widening ☐
Narrowing ☐

Problem Severity
Insignificant ☐
Moderate ☐
Serious ☐
Problem Extent
None ☐
Local ☐
General ☐
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in percent (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:- Buried pipes making change in channel flow

SECTION 3 - CHANNEL DESCRIPTION

PART 6: CHANNEL DESCRIPTION

Dimensions
Av. top bank width (m) 1
Av. channel depth (m) 2
Av. water width (m) ___
Av. water depth (m) ___
Reach slope ___
Mean velocity (m/s) ___
Manning's n value ___

Flow Type
None ☐
Uniform/Tranquil ☐
Uniform/Rapid ☐
Pool+Riffle ☑
Steep + Tumbling ☐
Steep + Step/pool ☐
(Note: Flow type on day of observation)

Bed Controls
None ☐
Occasional ☑
Frequent ☐
Confined ☐
Number of controls ___

Control Types
None ☐
Solid Bedrock ☐
Weathered Bedrock ☐
Boulders ☐
Gravel armor ☐
Cohesive Materials ☐
Bridge protection ☑
Grade control structures ☐

Width Controls
None ☐
Occasional ☑
Frequent ☐
Confined ☐
Number of controls ___

Control Types
None ☐
Bedrock ☐
Boulders ☐
Gravel armor ☐
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☑
Dykes or groynes ☐

Notes and Comments:- Pool + riffle based around willow roots.

PART 7: BED SEDIMENT DESCRIPTION

Bed Material
Clay ☑
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☑
cobbles + boulders ☐
boulders + bedrock ☐
Bed rock ☐

Bed Armour
None ☑
Static-armour ☐
Mobile-armour ☐

Sediment Depth
Depth of loose Sediment (cm) ___

Surface Size Data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Substrate Size Data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bed Forms (Sand)
Flat bed (None) ☑
Ripples ☐
Dunes ☐
Bed form height (m) ___

Island or Bars
None ☑
Occasional ☐
Frequent ☐

Bar Types
None ☐
Pools and riffles ☐
Alternate bars ☑
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bar Substrate data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Notes and Comments:-

Channel Sketch Map

Map Symbols

Study reach limits
Cross-section
Bank profile

North point
flow direction
impinging flow

Cut bank
exposed island/bar
structure

Photo point
Sediment sampling point
Significant vegetation

Representative Cross-section

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☑
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☑
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
angle (degrees) ___

Bank Profile Shape
(see sketches in manual)

Tension Cracks
None ☑
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 2
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 3
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 4
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coef. ___

Notes and Comments:-

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐

Tree species
(if known)

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☑
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☑
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☑
Climax-vegetation ☐

Health
Healthy ☑
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☑
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☑
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Bank Top Edge
Bank Toe
Water's Edge

Failed debris
Attached bar
Undercutting

Engineered Structure
Significant vegetation
Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
General ☑
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☑
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ____

Rate of Advance
m/yr (if applicable and known) ____

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☐
Significant ☑
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☐
General ☑
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☑
Impinging flow ☑
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1		*Process 2*	
Toe (undercut)	☑	*Toe (undercut)*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐
Process 3		*Process 4*	
Toe (undercut)	☐	*Toe (undercut)*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
General ☑
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☑

Failure Scars+Blocks
None ☐
Old ☐
Recent ☑
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☑
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☑
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☑
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1		*Mode 2*	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☑	*Whole bank*	☐
Mode 3		*Mode 4*	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☑
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known) ____

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☐
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) ___
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
Average angle (o) ___

Bank Profile Shape
(see [illegible] manual) ☐

Tension Cracks
None ☐
Occasional ☐
Frequent ☐
Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1		**Material Type 2**		**Material Type 3**		**Material Type 4**	
Toe	☐	Toe	☐	Toe	☐	Toe	☐
Mid-Bank	☐	Mid-Bank	☐	Mid-Bank	☐	Mid-Bank	☐
Upper Bank	☐	Upper Bank	☐	Upper Bank	☐	Upper Bank	☐
Whole Bank	☐	Whole Bank	☐	Whole Bank	☐	Whole Bank	☐
D50 (mm)	___	D50 (mm)	___	D50 (mm)	___	D50 (mm)	___
sorting coefficient	___	sorting coefficient	___	sorting coefficient	___	sorting coef.	___

Notes and Comments:-

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐
Orientation
Angle of leaning (o) ___

Tree Types
None ☐
Deciduous ☐
Coniferous ☐
Mixed ☐
Tree species (if known) ___

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-

Bank Profile Sketches

Profile Symbols

Bank Top Edge	Failed debris	Engineered Structure
Bank Toe	Attached bar	Significant vegetation
Water's Edge	Undercutting	Vegetation Limit

PART 10: LEFT BANK EROSION

Erosion Location
General ☑
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☑
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☐
Significant ☑
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☐
General ☑
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☑
Impinging flow ☑
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☑
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
General ☑
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☑

Failure Scars+Blocks
None ☐
Old ☐
Recent ☑
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☐
Significant ☑
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☐
General ☑
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☑
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☑

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☑
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known) ___

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 15: RIGHT BANK EROSION

Erosion Location

General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status

Intact ☐
Eroding:dormant ☐
Eroding:active ☐
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ___

Rate of Advance
m/yr (if applicable and known) ___

Interpretative Observations

Severity of Erosion

Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion

None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Processes

Parallel flow ☐
Impinging flow ☐
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1

Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2

Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3

Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4

Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location

General ☐
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status

Stable ☐
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks

None ☐
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity

Insignificant ☐
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent

None ☐
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode

Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1

Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2

Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3

Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4

Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Copmments:-

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris

None ☐
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation

None/fallow ☐
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age

Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known) ___

Health

Healthy ☐
Unhealthy ☐
Dead ☐

Roots

Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile

Planar ☐
Concave upward ☐
Convex upward ☐

Present Debris Storage

No bank debris ☐
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance

Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

No 3.

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER

LOCATION Next Rd crossing ~~[illegible]~~ with No. 50 of rd crossing with rock structure. photo

DATE time: 11:45 am

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

Rock chute — followed by ~~[illegible]~~ circular failure of R bank slip.
Abutment / undercutting of tree roots.
Straight slit of a channel — could have been old bog/marsh land.
Blackberry covered section
~~After~~ ~~next~~ lunch → 1m wide 0.5m deep. more meandering channel some
fine gravel on bed — trailing veg — instream wood.
pipe with crossing → d/s pool + incision. then trib junction wide angle ~~bet~~ junction
and pool
Erosion control structure at horse property evidence of erosion around pipe —
concreted photo 76
Channel then becomes more shallow and enters a back water area — Maybe an artifact
of bridge crossing with 3 pipes. D/S pipes massive erosion photo 86 — overflow
area #90 creating drop + greater time of sat?
Tortuous meanders ~~[illegible]~~ in ~~g~~ cow grazed paddock — meander cutoff

No. 4

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Lt Stringybark

LOCATION u/s Evans Grove Rd.

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

#111 debris in stream concrete just u/s of culvert.
Meander cut off - flood directed through pipe - impinging flow.
Wetland next to Connie's place → then Chris' monitoring site.
Stormwater pipes + erosion just d/s of Connie's place.
Rocked section + willows on TRB u/s of road. by nursery
o'bank sand in this reach.

/ No. 5.

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Lt Stangback

LOCATION Walking D/S from Victoria Rd.

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

Gravel bed sed. - bars
Off stream storage pond
willow collapsed in channel - creating channel widening.
Large amount of brambles. Channel 3m wide x 1m deep.
Willows in stream creating hard bed with roots and chute. → midstream willow leading to widening either side. channel 4m x 1.5m. #5 + #6. + 7 + 8

No. 6

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Lt Strangbeck

LOCATION D/S Vic Rd

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

Stream channel 4m x 1m just u/s of willows.
In stream willow constricting flow root mat creating chute.
Narrows + widens / ~~bends~~ by willows
x-section was  shallows for 200m
Rock chute in rock bed + banks no d/s protection - odd [illegible]
Night mare bank works # 18
D/S second chute - tortuous meander with undercut banks
18? of LWD 6-5m wide 2.5m deep.
Next property bramble covered 27+28
After bramble ~ 3m deep
Gully incision [illegible] with [illegible] bed.
[illegible] plot [illegible] photo
Strang 20 - looks [illegible]
down to 20S x 1m [illegible]
The [illegible]

No. 7

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Purpose of Stream Reconnaissance:-

Logistics of Reconnaissance Trip:-

RIVER Little [illegible]

LOCATION D/s to resv.

DATE

PROJECT

STUDY REACH From To

SHEET COMPLETED BY

RIVER STAGE

TIME: START

TIME: FINISH

General Notes and Comments on Reconnaissance Trip:-

Rock just d/s from road creating riffle pool water sound a bit [illegible]
Tight meanders - erosion on outer bends (reasonable riparian veg)
O'bank flow material on floodplain debris line [illegible]
Undercut banks - o'hang veg - channel 2m x 0.8m
Crossing with [illegible] rock
Then grazed up to stream - still meandering
Undercut banks by about 0.3m [illegible] only 0.4 [illegible]
Flow variability with chutes [illegible] fixed gravelly [illegible]
Ponding around bridge just u/s of res.
Resv look shallow.