A9.2 - Hydrodynamic Modelling (River Don)

0010332   July 2007

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Contents

1 Introduction

1.1 General Background

1.1.1 This report is a technical appendix of the Water Environment chapter of the Stage 3 Environmental Impact Assessment (EIA) for the Northern Leg of the Aberdeen Western Peripheral Route (AWPR).

1.1.2 The proposed scheme crosses one of the major water courses in the Aberdeenshire area, River Don, as shown in Figure 9.3a. The approximate road crossing coordinates over the River Don are 388111E, 814595N, and the hydrodynamic modelling results for the crossing are presented in this report. The Goval Burn has a confluence with the River Don and was therefore also included within this assessment, as explained below in paragraph 3.1.6.

1.1.3 The proposed scheme crosses numerous other smaller watercourses that will be affected by and will affect the development, and the flood risk assessment of these smaller watercourses is considered in Appendix A9.1 (Surface Water Hydrology) of the ES.

1.2 Assessment Aims

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

1.2.2 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 crossing 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 with 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 potential 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 potential 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 potential 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
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 the 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, a mathematical model of the watercourse was developed based on the one-dimensional unsteady state ISIS river modelling software. Data from a channel cross-section survey carried out in 2004 were used to construct the model. Low flow calibration of the mathematical model was undertaken using water levels measured during a channel cross-section survey.

2.2.4 Design event simulations for a range of % AEP flood events were carried out and consequent flood risk was determined in the vicinity of the proposed river crossings for both existing situation and several of river crossing options. Indicative flood extents were then mapped using the results from the ISIS model (Figure 9.3c). Only the final chosen design option is presented in this report.

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 have 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 scaling factor was 0.968 for the River Don.

3.1.4 Final flows for various % AEP flood events used for model simulations are summarised in Table 3.1.

Table 3.1 – River Don at Upstream Boundary of the Model (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 9.3b shows the extents of the modelled reaches 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 the 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 simulations to assess the flood risk for the existing situation. Model simulations were carried out using flood flows estimated using the 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 selection of Mannings n values of 0.045 and 0.055 to represent the channel roughness in the channel and on the floodplains respectively. 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 9.3ci and ii 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 event in the River Don. However, the indicative extent of the inundation plan (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. Comparison of the extent of inundation plan with the SEPA's *Indicative River and Coastal Flood Map (Scotland)* shows that indicative flood extent for 0.5% AEP flood event closely matches to the extent shown on SEPA plans.

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.

3.3 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 Introduction

4.1.1 The mathematical model of the River Don representing the existing situation was amended to represent each particular river crossing option in turn to assess the effect of each of the proposed river crossing options on the peak water levels. Several options were modelled and the results used to inform the choice of a final design. The impacts for the final design are reported below.

Five Span Viaduct Bridge

4.1.2 The bridge design comprises a five span viaduct bridge with right approach embankment. The extent of the embankment in the floodplain has been represented by truncating the channel cross-section representing the floodplain channel and the toe of the embankment starts approximately 85m away from the centreline of the river.

4.2 Impact Assessment

4.2.1 The effect of the bridge crossing over the River Don on the peak water levels for 0.5% AEP flood event in comparison with the base scenario is shown in Table 4.1. 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 (1000 year return period) flood event was carried out to ensure the bridge would not be overtopped. This indicates that at the 0.1% AEP flood event, 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 the 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 – Effect of Bridge Crossing on Peak Water Levels

Section Reference	Existing Situation 0.5% AEP (mAOD)	Five Span Viaduct with embankment (increase over baseline (mm))	Magnitude of Impact
River Don			
DON_18	38.86	0	
DON_19	38.48	<5	
DON_20	38.47	<5	
DON_21	38.52	<5	
DON_22	38.51	<5	
DON_23	38.50	<5	Negligible
DON_24	38.49	<5	
DON_25	38.48	<5	
DON_26	38.46	<5	
DON_27	38.45	<5	
DON_28	38.39	0	
DON_28U	40.15	0	
Goval Burn			
GB_10	38.28	0	
GB_11	37.96	0	
GB_12	37.88	0	
GB_13	37.86	0	
GB_13ND	37.87	0	
GB_13D	37.83	0	
GB_14	37.83	0	
GB_15	37.83	0	Negligible
GB_16	37.83	0	
GB_17	37.82	0	
RGBUL_1	37.87	0	
RGBUR_1	37.86	0	
RGBL_1	37.82	<5	
RGBR_1	37.82	<5	

4.2.3 The proposed five span viaduct bridge 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. In the model the volume of flood storage replaced by the road embankment was calculated and the flood storage reservoir unit was adjusted to reflect the reduction in flood storage volume. Results are shown in Table 4.1.

4.3 Scheme Summary

4.3.1 The model results indicate that there would be a marginal increase in the predicted peak water levels (<5mm) for the 0.5% AEP event on both the River Don and the Goval Burn. Changes to water levels on the Goval Burn are largely dictated by changes to water level predictions on the River Don and a backwater effect upstream on the burn. It should be noted that the difference in water levels for pre and post-scheme situations is within the accuracy of model predictions which is defined as +/-10mm.

4.3.2 This change in water levels is considered to be of negligible magnitude (Table 2.2) since all increases to water level are predicted to be of 5mm or less. As the River Don was assessed to be a medium sensitivity watercourse, this results in a Negligible impact significance (Figure 9.3c).

5 Mitigation

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. Therefore 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

6.1.1 From the hydrodynamic modelling results, it is evident that the proposed crossing over the River Don would not have a significant impact on the water levels

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 (1 in 200 year return period) flood event, and in accordance with the defined criteria, are presented in the matrix below (Table 6.1).

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	Negligible

7 References

Institute of Hydrology, 1999. Flood Estimation Handbook. Wallingford.