FLOOD RISK ASSESSMENT

OF

WESTNEWTON BRIDGE – SCOUR PROTECTION.

AT

B6351 CROSSING OF COLLEGE BURN
NGC 390783,630383

FOR

NORTHUMBERLAND COUNTY COUNCIL

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

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APPENDICES

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1.0 INTRODUCTION

At the request of Mr Peter Brewis, on behalf of Northumberland County Council, County Hall, Morpeth, Northumberland NE61 2EF, a Flood Risk Assessment of the Proposed Works at Westnewton Bridge, has been undertaken in support of an Application for Planning Approval.
The Application is for repair of flood damage to the bridge, for reinforcement of the river channel, and installation/construction of protection measures.

1.1 Flood Risk Assessment Methodology and Objectives

It is recognised that developments that are designed without regard to flood risk may endanger lives, damage property, cause disruption to the wider community, damage the environment, be difficult to insure and require additional expense on remedial works. Current guidance on development and flood risk[1] identifies several key aims for a development to ensure that it is sustainable in flood risk terms. These aims are as follows:

- ✓ the development should not be at a significant risk of flooding and should not be susceptible to damage due to flooding;
- ✓ the development should not be exposed to flood risk such that the health, safety and welfare of the users of the development, or the population elsewhere, are threatened;
- ✓ normal operation of the development should not be susceptible to disruption as a result of flooding;
- ✓ safe access to and from the development should be possible during flood events;
- ✓ the development should not increase flood risk elsewhere;
- ✓ the development should not prevent safe maintenance of watercourses or maintenance and operation of flood defences;
- ✓ the development should not be associated with an onerous or difficult operation and maintenance regime to manage flood risk. The responsibility for any operation and maintenance required should be clearly defined;

[1] *CIRIA, 2004, Funders Report CP/102 'Development and Flood Risk – Guidance for the Construction Industry.*

1.0 INTRODUCTION [contd.]

1.1 Flood Risk Assessment Methodology and Objectives [contd.]

- ✓ future users of the development should be made aware of any flood risk issues relating to the development;
- ✓ the development design should be such that future users will not have difficulty obtaining insurance or mortgage finance, or in selling all or part of the development, as a result of flood risk issues;
- ✓ the development should not lead to degradation of the environment; and
- ✓ the development should meet all of the above criteria for its entire lifetime, including consideration of the potential effects of climate change.

The Flood Risk Assessment [FRA] is undertaken with due consideration of these sustainability aims.

The key objectives of the Study are:

- ✓ to assess the flood risk to the proposed development and to demonstrate the feasibility of appropriately designing the development such that any residual flood risk to the development and its users would be acceptable;
- ✓ to assess the potential impact of the proposed development on flood risk elsewhere and to demonstrate the feasibility of appropriately designing the development such that the development would not increase flood risk elsewhere; and
- ✓ to satisfy the requirements of national planning policy which require FRAs to be submitted in support of planning applications.

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1.0 INTRODUCTION [contd.]

1.2 Project Scope

In order to achieve the aims outlined above, a staged approach has been adopted in undertaking this FRA, in accordance with current best-practice. A screening study has initially been undertaken to identify whether there are any potential sources of flooding at the site which may warrant further consideration. Any potential flooding issues identified in the screening study have subsequently been considered in a site specific assessment, the aim of which is to review all available information and provide a qualitative assessment of the flood risk to the site and the impact of the site on flood risk elsewhere.

The Study has been undertaken with due regards to the Environment Agency's National Standing Advice on Development and Flood Risk[2]. This advice enables local planning authorities to make decisions on low risk planning applications where flood risk is an issue, without directly consulting the Agency for an individual response.

1.3 Report Structure

The Study has the following report structure:

- ✓ Section 2 identifies the sources of information that have been consulted during the Study;
- ✓ Section 3 describes the application area including the existing and proposed development;
- ✓ Section 4 outlines the flood risk to the existing and proposed development;
- ✓ Section 5 presents a summary and conclusions;

[2] Environment Agency, March 2007, National Standing Advice to Local Planning Authorities for Planning Applications – Development and Flood Risk.

2.0 SOURCE OF INFORMATION

General information regarding the site setting, local geology and hydrology of the application site has been obtained from the following sources:

- ✓ Ordnance Survey Digital Data File of the site and surrounding area reproduced in hard copy at Appendix 1 at a scale of 1:1000@A1;
- ✓ British Geological Survey Map Sheet 3 1:50,000 scale map, solid and drift;
- ✓ Environment Agency's National Standing Advice on Development and Flood Risk;
- ✓ Environment Agency's Flood Map;
- ✓ Environment Agency's Flood Defense Plans and Undefended Flood Node Plan;
- ✓ National Planning Policy Framework – 10. Meeting the challenge of climate change, flooding and coastal change;
- ✓ Technical Guide to National Planning Policy Framework;
- ✓ cbec eco-engineering UK Ltd's 'Westnewton Bridge Modelling and Design' at Appendix C1
- ✓ River Catchment Services Peer Review of above at Appendix C2
- ✓ NCC Method Statement for the Works at Appendix C3

Information regarding the current fluvial, pluvial and tidal flood risk at the application site, and local flood defences, has been obtained from the Environment Agency's website and Customers and Engagement Team, and confirmed through direct contact with Planners and Engineers at the Environment Agency's Local Office.

Information

Current pre-development site plans and proposed development plans have been provided by the Applicant and are reproduced at Appendices A5 – A7.

3.0 DESCRIPTION OF APPLICATION AREA

3.1 Site Location

Westnewton Bridge is located over the College Burn on the B6351 County Road between Westnewton and Kirknewton at NGC 390783,630383. The Scour Protection Works extend from the line of the dismantled railway bridge to the north, and the historic ford crossing to the south, all as detailed on the Site Reference Plan No. HB127276/B/B6351/06/34 at Appendix A6

3.2 Existing Development

The bridge site is presently unprotected from flood damage.

A severe flood event in September 2012 resulted in near catastrophic damage to the bridge pier foundations by under-scour and the burn diverted through the western relief archway rather than the main arch channel.

Emergency measures were undertaken by Northumberland County Council shortly thereafter to safeguard the foundations, and the river channel was dredged temporarily to return the course through the main central arch.

Extensive investigations and modelling have been carried out and an engineering design solution has now been completed to prevent recurrence.

3.3 Proposed Development

The design proposal is to protect the bridge pier supports by installing a sheet pile contained concrete apron round the piers and abutments, and across the channels, to prevent under-scour, and to realign the burn by various civil engineering measures to maintain its original course through the central arch prior to the flood of 2012, and to prevent recurrence of the damage occasioned in future flood conditions.

4.0 FLOOD RISK

4.1 Potential Sources of Flooding – Level 1 Screening Study

All potential sources of flooding must be considered for any proposed development. A summary of the potential sources of flooding and a review of the potential risk posed by each source at the application site is presented in Table 4-1.

Table 4-1
Potential Risk Posed
by Flooding Sources

(i)	Fluvial flooding	Yes
(ii)	Tidal flooding	No
(iii)	Flooding from rising/high groundwater	No
(iv)	Overland flow flooding	No
(v)	Flooding from artificial drainage systems	No
(vi)	Flooding due to infrastructure failure	No
(vii)	Contributing to flooding elsewhere	Yes

4.0 FLOOD RISK [contd.]

4.2 Site Specific Assessment

4.2.1 Fluvial Flooding

The College Burn, which is crossed by Westnewton Bridge, flows under the bridge and joins with the Bowmont Water to form the River Glen at the confluence, all as detailed on the Site Location Plan at Appendix A1.
Being within the College Burn Channel and Floodplain, the site is obvious susceptible to flooding and the purpose of this assessment is to examine the effects of any flooding on the temporary works and the safety of the workforce and plant during construction, and on the permanent works thereafter, particularly with regard to exacerbation of flooding elsewhere.

A fully detailed Method Statement for the construction has been prepared by Northumberland County Council and is at Appendix C3.

A fully detailed Modelling and Design Report has been prepared by cbec eco-engineering UK Ltd and is at Appendix C1.

A Peer Review Report of the Modelling and Design Report has been undertaken by River Catchment Services Ltd and is at Appendix C2.

Since the 2008 and 2009 flood events had return periods in excess of 100years, the design works have been undertaken with a 200 year return flood event. (cbec eco-engineering's Report page 18)

Regarding the effect of flooding on the temporary works and on the workforce during the construction, the method statement sets out the criteria for works to be carried out within the river channel. It can be seen that works will only be carried out that can be completed within the working day, and that work will only be carried out subject to a satisfactory catchment wide weather report for that day (page 2).
The risk to the temporary works and the workforce is therefore LOW.

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4.0 FLOOD RISK [contd.]

4.2 Site Specific Assessment [contd.]

4.2.2 Tidal Flooding

The development site is located outside the reach of any tidal influence and is therefore not at risk from tidal flooding.

4.2.3 Overland Flows

Being an open watercourse, the site is not susceptible to overland flows and is therefore not at risk.

4.2.4 Rising Ground Water Levels

Being an open watercourse, the site is not susceptible to rising ground water levels and is therefore not at risk.

4.2.5 Infrastructure Failure

Being an open watercourse, the site is not susceptible to infrastructure failure. and is therefore not at risk.

4.2.6 Existing and Planned Flood Defences

Historic flood defences are present in various locations adjacent to the College Burn per ebec eco-engineering's Report (pages 10-16 and Appendices A & B).

Proposed defences are at the right bank historic ford crossing per ebec eco-engineering's Report (pages 29) and narrative at 4.2.7 following.

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4.0 FLOOD RISK [contd.]

4.2 Site Specific Assessment [contd.]

4.2.7 Contribution to Flooding Elsewhere in the Vicinity

With regard to the effect of the permanent works on flooding elsewhere, the modelling and design report shows that the permanent works prevent inundation of the right bank floodplain south of the B6351 by construction/raising of the embankment on the right bank at the location of the historic ford, and also induces a reduction in the inundation area along the line of the redundant railway line to the north of the B6351 by the removal of the constriction imposed by the left bank redundant railway bridge abutment, greatly helping to reduce flood risk to Jamarus Lodge on the right bank between the B6351 and the redundant railway line. (cbec eco-engineering's Report pages 30-32)

The permanent works do not therefore contribute to flooding elsewhere, but in fact alleviate the extent.

5.0 SUMMARY AND CONCLUSION

The existing site conditions are such that Westnewton Bridge is at significant risk of catastrophic failure in the event of a flood similar to that of 6th September 2012.

Extensive investigation has taken place of the existing conditions present locally to the bridge, and for eight kilometres upstream, in the form of desk study, fluvial audit, and topographic and LiDAR surveys. This information was used to determine the most appropriate self-maintaining solution to the problem and inform the required design.

Using this, the existing condition was modelled to establish a control to set against the proposed design. Results for a 200 year return period showed inundation of the right bank at the historic ford spreading northward and eastwards towards the B63521, and also at the right bank downstream of the bridge, opposite the redundant railway bridge abutment, spreading eastward between the B6351 and the railway embankment. Resolution measures for these and other issues apparent within the existing condition model resulted in the final design which prevents flooding of the right bank by raising the ground level at the historic ford and of the property between the road and railway embankment by removing the constriction of the railway bridge abutment, whilst installation of 'soft' engineering measures channel the flow from upstream of the bridge through the main arch and prevent silting. The foundations of the bridge are protected by a concrete apron set between sheet piles set at bed level.

The existing Conditions model has been assessed against the Environment Agency's Flood Map for a one in 100 year storm return and is consistent with the EA model. The EA Flood Map, Flood Node Plan and Node Level and Flow values are at Appendices A4 & A5. cebc eco-engineering UK Ltd model graphics are at Appendix B2.

The cbec eco-engineering Report has been considered by Professor Malcolm D Newson of River Catchment Services who has concluded that the proposed works represents the best predictive and designs going forward.

5.0 SUMMARY AND CONCLUSION [contd.]

Although the works to install the necessary measures are within the channel and floodplain of the College Burn and therefore susceptible to flooding, measures indicated within the construction method statement will be undertaken during construction to ensure that the temporary works do not constrict the flow in flood conditions and that the workforce and plant are not in danger from flash flooding.

The proposed works are therefore not at significant risk from flooding from any source and will not contribute to the risk of flooding elsewhere

A B Lowe
Director.

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APPENDICES

APPENDICES

Appendix A	**Plans**		
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	A2 - Existing Site Plan	1:1000@A1	(Northumberland County Council)
	A3 - Flood Map	1:2500 @A4	(Environment Agency)
	A4 - Node Point Locations	1:1000@A3	(Environment Agency)
	A5 - Site Boundary Plan	1:1000@A1	(Northumberland County Council)
	A6 - Proposed Works Reference	1:1000@A1	(Northumberland County Council)
	A7 - Works Areas (1-6) Plans	1:1000@A1	(Northumberland County Council)
Appendix B	**Photographs**		
	B1 - Annotated Aerial Photograph		(cbec eco-engineering UK Ltd)
	B2 - Scheme Photographs		(cbec eco-engineering UK Ltd)
Appendix C	**Documents**		
	C1 - Bridge Modelling and Design		(cbec ecoengineering UK)
	C2 - Peer Review of C1		(River Catchment Services)
	C3 – Method Statement		(Northumberland County Council)

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Appendix A

Plans

A1 - Site Location Plan	1:1250@A1	(Northpoint Consulting Ltd)
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Appendix A

A1 - Site Location Plan 1:1250@A1 (Northpoint Consulting Ltd)

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Drawn: ABL
Checked: DW
Scale\s: 1:1000@A1
Date Drawn: 04 FEB 15

Client: NORTHUMBERLAND COUNTY COUNCIL
Project Title: WESTNEWTON BRIDGE SCOUR PROTECTION
Drawing Title: SITE LOCATION PLAN

NORTHPOINT

Project No.: 108201/15
Drawing No.: N 100
Revision: 0
Sheet Size: A1

Appendix A

A2 - Existing Site Plan 1:1000@A1 (Northumberland County Council)

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NOTES:

1.0 GENERAL

1.1 ALL DIMENSIONS ARE IN MILLIMETERS (mm) UNLESS STATED OTHERWISE.

LEGEND

OUTLINE OF SCHEME BOUNDARY

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Job Title
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Drawing Title
OUTLINE BOUNDARY OF SCHEME

Scales 1/1000

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Appendix A

A3 - Flood Map 1:2500 @A4 (Environment Agency)

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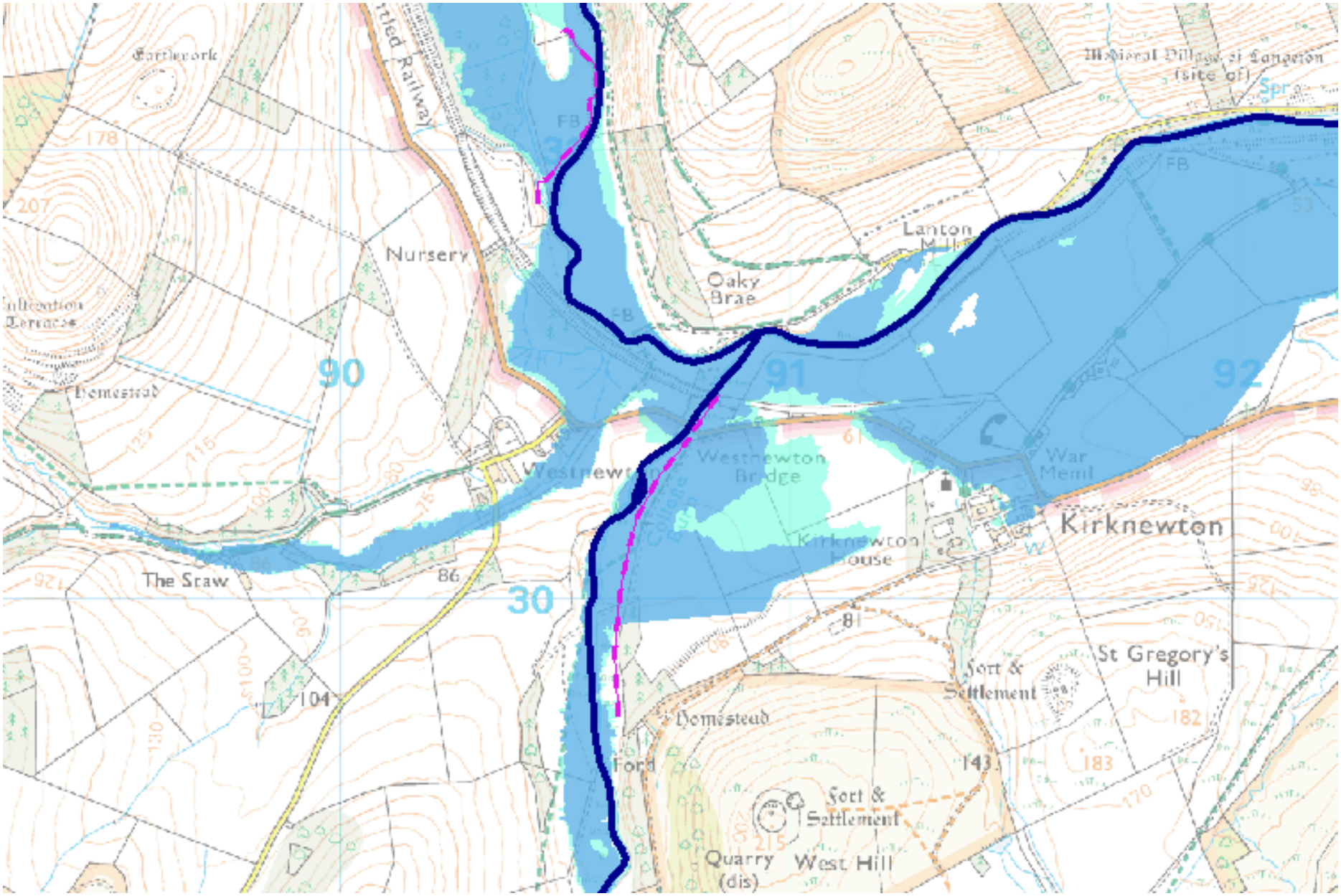

Environment Agency Flood Map

Appendix A

A4 - Node Point Locations 1:1000@A3 (Environment Agency)

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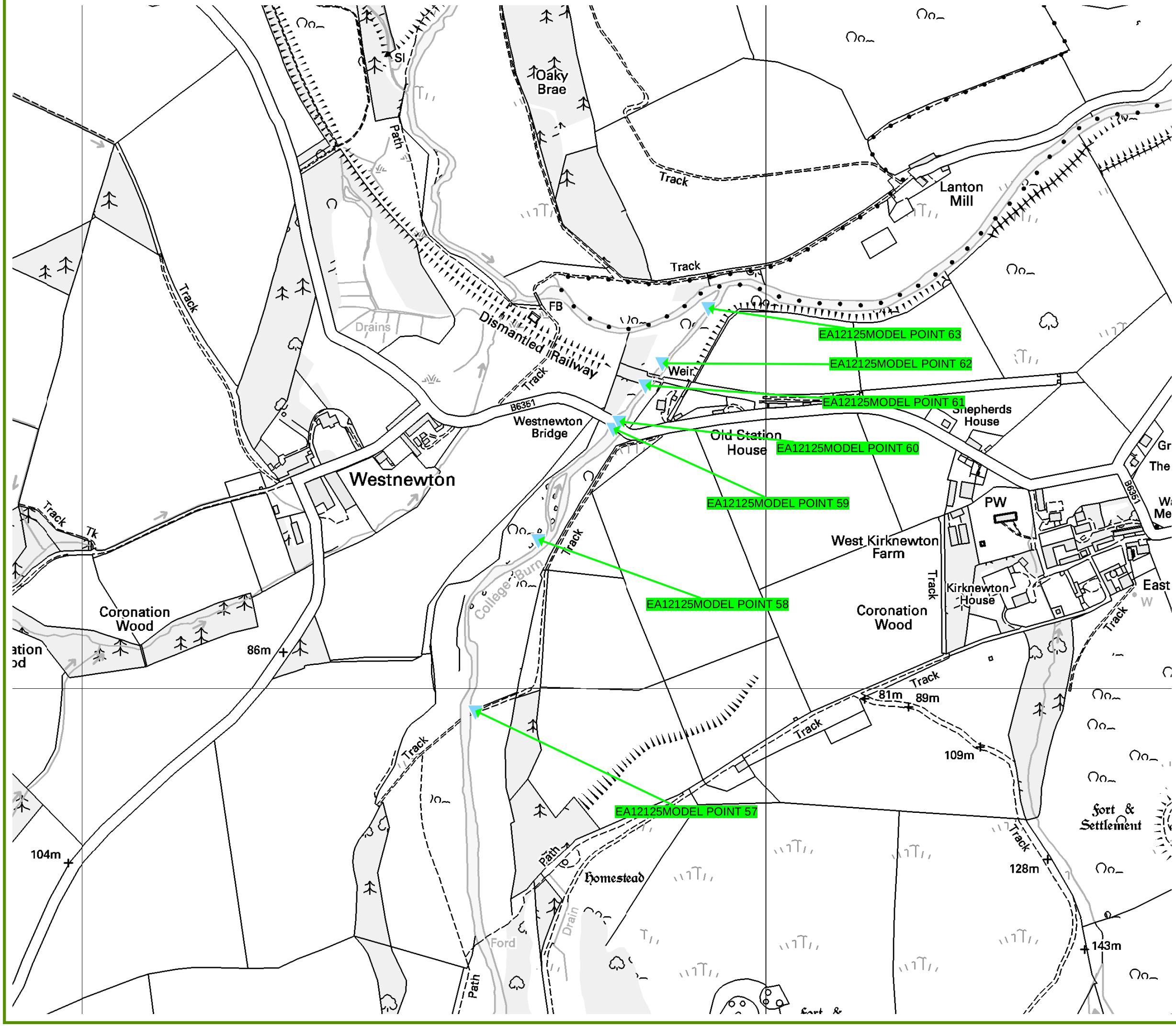


Environment Agency

ENVIRONMENT AGENCY

Legend

Node Points with Modelled Flood Levels ▼

Node Point Locations
Westnewton

Date: Feb 2015 Scale: 1:10,000 Status: Final

NFCDD data quality flag: Adequate

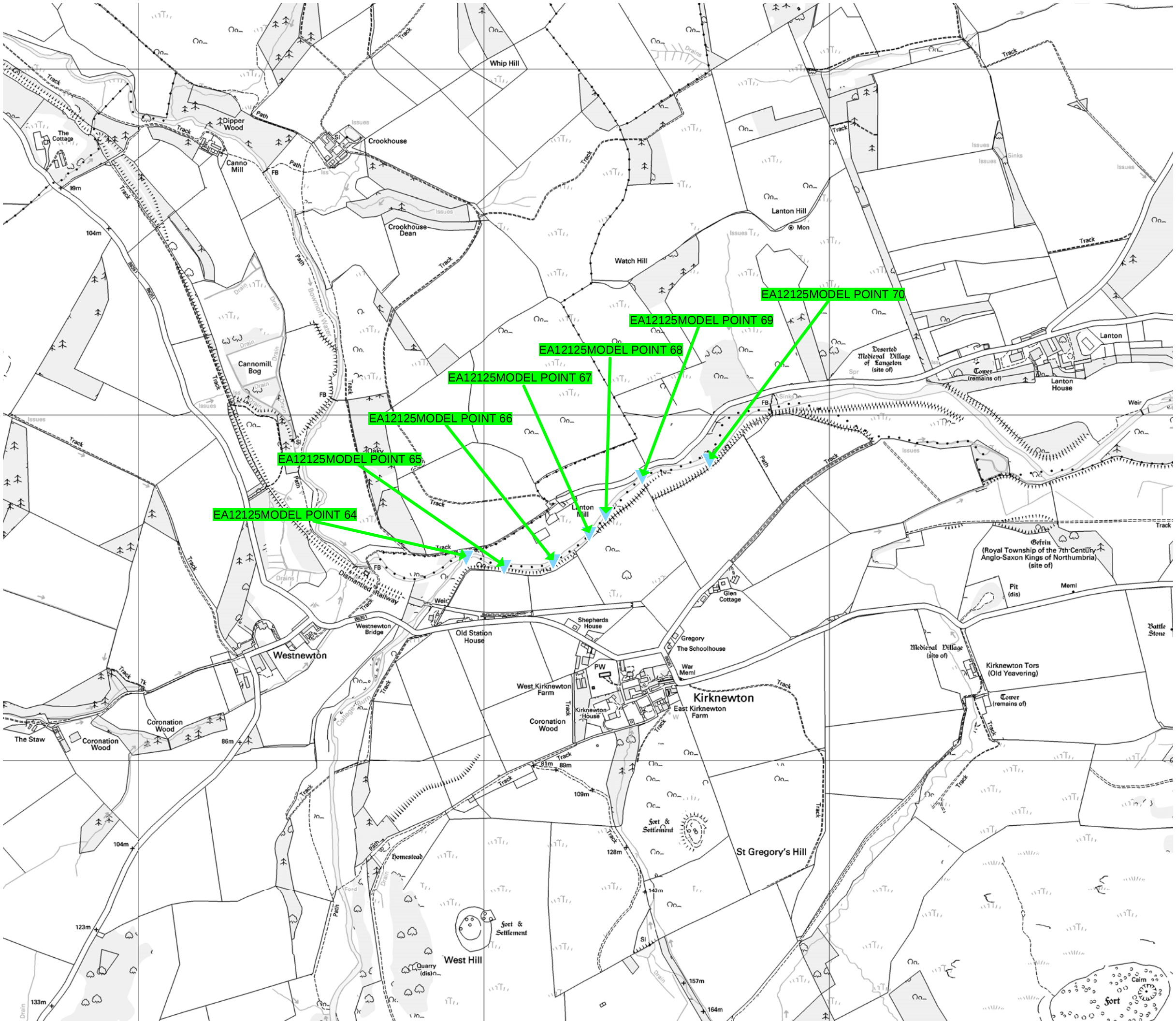
Data Source: NFCDD - data downloaded on 06 Feb 2015

Approved by: Phil Marshall 06 Feb 2015

Westnewton Node Point Attributes Table
JC Feb 2015

Modelled Flood Group = EA121258

Node Point Name (NGR)	Return Period (1:x years)	Level Value (mAOD)	Flow Value (Cumecs)
EA12125MODEL POINT 57	100	71.94	62.1
NT 90572 29970	1000	72.03	104.4
EA12125MODEL POINT 58	100	68.01	62.1
NT 90663 30220	1000	68.32	104.4
EA12125MODEL POINT 59	100	65.84	62.1
NT 90771 30384	1000	66.73	104.4
EA12125MODEL POINT 60	100	65.52	62.1
NT 90781 30397	1000	65.79	104.4
EA12125MODEL POINT 61	100	64.85	62.1
NT 90822 30445	1000	65.22	104.4
EA12125MODEL POINT 62	100	64.41	62.1
NT 90847 30478	1000	64.88	104.4
EA12125MODEL POINT 63	100	63.26	62.1
NT 90910 30558	1000	63.68	104.4



ENVIRONMENT AGENCY
Yorkshire and North East Region
North East Area

Legend

Node Points with Modelled Flood Levels ▼

Node Point Locations
Kirknewton, Wooler

Date: Sept 2014 Scale: 1:10,000 Status: Final

NFCDD data quality flag: Adequate

Data Source: NFCDD - data downloaded on 29 Sept 2014

Approved by: Phil Marshall 29 Sept 2014

Kirknewton Node Point Attributes Table *Sept 2014 JC*

Modelled Flood Group = EA121258

Node Point Name (NGR)	Return Period (1:x years)	Undefended Level Value (mAOD)	Undefended Flow Value (Cumecs)
EA12125MODEL POINT 64	100	62.87	138
NT 90949 30594	1000	63.22	222.4
EA12125MODEL POINT 65	100	61.9	138
NT 91055 30564	1000	62.18	222.4
EA12125MODEL POINT 66	100	60.66	138
NT 91198 30581	1000	60.93	222.4
EA12125MODEL POINT 67	100	59.35	138
NT 91302 30660	1000	59.35	222.4
EA12125MODEL POINT 68	100	58.76	138
NT 91349 30717	1000	58.76	222.4
EA12125MODEL POINT 69	100	57.96	138
NT 91456 30822	1000	57.96	222.4
EA12125MODEL POINT 70	100	56.48	138
NT 91651 30874	1000	56.48	222.4

Appendix A

A5 - Site Boundary Plan 1:1000@A1 (Northumberland County Council)

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OUTLINE BOUNDARY OF SCHEME

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Appendix A

A6 - Proposed Works Reference 1:1000@A1 (Northumberland County Council)

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NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH;
HB127276/.../24 AREA 1. (BRIDGE WORKS)
HB127276/.../25 AREA 1. (TRAINING LOGS SECTIONS)
HB127276/.../26 AREA 2. (ABUTMENT WORKS)
HB127276/.../27 AREA 3. (B) (PLAN ON EMBANKMENT WORKS)
HB127276/.../28 AREA 4. (EMBANKMENT WORKS).
HB127276/.../29 AREA 1. (APRON DETAILS).
HB127276/.../30 AREA 5. (PLAN AND SECTION).
HB127276/.../31 AREA 6. (PLAN AND SECTION).

2.0 EXISTING DETAILS

2.1 EXISTING STRUCTURE IS A SEVEN SPAN MASONRY ARCH BRIDGE SADDLED IN 1994. 12.29 SPAN MAIN RIVER ARCH. 4 x 3.05m SPAN FLOOD ARCHES ARE BLOCKED OFF.

NOTE AMENDMENT		PF	FEB'15 (B)
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SOFT ENGINEERING MEASURES TO CUT BACK /REMOVED		PF	JAN'15 (A)
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Drawing Title
PROPOSED WORKS
SITE REFERENCE PLAN

Scales 1/1000

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Drawing Number HB127276/B/B6351/06/23 Rev B

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Appendix A

A7 - Works Areas (1-5) Plans 1:1000@A1 (Northumberland County Council)

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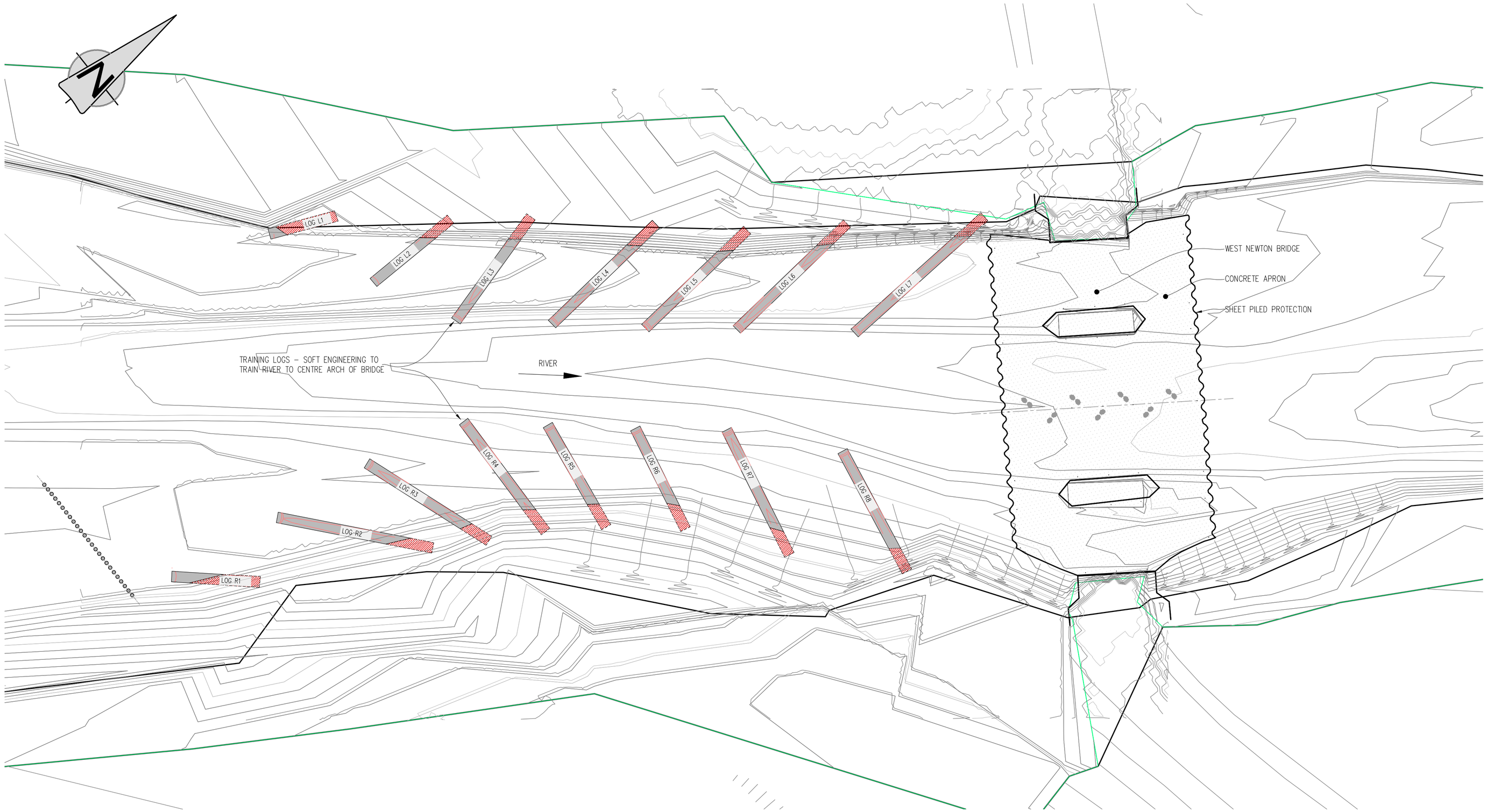
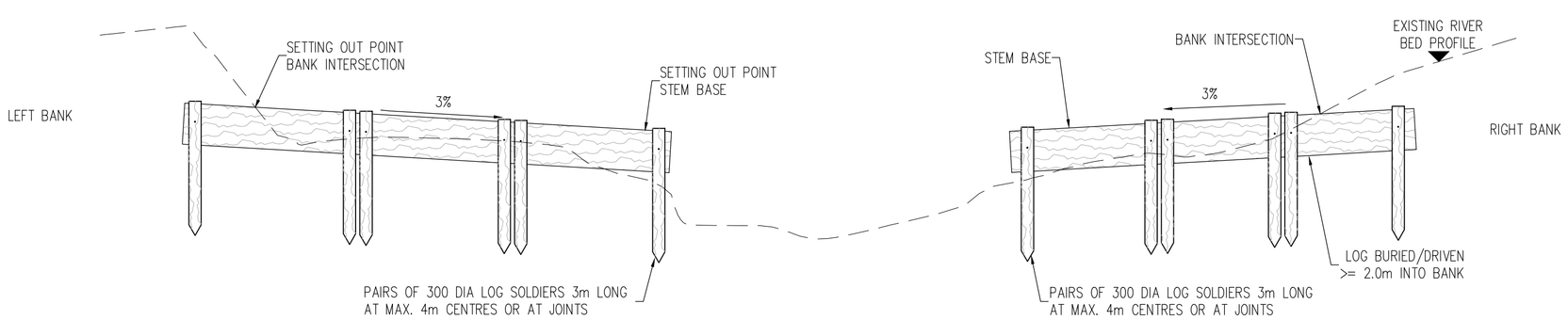


TRAINING LOGS AND BRIDGE SCOUR PROTECTION PLAN

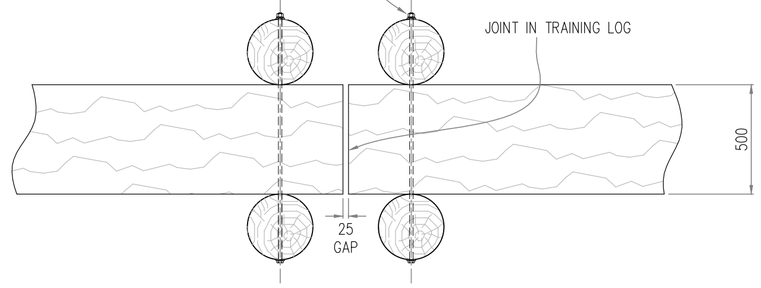
SCALE 1/200



TYPICAL DETAIL SHOWING TRAINING LOGS INSTALLATION Ⓐ

SCALE: 1/100

SOLDIERS FIXED TO TRAINING LOGS WITH 16mm DIA THRO' BOLTS. BOLTS TO BE GALVANISED WITH 50 Sq. x 6 PLATES AND NUTS ALL GALVANISED



TYPICAL PLAN VIEW ON TRAINING LOG BOLTING ARRANGEMENT

SCALE: 1/20

STEM BASE AND BANK INTERSECTION CO-ORDINATES AND ELEVATIONS

Log Id	Point Location	Easting	Northing	Elevation
LOGL1	STEM BASE	390726.74	630337.28	65.43
	BANK	AS ABOVE	AS ABOVE	AS ABOVE
LOGL2	STEM BASE	390735.25	630341.68	65.58
	BANK	390735.17	630347.15	65.75
LOGL3	STEM BASE	390742.05	630345.11	65.56
	BANK	390739.85	630352.88	65.80
LOGL4	STEM BASE	390747.43	630351.36	65.54
	BANK	390746.57	630360.48	65.83
LOGL5	STEM BASE	390752.64	630357.36	65.52
	BANK	390751.78	630366.29	65.78
LOGL6	STEM BASE	390757.57	630363.37	65.29
	BANK	390756.63	630373.24	65.69
LOGL7	STEM BASE	390764.05	630371.03	65.29
	BANK	390763.34	630382.78	65.64

Log Id	Point Location	Easting	Northing	Elevation
LOGR1	STEM BASE	390744.52	630312.55	65.63
	BANK	390746.18	630314.90	65.71
LOGR2	STEM BASE	390746.20	630322.67	65.63
	BANK	390753.82	630329.15	65.90
LOGR3	STEM BASE	390747.91	630321.13	65.58
	BANK	390756.39	630334.42	65.86
LOGR4	STEM BASE	390749.80	630329.80	65.56
	BANK	390758.65	630339.52	65.82
LOGR5	STEM BASE	390754.48	630345.16	65.54
	BANK	390761.67	630344.06	65.75
LOGR6	STEM BASE	390759.33	630350.77	65.52
	BANK	390765.91	630349.37	65.72
LOGR7	STEM BASE	390764.26	630356.79	65.39
	BANK	390773.07	630354.93	65.66
LOGR8	STEM BASE	390771.81	630363.39	65.29
	BANK	390780.54	630361.80	65.56

NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH;
HB127276/.../23
(SITE REFERENCE PLAN.)
HB127276/.../25 AREA 1.
(TRAINING LOGS SECTIONS)
HB127276/.../29 AREA 1.
(APRON DETAILS).

3.0 PROPOSED WORKS

3.1 CONSTRUCT CONCRETE APRON WITH SHEET PILED OUT OFF WALLS.
3.2 INSTALL SOFT ENGINEERING, TRAININ LOGS UPSTREAM OF BRIDGE.

CONTRACT DRAWING No.

DRAWING SIZE A1

Northumberland County Council

REVISION	By	Date	Rev.
AMENDMENT TO TRAINING LOGS ELEVATION CHECKED : PASSED :	PF	28.10.14	Ⓐ

Drawing Status
PRELIMINARY

Client
NORTHUMBERLAND COUNTY COUNCIL
COUNTY HALL, MORPETH.
NORTHUMBERLAND. NE61 2EF

Job Title
WEST NEWTON – KIRKNEWTON B6351 ROAD
WEST NEWTON BRIDGE
SCOUR PROTECTION WORKS

Drawing Title
PROPOSED WORKS – AREA 1
TRAINING LOGS &
SCOUR PROTECTION TO BRIDGE
PLAN, DETAIL & SCHEDULE (Sheet 1 of 2)

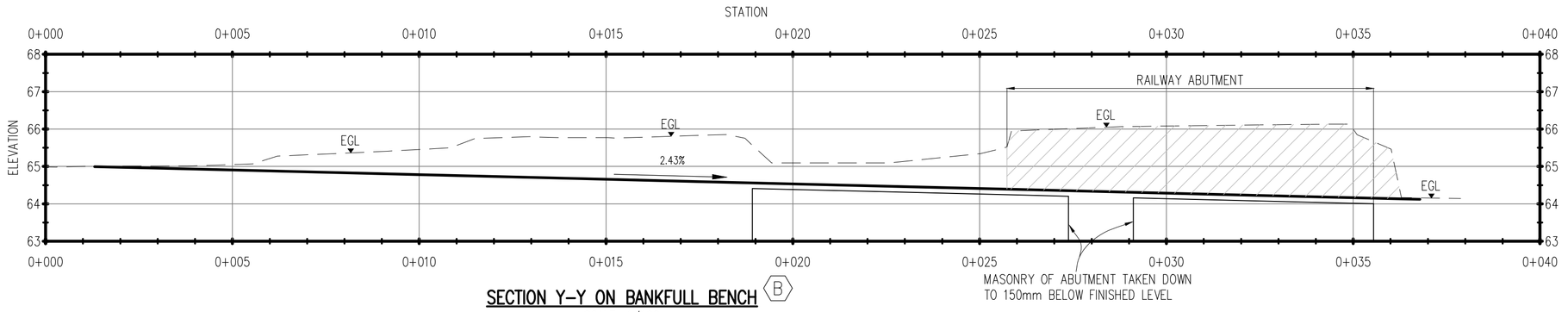
Scales AS SHOWN

Northumberland County Council
HIGHWAYS & NEIGHBOURHOOD SERVICES

Drn	Date	Checked	Passed
PF	23.09.14		

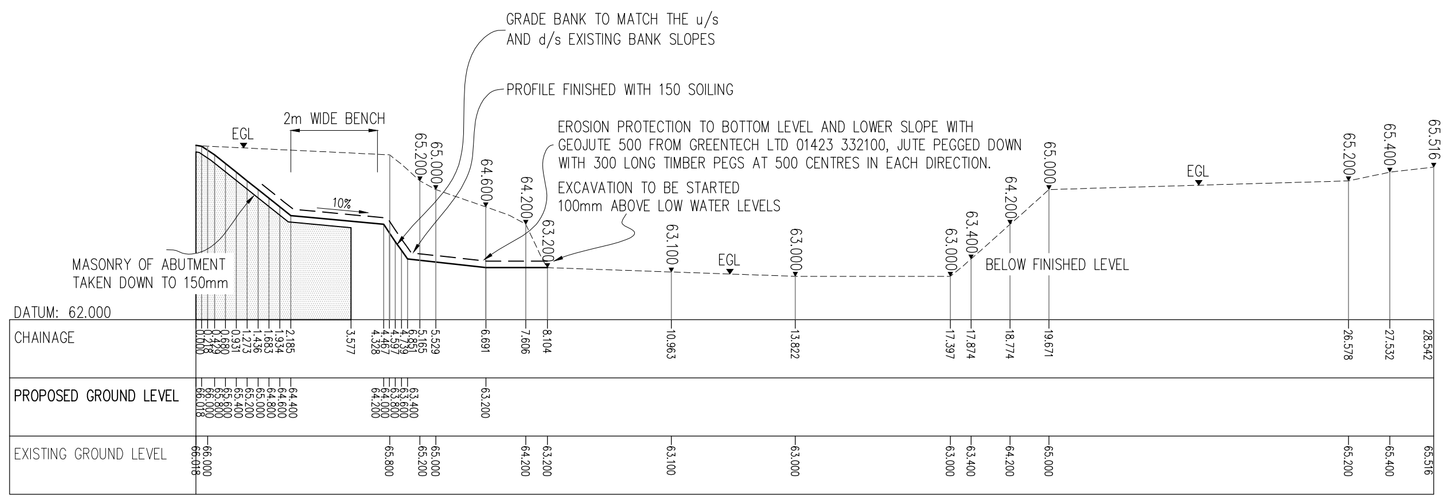
Drawing Number HB127276/B/B6351/06/24 Rev A

Job Number/File Number Rev



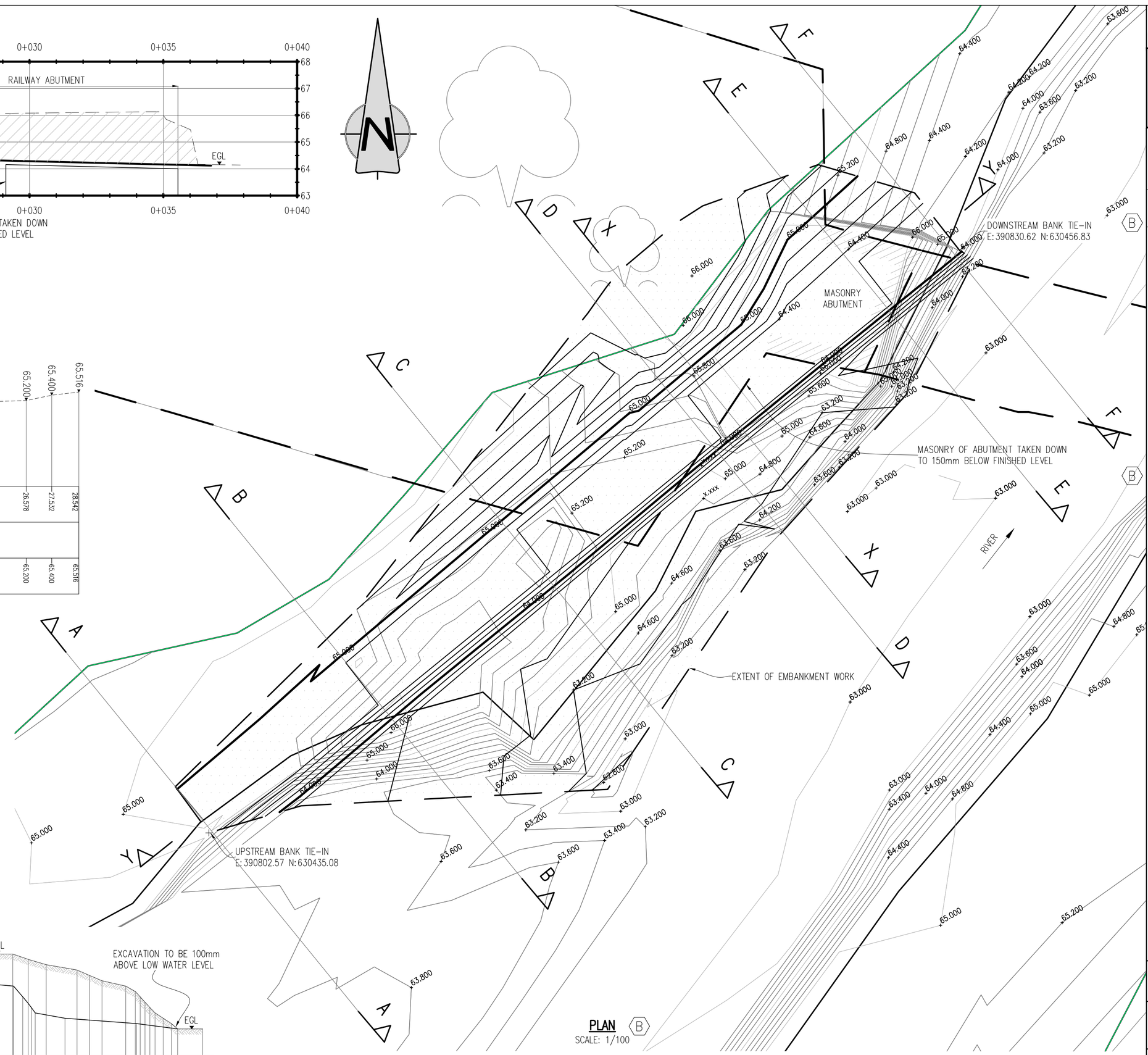
SECTION Y–Y ON BANKFULL BENCH (B)

SCALE: 1/100



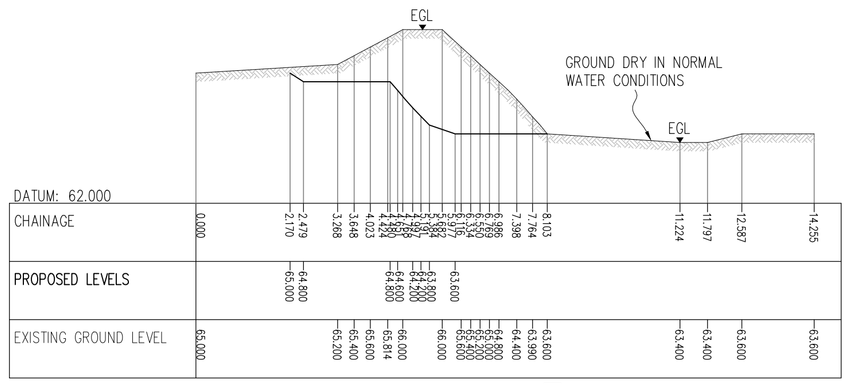
SECTION X–X TYPICAL DETAILS (B)

SCALE: 1/100



PLAN (B)

SCALE: 1/100



SECTION B–B (B)

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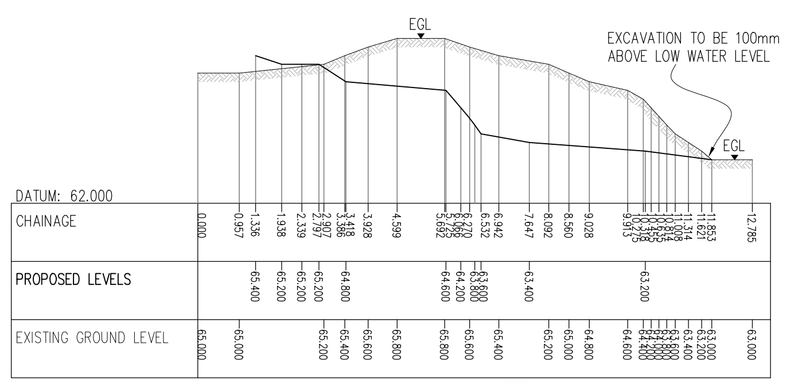

SECTION C–C (B)

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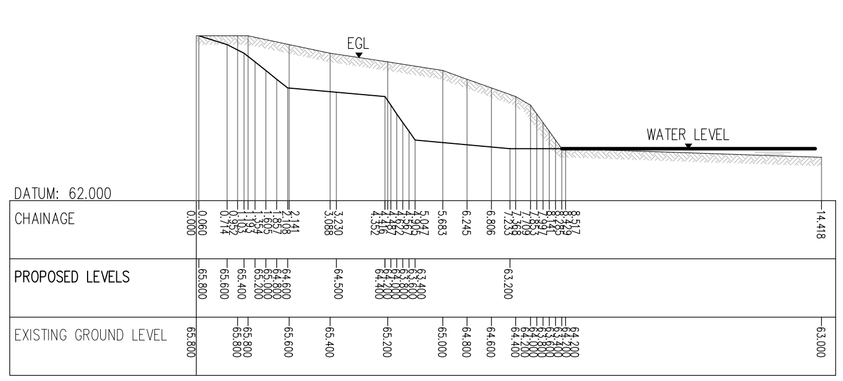

SECTION D–D (B)

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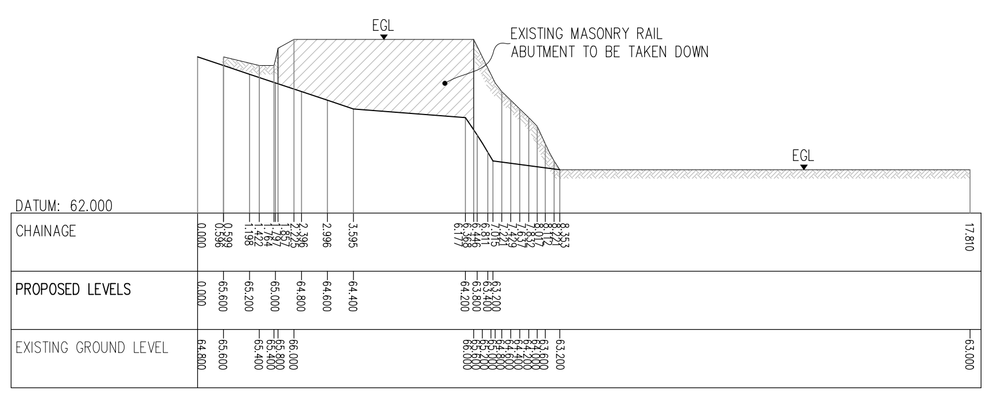
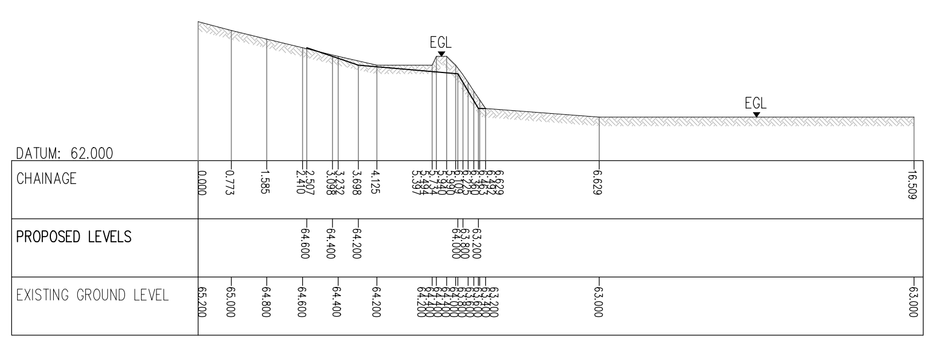


SECTION E–E (B)

SCALE: 1/100



SECTION F–F (B)

SCALE: 1/100

CONTRACT DRAWING No.

DRAWING SIZE A1

Northumberland County Council

NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH;
HB127276/.../23 (SITE REFERENCE PLAN.)
HB127276/.../24 AREA 1 (BRIDGE WORKS)

2.0 EXISTING DETAILS

2.1 EXISTING STRUCTURE IS A SEVEN SPAN MASONRY ARCH BRIDGE SADDLED IN 1994. 12.29 SPAN MAIN RIVER ARCH. 4 x 3.05m SPAN FLOOD ARCHES ARE BLOCKED OFF AND TWO 6.1m SPAN SIDE ARCHES ARE BLOCKED, BUT NOT COMPLETELY.

3.0 PROPOSED WORKS

3.1 TAKE DOWN ABUTMENT AND TAKE MASONRY TO WESTNEWTON ESTATE (½ MILE AWAY).
3.2 STRIP TOPSOIL FROM AFFECTED AREAS AND STOCKPILE ON SITE.
3.3 REGRADE EMBANKMENT AND DISPOSE OF MATERIAL TO RAISE EMBANKMENT ON OTHER PART OF SCHEME.
3.4 REPLACE TOPSOIL AND PROTECT LOWER SLOPES WITH GEOTEXTILE.

REVISION	By	Date	Rev.
EXISTING SECTIONS AMENDED AND NEW SECTIONS ADDED TO SCHEME. CHECKED : PTS PASSED : JLR	PF	29.01.15	B
SECTION A–A RE–CUT. LEVELS ADDED TO SCHEME. CHECKED : PAB PASSED : STR	PF	30.10.14	A

Drawing Status
PRELIMINARY

Client
NORTHUMBERLAND COUNTY COUNCIL
COUNTY HALL, MORPETH.
NORTHUMBERLAND. NE61 2EF

Job Title
WEST NEWTON – KIRKNEWTON B6351 ROAD
WEST NEWTON BRIDGE
SCOUR PROTECTION WORKS

Drawing Title
PROPOSED WORKS
AREA 2
REMOVAL OF PINCH POINT AT
OLD RAILWAY BRIDGE ABUTMENT

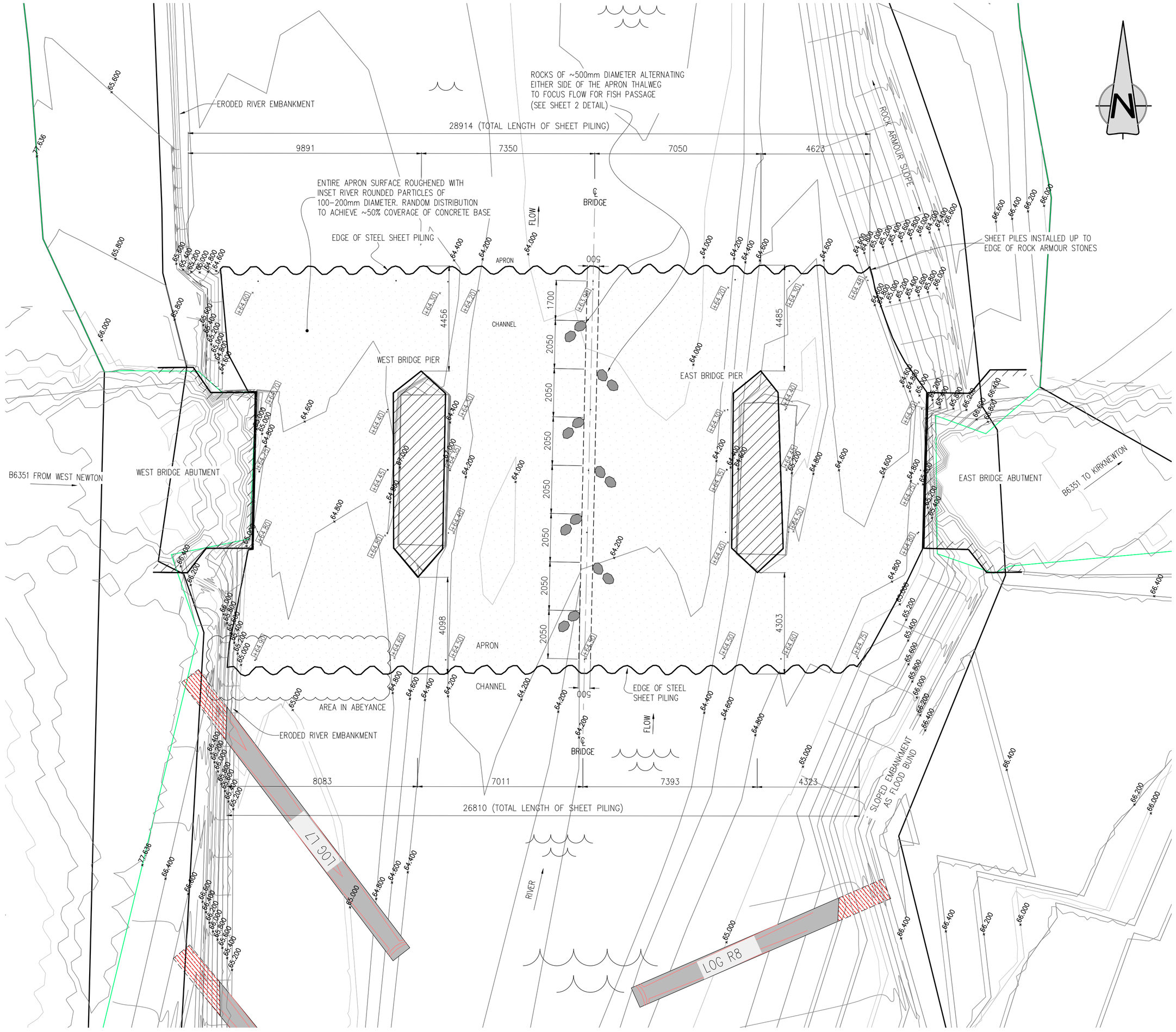
Scales AS SHOWN

Northumberland County Council
HIGHWAYS & NEIGHBOURHOOD SERVICES

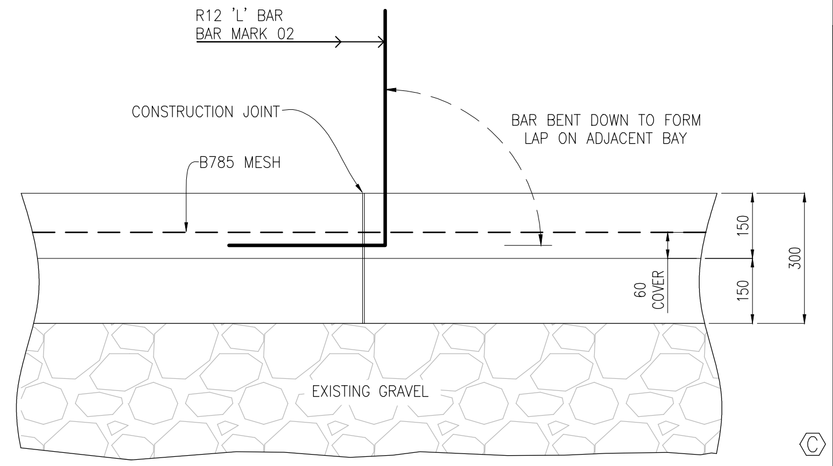
Drn	Date	Checked	Passed
PF	24.09.14	PAB	JLR

Drawing Number HB127276/B/B6351/06/26 Rev B

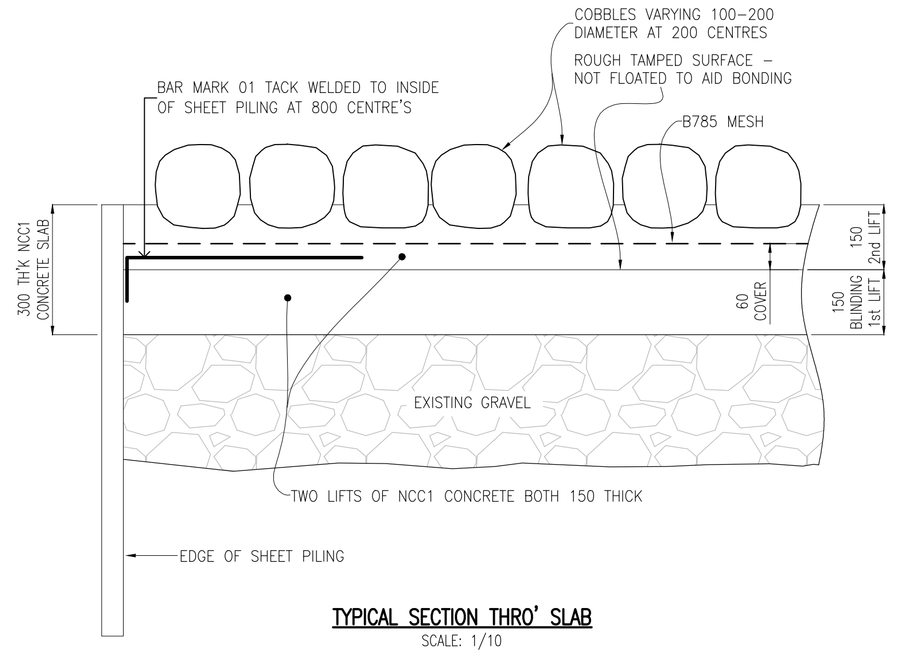
Job Number/File Number Rev



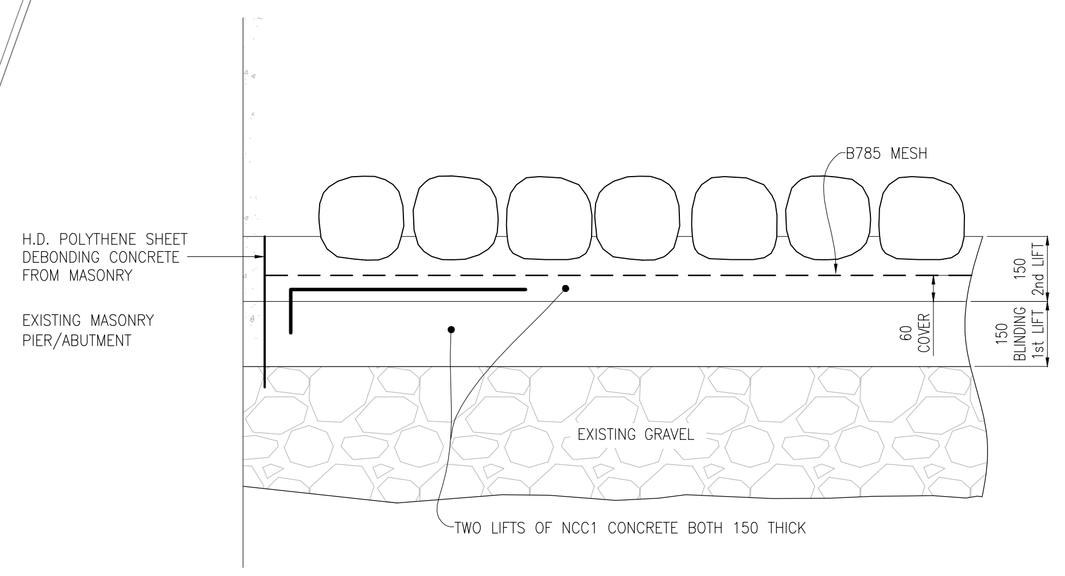
PLAN ON BRIDGE
SCALE 1/100



SECTION THRO' CONSTRUCTION JOINT
SCALE: 1/10



TYPICAL SECTION THRO' SLAB
SCALE: 1/10



TYPICAL SECTION THRO' SLAB ADJACENT TO MASONRY PIERS AND ABUTMENTS OF BRIDGE
SCALE: 1/10

CONTRACT DRAWING No.

DRAWING SIZE A1

Northumberland County Council

NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH;
HB127276/.../23
(SITE REFERENCE PLAN.)
HB127276/.../25 AREA 1.
(TRAINING LOGS SECTIONS)
1.4 METHOD STATEMENT APPROVED BY ENVIRONMENT AGENCY.

2.0 PROPOSED WORKS

2.1 INSTALL RC APRON WITH SHEET PILING PROTECTION.
2.2 CONCRETE TO BE NCC1.
2.3 COBBLES TO BE SIZED 100 TO 200mm DIAMETER SOURCED LOCALLY TO MATCH EXISTING RIVER COBBLES.
2.4 CONCRETE FIRST LIFT TO BE ROUGH TAMPED FOR KEY TO TOP LIFT.
2.5 TOP LIFT OF CONCRETE TO BE ROUGH FINISHED WITH BRISTLE BRUSH BETWEEN COBBLES.
2.6 SHEET PILING TO BE GRADE S275 3.5m LONG INSTALLED LENGTH. TYPE AU14 OR PU14 OR EQUIVALENT.
2.7 ALONG LINE OF SHEET PILES PRIOR TO INSTALLATION, PREAUGERING TO BE CARRIED OUT FOR FULL DEPTH OF SHEET PILES.

REVISION	By	Date	Rev.
NOTES ADDED. CHECKED : PAB PASSED : JLR	PF	16.02.15	C
TYPICAL SECTION ADDED TO SCHEME. NOTES ADDED. CHECKED : PASSED :	PF	JAN '15	B
AMENDMENT TO TRAINING LOGS ELEVATION CHECKED : PASSED :	PF	28.10.14	A

Drawing Status
PRELIMINARY

Client
NORTHUMBERLAND COUNTY COUNCIL
COUNTY HALL, MORPETH.
NORTHUMBERLAND. NE61 2EF

Job Title
WEST NEWTON – KIRKNEWTON B6351 ROAD
WEST NEWTON BRIDGE
SCOUR PROTECTION WORKS

Drawing Title
PROPOSED WORKS
AREA 1
REVISED APRON PLAN AND SECTION

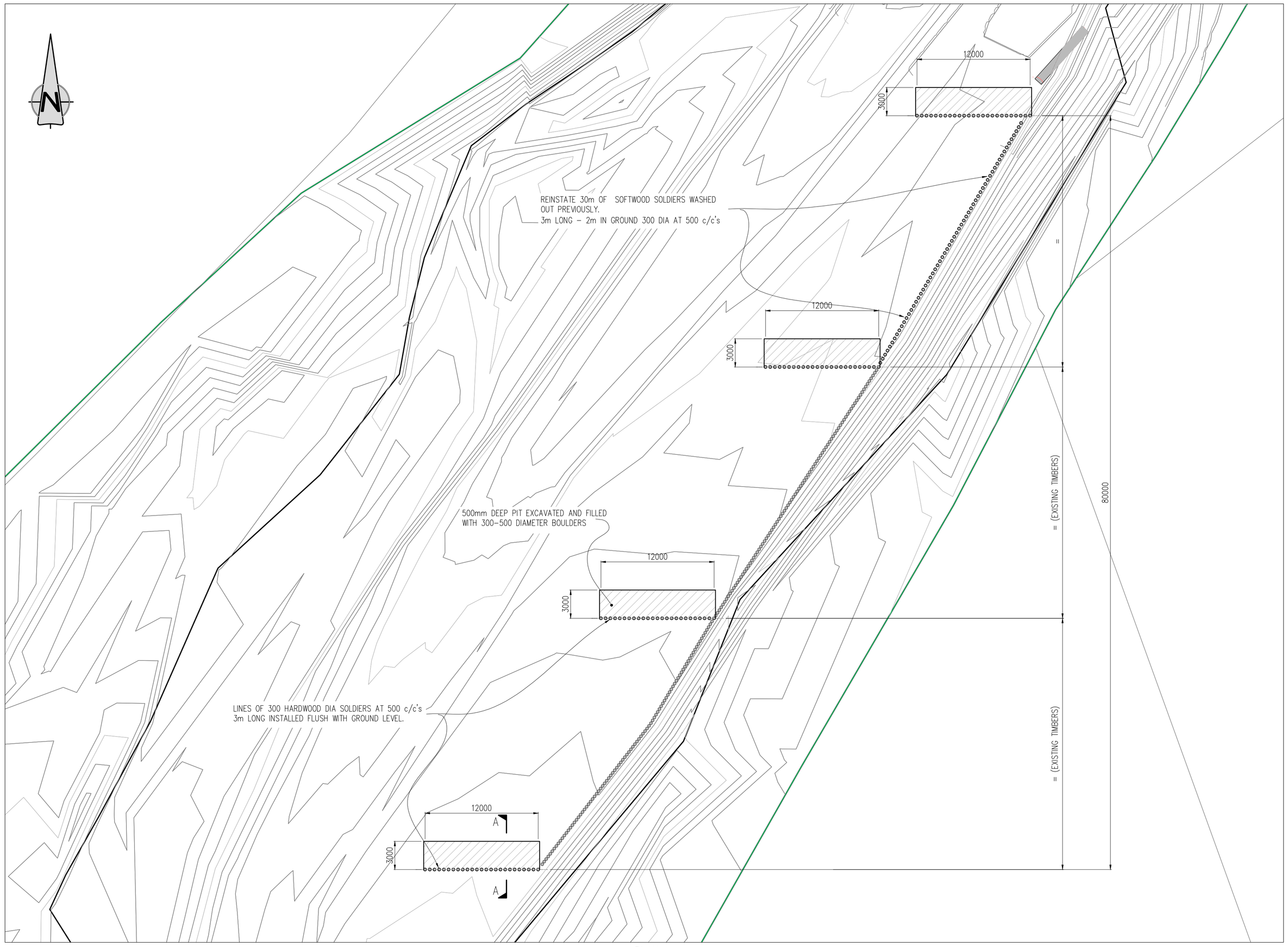
Scales AS SHOWN

Northumberland County Council
HIGHWAYS & NEIGHBOURHOOD SERVICES

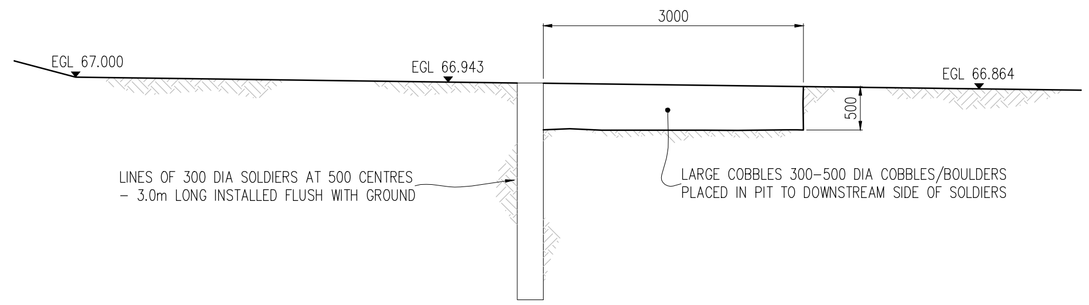
Drn	Date	Checked	Passed
PF	14.10.14	PAB	JLR

Drawing Number
HB127276/B/B6351/06/29
Rev C

Job Number/File Number
Rev



PLAN Ⓒ
SCALE: 1/250



SECTION A–A
SCALE: 1/50

CONTRACT DRAWING No.

DRAWING SIZE A1

Northumberland County Council

NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH; HB127276/.../23 OVERALL PLAN. (SITE REFERENCE PLAN)
Ⓒ 1.4 METHOD STATEMENT APPROVED BY ENVIRONMENT AGENCY.

Ⓒ **2.0 TIMBER**
2.1 TIMBER REQUIRES NO TREATMENT. NO BARK STRIPPING AND CAN BE FRESHLY FELLED.

Ⓒ **3.0 BOULDERS**
3.1 TO BE FROM A LOCAL QUARRY AND TO MATCH EXISTING RIVER MATERIALS.

REVISION	By	Date	Rev.
NOTES ADDED. CHECKED : PAB PASSED : JLR	PF	16.02.15	Ⓒ
ALTERATIONS TO SOFT ENGINEERING CHECKED : PAB PASSED : STR	PF	JAN '15	Ⓑ
SOLDIERS ADDED TO PLAN CHECKED : PAB PASSED : STR	PF	28.10.14	Ⓐ

Drawing Status
PRELIMINARY

Client
NORTHUMBERLAND COUNTY COUNCIL
COUNTY HALL, MORPETH.
NORTHUMBERLAND. NE61 2EF

Job Title
WEST NEWTON – KIRKNEWTON B6351 ROAD
WEST NEWTON BRIDGE
SCOUR PROTECTION WORKS

Drawing Title
AREA 5
PLAN AND CROSS SECTION

Scales AS SHOWN

Northumberland County Council
HIGHWAYS & NEIGHBOURHOOD SERVICES

Drn	Date	Checked	Passed
PF	17.10.14	PAB	JLR

Drawing Number: HB127276/B/B6351/06/30 — Rev C
Job Number/File Number — Rev

CONTRACT DRAWING No.

DRAWING SIZE A1

NORTHUMBERLAND
Northumberland County Council

NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH;
HB127276/.../23 SITE REFERENCE PLAN.
HB127276/.../24 AREA 1. (BRIDGE WORKS)
HB127276/.../25 AREA 1. (TRAINING LOGS SECTIONS)
HB127276/.../26 AREA 2. (ABUTMENT WORKS)
HB127276/.../27 AREA 3. (PLAN ON EMBANKMENT WORKS)
HB127276/.../28 AREA 4. (EMBANKMENT WORKS).
HB127276/.../29 AREA 1. (APRON DETAILS).
HB127276/.../30 AREA 5. (PLAN AND SECTION).
HB127276/.../31 AREA 6. (PLAN AND SECTION).

2.0 EXISTING DETAILS

2.1 EXISTING STRUCTURE IS A SEVEN SPAN MASONRY ARCH BRIDGE SADDLED IN 1994.
12.29 SPAN MAIN RIVER ARCH.
4 x 3.05m SPAN FLOOD ARCHES ARE BLOCKED OFF.

SCHEDULE OF LAND REQUIREMENTS

PLOT No.	AREA (sq.m.)	INTEREST REQUIRED	COLOUR	OWNER/AGENT	TENANT	COMMENT
1a	2669	LICENCE	GREEN	MR S. DOUGLAS-HOME. WESTNEWTON ESTATE, WESTNEWTON, WOOLER. NE71 6XJ.	MR R. WHITTEN. WEST LOWICK, BERWICK UPON TWEED. TD15 2JX	
1b	507	LICENCE	GREEN			
1c	270	LICENCE	GREEN			
1d	1497	LICENCE	GREEN			
2	118	TITLE	PINK			
3	345	LICENCE	GREEN	MR T. REED-JONES. BRIDGE HOUSE, KIRKNEWTON, WOOLER. NE71 6XF.	NONE.	
4	51	TITLE	PINK			
5	1110	LICENCE	GREEN	MR C. MARTIN EAST KIRKNEWTON FARM, KIRKNEWTON, WOOLER. NE71 6XF.	NONE.	
6	144	TITLE	PINK			
7a	2126	LICENCE/EASEMENT	BLUE			
7b	2327	LICENCE/EASEMENT	BLUE			
7c	1066	LICENCE	GREEN			
7d	265	LICENCE	GREEN			
7e	2329	LICENCE	GREEN			
7f	2207	LICENCE	GREEN			

REVISION	By	Date	Rev.
NOTE AMENDED CHECKED : PAB PASSED : JLR	PF	16.02.15	B
AREA AND ACCESS DELETED CHECKED : PAB PASSED : JLR	PF	JAN'15	A

Drawing Status
LAND PLAN

Client
NORTHUMBERLAND COUNTY COUNCIL
COUNTY HALL, MORPETH.
NORTHUMBERLAND. NE61 2EF

Job Title
WEST NEWTON – KIRKNEWTON B6351 ROAD
WEST NEWTON BRIDGE
SCOUR PROTECTION WORKS

Drawing Title
LAND PLAN

Scales 1/1000

NORTHUMBERLAND
Northumberland County Council
HIGHWAYS & NEIGHBOURHOOD SERVICES

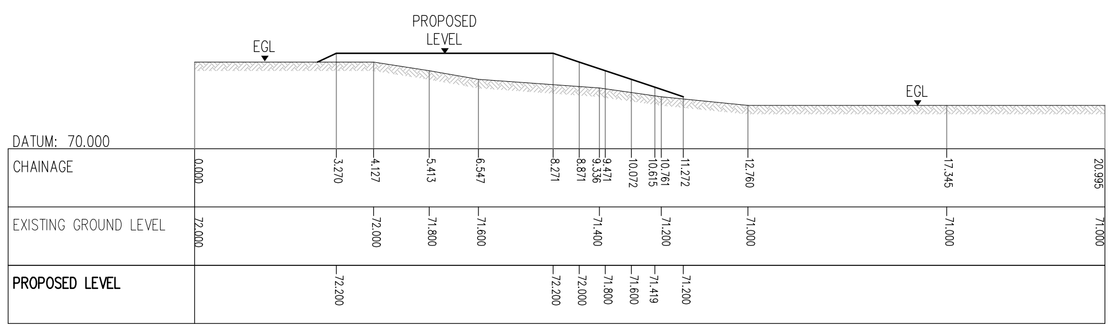
Drn	Date	Checked	Passed
PF	23.09.14	PTS	PAB

Drawing Number **HB127276/B/B6351/06/32** Rev **B**

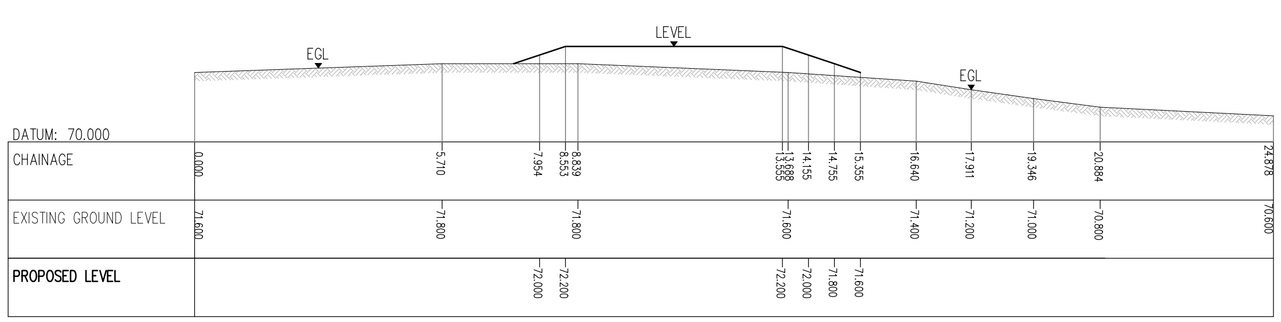
Job Number/File Number Rev

PLAN
SCALE: 1/100

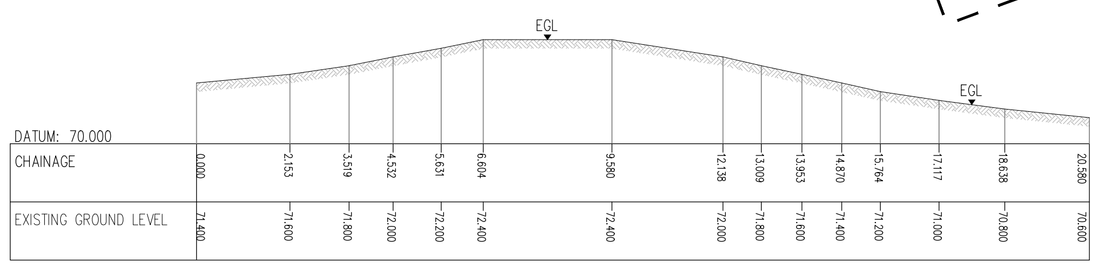
SECTION A–A (A)
SCALE: 1/100



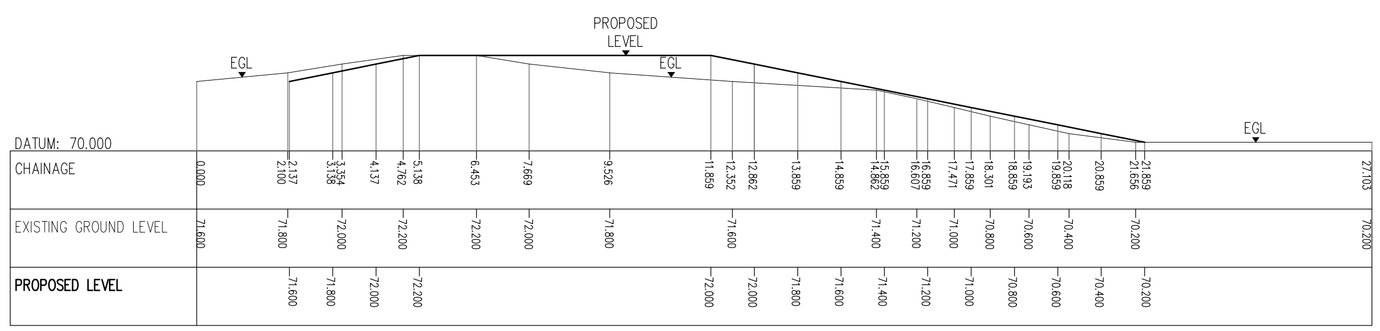
SECTION B–B (A)
SCALE: 1/100



SECTION C–C (A)
SCALE: 1/100



SECTION E–E (A)
SCALE: 1/100



SECTION D–D (A)
SCALE: 1/100

CONTRACT DRAWING No.

DRAWING SIZE A1

Northumberland County Council

NOTES

1.0 GENERAL

1.1 ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.
1.2 LEVELS ARE TO A LOCAL GRID REFERENCE.
1.3 THIS DRAWING TO BE READ IN CONJUNCTION WITH; HB127276/.../23 (SITE REFERENCE PLAN).

2.0 PROPOSED WORKS

2.1 EMBANKMENT TO BE RAISED WITH MATERIAL STORED IN AREA 3.

REVISION	By	Date	Rev.
SECTIONS ADDED	PF	17.02.15	A
CHECKED : PAB PASSED : JLR			

Drawing Status
PRELIMINARY

Client
NORTHUMBERLAND COUNTY COUNCIL
COUNTY HALL, MORPETH,
NORTHUMBERLAND, NE61 2EF

Job Title
WEST NEWTON – KIRKNEWTON B6351 ROAD
WEST NEWTON BRIDGE
SCOUR PROTECTION WORKS

Drawing Title
PROPOSED WORKS
AREA 4
RAISING OF EMBANKMENT CREST
PLAN & ADDITIONAL SECTIONS

Scales AS SHOWN

Northumberland County Council
HIGHWAYS & NEIGHBOURHOOD SERVICES

Drn	Date	Checked	Passed
PF	30.01.15	PAB	JLR

Drawing Number HB127276/B/B6351/06/33 Rev A
Job Number/File Number Rev

Appendix B

Photographs

B1 - Annotated Aerial Photograph (cbec eco-engineering UK Ltd)

B2 - Scheme Photographs (cbec eco-engineering UK Ltd)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

Appendix B

B1 - Annotated Aerial Photograph (cbec eco-engineering UK Ltd)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

Appendix B

B2 - Scheme Photographs (cbec eco-engineering UK Ltd)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

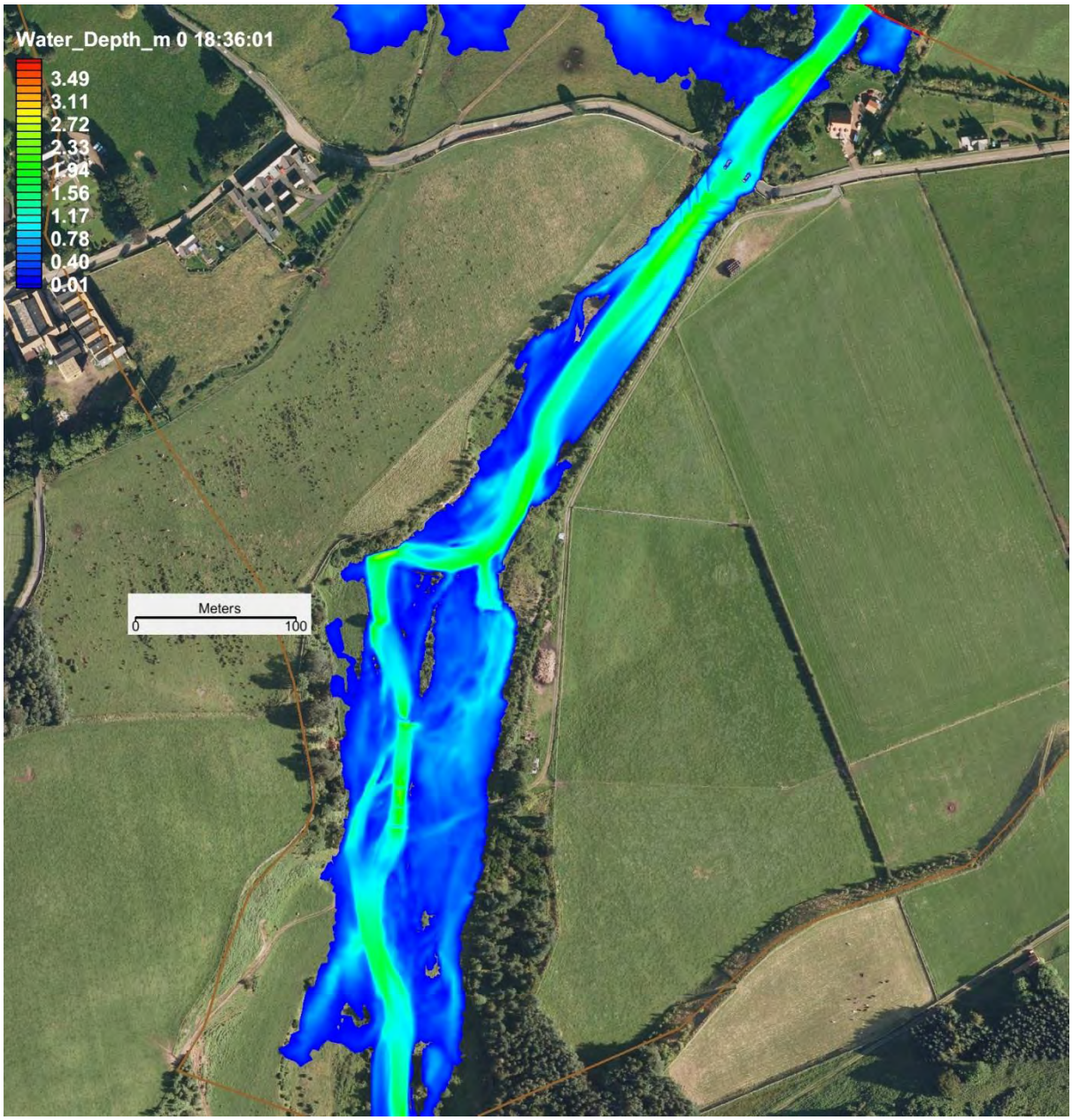


Figure 3.1. Maximum inundation predicted for combined design changes at Westnewton Bridge (Q_{200yr}).

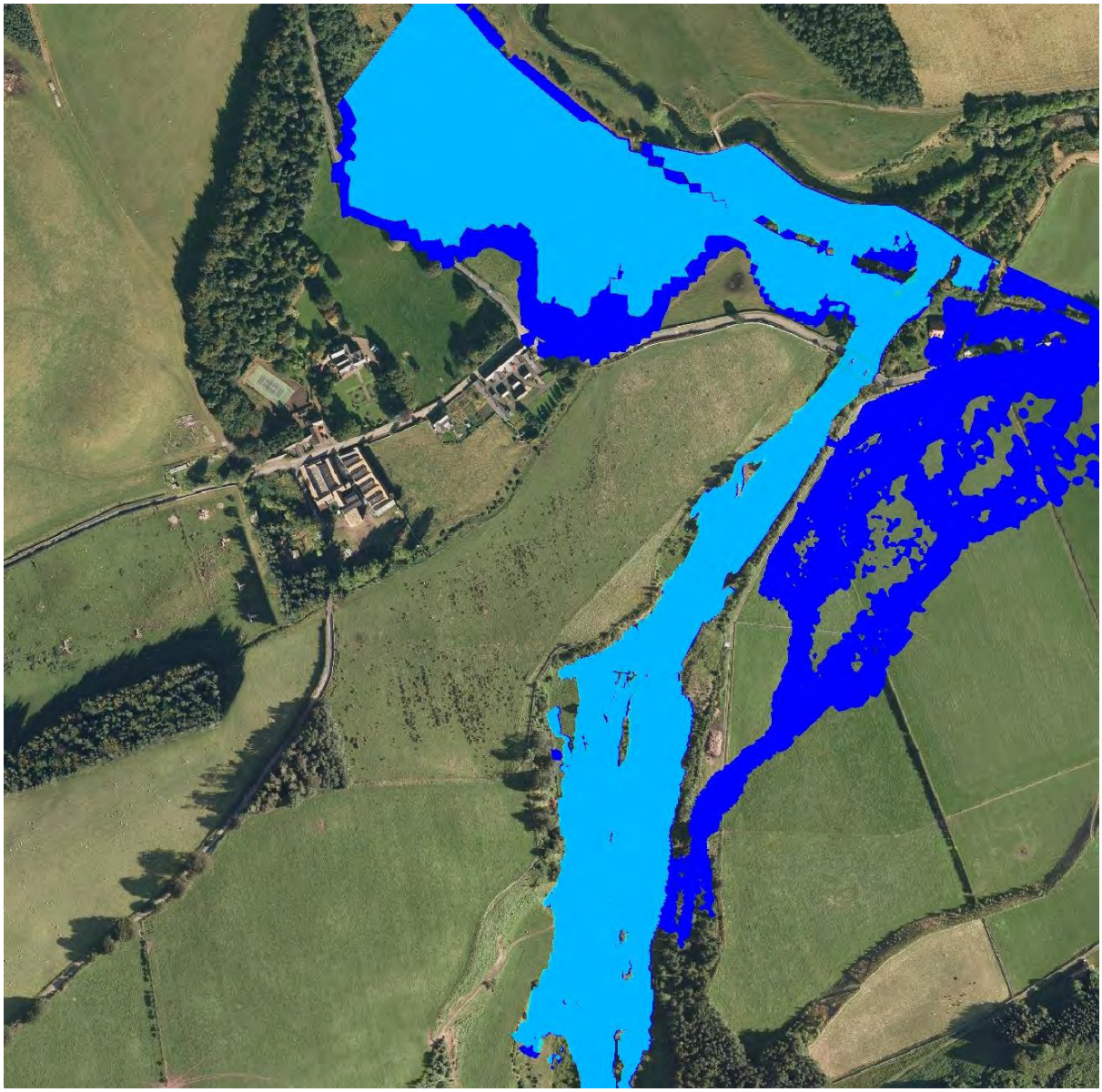


Figure 3.2. Comparison of inundation extents between existing and design at Q_{200yr} peak. Dark blue- existing conditions; light blue- design.

Appendix C

Documents

C1 - Bridge Modelling and Design	(cbec ecoengineering UK)
C2 - Peer Review of C1	(River Catchment Services)
C3 – Method Statement	(Northumberland County Council)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

Appendix C

C1 - Bridge Modelling and Design (cbec ecoengineering UK)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

WESTNEWTON BRIDGE MODELLING AND DESIGN

FINAL REPORT

Prepared for

Northumberland County Council

Prepared by

cbec eco-engineering UK Ltd

June 2014

cbec Project #: U13-1003

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info@cbecoeng.co.uk

cbec eco-engineering UK Ltd
3 Aberdeen Road, Alford Aberdeenshire, AB33 8ED
Company Number: SC385000 | VAT Number: GB111101405

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GLOSSARY OF ACRONYMS

Acronym	Meaning
2D	2 Dimensional
AOD	Above Ordnance Datum
CAD	Computer Aided Design
cms	Cubic Metres per Second
Defra	Department of Environment, Food and Rural Affairs
DEM	Digital Elevation Model
EA	Environment Agency
FEH	Flood Estimation Handbook
GIS	Geographic Information System
hrs	Hours
LiDAR	Light Detection And Ranging
NCC	Northumberland County Council
NE	Natural England
OS	Ordnance Survey
Pa	Pascals
ReFH	Revitalised Flood Hydrograph
RTK-GPS	Real-time Kinematic Global Positioning System
SAC	Special Area of Conservation
SRH 2D	Sedimentation and River Hydraulics Two-Dimensional
SSSI	Site of Special Scientific Interest
TIN	Triangulated Irregular Network

1. INTRODUCTION

The College Burn at Westnewton Bridge, near Kirknewton, is a dynamic gravel bed system. Recent large flood events have resulted in channel migration and deposition of alluvial material in the vicinity of the bridge, significantly reducing conveyance capacity and potentially compromising the structural integrity of piers. Furthermore, general sediment deposition and accumulation of large wood material in the reach upstream has resulted in an increase in the elevation of the channel corridor, presenting a potential increased flood risk to Kirknewton. This report describes an assessment of the hydrodynamic and sediment transport processes on the College Burn and the subsequent development of measures to protect the bridge and reduce flood risk to Kirknewton.

1.1 BACKGROUND

The College Burn is a tributary of the River Glen, in turn a tributary of the River Till within the Tweed system (Figure 1.1). In the area of Westnewton Bridge, the burn is a dynamic gravel bed system with a high storage of sediment as alluvial bar features within the active river corridor. High sediment supply from upstream sources has been deposited in the lower gradient River Glen valley (the confluence with which is ~250 m downstream from Westnewton Bridge), creating a characteristic alluvial fan feature over the last 10,000 to 15,000 years.

Relatively recent human intervention has confined the burn into a narrowed active corridor through flood embankments constructed on either side of the channel. This has restricted sediment storage to a confined area which, over time, has resulted in this river corridor being raised relative to the adjacent floodplain. This situation now presents an increased flood risk to Kirknewton, situated under a kilometre to the east of the burn. Furthermore, dynamic channel process (mainly in relation to recent large flood events) had caused significant migration of the main channel in the location of the bridge, resulting in the westerly minor arch taking all of the flow under normal conditions, undermining of the bridge piers and some erosion of the easterly flood embankment.

As a consequence of this, NCC undertook some emergency river engineering works to realign (straighten) the channel back through the centre major bridge arch and repair the damage to the bridge pier foundations. However, there are concerns that this alignment is unstable given the highly dynamic character of the river in this area. Indeed, already some evidence of lateral migration has been observed within the straightened section of the channel. Furthermore, given the protected status of the burn (both specific as an SSSI and as part of the broader River Tweed SAC), Natural England and the Environment Agency required that works to provide a longer-term and sustainable solution to the sedimentation issue were as unobtrusive as possible. The requirements were for the implementation of ‘soft’ as opposed to ‘hard’ engineering approaches and explicitly considering the issues of fish passage beyond the bridge. NCC asked cbec to model the hydrodynamics of the site to guide a design process that provided a more sustainable solution to the protection of the bridge and the management of flood risk to Kirknewton.

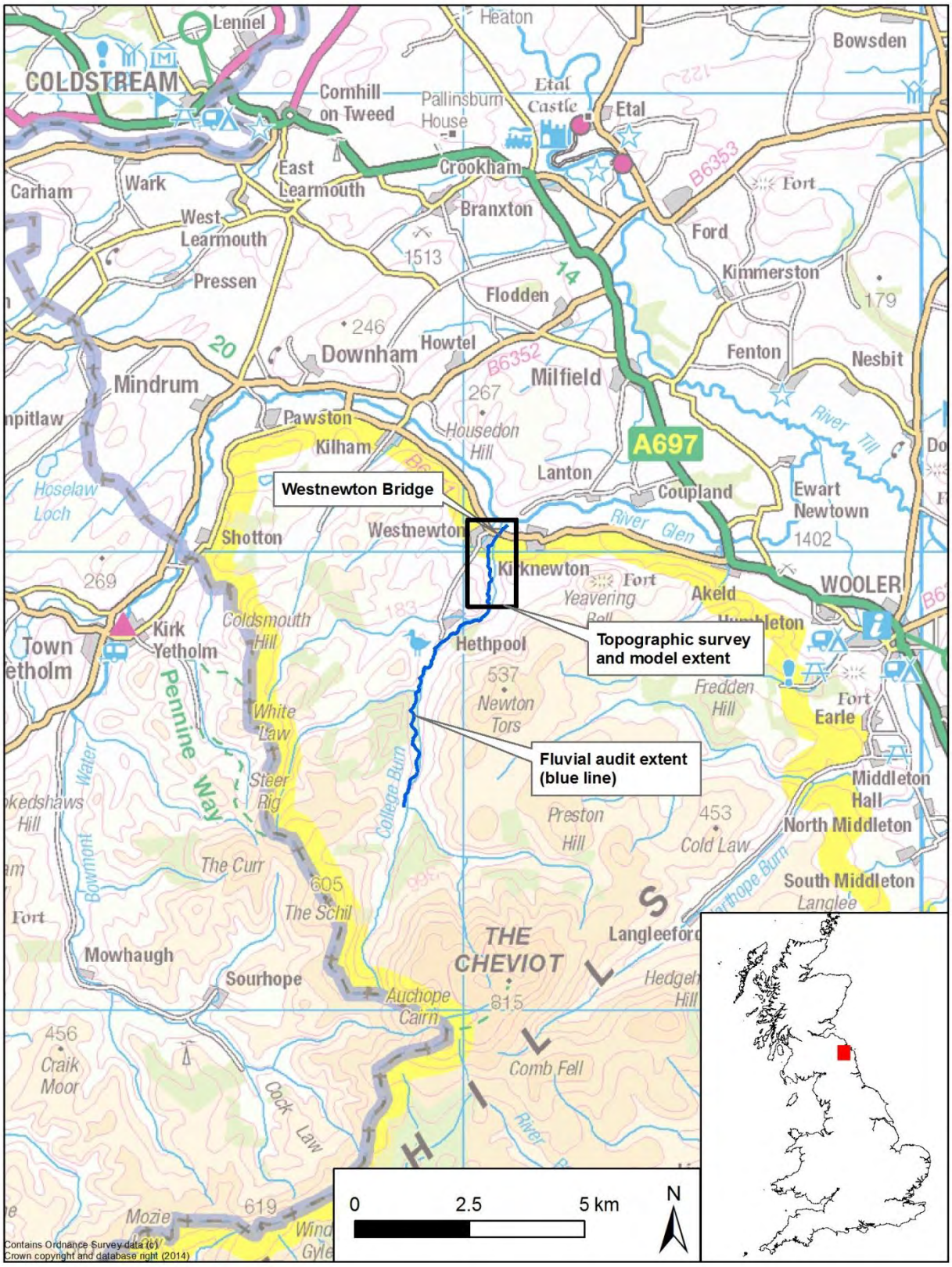
1.2 PROJECT APPROACH

Our approach to developing a sustainable management option was based on the philosophy of ‘process-based restoration’, as far as practically possible. The underlying concept is that tackling the impacts to the processes of water and sediment supply, transport and storage at the largest possible spatial scale will permit the river to recover naturally and in a stable, self-sustaining manner. In this way the river itself will subsequently do the work of maintaining a ‘natural’ and self-regulating

environment with the minimal requirement for subsequent intrusive interventions. The approach therefore 'treats the cause rather than the symptom', providing a much more sustainable solution than traditional engineering approaches would. In the case of Westnewton Bridge, the practical application of this was to understand the drivers of dynamic geomorphic activity in the reach upstream of the bridge and to determine the processes that would optimally stabilise such a channel under natural conditions.

A number of methodologies were applied during the design process. These were used to determine the most appropriate general management approach and then provide the detail of the design. The initial stage was undertaken through a combination of historical assessment and field-based geomorphic assessment ('fluvial audit'), reported in Sections 2.1 and 2.2. The historical map-based assessment provided an understanding of 'reference conditions' for the site and how the legacy of human impacts has influenced the physical condition of the site. The 8 km fluvial audit (Figure 1.1) determined current geomorphic form/ process. The broad-scale understanding of the geomorphic characteristics of the College Burn provided context for the site-specific assessment.

Quantitative data collection and associated analyses within the area of the bridge (Figure 1.1) were used to provide further detail on existing conditions, to inform the design. These included sediment sampling of the project reach, hydrological assessment and topographic survey, with 2D hydrodynamic modelling of existing conditions (Sections 2.3 to 2.6). Initial designs were subsequently developed and refined through an iterative modelling – design adjustment process (Section 3).



Notes:	cbec eco-engineering	*Westnewton Bridge modelling & design* **Site Location**		
		Project No. U13-1003	Created By: CM	**Figure 1.1**

2. ASSESSMENT OF EXISTING CONDITIONS

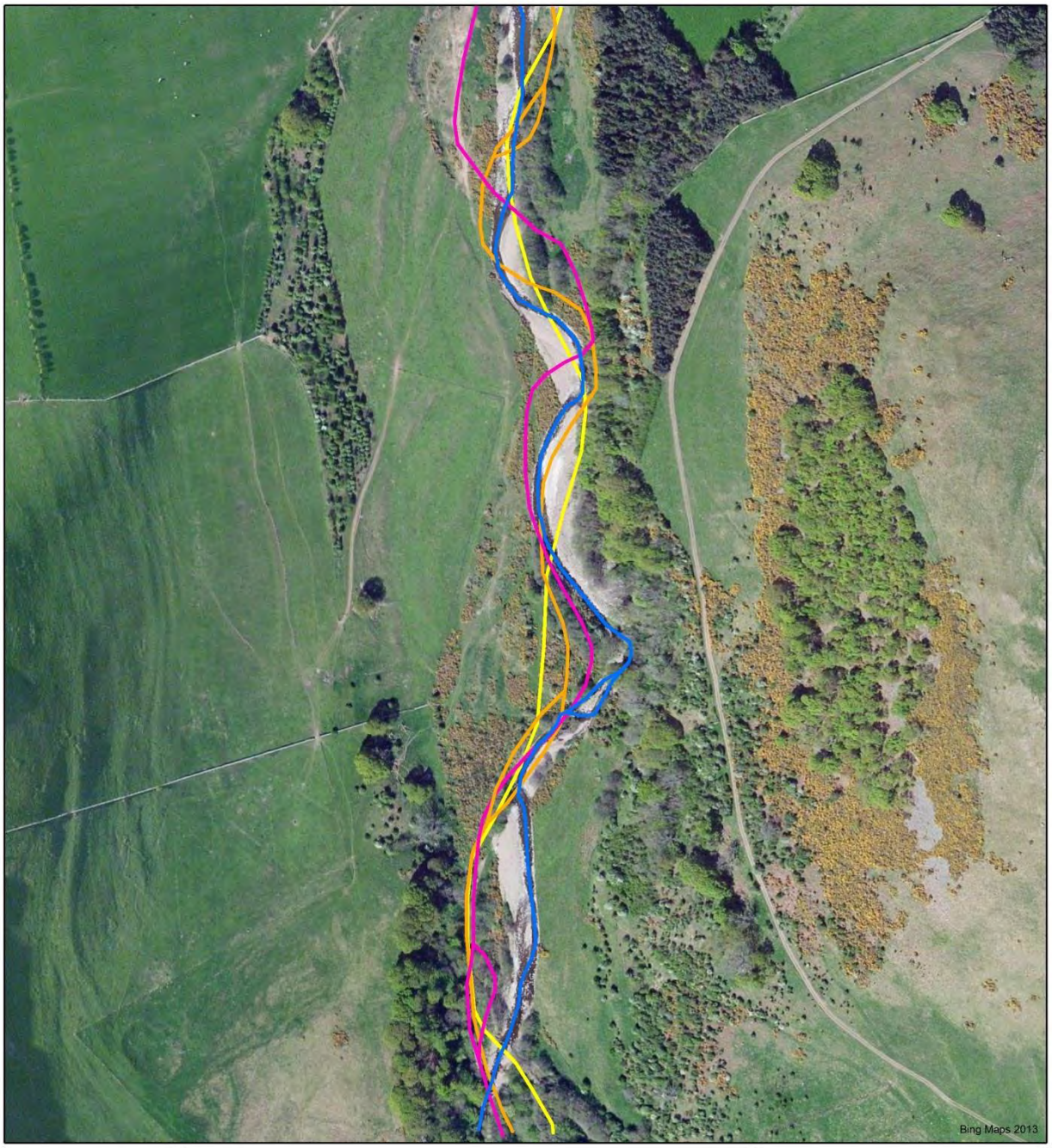
2.1 HISTORIC ASSESSMENT

Under the process restoration approach adopted here, an understanding of channel reference condition (i.e. the pre- or low-impact state of the river) provides an important basis for the subsequent development of designs that are physically appropriate to the system and its imposed conditions. Assessment of historic channel planform was used to determine the degree of dynamic behaviour of the channel in the reach upstream and downstream of Westnewton Bridge. Three OS maps for the area (published 1864, 1897 and 1923-1924) were geo-referenced and the river line for each date was digitised using GIS (Figure 2.1 and Figure 2.2).

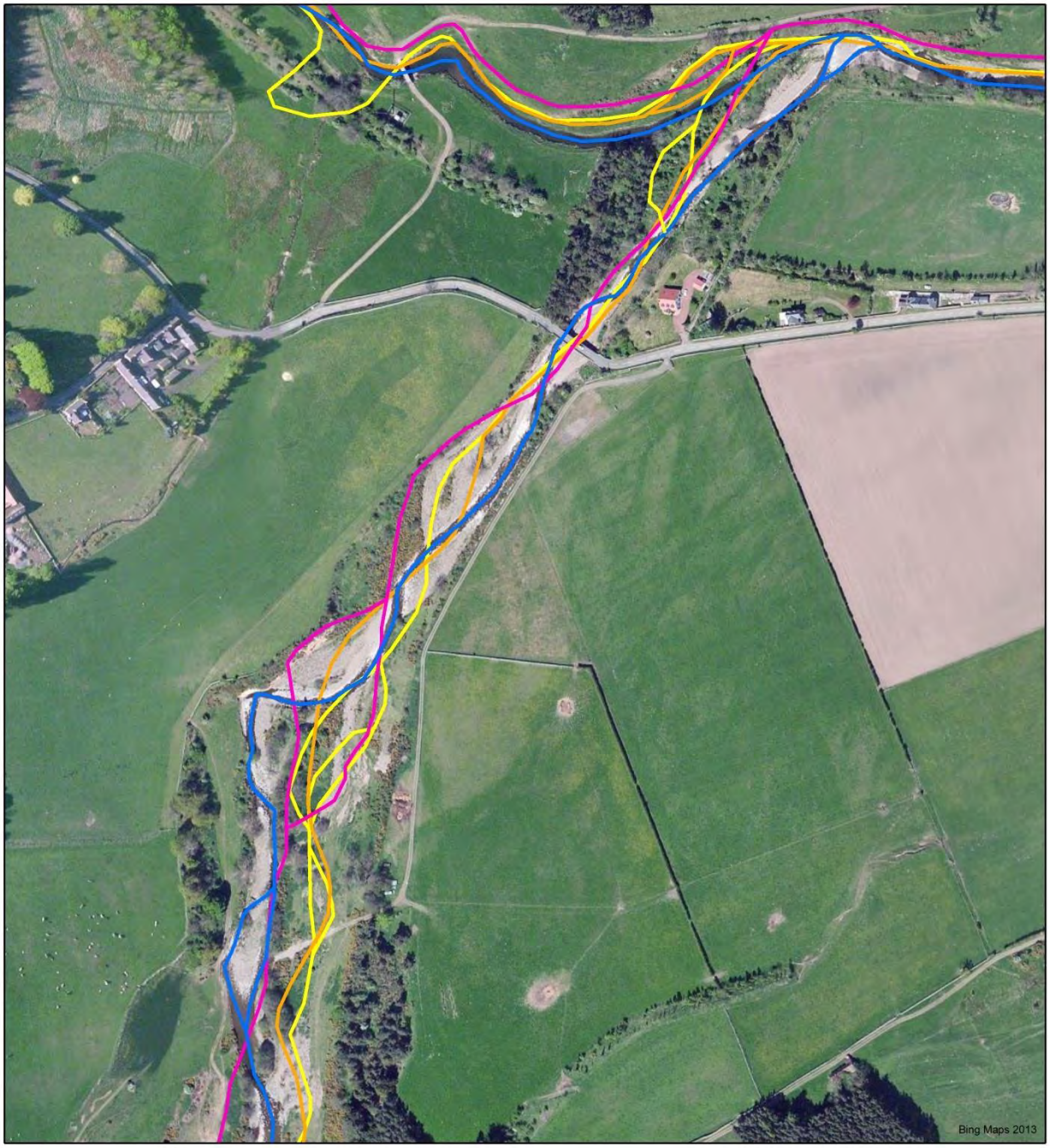
Despite confinement by embankments, the channel centrelines indicate that the College Burn has experienced a significant degree of lateral migration over the previous 150 years. The channel migration has not been in a consistent direction over time at most locations; rather the maps suggest ongoing shifting of the channel centreline to various positions within a wider channel corridor. Such behaviour is consistent with wandering-type channels with high sediment supply and highlights the dynamic nature of the reach over a relatively long timescale. However, the confinement of the burn between embankments (i.e. prior to the earliest OS map) has meant that there have been no major changes in channel course of the channel through avulsion processes[1], as would be typical in a natural alluvial fan environment. Recent large-scale flood events occurred in 2008 and 2009, both of which had return periods of over 100 years. These caused significant channel change in many parts of the Till catchment, including the College Burn, contributing to some of the channel change observed in the historic assessment and responsible for the need for the recent emergency channel realignment works upstream of the bridge.

The maps indicate that a bridge has been present at Westnewton since prior to 1864 and that this has been a consistent constraint on the burn. The lowest degree of change in channel centreline location is in the 150 m of channel centred upon the bridge, suggesting a degree on ongoing channel management in this region. Downstream of the bridge, the historic channel lines indicate that the College Burn has moved progressively eastwards since 1864. Its confluence with the River Glen has moved downstream by approximately 100 m over this time period, at least some of this change having occurred during the 2008 and 2009 floods.

[1] Such an avulsion event breached the west embankment in an extreme event in the 1950s, although engineering works returned the active channel to the current river corridor shortly afterwards.



Notes:		*Westnewton Bridge modelling & design*		
		Historic Channel Centerline - Upstream		
		Project No. U13-1003	Created By: CM	**Figure 2.1**



Legend

Historic channel centreline

- 2012
- 1923/1924
- 1897
- 1864

N

0 50 100 m

Notes:

Westnewton Bridge modelling & design

Historical Channel Centerline - Downstream

Project No. U13-1003	Created By: CM	**Figure 2.2**

2.2 FLUVIAL AUDIT

A fluvial audit was undertaken to assess the current geomorphic character of the burn. The information generated was subsequently used to inform the selection of management options and to ensure that the general approach to design was appropriate to the contemporary physical process regime of the channel. The audit was carried out between Southernknowe (OS NGR NT 887 244) and the confluence with the River Glen (NT 909 306), a distance of approximately 8 km. The fluvial audit was undertaken in March 2013.

2.2.1. Approach

The survey method used was based on cbec's fluvial audit methodology, developed by Dr Hamish Moir. The general principle of the methodology is to characterise the geomorphic and sedimentary regimes of the river by classifying channel character in terms of observed morphology, the physical expression and integration of fluvial processes. The detailed methodology is provided in Appendix A.

Any feature that provided an indication of, or influence to, fluvial form/ process was recorded using a hand held GPS to mark its location and extent. The type of feature and any associated attributes were recorded. These were classified into a number of main categories:

- Reach type (i.e. channel morphology)
- Morphological units (e.g. pool, riffle, run, glide)
- Bed substrate material (classified in terms of dominant and sub-dominant sizes using the Wentworth terminology)
- Bank erosion (severity, bank height and material)
- Depositional features (i.e. alluvial barforms exposed at 'normal' flows, including type of feature, material, stability)
- Tributaries (significance, sediment supply)
- Instream and riparian engineered structures (type and severity/impact)
- Woody debris

The data were subsequently entered into a GIS (using ArcMap software) to allow visualisation and spatial analysis.

2.2.2. Findings

Maps showing the features recorded in the fluvial audit are provided in Appendix B and are discussed below.

The majority of the reach had a pool-riffle/ plane bed (i.e. pool-riffle dominant, plane bed sub dominant) reach type, with shorter sections of plane bed/ pool-riffle and pool-riffle (Figures B1 and B2). This is typical of wandering-type channels, where high rates of sediment supply, transport and storage give rise to the development of bedforms (e.g. riffles, alluvial bars). In the downstream-most 500 m of the survey reach, where recent dredging and straightening had taken place, the reach type became plane bed. There was a short cascade section where the channel was bedrock-controlled, at Hethpool Linn waterfall. Elsewhere, the channel substrate was dominated by gravel and cobble-sized material.

Sediment deposition was extensive throughout the surveyed reach (Figures B3 and B4), mostly in the form of alluvial cobble/ gravel bars (Figure 2.3). The majority of these were un-vegetated and appeared active. There were also a number of large-scale flood deposits, which occurred throughout

the reach. It is likely that these are associated with the large floods that occurred in 2008 and 2009. Most of these deposits were semi-vegetated, suggesting that some stabilisation had occurred. Many of the larger alluvial deposits had associated secondary or high flow channels around the distal side of the feature. Towards the downstream extent of the reach, there were significant overbank gravel deposits resulting from recent flood events (Figure 2.4).

Bank erosion was similarly widespread within the surveyed reach (Figures B5 and B6). Most erosion was into alluvial floodplain deposits of cobble and gravel, often within a fine sediment (silt/sand) matrix, and eroding banks were typically between one and two metres in height (Figure 2.5). Erosion often occurred opposite depositional features, in response to their effect of forcing flow towards the outer bank. A number of locations of major erosion throughout the reach represented significant sediment sources and also indicated ongoing lateral channel adjustment. In several locations, erosion directly into higher terraces or hillslopes was taking place, exposing faces of up to 10 m in height and providing a further sediment source of gravel, cobble and fines (Figure 2.6).

Engineering directly impacting the active channel was limited throughout most of the reach (Figures B7 and B8). There were bridges at the upstream extent and in the centre of the reach, as well as Westnewton Bridge itself, towards the downstream extent. The two bridges further upstream both had associated ford structures, which effectively acted as weirs. There was some evidence of minor dredging activity and bank re-profiling in a limited area in the upper part of the surveyed reach. The majority of channel engineering was found in the downstream-most 500 m of the surveyed extent (Figure B8). There was an embankment on the right bank throughout this section. This had been recently rebuilt at its upstream end, where it was set-back from the channel. Further downstream, the embankment was immediately adjacent to the active channel corridor (Figure 2.7). The embankment was approximately 2 m high. The embankment also continued further upstream, but was old and indistinct here.

Bank protection was observed on both banks upstream of Westnewton Bridge. On the left bank this consisted of intermittent rip-rap behind an alluvial bar. On the right bank the protection was vertical wooden posts, which were protecting the embankment. Downstream of the bridge, rip-rap bank protection was found on the right bank for approximately 90 m (Figure 2.8). Further downstream, wooden bank protection extended along most of the right bank as far as the confluence with the River Glen.

Dredging and reworking of the channel had taken place around the bridge, leaving a straight channel within re-profiled gravel/cobble deposits (Figure 2.7). The extended for approximately 170 m upstream of the bridge and 60 m downstream. The re-aligned channel passed through the central arch of Westnewton Bridge, which is a three-arch stone bridge. There was evidence of past dredging activity, suggesting that such channel management has been required to maintain the conveyance of flows past the bridge.

The fluvial audit results highlight the dynamic nature of the system. The extensive depositional bar features and associated bank erosion indicate high rates of sediment transport and channel change, especially in response to large flood events. Development of a management strategy for Westnewton Bridge must therefore take into account the high rate of sediment supply to the reach, the high energy of the system and the potential for large-scale channel change.

Figure 2.3. Alluvial bar deposition with associated bank erosion.

Figure 2.4. Overbank gravel deposition towards the downstream extent of the study reach.

Figure 2.5. Bank erosion within the upper half of the survey reach.

Figure 2.6. Terrace erosion in the central part of the reach.

Figure 2.7. Straightened/ dredged channel upstream of Westnewton Bridge, showing embankment and bank protection on right.

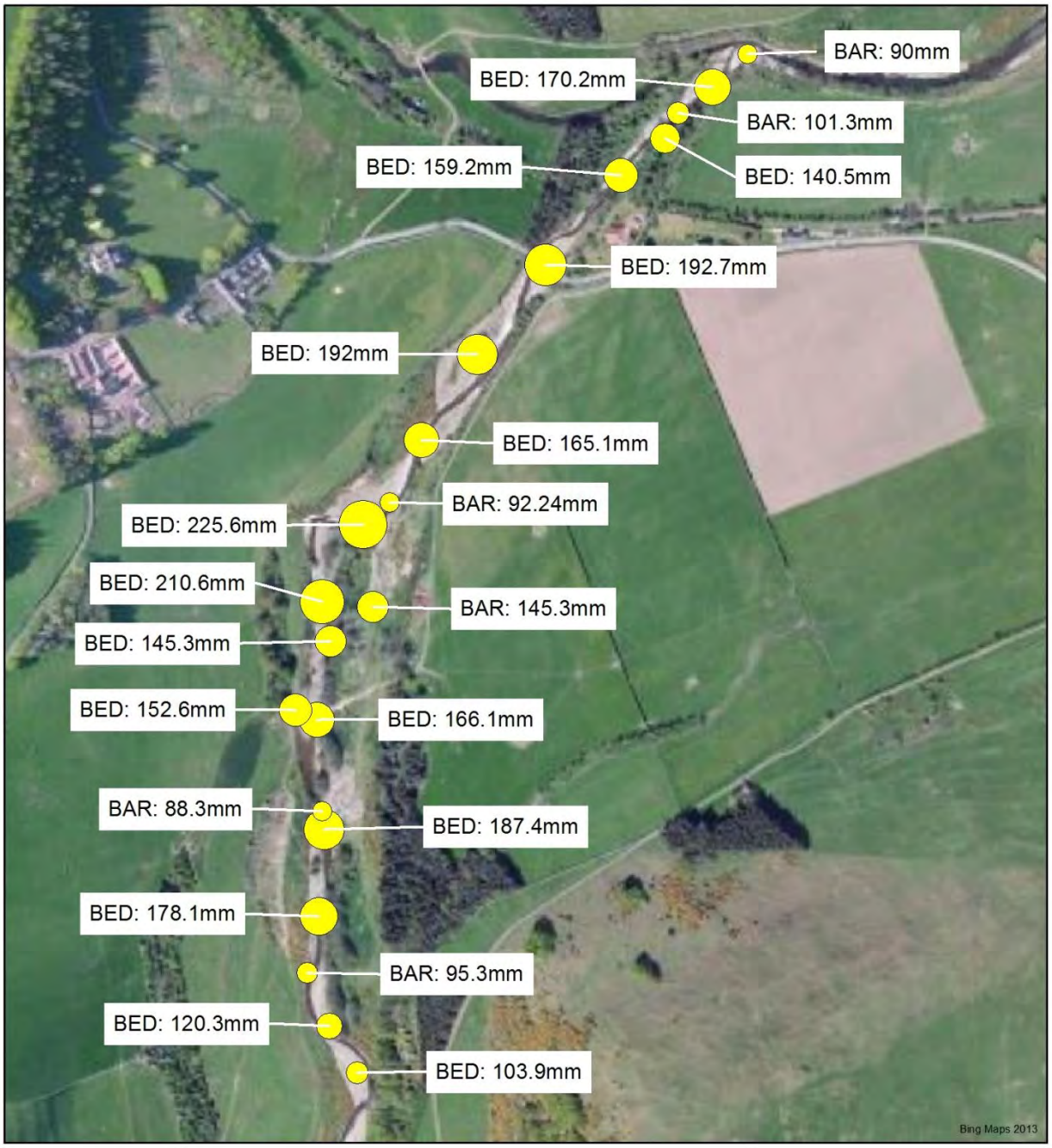
Figure 2.8. Looking upstream towards Westnewton Bridge showing straightened channel and bank protection on left of picture.

2.3 SEDIMENT CHARACTERISTICS

Sediment sampling of the project reach was conducted employing the 'Wolman-walk' pebble count methodology. A total of 21 samples were taken over a 1.1 km section of the channel extending from NT 906 296 to the confluence with the River Glen. Quantification of particle size was important to allow accurate representation of bed roughness within the subsequent hydrodynamic modelling.

The locations of sediment samples are indicated on Figure 2.9. Samples were spaced throughout the reach and taken on a representative range of morphological units (i.e. bar surfaces and channel bed), indicated on Figure 2.9. For each sample the D_{84} (i.e. 84th percentile particle diameter) was calculated. This is indicated on Figure 2.9.

The D_{84} from all samples is within the cobble size bracket, indicating a relatively coarse bed and further highlighting the high-energy nature of the river here. There was no apparent systematic variation in particle size with distance downstream through the reach. However, in general, samples taken from the channel bed had a larger D_{84} than those taken on bars.



Legend

D84 (mm, 200 times exaggeration)

N

0 75 150 m

Notes:		*Westnewton Bridge modelling & design* **D_{84} from Sediment Samples**		
		Project No. U13-1003	Created By: CM	**Figure 2.9**

2.4 TOPOGRAPHIC SURVEY

cbec conducted a topographic survey of the 1.5 km study reach, extending upstream to OS NGR NT 905 294 and downstream to the confluence with the River Glen. The survey included the channel and associated features was conducted using a combination of RTK-GPS (Leica GS08 rover and base station) and Total Station (Trimble S6) instrumentation. All total station measurements taken from control points set with RTK-GPS. The survey points were typically captured by cross section including floodplain elevations of both banks where possible. The locations of cross sections were defined by the nature of the channel morphology and were surveyed to capture variation in topography of the vertical and horizontal planes. The morphological cues for cross section capture included hydraulic controls, grade control structures, breaks in channel slope, expansions or contractions in channel width, and flow divergence/ convergence points.

Where the channel exhibited uniform cross sectional characteristics cross sections were surveyed to capture channel sinuosity. Additional features were surveyed to capture channel heterogeneity including; terraces, braids, significant bar features, high flow channels through floodplain areas, and bridge piers. To facilitate interpretation of the survey data, and appropriate break line creation in CAD, all surveyed points were accompanied by an appropriate point code indicating the specific feature type.

A DEM was developed from the raw topographic data and additional LiDAR data (purchased from the Environment Agency) in Autodesk Civil 3D 2011 (CAD) to represent existing channel/ floodplain conditions for the site. This was used as the boundary surface for a 2D hydrodynamic model (using the SRH2D platform) of the site extents. To integrate the topographic survey with LiDAR data, points constituting the outer margins of the topographic survey were isolated and the relative elevations of the LiDAR were sampled in ArcGIS. The difference between the surveyed and LiDAR elevations were calculated and a colour-coded shapefile produced to provide a visual cue of where the topographic survey points and LiDAR data were in agreement and where significant difference was present.

Where little or no difference was observed, the points were used to form the boundary interface between the two datasets. Where the two datasets were not in agreement the boundary was offset using recent aerial images as cues to set the inner limits of the LiDAR data. The LiDAR was then clipped to the resulting inner boundary polygon to be combined with the existing ground surface created in AutoCAD Civil 3D from the topographic survey data.

2.5 HYDROLOGY

Flood discharges were calculated for the College Burn at 390850E, 630500N.

Table 2.1 Q_{2yr} and Q_{200yr} Estimated Discharges

Q_{2yr} Estimated peak flow (cms)	Q_{200yr} Estimated peak flow (cms)
26.3	81.7

The discharges were computed using catchment descriptors obtained from the FEH CD-ROM v3 software and generated using the Revitalized Rainfall Runoff method (ReFH). The recommended time step and duration were used as well as the recommended model parameters obtained from the

catchment descriptors. The Q_{200yr} hydrograph, used as the test hydrograph for modelling, is shown in Figure 2.10**Error! Reference source not found.**.

2.6 MODELLING (EXISTING CONDITIONS)

Given that the recent 2008 and 2009 flood events at Westnewton were greater than the 100 year return event, all modelling work for design was undertaken with an estimated 200 year return period flood (Q_{200yr}).

The rising limb of a hydrograph can cause significantly greater stresses than are experienced using a steady state/ constant flow condition, so unsteady modelling of the hydraulics was also employed throughout. A state of the art unsteady 2D hydraulic solver SRH-2D (Lai, 2009; Pasternack, 2011) was used to compute the Q_{200yr} flow in the channel and onto the floodplains. This code was chosen for the College Burn because of its ability to accurately and efficiently model complex stream-wise and cross stream flow in the channel, flow over terrain modelled by spatially varying bed friction, complex patterns of shear stress, regions of subcritical, transcritical and supercritical flow, and flow over embankments onto floodplains. SRH-2D meets all of the requirements of the recent EA/ Defra review of 2D hydraulic modelling packages for use in the UK for flood risk studies (Neelz and Pender, 2009; Lai, 2009). SRH-2D is extensively validated (Lai, 2008) and has been used by cbec UK on many UK river restoration and design studies.

The modelling process consists of discretising the channel and floodplain with a computational mesh, where quadrilateral elements of small size are used in the main channel and largely aligned with the stream-wise direction, and larger, typically triangular or trapezoidal elements are used to discretise the floodplains. SRH-2D allows the use of elements of varying size within the channel- more detail (i.e. finer mesh resolution) was used in the main regions of interest at the run-up to the bridge and over the apron for example. The surface elevations of the mesh are interpolated from the CAD DEM and surface frictions are chosen to represent the finer scales and materials present on the bed. Bed and bar D84 particle sizes and photographs were used to determine the surface frictions and a map of friction polygons for the mesh. The surface friction distribution is shown in Figure 2.11 and tabulated in Table 2.2. The surface fiction at the exit to the domain was increased to ensure realistic subcritical flow at the exit of the model.

For Westnewton Bridge, the mesh process was an iterative one; first a course, medium and fine mesh was iterated to provide a model of existing conditions, then iterative design work was undertaken, then a common mesh structure for existing and design conditions was employed to compare flows under existing and design conditions. The differences between the existing conditions and design mesh were the surface elevations and bed frictions only. An overview of the final modelling mesh is shown in Figure 2.12. Mesh element sizes reflect the expected flow conditions: a small size of 1.5 m x 1 m is typical in the channel (around 15-20 elements from top of bank to top of bank for detail), 2 m x 2 m on the near bank floodplains, rising to 10 m x 10 m at the edges of the floodplain far from the channel. Extra detail was provided in the proposed design area at the run up to the bridge (0.5 m x 0.5 m) and on the bridge apron itself (1 m x 0.5 m).

On the apron, mesh elements were aligned parallel to the bridge piers. The bridge soffit or springing levels are not modelled with a 2D model. After initial modelling for existing conditions was undertaken, results were reviewed by the client, and it was decided to modify the mesh to represent naturally occurring log jams that were observed to significantly affect the flow during recent floods.

These jams were created in the model by raising the mesh bed level to create an obstruction and had the effect of recreating observed flooding patterns more accurately than the bare mesh (Brewis, pers. comm.). These log jams were used for all future model runs as they represent the worst case for inundation. Their positions are indicated in Figure 2.13.

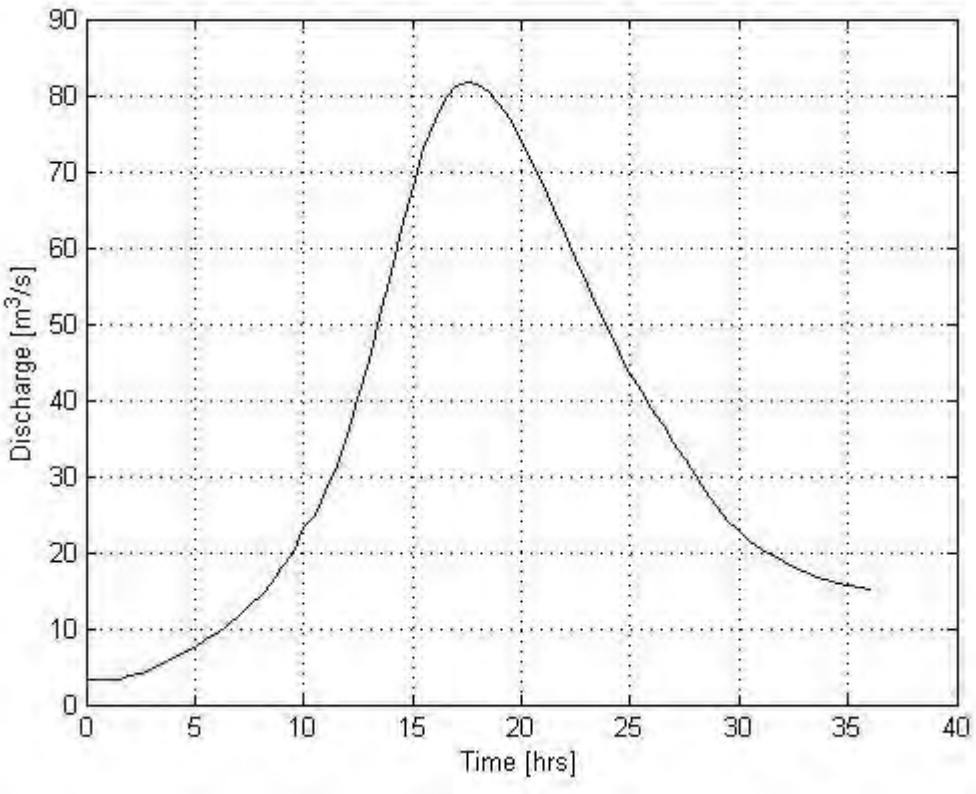


Figure 2.10. Inlet hydrograph established using the ReFH methodology for the College Burn at Westnewton Bridge. Peak is 81.7cms; Q2yr median discharge is approximately 23cms.

Table 2.2. Friction Values

Material	Number	n
Bed	1	0.039
Bed	2-5	0.035
Bed	6	0.039
Floodplain	7	0.06
Floodplain (rough)	8	0.07
Gorse	9	0.039
Gorse (thick)	10	0.044
Apron (existing bed)	11	0.035
Apron (concrete bed)	11	0.015
Apron (roughened bed)	11	0.035
Tree/log	12	0.045
Tree/log	13	0.045

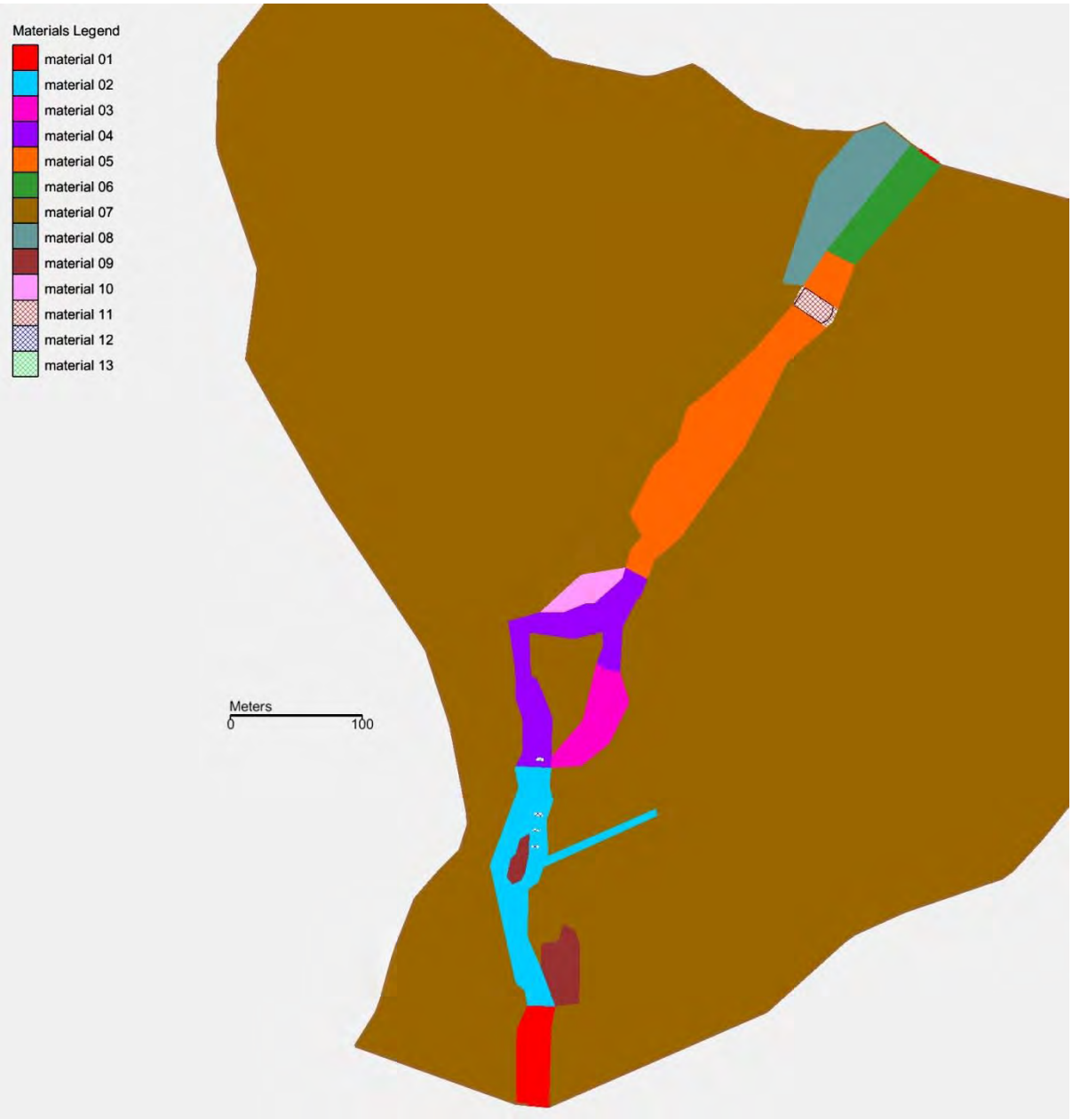


Figure 2.11. Surface material types for model (Manning n).

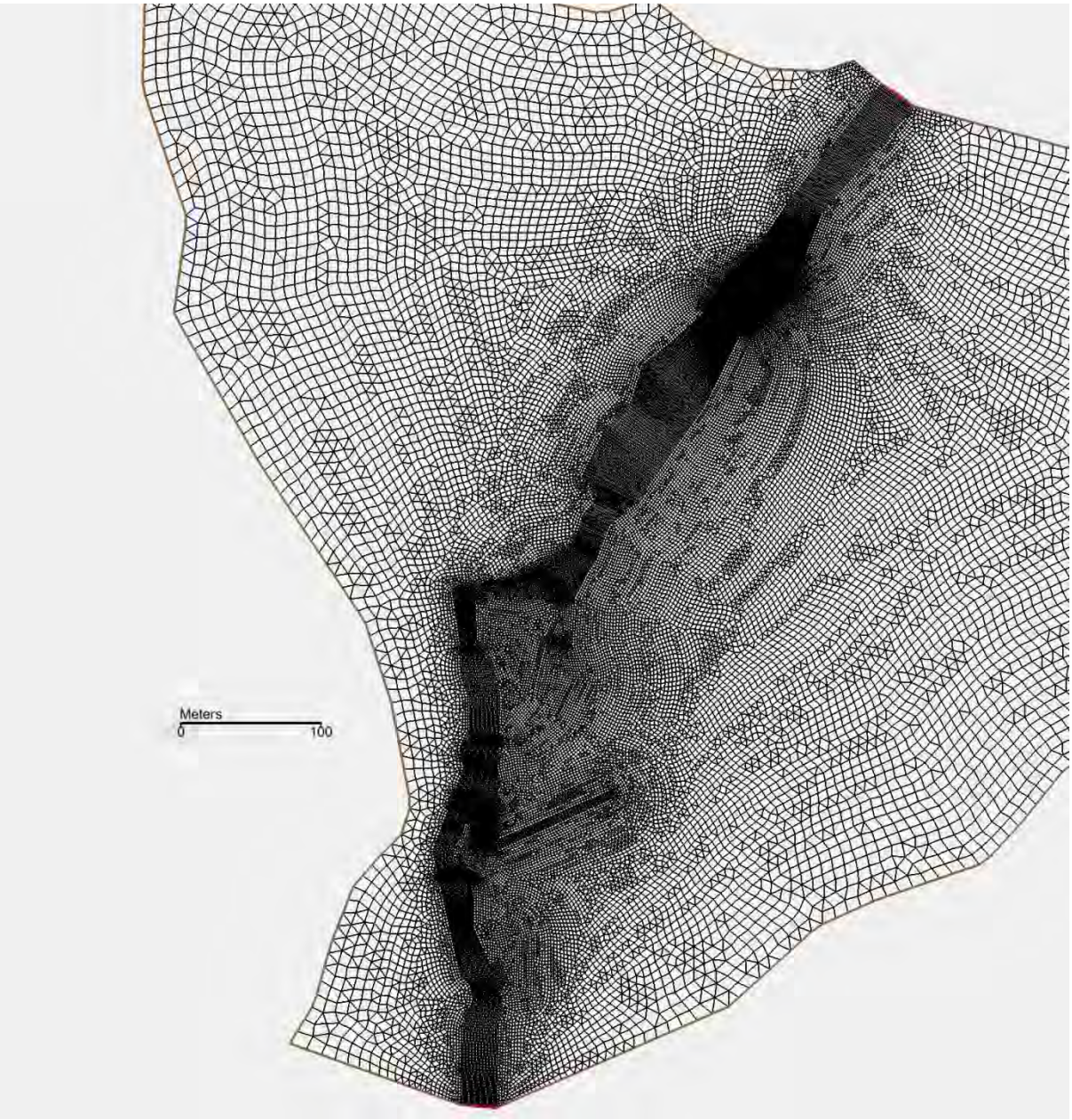


Figure 2.12. 2D hybrid mesh for model showing finer quadrilateral elements in channel and triangular and quadrilateral elements on floodplain.

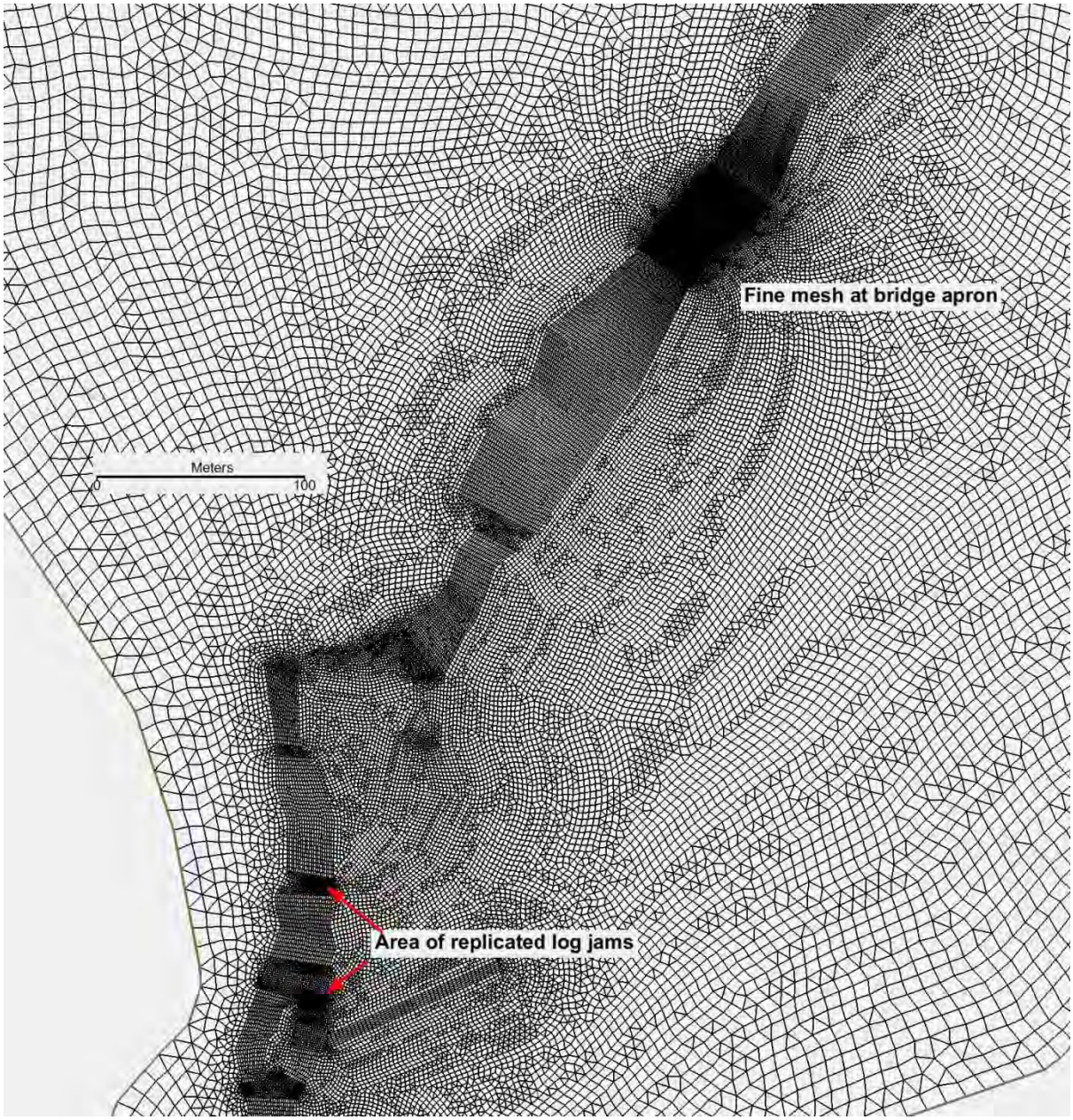


Figure 2.13. Detail of mesh showing position of typical natural log jams.

At the downstream end of the survey, the College Burn confluences with the River Glen. No data on water surface elevation at this point was available for the study and so the College Burn model was truncated to end upstream of the confluence at a point of approximately average slope and a normal depth assumption used to calculate water surface elevation. The slope at the exit was approximately 0.011. To obtain subcritical flow, the friction used at the exit was set as n=0.039. The normal depth assumption was significantly far from the design area not to affect levels at the bridge, and this was confirmed by varying the exit water surface level.

2.6.1. Existing Conditions Model Results

During the Q_{200yr} hydrograph, the Q_{2yr} peak value of 26 cms is reached at approximately 10.5 hrs. At this point, the discharge in the channel is close to the median discharge, and this level is often taken to be close to 'bank full' for UK rivers. Figure 2.14 shows the water depth predicted for this point of the hydrograph. There are three main areas of out of bank or incipient out of bank flow. First, water is seen to run up the track from the right bank approximately a quarter of the way from the bottom of the figure and onto the gravel area further downstream (as observed anecdotally). Secondly, there is flow on the right bank up to the embankment on the straightened section upstream of the bridge. Thirdly, there is flow onto the banks just upstream of the railway abutment in the upper part of the figure, and this abutment is seen to cause a significant restriction to the flow.

Figure 2.14. Water depth for existing conditions computed at a discharge of 26cms (~Q2yr peak) during the Q200 year hydrograph

Figure 2.15 shows the bed shear stress computed at the Q_{2yr} discharge, 10.5 hrs into the Q_{200yr} test hydrograph. Bed shear peak is 147 Pa at the sharp right bend central to the figure, but there are high shears of 110 Pa immediately upstream of the bridge and 120 Pa immediately downstream. There is a further peak of 100 Pa at the downstream railway abutment.

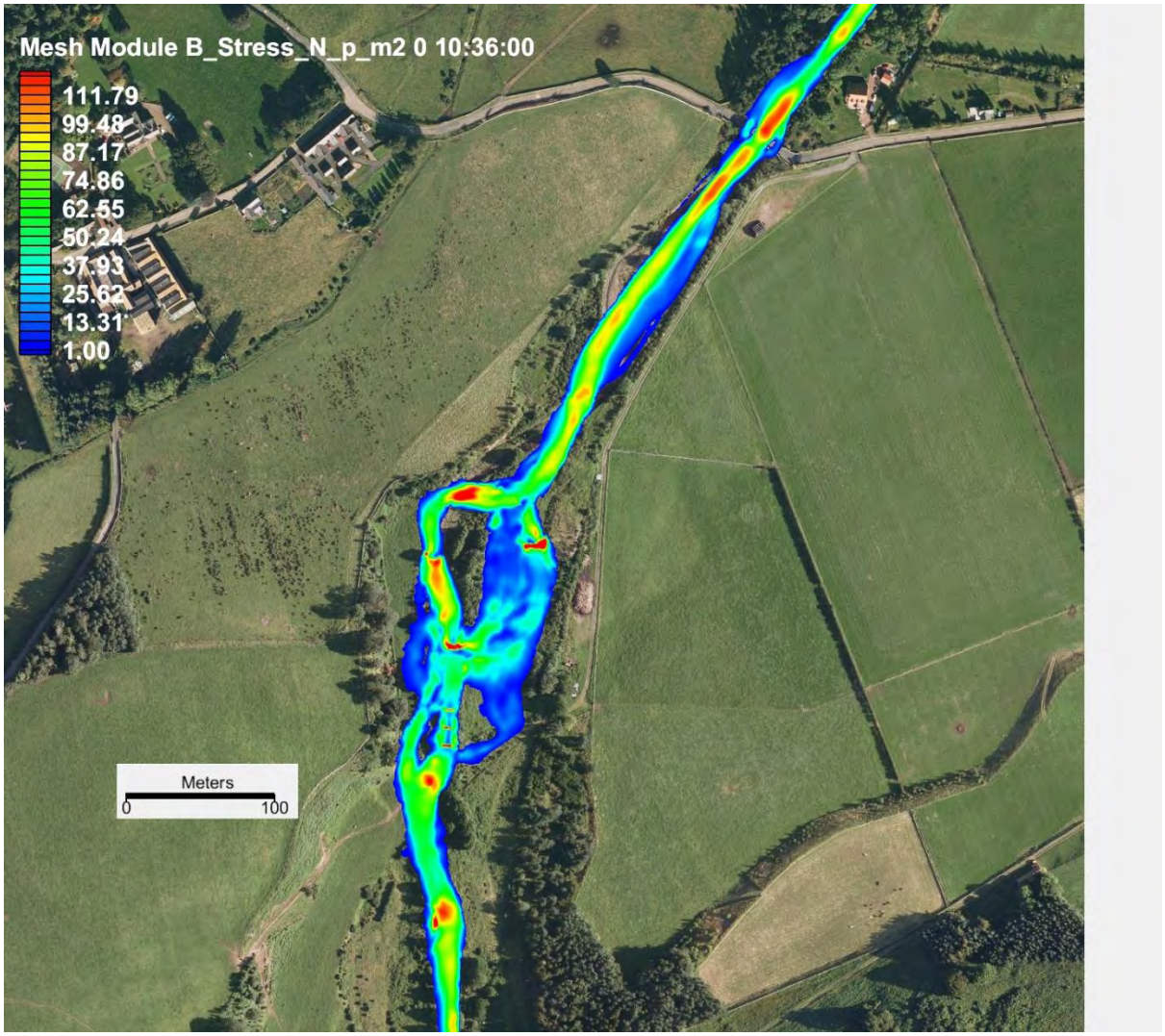


Figure 2.15. Bed shear stress for existing conditions computed at a discharge of 26 cms (~Q_{2yr} peak) during the Q_{200yr} hydrograph.

Maximum inundation predicted for existing conditions during the Q_{200yr} event is shown in Figure 2.16. At the upstream end of the model (bottom of the figure) there is a flood route towards Kirknewton onto the right hand floodplain. At the downstream end (top end of the figure) there is significant out of bank flow running from the old railway abutment on the left bank along the embankment to the left. Moreover, there is significant potential for the straightened section upstream of the bridge to re-meander and bypass the bridge. These three areas are the foci for design. There are some significant areas of high shear stress predicted at the Q_{200yr} peak flow. These are shown in Figure 2.17; (1) at the upstream end of the straightened section of channel there is a local peak of 196 Pa, (2) immediately upstream of the bridge there is a local peak of 177 Pa, (3) immediately downstream there is a local peak of 181 Pa, (4) immediately downstream of the railway abutment there is a peak of 200 Pa.

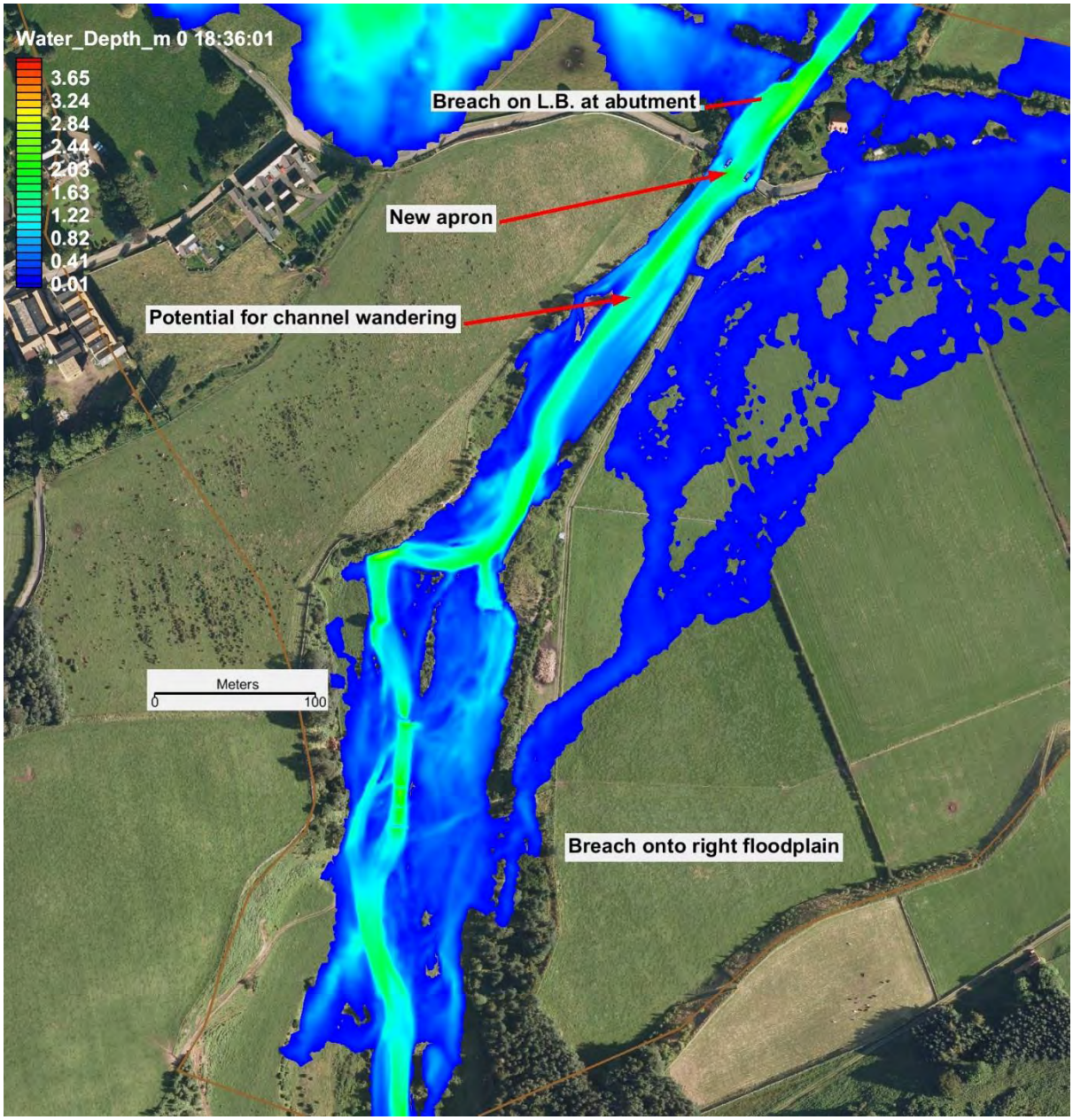


Figure 2.16. Maximum inundation during a Q_{200yr} flood hydrograph, showing potential redesign areas.

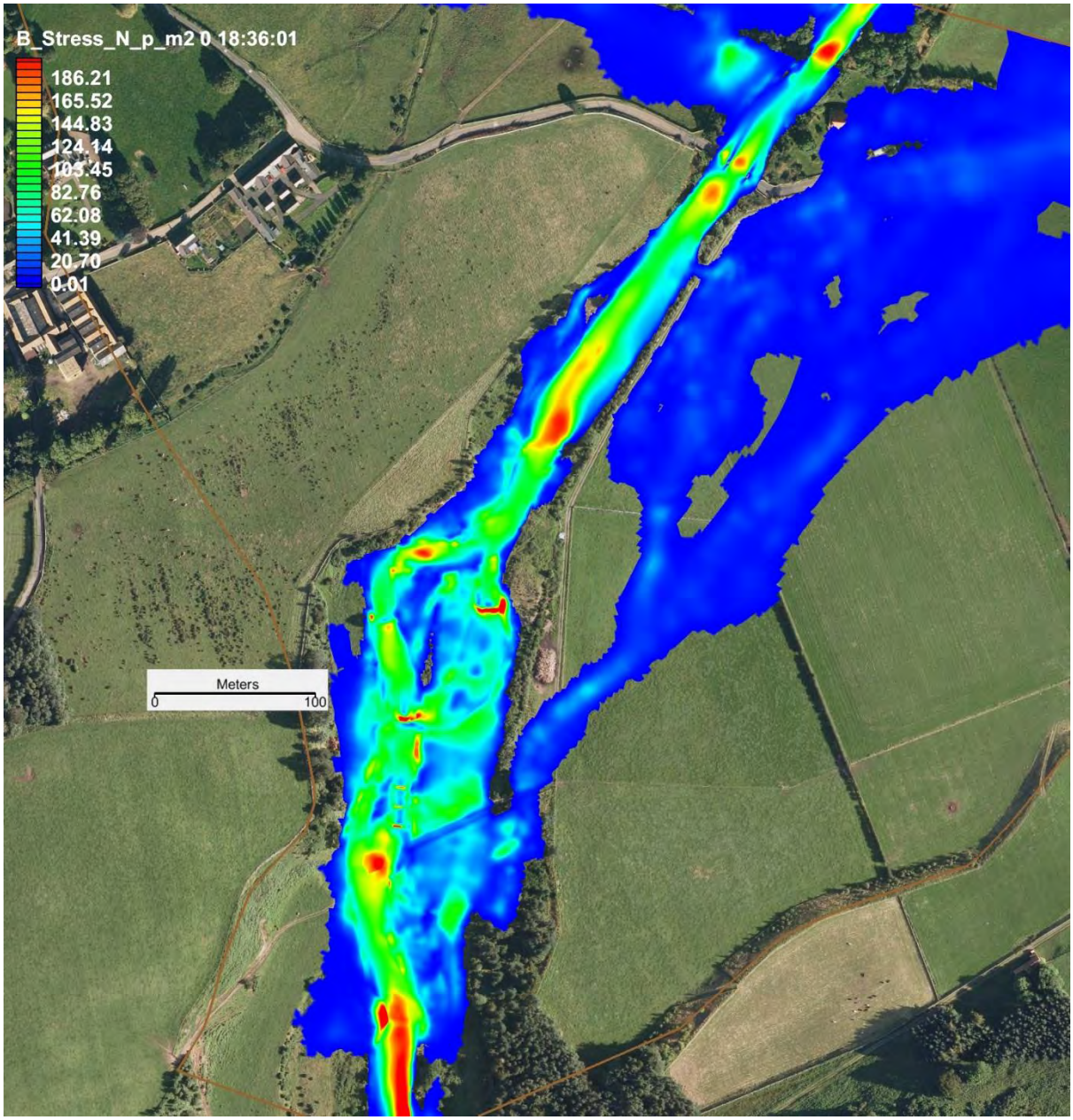


Figure 2.17. Bed shear stress at Q_{200yr} peak for existing conditions.

3. DESIGN PROCESS

The requirements of the design were to:

1. 'Train' the channel upstream of the bridge so that it approached the central arch normal to the orientation of the structure.
2. As much as was practicable, utilise a 'soft' engineering approach that considered natural fluvial processes (relating to the protected status of the burn).
3. Ensure unhindered fish passage beyond the bridge under normal flow conditions.
4. Introduce a new embankment to prevent flow onto the right hand floodplain.
5. Modify the abutments of the dismantled railway bridge ~100 m north (downstream) of Westnewton Bridge.

The primary component of the design is the training of the channel upstream of Westnewton Bridge. Based on the geomorphic character of the site and the constraints related to the protected status of the site/ environmental legislation, it was decided that the use of large wood structures was the most appropriate design strategy. In natural settings, large wood structures can provide a significant stabilising effect on local channel course, training flow towards the channel centre and protecting banks composed of otherwise highly erodible material. For the Westnewton design, it was proposed that a series of large logs (with root balls intact) were to be introduced to the channel margins. These were to be arranged in left-right bank pairs with the root ball end at the channel margin and the trunks buried into the banks pointing away from the channel at ~45 degrees to the direction of flow and ~3% slope angle from root ball to bank intersect.

The specific configuration (longitudinal and lateral spacing between logs, trunk orientation) of the structures was optimised through an iterative modelling process. Initially a single log pair (i.e. individual logs situated opposite each other on left and right banks of the channel) was introduced to the design and the design Q_{200yr} hydrograph modelled to determine the hydraulic (and inferred sediment transport) influence of the structure. Based on analysis of this output, a series of appropriately spaced and orientated log pairs were introduced to the design and the same flow magnitude was modelled. The effect on hydraulics of the interactions between the series of log pairs was then assessed and their configuration further refined to provide training at both medium to high flows.

A spreadsheet was provided that computed drag and buoyancy loads on the partially buried logs at the peak Q_{200yr} flow. These loads depend implicitly on the sourced wood for the log structures (lengths, widths and protruding height), but exemplar values are given in this report (Appendix C).

In terms of unhindered fish passage (predominantly considering sea trout and Atlantic salmon), the design of the new bridge apron required to provide appropriate/ suitable hydraulic characteristics under the typical range of flow (discharge) conditions under which upstream migration would occur. This involved the roughening of the concrete apron structure with cobble and boulder sized material to provide variation of flow depths and velocities that could be exploited by fish. Specifically, the design involves a series of paired boulders that alternate on either side of the apron centre-line and induce a sinuous flow pattern. This reduces mean flow velocity through the lower elevation centre of the apron with hydraulic resting areas in the lee of boulders. The entire extents of the apron (i.e. including the central section with the paired boulders) are to have 100 – 200 mm river cobbles inset into the concrete at approximately 50% areal coverage in order to reproduce the bed roughness characteristics of the channel immediately upstream of the apron. This aspect of the design was to

prevent a step change in shear stress at the edges (upstream and downstream) of the apron, and prevent accelerated flow that would occur over smooth concrete. This limits the potential for differential sediment transport patterns (i.e. erosion or deposition) in the vicinity of the apron that could reduce its functionality (both in terms of conveyance of flow and passage by fish) over time.

Given the very dynamic nature of the burn (as identified during the historical and geomorphic assessments stages of the project), it is unlikely that any design will remain stable in the long term and there will be the requirement for periodic repair/ adjustment of the design, particularly in response of large flood events. An outline strategy for a post project monitoring plan and considerations for the 'adaptive management' of the design are provided in Section 4. However, the design approach proposed aims to provide the most sustainable and stable option given the highly dynamic geomorphic condition of the site and the restrictions imposed by the protected status of the site.

In addition to the training of flow through the bridge piers, additional design was done to raise an embankment upstream where existing conditions modelling indicated a significant flood route. The required level of this embankment (72.2 m AOD) was determined by computing water levels in the existing conditions model and raising the local level at the breach to the flood level (71.8 m AOD) plus 0.5 m freeboard.

The final design change consisted of remodelling the railway abutment on the left bank downstream of the bridge. Here, an approximately 2-m-wide shelf[2] was created by levelling a portion of the abutment. This increases conveyance and removes a large part of the restriction to flow caused by the abutment.

The results of the design model, incorporating the training log pairs, a roughened apron, extra embankment and modified abutment are shown in the next section.

3.1 PRODUCTION OF DESIGN TIN

The Triangulated Irregular Network (TIN) surfaces of the design components were created using Autodesk Civil 3D 2011 (Civil 3D) for the existing ground conditions and four separate design areas. The design areas are:

1. The training logs
2. The bridge apron
3. The embankment track access
4. The rail bridge abutment setback

A TIN surface was created from the field surveyed topographic survey points and connecting break lines added ensure correct interpretation by Civil 3D's triangulation algorithms. The resulting surface was then combined with LiDAR data to produce surface that accurately represents the existing ground conditions. For the Training Logs a feature line CAD entity was created in Civil 3D representing a typical log with a 3% gradient rising from the root ball end. Sub-surfaces were then developed of mirrored pairs of logs embedded into the existing ground at design locations, elevations, and rotated to the design angles of inflection relative to the flow. These sub surfaces were exported for entering in to the mesh for 2D modelling. Further iterative design steps followed until the final arrangement was determined. For the Rail Bridge Abutment Setback a design 'top of bank' was defined by creating a

[2] The setback shelf was not consistently 2 m but is 'field-fitted' to link the upstream 'normal' bank elevation to an appropriate equivalent downstream bank elevation.

line connecting the exiting 'top of bank' upstream of the Rail Bridge to a representative location downstream of the structure. The 'bank toe' of these two locations where also connected to form the design bank face. The line of the existing 'bank toe' was extracted and joined to the design 'bank toe' to form a polygon prescribing the additional bed area resulting from the design. The design 'top of bank' was offset by 2 m to form a bankfull bench and then the 'grade to surface' tool used to grade this bench a 3:1 to the existing ground. The resulting DEM was exported to the modelling mesh and 2D modelling showed no further adjustments where required. For the Bridge Apron design only the materials and central fish passage assisting rock alignments differed from original drawings supplied by Northumberland County Council. Consequently this required only scaled graphical representation of these changes. The required design elevation at the Embankment Track Access was determined independently within the 2D modelling process. An additional 'freeboard' of 0.5 m was added (resulting in an elevation of 82.3 m AOD) and a representative embankment at that elevation was designed in Civil 3D.

3.2 DESIGN MODEL RESULTS

The design (as shown by the accompanying drawings, Appendix D) consists of a raised embankment on the right bank, upstream of the track at 390622E, 629978N; a series of log pairs to maintain stable 'trained' flow leading to the bridge apron; a bench area to increase conveyance at the railway abutment at 390804E, 630441N. In addition to the detail contained in the model, the bridge apron is to be roughened by 50% coverage 100mm-200mm diameter inset cobble and larger alternate boulder pairs near the centre. In the design model, the concrete apron was given a roughness similar to the adjacent channel (n=0.035).

The design modelling demonstrates that the design is successful in reducing inundation (especially for the right bank flood route to Kirknewton), training the flow to be stable through the bridge during the Q_{200yr} flood, and removing the restriction to flow at the railway abutment. The design shear stresses are similar (on average) to existing conditions but the design produces some localised peaks at the final log pair upstream of the apron[3] (from the root balls of the final log pair to immediately upstream of the apron lip, ~15 m longitudinally) and a higher shear stress at the downstream apron lip[4] (mainly located on the apron itself but also ~3 m downstream of the lip). Armouring the bed with a grade of 200-400 mm boulders for 15 m from the root balls of the final log pair to the upstream lip of the apron and of a thickness equivalent to one maximum particle size diameter (i.e. 0.4 m) is advised. Also, 3 m of the channel bed from the downstream apron lip should be armoured with a grade of 200 – 400 mm diameter particles, of one maximum particle size diameter in thickness (i.e. 0.4 m). Each aspect of the design model results is discussed in detail below.

3.2.1 Inundation extents at Q_{200yr} peak

The inundation onto the right hand floodplain towards Kirknewton is prevented by the upstream embankment, as shown in Figure 3.1. The downstream inundated area, running along the old railway embankment, is also reduced by increasing conveyance with the design shelf at the railway abutment. The figure also shows that the training logs are fully inundated at the Q_{200yr} peak. Figure 3.2 shows a comparison of total modelled inundation extent for the existing conditions and design model. Note

[3] This peak in shear stress indicates incipient mobility for 200-240 mm diameter particles.
[4] This peak in shear stress indicates mobility of particles under 200 mm diameter.

however, that the side edges of the model, except at the exit channel, are modelled as walls; in reality, flow would continue out of the downstream edges. Inundation is clearly seen to be reduced for design.

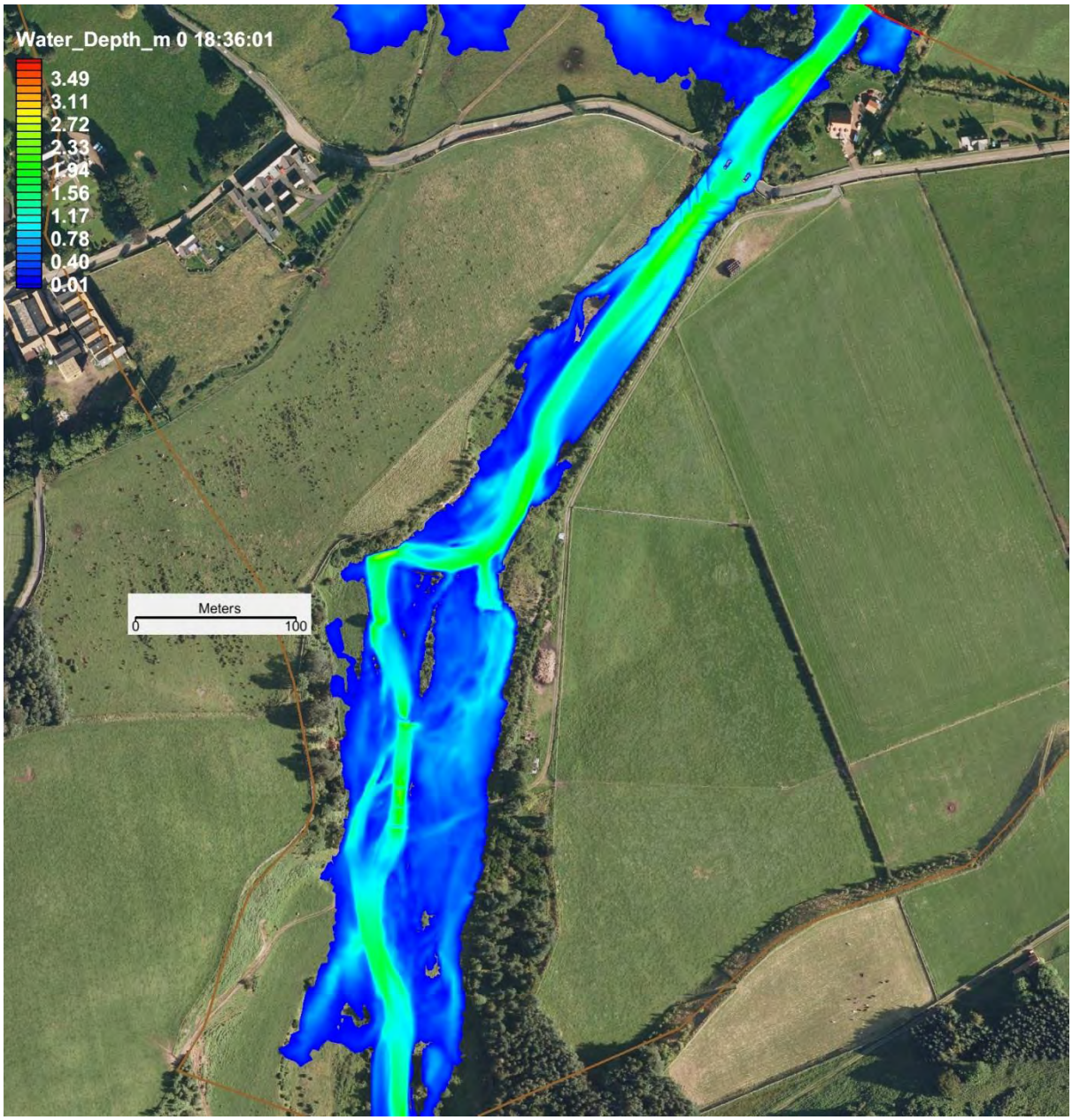


Figure 3.1. Maximum inundation predicted for combined design changes at Westnewton Bridge (Q_{200yr}).

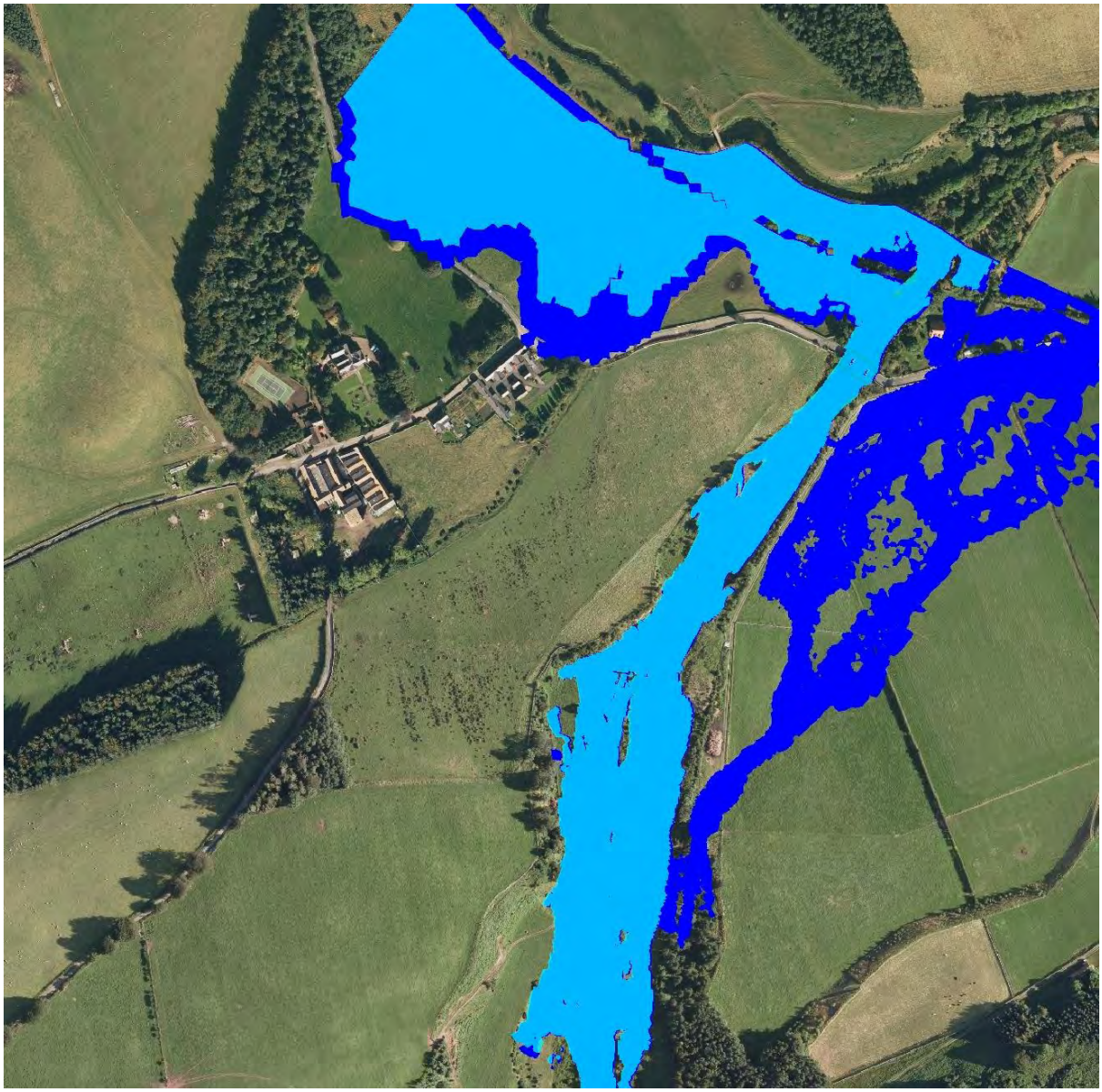


Figure 3.2. Comparison of inundation extents between existing and design at Q_{200yr} peak. Dark blue- existing conditions; light blue- design.

3.2.2 Training effect of the log pairs.

The major design modification to the College Burn is a set of 15 logs; the downstream 12 of these are arranged in pairs (i.e. six pairs), angled at approximately 45 degrees to the channel direction while the three furthest upstream (one left bank, two right bank) are angled closer to the channel direction and largely buried. The logs are partially submerged and buried at their bank end, and further anchoring is also recommended to prevent the logs moving or being undermined. The near log velocities calculated by the hydraulic model were used in a spreadsheet to estimate drag and buoyancy loads on each log (refer to log load calculations, Appendix C). Logs that are significantly exposed to the flow require ballast or anchoring to assure stability and longevity of the design.

The logs, if maintained in place, result in an afflux and redirection of flow towards the channel centre. This afflux is not large enough to cause the existing river embankments to breach at Q_{200yr} peak. Figure 3.3 shows water depth and velocity vectors for design, centred on the log array, at the Q_{2yr} discharge

level. A clear angling of the flow towards the centre of the channel is observed, and all of the log pairs are effective in redirecting flow. Figure 3.4 shows this training effect at the Q_{200yr} peak. At this level, most of the logs are submerged in deep water, and so their training effect is diminished- however, the final log pair is still effective at directing flow towards the channel centre, and hence stabilising the flow direction. Figure 3.5 is instructive in demonstrating the added stability the logs give to the flow direction during the design Q_{200yr} event; the figure shows the mean flow velocity angle (weighted by depth) on the approach to the bridge on the apron. For existing conditions there is a larger range of flow angles for the Q_{200yr} event (existing mean of 47 degrees, range of 5.8 degrees and standard deviation of 1.9 degrees) than for design condition with log stabilisation of the flow (mean of 48 degrees, range of 3.9 degrees and standard deviation of 1.2 degrees). The flow direction is therefore stabilised through the bridge by the design log pairs.

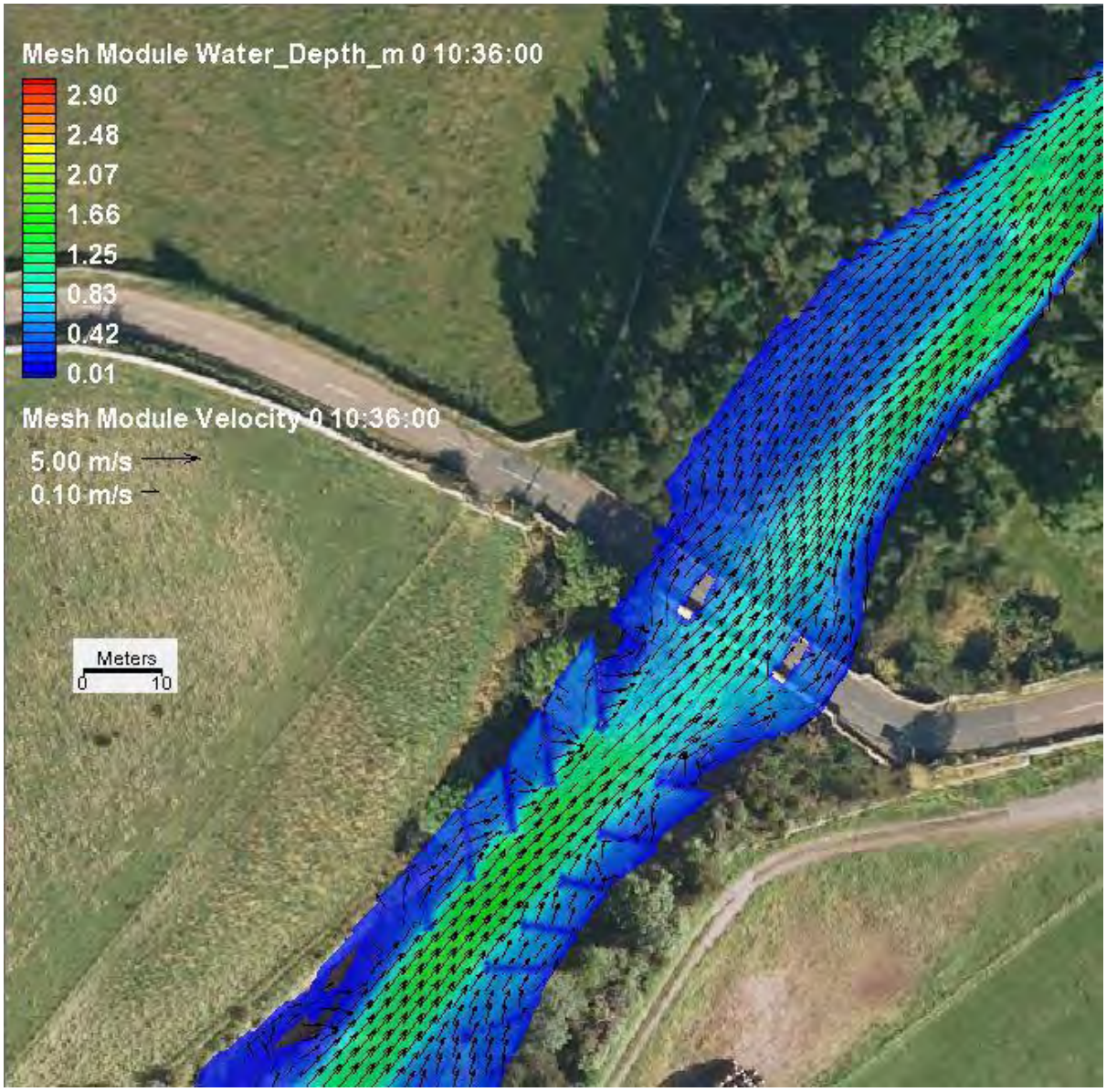


Figure 3.3. Training effect of log pairs at Q_{2yr} peak flow. All pairs act to direct flow into centre channel.

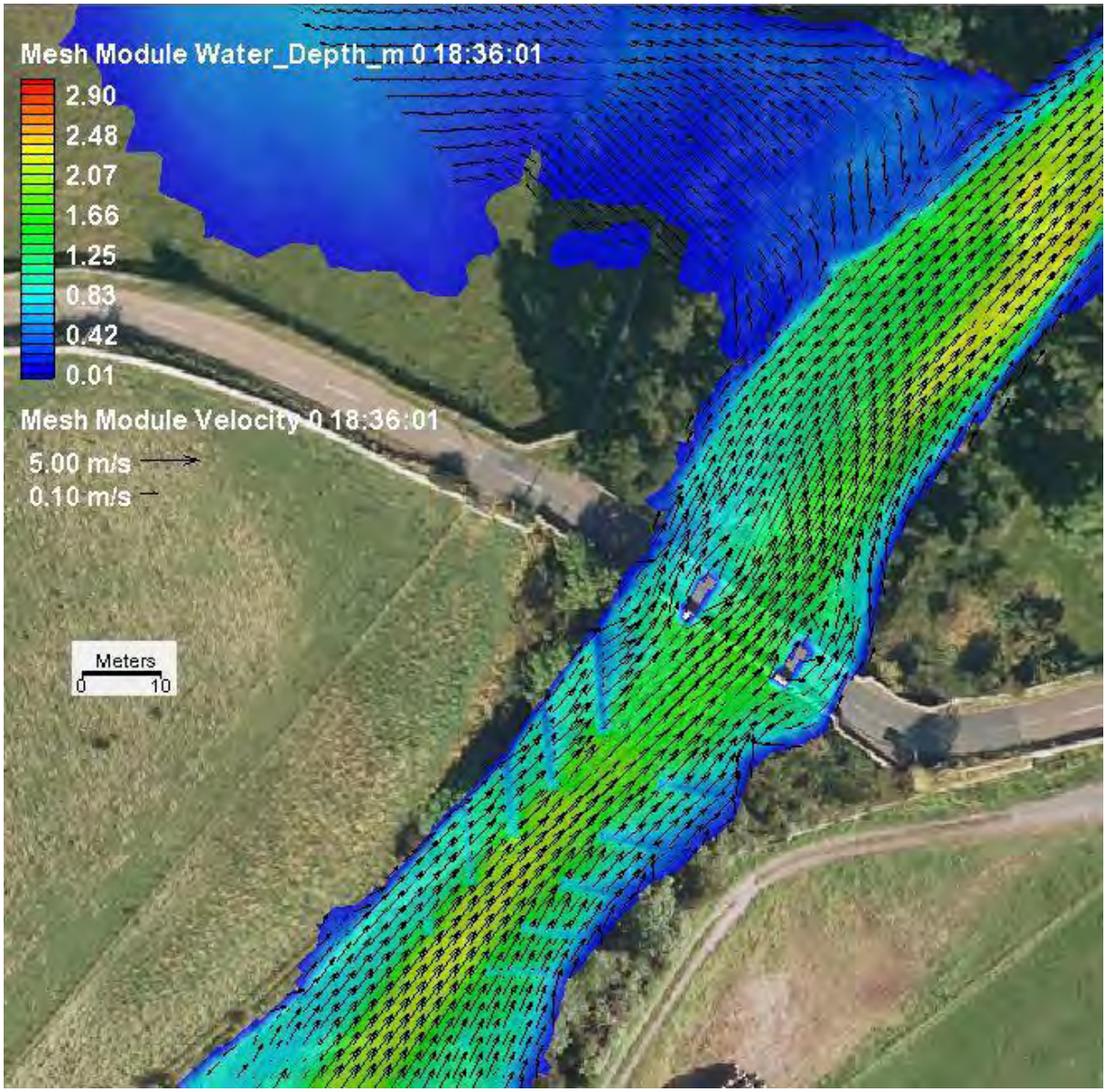


Figure 3.4. Training effect of log pairs at Q_{200yr} peak flow. Final log pair still acts to direct flow into centre channel.

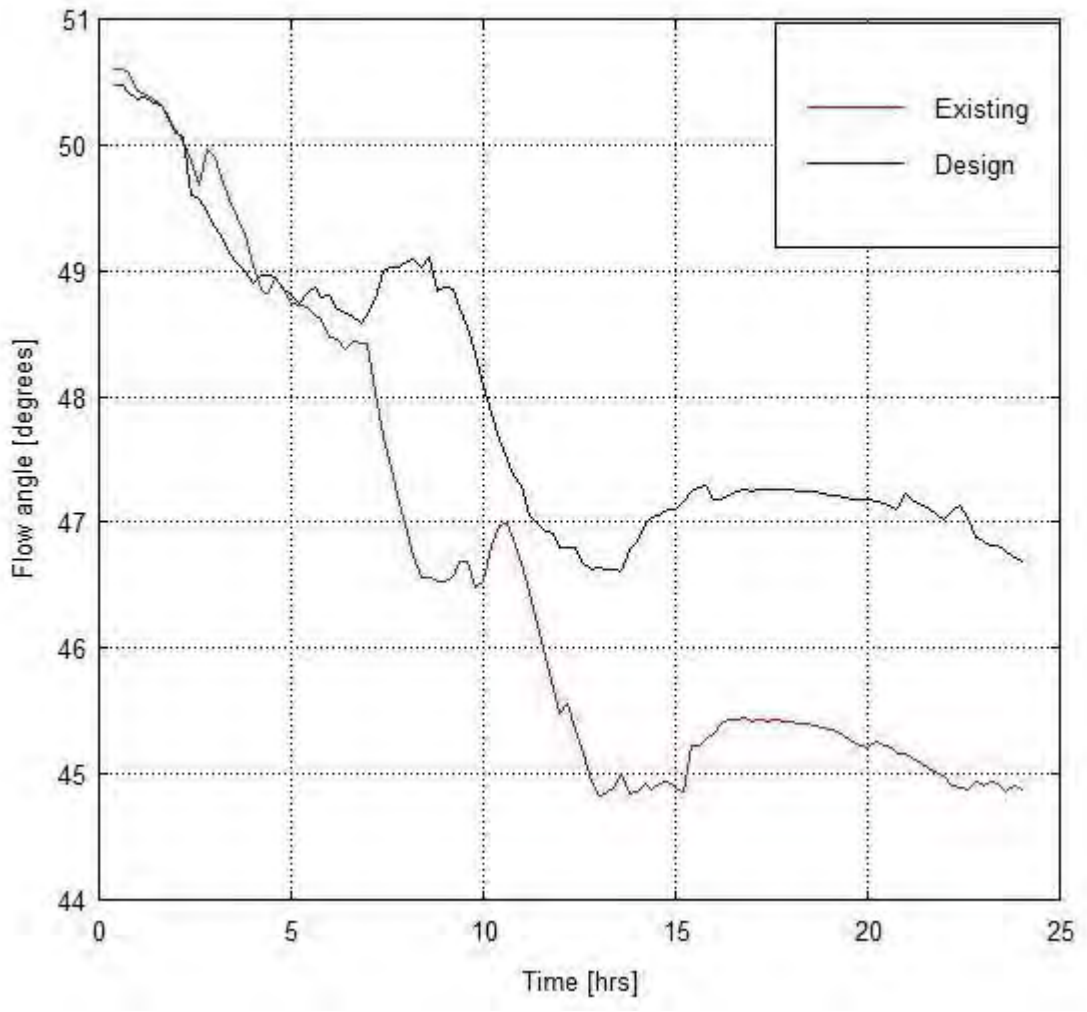


Figure 3.5. Mean water flow angle on approach to the bridge on apron during Q_{200yr} hydrograph. Existing condition mean 46.7 degrees with a range of 5.8 degrees; Design condition mean 48 degrees, with a range of 3.9 degrees. Design condition is stable over the Q_{200yr} peak and closer to the mean thalweg direction than existing conditions.

3.2.3 Bed shear stresses

The peak mean shear stress measured along the thalweg during the Q_{200yr} hydrograph is 119 Pa for existing conditions and 117 Pa for design conditions, i.e. similar for existing and design.

Figure 3.6. shows the bed shear stress at the peak of the Q_{200yr} hydrograph for design conditions showing that the pattern of shear stress is slightly modified by the design at the log locations, the apron, immediately downstream of the apron and at the old railway abutment. Figure 3.7 shows the bed shear stress and velocity vectors over the log pairs and bridge apron at the peak of the Q_{200yr} hydrograph for design conditions.

Notably, the shear in the channel is reduced on the upstream approach to the bridge adjacent to the logs (caused by the afflux of the combined log pairs) but experiences a peak in the channel at the last log pair (likely resulting in some local scour here unless increased armouring is implemented). The design hydraulic model treats the apron as a region of constant roughness/friction, and this model

predicts a secondary peak in shear stress centred on the concrete apron, and this increase over existing conditions carries on to the channel downstream of the apron lip. In reality, the shear stress distribution on the apron, and immediately downstream, will be complex and affected by the un-modelled local effects of the boulder pairs[5] recommended to assist fish passage. It might be expected that the larger boulder pairs will further dissipate energy over, meaning that model may represent the 'worst case scenario' in terms of shear stresses over the apron.

Figure 3.8. and Figure 3.9 show the shear stress values for existing and design conditions along the thalweg (from the ~90 degree channel bend mid-reach along a 400m stretch of straightened channel through the log pairs, bridge and down to the railway abutment) for both the Q_{2yr} level the Q_{200yr} peak. The position of the upstream and downstream apron lip and the railway abutment are shown. The maximum mobilised particle diameter, based on a Shields parameter of 0.04 for incipient motion, is shown in Figure 3.10 and Figure 3.11. These figures indicate that the higher shear stress values at the apron lip may warrant some armouring of the channel to prevent local scour from undermining the apron, and that this situation should be regularly monitored after high flood events. The extent of the required armouring may be estimated from Figure 3.10 and Figure 3.11 and is discussed in Section 3.2. However, the average sediment transport in the channel is not predicted to change greatly as a result of the design.

Notably, the design changes to the abutment increase conveyance and reduce the water velocity in the channel downstream of the abutment position. This design change can be clearly seen to reduce a peak in channel shear stress and will reduce erosion in this area.

[5] Each boulder will create a wake of much slower velocity and shear stress with the interactions between the wakes of the boulder pairs being complex; these interactions have not been modelled explicitly.

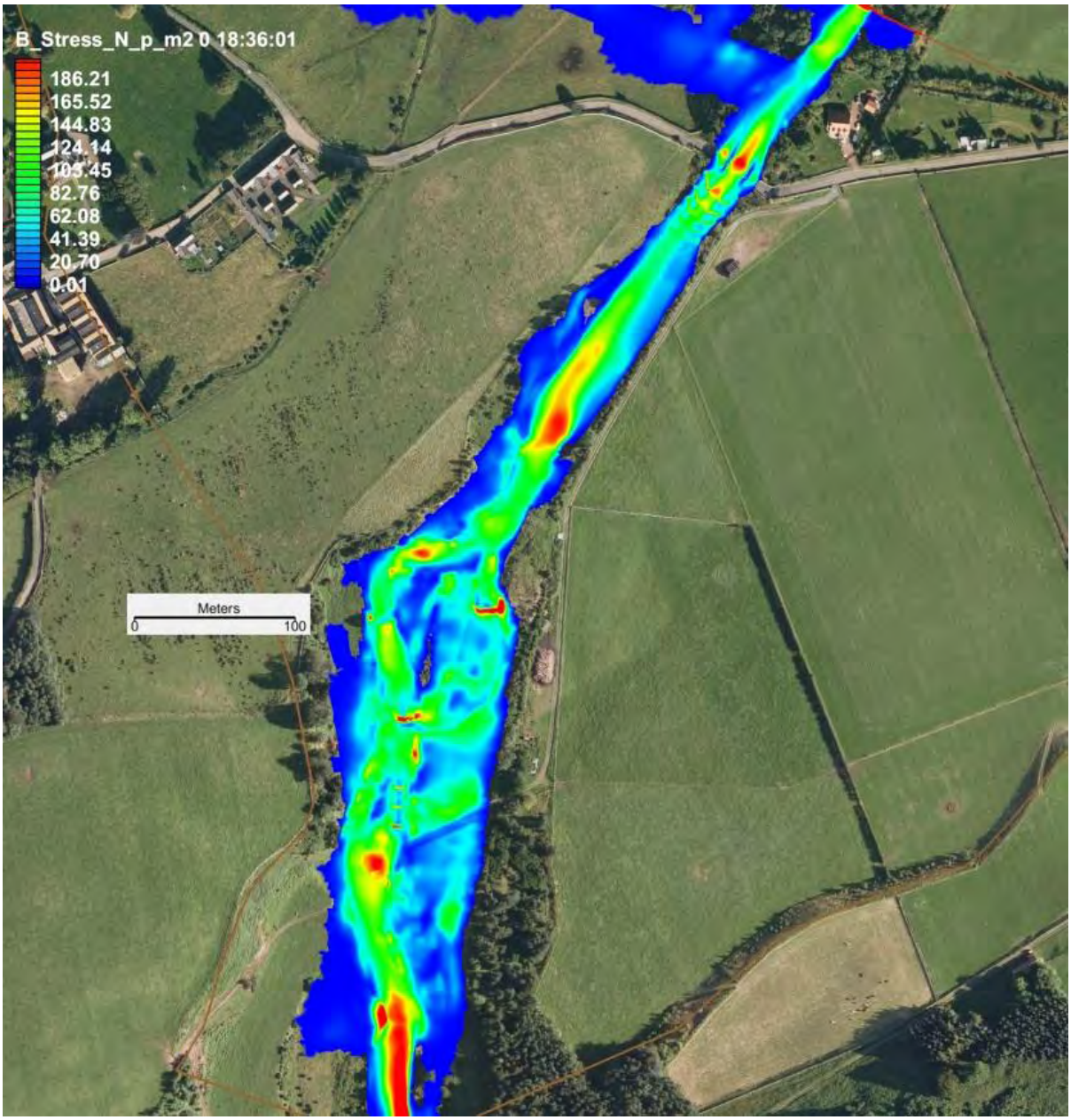


Figure 3.6. Bed shear stress for design condition at Q_{200yr} peak.

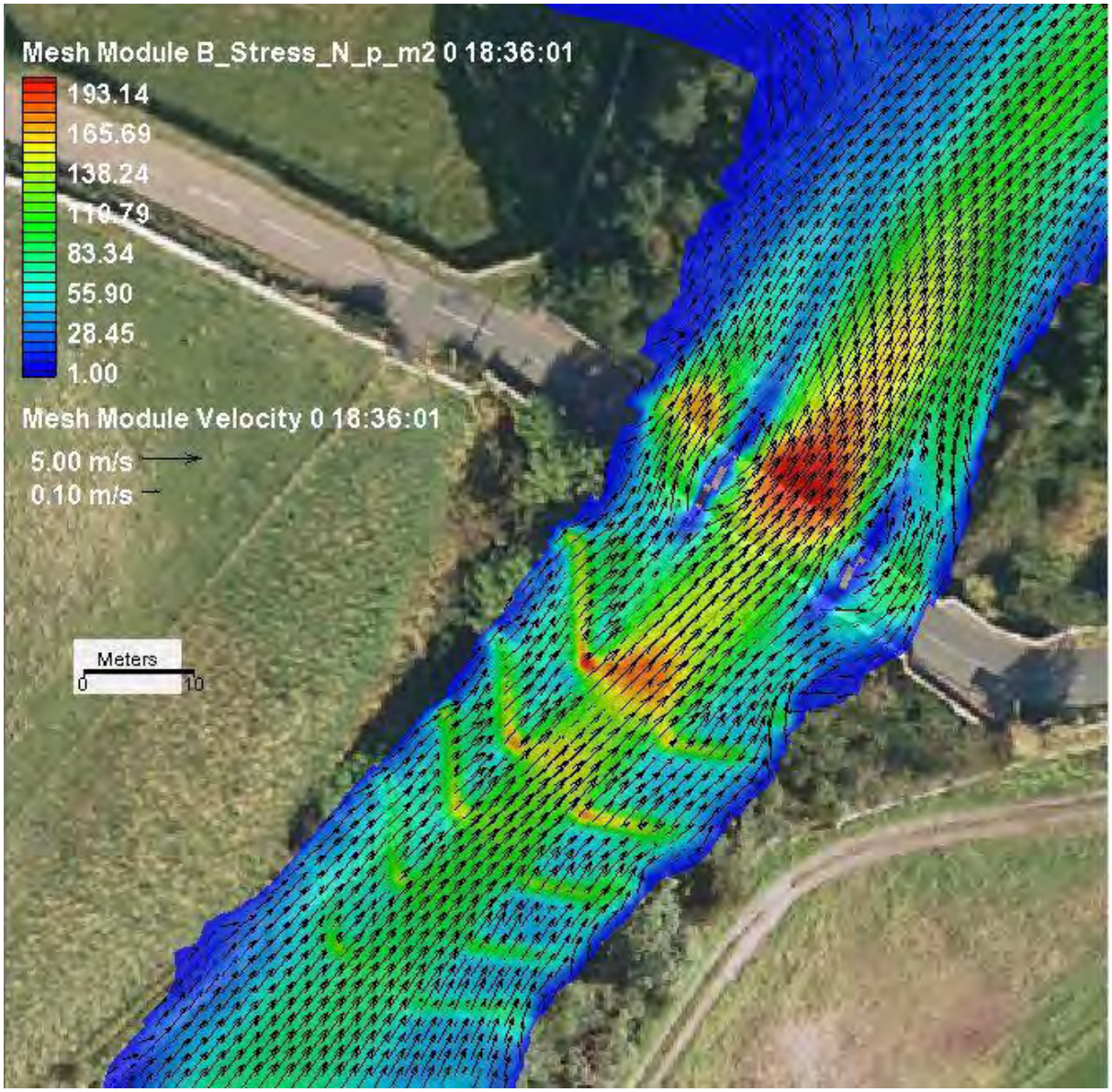


Figure 3.7. Bed shear stress and velocity vectors over the log pairs and on the bridge apron at Q_{200yr} peak.

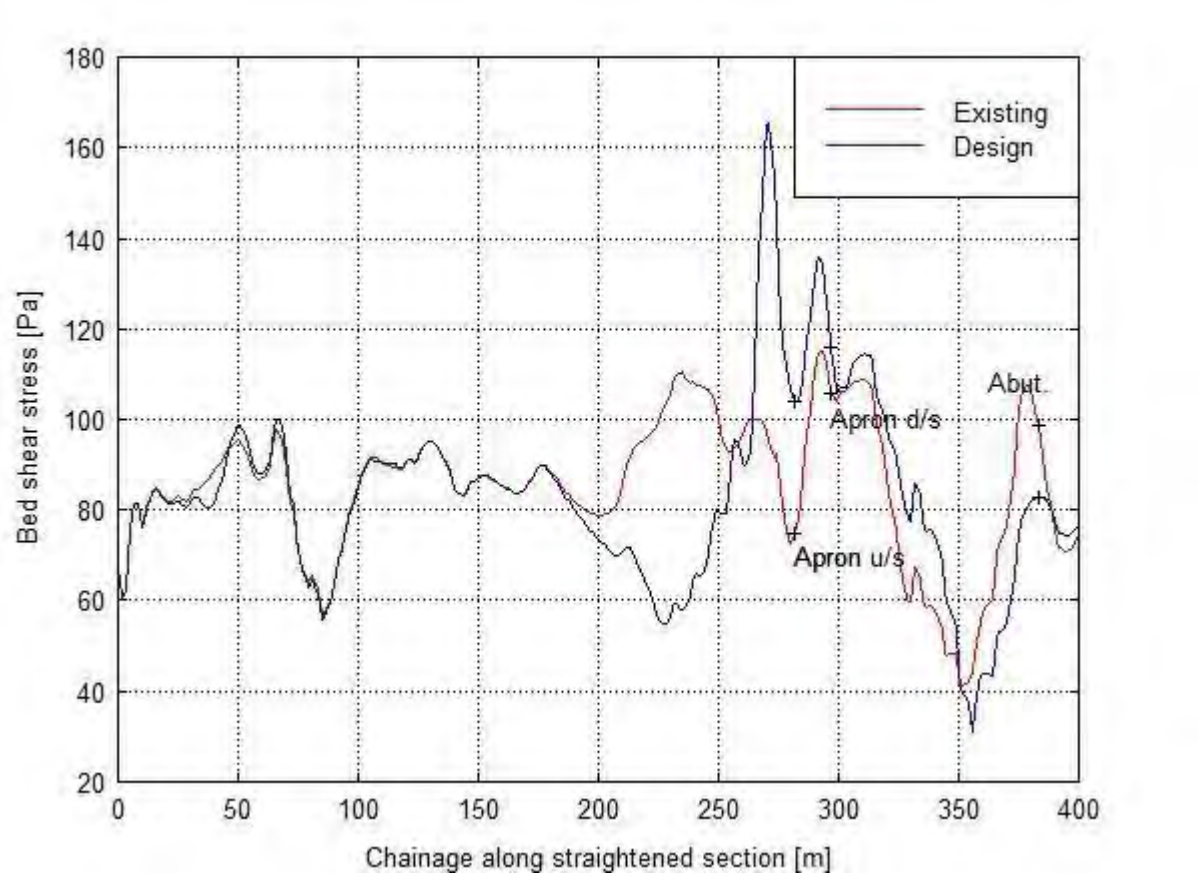


Figure 3.8. Bed shear stress along thalweg for existing (red line) and design (blue line) at Q_{2yr} level. Positions of apron and abutment indicated. Only the thalweg from the mid-reach 90 degree bend along the straightened section to the model exit is shown.

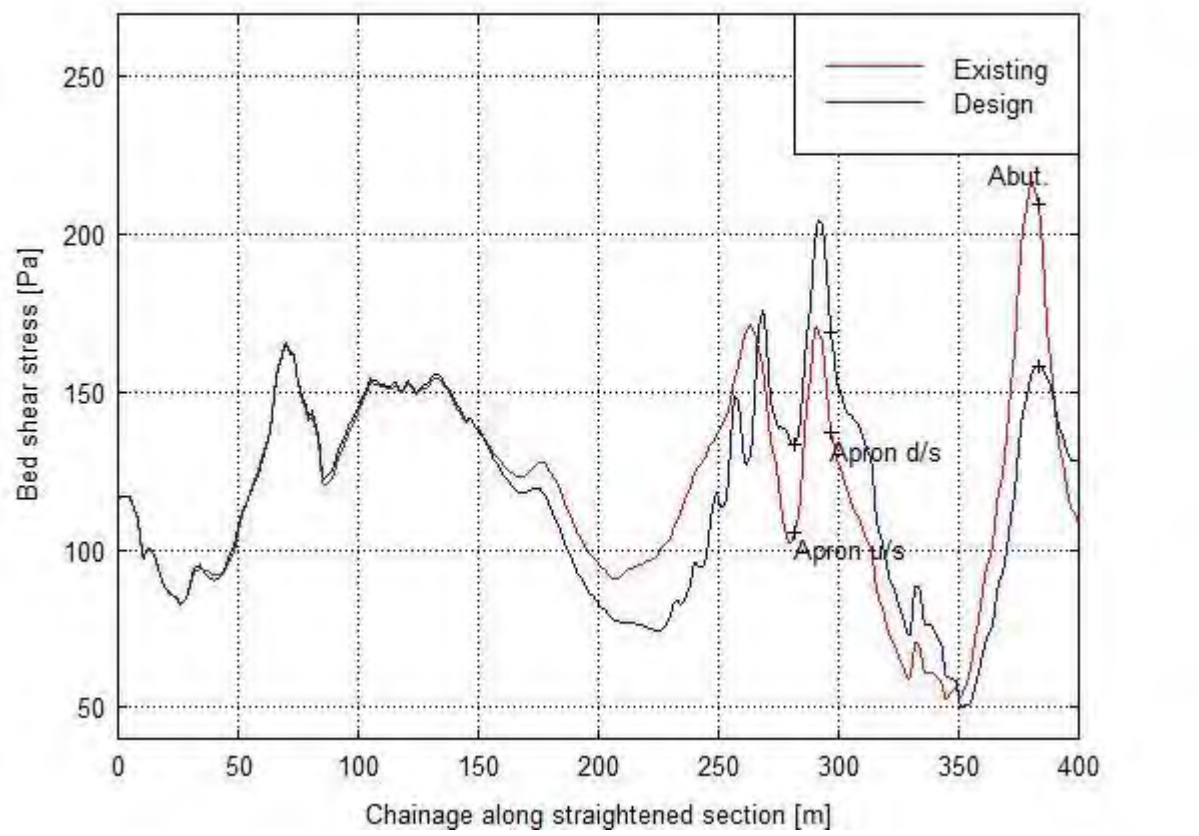


Figure 3.9. Bed shear stress along thalweg for existing (red line) and design (blue line) at Q_{200yr} peak. Positions of, apron and abutment indicated. Only the thalweg from the mid-reach 90 degree bend along the straightened section to the model exit is shown.

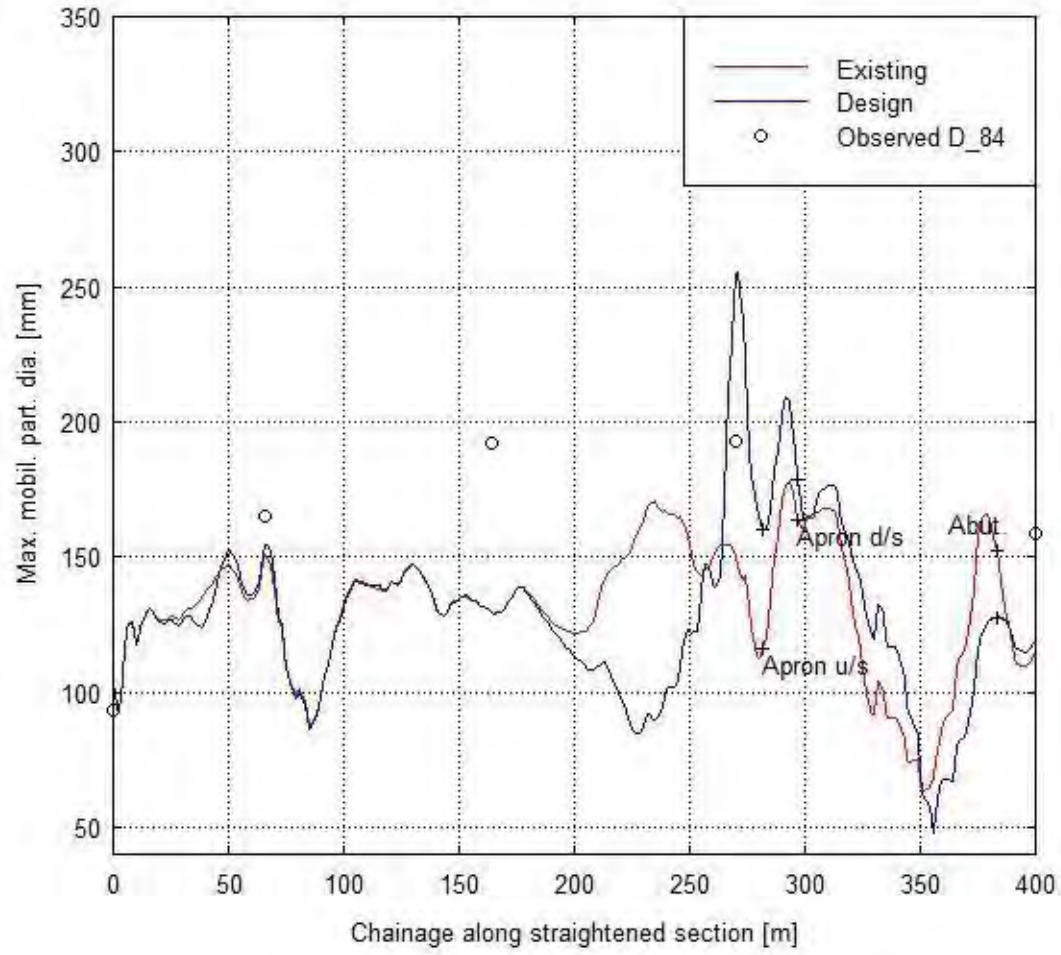


Figure 3.10. Maximum mobilised particle diameter for a Shields stress = 0.04 at Q_{2yr} peak. Only the thalweg from the mid-reach 90 degree bend along the straightened section to the model exit is shown. Observed D_{84} particle size shown for comparison.

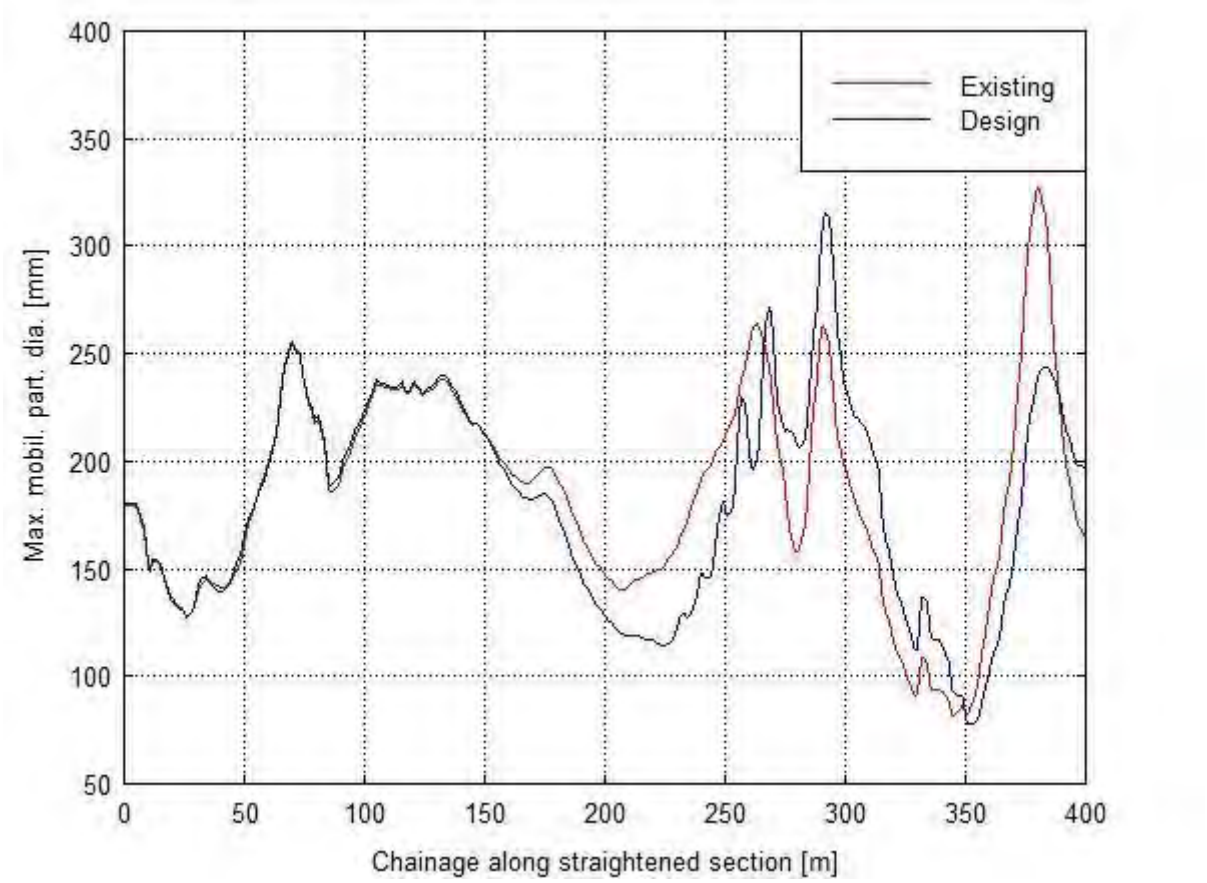


Figure 3.11. Maximum mobilised particle diameter for a Shields stress = 0.04 at Q_{200yr} peak. Only the thalweg from the mid-reach 90 degree bend along the straightened section to the model exit is shown.

3.3 LOG LOAD CALCULATIONS

The log load calculations are presented in Appendix C and provided in the associated Excel spreadsheet. The spreadsheet was created during the project to estimate the drag and buoyancy loads on the training logs during the Q_{200yr} peak. The methodology adopted was that of Brooks et al., 2006 and Abbe and Brooks, 2011.

Calculations on engineered log structures in rivers are subject to uncertainty, and the risks of a log structure coming free are significant- especially at Westnewton Bridge where the logs are large and could potentially block or damage the bridge itself. There are uncertainties in the magnitude of the discharge though the channel, actual (rather than depth averaged) velocity on approach to the logs, and estimation of the drag coefficient of wood structures. As a result, the calculations of the loads generated on the logs should be treated with caution, and a factor of safety has been used. For buoyant forces, a factor of safety of 2 has been used (and a dry wood density of 900 kg/m^3 assumed); for drag forces, a factor of safety of 1.6 is assumed. The log load calculations depend implicitly on the actual log dimensions used in construction- for the spreadsheet given a sample log size of 15 m length and 0.5 m diameter has been used. Depth averaged velocities vary over the logs, but the approach velocity of the water (i.e. as near as can be estimated to the free-stream) is 1.8 - 2.3 m/s. These

approximate values have been used to determine drag forces based on projected area in the flow (i.e. not including the area of the log buried into the bank) and assuming that the flow is normal to the log (the worst case for drag). The spreadsheet estimates a required ballast force or anchoring force required for each log. As an approximate guide the maximum load experienced is 1.6 tonnes, but this assumes that the log is maintained in place and is not undermined. Appendix C should be referred to for the detail in the log load calculations, and the values of length, width and exposed height of log adjusted depending on the 'as built' dimensions. Care should be taken during construction to protect the logs from undermining, scour, etc. If very rough logs are used in construction, the drag coefficient may be increased within the suggested range.

3.4 ENGINEERING DESIGN DRAWINGS

Engineering drawings were created in Civil 3D to give a precise and accurate representation of the designs (Appendix D). These drawings include scaled plan views of the designs showing the horizontal positioning of all design elements. Scaled cross sections and long profiles that were extracted at critical design locations to inform the vertical dimensions of the design, and their relationship to the existing ground, were provided where necessary. Detail sheets were also produced to show the design elements, not sufficiently represented in plan, section or profile views.

4. MONITORING/ ONGOING MANAGEMENT OF DESIGN

As discussed above, the highly dynamic geomorphic character of the site means that no design can be guaranteed to be stable in the long-term. Although the design produced is the most appropriate given physical processes and site constraints, post-construction monitoring and the potential for 'adaptive management' are strongly advised. A full topographic survey of a section of the channel extending ~200 m upstream and ~100 m downstream of the bridge should be conducted immediately after construction with further periodic resurveys undertaken after significant flood events (but at least annually even if no large flow events occur). Sediment sampling (Wolman-walk pebble counts) should also be conducted at the same time as topographic surveying, the information gathered providing further indication of sediment transport processes that may indicate implications for the design. Periodic walk-over surveys should also be conducted, inspecting specific elements of the design (e.g. condition of the log structures, sediment accumulating on the bridge apron, etc.) and recording condition with detailed photographs.

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APPENDIX A

FLUVIAL AUDIT METHODOLOGY

Fluvial Audit Methodology

INTRODUCTION

The procedure used to characterize the geomorphic and sedimentary regimes of the College Burn is an adaptation of the 'Fluvial Audit' methodology proper as described in Sear et al. (1995). It has been developed by Dr. H. Moir over the last 10 years for the application to Scottish river systems and used in peer-reviewed, published scientific literature (Moir et al. 2004, Moir and Pasternack 2008) and a number of grey literature project reports.

The approach is explicitly more process-based than 'Fluvial Audit', classifying channel character in terms of observed morphology, the physical expression and integration of fluvial processes. 'Fluvial Audit' is process-based in principal but is designed to incorporate data from the River Habitat Survey (RHS) methodology which is not process-based. The inventory approach to classifying stream character in RHS tends to confuse form and process and is therefore not the best approach to inform as to controls on the geomorphic character of a river system. Where there is not access to existing RHS data there is little justification in employing the 'Fluvial Audit' methodology proper.

APPROACH

The approach adopted here has two central theoretical concepts that concern the controls on the distribution of geomorphic process regimes in a river network. These are:

1. The hierarchical organisation of fluvial networks.

The physical characteristics of river systems are organized in a nested hierarchy, with physical processes operating at larger scales influencing those at successively finer resolutions (Frissell et al., 1986), ultimately controlling the micro-scale distribution of hydraulic and sediment transport processes (Figure A-1). The micro-, meso- and reach scales are therefore all equally critical elements within this hierarchy, with different geomorphic and ecological processes being relevant at each resolution. For instance, micro-scale factors will dictate the specific location that an animal selects habitat while the spatial distribution of meso-scale features will control the locations within a particular reach type where such conditions exist. The classification approach adopted here concentrates on the reach and morphological unit (meso) scales. The reconnaissance nature of the methodology precludes characterisation at the micro-scale that would require some degree of quantitative measurement and significantly increase survey time. Reach type is typically characterized at a relative scale of 10-100 channel widths in length with morphological units in the range 1-5 channel widths.

2. Basic physical controls on channel morphology.

The morphological character of the channel at a given location (i.e. reach type) is defined in terms of the relative balance between sediment supply and transport capacity (Figure A-2). In the case of Scottish upland gravel-bed streams, reach types typically progress from 'wandering' (Ferguson and Werritty, 1991) to pool-riffle to plane bed to step pool to cascade as the ratio of sediment supply to transport capacity decreases. This sequence represents a decreasing storage of alluvial sediment (mainly gravel and cobble sizes) within the active channel. The continuum also tends to be

associated with increasing channel slope and mean substrate size and a decrease in the frequency of dynamic channel behaviour. Some stretches of a stream may exhibit features of more than one reach type and are therefore classified as having transitional morphologies (e.g. pool-riffle/plane bed). An additional reach type of 'slow glide' is required in lower energy systems. This is a morphology indicative of a channel condition with low sediment supply and transport capacity (Figure A-2). At the next spatial scale down, characteristic morphological units are associated with each reach type over a longitudinal scale of many (>10) channel widths (Montgomery and Buffington, 1997); indeed, the assemblage of morphological units to some extent defines reach type. Despite being explicitly linked through the concept of hierarchical organization, reach type and morphological unit scale data provide different information. Reach type indexes the general spatial distribution of 'geomorphic regime' of a river system (i.e. the approximate ratio of sediment supply to transport capacity) while morphological unit data provides higher resolution qualitative insight as to meso-scale hydraulic, sedimentary and instream habitat conditions.

Set within these central concepts, the spatial distribution of channel morphology classifications (at the reach and morphological unit scales) and factors that influence the sediment supply and transport capacity regimes are recorded. All spatial information is obtained from a hand-held Global Positioning System (GPS) with typical accuracy ±5m.

Reach type classification

This is a qualitative, expert judgment classification approach and developed from established procedures (Montgomery and Buffington, 1997; Brierley and Fryirs, 2000). As discussed above, it is based on the physical character of the channel, particularly the presence and type of bedforms. Classification is not carried out based on a single point observation. Rather, channel condition is observed over at least 10 channel widths so that the classification is commensurate with the spatial resolution defined for reach type (Figure A-1).

Classification of controls on process regime

Additional to the reach-scale morphological classification, factors that influence the process regime of the channel (i.e. those potentially influencing the delivery and movement of sediment to the channel) are also recorded. These data can subsequently be linked to the morphological data to provide some insight as to the dominant controls on spatial patterns of physical channel condition. These factors are recorded as linear (e.g. bank erosion, tree cover, bank protection) or point data (e.g. tributary input, large woody debris, weir). The upstream and downstream limits of linear features are recorded. Where relevant, the river bank the data is associated with is also recorded. Data is collected in the following three categories:

i) *Sediment input/ storage*:

a. Bank erosion (including poaching by livestock). Linear (often point for poaching). This is categorized in terms of severity depending on the condition of the bank, height of bank and other indicators as to sediment input rate (e.g. previously bank-side fences within channel. Collapsing bank-side trees, condition of adjacent channel bed).
b. Tributaries. Point. These are characterized as low, moderate or large relative sediment input depending on the character of main-stem channel at the confluence

(e.g. presence of confluence bar) and the characteristics of tributary sub-basin (e.g. drainage area relative to the main-stem channel, relief, rainfall).

c. Depositional sedimentary features. Linear. The longitudinal extent, type (e.g. point, lateral, transverse, medial) and 'dynamic condition' of bar features is recorded. 'Dynamic condition' is a subjective definition depending on the appearance of the bar (e.g. vegetated or not, sorting, abrasion marks on clasts etc).

ii) *Vegetation*:

a. Bank-side tree cover. Linear. Recorded when tree cover is suffiently close to the active channel to influence fluvial process (e.g. local hydraulics, bank stability).

b. Large Woody Debris (LWD). Linear or point depending on extent of feature. The degree to which the feature spans the active channel (and, therefore, impacts fluvial processes) can be recorded.

c. Macrophytes. Linear. Sections of the channel bed exhibiting extensive macrophyte cover are recorded. Macrophythes can be a very important control on fluvial process in low energy river systems.

iii) *River engineering*:

a. Bank protection. Linear. The extent, type (e.g. gabions, boulder, wall etc) and state of repair of bank protection is recorded and then categorized in terms of likely impact to fluvial processes as low, moderate or high.

b. Bridges. Point. The number of bridge piers impacting fluvial process (i.e. piers within the active channel) and the clearance from the channel bed to the bridge span (indicating the likelihood of impedance of flood flows) are recorded.

c. Weirs. Point. The height and state of repair of weir structures are recorded.

d. Croys/ groynes. Point. The height, state of repair and extent into the active channel of croys/ groynes are recorded.

e. Fence crossings. Point. Fences that transversely cross the channel and potentially impact the movement of water, sediment and debris are recorded. Evidence of trapped debris or associated sedimentary deposits is recorded.

f. Ford crossings. Point. Vehicle ford crossings are recorded with the observed impact to the channel bed noted.

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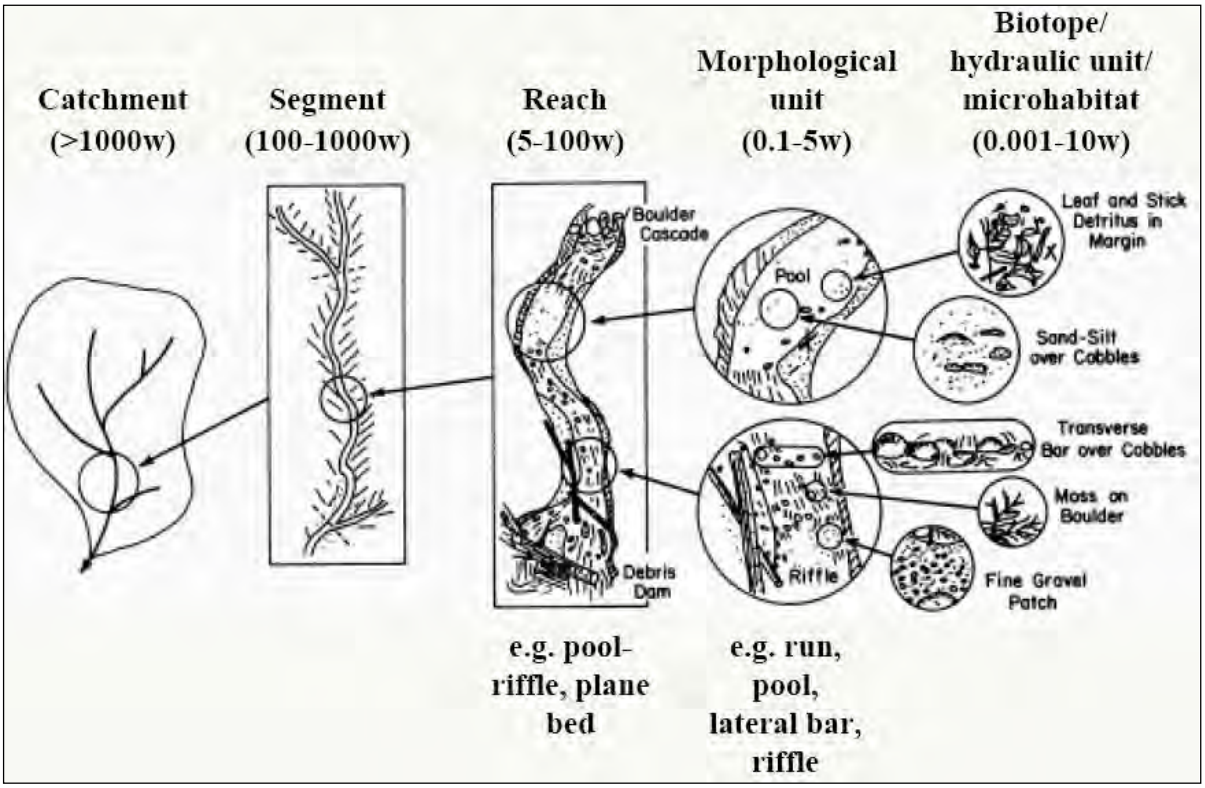


Figure A-1. Conceptual diagram of the spatial hierarchical organization of river networks (modified from Frissell et al. 1986).

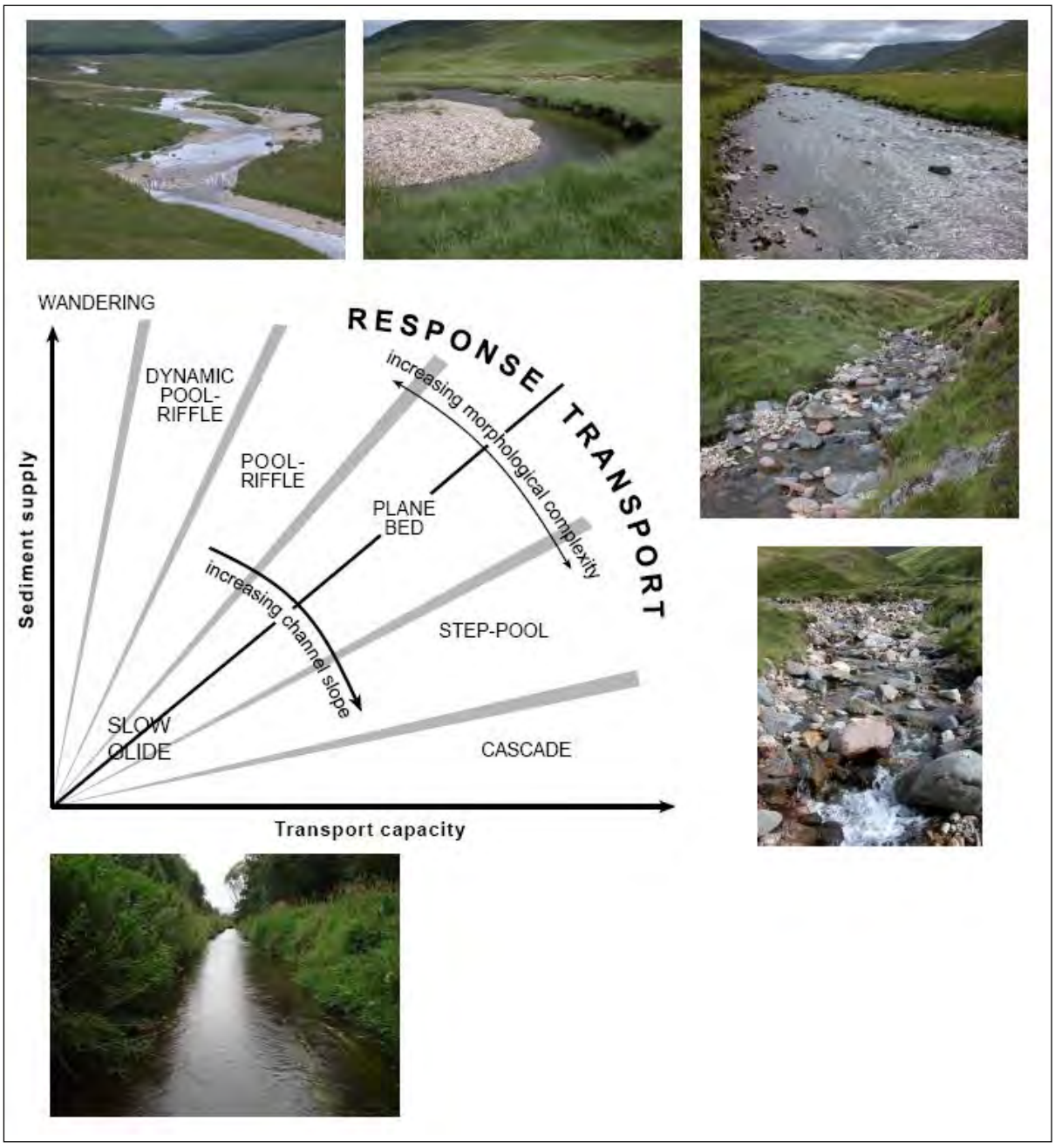


Figure A-2. Conceptual diagram of the physical controls on reach-scale channel morphology (modified from Moir et al., 2004).

APPENDIX B

FLUVIAL AUDIT MAPS

Legend

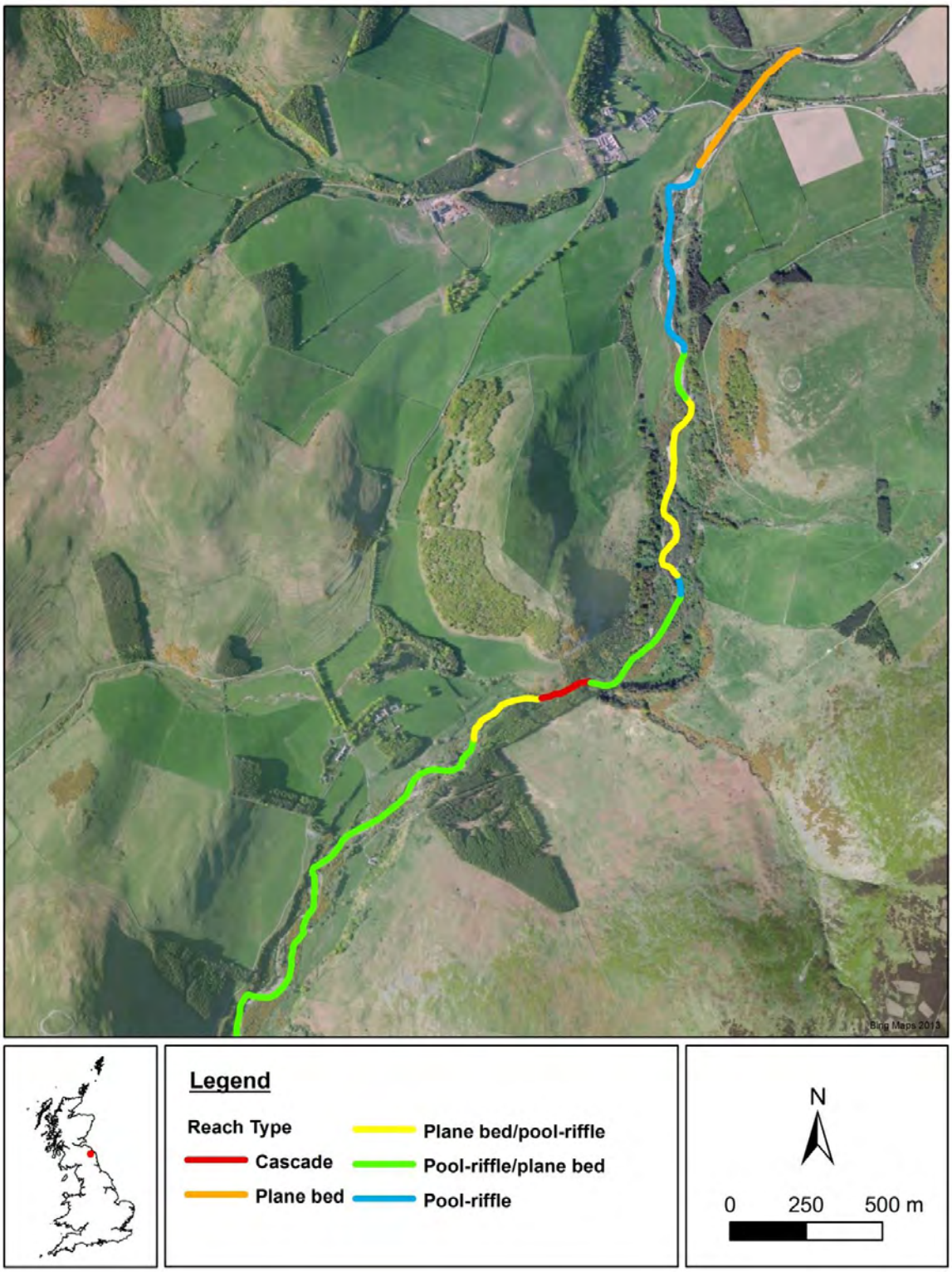
Reach Type

- Cascade
- Plane bed
- Plane bed/pool-riffle
- Pool-riffle/plane bed
- Pool-riffle

N

0 250 500 m

Notes:	cbec eco engineering	*Westnewton Bridge modeling & design* **Reach type - upstream**		
		Project No. U13-1003	Created By: GK	**Figure B1**



Notes:	cbec eco engineering	*Westnewton Bridge modeling & design* **Reach type - downstream**		
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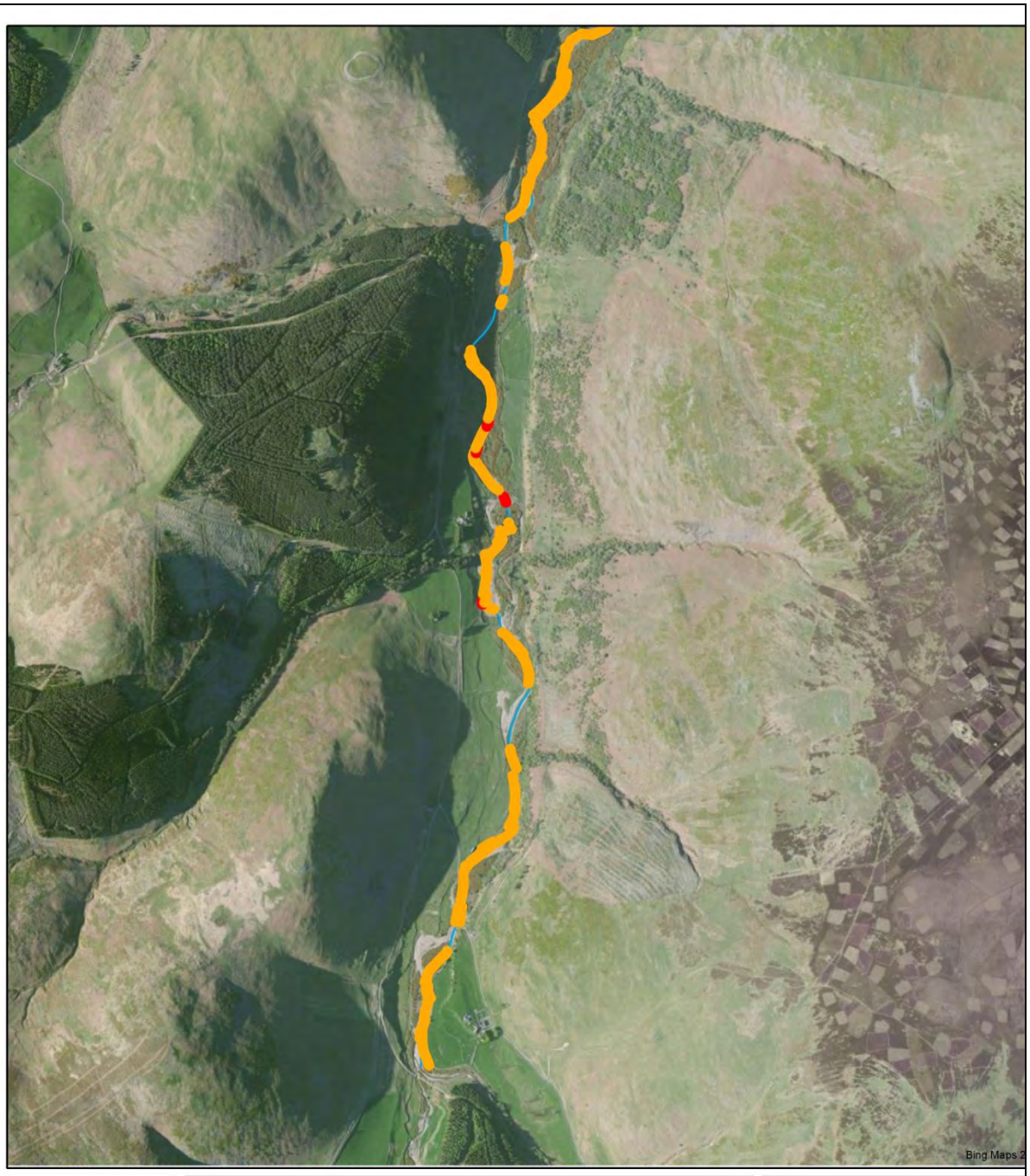


Legend

Sediment Deposition — **Surveyed River**

cobble

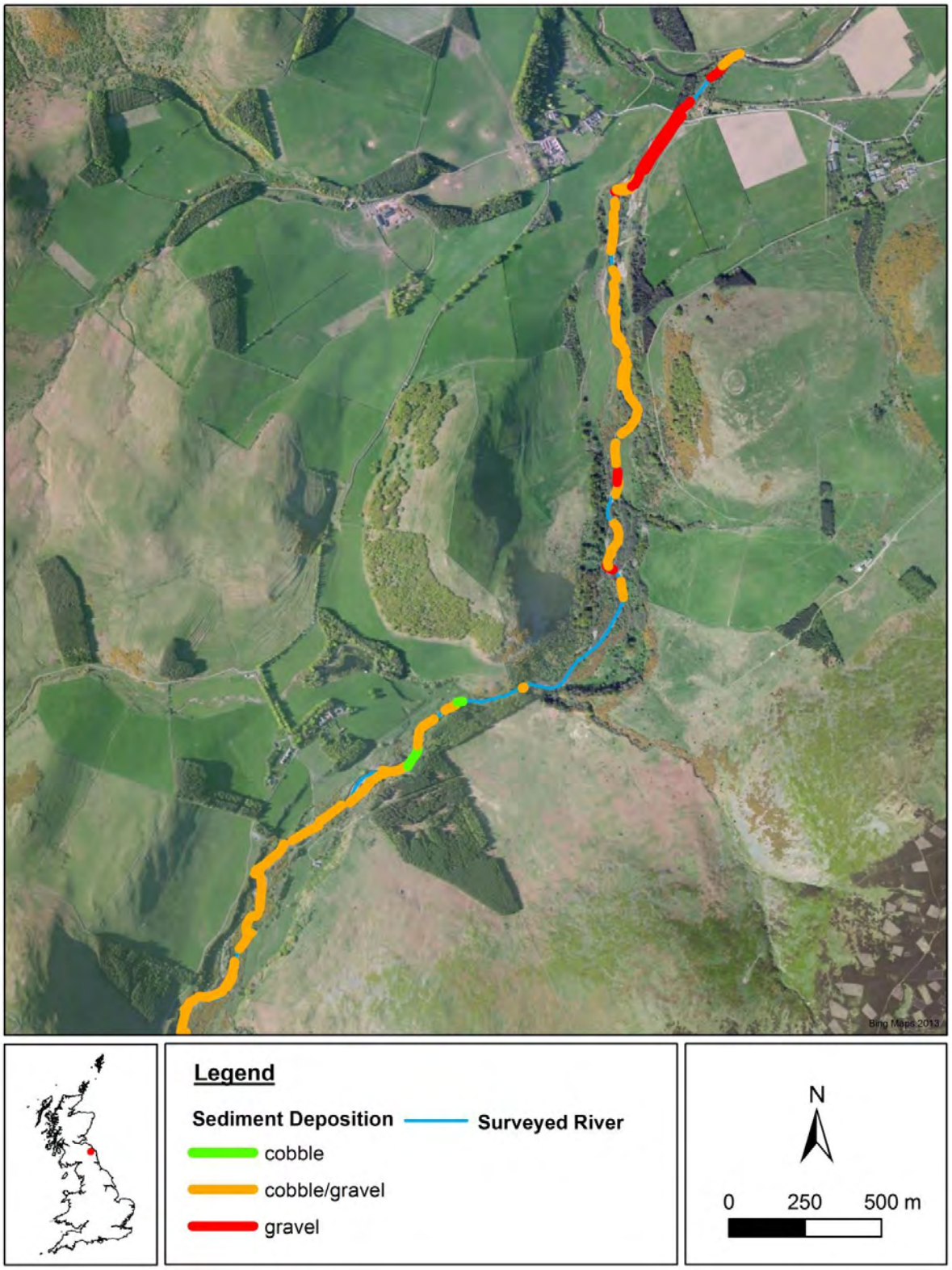
cobble/gravel

gravel

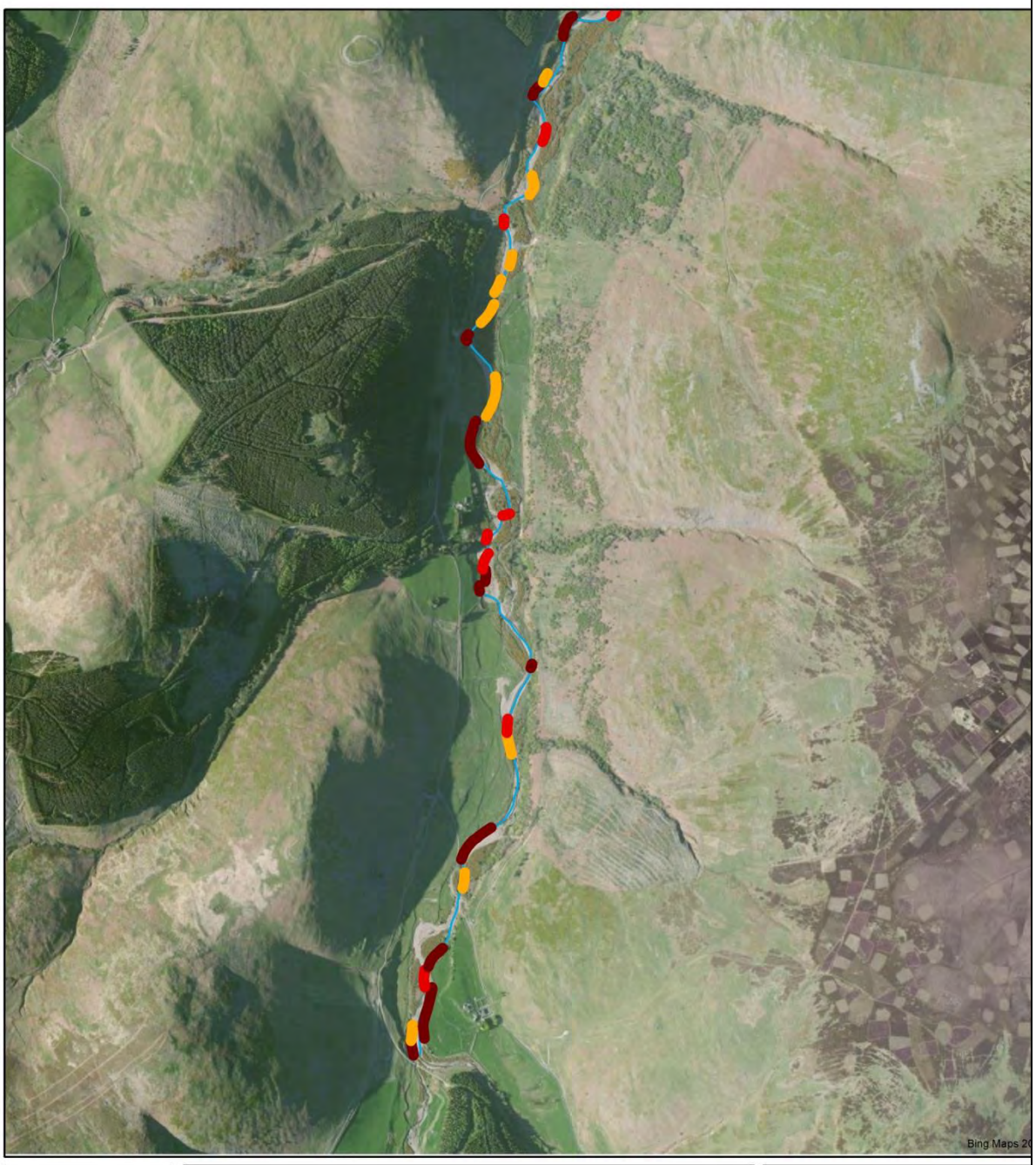
N

0 250 500 m

Notes:	cbec eco engineering	*Westnewton Bridge modeling & design* **Alluvial deposition - upstream**		
		Project No. U13-1003	Created By: GK	**Figure B3**



Notes:		*Westnewton Bridge modeling & design*		
		Alluvial deposition - downstream		
		Project No. U13-1003	Created By: GK	**Figure B4**



Legend

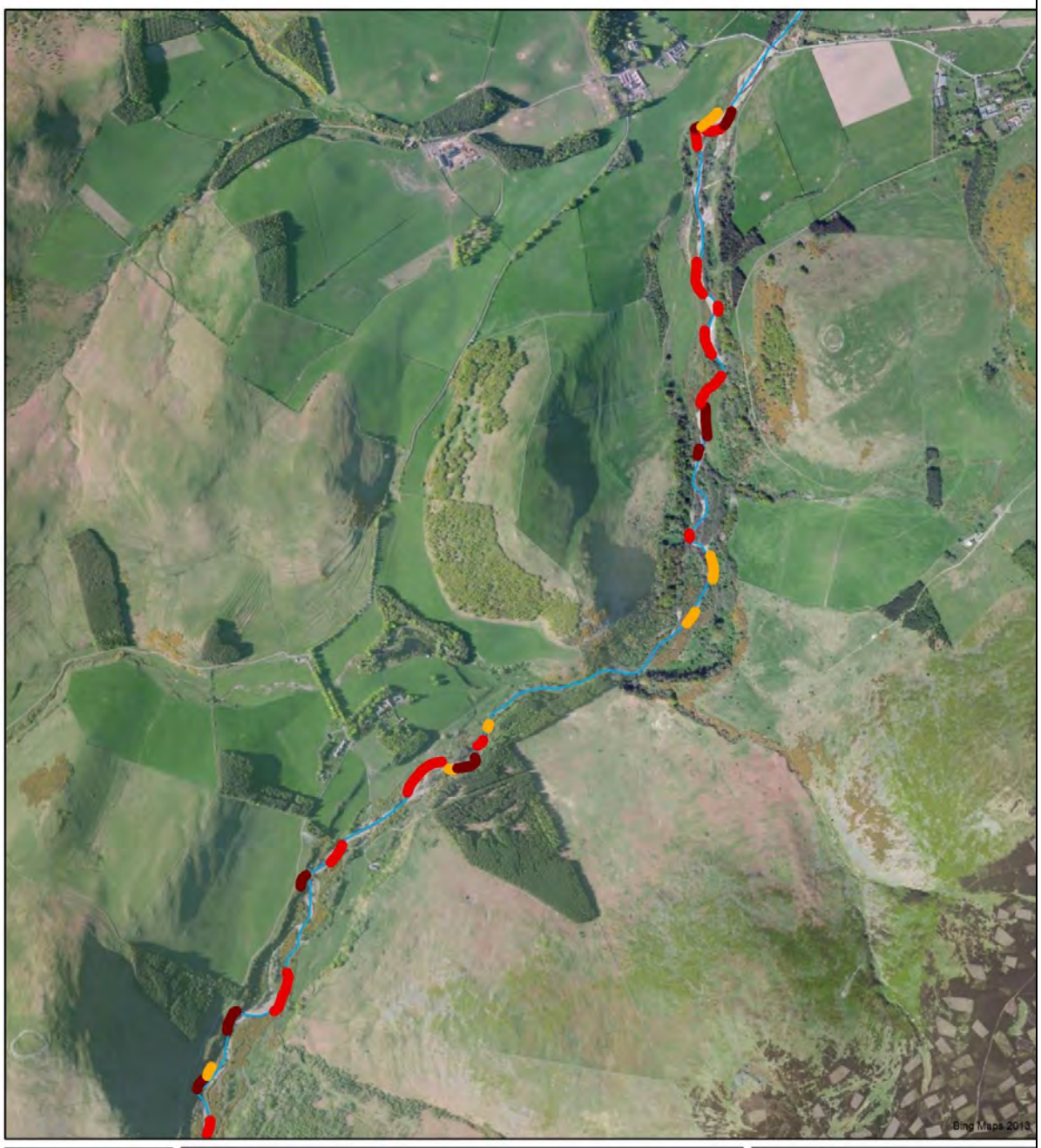
Bank Erosion
- major
- moderate
- minor

Surveyed River

N

0 250 500 m

Notes:		*Westnewton Bridge modeling & design* **Bank erosion - upstream**		
	cbec eco engineering	Project No. U13-1003	Created By: GK	**Figure B5**



Legend

Bank Erosion
- major
- moderate
- minor

Surveyed River

N

0 250 500 m

Notes:		*Westnewton Bridge modeling & design* **Bank erosion - downstream**		
	cbec eco engineering	Project No. U13-1003	Created By: GK	**Figure B6**

Legend

Engineering

- Bank Protection
- Bridge (no piers)
- Bridge (with piers)
- Dredged/straightened
- Other
- Weir
- Embankments
- **Surveyed River**

N

0 250 500 m

Notes:		*Westnewton Bridge modeling & design* **Engineering - upstream**		
	cbec eco engineering	Project No. U13-1003	Created By: GK	**Figure B7**

Notes:	cbec eco engineering	*Westnewton Bridge modeling & design* **Engineering - downstream**		
		Project No. U13-1003	Created By: GK	**Figure B8**

APPENDIX C

LOG LOAD CALCULATIONS

A spreadsheet was created during the project to estimate the drag and buoyancy loads on the training logs during the Q200year peak. The methodology adopted was that of Brooks et al., 2006, and Abbe and Brooks, 2011.

Calculations on engineered log structures in rivers is subject to uncertainty, and the risks of a log structure coming free are significant – especially at Westnewton Bridge where the logs are large and could potentially block or damage the bridge itself. There are uncertainties in the magnitude of the discharge though the channel, actual (rather than depth averaged) velocity on approach to the logs, and drag coefficient of wood structures. As a result, the calculations of the loads generated on the logs should be treated with caution, and a factor of safety has been used. For buoyant forces, a factor of safety of 2 has been used (and a dry wood density of 900kg/m^3 assumed); for drag forces, a factor of safety of 1.6 is assumed. The log load calculations depend implicitly on the actual log dimensions used in construction- for the spreadsheet given a sample log size of 15m length and 0.5m diameter has been used. These values (factor of safety, basic log dimensions and height of log protruding above surface) are in green shading at the top of the spreadsheet and may be altered depending on construction. See Figure C12.

GREEN SHADING INDICATES VARIABLES WHICH MAY BE ALTERED BY DESIGNER		
NOMENCLATURE & DEFINITIONS		
GENERAL:		
FSD	1.6	FACTOR OF SAFETY FOR DRAG
FSB	2	FACTOR OF SAFETY FOR BOUYANCY
D	0.5	LOG DIAMETER (m) (DEPENDS ON LOGS AS USED IN CONSTRUCTION)
L	15	LOG LENGTH (m) (DEPENDS ON LOGS AS USED IN CONSTRUCTION)
H	0.4	HEIGHT OF LOG ABOVE SURFACE (m) (CONSERVATIVE DESIGN BUT BEFORE EROSION)

Figure C12 Basic input variables for spreadsheet

A plan view of the design logs placed in the hydraulic model DEM is also given in the spreadsheet and shown here in Figure C13.

REFERENCES

Abbe T, Brooks A, 2011. Geomorphic, Engineering, and Ecological Considerations when using wood in River Restoration, in Stream Restoration in Dynamic Fluvial Systems, A Simon, S Bennet and J Castro editors, AGU Washington

Brooks, A. et al., 2006. Design guideline for the reintroduction of wood into Australian stream, Land & Water Australia, Canberra.

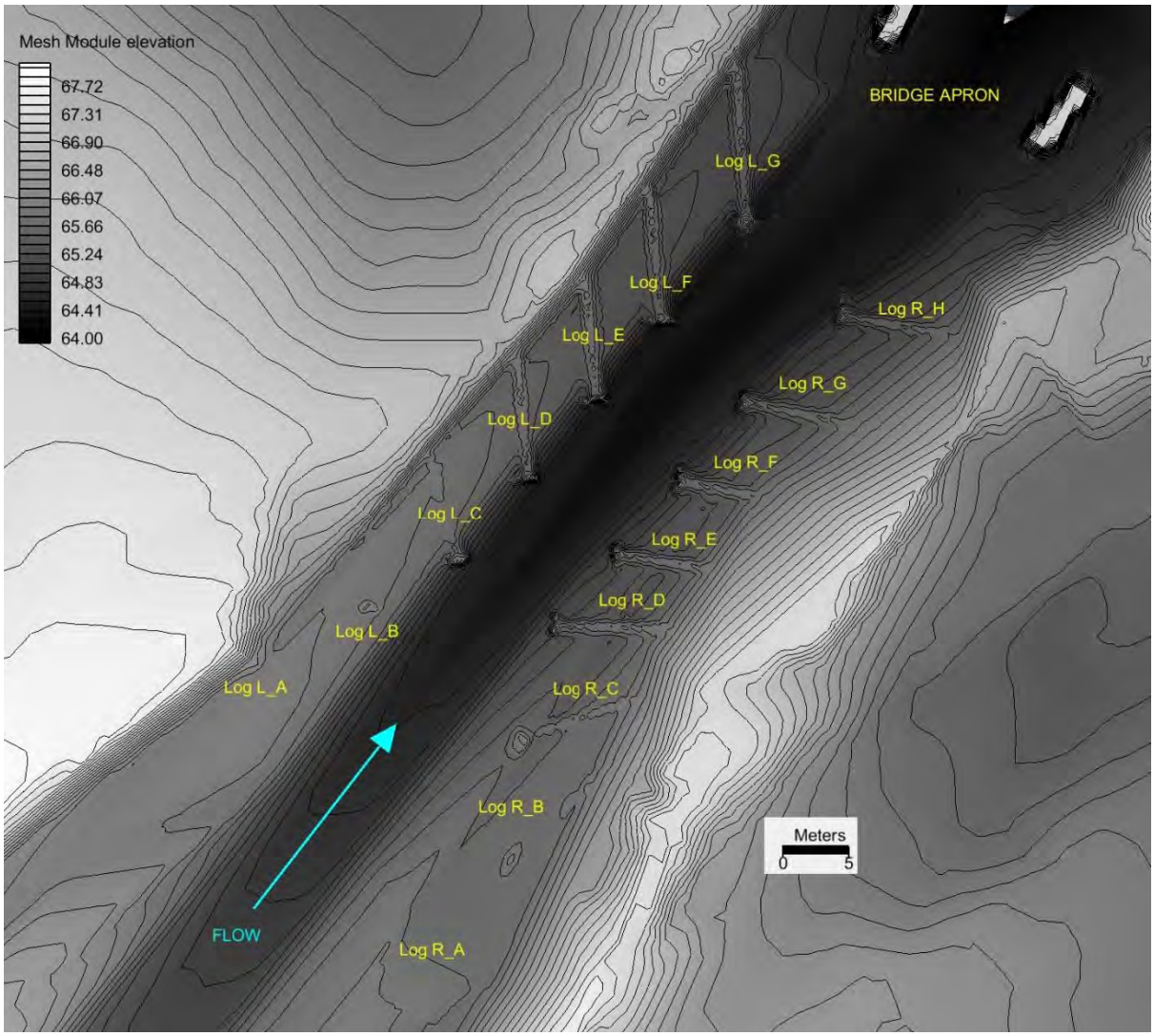


Figure C13 Plan view of design log pairs.

The right bank logs are labelled R_A to H and the left bank logs L_ A to G. Only logs C and downstream are modelled in the spreadsheet as logs A to B are more fully submerged in the bed material. Locations of the log root ball and buried bank end are taken from the appropriate CAD drawings and are as modelled in the 2D hydraulic model.

To calculate drag forces on the semi-submerged logs an area consisting of the exposed height times exposed length is used, and the drag coefficient is estimated as that of a cylinder (0.8-1.2) a range of values published in Gippel et al., 1996.

For the root wads, no extra anchoring resistance is assumed.

For the ballasting weight of bed material a density of quartz gravel has been assumed (2650kg/m^3), and a friction angle of 40 degrees assumed (Brooks et al., 2006).

The formulae used to determine the buoyant forces and drag forces on each log are summarised in Figure C14. The computations of drag force require an estimate of the 'freestream' depth average velocity in front of each log and this has been estimated from the 2D hydraulic model output at the Q200 year peak (shown on the spreadsheet). Note though that the drag force varies with the square

of velocity. Bed shear stress on each log was estimated by the 2D hydraulic model at the Q200 year peak. Pressure drag (from the drag coefficient) dominates the drag forces.

Description	Symbol or formula	Unit
Factor of safety	F_s	-
Length of log	L	m
Diameter of log	D	m
Length of log exposed to flow	L_E	m
Height of log exposed to flow	H	m
Projected area of log exposed to flow	$S_E = HL_E$	m^2
Volume of log submerged in flow	$V_S = \pi(D/2)^2 L_E$	m^3
Density of water	ρ	^{3}
Density of wood	ρ_{wood}	^{3}
Depth average flow velocity	U	m/s
Drag coefficient	C_D	-
Angle of repose for gravel	ϕ	radians
Buoyancy force	$F_B = V_S \rho g \left(1 - \frac{\rho_{\text{wood}}}{\rho}\right)$	N
Ballast weight req. for buoyancy	$W_B = F_B F_s$	N
Pressure drag	$F_{Dp} = \frac{1}{2}\rho U^2 S_E C_D$	N
Shear force	$F_{Ds} = L_E D\tau$	N
Total drag force	$F_D = F_{Dp} + F_{Ds}$	N
Friction force	$F_f = (W_B - F_B)\tan\phi = F_D F_s$	N
Ballast weight req. for drag	$W_B = F_B + \frac{F_D F_s}{\tan\phi} - \pi(L - L_E)(D/2)^2 \rho_{\text{wood}} g$	N

Figure C14 Formulae used to determine drag and buoyant forces on logs.

The spreadsheet determines the amount of extra ballast/ anchoring load required for each of the logs. It is recommended that the maximum value for any of the logs is used on each log, given that the velocities over the logs are dependent on all of the logs being in place. For the sample dimensions and assumptions described above, the maximum required restraining force is 1.6tonnes (15.6kN).

The log structures should be maintained to ensure adequate integrity of ballast and or anchors, structural integrity of the logs, trapping of debris, deposition, scour and undercutting of the logs by flow.

COLLEGE BURN AT WESTNEWTON BRIDGE

VERTICAL LOADS ANALYSIS ON DESIGN TRAINING LOGS (NO MOMENTS/TORQUES CONSIDERED).

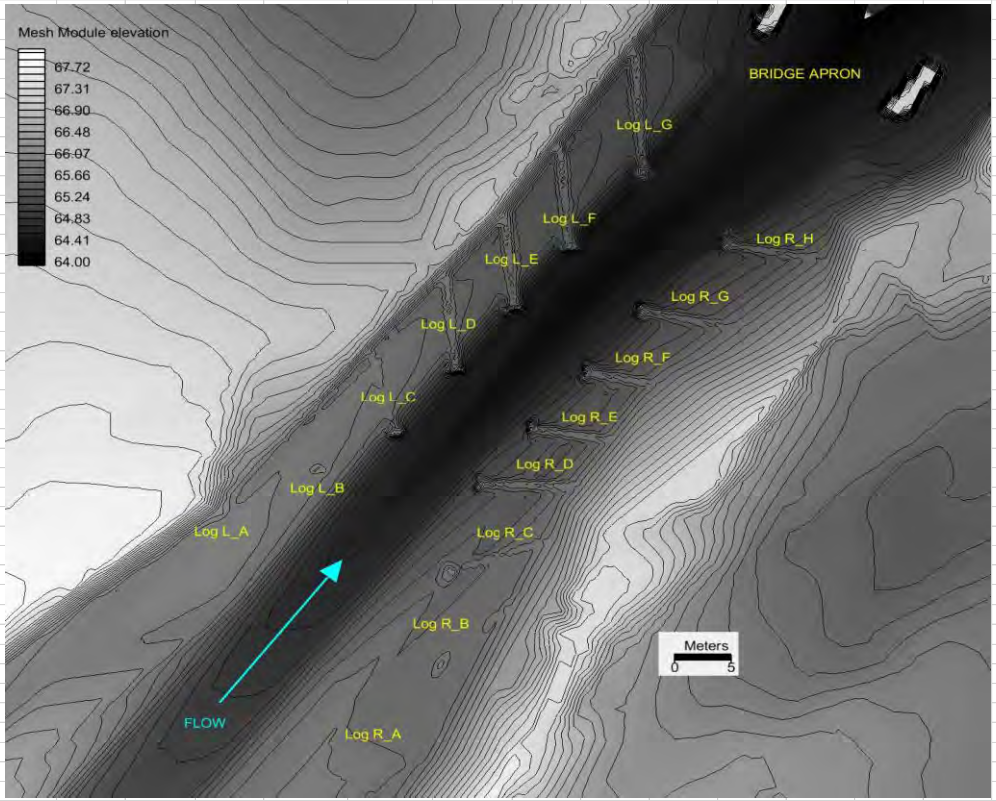
PREPARED BY CBEC UK LTD, APRIL 2014

LARGE FACTORS OF SAFETY SHOULD BE USED, AND BED EROSION/MAINTENANCE CONSIDERED.

ORANGE SHADING IS OUTPUT OF MAX BALLAST WEIGHT REQUIRED FOR EACH LOG.

GREEN SHADING INDICATES VARIABLES WHICH MAY BE ALTERED BY DESIGNER

ORIENTATION PLOT FROM 2D HYDRAULIC MODEL



NOMENCLATURE & DEFINITIONS

GENERAL:		
FSD	1.6	FACTOR OF SAFETY FOR DRAG
FSB	2	FACTOR OF SAFETY FOR BOUYANCY
D	0.5	LOG DIAMETER (m) (DEPENDS ON LOGS AS USED IN CONSTRUCTION)
L	15	LOG LENGTH (m) (DEPENDS ON LOGS AS USED IN CONSTRUCTION)
H	0.4	HEIGHT OF LOG ABOVE SURFACE (m) (CONSERVATIVE DESIGN BUT BEFORE EROSION)
X(ROOT)		APPROX EASTING OF ROOT BALL (m)
X(BURIED)		APPROX EASTING OF POINT WHERE LOG BECOMES BURIED (m)
Y(ROOT)		APPROX NORTHING OF ROOT BALL (m)
Y(BURIED)		APPROX NORTHING OF POINT WHERE LOG BECOMES BURIED (m)
RHO_WOOD	900	DRY DENSITY OF LOGS (kg/m^3) [ASSUMED]
L_E		EXPOSED LENGTH (m)
S_E		AREA EXPOSED TO FLOW (PROJECTED) (m^2)
V_S		SUBMERGED VOLUME (m^3)
press		POST SCRIPT- PRESSURE RELATED FORCES
shear		POST SCRIPT- SHEAR RELATED FORCES
_D		POST SCRIPT- DRAG RELATED
_B		POST SCRIPT- BOUYANCY RELATED
FLUID MECHANICS:		
RHO	1000	DENSITY OF WATER (kg/m^3)
RE	2.20E+06	REYNOLDS NUMBER
Cd	0.8	CYLINDER DRAG COEFFICIENT [RANGE 1.2-0.8]
F_D		DRAG (N)
TAU		BED SHEAR (Pa)
F_B		BOUYANCY FORCE (N)
U		FLOW VELOCITY (m/s)
BED MATERIAL:		
WBL		BALLAST WEIGHT (kg)
PHI	40	FRICTION ANGLE COARSE GRAVEL (DEGREES) [D'AOUST AND MILLAR, 2000]

OTHER ASSUMPTIONS

DESIGN FLOW IS Q200yr ESTIMATE	
H=0.4M	EXPOSED HEIGHT IS 0.4M MAX FOR DESIGN SCENARIO- THIS MAY INCREASE WITH EROSION
U	MAX DEPTH AVERAGED VELOCITY MAGNITUDE ON APPROACH TO EACH LOG (SEE FIGS)
TAU	MAX BED SHEAR OVER LOG SECTIONS (AT MIDPOINT) FROM 2D HYDRAULIC MODEL
_A,_B LOGS ARE SO WELL BURIED THAT NO LOAD COMPUTATIONS NECESSARY	

COMPUTATIONS

	LOG GEOMETRY FROM CAD MODEL/DEM				Exposed length	Projected area	Subm. volume	HYDRAULICS			Total bouyancy	*Pressure drag (N)*	*Friction drag (N)*	Total drag (N)	Extra ballast (N)	Extra ballast (N)	Ballast required TONNES	(kg/m)
LOG NAME	**X (ROOT)**	**Y(ROOT)**	**X(BURIED)**	**Y(BURIED)**	**L_E**	**S_E**	**V_S**	**U**	**TAU**		**F_B**	**F_D press**	**F_D shear**	**F_D**	**WBL_D**	**WBL_B**	**WBL**	**WBL/L**
L_C	390742.1	630345.1	390739.9	630352.9	8.08	3.23	1.58	1.90	64		1555	4665	258	4923	-1553	3110	**0.32**	**46**
L_D	390747.4	630351.4	390746.6	630360.5	9.16	3.66	1.80	2.20	78		1764	7094	357	7451	5167	3527	**0.53**	**90**
L_E	390752.6	630357.4	390751.8	630366.3	8.97	3.59	1.76	2.30	100		1727	7592	448	8040	5749	3454	**0.59**	**97**
L_F	390757.6	630363.4	390756.6	630373.2	9.91	3.96	1.94	2.50	110		1907	9908	545	10453	11972	3815	**1.22**	**240**
L_G	390764.0	630371.0	390763.3	630382.8	11.77	4.71	2.31	2.30	109		2267	9965	642	10607	15674	4533	**1.60**	**495**
R_C	390747.4	630331.3	390756.4	630334.4	9.47	3.79	1.86	1.80	42		1823	4908	199	5107	1593	3646	**0.37**	**67**
R_D	390749.8	630339.8	390758.7	630339.5	8.86	3.54	1.74	1.90	67		1705	5116	297	5413	812	3411	**0.35**	**57**
R_E	390754.5	630345.2	390761.7	630344.0	7.28	2.91	1.43	2.00	77		1402	4660	280	4940	-3095	2803	**0.29**	**37**
R_F	390759.3	630350.8	390765.9	630349.4	6.73	2.69	1.32	2.00	90		1296	4307	303	4610	-4830	2591	**0.26**	**32**
R_G	390764.3	630356.8	390773.1	630354.9	9.00	3.60	1.77	2.10	106		1732	6349	477	6826	3436	3465	**0.35**	**59**
R_H	390771.8	630363.4	390780.3	630361.8	8.87	3.55	1.74	1.90	93		1708	5125	413	5538	860	3417	**0.35**	**57**

FIGURES: HEIGHT ABOVE BED OF PROTRUDING LOG (BLACK LINES); VELOCITY ALONG A LINE CONNECTING LOG MID-POINTS) RED (LEFT) AND BLUE (RIGHT) LINES.

OTHER ASSUMPTIONS

DESIGN FLOW IS Q200yr ESTIMATE

H=0.4M EXPOSED HEIGHT IS 0.4M MAX FOR DESIGN SCENARIO- THIS MAY INCREASE WITH EROSION

U MAX DEPTH AVERAGED VELOCITY MAGNITUDE ON APPROACH TO EACH LOG (SEE FIGS)

TAU MAX BED SHEAR OVER LOG SECTIONS (AT MIDPOINT) FROM 2D HYDRAULIC MODEL

_A,_B LOGS ARE SO WELL BURIED THAT NO LOAD COMPUTATIONS NECESSARY

COMPUTATIONS					Exposed	Projected	Subm.			Total	*Pressure*	*Friction*	Total	Extra	Extra	**Ballast required**	
	LOG GEOMETRY FROM CAD MODEL/DEM				length	area	volume	HYDRAULICS		bouyancy	*drag (N)*	*drag (N)*	drag (N)	ballast (N)	ballast (N)	TONNES	(kg/m)
LOG NAME	X (ROOT)	Y(ROOT)	X(BURIED	Y(BURIED)	L_E	S_E	V_S	U	TAU	F_B	F_D press	F_D shear	F_D	WBL_D	WBL_B	WBL	WBL/L
L_C	390742.1	630345.1	390739.9	630352.9	8.08	3.23	1.58	1.90	64	1555	4665	258	4923	-1553	3110	**0.32**	**46**
L_D	390747.4	630351.4	390746.6	630360.5	9.16	3.66	1.80	2.20	78	1764	7094	357	7451	5167	3527	**0.53**	**90**
L_E	390752.6	630357.4	390751.8	630366.3	8.97	3.59	1.76	2.30	100	1727	7592	448	8040	5749	3454	**0.59**	**97**
L_F	390757.6	630363.4	390756.6	630373.2	9.91	3.96	1.94	2.50	110	1907	9908	545	10453	11972	3815	**1.22**	**240**
L_G	390764.0	630371.0	390763.3	630382.8	11.77	4.71	2.31	2.30	109	2267	9965	642	10607	15674	4533	**1.60**	**495**
R_C	390747.4	630331.3	390756.4	630334.4	9.47	3.79	1.86	1.80	42	1823	4908	199	5107	1593	3646	**0.37**	**67**
R_D	390749.8	630339.8	390758.7	630339.5	8.86	3.54	1.74	1.90	67	1705	5116	297	5413	812	3411	**0.35**	**57**
R_E	390754.5	630345.2	390761.7	630344.0	7.28	2.91	1.43	2.00	77	1402	4660	280	4940	-3095	2803	**0.29**	**37**
R_F	390759.3	630350.8	390765.9	630349.4	6.73	2.69	1.32	2.00	90	1296	4307	303	4610	-4830	2591	**0.26**	**32**
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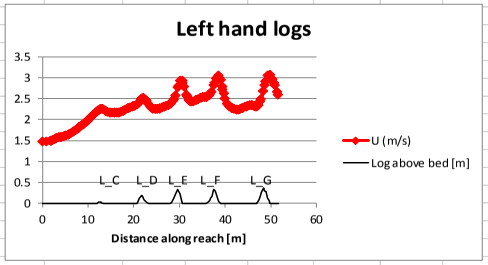
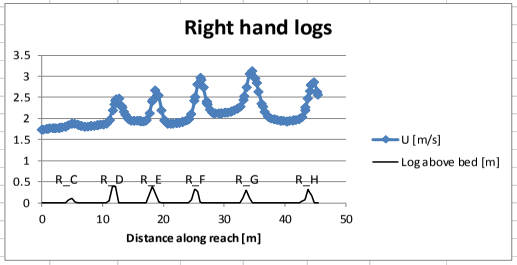
FIGURES: HEIGHT ABOVE BED OF PROTRUDING LOG (BLACK LINES); VELOCITY ALONG A LINE CONNECTING LOG MID-POINTS) RED (LEFT) AND BLUE (RIGHT) LINES.



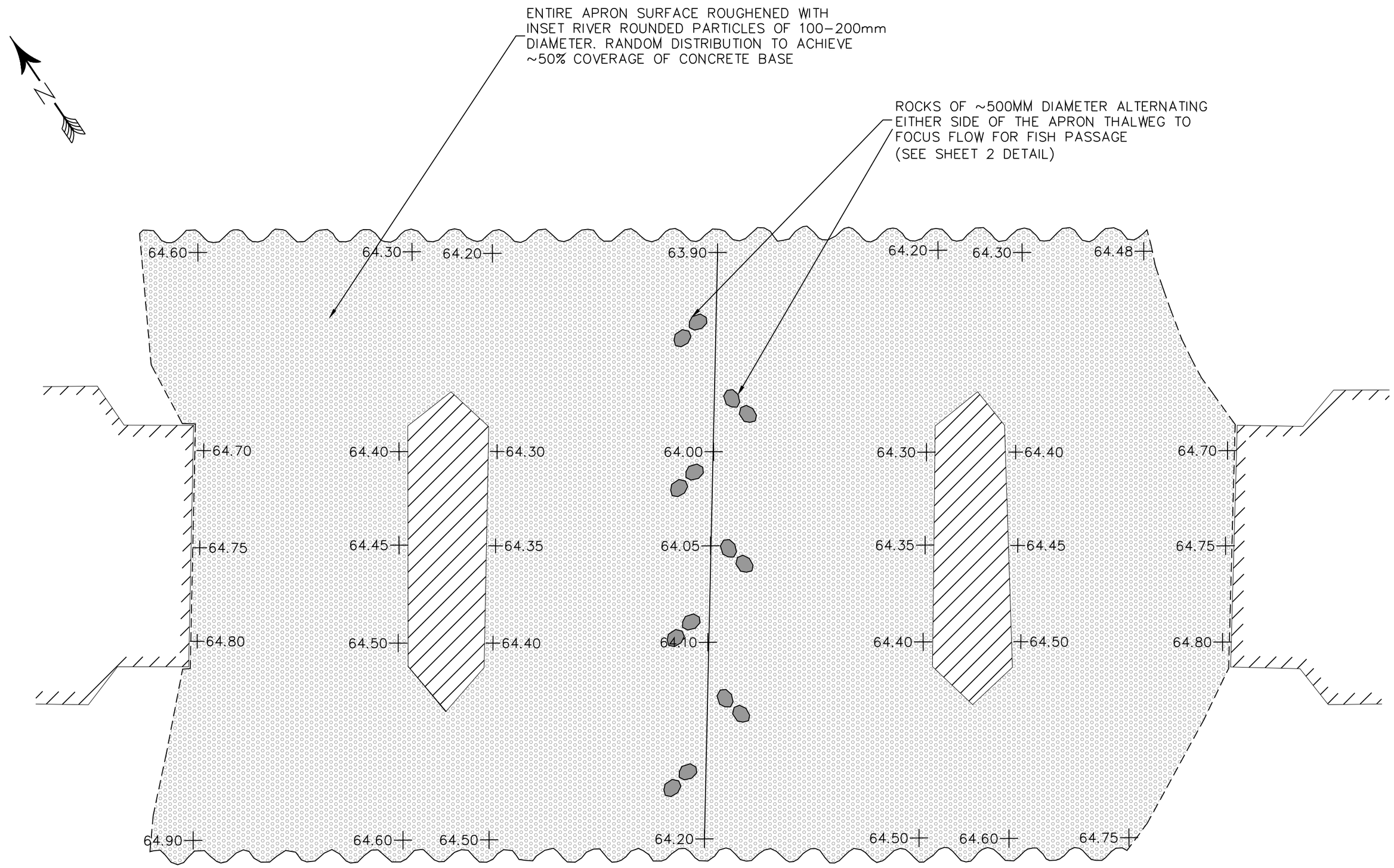


FORMULAE USED (SEE SIMON ET AL, STREAM RESTORATION IN DYNAMIC FLUVIAL SYSTEMS, AGU, 2011)

Description	Symbol or formula	Unit
Factor of safety	F_s	-
Length of log	L	m
Diameter of log	D	m
Length of log exposed to flow	L_E	m
Height of log exposed to flow	H	m
Projected area of log exposed to flow	$S_E = HL_E$	m^2
Volume of log submerged in flow	$V_S = \pi(D/2)^2 L_E$	m^3
Density of water	ρ	^{3}
Density of wood	ρ_{wood}	^{3}
Depth average flow velocity	U	m/s
Drag coefficient	C_D	-
Angle of repose for gravel	ϕ	radians
Buoyancy force	$F_B = V_S \rho g \left(1 - \frac{\rho_{wood}}{\rho}\right)$	N
Ballast weight req. for buoyancy	$W_B = F_B F_s$	N
Pressure drag	$F_{Dp} = \frac{1}{2}\rho U^2 S_E C_D$	N
Shear force	$F_{Ds} = L_E D\tau$	N
Total drag force	$F_D = F_{Dp} + F_{Ds}$	N
Friction force	$F_f = (W_B - F_B)\tan\phi = F_D F_s$	N
Ballast weight req. for drag	$W_B = F_B + \frac{F_D F_s}{\tan\phi} - \pi(L - L_E)(D/2)^2 \rho_{wood} g$	N

APPENDIX D

DESIGN DRAWINGS



NOTE: ALL ELEVATIONS ARE ABOVE ORDNANCE DATUM

NOTE: ONLY THE ELEVATIONS AND SURFACE MATERIALS OF THE APRON DIFFER FROM NORTHUMBERLAND COUNTY COUNCIL DRAWING HB127276/B/B6351/0622 WEST NEWTON BRIDGE GA OPTION 1 (DATED 26/06/13). FOR ALL OTHER ELEMENTS REFER TO THE NCC DRAWING

0 1m 2m 4m

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JOB NUMBER
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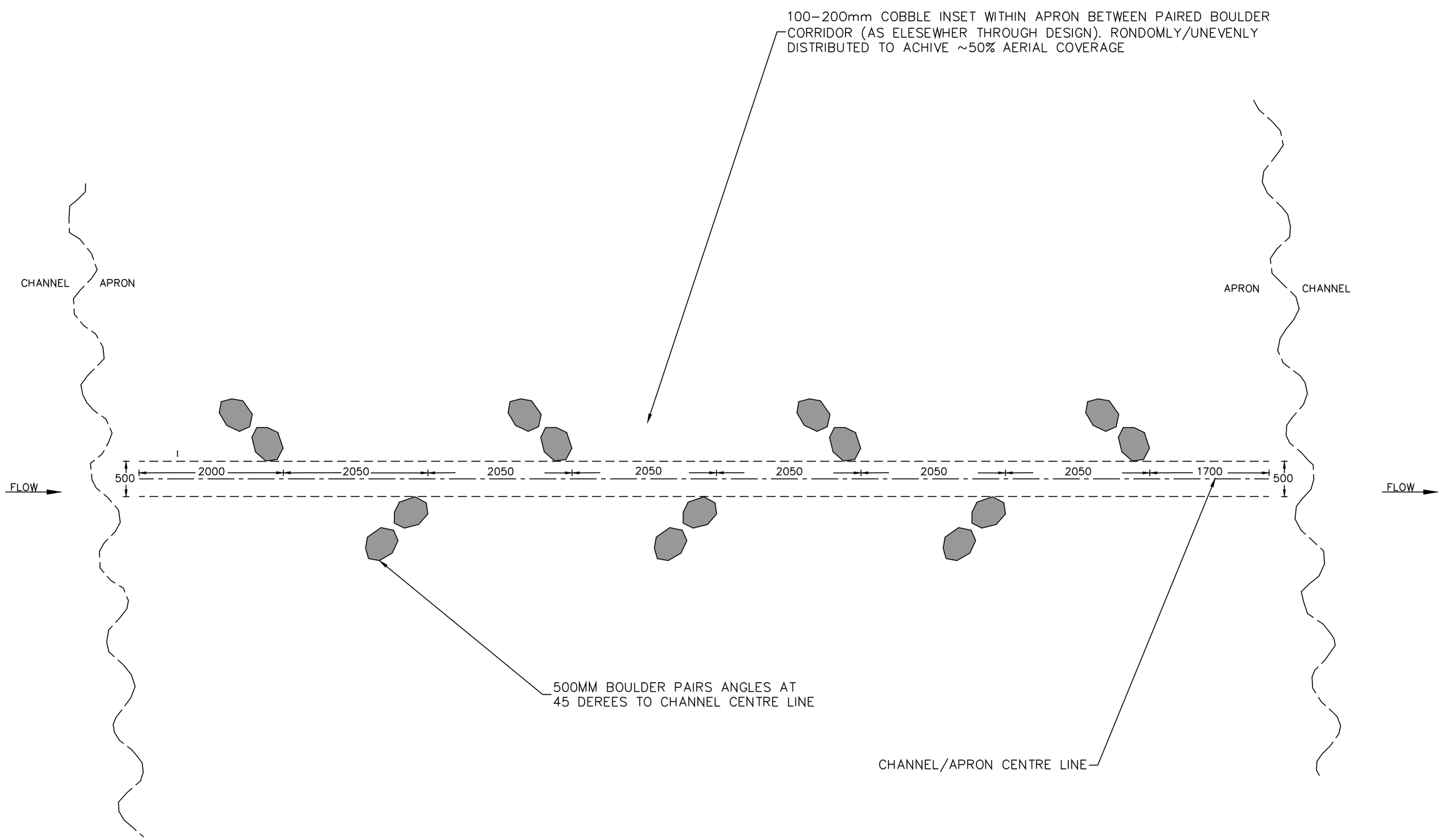

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS

0 500 1000 2000

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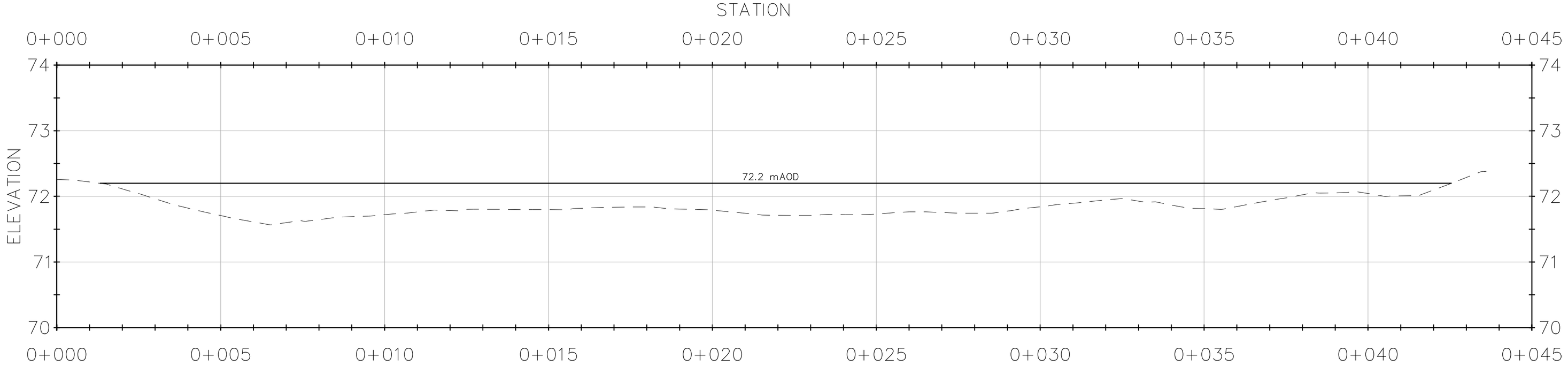
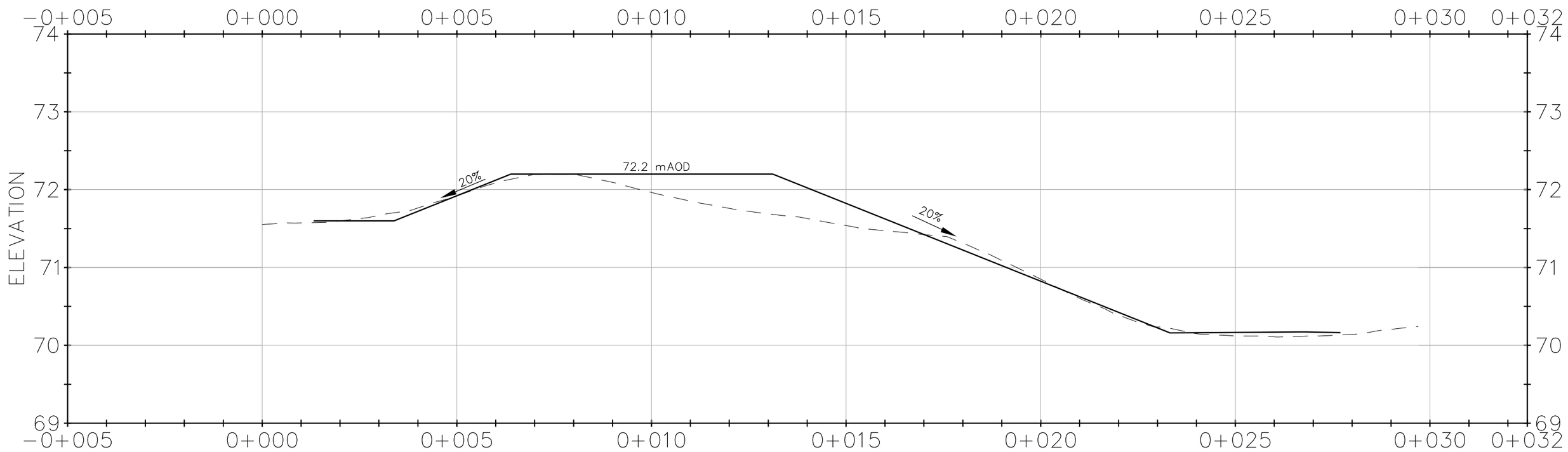
EMBANKMENT PROFILE A–A



EMBANKMENT TRACK PROFILE B–B



NOTE: ALL SLOPING FACES OTHER THAN VEHICLE ACCESS TRACKS TO BE GRADED TO 33.33%

NOTE: EMBANKMENT DESIGN IS INDIACTIVE AND CAN BE ALTERED DEPENDING ON AVAILABLE MATERIALS. THE CRITICAL FACTORS ARE THAT VEHICLE ACCESS IS POSSIBLE AND THAT THE THE UPPER SURFACE OF THE EMBANKMENT IS AT 72.2 m AOD

VERTICAL SCALE 0 0.5m 1m 2m

HORIZONTAL SCALE 0 1m 2m 4m

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EMBANKMENT SECTIONS

FILE NAME WNB_embank

JOB NUMBER U13–1003

DATE APRIL 2014

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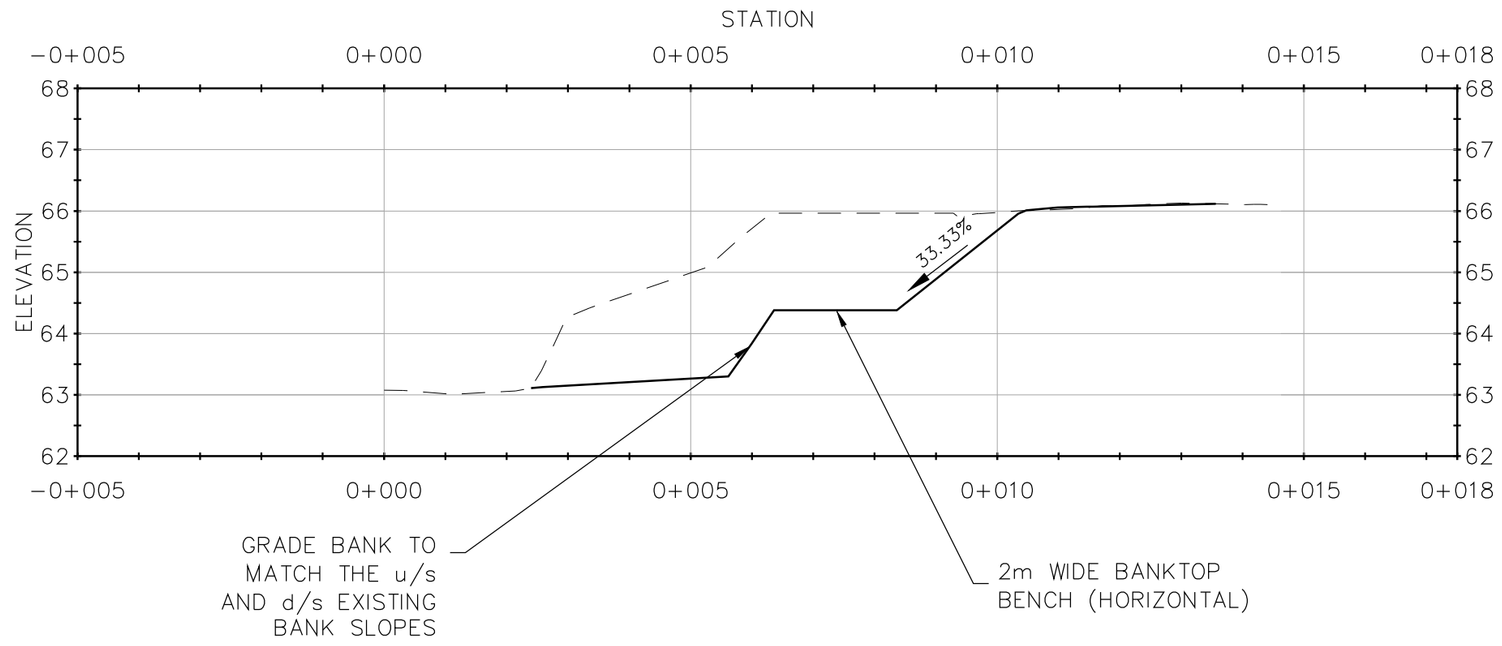
FILE NAME: WNB_embank

JOB NUMBER: U13-1003

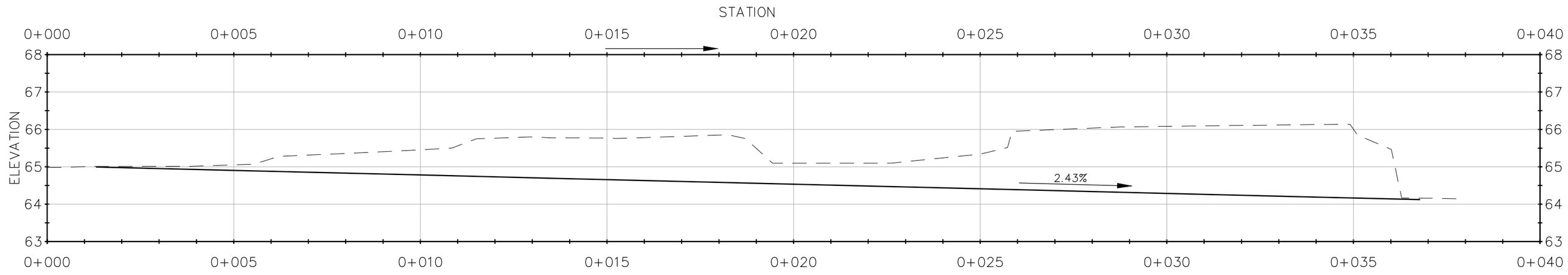
DATE: APRIL 2014

SHEET NO.: 1 OF 2

ABUTMENT SETBACK SECTION A–A



PROFILE B –B ON BANKFULL BENCH



HORIZONTAL and VERTICAL SCALE

0 1m 2m 4m

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FILE NAME
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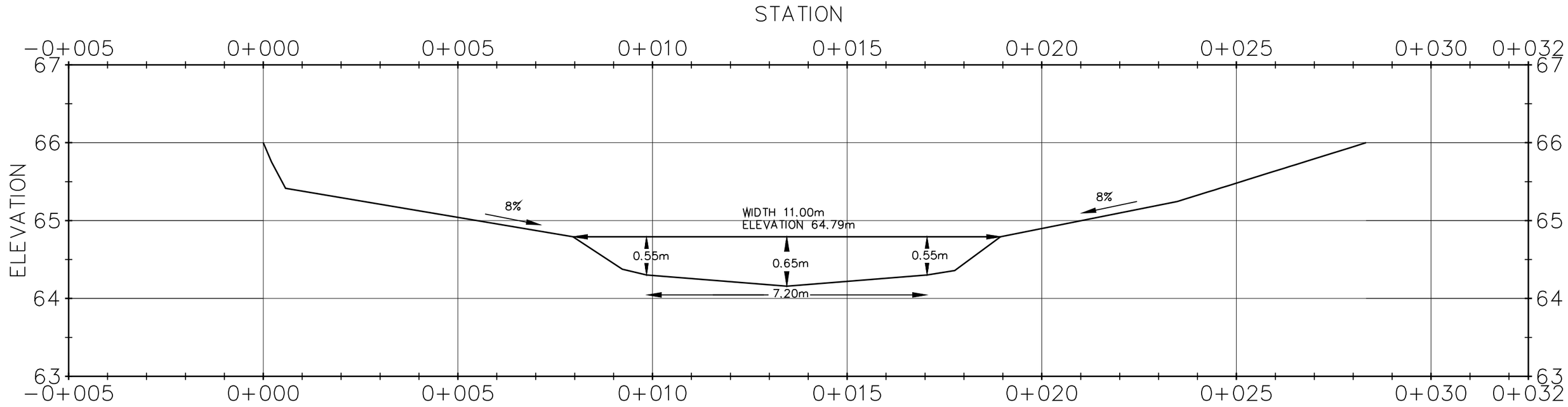
CHANNEL REINSTATEMENT SECTION G – G



NOTE: ORIENTATION OF SECTIONS G–G ONLINE WITH THE STEM BASE POINTS OF LOGS L7 & R8

NOTE: INSET CHANNEL BANK TOP ELEVATION EQUAL TO THE RESPECTIVE LOG BASE STEM ELEVATION MINUS 500mm (ASSUMING STEM BASE DIAMETER OF 1000mm)

VERTICAL SCALE 0 0.5m 1m 2m

HORIZONTAL SCALE 0 1m 2m 4m

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WEST NEWTON BRIDGE

SECTION G

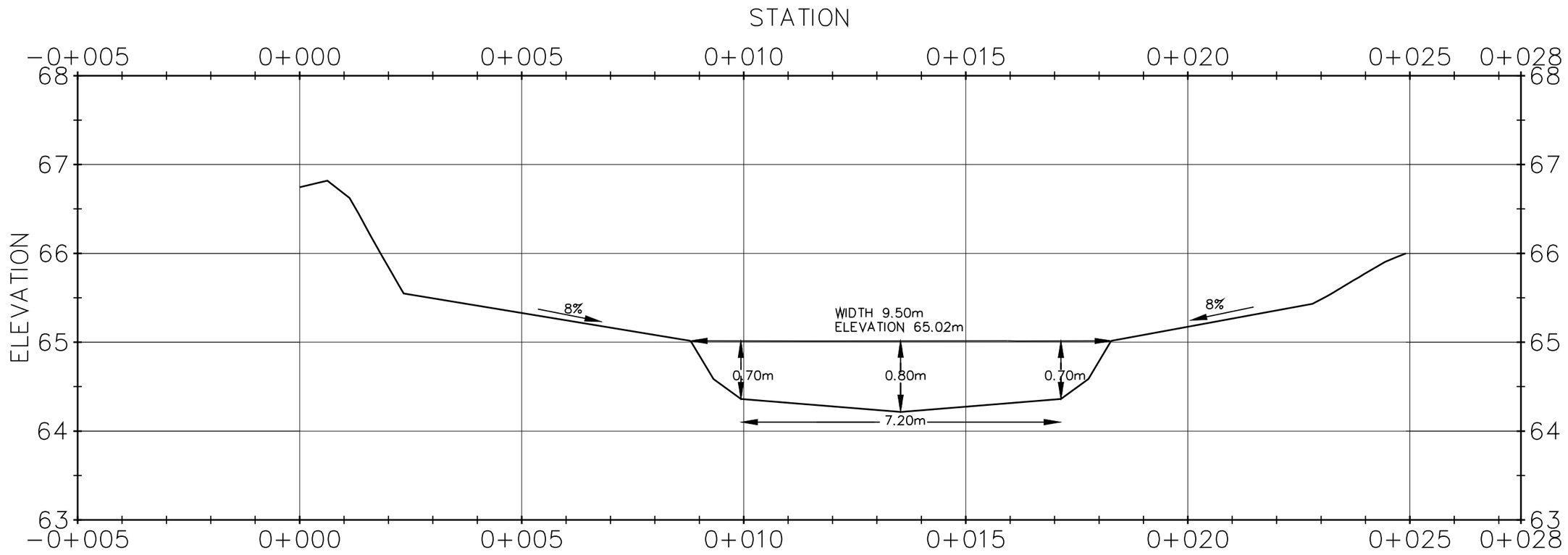
FILE NAME WNB_logs

JOB NUMBER U13–1003

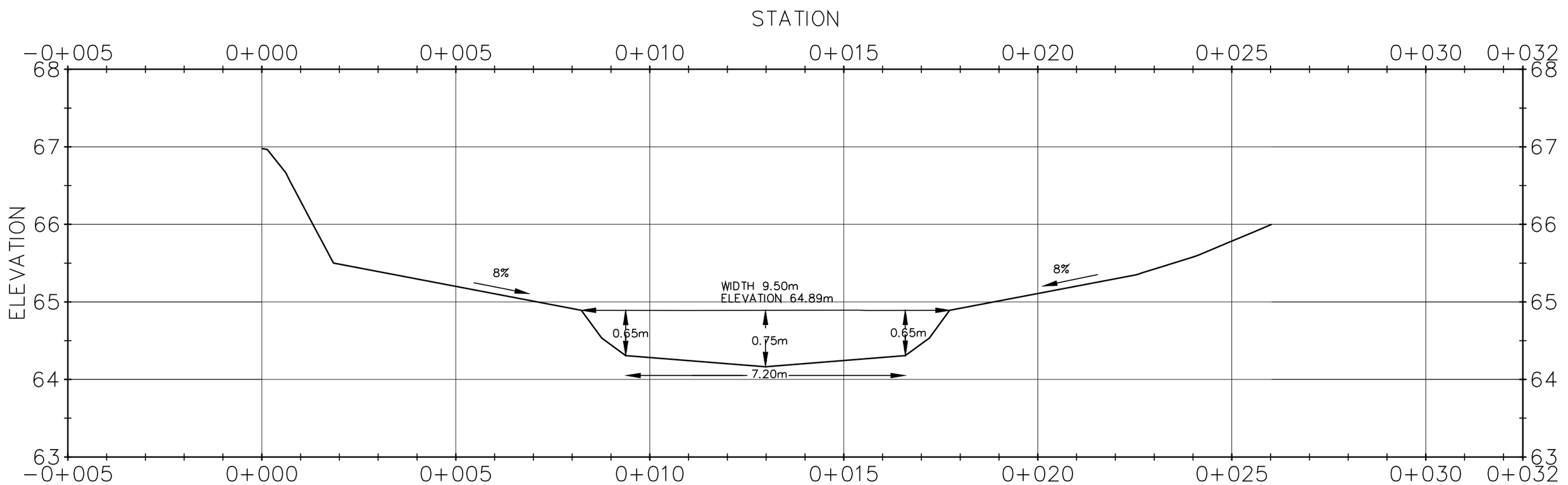
DATE APRIL 2014

SHEET NO. 6 OF 6

CHANNEL REINSTATEMENT SECTION E – E



CHANNEL REINSTATEMENT SECTION F – F



NOTE: ORIENTATION OF SECTIONS A–A AND B–B ONLINE WITH THE STEM BASE POINTS OF LOGS L1 & R2, AND L2 & R3, RESPECTIVELY

NOTE: INSET CHANNEL BANK TOP ELEVATION EQUAL TO THE RESPECTIVE LOG BASE STEM ELEVATION MINUS 500mm (ASSUMING STEM BASE DIAMETER OF 1000mm)

VERTICAL SCALE 0 0.5m 1m 2m

HORIZONTAL SCALE 0 1m 2m 4m

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WEST NEWTON BRIDGE

SECTIONS E & F

FILE NAME: WNB_logs

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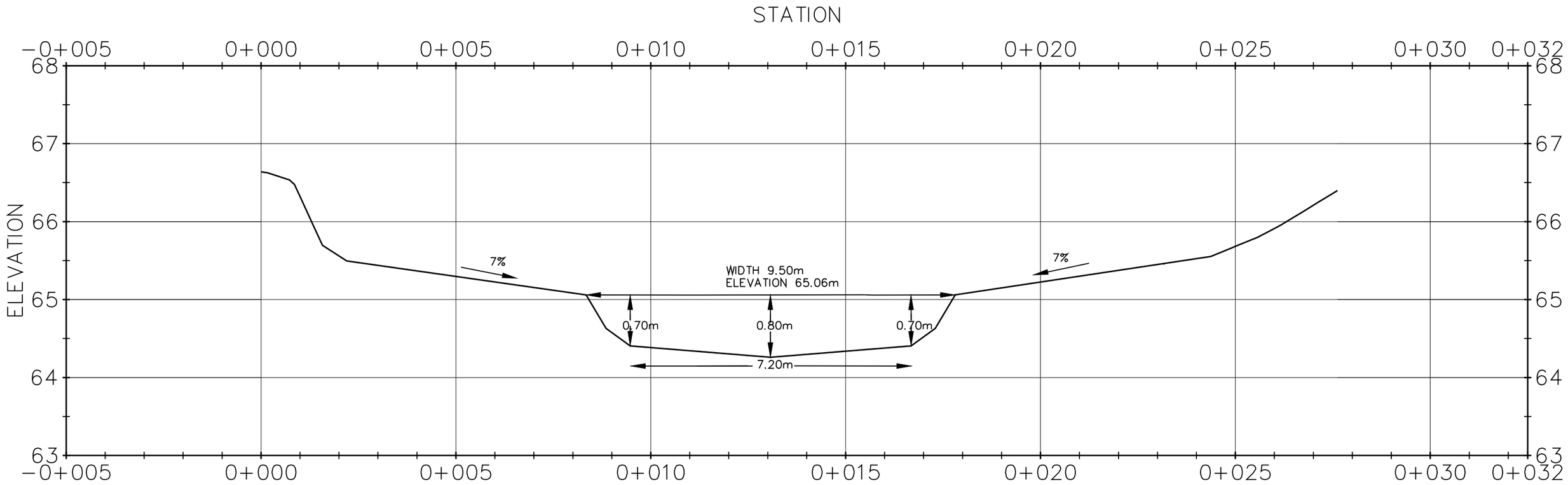
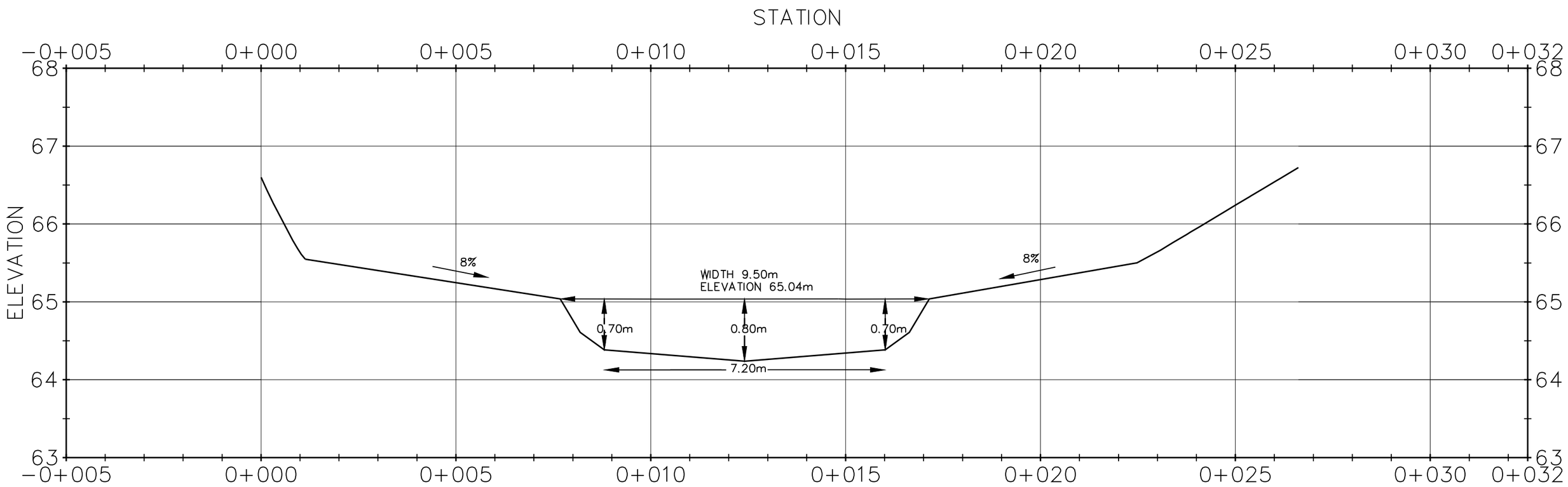
CHANNEL REINSTATEMENT SECTION C – C



CHANNEL REINSTATEMENT SECTION D – D



NOTE: ORIENTATION OF SECTIONS A–A AND B–B ONLINE WITH THE STEM BASE POINTS OF LOGS L3 & R4, AND L4 & R5, RESPECTIVELY

NOTE: INSET CHANNEL BANK TOP ELEVATION EQUAL TO THE RESPECTIVE LOG BASE STEM ELEVATION MINUS 500mm (ASSUMING STEM BASE DIAMETER OF 1000mm)

VERTICAL SCALE 0 0.5m 1m 2m

HORIZONTAL SCALE 0 1m 2m 4m

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WEST NEWTON BRIDGE

SECTIONS C & D

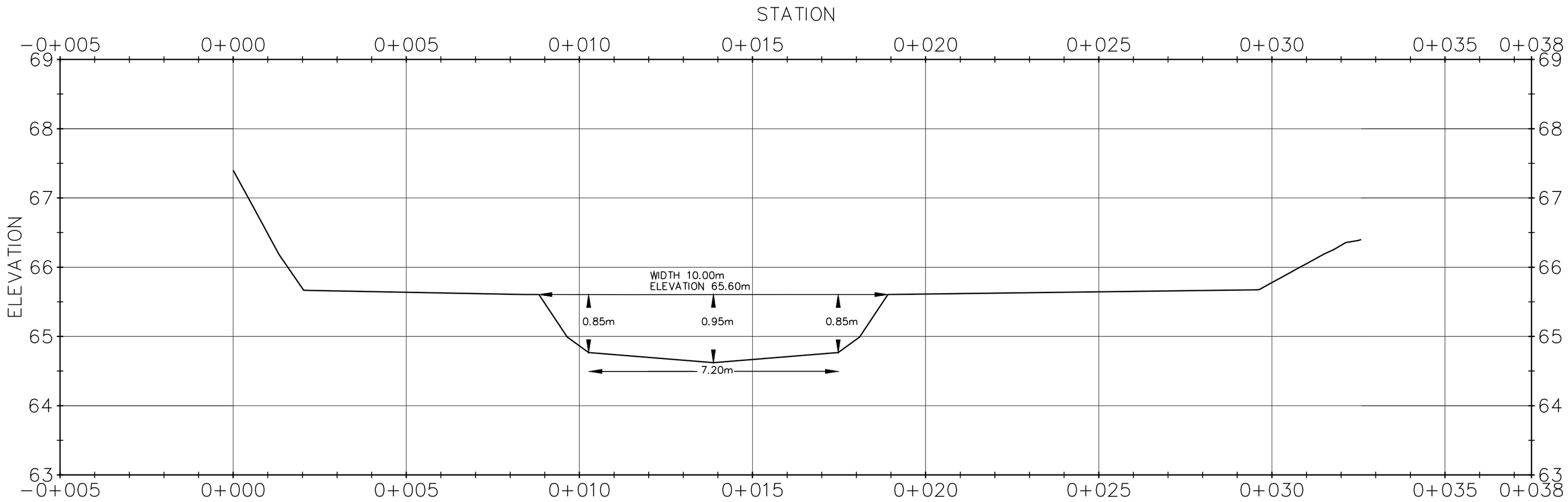
FILE NAME: WNB_logs

JOB NUMBER: U13–1003

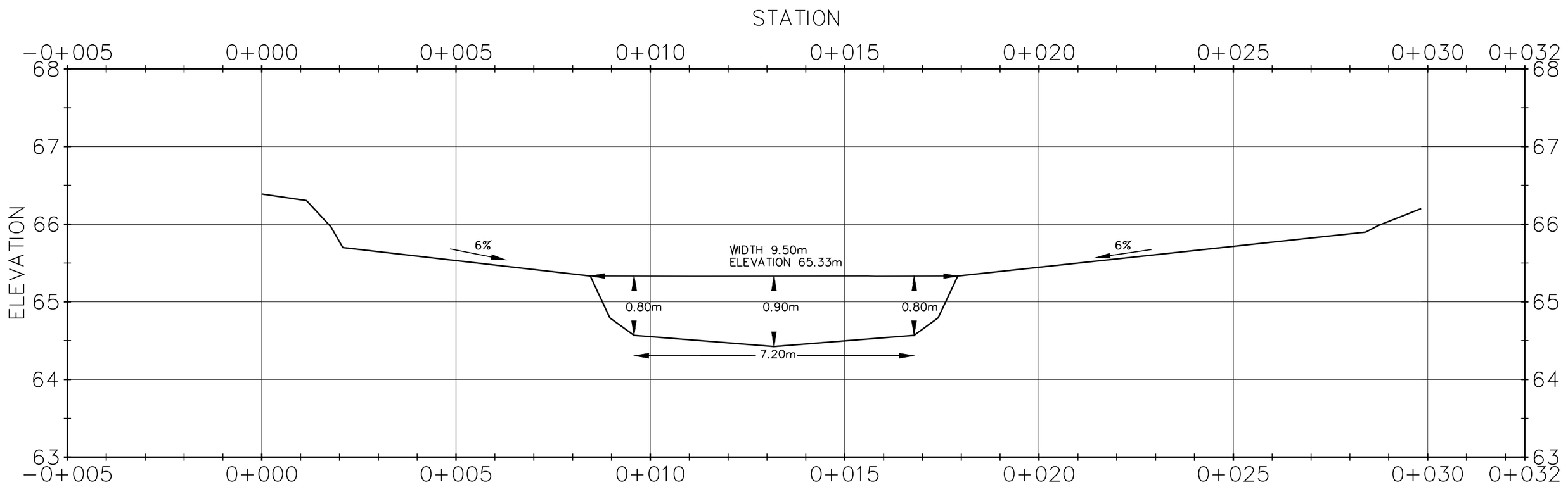
DATE: APRIL 2014

SHEET NO.: 4 OF 6

CHANNEL REINSTATEMENT SECTION A – A



CHANNEL REINSTATEMENT SECTION B – B



NOTE: GRADE SECTION A–A INSET FLOODPLIAN SLOPE TO MATCH UPSTREAM CONDITIONS

NOTE: ORIENTATION OF SECTIONS A–A AND B–B ONLINE WITH THE STEM BASE POINTS OF LOGS L1 & R2, AND L2 & R3, RESPECTIVELY

NOTE: INSET CHANNEL BANK TOP ELEVATION EQUAL TO THE RESPECTIVE LOG BASE STEM ELEVATION MINUS 500mm (ASSUMING STEM BASE DIAMETER OF 1000mm)

VERTICAL SCALE 0 0.5m 1m 2m

HORIZONTAL SCALE 0 1m 2m 4m

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SECTIONS A & B

FILE NAME: WNB_logs

JOB NUMBER: U13-1003

DATE: APRIL 2014

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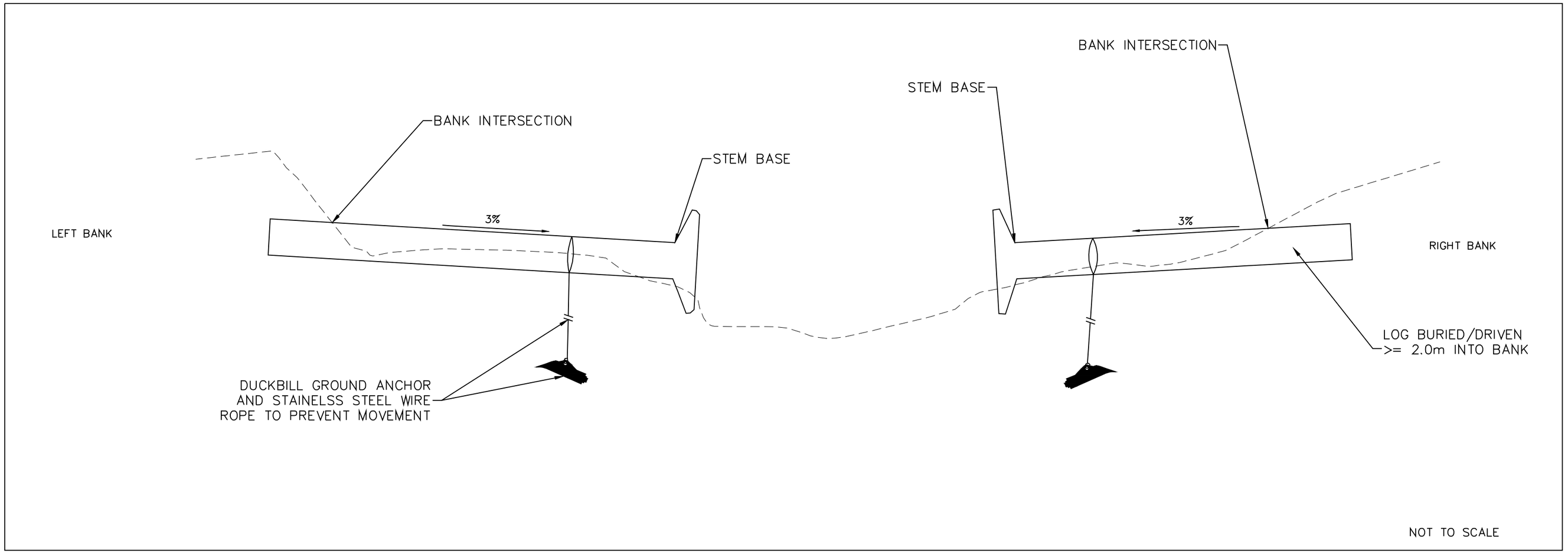
EXAMPLE OF TYPICAL INSTALLATION OF TRAINING LOGS



STEM BASE AND BANK INTERSECTION CO-ORDINATES AND ELEVATIONS

Log Id	Point Location	Easting	Northing	Elevation
LOG L1	STEM BASE	390726.74	630337.28	65.61
	BANK	AS ABOVE	AS ABOVE	AS ABOVE
LOG L2	STEM BASE	390735.25	630341.68	65.58
	BANK	390735.17	630347.15	65.75
LOG L3	STEM BASE	390742.05	630345.11	65.56
	BANK	390739.85	630352.88	65.80
LOG L4	STEM BASE	390747.43	630351.36	65.54
	BANK	390746.57	630360.48	65.81
LOG L5	STEM BASE	390752.64	630357.36	65.52
	BANK	390751.78	630366.29	65.78
LOG L6	STEM BASE	390757.57	630363.37	65.39
	BANK	390756.63	630373.24	65.69
LOG L7	STEM BASE	390764.05	630371.03	65.29
	BANK	390763.34	630382.78	65.64

Log Id	Point Locatio	Easting	Northing	Elevation
LOG R1	STEM BASE	390744.52	630312.55	65.63
	BANK	390746.18	630314.40	65.71
LOG R2	STEM BASE	390746.20	630322.67	65.61
	BANK	390753.82	630329.15	65.90
LOG R3	STEM BASE	390747.44	630331.33	65.58
	BANK	390756.39	630334.42	65.86
LOG R4	STEM BASE	390749.80	630339.80	65.56
	BANK	390758.65	630339.52	65.82
LOG R5	STEM BASE	390754.48	630345.16	65.54
	BANK	390761.67	630344.06	65.75
LOG R6	STEM BASE	390759.33	630350.77	65.52
	BANK	390765.91	630349.37	65.72
LOG R7	STEM BASE	390764.26	630356.79	65.39
	BANK	390773.07	630354.93	65.66
LOG R8	STEM BASE	390771.81	630363.39	65.29
	BANK	390780.54	630361.80	65.56

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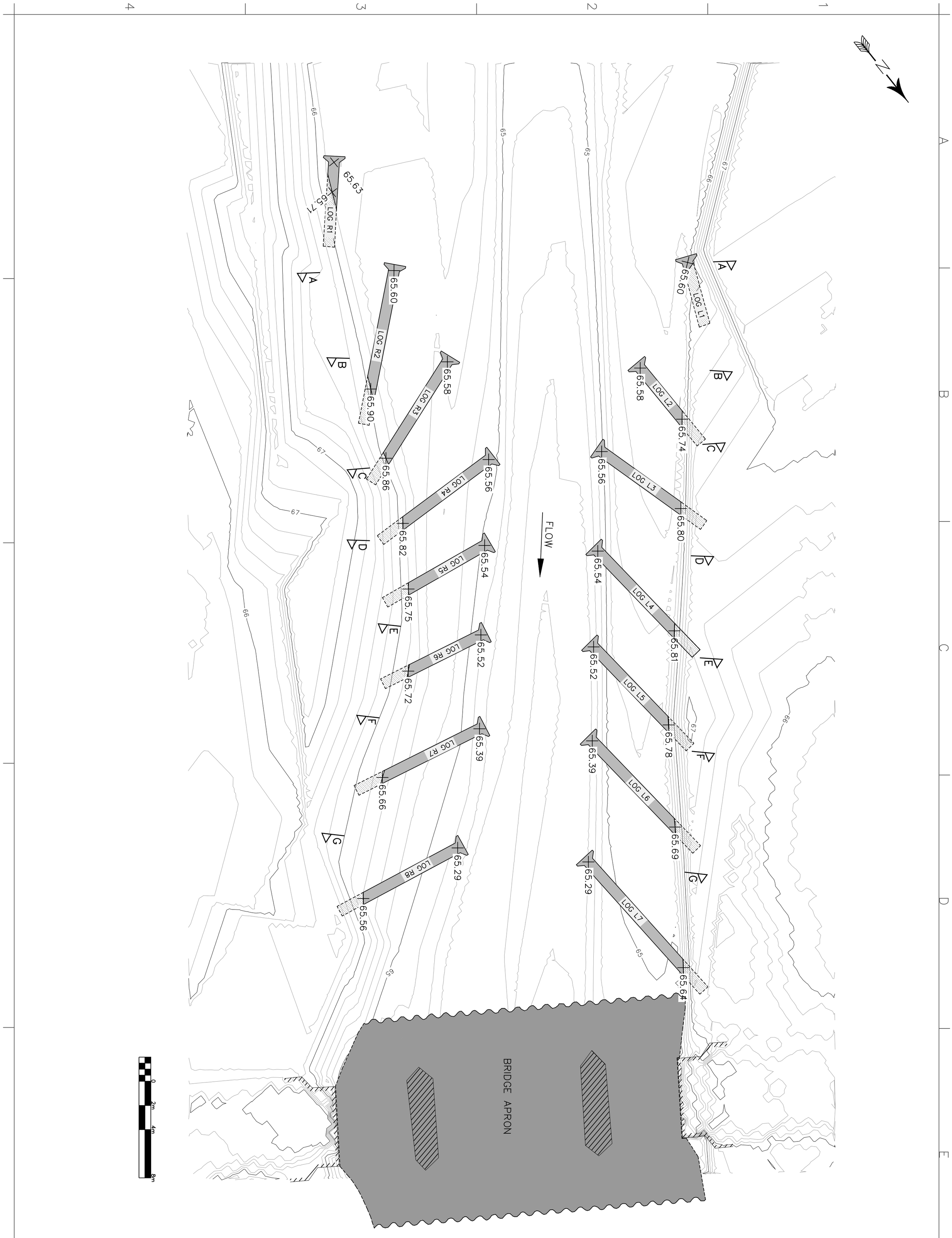
LOG PLACMENT DETAIL

FILE NAME WNB_logs
JOB NUMBER U13-1003
DATE APRIL 2014
SHEET NO. 2 OF 6



SHEET NO. 1 OF 1	FILE NAME WNB	WEST NEWTON BRIDGE APRON PLANVIEW	NORTHUMBERLAND COUNTY COUNCIL
DATE APRIL 2014	JOB NUMBER U13-1003		

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Restoration Specialists for Freshwater
and Coastal Environments

www.cbecoeng.co.uk
T/F: 01975 564 492
info@cbecoeng.co.uk

cbec eco-engineering UK Ltd
3 Aberdeen Road, Alford Aberdeenshire, AB33 8ED
Company Number: SC385000 | VAT Number: GB111101405

Appendix C

C2 - Peer Review of C1 (River Catchment Services)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

Westnewton Bridge Modelling and Design
Draft Report from cbec eco-engineering UK Ltd., June 2014

Peer Review by Professor Malcolm D Newson, River Catchment Services, Corbridge NE45 5PE

Declaration of interest: I am an occasional sub-contractor for river projects led by cbec UK

Introduction

The College Burn would, in a wild landscape such as the Rocky Mountains or South Island New Zealand, be avoided as a settlement and communications site, but in the UK's crowded and historic settlement pattern it has significant property and infrastructure risks from flooding and erosion.
I have been familiar with the site for over a decade and have professionally advised individual landowners and Tweed Forum on remedial actions from a geomorphological perspective.
The conservation interest and legal protections reduce the options for conventional engineering solutions and NCC Highways have shown due consideration for this dilemma in the new approach to protecting the road bridge. In turn, perhaps thanks to a tight project specification, cbec have used up-to-date, industry-standard geomorphological and hydraulic assessments over an appropriate scale above and below the bridge.

Engineering and geomorphological contexts for the bridge

The flood events of 2008 and 2009 illustrated the threat of flow volume/direction variation during 'large, rare' floods on the toe of an ancient alluvial fan. Thus, the bridge abutments were 'attacked' from high stream power being 'jetted' like a fire hose through the different arches, determined by flow level, efflux upstream and channel constrictions downstream (as well as the obvious constriction of the arches themselves).
Such hydraulic and sediment transport situations can never be exactly predicted but current knowledge allows a responsible risk-based approach to predicting and designing engineering interventions. The cbec draft report delivers the optimum level of responsible analysis currently available for a problematic site. Unlike many other geomorphology consultants, the cbec team are long experienced in high energy, coarse sediment systems. They are also experienced at practical channel restoration measures.

The detail

The draft report shows the following vital components:

- Historical context (p. 7) – vital to geomorphological prediction and design. The centreline maps are very useful background;
- Fluvial Audit (p. 10) – industry standard assessment technique and essential information to carry forward to modelling, mainly in terms of sediment sources (photos pp.12-14) and sediment sizes (p. 16);
- Topo survey (p.17) essential for modelling flow depths and shear stresses at the bridge;
- Hydrology/hydraulics: ReFH prediction of flood flow discharges vital in an ungauged catchment – again vital to the modelling;
- Manning 'n' values (pp. 20/21) – is this a cusp for debate – subtle changes here could alter the model outcomes – but I'm comfortable with the initial selection of values – where did they come from?
- Model outputs: Figures 2.14 to 2.17 are extremely useful and help create the NCC evidence base for intervention (given the ecological sensitivity);
- Design: the four target objectives on p. 29 are accurate. I've never seen an angle of approach analysis before – this is highly desirable but I'm sure laced with risks;

- Shear stress/particle size analysis (pp. 37 – 42) – some would argue (in the academic world) with a shear stress approach but it is defendable at this site;
- Appendix C – Log load calculators – vital in terms of the new government definitions of river channel management – 'dredging' is not any longer the answer and at West Newton has never brought a solution.

Conclusions

As is evident from my detailed comments above, I consider the cbec draft to represent the best predictive and designs going forward.
You may require some information on the precautions an engineer would build in given the uncertainty of modelling but the biggest remaining uncertainty consists of 'conditions on the day of the flood', for example delivery of material from landslides upstream and of fallen trees – under those conditions 'all bets are off' but the failure of any current engineering intervention can be countered by the good evidence base presented by cbec and the randomness of alluvial fan geomorphology!

I can recommend the cbec report from an objective position in professional geomorphology.

M.Newson 17.06.14

Appendix, requested by Don Brown (NCC) 29.07.14

Concerning NCC's understandable concerns about controlling the related issues of voluminous sediment accrual to the bridge reach and the changes of flow direction and hydraulics which would ensue at the bridge, I have now walked the site in its current (ever changing!) state, acco0mpanied by Peter Brewis who explained the concepts behind a broader intervention at this site.

Two items from the peer review are vital for risk management by NCC: cbec have assiduously followed industry standard techniques to predict the value and impacts of their proposals *at the bridge*. Secondly, there are no 'for-ever wins' at this site and thus NCC need to wrap the cbec study in a slightly *broader sediment management context*. The ideal would be to enagage in a catchment management programme addressing excessive erosion sources of sediment and riparian tree condition, both of which set the context for the engineering response at West Newton bridge. However, this is not possible and the only available agenda is to manage flow re-routing (in flood) and the resulting sediment transfer from an area upstream of the bridge to the formerly-dredged bridge environment. Cbec recommendations seek to manage the hydraulics of conveyance through the bridge but my observations approach from the angle of protecting against damaging channel change upstream (changing the hydraulic conditions modelled by cbec) and the delivery of a huge volume of sediments 'poised' there for transport on a 'large rare' flood (climate is changing and so cbec have gone up to the 200-year flood).

The College Burn at West Newton Bridge is a modern river on an ancient alluvial fan. Throughout the world (Las Vegas, Eilat etc.) life on alluvial fans is very risky: the UK is fortunate that its fans are now vegetated but that in itself can pose a problem (see below). The diversion of flood waters which occurred in 1948 – east towards Post Office Lane in Kirknewton – remains a flow option in extreme floods and was included in the cbec modelling (both operating and closed off). Hence it seems logical that use is made of 'temporary' spoil from clearing the bridge conveyance is used to raise the bank protection by 300mm. – so long as new flood spill vulnerability is not created and flow patterns not influenced in relation to remarks below.

An unintended consequence of sediment management in the bridge/downstream reach has been that subsequent flood-delivered gravel/cobble material has accrued in the upper part of the bridge reach and is 'waiting' to arrive and to frustrate engineering solutions to protect the bridge stability. Paradoxically, the growth of both herb/shrub vegetation on these deposits is not an answer guaranteeing sediment stability in extreme events (despite the fact that 'green engineering' is desirable in this habitat-sensitive site). Damaged, falling and deposited 'Large Woody Debris' (LWD) has local habitat benefits but these need to be considered against a flood-delivered chaos of Alder trees at the bridge. The other upstream danger is that, at two prominent sites, channel migration will occur if 'head cuts' (channel change occurs downstream – upstream, not the reverse) are not fixed in their current positions.

There are, therefore, two current engineering options available to NCC/EA upstream of the bridge reach (remembering that a catchment-scale solution is not available):

- Securing the recent depositional bar on the east side of the upstream channel in the area formerly protected by Tweed Forum log posts. Current vegetation colonization is a promising start but risks disruption in high flood until succession proceeds further. The biggest danger here is that flows diverted to the east bank will, via head cutting in flood, swing the flow approach to the bridge, undermining some of the assumptions of the cbec hydraulic model.
- Securing flows, possibly increased by the proposed flood bank upstream (see above) around another east bank route with a 2m vertical head cut exposing the true nature of the 'lurking sediment rush' to the bridge.

In both cases, 'green engineering' would suggest a mixture of wooden stake/ willow stake and creative use of dredging spoil to raise the level of deposits such that a diversionary flow does not establish during a rare flood and become established afterwards.

The most important message for stakeholders comes in two parts:
There are no guarantees of engineering stability to protect communities or land in a river like the College Burn;
An engineering solution will require flood-related maintenance, notably of trees (Alder prominent) to retain a balance between the habitat advantages of a 'wild' river and the established community infrastructure of a very risky site.

MN 05.09.14

Appendix C

C3 – Method Statement (Northumberland County Council)

NORTHPOINT
CONSULTING

14 Brenkley Way
Blezard Business Park
Seaton Burn
Newcastle upon Tyne
NE13 6DS

West Newton Bridge B6351
Scour protection

Method Statement for application for Land Drainage Consent
Version 2.0

Outline

Following a near catastrophic failure of the foundations during a flood event on the 6th September 2012, repairs are proposed to protect against future. The footing levels of the foundations have been shown to be shallow and are susceptible to undermining during flooding events. To prevent further possible damage to the bridge, it is proposed to install a concrete invert around the foundations together with other means to mitigate deposition.

The concrete slab bounded between lines of sheet piles, will replace the current river invert. The surface of this new invert will mirror the river bed with boulders embedded in the concrete surface and will be profiled to provide a central channel to aid fish passage. This central area is to have much larger boulders forming a channel to focus the flow, again, to further aid fish passage.

The proposals have been developed after a study by Cbec Eco-Engineering Ltd who have conducted an assessment of the hydrodynamic and sediment transport processes on the College Burn in the vicinity of the bridge. This report is appended to this application.

All areas of work have been subject to ecological survey, assessment, and consideration of the effects of the proposals on the river environment and ecology. An Appropriate Assessment has been undertaken by Econorth Ltd who have liaised with Natural England, the Environment Agency and the Conservation Team of Northumberland County Council in consideration of the proposals. Their findings are appended to this method statement.

A review of the hydro-geomorphology assumptions and modelling has been carried out by Malcolm Newson of River Catchment Services Ltd and this is appended to this method statement.

The soft engineering works to protect the river corridor from 'cut back' scour have been proposed to ensure that, in the short to medium term, the rivers' propensity to further meandering is limited. This is in accordance with the recommendations contained in Malcolm Newson's review. In essence these protection works will not change the river corridor, but will limit the immediate likelihood of significant alignment change.

General

An Ecological Clerk of Works (ECoW) will also be employed directly to reinforce and ensure compliance on site any and all required Environmental Legislation.

The role of the ECoW is will include the following elements:

- Toolbox Talk with key site personnel – highlighting key ecological and environmental issues.
- Monitoring sediment control and water treatment.

- Ensuring compliance with ecological method statements to protect species such as otter.
- Monitoring pollution prevention.
- Inputting into and overseeing site restoration from an ecological perspective.

All plant and machinery on site will have vegetable oils rather than mineral lubricants and spill kits will be available in the event of accidents.

Entry into the river corridor environment will be strictly in accordance with this method statement any/all Environmental Restrictions required by the Environment Agency and Natural England.

A weather watch will be undertaken so that operations started in any working shift can be finished thereby minimising the exposure to high waters from flash flooding. For example, should thundery weather be forecast then the contractor shall not carry out works that would put the bridge at risk of scour.

Installation of concrete apron and sheet piling around bridge

Step 1 – Reduction of gravel levels to river invert profile – Sketch no HB127276/SK111.

This step and step 2 is required so that the river can be diverted temporarily through the west arch.

On the downstream side of the bridge, access to the area will from the works zone to demolish the old railway abutment – see site reference plan drawing number 23.

Machinery will move to the works area along an existing gravel shoal above water level.

A line of dumpy bags will be placed along the centre of the river so that flow is pushed away from the LH side. This will create the initial working zone. Sedimats will be placed on the LH side edge of the river to catch any minimal siltation.

Area B will be reduced in level so that the invert is equal to the corresponding river bed level. Arisings will be stored in the compound in the adjacent field. Once complete the excavator will cross the river and reposition the dumpy bags so that flow is directed to the LH side. Sedimats will also be laid to the RH edge of the river. Area A will be reduced in level to match area B. Arisings will be carried in a dumper and stored in the compound in the adjacent field. It is likely that the dumper will have to traverse the river several times.

Step 2 – Reduction of gravel levels to river invert profile – Sketch no HB127276/SK112.

The operation is the same as step 1 but is carried out to the upstream side of the bridge.

The excavator will have to cross the river to get to area C and a dumper will have to cross the river several times with arisings to be temporarily deposited in the compound.

Step 3A – Pre-augering of gravel along line of proposed upstream sheet pile wall – Sketch no HB127276/SK113.

Access to the working area for the piling rig will be either over the flood bund as shown on the sketch or, the machine will have to track down the gravel shoal upstream of the work on the RH side of the river. This route is approximately 250 metres long.

Management of the river flows and filtration will be carried out as step 2. The piling rig will have to cross the river for the operations.

To create a stable piling platform, the gravel along the line of the new pile wall will have to be compacted. This line will be approximately 5 metres wide but is critical for the safe operation of the piling rig and crew. The compaction process will also aid the stability of the river bed following installation of the permanent works.

The piling rig will drill into the gravels/cobbles along the line of the sheet piled wall to ensure that there are no significant obstructions. If any are found an excavator will dig out the stones with work carried out in the zone of water management. Filtration of any water can be carried out by pumping to a siltbuster type facility and returned to the river.

Step 3B – Pre-augering of gravel along line of proposed upstream sheet pile wall – Sketch no HB127276/SK114.

River flows will be temporarily diverted to the LH bank and through the west arch by placing dumpy bags down the centre of the river. The river will follow the channel already excavated in earlier steps.

Again to create a stable piling platform, the gravel along the line of the new pile wall will have to be compacted in a similar way to step 3A.

The piling rig will drill into the gravels/cobbles along the line of the sheet piled wall to ensure that there are no significant obstructions. If any are found an excavator will dig out the stones with work carried out in the zone of water management. Filtration of any water can be carried out by pumping to a siltbuster type facility and returned to the river.

Step 4A – Installation of pilling to proposed upstream sheet pile wall – Sketch no HB127276/SK115.

River flows will be temporarily diverted to the RH bank by placing dumpy bags down the centre of the river.

The piling rig will cross the river to install the sheet piles on that side of the river. Sheet piles will be carried by an excavator that may have to cross the river to deliver the sheet piles.

The piling rig will install the sheet piles. All piles installed in any working shift will be fully inserted so that the free board height is minimal and presents the least risk of retention of any flood waters.

Water management and filtration will be as previous steps.

Step 4B – Installation of pilling to proposed upstream sheet pile wall – Sketch no HB127276/SK116.

River flows will be temporarily diverted to the LH bank and through the west arch by placing dumpy bags down the centre of the river. The river will follow the channel already excavated in earlier steps.

The works will be carried out by working within the controlled area of water management.

The piling rig will install the sheet piles. All piles installed in any working shift will be fully inserted so that the free board height is minimal and presents the least risk of retention of any flood waters.

Water management and filtration will be as previous steps.

Step 5A – Pre-augering of gravel along line of proposed downstream sheet pile wall – Sketch no HB127276/SK117.

River flows will be temporarily diverted to the LH bank but through the centre arch by placing dumpy bags down the centre of the river.

Again to create a stable piling platform, the gravel along the line of the new pile wall will have to be compacted in a similar way to step 3A.

The piling rig will drill into the gravels/cobbles along the line of the sheet piled wall to ensure that there are no significant obstructions. If any are found an excavator will dig out the stones with work carried out in the zone of water management. Filtration of any water can be carried out by pumping to a siltbuster type facility and returned to the river.

Step 5B – Pre-augering of gravel along line of proposed downstream sheet pile wall – Sketch no HB127276/SK118.

River flows will be temporarily diverted to the LH bank and through the west arch by placing dumpy bags down the centre of the river.

Again to create a stable piling platform, the gravel along the line of the new pile wall will have to be compacted in a similar way to step 3A.

The piling rig will drill into the gravels/cobbles along the line of the sheet piled wall to ensure that there are no significant obstructions. If any are found an excavator will dig out the stones with work carried out in the zone of water management. Filtration of any water can be carried out by pumping to a siltbuster type facility and returned to the river.

Step 6A – Installation of piling to proposed downstream sheet pile wall – Sketch no HB127276/SK119.

River flows will be temporarily diverted to the LH bank but through the centre arch by placing dumpy bags down the centre of the river. The river will follow the channel already excavated in earlier steps.

The works will be carried out by working within the controlled area of water management.

The piling rig will install the sheet piles.

Water management and filtration will be as previous steps.

Step 6B – Installation of piling to proposed downstream sheet pile wall – Sketch no HB127276/SK120.

River flows will be temporarily diverted to the LH bank and through the west arch by placing dumpy bags down the centre of the river. The river will follow the channel already excavated in earlier steps.

The works will be carried out by working within the controlled area of water management.

The piling rig will install the sheet piles.

Water management and filtration will be as previous steps.

Step 7A – Construction of concrete invert between sheet piled walls – Sketch no HB127276/SK121

Water management will be maintained as the previous step.

Small tracked excavators will reduce the levels of gravel between the sheet piled walls to the necessary levels. Arisings will be taken by dumper to the temporary stock piles in the

compounds. This will require the dumpers to cross the river a number of times on the downstream side of the bridge. On the upstream side, the dumpers will exit via a dry route.

The inverts will be concreted as per the drawings. The operations are expected to be carried out in dry conditions but if water has to be removed, it will be pumped to adjacent fields before returning naturally to the river after filtering through ground strata.

Step 7B – Construction of concrete invert between sheet piled walls – Sketch no HB127276/SK122

River flows will be temporarily diverted to the RH bank by placing dumpy bags down the centre of the river.

Small tracked excavators will reduce the levels of gravel between the sheet piled walls to the necessary levels. Arisings will be taken by dumper to the temporary stock piles in the compounds. This will require the dumpers to cross the river a number of times on the upstream side of the bridge. On the downstream side, the dumpers will exit via a dry route.

The invert will be concreted as per the drawings. The operations are expected to be carried out in dry conditions but if water has to be removed, it will be pumped to adjacent fields before returning naturally to the river after filtering through ground strata.

Installation of log arrays for training water through the centre arch of the bridge

Construction of log arrays upstream of bridge – Sketch no HB127276/SK123.

The river will be temporarily diverted away from the work areas by the placement of dumpy bags around the work zone. Sedimats and straw bales will be positioned downstream as shown the enclosed sketch to catch or trap any siltation.

The log arrays will be anchored by timber soldiers buried in excavated pits.

Any water removed by pump from the works area will be filtrated before being returned to the watercourse.

An excavator will have to transverse the river several times together with dumpers who will be carrying the timber to construct the arrays.

Installation of log stockades for protection against further 'cut back' scour during flood events

Construction of soft engineering log stockades upstream of bridge – Sketch no HB127276/SK124.

The works are approximately 5 to 10 metres away from the edge of the river so water management techniques are not envisaged..

The log stockades will be installed by being buried in excavated pits.

The access route will be along a track remaining from the emergency works carried out in 2012.

Demolition of old railway abutment and re-profiling of embankment to remove pinch point in river.

Demolition of old railway bridge abutment – Sketch no HB127276/SK125.

The access route from the compound to the works area will not require the removal of any trees. The few shrubs that need clearing will be removed winter 2014/15.

The works are adjacent to the river but no work is envisaged in the water.

The masonry of the abutment will be taken down by an excavator and temporarily stored in the compound. All stone will become the property of Westnewton Estate.

The finished earthworks profiles will be recovered with soling initially removed prior to the abutment demolition. The lower slopes will be protected from scour with a pegged down jute geotextile.

Raising crest height of flood bund and provision of scour protection to existing 'cut back'

Raising crest height of flood bund and provision of scour protection to existing 'cut back'– Sketch no HB127276/SK126.

Vegetation to areas 3 and 4 will be removed in winter.

Access to all areas will be along the existing farm tracks and across grass pasture to area 6. No formal tracks will be created on the grass pasture.

No works are within 10 metres of the river corridor so no water management plans are proposed.

Top soil to area 4 will be stripped and set aside. Material will be transported from area 3 by dumper to area 4 where it will be spread and the topsoil reinstated. Planting will be agreed with the landowner.

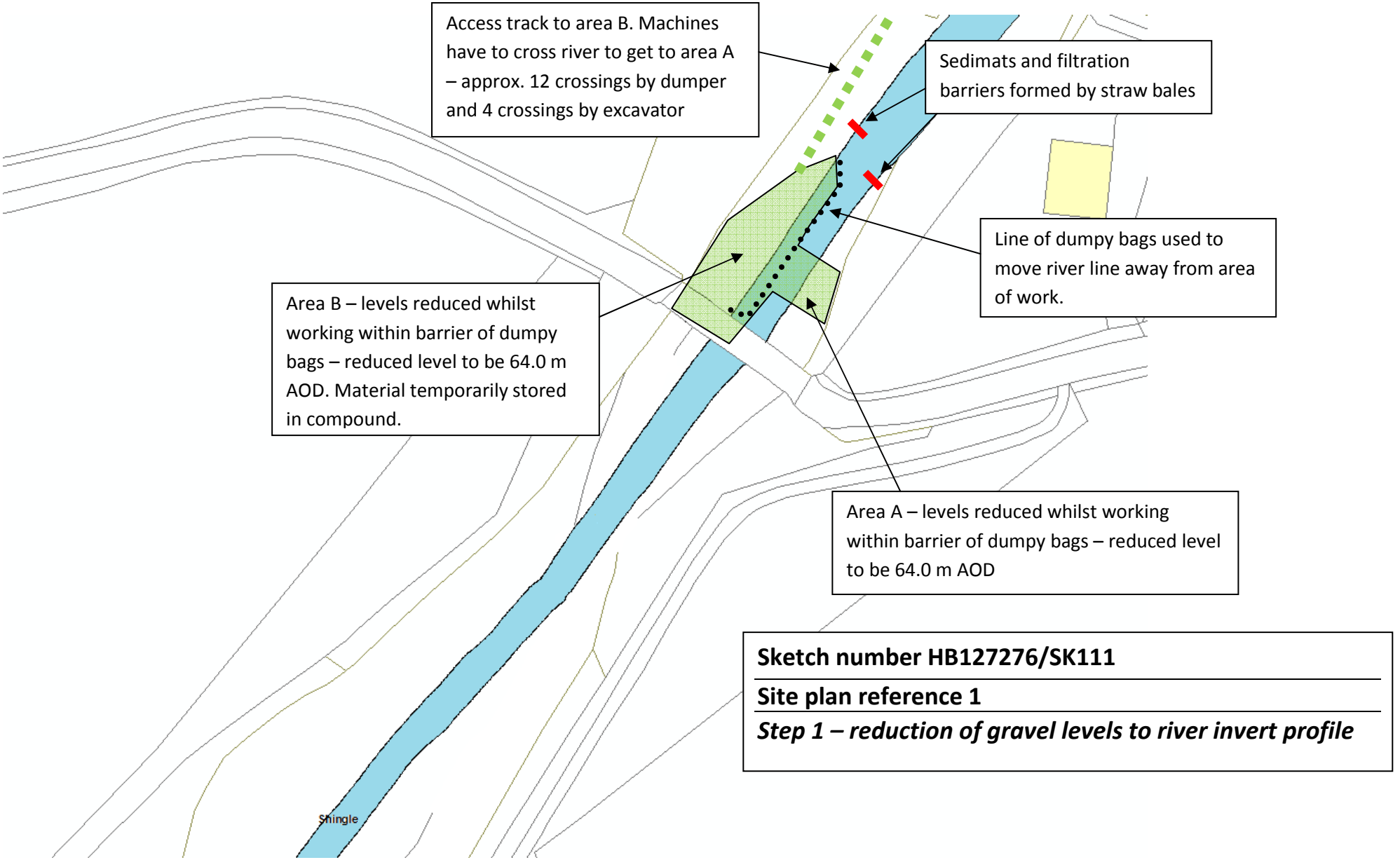
An existing farm track over the flood bund will be reinstated in like for like materials.

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK111

Site plan reference 1

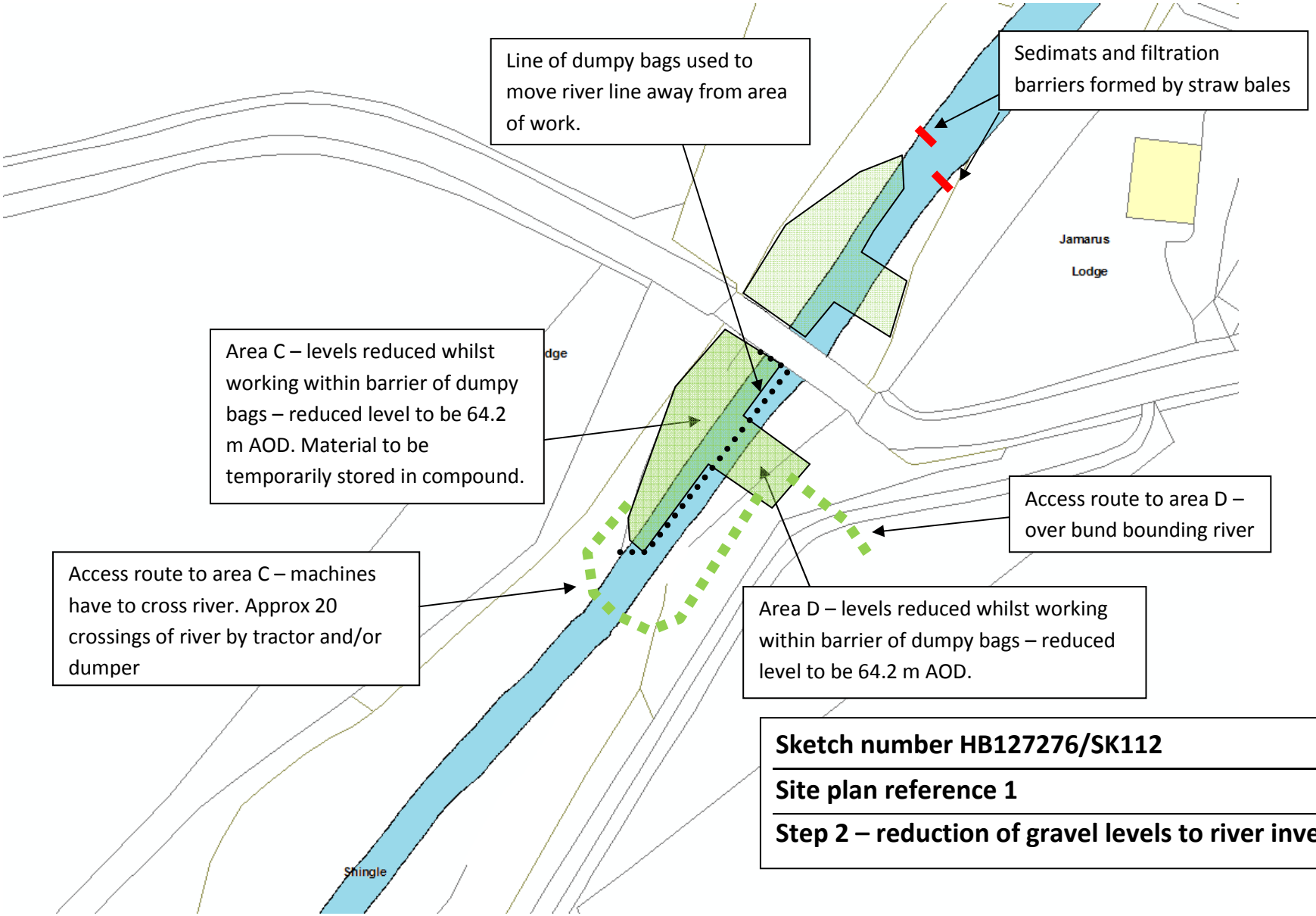
Step 1 – reduction of gravel levels to river invert profile

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK112

Site plan reference 1

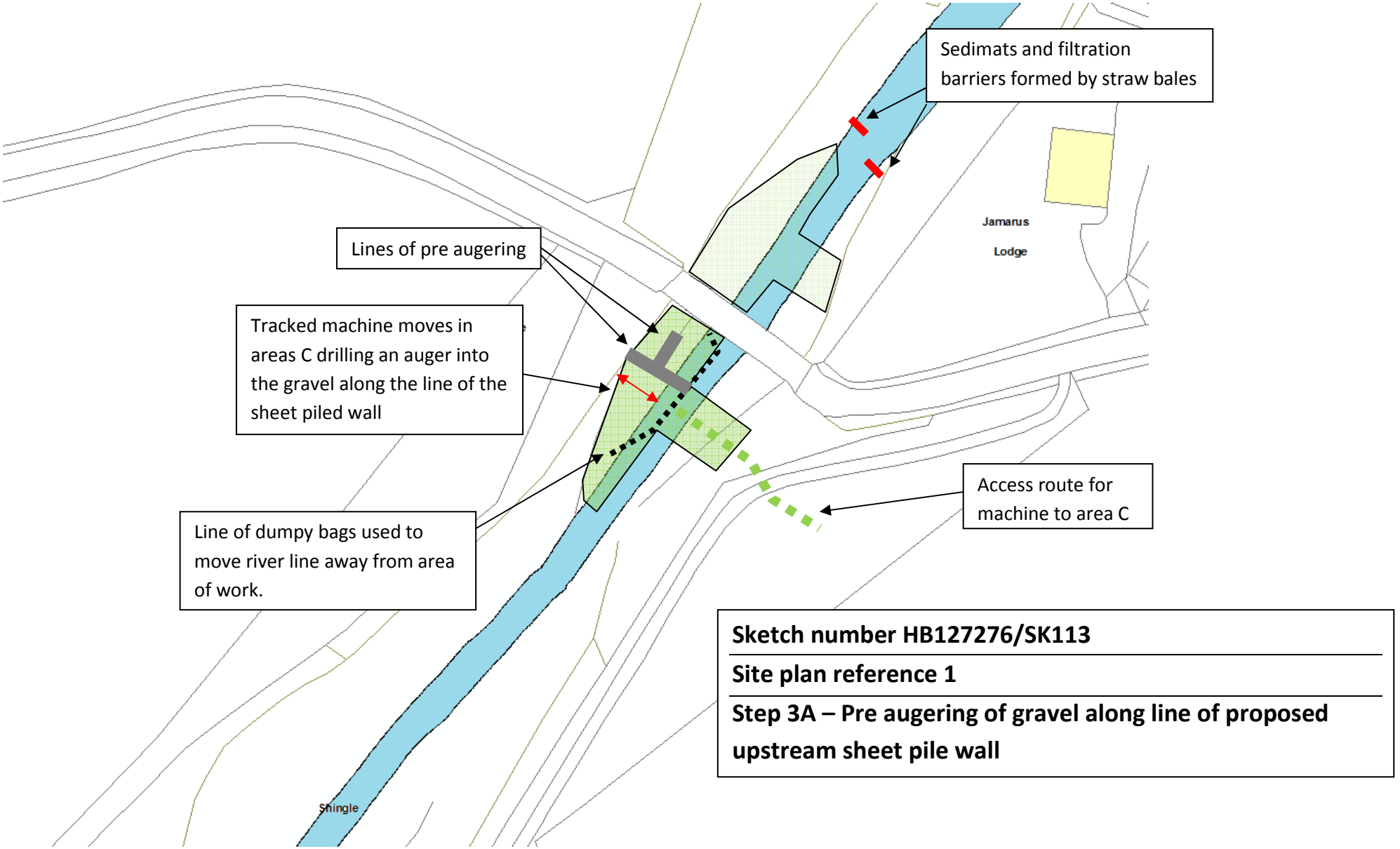
Step 2 – reduction of gravel levels to river invert profile

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency

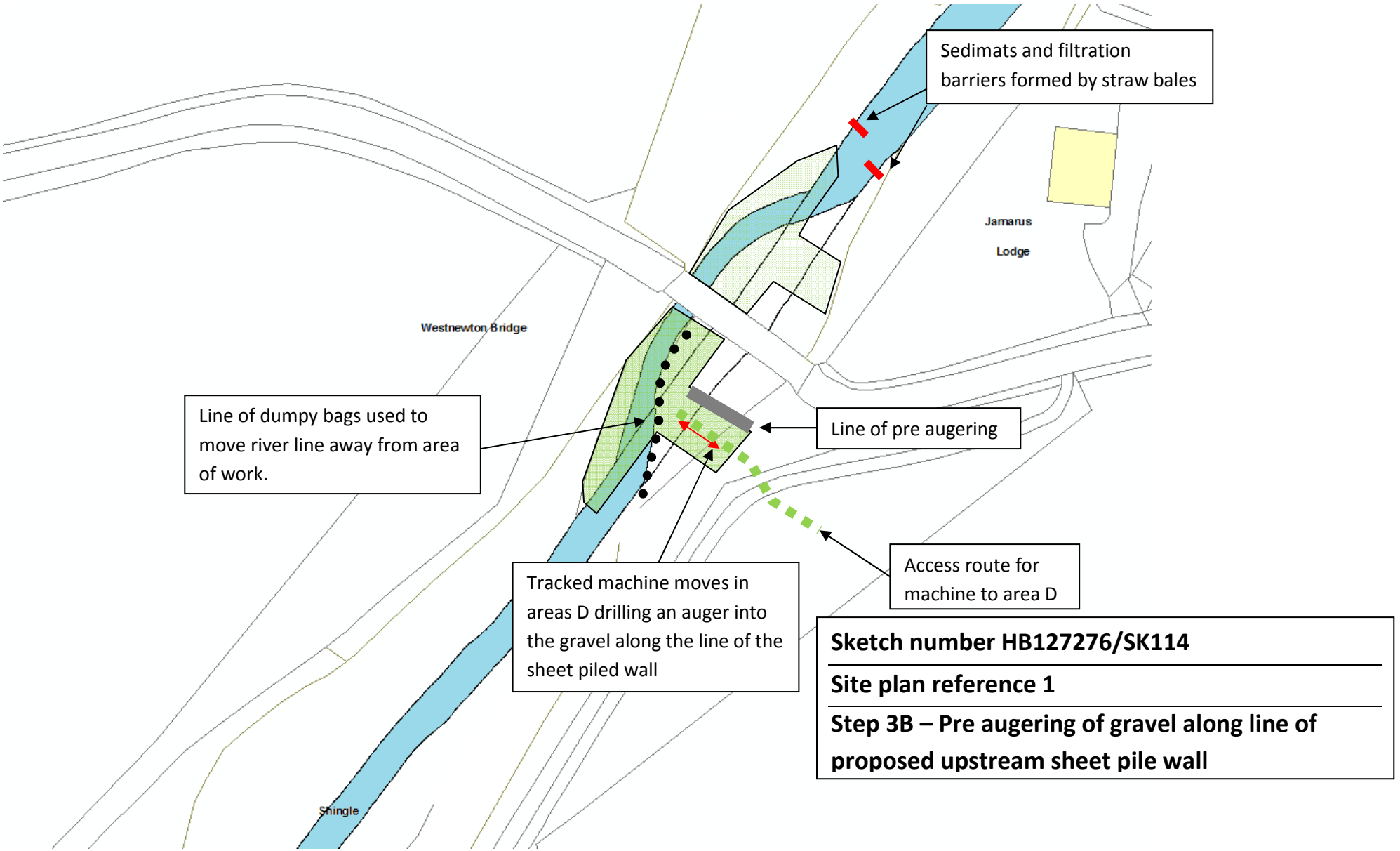


Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency

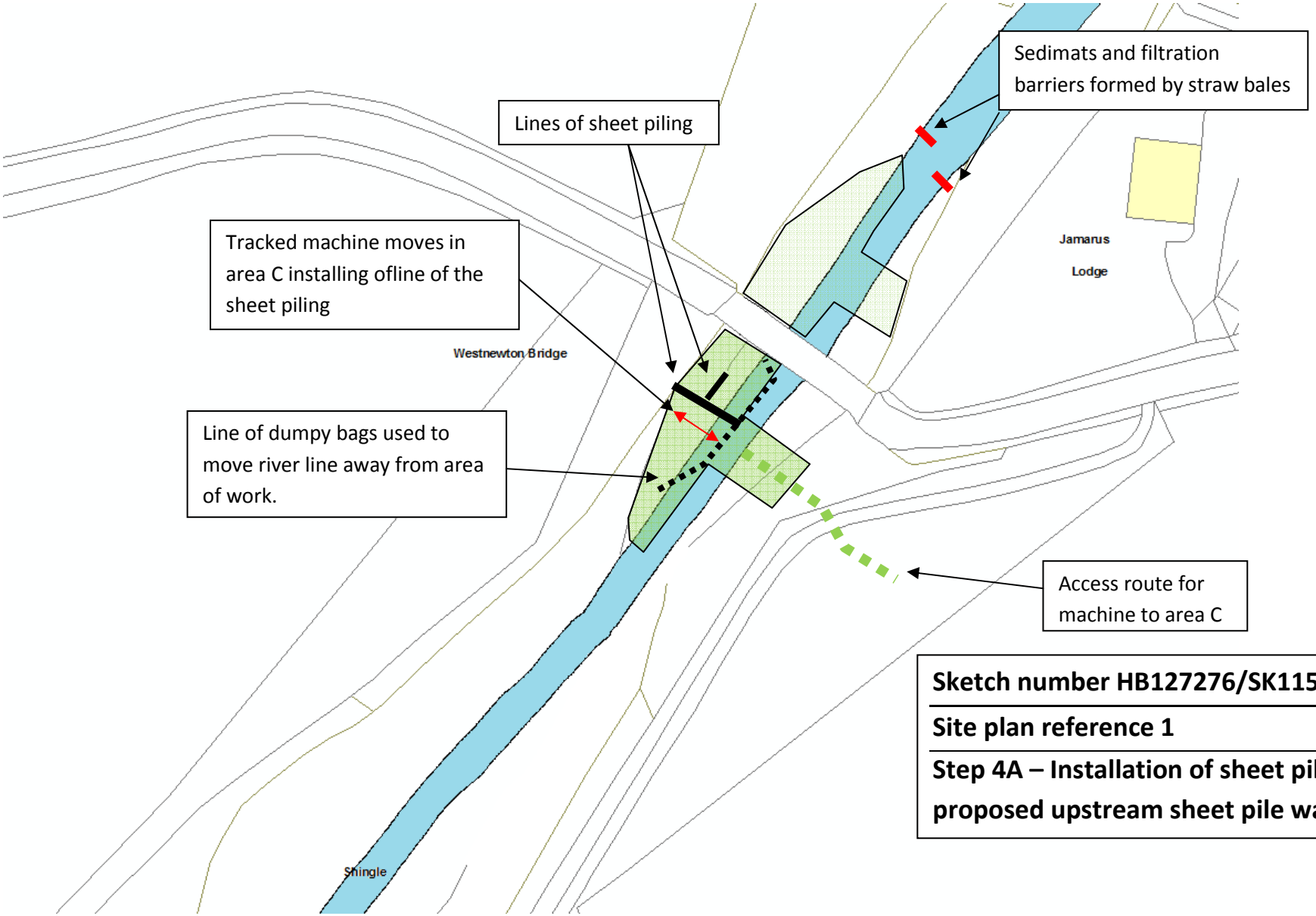


Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK115

Site plan reference 1

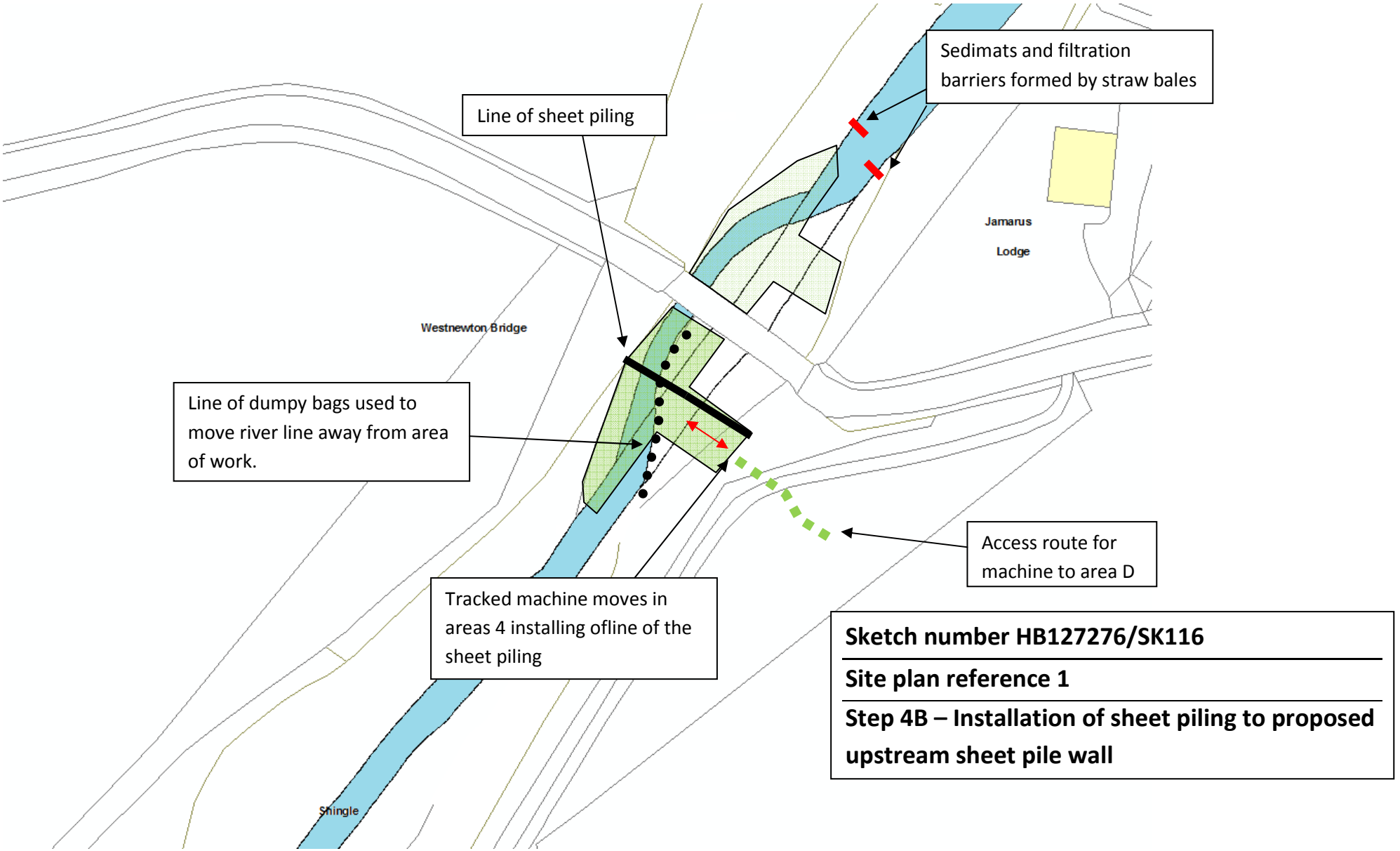
Step 4A – Installation of sheet piling to proposed upstream sheet pile wall

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK116

Site plan reference 1

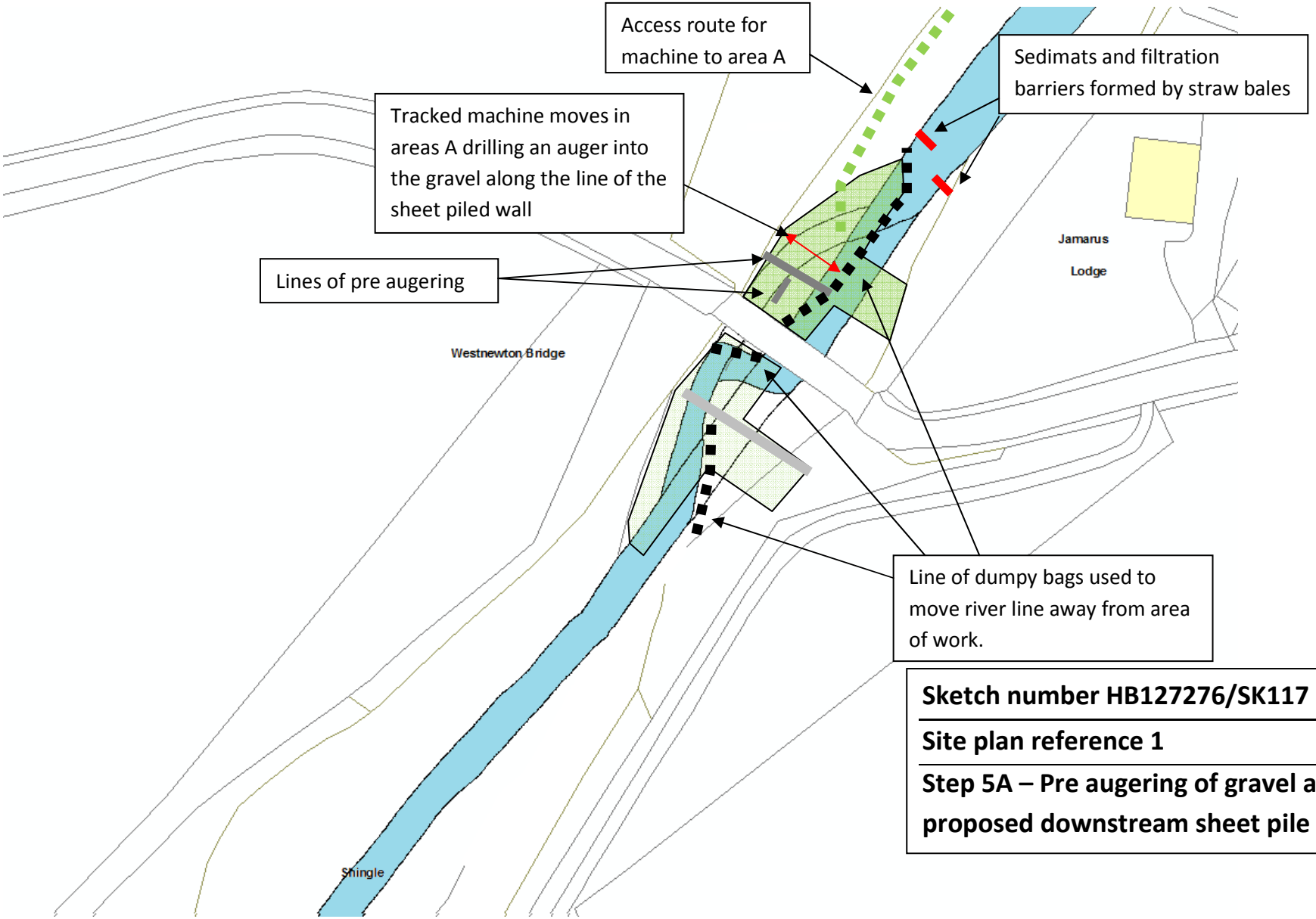
Step 4B – Installation of sheet piling to proposed upstream sheet pile wall

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK117

Site plan reference 1

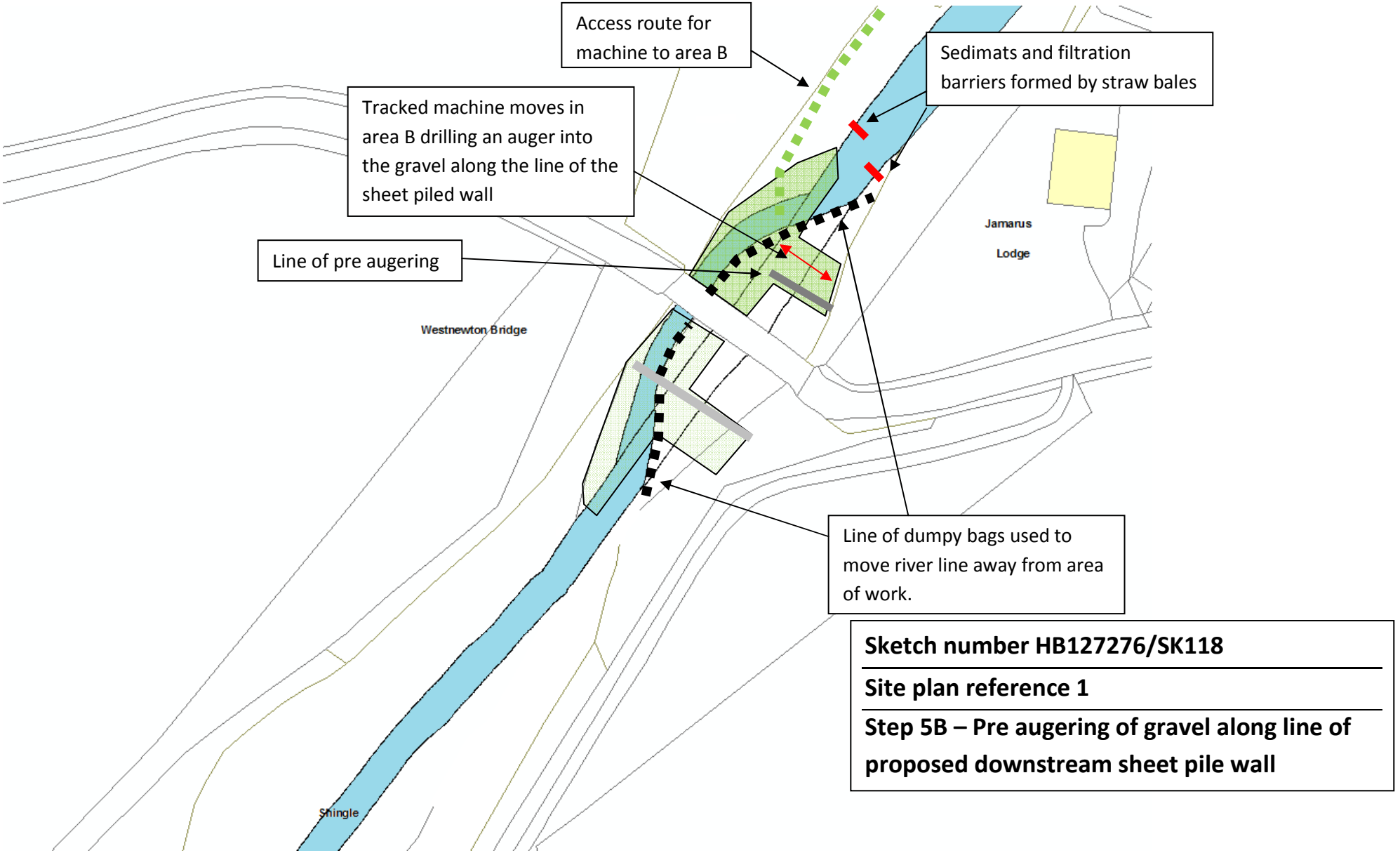
Step 5A – Pre augering of gravel along line of proposed downstream sheet pile wall

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK118

Site plan reference 1

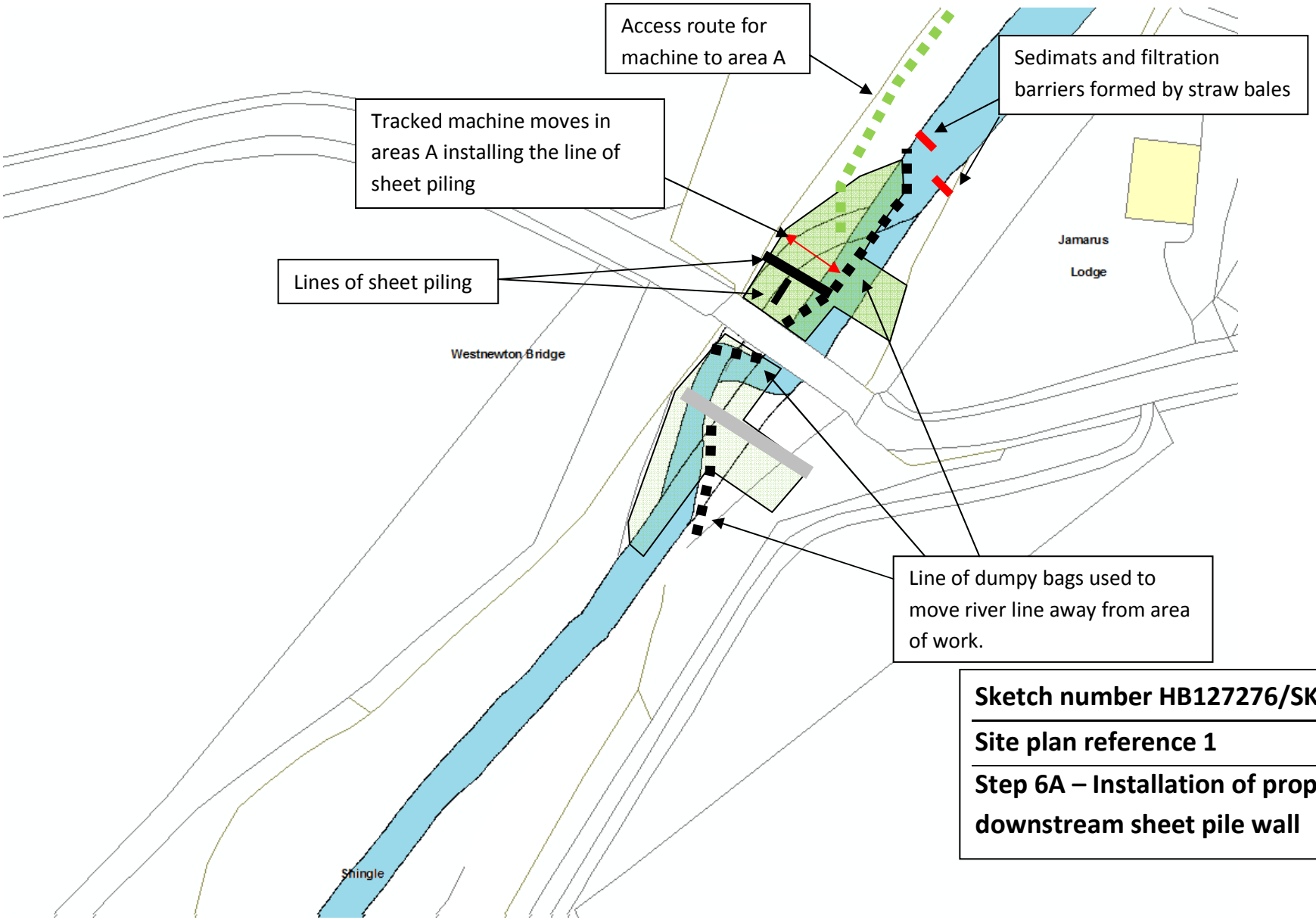
Step 5B – Pre augering of gravel along line of proposed downstream sheet pile wall

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK119

Site plan reference 1

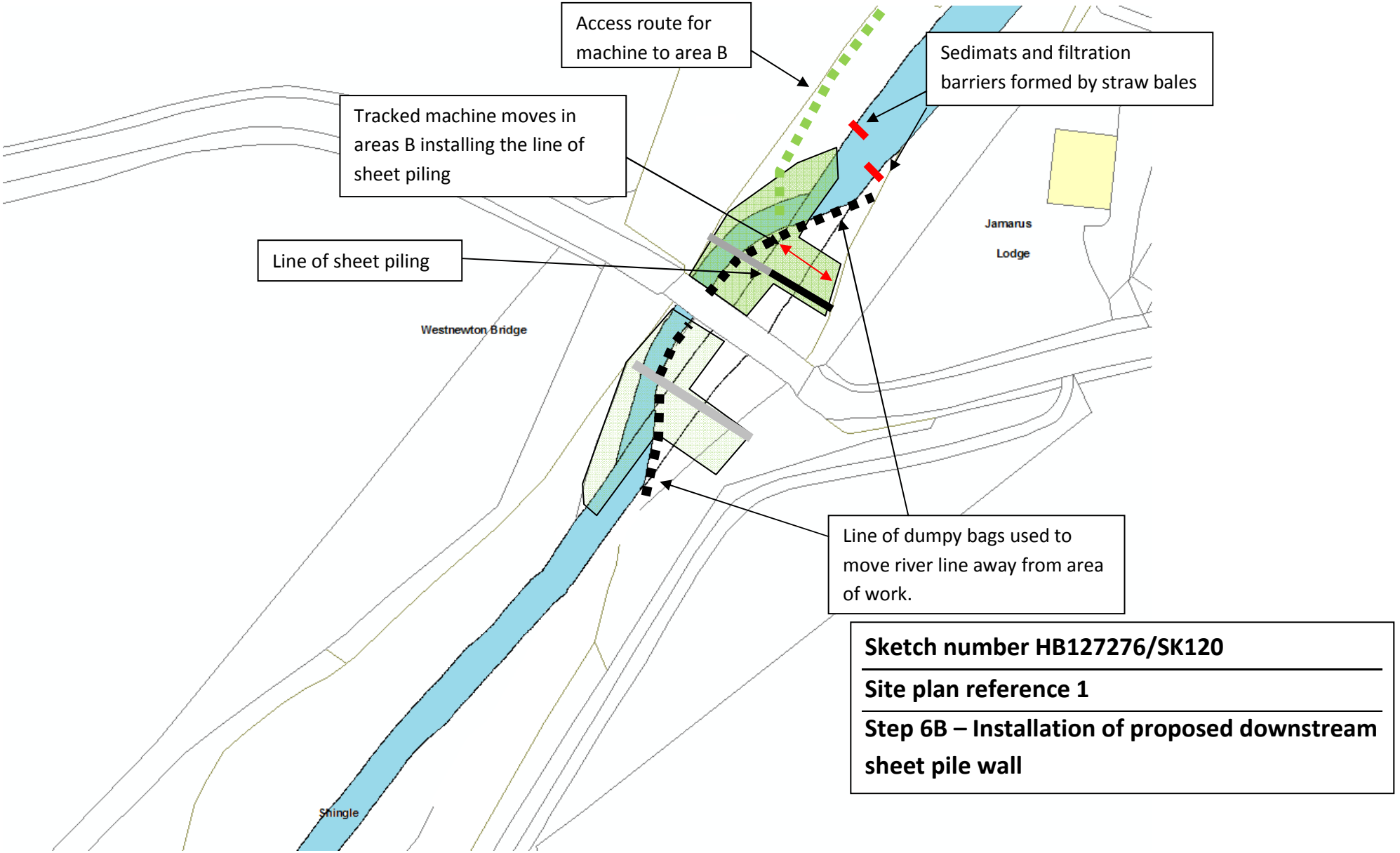
Step 6A – Installation of proposed downstream sheet pile wall

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK120

Site plan reference 1

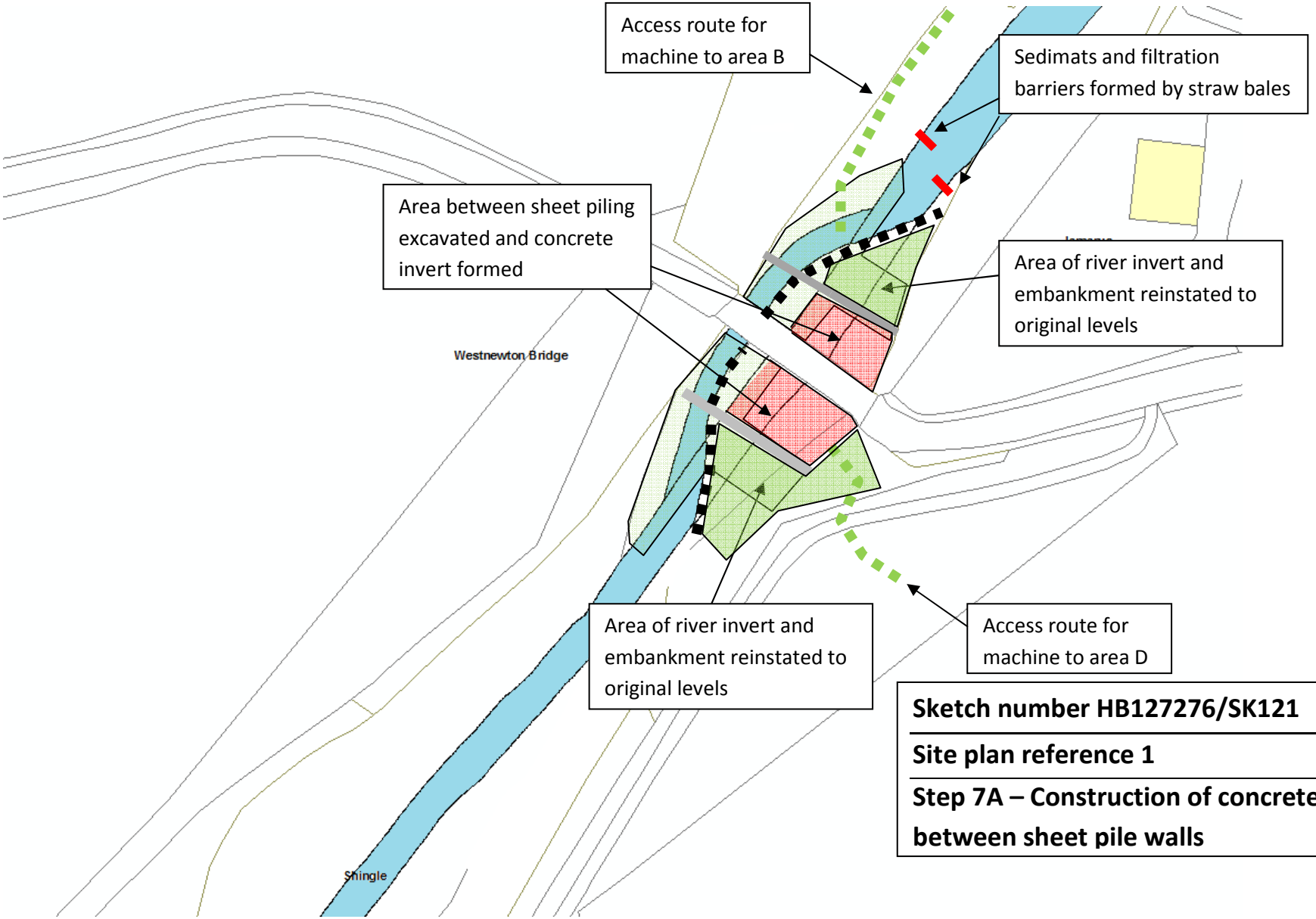
Step 6B – Installation of proposed downstream sheet pile wall

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK121

Site plan reference 1

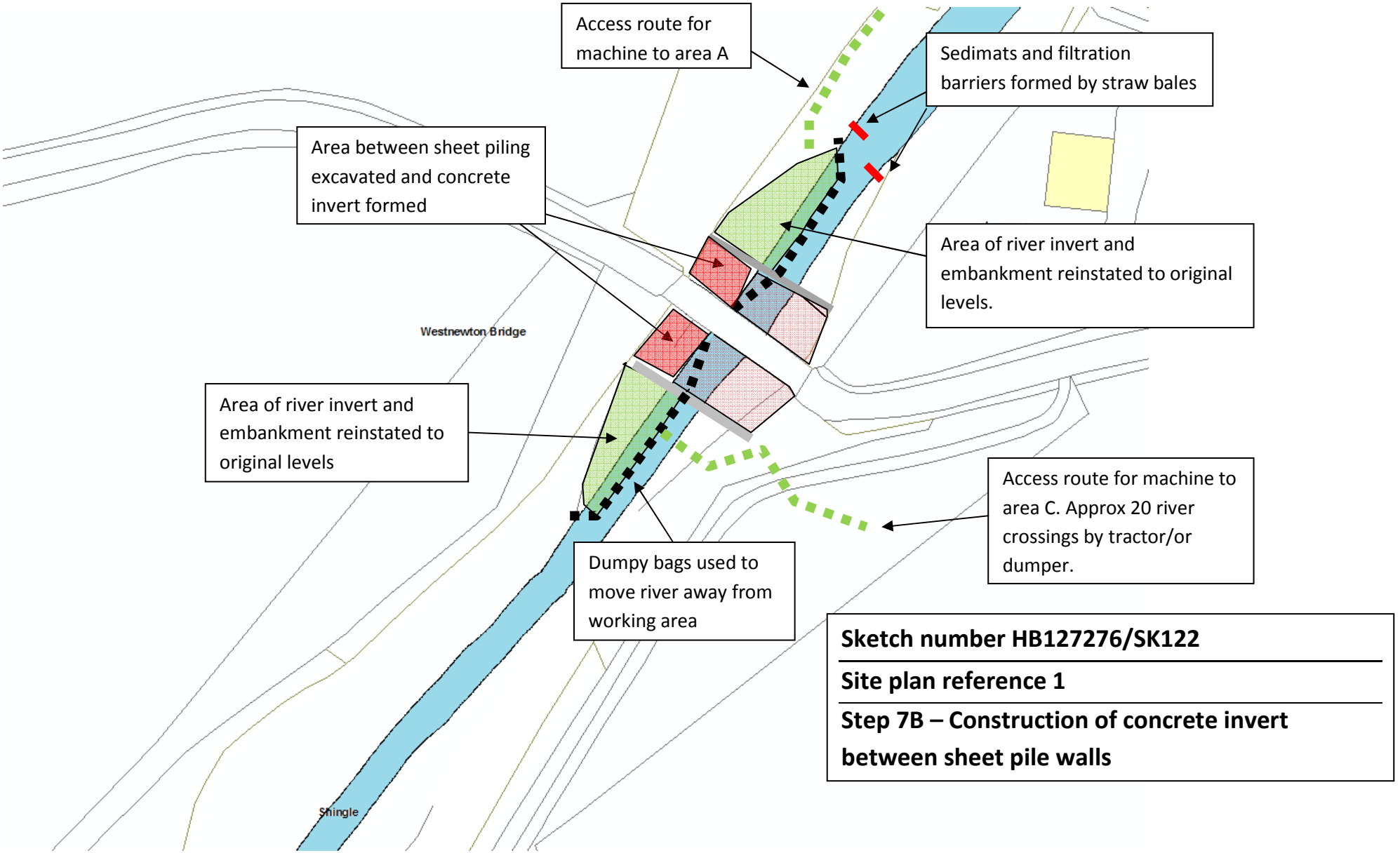
Step 7A – Construction of concrete invert between sheet pile walls

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK122

Site plan reference 1

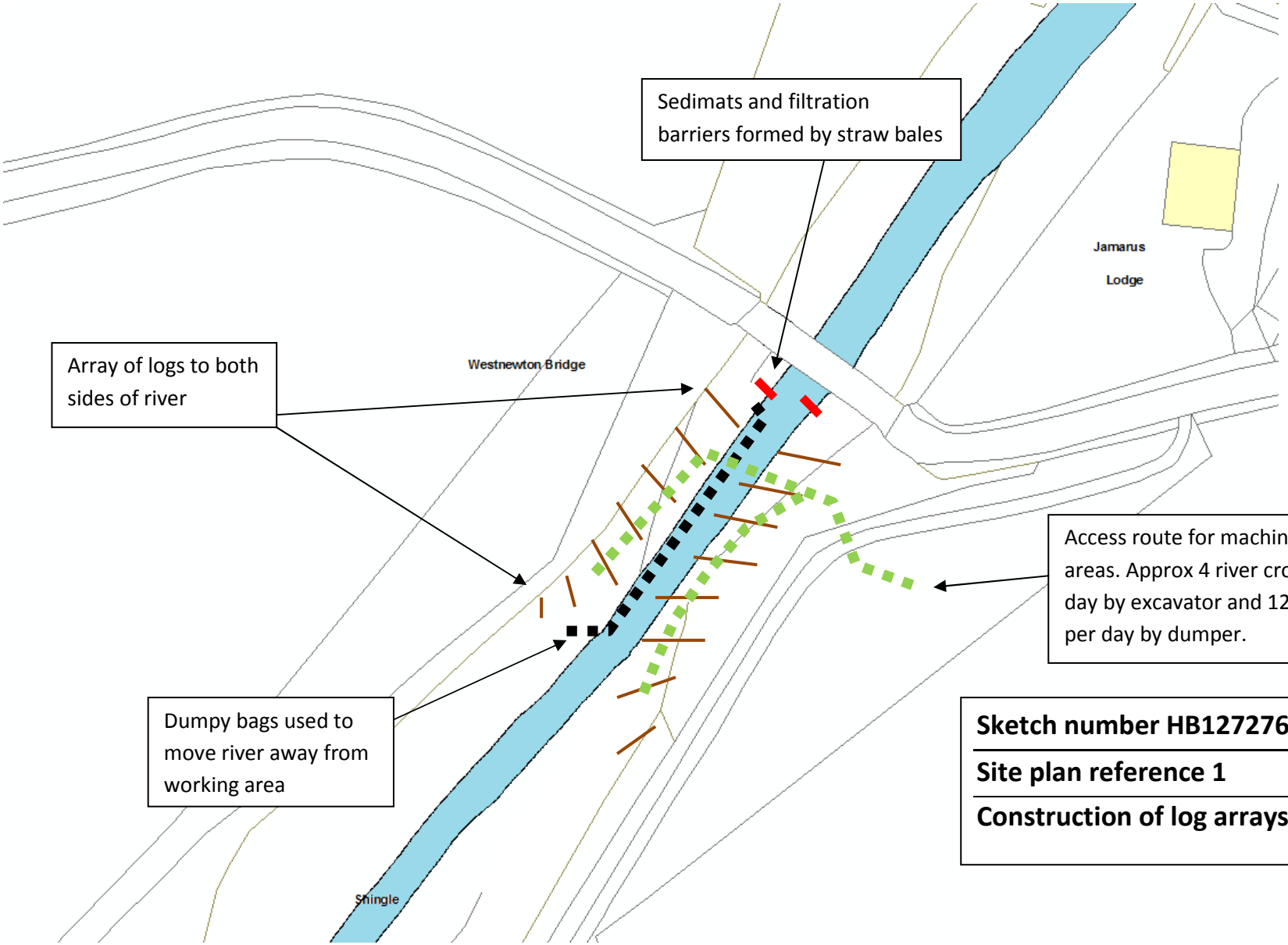
Step 7B – Construction of concrete invert between sheet pile walls

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK123

Site plan reference 1

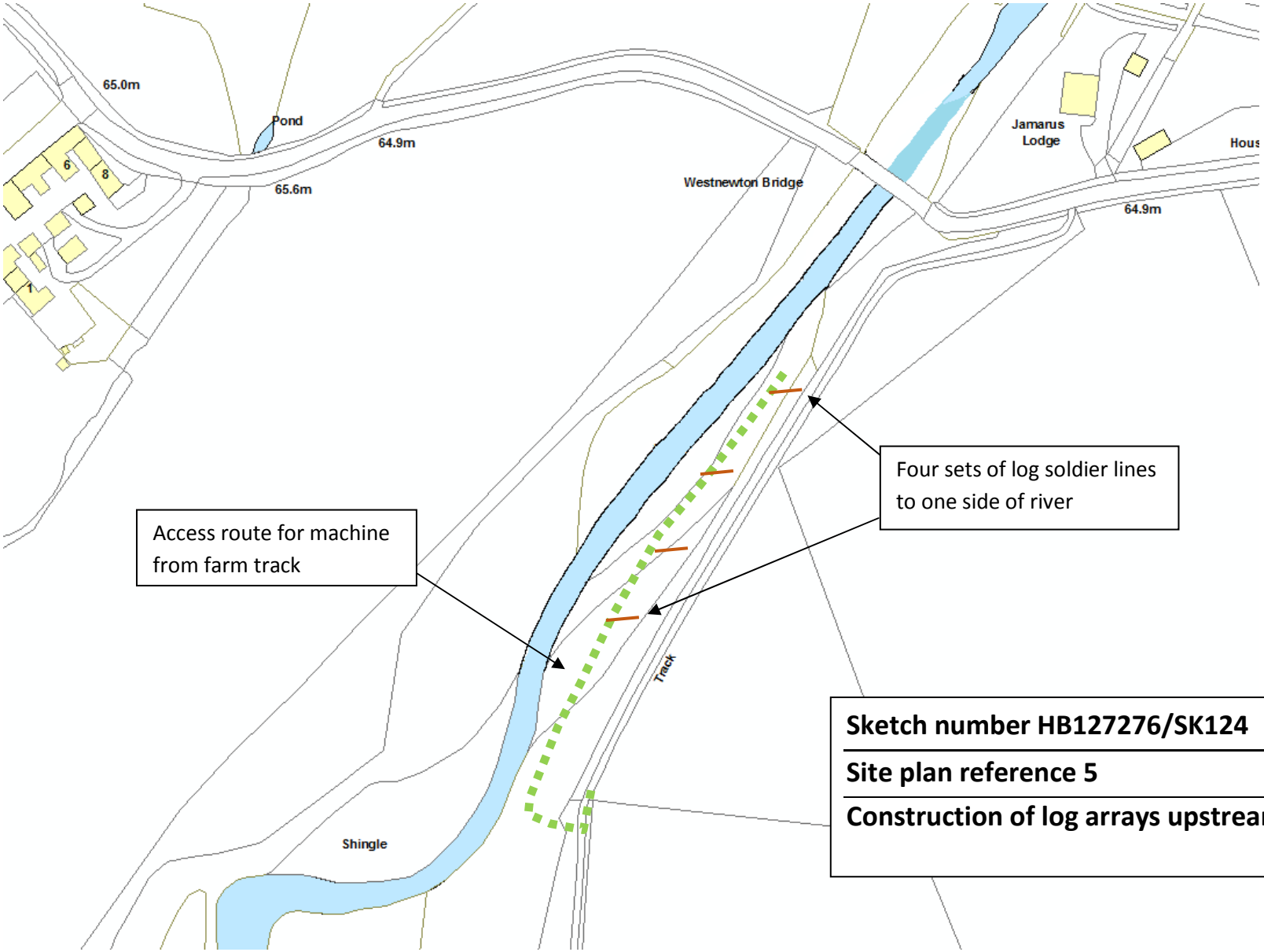
Construction of log arrays upstream of bridge

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Sketch number HB127276/SK124

Site plan reference 5

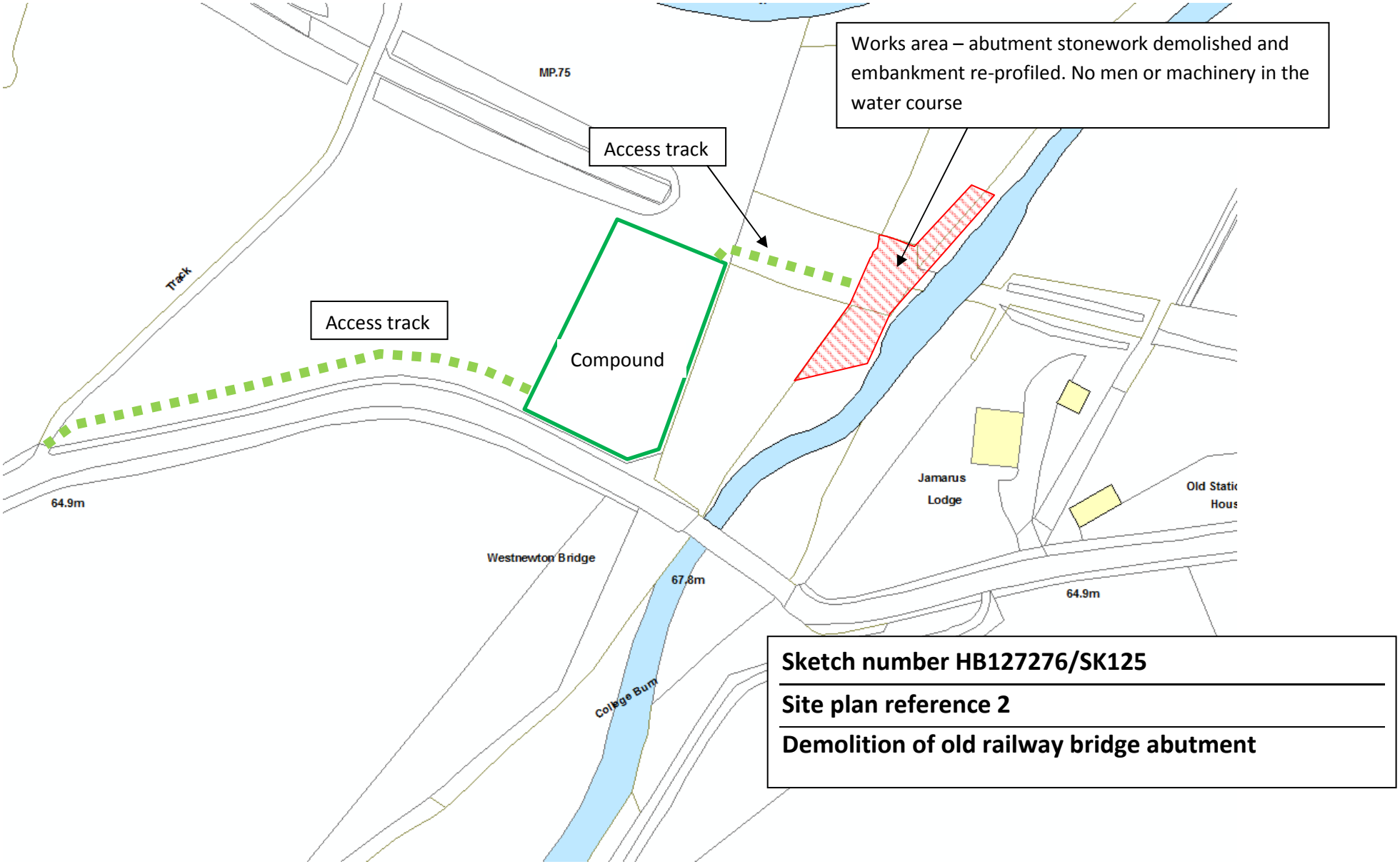
Construction of log arrays upstream of bridge

Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency



Westnewton Bridge B6351

Project number HB127276

Scour protection

Works sequence to be read in conjunction with method statement submitted to Environment Agency