GUNNEDAH SECOND ROAD OVER RAIL BRIDGE

Hydrologic/Hydraulic Assessment Report

Prepared for:

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SEC143-TD-HY-REP-0001 Rev A

Limitations Statement

The sole purpose of this report and the associated services performed by Kellogg Brown & Root Pty Ltd (KBR) is to provide a Hydrologic/Hydraulic Assessment in accordance with the scope of services set out in the contract between KBR and Roads and Maritime Services – Northern Division ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

KBR derived the data in this report primarily from visual inspections, examination of records in the public domain, interviews with individuals with information about the site and previous assessments undertaken by others. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, KBR has relied upon and presumed accurate certain information (or absence thereof) relative to the site provided by government officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, KBR has not attempted to verify the accuracy or completeness of any such information.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between KBR and the Client. KBR accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

Revision History

Revision	Date	Comment	Signatures		
			Originated by	Checked by	Approved by
A	12/12/2013	Issue for Review	M Kang	Z Lepojevic	W Zborowski

CONTENTS

1 Introduction

1.1 BACKGROUND

Kellogg Brown and Root (KBR) Pty Ltd has been engaged by Roads and Maritime Services (RMS) to identify a preferred option for a new road over rail bridge in Gunnedah, New South Wales.

The Oxley Highway is a main route which connects Tamworth and Coonabaran via Gunnedah and is predicted to receive an increase in traffic due to major coal developments in the Gunnedah Basin.

An increase in frequency of trains and also the longer length of coal trains cause significant delays at the existing rail crossings within Gunnedah. A grade separation to replace the New Street level crossing will assist in alleviating traffic pressures, facilitate efficiency and improve safety for both vehicles and pedestrians and assist council in improving local transport infrastructure.

This report has been prepared to assist in the investigation of the flooding impacts of the shortlisted options in the vicinity of Blackjack Creek.

1.2 GENERAL DESCRIPTION OF THE STUDY AREA

Blackjack Creek drains runoff from a catchment area of approximately 24km^2 to the south of the Oxley Highway over a length of 8km between the upper reach catchment boundary to the cross drainage structures at the Oxley Highway. Between the Oxley Highway and the railway culvert bridge, Ashfords Watercourse (refer to Appendix F) which consists of a rectangular concrete channel joins the eastern side of the Blackjack Creek bank (refer to Figure 1).

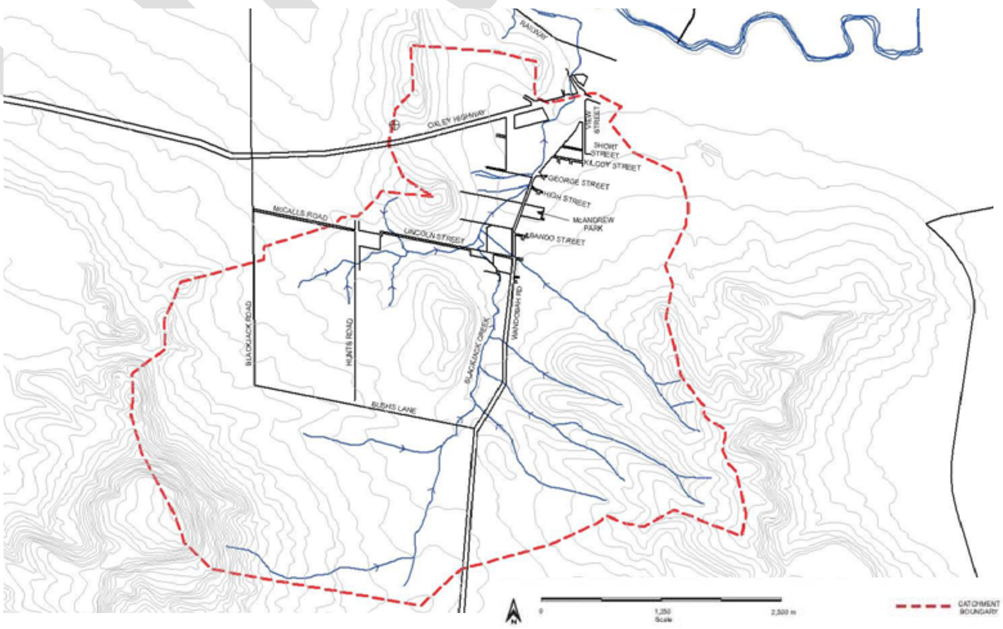

Figure 1: Blackjack Creek Catchment Area (Lyall, 2005)

The creek then discharges to the floodplain of the Namoi River, which is a significant floodplain impacting the township of Gunnedah and directly impacting the study area.

1.3 SCOPE AND OBJECTIVES OF THIS ASSESSMENT

Whilst various flood related studies have been completed in the past, the purpose of this study is to:

1. Estimate changes in water levels (afflux) upstream and downstream of the proposed alignment options for a 100 year Average Recurrence Interval (ARI) and
2. Calculate velocities around the proposed bridge piers for a 100 year ARI in Blackjack Creek as a result of construction of Option B and Option B/C and potential for scour and erosion.

Providing a flood extent and flood levels for pre/post construction of the proposed road alignment is not part of the scope.

The three (3) options shortlisted at the time of the Preferred Option Report dated September 2013 are illustrated in Figure 1 below.

Option A, being geographically removed from Blackjack Creek, does not contribute any impact to flooding. Therefore Option A was excluded in this assessment.

Option B and B/C have a similar tie-in configuration at Warrabungle Street. The major difference between the options is the departure angle from the Oxley Highway roundabout. Both options are located on the top of the existing embankment.

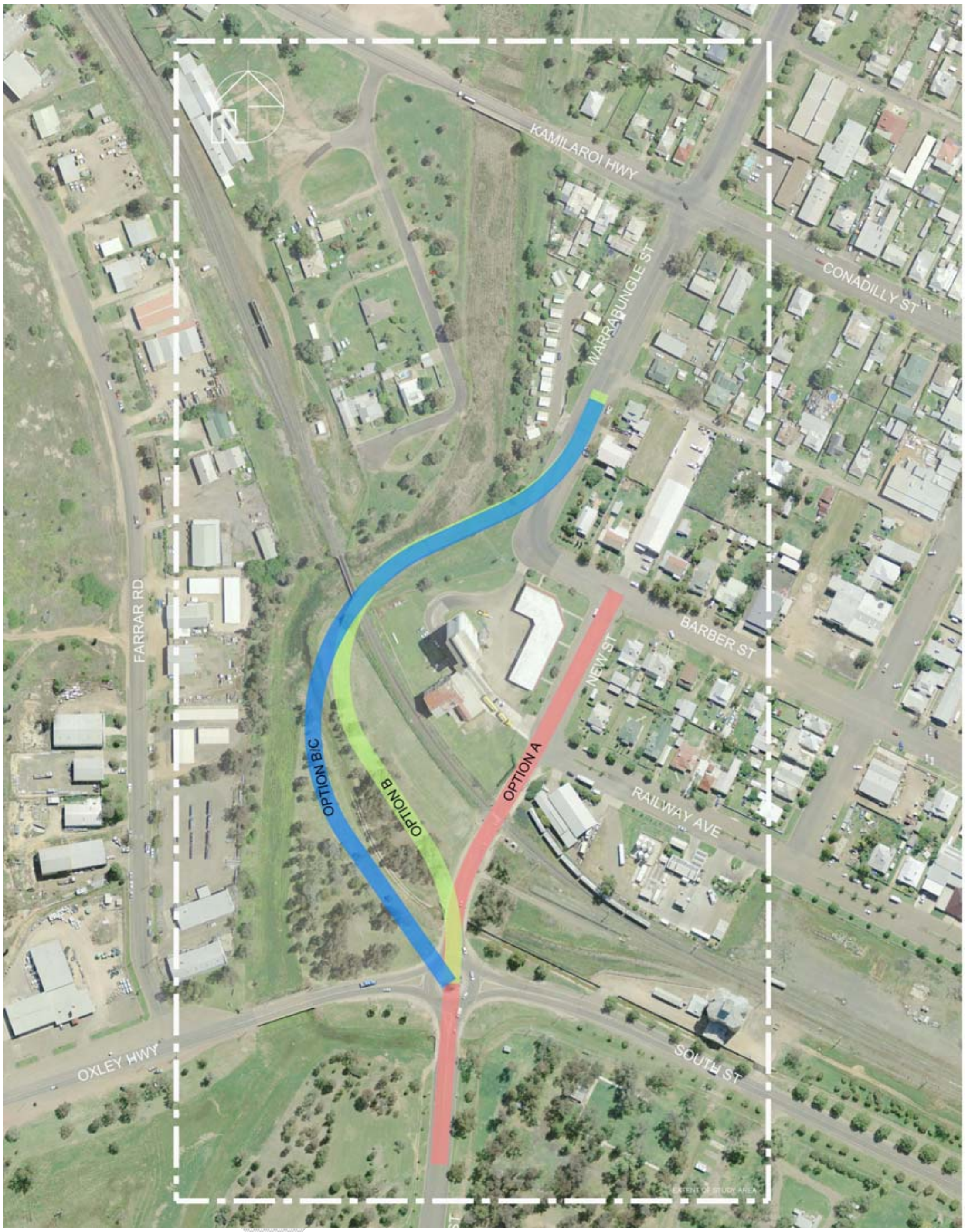

Figure 1: Map of Options A, B and B/C

2 Previous Studies & Information Sources

2.1 FLOOD INUNDATION MAP: NAMOI RIVER AT GUNNEDAH (NSW WATER RESOURCES COMMISSION, 1978)

This map only includes the flood extent of the Namoi River. As it was produced 35 years ago, the condition of Blackjack Creek would have changed and this may expand the flood extent further upstream of the Blackjack Creek corridor.

2.2 FLOOD STUDY REPORT GUNNEDAH AND CARROLL (SMEC, 1996)

The flood study report for Gunnedah prepared by SMEC in 1996 describes the results of a detailed flood study of the surrounding area of Gunnedah and the village of Carroll. This report superseded the Flood Inundation Map (NSW Water Resources Commission, 1978).

The study found that the flood elevation of Namoi River in the vicinity of the study area is RL 264.4m (Australian Height Datum, AHD) for the 100 year ARI. This flood elevation has been linearly interpolated by KBR between cross sections (the hydraulics model by SMEC) at Kelvin Road and upstream of the confluence of Blackjack Creek and Namoi River.

The KBR's topographic model shows that the Blackjack Creek invert level upstream of the railway bridge is approximately RL 260.0m. This suggests that the flood waters from Namoi River would introduce a backwater effect.

This study has been used to assess downstream condition for the proposed HEC-RAS model.

2.3 BLACKJACK CREEK FLOOD STUDY (LYALL & ASSOCIATES, 2005)

Lyall & Associates undertook a flood study for Blackjack Creek which drains the catchment of $24km^2$ upstream of the Oxley Highway culverts. This flood study includes report, hydrologic (RORB) and hydraulics (HEC-RAS) models.

The purpose of this flood study was to define flood behaviour in the streams in terms of flows, levels and flooding behaviour for flood frequencies between 5 and 100 years ARI and the Probable Maximum Flood (PMF).

This report can be summarised as follows;

- The small difference in flood levels between the 5 and 100 year ARI events where the flow velocities are generally less than 1m/s.
- Floodwaters extend over a width of floodplain up to 400m downstream of High Street at the 20 year ARI.
- The capacity of the culvert bridge at Oxley Highway would be sufficient for only up to a 20 year ARI.

The hydrologic and hydraulics models created by Lyall & Associates were utilised as a partial base model for this assessment.

2.4 GUNNEDAH LEP FLOOD PLANNING MAP SHEET FLD_005AA (GUNNEDAH SHIRE COUNCIL, 2012)

The discontinuity of the flood extent at the downstream of the railway bridge has been found on the Gunnedah Flood Planning Map (Figure 1). It is suspected that the flood extents from the different sources were combined together independently.

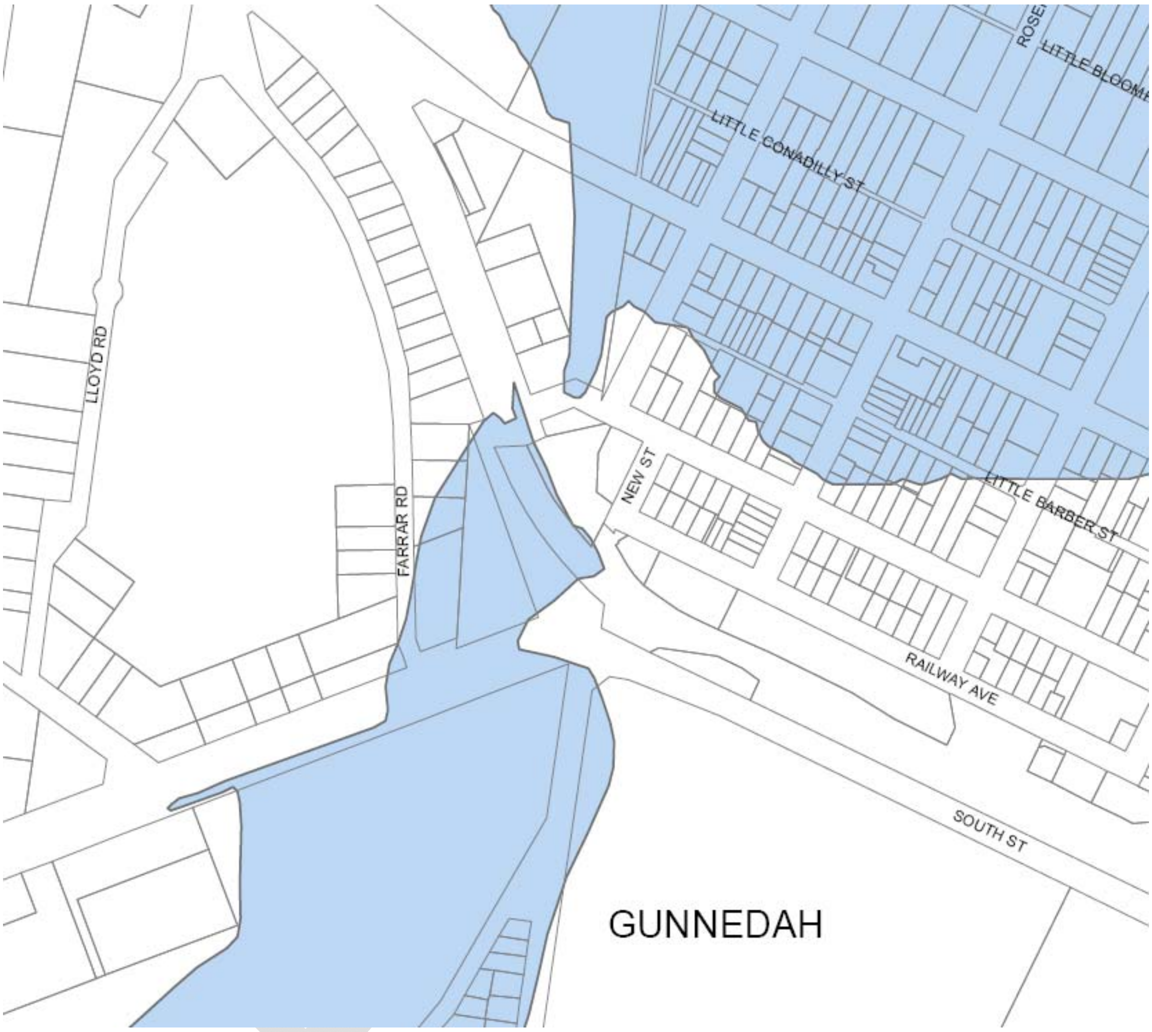

Figure 2: Gunnedah LEP Flood Planning Map (GSC, 2012)

3 Input Data

3.1 SITE INVESTIGATION

A site investigation was carried out on 18 July 2013 to inspect the study area including:

- Creek geometry and local topography to assess Manning's n coefficients
- Culvert crossings including measurements
- Other drainage infrastructures such as concrete open channel and swales
- Spot levels of the creek invert. Leica Viva NetRover (GPS) was used to obtain additional cross sections outside of the topographic survey.

The inspection proceeded from downstream of the Oxley Highway culverts to the Kamilaroi Highway culverts. The vegetation in the vicinity of the railway culvert bridge was found to be extremely dense. The creek channel is well defined although there were areas where the water was ponding locally, particularly upstream and downstream of the culverts.

3.2 TOPOGRAPHIC SURVEY INFORMATION

The 3-dimensional topographic ground survey information of the study area was produced by Moultrie Group on 6 November 2012.

3.3 EXISTING HYDROLOGIC/HYDRAULIC MODELS BY LYALL & ASSOCIATES (2005)

3.3.1 Existing hydrologic/hydraulic models

The following modelling information has been obtained from Lyall & Associates.

- Hydrology: RORB catchment file
    - It contains 12 sub-catchments.
    - A catchment for Ashfords Watercourse is missing.
    - A storm file was not provided.
    - The report was used to confirm the parameters used and the modelling philosophy.

- Hydraulics: HEC-RAS model (steady)
    - It does not cover the entire Blackjack Creek main streams and their tributaries.
    - It was found that the railway bridge was replaced with a culvert crossing after the modelling and the Kamilaroi Highway culvert crossing was not included in the model.

3.3.2 Discrepancy in peak discharges between models and report

The RORB model supplied by Lyall & Associates which only includes a catchment model has been reviewed and it was found that the reproduced peak discharges from the RORB model and Lyall's report were not identical.

RORB requires a catchment file, storm file and model parameters to run a hydrologic model. As a catchment file was only provided for this assessment, the missing information of the RORB model would have caused the discrepancy in peak discharges.

Section 4 provides details on verifying peak discharges for the new model.

4 Methodology

This flood assessment focuses on the rise in water levels (afflux) in Blackjack Creek affected by the proposed alignments and bridges in the floodplain.

It consists of hydrology and hydraulics design components. The existing hydrologic and hydraulic models developed by Lyall & Associates have been reviewed and reused where possible.

4.1 HYDROLOGY

4.1.1 Assumptions and parameters

- The RORB catchment model provided by Lyall & Associates has been used as a base model and then developed for this assessment
- The catchment characteristics of the Lyall's hydrologic model (catchment delineation, impervious and pervious area percentages) were adopted.
- Model parameters including coefficients of storage equation and rainfall losses were specified from the report (Lyall & Associates, 2005).

4.1.2 Modelling

The original RORB model provided by Lyall & Associates was reviewed and the new hydrologic model was developed on the basis of the following information.

- Blackjack Creek Flood Study report by Lyall & Associates (2005)
- The RORB catchment file for the flood study (Lyall, 2005)

It was found that the original RORB model provided by Lyall & Associates required to incorporate the following missing information.

- RORB storm file: As a project specific storm file was not provided, a new project specific storm file has been created.

  The rainfall Intensity-Duration-Frequency (IFD) data was extracted from Bureau of Meteorology (BoM) website. The 9 parameters extracted from BoM are:

  $I_{2y,\ 12h}$: 27.43 4.93 1.31 54.57 10.04 2.95

  Skew= 0.33, F2 = 4.33 and F50 = 15.94
- The additional Ashford Watercourse catchment (3.2km^2) was added into the existing RORB catchment file.

The peak discharge results from the following sources below are described in Table 1.

- The peak discharges provided in the Lyall's flood study report (2005)
- The peak discharges produced with the catchment file provided by Lyall & Associates, a new storm file created by KBR and the parameter values specified in the Lyall's report (2005).
- The peak discharges produced with the revised catchment file by KBR, a new storm file created by KBR and the parameter values specified in the Lyall's report (2005).

Table 1: Comparison of design peak discharges for the critical storm duration

Location	100yr ARI		
	Lyall's Report	Existing Lyall RORB	Revised model with Ashfords by KBR
	(m^3/s)	(m^3/s)	(m^3/s)
Main Arm at Lincoln Street	66	70	67
Tributary at Lincoln Street	45	46.5	44.5
Junction of Main Arm and Tributary d/s Lincoln Street	115	123	117
High Street	117	126	120
Short Street	126	137.5	131
Oxley Highway	127	139.5	132.5
D/S Oxley (D/S Ashfords)	144	Not modelled	147.5

The results from the different sources are very similar and the revised model with an additional catchment from Ashfords watercourse has been adopted as inflows for HEC-RAS modelling.

4.2 HYDRAULICS

4.2.1 Modification of the original HEC-RAS model by Lyall

The HEC-RAS model provided by Lyall & Associates covers approximately 4.5km (from the railway culvert bridge downstream to Hunts St upstream) of the mainstreams and tributaries of Blackjack Creek.

This original HEC-RAS model then was utilised as a base model (pre-construction of the proposed road alignment) to incorporate the following changes.

- The railway bridge in the original HEC-RAS model has been updated due to the replacement of the railway bridge with a culvert crossing after the flood study was undertaken by Lyall & Associates
- The original HEC-RAS model has been extended approximately 70m downstream to incorporate Kamilaroi Highway culverts and additional cross sections downstream.
- Extra cross sections have been included from the topographic survey information in the vicinity of the alignment options. The cross section locations have been determined by new proposed bridge pier locations.

4.2.2 Manning's n coefficients

The Manning's 'n' coefficients have been amended based on the site visit, photos, experience and also to incorporate new viaduct piers.

4.2.3 Viaduct and Wall Scenarios for Each Option

The following scenarios were modelled for each option for post-construction of the proposed viaduct and road alignment.

- Viaduct (30m span) construction allowing with reinforced soil walls provided up to 4.5m height
- Reinforced soil wall construction allowing only the minimum opening for the ARTC rail clearances (17m minimum horizontal clearance).

4.2.4 Boundary Condition & Sensitivity Analysis

Downstream boundary

The original HEC-RAS model has been extended 70m downstream to incorporate the Kamilaroi Highway culverts and additional cross sections.

Normal flow has been used for the downstream boundary condition in this study. The longitudinal slope of 0.53% was specified for downstream boundary, as an extrapolation of the existing channel slope.

Upstream boundary

It remains the same as the original Lyall's model which peak flows derived from RORB provided the boundary conditions at the upstream end of the model.

The upstream normal depth slopes specified by Lyall & Associates are as follows.

- Blackjack Creek = 0.42%
- Blackjack Creek tributary 1 = 1.53%
- Blackjack Creek tributary 2 = 6.98%

4.2.5 Sensitivity Analysis

It is anticipated there would be a backwater effect from Namoi River (refer Section 2.2) which would change the downstream boundary condition. As a sensitivity check, the water level at the downstream boundary was set to RL 264.4m (AHD) as per the flood study undertaken by SMEC (1996). However, it did not influence the afflux in the vicinity of proposed alignments.

A joint probability analysis of Blackjack Creek and Namoi River flooding behaviours is beyond the scope of this assessment.

The railway culvert bridge creates an obstruction in Blackjack Creek which would cause the flood water to back up behind of it. Therefore the railway culvert bridge works as a dam or weir to obstruct the flood waters to act as a lake upstream of the bridge. The velocities are less than 1.5 m/s and any piers or obstruction would have little effect on water afflux levels.

5 Results

The pre-construction HEC-RAS model has been adopted as a base model to identify the rise in water levels and the change in velocity for two (2) scenarios (viaduct and wall) for two (2) proposed road alignment options (Option B and Option B/C). In this assessment, the 100 year ARI was only considered.

5.1 REINFORCED SOIL WALL SCENARIO

It was found that the flood waters of the 100 year ARI for the reinforced soil wall scenario would overtop the existing levee and the railway line. From the drainage perspective, it is not a preferred scenario.

5.2 VIADUCT SCENARIO

The results of the viaduct scenario for each option at River Station (RS) 1.6 and RS 1.7 from this modelling are tabulated as below.

- RS1.6: Pier
- RS1.7: Upstream embankment

For the results and the locations of each River Station, refer to Appendix B and Appendix H.

Table 2: Afflux and velocity at RS 1.6 & 1.7

100yr ARI	Afflux (mm)		Velocity (m/s)		
	Option B	Option B/C	Existing	Option B	Option B/C
RS1.6 (Pier)	10	7	1.4	1.01	1.02
RS1.7 (Upstream Embankment)	20	40	1.57	1.54	1.43

5.2.1 Afflux

The afflux for Option B/C is 20mm higher that Option B at the upstream embankment. The Option B/C embankment is located between Blackjack Creek and the Ashfords Watercouse channel whereas the Option B embankment is further away from the Ashfords Watercourse channel. The embankment of Option B/C near the Oxley Highway takes a larger cross section area than Option B which would slightly reduce the capacity of the floodplain.

5.2.2 Velocities

The results show that the velocities of Option B and Option B/C are very similar at the pier (approximately 0.01 m/s difference) and the velocity for Option B is slightly higher than Option B/C, 0.1 m/s around the embankment. The velocities of each option appear to be very slow (~1.54 m/s). The existing railway bridge acts as a dam or weir which makes the floodplain as a retention basin upstream of the railway bridge. This demonstrates velocities are not a critical problem for a 100 year ARI event.

6 Conclusion

The hydraulic modelling results show that the flood impact of each option for the viaduct scenario would be insignificant as the afflux values for the Option B and Option B/C viaduct options are less than 10mm around piers. This is due in part to the viaduct approach with long spans between piers, so that the extent of obstruction and adjacent to the creeks is minimised.

However the afflux values in the vicinity of the Option B/C embankment near the Oxley Highway roundabout is approximately 40mm. The afflux of Option B/C is greater than Option B by 20mm because the embankment of the Option B/C alignment is in the middle of Blackjack Creek and the concrete dish drain. This would reduce the capacity of the floodplain.

These afflux values for the viaduct scenario for the both options appear to be manageable and would require a minor reinstatement works for the existing creek and channel.

The afflux values for the reinforced soil wall options were approximately 120mm. It appears that flood waters would overtop the existing levee and the railway line. This is not a preferred scenario from a drainage perspective as it would have a significant impact on the existing infrastructure.

The flow velocity is used primarily to identify potential scour issues at bridge and embankment support structures. A value exceeding 2 m/s is typically enough to produce scour.

This assessment demonstrates that the afflux values and the velocities produced from the modelling would have no significant issue for the proposed viaduct and road alignment construction and operation phases.

This report only covers the assessment of the rise in water levels in Blackjack Creek affected by the proposed alignments and bridges in the floodplain. In order to determine flood water levels and flood extent, two-dimensional hydraulic modelling should be considered in future project stages.

7 References

1. Pilgrim D. H. (Editor in Chief), 1987, Australian Rainfall and Runoff – A Guide to Flood Estimation, Institution of Engineers, Australia.
2. *Flood inundation map: Namoi River at Gunnedah*, 1978, 1:10,000, Water Resources Commission, N.S.W.
3. SMEC, *Flood Study Report Gunnedah and Carroll*, 1996, Gunnedah Shire Council.
4. SMEC, *Gunnedah and Carroll Floodplain Management Study*, 1999, Gunnedah Shire Council.
5. Lyall & Associates, 2005, *Blackjack Creek Flood Study*, Gunnedah Shire Council
6. Lyall & Associates, 2005, *Blackjack Creek Floodplain Risk Management Study and Plan*, Gunnedah Shire Council
7. *Gunnedah LEP Flood Planning Map Sheet FLD_005AA*, 2012, 1:40,000, Gunnedah Shire Council

Appendix A

RORB RESULT TABLE

RORBWin Batch Run Summary
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Program version 6.15 (last updated 30th March 2010)

Date run: 09 Sep 2013 09:12

Catchment file : O:\BRS\Projects\SEC\SEC143 - Gunnedah Road over Rail\2 Design Working\Civil\Flood Study\RORB\lyall.txt
Rainfall location: Gunnedah
Temporal pattern : AR&R87 Volume 2 for zone 2 (unfiltered)
Spatial pattern : Uniform
Areal Red. Fact. : Based on ARR87 Bk II, Figs 1.6 and 1.7
Loss factors : Constant with ARI

Parameters: kc = 4.80 m = 0.80

Loss parameters	Initial loss (mm)	Cont. loss (mm/h)
	15.00	2.50

Peak	Description
01	Calculated hydrograph, Areas A-E at Lincoln
02	Calculated hydrograph, Areas F-G at Lincoln
03	Calculated hydrograph, Area H at d/s Lincoln
04	Calculated hydrograph, Lincoln Street
05	Calculated hydrograph, Area I at High
06	Calculated hydrograph, High Street
07	Calculated hydrograph, Area J at Short
08	Calculated hydrograph, Area K at Short
09	Calculated hydrograph, Short Street
10	Calculated hydrograph, Area L u/s Oxley Hwy
11	Calculated hydrograph, OUTFLOW AT HIGHWAY

Run	Dur	ARI	Rain(mm)	ARF	Peak0001	Peak0002	Peak0003	Peak0004	Peak0005	Peak0006	Peak0007	Peak0008	Peak0009	Peak0010	Peak0011
1	10m	100y	29.25	0.93	10.6384	10.5117	5.2731	17.9662	5.0227	17.9838	12.1332	7.9154	20.4862	2.6749	18.5776
2	15m	100y	36.22	0.93	18.1056	17.8571	8.0719	30.4412	7.1744	30.3279	16.5076	11.4566	31.1639	4.0775	31.0847
3	20m	100y	41.71	0.93	24.3594	23.8425	9.8588	40.8148	8.4706	40.6311	19.5736	14.0186	41.6394	4.9527	41.4923
4	25m	100y	46.32	0.93	29.7575	28.9987	11.3464	49.8790	9.4685	49.5920	20.9510	15.0129	50.7910	5.6769	50.5923
5	30m	100y	50.23	0.93	34.4330	32.9976	12.4482	57.7329	10.2479	57.3436	21.7248	15.4609	58.7067	6.2418	58.4663
6	45m	100y	59.59	0.94	47.0526	42.4480	15.1709	79.1272	11.8813	78.5378	23.9973	17.2118	80.4132	7.5307	80.0356
7	1h	100y	66.81	0.95	56.8833	47.5179	16.4907	96.3110	12.8801	95.2743	26.3512	19.2049	97.7487	8.2059	97.3638
8	1.5h	100y	76.65	0.96	65.6925	47.5473	16.0164	115.023	12.1573	113.751	23.6147	16.7295	118.203	7.9232	117.923
9	2h	100y	84.16	0.98	71.2184	49.7198	16.3393	124.057	12.0759	125.299	24.1068	17.6506	133.141	8.0097	132.663
10	3h	100y	95.72	0.98	72.0203	49.7100	16.6605	124.973	13.1189	127.436	26.4030	18.9595	137.673	8.3061	138.865
11	4.5h	100y	108.73	0.98	70.0041	46.2723	14.9893	122.619	11.2633	125.821	22.4820	16.1634	137.288	7.3818	139.167
12	6h	100y	119.04	0.98	68.9894	44.5191	14.2712	118.511	10.2232	123.644	19.9290	13.4566	135.238	6.9375	136.682
13	9h	100y	135.38	0.99	59.9129	41.3620	13.2614	104.691	9.6877	105.519	18.8897	12.6792	114.929	6.4525	115.432
14	12h	100y	148.37	0.99	62.9497	44.1214	14.8282	105.956	10.9020	109.267	19.1097	12.8930	117.359	7.2782	120.038
15	18h	100y	172.46	0.99	55.9232	38.3475	11.8178	97.0644	8.0433	98.8929	13.6212	9.1318	108.641	5.6940	112.490
16	24h	100y	191.43	0.99	69.0353	44.3830	14.3437	117.318	10.0909	124.433	16.8482	11.4808	133.981	6.9818	133.135
17	30h	100y	207.03	0.99	58.2882	34.4902	9.9230	102.701	7.0083	109.037	11.9158	7.8295	121.264	4.7142	123.474
18	36h	100y	220.13	0.99	57.9768	33.7382	9.8199	101.389	7.1045	108.143	12.1235	7.9912	120.012	4.7754	122.566
19	48h	100y	240.93	0.99	59.3760	34.6815	10.0023	103.993	7.2310	110.823	12.3449	8.1497	122.998	4.8643	125.547
20	72h	100y	268.22	1.00	38.6159	25.5948	8.0648	66.5269	5.5917	72.6966	8.9894	5.8144	82.8182	3.8796	89.6776

Elapsed Run Time (hh:mm:ss) = 00:00:01

RORBWin Batch Run Summary
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Program version 6.15 (last updated 30th March 2010)
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Date run: 11 Sep 2013 17:24

Catchment file : O:\BRS\Projects\SEC\SEC143 - Gunnedah Road over Rail\2 Design Working\Civil\Flood Study\RORB\Ashford water course added2.catg
Rainfall location: Gunnedah
Temporal pattern : AR&R87 Volume 2 for zone 2 (unfiltered)
Spatial pattern : Uniform
Areal Red. Fact. : Based on ARR87 Bk II, Figs 1.6 and 1.7
Loss factors : Constant with ARI

Parameters: kc = 4.80 m = 0.80

Loss parameters Initial loss (mm) Cont. loss (mm/h)
2.50

Peak Description
Calculated hydrograph, Areas A-E at Lincoln
01 Calculated hydrograph, Areas F-G at Lincoln
02 Calculated hydrograph, Area H at d/s Lincoln
03 Calculated hydrograph, Lincoln Street
04 Calculated hydrograph, Area I at High
05 Calculated hydrograph, High Street
06 Calculated hydrograph, Area J at Short
07 Calculated hydrograph, Area K at Short
08 Calculated hydrograph, Short Street
09 Calculated hydrograph, Area L u/s Oxley Hwy
10 Calculated hydrograph, total flow at Oxley
11 Calculated hydrograph, Ashford Water Course
12 Calculated hydrograph, OUTFLOW before railway bridg
13 15.00

Run	Dur	ARI	Rain(mm)	ARF	Peak0001	Peak0002	Peak0003	Peak0004	Peak0005	Peak0006	Peak0007	Peak0008	Peak0009	Peak0010	Peak0011	Peak0012	Peak0013
1	10m	100y	29.25	0.92	9.5781	9.4664	4.7839	16.1788	4.5815	16.2002	11.1176	7.2176	18.6900	2.4276	16.7524	17.3215	22.0309
2	15m	100y	36.22	0.92	16.3713	16.1486	7.3783	27.5312	6.5922	27.4355	15.2880	10.6185	28.2031	3.7296	28.1359	23.1223	31.6282
3	20m	100y	41.71	0.92	22.0784	21.6104	9.0730	36.9880	7.7851	36.8088	18.1216	12.9923	37.7368	4.5653	37.6209	26.1937	41.1954
4	25m	100y	46.32	0.92	27.0449	26.4126	10.5022	45.2937	8.7579	45.0250	19.5919	14.0823	46.1062	5.2641	45.9520	26.7484	50.3078
5	30m	100y	50.23	0.92	31.3042	30.2032	11.5031	52.4541	9.5314	52.0913	20.4676	14.6426	53.3195	5.7747	53.1209	25.9290	58.1709
6	45m	100y	59.59	0.93	43.0371	39.2682	14.2348	72.3313	11.1695	71.7846	22.7742	16.3813	73.4895	7.0784	73.1618	26.2172	80.1000
7	1h	100y	66.81	0.95	52.3412	44.5070	15.5509	88.4391	12.1833	87.5418	25.1042	18.2193	89.7047	7.7165	89.3161	30.7991	97.9343
8	1.5h	100y	76.65	0.96	61.2231	45.0734	15.1730	106.868	11.5994	105.446	22.6229	16.1300	109.207	7.5112	108.935	24.3568	119.784
9	2h	100y	84.16	0.97	67.0421	47.3144	15.6367	116.879	11.6146	117.459	23.0056	16.7572	123.762	7.6824	123.398	29.2614	136.299
10	3h	100y	95.72	0.98	68.2078	46.9807	15.8299	118.270	12.4392	120.194	25.3680	18.3288	130.831	7.8381	132.038	29.4619	146.429
11	4.5h	100y	108.73	0.98	67.0615	44.2473	14.4513	117.172	10.8256	119.802	21.5365	15.5605	130.522	7.0672	132.287	25.1299	147.151
12	6h	100y	119.04	0.98	66.1809	42.6513	13.8033	113.332	9.9273	118.053	19.2365	13.0741	127.896	6.7314	131.341	22.9224	145.346
13	9h	100y	135.38	0.98	57.6681	39.5927	12.8429	98.9395	9.2617	101.046	18.2394	12.3232	108.835	6.2570	109.849	21.6872	121.297
14	12h	100y	148.37	0.99	59.5830	41.8563	14.2277	99.4433	10.5432	103.476	18.7786	12.7491	111.933	6.9930	114.303	22.7608	127.337
15	18h	100y	172.46	0.99	54.5452	37.1969	11.5619	91.7728	7.9437	96.2277	13.2143	8.8875	104.860	5.5831	107.219	18.2667	118.737
16	24h	100y	191.43	0.99	65.7512	42.5701	13.8859	113.747	9.8485	118.821	16.6559	11.3937	127.010	6.7715	125.809	22.6398	142.072
17	30h	100y	207.03	0.99	56.7158	34.2315	9.9062	100.853	6.8371	106.119	11.7242	7.7203	117.612	4.6958	118.769	16.1739	134.942
18	36h	100y	220.13	0.99	56.4156	33.5565	9.6692	99.6413	6.9278	105.295	11.9230	7.8761	116.429	4.6358	117.910	16.2986	133.625
19	48h	100y	240.93	0.99	57.7693	34.4487	9.9283	102.146	7.0503	107.861	12.1391	8.0313	119.289	4.7216	120.747	16.6061	136.896
20	72h	100y	268.22	1.00	38.9445	24.9964	7.9154	64.4955	5.5111	73.2041	8.9069	5.7662	83.2034	3.8108	89.7441	13.3493	98.7070

Elapsed Run Time (hh:mm:ss) = 00:00:01

Appendix B

HEC-RAS RESULT TABLE

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	# Chl
Blackjack lower	1.7	100yr	existing opt b	147	265.09	267.28	266.25	267.37	0.003139	1.57	130.92	158.18	0.39
Blackjack lower	1.7	100yr	viaduct opt b	147	265.09	267.3	266.25	267.39	0.002985	1.54	133.62	160.08	0.38
Blackjack lower	1.7	100yr	opt bc-viaduct	147	265.09	267.32	266.26	267.4	0.002491	1.43	125.75	151.71	0.35
Blackjack lower	1.7	100yr	opt bc wall leve	147	265.09	267.43	266.26	267.49	0.002035	1.34	141.52	157.3	0.32
Blackjack lower	1.7	100yr	opt b wall leve	147	265.09	267.4	266.25	267.47	0.002206	1.38	151.77	171.35	0.33
Blackjack lower	1.65	100yr	existing opt b	147	265.03	267.21	266.23	267.28	0.002605	1.4	143.8	162.54	0.35
Blackjack lower	1.65	100yr	viaduct opt b	147	265.03	267.23	266.23	267.3	0.002463	1.37	147.24	165.64	0.34
Blackjack lower	1.65	100yr	opt bc-viaduct	147	265.03	267.23	266.32	267.32	0.003108	1.54	125.46	149.67	0.38
Blackjack lower	1.65	100yr	opt bc wall leve	147	265.03	267.36	266.32	267.43	0.002268	1.37	146.18	162.58	0.33
Blackjack lower	1.65	100yr	opt b wall leve	147	265.03	267.36	266.23	267.41	0.001767	1.21	169.43	177.24	0.29
Blackjack lower	1.63	100yr	existing opt b	147	264.64	267.14	265.9	267.17	0.000806	0.95	202.18	122.84	0.21
Blackjack lower	1.63	100yr	viaduct opt b	147	264.64	267.15	265.9	267.18	0.000925	1.02	184.37	107.97	0.22
Blackjack lower	1.63	100yr	opt bc-viaduct	147	264.64	267.14	265.93	267.18	0.001011	1.09	177.23	105.54	0.23
Blackjack lower	1.63	100yr	opt bc wall leve	147	264.64	267.29	265.93	267.33	0.00078	1	193.32	108.27	0.21
Blackjack lower	1.63	100yr	opt b wall leve	147	264.64	267.29	265.9	267.32	0.00072	0.94	200.36	110.53	0.2
Blackjack lower	1.62	100yr	existing opt b	147	264.41	267.12	265.76	267.15	0.000761	0.93	190.44	96.86	0.2
Blackjack lower	1.62	100yr	viaduct opt b	147	264.41	267.13	265.76	267.16	0.000747	0.93	191.57	96.96	0.2
Blackjack lower	1.62	100yr	opt bc-viaduct	147	264.41	267.13	265.76	267.16	0.00075	0.93	191.35	96.94	0.2
Blackjack lower	1.62	100yr	opt bc wall leve	147	264.41	267.27	265.82	267.3	0.00083	1.02	176.32	85.02	0.21
Blackjack lower	1.62	100yr	opt b wall leve	147	264.41	267.26	265.75	267.3	0.000815	1.01	176.04	82.95	0.21
Blackjack lower	1.61615	100yr	existing opt b	147	264.41	267.11	265.76	267.14	0.000766	0.94	190.06	96.82	0.2
Blackjack lower	1.61615	100yr	viaduct opt b	147	264.41	267.12	265.76	267.15	0.000754	0.93	190.99	96.91	0.2
Blackjack lower	1.61615	100yr	opt bc-viaduct	147	264.41	267.12	265.76	267.15	0.000757	0.93	190.72	96.88	0.2
Blackjack lower	1.61615	100yr	opt bc wall leve	147	264.41	267.26	265.82	267.3	0.000835	1.02	175.94	84.98	0.21
Blackjack lower	1.61615	100yr	opt b wall leve	147	264.41	267.26	265.75	267.3	0.00082	1.01	175.69	82.91	0.21
Blackjack lower	1.6	100yr	existing opt b	147	264.16	267.08	265.64	267.13	0.000805	1.02	166.29	78.54	0.21
Blackjack lower	1.6	100yr	viaduct opt b	147	264.16	267.09	265.64	267.13	0.000794	1.01	167.07	78.6	0.21

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	# Chl
Blackjack lower	1.6	100yr	opt bc-viaduct	147	264.16	267.09	265.64	267.13	0.000797	1.02	166.85	78.58	0.21
Blackjack lower	1.6	100yr	opt bc wall leve	147	264.16	267.21	265.76	267.28	0.0012	1.21	139.39	63.3	0.24
Blackjack lower	1.6	100yr	opt b wall leve	147	264.16	267.22	265.65	267.28	0.000923	1.13	148.75	65.69	0.22
Blackjack lower	1.59	100yr	existing opt b	147	264.16	267.08	265.64	267.12	0.00081	1.02	165.96	78.52	0.21
Blackjack lower	1.59	100yr	viaduct opt b	147	264.16	267.08	265.64	267.13	0.000804	1.02	166.35	78.55	0.21
Blackjack lower	1.59	100yr	opt bc-viaduct	147	264.16	267.08	265.64	267.12	0.000806	1.02	166.27	78.54	0.21
Blackjack lower	1.59	100yr	opt bc wall leve	147	264.16	267.21	265.76	267.27	0.001129	1.23	138.89	63.25	0.25
Blackjack lower	1.59	100yr	opt b wall leve	147	264.16	267.22	265.65	267.27	0.000929	1.13	148.43	65.66	0.23
Blackjack lower	1.55	100yr	existing opt b	147	264.08	267.04	265.63	267.08	0.000857	1.08	163.18	79.5	0.22
Blackjack lower	1.55	100yr	viaduct opt b	147	264.08	267.04	265.63	267.09	0.00085	1.07	163.6	79.54	0.22
Blackjack lower	1.55	100yr	opt bc-viaduct	147	264.08	267.04	265.63	267.09	0.000851	1.07	163.52	79.53	0.22
Blackjack lower	1.55	100yr	opt bc wall leve	147	264.08	267.15	265.77	267.22	0.001126	1.27	138.38	66.33	0.25
Blackjack lower	1.55	100yr	opt b wall leve	147	264.08	267.16	265.71	267.22	0.001093	1.25	140.11	66.06	0.25
Blackjack lower	1.54	100yr	existing opt b	147	264.08	267.03	265.63	267.08	0.000862	1.08	162.82	79.46	0.22
Blackjack lower	1.54	100yr	viaduct opt b	147	264.08	267.03	265.63	267.08	0.000864	1.08	162.72	79.45	0.22
Blackjack lower	1.54	100yr	opt bc-viaduct	147	264.08	267.03	265.63	267.08	0.000864	1.08	162.72	79.45	0.22
Blackjack lower	1.54	100yr	opt bc wall leve	147	264.08	267.14	265.77	267.21	0.001135	1.27	137.99	66.28	0.25
Blackjack lower	1.54	100yr	opt b wall leve	147	264.08	267.15	265.71	267.22	0.001101	1.26	139.73	66.01	0.25
Blackjack lower	1.1	100yr	existing opt b	147	264.09	266.85	265.69	267.05	0.000317	1.99	75.97	44.1	0.4
Blackjack lower	1.1	100yr	viaduct opt b	147	264.09	266.85	265.69	267.05	0.000317	1.99	75.9	44.03	0.4
Blackjack lower	1.1	100yr	opt bc-viaduct	147	264.09	266.85	265.69	267.05	0.000317	1.99	75.9	44.03	0.4
Blackjack lower	1.1	100yr	opt bc wall leve	147	264.09	267.02	265.69	267.19	0.00025	1.85	84.03	51.63	0.36
Blackjack lower	1.1	100yr	opt b wall leve	147	264.09	267.03	265.69	267.2	0.000247	1.84	84.5	52.08	0.36
Blackjack lower	1			Culvert									
Blackjack lower	0.5	100yr	existing opt b	147	264.07	265.89	265.67	266.41	0.015841	3.21	45.86	28.57	0.81
Blackjack lower	0.5	100yr	viaduct opt b	147	264.07	266.11	265.67	266.51	0.01042	2.81	52.29	28.6	0.66

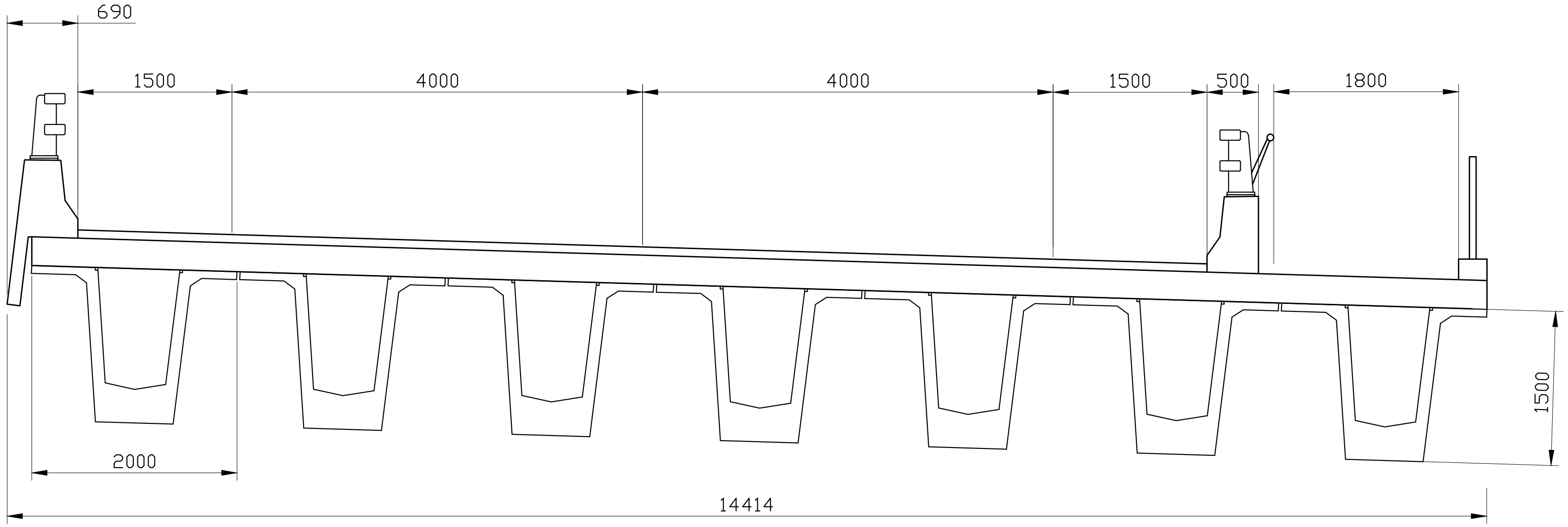
Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	# Chl
Blackjack lower	0.5	100yr	opt bc-viaduct	147	264.07	266.11	265.67	266.51	0.01042	2.81	52.29	28.6	0.66
Blackjack lower	0.5	100yr	opt bc wall leve	147	264.07	266.61	265.67	266.85	0.004729	2.2	68.01	33.76	0.46
Blackjack lower	0.5	100yr	opt b wall leve	147	264.07	266.62	265.67	266.86	0.004616	2.18	68.56	33.83	0.46
Blackjack lower	0.495	100yr	existing opt b	147	264.07	265.87	265.67	266.4	0.016336	3.24	45.42	28.57	0.82
Blackjack lower	0.495	100yr	viaduct opt b	147	264.07	266.1	265.67	266.5	0.01069	2.83	51.87	28.6	0.67
Blackjack lower	0.495	100yr	opt bc-viaduct	147	264.07	266.1	265.67	266.5	0.01069	2.83	51.87	28.6	0.67
Blackjack lower	0.495	100yr	opt bc wall leve	147	264.07	266.1	265.88	266.8	0.017344	3.71	39.6	19.9	0.84
Blackjack lower	0.495	100yr	opt b wall leve	147	264.07	266.1	265.89	266.81	0.016281	3.75	39.58	19.9	0.85
Blackjack lower	0.49	100yr	existing opt b	147	264.07	265.67	265.67	266.37	0.025058	3.7	39.75	28.54	1
Blackjack lower	0.49	100yr	viaduct opt b	147	264.07	265.45	265.67	266.44	0.044056	4.41	33.37	28.51	1.3
Blackjack lower	0.49	100yr	opt bc-viaduct	147	264.07	265.45	265.67	266.44	0.044056	4.41	33.37	28.51	1.3
Blackjack lower	0.49	100yr	opt bc wall leve	147	264.07	265.88	265.88	266.77	0.024928	4.17	35.25	19.88	1
Blackjack lower	0.49	100yr	opt b wall leve	147	264.07	265.89	265.89	266.78	0.023375	4.2	35.34	19.88	1
Blackjack lower	0.4	100yr	existing opt b	147	263.86	265.31	265.06	265.39	0.005245	1.67	135.77	193.96	0.48
Blackjack lower	0.4	100yr	viaduct opt b	147	263.86	265.33	264.99	265.41	0.004946	1.63	138.51	194.49	0.46
Blackjack lower	0.4	100yr	opt bc-viaduct	147	263.86	265.33	264.99	265.41	0.004946	1.63	138.51	194.49	0.46
Blackjack lower	0.4	100yr	opt bc wall leve	147	263.89	265.38	265.13	265.46	0.006271	1.81	130.54	183	0.51
Blackjack lower	0.4	100yr	opt b wall leve	147	263.89	265.39	265.13	265.46	0.006356	1.72	130.56	182.31	0.48
Blackjack lower	0.35	100yr	existing opt b	147	263.86	265.27	265.06	265.37	0.006229	1.78	128.01	192.46	0.52
Blackjack lower	0.35	100yr	viaduct opt b	147	263.86	265.28	265.06	265.37	0.006112	1.77	128.84	192.62	0.51
Blackjack lower	0.35	100yr	opt bc-viaduct	147	263.86	265.28	265.06	265.37	0.006112	1.77	128.84	192.62	0.51
Blackjack lower	0.35	100yr	opt bc wall leve	147	263.89	265.33	265.13	265.42	0.007746	1.96	121.72	181.18	0.56
Blackjack lower	0.35	100yr	opt b wall leve	147	263.89	265.34	265.13	265.43	0.007834	1.87	121.8	180.49	0.54
Blackjack lower	0	100yr	existing opt b	147	263.83	265.15	264.87	265.23	0.00506	1.54	137.61	195.69	0.46
Blackjack lower	0	100yr	viaduct opt b	147	263.83	265.16	264.87	265.23	0.00489	1.52	139.24	196.07	0.45
Blackjack lower	0	100yr	opt bc-viaduct	147	263.83	265.16	264.87	265.23	0.00489	1.52	139.24	196.07	0.45
Blackjack lower	0	100yr	opt bc wall leve	147	263.83	265.17	264.92	265.26	0.006407	1.85	125.7	182.05	0.53

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	# Chl
Blackjack lower	0	100yr	opt b wall leve	147	263.83	265.17	264.91	265.25	0.006464	1.78	126.33	182.22	0.51
Blackjack lower	-0.1	100yr	existing opt b	147	263.83	265.12	264.87	265.2	0.005894	1.63	130.53	194	0.5
Blackjack lower	-0.1	100yr	viaduct opt b	147	263.83	265.12	264.87	265.2	0.0059	1.63	130.48	193.99	0.5
Blackjack lower	-0.1	100yr	opt bc-viaduct	147	263.83	265.12	264.87	265.2	0.0059	1.63	130.48	193.99	0.5
Blackjack lower	-0.1	100yr	opt bc wall leve	147	263.83	265.11	264.92	265.22	0.00805	2.01	116.27	179.86	0.59
Blackjack lower	-0.1	100yr	opt b wall leve	147	263.83	265.12	264.91	265.22	0.008091	1.94	117	180.06	0.57
Blackjack lower	-0.5	100yr	existing opt b	147	263.62	265.03	264.69	265.09	0.004125	1.42	146.55	205.24	0.42
Blackjack lower	-0.5	100yr	viaduct opt b	147	263.62	265.03	264.69	265.09	0.004117	1.42	146.5	204.66	0.42
Blackjack lower	-0.5	100yr	opt bc-viaduct	147	263.62	265.03	264.69	265.09	0.004117	1.42	146.5	204.66	0.42
Blackjack lower	-0.5	100yr	opt bc wall leve	147	263.62	265.03	264.69	265.09	0.004117	1.42	146.5	204.66	0.42
Blackjack lower	-0.5	100yr	opt b wall leve	147	263.62	265.03	264.69	265.09	0.004117	1.42	146.5	204.66	0.42
Blackjack lower	-0.6	100yr	existing opt b	147	263.44	264.88	264.54	264.94	0.003982	1.36	145.28	186.16	0.41
Blackjack lower	-0.6	100yr	viaduct opt b	147	263.44	264.88	264.54	264.94	0.003982	1.36	145.28	186.16	0.41
Blackjack lower	-0.6	100yr	opt bc-viaduct	147	263.44	264.88	264.54	264.94	0.003982	1.36	145.28	186.16	0.41
Blackjack lower	-0.6	100yr	opt bc wall leve	147	263.44	264.88	264.54	264.94	0.003982	1.36	145.28	186.16	0.41
Blackjack lower	-0.6	100yr	opt b wall leve	147	263.44	264.88	264.54	264.94	0.003982	1.36	145.28	186.16	0.41
Blackjack lower	-0.7	100yr	existing opt b	147	263.02	264.27	264.25	264.53	0.018448	2.68	76.82	133.1	0.86
Blackjack lower	-0.7	100yr	viaduct opt b	147	263.02	264.27	264.25	264.53	0.018448	2.68	76.82	133.1	0.86
Blackjack lower	-0.7	100yr	opt bc-viaduct	147	263.02	264.27	264.25	264.53	0.018448	2.68	76.82	133.1	0.86
Blackjack lower	-0.7	100yr	opt bc wall leve	147	263.02	264.27	264.25	264.53	0.018448	2.68	76.82	133.1	0.86
Blackjack lower	-0.7	100yr	opt b wall leve	147	263.02	264.27	264.25	264.53	0.018448	2.68	76.82	133.1	0.86
Blackjack lower	-1	100yr	existing opt b	147	262.21	264.01	263.57	264.06	0.002513	1.17	171.64	187.77	0.33
Blackjack lower	-1	100yr	viaduct opt b	147	262.21	264.01	263.57	264.06	0.002513	1.17	171.64	187.77	0.33
Blackjack lower	-1	100yr	opt bc-viaduct	147	262.21	264.01	263.57	264.06	0.002513	1.17	171.64	187.77	0.33
Blackjack lower	-1	100yr	opt bc wall leve	147	262.21	264.01	263.57	264.06	0.002513	1.17	171.64	187.77	0.33
Blackjack lower	-1	100yr	opt b wall leve	147	262.21	264.01	263.57	264.06	0.002513	1.17	171.64	187.77	0.33

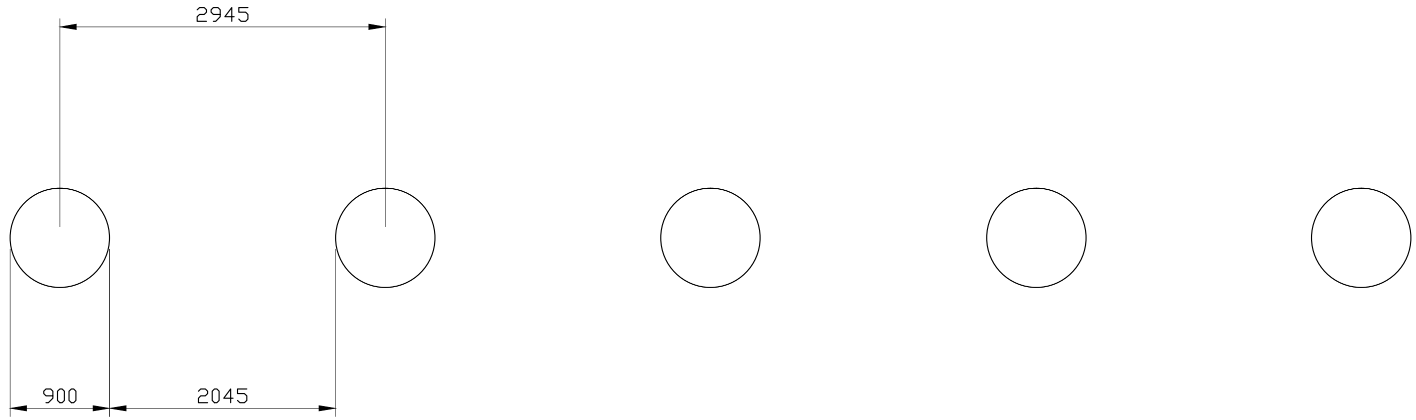
Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	# Chl
Blackjack lower	-2	100yr	existing opt b	147	262.21	263.55	263.55	263.78	0.0123	2.37	91.71	193.49	0.72
Blackjack lower	-2	100yr	viaduct opt b	147	262.21	263.55	263.55	263.78	0.0123	2.37	91.71	193.49	0.72
Blackjack lower	-2	100yr	opt bc-viaduct	147	262.21	263.55	263.55	263.78	0.0123	2.37	91.71	193.49	0.72
Blackjack lower	-2	100yr	opt bc wall leve	147	262.21	263.55	263.55	263.78	0.0123	2.37	91.71	193.49	0.72
Blackjack lower	-2	100yr	opt b wall leve	147	262.21	263.55	263.55	263.78	0.0123	2.37	91.71	193.49	0.72
Blackjack lower	-2.5			Culvert									
Blackjack lower	-3	100yr	existing opt b	147	262.12	263.34	263.34	263.61	0.015845	2.64	77.44	134.02	0.8
Blackjack lower	-3	100yr	viaduct opt b	147	262.12	263.34	263.34	263.61	0.015845	2.64	77.44	134.02	0.8
Blackjack lower	-3	100yr	opt bc-viaduct	147	262.12	263.34	263.34	263.61	0.015845	2.64	77.44	134.02	0.8
Blackjack lower	-3	100yr	opt bc wall leve	147	262.12	263.34	263.34	263.61	0.015845	2.64	77.44	134.02	0.8
Blackjack lower	-3	100yr	opt b wall leve	147	262.12	263.34	263.34	263.61	0.015845	2.64	77.44	134.02	0.8
Blackjack lower	-4	100yr	existing opt b	147	261.76	262.91	262.5	262.98	0.005317	1.38	127.79	152.99	0.46
Blackjack lower	-4	100yr	viaduct opt b	147	261.76	262.91	262.5	262.98	0.005317	1.38	127.79	152.99	0.46
Blackjack lower	-4	100yr	opt bc-viaduct	147	261.76	262.91	262.5	262.98	0.005317	1.38	127.79	152.99	0.46
Blackjack lower	-4	100yr	opt bc wall leve	147	261.76	262.91	262.5	262.98	0.005317	1.38	127.79	152.99	0.46
Blackjack lower	-4	100yr	opt b wall leve	147	261.76	262.91	262.5	262.98	0.005317	1.38	127.79	152.99	0.46

Appendix C

PIER ARRANGEMENT



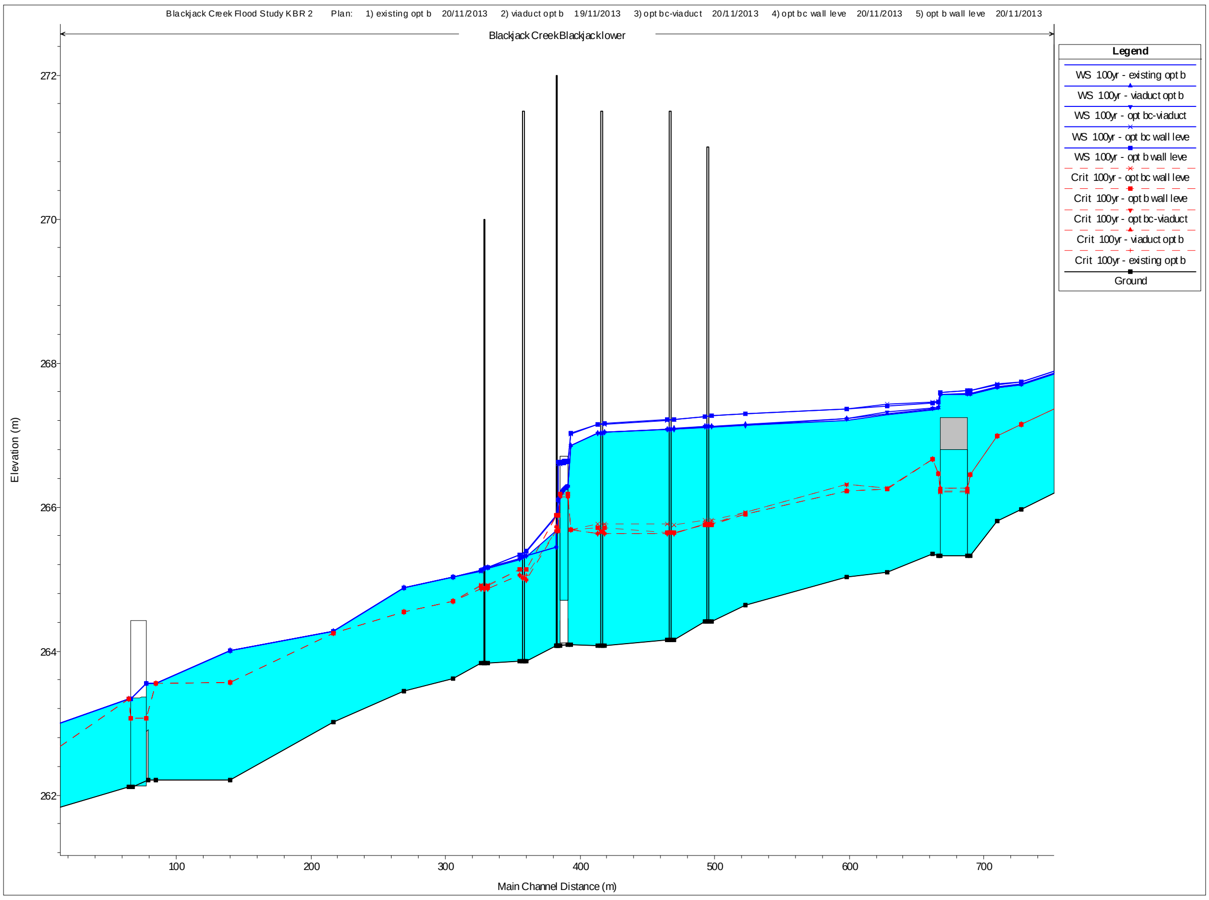
CROSS SECTION - 1500 DEEP GIRDERS

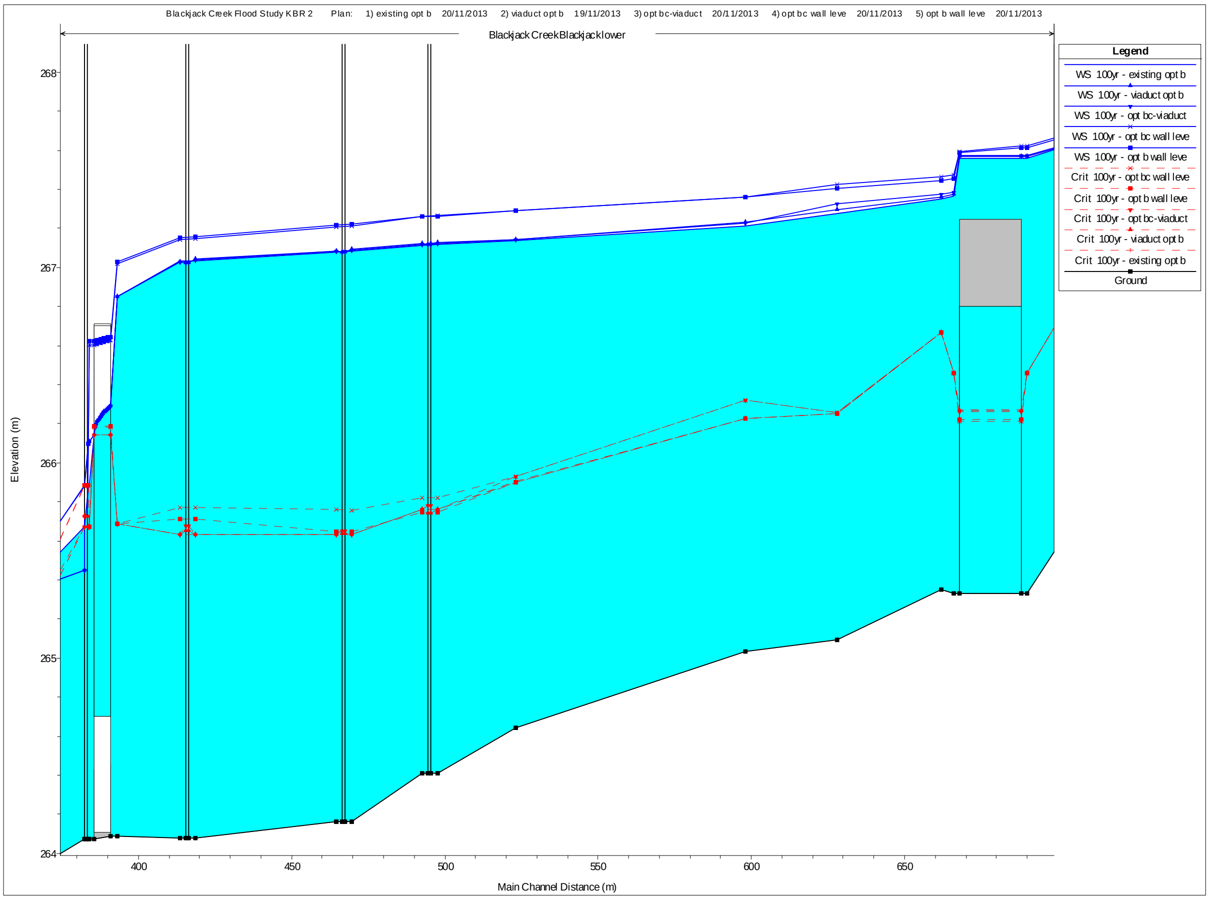


PIER ARRANGEMENT IN PLAN

Appendix D

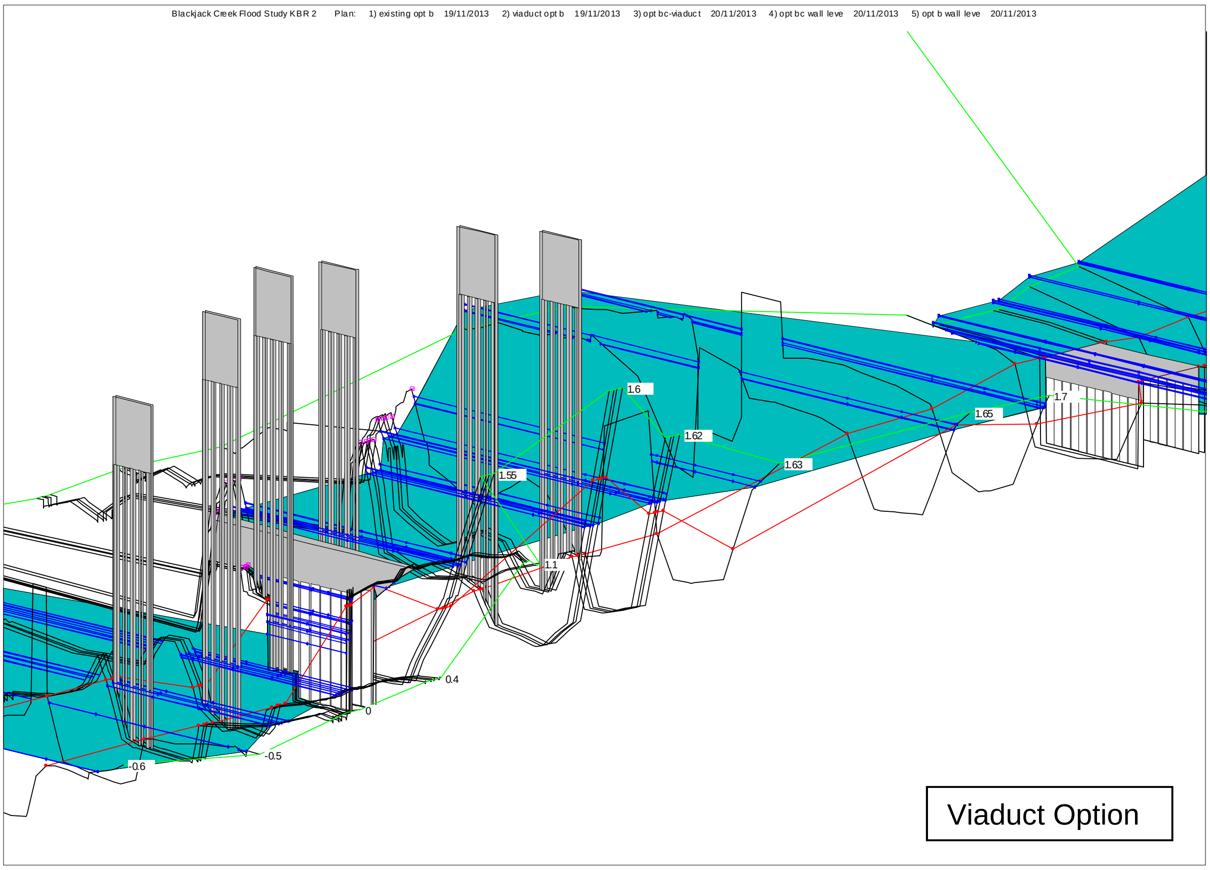
HEC-RAS
LONGITUDINAL SECTION

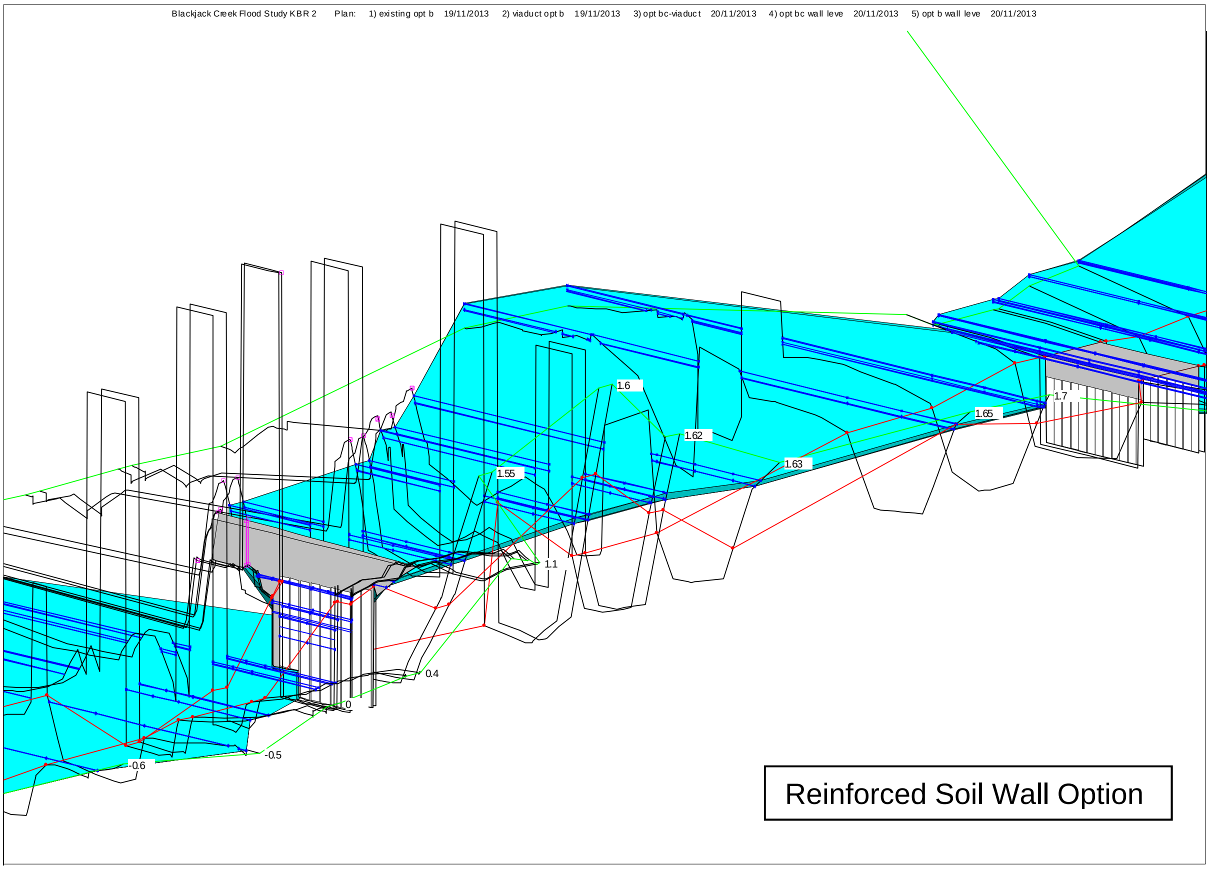

Blackjack Creek Flood Study KBR 2 Plan: 1) existing opt b 20/11/2013 2) viaduct opt b 19/11/2013 3) opt bc-viaduct 20/11/2013 4) opt bc wall leve 20/11/2013 5) opt b wall leve 20/11/2013
Blackjack Creek Blackjack lower
Legend
WS 100yr - existing opt b
WS 100yr - viaduct opt b
WS 100yr - opt bc-viaduct
WS 100yr - opt bc wall leve
WS 100yr - opt b wall leve
Crit 100yr - opt bc wall leve
Crit 100yr - opt b wall leve
Crit 100yr - opt bc-viaduct
Crit 100yr - viaduct opt b
Crit 100yr - existing opt b
Ground
Elevation (m)
Main Channel Distance (m)
272
270
268
266
264
262
100
200
300
400
500
600
700


Blackjack Creek Flood Study KBR 2 Plan: 1) existing opt b 20/11/2013 2) viaduct opt b 19/11/2013 3) opt bc-viaduct 20/11/2013 4) opt bc wall leve 20/11/2013 5) opt b wall leve 20/11/2013
Blackjack Creek Blackjack lower
Legend
WS 100yr - existing opt b
WS 100yr - viaduct opt b
WS 100yr - opt bc-viaduct
WS 100yr - opt bc wall leve
WS 100yr - opt b wall leve
Crit 100yr - opt bc wall leve
Crit 100yr - opt b wall leve
Crit 100yr - opt bc-viaduct
Crit 100yr - viaduct opt b
Crit 100yr - existing opt b
Ground
Elevation (m)
Main Channel Distance (m)
268
267
266
265
264
400
450
500
550
600
650

Appendix E

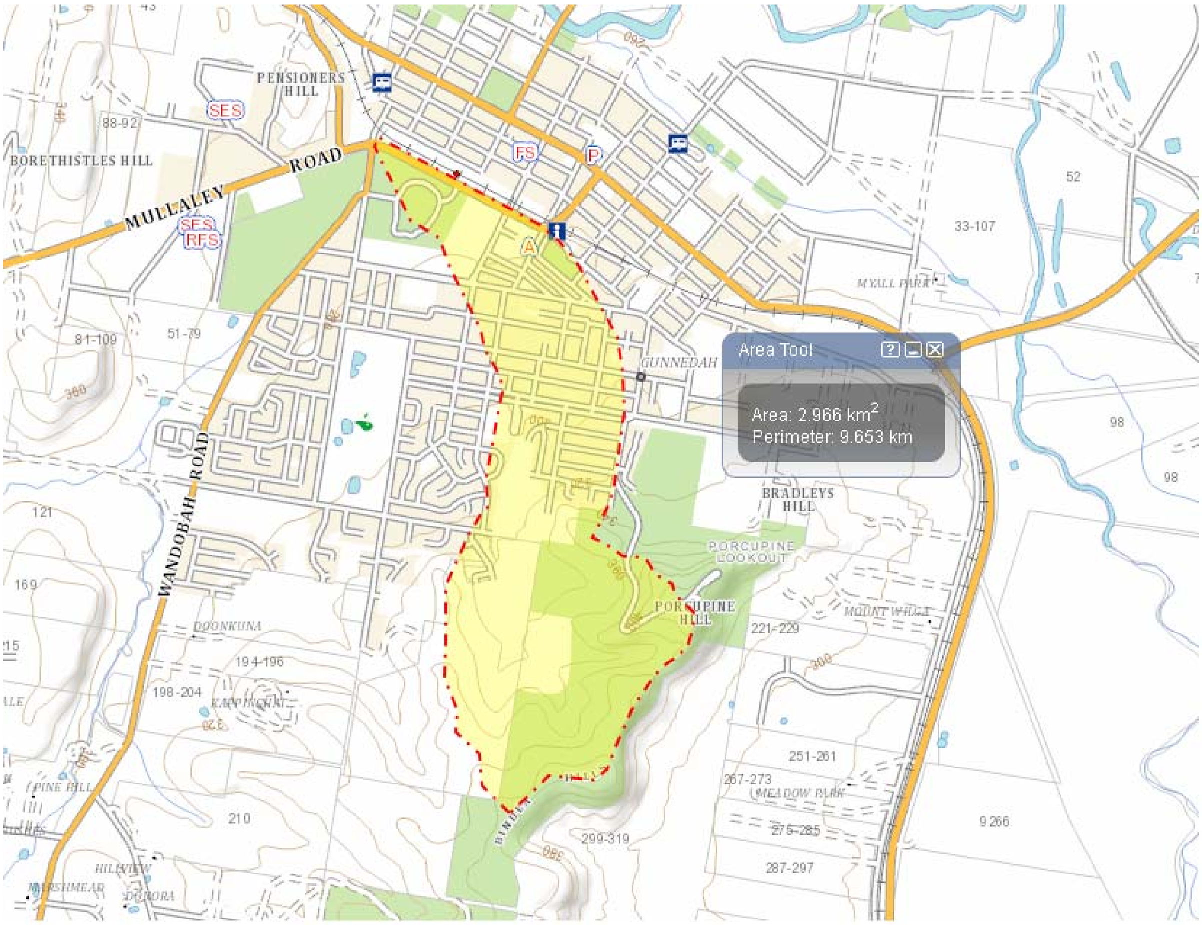
HEC-RAS
PERSPECTIVE PLOT
VIADUCT OPTIONS


Blackjack Creek Flood Study KBR 2   Plan: 1) existing opt b 19/11/2013 2) viaduct opt b 19/11/2013 3) opt bc-viaduct 20/11/2013 4) opt bc wall leve 20/11/2013 5) opt b wall leve 20/11/2013
1.6
1.62
1.63
1.65
1.7
1.55
1.1
0.4
0
-0.5
-0.6
Viaduct Option


Blackjack Creek Flood Study KBR 2   Plan: 1) existing opt b 19/11/2013 2) viaduct opt b 19/11/2013 3) opt bc-viaduct 20/11/2013 4) opt bc wall leve 20/11/2013 5) opt b wall leve 20/11/2013
1.6
1.62
1.63
1.65
1.7
1.55
1.1
0.4
0
-0.5
-0.6
Reinforced Soil Wall Option

Appendix F

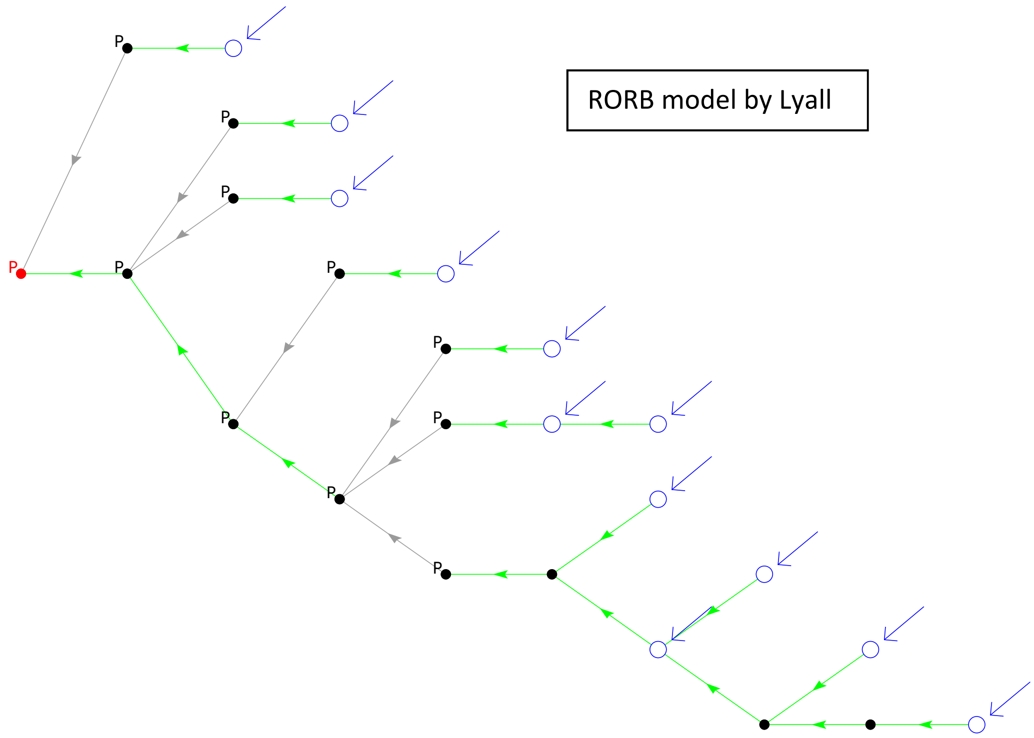
ASHFORD WATERCOURSE CATCHMENT

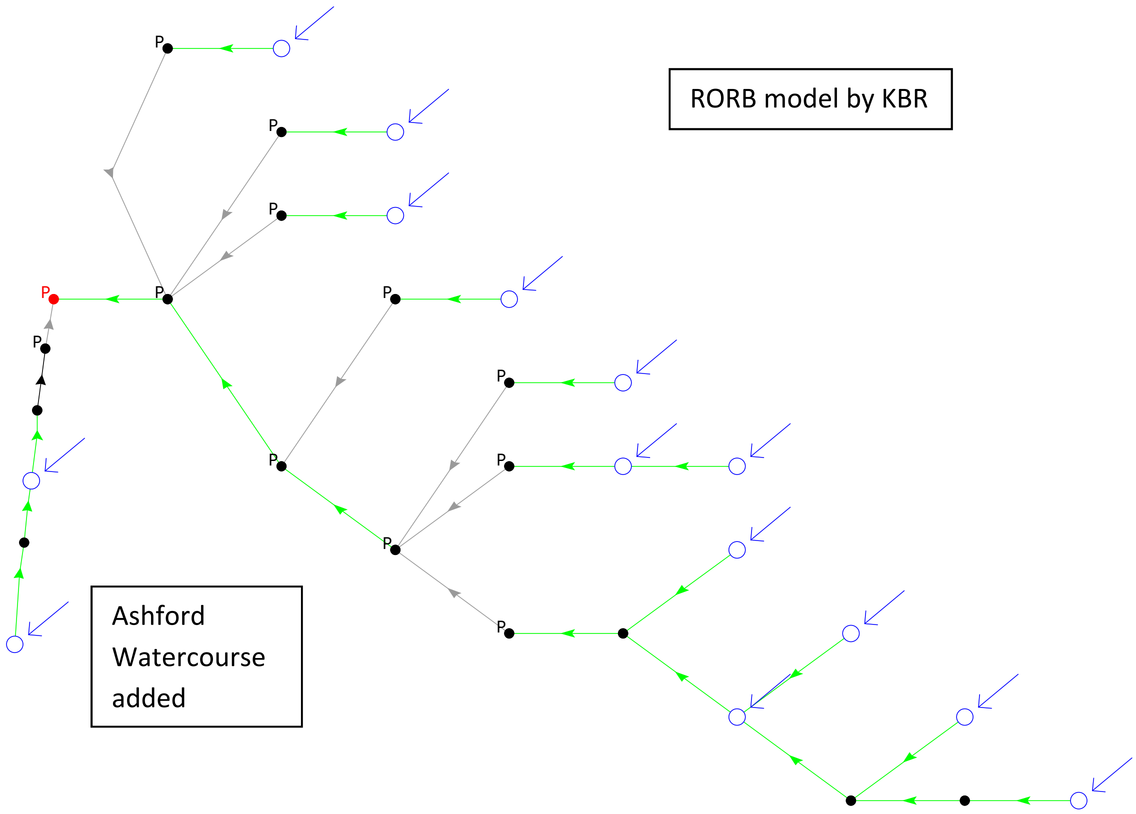


PENSIONERS HILL
SES
88-92
BORETHISTLES HILL
MULLALEY ROAD
SES
RFS
FS
P
A
81-109
51-79
GUNNEDAH
Area Tool
Area: 2.966 km2
Perimeter: 9.653 km
52
33-107
MYALL PARK
98
98
BRADLEYS HILL
PORCUPINE LOOKOUT
PORCUPINE HILL
221-229
WANDOBAH ROAD
121
169
DOONKUNA
194-196
198-204
251-261
267-273
MEADOW PARK
275-285
287-297
9 266
210
299-319
PINE HILL
HILLVIEW
MARSHMEAD

Appendix G

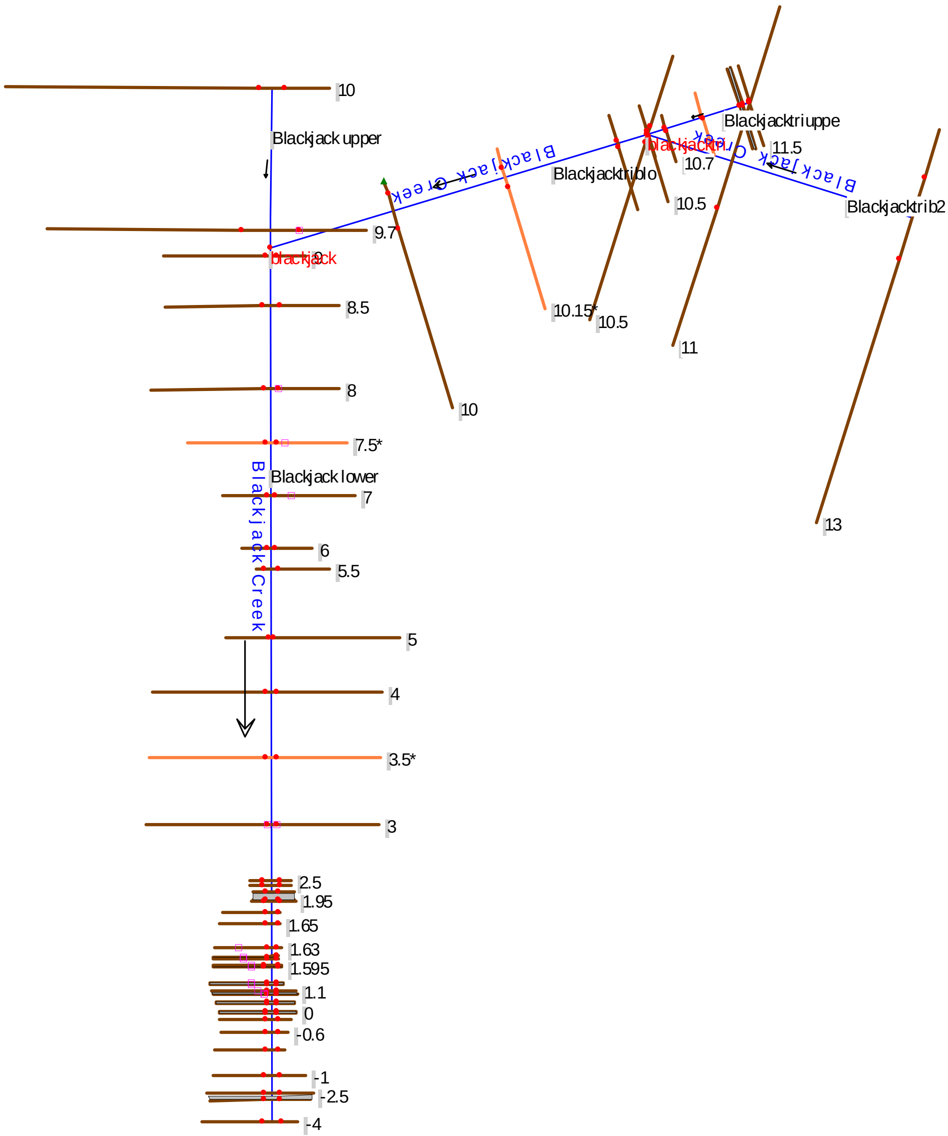
RORB PLAN


RORB model by Lyall


RORB model by KBR
Ashford Watercourse added

Appendix H

HEC-RAS PLAN


10
Blackjack upper
9.7
Blackjack
9
8.5
8
7.5*
Blackjack lower
7
6
5.5
Blackjack Creek
5
4
3.5*
3
2.5
1.95
1.65
1.63
1.595
1.1
0
-0.6
-1
-2.5
-4
Blackjack Creek
Blackjacktriblo
10
10.15*
10.5
10.7
10.5
11
Blackjacktriuppe
11.5
Blackjack Creek
Blackjacktrib2
13