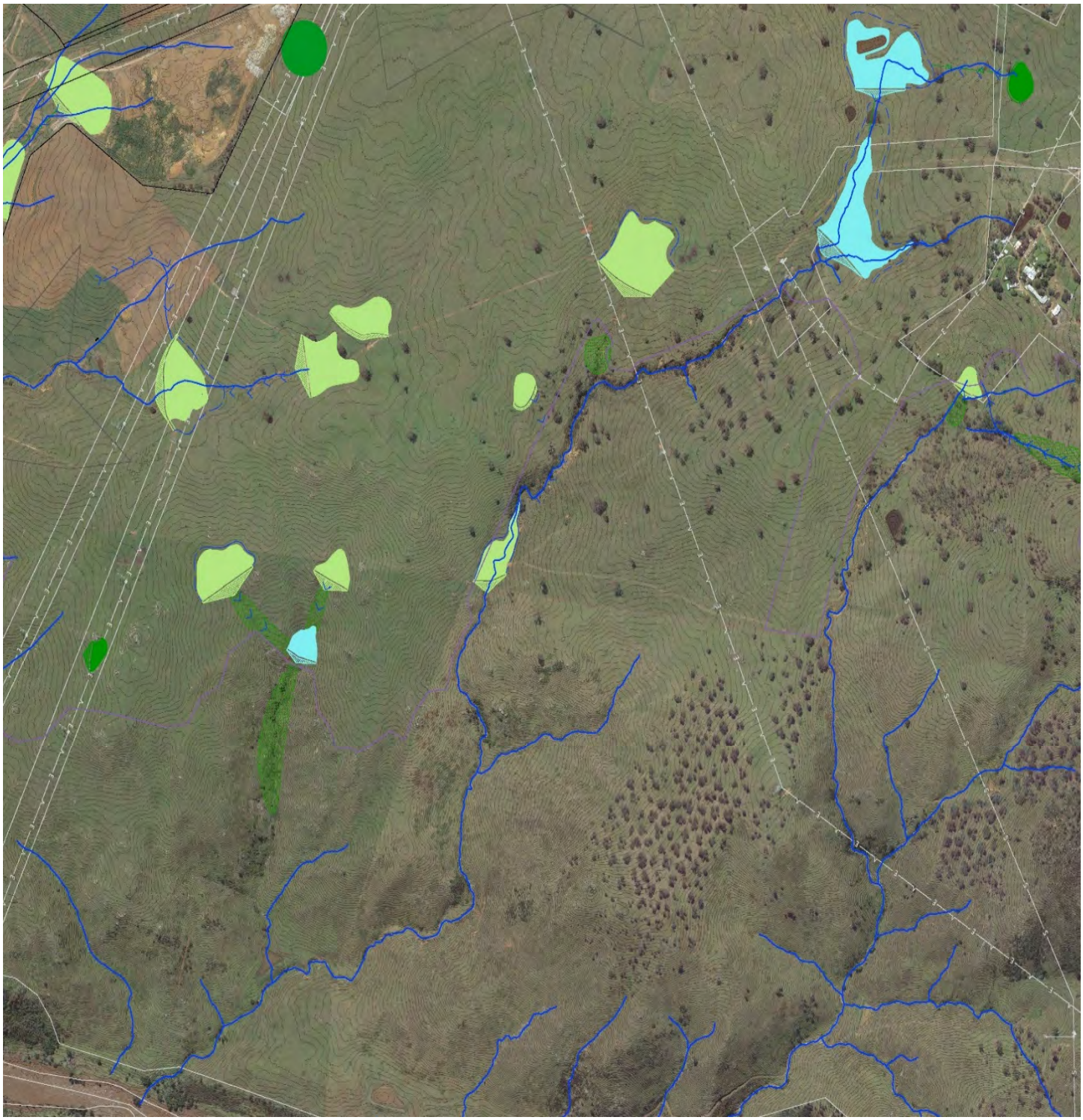

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WEST BELCONNEN DEVELOPMENT Phase 2 – Stream Strategies

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1 EXECUTIVE SUMMARY

Calibre Consulting (ACT) was engaged in January 2015 by the Riverview Group to undertake an assessment of likely works required to stabilise the Stream E from increased urban runoff that would be generated from urbanisation of the upper part of the catchment. This involved a visual inspection of the scour potential of the existing stream and assessment expected conditions post development. These assessments form the basis of the Stream Strategies, and recommended remediation measures.

A number of previous studies and reports have been undertaken of the West Belconnen development proposed water sensitive urban design (WSUD) strategy and subsequent impact of changes in flow regime through the existing gullies in the Murrumbidgee River corridor downstream of the development. The WSUD measures proposed in the development include 43 water quality ponds across the development scattered across the various catchments that discharge to the Murrumbidgee River and Ginninderra Creek. These ponds are to be designed to provide water quality treatment such that Regional Targets are met for any discharge from the development. These ponds will also be designed to reduce peak flows to pre-developed levels for all storm events from 1 to 100 year ARI.

Previous reports by AECOM and Calibre Consulting (formerly Brown Consulting) identify that the urban development will increase the runoff volume to Stream E which will result in increased runoff days than what currently exists. This means that rainfall events will lead to more frequent runoff and a longer duration of runoff. The impact of this change in runoff characteristics can cause environmental degradation and erosion. Dr Jane Roberts has undertaken an assessment of the potential impact of this increased runoff volume on the streams aquatic environment. This report by Calibre Consulting looks at the impact on erosion and likely protection measures.

A site walk was undertaken on 22 January 2015 to inspect the middle and lower sections of Stream E with the purpose of identifying what constructed measures may be required to increase stability to the existing stream and reduce scour potential from increased urban runoff. Generally the existing stream is considered to be in a stable, well vegetated condition and with bedrock control for much of the middle and lower sections of the stream. It is considered that increased runoff volumes would not result in increased erosion to the already stable areas in the stream. A number of areas have been identified for protection from possible increase in scour with the proposed measures detailed in this report. A number of hot spots of existing active scour have also been identified for remediation which is also detailed in this report and a previous report by Calibre Consulting in September 2014.

The upper section of the stream on the plateau area adjacent to the proposed development is a deeply incised well vegetated and stable gully, however, it is considered that this gully may be impacted by increased runoff volumes due to longer wetting periods and proliferation of aquatic vegetation that would occur. Following a preliminary review of the Precinct 1 development master plan, it has been identified that a low flow pipe can be installed around the perimeter of the development to divert urbanised low flows around this section of gully and discharge them into the proposed online pond. It is proposed that less frequent flows still be allowed to pass through the gully with a frequency more akin to the pre-developed flow frequency through the gully.

It is noted that the objective of the stream strategies proposed in this report is not to prevent existing erosion processes from occurring as this is a natural stream stabilisation process, but rather to have no adverse impact on the scour potential in the stream due to development upstream.

2 INTRODUCTION

The Riverview Group engaged Calibre Consulting (ACT) in January 2015 to prepare a report on Stream E Stabilisation Strategy. That is, to investigate the Stream E downstream of the development and prepare a report detailing likely protection measures to prevent increased erosion of the existing stream banks that may occur due to upstream urbanisation. Urbanisation can lead to more frequent low flows due to increase impervious surfaces and direct connections to flow paths.

A number of previous reports have been prepared for the Riverview Group to identify the WSUD strategy for the development in order to reduce the impact on the environment from urbanisation at West Belconnen. In the context of the stormwater, this has included consideration of the water cycle for the development, identifying engineering measures to reduce runoff peak flows to pre-developed levels and to reduce pollutant loading to above industry standard. The previous reports clearly identify a number of strategies that will be adopted in the development, however, the issue of the effects of increase in runoff volume on downhill streams has required a number of further investigations. This report summarises these investigations and identifies proposed remediation methods for managing increased runoff volumes and increased runoff days, which will result from urbanisation, in order to protect the existing downstream environment.

Stream E has been chosen as it drains the first few stages of the development and this work will therefore inform the scope of works associated with the first stage of the project. The methodology and approach adopted to date for assessment of Stream E is intended to be a model for assessment of other gullies in the Murrumbidgee River corridor area which will convey urbanised runoff. Stream E contains a number of different typologies along the creek and is therefore considered relevant to application of methods and outcomes to other gullies in the corridor area.

2.1 PROJECT AREA

The following plan prepared by AECOM shows the catchments across the West Belconnen development area inclusive of Catchment E. The stream under investigation in this report is the main stream located within Catchment E and has previously been commonly referred to as Stream E and this terminology will be utilised throughout this report to ensure consistency amongst the various reports and investigations undertaken on this stream. Refer to a copy of this plan in **Appendix A**.

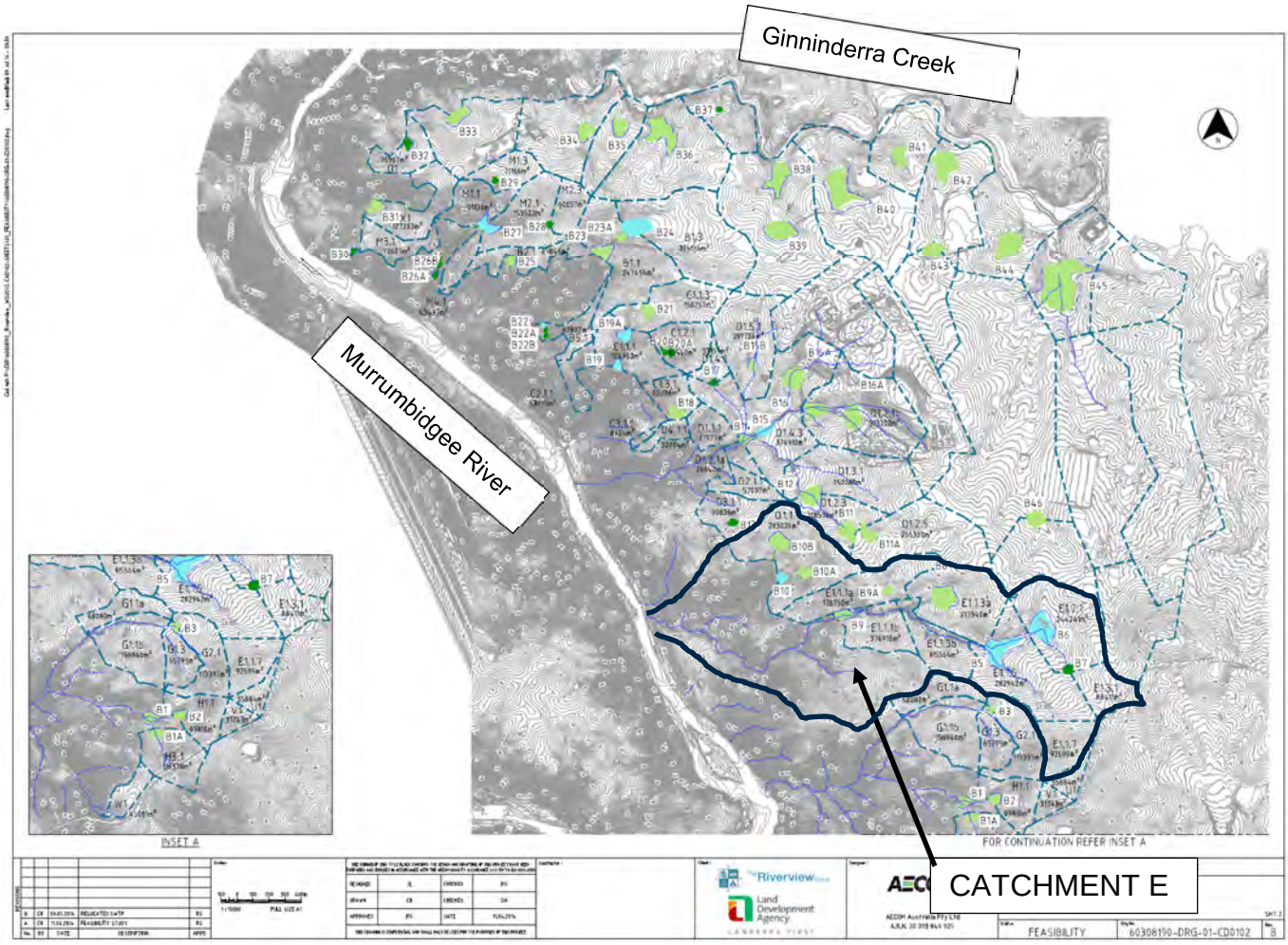

Figure 2-1: Locality Plan

2.2 SCOPE OF SERVICES

The following summarises the scope of works for this report.

- Conduct site walk of Stream E downstream of the development by Peter Lewis and Andrew McPhail of Calibre Consulting, Peter Foggarty from Soil and Land Conservation Consulting (SLCC) and Julien Lepetit from E2 Design Lab. This inspection occurred on the 22 January 2015.
- Identify likely remediation measures that may be implemented to protect the creek from potential increased risk of erosion from lower more frequent flows resulting from urbanisation of the upstream catchment area.
- Prepare sketch plans detailing these measures.
- Provide details of similar installed measures on other creeks.
- Prepare brief report describing these measures proposed.
- Peer review of the report and sketches by E2 Design Lab and SLCC.
- Prepare opinion of cost for the proposed measures.

The purpose of this report will be to inform considerations of likely environmental impacts to the existing Stream E from urbanisation in the upstream area of the catchment and strategies to protect the stream. This report will compliment a number of previous reports undertaken on Stream E and will help to support the rezoning application for the West Belconnen development.

Formal design of measures proposed in this report would be subject to further design work to be undertaken at a later stage. Stages 1, 2 and 3 of the West Belconnen development occur in the upper reaches of Stream E catchment, hence these proposed measures in Stream E would need to be designed and implemented prior to construction of the upstream development. These investigation works into Stream E will help to inform works required to be designed and constructed with the Stage 1 of the development.

3 PREVIOUS STUDIES

A number of previous studies have been undertaken to date which are pertinent to the outcomes of this current report.

1. Environmental reports identifying PWTL habitat areas were undertaken by Kevin Mills in July 2009 and by Dr Will Osbourne from the University of Canberra dated 10 May 2013. This work was undertaken to inform the delineation and establishment of Murrumbidgee River corridor which defines the limit of development adjacent to the river. The proposed development area does not encroach beyond this boundary. A large area of PWTL habitat and native box gum woodland exist within the identified corridor. A plan has been attached in **Appendix B** showing the location of PWTL habitat mapped by Dr Osbourne in the Stream E area.

   Since defining this river corridor, the development of the West Belconnen master plan has been prepared as part of the rezoning process for development. Associated engineering input into the master plan has identified a number of works required within the river corridor including trunk sewer mains, access roads to the river, fire trails, recreational walking paths, some WSUD measures and works within the existing streams. Investigations of these proposed works in the river corridor are currently being assessed by Riverview for their impact on threatened species in the corridor which is a significant consideration to the measures proposed and will form part of more detailed planning considerations.

   This current report on Stream E considers the impact of urban runoff along Stream E and consequent impact to PWTL from increased runoff as well as from construction of proposed measures within the stream to mitigate the impact of increased runoff. Dr Osbourne has been consulted as part of the further investigations into impacts of development runoff on the gullies and associated impact to PWTL from increased runoff volumes and possible protection works. Another key issue to be considered with any works within the river corridor within the stream is that of access for plant without disturbing PWTL habitat.

2. AECOM WSUD Report dated 19 September 2014. AECOM proposed a number of WSUD strategies for the urban area of the entire West Belconnen Development prepared in support of the proposed master plan and rezoning application. Five options were investigated with all options nominating the same 43 ponds of the same design, sizing and location distributed across the development. The difference between the options relates to the overall site wide water cycle management strategy for the development. AECOM's analysis was limited to end of pipes measures, as opposed to a complete stormwater treatment train process as there was no resolution of street layouts. A key driver of the water cycle options was a Green Star requirement to reduce the volume of runoff discharged from the development and maximise points under this scheme. The various options are therefore focused on how to reuse stormwater on site to reduce the erosion pressure associated with a stormwater discharge downstream.

   All the AECOM options require the ponds to provide reduction of peak flow rates to pre-developed as well as to provide water quality improvement at the discharge points to the Murrumbidgee River corridor to meet the ACT regional targets (ACT WSUD Code, 2009). The AECOM ponds and sizing requirements have been adopted with the consideration of all subsequent stream studies including this current report. It is important to note that the ponds proposed by AECOM for the development will ensure that peak flow rates will not be increased above the current pre-developed flow rates and therefore the peak flow velocities, shear stresses and depths of flow currently impacting on the existing stream will not be increased following development of the catchment upstream.

   The results of the AECOM modelling show that runoff volumes and runoff days for the urbanised runoff are increased above pre-developed in all water cycle options investigated. This means that the frequency of lower runoff events will increase as will the duration of these lower flows compared to existing. AECOM note that this increase in runoff volume could result in environmental degradation and increased scouring of the gullies in the corridor from being wetter for a longer duration. AECOM note that additional stabilisation or scour protection work may be warranted to maintain the existing condition of downstream gullies. This has led to a number of

additional investigations and reports to examine this issue of the likely impact to the existing gullies inclusive of this current report.

AECOM recommended that for the river corridor gullies to remain stable, that they should be revegetated to provide resilience for frequent flows of up to 1 year ARI flows and that runoff flows are restricted to pre-developed flow rates for all flows up to and including the 100 year ARI. AECOM also reported a number of other infrastructure options could be considered for the protection of the gullies including piping flows from the development through the river corridor and discharging them at the river via large pipes constructed through the corridor as well as constructing cut-off drains or pipes around the edge of the development to direct runoff into a few selected gullies that could potentially convey significant increased runoff from multiple catchments. AECOM summary was that additional investigation work was required to confirm impact of urbanised runoff on the gullies and to further investigate options for protecting the gullies.

3. AECOM Geomorphology Assessment dated 23 July 2014 involved an inspection of a number of key gullies draining to the Murrumbidgee River by an AECOM geomorphologist. Six key gullies draining to the river were inspected over the course of one day which was a brief cursory inspection of the gullies to ascertain the condition of the existing gullies and to provide an opinion as to their ability to accept increased runoff from the development. This report utilised three assessment criteria:

- High value features to be protected from increased runoff such as natural wetlands,
- Areas of active erosion in need of remediation for current flows as well as for increased runoff;
- Relatively stable areas with bed rock control or well vegetated expected to accommodate additional flows.

Stream E was included in this inspection and report. The report identified that the majority of the Stream E was considered to be relatively stable and was considered to be able to withstand increased flows. A number of localised unstable areas were identified in the stream, primarily in the lower section of the near the existing farm dam.

The following key points summarise the findings from this report:

- Existing stable zones being either bed rock controlled or well vegetated areas could probably accommodate additional stormwater discharge flow durations.
- Where erosion already exists in the stream, stabilisation works would be required.
- Historical erosion areas that have stabilised or reached equilibrium may have potential to receive increased flow duration with minimal or no impact.
- Geomorphically sensitive areas would require engineering protection if there is structural weakness present in the material. Where structural weakness is not present, these areas may be able to receive increased flow duration.
- Land management practices are necessary to control erosion such as preventing site access by stock, controlling feral animals and weeds.

The conclusion was that the six streams across the river corridor area are potentially suited to accommodating increased flow volumes and runoff days. Noting that a more detailed geomorphological study of each stream would be required.

4. Murrumbidgee River Corridor Phase 1 - Initial Stream Investigation by Calibre Consulting dated September 2014 draft report was prepared following the recommendation of the above AECOM reports. This more detailed assessment was commissioned by Riverview to undertake further investigation of the condition of the existing Stream E and consideration of its ability to receive additional flow volumes from urbanised runoff and impact on existing aquatic environment. The stream was inspected by Calibre Consulting, Peter Fogarty a geomorphologist from SLCC, and Dr Jane Roberts a riverine ecologist (previously with CSIRO) on 19 August 2014. This report concluded that the erosion identified originates from past land use management practices and the conversion of woodlands to agricultural land in particular. Stream E has consequently eroded to the

point of reaching a relatively stable condition at a new equilibrium. This extensive erosion would not be expected to re-activate with the proposed residential development, as the gully has now reached bed rock controls in many places. This assessment was based on the site inspection and historical evidence from aerial photos over the last 60 years, which shows that the current erosion gully does not appear to have changed over this time period. A number of 'Hot Spots' were identified during the site inspection where minor active erosion or areas of higher scour potential were observed. Proposed remediation measures for these hot spots were detailed in the report.

5. Ecological Appraisal by Dr Jane Roberts dated September 2014. Dr Roberts attended the site inspection with Calibre Consulting in August 2014 and prepared a separate report which identifies the existing "in channel" aquatic environment of Stream E. Dr Roberts characterised the upstream incised gully section of Stream E as an Ephemeral – Intermittent stream. However the middle and lower reaches are intermittently flowing streams, while persistent in the wetter winter periods. The stream was noted to have a number of wetland plant species present, both native and exotic, however was not considered to be of significant ecological value. It was noted that there appeared to be an environmental gradient of increasing wetness the further downstream you go with plant types and quantity changing as you move down the stream.

6. Triple Bottom Line assessment by Aither. Aither were engaged to prepare a TBL investigation of the WSUD options identified by AECOM. At the time of writing this report, the TBL had not been finalised, however, it is understood that the Business as Usual option and Intermediary option of irrigating selected open space areas only were the preferred options from the analysis. It is noted that as all WSUD options proposed by AECOM increase runoff volumes and duration in Stream E, and that all options utilise the same ponds within the development, regardless of the recommended option from the TBL, the same works would be proposed in Stream E as noted in this current report.

7. Hydrological investigation by Calibre Consulting in January 2015. This additional hydrological modelling and report undertook a more detailed MUSIC model of Stream E and its catchment based on historical rainfall data from the Bureau of Meteorology Station at Hall (Lochleigh) (Site:070045), for the period October 1903 to September 2014. The MUSIC model replicated the ponds proposed by the AECOM report. The assessment focused on a statistical analysis of rainfall, runoff and pollutants loadings to provide necessary input for additional consideration of the effect of urbanisation on Stream E on changes in flows. Results were presented for existing undeveloped catchment, developed with no stormwater mitigation, developed with stormwater mitigation. Mitigation options were modelled for one day or three day extended detention. This enabled assessment of hydrological changes in Stream E, in particular comparison of the number of runoff days

8. Development, flow regimes and in-stream vegetation in Catchment E, by Dr Jane Roberts, dated 15 February 2015. This report analyses the possible changes in hydrology utilising the modelling and statistical analysis prepared by Calibre Consulting in January 2015. The predicted changes in flow regime in the stream associated with the urban development were used to assess the impacts on the existing aquatic habitat. The report concludes there will be a substantial change to the flow regime from intermittent, mainly dry but highly variable, to a mainly wet with little or no dry phases. Consequently the report concludes a likely change in plant diversity and dominance by large amphibious species such as ***Typha spp.*** and ***Phragmites australis***.

   This report underlined the importance of the management of the Extended Detention (EDD) drainage in the urban ponds and wetlands on the plateau. With a typical 72 hour draining period , the report advised that the gullies will change from intermittent to almost permanently flowing. Whereas a reduced drainage period of 24h only, will result in a flow regime with a pronounced seasonal signature. A trade-off between water quality (associated with longer EDD drainage time) and hydrological regime in the gullies may need to be resolved.

   The report recommended that soil and erosion expertise be sought to consider the impact of vegetation blockages and impedance of flows onto lateral bank erosion, specifically in the incised upper gully of Stream E.

4 EXISTING STREAM CONDITIONS

4.1 GENERAL SITE TOPOGRAPHY

Three distinct zones are present in all catchment areas draining to the Murrumbidgee River, including Stream E.

- Upper reaches are within an elevated plateau approximately 100m above the Murrumbidgee River. The proposed urban development is situated on this plateau. The river corridor boundary tends to coincide with the edge of the plateau area with most of the environmental habitat areas for PWTL and box gum woodland located within this corridor area on the steeper terrain. There are approximately 26 smaller catchment areas on this plateau area which discharge into the Murrumbidgee River corridor. These then amalgamate within the corridor area into 7 major gullies which discharge into the river. Refer to catchment plan in **Appendix A**.

  A number of gullies in the plateau area have been subject to severe erosion from past clearing and farming practices. The farmer has undertaken a number of significant erosion protection measures to stop this erosion such as large rock weirs and extensive gully filling.

- Middle reaches are typically a steep zone characterised by relatively steep longitudinal fall, rocky inverts, rock drops and pools.

- Lower reaches, adjacent to the Murrumbidgee River, are on flatter terrain as the streams approach the river.

4.2 EXISTING CONDITION OF STREAM E

The overall condition of Stream E is one of relative stability with localised areas where the bank is prone to slumping and / or wash by hillslope runoff. Further investigation has been undertaken since the Calibre Consulting Phase 1 – Initial Stream Investigations Condition assessment Section 3. Details are provided in subsequent sections for each of the Stream E reaches.

4.2.1 UPPER REACH

The upper reach of Stream E is located on the Plateau area. This is the reach where the gully is situated directly adjacent to the proposed urban development. The gully is deeply incised to a depth of approximately 10m. The existing banks and batters are steep (typically 1:1 or steeper) and with a significant vegetation cover. There are a number of localised hot spot where the batters are exposed and prone to surface wash and/or slumping.

Some surveyed cross-sections were undertaken of two areas of this gully and a general Manning's equation calculation undertaken to determine indicative flow depth and characteristics. A more detailed HEC-RAS model is recommended to be undertaken when designing gully protection measures based on a full detailed survey. The following flow characteristic, **Table 4-1** and **Table 4-2**, was determined from the catchment XP-RAFTS flow model and Manning's equation calculation for existing conditions.

Table 4-1: Stream E Flow Conditions – between Pond B5 and B8 (existing condition)

ARI Event	1	2	5	10	20	100
Flow rate (m^3/s)	0.58	1.70	3.06	3.97	5.30	8.80
Flow Depth (m)	0.49	0.78	1.01	1.12	1.25	1.52
Velocity (m/s)	1.10	1.30	1.45	1.53	1.61	1.78

Table 4-2: Stream E Flow Conditions – between Pond B8 and B9 (existing condition)

ARI Event	1	2	5	10	20	100
Flow rate (m^3/s)	0.94	2.68	4.78	6.19	8.1	13.30
Flow Depth (m)	0.28	0.49	0.68	0.79	0.92	1.21
Velocity (m/s)	1.14	1.56	1.81	1.92	2.04	2.24

Based on the above information we can compare the depth of the gully (up to 10m deep) and flow depth to gain a correct perspective regarding the flow characteristics. Flow depths are small in comparison to the depth of the incised gully. For the most part, this indicates that the majority of the batters, would not be subjected to particular erosive flows for the vast majority of storm events (up to and including the 100 year ARI). It is expected that more intense (and rare) storms would have the potential to erode the gully. These events however, are not typically considered in urban development planning and design. The nature and coverage of the vegetation observed in the gully indicates that as the velocities of the flows detailed above are generally less than 2m/s, these would not be expected to cause particular erosion. This preliminary assessment of the flow characteristics lines up with observations that the existing incised gully appears to be in a stable condition and has been for many years.

The most significant risk to gully erosion is considered to relate to the wetting/drying regime of the toe of the banks. As small frequent storms reach depth of 0.3 m to 0.5 m, and the flow duration is extended with the proposed development, the integrity of the toe of the banks is the most critical factor. For most of the length, it was observed that the historical erosion has reached bed rock at the invert of the gully and also revealed significant rock presence in the toe of the banks. While localised erosion may be possible in the future, the investigation results do not warrant a blanket treatment over the entire length of the Upper Reach. Adaptive management and addressing hot-spots is recommended as the best approach.

4.2.2 MIDDLE REACH

The middle reach is a particularly steep section of Stream E. This reach of the stream is typically bedrock controlled. A number of pools and rock drops existing in various locations along this section of the stream. Peak flows in this reach of the stream immediately downstream of Pond B9 are indicated in **Table 4-3**.

Table 4-3: Stream E Peak Flow – downstream of Pond B9

ARI Event	1	2	5	100
Flow rate (m^3/s)	1.23	3.41	6.02	16.62

No typical cross-sections were surveyed of this section of stream. The variability of gully cross-section and longitudinal grade would make any typical representation irrelevant. Consequently typical flow characteristics have not been determined. This was considered acceptable at this stage of the project due to the dominant bedrock control for this

entire stretch of the stream and observed stability of this reach of Stream E. For the size of the stream, the flows are not considered large. The more frequent flow rates which are generally associated with gully erosion are small compared to the existing stream profile and rocky features, which is probably indicative of the observed stability in much of this section of stream.

One sub-section of the stream has reached bedrock control, however, is a steep incised gully of around 3 to 4 metres in depth. This section of stream shows signs of localised active erosion of the sides of the gully, which can be observed to be self stabilising and revegetating over time. This process is considered to be normal for a healthy stream. This slow erosion process will continue to occur and our recommendation is that this does not indicate any particular instability in the stream, nor should it be interpreted later as a sign of poor urban stormwater management on the plateau.

Observations from site inspection in January 2015 are documented on sketches in **Appendix C.**

4.2.3 LOWER REACH

The lower reach of Stream E has a flatter longitudinal grade, with numerous bedrock controls, long ephemeral pools, narrow terraces, rocky banks in places and thick deposits of sediment, presumably formed from the material exported from the erosion of the large gully upstream. In places the sediment deposits have developed vertical erosion banks adjacent to the stream low flow channel. Vertical banks were particularly noticeable when first observed in winter. However these erosion banks were observed with significant vegetation cover in subsequent summer inspection. The vegetation covers includes many thick mat forming and stabilising species such as kikuyu grass, phragmites, and typha. Typically, the deposited sediments are now well consolidated and in a stable well vegetated condition with the exception of a small number of sites where undercutting and slumping have occurred.

A large farm dam has been constructed along the northern bank of Stream E with the embankment containing flows within Stream E. This dam has a formed grassed spillway which has no evidence of erosion.

Observations from site inspection in January 2015 are documented on sketches in **Appendix C.**

5 STREAM STRATEGIES

Based on the range of previous studies undertaken to date on Stream E, the following engineering measures are proposed for managing the urban stormwater runoff through Stream E. This methodology is to be further developed at Estate Development Plan (EDP) stage of the project and implemented prior to construction of the first stage of development. This method applied to Stream E is expected to be able to be applied across other gullies across the river corridor area with each stream to be investigated in detail prior to undertaking an EDP for an upstream development with that gullies catchment.

5.1 STORMWATER MANAGEMENT STRATEGIES

To minimise impact on downstream waterways stormwater management strategies are required within the development area. Measures are typically as per the AECOM recommendations but further refinements are proposed following recent investigations. The key components of the AECOM Water Sensitive Urban Design Report were a series of ponds, wetlands and integrated stormwater detention basins, subsequently referred to as ponds.

Recommended key pond design parameters as the basis of the Stormwater Management Strategy are listed below;

- Size ponds for regional water quality targets at the outlet to each stream. This was proposed by AECOM as the West Belconnen development water quality targets.
- Size ponds for reduction in 1 to 100 year ARI urbanised flows to pre-developed levels.
  Note: ACTPLA Waterways Code nominates 5 to 100 year ARI mitigation while AECOM nominate 2 to 100 year ARI mitigation. It is recommended that mitigation to the 1 year ARI event as stream forming flows, causing bank erosion, are generally between the 1 and 2 year ARI flows.
- Extended detention storage be designed to discharge within 24 hours following a storm event.
  Note: ACTPLA Waterways Code recommends extended detention storage be designed to be discharged over a period of 1 to 3 days, with 3 days not an uncommon design parameter adopted in the ACT. As per Dr Roberts notes, a 3 day extended detention time will result in a permanent flowing stream. It is recommended based on the recent Calibre Consulting and Dr Jane Roberts report that the extended detention be drained within 24 hours in order to significantly reduce the number of runoff days down Stream E, provide some seasonal variability and have some wetting and drying periods occurring to produce intermittent flow conditions and thereby reduce impact on Aquatic ecology by more closely replicating existing intermittent flow regime.

5.2 STREAM OBJECTIVES

There are a number of issues to be considered in regard to assessment of possible impacts from urban development of the upstream catchment on Stream E. In particular:

- Loss of amenity and ecological values of the riparian ecosystem/ habitat. The ecological reports by Dr Jane Roberts point to the relative absence of critical ecosystem values in Stream E and the likelihood of the stream to developing a new typology of ecosystems and amenity values with the increase in flows in the stream post development. It is noted that sections of the existing stream already has swathes of phragmites, and typha which are expected to spread along the stream. Phragmites in particular where currently occurring is observed to be providing a stabilising root mass. The objective is therefore to permit a change in vegetation to gradually occur and manage as required.
- Possible degrading of physical conditions by erosion and generation of safety risks. This is considered to be the main objective for Stream E leading to recommended protection measures detailed in this report to preserve the physical integrity of the stream bed and banks so that functional ecosystems and vegetation can evolve in line with increased water availability without this change in vegetation increasing natural erosion rates. The hot spot

remediation works proposed by Calibre Consulting in September 2014 are also critical to protection of the physical integrity of the stream.

- Export of sediments and eroded material downstream. While Stream E has in recent decades been trending to a stable condition, natural cutting and filling will continue to occur in major runoff events. The aim of management of the stream is to ensure a new phase of instability is not initiated and the current 'natural' cutting and filling (erosion and stabilisation) processes are not exacerbated by the urban stormwater excess. The rate of erosion following development should be no greater than what currently exists. This fundamental objective underlies the recommendations of this report. Existing, localised sites of sheet wash and slumping on batters, and incision points in channel sediment are proposed for stabilisation measures, particularly where it is considered that increased runoff volumes or wetness may weaken the existing stream or increase scour potential. With the exception of these isolated works, it is the opinion of the team that the remainder of the stream would remain stable under increased runoff volumes. An adaptive management strategy, involving regular monitoring would be the most appropriate management response.

5.3 STREAM STABILISATION STRATEGIES

Following the site inspection and consideration of the previous reports undertaken on Stream E, the following stabilisation measures are proposed for Stream E to achieve the objectives identified in **Section 5.2** above.

5.3.1 UPPER GULLY

While the stormwater management strategies recommended in **Section 5.1** will mitigate developed flows to pre-developed conditions, the impacts of more frequent wetting and a longer period of moist conditions needs to be considered. The existing streams upper gully appears stable for existing flow conditions even over an extended period of time of 70 years. Erosion occurs when the resistance of the soil is exceeded by the scour energy of flowing water. Resistance of the soil in the gully sides may be decreased somewhat by more frequent wetting, but it may well be increased if vegetative protection by plants is enhanced by increased water.

More detailed in-stream hydraulic investigation, geotechnical and soil testing and modelling would be required to better assess this process. Any attempts to effect stabilisation works within the incised gully will be significantly constrained by the considerable depth, confined width and steep batters making accessibility for construction and maintenance difficult.

It is also conceivable that changes to gully floor vegetation from increased low flows may result in flow diversions against the gully walls and potentially increase scour potential as noted by Dr Jane Roberts. On balance, it is seen as advantageous to avoid changing flow conditions in this gully.

Based on access constraints and potential erosion effects from vegetation changes it is proposed to bypass more frequent low flows around the gully via a pipe which can be constructed adjacent to the development boundary and allow only higher flows to pass through the gully as they currently do. Given the stable nature of this existing section of stream, the piped solution past this stretch of the gully will protect the current stable vegetated condition of this gully. Currently flows enter the gully at a few defined locations which were identified by Calibre Consulting as hot spots requiring remediation and protection against scour which will permit these less frequent flows to enter the gully without creating scour problems.

Diverting increased frequent low flows around this gully could be designed so that the frequency of runoff events through the gully would be closer to the frequency of flows that currently occur pre-development and can be assessed with design of the ponds at EDP stage.

Master Planning of Precinct 1 of the development has allowed consideration of this pipe size and alignment which is shown on Sheet 17 in **Appendix C.** The indicative size of pipe is between 900 and 1050mm dia which not unreasonable in an urban context.

Key design parameters of this diversion pipeline are:

- Focus on the frequent flows less than the 2 year ARI event;
- Be based on daily flow analysis along the upper reach of Stream E for an analysis period of at least 30years;
- Maintain environmental flow down the Gully, both in annual flows and seasonally variability to maintain existing aquatic and vegetated stable environment; and
- Specific analysis to be undertaken at EDP Phase to size this bypass pipe.

The Hot Spot remediation works proposed by Calibre Consulting (Sept 2014) for this gully should still be undertaken to rectify minor active erosion areas which generally occur on the upper side of the gully banks and pose safety issue.

No PWTL habitat exists near the gully, however, native box gum woodland is situated adjacent the gully. Access to the gully for repair of hotspots will require careful planning to minimise impact to the regenerating woodland. The proposed diversion pipe will encroach into the river corridor, but can be routed to avoid existing trees.

5.3.2 MIDDLE AND LOWER REACHES

These reaches of the stream are currently considered to be in a stable condition and are assessed as almost entirely governed by frequent bedrock controls. Based on the visual site inspection undertaken in January 2015, the majority of these sections of stream appear to be in a stable condition, and it is considered this section of stream will continue to be stable with increased runoff volume and flow duration from the upstream development. This correlates with the initial advice from the AECOM geomorphologist report.

A few selected areas were identified where increased runoff could impact on the stability of the existing stream. A number of engineered mitigation measures have been proposed in these areas to provide protection of the existing stream from the increased flows. Importantly, as outlined in section 4.2, it was determined that the most significant risk to the integrity of the gully would be associated with the small frequent storms including the 1 to 2 year ARI flows that modify the wetting/drying regime of the toe of the banks. Accordingly, the proposed solutions focus on stabilising the banks immediately adjacent the stream bed. Refer to sketches in **Appendix C** for details of proposed works for long term stability.

A few isolated hot spots have been identified where active erosion is occurring and should be rectified to prevent this erosion continuing. Refer to sketches in **Appendix C** for details of proposed hot spot remediation works.

On the middle steeper section of stream there are a number of access tracks provided to support farming activities and includes some graded tracks across the stream which could provide adequate access for construction plant. There is very little PWTL habitat immediately adjacent to this section of creek meaning that the proposed works would likely be undertaken without disturbance to PWTL habitat.

On the lower section of the stream there is only one key area where access by construction plant may be an issue which is the area adjacent Hot Spot 10, 11 and 12. The location and extent of the proposed stabilisation works is however not expected to impact on PWTL habitat. We recommend that further assessment of construction methodology to protect the PWTL habitat be carried out as the project progresses.

5.3.3 REMEDIATION MEASURES

The Stream assessment of the middle and lower reaches has been indicated within **Appendix C**. This includes proposed Stabilisation measures. **Appendix D** indicates the typical types of remediation measures proposed. They are categories into five (5) types of measures:

1. Minor rock ramps (engineered)
2. Major rock ramps (engineered)
3. Toe protection (soft engineering)
4. Batter, top soil and revegetate (soft engineering)
5. Weed and revegetate (ecological)

The five types of measures are discussed further below:

Type 1 - Minor Rock Ramps

- Protect the low flow channel where the bed has been cutout or scoured and instability may continue to extend upstream.
- Typical fall of less than 1m,
- Constructed of graded rock bedded onto geo-fabric.
- Also called Riffles.
- Various examples and sketches are presented in **Appendix D**.

Type 2 - Major Rock Ramps

- Protect channel bed and banks where there is a risk of instability from incision into the bed and undercutting of banks
- Typical fall in excess of 1m
- Constructed of larger graded rock, and requiring high degree of shaping and preparation of site;
- Various examples and sketches are presented in **Appendix D**.

Rock Ramps Type 1 and 2 are both constructed bed controls. That is proposed in locations where there is a steep drop in invert grade with relatively flat upstream and downstream channel inverts. The measure is located at an existing scour head that if untreated will travel (erode) upstream creating more incised channels or unstable banks. Ramps are typically design with 1 in 10 to 1 in 20 sloped downstream faces and 1 in 4 upstream faces. Topsoiling and revegetation can also be utilised at rock ramps to assist with stability, aesthetics and ecological outcomes.

Both Type 1 and 2 measures have pervious or leaky weirs. Often designed and constructed with no fines rock work to enable some infiltration through the structure but siltation will occur upstream of the bed controls. The crest of the ramp is typically designed to be higher than upstream channel invert. Subject to site survey and design integration into existing topography Rock Berms or Rock Rib could be used across the overbank flow area, perpendicular to flow, to minimise scour potential in the overbank areas.

Ramps can also be called riffles, rock weirs, Schauberger Boulder Bed Control or Schauberger Ramp. Subject to design and flow conditions a plunge pool or pond can be formed at the end of downstream ramp.

Type 3 - Toe Protection

Required where stream bank or gully wall at risk of undercutting and slumping, Works can be based on providing woody debris, rock, gabion basket or soil log type vegetated solution at the toe of the batter. For this stream we have recommended a soil log type vegetated solution at various instability points. Examples are presented in **Appendix D.**

Type 4 - Batter, Topsoil and Revegetate

Where batter steepness could lead to significant slumping, earthworks can be undertaken to flatten the batter, typically to a grade of 1V to 4H. The batter surface is roughened then topsoiled and sown to perennial vegetation,

Topsoiling and tree planting to improve canopy cover and subsequent channel shading could be considered in the detailed design of stream works to reduce the widespread Typha growth. This could also be considered as a long term management strategy for the stream.

Type 5 - Weed and revegetate

Drainage lines are highly susceptible to weed invasion. Once established, weeds such as blackberry smother out grasses and other native vegetation, meaning that controlling them once established may result in exposure of unvegetated channel banks. An ongoing weed control program will avoid this risk.

6 STREAM MANAGEMENT

Riverview are establishing a River Corridor Trust that will be funded by the development and that will manage the river corridor from the edge of development to the banks of the Murrumbidgee River. A River Management Plan is currently being prepared by TRC. The streams flowing through the river corridor will also be managed by the Trust and included in the management plan.

The proposed stabilisation works and hot spot remediation works identified by Calibre Consulting will be undertaken with the first stage of the land development works in the upstream catchment area. Once stabilised, the streams will be managed into perpetuity by the Trust. This management plan will include the following measures in order to maintain the stream objectives identified in this report.

- Management of stock adjacent to the stream areas. These areas are highly sensitive to the impacts that stock will have on driving erosion processes. It is recommended that stock are excluded from the stream areas. If periodic fuel load reduction is required as part of the bush fire asset protection management then limited access of stock and stocking rates is recommended, excluding the following areas:-
    - The Upper Reach;
    - Low flow channel areas of the stream;
    - Stream areas with sensitive indigenous vegetation; and
    - Vegetation restoration areas.

  Careful management and monitoring of stock impacts is required to minimise erosion and impacts on established vegetation and stream integrity. Any damage to the streams by stock will need to be rectified by the Trust to ensure erosion does not occur.
- Monitor the natural erosion processes occurring. Undertake regular inspections of the streams for identification of potential scour issues. Inspections should also follow all significant storm events. Inspection of the structural integrity of engineered measures proposed for implementation in this report as well as the existing large farm dam adjacent the stream in the lower section of the stream are to be part of the monitoring program.
- Monitor and record the change in vegetation along the stream and any erosion effects from flows passing around the vegetation and effecting the stream banks.
- Management of invasive weeds. This would include but not limited to spraying and removal of blackberry.
- Tree planting program. This could occur in selected areas in the middle and lower sections of the stream for both erosion protection and shading of areas to limit growth of typha and phragmites in these selected areas.
- Implement new engineering remediation measures if any significant erosion occur which are beyond the natural erosion process. These measures would be aimed at limiting erosion and sedimentation downstream as well as public safety.
- Monitoring of Stream E will provide essential information to inform the design and consideration of stream works in the subsequent streams as development occurs over the 30 to 40 year life of the project. This should be treated as a continual learning and improvement process.

7 CONCLUSION

Previous reports have established that there will be an impact from development upon the stream flows in Stream E. The primary impact will be due to the increase in runoff volume generated by the more impervious development on the plateau area. Proposed WSUD measures incorporated into the development will incorporate the following:

- Management of flow rates to be no more than pre-developed which will manage flow rates and velocities in the existing stream to match pre-developed.
- Provide water quality treatment to Regional water quality targets to reduce the impact of upstream development on the water quality in the stream and Murrumbidgee River.
- Allow for stormwater harvesting and reuse to reduce runoff volumes discharged downstream.

Dr Jane Roberts attempted to quantify the impact to the existing flow regime from the development. The existing flow regime is one of intermittent flows. The design of the WSUD measures in the development are recommended to allow for extended detention to be drained in one day in order to still permit an intermittent flow regime to occur. This is recommend in order to reduce the impact on aquatic vegetation changes and PWTL migration. Should a 3 day extended detention duration be utilised, it is likely that the Stream E would have a continuous flow.

The existing stream displays signs of natural erosion and stabilisation processes occurring. These processes are normal for a healthy stream and the goal of the proposed works in the stream are to not make this process worse post development. A number of measures have been proposed to ensure stability of identified areas where it is considered possible that increased erosion may occur from more frequent low flow volumes post development.

A number of active erosion areas were observed which are not typical of a natural stream process and are the result of past and current land use practices such as stock access or clearing. Rectification measures are proposed to restore the eroded area, cease ongoing the erosion of these specific areas and improve safety.

While construction of physical rectification and stabilising measures are proposed to be undertaken with the first stage of development, into the future it will be important to incorporate an ongoing inspection, maintenance and adaptive management strategy into the function of the proposed river corridor management trust.

APPENDICES

APPENDIX A LOCALITY AND CATCHMENT PLAN

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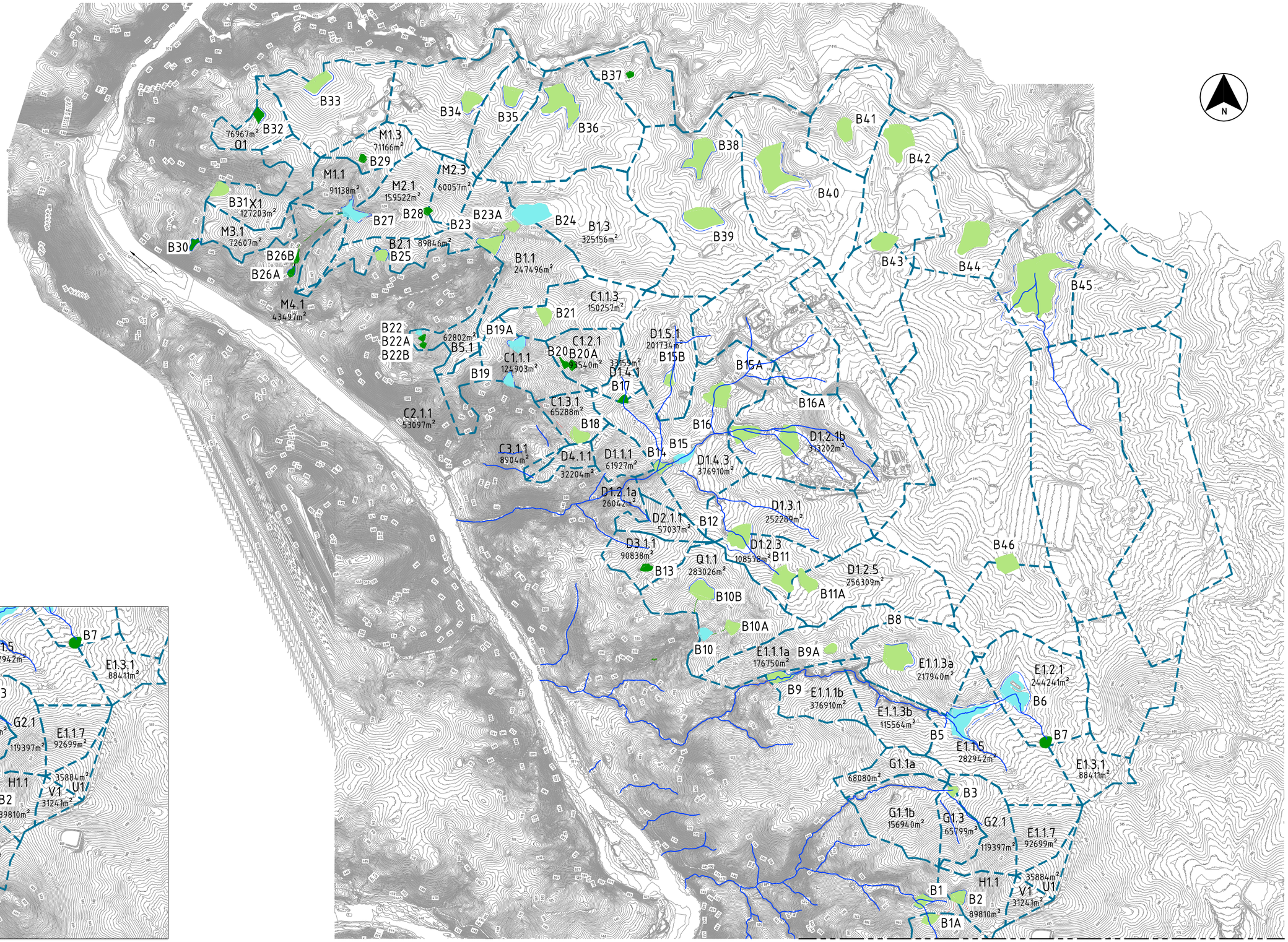

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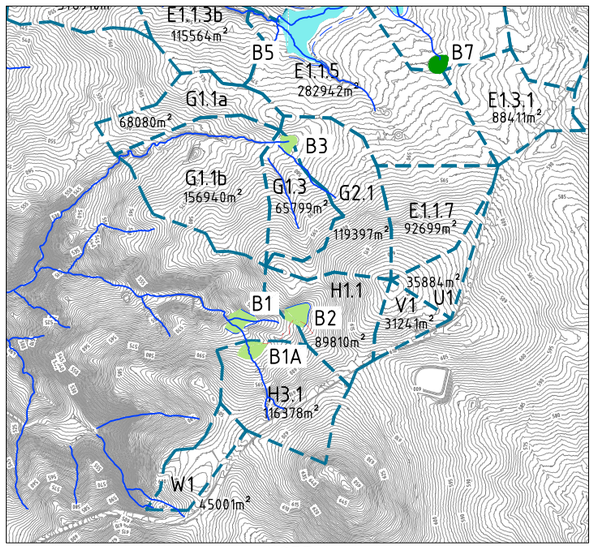

INSET A

REVISIONS				
B	CH	09.05.2014	RELOCATED SWTP	RS
A	CH	11.04.2014	FEASIBILITY STUDY	RS
No.	BY	DATE	DESCRIPTION	APPD

Scales:

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1 : 10000 FULL SIZE A1

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	JL	CHECKED	RS
DRAWN	CH	CHECKED	DA
APPROVED	RS	DATE	11.04.2014

THIS DRAWING IS CONFIDENTIAL AND SHALL ONLY BE USED FOR THE PURPOSES OF THIS PROJECT.

Contractor :

Client : The Riverview Group; Land Development Agency; CANBERRA FIRST

Designer : AECOM

AECOM Australia Pty Ltd
A.B.N. 20 093 846 925

Project: WEST BELCONNEN WSUD

Title: BASIN GENERAL ARRANGEMENT PLAN

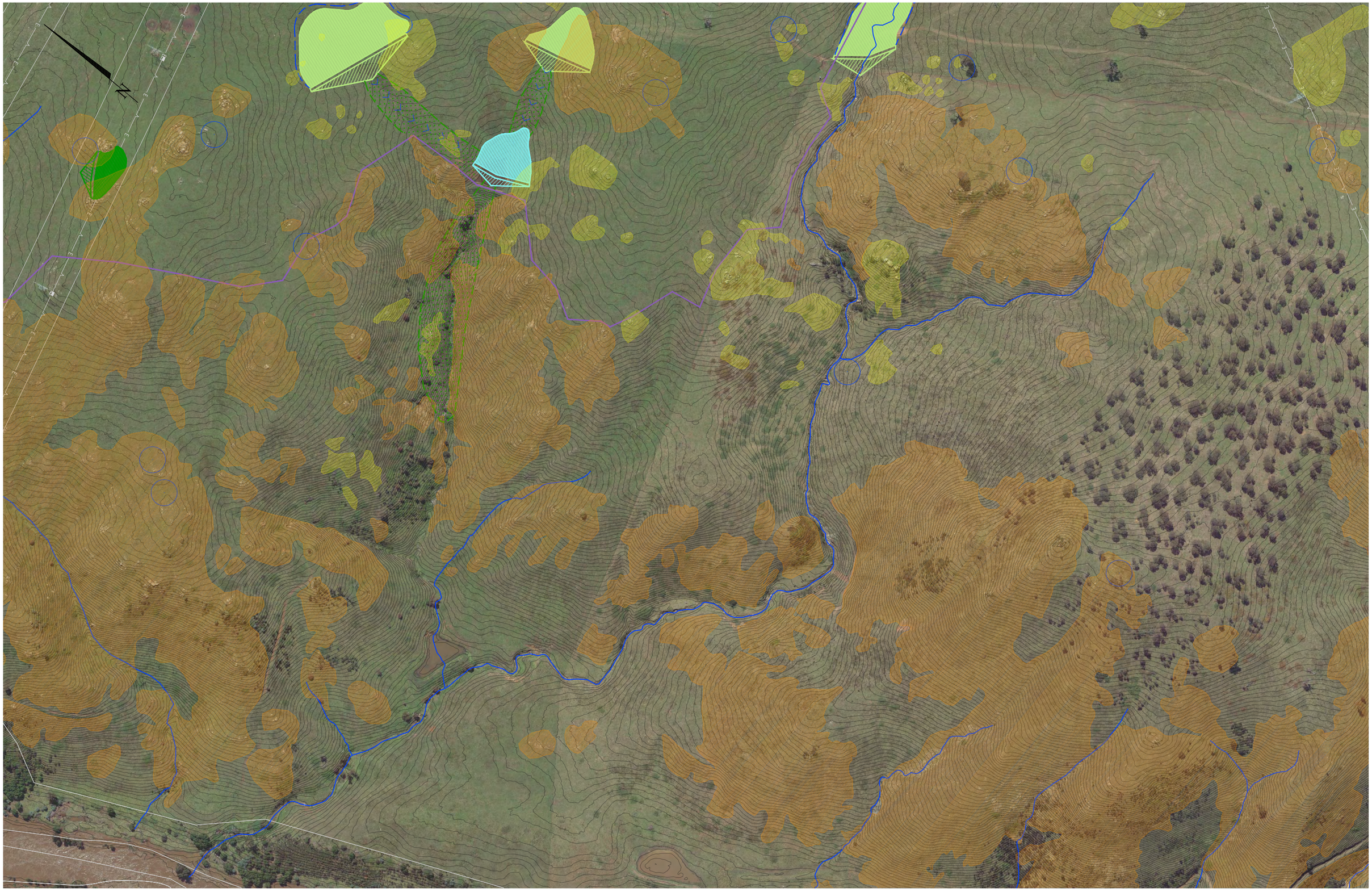
SHT 2

Status: FEASIBILITY

Drg No. 60308190-DRG-01-CD0102

Rev. B

APPENDIX B PWTL HABITAT PLAN



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West Belconnen Development
Gully E Stabilisation

For Discussion Purposes Only
Sheet 18

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Gully E Stabilisation

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Sheet 19

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Sheet 20

APPENDIX C STREAM E ASSESSMENT PLANS

High flow weir from dam. Provide scour protection or monitor spillway for erosion.

HS5

Photo 0287

3m deep scour head. Construct major rock ramp at scour head with permeable leaky weir.

HS4

Photo 0871

Photo 0293

HS3

Existing willows and two 1m scour heads. Remove willows and construct major rock ramp. Minor associated channel battering and revegetation.

Gully in River Reserve over grown with blackberries and willows and could not be accessed for inspection. Management of blackberries and invasive trees is necessary.

HS2

Photo 0303

HS1

1m drop scour head in low flow channel. Construct minor rock ramp with permeable leaky weir.

Photo 0307

Scour head within river corridor on downstream side of access track. Construct rock ramp.

Legend

Hot Spot (HS)

General Notes for Sheet 1
Gully Area:

1. Gully has stable vegetation (e.g. Photo 0293).
2. Flat longitudinal grade of channel with long pools.
3. Non-dispersive soils.
4. Lots of rock and existing bed control structure (rock)
5. Scour in gully limited to four hotspots (HS1 to HS4).
6. Limited gully works proposed for stabilisation.
7. Minimal intervention recommended.
8. All works proposed subject to survey and detailed design.

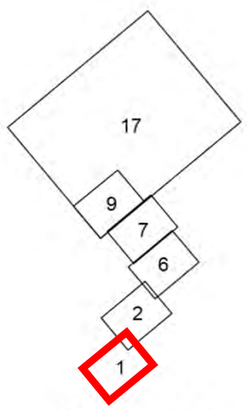

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Photo 0871- Dam high flow weir outfall

Photo 0293 – Existing stable vegetated gully

Photo 0303

Photo 0307 – Existing pool and stable vegetated gully

Note: Photos were taken during site visit on 22 January 2015

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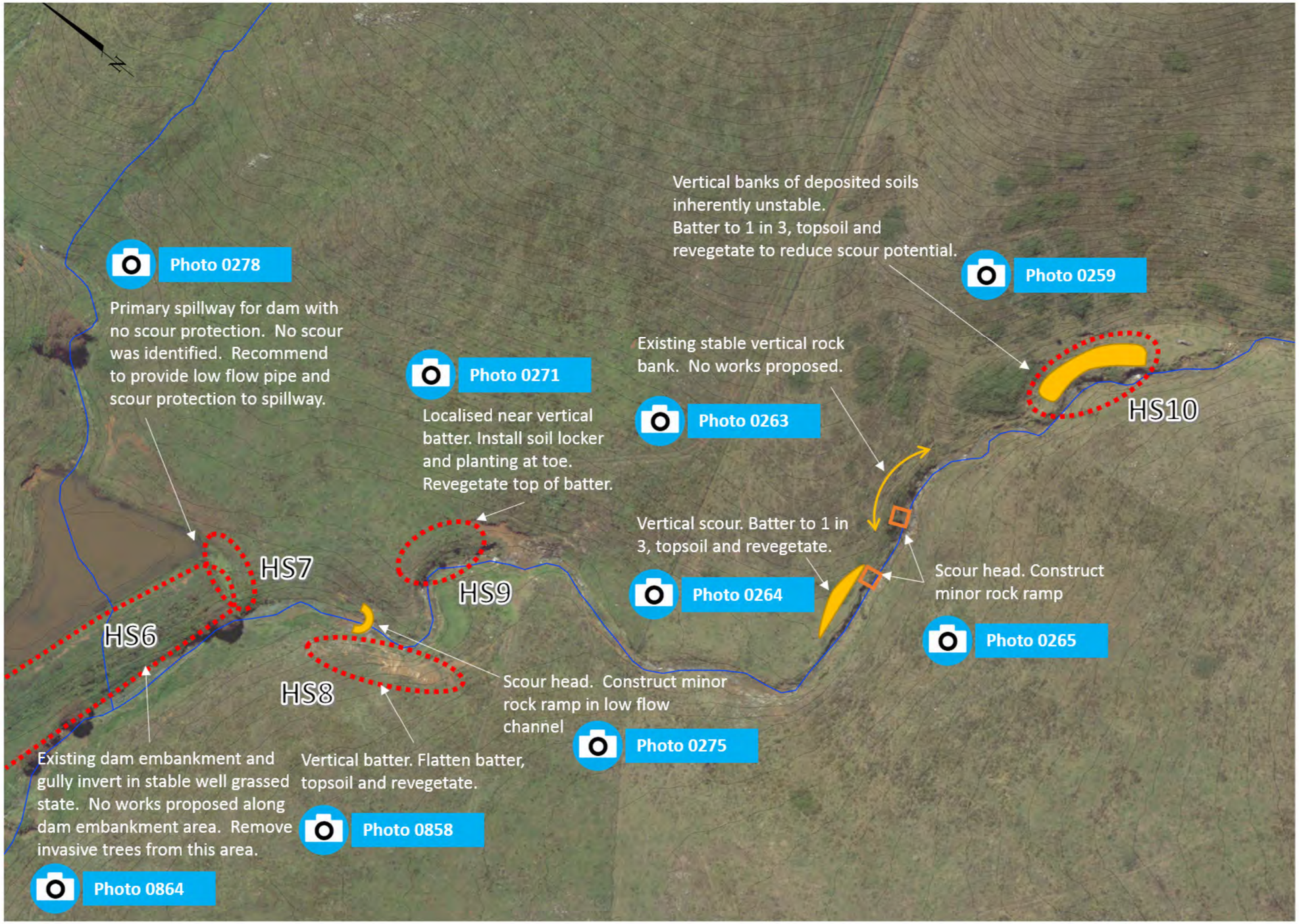

Legend

Hot Spot (HS)

General Notes for Sheet 2
Gully Area:

1. Gully has many natural bedrock weirs and invert along this reach.
2. Batters typically stable and well vegetated except where indicated.
3. Non-dispersive soil.
4. Areas of deep sediment deposits which have vertical eroded batters to be stabilised.
5. Flat longitudinal grade of channel with bedrock controlled steps and long pools.
6. Extensive phragmites plants between HS10 and HS13, providing soil stabilisation.
7. All works proposed subject to survey and detailed design.

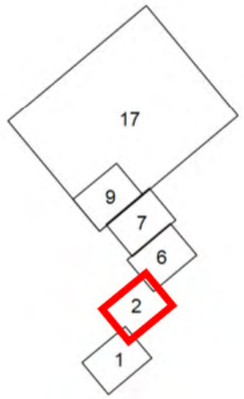

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Photo 0259

Photo 0263

Photo 0264

Photo 0265

Photo 0271

Photo 0858

Photo 0275

Photo 0278 – Grassed dam spillway

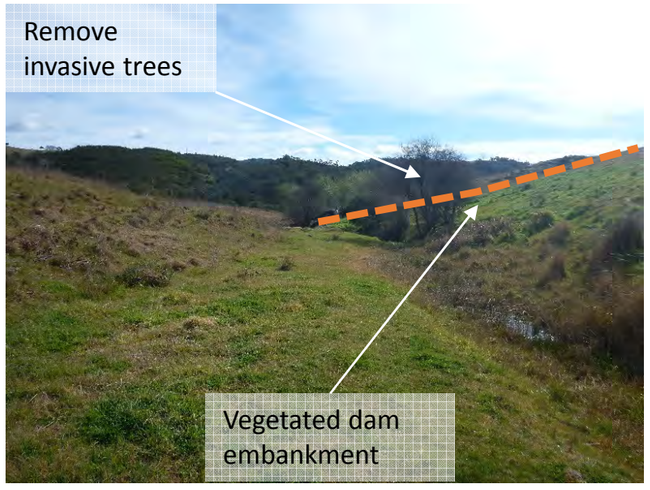

Photo 0864 – Stable vegetated gully adjacent dam

Note: Photos were taken during site visit on 22 January 2015

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Incised section of gully approximately 3-4m deep, with bedrock control and steep vegetated batters. No works proposed to batters due to steep topography adjacent. Recommend leaky rock weirs placed across gully to reduce flow velocities in several locations to protect from more frequent urban runoff.

Photo 0228 & 0231

Some active erosion and vegetation restabilisation process occurring.

Photo 0230

Existing rock ramp and pools

Photo 0235

Bank slump revegetation

Existing rock ramp into plunge pool

Photo 0238

Existing rock weir

Photo 0241

HS13

Vertical batter in deposited soil. Batter back, provide toe protection with gabion or rock, topsoil and planting on batter.

Rock toe left hand side bank. Near vertical above, leave as it is.

Scour head upstream in low flow channel. Construct minor rock ramp with permeable leaky weir.

Photo 0253

Scour batter. Flatten batter to 1 in 3, topsoil and revegetate

Vertical batters. Batter to 1 in 3, topsoil and revegetate. Permeable weir extension across adjacent overflow areas.

Photo 0245

HS12

Steep stable rocky bank. No works proposed.

Photo 0245

HS11

Photo 0252

Legend

Hot Spot (HS)

General Notes for Sheet 6 Gully Area:

1. Flatter longitudinal grades downstream of HS13 with rock steps and long pools.
2. Batters are typically stable downstream of HS13 except where indicated.
3. Extensive phragmites plants between HS10 to HS13.
4. Steep grade and bedrock controlled upstream of HS13. No protection works proposed except where indicated. Batters have good vegetation cover.
5. All works proposed subject to survey and detailed design.

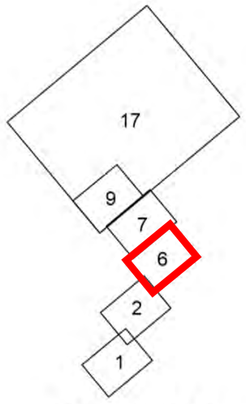

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Photo 0228 – Bedrock controlled gully with steep stable batters

Photo 0230

Photo 0231 – Bedrock controlled gully with steep stable batters

Photo 0235 – Existing rock ramp and pool

Photo 0238 – Existing rock ramp

Photo 0241 – Existing rock ramp

Photo 0245

Photo 0252 – Stable gully with phragmites

Photo 0253

Note: Photos were taken during site visit on 22 January 2015

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Bedrock weir

Stable rock near vertical bank. No works proposed.

Good existing vegetation cover

Steep rocky channel, bedrock natural weirs no works proposed

Photo 0214 & 0209

Bank erosion (1.5-2m). Vertical alluvium fill erosion. Batter to 1 in 1 back to rock strata and retain existing trees at top of batter. Install toe protection with 'soil log', topsoil and planting

Photo 0219

Add planting or toe protection to old slump

Photo 0222

Bedrock controls and pools; approximately 1m drops.

Existing rock drop and pools

Remove and control willow tree, noxious weeds

HS14

Minor erosion head. Construct minor rock ramp

Legend

Hot Spot (HS)

General Notes for Sheet 7 Gully Area:

1. Lower half of creek is flatter, consisting of natural rock drops and pools with stable grassed batters except where indicated.
2. No works proposed except where indicated.
3. Upper half of sheet is steep bed rock controlled channel with no works proposed.
4. Non dispersive soil.
5. Any earthworks to be re-topsoiled and revegetated.
6. All works proposed subject to survey and detailed design.

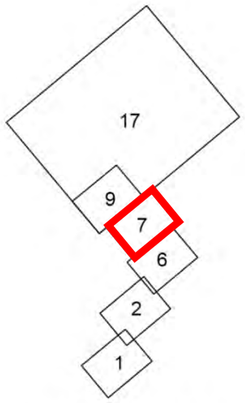

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Photo 0209 – Bedrock controlled gully

Photo 0214 – Bedrock controlled gully

Photo 0219

Photo 0222

Note: Photos were taken during site visit on 22 January 2015

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Discharge low flow pipe into pond

AECOM proposed
Pond B9

HS15

Bank erosion to low flow channel bank. Current subdivision stormwater management strategy proposes a stormwater quality control pond/wetland embankment in this location

Steeper bedrock controlled with natural rock ramps and pools. Well vegetated batters. No works proposed.

Photo 0184, 0188 & 0190

Minor slump. Batter and revegetate.

Photo 0203

Bedrock controlled. Flatter well grassed sides and slopes. No works proposed except where indicated.

Photo 0198 & 0204

Bedrock controlled. Batter well grassed sides and slopes. No works proposed except where indicated.

Legend

Hot Spot (HS)

General Notes for Sheet 9
Gully Area:

1. Channel typically bedrock controlled with well grassed banks with little erosion. No works proposed except where indicated.
2. Weeding to be undertaken progressively to ensure vegetation cover remains.
3. Non dispersive soil.
4. All works proposed subject to survey and detailed design.

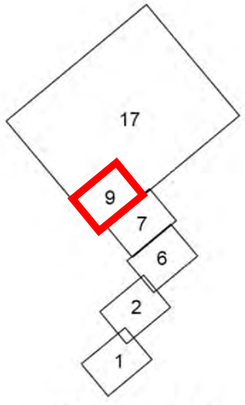

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Photo 0184 – Bedrock controlled gully

Photo 0188– Bedrock controlled gully

Photo 0190 – Bedrock controlled gully

Photo 0198 – Stable vegetated gully

Photo 0203

Photo 0204 – Stable vegetated gully

Note: Photos were taken during site visit on 22 January 2015

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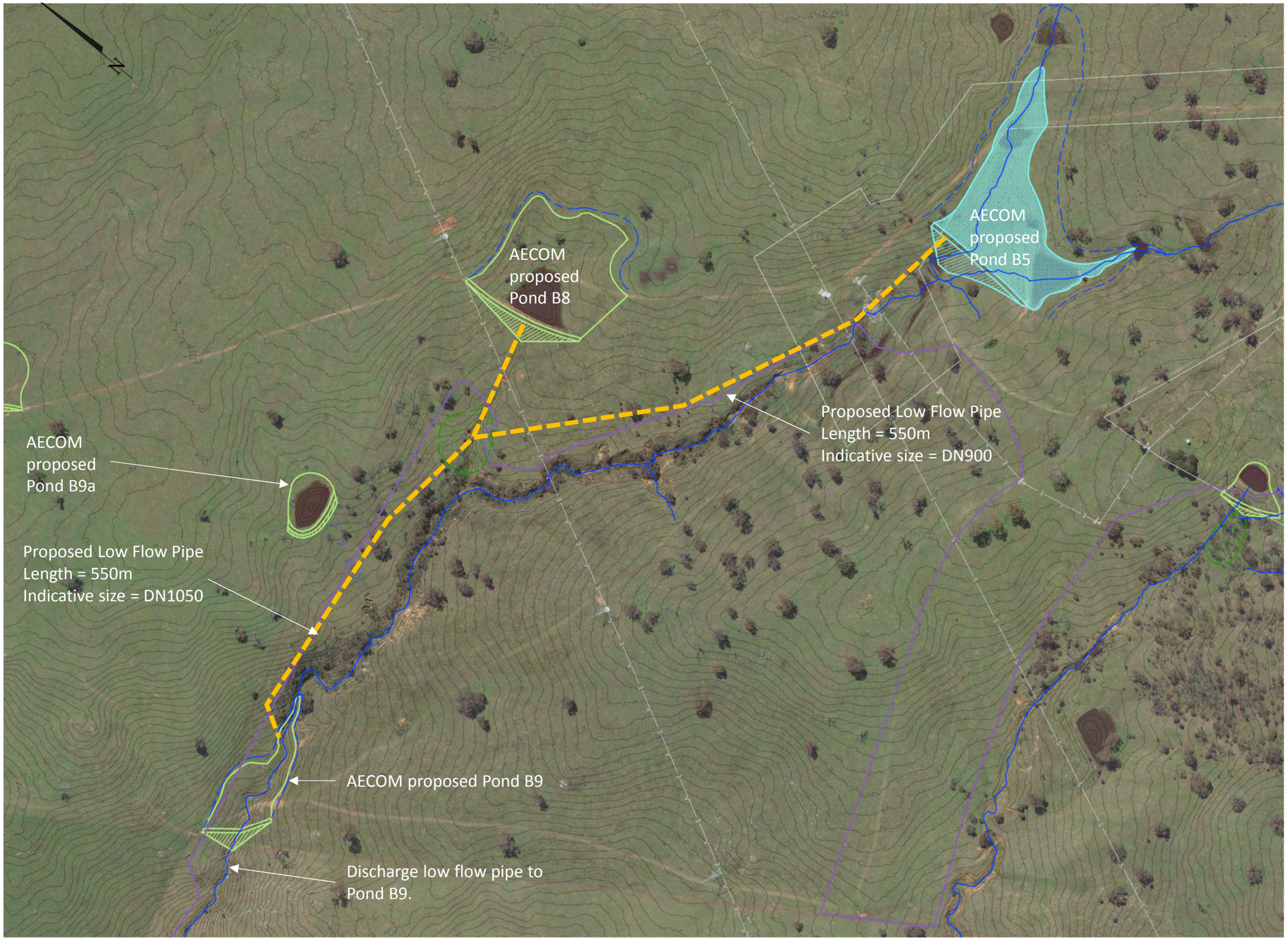
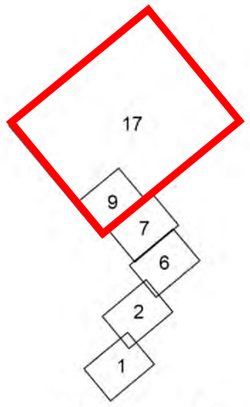


General Notes for Sheet 17 Gully Area:

1. No protection works proposed with gully due to limited access.
2. Hotspot remediation works proposed along gully. Refer Brown Consulting report dated September 2014 for details.
3. Construct pipe to bypass frequent urbanised runoff around incised gully to maintain closer to natural flow frequent through gully.
4. Allow large less frequent flows to be conveyed through gully as currently occurs.
5. Discharge low flows at spillway outlet of Pond B9 into bedrock controlled creek section.
6. Possible relocation of ponds subject to final design.
7. All works proposed subject to survey and detailed design.



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APPENDIX D REMEDIATION MEASURES

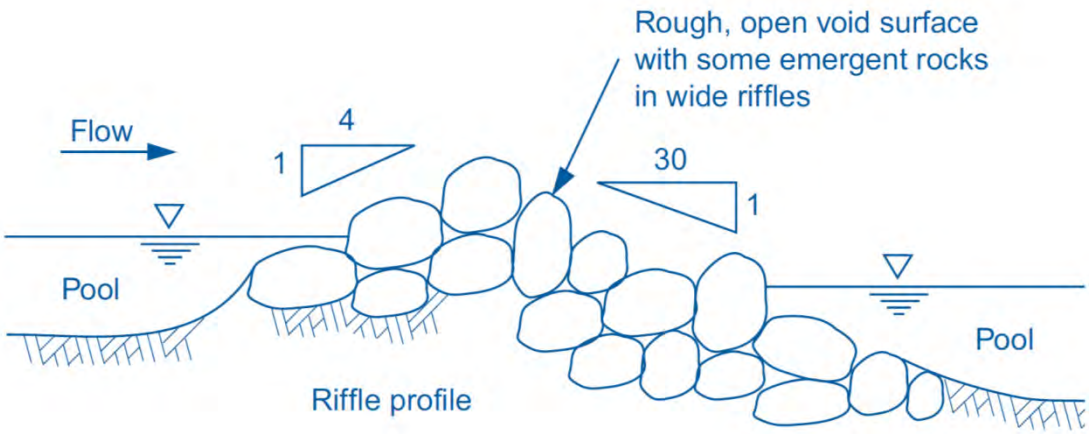


Image sourced from Natural Channel Design Guidelines
Figure A.14 Typical Riffle Profiles

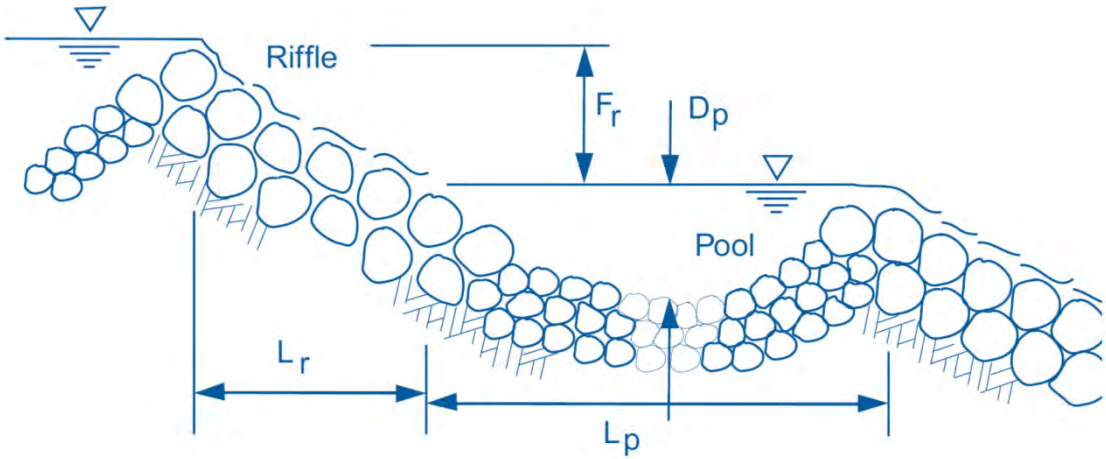
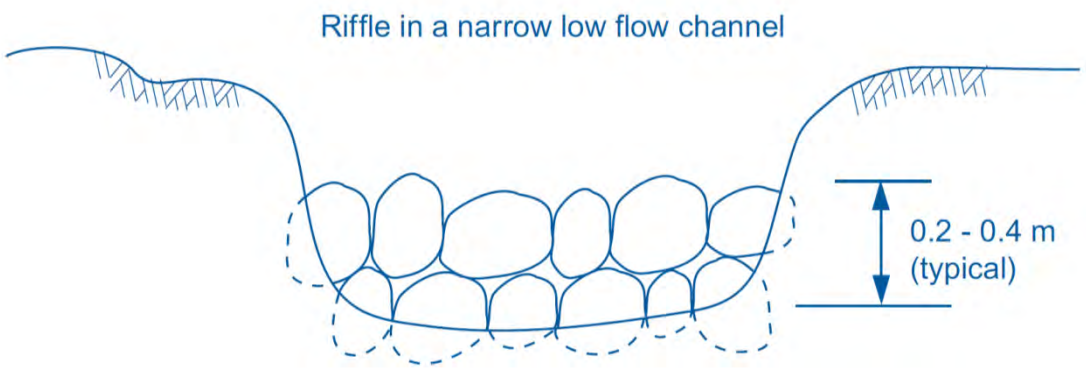


Image sourced from Natural Channel Design Guidelines
Figure 3.10 Pool-riffle System



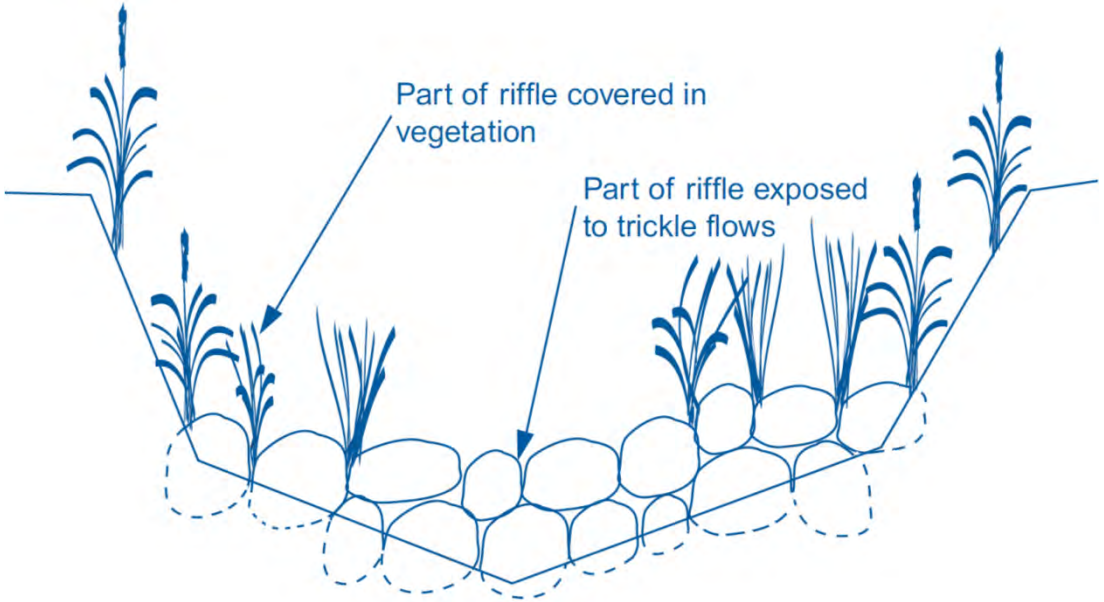


Image sourced from Natural Channel Design Guidelines
Figure A.14 Typical Riffle Profiles

West Belconnen Development

Gully E Stabilisation

For Discussion Purposes Only

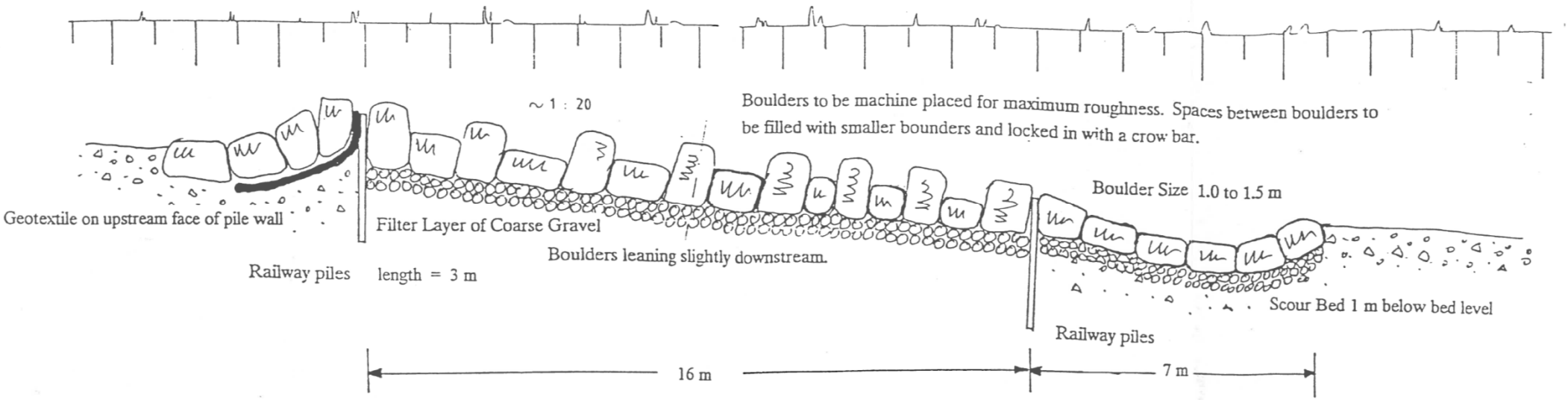
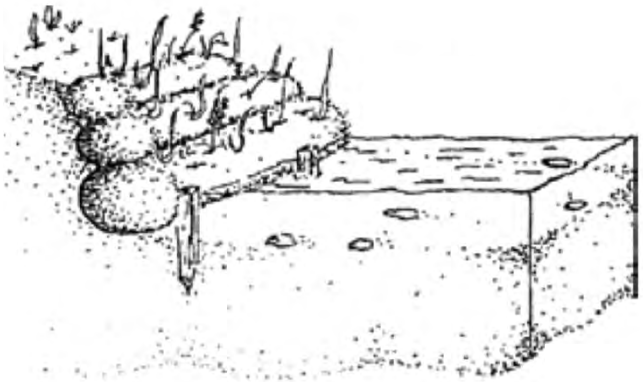


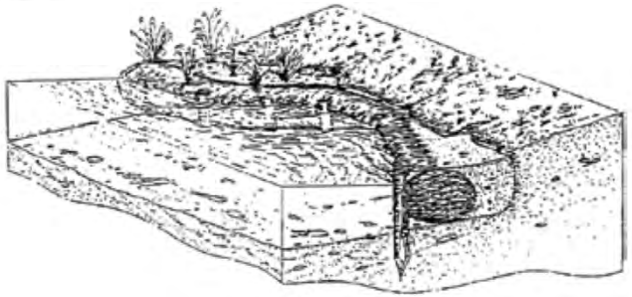
Image sourced from New South Wales Department of Water Resources
Figure A2.4 Schauberger Ramp

West Belconnen Development

Gully E Stabilisation

For Discussion Purposes Only





West Belconnen Development

Gully E Stabilisation

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