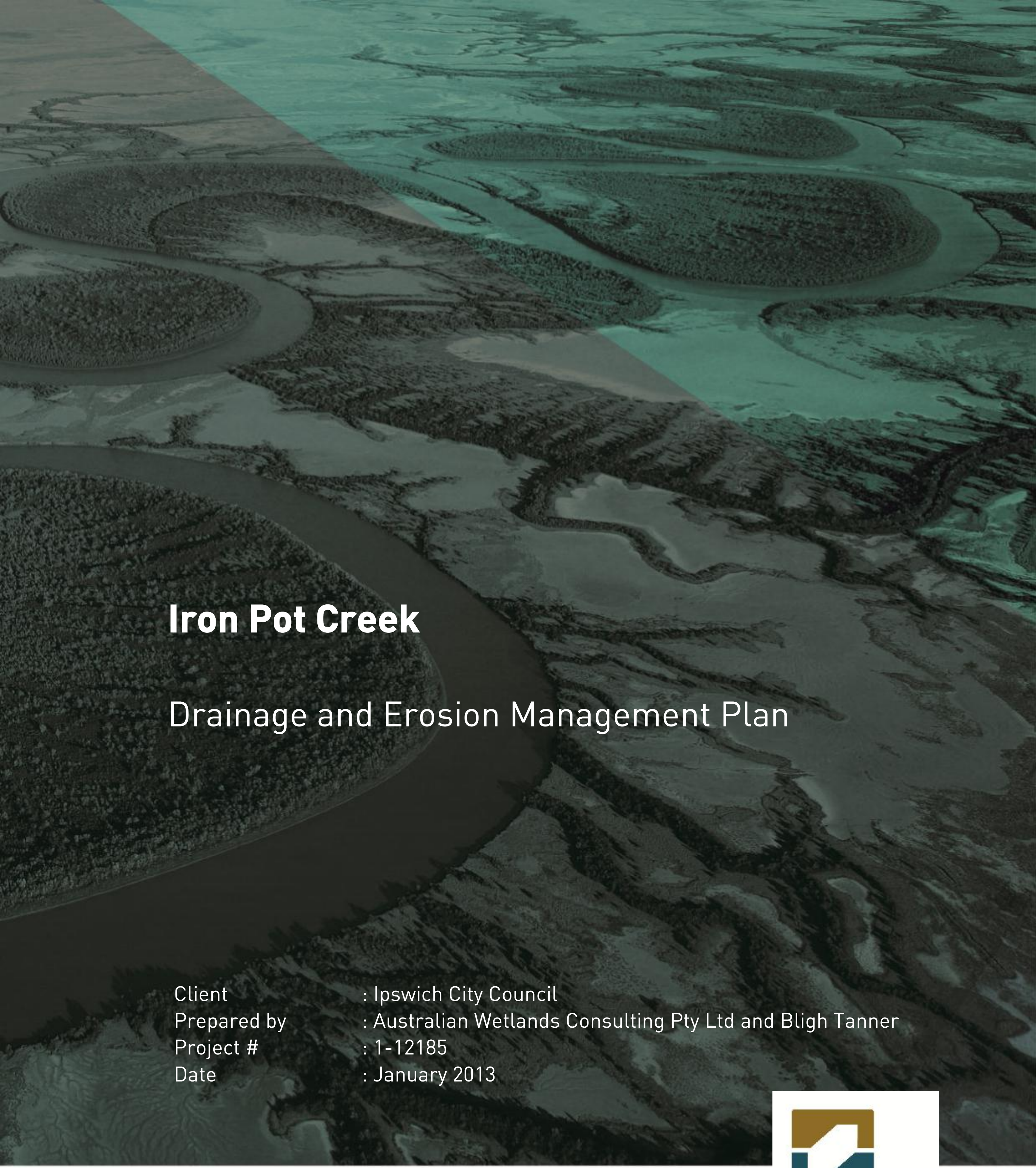

Iron Pot Creek

Drainage and Erosion Management Plan

Client : Ipswich City Council
Prepared by : Australian Wetlands Consulting Pty Ltd and Bligh Tanner
Project # : 1-12185
Date : January 2013

BLIGH TANNER
CONSULTING ENGINEERS

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Iron Pot Creek

Drainage and Erosion Management Plan

Project control

Project name: **Iron Pot Creek**
Drainage and Erosion Management Plan

Job number: 1-12185
Client: Ipswich City Council
Contact: Mark Bastin

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1 Executive Summary

The northern section of Iron Pot Creek has significant and active stream erosion issues which pose a threat to public safety, private property, the environmental values of the creek and downstream waterways, and potentially to Council infrastructure.

Iron Pot Creek is located in Pine Mountain approximately 6.5 km north-east of the Ipswich City Centre, and this Drainage and Erosion Management Plan focuses on the reach upstream of the Warrego Highway.

This Plan is based on the findings of an extensive consultation with local residents, a detailed ecological and geomorphologic assessment of the stream, and modelling simulations of streamflow behaviour.

Collectively, these methods provide an understanding of the current state of erosion, the underpinning causes and erosion processes, the priority areas for attention, and what management interventions are likely to be effective and appropriate.

Background

Much of the catchment prior to urban development was a mosaic of regenerating native vegetation and grazing and it is difficult to determine to what extent Iron Pot Creek was modified as a result of original land clearing. It is clear, however, that concentration of stormwater runoff within formalised drainage networks is a key contributor to creek erosion.

Numerous complaints over the years have been received by Council from local residents regarding bank stabilisation and erosion issues between Walter Zimmerman Park and Iron Pot Creek Reserve. The erosion caused from stormwater runoff in this area potentially, adversley impacts on public safety and adjoining properties. In addition, erosion and sediment impacts have continued downstream to Iron Pot Creek Reserve.

A variety of remedial works to date have been undertaken by Council to varying degrees of success within the Walter Zimmerman Park area. Further to this, a number of residents have been using materials such as rock, soil and timber to backfill gully erosion and stabilise stream banks. This has been occurring in an ad-hoc manner, again with varying degrees of success.

In July 2012, Council commissioned this Drainage and Erosion Management Plan to better understand the erosion problem and to establish a holistic and strategic approach to identifying and prioritising remediation works.

What are the causes of the erosion?

Several processes are contributing to erosion in Iron Pot Creek. Each process varies across the catchment, and in some areas, only one of these processes is sufficient to trigger significant erosion. Key processes include:

1. Concentration of flow paths and drainage lines, which focuses runoff energy into gullies and leads to channel erosion.

2. Increased rates of runoff due to impervious surfaces (roads and roofs), the clearing of native vegetation and loss of surface depressions, and compaction of topsoils, and exposure of subsoils. The increased rates of runoff result in increased shear stress, particle erosion and entrainment within the gullies and creek line.

3. Dispersive soils, which are present across parts of the catchment, are highly erodible because they lose structural stability when wet. This can lead to subsurface tunnel erosion, gully erosion and increased rates of bank erosion.

4. Channel incision, often triggered by one of the above mentioned processes or by in-stream works for culverts, creates head cuts that migrate upstream.

5. Unstable banks, caused by vegetation clearing or above processes, cause widening of the channel can also trigger lateral gully erosion.

6. The channel has become enlarged, which means that large storm events are contained within the stream channel rather than spilling over the stream banks and engaging the floodplain. This means more energy is focussed within the stream banks.

Current state of erosion

All sections of Iron Pot Creek are experiencing some degree of erosion in the form of bank scour, bed lowering and head cuts with the most significant erosion sites located within Management Zones 1b, 2a and 3 (refer Appendix A for zone locations). While some of these erosion sites will stabilise naturally, there are instances where the proximity of private properties and infrastructure mean that channel adjustments (e.g. stream widening) are not acceptable and so management intervention is required.

What happens if nothing is done?

If nothing is done to address erosion in the creek, it is likely that the channel in the middle to upper section of the creek will widen which could affect private property, council assets and impact on the environmental values of the creek as well as contributing significant sediment loads to downstream waterways, including the Bremer River. Some areas of stream bank are unstable and have sheer cliffs several metres high which pose potential public safety risks. Lateral gullies draining into the creek are likely to extend further uphill and become deeper and wider, affecting adjacent properties and Council assets (roads and culverts).

What can be done?

There is considerable scope to achieve improvements in creek health in ways that are cost effective and site sensitive. The Rehabilitation strategy recommended within this study is informed by the root causes of erosion within Iron Pot Creek and seeks to address this root cause rather than simply respond to symptoms. A preference has been given to bioengineering solutions which consider geomorphic and ecological processes and seek to work with the creeks natural trajectory rather than simply installing structural responses such as gabions and concrete.

A number of publications have been considered in rehabilitation designs including:

- Ipswich City Council (ICC), Riparian Corridor Revegetation Guideline
- ICC (2010), Waterway and Channel Rehabilitation Guidelines
- ICC (2009), Waterway Health Strategy
- Brisbane City Council (2004), Erosion Treatments for Urban Creek Guidelines, Version 3
- BCC (2000), Natural Channel Design Guidelines

Rehabilitation works are presented in Appendix A, however the final extent of works at each location is subject to detailed investigation and design. Each recommendation is supported by an estimate outlining detailed design and construction costs.

A review of planning and approval requirements shows that much of the works are either not subject to development approval, or are self-assessable under the 'Minor waterway barrier works – Part 1: Minor Dams and Weirs' (DAFF, 2011)

Community views

The community living in the vicinity of Iron Pot Creek was consulted in order to gather information about the causes and nature of erosion in the catchment, understand community views about what could be done about it, and to help prioritise erosion control works. Community knowledge has helped understand erosion processes and to identify priority areas for works. Many residents wanted sound advice about what they could do to better manage erosion, and many were undertaking their own erosion control works. Many residents wanted better and more coordinated support from Council.

Summary of recommendations and actions

Recommendations and actions fall within the following key themes:

- Instream works
- Vegetation management
- Community engagement and education
- Introduction of appropriate development controls
- Post construction monitoring

The staging of works will be subject to the availability of resources and broader Council objectives for environmental rehabilitation works across the City. Management Zones 1b, 1e, 2a and 2b are the highest priority for in stream works and should be addressed within 12-24 months. It is anticipated that subsequent actions will be implemented over several years. Prioritised actions are provided within Appendix B.

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2 Introduction and Background

This report has been completed by Australian Wetlands Consulting (AWC) and Bligh Tanner (BT) on behalf of Ipswich City Council (ISC) to address issues of bank instability and erosion between Walter Zimmerman Park and Iron Pot Creek Reserve.

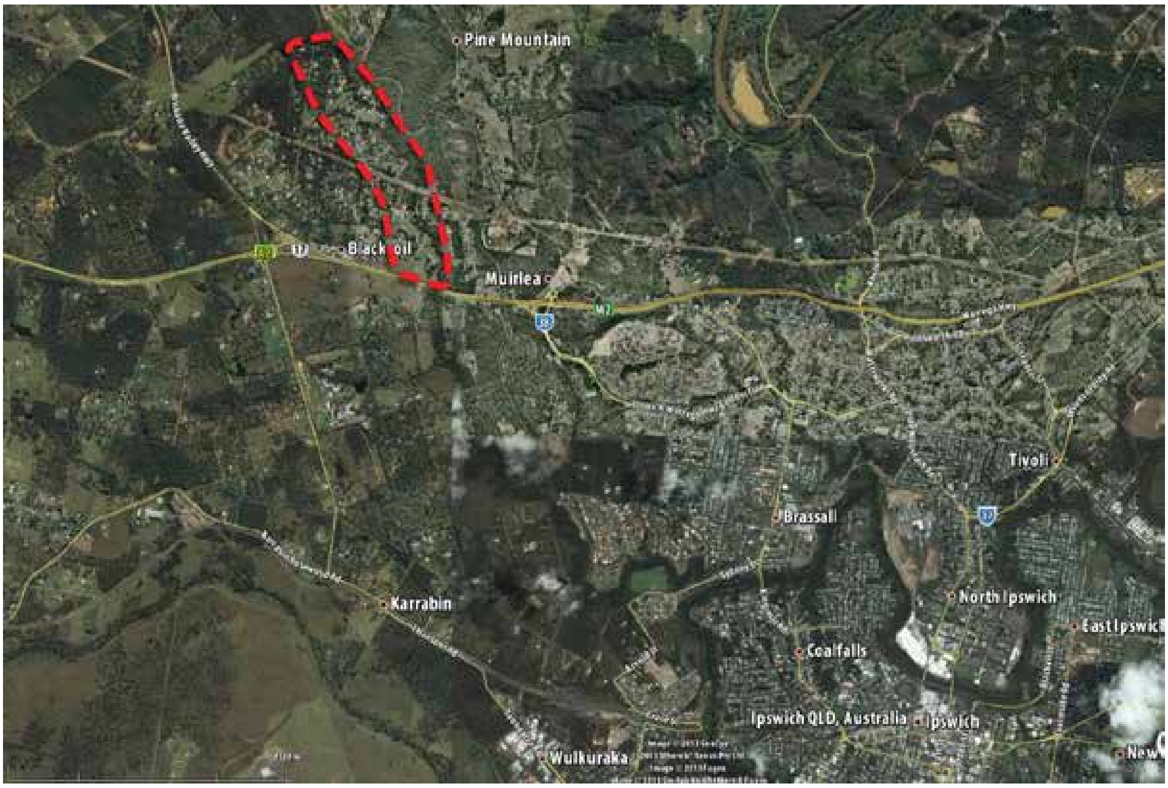
Extensive erosion occurs within Iron Pot Creek and associated tributaries, the causes of which are a combination of historical land clearing, urban development that increases and accelerates runoff and construction of infrastructure - including rail and power corridors. Erosion has enlarged (both deepened and widened) the creek channel causing an increase in flow volumes and velocities leading to extensive bank erosion, massive mobilisation of sediment and potential damage to private property.

This investigation considers creek character including hydrology, hydraulics, geomorphology and ecology to determine causes and processes associated with erosion while being mindful of legislative, policy and social context. Recommendations are presented within a prioritised action plan and include cost estimates.

2.1 The study area

The site is situated approximately 6.5 km north-west of Ipswich City Centre, running from Desbrow Street down to the Warrego Highway and encompasses Walter Zimmerman Park in the north and Iron Pot Creek Reserve in the south. The study area encompasses approximately 4 kilometres of creek line and adjoining reserves.

Figure 2-1 Locality Map



Walter Zimmerman Park has been enhanced for public usage and provides a visitor access node with playground equipment, picnic areas and a series of walking trails. Iron Pot Creek runs for approximately 4km through Walter Zimmerman Park and Iron Pot Creek reserve and is not utilised for any specific recreational purposes. The Reserve is downstream of low density residential development and regrowth native forest representing several dry sclerophyll forest types.

The entire study area was likely cleared historically, however native forest regeneration has generally been very good. The western bank in proximity to Walter Zimmerman Park adjoins a number of private properties, where grass is mowed down to top of bank, while the eastern bank is fully vegetated.

The upstream section comprises a moderately entrenched stream on coarse alluvial sediments to fine gravel with intermittent sandstone outcrops. There are significant volumes of aggrading sediment substantially infilling the low flow channel. The loss of channel capacity is causing bank scour and overtopping in numerous locations, but no evidence of stream avulsion at this stage. This arrangement continues down to Bayley Road, beyond which the stream broadens into a freshwater wetland. The powerline easement running approximately east to west intersects the creek just west of Merlot Place and the access track in this location has altered stream levels, causing a backwater effect at least 100m upstream.

2.2 Causes of erosion and erosion types

Erosion is the process where a concentrated flow of water (either as rain or overland flow) exceeds the cohesive strength of a soil type and soils are mobilised. Within Iron Pot Creek, this erosion has resulted first from historical vegetation clearing associated with early settlement, whereby removal of vegetation has exposed soils and made them vulnerable to rainfall. Subsequent development has concentrated rainfall runoff within constructed drainage lines and discharged into Iron Pot Creek and its tributaries at volumes and velocities well in excess of those that occurred historically. These concentrated flows have scoured the creek bed and banks and caused a detrimental shift in creek shape and character. Creek character is discussed at length within Section 4.1, while changes in creek hydraulics and hydrology have been investigated and are reported on in Section 4.3.

Secondary forms of erosion within Iron Pot Creek include tunnelling and bank slumping. Tunnelling is a phenomenon of dispersive soils whereby the loss of vegetation and organic matter exposes subsoils which enables rainwater to concentrate and flow vertically down through soils and express at lower levels, typically within the adjoining creek. Tunnelling can be very difficult to control and its extent is often not well known within a locality. Bank slumping occurs when wetted soils unprotected by vegetation collapse under their own weight. This accumulated soil within the creek channel is then swept away in subsequent storms.

An overview of erosion processes and their locations within the study area is provided within the following Table 2-1.

Table 2-1 Erosion types, causes, locations and potential response

Erosion Type	Description and Cause
Headcut	Erosion of the creek channel migrating upstream. Caused by either changes in adjoining land use or modifications to the creek itself. The headcut creates a small waterfall or step in the creek.
Lateral bank erosion	Creek banks are scoured and the channel widens, particularly on outside bends of meanders. Typically caused by an increase in stormwater volumes and velocities, possibly in combination with clearing of vegetation.
Bed lowering	A process whereby the creek becomes increasingly incised, pools and riffles are swept away and channel slope increases. Caused by an increase in flow volumes and velocities to levels which exceed the shear stress capacity of bed materials (sands, gravel, boulders). Bed lowering is similar to a head cut but potentially occurring across an entire stream section rather than at a single location.
Tunnelling	Vertical erosion of dispersive soils which are exposed to rainfall and concentrated flows following loss of vegetation cover and topsoils.
Bank slumping	Creek banks lacking vegetation cover collapse under their own weight when wet, regardless of stream velocities.
Concentrated flows	Stormwater runoff is concentrated by urban drainage infrastructure and discharged into the creek at velocities which cause scour of creek bed and banks.

2.3 Objectives

The objectives of this drainage and erosion management plan are to:

- Reduce erosion and improve bank stability
- Recommend cost effective ‘green’ engineered staged remedial works that fit into the surrounding environment.

Further, the plan incorporates the following:

- Consideration of site hydrology
- Feedback from the community and Council staff
- Consideration of ongoing maintenance requirements
- Consideration of legislative requirements
- Consideration of environment impacts from the proposed works
- Consideration of creek condition and waterway health
- Cost effective ‘Green’/ environmental solutions
- Logical/affordable sequencing of works based on priorities.

3 Methods

3.1 Introduction

A combination of geomorphic, ecologic, hydrologic and hydraulic approaches were adopted and are described within the following sections.

The site was inspected by AWC and Bligh Tanner staff on five occasions from September to December, 2012. Weather conditions were warm and dry. Review of climate data from BoM (Amberley AMO Stn#040004) indicated that 4.8 mm of rainfall had been recorded since the first of July, of which 4.4 mm fell in the preceding week (31st August).

3.2 Geomorphology

Overview

Assessment of stream condition is a multi-faceted procedure that considers stream geology, sedimentology, hydrology and vegetation to create an appreciation of the geomorphic character of a stream as well as its historic, present and likely future condition. This has been achieved through the completion of a Level IV stream assessment (Rosgen, 1996). Methods for investigating these components are discussed within the following sections.

3.2.1 Stream Character

Stream type has been defined following Rosgen (1996) by considering the following stream components:

- **Valley Type** - This broad category considers catchment topography and geology to assign valley types within the catchment. Rosgen nominates 12 valley types which assist in assigning a broad stream class.

- **Stream Type** - Stream Types categorise a stream on a reach basis into seven broad categories (A to G) through assessment of topography, channel morphology and sediment. These broad categories provide a context for field observations compared to what would be considered typical of a particular stream type.

This broad classification is then made more precise through the quantification of a number of parameters which enable the designation of sub-categories within stream types (e.g. A1, A2, B1, B2, etc.). This is achieved through consideration of key geomorphic parameters including:

- **Sinuosity** - measures the ratio of valley length versus stream length and was derived from a measurement of both the flood prone area length and a creek centreline. The valley length relied upon aerial photography while the creek centreline was measured using a hand held GPS.

- **Stream grade** – is a measure of stream length versus changes in elevation

- **Width to depth ratio** – measures the ratio of bank full surface width to the mean depth of the bankfull channel and was derived from typical cross sections prepared using field measurements.

- **Entrenchment ratio** – measures the ratio of flood prone area width to bankfull width (flood prone area is determined by measuring elevation at twice the maximum bankfull depth)

- **Bank stability assessment rating** – this multi-criteria assessment developed by Pfankuch (1975) and amended by Rosgen (1996) enables a scoring and ranking of relative bank stability. The method factors the natural erosion potential of a stream type into the ranking. Categories assessed within the bank stability assessment are categorised as Excellent, Good, Fair or Poor depending upon the resulting bank stability score and the stream type being assessed. For the subject site, this four tiered ranking was found to not sufficiently differentiate the various stream reaches, so additional criteria including ecology and community context will also require consideration in the final prioritisation of rehabilitation sites. Parameters considered within the bank stability assessment are summarised in Table 3-1.

Figure 3-1 and Figure 3-2 show conceptually stream type categories adopted within the geomorphic assessment and illustrate how the parameters described above inform the classification.

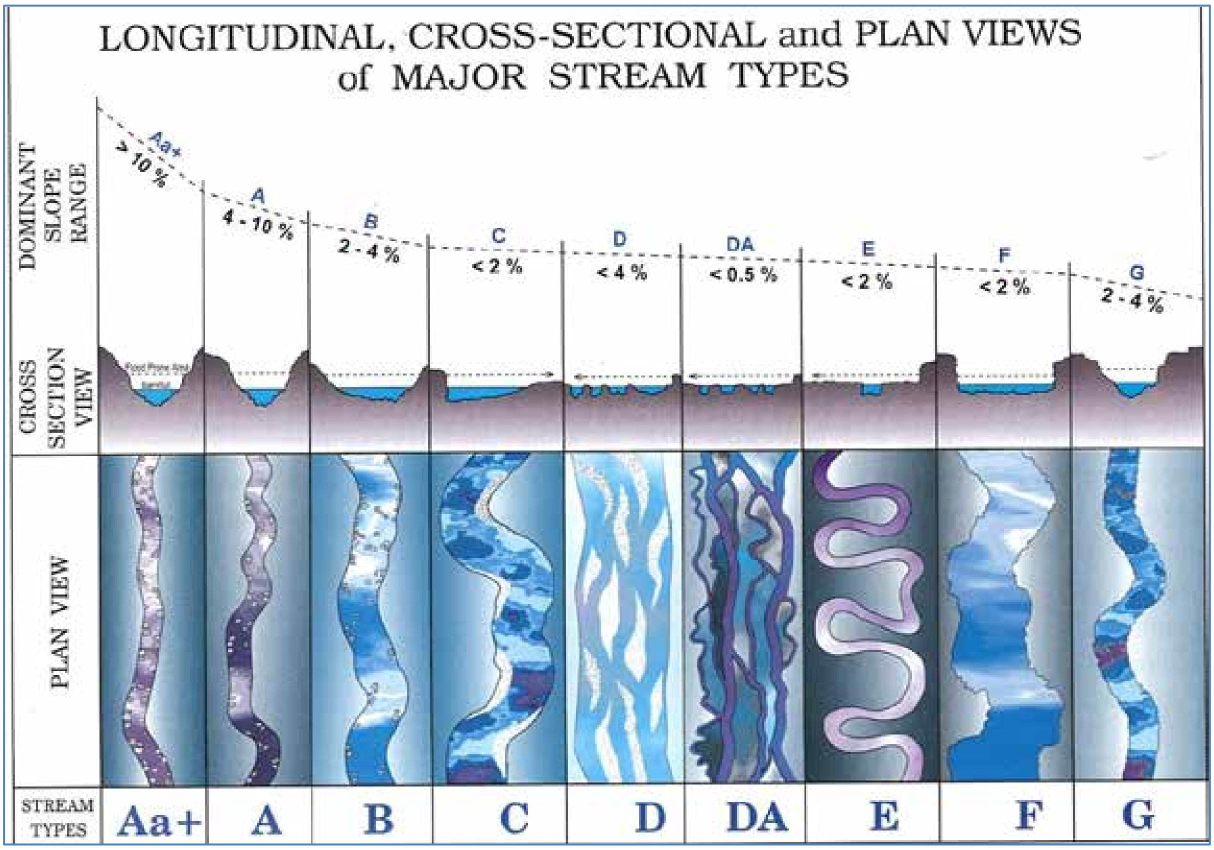


Figure 3-1 Stream types adopted within the geomorphic assessment (Source, Rosgen, 1996)

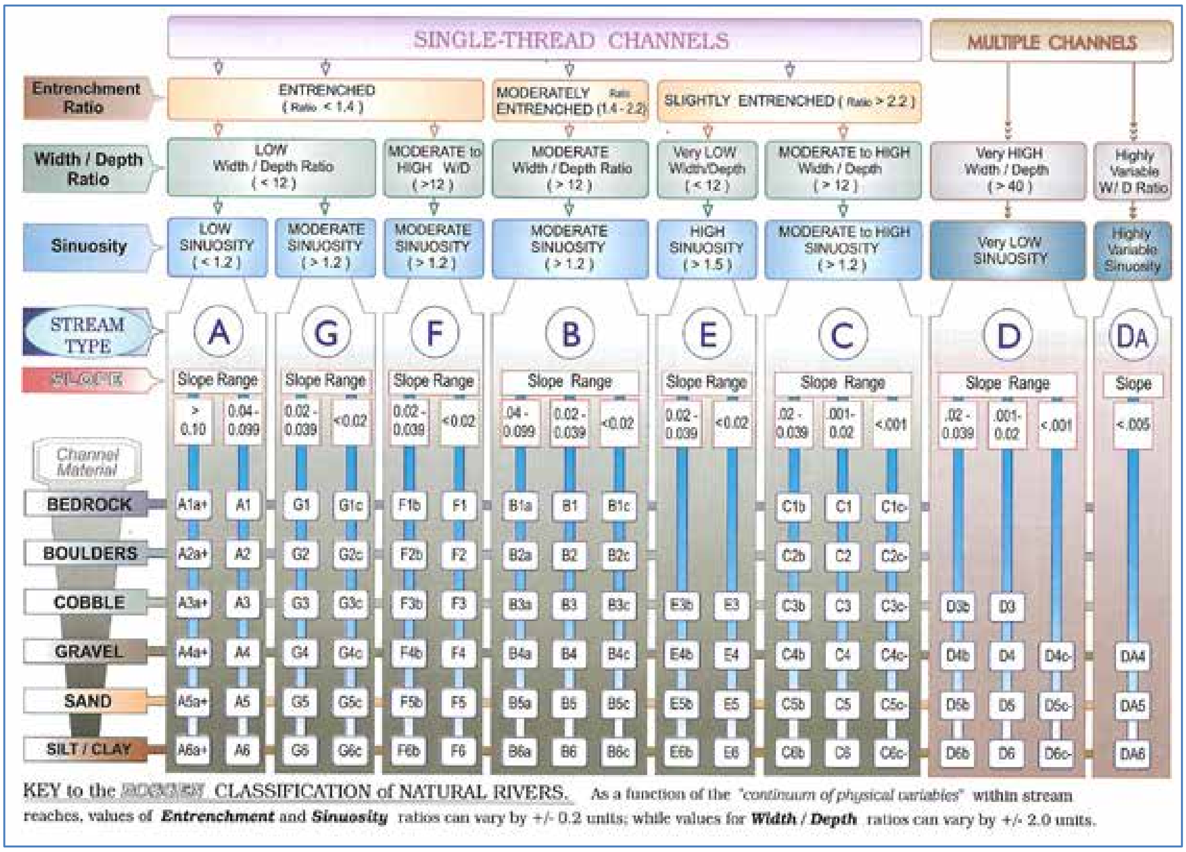


Figure 3-2 Detailed sub-categories within stream types (Source: Rosgen, 1996)

The Rosgen stream classification system also assists in understanding a streams historic and possible future condition in light of prevailing or altered condition. For example a type C stream may transition to type E in response to concentrated storm flows. This process is shown schematically within Figure 3-3 below.

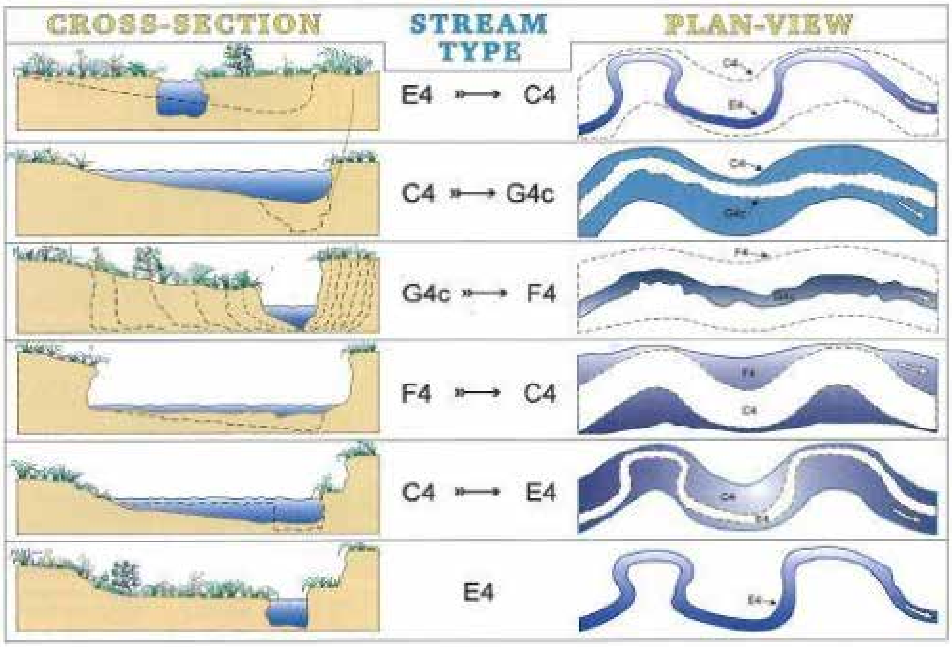


Figure 3-3 Evolution of stream types in response to changes in catchments (Source, Rosgen, 1996)

3.2.2 Channel Materials

Assessment of channel materials is relevant to an understanding of stream character and ecological condition and so bed and bank materials were sampled. Methods for sampling followed Wolman (1954) as described within Rosgen (1996) and are known as the “pebble count” method for determination of particle size distribution. Particle size was measured with a tape and callipers and classed within size range from 0.062mm to 1024mm. Sediments were collected at approximately 5m intervals working downstream on a “first blind touch” basis. The assessment was completed for the entire length of Zones One, Two and Three. Sediment character was noted in Zones Four and Five. In total, 340 sediment samples were collected.

3.2.3 Sediment Sampling and Erosion Potential

Sediment character is key in determining channel character and morphology. Erosion potential was determined through assessment of sediment character and performance of hydraulic modelling to determine scour potential through determination of sheer stress. Results of shear stress assessments are detailed within section 4.3.3, with these results informing the positioning and sizing of bank scour protection concept designs detailed within Appendix A. materials.

Table 3-1 Bank stability rating criteria (Rosgen, 1996/Pfankuch, 1975)

Bank	#	Category	Description
Upper Banks	1	Landform slope	Steepness of upper bank
	2	Mass Wasting	Extensive upper bank erosion
	3	Debris Jam Potential	Potential for accumulation of debris
	4	Vegetative Bank Protection	Extent of vegetative cover
Lower Banks	5	Channel Capacity	Capacity for flood conveyance
	6	Bank Rock Content	Rock component within lower banks
	7	Obstructions to Flow	Structures or debris present/absent
	8	Cutting	Bank undercuts and slumping occurring
	9	Deposition	Accumulation of sediment on bars
Bottom	10	Rock Angularity	Roughness or smoothness of stream material
	11	Brightness	Brightness is a reflection of ongoing instability
	12	Consolidation of Particles	Loosely assorted materials reflects instability
	13	Bottom Size Distribution	A large distribution suggests instability
	14	Scouring and Deposition	Bed erosion and sediment accumulation
	15	Aquatic Vegetation	Presence reflects instream stability

3.2.4 Soils

Characterisation of dispersive soils selected at key locations was completed using methods provided in part of the Soil Survey Standard Test Method – Emerson Aggregate Test (QLD Department of Sustainable Natural Resources, undated). The slaking and dispersion qualities of soil peds was determined based on Points 1, 2 & 3 of the methods only, detailed investigation beyond that was not required. An Emerson Class Number is provided with a Dispersion subclass if applicable. A Slaking subclass has also been determined.

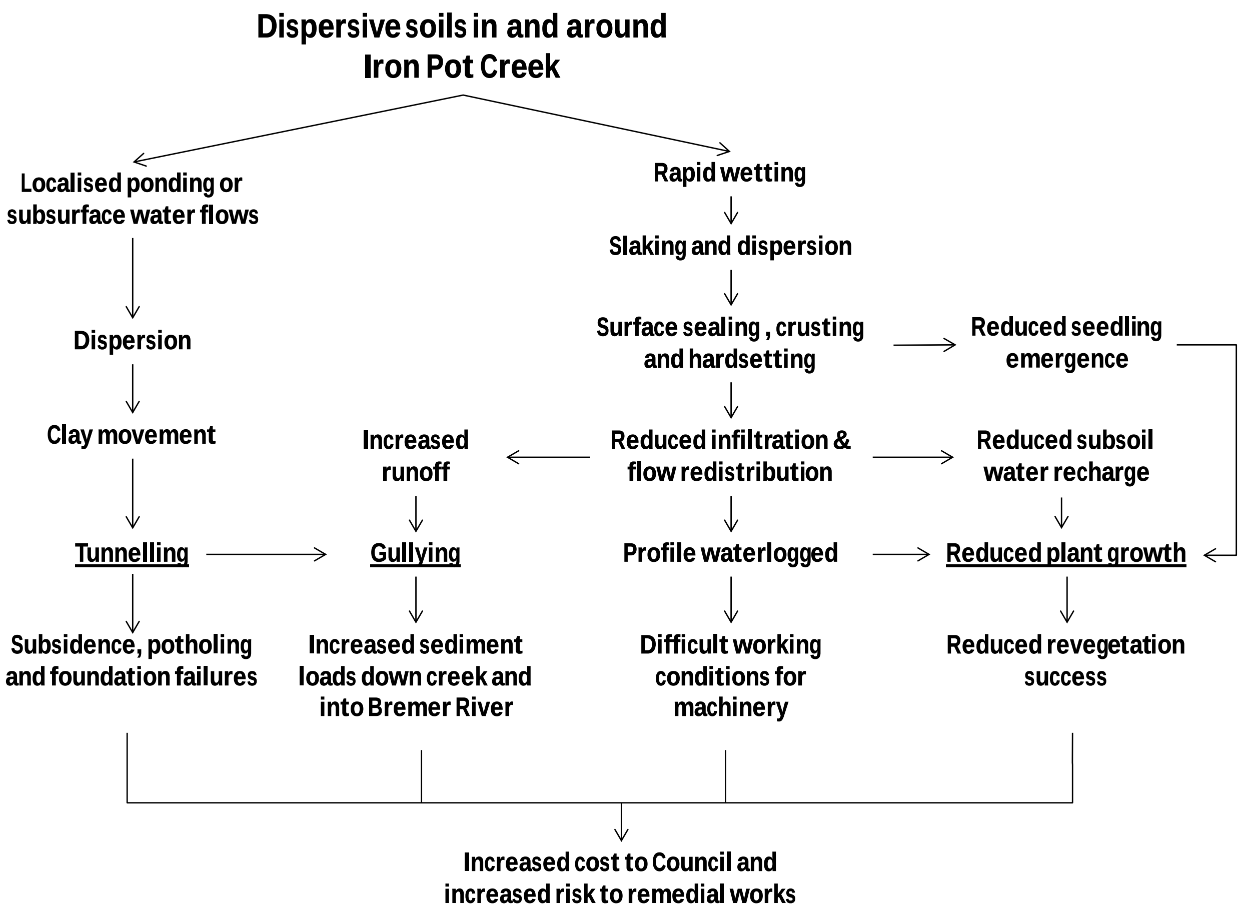


Figure 3-4 Soil Dispersion Diagram

(Figure adapted from So & Aylmore 1993).

3.3 Ecology

3.3.1 Desktop review

Mapping by Qld Dept. of Environment & Heritage (DEHP) indicates vegetation within the study area as comprising an amalgam of up to four Regional Ecosystems (REs) as shown at Table 3-2.

Table 3-2 Regional Ecosystems mapped within the study area

RE	Description	Conservation Status*
RE 12.9-10.2	*Corymbia citriodora, Eucalyptus crebra* open forest on sedimentary rocks	not of concern
RE 12.9-10.3	*Eucalyptus moluccana* on sedimentary rocks	of concern
RE 12.9-10.17	Open forest complex often with *Eucalyptus acmenoides, E. major, E. siderophloia* +/- *Corymbia citriodora* on sedimentary rocks	not of concern
RE 12.9-10.19	*Eucalyptus fibrosa* subsp. *fibrosa* open forest on sedimentary rocks	not of concern

* As per *Vegetation Management (VM) Act 1999*

RE 12.3.3 *Eucalyptus tereticornis* woodland to open forest on alluvial plains, listed as 'endangered' under the VMA is mapped immediately south of the study area. Vegetation in the north of the study area is mapped as Essential Habitat for the Koala.

A search of the Wildlife Online database identifies habitat for a range of threatened fauna species in the locality, including the green-thighed frog (*Litoria brevipalmata*) and koala (*Phascolarctos cinereus*).

3.3.2 Field Investigations

Vegetation within the general study area was assessed by review of recent aerial photography (Nearmap; 16 May 2012) and RE mapping (DEFP). Vegetation within the streamline and potential works area was assessed by traversing the entire length of Iron Pot Creek on foot and completing an inventory of all flora recorded on standard pro-forma and relating vegetation communities to standardised RE classifications. Targeted searches for threatened flora species identified from the Wildlife Online search (ie. Bailey's cypress, slender milkvine, Lloyd's native olive, cudgerie) where habitat was suitable, was also completed.

Any significant flora or habitat features were marked with flagging tape and recorded by GPS (Garmin etrex). Additionally the entire creekline was walked on foot and saved as a single track to provide stream configuration details for use in stream flow modelling drawings and design.

3.4 Hydrologic and hydraulic modelling

Hydrologic and hydraulic modelling involves the use of sophisticated computer models to simulate the way rainfall is converted into runoff, and then the behaviour of that runoff as it enters and passes down the stream. It has been used in conjunction with field observations and consultation with the community to build an understanding of how urbanisation has changed the erosivity of flows in the creek, and how any instream works should be designed.

The Iron Pot Creek was analysed using three hydraulic tools/methods. These tools were:

- XP-SWMM2012 software
- MUSIC software
- Rational Method

These tools and methodologies are described below. Results are presented in Chapter 4.

3.4.1 XP-SWMM2012

This software program enables hydrology and hydraulics to be modelled simultaneously. Design rainfall events are derived for a particular storm frequency or average recurrence interval (ARI) by applying the design rainfall intensity to the relevant design temporal pattern for Zone 3 as indicated in Australian Rainfall and Runoff (2007). It also has the capacity to analyse continuous logs of information (historic rainfall records). The resulting hydrographs are then routed through the drainage system to determine the peak discharge, velocity, flow depth and other important information such as shear stress, at a number of key locations. The drainage system can be created from a large selection of drainage structures (eg. pipes, open channels, box culverts, arcs, etc) or can be defined by the topographic characteristics of the terrain by the use of 2d analysis.

3.4.2 Creek layout and 3D base data

The layout (low and high flow areas) of the creek was obtained by analysing the 1m grid LIDAR (Light Detection and Ranging) data and cadastral drawings supplied by Ipswich City Council. This information was confirmed by the use of Global Positioning System devices used during site inspections. This information was transformed into a 3D surface model using 12D software and imported into XP-SWMM to create the surface layer. The LIDAR data, due to the way it is obtained and the coarseness of the data compared with the fine-scaled channel features, affects the accuracy of the data for some sections of the creek. However the accuracy of the modelling is more influenced by a lack of calibration due to the absence of streamflow records, and so limitations with the LIDAR data are not considered significant. Obtaining detailed survey for the whole study reach would have been cost prohibitive (although we recommend detailed survey in selected locations to support subsequent detailed design activities).

The hydraulic analysis focuses on the reach between Bayley Road to Desbrow Street, as the evidence indicates that many sections within this area present erosion problems.

3.4.3 Catchment Areas

The catchment areas and slope were calculated using the LIDAR data, the cadastral and drainage information supplied by Ipswich City Council. Subcatchments were defined on the main creek and tributaries at key locations such as road crossings, road culverts, tributary or drainage discharge points, major bends, and intermediate points, to differentiate catchments types and creek characteristics. This enables the routing model to be more realistic.

The fraction impervious and degree of urbanization were estimated using Nearmap and Google Earth aerial photography.

A total of 70 catchments, and 51 drainage nodes, were defined with a total area of 217 Ha to Bayley Road. Each catchment was then subdivided in into pervious and impervious subcatchments, with the impervious area being estimated from aerial photography. The total number of sub-catchments evaluated was 108.

Table 3-3 below summarises the catchments their characteristics. A catchment plan is included in the Appendices.

3.4.4 Calibration and Validation

There are no streamflow records for Iron Pot Creek so no data was available for calibration. This is a major limitation on the accuracy of the results. Confidence in the results has been improved by:

- Using rainfall-runoff parameters from analogous catchments where calibration has occurred.
- Deriving a range of estimates by using multiple models and techniques (eg. XP-SWMM, MUSIC and Rational Method)
- Comparing model results with anecdotal evidence from residents about water levels and catchment behaviour under large storms.

Due to the lack of calibration, the results should therefore be treated with caution and probably have an accuracy of no greater than +/- 30%. Nonetheless, the models provide a useful gauge about the relative impact that urbanisation has on the flow regime.

Table 3-3 Summary of subcatchment details

NAME	AREA (m²)	AREA (ha)	fall	distance	Slope	No Lots	No lots developed	Estimated impervious %
ME0.0	7,179	0.72			7.7%	2	1	10%
MW0.0	18,637	1.86			9.3%	5	4	15%
ME38.0	7,108	0.71	3	42	7.1%	2	1	15%
MW38.0	36,072	3.61	7	94	7.4%	8	7	20%
ME195.0	4,001	0.40	5	57	8.8%	1	1	15%
MW195.0	11,419	1.14	9	118	7.6%	0	0	0%
ME235.0	8,855	0.89	5	46	10.9%	1	1	20%
MW235.0	9,710	0.97	7	89	7.9%	0	0	0%
ME321.0	22,316	2.23	5	59	8.5%	3	2	10%
ME321-D1	12,734	1.27	3	44	6.8%	1	1	10%
MW321.0	15,047	1.50	8	111	7.2%	0	0	0%
ME376.0	26,209	2.62	12	120	10.0%	0	0	0%
MW376.0	15,947	1.59	7	102	6.9%	2	1	5%
MW538.0	23,299	2.33	6	94	6.4%	2	2	10%
ME678.0	23,102	2.31	7	100	7.0%			0%
MW678.0	10,164	1.02	5	58	8.6%	1	1	25%
ME950	16,389	1.64	8	102	7.8%	0	0	0%
MW950	12,984	1.30	6	58	10.3%	3	3	20%
ME1005	22,835	2.28	9	111	8.1%	0	0	0%
ME1257.0	14,804	1.48	7	87	8.0%	0	0	0%
MW1257.0	12,339	1.23	2	53	3.8%	1	1	10%
ME1508.0	19,962	2.00	10	98	10.2%	0	0	0%
MW1508.0	6,820	0.68	4	74	5.4%	2	2	25%
ME1600.0	4,415	0.44	3	70	4.3%	0	0	0%
ME2050.0	140,205	14.02	11	102	10.8%	0	0	0%
MW2050.0	16,815	1.68	5	61	8.2%	3	3	25%
ME2368.0	25,614	2.56	7	163	4.3%	1	0	0%
M2575.0	9,611	0.96	5	50	10.0%	1	1	5%
MW2368-D1	46,919	4.69	21	113	18.6%	6	6	20%
MW875-D1	19,669	1.97	7	51	13.7%	4	4	25%
MN1776-CULV	38,685	3.87	8	83	9.6%	6	6	20%
MS1776.0 - CULV	29,014	2.90	3	44	6.8%	6	6	20%
T1E65.0	38,023	3.80	10	96	10.4%	0	0	0%
T1W65.0	44,308	4.43	8	105	7.6%	0	0	0%
MT1700.0	77,191	7.72	4	70	5.7%	3	3	3%
T1C307.0	54,881	5.49	11	71	15.5%	0	0	0%
T2W0.0	11,690	1.17	5	50	10.0%	1	1	15%
MT2050.0	50,882	5.09	14	112	12.5%	9	7	10%
T4D1	10,829	1.08	11	102	10.8%	1	0	0%
T4D2	24,474	2.45	7	68	10.3%	2	2	30%
T2W145.0	15,933	1.59	6	70	8.6%	3	3	10%
T2-175-D1	26,478	2.65	10	80	12.5%	6	6	25%
T2-175-D2	12,187	1.22	7	52	13.5%	2	2	35%
T2-475-D1	56,389	5.64	13	142	9.2%	5	4	10%
T2-475-D2	20,349	2.03	8	67	11.9%	5	5	35%
T2-475-D3	96,209	9.62	20	174	11.5%	18	18	25%
MT2575.0	23,176	2.32	6	80	7.5%	3	1	5%
MT2575.0-2	76,758	7.68	10	77	13.0%	6	6	10%
MT2575.0-3	154,812	15.48	8	220	3.6%			1%
T2C200.0	22,260	2.23	3	113	2.7%	4	4	20%
T2C368.0	15,405	1.54	4	52	7.7%	3	3	30%
T3E1018.0	16,360	1.64	6	150	4.0%	0	0	0%
T3W1018.0	20,428	2.04	9	66	13.6%			0%
T3E1165	12,319	1.23	9	86	10.5%			0%
T3E1250.0	7,689	0.77	8	65	12.3%			0%
T3W1250.0	9,751	0.98	7	46	15.2%			0%
T3E1320.0	5,219	0.52	9	69	13.0%			0%
T3W1320.0	10,721	1.07	17	108	15.7%			0%
T3E238.0	44,245	4.42	7	99	7.1%			0%
T3W238.0	21,684	2.17	8	84	9.5%			0%
T3E428.0	116,868	11.69	7	150	4.7%			3%
T3W428.0	30,921	3.09	8	85	9.4%			0%
T3E50.0	35,166	3.52	6	83	7.2%			0%
T3W50.0	11,556	1.16	6	81	7.4%			0%
T3E678.0	33,580	3.36	9	95	9.5%			0%
T3W678.0	59,515	5.95	11	59	18.6%			0%
T3B1250.0	3,285	0.33	17	108	15.7%			0%
T3C1450.0	129,965	13.00	10	77	13.0%			0%
T3T1018	39,448	3.94	13	120	10.8%			0%
T3T1250.0	40,849	4.08	17	108	15.7%			0%

3.4.5 Design parameters

The Laurenson routing method was in XP-SWMM. This method is dependent on a number of parameters including the catchment area, flow path slope and urbanised percentage. The storage-delay time coefficient (B) was calculated automatically by the software.

3.4.6 Losses

The hydrologic modelling adopted an initial/continuing loss approach for the design storms and Horton loss approach for the continuous simulations. Catchments were split into individual sub areas (impervious and pervious surfaces). This enabled the loss models for each surface type to be applied directly to each. The loss values adopted are shown in Table 3-3 Continuing Loss coefficient for Design Storms and Table 3-4 below:

Table 3-4 Continuing Loss coefficient for Design Storms

Catchment	Initial Loss (mm)	Continuing loss (mm/hr)
Pervious	20	1.0
Impervious	2	0.1

Table 3-5 Horton Loss Coefficients for Continuous Simulations

Catchment	Max Infiltration Rate - Fo (mm/hr)	Min Asymptotic Infiltration (mm/hr)	Decay Rate of Infiltration (1/Sec)	Max Infiltration Volume (mm)	Remarks
Pervious Pre-development	150	1.0	0.01	0.0*	Used for modelling natural catchment condition.
Pervious	20	1.0	0.001	0.0*	
Impervious	2	0.1	3	2.5	

* No limit of volume

The Horton's regeneration of Infiltration Capacity coefficient was set to 0.01 for all catchment types.

3.4.7 1D Hydraulic Parameters

The 1D hydraulic links used and their main characteristics are summarised in Table 3-5 below.

Table 3-6. Summary of hydraulic modelling parameters

1D Hydraulic Link	Use	Manning Values	Remarks
Concrete Pipe	Existing pipe/culvert shown Ipswich City Council records	0.013	Not all the pipes networks were required in the model
Natural Channel	All sections of creek, tributaries and the bridge at Bayley Road.	Nat. Creek Overbanks 0.100 Main channel 0.025 Bridge Overbanks 0.015 Main channel 0.035	Sandy bed and heavily vegetated banks Concrete lined embankment and creek bed with some vegetation
Trapezoidal channel	Used to link catchments that discharge concentrated flows through sheet flow into the creek.	0.035	Large trapezoidal channel to link flows/catchments while providing a lag on the routing
Weirs	Used to link catchments that discharge concentrated flows into the creek and the topographic characteristics of the junction don't allow the use of 1D channels.	-	Large weirs to link flows/catchments without adding lag to the routing

3.4.8 2D Hydraulic Parameters

The parameters used on the 2D hydraulic model are related to the sizes and orientation of the modelling grids and the land-uses applied to the 2D domain.

The grid size used for the combined 1D/2D multi-domain model was 500 mm square with an orientation individually set to the general alignment of the low flow bed in each individual section.

The grid size used for the 2D multi-domain model was 1000 mm square for the creek main alignment and 2000 mm for the inundation and boundary areas. The grids were orientated -25 degrees from north to better align with the overall creek alignment.

The land-uses defined for the 2D models are listed in Table 3-6 below.

Table 3-7. 2D land uses

2D Land Use / Name	Manning's	Location / Remark
Creek bed	0.025	To represent sandy bed on creek low flow channel.
Creek bank	0.100	To represent a heavily vegetated high flow/inundation area.

No infiltration losses were modelled on the 2D domain as these were accounted for in the rainfall runoff simulation.

3.4.9 Outlet and Tailwater levels

As there is no stream gauges or flood level records at Warrego Hwy, Bayley Road or anywhere else on Iron Pot Creek stream, the tailwater levels were set to the minimum of the critical and normal depths on the section of channel located under the bridge at Bayley Road. The selection of this level is considered arbitrary and largely irrelevant as the velocities on the considered critical erosion sections of the creek would not be affected by it.

3.4.10 Hydraulic Models

As indicated previously, various types of numerical computer models were used in the analysis. These models are described below.

3.4.11 Continuous 1D Model

Two different scenarios were modelled with this configuration with the aim to evaluate/measure the impact of the development. The first scenario was the "existing" scenario in which the catchment characteristics were set to current and the losses were defined as noted in Table 3-4 above. The second model was a hypothetical "pre-development" model in which all the impervious areas were changed to pervious and the losses coefficients were increased.

Hydraulic Configuration

The hydraulic part of this model was created using 187 1D links that included 2,650m of Iron Pot Creek and 3,015m in five tributaries. On the upper section the creek was segmented on 25m length sections of natural channel (links). Longer section lengths were used at the lower section of the creek and on the tributaries. Shorter sections of channel were created on the critical sections (bend, meandering section) and on flow junction and catchment input.

The profiles of the natural channel were defined individually for each section using XP-SWMM cross-section tool and the surface layer created from Council's LIDAR data.

Predevelopment results should be used with caution because the simulation used the current channel morphology. In reality, the pre-developed channel would have been less eroded and had different hydraulic behaviour.

The pipe network was modelled in accordance to information supplied by Council.

The hydraulic parameters used are noted in Table 3-5.

Hydrology

Historic pluviograph data was used from Amberley AMO weather station located 6.5km south of Iron Pot Creek catchment (centre). According to the Australian Bureau of Meteorology, this station has a reliability of 98%. A period of 10 years was analysed, from 1990 to 1999 with a calculation time step of 15 seconds. To reduce the size of the output files, the data and the models were subdivided and ran on one year sets.

3.5 Review of LIDAR data

The assessment utilised LIDAR data available from the Department of Environment and Heritage Planning (DEHP) imported to ESRI ArcMap, MapInfo and AutoCAD and processed as required. Use of the LIDAR data enabled the development of a site contour plan, and generation of slope analyses to highlight erosion ‘hotspots’ which will inform concept treatment outputs.

In addition to the use of LIDAR data, a hand held GPS was used to track the creeks centre line from the headwaters to the Warrego Highway. This information was then exported to AutoCAD to assist in calculating geomorphic parameters.

4 Results

4.1 Geomorphology

4.1.1 Valley types

Following Rosgen (1996) there are potentially three Valley Types present within the study area: Type II, Type III, Type V and Type VIII. Planform has also been described using Brierley and Fryirs (2006) to provide a generalised description of stream character with less emphasis on geologic and interglacial processes uncommon in Australia (e.g. valleys created by glaciers). A brief summary of these Valley Types is provided in Table 4-1 below.

Table 4-1 Summary of Valley Types within study area

Zone	Valley Type	Comment
1a, 1b, 1c, 2a	II	Type II Valleys are typically associated with B type streams on slopes less than 4%, entrenched, laterally confined with a low sediment supply and bed materials comprising gravel, stone and rapid characteristics. G type streams can form in these valleys following disturbance.
2b, 3, 4	V	Type V Valleys are typically associated with C, D and G type streams with sediments the result of deposition and scour. These streams are typically moderately entrenched and landforms include alluvial terraces and floodplains.
5a, 5b	VIII	Type VIII Valleys are typically associated with depositional floodplain environments with adjoining flood terraces and are normally laterally unconfined. Stream types can include C, D, F and G.

4.1.2 Stream types

A number of stream types are present within the study area, consistent with changes in topography, geology and channel dimensions. These stream types must inform the development of rehabilitation options to ensure compatibility with the natural character of the creek in different localities. For example Zone 1a corresponds with stream type B3 transitioning to a G4 type stream in response to disturbance, which is characterised by low sinuosity, laterally confined rock and gravel lined stream. This stream type is naturally entrenched but resistant to bed lowering processes due to presence of cobble and bed rock within the stream bed. In contrast Zone 3 corresponds with stream type E5 and is a highly sinuous meandering channel with a high degree of lateral instability, but also a deposition zone for sediments transported from high energy zones upstream.

Zone 5 corresponds with stream type F and is laterally unconfined floodplain channel with very low grade, multiple channels and lagoons and a deposition zone for sediment transported from Zones 3 and 4. The exception being the lower portion of Zone 5 erosion in proximity of The Warrego Highway has resulted in bed lowering and apparent migration of a head cut upstream.

Stream types for the entire study area are presented within Table 4-2 below, while comment is also made on the likely historical form of the creek and its potential future condition without intervention. For example it would appear that Zones 1a and 1b have transitioned from stream types B4 or B5 to G4 and G3 in response to disturbance events with evidence of bed lowering and bank scour. This is potentially supported by a reference site showing a less incised gravel/cobble system within the Pine Mountain Bush Reserve. Similarly Zone 5a has potentially transitioned from stream type C5 to D5 in response to large amounts of sediment accumulating within this Zone, while Zone 5b is potentially transitioning from C5 to D5 to G5 as deepening headcut creates instability and creek bed lowering.

Table 4-2 Stream types for Iron Pot Creek, following Rosgen (1996)

Management Zone	Stream Type	Comment
1a	G3	Possibly B3 or B4 historically.
1b	G4 to G3	Possibly B4 historically.
1c	G4 to F5b	Possibly C4 to C5 historically.
2a	E5	Possibly C5 historically and could potentially transition to G5 and then C5 in future as sediments are worked through the system.
2b	G5	Possibly E4 historically.
3	E5	Possibly C5 historically and could potentially transition to G5 and then C5 in future as sediments are worked through the system.
4	E5 to E6	Current condition possibly indicative of historical condition. Sediment transport from Zone 3 may influence this zone in future.
5a	D5	Possibly C5 historically before substantial accumulation of sediment from upstream.
5b	D5	Possibly C5 historically, and transitioning to G5 as head cut and bed lowering continue.

4.1.3 Sinuosity and stream grade

Sinuosity measurements have confirmed the creek broadly adheres to geomorphic principles whereby sinuosity increases as stream grade reduces with Zones 2a, 3 and 4 having the greatest sinuosity. One impact of urbanisation of catchments is a reduction in sinuosity as stream velocities increase and the bankfull capacity of the stream is readily exceeded. This has implications for geomorphic and instream habitat diversity and can lead to shifts in stream. Zones 1c, 2a and 3 are possibly most susceptible to a reduction in sinuosity – Zones 1b due to increased stormwater discharge and Zones 2a and 3 due to significant accumulation of sediment within the bankfull channel. Further, increases in stormwater discharge and subsequent instream erosion can alter stream grades through bed lowering, channel straightening and scour of natural instream grade control features (pools and riffles).

Results for sinuosity measurements and channel grade are provided in Table 4-3 below.

Table 4-3 Results of sinuosity assessment

Zone	Valley Length (m)	Stream Length (m)	Sinuosity	Change in Elevation (m)	Grade %
1a	270	283	1.05	16	5.7
1b	225	306	1.36	7	2.3
1c	255	303	1.19	5	1.7
2a	282	482	**1.71**	5	1.0
2b	269	303	1.13	11	3.6
3	302	511	**1.69**	3	0.6
4	499	722	**1.45**	7	0.9
5a	436	460	1.06	3	0.6
5b	288	316	1.10	7*	2.2*

*Estimate only – LIDAR did not cover the extent of Zone 5. Most of this change in elevation is the result of a developing headcut at the bottom of Zone 5.

4.1.4 Sediment sampling

Particle size distribution and cumulative scores for particles size ranges were derived from the 340 sediment samples measured within Zones 1,2 & 3. The results show a reduction in sediment particle size moving downstream and with smaller particles noted within stream banks than within the creek bed (as would be expected). The results confirm there is a general mobilisation of sediment from Zones 1a and 1b and deposited within Zone 1c, and then transported through Zone 2 and deposited within Zone 3 and to a lesser extent within Zone 4. Sediment particles are predominantly fine sand through to Coarse Gravel, with Zones 1b, 2a, 4, and 5a displaying sediment ranges and distribution typical for the stream type category. In contrast Zones 1c, 3a and 3b show a substantially reduced range in sediment sizes and are dominated by loosely packed sands. These sands have smothered the creek channel to a depth of up to 600mm, reduced the bankfull capacity, smothered geomorphic features and are exacerbating bank scour on outer bends.

Figure 4-1 shows the cumulative sediment sampling results for all of the Zone's samples and confirms that the coarsest sediment fraction was within Zone 1a and the finest fraction within Zone 1c. The median sample size for the entire study area (d_{50}) ranged from approximately 150 µm through to approximately 90 mm. Sediment histograms for each Zone are displayed within Figures 3.2 – 3.4.

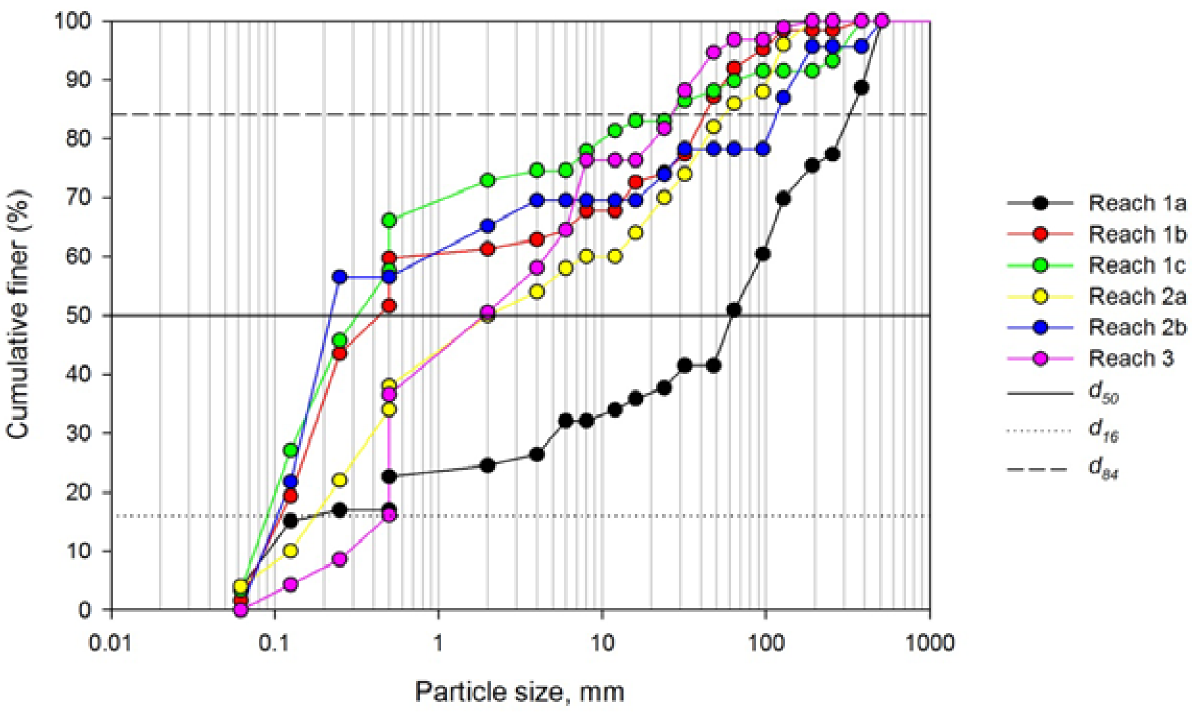
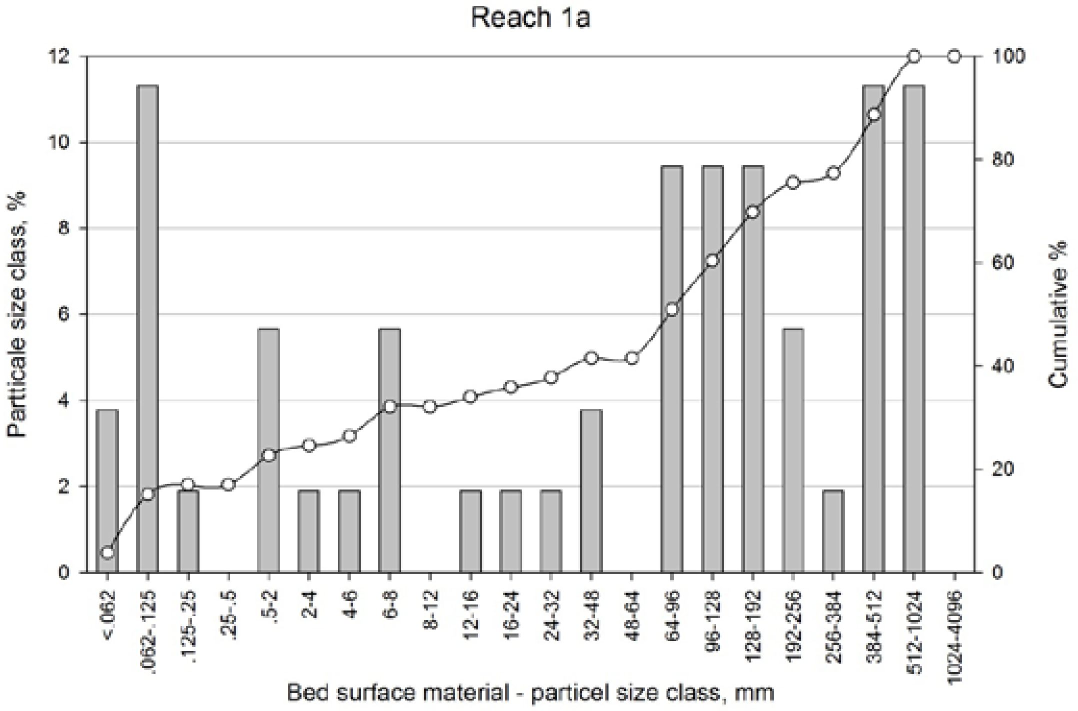


Figure 4-1 Cumulative Sediment Particle Size Results with log normal distribution.



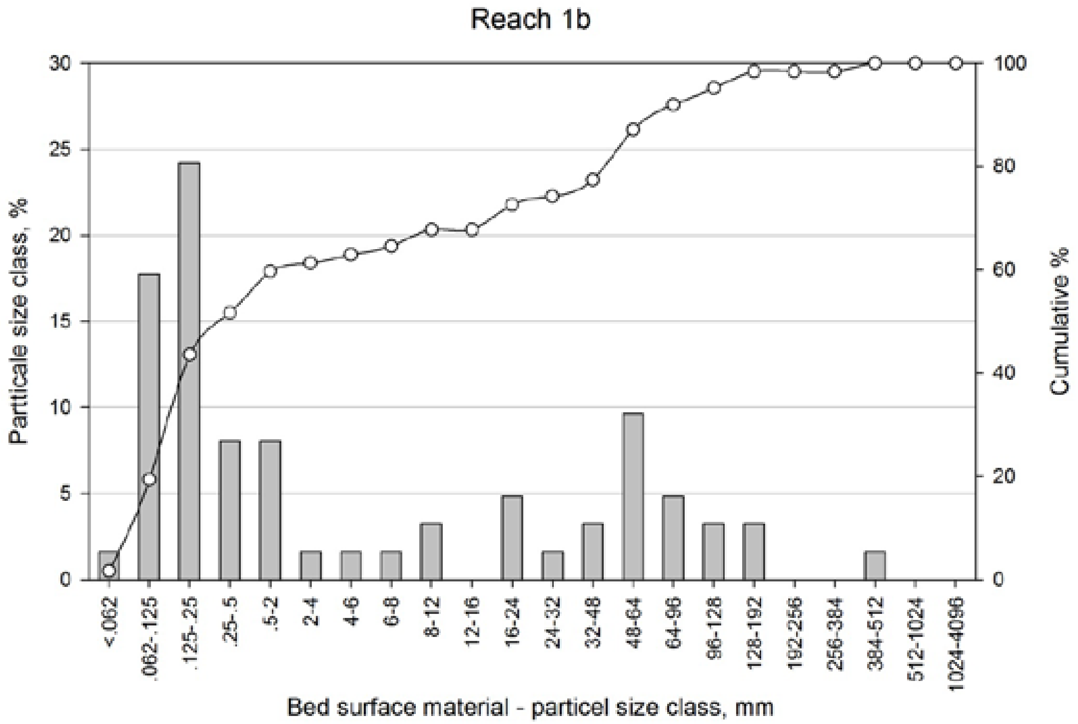
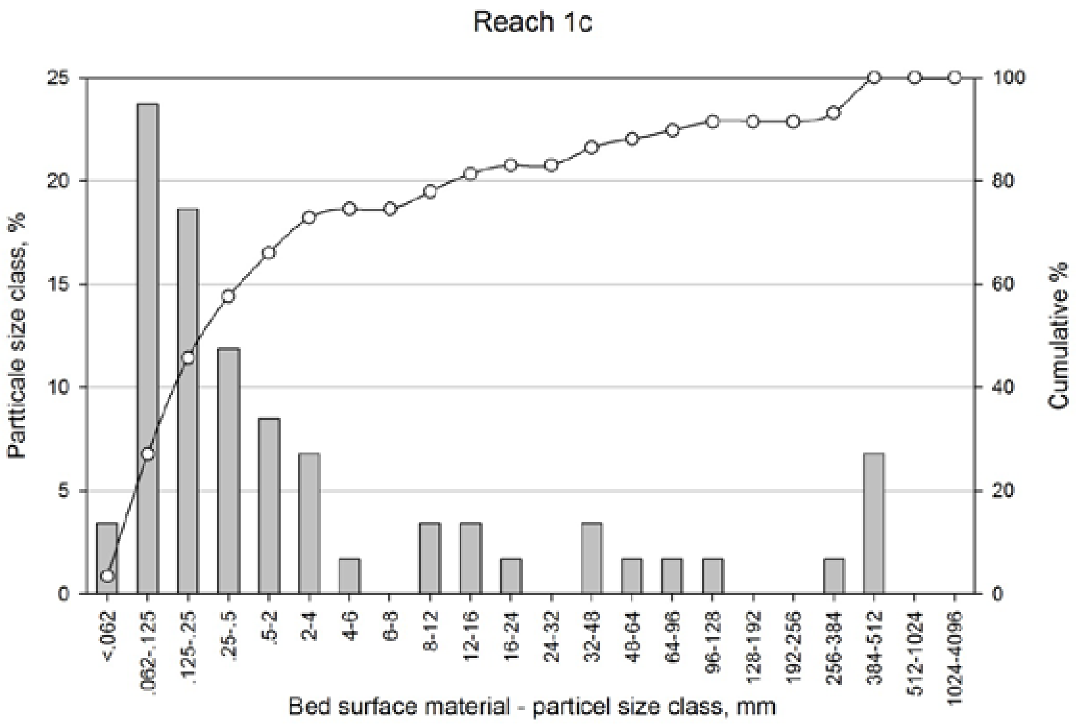


Figure 4-2 Sediment histogram for Zones 1a and 1b



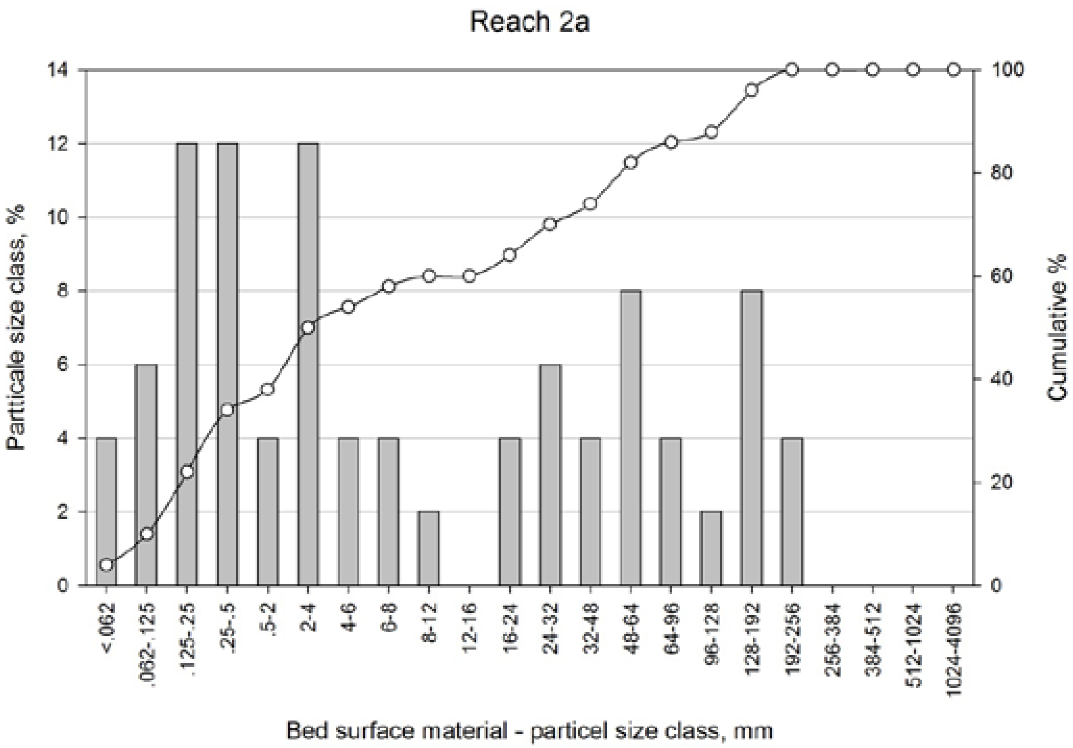
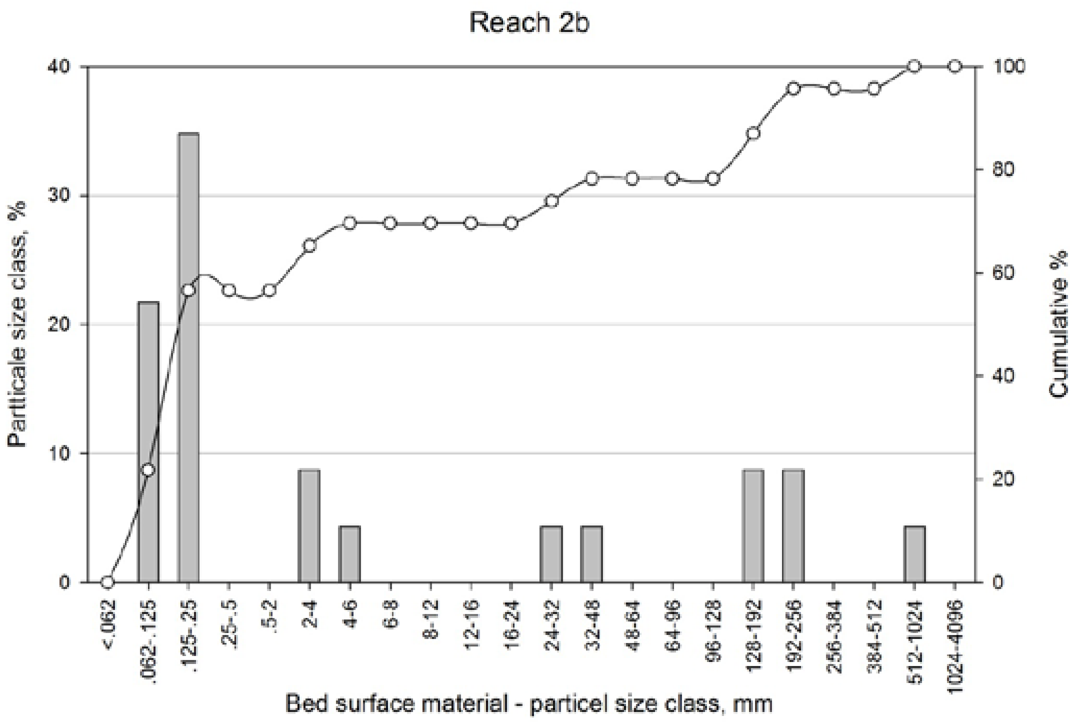


Figure 4-3 Sediment histogram for Zones 1c and 2a



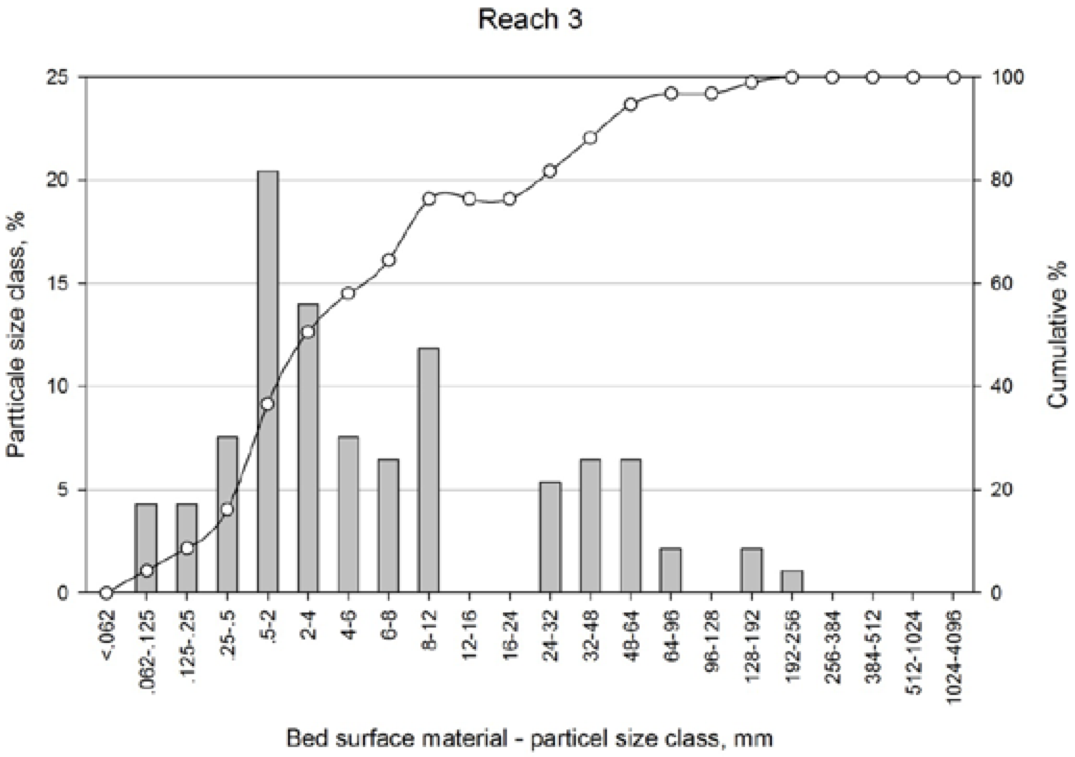


Figure 4-4 Sediment histogram for Zones 2b and 3

4.1.5 Width to depth ratios

Width to depth ratios derived from instream cross sections show a shift in values moving downstream, which is consistent with changes in stream types which are also observed through the Zones. That is, we see an increase in W:D ratio as the channel widens, stream grades reduce and sinuosity increases. Zone 2a has the lowest W:D ratio of 1.36, while Zones 4 and 5 score the highest, which is as expected, since the creek continues to widen once reaching the floodplain. The bottom section of Zone 5 would have had a higher score were it not for a developing head cut and associated bed lowering. Results are summarised in Table 4-4 below.

Table 4-4 Stream width and depth parameters and resulting W:D scores

Location	Bankfull Width	Bankfull Depth	W:D Ratio
1a	2.4	1.2	2.1
1b	6.6	1.8	3.67
1c	5.1	1.6	3.19
2a	6.5	1.6	4.1
2a	8.6	1.9	4.52
3	1.5	1.1	1.36
3	5.0	0.80	6.25
5	5	0.80	6.25

4.1.6 Entrenchment ratios

As a measure of vertical bank instability, stream entrenchment is a valuable parameter to consider in combination with W:D ratios to broaden an appreciation of instability for different stream types. Values ranged from 1.47 in Zone 2a (entrenched) through to 5.4 in Zone Five, which again was influenced by a head cut developing. While entrenchment is considered a feature of stream types B and E, entrenchment occurring within Zone 2 and 3 seems to be the result of changes in stream morphology post urban development (or post land clearing for agriculture). The results suggest some degree of bed lowering within Zones 1b, 2a and 2b, but which has now slowed due to the presence of bed rock within the stream bed. This does however increase the risk of lateral instability – erosion of creek banks. Entrenchment will probably worsen and increase in extent within Zone 5 without management intervention, since bedrock has not yet been intercepted within the stream channel. Results of entrenchment calculations are provided in Table 4-5 below and that Zone 3 is the most entrenched with the low flow channel generally only marginally wider than it is deep at the location sampled. Generally the entire creek line is at least moderately entrenched and likely to be at least in part the result of historic bed lowering in response to changes in land use.

Table 4-5 Bankfull and flood widths and entrenchment ratios

Location	Flood Width	Bankfull Width	Entrenchment Ratio	Comment
1a	9.9	2.4	4.125	Not entrenched
1b	13.2	6.6	2	Moderate
1c	17.2	5.1	3.3	Moderate
2a	35	6.5	5.38	Not entrenched
2a	35	8.6	4	Not entrenched
3	12.2	8.30	**1.47**	Entrenched
3	18.5	5	3.7	Moderate
5	27	5	5.4	Not entrenched

4.1.7 Bank stability ratings

An assessment of bank stability following Rosgen (1996) and Pfankuch (1975) enabled a quantitative score to be established for creek banks throughout the management zones. The results showed confirmed a high degree of bank instability, particularly in zones 1 and 2, Zone 2 having the greatest extent of unstable banks. Generally the severity and extent of bank instability decreases moving downstream. Zone 4 has only intermittent bank instability while in Zone 5 there is very little bank instability apart from in the vicinity of a developing head cut upstream of the Warrego Highway. Locations and extents of bank instability are shown within drawing LP02 to LP06 in Appendix A. Results of bank stability ratings are provided within Appendix B. The results show the most significant erosion to be in Zones 1b, 2a, 2c and 3, with Zones 4 and 5a the most stable. The results also suggest that erosion processes are ongoing however the stream has adapted to the new hydrologic regime in many locations through a transition in stream type. For example Zone 2a has evolved from stream type C5 to E5. There are some locations however where natural responses as bed lowering and channel widening may not be acceptable given proximity to private property or infrastructure.

4.1.8 Soil dispersivity

The results of the Emerson Aggregate Test are shown in Table 4-6. The results show that exposed sub-soils within the creekline are not dispersive but are generally lacking cohesion and susceptible to structural collapse when wetted.

4.1.9 Dispersive soils

Soils generally correspond with Sodosols, which are typified by sandy topsoil and clay-rich subsoils, however there is also sandstone combination to deeper soils, exposed through erosion. These soil types are highly erodible and making them very vulnerable to sheet, gully and tunnel erosion once disturbed or where stormwater runoff is concentrated. Tests of dispersivity show that soils within Iron Pot Creek are lacking in cohesion and susceptible to slaking when saturated. There is evidence of tunnelling within soils, expressing within vertical creek banks and cracks and potholes within private property adjoining the creek line. The extent of tunnelling throughout the catchment is difficult to determine and would require detailed investigation. The results suggest that dispersive soils sit above the incised creek in adjoining properties rather than in the creek. Typical soil character is displayed at Figure 4-5.

Table 4-6 Emerson Aggregate test results

Soil code (location)	2Hr	20Hr	Emerson Class
1A	No slaking (0), no dispersion	No change	Class 7 Slaking subclass 0
1A	Minor slaking (1), peds broken apart, no dispersion, some swelling	Peds broken further apart, slaking (2), no dispersion	Class 7 Slaking subclass 1
1B	No slaking (0) or dispersion, no swelling	No change	Class 8 Slaking subclass 0
1B	Mostly slaked (2), fallen apart. No dispersion, clear water, distinct grains	No change	Class 7 Slaking subclass 2
1B	Not slaked (0), no dispersion, peds intact	Slightly swelled, no change otherwise	Class 8 Slaking subclass 0
1C	No slaking (0) or dispersion, complete bolus remains	No change	Class 7 Slaking subclass 0
1C	Slaked completely (3), slight dispersion, slight milkiness	No change	Class 2(1) Slaking subclass 3
1C	No slaking (0), no dispersion, no swelling, peds intact	No change	Class 8 Slaking subclass 0
2a	Slaked completely (3), dispersed (2), obvious milkiness, pile of fine grains	No change	Class 2 (2) Slaking subclass 3
3	Completely slaked (3), no dispersion, no milkiness, coarse sand content	No change	Class 7 Slaking subclass 3

Figure 4-5 Soils typical of Iron Pot Creek

4.1.10 Summary of erosion types and processes

There are multiple erosion processes occurring in the Iron Pot Creek catchment, as summarised below. At different locations, different combinations of these processes are at work. Key issues contributing to erosion within the creek line include:

- The catchment is particularly steep (average grades >10%)
- The soils are highly erodible both non-cohesive soils and slightly dispersive clays. The soils are predominantly Sodosols which are 'alkaline and sodic soils with sharp texture contrast, and are vulnerable to sheet, tunnel and gully erosion due to poorly structured subsoils' (*Soils of Ipswich Field Guide*).
- The increase in impervious surfaces has increased the volume and frequency of surface runoff.
- Efficient urban drainage (using pipes and kerbs) concentrate runoff and speed it's delivery into the stream at focussed locations.
- Removal of native vegetation has reduced canopy interception, reduced infiltration capacity of soils, reduced evapotranspiration, and reduced surface roughness and depression storages. By comparison, most yards have been profiled so they are relatively smooth, with sparse/short turf, and are moderately compacted. Subsoils are likely to be at or near the surface.
- The combined change to the hydrology of the creek has increased the erosion potential substantially (for more detail refer to section 4.3).
- A tributary to Iron Pot Creek from the east drains through a predominantly natural catchment, and provides a useful reference of what Iron Pot Creek was like prior to urbanisation. It has similar slopes, soil types and rainfall, yet has relatively stable channel form.

- There is a severely eroded gully that runs through the rear of properties on 25 – 31 Wairuna Ct. This gully has no urbanisation in its catchment, and the erosion appears to have been triggered by the construction of the embankment for the former railway and the installation of a culvert beneath that embankment. This case is significant because it indicates that concentration of flows alone is enough to trigger significant gullying.
- Incision, widening and deposition are the main responses observed within the creek as a result of land clearing and concentration of stormwater flows.
- The incision of the creek bed has changed the hydraulic gradient for interflow (water moving laterally through the soils towards the creek). This is believed to be exacerbating the extent of tunnelling and pot-holing.
- Erosion is a naturally occurring process within the creek, however erosion rates observed are significantly higher than those that would be considered naturally.

Erosion types observed within Iron Pot Creek as a result of these various processes are detailed within Table 4-7 below. Potential rehabilitation options are also discussed.

Table 4-7 Summary of erosion types within Iron Pot Creek

Erosion Type	Description and Cause	Location(s) (refer Appendix A for Management Zones Site Map)	Potential Response
Headcut	Erosion of the creek channel migrating upstream. Caused by either changes in adjoining land use or modifications to the creek itself. The headcut creates a small waterfall or step in the creek.	Zone 5a	Inclusion of a grade control structure within the creek bed to halt the advancement of the headcut, as well as revegetation of adjoining and downstream locations. Detail is provided within drawings in Appendix A.
Lateral bank erosion	Creek banks are scoured and the channel widens, particularly on outside bends of meanders. Typically caused by an increase in stormwater volumes and velocities, possibly in combination with clearing of vegetation.	Zone 1b, 2a, 3	Construction of instream erosion protection measures which redirect stream energy away from the bank and into the creek channel. This could take the form of installation of large woody debris (LWD) or rock in combination with reshaping of batters, revegetation of batters and creation of pools and riffles instream. Detail is provided within drawings in Appendix A.
Bed lowering	A process whereby the creek becomes increasingly incised, pools and riffles are swept away and channel slope increases. Caused by an increase in flow volumes and velocities to levels which exceed the shear stress capacity of bed materials (sands, gravel, boulders). Bed lowering is similar to a head cut but potentially occurring across an entire stream section rather than at a single location.	Zones 1a, 1b, 2a, 3, upstream of 2a	Introduction of instream grade control structures such as boulders and LWD to reduce channel slope and recreate pools and riffles. Detail is provided within drawings in Appendix A.
Tunnelling	Vertical erosion of dispersive soils which are exposed to rainfall and concentrated flows following loss of vegetation cover and topsoils.	Zone 1a, 1b, 1c	Revegetation of exposed subsoils and introduction of drainage measures which limit concentration of flows. Potential solutions are shown within drawings in Appendix A.
Bank slumping	Creek banks lacking vegetation cover collapse under their own weight when wet, regardless of stream velocities.	Zone 1b, 1c, 2a	Reshaping and revegetating of banks and reinstatement of bank toes to support the upper bank. Detail is provided within drawings in Appendix A.
Concentrated flows	Stormwater runoff is concentrated by urban drainage infrastructure and discharged into the creek at velocities which cause scour of creek bed and banks.	Zone 1a, 1b, 1c, 2a, 2b, upstream of 2a	Reduce stormwater quantity and velocities through source control measures such as rainwater tanks and on-site detention. Create energy dissipation measures instream such as plunge pools and rock rip-rap which reduce stream flow energy to levels that reduce or remove potential for scour. Detail is provided within drawings in Appendix A.

4.2 Ecology

4.2.1 Vegetation

Vegetation at the site comprises an amalgam of dry sclerophyll forest types consistent with RE mapping (mostly RE 12.9-10.2 and 12.9-10.3) and typically dominated by gum-topped box (*Eucalyptus moluccana*). Other common canopy species include narrow-leaved ironbark (*E. crebra*) and Qld blue gum (*E. tereticornis*) – mostly in the southern portion of the study area, where vegetation is broadly consistent with RE 12.3.3. The midstorey generally consists of red ash (*Alphitonia excelsa*) and a variety of wattle species (*A. disparrima subsp. disparrima*, *A. concurrens*, *A. leiocarpa*). The weed species lantana also occurs commonly. The ground layer is sparse and comprises native grasses with weed species along much of the creekline (billygoat weed, creeping lantana, rhodes grass, paspalum).

A small localised stand of broad-leaved paperbark (*Melaleuca quinquenervia*) occurs around a small lagoon in the south of the study area and could be broadly considered as occurring within RE 12.3.3.

Vegetation at the site is generally in good condition, with five Class 2 declared pest species recorded (Singapore daisy, fireweed, groundsel, mother-of-millions, and prickly pear). A small localised infestation of Singapore daisy occurs within Zone 1B, while other species were recorded very infrequently. Immature Queensland blue gums within Zone 5B appear to have been planted.

A full flora inventory is attached at Appendix C.

4.2.2 Fauna habitat

The site has a broad suite of fauna, from disturbance adapted species common in rural and peri-urban fringe landscapes (e.g. Australian magpie, torresian crow, noisy miner) to more specialised and reclusive species (e.g. rainbow bee-eater, red-browed finch, buff-banded rail). Habitat for several threatened fauna species occurs along the main creekline (koala, green-thighed frog) and extends into adjacent vegetation to the north and south.

Habitat trees (i.e. dead trees, or trees with hollows, spouts or fissures) occur infrequently along the main watercourse.

4.2.3 Significant ecological matters

No significant naturally occurring flora species were observed. A planted Queensland nut (*Macadamia tetraphylla*) occurs on land behind a residence abutting Walter Zimmerman Park. The majority of vegetation along the creekline in the north of the site could be broadly interpreted as comprising RE 12.9-10.2, classified as 'of concern' under the VM Act. South of Bayley Street, vegetation is broadly consistent with RE 12.3.3 (*Eucalyptus tereticornis* woodland to open forest on alluvial plains) classified as 'endangered' under the VM Act.

The study area forms part of a broad corridor likely to be utilised by koalas and a number of trees were observed bearing scratch marks likely to be attributed to the species. The creekline may also provide habitat for the green-thighed frog and also potentially the tusked frog (*Adelotus brevis*). Habitat trees (dead trees and hollow-bearing trees) provide good quality resources for arboreal mammals, hollow-nesting birds and microchiropteran bats. Scattered trees of *Allocasuarina littoralis* and *A. torulosa* also provide resources for the vulnerable glossy black-cockatoo (*Calyptorhynchus lathami*) in addition to potential nesting hollows (as above).

4.3 Hydrologic and hydraulic modelling results

The hydrologic and hydraulic modelling results show the modest degree of urbanisation has likely had a profound impact on the hydrology of the creek.

The mean annual flow in the creek has increased by about 35%, and the number of days when streamflow occurs has probably halved (i.e. there is more runoff, but it occurs in shorter, sharper pulses compared with pre-development conditions when more water would have seeped into the stream as baseflow).

Estimates of peak flow rates for the creek are summarised in Table 4-8 below. Detailed analysis of the relationships between flow, depth, velocity and shear stress at a number of cross sections is included in Appendix G.

The results show significant increases in peak flows as a result of urbanisation. The increase in peak flows is generally higher for events in the range from the 1 yr ARI to 20 yr ARI, and less for the 50 yr ARI and 100 yr ARI events. This is to be expected because for larger storm events, the reduction in catchment losses associated with urbanisation is less significant.

The results show that Peak flows for the 2 yr ARI event (which is expected to have significant channel forming influence), are likely to have increased several-fold, depending on location in the catchment and how wet the catchment has been prior to the storm.

Some of the estimates vary significantly depending on the model/technique used. There is generally good agreement between SWMM and the Rational Method in the mid to upper reaches of the study area(CH 1508 to CH 2575) for all ARI's analysed.

For larger events (50 yr ARI and 100 yr ARI), MUSIC results align with SWMM and the Rational Method but appear unrealistic for more frequent events (the use of MUSIC to simulate design storms is an experimental technique and has been used to assist with deriving estimates in the absence of calibration data). The accuracy of MUSIC is likely to be limited because it runs on a 6 minute-timestep which may smooth the peaks of the hydrographs in this flashy catchment. MUSIC also lacks detailed channel and storage routing algorithms.

Rational method estimates are coarse, and implicit in the methodology is an assumption that a specified proportion of rainfall contributes to peak flows (rather than, say, an initial/continuing loss model). For this reason, at more frequent ARI's the peak flows using the Rational Method are typically higher compared with other methods which assume more of the rainfall is lost.

SWMM is the most sophisticated of the models, as it accounts for losses, routing and storage effects, yet it is 'data hungry' and dependent on calibration. The MUSIC and rational method estimates suggest the SWMM estimates are not unrealistic.

Although the peak flow rates should be used with caution due to the lack of calibration data, far greater confidence can be placed on the relative relationships between flow rates and shear stress, depth and velocity as these relationships are based on channel hydraulics (as presented in Appendix G).

Overall, the results highlight the importance of obtaining streamflow data so that the models can be calibrated to assist in evaluating detailed design works.

Table 4-8 Estimates of peak flow rates

Peak Flows (m^3/s)		MUSIC* (* ran using design storms)		RATIONAL METHOD		SWMM* 1D (* uncalibrated)	
ARI	Chainages	Pre-development	Existing	Pre-development	Existing	Pre-development	Existing
1	CH 2575	0.004	0.2	2	2	0.01	3
	CH 2368	0.005	0.5	3	3	0.01	4
	CH 2050	0.01	0.8	5	5	0.01	6
	CH 1776	0.01	1	5	6	0.01	6
	CH 1508	0.02	1	6	6	0.04	9
	CH 678	0.03	2	12	13	0.03	21
	CH 0	0.04	2	11	12	0.03	23
2	CH 2575	0.00	0.3	3	3	0.3	3
	CH 2368	0.01	0.6	4	4	0.3	5
	CH 2050	0.01	1	7	7	1	9
	CH 1776	0.01	1	7	8	1	9
	CH 1508	0.01	1	9	9	1	13
	CH 678	0.03	3	17	18	3	28
	CH 0	0.04	2	16	16	3	31
5	CH 2575	2	3	5	5	2	5
	CH 2368	3	2	6	6	2	7
	CH 2050	4	2	10	10	4	12
	CH 1776	4	2	11	12	4	12
	CH 1508	5	4	13	13	5	18
	CH 678	11	9	24	26	11	39

Peak Flows (m³/s)		MUSIC* (* ran using design storms)		RATIONAL METHOD		SWMM* 1D (* uncalibrated)	
ARI	Chainages	Pre-development	Existing	Pre-development	Existing	Pre-development	Existing
	CH 0	9	7	23	24	11	42
10	CH 2575	9	9	6	6	3	6
	CH 2368	9	9	7	7	3	8
	CH 2050	13	11	12	12	6	14
	CH 1776	14	11	13	14	6	14
	CH 1508	15	14	15	16	8	21
	CH 678	40	39	29	31	18	47
	CH 0	30	27	28	29	18	50
20	CH 2575	13	13	7	7	4	7
	CH 2368	12	12	8	8	4	9
	CH 2050	17	15	15	15	9	16
	CH 1776	18	16	16	17	10	17
	CH 1508	19	19	19	19	12	24
	CH 678	56	54	36	38	27	56
	CH 0	39	38	34	36	28	60
50	CH 2575	15	15	10	10	5	8
	CH 2368	14	14	11	11	5	11
	CH 2050	21	19	19	20	12	19
	CH 1776	23	21	21	22	13	19
	CH 1508	25	24	24	25	17	28
	CH 678	65	63	48	50	38	64

Peak Flows (m³/s)		MUSIC* (* ran using design storms)		RATIONAL METHOD		SWMM* 1D (* uncalibrated)	
ARI	Chainages	Pre-development	Existing	Pre-development	Existing	Pre-development	Existing
	CH 0	48	48	45	47	40	67
100	CH 2575	17	17	11	11	6	9
	CH 2368	17	16	13	13	6	13
	CH 2050	25	23	22	23	15	22
	CH 1776	27	25	25	26	15	22
	CH 1508	29	28	29	30	21	32
	CH 678	74	73	56	59	48	71
	CH 0	57	57	53	56	51	74

The two-dimensional modelling, described in the following section, reveals how the above flows translate into flood extents, velocities, and shear stress.

4.3.1 Modelled flows and water depths

The creek has enlarged significantly, so that large flood events like the 100 yr ARI are almost completely contained within the creekbanks in the upper reaches (for Reaches 1a to 1c, except where there are constrictions like the culvert on Wairuna Ct). Figure 4-6, Figure 4-7, Figure 4-8, Figure 4-9 and Figure 4-10 shows water depths through management zones 1 to 4.

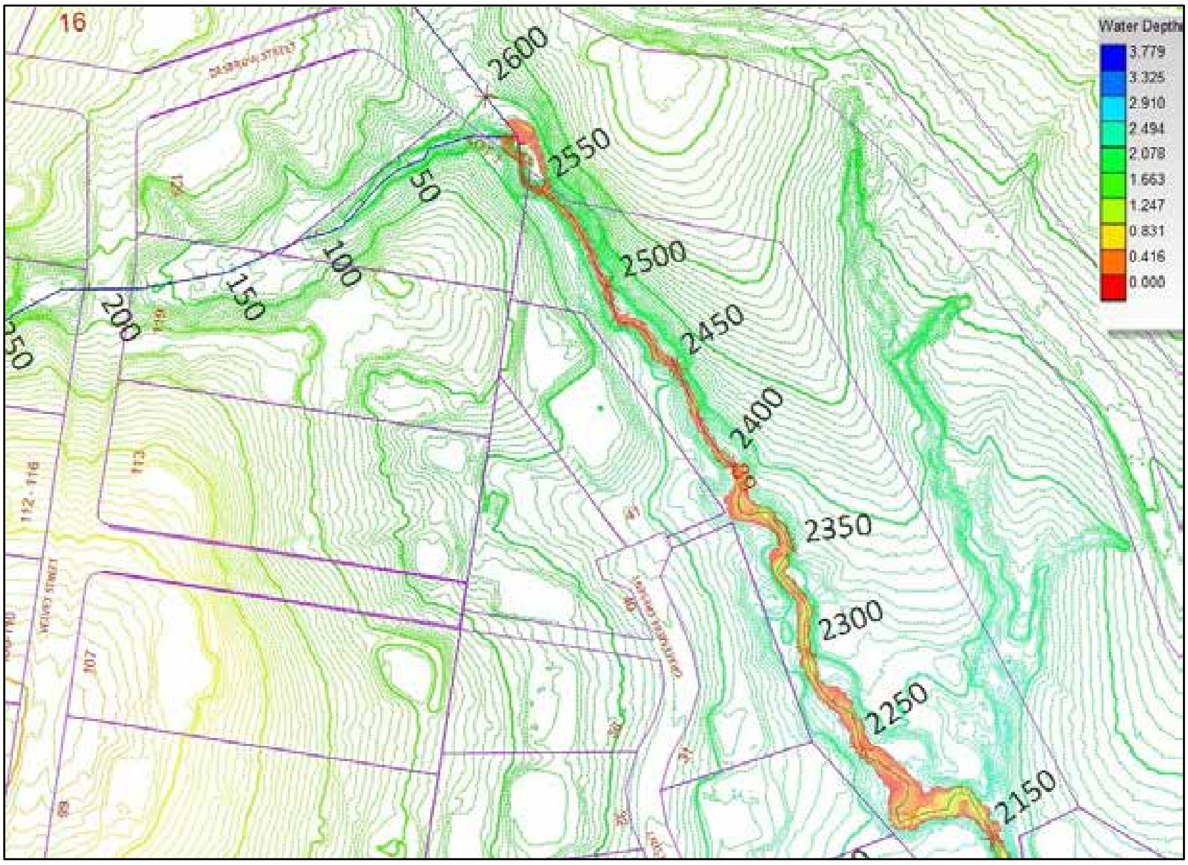


Figure 4-6 Iron Pot Creek Zones 1A and 1B Q100 water depth and extent (uncalibrated)

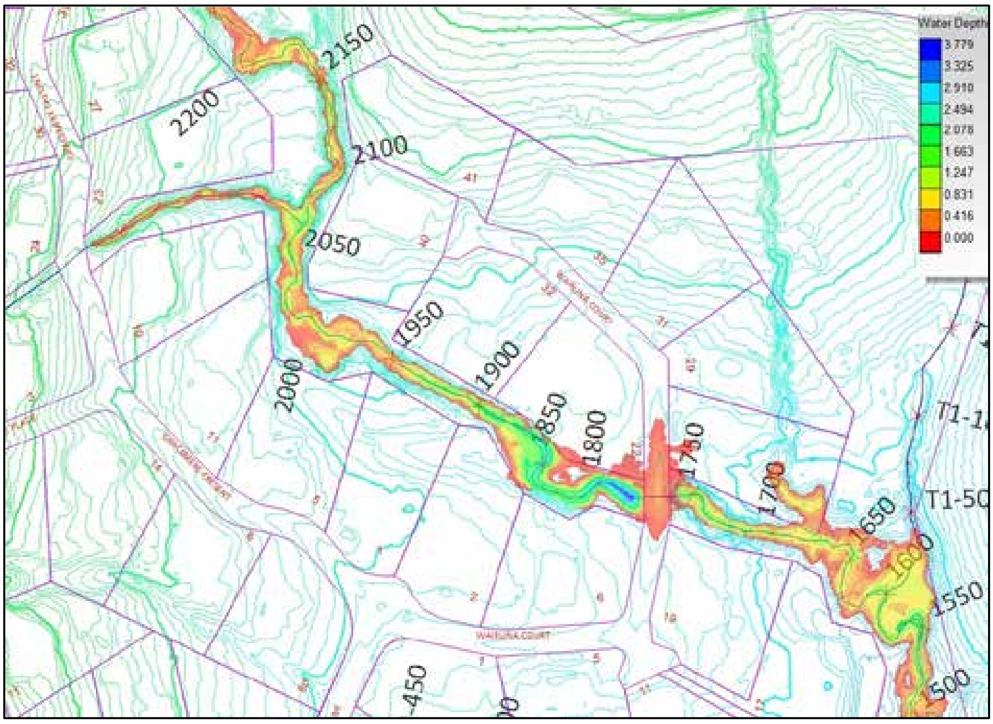


Figure 4-7 Iron Pot Creek Zone 1C Q100 water depth and extent (uncalibrated)

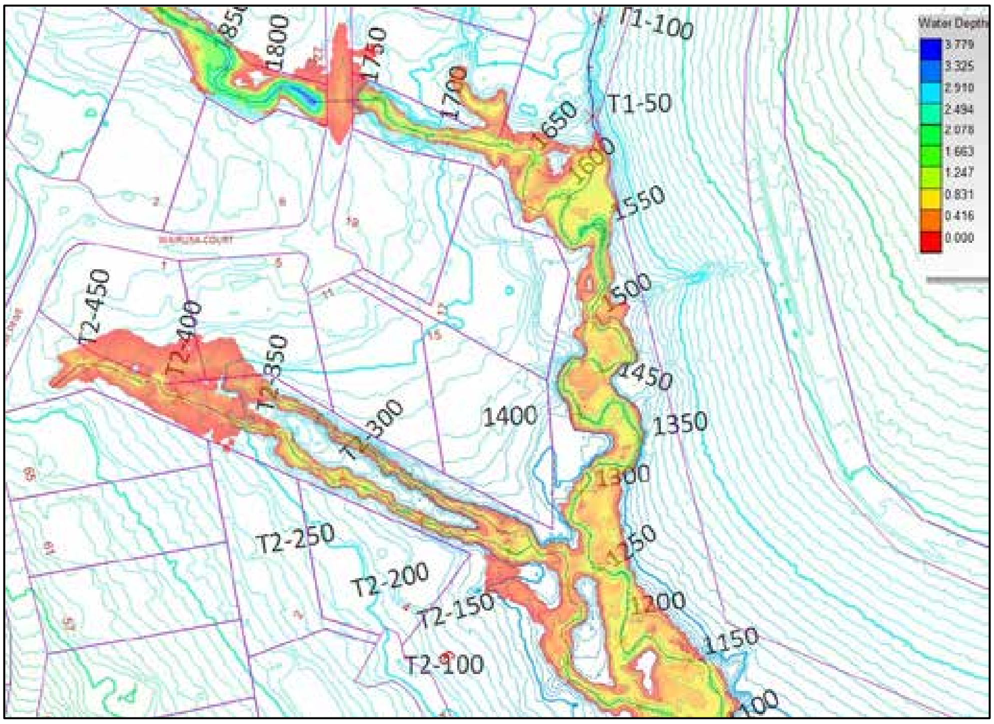


Figure 4-8 Iron Pot Creek Zone 2A Q100 water depth and extent (uncalibrated)

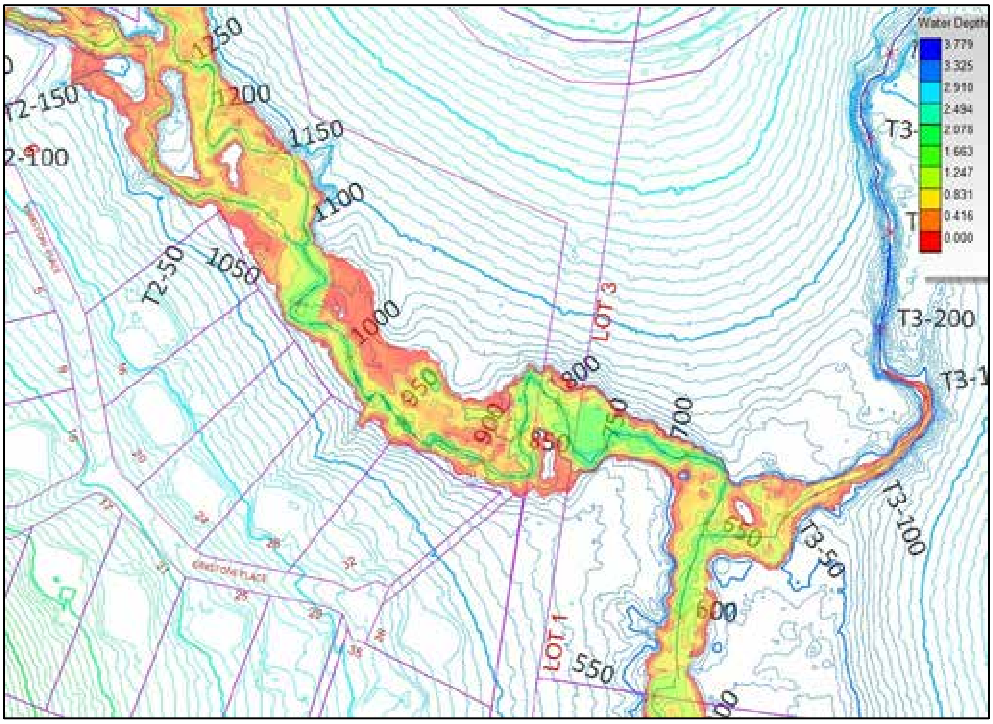


Figure 4-9 Iron Pot Creek Zone 2A lower section Q100 water depth and extent (uncalibrated)

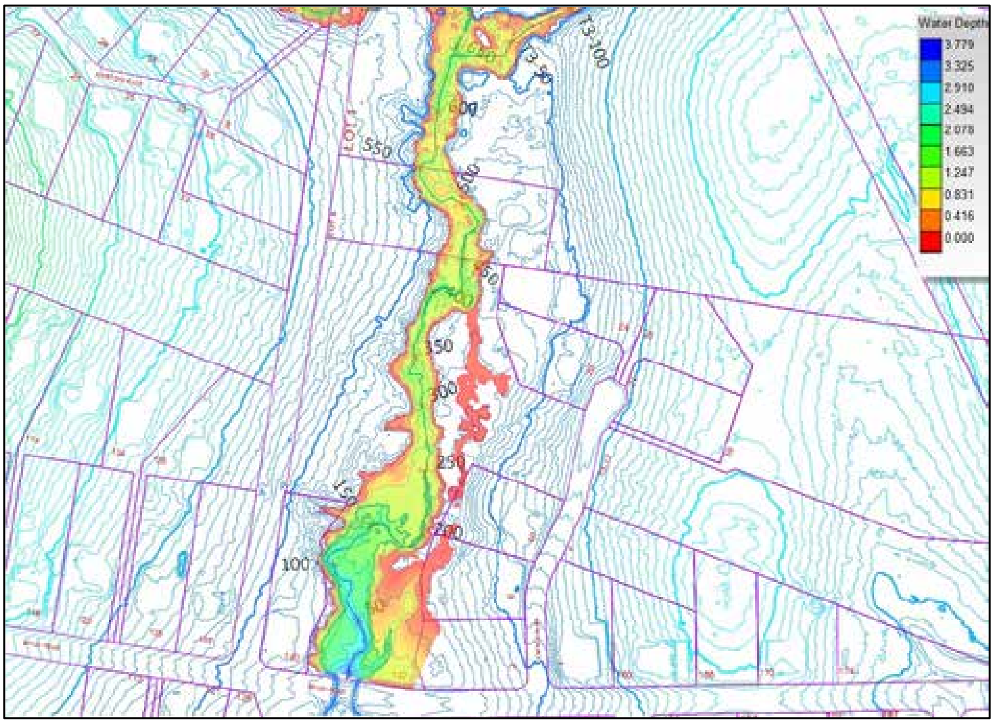


Figure 4-10 Iron Pot Creek Zone 4 Q100 water depth and extent (uncalibrated)

4.3.2 Velocities

The flows are highly non-uniform and velocities in the channel vary widely depending on the specific location in the cross section. Velocities throughout the creek are highly variable and influenced by localised channel shape and turbulence. Overall, average peak velocities through the creek are roughly doubled compared to natural conditions (for a 2 yr ARI storm) refer Figure 4-11.

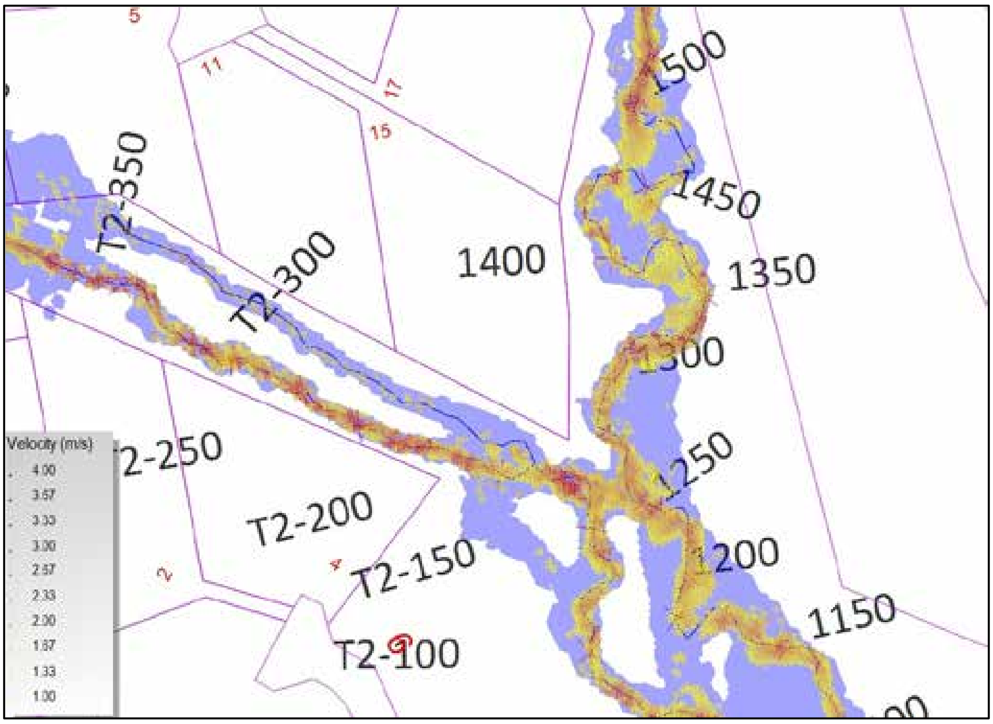


Figure 4-11 Iron Pot Creek Zone 2A Q100 peak velocity

4.3.3 Shear Stress Calculations

Shear stress is the force exerted by streamflows on the stream bed and bank, and is a more useful indicator of erosion than velocities. The detailed 2D modelling undertaken for this project enables the complex channel geometry to be taken into consideration so that the force of flows on bends and various channel features can be understood. Selected plots of shear stress in the creek are presented in the following figures. As a very crude guide to interpreting shear stress values, the shear stress value in Pa roughly equates to the particle size, in mm, that such a force could erode. For example, a shear stress value of 50 Pa could move a particle 50 mm in diameter. Shear stress results for zones 1C and 2A are provided in Figure 4-12. They show that in many areas shear stress values exceed 100 Pa, and occasionally exceed 500 Pa, meaning rocks up to 500 mm diameter could be mobilised by floodwaters. This is consistent with anecdotal evidence provided by residents who have placed rocks in the creek to try and stem erosion.

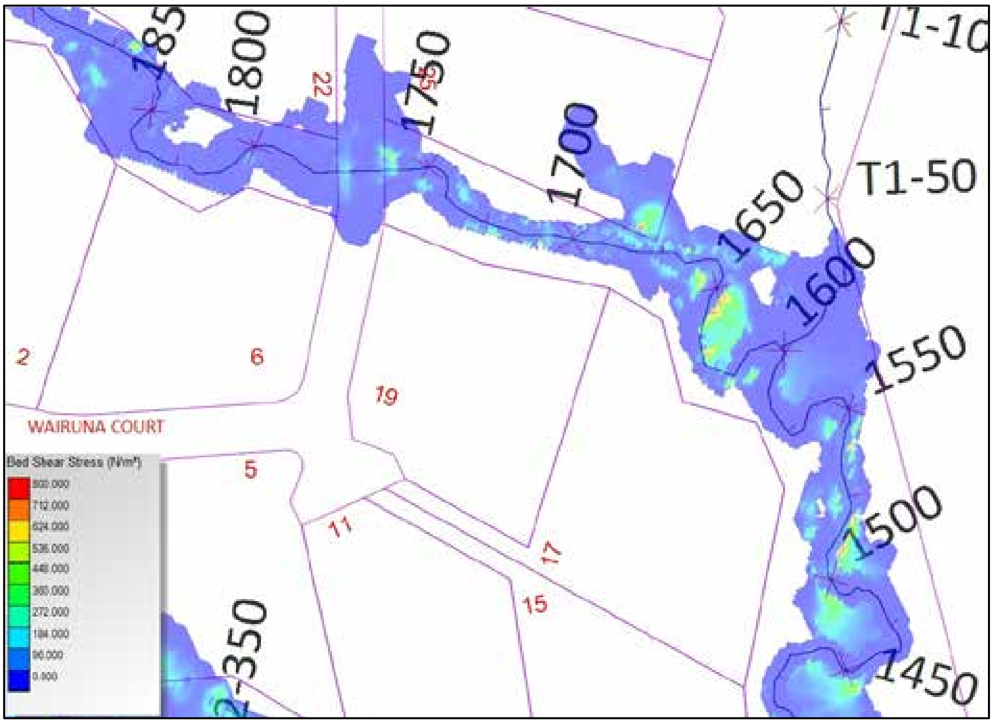


Figure 4-12 Zones 1C and 2A shear stress results

4.3.1 Erosion Potential Index

The erosion potential index (EPI) was determined using the methodology outlined in Water by Design (2007). This method evaluates the extent to which shear stress—above the critical shear stress the bed material in the channel—has increased compared to natural conditions. The higher the EPI value, the greater the increase in erosion potential compared to natural conditions. Simplified methods like this are not well suited to Iron Pot creek because the bed material is highly variable and doesn't have a single critical shear stress (due to the range of particle sizes and the presence of cohesive and non-cohesive material) and because the shear stress exerted by stream flows are highly variable within and between cross sections. Nonetheless, the method was used to help provide an indication of how effective some catchment interventions might be in reducing the amount of flow. The results in Figure 4-13 below show how the EPI might change if all dwellings installed 20 kL rainwater tanks connected to 75% of their roof areas, and assuming the tanks were configured to ensure the top 1 m of the tank was reserved for flood detention purposes. The results show there would be very little benefit from such an approach, and this is probably because roads and other ground-level impervious surfaces have a large impact on hydrology which is difficult to mitigate in a retrofit situation by addressing roof areas alone.

Detention and retention of runoff would be highly beneficial (it could mean less instream works were required because it would address one of the key causes of erosion), however it is difficult to retrofit enough detention or retention into the catchment, especially given the relatively steep slopes.

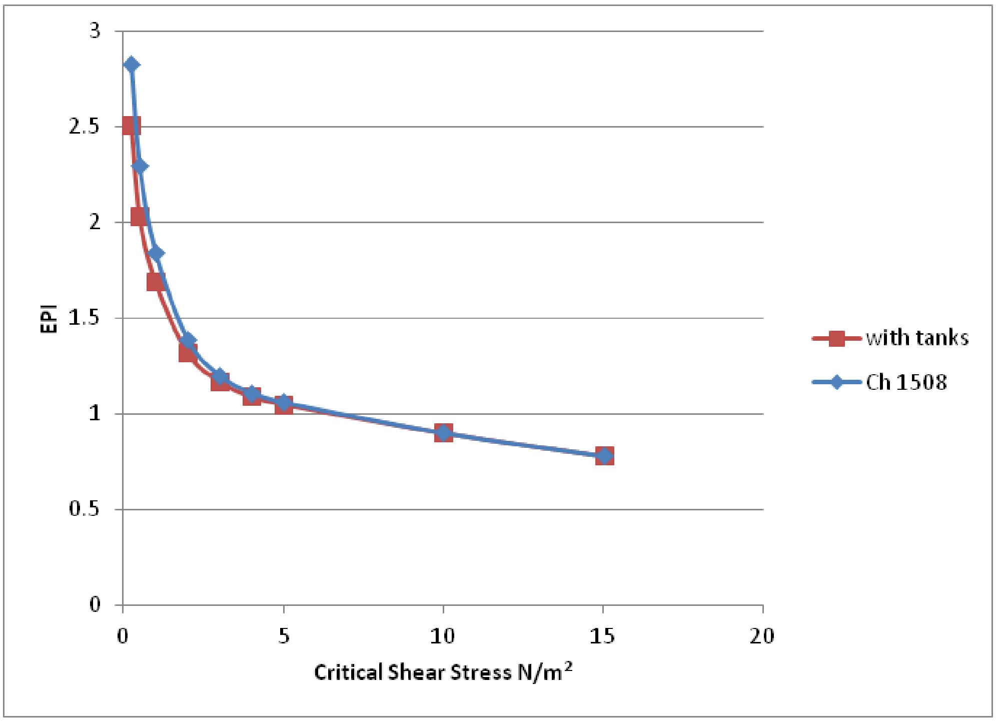


Figure 4-13 Widespread adoption of large rainwater tanks would have a very minor impact on the erosion potential index.

5 Recommended Instream Rehabilitation Works

The following section reviews options for rehabilitation of Iron Pot Creek, prioritises locations for rehabilitation within the management zones and provides construction cost estimates in support of these priority actions.

5.1 Rehabilitation Options

Any rehabilitation undertaken must be informed by the root causes of erosion within Iron Pot Creek and seek to address this root cause rather than simply respond to symptoms. A preference has been given to bioengineering solutions which consider geomorphic and ecological processes and seek to work with the creeks natural trajectory rather than simply installing structural responses such as gabions and concrete.

A number of resources have been considered in rehabilitation designs including:

- Ipswich City Council (ICC), Riparian Corridor Revegetation Guideline
- ICC (2010), Waterway and Channel Rehabilitation Guidelines
- ICC (2009), Waterway Health Strategy
- Brisbane City Council (2004), Erosion Treatments for Urban Creek Guidelines, Version 3
- BCC (2000), Natural Channel Design Guidelines

Rehabilitation works are detailed within drawings in Appendix A, however the final extent of works at each location is subject to detailed investigation and design. Each recommendation is supported by an estimate of construction cost, including the preparation of detailed design. These workings are presented within Section 5.3, while imagery from relevant case studies is provided within appendix F.

Final placement and extent of rehabilitation works will ensure that instream structures do not simply armour a locality and deflect problems elsewhere or that structures are outflanked either up or downstream. Proposed structures are intended to reduce flow velocity and scour locally, generally by deflecting flows away from the bank toe and into the stream bed to create pools which will slow and spread stream flows. In some instances these pools will be created to ensure energy dissipation is achieved. Headcuts within zones 1 and 5 will be halted within a plunge pool arrangement which halts the advancement of the headcut upstream while also preventing downstream scour. It is proposed that stream grade is be reduced through check dams which will counter stream bed lowering that has occurred, slow stream flows and encourage settling of sediment.

5.1.1 Materials selection

Ideally selection of construction materials will be informed by materials present within the stream, i.e. gravel, cobble, stone and timber to ensure a more site sympathetic design. Though the construction life of natural materials, mainly timber, is reduced compared to artificial materials an effective life of 20+ years is anticipated. Further, any instream works are supported by targeted revegetation which ensures that natural sources of timber will be recruited within the creek over time, the intention being that we are reinstating a regime where processes of erosion, decay and recruitment are in dynamic equilibrium and the need for ongoing maintenance and replacement is significantly reduced. In locations where protection of infrastructure or public safety are critical, it is recommended that hard engineering responses are adopted (e.g. concrete and gabions) while ensuring that erosion problems are not diverted downstream.

5.2 Priority rehabilitation zones

Priority locations for rehabilitation have been selected on the basis of the degree of instability observed as well as proximity to private property. Bank instability is generally most severe within Zone 2a, however generally this zone is well set back from private property. Zones 1a, 1b, 1c and 1d are the Zones with closest proximity to private property..

There is isolated instability within Zones 3 and 4 which, from a conservation perspective, ought to be investigated to avoid currently small problems becoming more significant in the future. Similarly the head cut within Zone 5 poses no immediate threat to private property or infrastructure, however if left unchecked will potentially develop into a significant erosion problem within Zones 5a and 5b.

Instream treatment responses to the various issues are presented in table 5-1. The rationale for the use of various treatment measures is provided within Appendix B, while concept designs are provided within Appendix A – Concept Designs. A summary of priority locations and rehabilitation responses are provided within Table 5-1. For ease of reference priority actions are located against chainage shown within drawing LP02 to LP05.

Table 5-1 Summary of Priority Instream Rehabilitation Areas

Mgmt Zone	Chainage	Issue	Response
1a	115 to 145	Bed lowering and unstable banks	Grade control structure and revegetation of batters. Investigate reinstatement of flood chutes within council reserves.
1a	165 to 205	Erosion and undercutting of stream banks	Reinstatement of bank toe in combination with bank stabilisation and revegetation
1a	260 to 300	Erosion and undercutting of stream banks	Reinstatement of bank toe in combination with bank stabilisation and revegetation
1a	350 to 375	Bank erosion north of footbridge	Reinstatement of bank toe in combination with bank stabilisation and revegetation
1b	395 to 410	Significant erosion approximately 30 m south of footbridge, including tunnelling within dispersive soils	Bank profiling, toe protection, realign creek channel, revegetation. Investigate reinstatement of flood chutes within council reserves.

Mgmt Zone	Chainage	Issue	Response
1c	725 to 760	Bank scour and slumping on outside bend, encroaching on private property, unstable banks up to 5m high	Bank profiling, toe protection, realign creek channel, revegetation
1d	n/a	Significant scour and slumping due to high velocities.	Plunge pools and energy dissipation using rock gabion structure or equivalent
1e	n/a	Bed lowering, scour and slumping of creek banks, damage to native vegetation	Grade control structures and plunge pools at 15 m to 25 m intervals. Plunge pool and energy dissipation immediately below rail culvert.
2a	1120 to 1210	Scour on outer bends, buried creek bed, slumping creek banks	Bank profiling, toe protection, realign creek channel, revegetation, channel pool creation
2a	1280 to 1445	Scour on outer bends, buried creek bed, slumping creek banks	Bank profiling, toe protection, realign creek channel, revegetation, channel pool creation
2b	100 to 240	Failure of past rectification works, some bank scour, head cuts locally	Installation of grade control structures at 3-5 locations, bank toe protection at 3-5 locations
3	1465 to 1480	Scour on outer bends, buried creek bed	Bank profiling, toe protection, adjust channel dimensions, revegetation, channel pool creation
3	1875 to 1890	Scour on outer bends, buried creek bed	Bank profiling, toe protection, adjust channel dimensions, revegetation, channel pool creation
3	1930 to 1945	Scour on outer bends, buried creek bed	Bank profiling, toe protection, adjust channel dimensions, revegetation, channel pool creation
4	2000 to 2015	Scour on outer bends	Bank profiling, toe protection, adjust channel dimensions, revegetation
4	2070 to 2085	Scour on outer bends	Bank profiling, toe protection, adjust channel dimensions, revegetation
4	2200 to 2215	Scour on outer bends	Bank profiling, toe protection, adjust channel dimensions, revegetation
4	2590 to 2610	Scour on outer bends	Bank profiling, toe protection, adjust channel dimensions, revegetation

Mgmt Zone	Chainage	Issue	Response
5b	3460 to 3540	Head cut has caused bed lowering and bank slumping and smothering of downstream pools	Grade control structure, plunge pool, bank profiling and revegetation

5.3 Instream rehabilitation cost estimates

Construction costs for rehabilitation works are provided and were informed by case studies of similar works. Costs are typically built around a lineal metre rate and then multiplied by the length of rehabilitation required at a particular location. This approach enables Council to easily revise the cost of rehabilitation if the extent of works increases or works need adjustment to fit within an available budget. There are some exceptions to this arrangement, for example plunge pools.

For the purpose of preparing cost estimates, a number of rehabilitation types have been created and the assumed materials and effort required for each type are explained. These types are summarised within Table *5-2* below and illustrated within concept drawings at Appendix A.

Table 5-2 Unit rate costs for proposed rehabilitation measures

Rehabilitation Type	Assumptions	Lineal metre or unit rate
Grade control structure	Rock or timber is required to halt bed lowering and advancement of head cuts and reduce creek grades	$2,500 ea
Bank toe revetment	Scouring of outer creek bends requires armouring and dissipation of flow energy	$1,500 lin.m
Plunge pool	Significant changes in creek grade or flows from stormwater culverts require flow energy to be reduced	$5,000 ea
Rock or timber vane	Flows require diversion away from a creek bank and into the central channel	$2,500 ea
Revegetation	Exposed embankments require stabilisation via revegetation, likely in combination with importing of soil/organic matter and jute matting	$15/m2 - $25/m2

6 Whole of Catchment Actions

Additional management actions for Iron Pot Creek are detailed within the Creek Rehabilitation and Management Plan in Section 8. Some of these actions are site specific while others relate to management of the corridor as a whole, for example weed control is generally required through the corridor, with lantana and Singapore daisy being two notable weed species. Issues requiring management across the catchment are discussed in the following sections.

6.1 Weed management

The creek corridor is in relatively good condition overall, with the species of greatest concern being Singapore daisy, creeping lantana and lantana. As a Class 2 declared pest species, Council has an obligation to control Singapore daisy, in addition to the less frequent fireweed, groundsel, mother-of-millions and prickly pear. Clearance of dense Lantana east of Wairuna Court (near Zone 2A) would also be beneficial in both providing access to determine erosion issues and providing opportunities for native regeneration. The creekline is generally free of highly invasive species spread by water, which is an encouraging sign.

6.2 Community education

Community education around natural resource management issues is integral to successfully managing waterways and adjoining riparian zones. There are numerous landholder activities detrimental to waterway health – particularly clearing of native vegetation and dumping of garden waste – however there is in many instances a genuine desire to assist in maintaining a healthy waterway. This desire should be fostered and guided in ways that are consistent with best practice and broader Council strategies. Active engagement with the community to achieve environmental outcomes will often be considerably cheaper than Council acting alone.

6.3 Motorbikes

There is some evidence of motorbikes within Walter Zimmerman Reserve and the adjoining DTMR lands, which has potential implications for any rehabilitation efforts. Engagement with community members may be required to determine the significance of the problem and therefore determine if additional control measures are needed as rehabilitation works are being implemented.

6.4 Integrated watercycle management

Preliminary analysis shows that local roofwater harvesting, even if adopted extensively across the catchment with large tanks, would have only a marginal benefit in reducing the erosivity of streamflows.

Stormwater harvesting could theoretically increase the demand for harvested water, and therefore further reduce the erosiveness of streamflows (for frequent, minor storm events) although it is considered too costly to retrofit a scheme with dual reticulation into this catchment.

6.4.1 Long term options

The area is currently unsewered, and sanitation is provided by septic tanks. At some future date the area might become sewered, and this could create an opportunity to better manage surface runoff.

If the area is sewered, and if indirect potable reuse becomes socially and politically acceptable, then stormwater could be harvested via the sewer network and contribute to the regional water supply. Careful attention would be needed to appropriately design the sewer system with appropriate holding tanks and wet weather capacity, nonetheless it is technically feasible and could deliver both a good local outcome as well as regional water supply benefits.

6.5 Development controls

At this stage it appears as though retrofitting measures to detain and retain increased stormwater runoff would not be cost-effective in terms of reducing the erosivity of flows. However further development is likely to exacerbate erosion if not carefully managed. Further urbanisation of the catchment should be avoided to the extent possible.

Where further urban development is unavoidable, (for example, an application to build in a lot currently zoned as urban), then all reasonable and practicable measures should be taken to minimise changes to the hydrology of the site. These may include:

a. Slab on ground housing should be discouraged in favour of suspended floors. This would minimise disturbance and exposure of dispersive subsoils, and help retain current topsoil cover which is important for its infiltration capacity (to reduce runoff) and its organic content (to help stabilise dispersive soils).

b. Rainwater tanks should be installed to minimise net increases in runoff and to capture and attenuate small to medium storm events. All roof areas draining to a tank, and tanks should be plumbed to all internal non-potable uses as well as outdoor taps. Rainwater tank overflows should drain to gravel infiltration trenches to avoid concentrated runoff leaving the lot.

c. Impervious surfaces should be minimised, for example driveways should be permeable (i.e. gravel, permapave or similar)

d. On-site detention systems should be installed to ensure no increase in peak flows for prescribed ARI storm events (further work is needed to determine relevant sizing). Rainwater tanks could have a dedicated airspace for flood detention (by locating the overflow pipe part-way down the tank wall), which could operate in lieu of or in conjunction with ground level detention measures.

e. Landscaping must not concentrate flow paths within the site or on to adjacent properties.

f. Adequate setbacks from drainage lines should be enforced to reduce the likelihood that of dwellings may become vulnerable to erosion.

g. Appropriate compliance and inspection mechanisms to ensure these controls are implemented and maintained.

Further work and analysis is needed to optimise the abovementioned suite of development controls, however in the absence of such optimisation it is recommended that Council take a highly conservative approach given how vulnerable the stream and gullies are to erosion.

There is a significant extent of erodible soil across the Ipswich City Council area. Detailed investigations should be undertaken to validate the extent of dispersive soils as outlined in Soils of Ipswich Field Guide and stringent development controls should be applied that minimise the extent of hydrologic change and soil disturbance within those catchments, so that similar situations to Iron Pot Creek are not repeated.

6.6 Soil management

Dispersive and slaking soils require particular management to limit erosion, since the consequences of tunneling and potholing can be difficult and expensive to manage. Effective land management practices for limiting soil degradation include:

- Limiting traffic and soil compaction which destroys soil structure, particularly when soils are wet. This includes illegal use of motorbikes within bushland reserves
- Maintaining native vegetation cover to increase organic matter and protect soils from water erosion
- Managing stock to avoid susceptible soils (mainly horses in this catchment) to reduce soil compaction and damage to vegetation.
- Surface water management – avoiding concentration of stormwater runoff, particularly in the vicinity of compacted soils and appropriate energy dissipation and scour protection (e.g. rip-rap and plunge pools) at formalised stormwater discharge points.

6.6.1 Rehabilitation of degraded soils

In instances where soil erosion is active, rehabilitation may need implementing. The principle means this is achieved is through control of stormwater run-off, improvement of soil character and reintroduction of vegetation and organic matter. Options to achieve these improvements include:

- Minimising the concentration of stormwater
- Using protective and energy dissipation measures for stormwater discharge points
- Protecting and enhancing vegetative cover
- Ameliorating soils to reduce dispersivity – generally with the addition of lime or gypsum.

For the subject site where tunneling is expressing on exposed creek banks (refer Figure 6-1), concept designs have been developed encompassing the above principles and detailed within Appendix A. These designs draw upon recommendations made within a number of sources including case studies and technical guidelines prepared by various state agencies. Soils impacted by tunneling in combination with bank scour are proposed to be treated as follows:

- Protecting bank to with rock or timber armouring to halt bank collapse,
- Regarding of vertical embankments to the extent that constraints such as property boundaries and native vegetation will permit,
- Covering dispersive soils in a layer of coarse sand or gravel (approx. 100mm thick),
- Covering this layer with a minimum of 150mm of organic rich topsoil,
- Protecting topsoil on steeper batters with jute matting,
- Planting appropriate native plant species.

For tunneling occurring away from the creekline and within private property, the following general recommendations are suggested:

- Divert storm flows away from affected areas using mounds rather than drains,
- For shallow tunnels deep ripping, cultivation and replanting can destroy tunnel systems,
- Where dispersive soils are too deep for ripping, the affected area can be excavated, ameliorated, repacked and vegetated. Re-packed soils require thorough compaction, ensuring the surface is mounded to prevent surface water ponding,
- Gypsum should be re-applied to the affected area every 2-3 years,
- Trafficking and grazing of affected areas should be avoided,
- There are reports of hydrological barriers being effective in intercepting water flowing within tunnels. This involves installation of a sand-gypsum mixture within a trench running through and perpendicular to the tunnel combined with an earth mound immediately upslope to divert surface runoff around the trench. Water within the tunnel is intercepted and expresses at the surface.

The extent and severity within the catchment requires a comprehensive investigation to determine what the most appropriate management responses might be.

Figure 6-1 Expression of tunnelling on exposed creek banks within Zone 1b

7 Statutory Review

7.1 Introduction

A review of legislation/approvals for the proposed works is required to determine what may be required to fulfill any specific requirements to satisfy any other government authorities/agencies. Relevant legislation / regulation include:

- *Consolidated Ipswich Planning Scheme 2006*;
- *Sustainable Planning Act 2009*
- *Fisheries Act 1994*;
- *Vegetation Management Act 1999*;
- *Water Act 2000*;
- DAFF Waterway Barrier Self-Assessment Code
- DEHP instream guidelines.

A summary of the legislation and guidelines and their applicability to the proposed works is provided below.

7.2 Consolidated Ipswich Planning Scheme 2006

A search of the Ipswich Planning Scheme 2006 zoning maps, indicates the study area is located within recreation and residential areas. The proposed works are consistent with the aims and objectives of the recreation and residential zones by increasing visual amenity of the public and increasing environmental values of the creek.

While the study area is not mapped in the Overlay Codes as being within a Key Resource Area, having Difficult Topography or as being within an Urban Stormwater Flow Path Area, it is mapped as being bisected by the Adopted Flood Regulation Line as per the *Temporary Local Planning Instrument 01/2012 – Flooding Regulation* (refer to Figure 7-1).

Earthworks not associated with a material change of use are Code Assessable if within the Adopted Flood Regulation Line (as part of the study area is). 'Probable Solutions' in the Code for Earthworks state that earthworks must not negatively affect flood conveyance characteristics or reduce flood storage capacity through the importation of fill, or any alteration to a watercourse or floodway. The proposed works are likely to be compliant with the Specific Outcomes for Flooding and Draining of Earthworks.

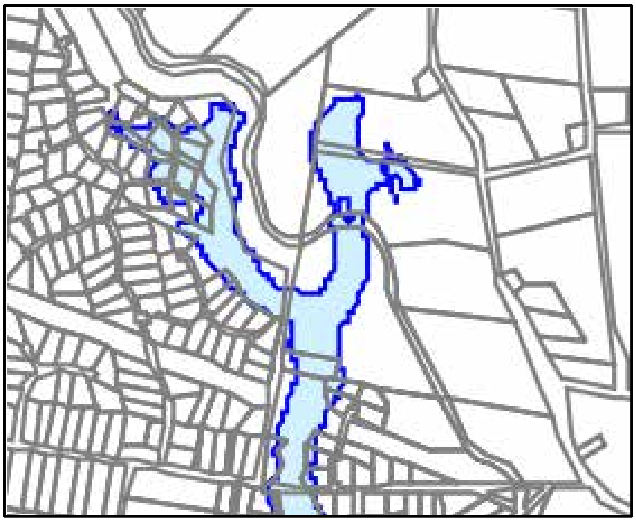


Figure 7-1 The study area, as mapped in Overlay Map OV5 Flooding and Urban Stormwater Flow Path Areas. The area defined in blue is the Adopted Flood Regulation Line.

Division 15 of the Planning Scheme also provides requirements for any excavation works (other than flooding requirements which are covered as above). However, if the earthworks comply with certain parameters, they may be deemed ‘exempt earthworks’ in accordance with Schedule 8 of the Scheme. These parameters include earthworks which:

- Do not comprise more than 1000 m^2 in area;
- Do not exceed an average depth of 500 mm; or
- Do not exceed a maximum depth of 800 mm; or
- Do not involve earth batters with a slope greater than 1 in 8; or
- Do not interfere with the natural flow of stormwater; or
- Are not undertaken in a natural gully or overland flow path or below the adopted flood level; or
- Are not undertaken within a public utilities easement; or
- Are not within 3m of an adjoining property; or
- Involve fill material which is clean, dry, solid, inert material, or
- Are not within 3m of a Local Government infrastructure item.

Elements of the design may need approvals based on the above criteria, however this is subject to detailed design.

In the unlikely event that clearing of vegetation is required for the project, it is self-assessable where the acceptable solutions are complied with. ‘Probable Solutions’ in the Overlay Code for Native Vegetation state that the clearing of vegetation should not involve the removal of native vegetation from land within a Designated Watercourse or land within 30 metres of a Designated Watercourse or within 10 metres from top of bank of a Designated Watercourse where the slope of bank exceeds 15% (as shown at Figure 7-2).

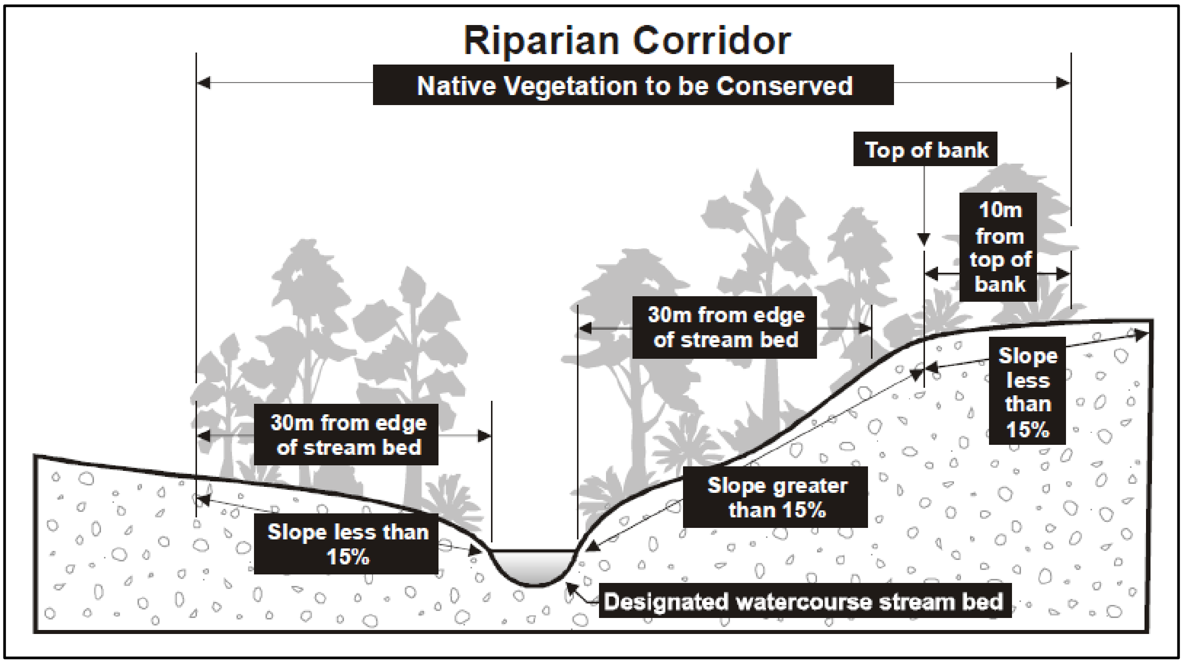


Figure 7-2 Defining Extent of Riparian Corridor for Protection of Native Vegetation (Source: Ipswich Planning Scheme – Development Constraints Overlays)

7.3 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (SPA) establishes the system of planning and environmental impact assessment in QLD. The Act seeks to achieve ecological sustainability in the planning and development process, specifically Clause 5 1(c) of the SPA states that "*avoiding, if practicable, or otherwise lessening, adverse environmental effects of development"* is required to advance the purpose of the Act.

The proposed works are likely to fall within the definition of Operational Works. Section 10(1) of the SPA defines Operational Work as:

> *"…(f) clearing vegetation, including vegetation to which the Vegetation Management Act applies; or*
>
> *(g) undertaking operations of any kind and all things constructed or installed that allow taking or interfering with water, other than using a water truck to pump water, under the Water Act 2000; or….*
>
> ***(i) constructing or raising a waterway barrier works…"***

Clause 232(2) of the SPA allows for exemptions from development assessment, by declaring that some development cannot be declared a particular development type (e.g. self-assessable development, development requiring compliance assessment, assessable development or prohibited development). Under Table 4 of Schedule 4 of the *Sustainable Planning Regulation* (2009) (SP Regulation), Operational Work "*…carried out by or on behalf of a public sector entity authorised under a State law to carry out the work"*, cannot be declared development of a particular type. Works by Ipswich City Council and their contractors (AWC or Bligh Tanner) are therefore exempt from development assessment.

Schedule 7, Table 2 of the SP Regulation however states that in some instances, State agencies will retain their jurisdictions over certain development, requiring an application for the work. Any approvals that may be required under other Acts are outlined in the Sections below.

A search of the declared Wild River Areas has identified that Iron Pot Creek is not a Wild River Area.

7.4 Fisheries Act 1994

The primary purpose of the *Fisheries Act 1994* is the use, conservation and enhancement of the communities fisheries resources and fish habitats according to ecological sustainable principles. Any activities that may affect fish habitats are regulated under the Act, and approvals for these activities must be obtained from the Department of Agriculture, Fisheries and Forestry (previously DEEDI).

The proposed works are not anticipated to divert or dam Iron Pot Creek, nor are any drainage structures anticipated to be installed. The obstruction or minimisation of fish passage or the removal of marine vegetation is also not anticipated, and as such no approvals are anticipated under the Fisheries Act. Where any minor waterway barrier works are to be constructed to minimise flow, works will be required to comply with the DAFF Self Assessable Code: ‘Minor waterway barrier works – PART 1: MINOR DAMS AND WEIRS’. Under the Code, a waterway barrier means a dam or weir or any other barrier across a waterway if the barrier limits fish stock access and movement along a waterway (refer to Section 7.7 for the requirements).

A search of the declared Fish Habitat Areas has identified that Iron Pot Creek is not a declared fish habitat.

7.5 Vegetation Management Act 1999

The Vegetation Management Act 1999 regulates the clearing of mapped, remnant vegetation on freehold land. As noted, mapping by DEHP indicates vegetation within the study area as comprising an amalgam of up to four Regional Ecosystems as follows:

- RE 12.9-10.2: *Corymbia citriodora, Eucalyptus crebra* open forest on sedimentary rocks
- RE 12.9-10.3: *Eucalyptus moluccana* on sedimentary rocks
- RE 12.9-10.17: Open forest complex often with *Eucalyptus acmenoides, E. major, E. siderophloia* +/- *Corymbia citriodora* on sedimentary rocks
- RE 12.9-10.19: *Eucalyptus fibrosa* subsp. *fibrosa* open forest on sedimentary rocks

While most of these REs are listed as ‘not of concern’ RE 12.9-10.3 is listed as ‘of concern’ under the *Vegetation Management Act 1999* (VMA). RE 12.3.3 *Eucalyptus tereticornis* woodland to open forest on alluvial plains, listed as ‘endangered’ under the VMA is mapped immediately south of the study area. Vegetation in the north of the study area is mapped as Essential Habitat for the Koala.

As noted previously clearing of vegetation for the project is exempt from approvals.

7.6 Water Act 2000

The *Water Act 2000* provides for the sustainable management of water and other resources in Queensland, and also provides a regulatory framework for providing water and sewerage services and the establishment of water authorities. The *Water Act 2000* outlines several permits/licences that may be required for the proposed works, including a riverine protection permit for any works that may destroy vegetation within a watercourse or excavation or placing fill within a watercourse.

However, works that may destroy vegetation or involve excavation or placing fill within a watercourse that is undertaken by a public sector entity or their contractors may be exempt from requiring a license or permit, provided the works comply with the DERM (now DEHP) 'Guidelines for activities in a watercourse, lake or spring carried out by an entity'. It is anticipated that the proposed works comply with these guidelines (refer to Section 7.8 below).

7.7 DEHP (2012) Guidelines

The purpose of Version 7 of the Guideline 'Activities in a watercourse, lake or spring carried out by an entity' (DEHP, 2012) is to allow an entity to undertake necessary activities in a watercourse without the need for a riverine protection permit. The activities covered under the guideline are the destroying of native vegetation, placing fill and excavating in a watercourse, lake or spring that is regulated under the *Water Act 2000* for "*…restoration, flood mitigation, erosion protection or weed control.*" The definition of an entity includes a local government and their contractors. Therefore, the proposed works to be undertaken by Ipswich City Council, AWC and Bligh Tanner would not require any additional approvals provided that the works comply with the requirements of the guideline.

The extent that an activity involves the clearing of native vegetation, this guideline only applies to clearing that is:

- *Less than 0.5 hectares, and*
- *The vegetation is:*
    - *A least concern regional ecosystem shown on the regional ecosystem map or remnant maps as remnant vegetation, or a least concern regional ecosystem shown as Category B or on a Property Map of Assessable Vegetation, or*
    - *Shown as non-remnant vegetation on the regional ecosystem or remnant map or shown as Category X on a Property Map of Assessable Vegetation, and*
    - *Carried out in accordance with the Guideline.*

The guideline does not set a limit on the quantity of material that can be excavated or placed in a watercourse, lake or spring during the course of the activities, however they must not exceed the amount necessary to achieve the required outcome.

The level of investigation and data collection during the completion of this Drainage and Erosion Management Plan has been completed in accordance with the guideline, especially where excavations and filling works are greater than 500 m³. The matters that have been considered and incorporated in this report include:

- The effects of the proposed activity on water quality;
- The quantity of native vegetation to be destroyed or material to be excavated or filled;
- The type of vegetation to be destroyed or material to be excavated or filled;
- The seasonal factors influencing the watercourse, lake or spring

- The position in the watercourse, lake or spring of the vegetation to be destroyed or the proposed excavation or placing of fill;
- The reasons for carrying out the activity; and
- The extent the activity may have an adverse effect on the physical integrity of the watercourse, lake or spring.

Other requirements of the guideline include notification to the local department office of the DEHP, consent of adjacent land owners and records kept of the works undertaken. Table 7-2 below lists the required outcomes that must be achieved when undertaking activities to meet the requirements of the guideline, and how the proposed works meet the requirements of the guideline.

Table 7-1 Assessment of the proposed works against the Guideline

Required Outcome	Acceptable Solutions	Meets Acceptable Solution / Alternative Solution proposed
1. The activity is limited to the extent necessary or as an unavoidable part of the construction, installation, removal, maintenance or protection of the relevant infrastructure or the protection or enhancement of the stability of a watercourse, lake or spring.	*Acceptable solutions:* · *The extent of activities is carried out only where necessary and unavoidable as stated in the record of the activity.* · *The area of disturbance is restricted to the area necessary as stated in the record of the activity.* · *Where available, an existing access track is used instead of constructing a new access track.* · *The number of bank cuttings and fills required (e.g. for access tracks) is kept to a minimum.* · *Activities are complete as quickly as possible.* · *Mature native trees are not destroyed in association with destruction of non-native vegetation (e.g. weed control)*	Meets the acceptable solutions – all works proposed will be limited to those areas that have currently been eroded or where improvement actions can be applied to ensure ongoing erosion does not occur.
2. Carrying out the activity must not adversely impact water quality within the watercourse.	· *Water run-off is diverted around areas of disturbance.* · *Sediment generated by activities is managed by use of sediment traps in order to minimise water turbidity outside the work site.* · *All machinery used in the activities is stored, refueled and maintained outside the outer banks of the watercourse, lake or spring.* · *Activities are not carried out on the outside of the watercourse bend, on steep banks or where the soil type is prone to erosion (dispersive soils).* · *Only pesticides and herbicides that are registered for use in aquatic environments are used (i.e. breaks down in water). When*	Meets the acceptable solutions – the proposed works are intended to improve the water quality of Iron Pot Creek by stabilising the stream bed and minimising future erosion and scouring. All works would be subject to this Erosion and Sediment Control Plan, which outlines appropriate mitigation measures to ensure that water quality impacts do not occur during the works or following completion of the

Required Outcome	Acceptable Solutions	Meets Acceptable Solution / Alternative Solution proposed
	using pesticides, only use those registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA) for the intended use, at the suggested rates and only by methods registered on the label. · *Where activities may disturb ASS, refer to the Department of Local Government and Planning, and the Department of Natural Resources and Mines, 2002 SPP 2/03 Guideline: Planning and Management Development Involving ASS and follow management principles in accordance with the Department of Natural Resources and Mines, 2002, Soil Management Guidelines in the Queensland Acid Sulphate Soils Technical Manual.* · *Fill placed under the authority of this guideline is limited to fill which occurs naturally and is free from contamination i.e. does not contain weeds, chemicals, oils, pesticides, trash, etc.*	works. The interception of ASS is not anticipated.
3. Carrying out the activity must not impound or impeded the natural flow of water within the watercourse.	· *Constructed drainage and discharge structures do not alter the natural bed and bank profile.* · *Material excavated that is not waste material is spread evenly within the bed and banks of the watercourse such that it does not interfere with the flow of water.* · *Stockpiling of fill does not occur within the bed and banks.* · *Natural stream bed controls or features that create natural waterholes (riffles, logs, sediment or rock bars) are not lowered or removed.* · *Access tracks and crossings do not interrupt low flow along the watercourse i.e. they are at the natural bed level or include culverts or pipes that allow flow at the natural bed level both upstream and downstream of the crossing.* · *Any access tracks, crossings or culverts are orientated perpendicular to the stream channel ± 10o.* · *Culverts are of a sufficient size to ensure uninterrupted low flows, and to minimise the occurrence of blockage of culverts caused by*	Meets the acceptable solutions – the proposed works are not anticipated to block the natural flow of the water or obstruct fish passage. No damming or diversion works are proposed, and drainage structures will not be installed.

Required Outcome	Acceptable Solutions	Meets Acceptable Solution / Alternative Solution proposed
	flood-borne debris.	
4. Carrying out the activity must not result in de-stabilisation of the bank associated with the watercourse.	· *Trees are cut near or at ground level to retain the root mass in the ground.* · *Bed and bank stabilisation measures such as rock revetment, reinforced matting and large woody debris, log piling or similar are used.* · *Access tracks are:* o *Provided with a scour apron and cut off the wall on the downstream side sufficient to prevent bed erosion.* o *Orientated perpendicular to the stream channel ± 10o.* o *Located on a relatively straight reach of the watercourse.* o *Located at riffles.* · *Ramps cut into the bank for crossings and access are orientated downstream.* · *Mechanically cleared banks are stabilised before clearing adjacent areas.* · *Fill placed on the bed of the stream does not redirect flow into a bank.* · *Only naturally occurring fill is used for backfill around in-stream structures and/or to return a bank profile to pre-disturbance condition.* · *Areas of bank cleared of vegetation and not required for the final works associated with the activity are revegetated with native trees, shrubs and grasses endemic (local) to the area.*	Meets the acceptable solutions – the proposed works are to stabilise areas of Iron Pot Creek that are currently subject to erosion and scour issues.

8 Consultation with landowners

The community living in the vicinity of Iron Pot Creek was consulted in order to gather information about the causes and nature of erosion in the catchment, understand community views about what could be done about it, and to help prioritise erosion control works.

8.1 Consultation Process

All residents within the catchment of the study area were sent a letter that introduced the project and invited them to make contact.

Six residents made contact in the three weeks after the letter was sent. Each of these respondents had property immediately adjacent to or containing, eroded creek-lines or gullies. All respondents were interviewed over the phone, and then invited to attend a meeting on-site to discuss their particular issues and experiences.

Additional residents with properties adjoining the creek were opportunistically doorknocked, however many were not home or properties inaccessible due to dogs.

Some residents were contacted during large storm events (e.g. on Saturday 17/11/2012) to gather anecdotal and photographic evidence about runoff behaviour in the catchment.

For privacy reasons, the specific names and addresses of residents involved in the consultation is confidential.

8.2 Key Findings

- One of the respondents who lived just outside the formal study area had significant erosion in their backyard. We believe this should be included in the study.

- The consultation identified that in-stream works (rock armouring) had taken place several weeks before the commencement of this study. This work was to arrest erosion of private property, and created an expectation for at least one resident that Council may also do work on their property.

- One landowner was advised not to undertake private works as they could be liable for consequential flooding impacts.

- Despite the above, several landowners have undertaken significant 'DIY' erosion control works. One resident claimed to have imported 20 truckloads of rock, another between 50 – 80 truckloads of miscellaneous fill, and another 170 truckloads of fill.

- In two of the backyards inspected, there was evidence of pot-holing which indicates subsoil tunnel erosion and potential risk of gully formation.

- Two residents were intentionally undertaking landscaping works in their yards designed to slow the rate of runoff and divert it away from gullies.

- Most residents had rainwater tanks but none reported having these connected to indoor uses. They were generally used infrequently for uses such as irrigation or car washing.

- In the longer term, a holistic erosion and drainage strategy will need to involve working in the catchment, and not just in the eroded parts of the stream. It is noted that no residents without immediate erosion issues made contact, which may suggest that engaging other residents may require more strategic engagement methods.

- Selected verbatim quotes from residents are provided below:

  - ‘When it rains out here it’s scary, really scary it’s that heavy. And it’s usually at night so you don’t know what you’re going to wake up to, you can hear the gully raging’

  - ‘The soils here are shit… they’re as hard as rock, but when they get wet they turn to slop. I’ve seen a car bogged to its axles in a front yard, and the truck that tried to pull it out got bogged too... they needed to bring in a crane’

  - ‘I just want to know what I can do about it myself’

  - ‘I’m sick of getting nowhere with Council on this’

  - ‘I know we’re not meant to be doing that [filling in the gully head] but what else are we meant to do?’

  - ‘Just recently a lot of smaller shrubs have died off. Revegetation is difficult’

  - ‘The erosion is gradually getting worst causing damage to our property and posing a safety risk to our child and pets.

8.3 How the community views have been considered

The study area was expanded to account for erosion to the east of Wairuna Crt, after one resident highlighted extensive erosion at the rear of their property.

The residents helped identity priority areas for attention (this validated the findings of the erosion condition assessment).

Residents observations about streamflows and what happens during large storms has helped validate the hydrologic and hydraulic modelling (this is important as there were no streamflow records to calibrate the models to).

9 Creek Rehabilitation and Management Plan

On the basis of the various investigations completed through this study, a creek rehabilitation and management plan has been prepared. This plan details proposed actions within the creek as well as within the adjoining reserves, private properties and Iron Pot Creek catchment as a whole. Where an action is recommended within every management zone (e.g. weed control), this action is included within the whole of catchment section rather being repeated for every management zone.

Actions are prioritised as high, medium or low dependent upon key criteria including severity of bank erosion, risk to property, risk to public safety and environmental considerations. These criteria are combined within a matrix to derive a relative score within a spreadsheet and can be refined in light of changes in circumstances or Council priorities. This is particularly relevant for the definition of major, moderate and minor capital works, which for the purpose of this assessment were nominated as >$50,000, $25,000 - $50,000 and $<$25,000 respectively. Table 9-1 below details the matrix used for prioritisation.

Table 9-1 Criteria for prioritisation of actions

Criteria for Prioritisation	Rank	Score
Public Risk	High ,Medium, Low, NA	5, 3, 1, 0
Risk to Environment	High ,Medium, Low, NA	5, 3, 1, 0
Risk to Bank Stability	High ,Medium, Low, NA	5, 3, 1, 0
Capital Works Required	Minor, Moderate, Major, NA	5, 3, 1, 0

Following allocation of a score, each action is then categorised as being very high, high, medium or lowest priority. Timeframes for actions have been proposed for the purpose of developing a works program. The final timeframe for implementation of actions will be determined by broader factors including funding constraints and whole of Council priorities. Timeframes are as follows:

- Very High Priority – less than two years
- Highest Priority – two to three years,
- Medium Priority – three – five years
- Lowest Priority – five to ten years

An estimate of cost is provided for each action, as is a comment on the benefit of a recommendation and the potential consequence of inaction. Costs are based on unit rates detailed within section 5.3 and industry rates for environmental rehabilitation works.

9.1 Summary of recommendations and actions

Recommendations and actions fall within the following key themes:

- Instream works
- Vegetation management
- Community engagement and education
- Introduction of appropriate development controls
- Post construction monitoring

The staging of works will be subject to the availability of resources and broader Council objectives for environmental rehabilitation works across the City. Priority locations for instream works are within Management Zones 1b and 2a, 2b and 2c particularly with a recommendation for works to be progressed in this area as quickly as possible (i.e. less than 12 months). It is anticipated that subsequent actions be implemented over several years. Prioritised actions are provided within appendix B.

10 Conclusion

Any creek will work towards establishing equilibrium between erosion and accretion processes, and eventually achieve a greater level of stability. However it is likely that through this process the creek will change in planform and geomorphic character. In instances where the creek immediately adjoins private property and public infrastructure this natural adjustment may not be acceptable.

An increase in stormwater volumes and velocity mean that the creek probably cannot return to its natural state since the conditions which created that natural state have been removed. This means that recovery potential for most zones (apart from perhaps zone 4 and 5a) is low. Instream works will need to accommodate the new catchment hydrology, while protecting property and infrastructure and preferably doing this in a way that is environmentally sensitive. Armouring of sections of creek without addressing flow energy will generally deflect problems further downstream, therefore rehabilitation solutions must protect stream bed and banks while dissipating flow energy locally – that is slowing water down.

Through Management Zones 1a and 1b and 5b particularly we have seen an increase in channel slope as instream features have either been eroded or smothered with sediment. This increase in slope also straightens and lowers the creek channel meaning that the creek is disconnected from its floodplain, further exacerbating the erosion potential of storm flows through increased runoff being maintained within the creek. This general enlargement of the channel now means that all flows up to and including the 100 yr ARI event are contained within the creek channel, which has implications for the sizing of rehabilitation measures. Flow velocities are not uniform within the creek channel and generally faster flows occur on outer bends and central channel and are slower on inner bends and immediately above the creek bed (Leopold *et al.*, 1992).

Rehabilitation measures have been prioritised on the basis of severity of erosion and proximity to private property, with rehabilitation works within zones 1b being a particular priority. Concept designs developed in conjunction with this plan provide bioengineering responses via which the stream can be rehabilitated while maintaining and enhancing stream character and ecology. Such approaches are not only ecologically sustainable but also cost effective to construct and maintain.

11 References

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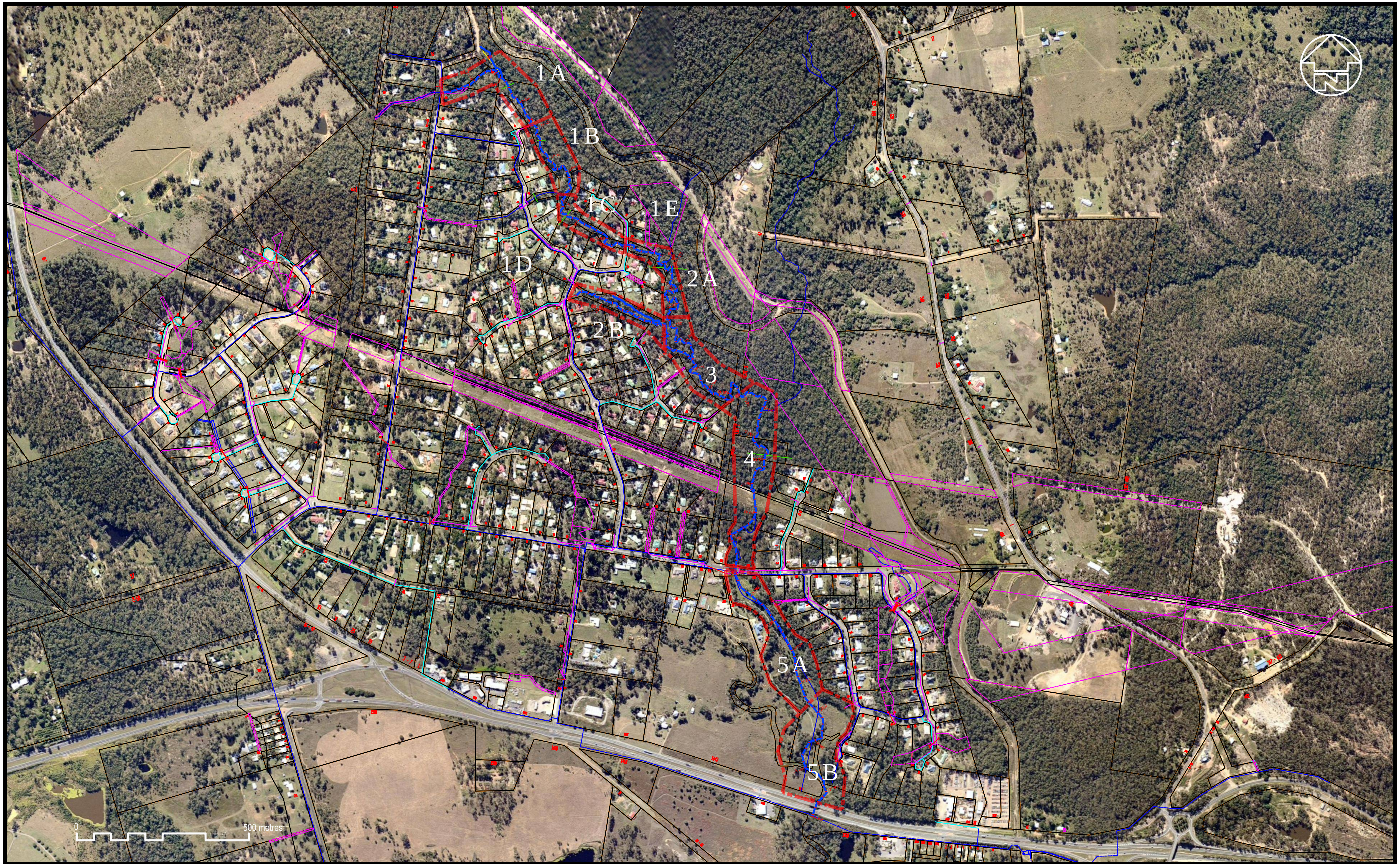
Rutherford, I., Jerie, K., Marsh, N., (2000). *A Rehabilitation Manual for Australian Streams*, Volumes 1 and 2. Cooperative Research Centre for Catchment Hydrology, Victoria.

Appendix A – Concept Designs



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PROJECT
IRON POT CREEK
NORTH DRAINAGE & EROSION MANAGEMENT PLAN

SCALE 1:10,000 @ A3

DRAWING
MANAGEMENT ZONES
SITE MAP

DRAWING CREATED 9/10/2012

DWG No.
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CAD FILE No.
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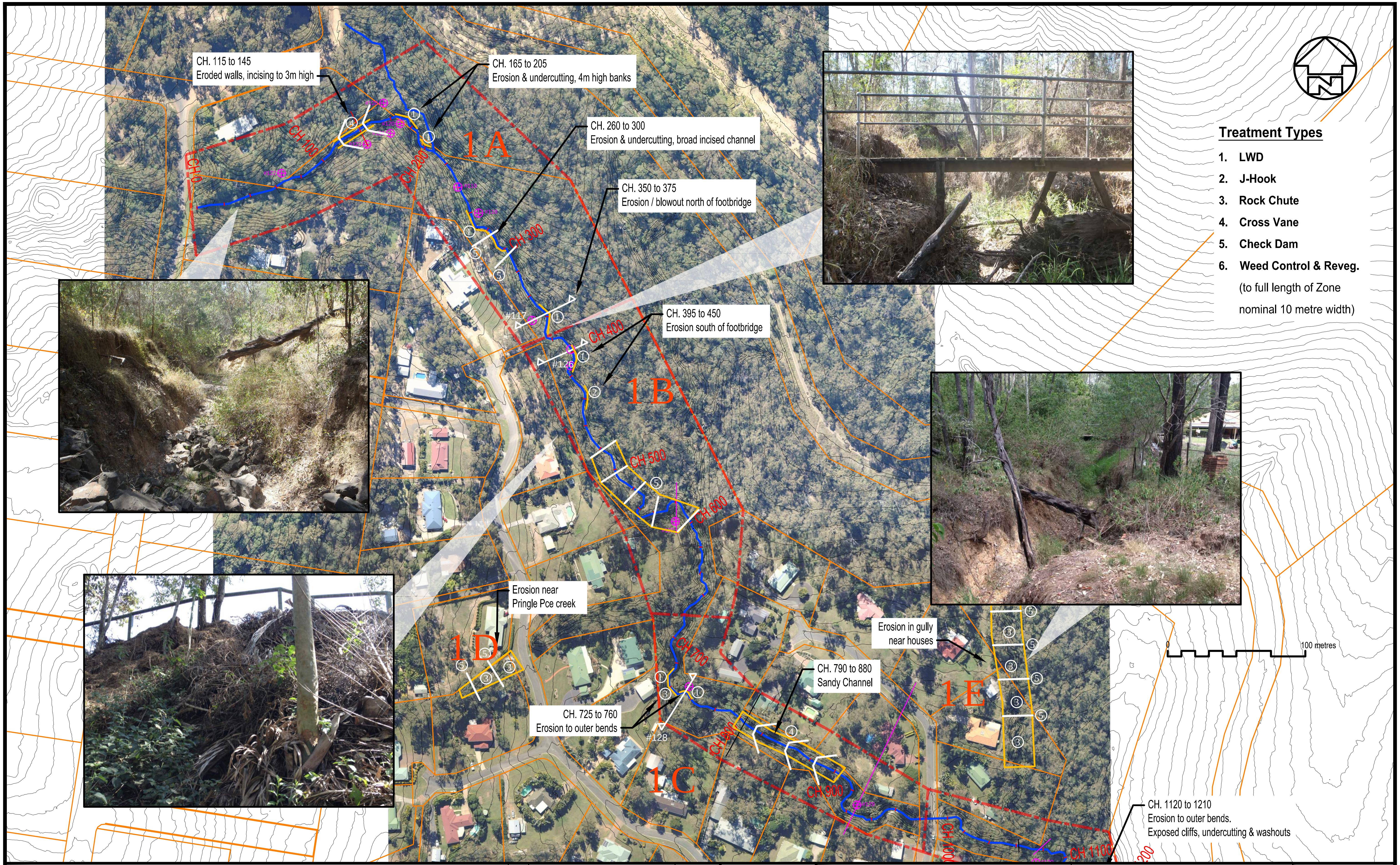

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PROJECT
IRON POT CREEK
NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING
MANAGEMENT ZONES
ZONE 1: SITE ANALYSIS PLAN

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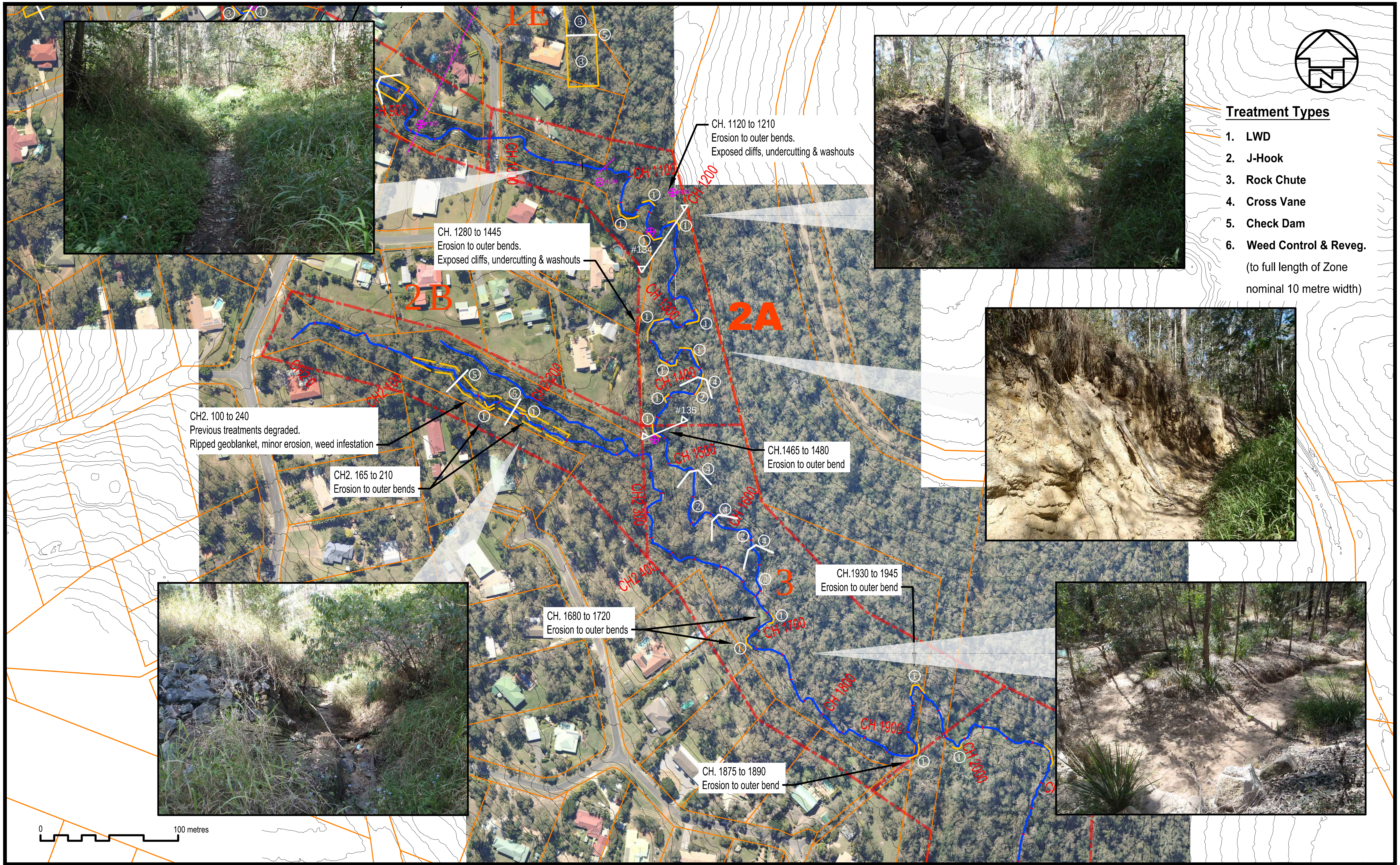

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PROJECT: IRON POT CREEK NORTH DRAINAGE & EROSION MANAGEMENT PLAN	DRAWING: MANAGEMENT ZONES ZONE 2 & 3
SCALE: 1:2,500 @ A3	DRAWING CREATED: 9/10/2012

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CAD FILE No. 1-12185_IPC_LP.dwg

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PROJECT
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NORTH DRAINAGE & EROSION MANAGEMENT PLAN

SCALE 1:2,500 @ A3

DRAWING
MANAGEMENT ZONES
ZONE 4

DRAWING CREATED 9/10/2012

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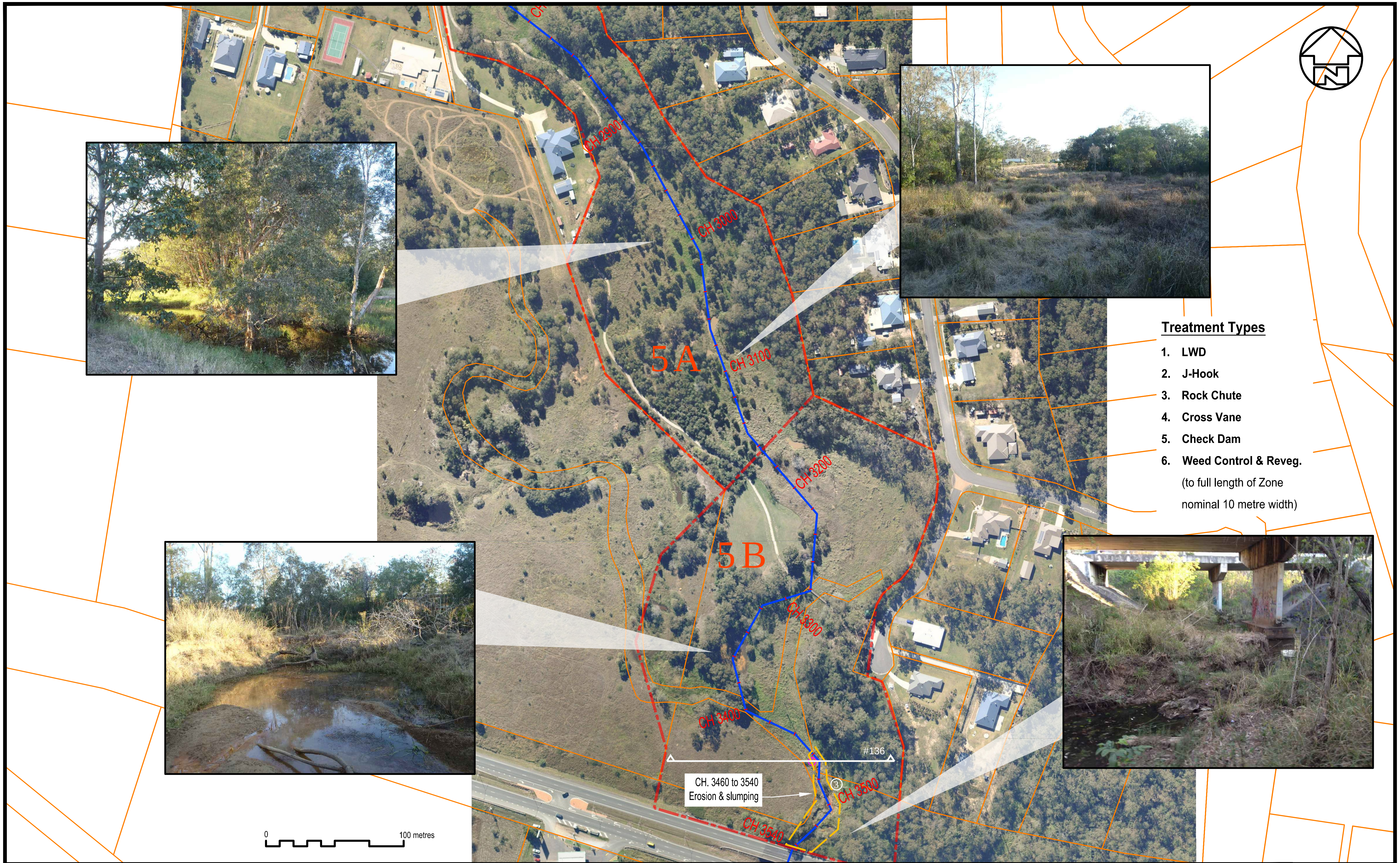

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PROJECT	IRON POT CREEK NORTH DRAINAGE & EROSION MANAGEMENT PLAN
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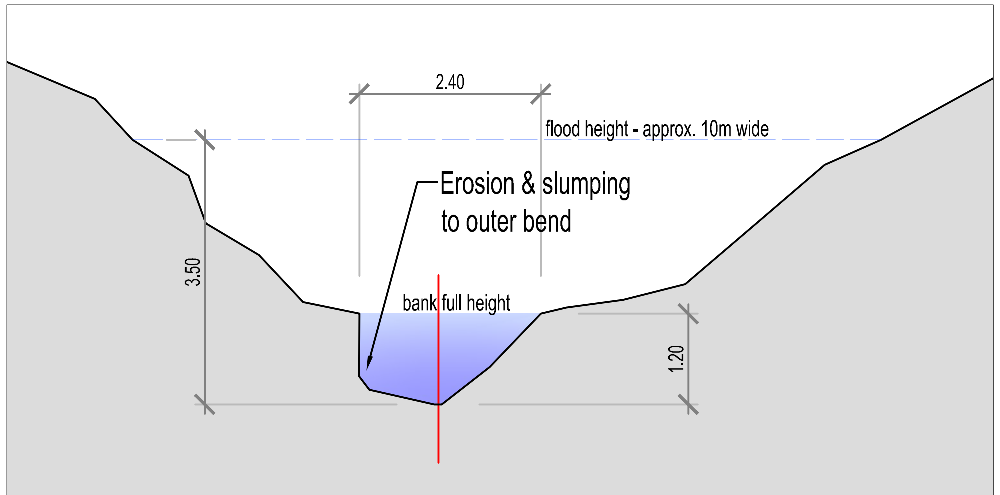
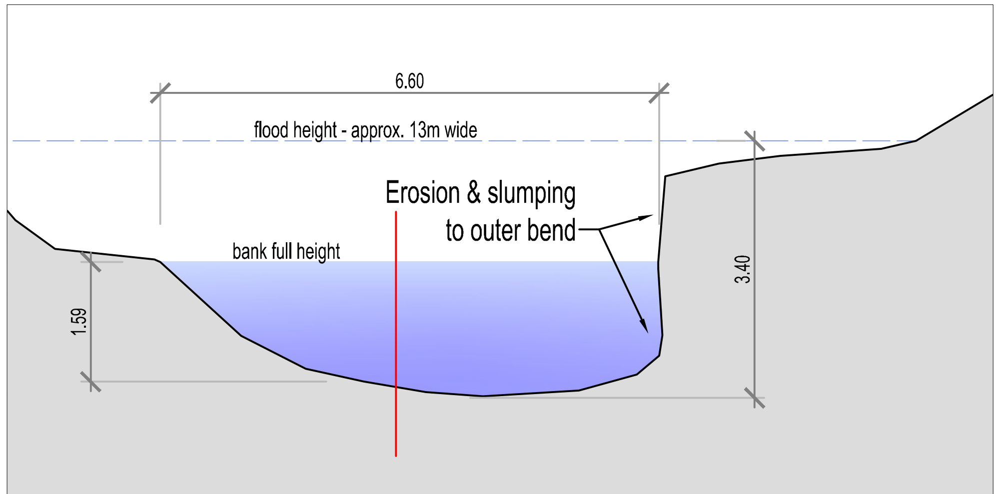


TYPICAL SECTION: ZONE 1A



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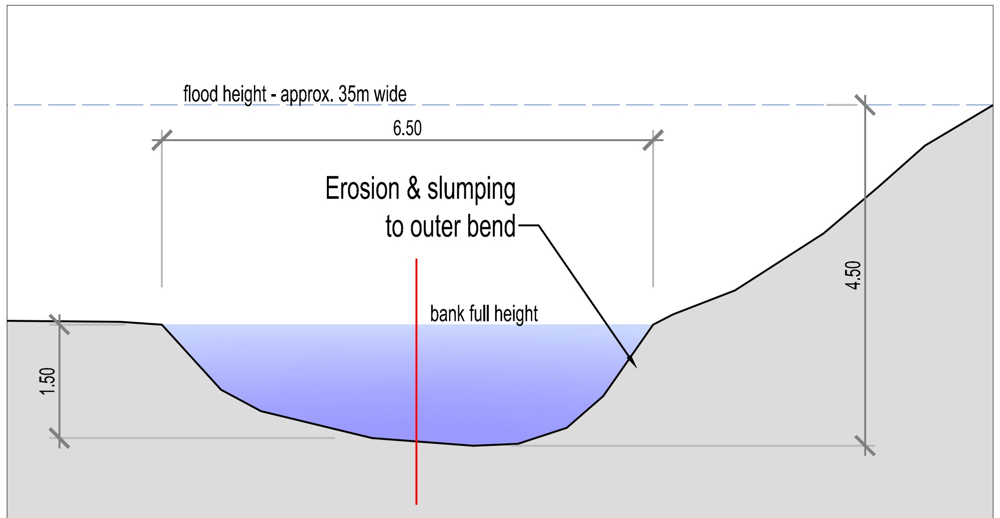

TYPICAL SECTION: ZONE 1C

Zone 1a, 1b, 1c, 1d &1e

Stream types: G4 to G3 (1a, 1b); G4 to F5b (1c)

Bank Stability Ratings: Fair to Good (1a); Poor to Good (1b); Fair to Good (1c)

Comments

Zones 1a 1b comprise a naturally incised and steep gully, subjected to high energy, but short duration storm flows. Stream scour and movement of sediment is to some extent a natural feature of these stream types. Much of the creek bed is stone or cobbles making further bed lowering unlikely, however scour of outer banks may continue. There is significant scour of a number of beds in Zone 1b. Stream grades reduce in Zone 1c, stream meanders increase, as does accumulation of sediment. There is isolated bank scour, dumping of garden waste and extensive weed cover. Zone 1d is a short gully adjoining Pringle Place and experiences very powerful storm flows.

Zone 1e is a tributary of Zone 2a and is an incising gully, actively unstable as a result of concentrated discharge from the rail corridor to the north.

Main issues

- Isolated locations with moderate to major bank scour
- Widespread weeds, principally Lantana
- Some dumping of garden waste by land owners
- Significant storm flows in Zone 1d

Summary Actions	Priority
Prepare site specific erosion control measures including grade control structures	M
Implement erosion control measures	H
Engage with the community around drainage, management of creek banks and dumping of garden waste	H
Prepare and implement a weed control strategy within Council lands in collaboration with adjoining land owners	M
Ensure any works by Council are well coordinated and consistent with the recommendations of this plan	H
Prepare and distribute education materials on effective management of dispersive soils and appropriate rehabilitation measures.	H
Prepare site specific rehabilitation strategies for creek banks in the vicinity of Gracemere Cr and Pringle Pl. Plunge pool, rip rap, grade control structures, bank stabilisation works and revegetation required	VH

Treatment Cost Estimate for Zone 1a, 1b, 1c, 1d & 1e

Treatment Type	Item / Unit	Cost per Unit	Total
1. LWD	8 x 20 lin. m	$1500 / lin. m	$252,800
2. J-Hook	1 x 5 m3	$220 / m3	$1,100
3. Rock Chute	7 x 7.5 m3	$220 / m3	$11,550
4. Cross Vane	5 x 10 m3	$220 / m3	$110,000
5. Check Dam	14 x 6 m3	$220 / m3	$18,480
6. Weed Control & Reveg.	14300 m2	$2.50 / m2	$35,750
		Total	**$429,680**

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PROJECT: IRON POT CREEK
NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING: MANAGEMENT ZONES
ZONE 1: TYPICAL SECTIONS
SITE ANALYSIS & SUMMARY ACTIONS

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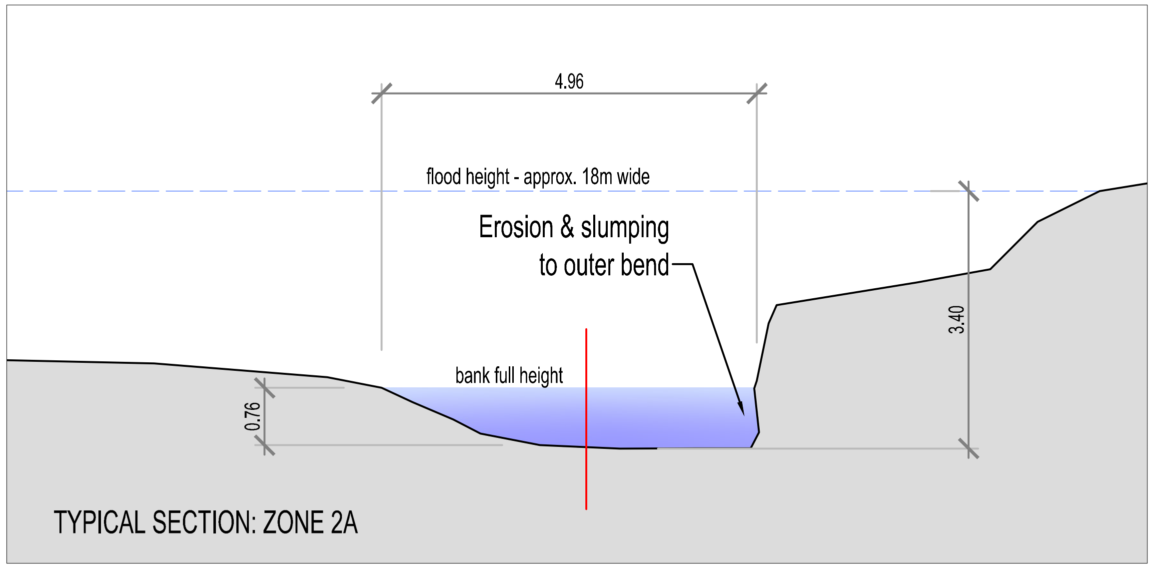

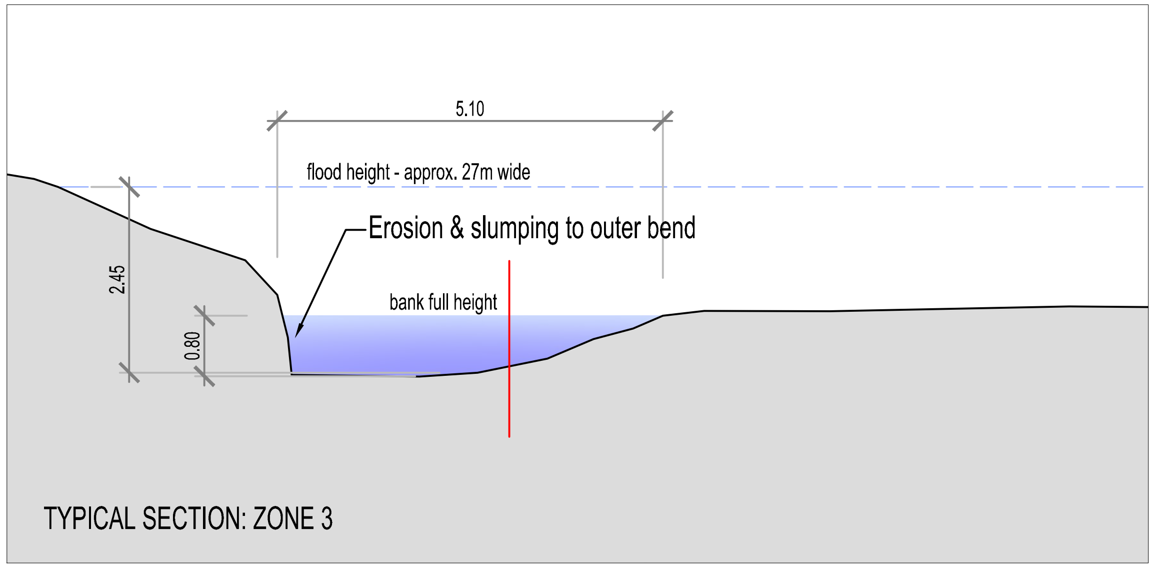

Zones 2a, 2b & 3

Stream types: E5 (2a); G4 to G5 (2b); E5/E5b (3)

Bank stability Ratings: Poor to Fair (2a); Poor to Good (2b); Poor to Good (3)

Comments

Zones 2a and 3 is a broad meandering stream with a well-defined low channel that has been smothered with coarse sand. A reduction in stream grades has created significant meanders, the outer bends of which are subjected to lateral scour. In larger storm events the full stream width of around 30m is engaged but only at moderate depths (1m-1.5m). Bank scour is more extensive in Zone 2a compared to Zone 3. Zone 2b is an incised and steep gully with historic restoration works that need revisiting. There is bank scour and slumping in a number of locations, as well at least one head cut.

Main Issues

- Scour of outer beds, particularly in Zone 2a
- Failure of historic rehabilitation works within Zone 2b
- Substantial deposition of sediments smothering the low flow channel in Zone 2a and Zone 3
- Extensive weed presence and dumping of garden waste

Summary Actions	Priority
Prepare stream rehabilitation designs for nominated locations	VH
Implement rehabilitation measures at priority locations	VH
Engage with the community around dumping of garden waste and encroachment within Council reserves	H
Implement a weed management strategy	M

Treatment Cost Estimate for Zones 2a, 2b, 2c, 3

Treatment Type	Item / Unit	Cost per Unit	Total
1. LWD	16 x 20 lin. m	$1500 / lin. m	$480,000
2. J-Hook	4 x 5 m3	$220 / m3	$4,400
4. Cross Vane	4 x 10 m3	$220 / m3	$8,800
5. Check Dam	2 x 5 m3	$220 / m3	$2,200
6. Weed Control & Reveg.	14620 m2	$2.50 / m2	$36,550
		Total	$531,950

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NORTH DRAINAGE & EROSION MANAGEMENT PLAN

SCALE: 1:100 @ A3

DRAWING: MANAGEMENT ZONES
ZONES 2 & 3: TYPICAL SECTIONS
SITE ANALYSIS & SUMMARY ACTIONS

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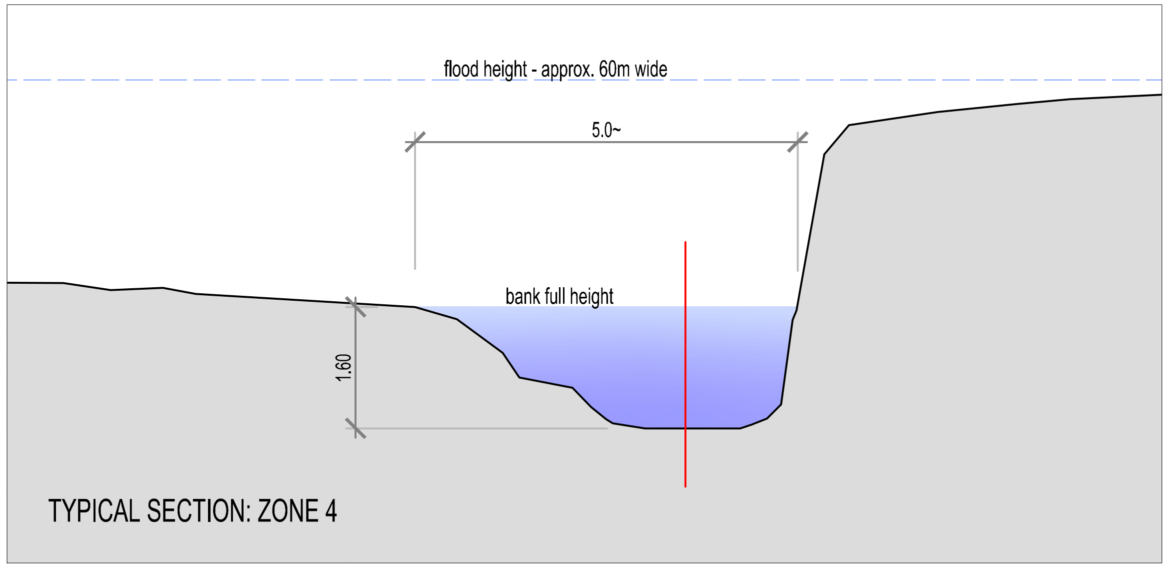

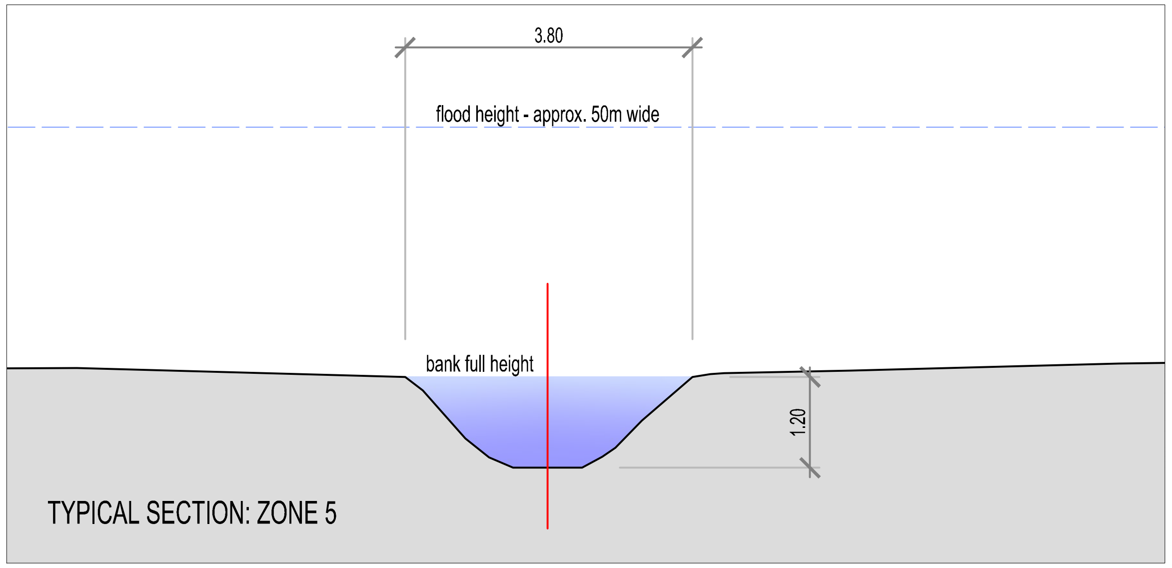

Management Zones 4, 5a, 5b

Stream types: E4 to E5 (4); D5b (5a); G5 (5b)

Bank Stability Ratings: Fair to Excellent (4); Good to Excellent (5b); Poor to Good (5b)

Comments

Zone 4 comprises a broad meandering stream with a well-defined low flow channel and intermittent pools. The zone is generally in excellent condition apart from isolated bank scour and intermittent weeds notably Lantana. Ironpot Creek discharges into Zone 5a via box culverts under Bayley Road and then spreads into a broad flood plain with a mosaic of low flow channels. There are no scour or erosion issues in this zone. On approach to the Warrego Highway a creek channel forms again where there is a head cut developing as well bed lowering and unstable banks.

Main Issues

- Isolated bank scour
- Some weed incursion
- Head cut and bed lowering upstream of the Warrego Highway

Actions

Summary Actions	**Priority**
Prepare stream rehabilitation designs for nominated locations	H
Implement rehabilitation measures at priority locations	H
Address head cut which is advancing upstream stream in Zone 5a	VH
Implement a weed management strategy	M

Treatment Cost Estimate for Zones 4, 5a, 5b

Treatment Type	**Item / Unit**	**Cost per Unit**	**Total**
1. LWD	5 x 20 lin. m	$1500 / lin. m	$150,000
3. Rock Chute	1 x 7.5 m3	$220 / m3	$1,650
6. Weed Control & Reveg.	15020 m2	$2.50 / m2	$37,550
		Total	**$189,200**

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PROJECT: IRON POT CREEK
NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING: MANAGEMENT ZONES
ZONES 4 & 5: TYPICAL SECTIONS
SITE ANALYSIS & SUMMARY ACTIONS

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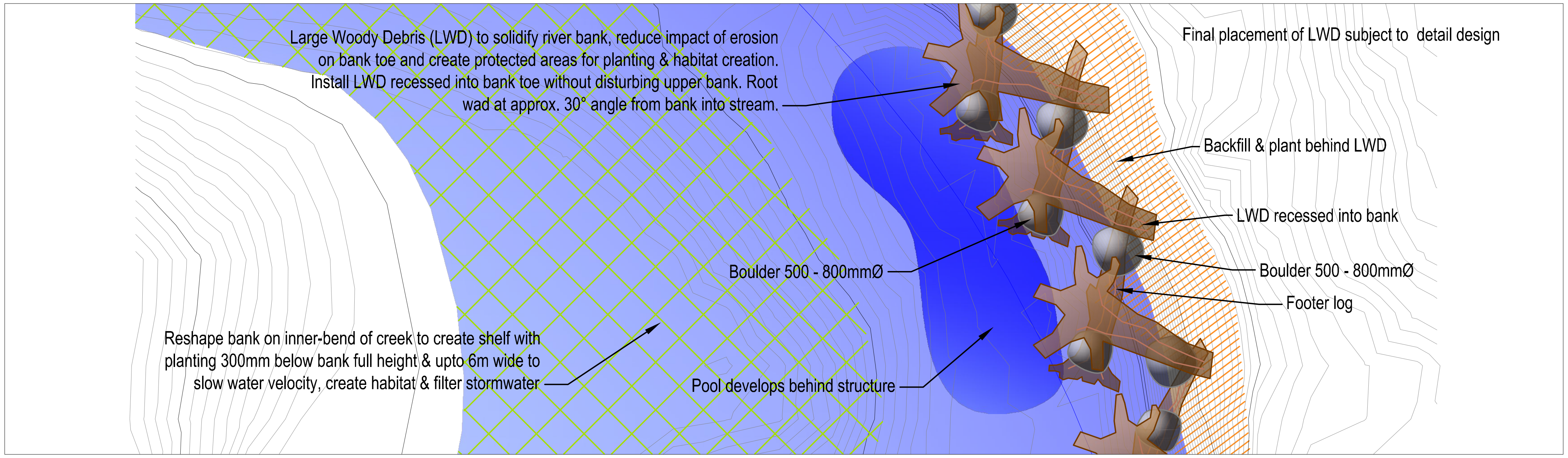

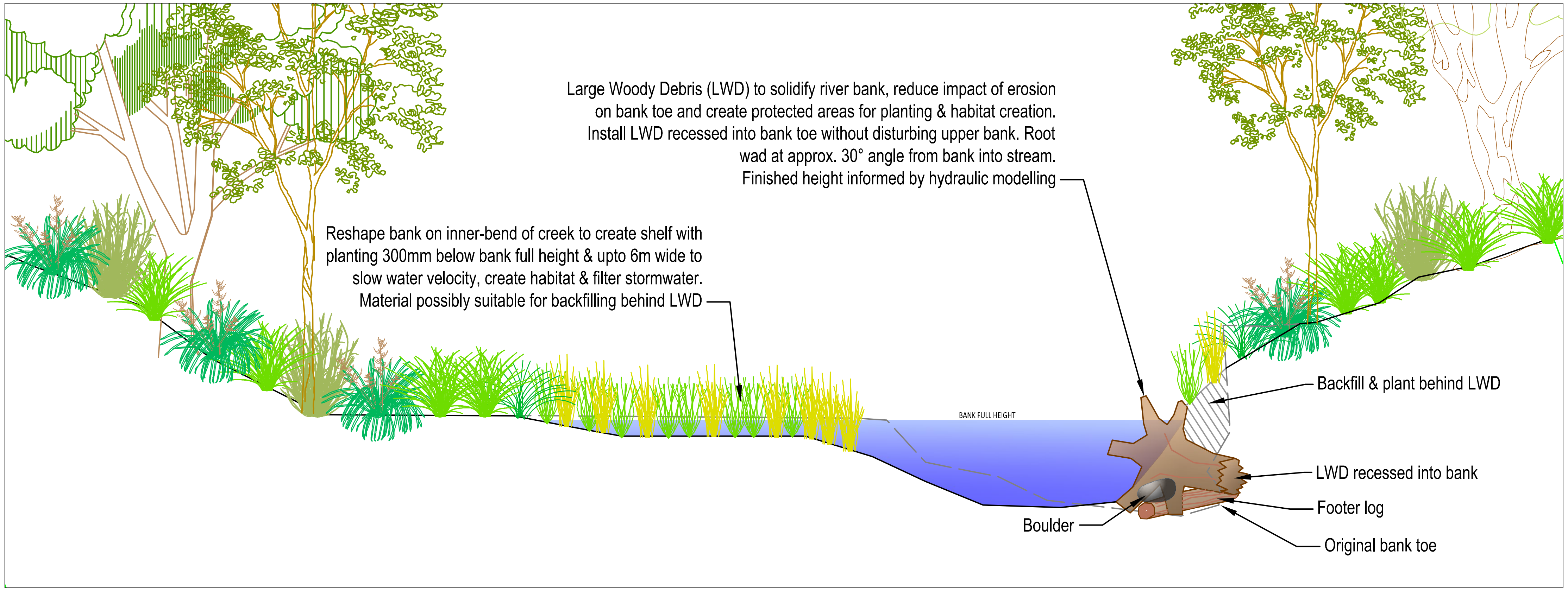

Flora Revegetation List

Botanical name	Common name	Form
Acacia concurrens	black wattle	shrub
Acacia disparrima subsp. disparrima	hickory wattle	shrub
Acacia irrorata	green wattle	shrub
Allocasuarina littoralis	black she-oak	small tree
Alphitonia excelsa	red ash	small tree
Breynia oblongifolia	coffeebush	shrub
Bursaria spinosa	blackthorn	shrub
Corymbia citriodora	spotted gum	tree
Corymbia intermedia	pink bloodwood	tree
Cupaniopsis parvifolia	small-leaved tuckeroo	small tree
Dodonaea triangularis	hopbush	shrub
Eucalyptus crebra	narrow-leaved ironbark	tree
Eucalyptus moluccana	gum-topped box	tree
Eucalyptus tereticornis	Qld blue gum	tree
Flindersia collina	leopard ash	small tree
Glochidion ferdinandi	cheese tree	small tree
Jacksonia scoparia	dogwood	shrub
Jagera pseudorhus	foambark	small tree
Lomandra confertifolia subsp. pallida	mat-rush	groundcover
Lomandra longifolia	mat-rush	groundcover
Lophostemon confertus	brush box	tree
Lophostemon suaveolens	swamp box	tree
Microlaena stipoides	weeping grass	groundcover
Petalostigma pubescens	quinine bush	shrub
Poa cheellii	tussock grass	groundcover
Psydrax odorata	sweet Susie	small tree
Themeda australis	kangaroo grass	groundcover
Trema tomentosa	native peach	shrub

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TREATMENT 1: LWD
BANK TOE PROTECTION

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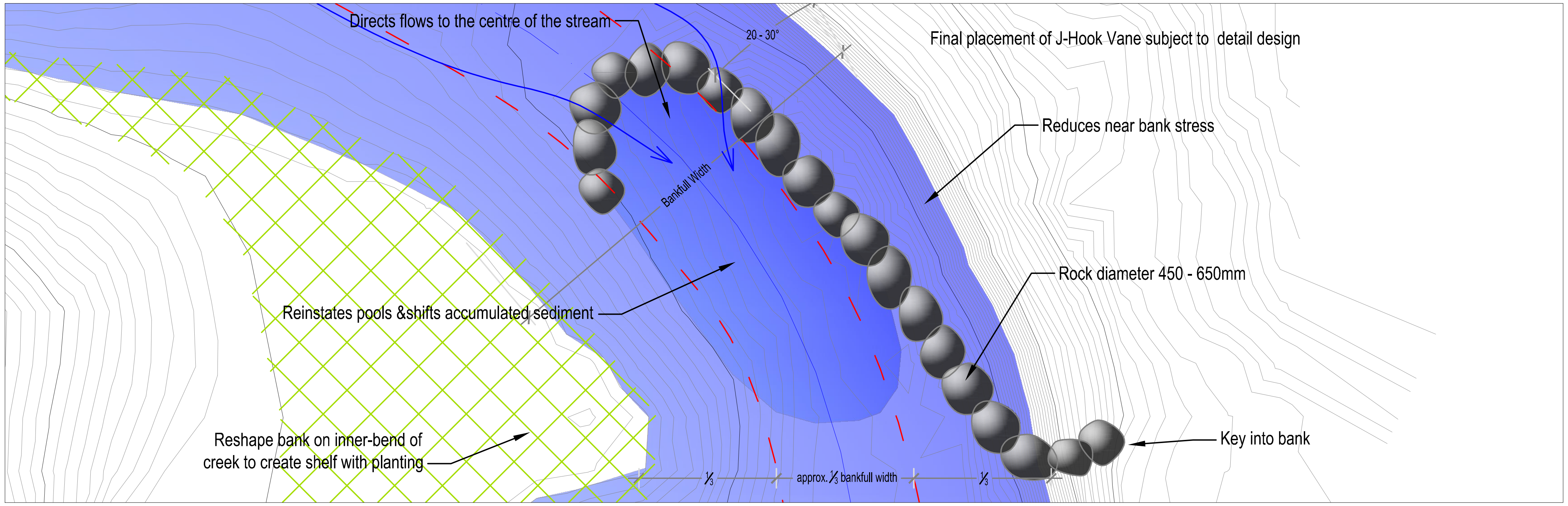

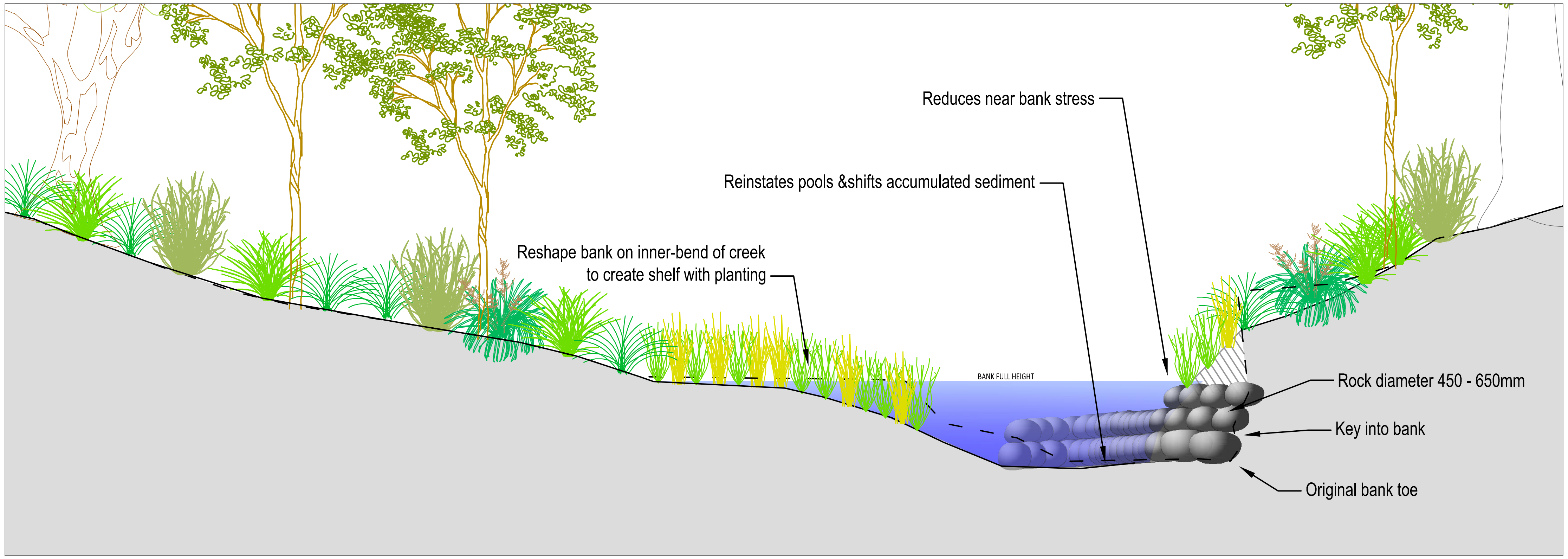

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PROJECT

IRON POT CREEK

NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING

TREATMENT 2: J-HOOK VANE

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CAD FILE No.
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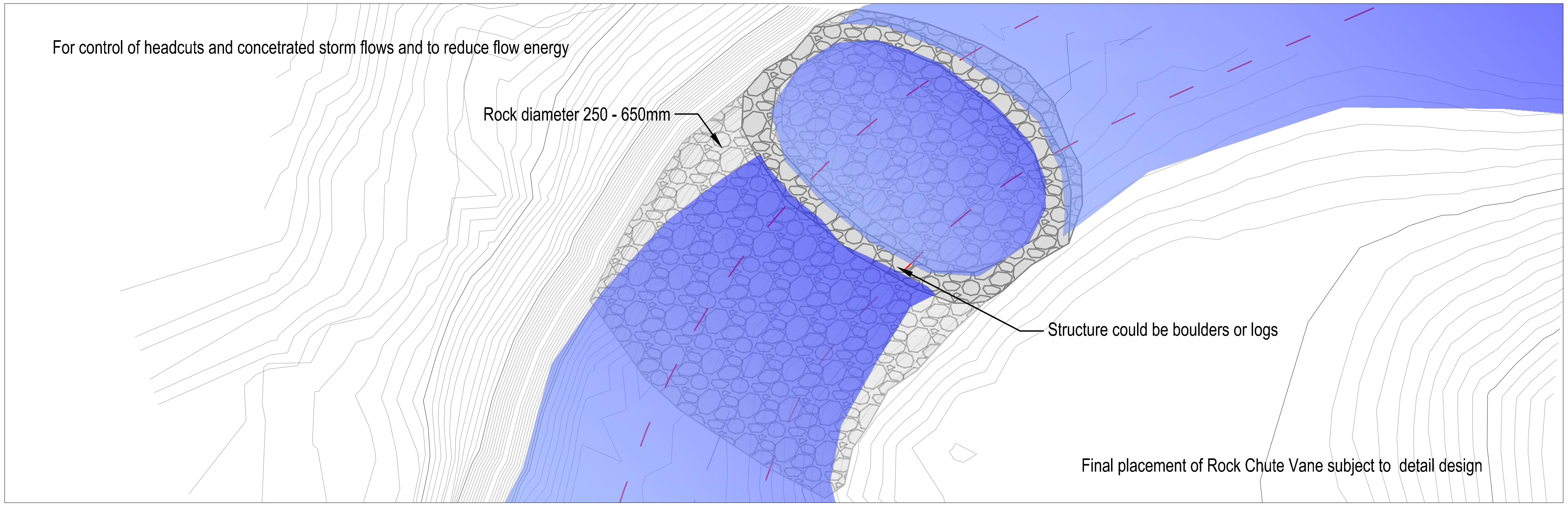

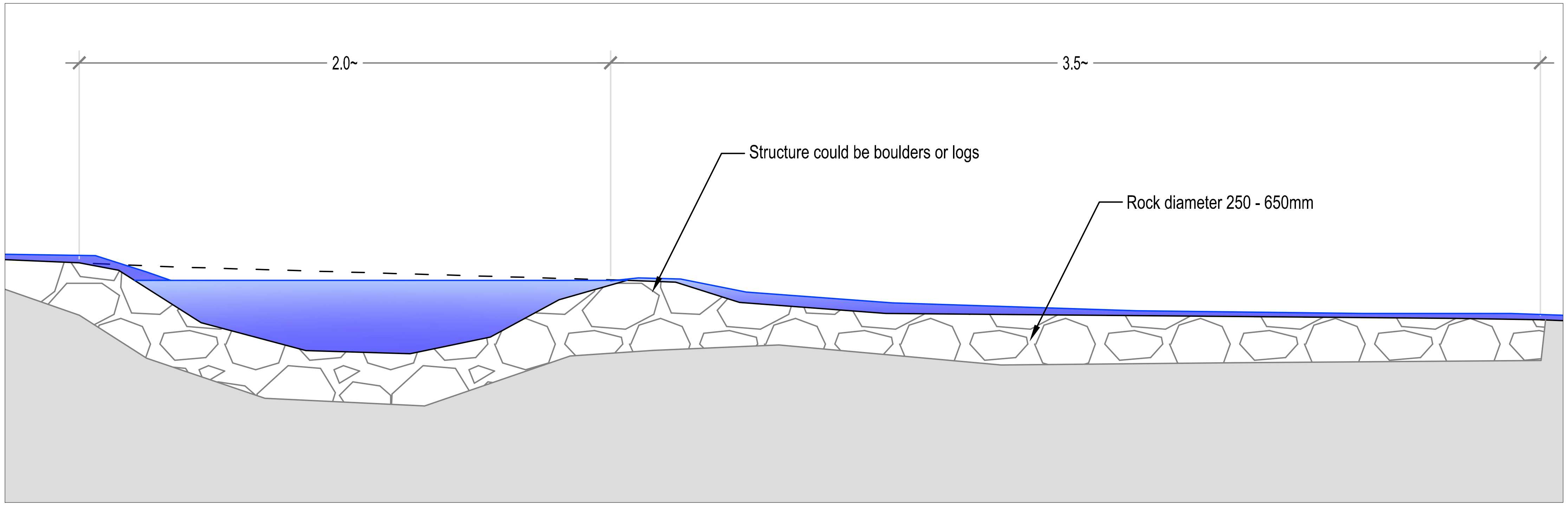

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NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING
TREATMENT 3: ROCK CHUTE

DWG No.
AWC_1-12185_LP11

CAD FILE No.
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DRAWING CREATED
9/10/2012

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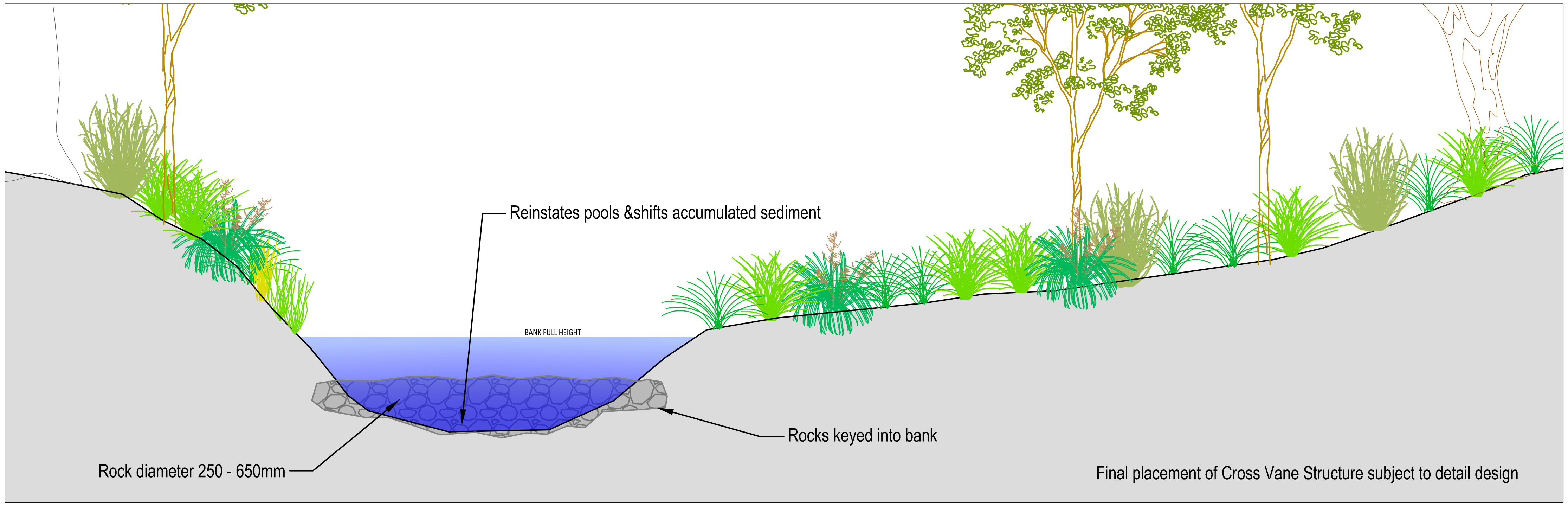

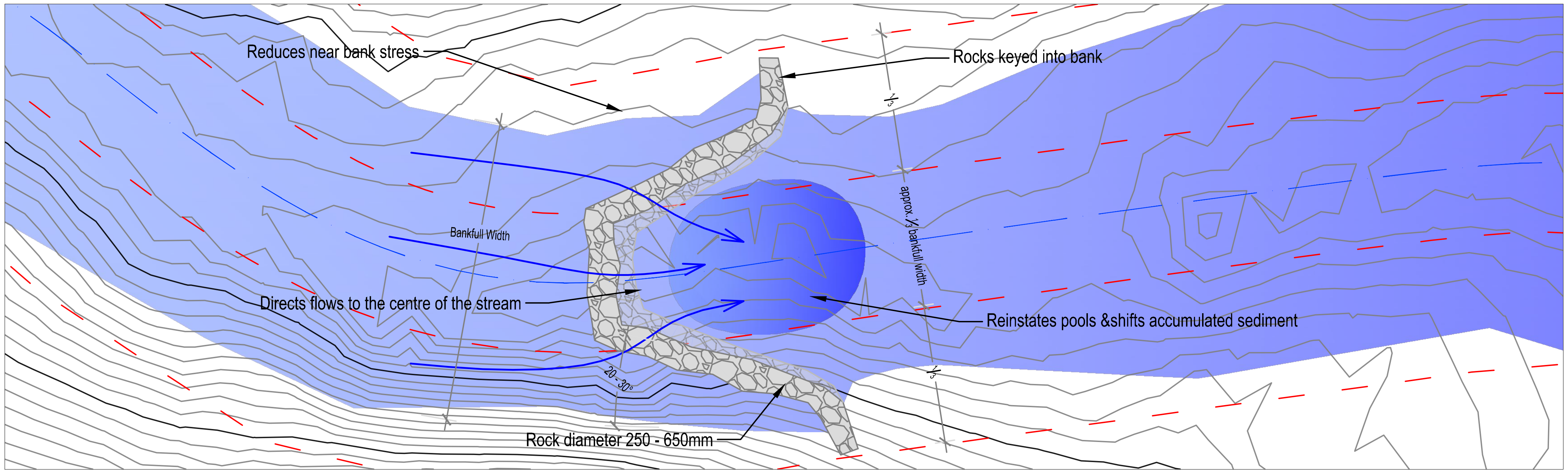

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REV.	ISSUE / AMENDMENTS	DATE

DESIGNED	DM
DRAWN	PB
CHECKED	DM

PROJECT
IRON POT CREEK
NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING
TREATMENT 4:
CROSS VANE STRUCTURE

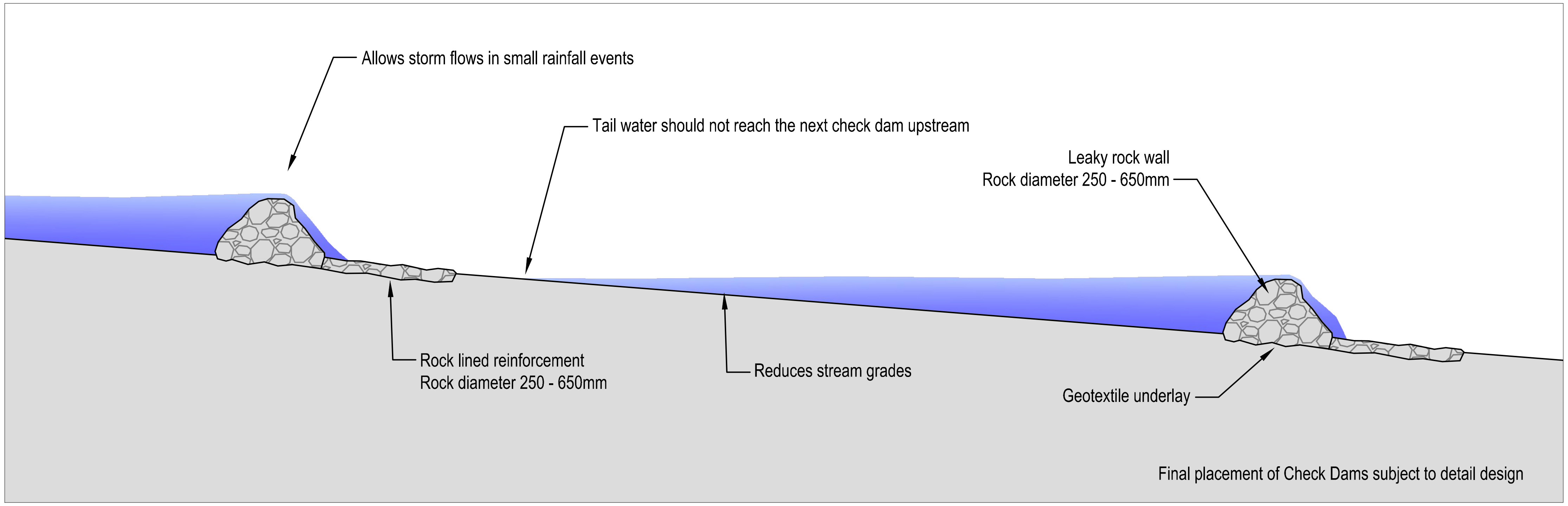
DWG No.
AWC_1-12185_LP12

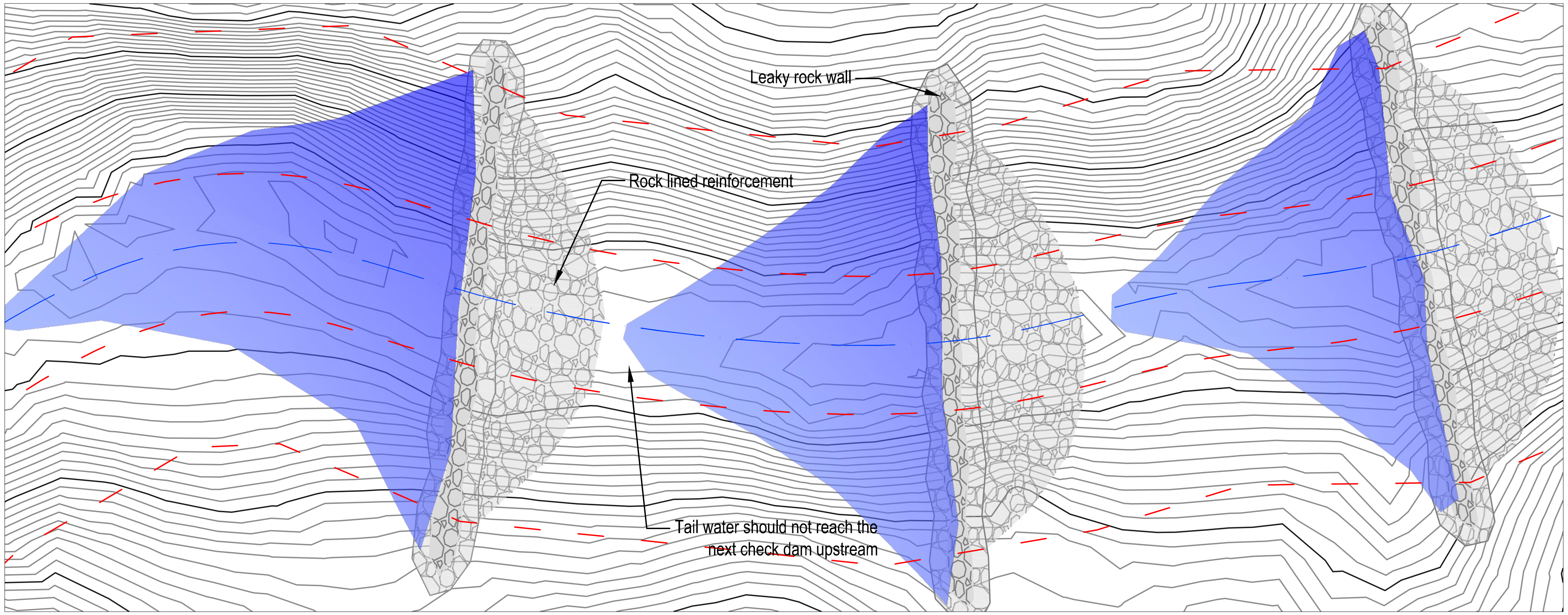
CAD FILE No.
1-12185_IPC_LP.dwg

SCALE

DRAWING CREATED
9/10/2012

REV.





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BLIGH TANNER
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REV.	ISSUE / AMENDMENTS	DATE

DESIGNED DM
DRAWN PB
CHECKED DM

PROJECT
IRON POT CREEK
NORTH DRAINAGE & EROSION MANAGEMENT PLAN

DRAWING
TREATMENT 5: CHECK DAM

DWG No. AWC_1-12185_LP13
CAD FILE No. 1-12185_IPC_LP.dwg
SCALE
DRAWING CREATED 9/10/2012
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Appendix B – Action Plan

Mgt Zone	Issue	Action	Priority		Comment/Benefit/Consequence of Inaction
1a					
i	Scour at numerous locations creating bank instability	Prepare detailed rehabilitation plans for locations identified within in appendix A	VH		Refer to whole of catchment actions
ii		Implement creekline rehabilitation measures following completion of detailed design	H		Final cost and priority of works subject to detailed design. Proximity of works to private property is generally reduced.
iii	Community actions within and adjoining the riparian zone potentially contributes to bank erosion and the spread of weeds	Engage with the community around drainage, management of creek banks and dumping of garden waste	VH		Internal Council activity via which creek protection can be used in collaboration with the community. Ongoing works by individuals could be potentially more damaging for the creek.
iv	Extensive weed presence, notably Lantana	Prepare weed control plan	M		Determine extent of Lantana on private and public land prioritise control in conjunction with creek rehabilitation efforts
1b					
i	Landholders have concern about ongoing erosion and threats to private property	Engage with landholders regarding concerns of erosion adjoining private property	VH		Ongoing communication and updating of Council's planned strategy will be required. It is also important to educate those landholders carrying out rehabilitation works on private property.
ii	Extensive weed infestations occur within the creek, including Lantana and Singapore Daisy	Prepare weed control strategy	H		Determine extent of weeds on private and public land prioritise control in conjunction with creek rehabilitation efforts
iii	Dumping of weeds and garden waste within the creek line	Engage with landholders about the impact of garden waste on native vegetation	VH		Part of Council operations in managing public reserves
iv	Landholders have attempted to undertaken erosion	Engage with landholders around management of	VH		Directing community effort and resources will ensure a coordinated and consistent approach

Mgt Zone	Issue	Action	Priority		Comment/Benefit/Consequence of Inaction
	control both on private land and within drainage reserves	drainage lines and erosion. Prepare education materials advising landholders on rights and obligations concerning erosion control strategies as well as preferred and proven control measures.			to creek rehabilitation
v	Lack of coordination in Council efforts to control erosion.	Ensure all sections of Council work in a coordinated and strategic manner.	H		Council works must be consistent and prioritised to ensure best outcomes for resources allocated
vi	Tunnelling on dispersive soils on private property.	Prepare and distribute education materials on effective management of dispersive soils and appropriate rehabilitation measures.	M		Management of dispersive soils on private property is an important long term need that will also contribute to creek stability
vii	Significant erosion occurring with Zone 1b in the vicinity of Gracemere Crescent and Pringle Place	Prepare site specific rehabilitation strategies for these locations. Plunge pool, rip rap, grade control structures, bank stabilisation works and revegetation required	VH		Erosion is active within and adjoining private properties. Works are required to halt this process. The creek will continue to migrate into private property without intervention.
1c					
i	Landholders have concern about ongoing erosion and threats to private property	Engage with landholders regarding concerns of erosion adjoining private property	VH		Directing community effort and resources will ensure a coordinated and consistent approach to creek rehabilitation

Mgt Zone	Issue	Action	Priority		Comment/Benefit/Consequence of Inaction
ii	Extensive weed infestations occur within the creek, including Lantana and Singapore Daisy	Prepare weed control strategy	H		Weeds should be managed in a coordinated and prioritised manner. Weed spread will compromise the long term viability of native vegetation
iii	Dumping of weeds and garden waste within the creek line	Engage with landholders about the impact of garden waste on native vegetation	H		Part of Council operations in managing public reserves
iv	Existing culvert under Wairuna Court may be acting as a hydraulic constraint	Investigate the adequacy of the current culvert arrangement.	H		This investigation would inform creek rehabilitation works and risks of localised flooding
1d					
i	Significant erosion occurring upstream of Zone 2a, immediately adjoining 29 and 31 Wairuna Court	Prepare site specific rehabilitation strategies for these locations. Plunge pool, rip rap, grade control structures, bank stabilisation works and revegetation required	H		Works perhaps need to be undertaken in consultation with QR
2a					
i	Extensive erosion occurring on outer bends	Develop detailed designs for priority locations.	H-VH		Final cost subject to detail design. Many areas of instability pose no immediate risk to property or infrastructure
ii	Weed incursion is extension throughout this zone	Prepare weed management strategy.	H		Weeds should be managed in a coordinated and prioritised manner. Weed spread will compromise the long term viability of native vegetation
iii	Dumping of weeds and garden waste within the creek line	Engage with landholders about the impact of garden waste on native vegetation	VH		Part of Council operations in managing public reserves
iv	Mowing occurring within the riparian zone	Engage with landholders to explain the role that	VH		Part of Council operations in managing public reserves

Mgt Zone	Issue	Action	Priority		Comment/Benefit/Consequence of Inaction
		native vegetation plays in maintaining bank stability.			
v	Bankfull channel is smothered in sediment and exacerbating lateral scour of creek banks	Introduce instream structure which work to reinstate pool and riffle features and reduce scour potential for outer bends.	VH		Final cost subject to detail design
2b					
i	Previous rehabilitation works have failed and creek scour has continued	Confirm mechanisms for failure and prepare revised rehabilitation measures.	H-VH		Reasons for failure need to inform future designs
ii	Weed incursion is extension throughout this zone	Prepare weed management strategy.	H		Weeds should be managed in a coordinated and prioritised manner. Weed spread will compromise the long term viability of native vegetation
3					
i	Isolated erosion points, mainly in the downstream components of the zone	Prepare and implement erosion control strategies	H-VH		Final cost subject to detail design
ii	Bankfull channel is smothered in sediment and exacerbating lateral scour of creek banks	Introduce instream structure which work to reinstate pool and riffle features and reduce scour potential for outer bends.	M-H		Final cost subject to detail design
iii	Motorbikes are being ridden within the reserve causing erosion and damage to native plants	Enforce reserve prohibition of motor bike riding.	VH		Part of Council role in managing public reserves
iv	Some landholders have encroached into the reserve,	Engage with landholders to explain the role that	VH		Part of Council role in managing public reserves

Mgt Zone	Issue	Action	Priority		Comment/Benefit/Consequence of Inaction
	mowing creek banks and dumping garden waste	native vegetation plays in maintaining bank stability.			
4					
i	Isolated scour points at two locations	Prepare and implement erosion control strategies	H		Small amount of work required to limit potential for larger future problems
ii	Weed incursion is extension throughout this zone	Prepare weed management strategy	H		Weeds should be managed in a coordinated and prioritised manner. Weed spread will compromise the long term viability of native vegetation
		Undertaken weed control in priority locations	H		Cost subject to weed assessment
5a					
i	Isolated weed incursion and lack of native vegetation cover	Weed control and revegetation	L-M		Remnant vegetation communities should be protected and enhanced
5b					
i	Isolated weed incursion and lack of native vegetation cover	Weed control and revegetation	L-M		Remnant RE could be preserved and enhanced ensuring long term viability.
ii	Head cut has formed in lower sections of this zone	Prepare and implement strategy for control	H - VH		Problem should be addressed early to prevent migration of head cut and become increasingly expensive in the future.
iii	A feral goat was observed in this zone	Investigate the need for feral animal control within Walter Zimmerman and Ironpot Creek Reserves	L-M		The significance of feral animals as an issue is unclear, and warrants at least a preliminary investigation to determine if a significant issue exists.
iv					
General – Whole of Catchment					
i	Rates of erosion and scour are difficult to quantify	Monitoring points should be established	H		This work would inform current designs and provide base line information for other

Mgt Zone	Issue	Action	Priority		Comment/Benefit/Consequence of Inaction
		within the creekline			catchments within the city
		Annual surveys for five years	H		
ii	The extent of tunnelling within dispersive soils on public and private lands is unknown	Trial methods for amelioration of tunnelling within private property	M-H		Trials could assist in educating the community around managing dispersive soils
iii	Weeds are extensive throughout the catchment	Prepare a weed management strategy for Ironpot Creek and its tributaries	H		The strategy could ensure effective and targeted weed control consistent with ICC weed control strategies and the SE QLD Ecological Restoration Framework (2012)
iv	Erosion control works have been ad hoc and uncoordinated	Coordination between Council departments with respect to rectification works and communication with the community	VH		Council's rehabilitation efforts must be consistent with best practice and well coordinated to ensure efficient use of resources and a greater chance of success.
v	Baseline and ongoing monitoring is required to enable verification of severity of degradation and the success of rehabilitation efforts	Survey the creek thalweg to at least 0.05m resolution before and after rehabilitation works to monitoring the effectiveness of reintroducing geomorphic features to instream complexity and stability	H - VH		Monitoring will assist in confirming the effectiveness of rehabilitation strategies for Ironpot Creek and elsewhere, ensuring that rehabilitation efforts are beneficial and well-targeted.
vi	There is evidence of erosion within gullies below the rail corridor	Complete condition assessment of drainage lines discharging from DTMR rail corridor and determine rehabilitation requirements prior to a lease being finalised.	M-H		Concentrated stormwater runoff from the rail corridor will continue to scour gullies downstream, in some instances damaging private property. The burden of rectification should be at least in part shared with DTMR.

Appendix C - Bank Stability Rating Results

Site number	Stream type	1. Landform Slope	2.Mass Wasting	3.Debris Jam Potential	4.Vegetation Protection	5.Channel capacity	6. Bank rock content	7. Obstructions	8. Cutting	9. Deposition	10. Rock angularity	11. Brightness	12. Consolidation	13. % stable materials	14. Deposition/Scouring	15. Aquatic vegetation	Overall channel stability	Stability Rating
Management Zone 1																		
1a	G3	6	6	6	6	2	8	4	6	4	8	3	3	8	12	3	**85**	Good
1a	G3	6	8	6	8	3	8	4	16	10	3	3	4	16	12	4	**111**	Fair
1a	G3	6	9	6	10	4	10	4	16	10	3	3	3	16	16	3	**119**	Fair
1a	G3	6	9	6	10	3	8	4	16	12	4	3	4	16	18	4	**123**	Fair
1a	G4	6	9	6	10	3	8	4	14	10	3	3	4	16	10	4	**110**	Fair
1b	G4	6	9	6	10	3	8	4	16	10	3	3	4	16	10	4	**112**	Fair
1b	G4	8	12	8	12	3	8	8	16	12	3	3	4	16	10	4	**127**	Poor
1c	G5	6	9	6	9	2	6	6	12	8	3	3	8	12	12	3	**105**	Good
1c	G5	6	6	6	6	2	4	4	6	8	2	3	8	16	12	3	**92**	Good
1c	G5	6	6	4	6	3	6	4	6	12	3	3	8	16	12	3	**98**	Good
1c	G5	6	9	6	9	1	6	6	6	16	3	3	8	16	18	3	**116**	Fair
1d	G5	8	12	8	12	3	8	8	16	12	3	3	4	16	10	4	**127**	Poor
Management Zone 2																		
2a	E5	2	3	2	3	1	6	4	4	4	1	1	2	4	6	2	**45**	Good
2a	E5(C5)	6	12	6	8	3	6	12	12	16	6	1	8	12	20	2	**130**	Poor
2a	E5(C5)	6	12	6	8	2	6	10	10	16	6	2	8	12	18	4	**126**	Poor
2b	G4	6	9	4	6	1	6	6	16	12	3	3	8	12	18	4	**114**	Fair
Management Zone 3																		
3	E5(C5)	6	9	4	9	3	6	6	12	12	3	3	8	12	18	4	**115**	Fair
3	E5(C5)	6	6	4	6	2	4	4	10	16	2	2	8	12	18	4	**104**	Fair
3	E5(C5)	6	6	4	6	3	8	4	10	16	3	3	8	12	18	4	**111**	Fair
Management Zone 4																		
4	E5	2	3	2	3	1	6	4	4	4	1	1	2	4	6	2	**45**	Good
Management Zone 5																		
5a	D5	2	3	2	3	1	6	4	4	4	1	1	2	4	6	2	**45**	Good
5b	G5 (C5)	4	9	4	9	2	8	4	12	16	4	3	8	16	24	2	**125**	Fair

Appendix D - Cost Estimate

Construction costs for rehabilitation works are provided and were informed by case studies of similar works. Costs are typically built around a lineal metre rate and then multiplied by the length of rehabilitation required at a particular location. This approach enables Council to easily revise the cost of rehabilitation if the extent of works increases or works need adjustment to fit within an available budget. There are some exceptions to this arrangement, for example plunge pools.

For the purpose of preparing cost estimates, a number of rehabilitation types have been created and the assumed materials and effort required for each type are explained in section 5.3. These measures have informed cost estimates detailed within this section and costs included within the Creek Rehabilitation and Management Plan provided in section 9.

Treatment Cost Estimate for Zone 1a, 1b, 1c, 1d & 1e

Treatment Type	Item / Unit	Cost per Unit	Total
1. LWD	8 x 20 lin. m		
2. J-Hook	1 x 5 m3		
3. Rock Chute	7 x 7.5 m3		
4. Cross Vane	5 x 10 m3		
5. Check Dam	14 x 6 m3		
6. Weed Control & Reveg.	14300 m2		

Treatment Cost Estimate for Zones 2a, 2b & 3

1. LWD	16 x 20 lin. m		
2. J-Hook	4 x 5 m3		
4. Cross Vane	4 x 10 m3		
5. Check Dam	2 x 5 m3		
6. Weed Control & Reveg.	14620 m2		

Treatment Cost Estimate for Zones 4, 5a, 5b

1. LWD	5 x 20 lin. m		
3. Rock Chute	1 x 7.5 m3		
6. Weed Control & Reveg.	15020 m2		

Appendix E - Flora Inventory

Botanical name	Common name
Acacia complanata	flatstem wattle
Acacia concurrens	black wattle
Acacia disparrima subsp. disparrima	hickory wattle
*Acacia farnesiana**	prickly acacia
Acacia irrorata	green wattle
Acacia leiocarpa	black wattle
Acacia maidenii	maidens wattle
Acacia penninervis	veined wattle
Adiantum diaphanum	filmy maidenhair
Adiantum hispidulum	rough maidenhair
*Ageratum houstonianum**	billygoat weed
Alectryon tomentosum	hairy alectryon
Allocasuarina littoralis	black she-oak
Allocasuarina torulosa	forest oak
Alphitonia excelsa	red ash
Alpinia caerulea (p)	native ginger
Alstonia stricta	bitter bark
*Asparagus aethiopicus**	ground asparagus
*Asparagus plumosus**	climbing asparagus
*Axonopus virginicus**	whiskey grass
*Baccharis halimifolia**	groundsel
*Bidens pilosa**	farmers's friends
Bolboschoenus fluviatilis	club-rush
Breynia oblongifolia	coffeebush
*Bryophyllum delagoense**	mother of millions
Bursaria spinosa	blackthorn
*Callisia fragrans**	inch plant
Calochlaena dubia	rainbow fern
*Canna indica**	canna lily
Capillipedium spicigerum	scented-top
*Capsicum annuum**	chilli bush
Carissa ovata	currantbush
Castanospermum australe (p)	blackbean
*Celtis sinensis**	hackberry
Centella asiatica	pennywort
Cheilanthes sieberi	mulga fern
*Chloris gayana**	rhodes grass
Christella dentata	binung
*Cirsium vulgare**	spear thistle
Clerodendum floribundum	lollybush

*Colocasia esculenta**	taro
Commelina cyaneae	scurvy weed
*Conyza bonariensis**	fleabane
Corymbia citriodora	spotted gum
Corymbia intermedia	pink bloodwood
Corymbia maculata	spotted gum
*Crassocephalum crepidioides**	thickhead
Cryptocarya sp. Worlds End Pocket	totem pole
Cupaniopsis parvifolia	small-leaved tuckeroo
Cymbopogon refractus	barbed-wire grass
Cyperus haspan	cyperus
Cyperus polystachyos	bunchy sedge
*Desmodium intortum**	green-leaved desmodium
Desmodium rhytidophyllum	trefoil
Dianella caerulea	flax lily
Dodonaea triangularis	hopbush
Dodonaea triquetra	hopbush
*Duranta repens**	duranta
*Echinochloa crus-gallii**	barnyard grass
Eclipta prostrata	eclipta
Eleocharis acuta	spike-rush
Entolasia stricta	wiry panic
Eucalyptus carnea	white mahogany
Eucalyptus crebra	narrow-leaved ironbark
Eucalyptus moluccana	gum-topped box
Eucalyptus propinqua	small-fruited grey gum
Eucalyptus tereticornis	Qld blue gum
*Eucalyptus torrelliana**	cadaghi
Eustrephus latifolius	wombat berry
*Ficus elastica**	rubber tree
Ficus rubiginosa	Port Jackson fig
Flindersia australis	teak
Flindersia collina	leopard ash
Gahnia aspera	saw-sedge
Glochidion ferdinandi	cheese tree
Glycine tabacina	slender glycine
*Gomphocarpus physocarpus**	balloon cotton bush
Hardenbergia violacea	false sarsparilla
Hygrophila angustifolia	hygrophila
*Hypochaeris radicata**	flatweed
Imperata cylindrica	blady grass
Indigofera australis	indigo
*Jacaranda mimosifolia**	jacaranda
Jacksonia scoparia	dogwood
Jagera pseudorhus	foambark
Juncus planifolius	sedge
Juncus polyanthemus	sedge

*Lantana camara**	lantana
*Lantana montevidensis**	creeping lantana
Leersia hexandra	ricegrass
*Leucaena leucocephala**	lead tree
Leucopogon lanceolatus	beard heath
Leucopogon leptospermoides	beard heath
Lomandra confertifolia subsp. pallida	mat-rush
Lomandra hystrix	stream mat-rush
Lomandra longifolia	mat-rush
*Lonicera japonica**	Japanese honeysuckle
Lophostemon confertus	brush box
Lophostemon suaveolens	swamp box
Macadamia tetraphylla (p)	Queensland nut
Maclura cochinchinensis	cockspur
Mallotus philippensis	red kamala
Melaleuca quinquenervia	broad-leaved paperbark
Melaleuca viminalis	river bottlebrush
Melia azedarach	white cedar
*Melinis repens**	red natal grass
Microlaena stipoides	weeping grass
*Monstera deliciosa**	fruit salad plant
*Morus alba**	mulberry
*Murraya paniculata**	mock orange
Myrsine variabilis	muttonwood
*Neonotonia wightii**	glycine
Nymphaea indica	water snowflake
*Ochna serrulata**	ochna
Oplismenus aemulus	basket grass
*Opuntia sp.**	prickly pear
Ottelia ovalifolia	ottelia
Oxalis chnoodes	oxalis
Pandorea sp. Ipswich	bower vine
*Panicum maximum**	guinea grass
Parsonsia straminea	monkey rope
*Paspalum mandiocanum**	broad-leaved paspalum
*Passiflora suberosa**	corky passionfruit
*Pennisetum clandestinum**	kikuyuy
Persicaria attenuata	smartweed
Persicaria decipiens	smartweed
Persoonia sericea	geebung
Petalostigma pubescens	quinine bush
*Phytolacca octandra**	inkweed
Pittosporum revolutum	hairy pittosporum
*Plantago lanceolata**	plantain
Plectranthus graveolens	plectranthus
Poa cheellii	tussock grass
Polyscia elegans	celerywood

Potamageton octandrus	pondweed
Pratia concolor	poison pratia
Pratia purpurascens	whiteroot
Psydrax odorata	sweet Susie
*Ricinis communis**	castor oil plant
Rubus parviflorus	native raspberry
*Rumex crispus**	curled dock
*Schefflera actinophylla**	umbrella tree
*Schinus terebinthifolius**	pepper tree
*Scoparia dulcis**	scoparia
*Senecio madagascariensis**	fireweed
*Senna pendula var. glabrata**	winter senna
*Sida rhombifolia**	paddy's lucerne
Sigesbaeckia orientalis	Indian weed
*Solanum americanum**	glossy nightshade
*Solanum mauritianum**	wild tobacco
*Solanum nigrum**	blackberry nightshade
*Solanum seaforthianum**	climbing nightshade
Solanum stelligerum	devil's needles
*Sonchus oleraceus**	milk thistle
*Sorghum halepense**	jonson grass
*Sphagneticola trilobata**	Singapore daisy
*Syagrus romanzoffiana**	cocos palm
Syncarpia glomulifera	turpentine
*Tagetes minuta**	stinking roger
Themeda australis	kangaroo grass
*Thunbergia alata**	black-eyed susan*
*Tradescantia albiflora**	trad
Trema tomentosa	native peach
Triglochin striata	water ribbons
Trophis scandens	burny vine
Typha sp.	cumbungi
*Verbena bonariensis**	purpletop
Wikstroemia indica	tie bush
*Xanthium occidentale**	noogoora burr

*Introduced species
(p) planted tree

Appendix F – Project Examples

Brunswick River, Mullumbimby: Pre-restoration works 9-2-09
Extreme erosion, scouring, slumping, bank loss

Post restoration works 27-10-10: Bank toe reinforced with LWD & rock scallops. Mangroves & reveg establishing behind structure.

12-1-12: LWD & rock structure stabilised bank, plants established

12-1-12: bank erosion halted. Riparian reveg established

Currumbin Creek: Pre-restoration
Extreme erosion, scouring, slumping, bank loss

Currumbin Creek: Post restoration works Bank toe reinforced with LWD & rock scallops. Reveg establishing behind structure.

Springfield Lakes Estate, Ipswich: Plunge Pool construction

Springfield Lakes Estate, Ipswich: Rock Chute construction

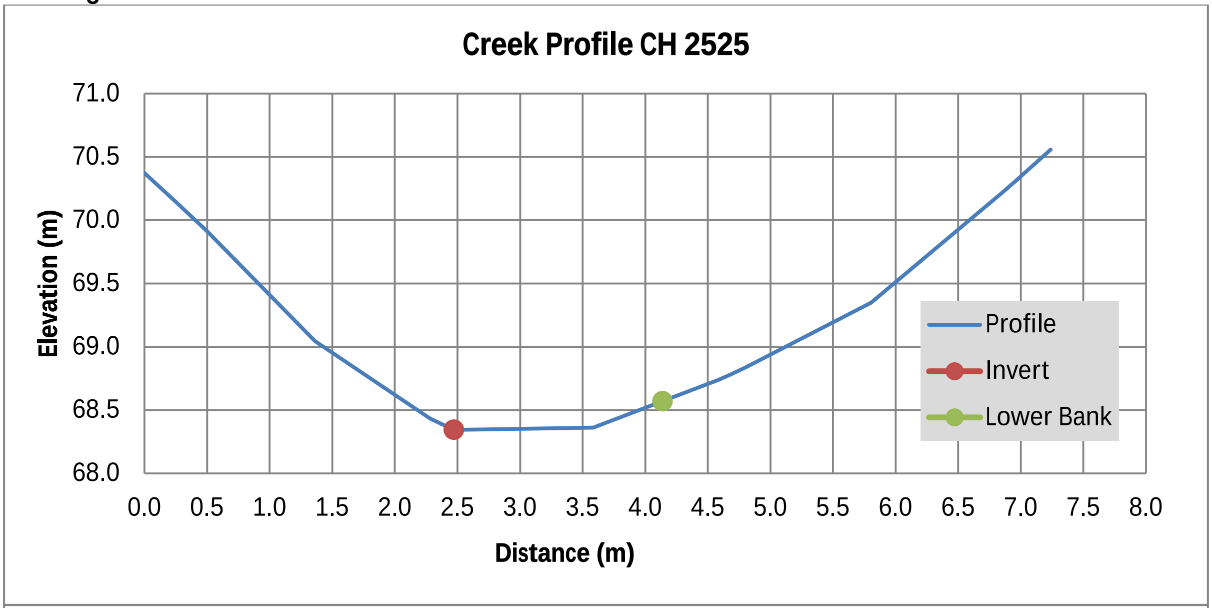
Appendix G - Model Results

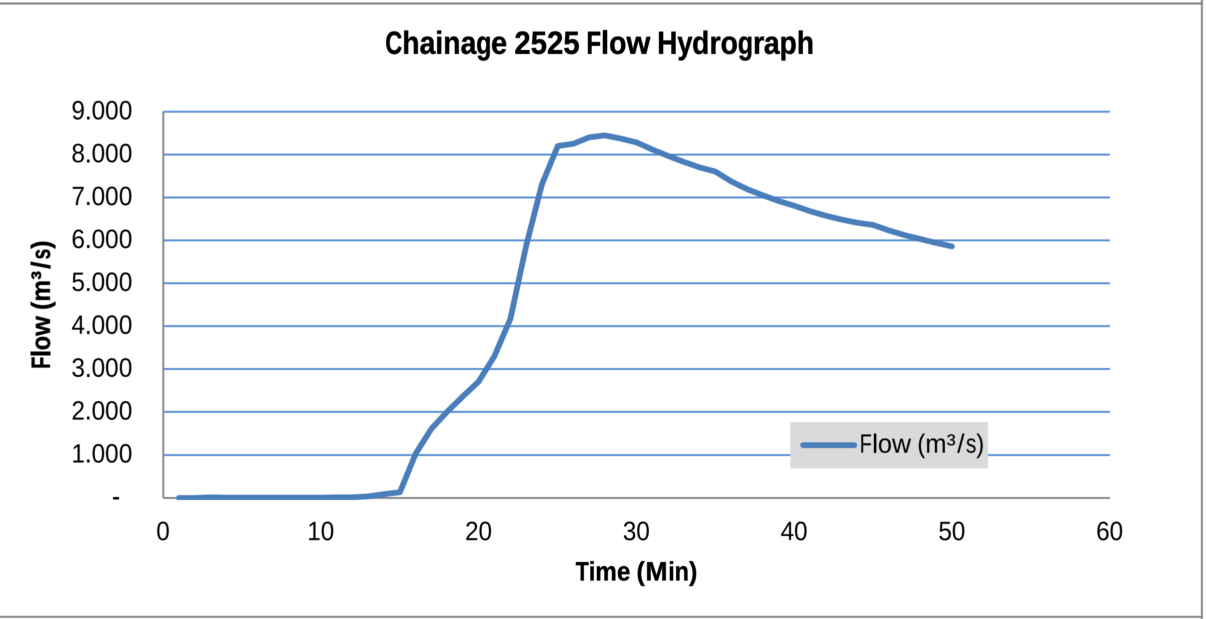
The following pages contain the results of the two-dimensional XP-SWMM modelling. Results are presented for six selected locations (refer subcatchment plan for chainage locations), and at each of these locations, the following are presented:

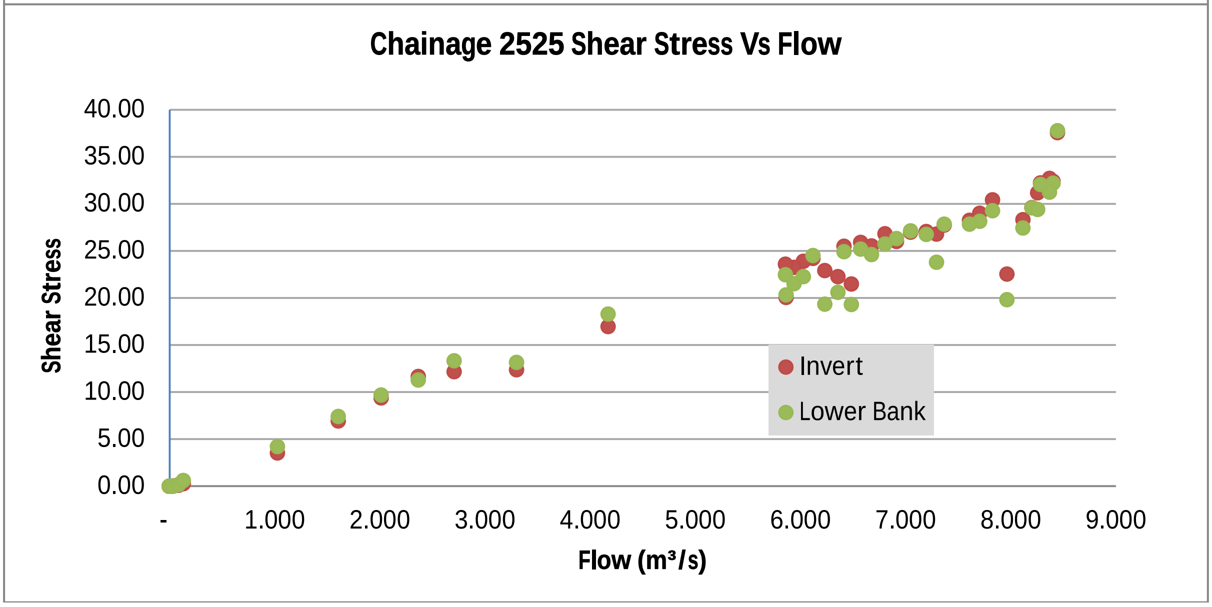
1. Cross sectional profile (based on LIDAR data). On the cross section, a red and green dot mark the location of the channel invert, and a nominal lower bank location.
2. A flow hydrograph, based on a synthetic 100 year average recurrence interval, 60minute storm
3. Relationship between shear stress and flow – shown for the invert location (red dots) and lower bank location (green dots) as indicated on the cross section.
4. Relationship between water depth and flow (stage discharge).
5. Relationship between velocity and flow.

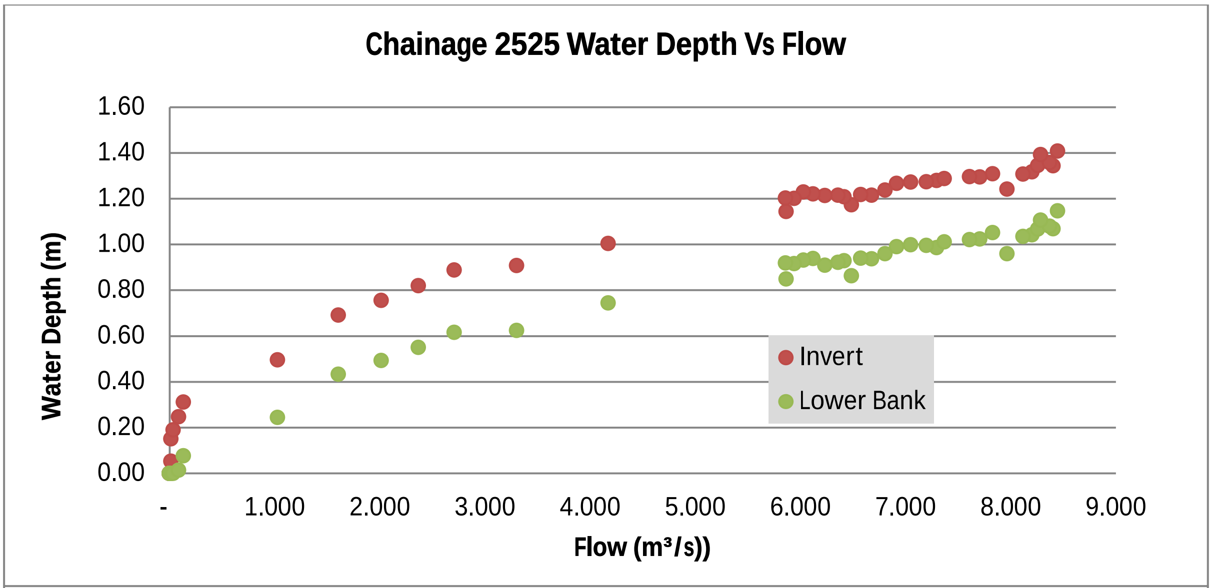
Although the peak flow rate should be used with caution due to the lack of calibration data, far greater confidence can be placed on the relative relationships between flow rates and shear stress, depth and velocity as these relationships are based on channel hydraulics.

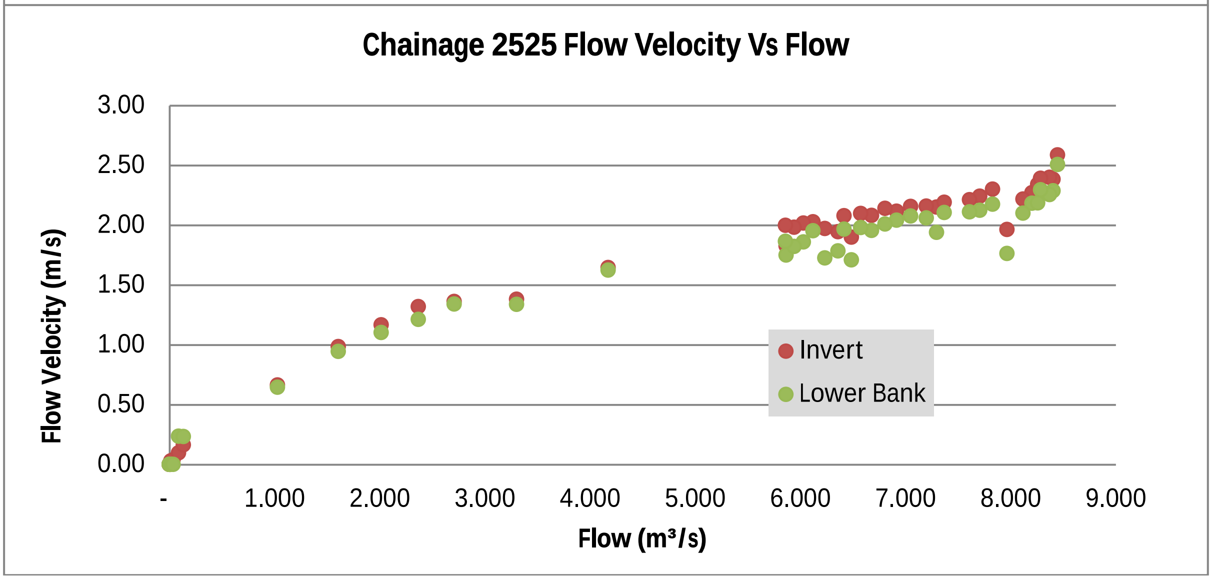
Chainage 2525 Results



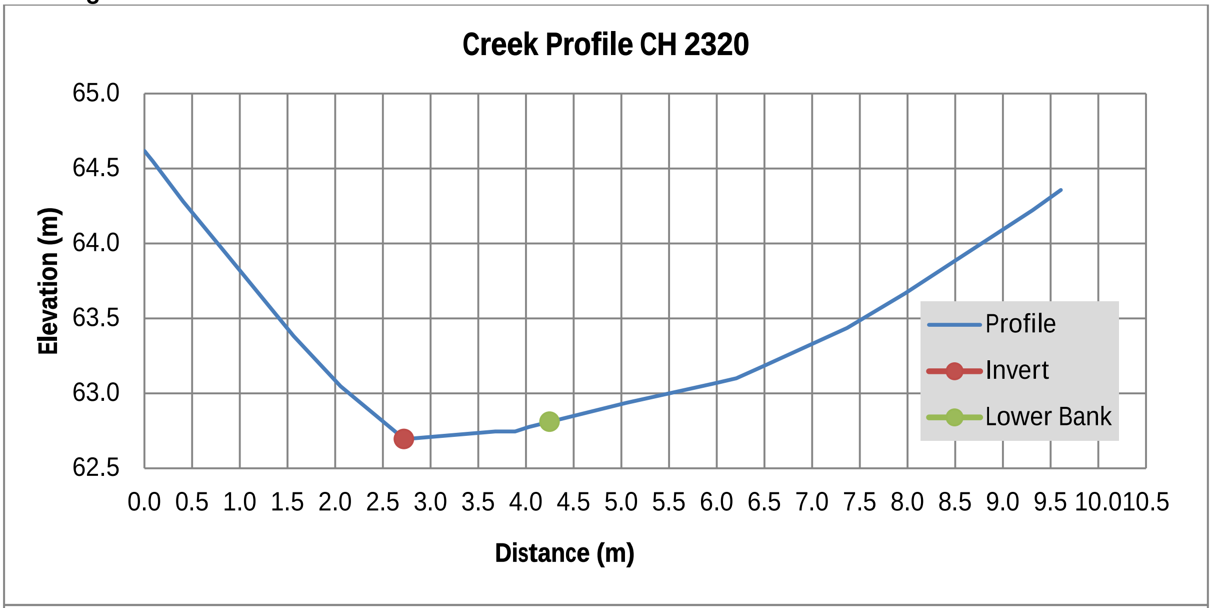


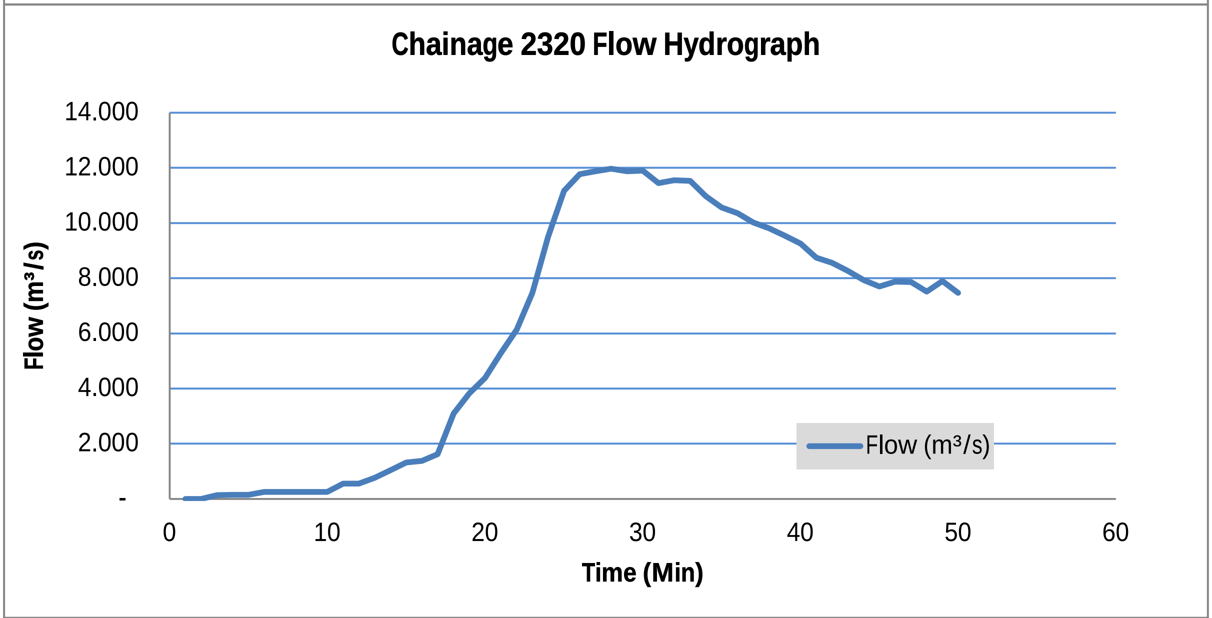


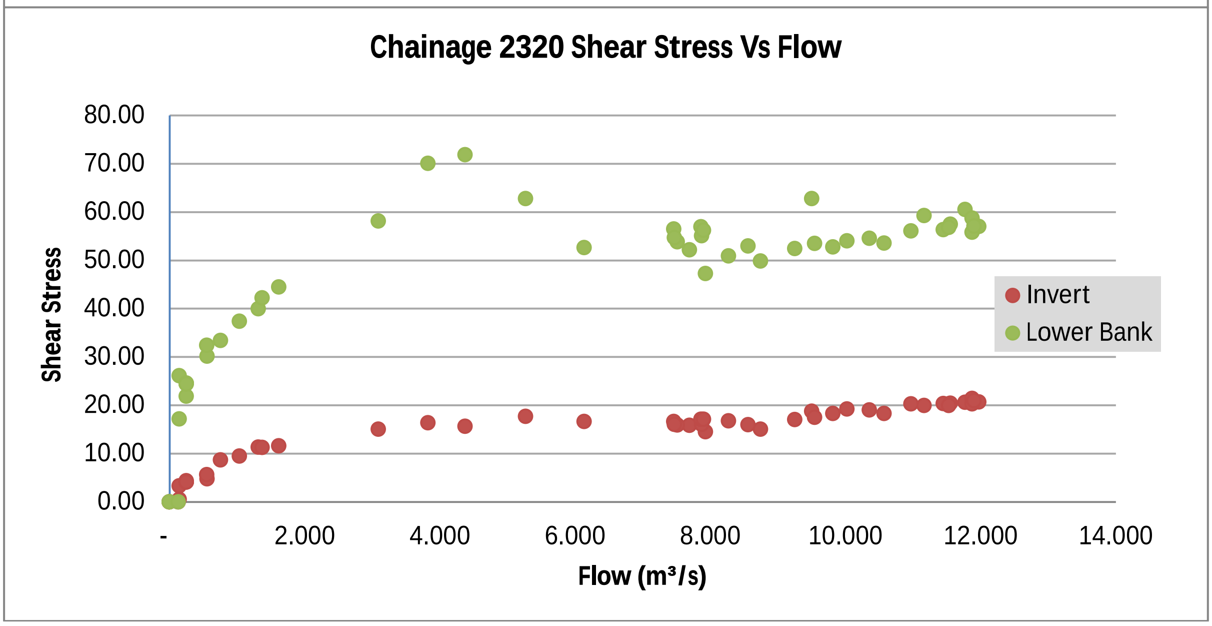

Chainage 2525 Water Depth Vs Flow
Water Depth (m)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
Flow (m³/s))
Invert
Lower Bank

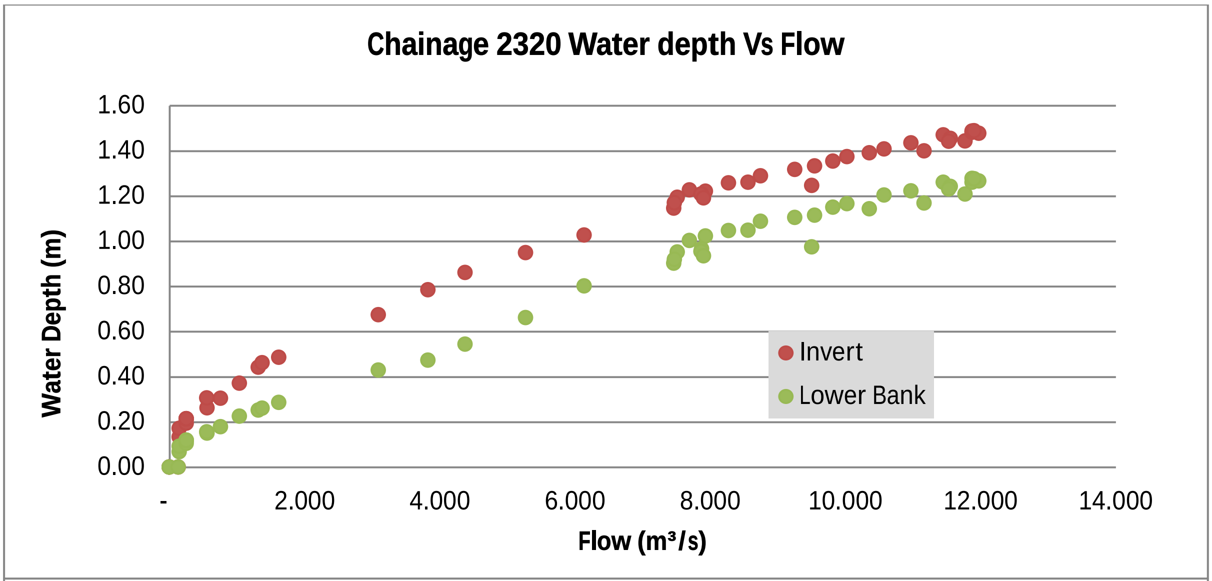

Chainage 2525 Flow Velocity Vs Flow
Flow Velocity (m/s)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
Flow (m³/s)
Invert
Lower Bank

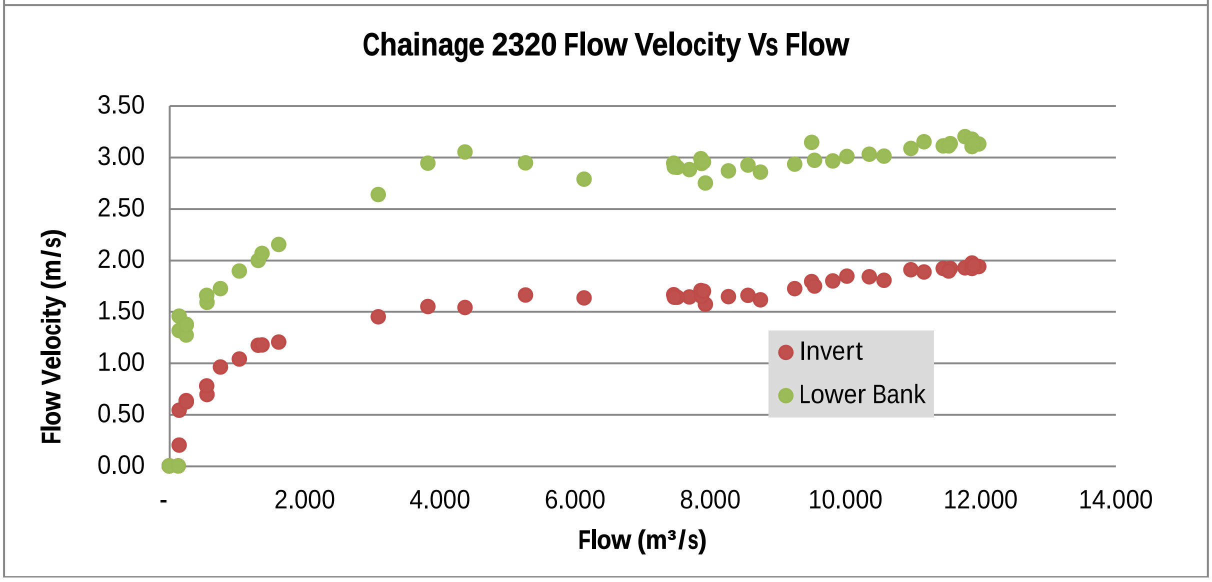
Chainage 2320 Results



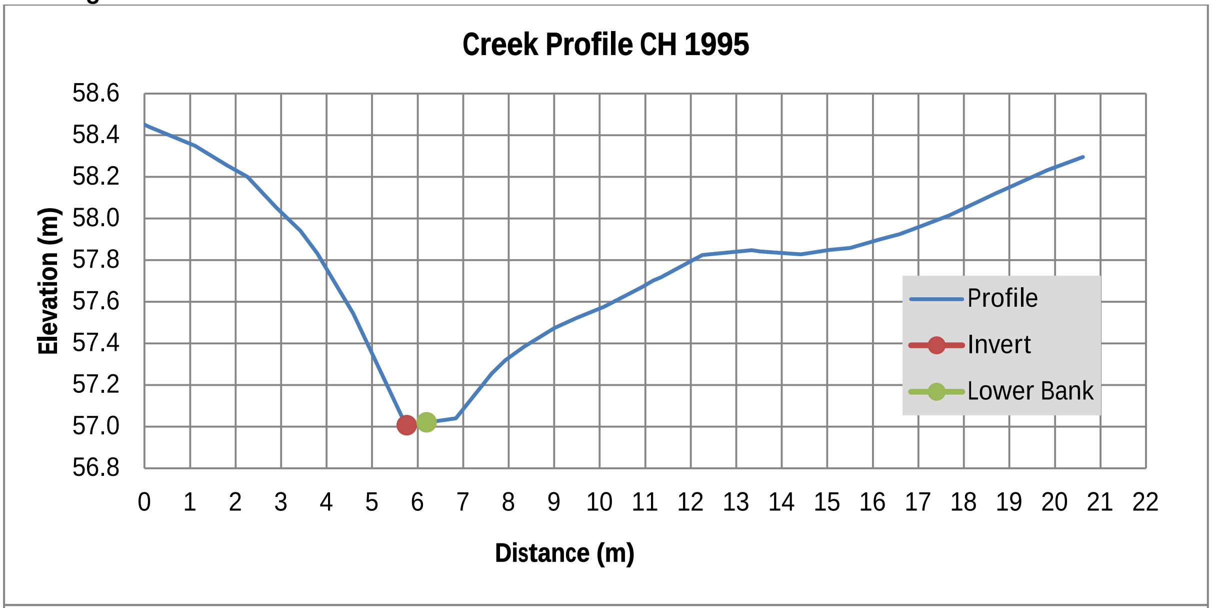


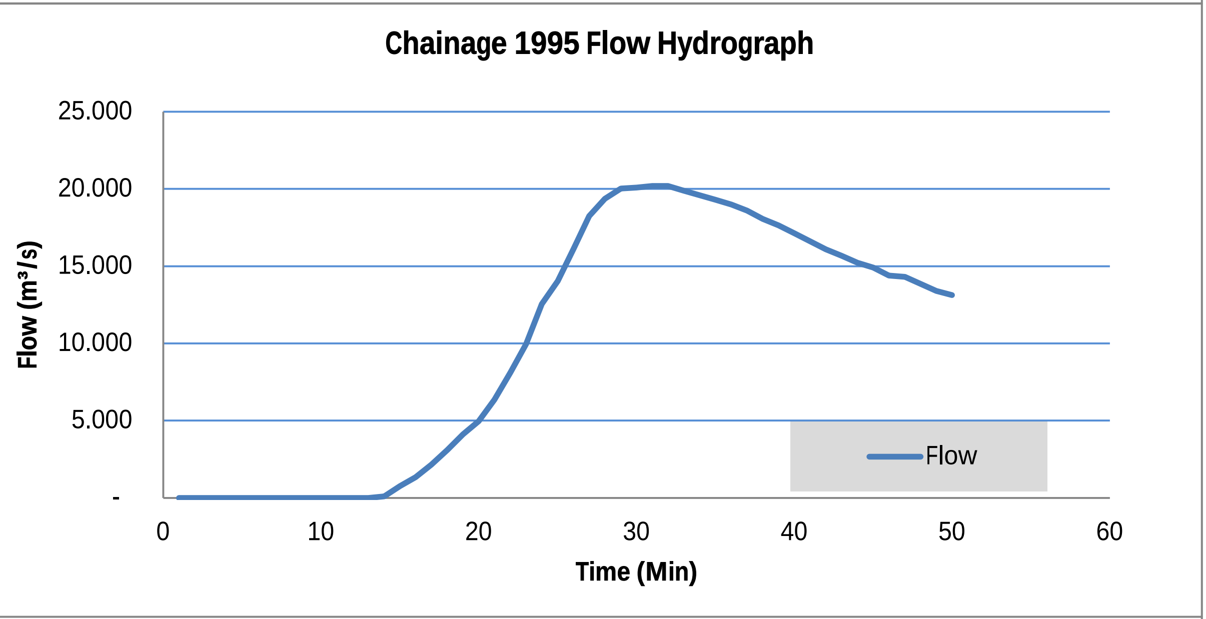


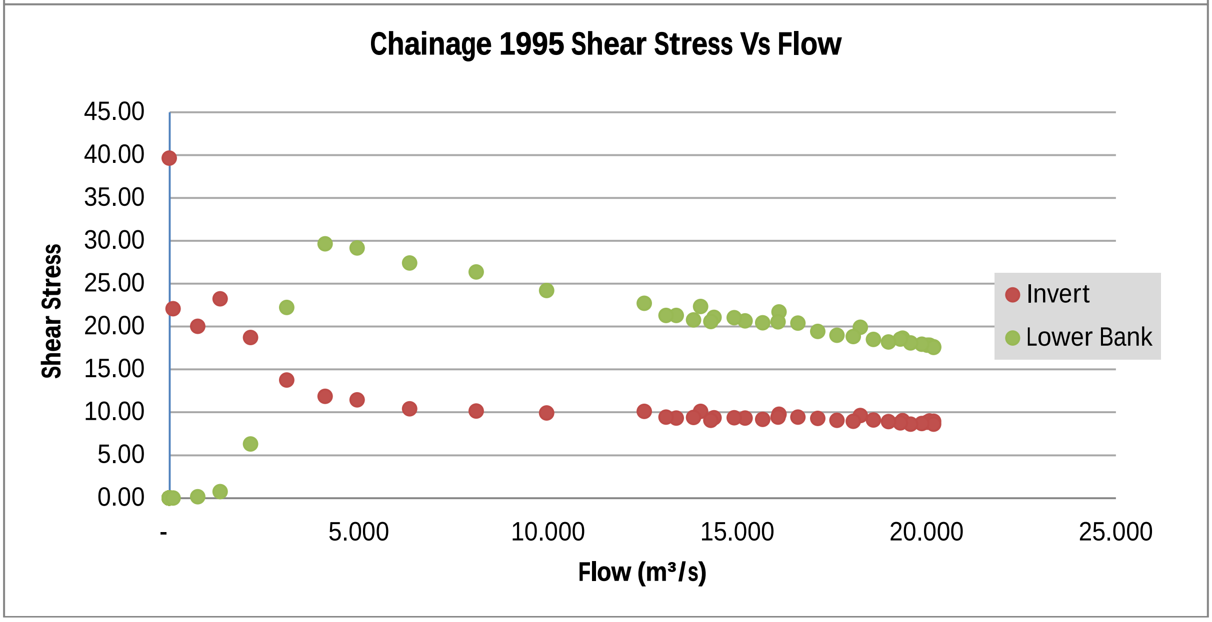

Chainage 2320 Water depth Vs Flow
Water Depth (m)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-
2.000
4.000
6.000
8.000
10.000
12.000
14.000
Flow (m³/s)
Invert
Lower Bank

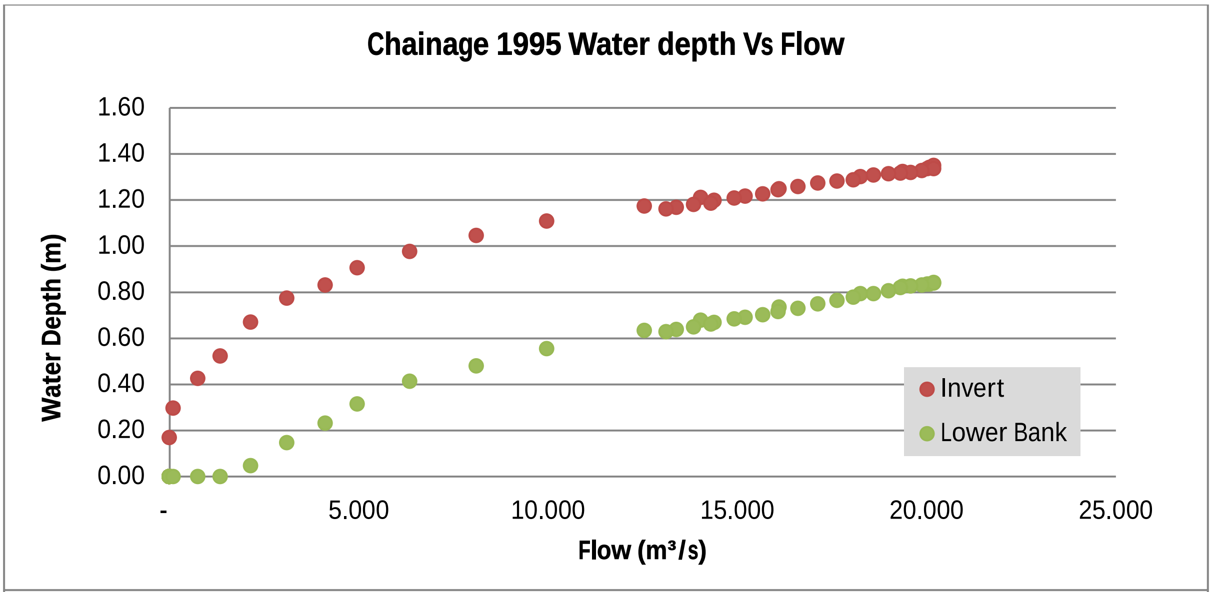

Chainage 2320 Flow Velocity Vs Flow
Flow Velocity (m/s)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-
2.000
4.000
6.000
8.000
10.000
12.000
14.000
Flow (m³/s)
Invert
Lower Bank

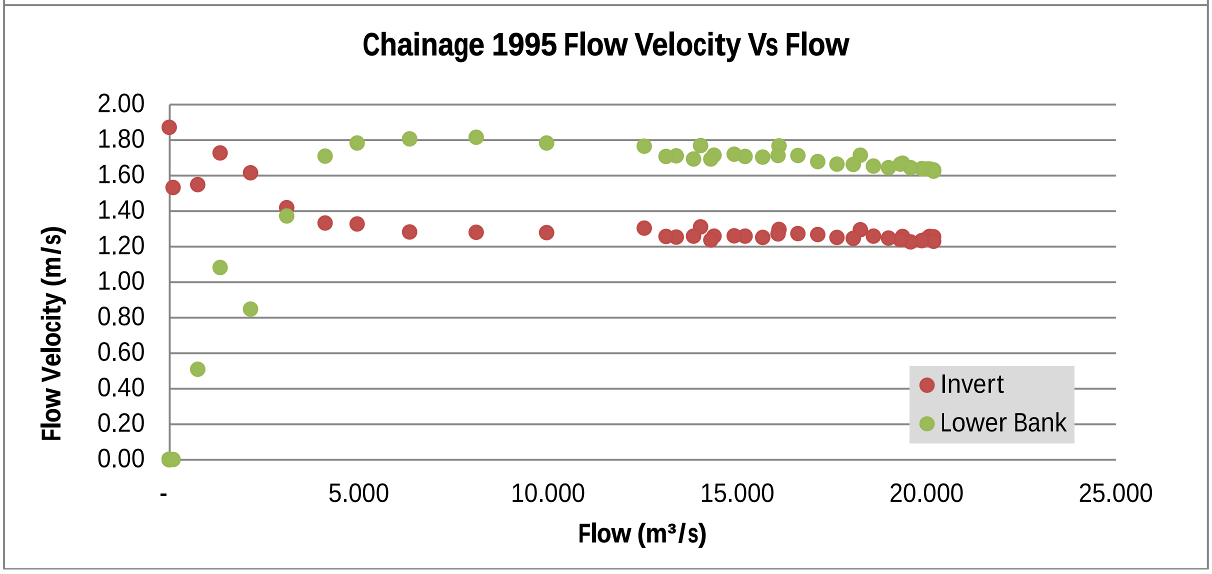
Chainage 1995 Results



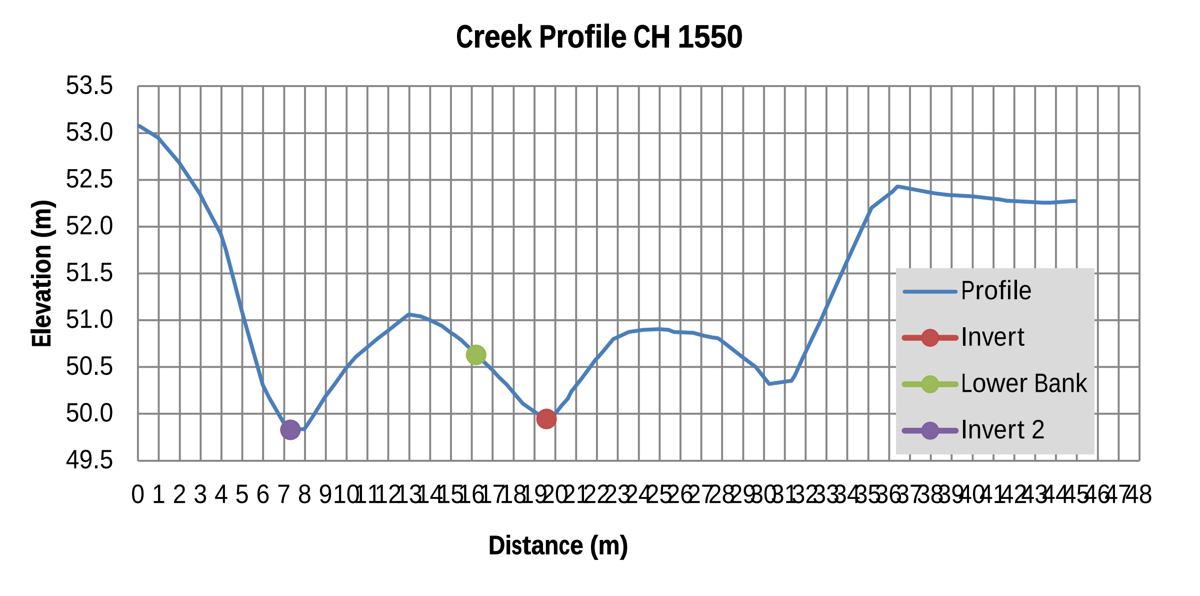


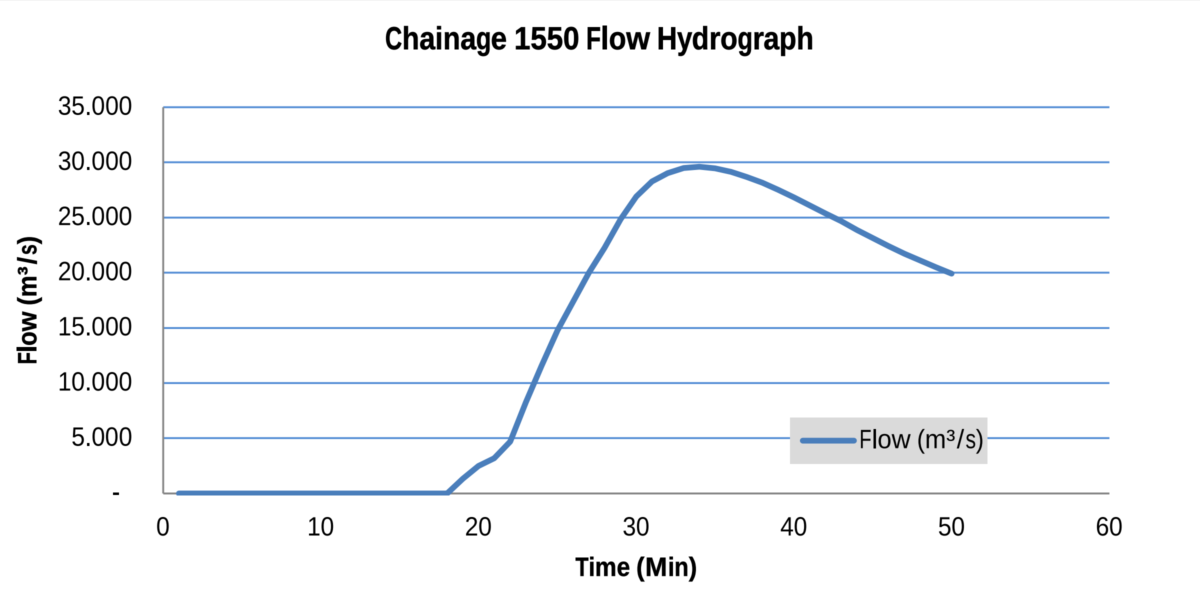


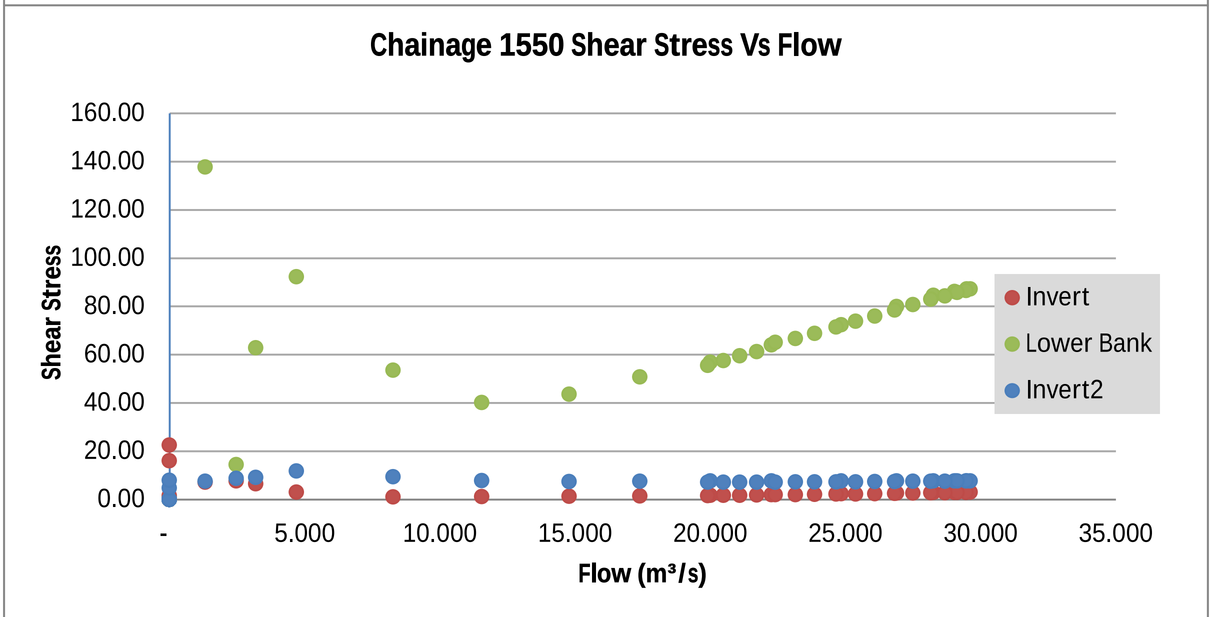

Chainage 1995 Water depth Vs Flow
Water Depth (m)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-
5.000
10.000
15.000
20.000
25.000
Flow (m³/s)
Invert
Lower Bank

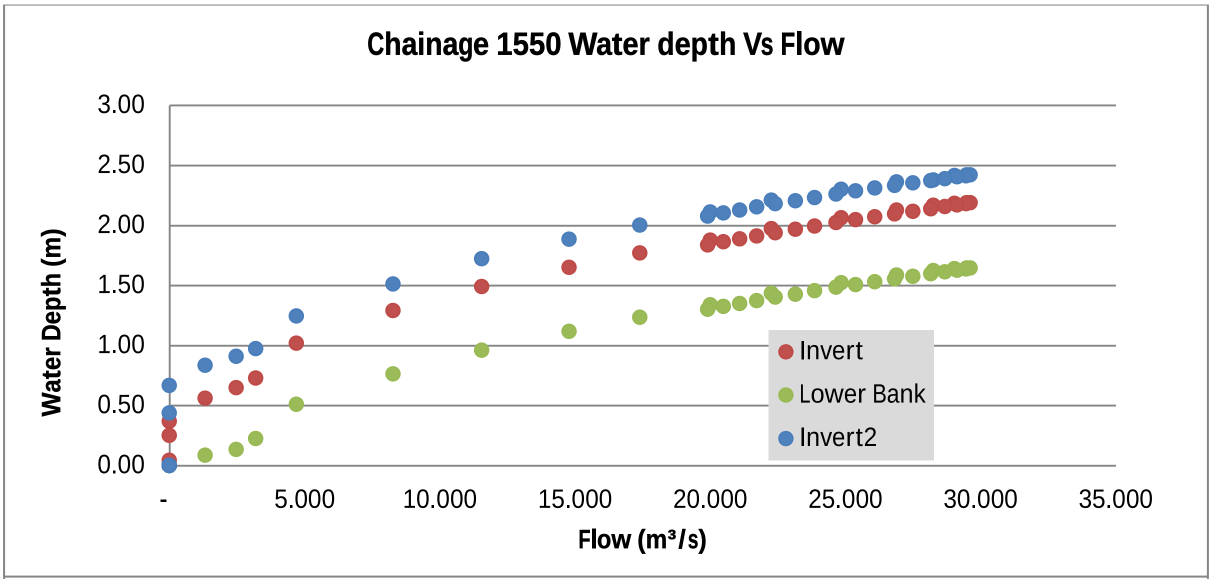

Chainage 1995 Flow Velocity Vs Flow
Flow Velocity (m/s)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-
5.000
10.000
15.000
20.000
25.000
Flow (m³/s)
Invert
Lower Bank

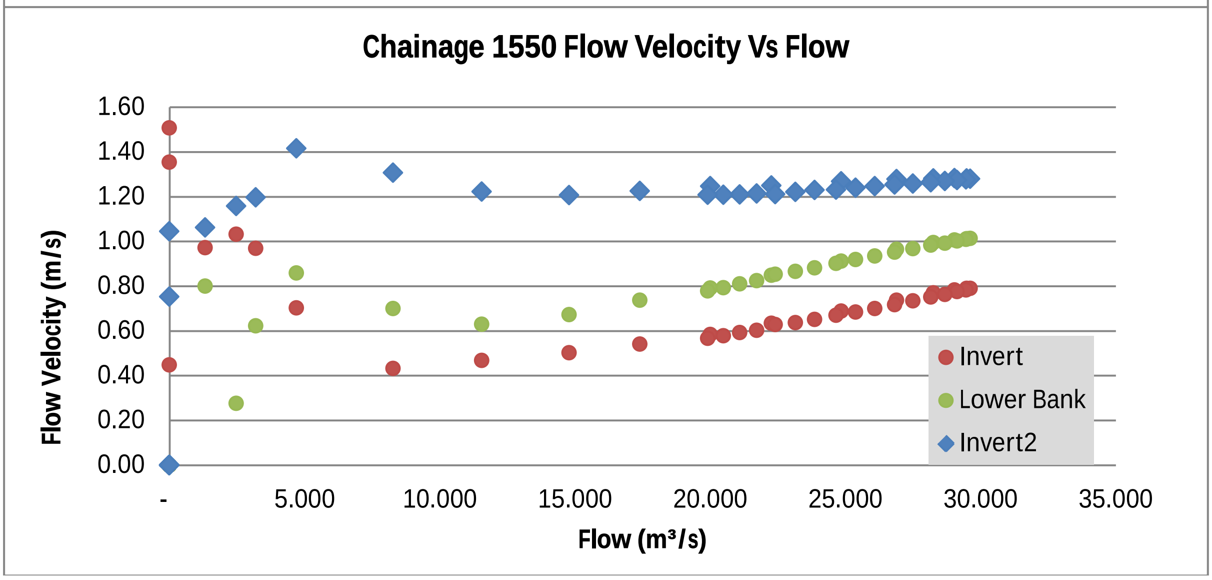
Chainage 1550 Results



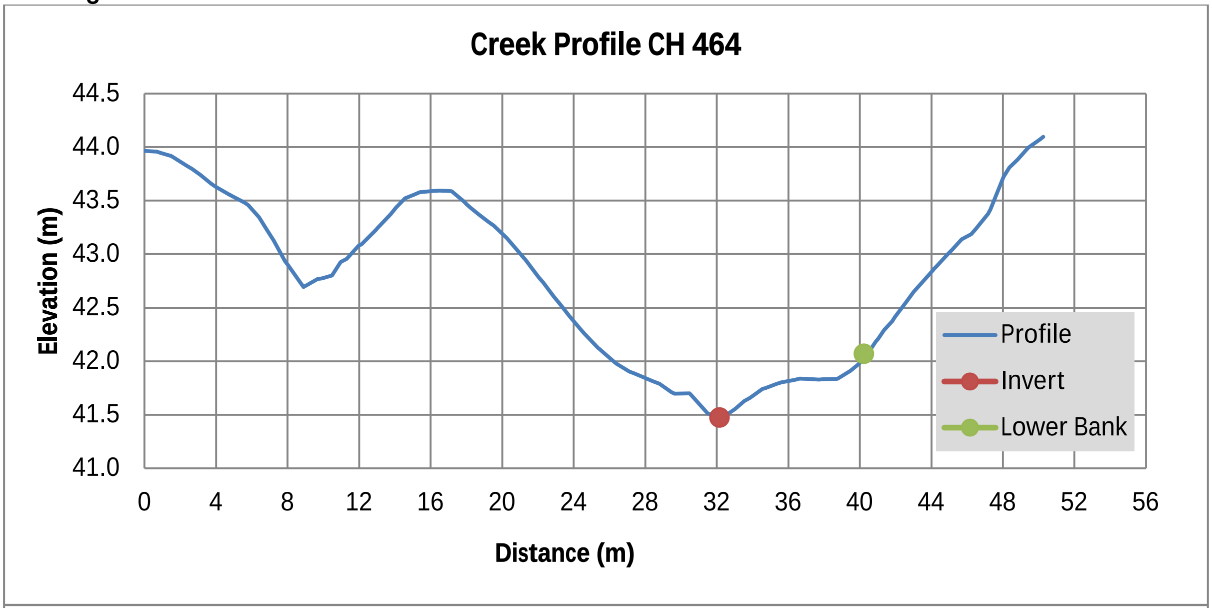


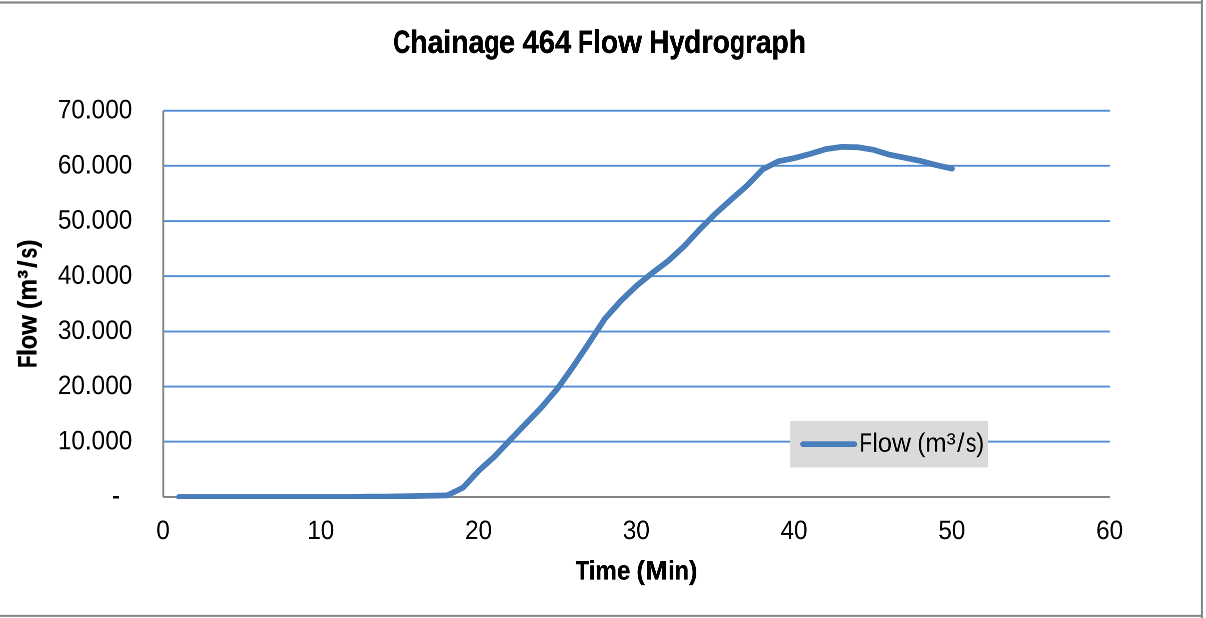


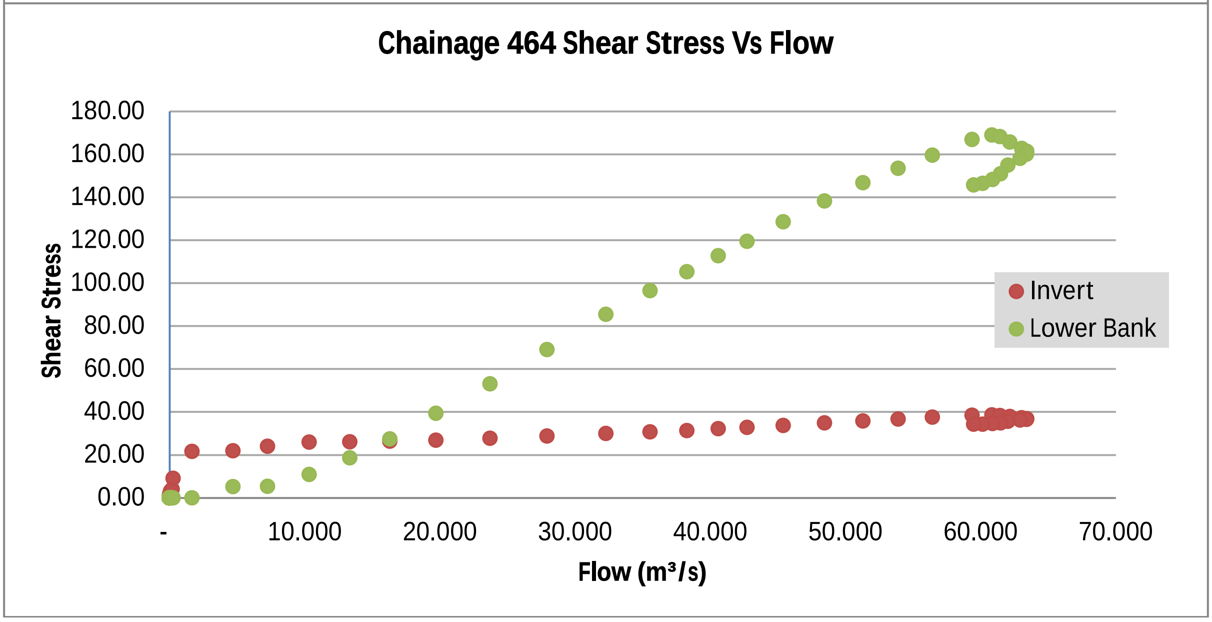

Chainage 1550 Water depth Vs Flow
Water Depth (m)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-
5.000
10.000
15.000
20.000
25.000
30.000
35.000
Flow (m³/s)
Invert
Lower Bank
Invert2

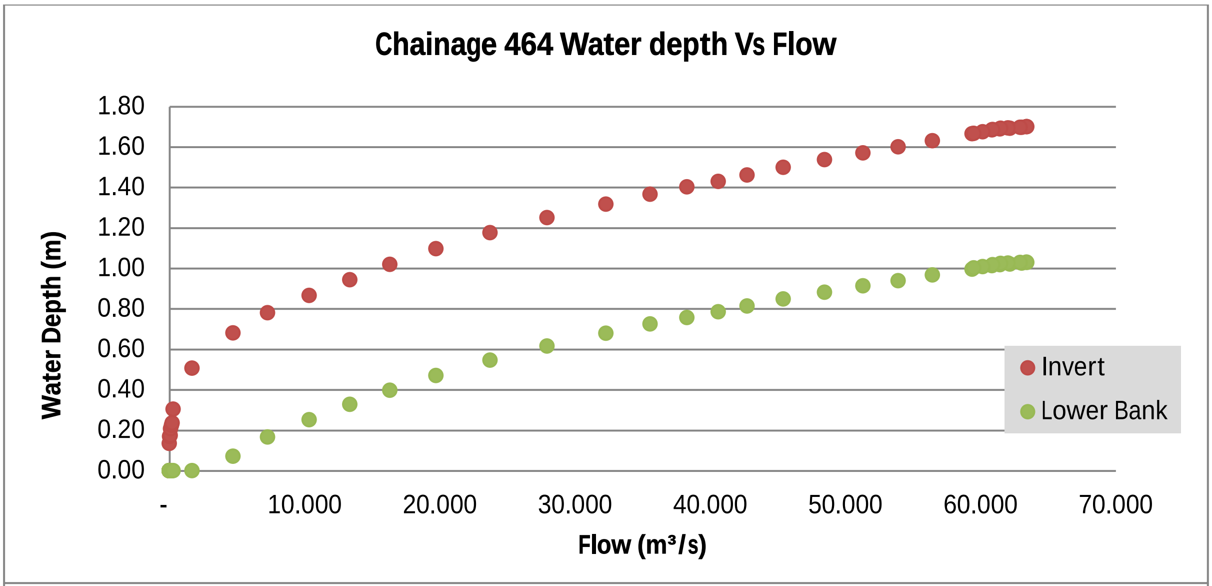

Chainage 1550 Flow Velocity Vs Flow
Flow Velocity (m/s)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-
5.000
10.000
15.000
20.000
25.000
30.000
35.000
Flow (m³/s)
Invert
Lower Bank
Invert2

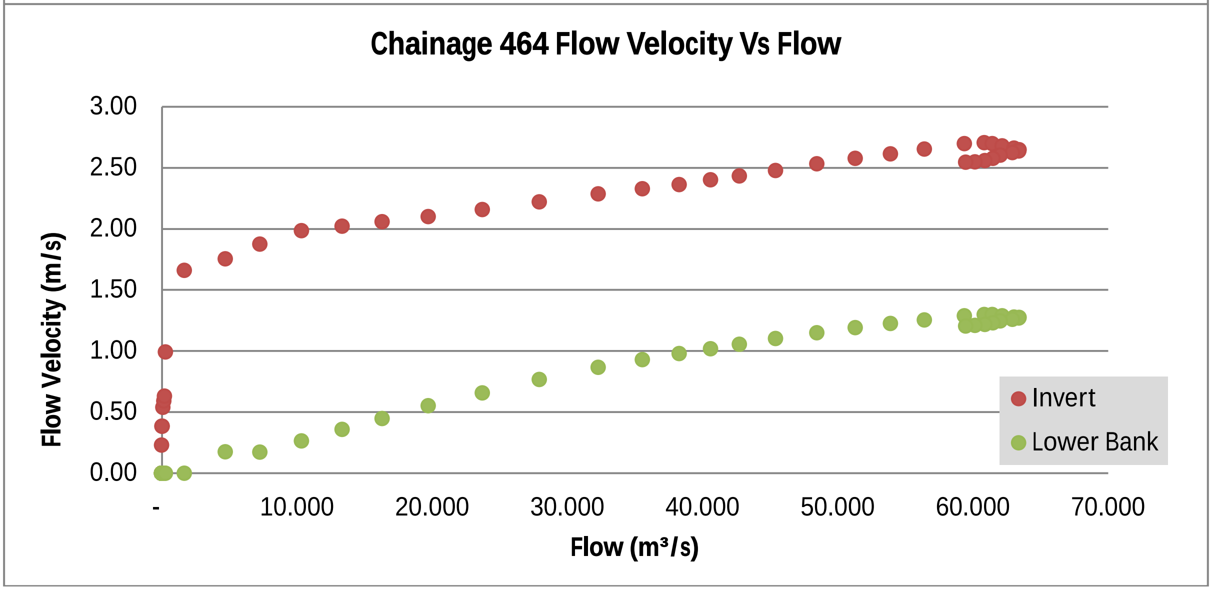
Chainage 464 Results



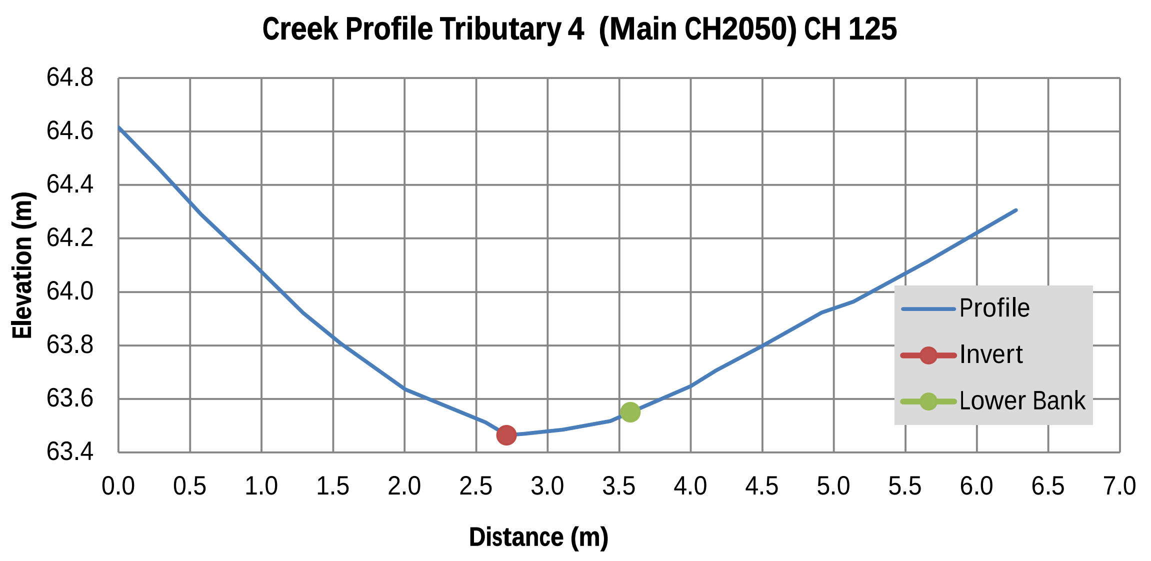


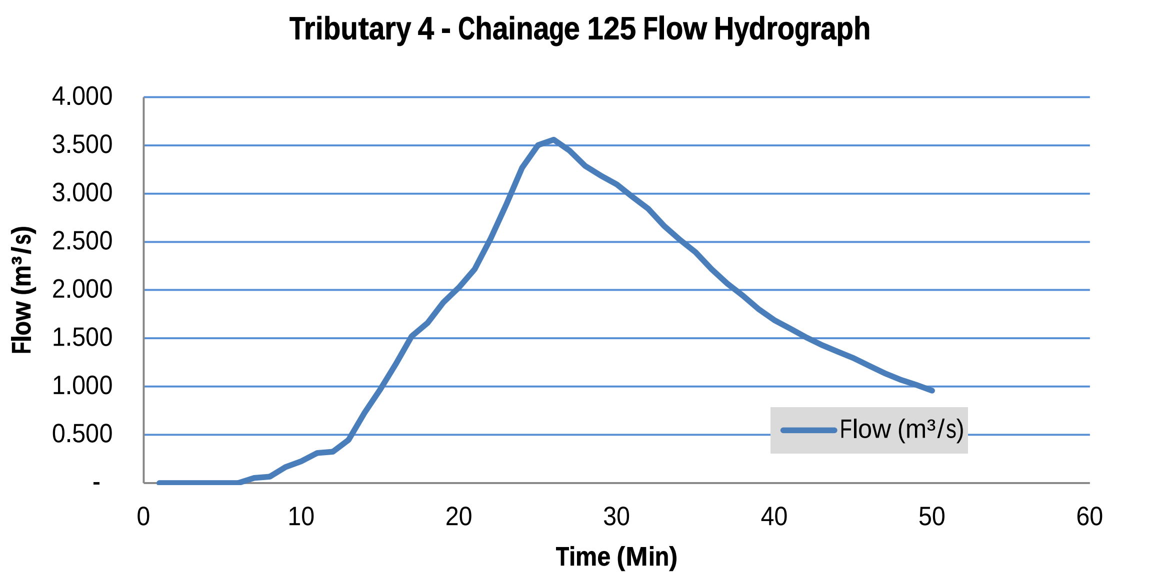


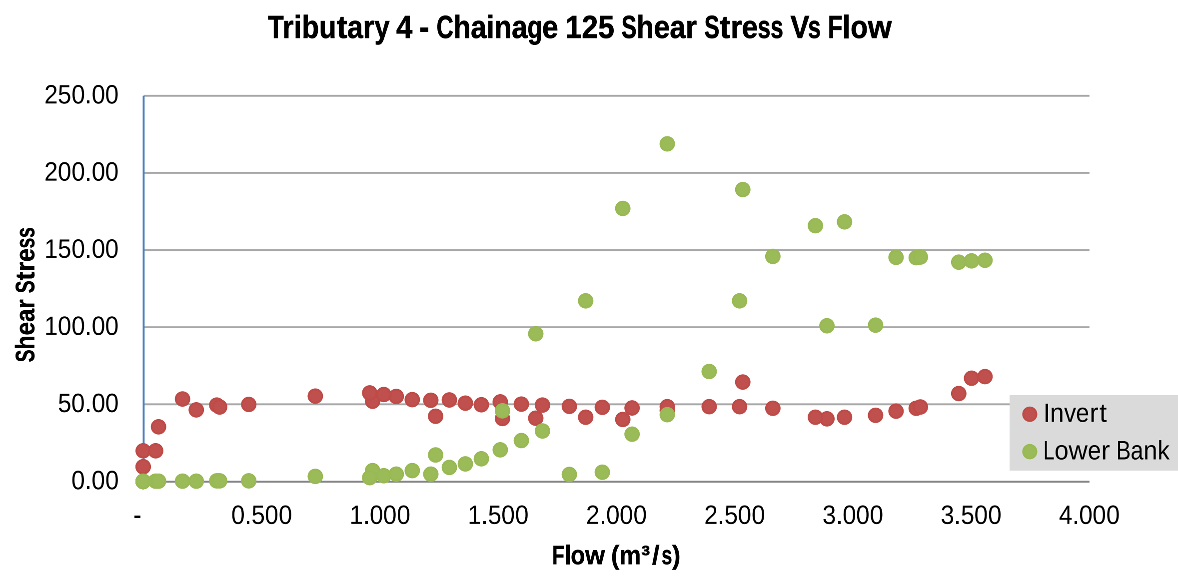

Chainage 464 Water depth Vs Flow
Water Depth (m)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-
10.000
20.000
30.000
40.000
50.000
60.000
70.000
Flow (m³/s)
Invert
Lower Bank

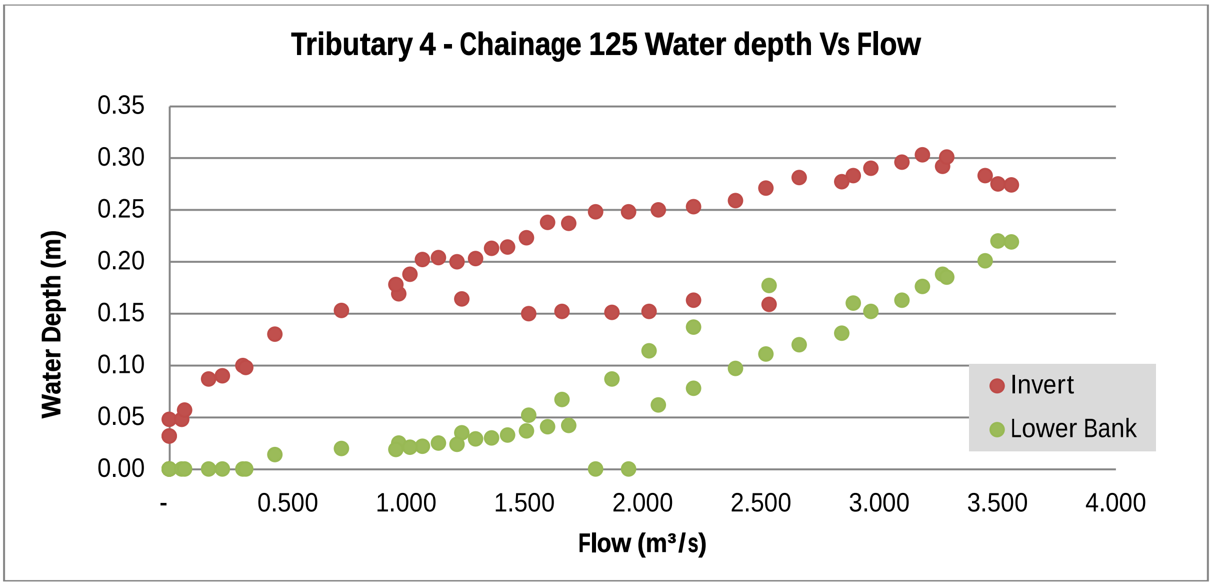

Chainage 464 Flow Velocity Vs Flow
Flow Velocity (m/s)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-
10.000
20.000
30.000
40.000
50.000
60.000
70.000
Flow (m³/s)
Invert
Lower Bank

Chainage Tributary 4 (Main creek discharge CH2050) CH 125

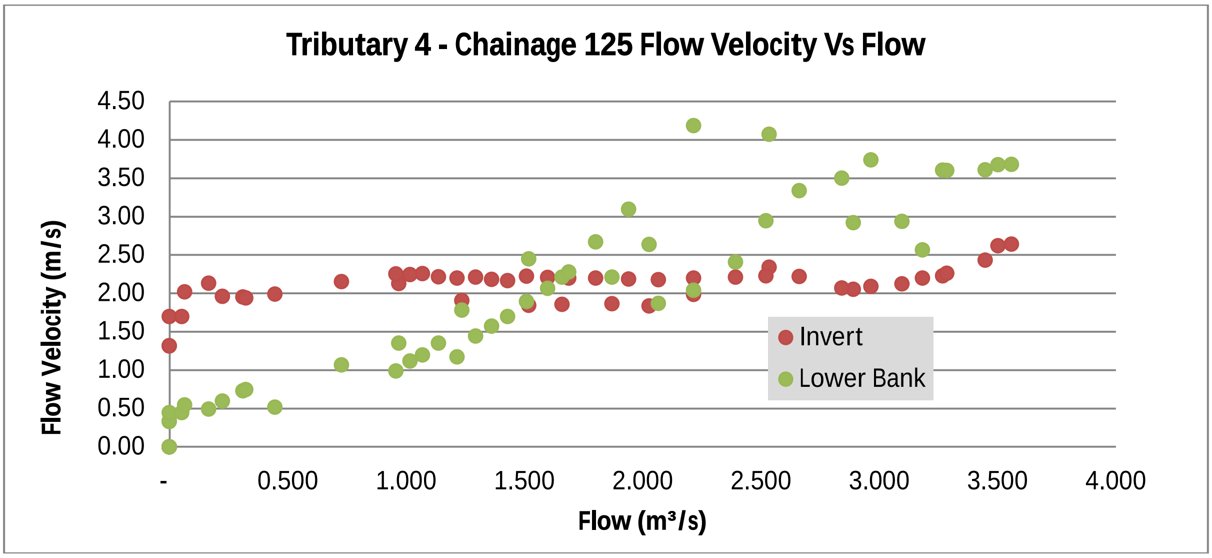




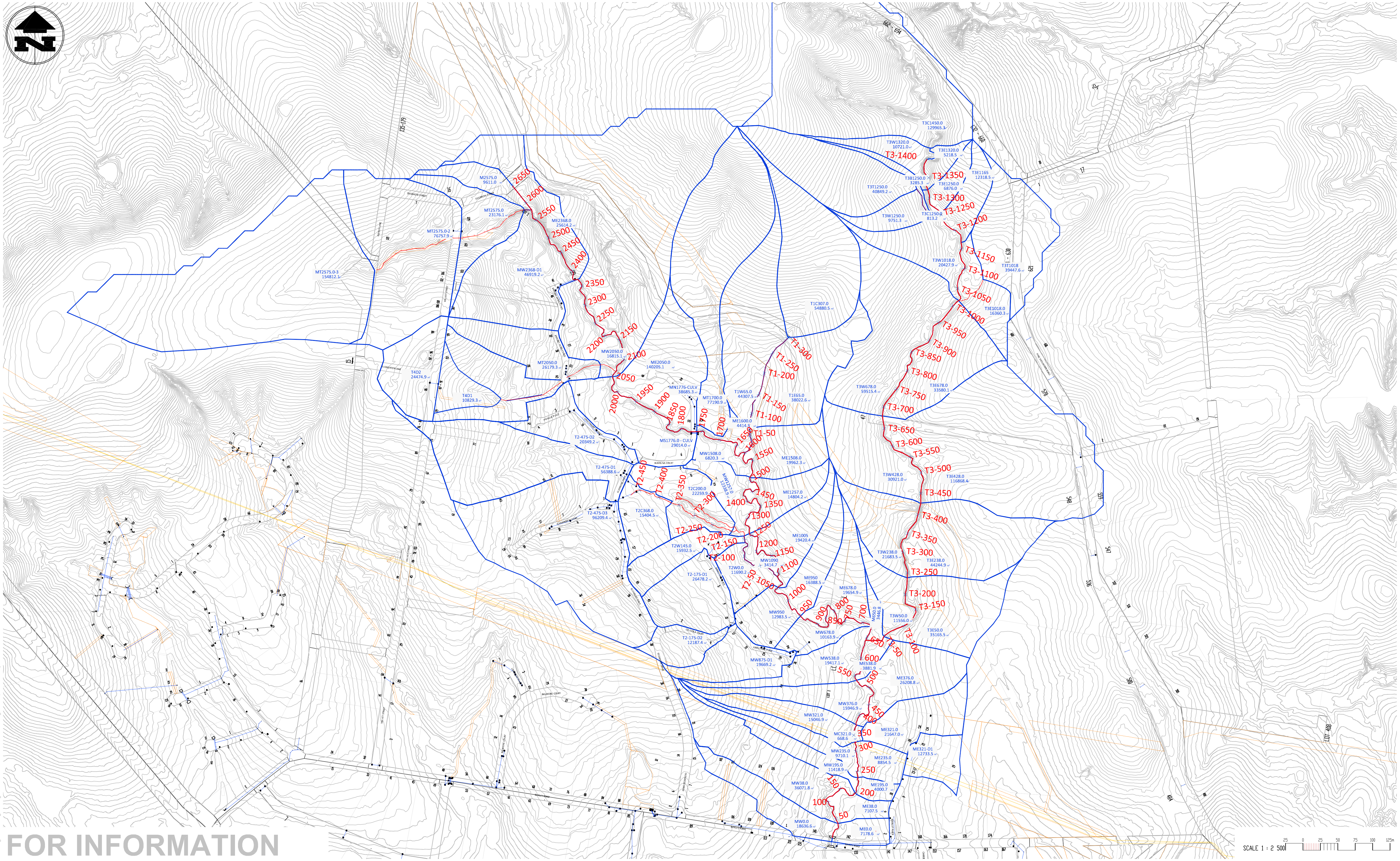




(Note the plot above indicates that the model is predicting super-critical flow on the rising limb of the hydrograph, and sub-critical flow on the falling limb).



Appendix H – Subcatchment Plan



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REV	DATE	DESCRIPTION	DESIGN	DRAWN	CHECKED	APPROVED	RPEQ
A	11 March 2013	FOR INFORMATION	JC	JC	AH	AH	-

PROJECT: IRON POT CREEK EROSION MANAGEMENT

LOCATION: PINE MOUNTAIN, QLD

CLIENT: IPSWICH CITY COUNCIL

DRAWING TITLE: IRON POT CREEK CATCHMENT AND CHAINAGE PLAN TO BAYLEY ROAD

ARCHITECT: -

ASSOCIATE CONSULTANT: AUSTRALIAN WETLANDS CONSULTING

SCALES: 1:2500 @ A1

JOB NO: 2012.236.600

DRAWING NO: BT-SW-01 REVISION: A

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