Aberdeen Western Peripheral Route

A9.2 - Hydrodynamic Modelling Assessment

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1 Introduction

1.1 General Background

1.1.1 Aberdeen City Council and Aberdeenshire Council are currently investigating the feasibility of the Aberdeen Western Peripheral Route (AWPR), a 35km dual carriageway bypassing Aberdeen city on the western side of Aberdeen City with a 11km Fastlink to Stonehaven. This project is funded by Scottish Executive, Aberdeen City Council and Aberdeenshire Council.

1.1.2 Jacobs was commissioned to develop a scheme that meets the objectives set out within the Modern Transport System (MTS) integrated transport strategy and the AWPR scheme-specific objectives developed for the STAG 1 Part 1 Assessment. As part of the environmental assessment, risk of direct flooding due to the proposed road crossing of the River Don has been investigated. This report presents the summary findings of the flood risk assessment.

1.2 The Proposed Scheme

1.2.1 Jacobs has been commissioned by the Aberdeen Western Peripheral Route (AWPR) Managing Agent to undertake the Stage 3 Environmental Impact Assessment of a proposed road scheme near Aberdeen, Scotland. The proposed scheme will form a new 35km dual carriageway bypassing Aberdeen city on the western side of Aberdeen City with a 11km Fastlink to Stonehaven. The entire scheme is divided in three sections:

- Northern Leg including the main line from Kingswells to the A90 Blackdog Junction;
- Southern Leg comprising of Charlestown to Kingswells main line section; and,
- Fastlink connecting Stonehaven with the Southern Leg route at Milltimber.

1.2.2 The Northern Leg comprises a 16km route from Kingswells and Blackdog to the west and north of the City of Aberdeen. Further information about the road scheme is contained in Chapter 4 (The Proposed Scheme).

1.2.3 The proposed road crosses one of the major water courses in the Aberdeenshire area, River Don to the north, as shown in Figure 9.4. The approximate road crossing coordinates on River Don are 388111E, 814595N.

1.2.4 The proposed scheme crosses numerous other smaller watercourses that will be affected by and will affect the development. Flood risk assessment of smaller watercourses, except for Goval Burn, has been considered in the Surface Water Hydrology Appendix of the Environmental Statement.

1.3 Assessment Aims

1.3.1 To determine the flood risk associated with the construction of the proposed trunk road, an assessment of flooding characteristic of the region has been completed. This has required a hydrological analysis of the contributing catchments and the development of a one-dimensional numerical hydraulic model of River Don.

1.3.2 The aim of hydrological analysis was primarily to provide the calibration and design event flow inputs to the river model. The hydraulic study aimed to predict peak water levels in the River in the vicinity of the proposed crossings using a mathematical river model. The hydraulic analysis aids in determining the most appropriate river crossing method by assessing the change in flood risk in the vicinity by a variety of proposed structures.

2 Approach and Methods

2.1 General Approach

2.1.1 For the purposes of this assessment the indicative criteria used to assess the sensitivity of flood risk and the magnitude of the predicted impact are defined in Table 2-1 and Table 2-2. The resultant significance of impact is defined by reference to both the sensitivity of the feature and the magnitude of impact, according to the matrix presented in Table 2-3.

Table 2-1 – Criteria to Assess the Flood Risk Sensitivity

Sensitivity	Criteria
High	A watercourse with direct flood risk to the adjacent populated areas and/or presence of critical social infrastructure units such as hospitals, schools, safe shelters, etc. In this scenario, the watercourse with any new development is highly sensitive to increase in the flood risk by the possible increase in the water levels.
Medium	A watercourse with possibility of direct flood risk to the less populated areas without any critical social infrastructure units such as hospitals, schools, safe shelters, etc., and/or utilisable agricultural lands. In this scenario, the watercourse with any new development is moderately sensitive to increase in the flood risk by the possible increase in the water levels.
Low	A watercourse passing through uncultivated agricultural land and/or critical infrastructure in the immediate vicinity of the proposed crossings. In this scenario, the watercourse with new developments would be less sensitive to increase in the flood risk by the possible increase in the water levels.

Table 2-2 – Criteria to Assess the Magnitude of the Flood Risk for 0.5% AEP Flood Event

Magnitude	Criteria
High	Major shift away from baseline conditions. Increase in the predicted peak water levels in the watercourse is greater than 100mm at locations immediately upstream of the area.
Medium	Moderate shift away from the baseline conditions. Increase in the predicted peak water levels in the watercourse varies between 50mm and 100mm at locations immediately upstream of the area.
Low	Minor shift away from the baseline conditions Increase in the predicted peak water levels in the watercourse varies between 10mm and 50mm at locations immediately upstream of the area.
Negligible	Very slight change to the baseline conditions. Increase in the predicted peak water levels in the watercourse is less than 10mm at locations immediately upstream of the area.

Table 2-3 – Impact Significance Matrix

Sensitivity / Magnitude	High	Medium	Low
High	Substantial	Moderate/Substantial	Moderate
Medium	Moderate/Substantial	Moderate	Slight

Sensitivity / Magnitude	High	Medium	Low
Low	Moderate	Slight	Negligible
Negligible	Slight/Negligible	Negligible	Negligible

2.2 Impact Assessment Methodology

2.2.1 The flood risk assessment study required the collation and review of the historic information available, relevant to the modelled reaches, including the hydrological information relating to River Don catchment and the channel cross-section information.

2.2.2 The hydrological analysis of the annual maxima series flow data at the Parkhill Gauging Station on the River Don established a flood frequency curve for a range of % Annual Exceedance Probability (AEP) flood events (2 year to 200 year return period). This was based on the methodology set up by the Flood Estimation Handbook (IH, 1999).

2.2.3 To assess the risk of flooding, one-dimensional unsteady state ISIS river modelling software platform based mathematical model of the watercourse was developed. Data from a channel cross-section survey carried out in 2004 was used to construct the model. Low flow calibration of the mathematical model was undertaken using water levels measured during channel cross-section survey.

2.2.4 Design event simulations for a range of % AEP flood events periods were carried out and consequent flood risk was determined in the vicinity of the proposed river crossings for both existing situations and several of river crossing options. Indicative flood extents were then mapped using the results from the ISIS model (Figure 9.3c)

2.3 Limitations

2.3.1 It must be emphasised that water levels are predictions from a one–dimensional mathematical model of the River Don which does not include effects such as variation of water surface across the channel cross-section, local effects, and fluctuations or elevation of water surface due to wind induced turbulence during flood events etc. The reaches of the River Don used for the assessment has been calibrated to low flows measured during channel cross-section surveys and may not be entirely representative of the conditions during high flow events.

3 Baseline

3.1 Hydrological Assessment

3.1.1 Calibration event flow values were extracted from the Parkhill Gauging Station flow records held by SEPA for the days when water level data was collected.

3.1.2 Design peak flows were estimated using the methodology set up by the Flood Estimation Handbook (FEH). Both single-site analyses of the limited annual maxima series flow records at the Parkhill Gauging Station and FEH pooling-group analyses were undertaken. In a departure from standard FEH practice, in discussions with SEPA, greater weighting was given to the single-site growth rate following further analysis of the recorded flows at other gauging stations upstream of Parkhill.. Further information can be found in Appendix A9.1 Surface Water Hydrology and Appendix A9.5 Annex 19.

3.1.3 The FEH Unit Hydrograph Rainfall-Runoff model was used to estimate design hydrograph inflow shapes at the upstream end of the model. In terms of design peak flow the flood frequency curve determined from the statistical analysis (see above) was viewed as providing the better estimate. Consequently the hydrographs obtained from the rainfall-runoff model were scaled to agree with peak flows of the statistical approach. The hydrographs were further scaled as the adopted gauging stations were not located at exactly the upstream boundary of the hydraulic model, this scaling accounts for additional areas either included or excluded in the gauged catchments' relative to the models' upstream location. This areal adjustment factor was 0.968 for the River Don.

3.1.4 Flows for various % AEP flood events are summarised in the Table 3.1.

Table 3.1 – River Don at Parkhill Gauging Station (Appendix A9.5 Annex 19)

Annual Exceedance Probabiliy (%)	Growth factors	Design flows (m^3/s)
50	1.00	142
20	1.46	208
10	1.85	263
4	2.35	333
2	2.70	383
1	3.08	438
0.5	3.51	498

3.1.5 As mentioned previously, flow data for the low-flow calibration events were extracted from the flow records at Parkhill Gauging Station. These flows were also scaled with an areal adjustment for use in the mathematical model. Further information can be found in Appendix A9.1 Surface Water Hydrology and Appendix A9.5 Annex 19.

3.1.6 Additionally it was recognised that within the study area the Goval Burn, a reasonable sized tributary, had a confluence with the River Don. This burn was known to cause flooding during periods of high flows on the River Don as a result of backing up from the main river; consequently it was included in the model for completeness. Figure 9.4 shows the extents of the river model on both the River Don and the Goval Burn, whilst Table 3.2 summarises the various % AEP flood events for the Goval Burn. Further information on the calculation of the design flows for the Goval Burn can be found in Appendix A9.1 Surface Water Hydrology.

Table 3.2 – Design Flows for the Goval Burn (Appendix A9.5 Annex 13)

AEP (%)	Design flows (m^3/s)
50	4.0
20	5.6
10	6.8
4	8.4
2	10.0
1	11.6
0.5	13.6

3.2 Hydraulic Modelling

3.2.1 Further to the hydrological assessments, a baseline mathematical model for River Don representing the existing situation was constructed to establish the baseline water levels in the watercourse for various % AEP flood events. Figure 9.3B shows the extents of the modelled reach of the River Don.

3.2.2 Following the limited calibration, the mathematical model was used to carry out design event simulation to assess the flood risk for existing situation. Model simulations were carried out using flood flows using methodology as described in section 2 (Approach and Methods) of this report, to predict peak water levels in both watercourses for 50%, 20%, 10%, 4%, 2%%, 1% and 0.5% AEP (2, 5, 10, 25, 50, 100 and 200 year return periods) flood events. Sensitivity of predicted peak water levels for 0.5% AEP flood event to 20% increase in flow and channel roughness coefficient (Manning's n) was also assessed.

3.2.3 Generally the calibration process led to Mannings n values of 0.045 in the channel and 0.055 on the floodplains. The downstream boundary was a stage-discharge relationship derived using channel characteristics; bed slope and channel roughness.

3.2.4 The predicted peak water levels in the main river channel in the vicinity of the proposed road crossing of the River Don are presented in the Table 3.3. Figure 9.4B shows the location of the model nodes used for the comparison.

Table 3.3 – Design flood events peak water level predictions

Location	Predicted Peak Water Level (mAOD)						
	50%	20%	10 %	4%	2%	1%	0.5%
River Don							
DON_24	36.34	36.91	37.30	37.67	37.92	38.20	38.49
DON_25	36.33	36.91	37.28	37.65	37.90	38.19	38.48
DON_26	36.24	36.87	37.25	37.62	37.88	38.17	38.46
DON_27	36.12	36.82	37.22	37.60	37.86	38.15	38.45
DON_28	36.07	36.73	37.13	37.53	37.80	38.10	38.39
DON_29	36.05	36.68	37.08	37.49	37.77	38.07	38.37

3.2.5 In the vicinity of the proposed river crossing, overtopping into the floodplain occurs during a 10% AEP or rarer flood events in the River Don. However, the indicative extent of inundation plot (Figure 9.3C) suggests that, due to the predominantly rural area surrounding the proposed crossing, it would be unlikely that there would be any non-agricultural flooding.

3.2.6 Mathematical model predictions indicate that the predicted peak water levels in the River Don along the reach, including above channel cross-sections, could be increased by up to 450mm for a 1% AEP flood event with 20% increase in flood flows due to climate change.

3.2.7 The main impact of the proposed scheme on the watercourses is the possible increase in water levels and the likely increase in the risk of flooding in the vicinity of the proposed river crossings.

3.3 River Don Sensitivity Assessment

3.3.1 From the results of the baseline simulations of the flood model and following the criteria set out in Table 2-1, the sensitivity of the River Don is considered to be medium. The watercourse potentially poses a direct flood risk to the less populated areas without any critical social infrastructure units such as hospitals, schools, and/or utilisable agricultural lands. Figure 9.3C shows the indicative extent of inundation in the vicinity of the proposed river crossing for 0.5% AEP flood event and indicates that non-agricultural flooding at that return period is unlikely.

4 Potential impacts

4.1 Impact Assessment - River Don Bridge Options

4.1.1 To assess the effect of each of the proposed river crossing options on the peak water levels, the mathematical model of the River Don representing the existing situation was amended to represent each particular river crossing option in turn. Each option was modelled as detailed below.

Option 1

4.1.2 Five Span Viaduct Bridge; containing five spans extending 210m over the main channel and floodplains. The viaduct bridge contains intermediate support in the form of four pairs of 2m diameter circular piers. The bridge has been designed to entirely span the watercourse and have no in channel supports.

4.1.3 The proposed alignment of the Aberdeen Western Peripheral Route also requires the augmentation of B977 which currently crosses Goval Burn to the north west of River Don. The proposed bridge structure for B977 was represented in the mathematical model using a USBPR bridge unit. The proposed route will pass through the floodplain areas located over both banks of the Goval Burn, which is represented using floodplain storage reservoir units within the model. In order to represent the effect of the proposed road embankment on the water levels in the Goval Burn and the River Don, the flood storage volume likely to be replaced by the embankment was incorporated into the level - area relationship of the relevant storage reservoir units.

Option 4

4.1.4 Five Span Viaduct Bridge with right approach embankment. This option includes 4 sub options, 4a, 4b, 4c and 4d. Option 4 is primarily Option 1 however in the right floodplain the existing floodplain has been infilled to form an approach embankment. The extent of the embankment in the floodplain has been represented by truncating the channel cross-section representing the floodplain channel. The approach embankment was constructed to a 1 in 2 slope. The following lengths relate to the distance from the centre point of the river channel to the toe of the approach embankment;

- Option 4a; toe starts about 80m from the centreline of river
- Option 4b; toe starts about 85m from the centreline of river
- Option 4c; toe starts about 90m from the centreline of river
- Option 4d; toe starts about 95m from the centreline of river

Option 5

4.1.5 Three Span Viaduct Bridge; containing three spans extending 210m over the main channel and floodplains. The viaduct bridge was has intermediate support in the form of two pairs of 2m diameter circular piers. The design would also require the augmentation of B977, the proposed alignment of the road embankment and its implication on the available flood storage in the adjacent floodplains has been represented in a similar manner to that of Option 1.

Option 6

4.1.6 Three Span Viaduct Bridge with right approach embankment. This option includes 4 sub options, 6a, 6b, 6c and 6d. Option 6 is primarily Option 5 however in the right floodplain the existing floodplain has been infilled to form an approach embankment. The extent of the embankment in the floodplain has been represented by truncating the channel cross-section representing the floodplain channel.. The approach embankment was constructed to a 1 in 2 slope. The following lengths relate to the distance from the centre point of the river channel to the toe of the approach embankment;

- Option 6a; toe starts about 80m from the centreline of river
- Option 6b; toe starts about 85m from the centreline of river
- Option 6c; toe starts about 90m from the centreline of river
- Option 6d; toe starts about 95m from the centreline of river

4.2 Impact Assessment - River Don Bridge Results

4.2.1 The effect of various bridge crossing options over the River Don on the peak water levels for 0.5% AEP flood event in comparison with the base case is shown in Table 4.1 and 4.2. These results indicate that the risk of flooding to properties in the area, as a result of the proposed development, is unlikely. Additionally a check on water levels for the 0.1% AEP flood event was carried out to ensure the bridge would not be overtopped. This indicates that at the 0.1% AEP water levels are unlikely to reach the bridge soffit.

4.2.2 The proposed bridge structures are located at model node DON_28U and GB_13ND on River Don and Goval Burn respectively. RGBUL_1, RBUR_1, RGBL_1 and RGBR_1 are all flood storage reservoir units describing the flood level with the floodplain adjacent to the Goval Burn.

Table 4.1 – River Don Bridge Options 1, 4a, 4b, 4c and 4d (Refer to Figure 9.3C)

Section Reference	Existing Situation (mAOD)	Difference in peak water level (mm)					Magnitude of Impact
		Option 1	Opton4a	Option 4b	Option 4c	Option 4d	
			Fill (~80m)	Fill (~85m)	Fill (~90m)	Fill (~95m)	
River Don – Main Channel							
DON_18	38.86	<10	11	10	<10	<10	Low
DON_19	38.48	13	18	16	15	14	
DON_20	38.47	18	24	22	20	19	
DON_21	38.52	16	21	20	18	17	
DON_22	38.51	16	22	20	18	17	
DON_23	38.50	16	22	20	18	17	
DON_24	38.49	16	22	20	18	17	
DON_25	38.48	16	22	20	18	17	
DON_26	38.46	16	23	21	19	17	
DON_27	38.45	17	23	21	19	18	
DON_28	38.39	18	16	16	17	17	
DON_28U	40.15	<10	<10	<10	<10	<10	
Goval Burn							
GB_10	38.28	<10	<10	<10	<10	<10	Negligible
GB_11	37.96	<10	<10	<10	<10	<10	
GB_12	37.88	<10	<10	<10	<10	<10	
GB_13	37.86	<10	<10	<10	<10	<10	
GB_13ND	37.87	<10	<10	<10	<10	<10	
GB_13D	37.83	<10	<10	<10	<10	<10	
GB_14	37.83	<10	<10	<10	<10	<10	
GB_15	37.83	<10	<10	<10	<10	<10	
GB_16	37.83	<10	<10	<10	<10	<10	
GB_17	37.82	<10	<10	<10	<10	<10	
RGBUL_1	37.87	<10	<10	<10	<10	<10	
RGBUR_1	37.86	<10	<10	<10	<10	<10	
RGBL_1	37.82	<10	<10	<10	<10	<10	
RGBR_1	37.82	<10	<10	<10	<10	<10	

Table 4.2 – River Don Bridge Options 5, 6a, 6b, 6c and 6d (Refer to Figure 9.3C)

Section Reference	Existing Conditions (m AD)	Difference in peak water level (mm)					Magnitude of Impact
		Option 5	Option 6a	Option 6b	Option 6c	Option 6d	
			Fill (~80m)	Fill (~85m)	Fill (~90m)	Fill (~95m)	
River Don – Main Channel							
DON_13	40.15	<10	<10	<10	<10	<10	Option 5 Option 6b Option 6c Option 6d Negligible Option 6a Low
DON_14	39.71	<10	<10	<10	<10	<10	
DON_15	39.54	<10	<10	<10	<10	<10	
DON_16	39.11	<10	<10	<10	<10	<10	
DON_17	39.10	<10	<10	<10	<10	<10	
DON_18	38.86	<10	<10	<10	<10	<10	
DON_19	38.48	<10	12	<10	<10	<10	
DON_20	38.47	<10	16	10	<10	<10	
DON_21	38.52	<10	14	<10	<10	<10	
DON_22	38.51	<10	14	<10	<10	<10	
DON_23	38.50	<10	14	<10	<10	<10	
DON_24	38.49	<10	14	<10	<10	<10	
DON_25	38.48	<10	14	<10	<10	<10	
DON_26	38.46	<10	14	<10	<10	<10	
DON_27	38.45	<10	15	<10	<10	<10	
DON_28	38.39	10	<10	<10	<10	<10	
DON_28U	40.15	<10	<10	<10	<10	<10	
Goval Burn							
GB_10	38.28	<10	<10	<10	<10	<10	Negligible
GB_11	37.96	<10	<10	<10	<10	<10	
GB_12	37.88	<10	<10	<10	<10	<10	
GB_13	37.86	<10	<10	<10	<10	<10	
GB_13ND	37.87	<10	<10	<10	<10	<10	
GB_13D	37.83	<10	<10	<10	<10	<10	
GB_14	37.83	<10	<10	<10	<10	<10	
GB_15	37.83	<10	<10	<10	<10	<10	
GB_16	37.83	<10	<10	<10	<10	<10	
GB_17	37.82	<10	<10	<10	<10	<10	
RGBUL_1	37.87	<10	<10	<10	<10	<10	
RGBUR_1	37.86	<10	<10	<10	<10	<10	
RGBL_1	37.82	<10	<10	<10	<10	<10	
RGBR_1	37.82	<10	<10	<10	<10	<10	

4.2.3 Option 1b represents a change in the alignment of the B977 road embankment over the Goval Burn. The alignment of the road embankment was moved to further south. As in the previous River Don models the volume of flood storage replaced by the road embankment was calculated and the flood storage reservoir unit was adjusted adjusted to reflect the reduction in flood storage volume. Results are shown in Table 4.3.

Table 4.3 – Goval Burn Options 1 and 1b (Refer to Figure 9.3C)

Section Reference	Existing Situation (mAOD)	Difference in peak water level (mm)		Magnitude of Impact
		Option 1	Option 1b	
Goval Burn				
GB_10	38.28	<10	<10	Negligible
GB_11	37.96	<10	<10	
GB_12	37.88	<10	<10	
GB_13	37.86	<10	<10	
GB_13ND	37.87	<10	<10	
GB_13D	37.83	<10	<10	
GB_14	37.83	<10	<10	
GB_15	37.83	<10	<10	
GB_16	37.83	<10	<10	
GB_17	37.82	<10	<10	
RGBUL_1	37.87	<10	<10	
RGBUR_1	37.86	<10	<10	
RGBL_1	37.82	<10	<10	
RGBR_1	37.82	<10	<10	

4.3 Scheme Summary

4.3.1 The model predictions indicate that, for the various river crossing options investigated, there would be a small change in the peak water levels in the River Don and Goval Burn at locations within the main channel and floodplain areas. The largest increase in peak water levels would be limited to 25mm. The magnitude of impact on water levels in the River Don are considered to be low for Options 1, 4a, 4b, 4c,4d and 6a and negligible for Options 5, 6b,6c and 6d. The magnitude of impact upon water levels is considered to be negligible for all bridge options for the Goval Burn. Further, the alternate alignment of the B977 road embankment on the Goval Burn has negligible effect on the risk of flooding in the areas in the vicinity of the watercourse.

4.3.2 This results in a slight to negligible significance of impact for the River Don and negligible impact on the Goval Burn (Refer to Figure 9.3C).

5 Mitigation and Recommendations

5.1 Impact Assessment - Don Bridge Options

5.1.1 Over a period of time, due to vegetation growth in the riverbanks and the floodplains, the value of the roughness coefficient could increase. This could increase the resistance to flow and could subsequently cause increase in water levels in the watercourses. It is advisable to carry out periodic maintenance of the riverbanks and the floodplains to reduce the effect of changes in roughness coefficient on the water levels.

6 Residual Impacts

6.1 Impact Assessment - Don Bridge Options

6.1.1 From the hydrodynamic modelling results, it is evident that, the proposed river crossing (bridge options) over the River Don would have insignificant impact on the water levels. For the purposes of finalising a bridge option for the outline design the aesthetics steering committee decided upon a five-span viaduct bridge (for further information please refer to Chapter 11: Landscape). This relates to bridge option 1 within this report

6.1.2 Consequently the significance of the predicted flood risk impacts of the preferred bridge option with reference to the sensitivity of the river and the magnitude of the flood risk for a 0.5% annual probability (200 year return period) flood event, in accordance with the defined criteria, are presented in the below matrix.

Table 6-1 – Watercourse Predicted Impact Evaluation for River Don and Goval Burn

Water Course	Factors considered	Sensitivity	Magnitude	Significance
Flood Risk	Impact of crossing	Medium	Negligible/Low	Negligible/Slight