Appendix 16.1

Water Features Survey

WAT-FORM-10: Water Features Survey Identification Form

Applicant Name	**Mouchel Fairhurst JV**	**Borehole Location (e.g. Black Farm, Stirling)**	
Survey Completed by: (Name)	**Marta Lubiejewska-Jones**		
(Company)	**Mouchel Fairhurst JV**	**Borehole NGR**	
(Telephone No.)		**Date(s) of survey**	**Aug 2012**

No	**NGR** / **CAR Ref**	**Type (well/borehole/pond/spring / river/wetland etc)** / **Use (Agricultural/drinking water/industrial etc**	**Abstraction Rate (m3/d)** / **Pump Suction Depth (m)**	**Diameter of Borehole (mm)** / **Dip Tube installed (Y/N)**	**Datum (m)** / **Depth of Borehole (m)**	**Depth to rest water level (m) (date)** / **Depth to pumped water level (m)**	**Water feature description (inc. any access issues)**
Eg 1	NE 1234 5678	Borehole	Approx 70m3/d April-September	600mm	Top of casing. Elevation in mAOD not known.	10m from borehole log	Borehole is sealed and there is no access for dip tube. Borehole details have been given verbally by farmer. Borehole is used for irrigation.
	CAR/L/0001	Agricultural	25m	N	35m	Not known	
Eg 2	SE 4567 8912	Wetland	n/a	n/a	n/a	n/a	Wetland type 3d – seepage/flushes. 10m x 20m. Part of a designated SAC. See wetland typology field survey form for details.
	n/a	n/a	n/a	n/a	n/a	n/a	

The above details are examples of information required to complete this form and have no relevance to the proposed A737 Dalry Bypass Scheme.

Notes:

1. This form should be read in conjunction with drawing A737MFJV/ST3/D/002_rev 01 ‘Water Features Location Plan’.
2. Information on water features listed below is based on a review of OS maps, general walkover survey, Envirocheck Report dated June 2012 as well as information provided by North Ayrshire Council. It should be noted that the list may not be exhaustive and other water features, not identified in the table, may also be present in the area of interest.
3. Positional accuracy of Envirocheck Report based information 100m.

No	NGR	Type (well/borehole/pond/spring / river/wetland etc)	Abstraction Rate (m3/d)	Diameter of Borehole (mm)	Datum (m) GL- approx. ground level	Depth to rest water level (m) (date)	Water feature description (inc. any access issues)
	CAR Ref	**Use (Agricultural/drinking water/industrial etc**	**Pump Suction Depth (m)**	**Dip Tube installed (Y/N)**	**Depth of Borehole (m)**	**Depth to pumped water level (m)**	
W1	NS 2872 4827	River	n/a	n/a	50 (GL)	n/a	Boll Burn Caaf Water tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W2	NS 2895 4857	River	n/a	n/a	25 (GL)	n/a	Caaf Water River Garnock tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W3	NS 2915 4772	Spring	n/a	n/a	44.4 (GL)	n/a	Issues/Sinks Not inspected
	n/a	n/a	n/a	n/a	n/a	n/a	
W4	NS 2955 4743	Spring	n/a	n/a	35 (GL)	n/a	Issues/Springs River Garnock tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W5	NS 2918 4895	River	n/a	n/a	25 (GL)	n/a	Putyan Burn River Garnock tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W6	NS 2934 4888	River	n/a	n/a	25 (GL)	n/a	River Garnock
	n/a	n/a	n/a	n/a	n/a	n/a	
W7	NS 2972 4826	Spring	n/a	n/a	20.2 (GL)	n/a	Issues River Garnock tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W8	NS 3000 4824	Spring	n/a	n/a	30.6 (GL)	n/a	Issues River Garnock tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W9	NS 3041 4807	River	n/a	n/a	40 (GL)	n/a	Bombo Burn River Garnock tributary
	n/a	n/a	n/a	n/a	n/a	n/a	
W10	NS 3055 4852	Spring	n/a	n/a	50 (GL)	n/a	Issues Bombo Burn tributary
	n/a	n/a	n/a	n/a	n/a	n/a	

No	NGR / CAR Ref	Type (well/borehole/pond/spring / river/wetland etc) / Use (Agricultural/drinking water/industrial etc	Abstraction Rate (m3/d) / Pump Suction Depth (m)	Diameter of Borehole (mm) / Dip Tube installed (Y/N)	Datum (m) GL- approx. ground level / Depth of Borehole (m)	Depth to rest water level (m) (date) / Depth to pumped water level (m)	Water feature description (inc. any access issues)
W11	NS 3009 4934	Unknown	n/a	n/a	40 (GL)	n/a	Source and full extent unknown. Partially inspected. Potential connectivity with W12
	n/a	n/a	n/a	n/a	n/a	n/a	
W12	NS 3041 4917	Spring	n/a	n/a	57 (GL)	n/a	Issues/Sinks
	n/a	n/a	n/a	n/a	n/a	n/a	Potential connectivity with W11, boggy but not flowing at the time of site walkover
W13	NS 3086 4896	Spring	n/a	n/a	60 (GL)	n/a	Issues
	n/a	n/a	n/a	n/a	n/a	n/a	Bombo Burn tributary
W14	NS 3032 4939	Unknown	n/a	n/a	55 (GL)	n/a	Source and full extent unknown. Partially inspected
	n/a	n/a	n/a	n/a	n/a	n/a	
W15	NS 3023 4965	Spring	n/a	n/a	35 (GL)	n/a	Issues
	n/a	n/a	n/a	n/a	n/a	n/a	River Garnock tributary
W16	NS 3127 4942	Spring	n/a	n/a	70 (GL)	n/a	Issues
	n/a	n/a	n/a	n/a	n/a	n/a	Bombo Burn tributary
W17	NS 3125 5022	River	n/a	n/a	74 (GL)	n/a	Coalheughglen Burn
	n/a	n/a	n/a	n/a	n/a	n/a	River Garnock tributary. Heavy modified, known history of flooding
W18	NS 3128 5040	Spring	n/a	n/a	76 (GL)	n/a	Issues
	n/a	n/a	n/a	n/a	n/a	n/a	Full extent unknown, potential connectivity with W17
W19	NS 3186 4994	Spring	n/a	n/a	78 (GL)	n/a	Issues
	n/a	n/a	n/a	n/a	n/a	n/a	

No	NGR / CAR Ref	Type (well/borehole/pond/spring / river/wetland etc) / Use (Agricultural/drinking water/industrial etc	Abstraction Rate (m3/d) / Pump Suction Depth (m)	Diameter of Borehole (mm) / Dip Tube installed (Y/N)	Datum (m) GL- approx. ground level / Depth of Borehole (m)	Depth to rest water level (m) (date) / Depth to pumped water level (m)	Water feature description (inc. any access issues)
W20	NS 3101 5115	Spring	n/a	n/a	50 (GL)	n/a	Issues
	n/a	n/a	n/a	n/a	n/a	n/a	River Garnock tributary
W21	NS 3106 5141	Spring	n/a	n/a	65 (GL)	n/a	Issues/Sinks
	n/a	n/a	n/a	n/a	n/a	n/a	River Garnock tributary
WF1	NS 3016 4870	Wetland	n/a	n/a	37.5 (GL)	n/a	Marshland
	n/a	n/a	n/a	n/a	n/a	n/a	
WF2	NS 3018 4944	Wetland	n/a	n/a	30 (GL)	n/a	Marshland
	n/a	n/a	n/a	n/a	n/a	n/a	
WF3	NS 3134 4924	Pond	n/a	n/a	65 (GL)	n/a	Origin unknown
	n/a	n/a	n/a	n/a	n/a	n/a	
WF4	NS 3118 4995	Pond	n/a	n/a	80 (GL)	n/a	Located near shallow mine workings
	n/a	n/a	n/a	n/a	n/a	n/a	
WF5	NS 3176 5026	Pond	n/a	n/a	85 (GL)	n/a	Origin unknown
	n/a	n/a	n/a	n/a	n/a	n/a	
WF6	NS 3148 5087	Wetland	n/a	n/a	80 (GL)	n/a	Marshland covering majority of Highfield area
	n/a	n/a	n/a	n/a	n/a	n/a	
WF7	NS 3171 5101	Pond	n/a	n/a	80 (GL)	n/a	Origin unknown
	n/a	n/a	n/a	n/a	n/a	n/a	
FC1	NS 2943 4867	Weir	n/a	n/a	n/a	n/a	Weir on River Garnock (W6)
	n/a	n/a	n/a	n/a	n/a	n/a	

No	NGR / CAR Ref	Type (well/borehole/pond/spring / river/wetland etc) / Use (Agricultural/drinking water/industrial etc	Abstraction Rate (m3/d) / Pump Suction Depth (m)	Diameter of Borehole (mm) / Dip Tube installed (Y/N)	Datum (m) GL- approx. ground level / Depth of Borehole (m)	Depth to rest water level (m) (date) / Depth to pumped water level (m)	Water feature description (inc. any access issues)
FC2	NS 2950 4844	Weir	n/a	n/a	n/a	n/a	Weir on River Garnock (W6)
	n/a	n/a	n/a	n/a	n/a	n/a	
FC3	NS 2969 4817	Weir	n/a	n/a	n/a	n/a	Weir on River Garnock (W6)
	n/a	n/a	n/a	n/a	n/a	n/a	
FC4	NS 2977 4932	Weir	n/a	n/a	n/a	n/a	Weir on River Garnock (W6)
	n/a	n/a	n/a	n/a	n/a	n/a	
AB1	NS 2918 4749	Spring or groundwater abstraction, Type B	Unknown	Unknown	Unknown	Unknown	Old Monkcastle, Dalry Road, Kilwinning, ref.: B/GV/012a. Exact location unknown
	Unknown	Water supply	Unknown	Unknown	Unknown	Unknown	
AB2	NS 2918 4749	Spring or groundwater abstraction, Type B	Unknown	Unknown	Unknown	Unknown	Laigh Monkcastle, Dalry Road, Kilwinning, ref.: B/GV/012b. Exact location unknown
	Unknown	Water supply	Unknown	Unknown	Unknown	Unknown	
AB3	NS 2945 4815	Borehole, Type B	Unknown	Unknown	Unknown	Unknown	Hillend Farm, Dalry, ref. B/GV/010a. Exact location unknown
	Unknown	Water supply	Unknown	Unknown	Unknown	Unknown	
AB5	NS 3064 5087	Well	Unknown	Unknown	Unknown	Unknown	Located near East Kersland property
	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	
PSD1	NS 2939 4875	Point Source Discharge	n/a	n/a	n/a	n/a	Scottish Water combined sewer overflow to River Garnock (W6). Ref. Details unknown
	Unknown	n/a	n/a	n/a	n/a	n/a	
PSD2	NS 2976 4919	Point Source Discharge	n/a	n/a	n/a	n/a	Scottish Water combined sewer overflow to River Garnock, ref. 12907
	Unknown	n/a	n/a	n/a	n/a	n/a	

No	NGR	Type (well/borehole/pond/spring / river/wetland etc)	Abstraction Rate (m3/d)	Diameter of Borehole (mm)	Datum (m) GL- approx. ground level	Depth to rest water level (m) (date)	Water feature description (inc. any access issues)
	CAR Ref	**Use (Agricultural/drinking water/industrial etc**	**Pump Suction Depth (m)**	**Dip Tube installed (Y/N)**	**Depth of Borehole (m)**	**Depth to pumped water level (m)**	
OT1	NS 3011 4966	Old coal mine adit	n/a	n/a	n/a	n/a	BGS ref.: Ns34nw42
	Unknown	Mine water	n/a	n/a	n/a	n/a	Approximate position of 'Day Level' outfall to River Garnock. Approximate (unconfirmed) discharge rate 2250 – 2750l/min.
OT2	NS 3108 4994	Old coal mine adit	n/a	n/a	n/a	n/a	Approximate line of 'Day Level' to River Garnock in Borestone Coal
	n/a	Mine water	n/a	n/a	n/a	n/a	

No	NGR	Type (well/borehole/pond/spring / river/wetland etc)	Abstraction Rate (m3/d)	Diameter of Borehole (mm)	Datum (m) GL- approx. ground level	Depth to rest water level (m) (date)	Water feature description (inc. any access issues)
	CAR Ref	Use (Agricultural/drinking water/industrial etc	Pump Suction Depth (m)	Dip Tube installed (Y/N)	Depth of Borehole (m)	Depth to pumped water level (m)	
D1	NS 2929 4792	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D2	NS 2923 4811	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D3	NS 2923 4823	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D4	NS 2943 4830	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D5	NS 2953 4801	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D6	NS 2952 4885	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D7	NS 2993 4856	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D8	NS 3016 4842	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D9	NS 3008 4870	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	

No	NGR	Type (well/borehole/pond/spring / river/wetland etc)	Abstraction Rate (m3/d)	Diameter of Borehole (mm)	Datum (m) GL- approx. ground level	Depth to rest water level (m) (date)	Water feature description (inc. any access issues)
	CAR Ref	Use (Agricultural/drinking water/industrial etc	Pump Suction Depth (m)	Dip Tube installed (Y/N)	Depth of Borehole (m)	Depth to pumped water level (m)	
D10	NS 3020 4884	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D11	NS 3070 4917	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D12	NS 3062 4959	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D13	NS 3053 4984	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D14	NS 3092 4959	Ditch/Drain	n/a	n/a	n/a	n/a	Road drainage ditch
	n/a	n/a	n/a	n/a	n/a	n/a	
D15	NS 3102 4960	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D16	NS 3082 5012	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D17	NS 3136 5078	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D18	NS 3160 5093	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D19	3168 5125	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	

No	NGR / CAR Ref	Type (well/borehole/pond/spring / river/wetland etc) / Use (Agricultural/drinking water/industrial etc	Abstraction Rate (m3/d) / Pump Suction Depth (m)	Diameter of Borehole (mm) / Dip Tube installed (Y/N)	Datum (m) GL- approx. ground level / Depth of Borehole (m)	Depth to rest water level (m) (date) / Depth to pumped water level (m)	Water feature description (inc. any access issues)
D20	NS 3208 5083	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	
D21	NS 3235 5120	Ditch/Drain	n/a	n/a	n/a	n/a	
	n/a	n/a	n/a	n/a	n/a	n/a	

Add more rows and continue on new page if required.

Appendix 16.2

Water Environment Photographs

Photo 1 – Caaf Water (W2) upstream of confluence with River Garnock, looking downstream

Photo 2 – River Garnock (W6) downstream of the proposed Viaduct, looking upstream

Photo 3 – Unnamed tributary of River Garnock (W8) at the proposed Bypass crossing, looking downstream

Photo 4 – Unnamed tributary of River Garnock (W8) upstream of railway crossing, looking downstream

Photo 5 – Unnamed tributary of River Garnock (W15) upstream of River Garnock walkway, looking upstream

Photo 6 – Coalheughglen Burn (W17) at the proposed Bypass crossing, looking downstream

Photo 7 – Coalheughglen Burn (W18) at the existing A737 crossing, looking upstream

Photo 8 – Tributary of Coalheughglen Burn (W18) at the proposed Bypass crossing

Photo 9 – Proposed location for SuDS Basin 1, looking NE

Photo 10 – Proposed location for SuDS Basin 2, plan view

Photo 11 – Proposed location for SuDS Basin 3, plan view

Photo 12 – Proposed location for SuDS Basin 4, looking NE

Photo 13 – Proposed location for SuDS Basin 5, looking NW

A737 Dalry Bypass

Stage 3

Flood Risk Assessment

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June 2013

Document Control Sheet

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Issue	Status	Author	Date	Check	Date	Authorised	Date
01	Final	E. Clarke	March 2013	E. Connon	March 2013	E. Connon	March 2013
02	Final	E. Clarke	June 2013	R. Minto	June 2013	E. Connon	June 2013

Distribution

Organisation	Contact	Copies

Contents

1 Introduction

This report has been completed by Fairhurst as part of the Mouchel Fairhurst Joint Venture (MFJV) on behalf of Transport Scotland. The report forms the Flood Risk Assessment for the proposed A737 Dalry Bypass.

The existing A737 road is located in North Ayrshire and extends in a south-westerly direction from Junction 29 of the M8 through the towns of Beith and Dalry before turning south towards Kilwinning. High traffic volumes on the A737 are thought to contribute to congestion within Dalry and the surrounding road networks. A bypass is proposed to extend from the A737 at Highfield on the north-east side of Dalry, to Hillend on the south side of Dalry.

In accordance with the Design Manual for Roads and Bridges (DMRB) Volume 5, Section 1, Part 2 (TD37/93) requirements, the proposed scheme has been progressed through the Stage 1 and Stage 2 assessment processes. The Stage 1 and 2 assessments evaluated various route options for the scheme against certain environmental, engineering, economic and traffic criteria and arrived at a "preferred route option" for progression to the current Stage 3 assessment. The Stage 3 assessment considers the preferred scheme in greater detail against the above criteria and in particular requires the assessment of significant environmental effects of the project in accordance with the requirements of Section 20A and 55A of the Roads (Scotland) Act 1984.

As part of the scheme development process, consultations have taken place with key stakeholders including SEPA, SNH and North Ayrshire Council. SEPA has confirmed that where construction takes place in the functional floodplain, a full analysis of the effects on flow and flood storage is required and that mitigation is considered if necessary.

To satisfy these requirements and those of the DMRB, this report has been prepared in accordance with the SEPA guidance document *"Technical Flood Risk Guidance for Stakeholders"* and the DMRB (2009), Volume 11, Environmental Assessment, Section 3; Environmental Assessment Techniques, Part 10 (HD 45/09); Road Drainage and the Water Environment.

This report assesses the potential flood risk from fluvial, pluvial, groundwater, & existing drainage infrastructure sources on the proposed scheme in sections 6, 7, 8, & 9. The impact of the proposed scheme on flood risk elsewhere is considered in section 10. Where a potential source of flooding or impact is identified, the report provides details of the proposed mitigation measures to be adopted. The proposed scheme is sufficiently far inland that there are no flood risks from coastal sources such as high tides, storm surge or wave action and so these will not be considered any further in this report.

Previous studies of flooding in the River Garnock catchment have been carried out by Babtie Group (now Jacobs) in 2003, Haskoning (2005 & 2008), Mouchel (2010) and most recently by Halcrow (2012). These studies are considered in greater detail in the report.

A detailed topographic survey of the proposed scheme corridor and affected watercourses has been carried out to enable a more detailed assessment of flood risk.

2 Existing Situation

2.1 Location and Topography

The Scheme is located to the east of Dalry and extends for a distance of approximately 3.8km, from some 1.2km north of the Highfield area to the Hillend area located to the south of Dalry. The location of the proposed bypass is shown on drawing A737MFJV/ST3/D/001 included in Appendix A. This area was previously dominated by mine workings but has since been returned to arable farmland and rough grazing.

The northern section of the scheme is located on relatively high ground at levels of up to 82mAOD. Heading south, ground levels drop to approximately 20mAOD in the River Garnock valley.

2.2 River Garnock

The most significant watercourse in the vicinity of the proposed bypass is the River Garnock. It flows in a southerly direction from the headwaters north of Kilbirnie to its confluence with the River Irvine in Irvine Harbour. The River Garnock has a total catchment area of approximately 175km^2 and a catchment area of 120km^2 immediately downstream of the proposed Scheme. The headwaters are located at approximately 500-600mAOD and consist of predominantly upland rural land-use. The lowland areas of the catchment are flatter with small urban clusters located at Kilbirnie, Dalry and Kilwinning. Small areas of forestation exist particularly around Kilbirnie, however they are not considered to have a significant affect on the flow regime in the River Garnock.

The main tributaries of the River Garnock are the Rye Water and Caaf Water entering at Dalry, and the Lugton Water entering at Kilwinning. There are no reservoirs or lakes in the headwaters of the River Garnock; however the Rye and Caaf both contain reservoirs which provide some attenuation of peak flows.

The Putyan Burn enters the River Garnock on the southern edge of Dalry and approximately 800m upstream from the proposed crossing location.

The SEPA flood map of the area provides an indication of likely inundation in the 0.5% annual probability event. Although the flood map was produced using methodology designed to provide a strategic overview of flood risk, it does show that flooding associated with the River Garnock should be considered in more detail.

2.3 Caaf Water

The Caaf Water is a main tributary of the River Garnock with a total catchment area of about $28km^2$. The Caaf Water rises on Green Hill and flows south through the Knockendon and Caaf Reservoirs before turning south-east and then east. The Caaf Water joins the River Garnock to the south of Dalry, near to the proposed location for the connection of the Dalry Bypass with the existing A737. The upland catchment of the Caaf is dominated by moorland and the aforementioned reservoirs. The lowland catchment is characterised by predominately rural land use with little urbanisation.

2.4 Coalheughglen Burn

The Coalheughglen Burn is a minor watercourse and tributary of the River Garnock. It rises some distance north east of the Highfield area and flows alongside the existing A737, joining the River Garnock on the outskirts of Dalry. The Coalheughglen Burn has a catchment area of approximately $1.2km^2$ and is predominantly rural. The location of the Coalheughglen Burn in relation to the Scheme is shown on drawing A737MFJV/ST3/D/002 included in Appendix A.

2.5 Minor Watercourses & Ditches

There are several other minor watercourses and drainage ditches along the route of the proposed bypass. Many of these have been altered by local farmers over the years to aid land drainage. The aforementioned ditches together with other water features present in the vicinity of the bypass are identified on drawing A737MFJV/ST3/D/002 included in Appendix A.

2.6 Groundwater

MFJV report entitled *A737MFJV/D/05 Review of Hydrogeological Information and Proposed Conceptual Model* provides a detailed review and assessment of the existing geology and hydrogeology of the area. The report identifies potential impacts of the Scheme on groundwater and measures required to mitigate these impacts.

2.7 Existing Flooding Incidents

Local residents have reported flooding on the road between the existing A737 and the B707 in the Highfield area. The source of flooding is unconfirmed, but may be attributed to overland runoff from the fields and local roads.

Land drainage works carried out by the Local Authority appear to have improved the situation and there have been no further flood events reported since the works were completed several years ago.

No other significant flooding incidents have been reported along the proposed bypass route.

3 Proposed Scheme

The main objective of the Scheme is to reduce traffic congestion in the town centre of Dalry. This will be achieved by constructing a bypass extending from approximately 1.2km north east of Highfield area to Hillend area, south of Dalry. Modifications to existing roads and additional local roads will be required at Highfield to maintain local access.

The proposed route of the A737 Dalry Bypass is shown on drawing A737MFJV/ST3/D/001 included in Appendix A.

The bypass will cross the existing Glasgow to Ayr railway line and the River Garnock to the south east of Dalry on a 300m long viaduct. The viaduct will comprise earth abutments with three sets of piers to support the bridge deck. The bridge abutments will be located outwith the functional floodplain. The piers will be located outwith the main river channel, but within the functional floodplain of the River Garnock.

4 Legislation & Design Standards

Scottish Planning Policy (SPP) defines functional floodplain as areas with, "*generally greater than 0.5% (1:200) probability of flooding in any one year"*. These areas are defined as medium to high risk and development should only take place here when it is essential for operational reasons (e.g. transport infrastructure). "*In such cases, the development should be designed to remain operational in times of flood and not impede water flow, and the effect on the flood water storage capacity should be kept to a minimum."*

The Flood Risk Management Act (2009) introduces a more sustainable approach to flood risk management, including a requirement for assessing the impacts of climate change. The Act places specific roles and responsibilities on local authorities and SEPA in relation to flood risk management. The Act also requires that all sources of flooding be considered in the assessment of flood risk including fluvial, coastal, pluvial, sewers and groundwater.

This report aims to satisfy the requirements of SPP and the Flood Risk Management Act by assessing the potential impact of the proposed A737 Dalry Bypass scheme in accordance with the following guidance documents:

- *Design Manual for Roads and Bridges (DMRB) (2009), Volume 11: Environmental Assessment, Section 3: Environmental Assessment Techniques, HD45/09: Road Drainage and the Water Environment.*
- *SEPA Document SS-NFR-P-002: Technical Flood Risk Guidance for Stakeholders. Version 6, 2010.*

5 Previous Studies

5.1 Previous Modelling Studies

Following several severe flood events in Kilbirnie and Glengarnock in 1998, 2000, 2004 & 2008, several studies into flooding and flood alleviation schemes have been undertaken at various locations throughout the River Garnock catchment.

Initially, a hydraulic model of the River Garnock was commissioned by North Ayrshire Council to assess flood risk throughout the main urban areas of the catchment. The ISIS 1D model was constructed by Babtie Group and completed in July 2003. The model extended from the road bridge between Black Barn and Holehouse (upstream of Kilbirnie) to the weirs west of Longford Railway Bridge (downstream of Kilwinning). The model consisted of 151 channel cross-sections located at optimum spacings to provide a degree of accuracy such that reducing the spacing did not improve the accuracy of the model significantly. Of the 151 cross-sections, 39 were located at hydraulic structures. The model was calibrated against a known flood event on 22 October 1998. The flood levels predicted by the model compared favourably to the recorded levels, suggesting the model was reliable.

Following this, the Babtie ISIS model was adopted by Royal Haskoning as part of their "*Kilbirnie and Glengarnock Flood Appraisal Study"* in 2005. This study aimed to assess various flood prevention schemes in the catchment.

The River Garnock ISIS model was then adopted by Mouchel as part of their *"River Garnock Upper Catchment Flood Alleviation Scheme"* assessment. This included revising the original model with updated hydrology. The updated model was then used to develop options for a flood alleviation scheme in the Upper Garnock catchment.

Finally, a review of the Mouchel model was undertaken by Halcrow and additional revisions to the input hydrology incorporated into the model in 2012. The original model was trimmed down to concentrate on the section between Kilbirnie and Kilwinning, but still included the area around Dalry. Further recommendations on improving the input hydrology were made by Halcrow and these are now being implemented in the model.

Halcrow further refined the model by constructing a linked ISIS-TUFLOW 1-D/2-D hydro-dynamic model of the areas upstream of Kilbirnie and downstream of Glengarnock. This allowed more detailed modelling of the floodplains and the production of flood maps in these areas. The ISIS-TUFLOW linked model does not cover the area of interest downstream from Dalry.

5.2 Previous Stages of the Proposed Scheme Flood Risk Assessment

This Stage 3 Flood Risk Assessment follows on from the FRA study carried out in 2008 as part of the Stage 2 Route Option Appraisal process for the Dalry Bypass. The Stage 2 assessment concentrated on the flood risk associated with the River Garnock and the potential development in the functional floodplain associated with each route option. The Stage 2 assessment used flood levels from the Royal Haskoning ISIS model to define the functional floodplain at the proposed crossing location.

The previous study recommended that a more detailed assessment would be required at Stage 3 to accurately determine the extent of the functional floodplain and the potential impact of the Scheme on the River Garnock. The assessment would also consider alternative sources of flood risk to the proposed Scheme and the impact of the Scheme on flooding elsewhere. The above is considered in detail in the following sections of this report.

6 Fluvial Flood Risk

This chapter considers three aspects of fluvial flooding as follows:

- River Garnock and Caaf Water
- Coalheughglen Burn
- Other Minor Watercourses

6.1 River Garnock and Caaf Water

6.1.1 Introduction

The development of the existing River Garnock ISIS model in previous studies has concentrated on the areas around Kilbirnie and Glengarnock. Although the model also includes the area of interest as far as this scheme is concerned (south of Dalry), it contains little detail on the existing floodplain and tributaries at the proposed crossing location. The river channel cross-sections and existing structures throughout this section have also not been re-visited or checked since the original model was constructed in 2003. The proximity of the confluence between the Caaf Water and the River Garnock to the proposed crossing location requires a more detailed assessment of flood levels in the Caaf Water than has been previously been carried out.

As a consequence, a 1D ISIS model of the River Garnock and the Caaf Water has been constructed to allow a detailed assessment of flood levels and subsequent flood risk to the proposed Scheme. Section 6.1.2 provides details of the hydrological assessment of the River Garnock and Caaf Water catchments and Section 6.1.3 gives details of the climate change allowance in prediction of the peak flows. The hydraulic modelling process is described in Section 6.1.4 and the modelling results are presented in Section 6.1.5.

Further details and supporting information on the hydrological and hydraulic modelling of the River Garnock and its tributaries are provided in the supporting document entitled *A737MFJV/D/04 – River Garnock Modelling Report.*

6.1.2 Hydrological Assessment

River Garnock

Input hydrographs representing the flows from the upstream section of the River Garnock, have been extracted from the Halcrow ISIS-TUFLOW 1-D/2-D model. These are considered to more accurately represent upstream flooding and attenuation than any new hydrological analysis carried out and will provide a consistent approach between this assessment and the previous studies.

The Putyan Burn enters the River Garnock on the southern edge of Dalry and within the proposed model extents. Again, the flows for this tributary have been extracted from the Halcrow model.

It is acknowledged that the 2012 Halcrow report identified further improvements that could be made to the existing model hydrology. Some of these are in the process of being incorporated into the existing model but have not been completed in time to be included in this assessment.

Table 1: Peak flow values extracted from the ISIS-TUFLOW 1-D/2-D model at the railway crossing in Dalry (NGR: NS297492). – Data provided by Halcrow.

Return period	10yr	50yr	100yr	200yr	200yr+CC
Peak flow [m^3/s]	113.45	199.95	233.79	295.06	340.03

It is not clear what assumptions were made to account for climate change in the Halcrow model, however Table 1 shows that a 15% increase in the 200yr flow has been included. A review of climate change data for the River Garnock catchment is undertaken in section 6.1.3.

Caaf Water

The Caaf Water was originally included in the existing model as an FEH Rainfall-Runoff input flow only. No detailed hydrological assessment of the Caaf Water has been carried out to date. Given the potential influence of the Caaf Water on flood levels at the proposed crossing, a detailed hydrological assessment has been carried out as part of this investigation.

There is no gauging station located on the Caaf Water so statistical methods of estimating peak flows have been used. These comprise the FEH Rainfall-Runoff and the FEH Pooling Group methods.

The 200yr peak flow derived from the FEH Rainfall-Runoff and Pooling Group assessments is 57.33m^3/s and 45.32m^3/s respectively. The FEH Rainfall-Runoff method does not take into account the attenuation of peak flows as a result of reservoirs and lakes whereas the pooling group method does. As previously stated, the Caaf Water catchment contains three reservoirs and therefore consideration should be given to the impact these will have on peak flows.

As a result, it was decided that the FEH pooling group flows would best represent the Caaf Water hydrology and these have been adopted in the hydraulic model of the watercourse.

Table 2: FEH pooling group growth curve and peak flow values for the Caaf Water

Return period	2yr	10yr	50yr	100yr	200yr
Growth factor	1.00	1.552	2.163	2.479	2.836
Peak flow [m^3/s]	15.98	24.80	34.56	39.61	45.32

A detailed summary of the hydrological assessment is provided in Report A737MFJV/D/04 – "*River Garnock Modelling Report*".

6.1.3 Climate Change

The UK Climate Impacts Programme (UKCIP) is funded by the Department of the Environment to investigate the potential impacts of climate change in the United Kingdom. The UKCIP has produced assessments of the potential impacts based on rates of increase in global greenhouse gas emissions consistent with the projections of the Intergovernmental Panel on Climate Change (IPCC).

In 1998 the UKCIP published their Technical Report No. 1 entitled "Climate Change Scenarios for the United Kingdom". Revised scenarios were published in June 2009.

UKCP09 provides relative changes in precipitation at a 25km grid resolution. These show a range of relative increases in annual and seasonal precipitation scenarios that could be expected for the River Garnock catchment for different future emission scenarios. For the 2080s under a high emission scenario, an annual decrease of 1.3% has been estimated (50 percentile). However, when looking at the seasonal variability, an increase of 28.6% is estimated for autumn (50 percentile) whereas a decrease of 22.6% is predicted for summer (50 percentile).

For the purpose of this assessment climate change has been accounted for by adding 30% to the 200yr design peak flow for both the River Garnock and the Caaf Water.

The final peak flows used in the hydraulic model of the River Garnock and Caaf Water are shown in Table 3.

Table 3: Final River Garnock and Caaf Water peak flow values

Return period	Peak flow [m^3/s]					
	2yr	10yr	50yr	100yr	200yr	200yr + CC
River Garnock	-	113.45	199.95	233.79	295.06	383.5
Caaf Water	15.98	24.80	34.56	39.61	45.32	58.92

6.1.4 Hydraulic Modelling

The new ISIS 1D model has been constructed for the reach of the River Garnock between the railway bridge in Dalry and Monk Castle – approximately 2.8km downstream from the railway bridge. The start point at the railway bridge has been chosen as the flow will be constrained within the channel by the bridge structure at this location. The downstream boundary at Monk Castle has been chosen as there are no external factors that will affect the downstream boundary condition at this location (e.g. structures, confluences with other watercourses, tides).

The new model incorporates updated topographical survey information of the main river channel and floodplain. In total there are 22 cross-sections on the River Garnock and 8 cross-sections on the Caaf Water. The surveyed cross-sections extend across the whole width of the floodplain but have been trimmed back to top of bank level where the floodplain has been represented with an offline floodcell. The location of the cross-sections is shown on drawing A737MFJV/ST3/D/017 included in Appendix A.

Floodplains have been represented as offline floodcells at three locations; these are shown on drawing A737MFJV/ST3/D/017 in Appendix A. The stage/flow relationship in each floodplain area has been defined using NEXTMap DTM data. Part of the floodplain area on the west side of the River Garnock (between the Putyan Burn and the Caaf Water) is separated from the river by a raised embankment. This floodcell has been split into two sections to better represent the different ground levels. The Caaf Water has been connected to the lower floodcell at this location as well.

Five bridges were re-surveyed and included in the ISIS model:

- the railway bridge in Dalry (NGR NS295493)
- The footbridge on the River Garnock to the south of Dalry (NGR NS293489)
- The bridge to the Wilsons Car Auction site (NGR NS296479)
- The A737 bridge on the Caaf Water (NGR NS292484)
- The pipe bridge on the Caaf Water at the junction with the River Garnock (NGR NS295482)

Several weirs can be found across the River Garnock channel. These weirs are expected to be drowned under several meters of water during extreme flood events and therefore have no impact on the flood levels. When explicitly included into the model, a local head loss is calculated for each weir, exaggerating the influence of the weirs under drowned conditions. Following recommendations from the model software developers, it was decided not to include the weirs in the model. If the model is used to predict lower return period events, the weirs should be included.

The flow hydrograph provided by Halcrow was used as the upstream boundary of the River Garnock. The upstream boundary of the Caaf Water consists of a FEH rainfall runoff hydrograph with the peak adjusted to fit the values presented in Table 3 for the corresponding return periods. In adopting a precautionary approach, the Caaf Water hydrograph was also delayed so the peak flow coincides with the River Garnock's peak flow. In reality, the critical duration of the Caaf Water is considerably less than the River Garnock and it would be expected that the peak flows do not coincide.

Roughness conditions were assessed during a site walk-over. It was found that the banks of the River Garnock are densely vegetated so a roughness value of 0.06 has been adopted for these areas. A value of 0.035 has been adopted for the channel bed, and a value of 0.045 for floodplain areas covered by grazed grassland.

6.1.5 Results

The predicted flood levels at the location of the proposed crossing are summarised in Table 4. Drawing A737MFJV/ST3/D/018 included in Appendix A shows the 200yr flood extent in relation to the proposed viaduct structure.

Table 4 – Flood Levels at XS15

Return Period (yrs)	200yr Flood Level (mAOD)
10	21.22
50	22.34
100	22.71
200	23.13
200+CC	23.47

The results indicate that the proposed Bypass bridge deck will remain approximately 9m above the 200yr flood level. The toe of the proposed bridge abutment on the west side of the River Garnock is at a level of approximately 25.0mAOD. This is approximately 1.9m above the 200yr flood level so the bridge abutments will also remain outwith the functional floodplain.

Three sets of piers will be located within the River Garnock functional floodplain to support the viaduct over the River Garnock and the Glasgow-Ayr railway. A more detailed assessment of the effects of the bridge piers on flows in the River Garnock is provided in the report entitled *A737MFJV/D/04 River Garnock Modelling Report.*

6.1.6 Comparison with Previous Studies

Table 5 provides a comparison of the predicted 200yr flood levels between the Royal Haskoning, Halcrow and MFJV (current) models. The results suggest that with each development of the model, the flood level drops marginally. This is to be expected as a more detailed assessment of the floodplain storage areas has been incorporated at each stage of the model development.

The removal of the weir structures in the MFJV model also appears to have an effect on flood levels. Removal of the weirs is recommended by the model software developers where they are drowned out under a significant depth of water. In this case the water level in the River Garnock is almost 5m above the channel bed; this is considered sufficient to justify removing the weirs.

Table 5: Predicted 200yr flood levels from different models at various locations

Relevant Location	Cross-Section Labels		Royal Haskoning Levels (mAOD)	Halcrow Levels (mAOD)	MFJV Levels (mAOD)
	Royal Haskoning / Halcrow	MFJV			
370m d/s of footbridge south of Dalry	SEC_77	XS-9	24.38	24.22	23.70
	SEC_78	XS-10	24.39	24.32	23.53
	SEC_80	XS-11	24.35	23.97	23.54
	SEC_81	XS-12	24.40	24.10	23.52
Junction with Caaf Water	SEC_83	XS-13	23.79	23.30	23.24
Proposed crossing	n/a (1)	XS-15	23.82 (1)	23.45 (1)	23.13
d/s of proposed crossing	SEC_85	XS-16	23.86	23.64	23.19
Car auction crossing u/s	SEC_87	XS-17-US	23.58	n/a (2)	22.99
Car auction crossing d/s	SEC_87A	XS-17-DS	22.45	22.34	22.51
	SEC_88	XS-18	21.46	21.39	21.38
	SEC_90	XS-19	20.73	20.54	20.78
	SEC_91	XS-20	19.66	19.52	19.91

(1) No section located at the proposed crossing in the Royal Haskoning and Halcrow models. Levels shown in the table are interpolated values
(2) No level provided at this location in the set of results from Halcrow

6.1.7 Sensitivity Analysis

A sensitivity analysis has been carried out on the channel roughness, flows and floodplain extent.

The roughness values at each cross-section were increased by 20%, resulting in an increase in flood level by about 350mm at the proposed crossing. The bridge deck and abutments would still remain well above the 200yr flood level so the change is not considered significant.

The sensitivity to the peak flow variation can be seen by comparing the results for the 200yr event with and without climate change, as shown in Table 4. The increase in flood level is approximately 280mm at the proposed crossing. Again, this is not considered significant as the flood level will remain well below the level of the bridge deck and abutments.

Due to the relative imprecision of the NEXTMap DTM used to define the floodplain extent, a sensitivity analysis of the four floodcells was carried out. The areas defining the four floodcells were reduced by 50% and the impact of the flood levels at the proposed crossing assessed. Results show that the predicted flood levels at the proposed crossing increase by 30mm. This indicates that the model is not sensitive to the size of the floodplain area at this location.

The lack of sensitivity to such a large decrease in floodplain storage suggests there is another factor that has a greater impact on flood levels at the proposed crossing location. This could be explained by the presence of the Wilsons Car Auction site access bridge downstream from the proposed crossing location. A comparison of flood levels, with the Wilson's access bridge removed from the model, was carried out at a previous stage by Royal Haskoning. The assessment concluded that flood levels drop by up to 800mm at the proposed crossing location with the Wilson's access bridge removed, compared to the current scenario. This suggests that the car auction site access bridge is a more significant factor than floodplain storage.

6.2 Coalheughglen Burn

The Coalheughglen Burn rises to the east of Highfield and flows in a south-westerly direction through Highfield. The Burn crosses the existing A737 on the west side of Highfield area before discharging to the River Garnock.

The Coalheughglen Burn will require culverting under the proposed A737 Bypass just upstream from the Highfield area. It will also require diverting on the west side of Highfield to avoid clashing with the proposed road works.

To assess the impacts of the proposed works on the existing watercourse and to inform the design of the new culverts and diversion, a hydraulic model of the Coalheughglen Burn has been constructed. The model extends for 730m, between approximately 100m north of Highfield and the Lodge at Carsehead. Drawing A737MFJV/ST3/D/034 included in Appendix A and taken from the report entitled *A737MFJV/D/03 Coalheughglen Burn Modelling Report* shows the extent of the Coalheughglen Burn which has been modelled.

The modelling exercise showed that the existing culvert (EC4 on drawing A737MFJV/ST3/D/001 and EC1 on drawing A737MFJV/ST3/D/034) at Highfield does not have sufficient capacity to convey the predicted 200yr event. During such an event, the flood water would overtop the banks and flood the low lying areas alongside the watercourse. The local road above the culvert would also be flooded to a maximum depth of 550mm. The existing 200yr flood extent for the Coalheughglen Burn is also shown on drawing A737MFJV/ST3/D/034 in Appendix A.

The modelling of the post-development scenario, including the watercourse diversion and two new culverts, concluded that the proposed modifications to the Coalheughglen Burn will not pose a risk of flooding to the Bypass in the 200yr flood event.

Further details and results of the Coalheughglen Burn modelling exercise are provided in the report entitled *A737MFJV/D/03 Coalheughglen Burn Modelling Report*.

6.3 Other Minor Watercourses

The A737 Bypass will pass through the catchment area of various other minor watercourses and ditches which are shown on drawing A737MFJV/ST3/D/002 in Appendix A. Considering the small size of the watercourses and ditches in question, the peak flows will not be significant. Where the Bypass is in cutting, earthworks drains at the top of cut-slopes will intercept flow and direct it towards the nearest SuDS Basin and/or watercourse. The cut-off drainage will be designed to allow for the additional flows from intercepted minor watercourses and ditches. Where the Bypass is on embankment, the minor watercourse or ditch will be culverted under the road to maintain the existing flow path. Refer to Section 9 for culvert design details.

Adopting these measures will address flood risk issues from minor watercourses.

7 Pluvial

7.1 Road Surface Drainage

The proposed drainage design for the Bypass will comprise a number of new and independent gravity drainage networks designed to collect and convey surface water runoff from impermeable surfaces.

The drainage (conveyance pipework) will be designed in accordance with the *Design Manual for Roads and Bridges (DMRB) (2006), Volume 4: Geotechnics and Drainage, Section 2: Drainage, Part 3, HD33/06: Surface and Sub-surface Drainage systems for Highways.*

The new drainage pipes (carrier and filter) will be designed to accommodate a 1 in 1yr storm plus an allowance for climate change, without surcharge. The drainage will then be checked against a 1 in 5yr storm event, plus an allowance for climate change, to ensure no surface flooding occurs.

Where this capacity is exceeded by an event greater than 1 in 5yr plus climate change, surface flooding of the carriageway may occur. This may lead to more severe flooding if it collects on the carriageway for example at low points in the road profile. To mitigate this, the carriageway will be designed to ensure the surface runoff does not collect, but is directed off the carriageway at discrete locations. Safe overland flood routes will be chosen to ensure flood risk is not increased downstream, for example into SuDS basins, watercourses and otherwise onto agricultural land.

7.2 Natural Catchment Runoff

In the event that rainfall exceeds the infiltration capacity of the natural ground, excess water will flow overland. This may create a flood risk to the proposed Bypass where existing ground levels fall towards the road.

Where the road is constructed on a viaduct, there will be no flood risk from natural catchment runoff.

Elsewhere the runoff from natural catchment areas that drain towards the scheme will be intercepted and drained through earthworks drainage and cut-off drains, thereby reducing flood risk. The cut-off drains will be designed in accordance with the requirements of the *Design Manual for Roads and Bridges (DMRB) (2006), Volume 4: Geotechnics and Drainage, Section 2: Drainage, Part 1, HD106/04: Drainage of Runoff from Natural Catchments.*

8 Groundwater

8.1 Introduction

Where groundwater levels exceed the proposed carriageway level (for example in cuttings), there is potential for groundwater to cause surface flooding on the carriageway. Groundwater levels were determined along the proposed route of the Bypass by an initial ground investigation carried out in 2008 by White Young Green Environmental. The investigation divided the proposed route into three sections – the northern section around Highfield, the central section around Peesweep Mount and Blairland Housing Estate, and the southern section in the River Garnock valley.

In the northern section, the initial ground investigation concluded that groundwater is locally controlled by mine workings which are at shallow depth. No artesian groundwater was found in the area.

In the central section, the results indicate that groundwater levels may rise to within 1m of the ground surface. This section of the Bypass is in cutting up to 11.5m below ground level, so it is expected that the Bypass will intercept groundwater at this location.

In the southern section, extremely high artesian pressures were encountered in the River Garnock valley. The southern section of the proposed Bypass is on embankment or the River Garnock viaduct so flooding from groundwater is not considered an issue.

The White Young Green Ground Investigation has been supplemented with the MFJV Stage 3 Ground Investigation, completed in 2013. Further information on the potential impacts of groundwater on the proposed Scheme is provided in the report entitled *A737MFJV/D/05 Hydrogeological Review and Risk Assessment*.

8.2 Roads in Cuttings

The high groundwater levels in the central section of the proposed Bypass have the potential to cause upwelling in the base of the cut. It will therefore be necessary to allow for this in the design of the road drainage system. A combined road surface and groundwater drainage system will be provided. This will be routed through a SuDS facility and discharged to a receiving watercourse via a single outfall. The drainage system will be sized to accommodate additional flows from intercepted groundwater where necessary.

8.3 Stabilisation of Mine Workings

In the northern section the ground investigation suggests that mine workings are relatively close to the surface and that stabilisation of the mine workings by grouting will be required to prevent subsidence. Available information indicates the groundwater level in this area is at depth below the mine workings so the impact of filling this void is considered to be negligible. Further information on the potential impacts of groundwater on the proposed Scheme is provided in the report entitled *A737MFJV/D/05 Hydrogeological Review and Risk Assessment*.

9 Drainage Infrastructure

9.1 Existing Sewers

Existing sewers and CSOs have the potential to cause flooding in the event that flows exceed their capacity or they become blocked. In either case, flows may surcharge manhole covers and flow overland, creating a flood risk to roads and properties.

Investigations have been carried out into the location of existing services in the vicinity of the proposed Scheme. This suggests that there is an existing Scottish Water sewer running along the west side of the River Garnock in a north-south direction. At this location, the A737 Bypass will be on a bridge over the River Garnock and the functional floodplain so it will not be at risk of flooding from the Scottish Water sewer.

No other sewers or CSOs are located within the vicinity of the Scheme.

9.2 Existing Culverts

Where watercourses are culverted beneath existing roads and housing areas, they have the potential to become blocked. In addition, culverts that were not designed according to the latest standards may be undersized and could form a restriction in extreme events. If this occurs, flows will back up and spill out of the channel and flow overland, creating a flood risk to properties and roads.

Existing culverts in close proximity to the proposed Scheme have been identified on drawing A737MFJV/ST3/D/001 included in Appendix A. Table 5 summarises the flood risk or lack thereof from each culvert.

Table 6 – Flood Risk from Existing Culverts

Existing Culvert Reference	Flood Risk to Proposed A737 Bypass
EC1	None – Bypass raised on viaduct in vicinity of culvert inlet.
EC2	None – Bypass on 5m high embankment in vicinity of culvert inlet.
EC3	None – Bypass on 5m high embankment in vicinity of culvert inlet.
EC4	None – Proposed scheme up-slope from culvert inlet.
EC5	None – Proposed scheme approximately 10m above culvert inlet.
EC6	Existing culvert to be replaced with compliant design. Flood risk reduced from existing situation.
EC7	Blockage or exceedence of capacity of the existing culvert may result in flow spilling onto the A737. Maintenance procedures to be implemented to mitigate risk of flooding to proposed scheme.

10 Impact on Flood Risk Elsewhere

10.1 Introduction

In accordance with the requirements of the DMRB, Volume 11, *Environmental Assessment*, this section identifies the potential impacts of the proposed Scheme on flood risk elsewhere. Where a potential impact is identified, mitigation measures to be adopted at the detailed design stage have been proposed.

Potential impacts and sources of flood risk include the road drainage network, new culverts on watercourses, new watercourse diversions, groundwater and the new bridge across the River Garnock. Consultations with SEPA have identified a particular requirement to assess the potential impacts of the River Garnock bridge piers on flows and in the functional floodplain.

10.2 Road Drainage Network

10.2.1 Discharges from the Road Drainage Network

The construction of the proposed Scheme will increase the proportion of impermeable surfaces in the catchment. This will increase the volume and rate of surface runoff via the road drainage network. The uncontrolled discharge of surface runoff from the road drainage network to existing watercourses during storm events has the potential to cause localised flooding and increase the risk of flooding downstream with consequential damage and disturbance to residential and commercial properties as well as to natural features.

The proposed surface water drainage strategy will therefore employ Sustainable Drainage Systems (SuDS) to mitigate the potential impacts of increased surface runoff rates and reduce flood risk in the receiving watercourse.

The SuDS proposals will be designed in accordance with the guidance in CIRIA Report C697 "*The SUDS Manual*", 2007, the DMRB, Volume 4, Section 2 "Drainage", and Planning Advice Note (PAN) 61 "*Planning and Sustainable Urban Drainage Systems*". The SUDS proposals for the proposed road development would promote the use of source control methods such as filter drains and swales. The site controls such as extended detention basins for attenuation and treatment of surface runoff prior to discharge to the existing watercourses would be an essential part of the drainage design. In accordance with the DMRB the attenuation basins will be designed for the 1 in 100yr flood event. Preliminary designs have assumed that peak discharge rates will be limited to the 1 in 2 year 'greenfield' runoff.

Following discussions with North Ayrshire Council, further attenuation will be provided in the designed freeboard to accommodate the 1 in 200yr flood event. This will ensure that the basins are designed appropriately to allow for climate change and other design uncertainties.

10.2.2 Overland Flow Routes from SuDS Basins

Five SuDS basins are proposed for the Scheme. Their locations are shown on drawing A737MFJV/ST3/D/001 included in Appendix A. In the event of exceedence of the SuDS basin design capacity or blockage of the outfall, water levels may rise above the top level of the basin and spill into the surrounding land. The basins will be designed to ensure that the spill is directed away from buildings and roads via overland flow routes or overflow outfall pipes and into the nearest receiving watercourse.

With the exception of SuDS Basin SB5, all overland flow routes between the SuDS Basins and the receiving watercourse are located on agricultural land with no property or infrastructure at risk of inundation.

At SuDS Basin SB5, water spilling from the basin will require to be routed overland to the Coalheughglen Burn downstream from Highfield. This will ensure that existing flood issues within Highfield are not exacerbated.

10.2.3 Exceedence of Road Drainage Capacity

Where the capacity of the road drainage system is exceeded by an event greater than 1 in 5yr plus climate change, surface flooding of the carriageway may occur. This may lead to flooding of surrounding properties if allowed to runoff uncontrolled. To mitigate this, the carriageway will be designed to ensure the surface runoff is directed off the carriageway at discrete locations. Safe overland flood routes (for example to SuDS basins, watercourses or agricultural land) will be provided at these locations to ensure flood risk to properties is not increased downstream.

10.3 New Bridge on the River Garnock

The new bridge crossing the Glasgow – Ayr railway line and the River Garnock will require 3 bridge piers to be located in the functional floodplain of the River Garnock. Bridge piers have the potential to cause local scour and erosion issues when located within watercourses.

The proposed bridge piers at the River Garnock will be located in the functional floodplain, but not in the main river channel. The size of the piers in relation to the width of the watercourse are such that the impact of the piers on flood levels is limited to the immediate vicinity of the piers and therefore will not affect flood risk elsewhere.

The proposed bridge abutments will be located outwith the functional floodplain of the River Garnock and will therefore not affect flood risk.

A detailed assessment of the impact of the piers on local flow velocities and erosion potential around the base of the piers has been carried out using ISIS-TUFLOW software. Refer to report A737MFJV/D/04 – "*River Garnock Modelling Report*" for further details and results on the assessment of the impact of the bridge piers.

10.4 New Access Track to East Abutment of River Garnock Viaduct

A new maintenance access track is required to the east abutment of the River Garnock viaduct. The access track will utilise the existing underpass under the Glasgow – Ayr railway line, with a new section of track in a cut-fill condition from the underpass to the abutment. The new section of track will be located within the functional floodplain of the River Garnock.

Compensatory Storage will be required to offset the lost flood storage volume associated with the construction of the access track in the floodplain. The total volume of compensatory storage required in the 200yr event is 40m^3. This will be provided by re-profiling ground levels on the opposite bank to provide "like-for-like" storage.

10.5 New Watercourse Crossings

New culverts will be required where new roads cross existing watercourses and ditches. Culverts have the potential to restrict flows in extreme events and can also become blocked leading to flooding of the surrounding land upstream from the culvert.

This will be avoided through the appropriate design of the culvert in the first instance. Culvert design will be based on the Highways Agency Design Manual for Roads and Bridges (DMRB), Volume 4, Geotechnics and Drainage, Section 2, Part 7. They will also take into consideration the guidance contained in the following documents:

- *WAT-SG-25: Good Practice Guide – River Crossings* (SEPA, 2010)
- *CIRIA Report 689 – Culvert Design and Operation Guide* (CIRIA, 2010)
- *Scottish Executive Consultation Paper – River Crossings and Migratory Fish* (Scottish Executive, 2000)

The DMRB requires culverts to be sized according to the classification of land at risk of flooding in the event of exceedence of the design standard (1 in 25yr for agricultural land of minimum value, 1 in 50yr for agricultural land of high value and isolated properties and 1 in 100yr for urban areas and villages).

All new culverts in the Scheme will be designed to accommodate the 1 in 100yr flow in free flow conditions where practicable. The design shall accommodate the 1 in 200yr event within the freeboard where practicable. The minimum diameter for culverts crossing the carriageway shall be 900mm. This shall reduce the potential for blockage or exceedence of the culvert capacity, irrespective of the land classification. Where new culverts cannot be sized in accordance with these criteria, they will be designed to limit inundation to areas of minimum land value in the design event.

The locations where new culverts are required are identified on drawing A737MFJV/ST3/D/001.

10.6 Watercourse Diversions

The Coalheughglen Burn and another minor watercourse in the Highfield area will be affected by the proposed A737 Dalry Bypass road alignment and will require localised diversions. The locations of the proposed diversions are shown on drawing A737MFJV/ST3/D/001 in Appendix A.

The design of the diversions will be undertaken in accordance with the following guidance documents:

- *Manual of River Restoration Techniques, RRC, 2002*
- *WAT-RM-02 Regulation of Licence-level Engineering Activities*

Hydraulic and geomorphological assessments of the affected watercourses will be undertaken to ensure that the proposed diversions will not have an adverse impact on the existing flow regime and sediment transportation leading to increased flood risk, channel erosion and siltation.

These measures will mitigate the impacts of the scheme on flood risk elsewhere.

10.7 Groundwater

As identified in Section 8.3, existing mine workings are found at shallow depth in the northern section of the Scheme. To prevent subsidence the shallow mine workings will be grouted. This could have the effect of closing groundwater flow paths and directing flows elsewhere; resulting in increased flood risk at an alternative location.

Further details of the shallow mine workings and the groundwater regime along the proposed route of the Bypass are provided in document *A737MFJV/D/05 Hydrogeological Review and Risk Assessment*.

10.8 Existing Flooding Around Highfield

As identified in Section 2.7, previous flooding incidents have been reported in the Highfield area, particularly around existing culvert EC4 (as identified on drawing A737MFJV/ST3/D/001). The reports are based on anecdotal evidence and observations by local residents. Although the flooding occurred in the vicinity of the aforementioned culvert, it was not thought to be associated with blockage or exceedance of the capacity of the culvert but instead was connected to overland flows from surrounding fields and roads. Alteration works carried out by the local authority appear to have resolved the issue and no further flood events have been reported since.

Earthworks drainage will be provided as part of the proposed scheme at the top of cuttings and at the toe of embankments. Around the Highfield area, these will intercept overland flow and direct it away from the areas that have flooded in the past. This will result in a marginal reduction in flood risk in the area.

The new culverts and watercourse diversion associated with the Coalheughlen Burn will be sized to accommodate the design event and therefore will not impact on flood risk in the Highfield area.

As a whole, the scheme will lead to a reduction in flood risk in the Highfield area.

11 Conclusions

The report has considered the potential flood risk to the proposed Scheme associated with fluvial, pluvial, groundwater, overland flow and drainage infrastructure sources. The report has also assessed the potential impacts of the scheme on flood risk elsewhere. The main findings are summarised as follows:

- Previous flood incidents have been reported in the Highfield area, but these appear to have been resolved through drainage works carried out by the local authority and are not likely to affect the Bypass.
- Modelling of the River Garnock has concluded that the Scheme will remain outside the functional floodplain of the River Garnock with the exception of the bridge piers.
- Drainage will be provided to intercept groundwater arisings from the road cutting
- Surface water runoff from natural catchments will be intercepted by cut-off drains to prevent flooding of the carriageway.
- Existing culvert EC7 may pose a flood risk to the proposed scheme in the event of a blockage or exceedence of the culvert capacity.

The Scheme will be designed and constructed to the relevant standards to minimise an increase in flood risk elsewhere.

- Discharges from the surface water drainage system will be attenuated to prevent an increase in flood risk downstream
- New culverts will be sized to convey the design flow where practicable and will incorporate measures to prevent blockage, thereby minimising flood risk to existing properties.
- New culverts that cannot be sized to convey the design flow shall be designed to limit inundation to areas of minimum land value in the design event.
- Watercourse diversions will be sized to convey the design flow and thereby minimise flood risk to existing properties.
- Overland flow routes from SuDS Basins will ensure that existing properties are not at risk of flooding in the event of failure or exceedence of capacity.
- Flood risk in the Highfield area will not be affected by the construction of the proposed scheme.

References and Supporting Information

Design Manual for Roads and Bridges (DMRB), Volume 5; Assessment and Preparation of Road Schemes, Section 1; Assessment of Road Schemes, Part 2, Scheme Assessment Reporting, (TD37/93). 2006.

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SEPA, Technical Flood Risk Guidance for Stakeholders, SS-NFR-P-002. 2010.

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A737MFJV/D/03 - Coalheughglen Burn Modelling Report. 2012

A737MFJV/D/04 - River Garnock Modelling Report. 2012

A737MFJV/D/05 - Hydrogeological Review and Risk Assessment. 2013

Design Manual for Roads and Bridges (DMRB), Volume 4; Geotechnics and Drainage, Section 2; Drainage, Part 3, Surface and Sub-surface Drainage Systems for Highways, (HD33/06). 2006.

White Young Green Environmental, Initial Ground Investigation. 2008.

Design Manual for Roads and Bridges (DMRB), Volume 4; Geotechnics and Drainage, Section 2; Drainage, Part 1, Drainage of Runoff from Natural Catchments, (HD106/04). 2006.

CIRIA C697 - The SUDS Manual. 2009.

PAN 61, Planning and Sustainable Urban Drainage Systems. 2001.

SEPA, Engineering in the Water Environment, Good Practice Guide, River Crossings. 2010.

CIRIA C689 - Culvert Design and Operation Guide. 2010.

Scottish Executive Consultation Paper – River Crossings and Migratory Fish. 2001.

River Restoration Centre - Manual of River Restoration Techniques. 2002.

SEPA, WAT-RM-02 Regulation of Licence-level Engineering Activities v4.0. 2011.

Appendix A – Drawings

A737MFJV/ST3/D/001 – Conceptual Drainage layout

A737MFJV/ST3/D/002 – Water Features Location Plan

A737MFJV/ST3/D/017 – River Garnock Model Cross-sections and Floodplain Areas

A737MFJV/ST3/D/018 – River Garnock Flood Extents

A737MFJV/ST3/D/034 – Coalheughglen Burn Hydraulic Modelling Flood Extent Envelope

CLIENT

TRANSPORT SCOTLAND

An agency of The Scottish Government

PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
06	Layout of drainage networks revised. Road model updated.	KAB	MLJ	ELC	May 13
05	Layout of drainage networks revised. Road model updated.	KAB	MLJ	RJM	Feb 13
04	SUDS SB1 position revised. Earthworks drainage added.	KAB	MLJ	RJM	Nov 12
03	Revised to suit updated road model.	KAB	MLJ	ELC	Sept 12
02	Revised to include Option 3B road alignment. Drainage layout revised and notes added.	KAB	MLJ	ELC	June 12

AMENDMENTS

DESIGN BY:	MLJ	CHECKED BY:	RJM
DATE:	May 12	DATE:	May 12
DRAWN BY:	KAB	APPROVED BY:	-
DATE:	May 12	DATE:	-
DRAWING STATUS	FOR INFORMATION		

ENGINEER

mouchel FAIRHURST

IN ASSOCIATION WITH

SIAS

DRAWING TITLE

Conceptual Drainage Layout

SCALE AT A1	DRAWING NO	REV
1:5000	A737MFJV/ST3/D/001	06

CLIENT

TRANSPORT SCOTLAND

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
02	AB4 removed	KAB	MLJ	ELC	May 13
01	Water features added following review of topographical survey and site walkover.	KAB	MLJ	ELC	Aug 12

AMENDMENTS

Notes:

1. This drawing to be read in conjunction with the completed SEPA WAT-FORM-10: Water Features Survey Identification Form.
2. This drawing shows known water features only. Other water features, not identified on the drawing, may also be present in the area of interest.
3. Drawing based on road alignment model `X_R_Stage_3_Design_Rev_0' received 10/08/12.

NOTES

DESIGN BY:	MLJ	CHECKED BY:	ELC
DATE:	June 12	DATE:	June 12
DRAWN BY:	MLJ	APPROVED BY:	ELC
DATE:	June 12	DATE:	June 12
DRAWING STATUS	FOR INFORMATION		

ENGINEER

mouchel FAIRHURST

IN ASSOCIATION WITH

SIAS amec

DRAWING TITLE

Water Features Survey
Water Features Location Plan

SCALE AT A0	DRAWING NO	REV
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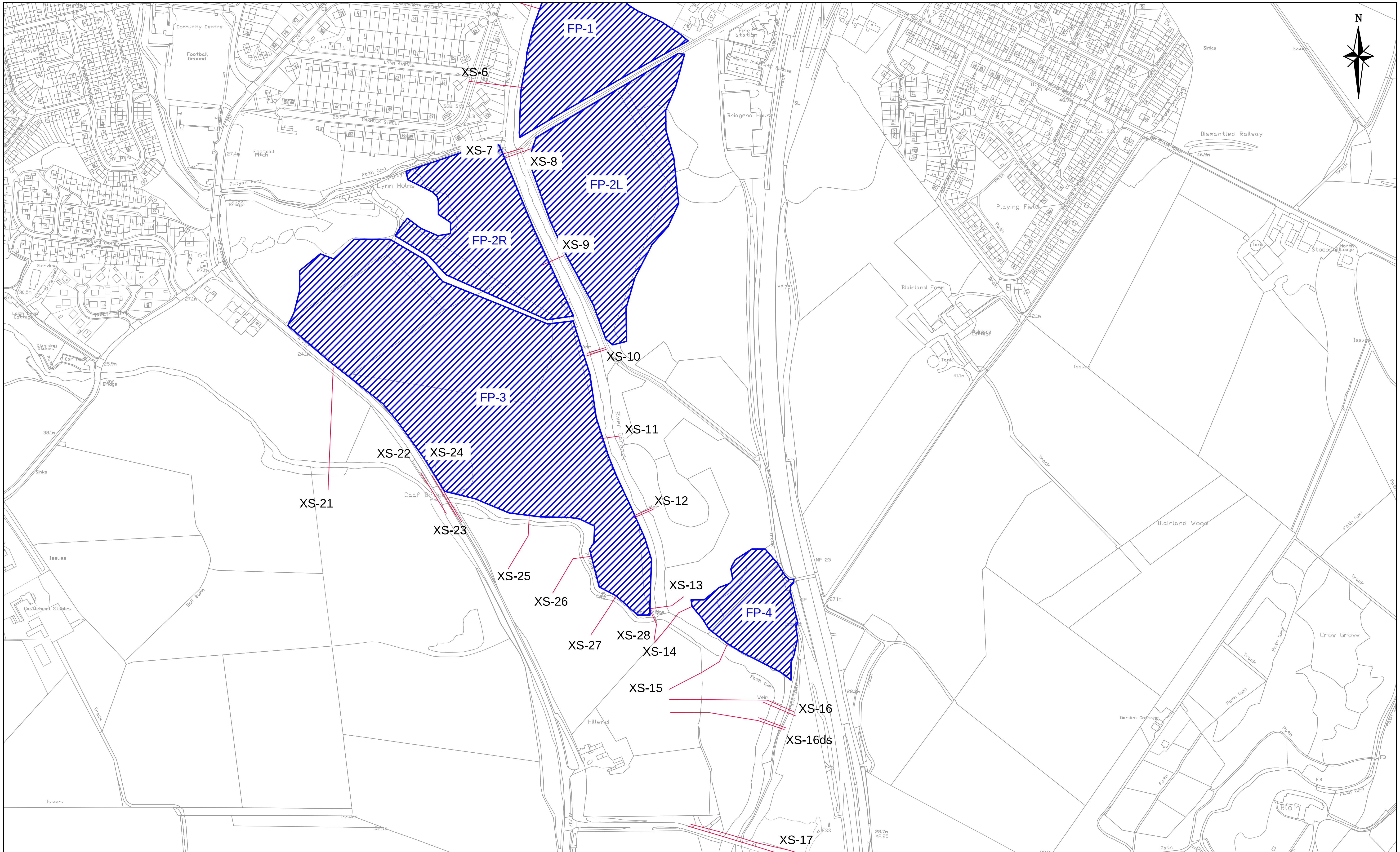

CLIENT	PROJECT TITLE		ENGINEER	DRAWING TITLE
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REV	REVISIONS	BY	CHKD	APP'D	DATE

AMENDMENTS

DESIGN BY:	LG	CHECKED BY:	EJC
DATE:	21/12/12	DATE:	21/12/12
DRAWN BY:	LG	APPROVED BY:	ELC
DATE:	21/12/12	DATE:	21/12/12
DRAWING STATUS	FOR INFORMATION		

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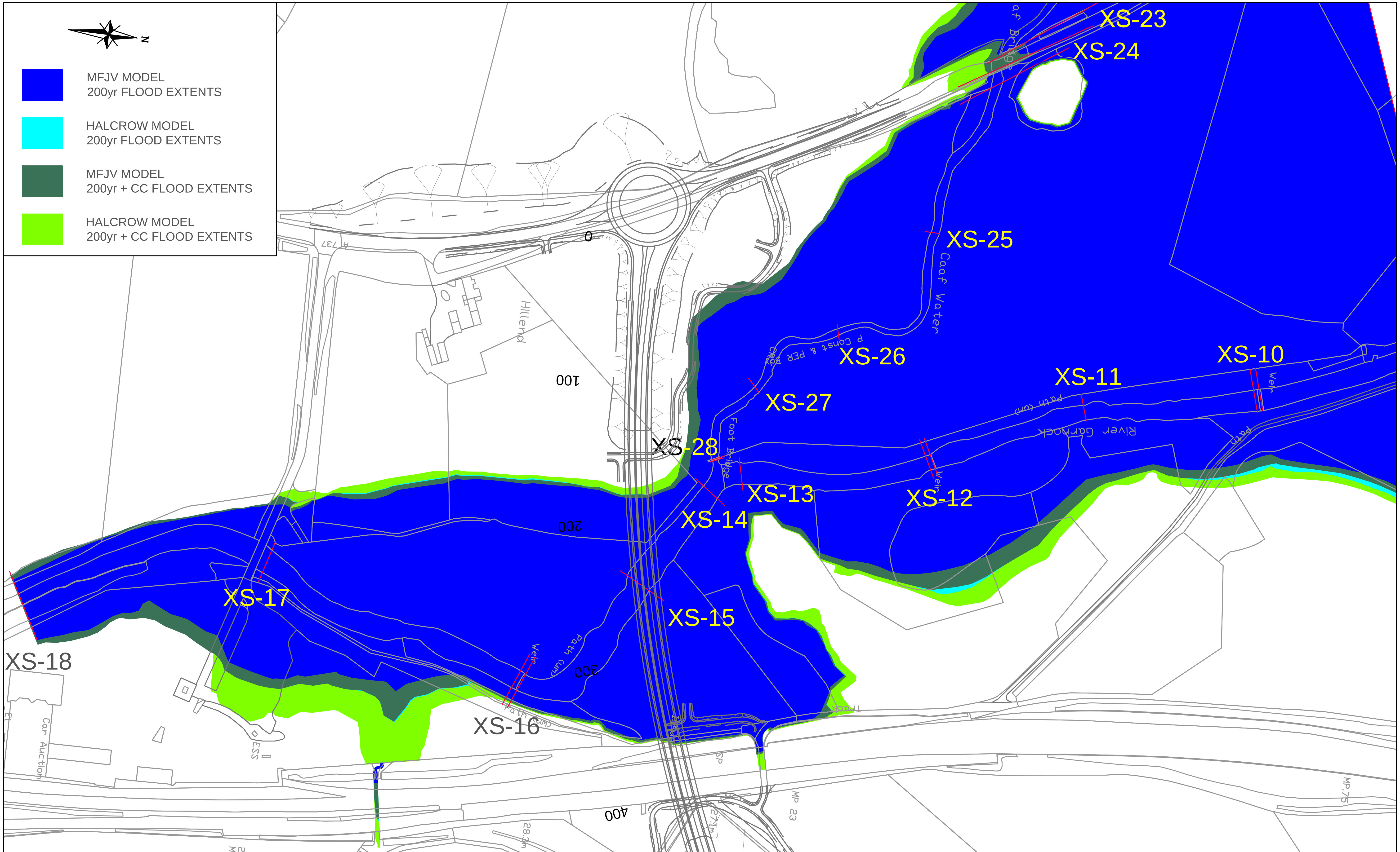

CLIENT	PROJECT TITLE	AMENDMENTS						ENGINEER	DRAWING TITLE
TRANSPORT SCOTLAND An agency of The Scottish Government	A737 Dalry Bypass							mouchel FAIRHURST IN ASSOCIATION WITH SIAS amec	Flood Risk Assessment 200yr Flood Extents

REV	REVISIONS	BY	CHKD	APP'D	DATE
02	Roads model updated.	KAB	EJC	ELC	June 13
01	200yr + CLIMATE CHANGE FLOOD EXTENTS ADDED	EJC	EJC	ELC	03/12/12

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DESIGN BY:	LG	CHECKED BY:	EJC
DATE:	28/11/12	DATE:	29/11/12
DRAWN BY:	LG	APPROVED BY:	ELC
DATE:	29/11/12	DATE:	29/11/12
DRAWING STATUS	FOR INFORMATION		

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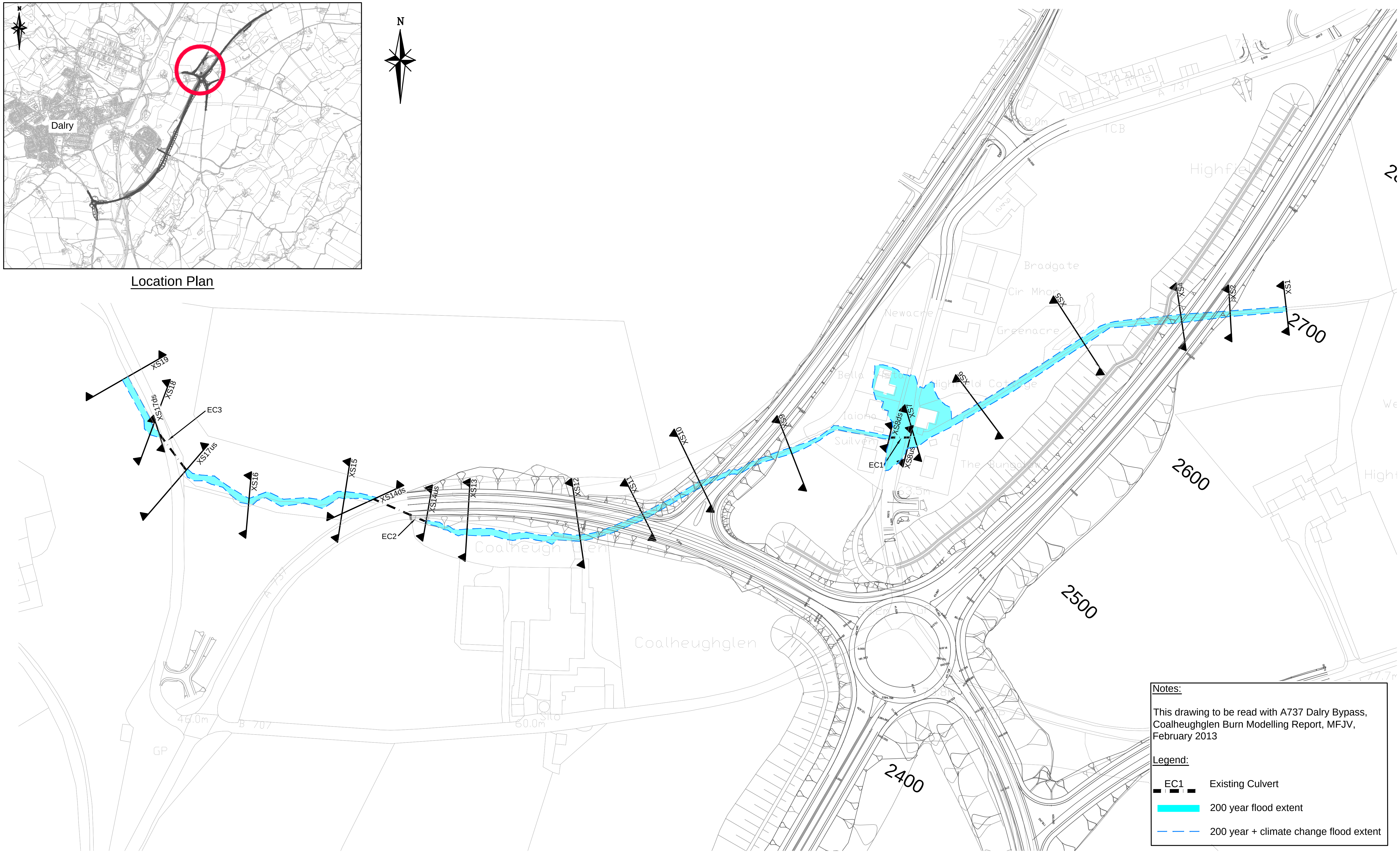

Notes:

This drawing to be read with A737 Dalry Bypass, Coalheughglen Burn Modelling Report, MFJV, February 2013

Legend:

- EC1 — Existing Culvert
- 200 year flood extent
- 200 year + climate change flood extent

CLIENT: TRANSPORT SCOTLAND — An agency of The Scottish Government

PROJECT TITLE: A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
01	Roads model updated.	KAB	MLJ	ELC	June 13

AMENDMENTS

DESIGN BY:	MLJ	CHECKED BY:	MLJ
DATE:	Feb 2013	DATE:	Feb 2013
DRAWN BY:	KAB	APPROVED BY:	ELC
DATE:	Feb 2013	DATE:	Feb 2013
DRAWING STATUS	Report		

ENGINEER: mouchel FAIRHURST

IN ASSOCIATION WITH SIAS

DRAWING TITLE: Coalheughglen Burn Hydraulic Modelling Flood Extent Envelope

SCALE @ A3	DRAWING NO	REV
1:2000	A737MFJV/ST3/D/034	01

Appendix 16.3

Flood Risk Assessment

A737 Dalry Bypass

Hydrogeological Review

and Risk Assessment

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June 2013

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Status: Final

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Record of Issue

Issue	Status	Author	Date	Check	Date	Authorised	Date
01	Final	N. Moran	Feb 2013	E. Connon	March 2013	E. Connon	March 2013
02	Final	W. Robinson/ J. Heather	May 2013	E. Connon	May 2013	E. Connon	May 2013
03	Final	W. Robinson	June 2013	J. Heather	June 2013	E. Connon	June 2013

Distribution

Organisation	Contact	Copies

Contents

1 Introduction

1.1 Introduction

A new road bypassing Dalry has been proposed. Hydrogeological information along the route has been reviewed with the aims of understanding the hydrogeology of the area.

Two areas are of particular concern: the central portion of the route where a cutting of depths down to nine metres below ground level and the southern end of the route, where high artesian water pressures have been recorded in exploratory boreholes.

Presented below are:

- a review of the geological structure of the area, including historical mining activities;
- information from ground investigations carried out along the proposed route;
- the hydrogeological conceptual model

1.2 Description of the route

The proposed A737 Dalry bypass is located immediately to the east of Dalry. The bypass starts to the north of Easter Highfield, approximately 1.5km north-east of Dalry and runs in a south-westerly direction crossing the Blair Road at an area known as Stoopshill, a number of farm tracks, the Glasgow to Ayr railway line and the River Garnock. It then continues in a westerly direction to rejoin the existing A737 approximately 600m south of Dalry.

The bypass is in a significant cutting along the middle part of the route, crossed by Blair Road Bridge, and a large bridge spanning the Glasgow to Ayr railway and the River Garnock at the southern end. At either end of the proposed bypass a new roundabout will be constructed where the road adjoins the existing A737.

The land that the bypass will cross through primarily comprises open undulating farmland that is used as grazing for livestock with very little vegetation. The topography generally slopes from higher ground in the north-east of the site to the River Garnock valley in the west.

A desk study and preliminary ground investigation have revealed that areas of the site have been subject to past disturbance from extensive mining of coal, ironstone and limestone. An old railway line crosses the road in two places and other potential sources of contamination include lime kilns, a tank house, a gas works and infilled quarries.

1.3 Local and regional geology

1.3.1 Solid geology

Structure

The site is located on the eastern limb of a south-westerly-plunging anticline structure. The dip of the rocks towards the east is very shallow: usually 7-10°.

A number of east-west and north-west to south-east trending normal faults are located regionally, although none are shown on the geological map to dissect any parts of the road corridor.

A fault runs east –west across the proposed bypass route. It crosses the route just north of Peesweep Hill, where the road cutting is planned. This fault results in a small displacement of up to 10m higher on the northern side.

A larger fault zone in the south of the proposed bypass area causes a displacement of about 25m upwards on the northern side. This fault zone passes through workings in the Dalry Black Band ironstone and unworked sections of the Borestone Coal, the Smithy Coal (just below the end of excavations), the Wee Coal and Third Post Limestone. The Lower Linn Limestone is truncated against the fault but re-appears in the higher ground north of the fault.

Solution features

There is local evidence of solution in the limestone from the presence of caves, Cleeves Cove (aka Blair Cove), about a kilometre to the south of the scheme. These are thought to be natural solution features rather than old mine galleries.

Caaf Water Limestone Formation

The proposed bypass route is mostly underlain by the Caaf Water Limestone Formation, of the Clackmannan Group of Carboniferous Age. This formation composed of cycles of marine limestones, mudstone, siltstone and sandstone. The four major limestone bands are shown from top to bottom in Table 1.

Table 1: Notable limestone bands in the Caaf Water Limestone Formation

Limestone band	Depth to top	Typical thickness (m)
Upper Linn Limestone	0	9.5
Lower Linn Limestone	24.5	5.5
Third Post Limestone	30	1.6
Index (Highfield) Limestone	31.6	2.5

The lithostratigraphical nomenclature of the Midland Valley of Scotland was reviewed in 1999 and it was decided that the Caaf Water Limestone Formation is synonymous with the Upper Limestone of the region.

Dalry Sandstone

The Caaf Water Limestone Formation is underlain by the Dalry Sandstone, more recently known as the Limestone Coal. The base of the Index Limestone of the Caaf Water Limestone Formation forms the top of the Dalry Sandstone. The formation is composed of sandstone, siltstone and mudstone with thin coal bands. These coal bands include the Wee Coal, the Smithy Coal and the Borestone Coal, which have all been mined at some time. The Dalry Black Band Ironstone lies approximately 60m below the Borestone Coal within the Dalry Sandstone.

The Kilbirnie Mudstone Formation lies immediately below the Dalry Sandstone. This formation is now regarded as part of the Limestone Coal. The Dalry Clay Band Ironstone, the deepest of the worked strata in this area, is part of the Kilbirnie Mudstone Formation.

1.3.2 Superficial geology

The superficial deposits in the area are typically boulder clay with varying degrees of sand and gravel. Alluvial clays, silt and coarser granular deposits are found in the river valley. Peat has been identified in the north of the site and in an isolated area south of Blair Road. Superficial deposits are generally up to 20m thick, with the shallowest bedrock (sometimes less than 1m of superficial cover) at the northern end of the study area.

1.4 Brief summary of mining

The area has been heavily mined over the last two centuries. The various workings underlie almost all of the proposed bypass route. The ironstone and claystone are the major economic deposits in this region: the coal is mined on a smaller scale. Quarrying of limestone is restricted to one formation: the Highfield Limestone at its outcrop at Highfield, at the northern part of the proposed bypass route.

Three formations containing coal have been exploited: the Wee Coal (highest), Smithy Coal and Borestone Coal (lowest). In the central and southern areas of the proposed bypass route, there are laterally extensive areas of Smithy Coal workings overlapping areas of the Wee Coal and Borestone Coal mines at depth. The Wee Coal, Smithy Coal and Borestone Coal workings are linked vertically by several shafts in this area.

An illustrative geological section along the proposed Bypass is shown on drawings A737MFJV/ST3/G/015 and a composite mine plan on drawings A737MFJV/ST3/G/013…/14 included in Appendix A.

2 Previous Ground Investigation

2.1 Aim of the ground investigation

The Stage 2 ground investigation was carried out between July and September 2008 by White Young Green Environmental. A stage 3 ground investigation was carried out by Ian Farmer Associates between December 2012 and April 2013. The aim of the investigation was to provide geological, geo-environmental and geotechnical data for the proposed scheme.

2.2 Brief review of findings

Made ground

Made ground was encountered in a number of isolated localities. The made ground was logged as a highly variable material consisting of a mixture of gravel, sand and clay. Domestic waste products were encountered in an infilled quarry and olfactory evidence of contamination was noted in a number of holes. The maximum thickness of made ground encountered was 3.6m although the true thickness was not proven at this locality so it may be thicker. The made ground is thought to be associated with historic development that has taken place along the road corridor.

Alluvium

Alluvial deposits were encountered within the floodplain of the River Garnock and in an isolated locality to the east of the Blairland Housing Development. The material comprises peat, soft clays, loose and medium dense sand and gravel and uncompacted silts. The material ranged in thickness from 3m up to 13m and was well-developed beneath the flood plain of the River Garnock. An area of peat up to 6m deep was also encountered at the northern end of the route.

Glacial Till

The glacial till is found throughout the study area and generally comprises clay with varying amounts of sand and gravel. The shallower horizons are generally soft to firm with the material becoming stiff to very stiff at depths greater than 1.5m below existing ground level (begl). The thickness of the glacial till varies from 1m to around 20m with the thicker areas being found in the central and southern parts of the site. Numerous boulders and cobbles, some over 1m in diameter, were recorded.

Glacial sands and gravels with varying amounts of silt and clay were recorded beneath the clay in some areas in the south-western portion of the road corridor. Although not laterally persistent this was found to be overlying the bedrock and up to a maximum thickness of 4.5m.

Bedrock

The bedrock to the north of Peesweep Mount comprises predominantly slightly weathered sandstone and mudstone with siltstone and coal encountered locally. The material was found to vary in strength from very weak to strong. In the southern half of the site the bedrock generally comprises moderately strong to strong limestone with sandstone encountered locally.

Groundwater

Groundwater was encountered in both the superficial and bedrock deposits. In a number of holes this was found to be under substantial artesian pressure.

The artesian groundwater conditions were seen in boreholes drilled to the south-west of Blair Road, with the northern most artesian groundwater recorded 200m south west of Blair Road. The artesian groundwater was recorded in a number of different strata including the basal granular glacial till, the glacial till / bedrock interface and in the bedrock. Pressure gauge readings from the 2008 White Young Green GI show that artesian groundwater heads of up to 55m above ground level are present, however vibrating wire piezometer readings from the Stage 3 GI indicate that the maximum artesian head is 9m above ground level.

2.3 Findings in various areas of the route

Areas for analysis

For analysis, the proposed route has been divided into three sections: the northern portion where the route will mostly be up on low embankments and shallow cuts; the central portion, adjacent to Peesweep Mount and the Blairland Housing Estate, where the major cut of up to 11.5m is proposed; and the southern portion, where the road will be built on an embankment and then a viaduct across the river valley. Each section has distinct characteristics and issues to be addressed.

Cross sections showing the anticipated thicknesses of materials and groundwater monitoring data can be seen in Appendix A. The groundwater was monitored fortnightly from the initial installation date and tehn on a weekly basis. The installations were typically monitored between 20 and 35 visits between Februay and April 2014.

Northern area

Rock was struck at shallow depths in some holes near to the northern end of the route, with a minimum of 0.3m and a maximum of 17.5m of drift deposits being encountered.

A number of boreholes in the northern part of the site did not encounter any groundwater in either the superficial depostis or the bedrock.

Conclusion for northern area:

Water was struck at various depths in rock, but a laterally extensive and consistent water body could not be confirmed. Groundwater is assumed to be locally controlled by mine workings, which are at shallow depths at this end of the proposed route. No artesian water was found in this area.

Monitoring indicates that discontinuous perched water deposits are present in the relatively low-permeability drift deposits.

Central cutting

Rock was encountered at depths of between 14.05m to 29.41m. Groundwater strikes were recorded both in the superficial deposits and in the bedrock.

Artesian groundwater in the bedrock was encountered in 2BH012 and 2BH024 at the south western end of the cutting. Sub-artesian groundwater was present in other boreholes where monitoring was carried out. The depth to groundwater increases as you progress north along the cutting.

Groundwater monitoring carried out within the superficial deposits indicates that a perched groundwater table is present from 0.2m to 1.0m depth with these materials.

Conclusion for central area

These results indicate that water is found in the superficial deposits and may rise to within 0.2m to 1m of the ground surface along the length of the cutting. Groundwater levels in the bedrock are artesian at the south western end of the cutting. The bedrock along the rest of the cutting contains sub-artesian groundwater with the depth increasing with progression north along the cutting.

Southern area – viaduct

Rock head was encountered at depths of between 12.5m (borehole GS016) to 18.94m (2BH003) bgl.

During the Stage 2 White Young Green GI, artesian water heads were measured either by extending the casing above ground level until the artesian head was contained or, where the piezometric surfaces were too high to allow this, by means of a pressure gauge attached to the casing. The highest artesian pressure recorded, in borehole GS011A, was equivalent to 55.1m above ground level.

During the Stage 3 ground investigation undertaken by Ian Farmer Associates vibrating wire piezometers were installed in the boreholes to measure the artesian pressure. It is considered that the measurements from these represent the actual groundwater conditions at the site. In order to specifically address potential artesian groundwater conditions for the viaduct foundation design 1 No or 2 No boreholes were drilled for each pier or abutment. The artesian groundwater was encountered in boreholes between Ch 100 to Ch 1070, although it was not encountered in all of the holes. The artesian heads ranged from 0.2m to 9.76m above existing ground level.

Conclusion – southern area

There is potential for high artesian water pressures to be encountered in the river valley. These will be discussed further below.

3 Hydrogeological Conceptual Model

3.1 Occurrence of artesian groundwater

The distribution of the boreholes displaying artesian heads and the large variation in heads suggest that the flow is mainly in fractures and voids.

Most boreholes with artesian water were near to the southern end of the proposed bypass in the river valley.

Several sub-artesian water levels in both the boulder clay and limestone were also recorded in the central and northern parts of the site.

3.2 Possible explanations for the generation of artesian groundwater pressures

Geological structure

The part of the site affected by artesian groundwater is on the eastern limb of a southerly plunging anticlinal structure. The more easterly boreholes did not demonstrate high artesian heads, so the artesian water is not caused by the anticline structure.

A larger fault zone in the south of the proposed bypass area causes a displacement of about 25m upwards on the northern side. This fault zone passes through workings in the Dalry Black Band ironstone and unworked sections of the Borestone Coal, the Smithy Coal (just below the end of excavations), the Wee Coal and Third Post Limestone. The Lower Linn Limestone is truncated against the fault but re-appears in the higher ground north of the fault. This fault zone provides a direct connection to higher ground (50maod) at Crow Grove to the east: water travelling down the fault zone could contribute to the high groundwater heads in the river valley.

Mining

The extensive mine workings allow groundwater flow through the system. It is believed that the high groundwater heads in the river valley are driven by water in the workings in the ironstone and clay band workings at depth. The ironstone and claystone workings are the most extensive and underlie almost all of the proposed bypass route. Most coal mining occurs below and south of Peesweep Hill.

In the central and southern areas of the proposed bypass route, there are laterally extensive areas of Smithy Coal workings overlapping areas of the Wee Coal and Borestone Coal mines. The Wee Coal, Smithy Coal and Borestone Coal workings are linked vertically by several shafts in this area, creating a hydraulic connection between them.

The smaller area of Smithy Coal mines at the northern end of the proposed bypass route is not connected to the larger area of workings to the south. The northern coal workings are thought to be drained by a ‘day level’ which is identified in the northern Smithy Coal excavations at about 24m AOD (50mbgl) and has been observed to discharge into the River Garnock to the west. The discharge from this day level has been estimated to be hundreds of litres per hour. The day level would have been excavated to keep the overlying mine workings dry; the deeper groundwater levels in this area and the observed discharge into the river indicate that it is still draining.

Source of water in the ironstone workings

The recharge area for the Ironstone is at and beyond the north east of the site. The workings have very high permeability and therefore the water is able to migrate through them without much loss of head. This is enough to generate the heads observed in boreholes drilled in the river valley. A number of mining roads in the Smithy Coal are thought to drain in a south westerly direction towards the River Garnock valley which could act as substantial high permeability conduits for groundwater flow.

It is believed that the southern fault zone is highly permeable due to the presence of collapsed workings, allowing confined groundwater to migrate upwards. These upwards pressures generate the artesian groundwater encountered in boreholes drilled in the river valley. The fault zone could also create a preferential pathway for water from higher ground to the east, as described earlier.

4 Possible Implications of the Scheme

4.1 Northern section

Old mine workings in the northern part of the proposed route may be consolidated by grouting. This could potentially have a negative effect on existing groundwater pathways. It is anticipated however that only mine workings above groundwater level will be grouted, thus the risk of closing of groundwater pathways by grouting is likely to be negligible.

4.2 Central section

The conceptual model for the area suggests that water in the rock is derived from deeper mine workings. The cutting is globally stable against uplift and passive dewatering will not be required. Only natural localised seepages are anticipated from the Glacial Till that will be picked up in the road drainage. Due to the low permeability of the Glacial Till flows are anticipated to be low and not considered to have a significant impact on the groundwater environment.

4.3 Southern Section

Private abstraction wells

Two private water abstractions exist in the vicinity of the southern extent of the Scheme. Information on the abstractions has been obtained from the North Ayrshire Council. The abstractions will be monitored during construction works to quantify any effects and mitigation measures will be put in place if necessary.

Artesian groundwater

High artesian heads are likely to cause difficulty when constructing viaduct foundations. It is proposed to construct the piles with permanent casing through the Upper Linn Limestone. This means grouting of solution features in the ULL can be avoided. Dewatering can be avoided by using drilling fluid during the construction of the piles. The fluid will be designed to balance the water pressures thus precluding their flow into the water environment.

5 Water Quality

Three water samples were taken from artesian boreholes in the River Garnock Valley during the Stage 2 ground investigation. All samples were recorded well below both the Drinking Water and the Environmental Quality standards with the exception of isolated instances of low pH and elevated iron and manganese.

The Stage 3 ground investigation included a comprehensive groundwater testing schedule.

Naturally occurring Aluminium, Iron, Manganese and Sulphate were encountered at many of the investigated locations in excess of EQS and Drinking Water Standards. These contaminant levels are typical of the pyritic rock formations in these Coal Measures, exacerbated by flooding of former mineworkings. In addition there were several isolated very minor exceedences of petroleum hydrocarbon fractions, Benzene and the polyaromatic hydrocarbon Benzo(g,h,i)Perylene.

The anthropogenic contaminants are anomalous and based on the great depth at which some of them have been recorded they are thought to be the result of minor contamination during site investigation. Re-sampling and re-testing have therefore been scheduled for confirmation. No results of the repeated testing have been available at the time of this report.

The organic contaminants recorded at slightly elevated levels are not thought to be a result of the historic contaminative land uses identified as part of the desk based investigations and reported in the Environmental Statement (A737 Dalry Bypass Environmental Statement, Chapter 11). Due to the presence of low permeability soils at all locations where organic contaminants were recorded and the significant depth at which some were encountered, it is more likely to be a result of minor contamination during the drilling of the boreholes in question. If these contaminants were part of a wider surface sourced pollution plume, it is reasonable to assume that much higher contaminant levels would have been encountered during the intrusive investigations. This was not the case.

Superficial groundwater samples tested revealed contamination comprising Manganese, Aluminium and Iron only. However these are all indicative of groundwater from pyritic coal measures and associated mudstones, where groundwater rebound after mine dewatering ceases, flushing sulphates and metals (iron, aluminium and manganese in this case) from pores, fissures and voids.

Groundwater quality data at location of exceedances, is summarised in Table 2 below.

Table 2 Site Investigation Elevated Contaminants in Groundwater

Contaminant	Maximum [µg/l]	Mean [µg/l]	Locations
Aluminium, Dissolved	48	30	2BH009, 2BH015C, G1, 2BH002, M1
Manganese, Dissolved	32000	4084	2BH002, 2BH004, 2BH002, 2BH007, 2BH006, 2BH073, 2BH004, 2BH005, 2BH017, 2BH003 2BH051, 2BH048
Sulphate as SO4	270mg/l	na	2BH005
Total Aluminium	52000	15341	2BH002, 2BH031, 2BH003, 2BH073, 2BH006, 2BH051, 2BH017, 2BH048, 2BH008, 2BH005, 2BH009, 2BH015C, 2BH007
Total Iron	150000	39765	2BH002, 2BH031, 2BH017, 2BH073, 2BH051, 2BH006, 2BH003, 2BH048, 2BH008, 2BH009, 2BH005, 2BH007, 2BH004
Total Manganese	3300	1578	2BH031, 2BH073, 2BH017, 2BH051, 2BH048

G1 refers to a private groundwater abstraction well. M1 refers to the day level mineworkings drainage channel.

It should be noted that total metal levels identified in the table are elevated above an EQS for dissolved phase in samples which in many cases contain acceptable levels of dissolved phase metal. This is indicative of Aluminium, Iron and Manganese being present in particulate or precipitate form in the identified groundwaters.

6 Water Risk Assessment

It is recognised that the proposed Scheme construction and operation can affect groundwater quality and quantity. A risk-based approach has been adopted to assess and manage potential risks associated with the groundwater. A summary of the Water Risk Assessment is included in Appendix B.

Appendix A – Drawings

A737MFJV/ST3/G/013…/14 Illustrative Composite Mine Plan

A737MFJV/ST3/G/015 Illustrative Geological Section

A737MFJV/ST3/G/005 Plan and Long Section Showing Anticipated Ground Conditions Along Route

A737MFJV/ST3/G/006 Plan and Long Section Showing Anticipated Ground Conditions Along Route

A737MFJV/ST3/G/007 Plan and Long Section Showing Anticipated Ground Conditions Along Route

A737MFJV/ST3/G/008 Plan and Long Section Showing Anticipated Ground Conditions Along Route

A737MFJV/ST3/G/009 Plan and Long Section Showing Anticipated Ground Conditions Along Route

CLIENT	PROJECT TITLE
TRANSPORT SCOTLAND An agency of The Scottish Government	A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
A	Addition of Smithy Coal workings and new SI boreholes.	AA	AG	AB	14/05/13

AMENDMENTS

This plan should be read in conjunction with:

- A737MFJV/ST3/G/012
- A737MFJV/ST3/G/014
- A737MFJV/ST3/G/015

Reference to "waste" infers areas of potential unrecorded workings.

NOTES

DESIGN BY:	AA	CHECKED BY:	AG
DATE:	04/10/2012	DATE:	04/10/2012
DRAWN BY:	AA	APPROVED BY:	JH
DATE:	04/10/2012	DATE:	04/10/2012
DRAWING STATUS	FOR INFORMATION		

ENGINEER

mouchel FAIRHURST

IN ASSOCIATION WITH

SIAS amec

DRAWING TITLE

Illustrative Composite Mineworking Plan
Southern part of route

SCALE AT A0	DRAWING NO	REV
1:2500	A737MFJV/ST3/G/013	A

CLIENT

TRANSPORT SCOTLAND

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
A	Addition of Smithy Coal workings and new SI boreholes.	AA	AG	AB	14/05/13

AMENDMENTS

This plan should be read in conjunction with:

- A737MFJV/ST3/G/012
- A737MFJV/ST3/G/013
- A737MFJV/ST3/G/015

Reference to "waste" infers areas of potential unrecorded workings.

NOTES

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DRAWING STATUS	FOR INFORMATION		

ENGINEER

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DRAWING TITLE

Illustrative Composite Mineworking Plan
Northern part of route

SCALE AT A0	DRAWING NO	REV
1:2500	A737MFJV/ST3/G/014	A

CLIENT

TRANSPORT SCOTLAND

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
A	Integration of new information provided by additional site investigation (17 boreholes).	AA	AG	AB	06/06/13

AMENDMENTS

This plan should be read in conjunction with:
- A737MFJV/ST3/G/012
- A737MFJV/ST3/G/013
- A737MFJV/ST3/G/014

Hatched areas represent areas of known mineral extraction.
Reference to "waste" infers areas of potential unrecorded workings.
Additional SI boreholes shown blue at approximate positions.

NOTES

DESIGN BY:	AA	CHECKED BY:	AG
DATE:	04/10/2012	DATE:	04/10/2012
DRAWN BY:	AA	APPROVED BY:	JH
DATE:	04/10/2012	DATE:	04/10/2012
DRAWING STATUS	FOR INFORMATION		

ENGINEER

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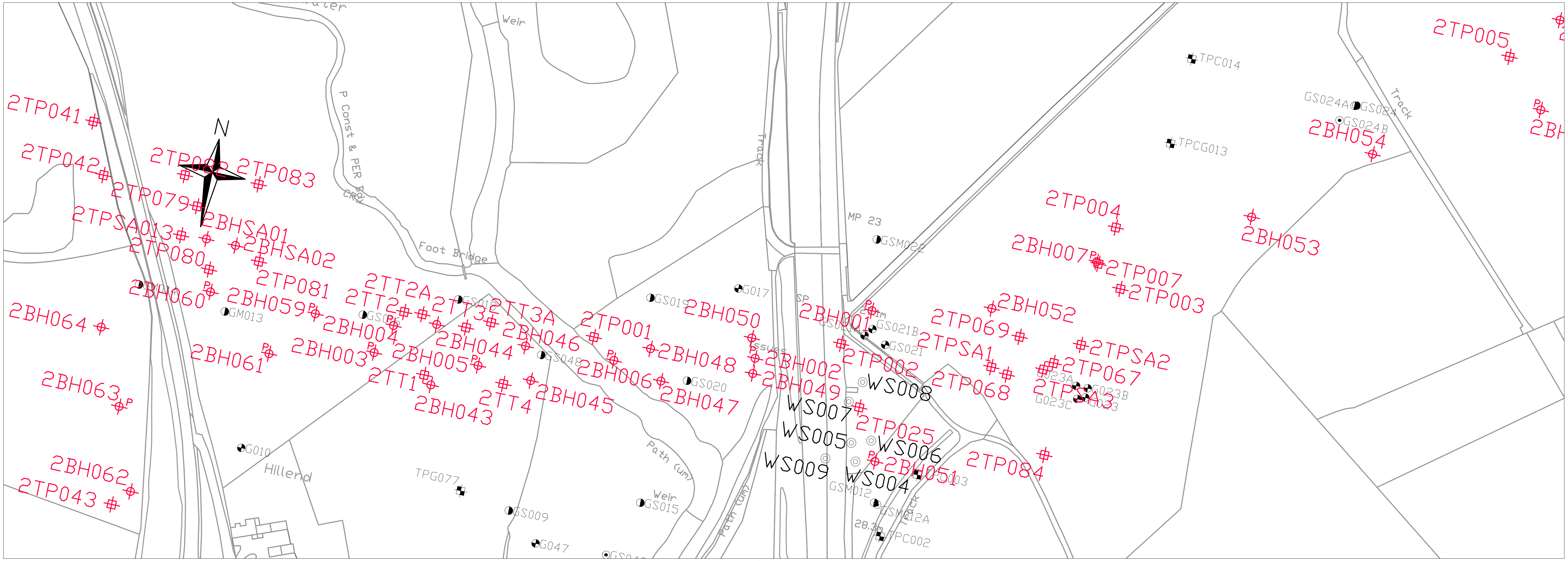
DRAWING TITLE

Illustrative Geological Section
Line of Proposed Route (A - B)

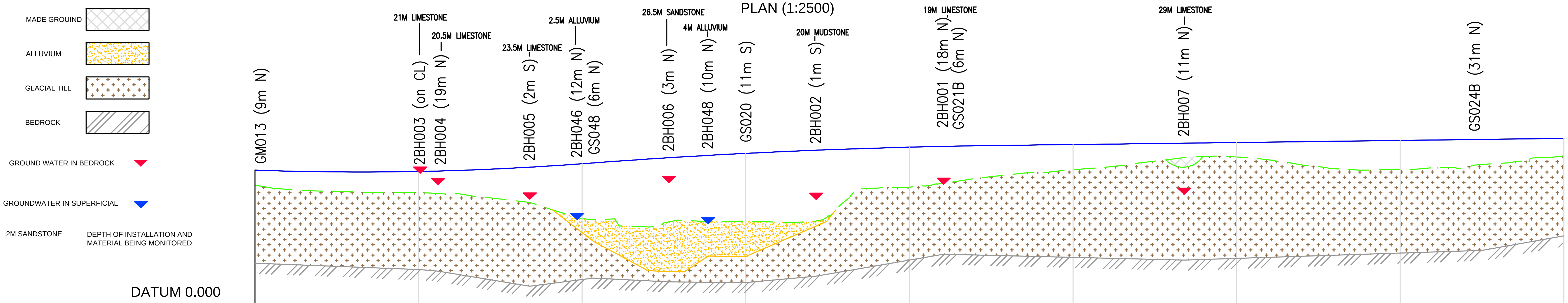
SCALE AT A0: 1:2500 (horizontal) and 1:1000 (vertical)

DRAWING NO: A737MFJV/ST3/G/015

REV: A



PLAN (1:2500)



DATUM 0.000

Chainage	0.0	100.0	200.0	300.0	400.0	500.0	600.0	700.0	800.0
Original GL	28.905	27.134	20.974	20.126	28.395	32.694	35.822	32.736	36.057
Proposed Level	32.600	32.275	34.173	36.698	38.224	38.863	39.363	39.863	40.363

LONG SECTION (1:2500H/1:1000V)

CLIENT
TRANSPORT SCOTLAND
An agency of The Scottish Government

PROJECT TITLE
A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
B	ADDITION OF MONITORING DATA	AB	WR	RA	JUN13
A	ADDITIONAL GI INCORPORATED, SECTION AMENDED TO SUIT	AG	WR	RA	APR13

AMENDMENTS

DESIGN BY:	WR	CHECKED BY:	WR
DATE:	12/07/12	DATE:	12/07/12
DRAWN BY:	FF	APPROVED BY:	RA
DATE:	12/07/12	DATE:	12/07/12
DRAWING STATUS		INFORMATION	

ENGINEER
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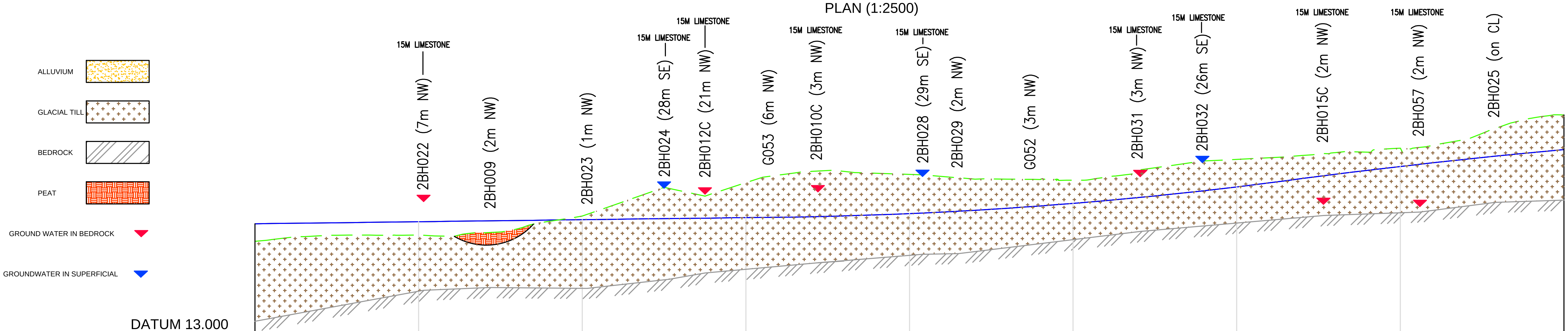
DRAWING TITLE
A737 DALRY BYPASS
PLAN & LONG SECTION SHOWING ANTICIPATED GROUND CONDITIONS ALONG ROUTE (SHEET 1 OF 5)

SCALE @ A3	DRAWING NO	REV
AS SHOWN	A737MFJV/ST3/G/005	B

PLAN (1:2500)



DATUM 13.000

Chainage	800.0	900.0	1000.0	1100.0	1200.0	1300.0	1400.0	1500.0	1600.0
Original GL	36.057	37.599	42.233	50.889	51.192	51.023	55.058	58.853	66.983
Proposed Level	40.363	40.863	41.363	41.863	42.852	45.348	49.383	54.377	58.506

LONG SECTION (1:2500H/1:1000V)

CLIENT

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
B	ADDITION OF MONITORING DATA	AB	WR	RA	JUN13
A	ADDITIONAL GI INCORPORATED, SECTION AMENDED TO SUIT	AG	WR	RA	APR13

AMENDMENTS

DESIGN BY:	WR	CHECKED BY:	WR
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DATE:	12/07/12	DATE:	12/07/12
DRAWING STATUS	INFORMATION		

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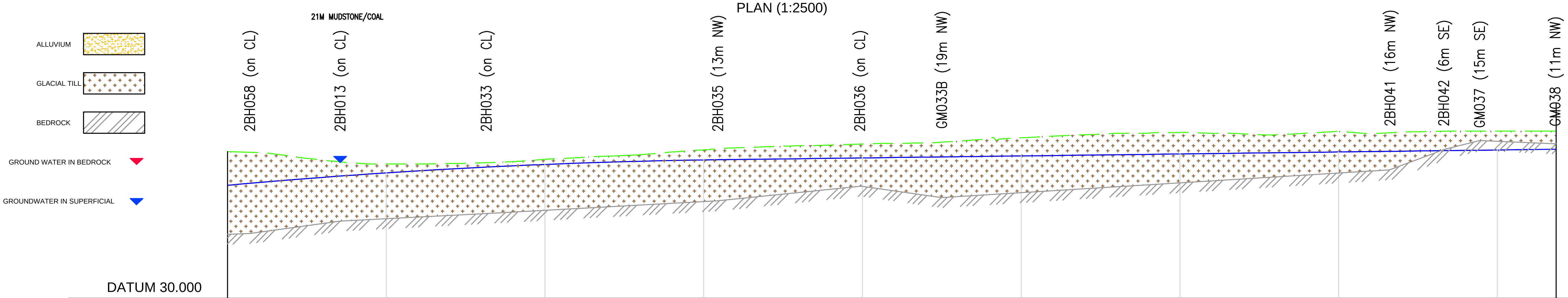
DRAWING TITLE

A737 DALRY BYPASS
PLAN & LONG SECTION SHOWING ANTICIPATED GROUND CONDITIONS ALONG ROUTE (SHEET 2 OF 5)

SCALE @ A3	DRAWING NO	REV
AS SHOWN	A737MFJV/ST3/G/006	B

PLAN (1:2500)



Chainage	1600.0	1700.0	1800.0	1900.0	2000.0	2100.0	2200.0	2300.0	2400.0
Original GL	66.983	63.857	65.052	67.445	68.898	70.478	71.820	72.098	69.981
Proposed Level	58.506	61.636	63.765	64.894	65.402	65.902	66.402	66.902	67.402

LONG SECTION (1:2500H/1:1000V)

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
B	ADDITION OF MONITORING DATA	AB	WR	RA	JUN13
A	ADDITIONAL GI INCORPORATED, SECTION AMENDED TO SUIT	AG	WR	RA	APR13

AMENDMENTS

DESIGN BY:	WR	CHECKED BY:	WR
DATE:	12/07/12	DATE:	12/07/12
DRAWN BY:	FF	APPROVED BY:	RA
DATE:	12/07/12	DATE:	12/07/12
DRAWING STATUS	INFORMATION		

ENGINEER

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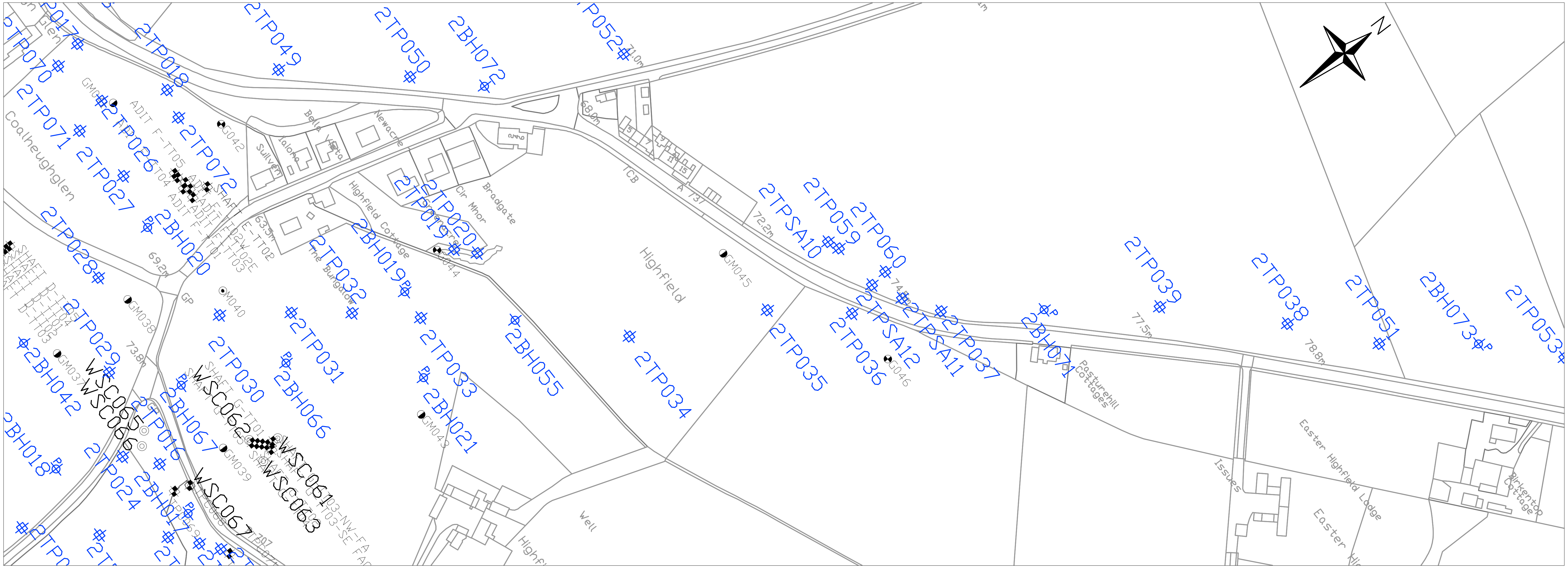
DRAWING TITLE

A737 DALRY BYPASS
PLAN & LONG SECTION SHOWING ANTICIPATED GROUND CONDITIONS ALONG ROUTE (SHEET 3 OF 5)

SCALE @ A3	DRAWING NO	REV
AS SHOWN	A737MFJV/ST3/G/007	B



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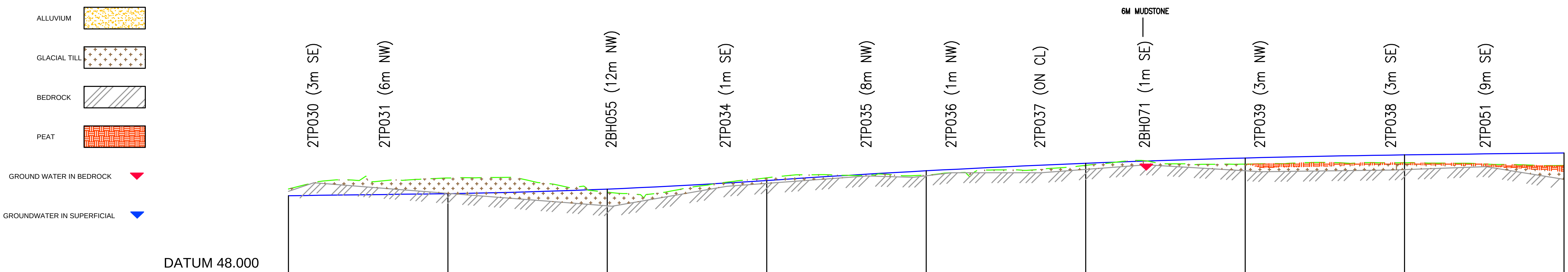

DATUM 48.000

Chainage	0.0	100.0	200.0	300.0	400.0	500.0	600.0	700.0
Original GL	69.320	72.045	68.511	72.106	72.789	75.223	75.539	75.883
Proposed Level	67.628	68.139	69.286	71.434	73.860	75.737	77.065	77.844

LONG SECTION (1:2500H/1:1000V)

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
B	ADDITION OF MONITORING DATA	AB	WR	RA	JUN13
A	ADDITIONAL GI INCORPORATED, SECTION AMENDED TO SUIT	AG	WR	RA	APR13

AMENDMENTS

DESIGN BY:	WR	CHECKED BY:	WR
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DRAWING STATUS	INFORMATION		

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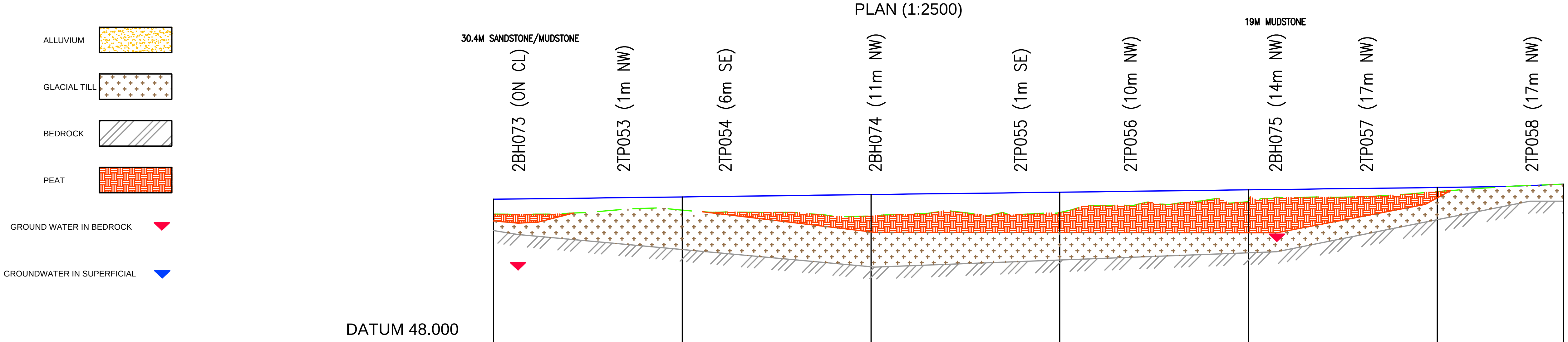
DRAWING TITLE

A737 DALRY BYPASS
PLAN & LONG SECTION SHOWING ANTICIPATED GROUND CONDITIONS ALONG ROUTE (SHEET 4 OF 5)

SCALE @ A3	DRAWING NO	REV
AS SHOWN	A737MFJV/ST3/G/008	B

PLAN (1:2500)



DATUM 48.000

Chainage	800.0	900.0	1000.0	1100.0	1200.0	1300.0
Original GL	75.176	76.032	74.790	75.508	78.072	79.988
Proposed Level	78.344	78.844	79.344	79.844	80.344	80.844

LONG SECTION (1:2500H/1:1000V)

CLIENT

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PROJECT TITLE

A737 Dalry Bypass

REV	REVISIONS	BY	CHKD	APP'D	DATE
B	ADDITION OF MONITORING DATA	AB	WR	RA	JUN13
A	ADDITIONAL GI INCORPORATED, SECTION AMENDED TO SUIT	AG	WR	RA	APR13

AMENDMENTS

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DATE:	12/07/12	DATE:	12/07/12
DRAWING STATUS	INFORMATION		

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DRAWING TITLE

A737 DALRY BYPASS
PLAN & LONG SECTION SHOWING
ANTICIPATED GROUND CONDITIONS
ALONG ROUTE (SHEET 5 OF 5)

SCALE @ A3	DRAWING NO	REV
AS SHOWN	A737MFJV/ST3/G/009	A

Appendix B – Water Risk Assessment

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Water Risk Assessment
(Prepared following completion of Stage 3 SI)

Activity		Source	Pathway	Receptor	Potential problem	No risk or Risk management
Construction of road in cutting below Blair Road	SCHEME CONSTRUCTION	Groundwater	Temporary drainage system	Unnamed tributary of River Garnock	Flood risk - Extensive dewatering of excavation if artesian groundwater encountered – risk of downstream flooding	Negligible risk of artesian groundwater due to remaining approx. 10m clay cap (after cut) providing effective containment of groundwater. Seepage through boulder clay will be dealt with by conventional dewatering
					Pollution - Surface water pollution if groundwater contaminated	Elevated levels of naturally occurring iron, manganese and aluminium present in groundwater compared with surface water content. Pre-treatment of the intercepted seepage water may be required before discharge
				Groundwater / surface water features	Water features - Temporary lowering of groundwater table impacting on ground and surface water	Negligible risk as anticipated groundwater flows are small (local seepage through boulder clay only). Low permeability boulder clay will result in small radius of influence
		Materials – concrete / cement grout	Spillage	Groundwater/ surface water	Pollution - Groundwater / surface water pollution	Negligible risk due to works undertaken well above the groundwater table / follow published SEPA guidance
	SCHEME OPERATION	Groundwater	Road drainage system / SuDS	Unnamed tributary of River Garnock / other water features	Flood risk - Insufficient drainage provided to intercept high groundwater flows	Permanent seepage (varying flows but not significant) through boulder clay anticipated but no designated groundwater drainage required. The new road drainage will be designed to intercept any groundwater seepage.
					Water Features - Permanent lowering of groundwater table impacting on surface water features fed by groundwater	Negligible risk as anticipated groundwater flows are small (seepage only)
					Pollution - Surface water pollution if groundwater contaminated	Negligible risk as the intercepted groundwater seepage will drain via new road drainage and SuDS prior to discharge to watercourse.

Prepared by: MLJ
Date: 16/04/2013

Activity		Source	Pathway	Receptor	Potential problem	No risk or Risk management
Grouting of covered mine workings	SCHEME CONSTRUCTION	Redundant mineworkings (stabilisation by grout)	Shafts, roadways, faults	Groundwater/ surface water features	Pollution - Groundwater/ surface water pollution	_Area 1_ (Highfield Limestone): potential risk of groundwater pollution due to grouting below groundwater level encountered during SI. However, void is isolated and gravel will be used to fill voids thus risk of contamination is minimised. _Area 2_ (Smithy Coal): negligible risk (majority BHs were dry during SI) due to the affected area being isolated. Dense grout will be used to fill voids _Area 3_ (Borestone Coal): located close to the Coalheughglen Burn and potentially draining to the R. Garnock Day Level. Contamination risk is low due to the grouting being at a much higher level than the Day Level. Further SI will establish full extent of grouting. Close monitoring of Day Level and nearby watercourses will be required.
					Flooding / drainage – Interference with groundwater pathways / changing flow patterns	_Area 1_ (Highfield Limestone) – low risk due to utilising gravel to fill voids (maintain flow path) – isolated void _Area 2_ (Smithy Coal) - negligible risk as the proposed works will be undertaken above the groundwater table (majority of BHs were dry during SI) and the grouting zone will be isolated. _Area 3_ (Borestone Coal) – a low risk of pathways blocking during grouting in this area (no groundwater encountered in BH during SI). Further SI will establish full extent of grouting. Close monitoring of the Day Level discharge and nearby water features may be required.
	SCHEME OPERATION	Redundant mineworkings (stabilisation by grout)	Shafts, roadways, faults	Groundwater/ surface water features	Flooding / drainage – Interference with groundwater pathways / changing flow patterns	Low risk but monitoring of nearby water features should continue during scheme operation and mitigation measures developed as appropriate.

mouchel FAIRHURST

Activity		Source	Pathway	Receptor	Potential problem	No risk or Risk management
Construction of viaduct foundations	SCHEME CONSTRUCTION	Groundwater	Dewatering / temporary drainage	River Garnock	Flooding - due to high rates of dewatering during pile construction (artesian groundwater present)	Flow rates will be confirmed but it is anticipated that it will be no more than 2000m^3/d. Considering the flows in the River Garnock the flood risk is considered negligible.
					Pollution - due to discharge of groundwater arisings	Elevated levels of naturally occurring iron, manganese and aluminium in groundwater when compared against surface water content. Treatment may be required prior to discharge to the River Garnock. However, if viable, any construction groundwater arisings should be returned to ground.
		Groundwater	Dewatering / temporary drainage	Groundwater / surface water features	Water Features - lowering of groundwater table impacting on surface water features fed by groundwater	No extensive dewatering (artesian water) is anticipated due to adoption of the following construction methods: - provision of permanently cased piles founded in the rock below Upper Linn Limestone, and - construction of piles with the bores full of high density or pressurised drilling fluids Normal construction dewatering only is therefore envisaged
		Materials – concrete / cement grout	Spillage	Groundwater/ surface water	Pollution / contamination – River Garnock	Selected construction method should minimise the risk of groundwater pollution – follow published SEPA guidance
	SCHEME OPERATION	Groundwater	Permanent drainage system	River Garnock	Flooding – River Garnock downstream	Seepage flows will be minimal thus the flood risk to the River Garnock is negligible.
					Pollution - River Garnock	Seepage flows will be minimal thus considering available dilution within the River Garnock the risk of pollution is considered as negligible

Prepared by: MLJ
Date: 16/04/2013

Appendix 16.4

Hydrogeological Review