Rowan



Site Specific Flood Risk Assessment

Coffey Construction Ltd, Slade, Saggart,
Co. Dublin

Date: 12th February 2022 – REV.D

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Table of Contents

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Background & Context

It is understood that Coffey Construction Ltd. have applied to South Dublin County Council for planning permission to recontour / infill lands at a site at Slade, Saggart, Co. Dublin (see Plate 1). It is also understood that the Local Authority has requested the following further information pertaining to the potential for flood risk at the site:

'4. Water Services has raised concerns in relation to surface water and flooding. Given the quantity of material proposed to be deposited, the proximity of a water source and presence of flood zones the applicant is requested to submit the following:

Surface Water

(1) Water Services have concerns that the proposed development will result in an increased surface water run off rate from the site which would exacerbate flooding issues downstream. The applicant is requested to submit a report which demonstrates that surface water run off rates will not be increased from the site.

(2) The applicant is requested to clarify what water pollution and silt pollution mitigation measures are implemented as part of the development. Silt fencing should also be included as part of these silt prevention measures.

(3) The applicant is requested to clarify what the long term proposals are for the development. How long will the fill remain in the proposed location and will the site be reseeded with grass or reinstated in any way to its natural state?

Flooding

(1) The proposed development site is located within Flood Zone A according to OPW's (Office of Public Works) CFRAM maps and South Dublin County Council's Strategic Flood Risk Assessment 2016-2022. The applicant is requested to submit a site-specific flood risk assessment report with the inclusion of a justification test in compliance with OPW Flood Risk Management Guidelines for Planning Authorities. The report shall demonstrate how flood risk will not be exacerbated on the site as well as upstream and downstream of the development. Details of the measures and design features to prevent/mitigate the risk of flooding to the proposed development and to adjoining lands shall be submitted.

(2) The applicant is requested to submit a map showing the location of the site and proposed infill'.

Plate 1. Aerial view of proposed infill site.

Consequently, Hydrec Environmental Consulting was engaged by Elaine Gibson, Senior Environmental Consultant at Rowan Engineering Consultants on behalf of the applicant to complete a Site-Specific Flood Risk Assessment. This document contains the details of said assessment and is structured in the following format:

- Section 2 outlines the planning and flood risk guidelines adhered too;
- Section 3 describes the site setting and existing environment;
- Sections 4 – 6 works through a staged approach to the flood risk assessment;
- Section 7 describes the outcome of the detailed flood risk assessment / hydraulic modelling outputs;
- Section 8 describes the mitigation measures described for the project;
- Section 9 assesses the requirement for a justification test; and
- Section 10 concludes on the findings of the assessment.

2.0 THE PLANNING SYSTEM & FLOOD RISK MANAGEMENT GUIDELINES

The following assessment has been carried out in accordance with *'The Planning System and Flood Risk Management Guidelines for Planning Authorities' (DoEHLG, 2009).* This document is referred to as the 'Guidelines' throughout the remainder of the report.

These guidelines recommend a staged approach to flood risk assessment that covers both the likelihood of flooding and the potential consequences. The stages of appraisal and assessment are:

- **Stage 1 Flood Risk Identification** – to identify whether there may be any flooding or surface water management issues related to either the area of regional planning guidelines, development plans and LAP's or a proposed development site that may warrant further investigation at the appropriate lower level plan or planning application levels;
- **Stage 2 Initial flood risk assessment –** to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information and to scope the extent of the risk of flooding which may involve preparing indicative flood zone maps. Where hydraulic models exist the potential impact of a development on flooding elsewhere and of the scope of possible mitigation measures can be assessed. In addition, the requirements of the detailed assessment should be scoped; and
- **Stage 3 Detailed flood risk assessment –** to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development or land to be zoned, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.

With reference to flood zones, flood zones are geographical areas within which the likelihood of flooding is in a particular range. There are three types or levels of flood zones defined for the purposes of these Guidelines:

- **Flood Zone A** – where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding);
- **Flood Zone B** – where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding); and

- **Flood Zone C** – where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

3.0 SITE DESCRIPTION & EXISTING ENVIRONMENT

3.1 Site Description & Proposed Development

It is understood that Coffey Construction Ltd. have applied to South Dublin County Council for planning permission to recontour / infill lands at a site at Slade, Saggart, Co. Dublin. It is also understood that this infill material will consist of inert soil, subsoil and stone excavated from an adjoining site where they are constructing a new 100,000m^3 covered reservoir of approximately 31,520m^2 in area with a height of c.6.7m for Irish Water. In total a volume of 35,000m^3 of material with an average fill level of c.3.5m above existing ground level is proposed. A minimum buffer distance of 10m from the Camac Stream is proposed across the site. Additionally, the applicant's have not scheduled any infilling of lands below an elevation of 135.81m in an effort to avoid the infilling of any Flood Zone A areas. It is understood that after all infill has been deposited onsite, the site will be reseeded and returned to agricultural use.

3.2 Hydrology

With the publication of Ireland's second River Basin Management Plan (RBMP), the RBMP 2018 – 2021 defines the entirety of the island of Ireland as a single River Basin District (RBD). This single RBD has been broken down into 46 catchment management units. These units are mainly based on the hydrometric areas in use by the local authorities. Each of the 46 catchment management units have been further broken down into 583 sub-catchments. The proposed development site is located within the Liffey & Dublin Bay Hydrometric Area (No.09) and WFD Catchment (No.09). Additionally, the site is located within the Liffey_SC_090 WFD Sub-catchment.

The Camac stream (2nd Order) which runs adjacent to the eastern / south-eastern boundary of the proposed infill site is the closest watercourse to the site (see Figure 1 & Plate 2). This waterbody flows in a general southern to northern orientation, whereby it is culverted under the L6018 – Local Road. From there it passes / diverted through the Millbrook Manor Nursing Home and afterwards merges with the Crockshane Stream c. 600m downstream. In total, the contributing upstream catchment from the site equates to an area of 5.821km^2.

LEGEND

Site Boundary

Stream / River

Drainage Channel

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:
Flood Risk Assessment Report
Coffey Construction Ltd -
Slade, Saggart, Co. Dublin

TITLE:
Hydrological features in the vicinity of the site

SCALE: 1:8,000@A3	DRAWN BY: PMcC
DRAWING NO: Figure 1.	REV. 0

Plate 2. View of the Camac stream, bordering the proposed development site and facing in a northern direction.

3.3 Geology

According to the Teagasc and EPA soils map, three different soil types are mapped to occur within the site. AminDW – Deep well drained (Mainly acidic) soil belonging to the Acid Brown Earths / Brown Podzolics soil group exists within the ground at a higher elevation in the northern portion of the site. BminSW – Shallow well drained (mainly basic) soil is mapped to occur as band across the centre of the site. Whilst, AlluvMin – mineral alluvium soils are found on the periphery of the Camac Stream.

In Ireland, the parent material underlying the majority of the country is comprised of quaternary sediments with the remainder composed of bedrock outcrop. These quaternary sediments have resulted from glacial movement, melting and deposition. Similarly, the Teagasc and EPA subsoil maps identify that there are three different subsoil types present (see Figure 2). Where AminDW is found, TLPSsS – Sandstone and shale till of predominantly clayey texture is present. GLs – Glaciofluvial sands & gravels are found to underly the AminSW soils, whilst undifferentiated alluvium subsoils are found in the vicinity of the Camac River. Correspondingly, three differing groundwater subsoil permeability classifications are found within the confines of the site. The alluvium subsoil is categorised as being of 'Low'

LEGEND

- Site Boundary
- A - Alluvium
- Gls - Sands & Gravels
- TLPSsS - Sandstone & Shale Till

HYDREC ENVIRONMENTAL CONSULTING

PROJECT: Flood Risk Assessment - Coffey Construction Ltd - Slade, Saggart, Co. Dublin

TITLE: Teagasc Subsoil Maps of Site & Surrounding Lands

SCALE: 1:1,250	DRAWN BY: PMcC
DRAWING NO: Figure 2	REV. A

permeability, the sandstone and shale till is categorised as being of 'Moderate' permeability, whilst the glaciofluvial sands and gravels mapped across the centre of the site are defined as being of 'High' permeability (see Figure 2).

Based on the GSI's 1:100k bedrock formation mapping, the majority of the site is underlain by the Pollaphuca Formation which comprises of medium grey, coarse, graded greywackes and dark grey shales. No bedrock outcrops are present within the boundaries of the site, with the closest outcrop identified approx. 1km to the north. According to The National Karst Database, no karst landforms are identified within or in close proximity the site.

4.0 STAGE 1 ASSESSMENT (SCREENING STAGE) – FLOOD RISK IDENTIFICATION

4.1 Review of Available Data Sets & Potential Sources of Flooding

4.1.1 Fluvial Flooding – Preliminary Flood Risk Assessment (PFRA)

River flooding or fluvial flooding occurs when the capacity of a watercourse is exceeded due to extreme rainfall resulting in excess waters spilling out onto low-lying areas. The Preliminary Flood Risk Assessment (PFRA) was a national screening exercise undertaken in 2011 to identify areas at potential flood risk. The country was divided into 420 map tiles for the purposes of disseminating the output of the assessment. These maps indicate the extent of the predicted 0.5% annual exceedance probability (AEP) for coastal flooding, the 0.1% AEP for fluvial flooding and the 1.0% AEP for pluvial flooding. Based on the PFRA, fluvial flooding from the Camac Stream on the eastern / south-eastern boundary of the site was predicated to occur. As a result, the proposed infill site was partially mapped as being potentially susceptible to fluvial flooding (see Plate 3).

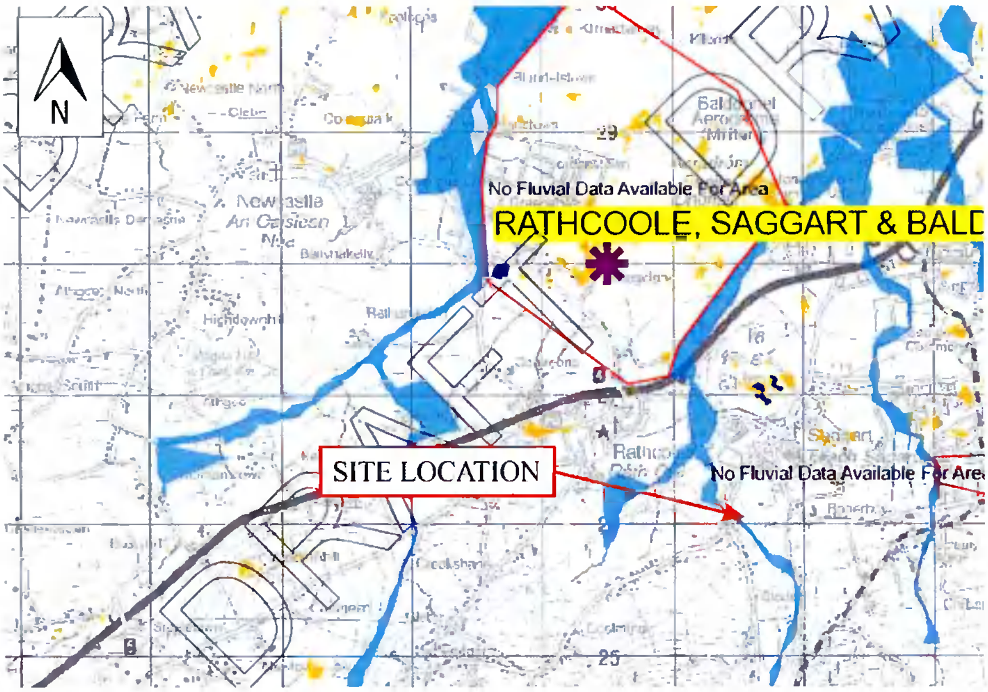


Plate 3. Extract from the Office of Public Works (OPW), Preliminary Flood Risk Assessment (PFRA) 2011.

4.1.2 Fluvial Flooding – Catchment Flood Risk Assessment and Management (CFRAM)

Following the PFRA, the catchment flood risk assessment and management (CFRAM) programme identified 300 Areas for Further Assessment where flood risk was deemed to be potentially significant. The Eastern CFRAM Study Area covers approximately 6,250 km^2 and includes four Units of Management (UoM); Hydrometric Area (HA) 07 (Boyne), HA08 (Nanny – Delvin), UoM09 (LiffeyDublin Bay) and HA10 (Avoca-Vartry). The Eastern CFRAM Flood Risk Review highlighted the Camac catchment as an Area for Further Assessment and a High Priority Watercourse based on a review of historic flooding and the extents of flood risk determined during the PFRA. The stretch of the Camac Stream bordering the applicant's site, is included within the Camac Hydraulic Model – Upper Catchment. As can be seen from the Camac Model flood extent mapping (see Plate 4), flooding under the 1 in 100-year scenario is predicted to occur within parts of the proposed infill site.

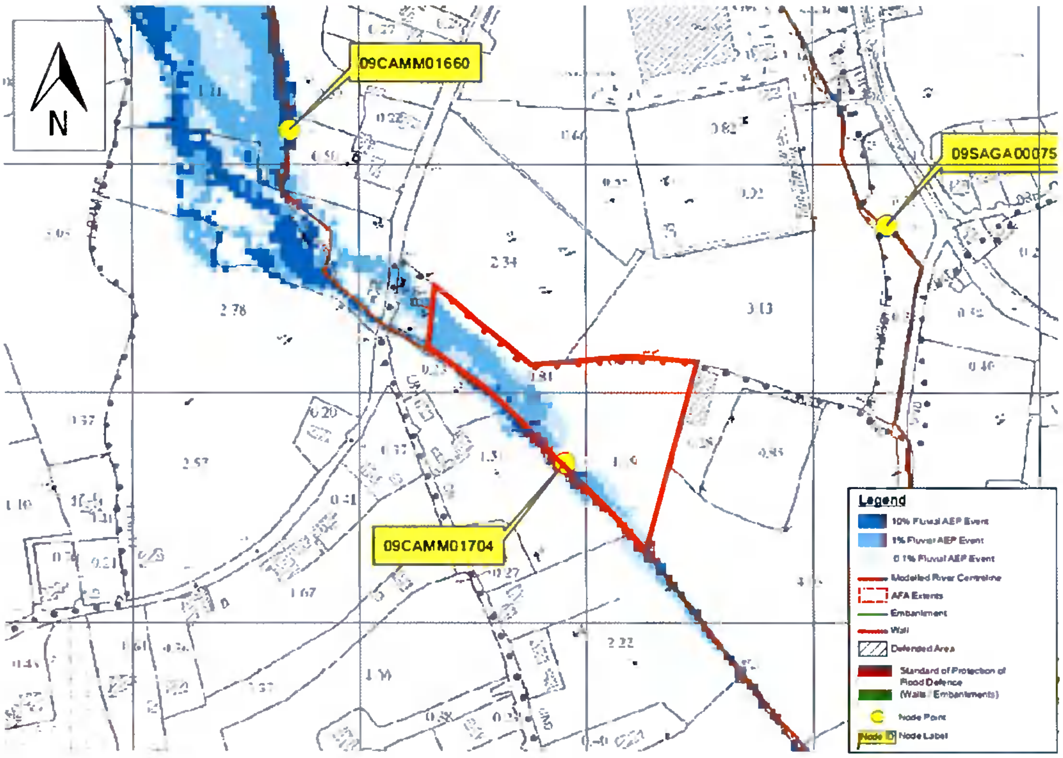


Plate 4. Extract from the Eastern CFRAM flood mapping showing the 10%, 1% and 0.1% fluvial flood extents based on current day scenario (i.e. site boundary outlined by red polyline).

4.1.3 Fluvial Flooding – National Indicative Flood Mapping (NIFM)

The National Indicative Fluvial Maps (NIFM) is a project which was finalised in December 2020 which provides an indication of areas that may flood during a flood of an estimated probability of occurring. These indicative fluvial flood maps were developed using hydrodynamic modelling, based on calculated design river flows, Digital Terrain Models, and other relevant datasets (e.g. land use, data on past floods, etc.) for all subject watercourses with an upstream catchment area of greater than 5 km^2. It should be noted that the NIFM are not as accurate as the Flood Maps produced under the CFRAM Programme but could be regarded as advance from the PFRA where available. Owing to the size of the catchment in which the site is situated, National Indicative Flood Mapping has not been produced for the Camac Stream in the vicinity of the site.

4.1.4 *Historic Flood Records*

On review of the historic flood event data obtained from the Office of Public Works (OPW) past flood event records (www.floodinfo.ie), it was revealed that no flood events have previously been recorded within the confines of the infill location. Similarly, there is no record within this dataset of any flood events occurring within the catchment upstream from the site. The following historic flood event was recorded a considerable distance from the site (i.e. >600m), however it should be noted that the extent of the flooding associated with this event was not recorded to have impinged onto the study site:

- Flooding at Mill Road, Saggart, Co. Dublin on the 24th October 2011. It was noted that overland flows passing through Mill Race Development lands built up behind a masonry wall causing the wall to collapse and flows to be routed through properties across Mill Road.

It is understood that in January 2021, planning permission was granted by the Local Authority for an extension of the Millbrook Manor Nursing Home which is situated to the north-west of the proposed infill site. It also understood that a Site-Specific Flood Risk Assessment (FRA) was prepared as part of that application. A review of that FRA has also been undertaken to further inform on the potential for flooding in the vicinity of the applicant's site. Details of the Section 50 application completed in 2014 for the diversion of the Camac Stream through the site was included within this document. The assessment concluded that the 1 in 100-year flood level (i.e. including climate change allowance) was calculated at 129.34m AOD. Subsequently it was determined that a freeboard of 1.34m for the 1% AEP could be achieved for the proposed culvert design.

4.1.5 *Pluvial Flooding*

Pluvial flooding occurs when extreme rainfall exceeds the soil infiltration capacity or drainage capacity causing excess rainwater to pond above ground at low points in the topography. The OPW's PFRA maps does not identify any part of the site as being susceptible to pluvial flooding.

4.1.6 Coastal Flooding

Coastal flooding is caused by higher sea levels than normal, largely as a result of storm surges, resulting in the sea overflowing onto land. The development site is located approx. 19km from the coast and therefore coastal flooding is not deemed to be an issue at the site.

4.2 Stage 1 Conclusion

Pluvial and coastal flooding are not anticipated to occur onsite and therefore no further assessment in terms of risk from either is required. According to the PFRA and CFRAM mapping, there is the potential for fluvial flooding to occur within the confines of the proposed infill site. It is therefore concluded that the assessment should proceed to Stage 2 (Scoping Stage) and concentrate on the potential fluvial flood risk.

5.0 STAGE 2 ASSESSMENT (SCOPING STAGE) – INITIAL FLOOD RISK ASSESSMENT

As mentioned previously, more detailed hydraulic modelling of the Camac Stream / River was completed as part of the Eastern CFRAM Study. In order to assess the sufficiency of the model in respect to the client's site the following reports have been reviewed:

Eastern CFRAM Study, HA09 Hydraulics Report (Final 09/08/2017); and

Eastern CFRAM Study, HA09 Hydrology Report (Final 29/04/2016).

At each node point published from the model an estimated water level (mAOD) for the 10% AEP Event (1 in 10-year), 1% AEP Event (1 in 100-year) and 0.1% (1 in 1000-year) is predicted. On such node (i.e. Node 09CAMM01704) is located on the Camac Stream adjacent to the proposed infill site (see Plate 4). Under the 1 in 100-year flood event a water level of 135.81m AOD was predicted (see Plate 4). These flood levels represent the current day scenario (i.e. without climate change allowance). On review of the Flood Extents and Flood Depth maps produced for the applicant's site, it was determined that certain portions of the site were classified as 'Flood Zone A'.

It is understood that post infilling, the site will be reseeded and returned to agricultural use. Consequently, the development can be classified as a *'Less Vulnerable Development'* according to Table 3.1 of the 'Guidelines'. As can be seen from Plate 5, *'Less Vulnerable Development'* is appropriate in lands demarcated as Flood Zone B (i.e. 1 in 1000-year event), whilst a Justification Test is required for development with a Flood Zone A (i.e. 1 in 100-year event). As mentioned previously, the applicants have considered the Flood Zone A map when selecting were to locate the infill material. All infill material has been scheduled for lands of elevations in excess of 135.81m AOD, which coincides with the level above the 1% AEP flood elevation modelled at Node 09CAMM01704 of the Camac Model. A small portion of flooding under the 1% AEP is also mapped to occur along the periphery of the Camac Stream, upstream of Node 09CAMM01704 and within the confines of the proposed infill site. However, on review of the LIDAR and topographical data produced for the site, no elevation below 135.81m AOD has been recorded. Thus, it was deemed necessary that a hydraulic model of the Camac Stream in the vicinity of the site should be completed. In addition, design / flood flows incorporating a climate change allowance should be modelled.

	Flood Zone A	Flood Zone B	Flood Zone C
Highly vulnerable development (including essential infrastructure)	Justification Test	Justification Test	Appropriate
Less vulnerable development	Justification Test	Appropriate	Appropriate
Water-compatible development	Appropriate	Appropriate	Appropriate

Plate 5. Matrix of vulnerability versus flood zone to illustrate appropriate development and that required to meet the Justification Test (Extract from The Planning System and Flood Risk Management Guidelines)

As the flood maps produced during the Eastern CFRAM study are dated 2017, it was deemed prudent that these flood levels should be checked based on current river channel conditions (i.e. to account for any potential deviation of the elevation of the riverbed over the past 4 years etc.).

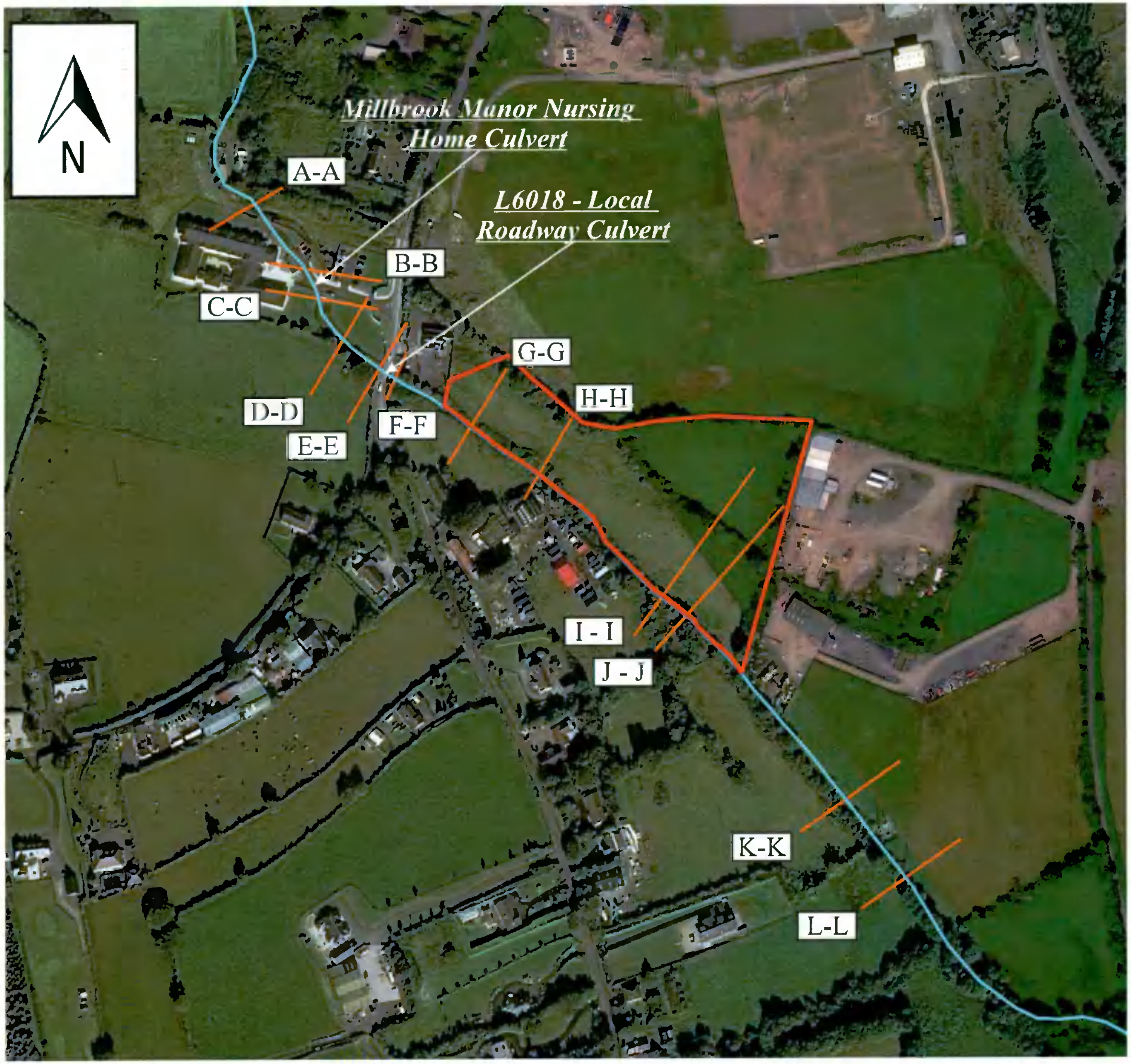
6.0 STAGE 3 ASSESSMENT – SITE SPECIFIC DETAILED FLOOD RISK ASSESSMENT

6.1 Site Survey

On the 06th of September 2021, Patrick McCabe of Hydrec Environmental Consulting visited the applicant's site and surrounding environs to assess the condition of the watercourse and to select the cross-section locations required to complete the hydraulic modelling aspect of the project. It was noted that the stream bed comprised largely of a gravel / cobble substrate with a degree of substrate siltation evident on the base of the channel. Minimal instream vegetation was observed during the assessment. Two pieces of instream infrastructure were noted, including (see Figure 3 & Plate 6):

- An arched bridge culvert (i.e. 2.135m rise and 3.429m span), located within the channel directly to the north-west of the site (i.e. L6018 – Local Road Culvert); and
- A rectangular box concrete culvert (1.359m rise and 3.843m span), located within channel and within the grounds of the Millbrook Manor Nursing Home.

Plate 6. Photo of L6018 – Local Road Bridge traversing the Camac Stream to the north-east of the site.



LEGEND

- Site Boundary
- Stream / River
- Cross Section Location
- Drainage Channel

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:
Flood Risk Assessment
- Coffey Construction Ltd. -
Slade, Saggart, Co. Dublin

TITLE:
Topographical cross sections locations used within the hydraulic model assessment

SCALE: 1:2,500@A3	DRAWN BY: PMcC
DRAWING NO: Figure 3.	REV. 0

Subsequent to the site visit, it was determined that twelve topographical cross sections and topographical data relating to the instream infrastructure was required to construct an accurate model of the watercourse. In total the model extent covers circa a 630m stretch of the Camac stream (i.e. including a sufficient distance upstream and downstream from the site). A summary of the cross-section locations and their justification for selection is described in Table 1. below.

Table 1. Description of the cross-section locations utilised in the HEC – RAS hydraulic model.

Cross Section No.	Description of Cross Section Location
Cross Section 1 (L-L)	170m upstream from the site under focus
Cross Section 2 (K-K)	105m upstream from the site under focus
Cross Section 3 (J-J)	Within the southern portion of the site
Cross Section 4 (I-I)	Within the southern portion of the site
Cross Section 5 (H-H)	Within the northern portion of the site
Cross Section 6 (G-G)	Within the northern portion of the site
Cross Section 7 (F-F)	Upstream of local roadway culvert
Cross Section 8 (E-E)	Downstream of local roadway culvert
Cross Section 9 (D-D)	Through Millbrook Manor Nursing Home
Cross Section 10 (C-C)	Upstream of Nursing Home lane culvert
Cross Section 11 (B-B)	Downstream of Nursing Home lane culvert
Cross Section 12 (A-A)	190m downstream of study site

All cross-section surveying was completed by Horizon Surveys Ltd in October 2021. This topographical data offers concise and highly accurate details of the top and bottom levels of the stream banks and the watercourse bed elevations. The cross profiles are included in Appendix 1. LIDAR data supplied by the Ordnance Survey Ireland (OSI), was utilised to define the floodplain extents. This topographical data was ground proofed using site elevation data taken by Coffey Construction Ltd and Horizon Surveys Ltd.

6.2 Peak Flow Estimation

6.2.1 Flood Studies Update (FSU) Flow Estimate

The Flood Studies Update (FSU) programme was undertaken by the Office of Public Works (OPW), to provide improved methods of extreme rainfall and flood estimation at both gauged and ungauged locations across the Republic of Ireland. The FSU web-based application portal facilitates the estimation of flood flows, extreme rainfall depths and other hydrological variables at river node points at 500m centres along the entire Irish river network.

At each node point, the Qmed value can be obtained from catchment descriptor data through the application of the following regression model:

$$Qmed_{rural} = 1.237 \times 10^{-5} \times AREA^{0.937} \times BFIsoils^{0.922} \times SAAR^{1.306} \times FARL^{2.21} \times DRAIND^{0.341} \times S1085^{0.185} \times (1 + ARTDRAIN2)^{0.408}$$

Where:

AREA = Catchment area (km^2);

BFIsoils = Base flow index derived from soils data;

SAAR = Long term mean annual rainfall amount (mm);

FARL = Flood attenuation by reservoirs / lakes;

DRAIND = Drainage density;

S1085 = Slope of the main channel between 10% and 85% of its length (m/km);

ARTDRAIN2 = Percentage of the catchment river network included in Drainage schemes.

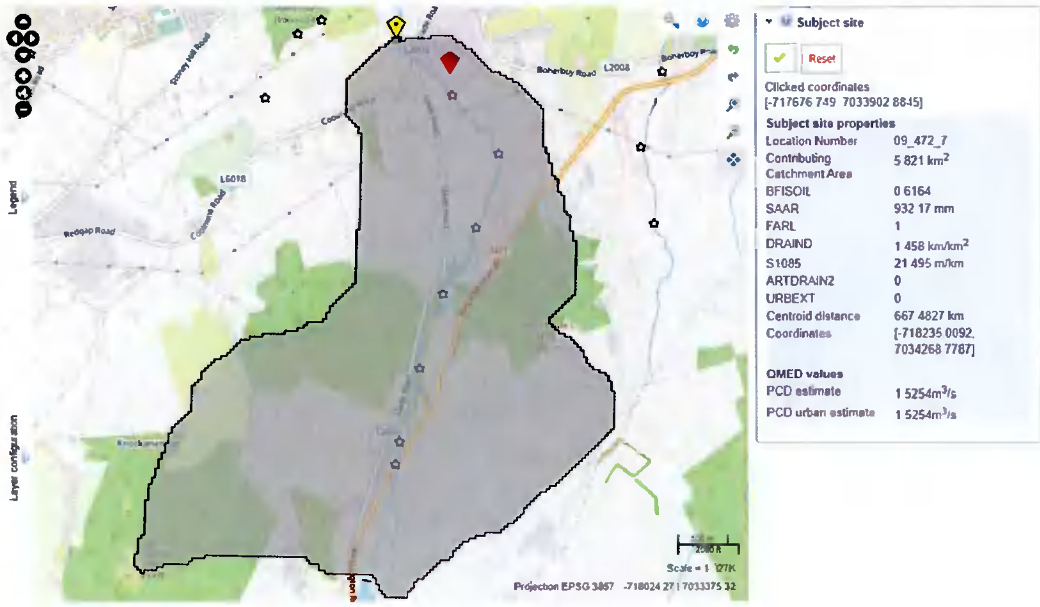


Plate 7. Output from the flood frequencies tool for gauged sites on the OPW FSU web portal.

The programme output for the subject site can be summarised as follows:

- Catchment Area: 5.821km^2
- SAAR: 932.17mm
- S1085: 21.495m/km

- Qmed: 1.525m^3/s

It is important to note that the use of the FSU Qmed is typically designed for catchments that are greater than 25km^2 in area. Caution should be exercised when using this methodology for smaller catchments. Given that the upgradient catchment area equates to 5.821km^2, it is imperative that other methodologies designed for use on smaller catchments are assessed and compared.

6.2.2 Flood Studies Supplementary Report 6

In the absence of sufficient flow records, one of the most appropriate methods for estimating ungauged design flood flows in Ireland is based on the Flood Studies Report (FSR) and subsequent modifications. The original 1975 Flood Studies Report (FSR) equation when tested showed that floods on small catchments were less well predicated than on large ones. The Flood Studies Supplementary Report (FSSR) No. 6 was introduced to overcome the shortcomings in the estimation of mean annual floods from small catchments through the use of the FSR. A total of 53 catchments with <20km^2 catchment area were used in the regression analysis during this study. The FSSR 6 Q_{BAR} equation for use on catchments of less than 20km^2 is:

$$Q_{BAR} = 0.00066 \times AREA^{0.92} \times SAAR^{1.22} \times SOIL^{2.0}$$

Using the FSSR 6 formula, the 1 in 1-year flow is as follows:

$$Q_{BAR} = 0.00066 \times 5.821^{0.92} \times 932.17^{1.22} \times 0.3^{2.0}$$

$$Q_{BAR} = 0.00066 \times 5.06 \times 4195.5 \times 0.09$$

$$Q_{BAR} = 1.26\ m^3/s$$

6.2.3 Institute of Hydrology (IH) 124

In 1994 the Institute of Hydrology carried out further regression studies on small catchments (areas <25km^2). A total of 87 catchments ranging from 0.9km^2 to 24.7km^2 were available. Seventy-one of these catchments were chosen as completely rural catchments having urban fractions of less than 0.025km^2. The following 3-variable equation was derived:

$$QBAR = 0.00108 \times AREA^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$$

This equation is widely used in Ireland to estimate flood flows and Greenfield runoff from small catchments (i.e. between 0.5km² and 25km²).

Using the IH124 formula, the 1 in 1-year flow is as follows:

$$Q_{BAR} = 0.00108 \times 5.821^{0.89} \times 932.17^{1.17} \times 0.3^{2.17}$$

$$Q_{BAR} = 0.00108 \times 4.80 \times 2980.64 \times 0.073$$

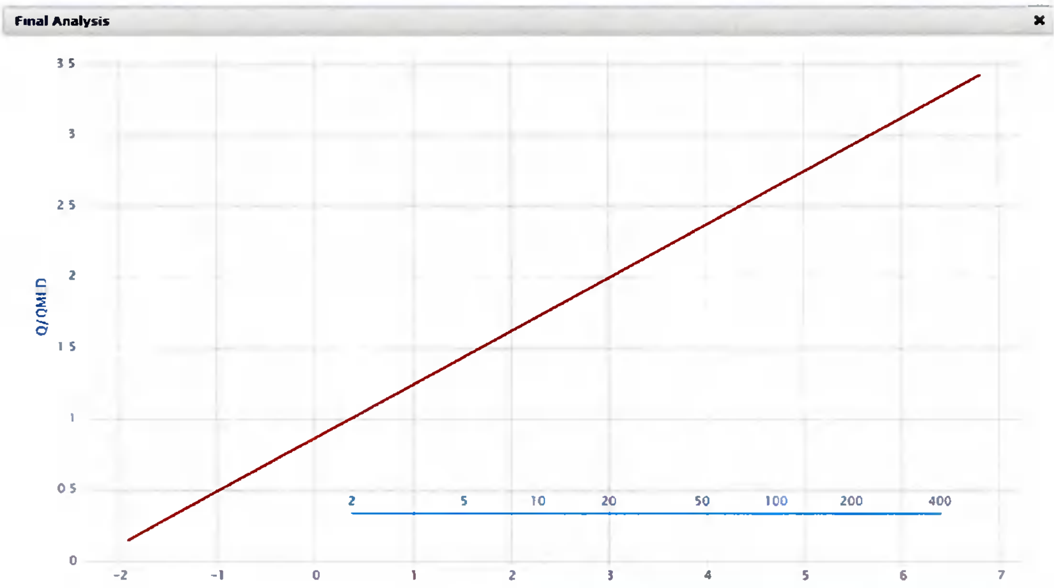
$$Q_{BAR} = 1.13\ m^3/s$$

6.2.4 Flood Frequency Growth Curve for Ireland

Single-Site Flood Frequency Analysis is a statistical analysis of flood data for a particular gauged location and is only possible at locations where recorded time-series data exists. It is a method used to derive flood growth curves and frequency curves so that peak flows can be calculated from the Qmed. The appropriate growth curve for an ungauged catchment is estimated using a Pooled Analysis. This method uses catchment characteristics (PCDs) to identify a number of gauged catchments that are hydrologically similar to the catchment of the subject site. The observed flood data for the "similar" gauged catchments are then pooled to effectively create a longer time-series and used to estimate the peak flow at the ungauged subject site. In this way Pooled Analysis may also be used to supplement Single Site Analysis to improve the robustness of the design estimation particularly for long return period events. A Pooled Flood Frequency Analysis has been performed to derive the AEP growth factors outlined in Table 2 and Plate 8 using the FSU method. These growth factors have been applied to the design flows estimated using the FSU methodology. Conversely, it is possible using the standard growth factors set out in the FSR to calculate the 1 in 100-year design flows for the FSSR 6 and IH 124.

Table 2. Determination of flood flows for selected return periods

Peak Flow Estimation Method	QMED / Q_{BAR} Value (m^3/s)	Growth Factor (1 in 100 Years)	Growth Factor (1 in 1000 Years)	1 in 100 Year Predicted Flow (m^3/s)	1 in 1000 Year Predicted Flow (m^3/s)
FSU	1.53	2.59	3.46	3.96	5.29
FSSR 6	1.26	1.96	2.6	2.47	3.28
IH 124	1.13	1.96	2.6	2.21	2.94



Distribution: EV1

	t=1.3	t=2	t=5	t=10	t=20	t=30	t=50	t=100	t=200	t=500	t=1000
Growth Factors	0.72	1	1.43	1.71	1.98	2.13	2.33	2.59	2.85	3.2	3.46
Design Peak Flows (m^3/s)	1.48	2.06	2.94	3.53	4.08	4.41	4.81	5.35	5.89	6.6	7.14

Plate 8. Pooled Flood Frequency Analysis derived from the OPW FSU web portal for the site.

6.2.6 Climate Change Allowance

It is proposed to apply a further growth factor of 1.2 to these estimated design year flows, in order to allow provision for predicted increased rainfall and associated run-off volumes over the coming century. The design flood flows (with allowance for climate change) are outlined in Table 3 below.

Table 3. Determination of flood flows for selected return periods

Peak Flow Estimation Method	1 in 100 Year Predicted Flow (m^3/s)	1 in 1000 Year Predicted Flow (m^3/s)	Growth Factor (Climate Change Allowance)	Plus Climate Change Allowance	
				1 in 100 Year Predicted Flow (m^3/s)	1 in 1000 Year Predicted Flow (m^3/s)
FSU	3.96	5.29	1.2	4.75	6.35
FSSR 6	2.47	3.28	1.2	2.96	3.94
IH 124	2.21	2.94	1.2	2.65	3.53

6.2.7 Recommended Design Flow

There was a relatively strong agreement between the design flows calculated using the FSSR 6 and IH 124 estimation methods. However, a more stringent 1 in 100-year design flow was estimated using the FSU methodology. Whilst not always utilised in catchments of <25km^2, in this instance this more rigorous design flow estimated from the FSU was used in the hydraulic model.

6.3 Hydraulic Modelling Assessment

In order to assess the extent of fluvial flooding in relation to the 1 in 1000-year flood event, a 1-Dimensional (1D) steady flow hydraulic model of the stream was constructed using the HEC-RAS hydraulic modelling software (latest version 5.0.7). The model was used to simulate the water level at different points along the stream under different flow regimes (see model outputs in Appendices 2 & 3). The model was compiled using the cross-sections surveyed on the 05th October 2021.

When constructing a 1D Steady Flow Hydraulic Model using HEC-RAS software, a number of user defined parameters are required to complete the computational procedure. This includes Manning's 'n-Values' (i.e. roughness coefficient) of the stream banks and channel at each cross-section. Contraction and expansion coefficients are also required to evaluate the amount of energy loss that occurs because of a flow contraction or expansion at each cross-section. The values used in the model are detailed in Table 4. The downgradient boundary condition of the model was determined using the 'Normal Depth' application of the software, whereby the channel slope was defined as 0.02m/m (i.e. relatively steep channel gradient). The 'Critical Depth' function was selected to model the upgradient boundary condition.

Table 4. Summary of roughness, contraction and expansion coefficients used in the hydraulic model

Cross Section No.	Roughness Coefficient (Manning's n Value)	Contraction Coefficient	Expansion Coefficient
Cross Section 1 (L-L) (RS = 212)	Left overbank – 0.035	0.1	0.3
	River channel – 0.033		
	Right overbank – 0.035		
Cross Section 2 (K-K) (RS = 211)	Left overbank – 0.035	0.1	0.3
	River channel – 0.033		
	Right overbank – 0.035		
Cross Section 3 (J-J) (RS = 210)	Left overbank – 0.035	0.1	0.3
	River channel – 0.033		
	Right overbank – 0.035		

Table 4 (Continued). Summary of roughness, contraction and expansion coefficients used in the hydraulic model

Cross Section No.	Roughness Coefficient (Manning's n Value)	Contraction Coefficient	Expansion Coefficient
Cross Section 4 (I-I) (RS = 209)	Left overbank – 0.035		
	River channel – 0.033	0.1	0.3
	Right overbank – 0.035		
Cross Section 5 (H-H) (RS = 208)	Left overbank – 0.035		
	River channel – 0.033	0.1	0.3
	Right overbank – 0.035		
Cross Section 6 (G-G) (RS = 207)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		
Cross Section 7 (F-F) (RS = 206)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		
Cross Section 8 (E-E) (RS = 205)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		
Cross Section 9 (D-D) (RS = 204)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		
Cross Section 10 (C-C) (RS = 203)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		
Cross Section 11 (B-B) (RS = 202)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		
Cross Section 12 (A-A) (RS = 201)	Left overbank – 0.035		
	River channel – 0.033	0.3	0.5
	Right overbank – 0.035		

Note: Manning's 'n-Values' derived from Chow, V.T., 1959 Open Channel Hydraulics, Mc Graw – Hill Book Company, N.Y

7.0 MODEL RESULTS

The conveyance capacity of each of the surveyed cross sections was assessed for suitability to transmit the Q100 flood flows within the Camac Stream. Each of the cross-sectional profiles including Q100 flood flows and Q100 flows plus climate change allowance are presented in Appendix 2 with the model data outputs for both flood events located in Appendix 3. Based on the hydraulic model produced for the watercourse, riverbank overtopping is not predicated to occur at the upgradient cross-section locations or at the cross sections within the northern portion of the site. Table 5. details the water levels predicated for the 1 in 100-year event (1% AEP) for each of the modelled cross sections.

Table 5. Water levels predicted for the stream in relation to the proposed infill site

Cross Section No.	Water Level Predicted (1% AEP)	Water Level Predicted (1% AEP (plus C.C allowance)
CS 1 (L-L)	141.98m AOD	142.05m AOD
CS 2 (K-K)	141.01m AOD	141.08m AOD
CS 3 (J-J)	136.92m AOD	136.98m AOD
CS 4 (I-I)	136.70m AOD	136.75m AOD
CFRAM Node Location	135.84m AOD	135.89m AOD
CS 5 (H-H)	133.94m AOD	133.98m AOD
CS 6 (G-G)	132.43m AOD	132.48m AOD
CS 7 (F-F)	131.25m AOD	131.36m AOD
CS 8 (E-E)	130.50m AOD	130.55m AOD
CS 9 (D-D)	130.14m AOD	130.19m AOD
CS 10 (C-C)	129.50m AOD	129.61m AOD
Nursing Home Culvert	129.36m AOD	129.45m AOD
CS 11 (B-B)	129.45m AOD	129.54m AOD
CS 12 (A-A)	129.02m AOD	129.09m AOD

Like the model produced for the Camac Stream as part of the Eastern CFRAM, channel overtopping was predicated to occur at a location in vicinity of Node 09CAMM01704. As discussed previously a 1 in 100-year level of 135.81m AOD was estimated at this point during the CFRAM project. A 1 in 100-year level of 135.84m AOD was modelled as part of this project at this location, thus representing a strong agreement between models. Once a climate change allowance of 20% is factored in, a 1 in 100-year flood level of 135.89m AOD was predicted.

Consequently, the lands to the north of the infill area and a small portion of land within the proposed infill area, below an elevation of 135.89m AOD will be susceptible to fluvial flooding under the 1% AEP. Figure 4 outlines the right of bank flood extents predicated for the 1 in 100-year flood event for applicant's site.

LEGEND

- Site Boundary
- Fluvial flood extent (1% AEP + 20% C.C)
- Stream / River

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:
Flood Risk Assessment - Coffey Construction Ltd. - Slade, Saggart, Co. Dublin

TITLE:
Extent of fluvial flooding under the 1-100 year event, to right of stream channel and within applicant's land

SCALE:	DRAWN BY:
1:1,000@A3	PMcC
DRAWING NO: Figure 4.	REV. 0

8.0 MITIGATION MEASURES

Following the inclusion of a 20% climate change allowance within the hydraulic model produced as part of this assessment for the Camac Stream, the 1 in 100-year Mid-Range Future Scenario flood level is modelled to overtop the stream bank in the vicinity of the original Node 09CAMM01704. Consequently, a small portion of lands proposed for infilling now falls within a Flood Zone A (Mid-Range Future Scenario). In order to allow for the infilling of the proposed lands and to mitigate against any displacement of flood water under the 1% AEP, level for level compensation is proposed. This approach is described in Sections 8.1 and 8.2.

It is also acknowledged that the Local Authority's Water Services Section have requested that surface water run off rates should not be increased post the infilling works. Section 8.3 and 8.4 describes how the greenfield runoff will not increase post infilling.

8.1 Description of Level for Level Compensation Approach

The '*Guidelines*' describe the requirements which need to be adhered to when designing compensatory flood plain storage. Any loss of flood storage must be compensated for by the reduction in the level of nearby ground. This level for level compensation provides the same surface area at the same elevation before and after development. This ensures that the same volume of flood storage is available at all levels of flooding and that a direct replacement for lost storage volume is achieved.

The elevation over which the displacement is occurring is divided into flood 'slices' (i.e. horizontal sections of equal size). For each flood slice, the volume of floodplain lost through the development at that floodplain slice elevation must be calculated. The flood 'slices' methodology is used to ensure that the shaping of the compensation area mimics that of the original floodplain. For compensation areas to be deemed appropriately designed, they must comply with the following requirements:

100mm – 300mm horizontal flood slices to be used;

Cut volumes should be greater than or equal to the fill volume for each slice;

Should be hydraulically linked to flood zone; and

Should not be located within existing flood zone.

8.2 Proposed Compensatory Storage Mitigation

In order to ensure that greater flood storage is available post infilling works, the following mitigation measures are recommended:

- An area of compensatory storage should be developed within the western portion of the site. Figure 5 shows how this area is hydraulically linked to the existing 1 in 100-year flood plain and to what elevation, the ground should be lowered too. As is demonstrated on Figure 5, this proposed compensation area is outside of the 1% AEP (plus climate change allowance) Flood Zone. It is appropriate to partially position this compensation area within the 10m set back buffer zone as no infilling will occur and the area will still act as a buffer zone during the infilling activities. Figure 7, demonstrates how a 10m set back distance of 10m from the edge of the infill area to the river bank will be achieved.

Given that infilling is proposed to a maximum fluvial flood depth of 300mm, two flood 'slices' each 150mm in depth is sufficient. Table 6. outlines the volume of flood storage which would be lost through the proposed infilling works and the volume that can be achieved through the provision of level for level compensatory storage. As can be seen from Table 6, >28m^3 of additional flood storage volume in excess of that lost during the 1 in 100-year event will be achieved following the implementation of this measure.

Table 6. Detail on Level for Level Compensation Storage Slices

Slice Elevation	Flood Volume Lost	Volume Gained by Compensatory Storage
135.59m – 135.74m AOD	9.15m^3	21.6m^3
135.75m – 135.89m AOD	5.175m^3	21.6m^3
Total	14.325m^3	43.2m^3

8.3 Onsite Infiltration Rate Assessment

In order to establish the infiltration rates onsite a soakaway test was carried out at four locations (TP01-TP04) in accordance with BRE Digest 365 Soakaways (BRE, 2016). TP01 was located within the lands mapped as containing TLPSsS – Sandstone and shale till (see Plate 9). TP02 and TP04 were excavated at either end of the band across the middle of the site mapped as consisting of GLs – Sands and gravels. While TP03 was excavated in the area mapped as containing A – Alluvium subsoils. A soil infiltration test was commenced within each trial pit on the 06th of September 2021 (see Photo Logs in Appendix 4). Each side of the trial pits were trimmed square. The walls of the trial pits were found to be stable and therefore the use of

LEGEND

Site Boundary

Fluvial flood extent

Proposed Infill Area

Compensatory Storage Area

HYDREC ENVIRONMENTAL CONSULTING

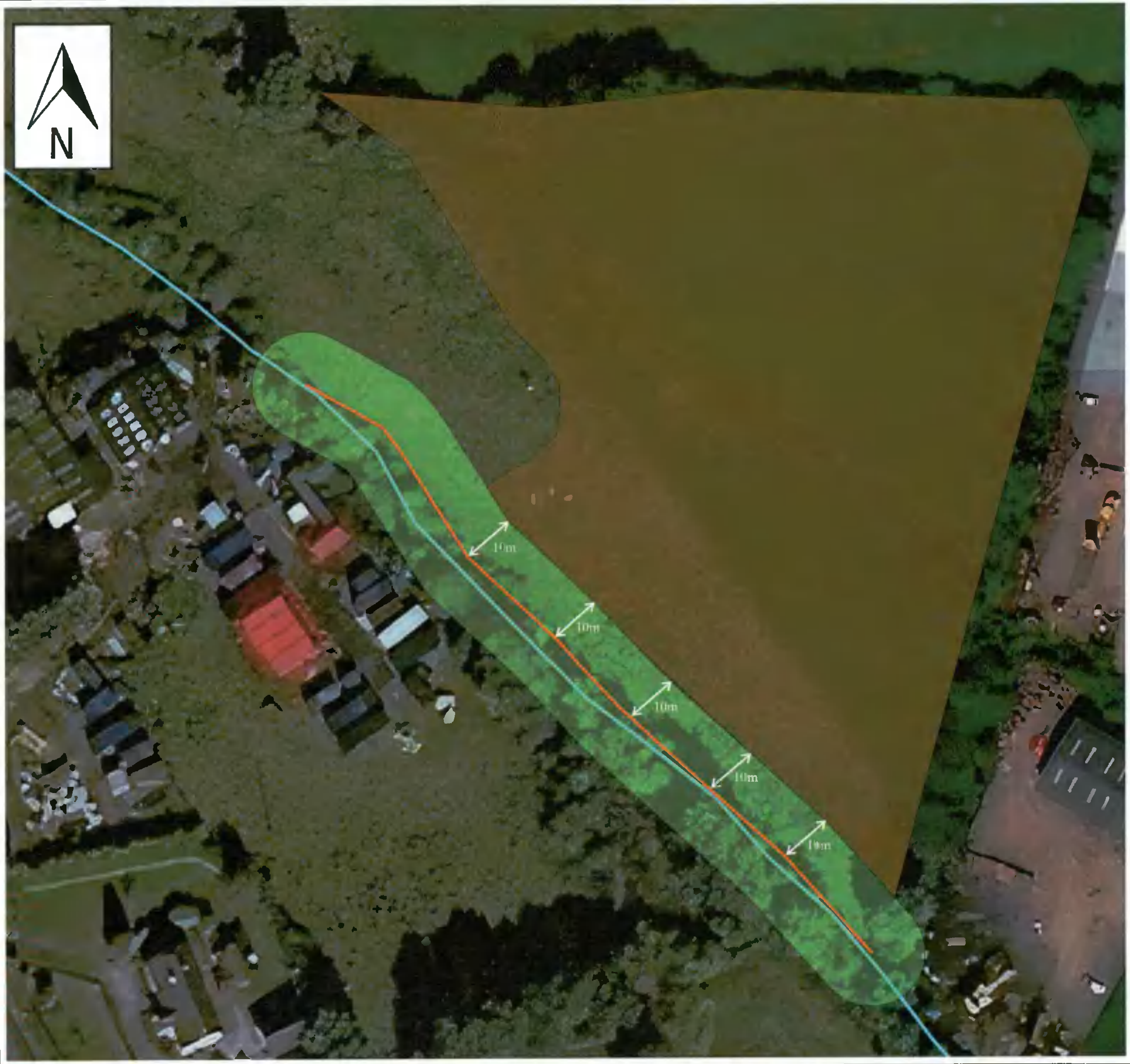
PROJECT:

Flood Risk Assessment
- Coffey Construction Ltd -
Slade, Saggart, Co. Dublin

TITLE:

Area proposed for infilling and compensatory storage onsite

SCALE: 1:800@A3	DRAWN BY: PMcC
DRAWING NO: Figure 5.	REV. B



LEGEND

- Top of Riverbank
- Proposed Infill Area
- 10m Set Back Distance.
- Watercourse

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:
Flood Risk Assessment
- Coffey Construction Ltd -
Slade, Saggart, Co. Dublin

TITLE:
Plan view map demonstrating the set back distances from infill area and river bank.

SCALE: 1:700@A3	DRAWN BY: PMcC
DRAWING NO: Figure 7.	REV. A

granular fill material was not required. No subsidence of the trial pit walls was observed. The soils encountered in each soakaway trial pit included:

TP01

- 0 – 0.3m b.g.l: Topsoil;
- 0.3m – 1.2m b.g.l: Firm brown slightly sandy, gravelly CLAY;
- 1.2m – 1.4m b.g.l: Stiff brown gravelly CLAY with occasional cobbles. Cobbles are angular to subangular. TP01 was terminated at a depth of 1.4m b.g.l.

TP02

- 0 – 0.3m b.g.l: Topsoil;
- 0.3m – 0.6m b.g.l: Soft to Firm very dark brown CLAY;
- 0.6m – 1.1m b.g.l: Firm slightly sandy, very gravelly CLAY with frequent cobbles. Cobbles are angular to subangular. Mottling noted at 0.7m b.g.l. TP02 was terminated at a depth of 1.1m b.g.l as groundwater ingress was noted at base.

TP03

- 0 – 0.3m b.g.l: Topsoil;
- 0.3m – 0.7m b.g.l: Soft to Firm very dark brown CLAY;
- 0.7m – 1.3m b.g.l: Silty, sandy, GRAVEL with frequent to abundant cobbles. Cobbles are angular / subangular to subrounded. TP03 was terminated at a depth of 1.3m b.g.l as groundwater ingress was noted at base. Groundwater quickly filled to a depth of 0.8m b.g.l.

TP04

- 0 – 0.3m b.g.l: Topsoil;
- 0.3m – 0.7m b.g.l: Soft to Firm dark brown CLAY;
- 0.7m – 1.4m b.g.l: Soft to Firm slightly sandy, gravelly CLAY with frequent cobbles. Cobbles are angular to subangular. Mottling noted at 0.7m b.g.l. TP04 was terminated at a depth of 1.4m b.g.l due to groundwater intrusion at base.

Plate 9. Location of infiltration test holes onsite

Ground conditions within the areas categorised as TLPSsS – Sandstone and shale till and A – Alluvium subsoils were found to be consistent with the subsoil type and permeability classifications assigned by the GSI mapping. However, GLs – glaciofluvial sands and gravels were not encountered across the site. Instead, glacial till of a lower permeability was encountered. Given the presence of groundwater within TP02 and TP04 – no drop in water level in these trial pits was recorded after filling with water. The evidence of soil mottling at 0.7m b.g.l would suggest that groundwater levels rise to this depth. Hence it is not anticipated that under wet conditions, any subsoil infiltration will occur below 0.7m b.g.l. Similarly, no drop in water level was recorded within TP03. An infiltration rate of 50mm/hr was observed in TP01.

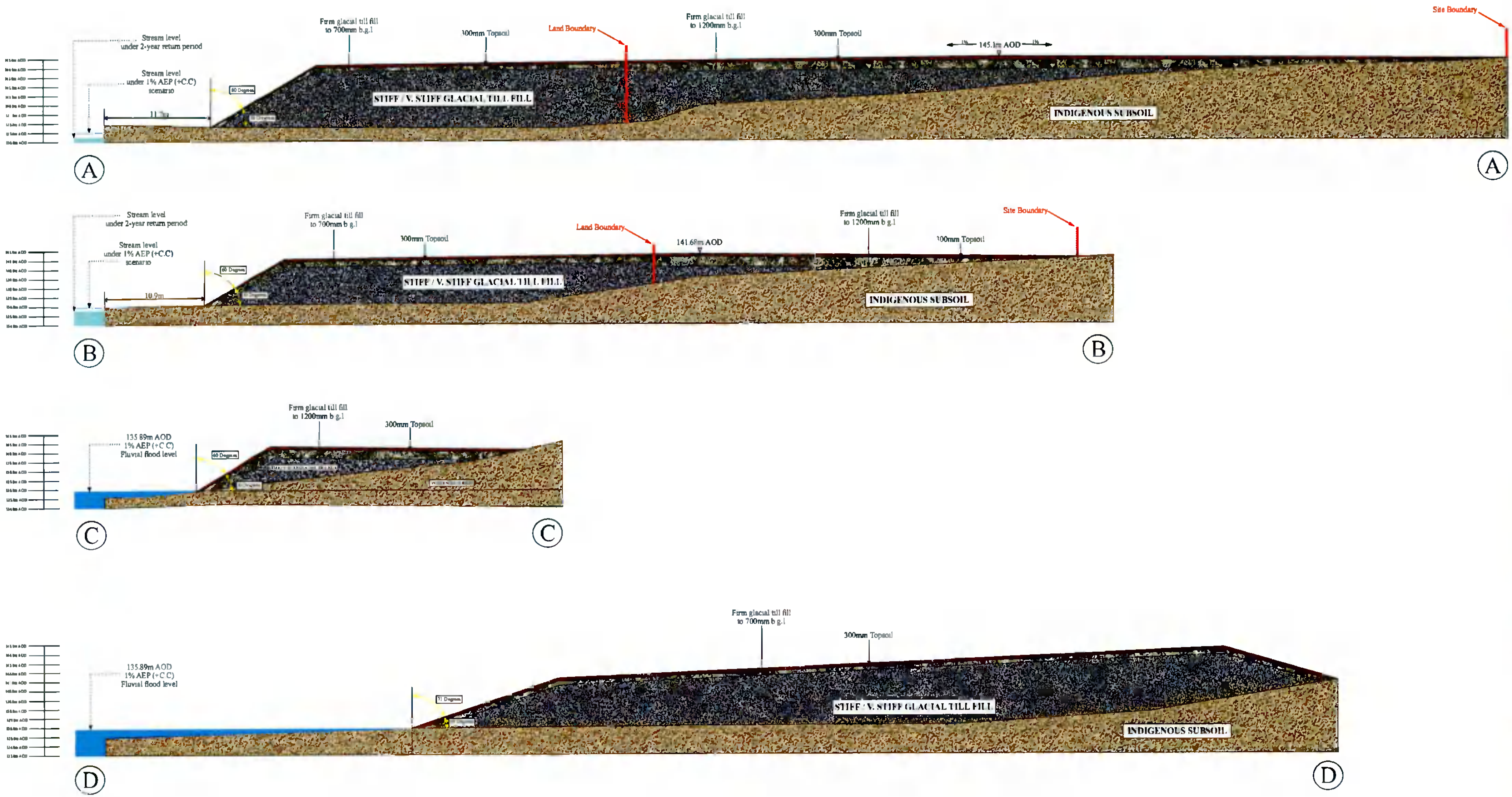
In order to assess the potential for subsoil permeability within the upper subsoil horizons of the land in the vicinity of TP03 (i.e. A – Alluvium subsoil) and TP04 (i.e soft to firm, glacial till CLAY), an infiltration test hole was dug to a depth below the topsoil level (i.e. 300mm b.g.l) in the vicinity of the original trial pit locations (see Plate 9). No infiltration was recorded with TP03A. An infiltration rate of 155mm/hr was recorded in TP04A.

8.4 Proposed Design to Control Surface Water Runoff Rate

In order to mimic existing subsoil permeability / greenfield runoff rates onsite, post infilling works, it is proposed to deposit differing soil types within different areas of the infill site (see Figure 6 (REV.E)). A minimum of 300mm of topsoil will be reinstated across the site once all infilling activities have ceased. This will compensate for any loss of infiltration / rainwater storage afforded by existing topsoil conditions.

The Ground Investigation completed Causeway Geotech in 2018 (Ref: 17-1375) for the neighbouring waterworks site, recorded glacial till (i.e. firm brown sandy gravelly CLAY) within the upper 1 – 2m horizons at a number of locations within the site. Stiffer glacial tills typically characterised as grey / black CLAY were encountered at lower depths in places. It is proposed that all infilling within the most northern portion of the site (i.e. area categorised as TLPSsS subsoil of moderate permeability, should consist of the shallower, firm brown sandy gravelly CLAYS (see Figure 6 (REV.E)). This type of material should be filled to 1.2m b.g.l. Similarly, this type of material should be infilled at a depth of 0.3m - 0.7m b.g.l in the area where shallow subsoil infiltration will occur (i.e. area previously classified as GLs – sands and gravels but is now reclassified as glacial till). This material can be underlain with stiffer boulder CLAYs as groundwater levels likely found under wet conditions (i.e. evidence of mottled soil) hinders any further infiltration. Thus, no loss of subsoil storage will occur as a consequence of infilling this material. Similarly, stiff / very stiff boulder clays are suitable for infilling below the topsoil layer in the area of the site where alluvium subsoils are present. The infiltration tests completed onsite, confirm that no infiltration presently occurs within this area due to the soil conditions (see Figure 6 (REV.E)).

SITE CONDITIONS POST INFILLING WORKS (UNDER THE 1 IN 100 YEAR (+C.C) FLOOD EVENT



HYDREC ENVIRONMENTAL CONSULTING

LEGEND:	
1% AEP fluvial flood depth	Stiff / Very Stiff Glacial Till Fill
Indigenous Ground	Imported Topsoil
Firm Glacial Till Fill	

Project:	Flood Risk Assessment - Coffey Construction Ltd - Slade, Saggart, Co Dublin	Figure 6.	Drawn By: PMcC
Title:	Cross sections detailing soil infill types to be deposited onsite	Scale: 1:200 @ A1	REV. E

9.0 VULNERABILITY & JUSTIFICTION TEST

Table 3.1 of the guidelines provides three vulnerability categories, based on the type of development that may be appropriate to each flood zone. In summary:

- **Zone A - High probability of flooding:** Most types of development would be considered inappropriate in this zone. Development in this zone should be avoided and/or only considered in exceptional circumstances, such as in city and town centres, or in the case of essential infrastructure that cannot be located elsewhere, and where the Justification Test has been applied. Only water-compatible development, such as docks and marinas, dockside activities that require a waterside location, amenity open space, outdoor sports and recreation, would be considered appropriate in this zone;

- **Zone B - Moderate probability of flooding:** Highly vulnerable development, such as hospitals, residential care homes, Garda, fire and ambulance stations, dwelling houses and primary strategic transport and utilities infrastructure, would generally be considered inappropriate in this zone, unless the requirements of the Justification Test can be met. Less vulnerable development, such as retail, commercial and industrial uses, sites used for short-let for caravans and camping and secondary strategic transport and utilities infrastructure, and water-compatible development might be considered appropriate in this zone;

- **Zone C - Low probability of flooding:** Development in this zone is appropriate from a flood risk perspective (subject to assessment of flood hazard from sources other than rivers and the coast) but would need to meet the normal range of other proper planning and sustainable development considerations

A Justification Test is an assessment of whether a development proposal within an area at risk of flooding meets specific criteria for proper planning and sustainable development and demonstrates that it will not be subject to unacceptable risk nor increase flood risk elsewhere. Table 3.2 of the guidelines illustrates those types of development that would be required to meet the Justification Test (see Plate 5). As a minimal amount of 1 in 100-year flooding (i.e. Flood Zone A) is predicted to occur within the footprint of the proposed infill area, a Development Management Justification Test was carried out in respect of the proposed project. This was completed in accordance with Section 5.15 of the Flood Risk Management Guidelines and incorporating the findings of this Site-Specific FRA. Table 7 presents the results of this test which conclude that the proposed development satisfies the criteria of the Justification test.

Table 7. Development Management Justification Test (Box 5.1 of the 'Guidelines')

Criterion	Response
5.1.1. The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines.	The RU zoning objective of the application site, seeks to protect and improve rural amenity and to provide for the development of agriculture.
5.1.2 (i) The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk.	The Flood Risk Assessment shows that the development will be predominantly positioned outside of the modelled 'Flood Zone A'. A compensatory storage area will be provided to offset the minimal loss of 'Flood Zone A'. Consequently, the proposed development will not displace flood water to adjoining lands and thus will not increase flood risk in the vicinity of the site or wider environment.
5.1.2 (ii) The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible.	Given that no loss of floodplain storage will occur, a heightened risk of flood damage to surrounding properties or the local road infrastructure is not anticipated under the 1 in 100-year event. Additionally, the Flood Zone A takes account of climate change (i.e. Mid-Range Future Scenario).
5.1.2 (iii) The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access.	The proposed development does not impact on any existing flood protection measures and will not prevent any potential future flood risk management measures, as a sufficient buffer between the infill area and watercourse will exist. Similarly, the proposed development will not cause an obstruction to any future OPW arterial drainage works.
5.1.2 (iv) The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.	The RU zoning objective of the application site, seeks to protect and improve rural amenity and to provide for the development of agriculture.

10.0 CONCLUSIONS & RECOMMENDATIONS

In consideration of the findings of this detailed site-specific flood risk assessment, the following conclusions and recommendations can be made:

- The OPW's CFRAM mapping / modelling indicates that a portion of the site is susceptible to fluvial flooding from the Camac Stream under the 1 in 100-year scenario;
- A hydraulic assessment of the Camac Stream, which was extended both upstream and downstream of the site was constructed by Hydrec Environmental Consulting in order to predict the 1 in 100-year flood event relative to the site and based on current river channel conditions / elevations (i.e. 2021);
- This model produced by Hydrec Environmental Consulting includes a 20% climate change allowance in relation to the Flood Zone A;
- Consequently, a small portion of the proposed infill area will fall within the 1% AEP (Mid-Range Future Scenario);
- To offset this loss, a compensation area which is currently outside of the 1% AEP Flood Zone but hydrologically linked to the existing flood plain has been proposed;
- Based on a level for level compensatory storage approach, a total of 43.2m^3 of compensatory storage volume can be achieved (i.e. once ground levels in the proposed 'Compensatory Storage Area' are reduced by 300mm). This represents an additional volume of 28.875m^3 to that of the quantify which will be displaced as a consequence of the infilling works;
- In order to mimic existing subsoil permeability / greenfield runoff rates onsite, it is proposed to deposit differing soil types as identified in the Causeway Geotech Ground Investigation within different areas of the infill site. These areas were selected as a consequence of the infiltration rates recorded (or lack of) during the site infiltration assessment completed on the 6th of September 2021 (see Figure 6 (REV.E)).
- Given the nature of the project (i.e. Less Vulnerable Development) and its minimal positioning within a Flood Zone A, a Development Management Justification Test was carried out in accordance with Section 5.15 of the Flood Risk Management Guidelines. Table 7 presents the results of this test which conclude that the proposed development satisfies the criteria of the Justification test;

- **To conclude the project subject to the specified mitigation measures being implemented, will not be at risk from flooding nor will it exacerbate flooding in the immediate vicinity or wider area.**

Signed:

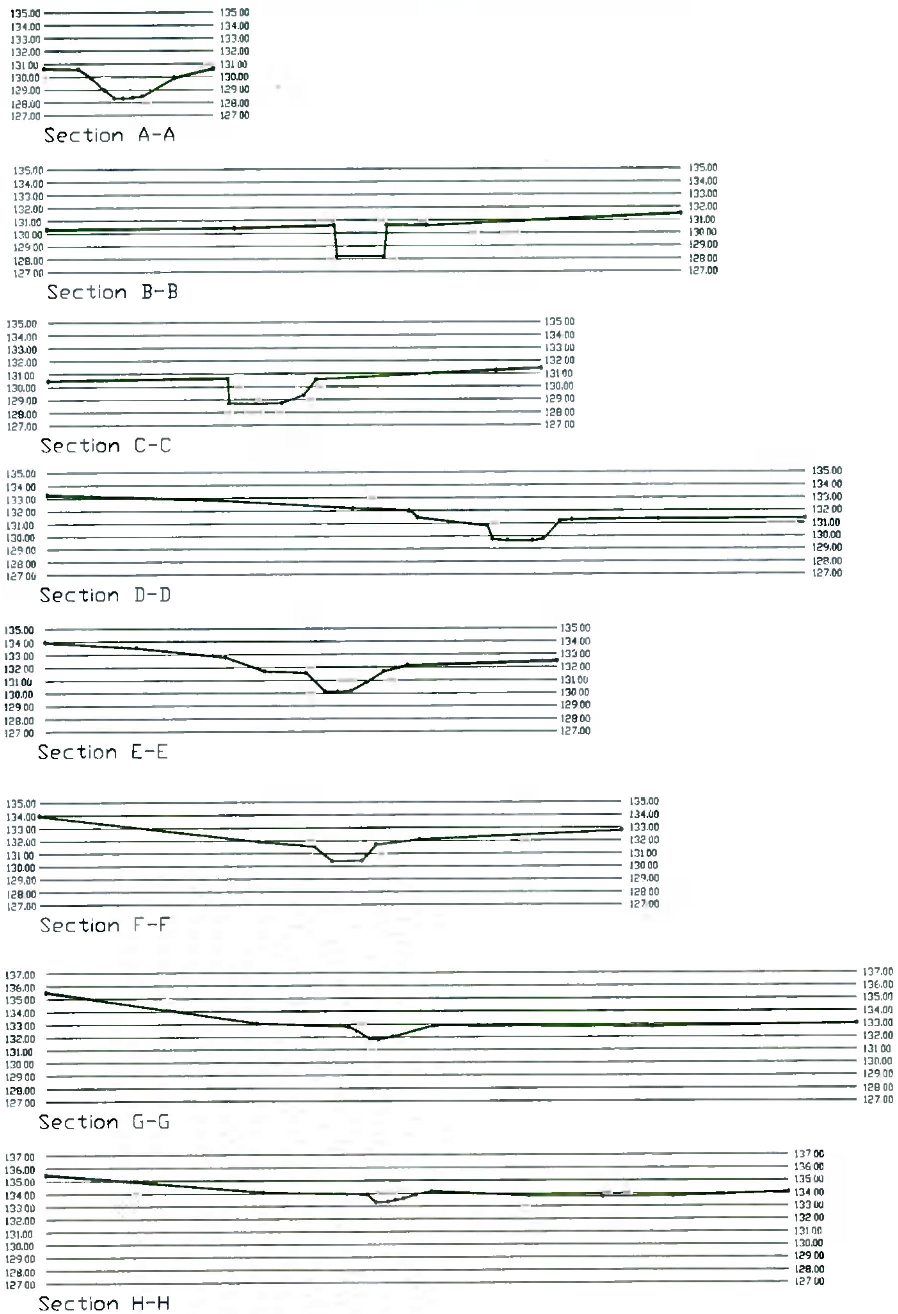
Patrick McCabe

Patrick McCabe B.Sc., M.Sc.

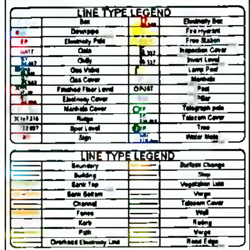
Hydrec Environmental Consulting

APPENDIX 1

HORIZON SURVEYS LTD – TOPOGRAPHICAL CROSS SECTIONS



NOTES
1. All levels are relative to Ordnance Datum Malin Head
2. 50m sq grid relative to Irish Transverse Mercator Co-ordinate reference system
3. Contours are at .25m intervals



REVISIONS

No.	Date	Description

RICS Horizon Group
Market Square, Castleblayney, Monaghan, Ireland

Client	XX
Professional	Hydrec
Project Title	River Survey at Saggart

Drawn	TD	Dwg No	01/001
Scale	1/200	Date	XX

A1

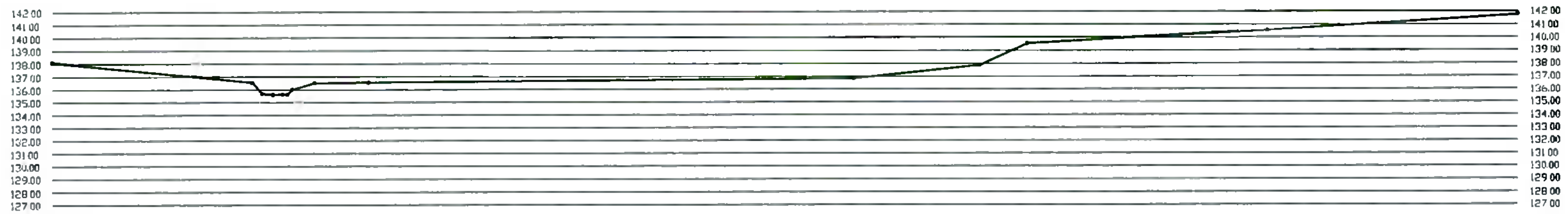
NOTES:
1. All levels are relative to Ordnance Datum Malin Head
2. 50m sq grid relative to Irish Transverse Mercator Co-ordinate reference system
3. Contours are at .25m intervals

LINE TYPE LEGEND

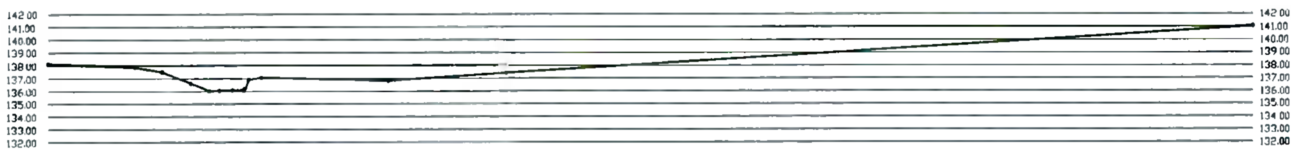
Bed	Electricity Box
Downpipe	Fire Hydrant
Electricity Pole	Free Station
Gate	Inspection Cover
Gully	Invert Level
Gas Valve	Lamp Post
Gas Cover	Manhole
Finished Floor Level	Post
Electricity Cover	Pillar
Manhole Cover	Telegraph pole
Ridge	Telecom Cover
Spot Level	Tree
Sign	Water Meter

LINE TYPE LEGEND

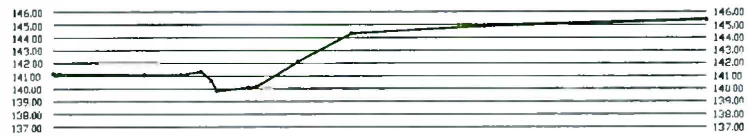
Boundary	Surface Change
Building	Step
Bank Top	Vegetation Line
Bank Bottom	Verge
Channel	Telecom Cover
Fence	Wall
Kerb	Railing
Path	Verge
Overhead Electricity Line	Road Edge



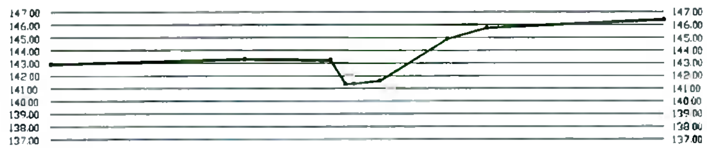
Section I-I



Section J-J



Section K-K



Section L-L

REVISIONS

No.	Date	Description

RICS Horizon Group

Market Square, Castleblayney, Monaghan, Ireland
Tel 042 9740671 Mobile 087 6640832 / 087 7923026
Website www.horizon-group.ie

Client
XX

Professional
Hydrec

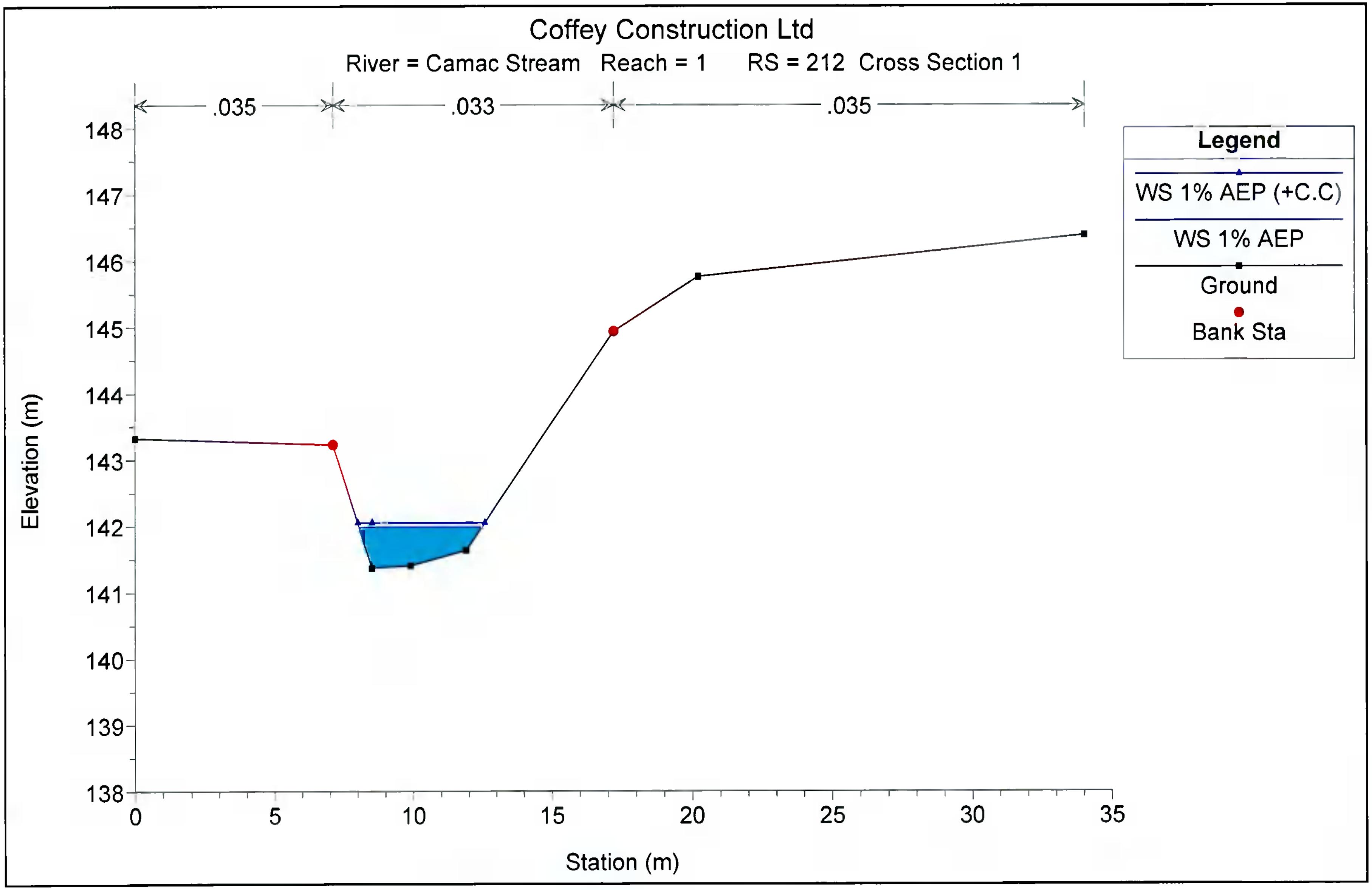
Project Title
River Survey at Saggart

Drawn	TD	Dwg No	01/001
Scale	1/200	Date	XX

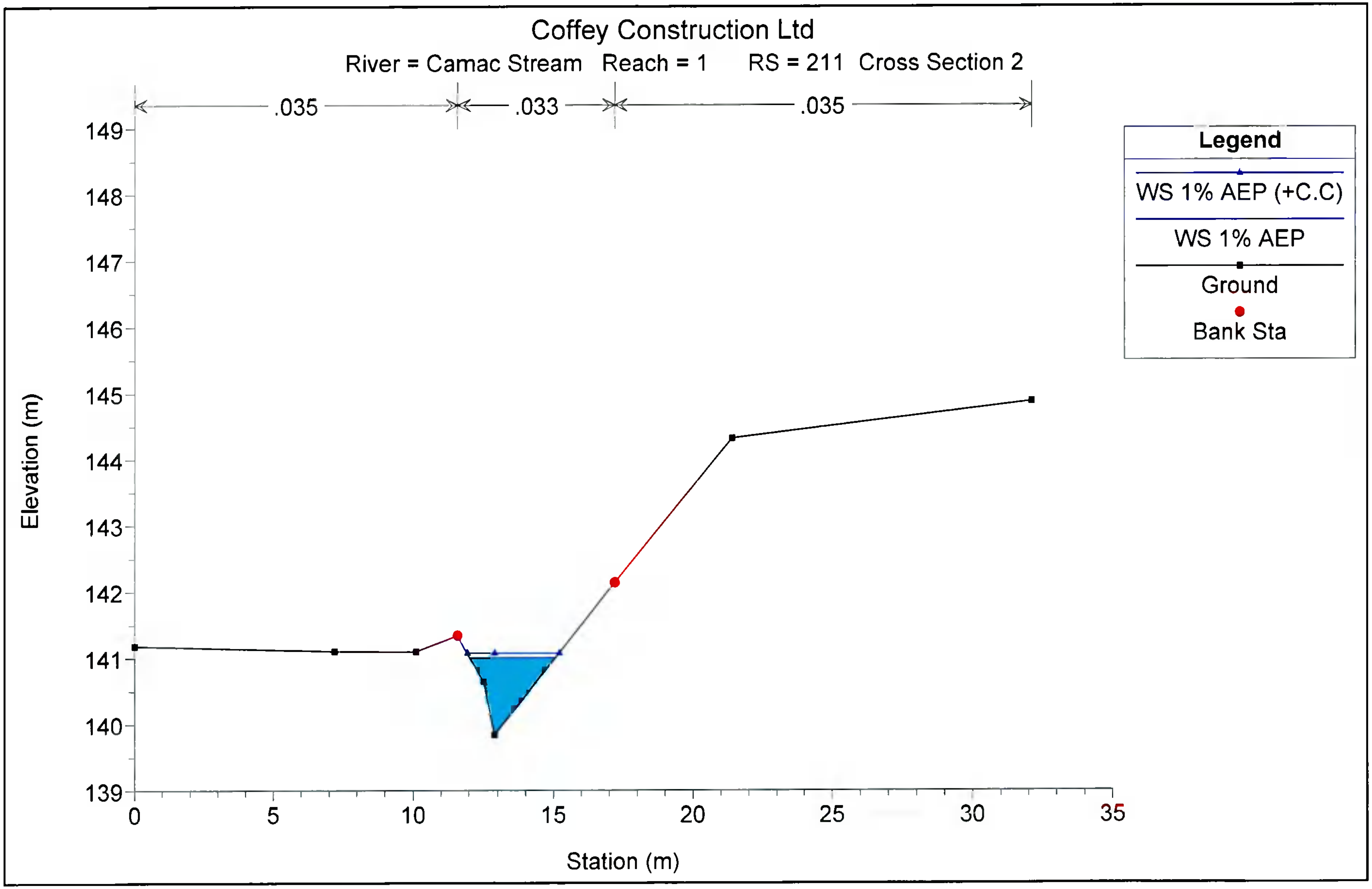
A1

APPENDIX 2

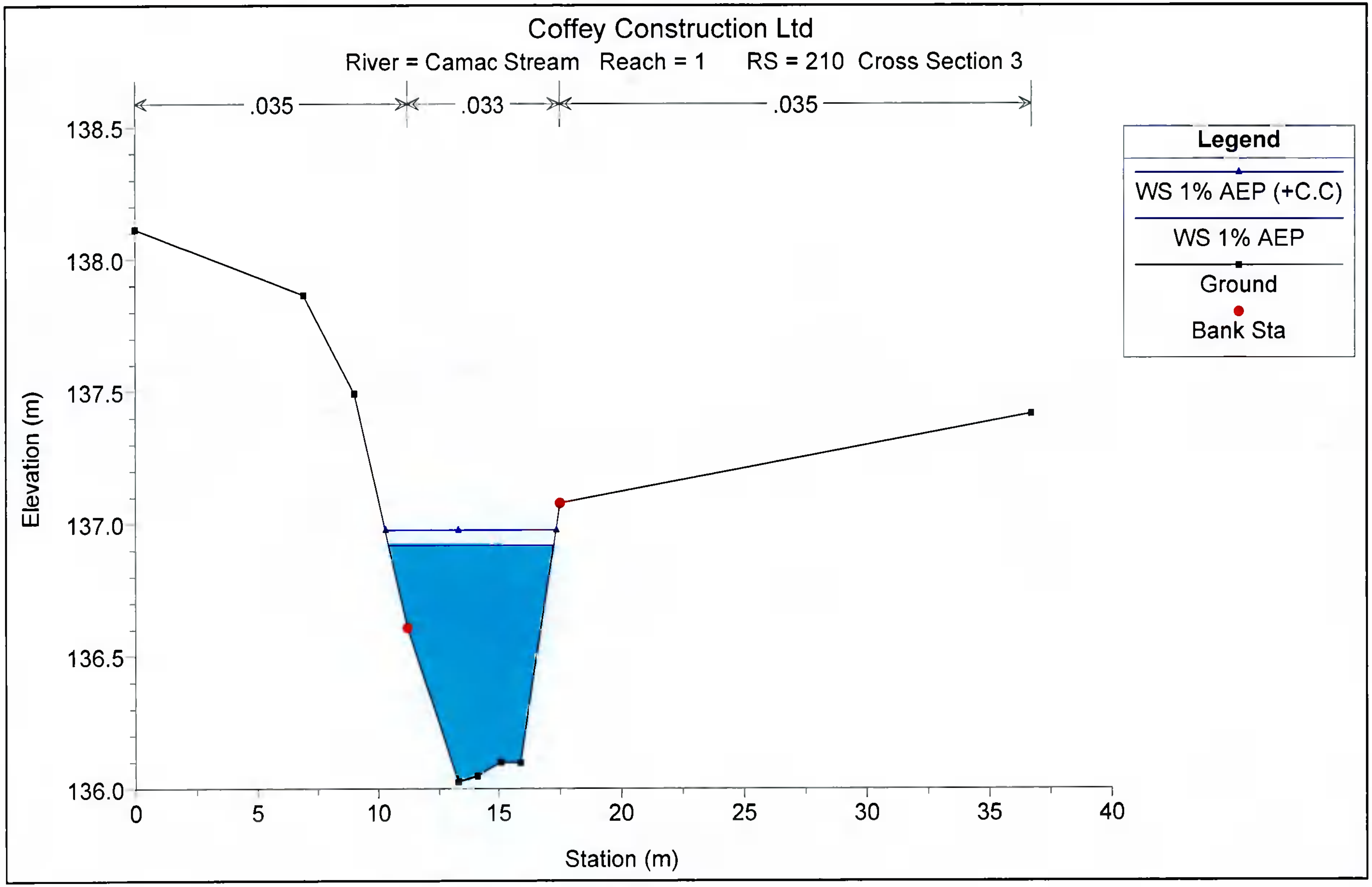
HEC-RAS CROSS SECTION PROFILES



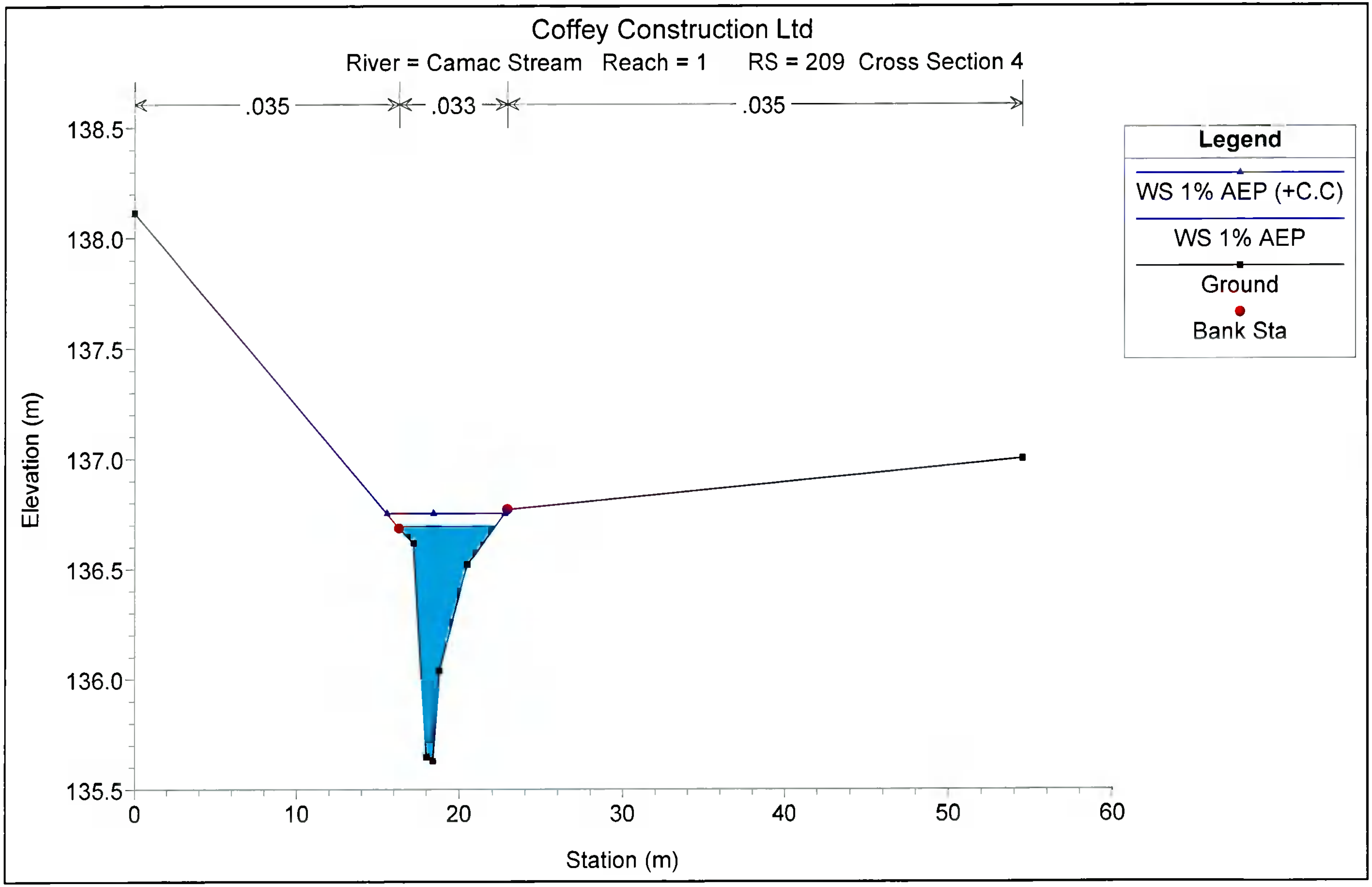
Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 212 Cross Section 1
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
148
147
146
145
144
143
142
141
140
139
138
0
5
10
15
20
25
30
35
Station (m)



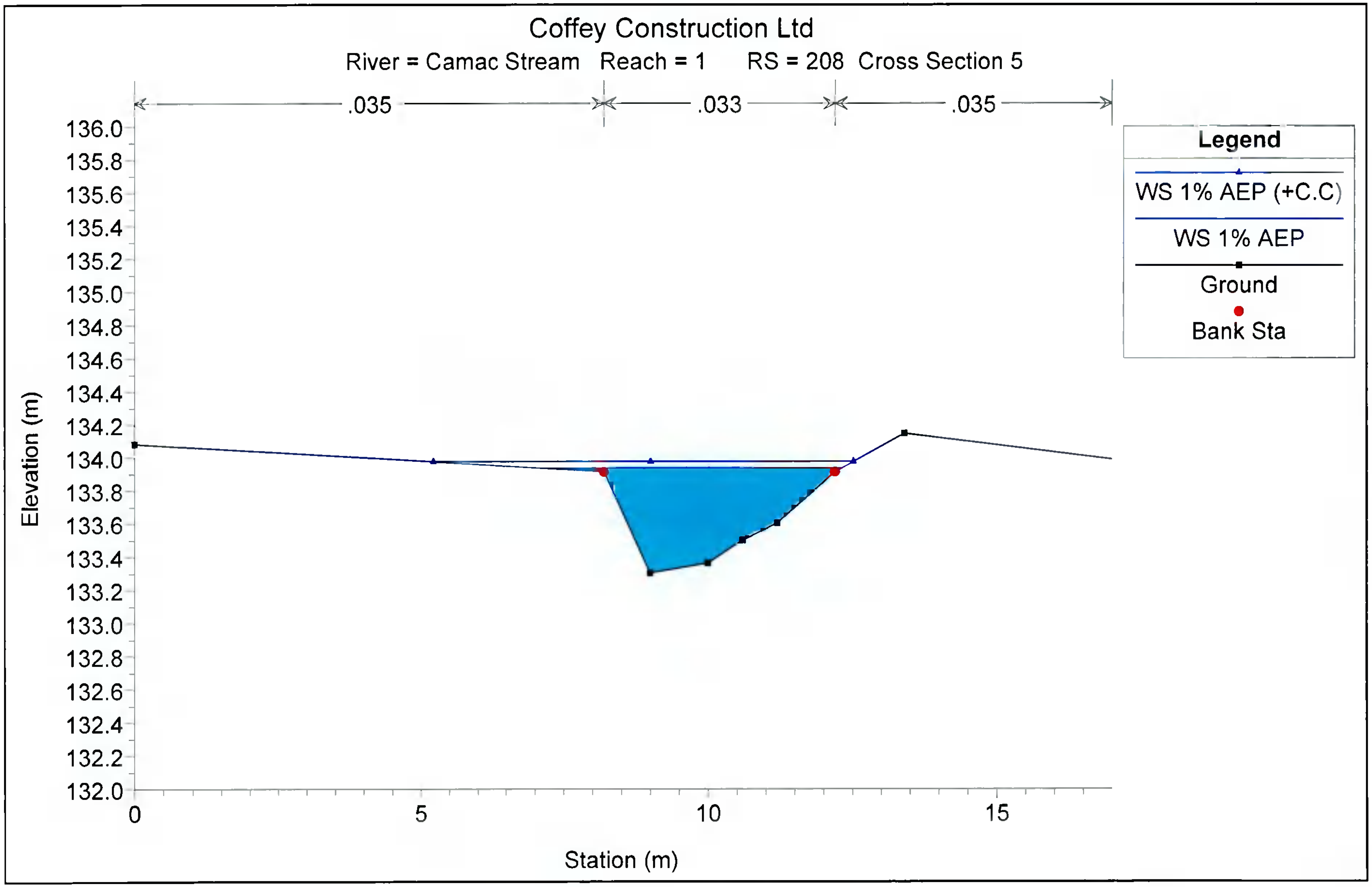
Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 211 Cross Section 2
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
149
148
147
146
145
144
143
142
141
140
139
0
5
10
15
20
25
30
35
Station (m)



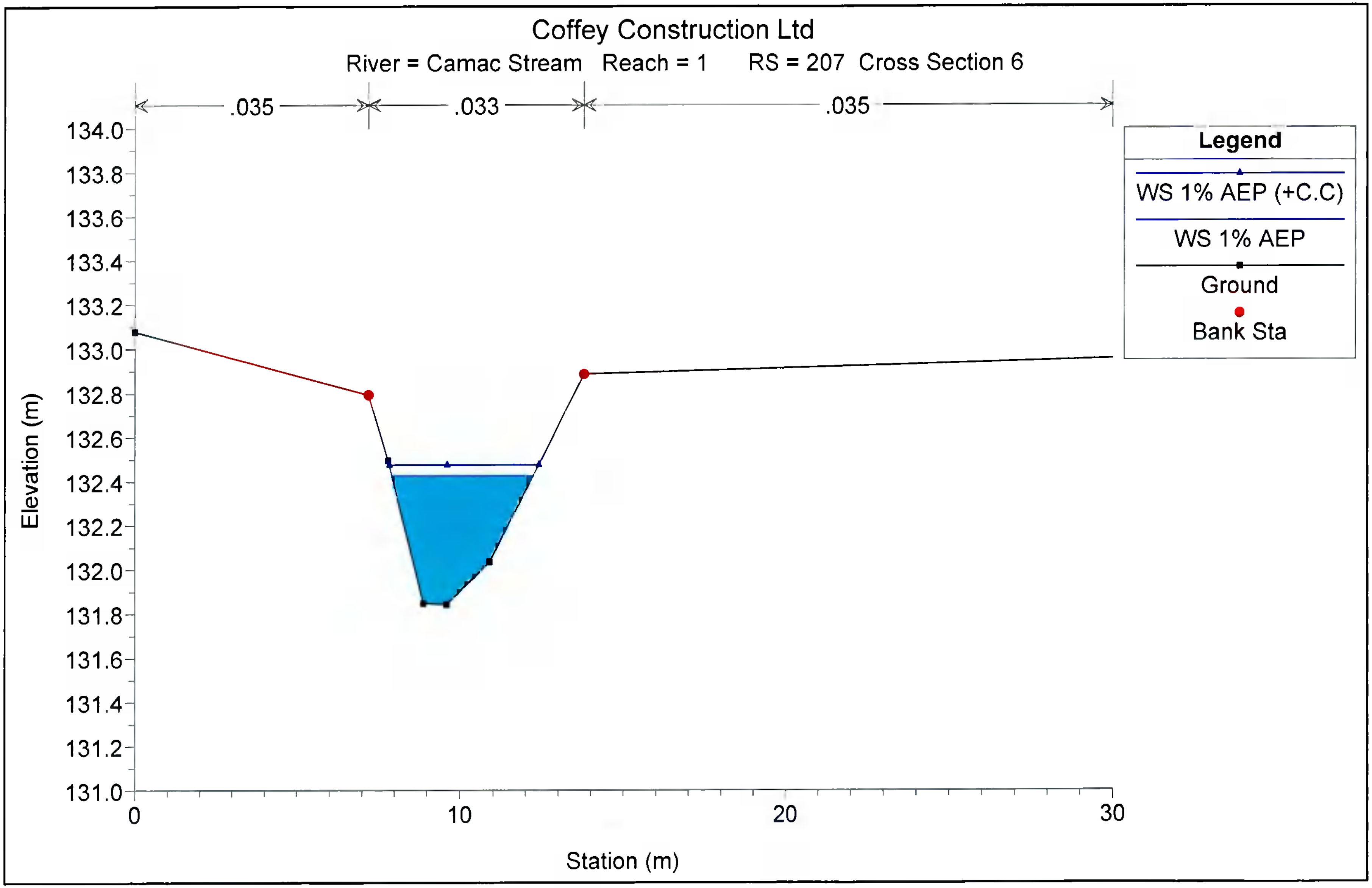
Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 210 Cross Section 3
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
138.5
138.0
137.5
137.0
136.5
136.0
0
5
10
15
20
25
30
35
40
Station (m)



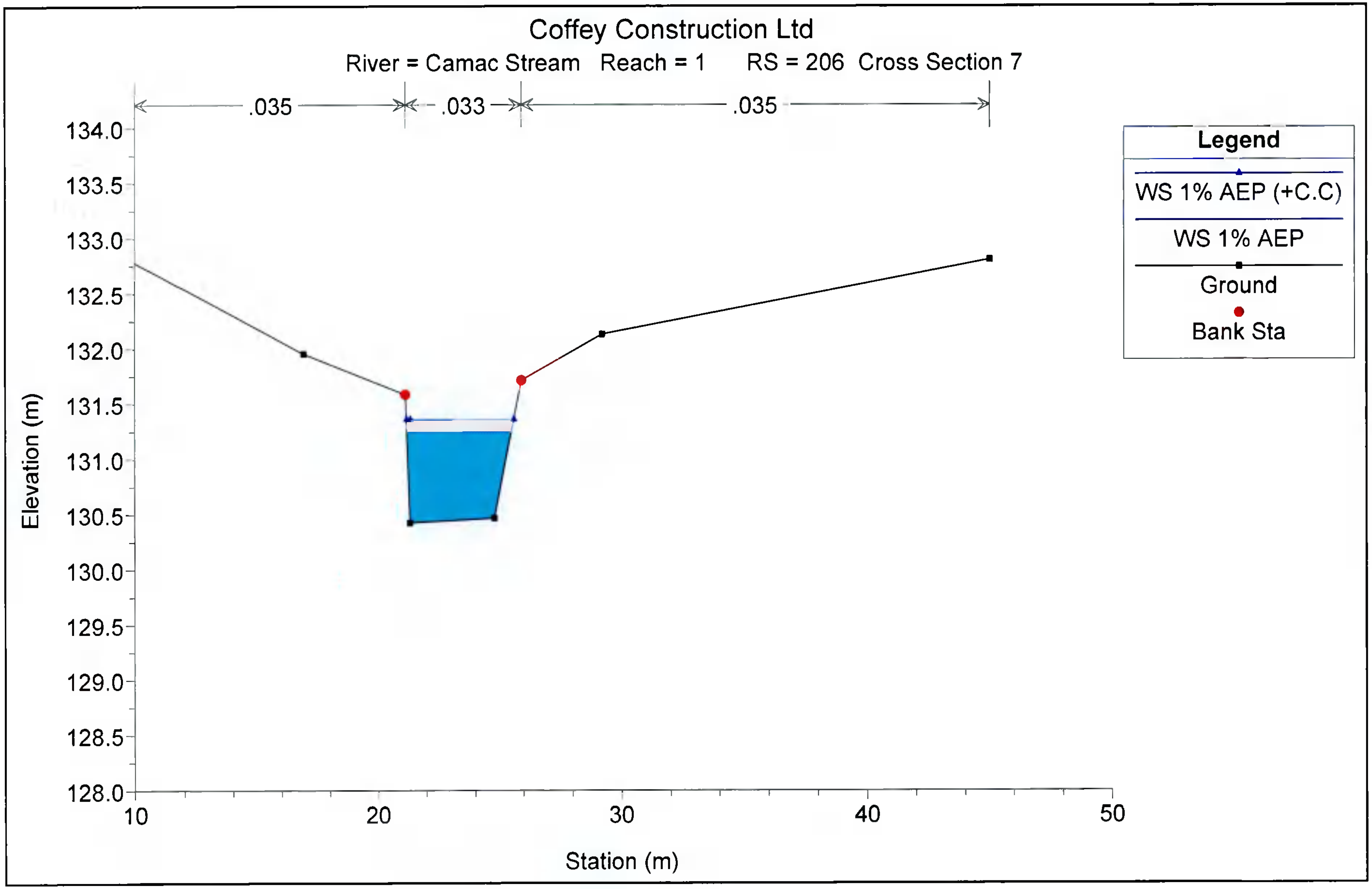
Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 209 Cross Section 4
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
138.5
138.0
137.5
137.0
136.5
136.0
135.5
0
10
20
30
40
50
60
Station (m)



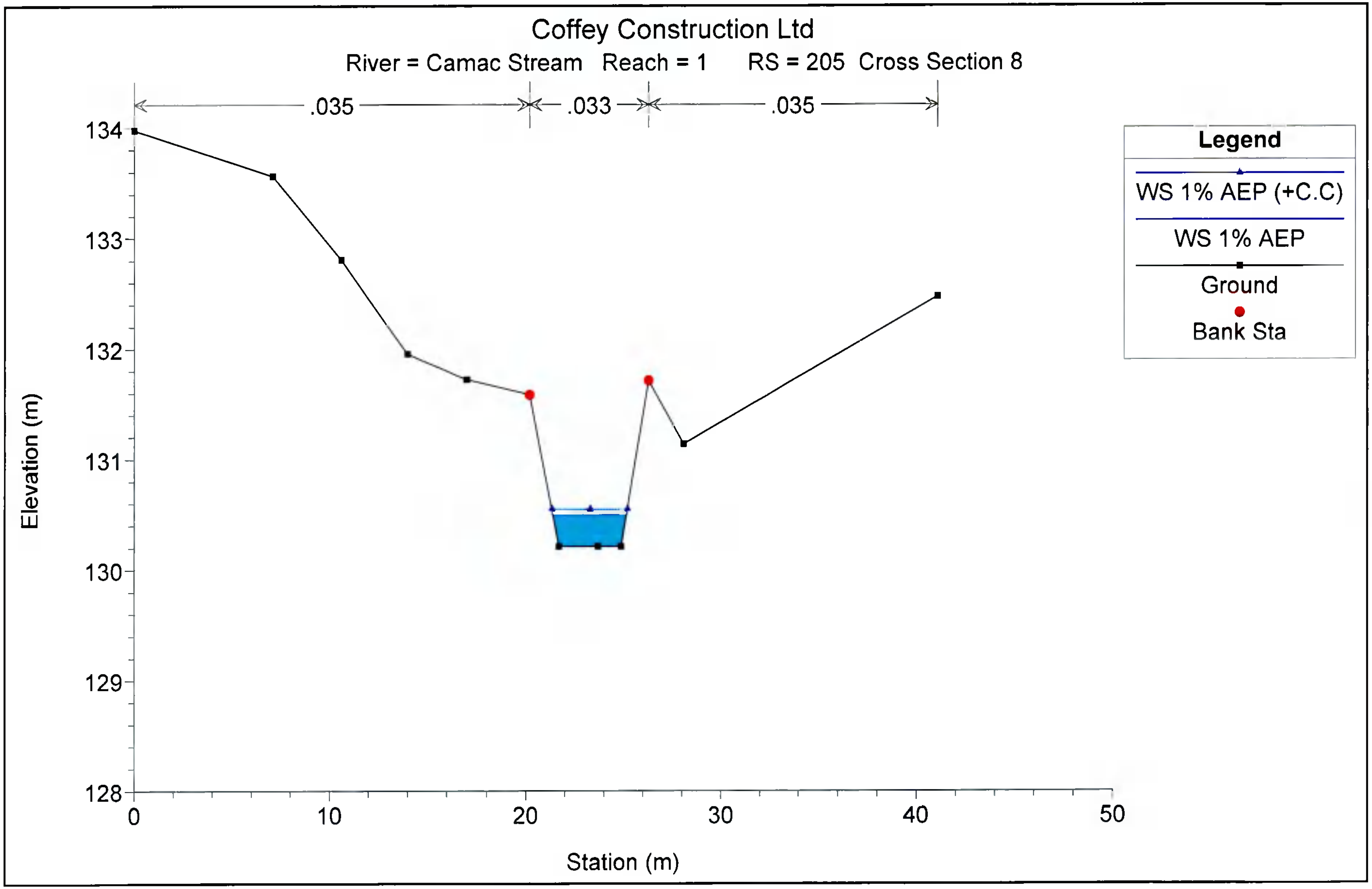
Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 208 Cross Section 5
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
136.0
135.8
135.6
135.4
135.2
135.0
134.8
134.6
134.4
134.2
134.0
133.8
133.6
133.4
133.2
133.0
132.8
132.6
132.4
132.2
132.0
0
5
10
15
Station (m)



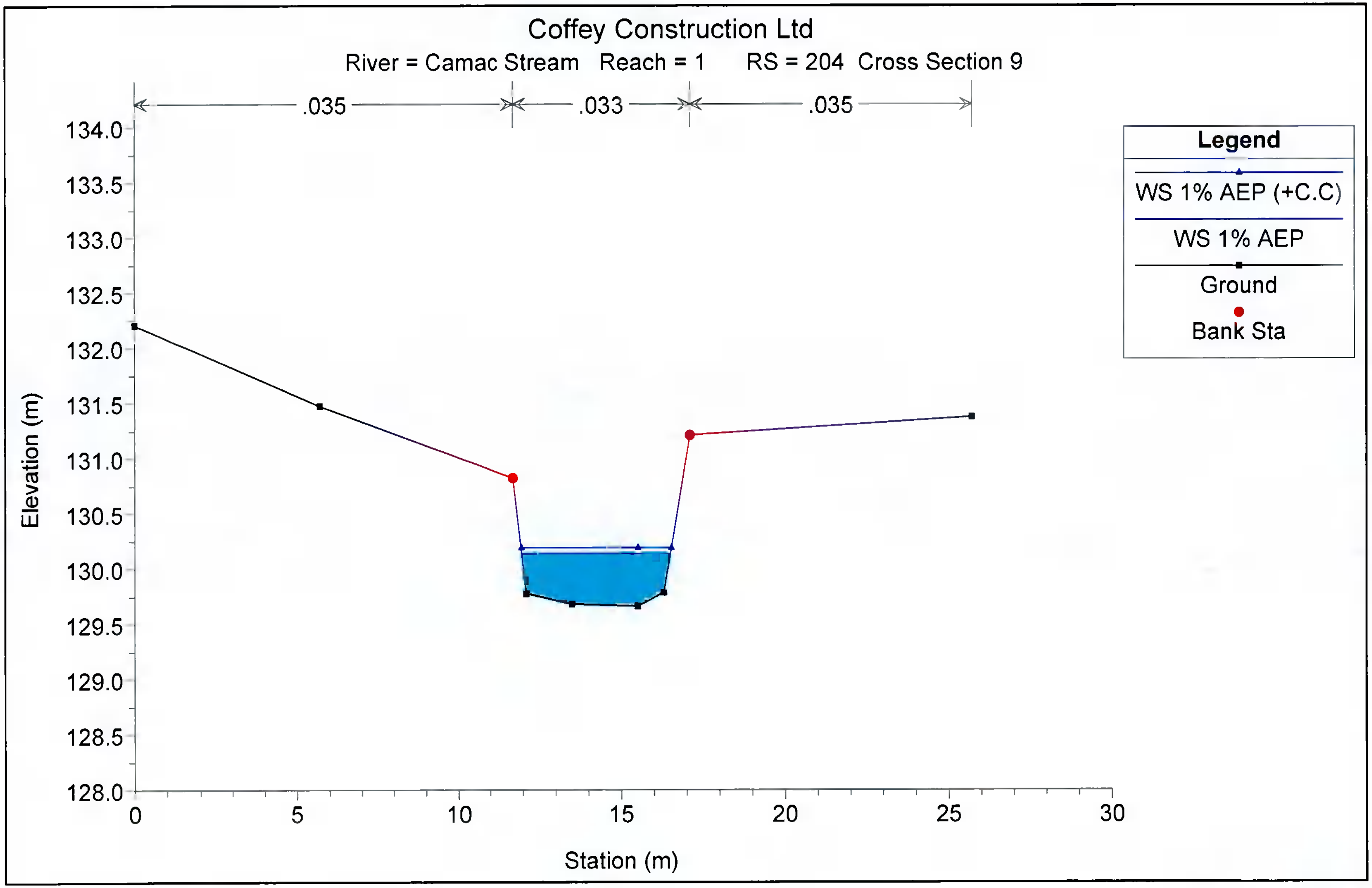
Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 207 Cross Section 6
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
134.0
133.8
133.6
133.4
133.2
133.0
132.8
132.6
132.4
132.2
132.0
131.8
131.6
131.4
131.2
131.0
0
10
20
30
Station (m)

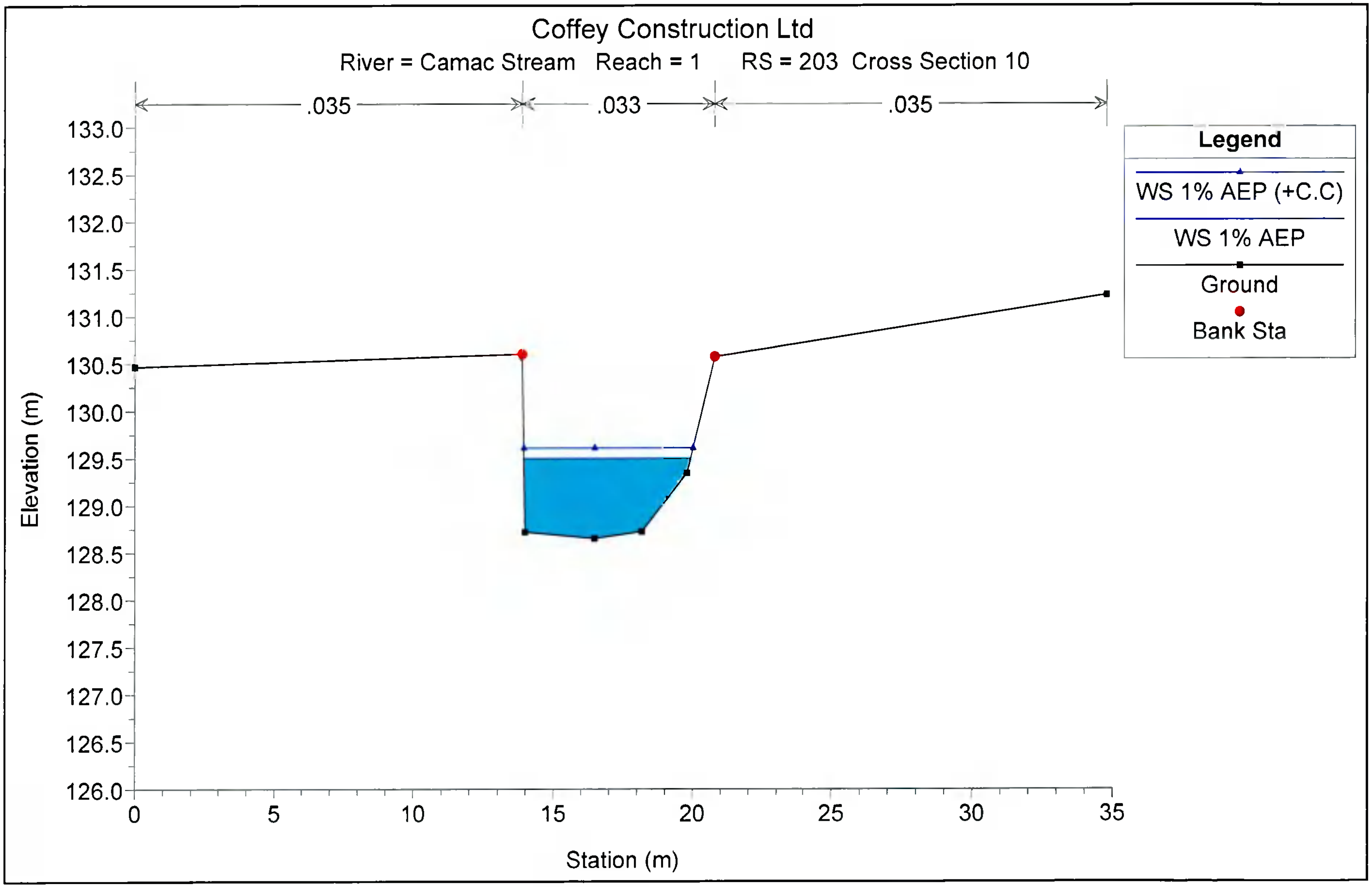


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 206 Cross Section 7
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
134.0
133.5
133.0
132.5
132.0
131.5
131.0
130.5
130.0
129.5
129.0
128.5
128.0
10
20
30
40
50
Station (m)

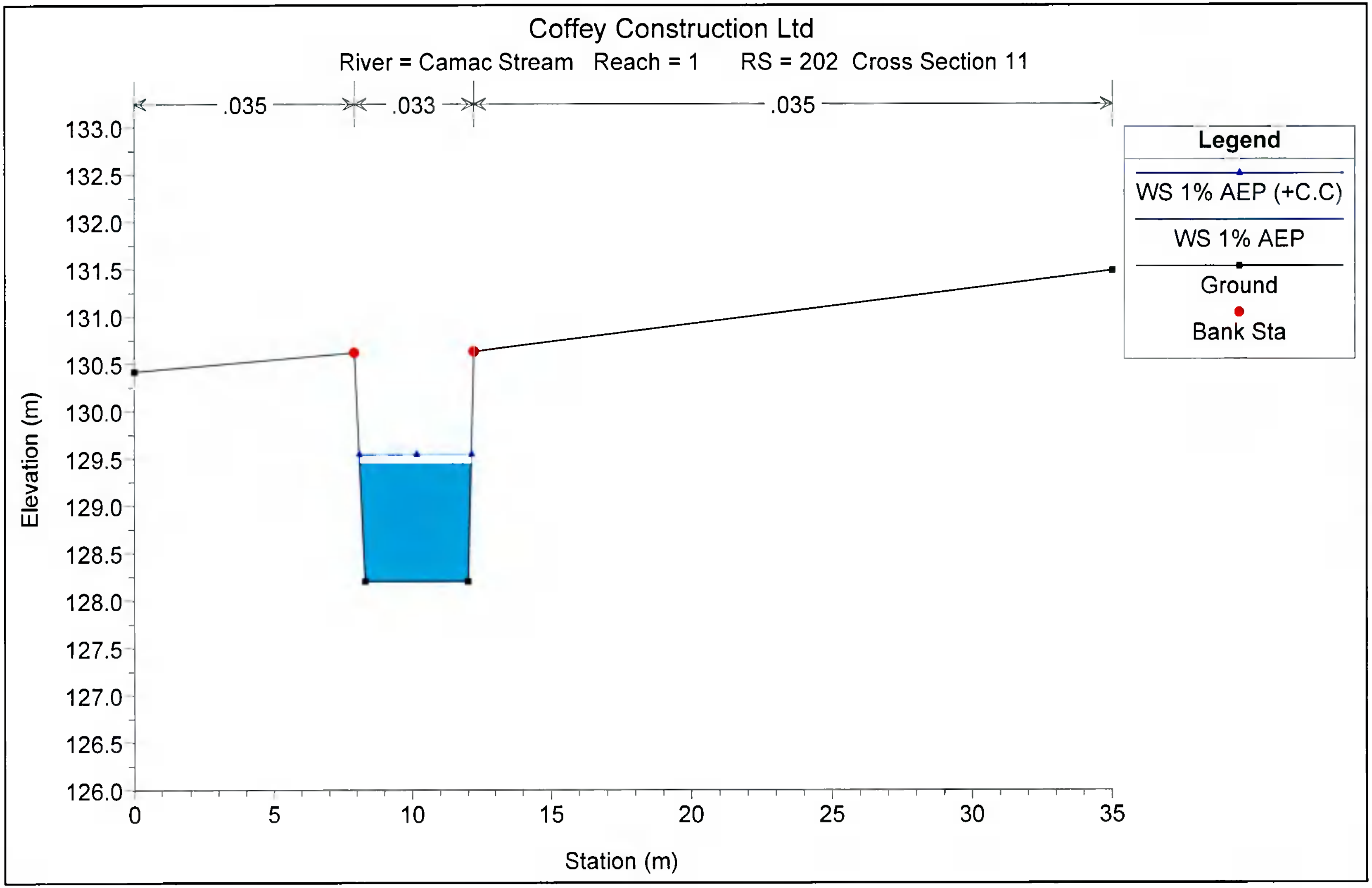


Coffey Construction Ltd
River = Camac Stream   Reach = 1   RS = 205 Cross Section 8
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
134
133
132
131
130
129
128
0
10
20
30
40
50
Station (m)

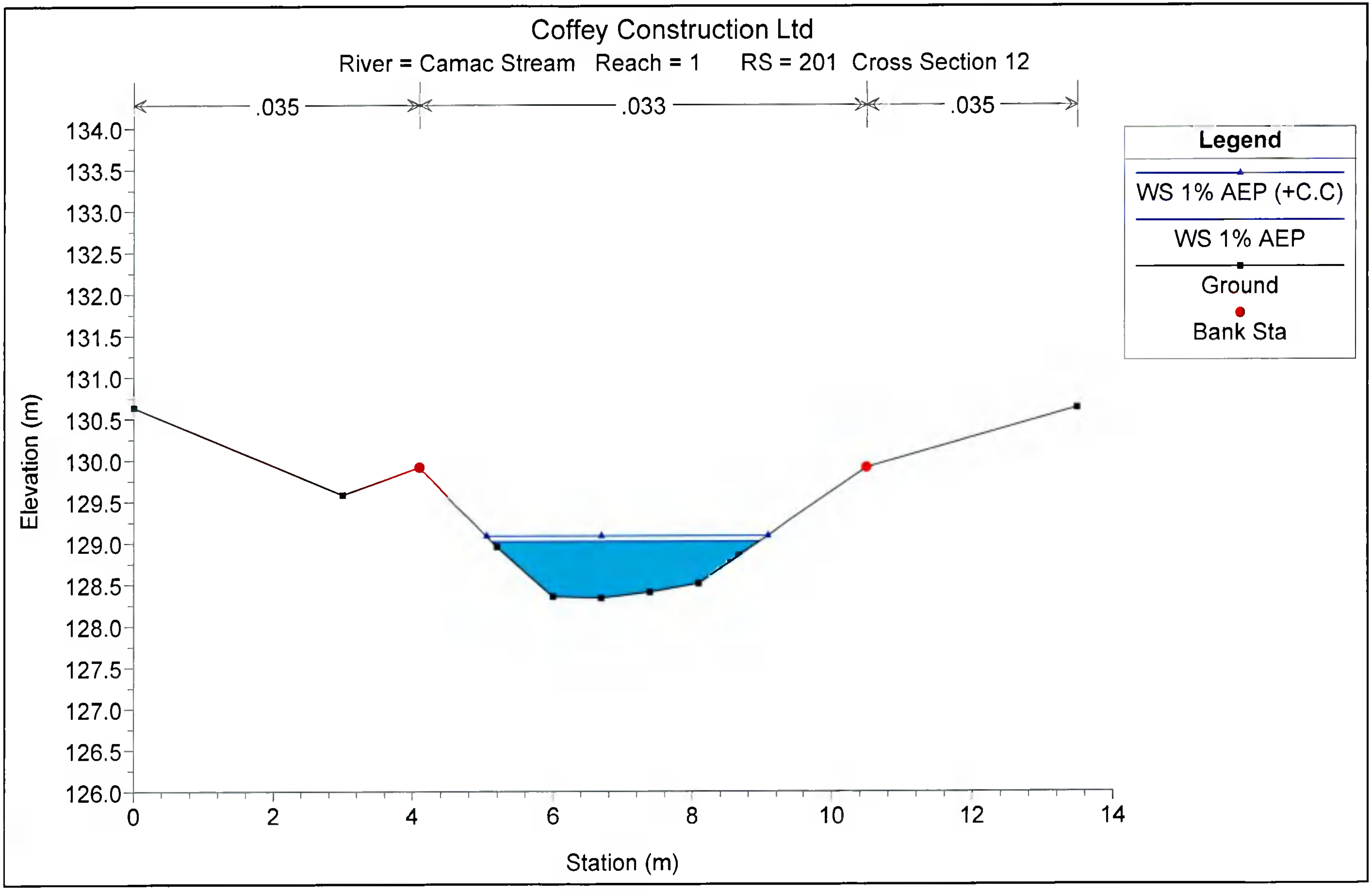

Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 204 Cross Section 9
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
134.0
133.5
133.0
132.5
132.0
131.5
131.0
130.5
130.0
129.5
129.0
128.5
128.0
0
5
10
15
20
25
30
Station (m)



Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 203 Cross Section 10
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
133.0
132.5
132.0
131.5
131.0
130.5
130.0
129.5
129.0
128.5
128.0
127.5
127.0
126.5
126.0
0
5
10
15
20
25
30
35
Station (m)



Coffey Construction Ltd
River = Camac Stream   Reach = 1   RS = 202 Cross Section 11
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
133.0
132.5
132.0
131.5
131.0
130.5
130.0
129.5
129.0
128.5
128.0
127.5
127.0
126.5
126.0
0
5
10
15
20
25
30
35
Station (m)


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 201 Cross Section 12
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
134.0
133.5
133.0
132.5
132.0
131.5
131.0
130.5
130.0
129.5
129.0
128.5
128.0
127.5
127.0
126.5
126.0
0
2
4
6
8
10
12
14
Station (m)

APPENDIX 3

HEC-RAS HYDRAULIC MODEL OUTPUTS

Plan: Plan 02 Camac Stream 1 RS: 212 Profile: 1% AEP

E.G. Elev (m)	142.18	Element	Left OB	Channel	Right OB
Vel Head (m)	0.20	Wt. n-Val.		0.033	
W.S. Elev (m)	141.98	Reach Len. (m)	1.73	1.73	1.73
Crit W.S. (m)	141.96	Flow Area (m2)		2.02	
E.G. Slope (m/m)	0.013411	Area (m2)		2.02	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.43	Top Width (m)		4.43	
Vel Total (m/s)	1.96	Avg. Vel. (m/s)		1.96	
Max Chl Dpth (m)	0.62	Hydr. Depth (m)		0.46	
Conv. Total (m3/s)	34.2	Conv. (m3/s)		34.2	
Length Wtd. (m)	1.73	Wetted Per. (m)		4.86	
Min Ch El (m)	141.37	Shear (N/m2)		54.78	
Alpha	1.00	Stream Power (N/m s)		107.23	
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	0.00	1.26	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.05	2.71	0.09

Plan: Plan 02 Camac Stream 1 RS: 212 Profile: 1% AEP (+C.C)

E.G. Elev (m)	142.26	Element	Left OB	Channel	Right OB
Vel Head (m)	0.22	Wt. n-Val.		0.033	
W.S. Elev (m)	142.05	Reach Len. (m)	1.73	1.73	1.73
Crit W.S. (m)	142.02	Flow Area (m2)		2.31	
E.G. Slope (m/m)	0.013076	Area (m2)		2.31	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.58	Top Width (m)		4.58	
Vel Total (m/s)	2.06	Avg. Vel. (m/s)		2.06	
Max Chl Dpth (m)	0.68	Hydr. Depth (m)		0.50	
Conv. Total (m3/s)	41.5	Conv. (m3/s)		41.5	
Length Wtd. (m)	1.73	Wetted Per. (m)		5.06	
Min Ch El (m)	141.37	Shear (N/m2)		58.59	
Alpha	1.00	Stream Power (N/m s)		120.44	
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	0.01	1.43	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.19	2.83	0.25

Plan: Plan 02 Camac Stream 1 RS: 211 Profile: 1% AEP

E.G. Elev (m)	141.30	Element	Left OB	Channel	Right OB
Vel Head (m)	0.29	Wt. n-Val.		0.033	
W.S. Elev (m)	141.01	Reach Len. (m)	1.74	1.74	1.74
Crit W.S. (m)	141.01	Flow Area (m2)		1.67	
E.G. Slope (m/m)	0.019438	Area (m2)		1.67	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	3.06	Top Width (m)		3.06	
Vel Total (m/s)	2.37	Avg. Vel. (m/s)		2.37	
Max Chl Dpth (m)	1.17	Hydr. Depth (m)		0.55	
Conv. Total (m3/s)	28.4	Conv. (m3/s)		28.4	
Length Wtd. (m)	1.74	Wetted Per. (m)		3.97	
Min Ch El (m)	139.84	Shear (N/m2)		80.16	
Alpha	1.00	Stream Power (N/m s)		190.07	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.00	1.13	0.00
C & E Loss (m)	0.01	Cum SA (1000 m2)	0.05	2.47	0.09

Plan: Plan 02 Camac Stream 1 RS: 211 Profile: 1% AEP (+C.C)

E.G. Elev (m)	141.40	Element	Left OB	Channel	Right OB
Vel Head (m)	0.32	Wt. n-Val.		0.033	
W.S. Elev (m)	141.08	Reach Len. (m)	1.74	1.74	1.74
Crit W.S. (m)	141.23	Flow Area (m2)		1.89	
E.G. Slope (m/m)	0.020281	Area (m2)		1.89	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	

Plan: Plan 02 Camac Stream 1 RS: 211 Profile: 1% AEP (+C.C) (Continued)

Top Width (m)	3.27	Top Width (m)		3.27	
Vel Total (m/s)	2.52	Avg. Vel. (m/s)		2.52	
Max Chl Dpth (m)	1.24	Hydr. Depth (m)		0.58	
Conv. Total (m3/s)	33.4	Conv. (m3/s)		33.4	
Length Wtd. (m)	1.74	Wetted Per. (m)		4.23	
Min Ch El (m)	139.84	Shear (N/m2)		88.71	
Alpha	1.00	Stream Power (N/m s)		223.50	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.01	1.28	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.16	2.57	0.25

Plan: Plan 02 Camac Stream 1 RS: 210 Profile: 1% AEP

E.G. Elev (m)	136.97	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.92	Reach Len. (m)	1.67	1.67	1.67
Crit W.S. (m)		Flow Area (m2)	0.12	4.04	
E.G. Slope (m/m)	0.001876	Area (m2)	0.12	4.04	
Q Total (m3/s)	3.96	Flow (m3/s)	0.04	3.92	
Top Width (m)	6.82	Top Width (m)	0.78	6.04	
Vel Total (m/s)	0.95	Avg. Vel. (m/s)	0.34	0.97	
Max Chl Dpth (m)	0.90	Hydr. Depth (m)	0.16	0.67	
Conv. Total (m3/s)	91.4	Conv. (m3/s)	1.0	90.5	
Length Wtd. (m)	1.67	Wetted Per. (m)	0.84	6.36	
Min Ch El (m)	136.02	Shear (N/m2)	2.69	11.69	
Alpha	1.03	Stream Power (N/m s)	0.92	11.34	
Frctn Loss (m)	0.00	Cum Volume (1000 m3)	0.00	0.87	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.05	1.84	0.09

Plan: Plan 02 Camac Stream 1 RS: 210 Profile: 1% AEP (+C.C)

E.G. Elev (m)	137.03	Element	Left OB	Channel	Right OB
Vel Head (m)	0.06	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.98	Reach Len. (m)	1.67	1.67	1.67
Crit W.S. (m)		Flow Area (m2)	0.17	4.38	
E.G. Slope (m/m)	0.002087	Area (m2)	0.17	4.38	
Q Total (m3/s)	4.75	Flow (m3/s)	0.07	4.68	
Top Width (m)	7.06	Top Width (m)	0.92	6.13	
Vel Total (m/s)	1.04	Avg. Vel. (m/s)	0.40	1.07	
Max Chl Dpth (m)	0.95	Hydr. Depth (m)	0.19	0.71	
Conv. Total (m3/s)	104.0	Conv. (m3/s)	1.5	102.5	
Length Wtd. (m)	1.67	Wetted Per. (m)	0.99	6.46	
Min Ch El (m)	136.02	Shear (N/m2)	3.53	13.87	
Alpha	1.04	Stream Power (N/m s)	1.42	14.82	
Frctn Loss (m)	0.00	Cum Volume (1000 m3)	0.01	0.99	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.16	1.91	0.25

Plan: Plan 02 Camac Stream 1 RS: 209 Profile: 1% AEP

E.G. Elev (m)	136.87	Element	Left OB	Channel	Right OB
Vel Head (m)	0.18	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.70	Reach Len. (m)	11.29	11.29	11.29
Crit W.S. (m)	136.70	Flow Area (m2)	0.00	2.11	
E.G. Slope (m/m)	0.017503	Area (m2)	0.00	2.11	
Q Total (m3/s)	3.96	Flow (m3/s)	0.00	3.96	
Top Width (m)	5.98	Top Width (m)	0.11	5.88	
Vel Total (m/s)	1.88	Avg. Vel. (m/s)	0.10	1.88	
Max Chl Dpth (m)	1.07	Hydr. Depth (m)	0.00	0.36	
Conv. Total (m3/s)	29.9	Conv. (m3/s)	0.0	29.9	
Length Wtd. (m)	11.29	Wetted Per. (m)	0.11	6.59	
Min Ch El (m)	135.63	Shear (N/m2)	0.79	54.99	

Plan: Plan 02 Camac Stream 1 RS: 209 Profile: 1% AEP (Continued)

Alpha	1.00	Stream Power (N/m s)	0.08	103.21	
Frctn Loss (m)	0.24	Cum Volume (1000 m3)	0.00	0.80	0.00
C & E Loss (m)	0.01	Cum SA (1000 m2)	0.03	1.72	0.09

Plan: Plan 02 Camac Stream 1 RS: 209 Profile: 1% AEP (+C.C)

E.G. Elev (m)	136.94	Element	Left OB	Channel	Right OB
Vel Head (m)	0.19	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.75	Reach Len. (m)	11.29	11.29	11.29
Crit W.S. (m)	136.75	Flow Area (m2)	0.03	2.46	
E.G. Slope (m/m)	0.016728	Area (m2)	0.03	2.46	
Q Total (m3/s)	4.75	Flow (m3/s)	0.01	4.74	
Top Width (m)	7.19	Top Width (m)	0.76	6.43	
Vel Total (m/s)	1.91	Avg. Vel. (m/s)	0.38	1.93	
Max Chl Dpth (m)	1.12	Hydr. Depth (m)	0.03	0.38	
Conv. Total (m3/s)	36.7	Conv. (m3/s)	0.1	36.7	
Length Wtd. (m)	11.29	Wetted Per. (m)	0.76	7.14	
Min Ch El (m)	135.63	Shear (N/m2)	5.41	56.53	
Alpha	1.01	Stream Power (N/m s)	2.06	108.90	
Frctn Loss (m)	0.24	Cum Volume (1000 m3)	0.00	0.91	0.01
C & E Loss (m)	0.01	Cum SA (1000 m2)	0.13	1.79	0.20

Plan: Plan 02 Camac Stream 1 RS: 208 Profile: 1% AEP

E.G. Elev (m)	134.23	Element	Left OB	Channel	Right OB
Vel Head (m)	0.29	Wt. n-Val.	0.035	0.033	0.035
W.S. Elev (m)	133.94	Reach Len. (m)	1.71	1.71	1.71
Crit W.S. (m)	134.06	Flow Area (m2)	0.01	1.59	0.17
E.G. Slope (m/m)	0.024013	Area (m2)	0.01	1.59	0.17
Q Total (m3/s)	3.96	Flow (m3/s)	0.00	3.85	0.11
Top Width (m)	7.95	Top Width (m)	1.09	4.00	2.86
Vel Total (m/s)	2.24	Avg. Vel. (m/s)	0.22	2.42	0.66
Max Chl Dpth (m)	0.64	Hydr. Depth (m)	0.01	0.40	0.06
Conv. Total (m3/s)	25.6	Conv. (m3/s)	0.0	24.8	0.7
Length Wtd. (m)	1.71	Wetted Per. (m)	1.09	4.28	2.98
Min Ch El (m)	133.30	Shear (N/m2)	2.61	87.29	13.09
Alpha	1.14	Stream Power (N/m s)	0.57	211.52	8.59
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.00	0.60	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.00	1.16	0.02

Plan: Plan 02 Camac Stream 1 RS: 208 Profile: 1% AEP (+C.C)

E.G. Elev (m)	134.30	Element	Left OB	Channel	Right OB
Vel Head (m)	0.32	Wt. n-Val.	0.035	0.033	0.035
W.S. Elev (m)	133.98	Reach Len. (m)	1.71	1.71	1.71
Crit W.S. (m)	134.10	Flow Area (m2)	0.09	1.74	0.30
E.G. Slope (m/m)	0.023930	Area (m2)	0.09	1.74	0.30
Q Total (m3/s)	4.75	Flow (m3/s)	0.04	4.48	0.23
Top Width (m)	10.93	Top Width (m)	2.99	4.00	3.94
Vel Total (m/s)	2.23	Avg. Vel. (m/s)	0.43	2.57	0.78
Max Chl Dpth (m)	0.68	Hydr. Depth (m)	0.03	0.44	0.08
Conv. Total (m3/s)	30.7	Conv. (m3/s)	0.3	29.0	1.5
Length Wtd. (m)	1.71	Wetted Per. (m)	2.99	4.28	4.11
Min Ch El (m)	133.30	Shear (N/m2)	7.10	95.39	16.94
Alpha	1.26	Stream Power (N/m s)	3.05	245.38	13.21
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.00	0.68	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	0.02	1.20	0.04

Plan: Plan 02 Camac Stream 1 RS: 207 Profile: 1% AEP

E.G. Elev (m)	132.74	Element	Left OB	Channel	Right OB
Vel Head (m)	0.32	Wt. n-Val.		0.033	
W.S. Elev (m)	132.43	Reach Len. (m)	1.73	1.73	1.73
Crit W.S. (m)	132.51	Flow Area (m2)		1.59	
E.G. Slope (m/m)	0.027653	Area (m2)		1.59	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.31	Top Width (m)		4.31	
Vel Total (m/s)	2.50	Avg. Vel. (m/s)		2.50	
Max Chl Dpth (m)	0.58	Hydr. Depth (m)		0.37	
Conv. Total (m3/s)	23.8	Conv. (m3/s)		23.8	
Length Wtd. (m)	1.73	Wetted Per. (m)		4.54	
Min Ch El (m)	131.84	Shear (N/m2)		94.64	
Alpha	1.00	Stream Power (N/m s)		236.38	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)		0.52	
C & E Loss (m)	0.05	Cum SA (1000 m2)		0.93	

Plan: Plan 02 Camac Stream 1 RS: 207 Profile: 1% AEP (+C.C)

E.G. Elev (m)	132.83	Element	Left OB	Channel	Right OB
Vel Head (m)	0.35	Wt. n-Val.		0.033	
W.S. Elev (m)	132.48	Reach Len. (m)	1.73	1.73	1.73
Crit W.S. (m)	132.57	Flow Area (m2)		1.81	
E.G. Slope (m/m)	0.027907	Area (m2)		1.81	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.57	Top Width (m)		4.57	
Vel Total (m/s)	2.63	Avg. Vel. (m/s)		2.63	
Max Chl Dpth (m)	0.63	Hydr. Depth (m)		0.40	
Conv. Total (m3/s)	28.4	Conv. (m3/s)		28.4	
Length Wtd. (m)	1.73	Wetted Per. (m)		4.82	
Min Ch El (m)	131.84	Shear (N/m2)		102.57	
Alpha	1.00	Stream Power (N/m s)		269.91	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)		0.58	
C & E Loss (m)	0.07	Cum SA (1000 m2)		0.96	

Plan: Plan 02 Camac Stream 1 RS: 206 Profile: 1% AEP

E.G. Elev (m)	131.33	Element	Left OB	Channel	Right OB
Vel Head (m)	0.08	Wt. n-Val.		0.033	
W.S. Elev (m)	131.25	Reach Len. (m)	13.00	13.00	13.00
Crit W.S. (m)	130.94	Flow Area (m2)		3.13	
E.G. Slope (m/m)	0.003573	Area (m2)		3.13	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.33	Top Width (m)		4.33	
Vel Total (m/s)	1.26	Avg. Vel. (m/s)		1.26	
Max Chl Dpth (m)	0.82	Hydr. Depth (m)		0.72	
Conv. Total (m3/s)	66.2	Conv. (m3/s)		66.2	
Length Wtd. (m)	13.00	Wetted Per. (m)		5.38	
Min Ch El (m)	130.42	Shear (N/m2)		20.42	
Alpha	1.00	Stream Power (N/m s)		25.81	
Frctn Loss (m)		Cum Volume (1000 m3)		0.41	
C & E Loss (m)		Cum SA (1000 m2)		0.67	

Plan: Plan 02 Camac Stream 1 RS: 206 Profile: 1% AEP (+C.C)

E.G. Elev (m)	131.45	Element	Left OB	Channel	Right OB
Vel Head (m)	0.09	Wt. n-Val.		0.033	
W.S. Elev (m)	131.36	Reach Len. (m)	13.00	13.00	13.00
Crit W.S. (m)	131.00	Flow Area (m2)		3.63	
E.G. Slope (m/m)	0.003353	Area (m2)		3.63	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	

Plan: Plan 02 Camac Stream 1 RS: 206 Profile: 1% AEP (+C.C) (Continued)

Top Width (m)	4.45	Top Width (m)		4.45	
Vel Total (m/s)	1.31	Avg. Vel. (m/s)		1.31	
Max Chl Dpth (m)	0.94	Hydr. Depth (m)		0.82	
Conv. Total (m3/s)	82.0	Conv. (m3/s)		82.0	
Length Wtd. (m)	13.00	Wetted Per. (m)		5.64	
Min Ch El (m)	130.42	Shear (N/m2)		21.16	
Alpha	1.00	Stream Power (N/m s)		27.68	
Frctn Loss (m)		Cum Volume (1000 m3)		0.46	
C & E Loss (m)		Cum SA (1000 m2)		0.69	

Plan: Plan 02 Camac Stream 1 RS: 205 Profile: 1% AEP

E.G. Elev (m)	131.28	Element	Left OB	Channel	Right OB
Vel Head (m)	0.78	Wt. n-Val.		0.033	
W.S. Elev (m)	130.50	Reach Len. (m)	1.72	1.72	1.72
Crit W.S. (m)	130.72	Flow Area (m2)		1.01	
E.G. Slope (m/m)	0.105747	Area (m2)		1.01	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	3.78	Top Width (m)		3.78	
Vel Total (m/s)	3.92	Avg. Vel. (m/s)		3.92	
Max Chl Dpth (m)	0.29	Hydr. Depth (m)		0.27	
Conv. Total (m3/s)	12.2	Conv. (m3/s)		12.2	
Length Wtd. (m)	1.72	Wetted Per. (m)		4.02	
Min Ch El (m)	130.21	Shear (N/m2)		260.31	
Alpha	1.00	Stream Power (N/m s)		1020.74	
Frctn Loss (m)	0.11	Cum Volume (1000 m3)		0.37	
C & E Loss (m)	0.18	Cum SA (1000 m2)		0.62	

Plan: Plan 02 Camac Stream 1 RS: 205 Profile: 1% AEP (+C.C)

E.G. Elev (m)	131.35	Element	Left OB	Channel	Right OB
Vel Head (m)	0.80	Wt. n-Val.		0.033	
W.S. Elev (m)	130.55	Reach Len. (m)	1.72	1.72	1.72
Crit W.S. (m)	130.78	Flow Area (m2)		1.20	
E.G. Slope (m/m)	0.089347	Area (m2)		1.20	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	3.89	Top Width (m)		3.89	
Vel Total (m/s)	3.95	Avg. Vel. (m/s)		3.95	
Max Chl Dpth (m)	0.34	Hydr. Depth (m)		0.31	
Conv. Total (m3/s)	15.9	Conv. (m3/s)		15.9	
Length Wtd. (m)	1.72	Wetted Per. (m)		4.17	
Min Ch El (m)	130.21	Shear (N/m2)		252.71	
Alpha	1.00	Stream Power (N/m s)		999.21	
Frctn Loss (m)	0.09	Cum Volume (1000 m3)		0.42	
C & E Loss (m)	0.18	Cum SA (1000 m2)		0.64	

Plan: Plan 02 Camac Stream 1 RS: 204 Profile: 1% AEP

E.G. Elev (m)	130.36	Element	Left OB	Channel	Right OB
Vel Head (m)	0.22	Wt. n-Val.		0.033	
W.S. Elev (m)	130.14	Reach Len. (m)	1.68	1.68	1.68
Crit W.S. (m)	130.14	Flow Area (m2)		1.91	
E.G. Slope (m/m)	0.016998	Area (m2)		1.91	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.54	Top Width (m)		4.54	
Vel Total (m/s)	2.08	Avg. Vel. (m/s)		2.08	
Max Chl Dpth (m)	0.48	Hydr. Depth (m)		0.42	
Conv. Total (m3/s)	30.4	Conv. (m3/s)		30.4	
Length Wtd. (m)	1.68	Wetted Per. (m)		5.01	
Min Ch El (m)	129.66	Shear (N/m2)		63.50	

Plan: Plan 02 Camac Stream 1 RS: 204 Profile: 1% AEP (Continued)

Alpha	1.00	Stream Power (N/m s)		131.84	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)		0.31	
C & E Loss (m)	0.01	Cum SA (1000 m2)		0.48	

Plan: Plan 02 Camac Stream 1 RS: 204 Profile: 1% AEP (+C.C)

E.G. Elev (m)	130.44	Element	Left OB	Channel	Right OB
Vel Head (m)	0.25	Wt. n-Val.		0.033	
W.S. Elev (m)	130.19	Reach Len. (m)	1.68	1.68	1.68
Crit W.S. (m)	130.20	Flow Area (m2)		2.14	
E.G. Slope (m/m)	0.017162	Area (m2)		2.14	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.59	Top Width (m)		4.59	
Vel Total (m/s)	2.22	Avg. Vel. (m/s)		2.22	
Max Chl Dpth (m)	0.53	Hydr. Depth (m)		0.47	
Conv. Total (m3/s)	36.3	Conv. (m3/s)		36.3	
Length Wtd. (m)	1.68	Wetted Per. (m)		5.12	
Min Ch El (m)	129.66	Shear (N/m2)		70.35	
Alpha	1.00	Stream Power (N/m s)		156.13	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)		0.35	
C & E Loss (m)	0.01	Cum SA (1000 m2)		0.49	

Plan: Plan 02 Camac Stream 1 RS: 203 Profile: 1% AEP

E.G. Elev (m)	129.55	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.		0.033	
W.S. Elev (m)	129.50	Reach Len. (m)	21.00	21.00	21.00
Crit W.S. (m)	129.12	Flow Area (m2)		4.17	
E.G. Slope (m/m)	0.001916	Area (m2)		4.17	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	5.97	Top Width (m)		5.97	
Vel Total (m/s)	0.95	Avg. Vel. (m/s)		0.95	
Max Chl Dpth (m)	0.85	Hydr. Depth (m)		0.70	
Conv. Total (m3/s)	90.5	Conv. (m3/s)		90.5	
Length Wtd. (m)	21.00	Wetted Per. (m)		6.90	
Min Ch El (m)	128.65	Shear (N/m2)		11.37	
Alpha	1.00	Stream Power (N/m s)		10.79	
Frctn Loss (m)		Cum Volume (1000 m3)		0.24	
C & E Loss (m)		Cum SA (1000 m2)		0.32	

Plan: Plan 02 Camac Stream 1 RS: 203 Profile: 1% AEP (+C.C)

E.G. Elev (m)	129.66	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.		0.033	
W.S. Elev (m)	129.61	Reach Len. (m)	21.00	21.00	21.00
Crit W.S. (m)	129.17	Flow Area (m2)		4.82	
E.G. Slope (m/m)	0.001781	Area (m2)		4.82	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	6.06	Top Width (m)		6.06	
Vel Total (m/s)	0.98	Avg. Vel. (m/s)		0.98	
Max Chl Dpth (m)	0.95	Hydr. Depth (m)		0.80	
Conv. Total (m3/s)	112.5	Conv. (m3/s)		112.5	
Length Wtd. (m)	21.00	Wetted Per. (m)		7.14	
Min Ch El (m)	128.65	Shear (N/m2)		11.80	
Alpha	1.00	Stream Power (N/m s)		11.61	
Frctn Loss (m)		Cum Volume (1000 m3)		0.27	
C & E Loss (m)		Cum SA (1000 m2)		0.33	

Plan: Plan 02 Camac Stream 1 RS: 202 Profile: 1% AEP

E.G. Elev (m)	129.48	Element	Left OB	Channel	Right OB
Vel Head (m)	0.03	Wt. n-Val.		0.033	
W.S. Elev (m)	129.45	Reach Len. (m)	1.74	1.74	1.74
Crit W.S. (m)		Flow Area (m2)		4.81	
E.G. Slope (m/m)	0.001039	Area (m2)		4.81	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.01	Top Width (m)		4.01	
Vel Total (m/s)	0.82	Avg. Vel. (m/s)		0.82	
Max Chl Dpth (m)	1.25	Hydr. Depth (m)		1.20	
Conv. Total (m3/s)	122.9	Conv. (m3/s)		122.9	
Length Wtd. (m)	1.74	Wetted Per. (m)		6.22	
Min Ch El (m)	128.20	Shear (N/m2)		7.88	
Alpha	1.00	Stream Power (N/m s)		6.49	
Frctn Loss (m)	0.00	Cum Volume (1000 m3)		0.18	
C & E Loss (m)	0.00	Cum SA (1000 m2)		0.22	

Plan: Plan 02 Camac Stream 1 RS: 202 Profile: 1% AEP (+C.C)

E.G. Elev (m)	129.59	Element	Left OB	Channel	Right OB
Vel Head (m)	0.04	Wt. n-Val.		0.033	
W.S. Elev (m)	129.54	Reach Len. (m)	1.74	1.74	1.74
Crit W.S. (m)		Flow Area (m2)		5.20	
E.G. Slope (m/m)	0.001203	Area (m2)		5.20	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.03	Top Width (m)		4.03	
Vel Total (m/s)	0.91	Avg. Vel. (m/s)		0.91	
Max Chl Dpth (m)	1.34	Hydr. Depth (m)		1.29	
Conv. Total (m3/s)	137.0	Conv. (m3/s)		137.0	
Length Wtd. (m)	1.74	Wetted Per. (m)		6.41	
Min Ch El (m)	128.20	Shear (N/m2)		9.56	
Alpha	1.00	Stream Power (N/m s)		8.74	
Frctn Loss (m)	0.00	Cum Volume (1000 m3)		0.20	
C & E Loss (m)	0.00	Cum SA (1000 m2)		0.22	

Plan: Plan 02 Camac Stream 1 RS: 201 Profile: 1% AEP

E.G. Elev (m)	129.26	Element	Left OB	Channel	Right OB
Vel Head (m)	0.24	Wt. n-Val.		0.033	
W.S. Elev (m)	129.02	Reach Len. (m)			
Crit W.S. (m)	129.02	Flow Area (m2)		1.82	
E.G. Slope (m/m)	0.015727	Area (m2)		1.82	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	3.84	Top Width (m)		3.84	
Vel Total (m/s)	2.17	Avg. Vel. (m/s)		2.17	
Max Chl Dpth (m)	0.68	Hydr. Depth (m)		0.47	
Conv. Total (m3/s)	31.6	Conv. (m3/s)		31.6	
Length Wtd. (m)		Wetted Per. (m)		4.21	
Min Ch El (m)	128.34	Shear (N/m2)		66.75	
Alpha	1.00	Stream Power (N/m s)		145.13	
Frctn Loss (m)		Cum Volume (1000 m3)			
C & E Loss (m)		Cum SA (1000 m2)			

Plan: Plan 02 Camac Stream 1 RS: 201 Profile: 1% AEP (+C.C)

E.G. Elev (m)	129.35	Element	Left OB	Channel	Right OB
Vel Head (m)	0.26	Wt. n-Val.		0.033	
W.S. Elev (m)	129.09	Reach Len. (m)			
Crit W.S. (m)	129.09	Flow Area (m2)		2.09	
E.G. Slope (m/m)	0.015411	Area (m2)		2.09	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	

Plan: Plan 02 Camac Stream 1 RS: 201 Profile: 1% AEP (+C.C) (Continued)

Top Width (m)	4.03	Top Width (m)		4.03	
Vel Total (m/s)	2.27	Avg. Vel. (m/s)		2.27	
Max Chl Dpth (m)	0.75	Hydr. Depth (m)		0.52	
Conv. Total (m3/s)	38.3	Conv. (m3/s)		38.3	
Length Wtd. (m)		Wetted Per. (m)		4.45	
Min Ch El (m)	128.34	Shear (N/m2)		71.00	
Alpha	1.00	Stream Power (N/m s)		161.41	
Frctn Loss (m)		Cum Volume (1000 m3)			
C & E Loss (m)		Cum SA (1000 m2)			

Plan: Plan 02 Camac Stream 1 RS: 205.5 Culv Group: Culvert #1 Profile: 1% AEP

Q Culv Group (m3/s)	3.96	Culv Full Len (m)	
# Barrels	1	Culv Vel US (m/s)	2.27
Q Barrel (m3/s)	3.96	Culv Vel DS (m/s)	3.53
E.G. US. (m)	131.33	Culv Inv El Up (m)	130.42
W.S. US. (m)	131.25	Culv Inv El Dn (m)	130.17
E.G. DS (m)	130.96	Culv Frctn Ls (m)	0.06
W.S. DS (m)	130.81	Culv Exit Loss (m)	0.17
Delta EG (m)	0.36	Culv Entr Loss (m)	0.13
Delta WS (m)	0.43	Q Weir (m3/s)	
E.G. IC (m)	131.17	Weir Sta Lft (m)	
E.G. OC (m)	131.33	Weir Sta Rgt (m)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (m)	130.93	Weir Max Depth (m)	
Culv WS Outlet (m)	130.50	Weir Avg Depth (m)	
Culv Nml Depth (m)	0.24	Weir Flow Area (m2)	
Culv Crt Depth (m)	0.51	Min El Weir Flow (m)	132.06

Plan: Plan 02 Camac Stream 1 RS: 205.5 Culv Group: Culvert #1 Profile: 1% AEP (+C.C)

Q Culv Group (m3/s)	4.75	Culv Full Len (m)	
# Barrels	1	Culv Vel US (m/s)	2.41
Q Barrel (m3/s)	4.75	Culv Vel DS (m/s)	3.68
E.G. US. (m)	131.45	Culv Inv El Up (m)	130.42
W.S. US. (m)	131.36	Culv Inv El Dn (m)	130.17
E.G. DS (m)	131.05	Culv Frctn Ls (m)	0.06
W.S. DS (m)	130.89	Culv Exit Loss (m)	0.19
Delta EG (m)	0.39	Culv Entr Loss (m)	0.15
Delta WS (m)	0.47	Q Weir (m3/s)	
E.G. IC (m)	131.28	Weir Sta Lft (m)	
E.G. OC (m)	131.45	Weir Sta Rgt (m)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (m)	131.00	Weir Max Depth (m)	
Culv WS Outlet (m)	130.55	Weir Avg Depth (m)	
Culv Nml Depth (m)	0.26	Weir Flow Area (m2)	
Culv Crt Depth (m)	0.58	Min El Weir Flow (m)	132.06

Plan: Plan 02 Camac Stream 1 RS: 202.5 Culv Group: Culvert #1 Profile: 1% AEP

Q Culv Group (m3/s)	3.96	Culv Full Len (m)	
# Barrels	1	Culv Vel US (m/s)	1.55
Q Barrel (m3/s)	3.96	Culv Vel DS (m/s)	0.83
E.G. US. (m)	129.55	Culv Inv El Up (m)	128.70
W.S. US. (m)	129.50	Culv Inv El Dn (m)	128.20
E.G. DS (m)	129.48	Culv Frctn Ls (m)	0.00
W.S. DS (m)	129.45	Culv Exit Loss (m)	0.00
Delta EG (m)	0.07	Culv Entr Loss (m)	0.06
Delta WS (m)	0.05	Q Weir (m3/s)	
E.G. IC (m)	129.43	Weir Sta Lft (m)	
E.G. OC (m)	129.55	Weir Sta Rgt (m)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (m)	129.36	Weir Max Depth (m)	
Culv WS Outlet (m)	129.45	Weir Avg Depth (m)	
Culv Nml Depth (m)	0.20	Weir Flow Area (m2)	
Culv Crt Depth (m)	0.48	Min El Weir Flow (m)	130.47

Plan: Plan 02 Camac Stream 1 RS: 202.5 Culv Group: Culvert #1 Profile: 1% AEP (+C.C)

Q Culv Group (m3/s)	4.75	Culv Full Len (m)	
# Barrels	1	Culv Vel US (m/s)	1.64
Q Barrel (m3/s)	4.75	Culv Vel DS (m/s)	0.92
E.G. US. (m)	129.66	Culv Inv El Up (m)	128.70
W.S. US. (m)	129.61	Culv Inv El Dn (m)	128.20
E.G. DS (m)	129.59	Culv Frctn Ls (m)	0.00
W.S. DS (m)	129.54	Culv Exit Loss (m)	0.00
Delta EG (m)	0.07	Culv Entr Loss (m)	0.07
Delta WS (m)	0.06	Q Weir (m3/s)	
E.G. IC (m)	129.53	Weir Sta Lft (m)	
E.G. OC (m)	129.66	Weir Sta Rgt (m)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (m)	129.45	Weir Max Depth (m)	
Culv WS Outlet (m)	129.54	Weir Avg Depth (m)	
Culv Nml Depth (m)	0.23	Weir Flow Area (m2)	
Culv Crt Depth (m)	0.54	Min El Weir Flow (m)	130.47

APPENDIX 4

PHOTO LOGS OF INFILTRATION TESTS

Plate A4.1 – TP01

Plate A4.2 – Location of TP02

Plate A4.3 – TP04

Plate A4.4 – TP03A

Plate A4.5 – TP04A

Appendix 7 – Flood Risk Assessment