Aberdeen Western Peripheral Route

Appendix 24.5 – SIMCAT Modelling Assessment of the Operational Phase of the AWPR affecting the River Dee and its Tributaries

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1 Introduction

1.1 General Background

1.1.1 This report is a technical appendix of the Chapter 24 (Water Environment) of the Environmental Impact Assessment for the Southern Leg section of the Aberdeen Western Peripheral Route (AWPR).

1.1.2 This report provides an assessment of water quality modelling on the River Dee Special Area of Conservation (SAC) and some of its tributaries. The report describes mitigation measures required to address potential adverse impacts and provides an indication of the overall cumulative impact on the SAC.

1.2 Relevant Legislative Background

1.2.1 The EC Water Framework Directive (WFD), which is transposed into Scottish law by the Water Environment and Water Services (Scotland) Act, 2003, aims to classify surface waters according to their ecological status and sets targets for restoring/improving the ecological status of waterbodies. This is a radical departure from the traditional methods of measuring water quality using chemical parameters. Under the WFD, the status of water is to be assessed using a range of parameters including chemical, ecological, morphological and hydrological measures, which will provide a holistic evaluation of the aquatic ecological health. Furthermore, there is a requirement under the WFD that natural water features will have to reach good ecological status by 2015 (WFD, 2000/60/EC). Some waterbodies may be designated as artificially/heavily modified and will have less stringent targets to meet. However, these areas will still need to demonstrate 'good ecological potential' by the year 2015 (SEPA, 2004).

1.2.2 The Water Environment (Controlled Activities) (Scotland) Regulations 2005 (CAR) state that it is an offence to undertake engineering works to wetlands, surface waters and groundwaters without CAR authorisation. There are three different types of authorisation under CAR; General Binding Rules (GBR), Registration and License (both simple and complex). The level of regulation increases as the activity poses a progressively deleterious impact on the water environment. The level of authorisation required for the AWPR is dependent on the activity proposed but is likely to range from GBR, covering some construction activities and outfalls, to licences required for outfalls (draining over 1km of road in length), culverting and watercourse realignment. All outfalls for the scheme will be designed and constructed to meet the requirements of the Controlled Activity Regulations (CAR).

1.3 Assessment Aims

1.3.1 The aim of the water quality modelling is to assess the potential water quality impacts of the proposed road drainage outfalls to the River Dee and its tributaries.

1.3.2 Pollution calculations are performed to calculate both the annual average and ninety five percentile concentration levels for each of the designed outfalls in the area, as set out in the Design Manual for Roads and Bridges (DMRB, 2006). Levels of mitigation are designed based on these calculations and the results detailed in Appendix A24.4 (Water Quality).

1.3.3 Metal toxicity (for aquatic life) increases with decreasing water hardness, and as a result the Environmental Quality Standard (EQS) concentration levels for metals such as zinc and dissolved copper reduces (Table 3). Hardness levels in the Dee SAC area are known to be very low (10-50mg/l SEPA, personal communication, 2004). This element, in combination with its designated status, means that the River Dee is considered to be a highly sensitive area. Following guidance set out in the DMRB, a SIMCAT (SIMulation of CATchments) model was set up to investigate the potential cumulative impact of the AWPR on those watercourses in the River Dee SAC catchment within the study area.

2 Approach and Methods

2.1 General Approach

2.1.1 This section sets out the methodology by which the water quality modelling assessment has been undertaken for the cumulative impact of the proposed scheme on watercourses in the study area within the River Dee catchment that are designated as part of the SAC:

- River Dee;
- Crynoch Burn; and
- Culter Burn.

2.1.2 This appendix should be read in conjunction with Appendix A24.4 (Water Quality), Appendix A24.3 (Fluvial Geomorphology), Appendix A24.2 (Hydrodynamic Modelling), Appendix 40.9 (Freshwater Ecology) and Appendix A24.1 (Surface Water Hydrology).

2.1.3 The assessment of potential impacts has been carried out using the general methodology detailed in Chapter 24, where the level of significance of a predicted impact is assessed based on the sensitivity of the receptor and the magnitude of impact. The system of assessing a specific watercourse follows the basic methodology detailed below:

- assess the baseline;
- assess the potential impact;
- provide mitigation measures; and
- assess the residual impact after implementation of mitigation measures.

2.1.4 The assessment has been carried out in accordance with the methods set out in the DMRB, Volume 11, Section 3, Part 10 (The Highways Agency et al., 2006). Quantification of the impacts of road drainage on water quality is based on the predicted concentrations of dissolved copper and total zinc in the receiving waters in the design year (2025) of the proposed scheme. These metals are used as indicators of the level of impact as they are generally the main metallic pollutants associated with road drainage and can be toxic to aquatic life in certain concentrations (The Highways Agency et al., 1993). In addition to dissolved copper and total zinc, suspended solids have been incorporated to the model to assess the cumulative impact on the River Dee SAC area during operation.

2.1.5 The criteria used to assess the sensitivity of surface water features and potential impacts are defined in Table 1 and Table 2.

2.1.6 The resultant significance of impact is defined by reference to both the sensitivity of the feature and the magnitude of impact for each pollutant investigated. An overall magnitude is then assigned based on the highest potential impact from each pollutant. The standard matrix linking the magnitude and sensitivity can be found in the Water Quality Assessment (Appendix A24.4). The mean and 95 percentile provided a wider range of assessment and makes an account for inherent uncertainties in modelling natural watercourse water quality conditions.

2.2 Catchment Water Quality Model

2.2.1 The cumulative requirement of this assessment involves a more complex procedure than the point source methodology set out in the DMRB, Volume 11, Section 3, Part 10 (The Highways Agency et al., 2006) and used in Appendix A24.4, due to the interaction of the River Dee and its tributaries. The assessment of potential impacts on the SAC watercourses has been completed using the Environment Agency (EA) model SIMCAT. SIMCAT is a 1D stochastic, steady state, deterministic model which represents inputs from point-source effluent discharges and the behaviour of solutes in the river (Cox, 2003).

2.2.2 SIMCAT is able to simulate a statistical distribution of discharge and water quality data for multiple effluent inputs along a network of watercourses. Through randomly modelling up to 2500 different boundary conditions (also know as the Monte Carlo approach), based on the input data, SIMCAT produces a distribution of results from which an assessment of the impact can be made on the predicted mean and ninety-five percentile concentrations.

Table 1 – Criteria to Assess the Sensitivity of Water Features

Sensitivity	Criteria
High	Surface Water Quality Large or medium watercourse with pristine or near pristine water quality, Class A1 and A2, respectively. Water quality not significantly affected by anthropogenic factors. Water quality complies with Dangerous Substances Environmental Quality Standards (EQS's). Water quality does not affect the diversity of species of flora and fauna. Natural or semi-natural ecosystem with sensitive habitats and sustainable fish population. Includes sites with international and European nature conservation designations due to water dependent ecosystems: e.g. Special Protection Area, Special Area of Conservation, Ramsar Site and European Community (EC) designated freshwater fisheries. Also includes all nature conservation sites of national and regional importance designated by statute including Sites of Special Scientific Interest, National Nature Reserves and Natural Areas (part of the Regional Biodiversity Action Plan [BAP]).
Medium	Surface Water Quality Medium or small watercourse with a measurable degradation in its water quality as a result of anthropogenic factors (may receive road drainage water), Class A2 or B. Ecosystem modified resulting in impacts upon the species diversity of flora and fauna in the watercourse. Moderately sensitive habitats. Includes non-statutory sites of regional or local importance designated for water dependent ecosystems.
Low	Surface Water Quality Heavily modified watercourses or drainage channel with poor water quality, resulting from anthropogenic factors, corresponding to Classes B, C and D. Major change in the species diversity of flora and fauna due to the significant water quality degradation; may receive road drainage water. Fish sporadically present. Low sensitive ecosystem of local and less then local importance.

Table 2 – Criteria to Assess the Magnitude of the Predicted Impact on Water Features

Magnitude	Criteria
High	Surface Water Quality Major shift away from the baseline conditions, fundamental change to water quality condition either by a relatively high amount over a long-term period or by a very high amount over an episode such that watercourse ecology is greatly changed from the baseline situation. Equivalent to downgrading from Class B to D or any change that downgrades a site from good status as this does not comply with the Water Framework Directive. Specifically for the purposes of the soluble pollution assessment a high impact will be classed as an increase to copper or zinc concentrations of 100% or greater over the baseline situation, plus/or a failure of Environmental Quality Standards EQS for either pollutant. Similarly, where assessed quantitatively, an increase of long-term (operational) suspended solid load by 100% over the baseline situation plus/or a failure of the requirements for sensitive species (i.e. freshwater pearl mussels or salmonids) will be classed as a high magnitude.
Medium	Surface Water Quality A measurable shift from the baseline conditions that may be long-term or temporary. Results in a change in the ecological status of the watercourse. Equivalent to downgrading one class, for example from C to D. Specifically for the purposes of the soluble pollution assessment a medium impact will be classed as an increase to copper or zinc concentrations of 60-99% over the baseline situation, plus/or a failure of Environmental Quality Standards EQS for either pollutant Similarly, where assessed quantitatively, an increase of long-term (operational) suspended solid load by 60-99% over the baseline situation plus/or a failure of the requirements for sensitive species (i.e. freshwater pearl mussels or salmonids) will be classed as a medium magnitude.
Low	Surface Water Quality Minor shift away from the baseline conditions. Changes in water quality are likely to be relatively small, or be of a minor temporary nature such that watercourse ecology is slightly affected. Equivalent to minor, but measurable change within a class. Specifically for the purposes of the soluble pollution assessment a medium impact will be classed as an increase to copper or zinc concentrations of 25-59% from the baseline situation but all EQS levels are met. Similarly, where assessed quantitatively, an increase of long-term (operational) suspended solid load by 25-59% over the baseline situation will be classed as a low magnitude.
Negligible	Surface Water Quality Very slight change from the baseline conditions such that no discernible effect upon the watercourse's ecology results. No change in classification. Specifically for the purposes of the soluble pollution assessment a medium impact will be classed as an increase to copper or zinc concentrations of 24% or less over the baseline situation but all EQS levels are met. Similarly, where assessed quantitatively, an increase of long-term (operational) suspended solid load by 24% or less over the baseline situation will be classed as a negligible magnitude.

2.2.3 Relevant EQS for dissolved Copper and total Zinc are provided in Table 3. The EQS are statutory concentration levels for watercourses and are used in the SEPA classification schemes. Consequently the assessment uses the statutory guidance to determine the level of impact of the scheme upon the receptor (receiving watercourse). The values presented represent the more stringent target of either the Dangerous Substance Directive (DSD) or the Freshwater Fisheries Directive (FWF). The values are taken from statutory guidance detailed in the Scottish Development Department Circular (SDD No. 34/1985) and the Water Research Centre Technical Reports TR209 and TR210 and have been agreed with SEPA (SEPA, pers. comm., 2005).

Table 3 – National Environmental Quality Standards for the Protection of all Freshwater Life

Parameter	Hardness Range (mg/l $CaCO_3$)	EQS (µg/l) (annual average)	EQS (µg/l) (95 percentile)
Copper (dissolved)	0-10	1	5
	10- 50	6	22
	50-100	10	40
	101-250	28	112
	> 250	28	112
Total Zinc	0-10	8	30
	10- 50	50	200
	50-100	75	300
	101-250	125	500
	> 250	125	500

Source: Guidelines for Copper and Total Zinc from DMRB (The Highways Agency et al., 1993) and Statuatory Levels as provided by SEPA (personal communication, SEPA, 2005). Taken from the statutory documents accompanying the Dangerous Substances Directive (DSD) and Freshwater Fish Directive (FWF).

2.2.4 As there are no published EQS values for suspended solids, guidance on the tolerances of freshwater pearl mussels to suspended solids was taken from literature prepared by Scottish Natural Heritage (SNH) and the Scottish Environment Protection Agency (SEPA): Ecology of the Freshwater Pearl Mussel, Conserving Natura 2000 Rivers, Ecology Series No. 2 (Skinner, Young and Hastie, 2003).

Table 4 – Guidelines for Tolerance of Selected Freshwater Species to Suspended Solid Load

Suspended sediment (mg/l)	Risk to freshwater pearl mussels and their habitat
>30	Unacceptable risk

Source: published advice from the Life in UK Rivers, Conserving Natura 2000 Rivers project.

2.2.5 Guidance on the tolerances of salmon to suspended solids was taken from the Canadian Department of Fisheries and Oceans (DFO, 2000). This was based on an assessment of risk to fish and their habitat of elevated levels of suspended solids from mining operations in the Yukon. Table 5 summarises the level of risk ascribed to various ranges of increase in suspended solids levels. Alabaster and Lloyd (1982) summarise that levels of suspended sediment below 25 mgl^{-1} will have no harmful effects on fish. Levels of 25-80 mgl^{-1} are acceptable as a rule of thumb, 80-400 mgl^{-1} are unlikely to support good fisheries and levels over 400 mgl^{-1} generally will not support substantial fish populations (refer to Appendix A40.9 Freshwater Ecology for more information).

2.2.6 Table 4 indicates that the constraints in terms of suspended load concentrations are more stringent for freshwater pearl mussels than for salmon. For this reason, the magnitude of impact has been assigned based on these concentration levels and a value of 30 mg/l has been set for the 95th percentile result as this is considered more stringent than setting it for the mean value.

Table 5 – Assessment of risk to fish and their habitat, check of elevated levels of suspended solids from mining operations in the Yukon

Suspended sediment (mg/l)	Risk to fish and their habitat
<25	Negligible risk
25-100	Low risk
100-200	Moderate risk
200-400	High risk
>400	Unacceptable risk

2.2.7 The hardness on the River Dee is reported by SEPA as 10 – 50 mg/l. Therefore Table 6 presents the EQS values pertinent to the SAC watercourses assessed within this study.

Table 6 – National EQS for the Protection of Freshwater Life in Watercourses within the River Dee SAC

Parameter	Hardness Range (mg/l $CaCO_3$)	EQS (Annual Average)	EQS (95 Percentile)
Copper (dissolved) (µg/l)	10- 50	6	22
Total Zinc (µg/l)	10- 50	50	200
Suspended Sediment (mg/l)	N/A	<30*	30*

* Note EQS value taken from recent research and guidance.

2.2.8 The methodology undertaken during this assessment has been discussed and agreed with SEPA as the project has progressed.

2.3 Consultation

2.3.1 Baseline conditions for water quality have been identified through consultation with statutory consultees, a review of relevant published literature, site visits, SEPA monitoring information and freshwater habitat sampling undertaken in between 2004 and 2006.

2.4 Cumulative Catchment Impact Assessment for the River Dee SAC

General

2.4.1 Due to the sensitivity of the River Dee, its designation as a SAC and reported low hardness values in the main river and its tributaries, a more detailed stochastic model has been constructed for this area.

2.4.2 The model has been constructed using SIMCAT a commercially available model developed by the Environment Agency (EA). SIMCAT is a Stochastic Optimisation Model, which calculates the water quality of a river throughout the catchment area. Stochastic Optimisation Modelling is used in the field of water quality modelling to produce the maximum amount of information from random river, effluent flow and water quality data derived from field monitoring programmes. SIMCAT applies the Monte-Carlo method to the Mass Balance Equation and deals with the uncertainty in the water quality data by adjusting the flows and pollutant levels to fit the observed distributions of flow and quality data.

2.4.3 The general methodology that was adopted is:

- Model build assuming existing baseline including the following data:
  i. river flow information;
  ii. river quality data; and,
  iii. existing outfall/effluent flow and quality data.
- Assessment of inflow data
- Model calibration and sensitivity testing
- Assessment of the baseline situation for:
  iv. concentration levels of copper; zinc; and, suspended solids.

- Modification of baseline model to incorporate proposed outfall information, using data from:

v. potential quality of road runoff (copper, zinc and suspended solids) from recent monitoring studies of similar sites and review of relevant literature; and,

vi. potential quantity of road runoff.

vii. Assessment of predicted impact situation for:

viii. concentration levels of copper; zinc; and, suspended solids.

ix. Modification of predicted impact model to incorporate proposed mitigation information, using data from:

x. recent research into pollution reduction factors as a result of SUDs measures.

xi. Assessment of residual impact situation for:

xii. concentration levels of copper; zinc; and, suspended solids.

Study Area

2.4.4 The catchment was divided into 28 distinct reaches in order to represent the required area of the Dee SAC catchment. The model structure, including the gauging stations is shown in Figures 24.7a-b. The model extends along the River Dee from Park Bridge, near Drumoak (NO 797982) to the Bridge of Dee (NJ 930035). The model incorporates the following watercourses as tributaries to the River Dee:

- Crynoch Burn;
- Culter Burn;
- Burn of Ardoe;
- Shanna Burn;
- Kiln Burn;
- Milltimber Burn;
- Murtle Burn;
- Beildside Burn;
- Blackiewell Burn;
- Brodiach Burn;
- Burnhead Burn;
- Gairn Burn;
- Kincausie Burn;
- Ord Burn; and
- Silver Burn.

Data Collection and Analysis

2.4.5 Hydrologists within Jacobs provided information on river water flows, which were predicted using the CEH Low Flow 2000 system and verified in-house. Annual and monthly flow duration curves were provided for use within the model. A more detailed explanation of the methodologies used to derive this data are provided in Appendix A24.1 (Surface Water Hydrology).

2.4.6 Baseline information for the water quality of each watercourse has been derived from SEPA monitoring data. The available data for the River Dee at Milltimber Bridge (B979 crossing), Culter Burn at Peterculter, Crynoch Burn at Milton Bridge and the Brodiach Burn downstream of Backhill Tip Kingswells are shown in Table 7 and the locations are shown in Figure 24.7a-b. The determinants modelled were dissolved copper, total zinc and suspended solids, in accordance with the DMRB.

2.4.7 A thorough analysis was undertaken of the data monitored for the River Dee at Milltimber Bridge (Harmonised Monitoring Station) using AARDVARK software. This software is designed to analyse and remove trends in collected data. The data were analysed by SEPA at their Stirling Offices and the data that were used in the model is presented in Table 8. For total zinc, significantly higher concentrations were observed from mid 2000 onwards. Consequently, the data set was restricted to this period when generating the summary statistics.

2.4.8 A similar trend was observed for dissolved copper and the dataset was restricted to the same time period. Analysis of suspended solid levels indicated a significant step change from late 1997 onwards, therefore summary statistics were generated for the time period 1997 to 2004.

2.4.9 Monitoring data were only available for the River Dee, Culter and Crynoch Burn. After discussions with SEPA, the known levels in the Culter and Crynoch Burns were used as donor inputs for tributaries where quality data were not available. The determinant inputs were allocated on a pro-rata basis, using the sampled data and the catchment area of each stream or tributary.

Table 7 – Water Quality Parameters for the River Dee, Culter Burn and Crynoch Burn

Parameter (Units)		**River Dee at Milltimber HM**	**Culter Burn at Peterculter**	**Crynoch Burn at Millton Bridge**	**Brodiach Burn Downstream of Backhill Tip Kingswells**
Category	2004	A1	A2	A2	C
Temperature (0C)	Aver.	8.5	8.2	8.1	8.6
	Max.	20	15.5	16	14
	Min.	2.5	2	1	1.5
Conductivity (µS/cm)	Aver.	86	298	221	568
	Max.	121	498	282	5590
	Min.	42	197	150	280
Total Hardness (mg/l)	Aver.	26	74	-	-
	Max.	44	93	-	-
	Min.	12	53	-	-
Dissolved Oxygen (mg/l)	Aver.	11.4	11.5	11.3	0.682
	Max.	13.7	15.9	14.0	5.8
	Min.	9.36	9.1	8.9	0.2
Total Suspended Solids (TSS) (mg/l)	Aver.	2.6	5.7	3.5	6.7
	Max.	6	16	16	22
	Min.	1	1	1.5	2
Dissolved Copper (mg/l)	Aver.	1.6	2.0	-	-
	Max.	6.5	4.9	-	-
	Min.	0.1	0.1	-	-
	95%	4.6	4.06	-	-
Total Zinc (mg/l)	Aver.	13.3	10.4	-	13.7

Parameter (Units)		River Dee at Milltimber HM	Culter Burn at Peterculter	Crynoch Burn at Millton Bridge	Brodiach Burn Downstream of Backhill Tip Kingswells
	Max.	53.2	24.6	-	29.8
	Min.	0.2	1.5	-	4.5
	95%	38.6	19.8	-	28.6

Source: Analysis of SEPA chemistry water quality data (SEPA, 1998 – 2004)

2.4.10 The data at each quality monitoring station were checked to identify potential outliers from the data. Such outliers were then removed, before final summary statistics were derived (mean, standard deviation and count). The distribution of the data was also determined by analysis of the data; most data were reasonably represented using the Log-Normal distribution.

2.4.11 Total suspended solids are currently monitored on both the Crynoch and the Culter Burns. As all of the tributaries on the south side of the River Dee drain similar (rural) catchments, Crynoch Burn was used as a donor catchment for suspended solid inputs for these tributaries. Culter Burn drains an urban catchment and was chosen as a donor catchment for the tributaries on the north side of the River Dee.

2.4.12 Dissolved copper and total zinc levels were only known for Culter Burn (and not Crynoch Burn). Culter Burn was therefore used as a donor catchment for all the tributaries. However, this catchment drains more urban areas than those tributaries located on the south side of the River Dee. Levels of both dissolved copper and total zinc may be over estimated in these tributaries as a result.

2.4.13 Following discussions with SEPA and Scottish Water, all significant existing point outfalls were included in the model, for example Drumoak Sewage treatment works located near Park Bridge (NO 793986) and Maryculter Sewage treatworks located at Kirkton of Maryculter on the Crynoch Burn (NO 863992). This data was provided by Scottish Water.

Table 8 – Analysed Water Quality Parameters for the River Dee (AARDVARK)

Determinant		Concentration (µg/l)	90% Confidence Intervals	
Dissolved Copper	Mean	1.7	1.25	2.15
	Standard Deviation	1.9	1.64	2.29
	Count	51	N/A	N/A
Total Zinc	Mean	23.33	16.49	30.17
	Standard Deviation	29.73	25.66	35.52
	Count	53	N/A	N/A
Suspended Solids	Mean	3670	3140	4190
	Standard Deviation	2940	2616	3366
	Count	87	N/A	N/A

Model Sensitivity Analysis and Calibration

2.4.14 Calibration was undertaken for each of the determinants and flow, based on known levels and concentrations throughout the fluvial system. The calibration process informed the incorporation of diffuse quality and flow inputs within the model.

2.4.15 In addition to calibration, a range of analyses were undertaken to test the sensitivity of the model to 10% increase and decrease to copper, zinc, suspended solid concentrations, mean and Q95 flows in the River Dee and each tributary. A software package known as River Quality Software

(RQS) was used to carry out the sensitivity checks, which uses the mass balance equation to determine how discharges to the River Dee and its associated tributaries affect the mean or percentile of river water quality. This software is regularly used by the Environment Agency to assess the sensitivity of specific watercourses. A similar process was undertaken using the mass balance equation to make simple predictions of changes in copper and zinc levels in the River Dee as a result of the AWPR (refer to Appendix A24.4).

2.4.16 RQS requires the input of upstream river data (mean and standard deviation) for each determinant along with the mean and Q95 flows. Downstream data is also required, i.e. the quality and flow data of the tributary being analysed.

2.4.17 The results of the sensitivity analysis on the tributaries of the River Dee indicate that for a 10% change in river flow and quality levels there is little or no change in downstream concentrations. The average impact on the 90 percentile river quality for a 10% change in river quality was approximately 6% for copper and suspended solids and 8% for zinc. A 10% change in river flows also had very little impact, less than 0.5% impact on mean and 95 percentile river flows for all tributaries. Through applying the assessment detailed in Table 2, this analysis suggests a magnitude of impact of negligible for all watercourses.

2.4.18 The results of this assessment indicate the predominant influence on water quality is the River Dee. This suggests that the potential dilution afforded by the main stem river rather than small effluent tributary inputs is likely to control the water quality of the River Dee SAC.

2.4.19 Additionally, a check was undertaken on the correlation of flows in the tributaries to the main stem. This is generally held at 0.6 within SIMCAT. However, a range of coefficients from 0.5-0.7 were checked.

2.4.20 Calibration was conducted on the SIMCAT model by comparing predicted results at locations where data had been measured as shown in Figure 24.7a-b and Table 7. Where the model was found to under predict flow and water quality values, diffuse flows were added to the reach to account for the difference. This was carried out manually and with the SIMCAT Auto Calibration function. SIMCAT is able to ‘mop up’ any shortfall in predicted results by adding any additional pollutants and flows to allow measured values and predicted results to match and thus provide a fully calibrated model from which to assess the impacts of AWPR outfalls.

2.4.21 As SIMCAT works using a number of simulations to produce a statistical distribution of results, the sensitivity to the number of simulations or ‘shots’ was also tested. A comparison of 1800, 2000, 2200 and 2500 shots was conducted on the baseline model and there was found to be virtually no difference at monitoring locations. Then, 2500 shots were used in further simulations as this is the maximum number of shots possible and is therefore thought to provide the best sample for the statistical distribution of results

Predicted Impact Model

2.4.22 To modify the baseline model to account for the proposed scheme, additional inputs of water quality and quantity were required at points of proposed scheme outfall locations. The outfalls have been identified at the following locations and are presented in Figure 24.7a-b:

- Burnhead Burn at chainage 200300;
- Jameston Ditch at chainage 204601 (tributary of the Burn of Ardoe);
- River Dee at chainage 102824;
- Gairn Burn at chainage 106085; and
- Westholme Burn at chainage 108650 (tributary of Culter Burn).

2.4.23 Detailed descriptions and assessments of the individual outfalls are provided in Appendix A24.4 (Water Quality).

2.4.24 Hydrologists within Jacobs derived the water quantity information using rainfall gauge information and area weighting based on the area of (road) blacktop draining to each outfall. Further details of this methodology are provided in Appendix A24.1 (Surface Water Hydrology).

2.4.25 Known values of water quality concentrations were taken from the Highways Agency report 'Long Term Monitoring of Pollution from Highway Runoff'. Within the report, Table 6.2 provides observed event mean highway runoff quality and Table 4.3 presents a comparison of pollutant levels with DMRB, which was compared against the monitoring values from M74 (from SEPA) and other sites. Results of recent monitoring campaigns undertaken by Scottish SUDS Monitoring Group were also investigated. The monitoring locations included Dunfermline and Edinburgh. As these SUDS were not specifically draining motorways and the monitored values are within the published values presented in Table 9, the published values were used in the SIMCAT model.

2.4.26 It was determined from the monitoring information referred to above, that data from the M74 motorway was consistently in the lower boundary of the known range of concentrations published in the Highway Runoff Report. A summary of reference concentrations are provided in Table 10.

2.4.27 Much uncertainty exists regarding the possible concentrations of pollutants in road runoff, which is indicated by the range of published values. To reflect this, in addition to using mean, maximum and minimum pollutant concentrations for the point source inputs in the model, sensitivity tests were undertaken. This involved testing an increase and decrease of 10% for all road point source inputs in the model, which resulted in a matrix of nine models. The results from these models were then used to provide a range of potential mean pollutant concentrations with an associated error for the River Dee SAC as a result of the proposed road scheme.

Table 9 – Published Guidance on Concentrations of Pollutants in Road Runoff

Reference	Mean Dissolved Copper (µg/l)	Mean Zinc (µg/l)	Mean Suspended Solids (mg/l)
M74 Motorway – SEPA and DMRB data (McNeill and Olley, 1998)	11.3	29.3	25.7 [1]
Highways Agency Runoff Report Table 6.2	20.58	140.3	114.58
CIRIA C609 Table 3.3 – North European applications	-	417.3	194.5
Highways Agency Runoff Report Table 4.3 DMRB (Rural Roads) Median EMC [2]	-	35 – 185	12 – 135
Highways Agency Runoff Report Table 4.3 WRc Site Mean Range	-	53 – 222	53 – 318

1. Suspended solids value is likely to be greater as two outliers were removed from calculations
2. Value exceeded by 10% and 90% of sites respectively

Table 10 – Pollutant Concentrations Used in SIMCAT Model for Point Source Inputs from Road Runoff

Determinant	Mean Value	Maximum Value	Minimum Value
Dissolved Copper (ug/l)	20.58	22.64	11.3
Total Zinc (ug/l)	140.3	417.3	29.3
Suspended Solids (mg/l)	114.58	318	25.7
Data Source	All determinants: Highways Agency Runoff Report Table 6.2	D Copper: Highways Agency T Zinc: CIRIA C609 Sus Seds: Highways Agency	All determinants: M74 Motorway – SEPA and DMRB data

2.4.28 From this review a low, mean and high value for each parameter was determined for each pollutant and used in the subsequent SIMCAT model. The values are presented in

Table 10.

Residual Impact Model

2.4.29 To modify the predicted impact (without mitigation) model to incorporate the proposed mitigation measures, an estimate of predicted pollutant removal efficiencies was utilised. Removal efficiencies used were based on best current available information from recent research and discussions with Professor C. Jefferies of Abertay University. These removal efficiencies were used to reduce the pollutant concentration for the point source road runoff inputs to account for the proposed mitigation measures. Table 11 and Table 12 present the removal efficiencies used for the assessment with the relevant literature that this is taken from.

2.4.30 The treatment trains for the scheme outfalls to the River Dee and its tributaries are detailed in the Water Quality Appendix. Treatment trains typically comprise of one detention basin and two treatment ponds, however in areas where more stringent mitigation is required extra levels of treatment are provided. The removal efficiencies that were used to reduce the concentration levels in the runoff are detailed in Table 12.

2.4.31 The estimated effect of the following mitigation was applied to each of the individual road outfall points:

- Burnhead Burn at chainage 200300: one detention basin, two treatment ponds and lining of the filter drains.
- Jameston Ditch at chainage 204601 (tributary of the Burn of Ardoe): one detention basin, three treatment ponds and lining of the filter drains.
- River Dee at chainage 102824: one detention basin, two treatment ponds and lining of the filter drains.
- Gairn Burn at chainage 106085: one detention basin, four treatment ponds and the lining of the filter drain.
- Westholme Burn at chainage 108650 (tributary of Culter Burn): one detention basin, four treatment ponds, a swale and the lining of the filter drain.

2.4.32 The discharge of each outfall has been capped at the present Greenfield Runoff rate for the Southern Leg area of the road, calculated as 4.3l/s/ha (Appendix A24.1). For mitigation simulations, the rainfall duration curves applied to the model were capped at the appropriate discharge based on the areas draining to the outfall and the calculated Greenfield Runoff rate at each outfall location. Detailed descriptions and assessments of the individual outfalls are provided in the Water Quality Appendix (A24.4).

Table 11 – Published Removal Efficiencies of Various Mitigation Measures

Mitigation Measure	Total Zinc Reduction	Dissolved Copper Reduction	Suspended Solids Reduction	Data Source
Filter drain	75%	20%	80-90%	DMRB
Oil separator	40%	<10%	30-80%	DMRB
Extended detention basin	65%	65%	65-90%	CIRIA C609
Sedimentation chamber and filter bed	50%	50%	70-90%	CIRIA C609
60 m long wet swale	≈63%	≈46%	≈83%	CIRIA C609
60 m long wet swale	70-90%	50-70%	60-90%	DMRB
Detention Basins/Treatment Ponds	50-80%	50-80%	50-80%	CIRIA C609

Table 12 – Removal Efficiencies of Mitigation Measures Used within SIMCAT

Mitigation Measure	Total Zinc Reduction	Dissolved Copper Reduction	Suspended Solids Reduction	Data Source
Filter drain	75%	20%	85%	DMRB
60 m long wet swale	70%	50%	60%	DMRB
Treatment Ponds	65%	65%	82%	CIRIA C609

2.5 Limitations to Assessment

2.5.1 The water quality modelling of the River Dee is limited to a certain extent by the amount of available good quality data.

2.5.2 As discussed earlier, the variability of the data-sets for copper and zinc required that the time-period was restricted to five years. In carrying out such a study, it is often the case that there will be variability in the level of data available throughout the catchment area. A thorough statistical analysis was carried out to ensure that the sampling error in the data was reduced to a minimum.

2.5.3 There are a number of assumptions inherent in using a stochastic water quality model like SIMCAT. Mixing is assumed to have taken place downstream of the discharge points. A log normal distribution of determinants is also assumed, unless otherwise indicated by the provision of specific distribution data. Flows are generally represented using a non parametric distribution based on the flow duration curve.

2.5.4 The greatest restraint that must be overcome is ensuring that the model is fit for purpose, for example the model should be sufficiently robust to provide predictions of water quality in the River Dee. With the level of data checking, the use of 95 percentiles, calculation of likely error, statistical analysis, and detailed sensitivity analysis conducted it is considered that the model reasonably represents the River Dee in the area.

2.5.5 All reported results should always be considered in light of the predicted variation associated with a particular result. The variation is an attempt to reflect the inherent uncertainty associated with predicting potential pollutant concentrations outfall from road drainage outfalls.

3 Baseline

3.1 General Study Area

3.1.1 In addition to the River Dee, there are 15 smaller watercourses within the modelled area. Each of the identified watercourses is described below and shown in Figures 24.7a-b.

3.1.2 The section of the River Dee directly relevant to the assessment is situated between Park Bridge and Bridge of Dee. Within this section, the river flows through predominantly agricultural land collecting water from several small tributaries: Culter Burn, Crynoch Burn, Milltimber Burn, Murtle Burn, Shanna Burn, Bielside Burn and Burn of Ardoe. On the north riverbank there are a number of residential areas: Peterculter, Milltimber, Milton of Murtle, Bielside, Cults, Garthdee and Kaimhill. The River Dee and its surrounding area are also used for recreational purposes. There is a campsite near the Crynoch Burn, a golf course and a sports centre at Bieldside. The area contains several riverside walks and the river is used for fishing and canoeing.

3.2 The River Dee SAC (River Dee, Crynoch and Culter Burns)

3.2.1 The River Dee rises in the Cairngorms to the west of Braemar and flows eastwards before entering the North Sea at Aberdeen. The main channel of the river is approximately 126km in length and drains a total catchment area to the North Sea of approximately 2,083km². It provides exceptional natural habitat conditions and water quality for Atlantic salmon, freshwater pearl mussel and otters and has been designated as a Special Area of Conservation (SAC). Within the study area, sections of Culter Burn and Crynoch Burn are also assigned SAC status. Both watercourses are also significant tributaries of the River Dee and provide important ecological and freshwater habitat.

3.2.2 Water is abstracted from the river at the Inchgarth Reservoir to supply drinking water to the Aberdeen area. The average water abstraction is 89.9 megalitres per day (Aberdeen City Council et al., 2002, cited in Mouchel, 2002).

3.2.3 The River Dee at Milltimber is classed as a Class A2 river with good biological, and excellent chemical and aesthetic characteristics (SEPA, 2005). As mentioned in the Water Quality Appendix (A24.4), the class allocated to a particular stretch of watercourse defaults to the poorest class from the assessment, therefore although the chemical and aesthetic parameters were classed as A1, the lower quality biological characteristics down-graded it to Class A2. The measured levels of dissolved oxygen, ammonia and BOD are typical for natural unpolluted rivers.

- saturated oxygen above 80% (SEPA class A1);
- ammonia concentrations below 0.25mg/l (SEPA class A1); and
- BOD below 2.5mg/l (SEPA class A1).

3.2.4 In natural waters, phosphorus is usually found in the range of 0.005 to 0.1mg/l unless water has passed through soil containing phosphate or has been polluted by organic matter (WHO, 1984 and Hammerton, 1996). Phosphorous compounds are present in fertilisers and in many detergents. Consequently, they can be carried into both ground and surface waters with sewage, industrial wastes and storm runoff (WHO, 1984). Following the EU Urban Wastewater Treatment Directive (91/271/EEC), the UK water quality standards for orthophosphates provide guideline annual values below 0.1mg/l. The measured annual average orthophosphates (0.01mg/l) in the River Dee are within the EU UWWT Directive guideline values.

3.2.5 The measured concentrations at Milltimber, over the period 1984 to 2005, (NJ858003) for copper are below the limits set by the Freshwater Fisheries Directive (FWFD, EQS value, 22µg/l) and the Dangerous Substances Directive (DSD, EQS value 6µg/l). The zinc annual concentrations at this sampling point for the same period are within the DSD limits (monitoring annual average concentration 16μg/l, EQS 50μg/l at hardness 10-50mg/l) and the 95-percentile concentration (monitoring concentrations for the 95^{th}-percentile 52μg/l, DSD EQS 95% 200μg/l) and the FWFD (200μg/l) (refer to Table 3). In summary, the concentrations of zinc in the River Dee:

- currently pass EQS for the DSD (both annual concentrations and 95-percentile values); and
- currently pass EQS for the FFD (95-percentile values).

3.2.6 Additionally, concentrations of copper in the River Dee:

- currently pass EQS for the DSD (annual concentrations); and
- currently pass EQS for the FWFD (95-percentile values).

3.2.7 The River Dee provides exceptional natural habitat conditions and water quality (spot sampling water quality at Milltimber category A2 and SEPA category A1/A2 within the SAC area) for sustainable existence of populations of native brown trout, sea trout and migratory salmon (refer to Appendix A25.9: Freshwater Ecology).

3.2.8 The proposed scheme would not cross Culter Burn, but it has been included for water quality modelling purposes as one of the main River Dee tributaries. It begins from Loch of Skene as Leuchar Burn, drains an area of approximately 149km^2 and enters the River Dee at Peterculter (NJ 837004). The burn has good (A2) water quality (SEPA, 2004) and is within the Dee SAC (Figure 25.1b). It provides good habitat for juvenile Atlantic salmon, as well as brown and sea trout. The European endangered brook lamprey is also present.

3.2.9 The confluence of the Crynoch Burn with the River Dee is located downstream of the Culter Burn at Inch of Culter (NJ 856004) and was also included as part of the water quality modelling study area. Crynoch Burn is formed after the confluence of Cairnie Burn and Burn of Monguich and has a catchment area of approximately 30.7km². It flows northeast through Durris Forest and enters the Dee at Culter camping site. The burn is within the Dee SAC (Figure 25.1b) providing valuable habitats for Atlantic salmon, brown and sea trout. SEPA monitoring data indicates good (A2) water quality for 2004.

3.2.10 Baseline levels of copper, zinc and suspended solids for the SAC area as predicted by the baseline SIMCAT model, are detailed in Table 6 and are presented in Figures 24.7b. Model results are extracted from the same point in the model for each scenario (Baseline, Potential Impact and Residual Impact).

Table 13 – Baseline Concentrations of Pollutants in SAC Watercourses

Model Node	Reading	Flow (m^3s^{-1})	Dissolved Copper (ug/l)	Total Zinc (ug/l)	Suspended solids (mg/l)
Culter Burn (at confluence with the River Dee)	Annual Average	0.95	1.14	5.81	3.21
	95 %iile	0.26	2.39	11.20	6.86
Crynoch Burn (at confluence with the River Dee)	Annual Average	0.40	0.43	2.18	3.50
	95 %iile	0.02	0.9	4.21	8.43
River Dee (at Milltimber)	Annual Average	50.57	1.63	13.28	3.68
	95 %iile	9.75	4.31	35.03	8.88
River Dee (Inchgarth Reservoir abstraction)	Annual Average	51.15	1.60	13.10	3.63
	95 %iile	9.98	4.26	34.60	8.78
River Dee (Bridge of Dee)	Annual Average	51.27	1.63	13.31	2.55
	95 %iile	10.02	4.32	35.09	4.44

3.2.11 Table 13 illustrates that all reported locations within the SAC fall well within the EQS values for each of the investigated pollutants for both the mean and 95th percentile results.

3.3 Minor Watercourses

3.3.1 The location and baseline conditions of all watercourses within the model are presented in Figure 24.7b. A brief description of each burn is provided below.

Burn of Ardoe

3.3.2 The Burn of Ardoe is a tributary of the River Dee that has a catchment area of approximately 2.9km². The burn is a small watercourse draining Hare Moss and Shanna Burn. It flows through predominately rural land and joins River Dee near the proposed AWPR crossing of the River Dee. Although it has good water quality (spot sampling category A2), the riverbed has been modified for agricultural purposes, which has changed the natural river habitat (please refer to Appendix A24.3 Geomorphology). Currently, it is considered to be of medium sensitivity.

Shanna Burn

3.3.3 The Shanna Burn is a small stream located downstream from the proposed AWPR crossing of the River Dee that has good water quality (spot sampling class A2). Shanna Burn is a tributary of Burn of Ardoe and has a catchment area of approximately 2.1km². Its source is located eastwards of Craigingles wood (NJ885004) and its main tributary is Kiln Burn. The burn drains predominantly rural areas and has been modified along its length please refer to Appendix A24.3 Geomorphology). As a result, it has been classed as a medium sensitivity.

Kiln Burn

3.3.4 Although Kiln Burn would not be crossed by the main road line, it is a tributary of the River Dee in the modelled SAC area. The burn springs at a point to the south of Craigingles Wood. It is a tributary of Shanna Burn and has a catchment area of approximately 0.7 km². As the burn drains a similar type of catchment as the Burn of Ardoe and Shanna Burn, it is assumed that the burn is likely to be of good water (A2) quality and has been designated as medium sensitivity.

Brodiach Burn

3.3.5 Although Brodiach Burn is a designated salmonid river, it is a predominantly straightened watercourse draining mainly agricultural land. Located in its catchment is the urban area of Westhill. It begins at Borrowstone Farm and flows in a south westerly direction. At Brodiach farm, the watercourse is crossed by a farm track and a minor road. It is crossed again by the A944 and B9119 at East Fiddie Farm and a minor road east of Easter Ord Farm. Downstream of the Backhill Tip Kingswells, Westhill the Brodiach Burn has been classified as having poor water quality (Class C) due to poor river chemistry and in particular high levels of Iron.

Silver Burn

3.3.6 Silver Burn is an upstream tributary of Ord Burn. It begins at the Moss of Auchlea, which is a District Wildlife Site (DWS) designated for its valuable wetland habitats. As a result, the burn is thought to have a high sensitivity. Feedback from local residents also suggests that the Silver Burn is utilised as a form of private water supply which was confirmed by a recent site visit where wells were noticed in the area.

3.3.7 The burn flows predominantly through agricultural land of a moderate to steep gradient mainly following field boundaries. At East Silverburn Farm, the watercourse is crossed by Silverburn Road (C127) and a farm track.

3.3.8 Silver Burn is currently not monitored by SEPA. Macroinvertebrate spot sampling (Jacobs, 2006) indicates that water quality of Silver Burn can be classed as having excellent (A1) water quality under the SEPA Water Classification Scheme.

Ord Burn

3.3.9 Ord Burn is a tributary of Leuchar Burn. It begins just west of the bottom boundary of Gairnhill Wood, flowing in a westerly direction, before meeting Leuchar Burn south-west of Inverord. Approximately halfway along its length, Ord Burn is met by Silver Burn and its downstream end feeds into a reservoir before joining Leuchar Burn.

3.3.10 The watercourse flows through gently sloping and mainly agricultural land and is quite straightened, running along field boundaries for its entire length. Just before the reservoir, Ord Burn is crossed by a Class B road which indicates it may be in receipt of road drainage.

3.3.11 Ord Burn is currently not monitored by SEPA. Macroinvertebrate spot sampling (Jacobs, 2006) indicates that water quality of Ord Burn can be classed by SEPA as having A2 (good) water quality.

Gairn Burn

3.3.12 Gairn Burn is a small tributary of Silver Burn and part of the Brodiach Burn catchment (Brodiach Burn is a designated salmonid river). It begins just east of Gairn Farm and flows south along field boundaries of pastureland of a moderate to steep gradient draining an area of approximately $0.8km^2$ to the point of crossing with the AWPR. A number of private water supply wells have been identified in the vicinity of the watercourse, located upstream from the proposed scheme crossing (refer to Chapter 23 and Figure 23.2f).

3.3.13 Gairn Burn is currently not monitored by SEPA. Macroinvertebrate spot sampling (Jacobs, 2006) indicates that water quality is of Class B (fair). Therefore, the burn was considered to be of medium sensitivity.

Milltimber Burn

3.3.14 Milltimber Burn begins just above Milltimber settlement, flows in the south-easterly direction through the urbanised area and discharges into the River Dee. It is assumed that the burn passes through a number of culverts and collects urban and agricultural drainage.

3.3.15 Spot sampling (Jacobs, 2006) indicates that water quality is of class B (fair). Due to the effects of urbanisation of this watercourse, a sensitivity of low has been assigned.

Blaikiewell Burn

3.3.16 Blaikiewell Burn is a moderately steep tributary of the Crynoch Burn set within a shallow 'v' shaped valley, draining an approximate area to the point of crossing of the proposed scheme of $4.5km^2$. The burn is straightened in its very upper reaches, but has more natural channel halfway down and farther downstream, where it flows through a narrow and wooded gorge. Just south of Eastland Bridge it is crossed by a class C (U63K) road and may therefore receive road drainage. Its confluence with the Crynoch Burn is within the River Dee SAC boundary.

3.3.17 Although Blaikiewell Burn is currently not monitored by SEPA, the spot sampling results from the macroinvertebrate survey carried out in summer of 2006 (Jacobs) indicated that Blaikiewell Burn is of excellent quality (class A1). Additionally, the burn is known to be an important otter commuting route to the River Dee and Crynoch Burn. Consequently the burn has been classed as high sensitivity for the purposes of this assessment.

Burnhead Burn

3.3.18 Burnhead Burn is the main tributary of Blaikiewell Burn, draining a catchment area of approximately 4.2km^2 to the point of crossing of the proposed scheme. It flows in an easterly direction alongside gently sloping tilled land following field boundaries. Midstream, near Blaikiewell Farmhouse the burn changes course and flows in a northerly direction until it joins Blaikiewell Burn. South of Burnhead farm, the watercourse is crossed by the Lochton-Auchlunies-Nigg (C5K) class C road.

3.3.19 Burnhead Burn is currently not monitored by SEPA. Recent spot sampling results (Jacobs, 2006) indicated good water quality, class A2 (see Appendix A25.9). Burnhead Burn is considered to have a high sensitivity as it is the main tributary of Blaikiewell Burn.

Kingcausie Burn

3.3.20 Kingcausie Burn is a tributary of the Crynoch Burn, draining an area of approximately 1.6 km^2 to the point of crossing of the proposed scheme. It begins in a gently sloping northern part of Cleanhill Wood and flows through predominantly woodland area. Its catchment becomes steeper near the confluence with Crynoch Burn. Private water supply wells have been identified in the catchment area (refer to Chapter 23.

3.3.21 Kingcausie Burn is not included in the SEPA water quality monitoring network. The spot sampling (Jacobs, Summer 2006) found the water quality to be class B (fair) quality. However, being a tributary of Crynoch Burn, which is within the River Dee SAC, Kingcausie Burn is classed as a high sensitivity watercourse.

Bieldside Burn

3.3.22 Bieldside Burn is located east of Murtle Den Burn and west of Inchgarth Reservoir, falling within the water quality modelling area. It drains in a southeasterly direction from its source to the northeast of Bieldside into the River Dee. It has a catchment area of approximately 1.5 km^2 and the spot sampling data indicated excellent (A1) water quality.

Murtle Burn

3.3.23 Murtle Den Burn feeds Upper Murtle Dam and flows in a southeasterly direction through a woodland gorge providing excellent water quality (spot sampling category A1). The burn drains predominately woodland and agricultural land and therefore has high sensitivity.

3.3.24 Murtle Burn is located downstream of the proposed River Dee crossing, draining predominately agricultural catchment of approximately 6.9 km^2. It begins at the outfall of the Upper Murtle Dam and discharges into the River Dee. The burn flows from the dam through the Camphill Estate. Along its route, the watercourse has been artificially straightened and passes through a number of culverts before its confluence with the Dee. It is assumed that the burn is likely to be of excellent water quality as spot sampling data indicated category A1. It has been classed as high sensitivity.

3.3.25 Loiston Burn outfall (chainage 800 on the A90) has not been considered within this report due to the attenuation effects of Loiston Loch. Pollutants released to this burn are likely to be diffused by the loch before out falling to the River Dee. The localised effects and magnitude of impact for Loiston Burn outfall are considered in the Appendix A24.4.

3.4 Summary

3.4.1 The sensitivity of the surface watercourses that were included in the SIMCAT model, were assessed using the criteria in Table 1 and guidance from the Water Framework Directive (WFD). The water quality of some of the minor watercourses is currently not monitored by SEPA. Spot sampling data have been used to classify the quality of the watercourses that have not been sampled by SEPA. Assumptions on water quality were also made based upon their location and proximity to urban areas, the quality of receiving and contributing watercourses and their association with ecological and nature conservation areas. Further information on the baseline situation for watercourses can be found in Appendix A24.4.

3.4.2 All of the watercourses in the area that would be affected by the proposed scheme are represented in the model and their associated sensitivities are summarised in Table 14. The model has been calibrated using diffuse flows and SIMCAT Auto Calibration. At gauged locations (Table 7), measured and predicted values were found to match following calibration.

3.4.3 The results of the RQS water quality sensitivity assessment indicate the predominant influence on water quality is the River Dee. This is due to the potential dilation afforded by the main stem river rather than small effluent tributary inputs.

3.4.4 Given the degree of sensitivity analysis, calibration, the level of data checking, the use of 95 percentiles, calculation of result variance, and statistical analysis conducted for the SIMCAT model it is considered that the model is fit for purpose and reasonably represents the River Dee in the SAC area.

Table 14 – Sensitivity of Surface Water Features: River Dee and its Tributaries

Watercourse	SEPA category	Spot sampling category	Sensitivity
Southern Section			
Burn of Ardoe	N/A	A2	Medium
Shanna Burn	N/A	A2	Medium
Kiln Burn	N/A	A2	Medium
Culter Burn	A2	A2	High
Brodiach Burn	C	C	Low
Silver Burn	A1	A1	High
Ord Burn	A2	A2	Medium
Gairn Burn	N/A	B	Medium
Milltimber Burn	N/A	B	Low
Crynoch burn	A2	A2	High
Blaikiewell Burn	A1	A1	High
Burnhead Burn	A2	A2	High
Kingausie Burn	B	B	High
Bieldside Burn	A1	A1	High
Murtle Burn	N/A	A1	High
River Dee	A1	A1	High

4 Potential Impacts

4.1 General

4.1.1 In order to measure the potential impacts of the proposed scheme, this assessment has initially been based on studying the direct potential effects of the untreated road runoff on the watercourses water quality, without the application of any form of treatment or mitigation measures. It is emphasised that the impacts presented in this section are predicted assuming no mitigation and hence represent the worst case scenario for the water environment. It should be noted that these are identified with the principal purpose of designing appropriate mitigation and are not expected to be the final impacts of the scheme.

4.2 Cumulative Potential Impacts – SAC Watercourses

4.2.1 Table 15 and Figure 24.7c present the predicted concentrations at five points through the SIMCAT model. These correspond to the points at which baseline information from the model have been extracted and relate to the watercourses assigned SAC status. A matrix of nine model scenarios were run to reflect the possible range of pollutant concentrations found in road runoff and thus provide error bands for the reported results.

4.2.2 The model indicates that there are likely to be only minor increases to pollutant concentration levels in the River Dee over the baseline scenario as a result of the proposed road, with no mitigation in place. In reference to Table 2, these impacts are assessed as being of negligible magnitude and therefore of Slight to Negligible significance as detailed in Table 16 and Table 17. No concentrations were elevated above EQS levels.

4.2.3 Each of the model runs provided very similar results for all points on the River Dee. The lack of sensitivity of the modelling to the variation of pollutant concentration levels used for the point source inputs is considered to be a result of the large dilution potential of the River Dee, as seen during the sensitivity runs completed during model construction. The smaller tributaries (Culter Burn and Crynoch Burn) are more sensitive to the tributary inputs due to their smaller size (and hence less dilution potential).

4.2.4 Culter Burn is predicted to have an increase in concentration of suspended solids of up to 27% from the baseline levels (Table 15). This demonstrates a higher impact than the River Dee and has an overall magnitude of low and an impact significance of Moderate.

4.2.5 Crynoch Burn has the lowest flows (Table 13) and smallest catchment of the three SAC watercourses investigated within this report. As a result, increases of up to 107% (Table 15 zinc) have been predicted by the model. This level of increase has lead to an overall magnitude of high and a Substantial significance for unmitigated road drainage outfall to this burn or its tributaries.

4.2.6 Although all pollutant values for each of the three watercourses within the SAC boundary are predicted to fall within the EQS values, it is important to ensure that any potential increase to concentration has no or minimal impact upon the river itself. This is particularly apparent for Crynoch Burn, which has a predicted impact significance of Substantial.

Table 15 – Predicted Concentrations of Indicator Metals in the SAC Watercourses (Output from SIMCAT Model)

Model Node	Reading	Dissolved Copper			Total Zinc			Suspended Solids		
		(ug/l)	Predicted Variance on result ±	% Increase Over Baseline	(ug/l)	Predicted Variance on Result ±	% Increase Over Baseline	(mg/l)	Predicted Variance on Result ±	% Increase Over Baseline
Culter Burn (at confluence with the River Dee)	Annual Average	1.19	0.02	4	6.87	0.96	18	4.09	0.77	27
	95 %iile	2.46	0.06	3	13.16	1.75	18	8.55	1.59	25
Crynoch Burn (at confluence with the River Dee)	Annual Average	0.52	0.03	21	3.76	1.35	72	4.88	1.14	39
	95 %iile	1.08	0.08	20	8.72	4.02	107	11.79	2.87	40
River Dee (at Milltimber)	Annual Average	1.63	0	0	13.42	0.12	1	3.80	0.10	3
	95 %iile	4.31	0	0	35.39	0.36	1	8.93	0.04	1
River Dee (Inchgarth Reservoir abstraction)	Annual Average	1.61	0	1	13.23	0.12	1	3.74	0.10	3
	95 %iile	4.27	0.01	0	34.90	0.29	1	8.83	0.03	1
River Dee (Bridge of Dee)	Annual Average	1.64	0.01	1	13.46	0.14	1	2.69	0.12	5
	95 %iile	4.32	0	0	35.48	0.38	1	4.58	0.13	3

Table 16 – Magnitude and Significance of Predicted Potential Cumulative Catchment Impact on each Pollutant for the Designated SAC Watercourses

Watercourse	Sensitivity	Parameter	Magnitude of Impact on Watercourse	Significance
Culter Burn (at confluence with the River Dee)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Suspended Sediment	Low	Moderate
Crynoch Burn (at confluence with the River Dee)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	High	Substantial
		Suspended Sediment	Low	Moderate
River Dee (at Milltimber)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Suspended Sediment	Negligible	Slight/Negligible
River Dee (Inchgarth Reservoir abstraction)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Suspended Sediment	Negligible	Slight/Negligible
River Dee (Bridge of Dee)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Suspended Sediment	Negligible	Slight/Negligible

Table 17 The Overall Magnitude and Significance of Predicted Potential Cumulative Catchment Impact on the Designated SAC Watercourses

Watercourse	Sensitivity	Magnitude of Impact on Watercourse	Significance
Culter Burn (at confluence with the River Dee)	High	Low	Moderate
Crynoch Burn (at confluence with the River Dee)	High	High	Substantial
River Dee (at Milltimber)	High	Negligible	Slight/Negligible
River Dee (Inchgarth Reservoir abstraction)	High	Negligible	Slight/Negligible
River Dee (Bridge of Dee)	High	Negligible	Slight/Negligible

5 Mitigation

5.1 General

5.1.1 The objective of the mitigation measures outlined below is to convey surface water runoff from the road surface to receiving watercourses without detrimental effect on water quality. Mitigation measures include those that aim to prevent, reduce or offset potential impacts as reported in Section 4.

5.1.2 Mitigation measures to prevent adverse impacts typically comprise solutions that are aimed at where the pollution would be generated. The risk of causing deterioration in water quality can be reduced by 'designing out' any risk. This includes the choice of route location and road alignment to avoid impacts, for example the avoidance of important/sensitive water features where possible.

5.1.3 Where potential adverse impacts cannot be prevented, i.e. there is a need for road runoff to be discharged to local watercourses and drainage ditches, appropriate mitigation measures will be implemented to reduce the potential for impacts on local water quality. These mitigation measures are detailed below.

5.1.4 Further information regarding specific mitigation measures are provided in Appendix A24.4 (Water Quality), including all mitigation measures that would be required to offset potential impacts during the construction phase. Appendix A24.3 contains mitigation specific to potential geomorphological impacts on watercourses. For mitigation specific to surface water hydrology and flooding issues please refer to the Appendix A24.1 and Appendix A24.2 provided mitigation measures specific to hydrological and flood risk impacts. Mitigation specific to ecology is provided in Chapter 25 (Ecology and Nature Conservation).

5.1.5 The drainage system of the proposed road scheme has been designed in accordance with the principles contained in Sustainable Urban Drainage Systems (SUDS): Design Manual for Scotland and Northern Ireland CIRIA C521 (Construction Industry Research and Information Association, 2000); Sustainable Urban Drainage Systems: Hydraulic, Structural and Water Quality Advice CIRIA C609 (Construction Industry Research and Information Association, 2004) and The SUDS Manual CIRIA C697 (Construction Industry Research and Information Association, 2007). SUDS techniques that would be implemented to reduce potential impacts during normal road operation are detailed below. For each outfall, a treatment train is proposed which would comprise a train of mitigation measures such as filter drains and catchpits, detention basins and treatment ponds (up to four in series).

5.1.6 Maintenance is an important factor in pollutant removal efficiency of treatment structures. An appropriate level of ongoing maintenance must be implemented to maximise removal efficiency over the life of the structure. Guidance on the minimum requirements is detailed in CIRIA guidance C609 (CIRIA, 2004) and C697 (CIRIA, 2007).

5.2 Water Quality Mitigation

5.2.1 The following mitigation measures have been incorporated into the scheme in reduce potential impacts on water quality.

Filter Drains and Catchpits

5.2.2 Filter drains consist of a perforated pipe laid in a trench backfilled with gravel and usually placed along the road verge. Filter drains can be used to convey highway drainage to the discharge point and also filter out pollutants such as suspended solids, hydrocarbons, iron. According to the DMRB (The Highways Agency et al. 1993), dissolved copper removal efficiency is 10-30% and total zinc removal efficiency is 70-80%. For the purpose of this assessment, the removal efficiencies assumed are 20% for dissolved copper and 75% for total zinc. Where necessary, piped carrier drains may be required to transfer surface water beneath the main carriageway and from the filter drains to designated outfall points.

5.2.3 Where the proposed scheme would be situated in a cutting, there is a greater risk of groundwater contamination. Where this is the case, the filter drain must be designed with an impermeable liner to minimise risk of pollution to groundwater.

5.2.4 All filter drains must be designed in accordance with the DMRB (The Highways Agency et al., 1993), taking cognisance of guidance contained in the CIRIA SUDS Design Manual C697 (CIRIA, 2007) and C521 (CIRIA, 2000), CIRIA C609 (2004) and CIRIA C648 (2006).

5.2.5 Catchpits consist of a small chamber with a sediment collection sump. These are designed to trap sediments and other debris and retain a proportion of the suspended solids present in the runoff and settle out hydrocarbons and metals. Catchpits are located at regular spacings (at intervals of no less than 90m) along filter drains and at the junctions of carrier drains.

Detention Basins/Treatment Ponds

5.2.6 Detention basins and treatment ponds must be constructed to discharge to each outfall. These end-of-line treatment systems provide biological treatment and removal of dissolved contaminants and nutrients. Detention basins are principally used to attenuate flows, while treatment ponds are required to treat the more polluted first flush component of road runoff. Further information on this can be found in Appendix A24.1 (Surface Water Hydrology).

5.2.7 A large proportion of pollutants in operational runoff are associated with sediment and therefore it is likely that the majority will accumulate in the filter drains and catchpits. Treatment ponds and detention basin systems provide both biological treatment and the removal, by settlement, of dissolved contaminants and nutrients.

5.2.8 Treatment ponds are reported to remove 50-80% of total zinc and dissolved copper from road drainage (CIRIA, 2004). For the purpose of this assessment, it is assumed that the efficiency removal is 65% for both total zinc and dissolved copper. The provision of detention basins in the treatment train will provide attenuation of peak flows, thereby reducing the risk of flooding in the receiving watercourse and promoting the deposition and removal of suspended solids. In general, all treatment systems are designed to attenuate flows for between 39 and 192 hours (design dependent) and to release water back into the receiving watercourse at pre-development rates, estimated as 4.3 l/s/ha (see Appendix 39.1 Surface Water Hydrology Appendix for more details). Treatment times are recommended for between 24-48 hours depending on the number of ponds and level of treatment required. Pollution removal rates decrease in efficiency as detention time in ponds increases, and studies have shown that a detention time beyond 24 hours does not result in a significant improvement in quality (CIRIA, 2004).

5.2.9 The required storage volume to treat road drainage (the treatment volume) is calculated based on the guidance contained in the CIRIA SUDS Design Manual (CIRIA, 2000) and the design guidance given in Treatment of Highway Runoff Using Constructed Wetlands (Environment Agency, 1998). CIRIA guidance states that ponds should be designed with storage volume, Vt (the volume generated by a mean annual flood) or in exceptional circumstances, 4Vt (four times the volume generated by a mean annual flood). In agreement, SEPA recommends that ponds draining particularly sensitive catchments be designed for storage volume 4Vt. Best design practice for pollutant removal, as detailed in CIRIA C609 (2004) and CIRIA C697 (2007), should be adhered to.

5.2.10 According to the Design Manual for Roads and Bridges (1998) the spillage risk removal efficiencies were determined to be 65% reduction for both total zinc and dissolved copper, irrespective of the treatment method.

Swales

5.2.11 Swales are vegetated surface features that drain water evenly off impermeable areas. The swale channel is broad and shallow and covered by grass or other suitable vegetation to slow down flows and trap pollutants (CIRIA, 2004). Swales can also be designed for a combination of conveyance, infiltration, detention and treatment of runoff (CIRIA, 2004). They are typically located next to highways but can also be constructed in landscaped areas within car parks and elsewhere.

5.2.12 Swales are generally effective at removing pollutants through filtration and sedimentation for frequent small storm events (CIRIA, 2004). For larger, less frequent storms of between a 50 and 10 per cent annual probability (1 in 2 and 1 in 10 year return period), they can act as a storage and conveyance mechanism. For larger storms with an annual probability of less than 10 per cent (return periods greater than 1 in 10 years), providing storage in swales may become impractical as catchment size increases and they are often used in conjunction with other techniques. They are reported to remove 70-90% total zinc, 50-70% dissolved copper and 60-90% of suspended solids from the road drainage (DMRB, 1998). For the purpose of this assessment, the removal efficiencies are assumed to be 70% for total zinc, 50% for dissolved copper and 60% for suspended solids (DMRB, 1998).

5.2.13 Swales are often integrated into the surrounding land use, for example public open space or road verges. Local wild grass and flower species can be introduced for visual interest and to provide a wildlife habitat. Care should be taken in the choice of vegetation as tussocks create local eddies, increasing the potential for erosion on slopes. Shrubs and trees can be planted but in this case the vegetated area will need to be wider and have a gentler slope (CIRIA, 2004).

Pollution Risk Removal Efficiencies

5.2.14 In order to assess the pollution risk from indicator metals as required by the DMRB (The Highways Agency et al. 2006), published removal efficiencies for each of the mitigation measures were utilised. As detailed in the methodology section, the two sources of information for determination of removal efficiencies include:

- Design Manual for Roads and Bridges (DMRB) 2006; and
- CIRIA C609 (2004) – Sustainable Drainage Systems; Hydraulic, Structural and Water Quality Advice.

5.2.15 Table 2.2 “Treatment Systems Efficiency” in the DMRB provides some broad estimate removal values for the complete range of treatment systems. Therefore, where possible, data from the recent CIRIA guide were used instead of the DMRB values as the values are based on current research.

5.2.16 The approach that was employed to develop the most appropriate treatment train for each discharge point used the relevant removal efficiencies for each of the components of the treatment train, taken from either CIRIA C609 (2004) or the DMRB (The Highways Agency et al.,2006). The point source pollution inputs representing the outfall of the road drainage system to watercourses were then modified to reflect the removal efficiency of each component of the proposed treatment train. The resulting concentration was compared to the required EQS levels and if required extra mitigation suggested. A summary of the required treatment train for each outfall can be found in the Water Quality Assessment Appendix A24.4.

5.2.17 Other proposed mitigation measures include:

- provision of scour protection at the drainage discharge outfall to protect the banks and bed of the receiving ditch and to limit erosion; and
- if herbicides are used, those recommended by SEPA for use near watercourses would be applied in line with manufacturer’s instructions to reduce pollution of watercourses.

5.3 Mitigation Summary

5.3.1 A summary of the required mitigation measures are detailed in Table 18.

Table 18 – Summary of Mitigation Measures for Operation

Type of Measure	Description
Prevent	Consideration of route location and road alignment to avoid impact to sensitive areas.
Reduce	A Sustainable Urban Drainage System (SUDS) should be provided to filter out pollutants and reduce the level of pollution from operational runoff entering watercourses. Filter drains and catch-pits should be constructed, where feasible, along the entire length of the proposed scheme. Detention basins and treatment ponds should be provided at appropriate outfalls prior to the discharge of road drainage into the receiving watercourse. This will attenuate peak flows from runoff to pre-development levels and will provide a suitable level of treatment of the road drainage prior to discharge. Regular maintenance of these treatment structures and the filter drains should be undertaken to ensure ongoing mitigation efficiency Regular maintenance of receiving watercourses and culverts to reduce the risk of blockages and thus increased flood risk Regular maintenance of detention basins and treatment ponds to ensure efficient operation and the settlement of solids and removal of pollutants (such as hydrocarbons). If herbicides are used, those recommended by SEPA for use near watercourses to be applied in line with manufacturer's instructions to reduce pollution of watercourses. Provision of scour protection at the drainage discharge outfall to protect the banks and bed of the receiving ditch and to limit erosion.

5.3.2 Mitigation, in the form of water quality treatment trains will treat road runoff prior to it being discharged to receiving watercourses. The following treatment trains have been proposed for outfalls to the River Dee catchment;

5.3.3 Burnhead Burn at chainage 200300: one detention basin and two treatment ponds and lining of the filter drains;

5.3.4 Jameston Ditch at chainage 204601 (tributary of the Burn of Ardoe): one detention basin, three treatment ponds and lining of the filter drains;

5.3.5 River Dee at chainage 102824: one detention basin and two treatment ponds and lining of the filter drains;

5.3.6 Gairn Burn at chainage 106085: one detention basin, four treatment ponds and the lining of the filter drain; and

5.3.7 Westholme Burn at chainage 108650 (tributary of Culter Burn): one detention basin, four treatment ponds, a swale and the lining of the filter drain.

6 Residual Impacts

6.1 General

6.1.1 This section presents the potential impacts of the scheme with the implementation of mitigation measures described in the previous section.

6.2 Residual Cumulative Impacts – SAC Watercourses

6.2.1 Table 19 and Figure 24.7d presents the predicted concentrations at five points through the SIMCAT model relating to the SAC watercourses. These points correspond to the points at which baseline and potential impact information have been extracted.

6.2.2 The model indicates that there is likely to be a 0% (Table 19) increase to concentration levels in the River Dee for the modelled pollutants, over the baseline scenario, with mitigation in place. Although the model predicts a 0% increase over baseline conditions the residual impacts are assessed as having negligible residual impact magnitude for all pollutants to reflect the potential uncertainties of the model and therefore of slight to negligible residual impact significance as detailed in Table 20.

6.2.3 The residual cumulative catchment impact upon the River Dee (Table 21) is predicted to be negligible which leads to an overall significance of slight to negligible. The matrix of nine models provided very similar results with mitigation, as indicated by the small (≤±0.1) predicted variance in results for all points on the River Dee.

6.2.4 Culter Burn outfall is predicted to have a 0% (Table 19) increase to concentration over the baseline scenario on water quality following the proposed mitigation measures. To reflect the potential uncertainties of modelling pollutants, a negligible residual impact is predicted indicating that overall there is a slight to negligible impact significance (Table 20) to this watercourse if the proposed mitigation measures are developed as part of the AWPR.

6.2.5 Crynoch Burn has the lowest flow and therefore the lowest dilution potential of all the SAC watercourses. For this reason, minor (≤±3%) increases in pollutant levels over baseline conditions would remain following mitigation. Following the application of mitigation, residual concentration predictions for Crynoch Burn show a potential maximum increase of 3% for pollutants in the burn. The predicted variance in simulated results for this burn is less than 1% and the magnitude of impact is predicted as being negligible for all pollutants. This leads to an overall residual impact significance of Slight to Negligible (Table 20).

6.2.6 The residual impact assessment demonstrates that with the proposed mitigation measures in place, the cumulative impact upon the water quality of the River Dee SAC is considered to be of Slight/Negligible significance. With the proposed scheme in place, concentration levels of pollutants within the modelled SAC watercourses are predicted to remain below EQS values for all determinants investigated.

Table 19 – Predicted Concentrations of Indicator Metals in the River Dee including Mitigation (output from SIMCAT model)

Model Node	Reading	Dissolved Copper			Total Zinc			Suspended Solids		
		(ug/l)	Predicted Variance on result ±	% Increase over Baseline	(ug/l)	Predicted Variance on Result ±	% Increase over Baseline	(mg/l)	Predicted Variance on Result ±	% Increase over Baseline
Culter Burn (at confluence with the River Dee)	Annual Average	1.14	0	0	5.80	0	0	3.21	0	0
	95 %ile	2.39	0	0	11.20	0	0	6.86	0	0
Crynoch Burn (at confluence with the River Dee)	Annual Average	0.44	0.01	2	2.24	0.04	3	3.51	0.01	0.3
	95 %ile	0.91	0	1	4.35	0.1	3	8.50	0	1
River Dee (at Milltimber)	Annual Average	1.63	0	0	13.28	0	0	3.68	0	0
	95 %ile	4.31	0	0	35.03	0	0	8.88	0	0
River Dee (Inchgarth Reservoir abstraction)	Annual Average	1.60	0	0	13.10	0	0	3.63	0	0
	95 %ile	4.26	0	0	34.60	0	0	8.78	0	0
River Dee (Bridge of Dee)	Annual Average	1.63	0	0	13.31	0	0	2.55	0	0
	95 %ile	4.32	0	0	35.10	0	0	4.44	0	0

Table 20 – Magnitude and Significance of Predicted Residual Cumulative Impact on each Pollutant for the Designated SAC Watercourses

Watercourse	Sensitivity	Parameter	Holistic Magnitude of Impact on Watercourse	Significance
Culter Burn (at confluence with the River Dee)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Susoended Sediment	Negligible	Slight/Negligible
Crynoch Burn (at confluence with the River Dee)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Susoended Sediment	Negligible	Slight/Negligible
River Dee (at Milltimber)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Susoended Sediment	Negligible	Slight/Negligible
River Dee (Inchgarth Reservoir abstraction)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Susoended Sediment	Negligible	Slight/Negligible
River Dee (Bridge of Dee)	High	Dissolved Copper	Negligible	Slight/Negligible
		Total Zinc	Negligible	Slight/Negligible
		Susoended Sediment	Negligible	Slight/Negligible

Table 21 – Overall Magnitude and Significance of Residual Cumulative Impact on the Designated SAC Watercourses

Watercourse	Sensitivity	Holistic magnitude of impact on watercourse	Significance
Culter Burn (at confluence with the River Dee)	High	Negligible	Slight/Negligible
Crynoch Burn (at confluence with the River Dee)	High	Negligible	Slight/Negligible
River Dee (at Milltimber)	High	Negligible	Slight/Negligible
River Dee (Inchgarth Reservoir abstraction)	High	Negligible	Slight/Negligible
River Dee (Bridge of Dee)	High	Negligible	Slight/Negligible

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