Aberdeen Western Peripheral Route

Appendix A24.6 – Sediment Modelling

B1033200 July 2006

Jacobs UK Ltd 95 Bothwell Street, Glasgow G2 7HX

Tel 0141 204 2511 Fax 0141 226 3109

Aberdeen Western Peripheral Route
Environmental Statement Appendices 2007
Part C: Southern Leg
Appendix A24.6 – Sediment Modelling

Contents

1 Introduction

1.1 General Background

1.1.1 This report is a technical appendix of 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 presents an assessment of the risk to the water quality of the River Dee as a result of potential sediment release into the river from the proposed mainline approach road construction sites. Potential increases in total suspended solids (TSS) in the river are modelled, as well as subsequent concentrations with mitigation measures in place in order to reduce sediment concentrations to within acceptable limits. Further assessment of the impact of fine sediment release and impact to morphological diversity is presented in Appendix A24.3 (Fluvial Geomorphology).

1.1.3 It should be noted that the model only addresses the construction of the approach roads rather than the bridge construction site. This is because the potential release of suspended solids during the bridge construction is difficult to quantify, and therefore makes it highly impractical to include in a quantitative sediment modelling assessment. Rather, the potential for suspended solids release during the bridge construction will be dealt with in a detailed method statement which will form part of the contractor's requirements and will be agreed with SEPA prior to the start of works on site. This activity will be regulated by SEPA under the Engineering Activities section of the Controlled Activities Regulations (CAR) (SEPA, 2007).

1.2 Assessment Aims

1.2.1 The purpose of the sediment modelling is to investigate the impact to suspended sediment loads in the River Dee from the construction of the mainline approach road in order to define a maximum allowable concentration for outfall into the river based on mean flow (Qmean) river conditions (Figure 24.6).

1.2.2 Mathematical modelling, with respect to sediment transport, of the downstream watercourse will allow assessment of the possible impact to sensitive species. Sensitive species identified in the River Dee for this assessment are migratory salmonids (e.g. *Salmo salar*) and freshwater pearl mussels (*Margaritifera margaritifera*).

1.2.3 This report should be read in conjunction with Chapter 24 (Water Environment) as well as Appendix A24.1 (Surface Water Hydrology), Appendix A24.3 (Fluvial Geomorphology), Appendix A24.4 (Water Quality) and Appendix A40.9 (Freshwater Ecology).

2 Approach and Methods

2.1 General Approach

2.1.1 The assessment has been conducted using the general methodology detailed in Chapter 5 (Method of Assessment), 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 assessment used will follow the basic methodology detailed below;

- assess the baseline;
- assess potential impacts on the River Dee;
- provide mitigation measures; and

- assess the residual impacts on the River Dee with the implementation of mitigation measures.

2.1.2 For the purposes of this assessment, the indicative criteria used to assess the sensitivity of the receiving watercourse is defined in Table 1, while the magnitude of the predicted impacts is defined in Table 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 as defined in Table 3. The magnitude of impact, detailed in Table 2, is assigned based on the tolerance information of the most sensitive species present in the study area, namely freshwater pearl mussels. The assessment methodology has been discussed and agreed with SEPA.

Table 1: Criteria to Assess the Sensitivity of Water Features

Sensitivity	Criteria
High	Large or medium watercourse with pristine or near pristine water quality, Class A1 or A2, respectively. Water quality not significantly affected by anthropogenic factors. Water quality complies with Dangerous Substances Environmental Quality Standards (EQS) (see Appendix A24.3 Water Quality for details). 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 EC designated freshwater fisheries. Also includes all nature conservation sites of national importance designated by statute including Sites of Special Scientific Interest and National Nature Reserves.
Medium	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	Heavily modified watercourses or drainage channel with poor water quality, resulting from anthropogenic factors, corresponding to Classes B, C or 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.

Table 2: Criteria to Assess the Magnitude of Predicted Impact on Water Quality and associated Ecology (FWPMs)

Magnitude	Criteria
High	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. For the purposes of this assessment, a predicted suspended solids concentration of above 30mg/l(exposure longer than 12 hours) will be considered a high magnitude impact (refer to Table 4).
Medium	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. For the purposes of this assessment, a predicted suspended solids concentration of above 30mg/l(exposure for 0-12 hours) will be considered a medium magnitude impact (refer to Table 4).
Low	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. For the purposes of this assessment, a predicted suspended solids concentration of between 26-29mg/lover a short period of time will be considered a low magnitude impact (refer to Table 4).
Negligible	Very slight change from the baseline conditions such that there is no discernible effect upon the watercourse's ecology. No change in classification. For the purposes of this assessment, a predicted suspended solids concentration of between 0-25mg/lover a short period of time will be considered a negligible magnitude impact (refer to Table 4).

Table 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 methodology adopted to assess the maximum allowable concentration for sediment release into the River Dee, from the mainline approach road construction sites, includes the following stages:

- data collation of elements such as proposed construction site alignment, dimensions, slope, site bed gradation;
- hydrological assessment of the peak runoff and drainage area of the construction sites for a range of return period rainfall events;
- construction of the one-dimensional (1-D) hydraulic model to represent the area of disturbance during construction of the mainline approach road for the River Dee;
- assessment of sediment concentrations for input into the mathematical model representing the main pathway for runoff to the main watercourse from the construction area;
- construction of the sediment transport models to include the construction site sediment generation together with the main watercourse;
- assessment of differing input concentrations from the construction sites and the resultant concentrations within the River Dee (after mixing);
- assessment of the magnitude and significance of predicted impacts on water quality and associated habitats, based on the criteria given in Table 2 and Table 3;
- assessment of the resultant concentrations within the River Dee (after mixing), with proposed mitigation measures, downstream of the outfall. Consequently, an assessment of the magnitude and significance of residual impacts on water quality and associated habitats, based on the criteria given in Table 2 and Table 3; then,
- potential concentrations will then be compared to published guidance (Table 4) to ascertain likely maximum allowable concentrations for site outfall, given mean flow conditions in the River Dee.

2.2.2 Potential long-term impacts on water quality during operation of the scheme are addressed in Appendix A24.3 (Fluvial Geomorphology) and Appendix A24.4 (Water Quality).

2.2.3 Guidance on the tolerances of freshwater pearl mussels to suspended solids has been taken from literature prepared by Skinner et al. (2003).

Table 4: Tolerance of FWPMs to Suspended Solid loads

Suspended Sediment (mg/l)	Risk to Freshwater Pearl Mussels and their Habitat
>30	Unacceptable risk

Source: Skinner, Young and Hastie (2003)

2.2.4 Guidance on the tolerances of salmon to suspended solids has been taken from the Canadian Department of Fisheries and Oceans (DFO, 2000). This is based on an assessment of risk to fish and their habitat of elevated levels of suspended solids from mining operations in the Yukon, US. 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 25mg/l will have no harmful effects on fish. Levels of 25-80mg/l are acceptable as a rule of thumb, 80-400 mg/l are unlikely to support good fisheries and levels over 400mg/l generally will not support substantial fish populations (refer to Appendix A25.9: Freshwater Ecology for further information).

2.2.5 As the guidelines for suspended load concentrations are more stringent for freshwater pearl mussels (see Table 4), the magnitude, and resulting significance, of impact has been assigned based on these concentration levels.

Table 5: Suspended Sediment Levels for Fish and their Habitat

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

Source: DFO (2000)

2.3 Construction Site Details

2.3.1 1-D mathematical models, using ISIS software, have been constructed to represent the proposed construction sites. The estimated areas of the construction sites are summarised in Table 6 (also refer to Figure 24.6). It is assumed in the assessment that all rainfall falling onto these sites will drain to the River Dee.

Table 6: Construction Site Details for Assessment

Item	River Dee South	River Dee North1	River Dee North2
Length (m)	Approx 2000	Approx 725	Approx 1150
Average width (m)	Approx 51	Approx 90	Approx 90
Area (m^2)	Approx 102,000	Approx 65,250	Approx 103,500
Slope (%)	Approx 2.78% between chainages 100000m and 102000m	Approx 0.1% between chainages 102025m and 102750m	Approx 6.7% between chainages 102750 and 103900m
Figures	Figure 24.6	Figure 24.6	Figure 24.6

2.3.2 The construction sites for the mainline approach road located on either side of the River Dee have been designated as 'North1', 'North2' and 'South' for the purposes of mathematical modelling, as shown in Table 6 and Figure 24.6. However, in order to model the construction sites representatively, the sediment transport models for North1 and North2 have been modelled together. Therefore the construction sites will be referred to as 'North' and 'South' for the remainder of this report.

2.4 Hydrology

2.4.1 The rainfall runoff has been used to derive predicted peak flows from the contributing construction sites. The assessment has also assumed that the ground surface is 'bare and untilled', i.e. with no vegetation (Rational Method).

2.4.2 It is assumed that the worst case scenario, with respect to the impact of sediment being released into the River Dee, is likely to occur when a localised high magnitude rainfall event occurs over the construction site whilst flows in the receiving watercourse are relatively low (i.e. Qmean). This combination of factors would result in least dilution of released sediments.

2.4.3 Therefore, sediment input to the receiving watercourse is assumed to be driven by a localised severe rainfall event, not a catchment-wide event, and Qmean design flows have been modelled in the receiving watercourse. The range of rainfall events considered give an overview of possible suspended load concentrations that may be released into the River Dee from each construction site. The peak flows for the events considered: 50% Annual Expected Probability (%AEP) (1 in 2 year event) (low), 10% AEP (1 in 10 year event) (low-medium), 1% AEP (1 in 100 year event) (medium) and the 0.5% AEP (1 in 200 year event) (high) are summarised in Table 7.

Table 7: Peak Runoff from Construction Sites

Return Period (years)	Predicted Peak Flows (Bare and Untilled)			
	River Dee South (m^3/s)	River Dee North1 (m^3/s)	River Dee North2 (m^3/s)	Total Dee Construction drainage area (m^3/s)
1:200	0.35	0.22	0.58	1.15
1:100	0.32	0.21	0.54	1.07
1:10	0.21	0.13	0.35	0.69
1:2	0.12	0.08	0.20	0.4

2.5 Hydraulic Model

2.5.1 A simple 1-D hydraulic model has been constructed, using ISIS software, to represent the construction sites. ISIS software is widely recognised and utilised within the water industry, in particular fluvial modelling. To simulate the distribution of released sediments within the River Dee, the mathematical model constructed to conduct the flood risk assessment has been adopted (refer to Appendix A24.2: Hydrodynamic Modelling).

2.5.2 In general, the following modelling assumptions have been made:

- The base flow in the main river hydraulic model is 46.11m^3/s. This is considered to represent a mean flow condition and therefore can only offer limited dilution of any released sediments.
- The mathematical model has been constructed based on topographical survey data from May 2004 and 2006 (refer to Appendix A24.2).
- The main river hydraulic model has been coupled with the sediment transport models to simulate sediment concentrations and transport within the river.
- The sediment load from the construction sites is assumed to enter the main river at the proposed bridge crossing location (NJ 859004).
- During the mean flow condition in the main river, the movement of bed sediments is considered to be minimal as the river bed is assumed to be armoured and relatively stable. This assumption is based on discussions with Professor Brian Willets, formerly of Aberdeen University (Brian Willets, pers. comm., 2004).

2.6 Sediment Model

Model of Construction Sites

2.6.1 The model assumes an average slope, following the proposed road gradient, and that surface water runoff will drain to the River Dee.

2.6.2 In order to model potential sediment transport from the construction sites, a representative soil particle size distribution (PSD) is required, which is assumed to form the bed of the mathematical model.

2.6.3 The representative PSD for construction site 'North' has been taken from borehole ST56 (11.15m depth sample), as supplied by Norwest Holst Ltd from ground investigations undertaken in 2006 (Figure 24.6). The stratum at this location is described as 'medium dense, brownish grey, gravelly medium to coarse SAND' (Norwest Holst, 2006). The grading analysis of the sample is summarised in Table 8.

Table 8: Particle size distribution from borehole taken within 'North' construction site area

Particle size	% of sediment passing sieve size
Silt (0.063 mm)	1%
Sand (2 mm)	81%
Gravel (64 mm)	18%
Cobbles (256 mm)	0%

Source: Norwest Holst (2006)

2.6.4 On the south side of the river, borehole KPH07 has been adopted (Figure 24.6). The stratum at this location is described as 'brown, silty, very sandy GRAVEL with cobble present' (Norwest Holst, 2006). The grading analysis of the sample is summarised in Table 9.

Table 9: Particle size distribution from borehole taken within 'South' construction site area

Particle size	% of sediment passing sieve size
Silt (0.063 mm)	16%
Sand (2 mm)	23%
Gravel (64 mm)	23%
Cobbles (256 mm)	38%

Source: Norwest Holst (2006)

2.6.5 In general, the following sediment transport modelling assumptions have been made:

- As the mean diameter of the sediment is greater than 0.15 mm, Engelund-Hansen sediment transport equation has been used to compute sediment transport within the watercourses, as recommended by the software manufacturers (refer to ISIS Sediment User Manual, Halcrow/HR Wallingford, 1999 for further details).
- Sediment transport has been modelled assuming a moderately graded, sorted algorithm with an active layer distribution. This means that erosion and deposition rates, i.e. the sediment transport rate, at the surface of the channel bed can be modelled at each channel section by inputting the proportion of sediment that makes up each size fraction (refer to ISIS Sediment User Manual, Halcrow, H.R. Wallingford, 1999 for further details).

Main River Model

2.6.6 The River Dee 1-D mathematical model has been constructed for the purposes of the AWPR flood risk assessment, using ISIS software. This model has not been calibrated for sediment modelling purposes, as there is no continuous dataset available for sediment trends in the River Dee. Only the discrete suspended solid concentration readings undertaken by SEPA are available, taken on average 12 times annually. This data is considered to be of insufficient detail to calibrate the sediment model, therefore sensitivity analyses have been undertaken to further understand the particular limitations and sensitivity of the model, given the assumptions and inputs used. Whilst this is a generally accepted method in the absence of calibration data, it would be preferable to calibrate the model for sediment transport purposes, rather than simply for hydraulic conditions. This would require suspended and bed sediment samples to be taken from the river, together with flow readings, for a range of river flows, and ideally for the duration of a storm at more than one location. However, this modelling investigation is only a comparative assessment, i.e. a comparison of baseline conditions with potential and residual impacts, and therefore it is considered that the model is sufficiently appropriate for use.

2.6.7 As the purpose of the sediment transport modelling is to assess the concentrations and distribution of sediment released into the main river due to construction activities, it is assumed that the main river bed is fixed, i.e. bed erosion of the natural river bed is prohibited. Due to the armoured, gravel bed nature of the river in this section, this is a reasonably appropriate assumption under low velocity conditions.

Impact Assessment

2.6.8 The assessment of potential impacts is conducted assuming that no mitigation would be in place during the construction of the mainline approach road. Residual impacts are assessed with the implementation of mitigation, which would be the form of Sustainable Urban Drainage Systems (SUDS).

2.6.9 Published guidance (Section 9.11.1, Ponds and Detention Basins, Sustainable Drainage Systems, CIRIA C609, 2004) on removal efficiency for SUDS measures have been adopted to reflect the effectiveness of mitigation measures. The residual model simulations have been carried out by considering a reduction factor equal to the mitigation efficiencies to the sediment loads reaching the watercourse. CIRIA C609 (2004) states that retention time beyond 24 hours does not provide any significant improvement in water quality and removal rates significantly decline. Removal rates for total suspended solids (TSS) are reported by Grizzard et al. (1986), quoted from Schueler (2000b), to be approximately 75% after a detention time of 24 hours (cited in CIRIA C609, 2004). Therefore, each level of mitigation has been modelled assuming a TSS removal efficiency (reduction factor) of 75% (see Table 10).

Table 10: TSS Pollutant Removal Efficiency (CIRIA, 2004)

Level of mitigation	% TSS remaining	Reduction factor applied
No mitigation	100	
1 Treatment Pond	25	100 – 75% = 25
2 Treatment Ponds	6.25	25 – 75% = 6.25
3 Treatment Ponds	1.56	6.25 – 75% = 1.56 (and so on)

2.7 Limitations to Assessment

Mathematical Model Limitations

2.7.1 In general, mathematical models are based on assumptions made during their development and application, and therefore have limitations which should be taken into account when interpreting the model results (see Appendix A24.2 Hydrodynamic Modelling for details). 1-D river models, such as ISIS, calculate a single average velocity and a single water level for each model cross section. However, in some areas the flow structure may be complex, particularly near structures where three-dimensional (3-D) effects may be dominant. Such localised effects include bridge scours, and effects of dunes and ripples which cannot be simulated in 1-D models, and this should be taken into account when using model predictions for sedimentation assessment purposes.

2.7.2 Additionally, ISIS assumes complete mixing across the channel and hence does not model the lateral spread of a sediment plume. Instead, it can only predict the passage of the plume downstream.

3 Baseline

3.1.1 The River Dee rises in the Cairngorms to the west of Braemar and flows eastwards before entering the North Sea at Aberdeen. It drains a catchment area of approximately 1,833km² up to the proposed road crossing.

3.1.2 The baseline sediment load in the watercourse has been abstracted from the total suspended solids (TSS) monitoring data provided by SEPA (2005). The estimated TSS corresponding to Qmean flow in the River Dee is 2.9 parts per million (ppm) at Milltimber. Maximum and minimum TSS values recorded are 26ppm and 1ppm, respectively (see Table 11).

Table 11: Total Suspended Solids for the River Dee (SEPA, 2005)

Parameter (Units)		River Dee at Milltimber
Total Suspended Solids (TSS) (mg/l)	Aver.	3
	Max.	26
	Min.	1

3.1.3 The section of the River Dee directly relevant to the assessment is shown in Figure 24.6. Upstream of the proposed bridge crossing, the river flows through predominantly agricultural land collecting water from several small tributaries. The River Dee and its surrounding area are also used for recreational purposes, including fishing and canoeing.

3.1.4 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).

3.1.5 The River Dee provides exceptional natural habitat conditions and water quality for the sustainable existence of populations of native brown trout, sea trout and migratory salmon (refer to Appendix A25.9: Freshwater Ecology). Spot sampling water quality at Milltimber is assessed as Class A2, and has been classed as A1/A2 by SEPA, with good biological and excellent chemical and aesthetic characteristics (SEPA, 2005; refer to Water Quality Annexes 26 and 27 for SEPA Water Quality classification criteria).

3.1.6 As the river supports populations of freshwater pearl mussels (Appendix A25.10: Freshwater Pearl Mussels), Atlantic salmon (Appendix A25.9: Freshwater Ecology) and otters (Appendix A25.5: Otter Report), the river is considered to be a Natura 2000 site and is designated as a Special Area of Conservation (SAC). The boundary of the SAC designation is the edge of a zone that extends 5m inland from the riverbanks of the Dee and a number of its tributaries (refer to Figure 25.1b). It also has a status of District Wildlife Site (DWS) and Site of Interest to Natural Science (SINS).

3.1.7 Therefore, the sensitivity of the River Dee has been classed as High.

4 Potential Impacts

4.1 General

4.1.1 It is emphasised that the potential impacts on water quality from sediment, generated by runoff, from the construction sites are considered to result in a short term impact upon water quality. However, elevated levels of sediment in the water column would have long-term detrimental effects on sensitive ecosystems that are dependent on water quality, such as the freshwater pearl mussel (Table 2).

4.1.2 For the purposes of the modelling assessment, it is assumed that 'sheet flow' of the surface water runoff occurs over the whole construction area following a rainfall event. This approach assumes that a large quantity of material is being transported and released into the main watercourse, which is considered an unlikely and unrealistic scenario.

4.1.3 Therefore, a number of sensitivity runs have been undertaken, considering the potential area of the construction sites that may contribute to sediment transport. Although it is difficult to quantify, it may be realistic to consider that say, 25% of the construction site area is likely to be mobile for the transport of surface sediments. This assumption is based on the following:

- It is likely that underlying soils within a large proportion of the construction site will be consolidated, i.e. compacted, due to the movement of heavy construction plant. This is likely to reduce the erodability of the soil, which cannot be simulated within the mathematical model.
- Uniform overland sheet flow would require the soil strata to be fully saturated and the contours of the construction site to be even, with a gradient in one direction. It is more likely that the construction site will be irregular and surface water runoff would initially follow the contours of the construction site and after a period of time collate in naturally formed drainage channels. In addition, the contractor may also form artificial channels to assist in the drainage of the site.

4.2 Impact Assessment

4.2.1 This section summarises the predicted sediment concentrations likely to runoff into the River Dee from both construction sites (North and South), as a result of a range of rainfall events of differing magnitude. It is considered appropriate to adopt the '25% construction site' scenario, as this is assumed to be a reasonable representation of the construction site area that is likely to be mobile for the transfer of surface sediments.

4.2.2 Table 12 summarises the combined sediment concentrations likely to runoff into the river if construction of the mainline approach road on either side of the river was to occur simultaneously. Sediment concentrations are calculated at three modelling locations, A, B and C: in the river at the point of release (the proposed mainline bridge crossing); and at two locations downstream – Dee3 and Dee5, respectively (see Figure 24.6).

Table 12 – Combined Sediment Concentrations at 25% Sensitivity (based on assumption that 25% of the construction site area will be mobile for surface runoff)

Return Period Rainfall Event (years)	Sediment Concentration (ppm) at Location A: Proposed Bridge Crossing	Magnitude (25%)	Significance	Sediment concentration (ppm) at Location B: Dee3	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location C: Dee5	Magnitude (25%)	Significance
Dee North and South combined									
200yr	688	Medium	Moderate/ Substantial	688	Medium	Moderate/ Substantial	166	Medium	Moderate/ Substantial
100yr	590	Medium	Moderate/ Substantial	590	Medium	Moderate/ Substantial	159	Medium	Moderate/ Substantial
10yr	265	Medium	Moderate/ Substantial	265	Medium	Moderate/ Substantial	97	Medium	Moderate/ Substantial
2yr	105	Medium	Moderate/ Substantial	105	Medium	Moderate/ Substantial	60	Medium	Moderate/ Substantial

4.2.3 The results in Table 12 show that if no mitigation is implemented, sediment concentrations within the River Dee, at each of the specified monitoring locations, exceed the maximum concentrations set for this assessment, i.e. 30ppm (Table 4).Consequently, the magnitude of direct impact on water quality and indirect impact on aquatic ecology are both considered to be of medium magnitude, with reference to the defined criteria for all rainfall return periods (Table 2). The impact significance is therefore assessed as Moderate/Substantial (refer to Table 3).

4.2.4 It is also noticeable that between Monitoring Locations A and B, there is no change in concentration, indicating that minimal dispersal and dilution has occurred over this distance. It also suggests that the river has sufficient energy to transport the total volume of suspended sediment downstream between both locations. However, there is a significant reduction in sediment concentrations at Location C, suggesting that the dilution and dispersal capacity of the river over this distance has a more pronounced effect and that a significant proportion of the sediment may be deposited.

4.2.5 Sediment release into the River Dee, from the proposed construction sites, is predicted to exceed the maximum threshold concentration value of 30ppm. To reduce the level of potential impact, mitigation measures are considered in the next section.

5 Mitigation

5.1 Water Quality Mitigation

5.1.1 In order to control surface water runoff (SWR) from the site, runoff will be collected in temporary constructed drainage channels leading to mitigation treatment ponds.

5.1.2 In order to reduce sediment concentrations to within acceptable limits, i.e. less than 30ppm, mitigation will consist of a ‘train’ of treatment ponds in series before outfall to the River Dee. It is assumed for this assessment that the sediment removal efficiency of each individual pond is in excess of 75% (see Section 2) and this should be achievable by adopting the guidelines in CIRIA C609 (2004) and CIRIA C697 (2007) during the design stage. Additionally, the ponds will be established and functional before construction commences. Further guidance on this is given in Appendix A24.4 (Water Quality).

5.1.3 In addition, SEPA have requested that real time monitoring of sediment concentrations during construction is undertaken before, and after, treatment to assess whether the sediment load in the treated runoff being released into the river is within acceptable limits, particularly during rainfall events. This would allow for early warning of any incidents of concentrated sediment release. It is proposed that the monitoring station would be installed upstream of the first treatment pond and downstream of the final treatment pond within the river (being upstream of the pearl mussel population). A warning trigger value and absolute maximum would be employed, at which time works would be stopped and an emergency response plan activated. This would include the installation of a bubble curtain in the vicinity of the mussel beds, which would be activated by the early warning trigger system in times of extreme low flow (i.e. less than Qmean), which may result in raised sediment concentrations.

6 Residual Impacts

6.1 Impact Assessment

6.1.1 Table 13 presents the combined predicted sediment concentrations (25% sensitivity) being released into the River Dee, with the implementation of two treatment ponds in series, on either side of the river.

6.1.2 The results in Table 13 show that with the implementation of two treatment ponds, predicted sediment concentrations exceed the maximum allowable concentration of 30ppm for the two higher return period rainfall events – 0.5% AEP and 1% AEP events (200yr and 100yr return rainfall periods, respectively). This results in an impact magnitude of medium and therefore an impact significance of Moderate/Substantial, with reference to Tables 2 and 3, respectively. However, sediment concentrations are within the acceptable tolerance levels of freshwater pearl mussels for the 10% AEP and 50% AEP events (10yr and 2yr return rainfall periods, respectively), which, as it suggests, are likely to occur with much higher frequency. This results in an impact magnitude of negligible, with reference to the defined criteria in Table 2 and therefore an impact significance of Slight/Negligible (Table 3).

6.1.3 In order to meet the required tolerance levels of freshwater pearl mussels for all rainfall events, an extra level of mitigation was incorporated into the North construction site. Table 14 presents the predicted sediment concentrations being released into the River Dee, with the implementation of three treatment ponds and two treatment ponds in series before outfall to the river, for the North and South construction sites, respectively.

6.1.4 The results in Table 14 show that the combined sediment release from all construction sites is predicted to be below the maximum allowable concentration of 30ppm. Consequently, the magnitude of direct impact on water quality and indirect impact on aquatic ecology are both considered to be negligible, with reference to the defined criteria, for all rainfall return period flows (Table 2). Therefore, impact significance is assessed as Slight/Negligible (Table 3).

6.1.5 It is important to recognise that the predicted concentrations, which have been modelled in the River Dee, are solely the result of runoff during construction of the mainline approach road. However, there will be various other construction activities likely to be occurring simultaneously in the vicinity of the River Dee, which may add to the overall concentrations within the river, and ultimately having a deleterious impact on the freshwater pearl mussel (fwpm) population. The construction activities in this section of the scheme would include the following, although the list is not exhaustive (refer to Chapter 24 and Appendices 24.3 Fluvial Geomorphology and 24.4 Water Quality for detailed information):

- Blaikiewell Burn bridge construction;
- Burnhead Burn outfall and culvert construction;
- Kingcausie Burn realignment;
- Milltimber Burn culvert and realignment; and
- River Dee outfall and bridge construction.

Table 13: Combined Sediment Concentrations (25% sensitivity, with two treatment ponds)

Return Period Rainfall Event (years)	Sediment Concentration (ppm) at Location A: Proposed Bridge Crossing	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location B: Dee3	Magnitude (25%)	Significance	Sediment concentration (ppm) at Location C: Dee5	Magnitude (25%)	Significance
Dee North and South combined									
200yr	46	Medium	Moderate/ Substantial	46	Medium	Moderate/ Substantial	46	Medium	Moderate/ Substantial
100yr	40	Medium	Moderate/ Substantial	40	Medium	Moderate/ Substantial	40	Medium	Moderate/ Substantial
10yr	19	Negligible	Slight/ Negligible	19	Negligible	Slight/ Negligible	19	Negligible	Slight/ Negligible
2yr	9	Negligible	Slight/ Negligible	9	Negligible	Slight/ Negligible	9	Negligible	Slight/ Negligible

Table 14: Combined Sediment Concentrations (25% sensitivity, with three treatment ponds (North) and two treatment ponds (South))

Return Period Rainfall Event (years)	Sediment Concentration (ppm) at Location A: Proposed Bridge Crossing	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location B: Dee3	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location C: Dee5	Magnitude (25%)	Significance
Dee North and South combined									
200yr	25	Negligible	Slight/ Negligible	25	Negligible	Slight/ Negligible	25	Negligible	Slight/ Negligible
100yr	22	Negligible	Slight/ Negligible	22	Negligible	Slight/ Negligible	22	Negligible	Slight/ Negligible
10yr	11	Negligible	Slight/ Negligible	11	Negligible	Slight/ Negligible	11	Negligible	Slight/ Negligible
2yr	6	Negligible	Slight/ Negligible	6	Negligible	Slight/ Negligible	6	Negligible	Slight/ Negligible

6.1.6 There is potential for the release of suspended sediment from these construction activities to increase the sediment concentrations entering the River Dee, upstream of the freshwater pearl mussel beds. The cumulative impact of these activities may result in TSS concentrations exceeding the acceptable limits for freshwater pearl mussels.

6.1.7 Given the high sensitivity of the River Dee and the presence of freshwater pearl mussels at this location, it is recommended that one of the constraints applied to the successful contractor will be for phased construction work, in order to minimise the risk of sediment release. Consequently, it has been assumed that only one side of the mainline approach road (either North or South) will be 'opened up' for construction at any time.

6.1.8 Table 15 presents the predicted sediment concentrations being released into the River Dee from the North construction site, with the implementation of three treatment ponds before outfall.

6.1.9 Table 16 presents the predicted sediment concentrations being released into the River Dee from the South construction site, with the implementation of two treatment ponds before outfall.

6.1.10 The results in Table 15 and Table 16 show that with the implementation of the proposed mitigation measures, sediment concentrations associated with each construction site are predicted to be within acceptable limits, i.e. less than 30ppm. Consequently, the magnitude of direct impact on water quality and indirect impact on aquatic ecology are both considered negligible, with reference to the defined criteria in Table 2. Impact significance is thus assessed as Slight/Negligible (Table 3).

6.1.11 Although the concentrations for the South construction site are not significantly lower than the combined construction site concentrations (Table 14), in order to reduce the potential sediment load reaching the watercourse phasing the mainline road construction is recommended.

Table 15 - Sediment Concentrations (25% sensitivity, with three treatment ponds (North))

Return Period Rainfall Event (years)	Sediment Concentration (ppm) at Location A: Proposed Bridge Crossing	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location B: Dee3	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location C: Dee5	Magnitude (25%)	Significance
Dee North									
200yr	13	Negligible	Slight / Negligible	13	Negligible	Slight / Negligible	13	Negligible	Slight / Negligible
100yr	11	Negligible	Slight / Negligible	11	Negligible	Slight / Negligible	11	Negligible	Slight / Negligible
10yr	7	Negligible	Slight / Negligible	7	Negligible	Slight / Negligible	7	Negligible	Slight / Negligible
2yr	4	Negligible	Slight / Negligible	4	Negligible	Slight / Negligible	4	Negligible	Slight / Negligible

Table 16 - Sediment Concentrations (25% sensitivity, with two treatment ponds (South))

Return Period Rainfall Event (years)	Sediment Concentration (ppm) at Location A: Proposed Bridge Crossing	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location B: Dee3	Magnitude (25%)	Significance	Sediment Concentration (ppm) at Location C: Dee5	Magnitude (25%)	Significance
Dee South									
200yr	23	Negligible	Slight / Negligible	23	Negligible	Slight / Negligible	23	Negligible	Slight / Negligible
100yr	20	Negligible	Slight / Negligible	20	Negligible	Slight / Negligible	20	Negligible	Slight / Negligible
10yr	10	Negligible	Slight / Negligible	10	Negligible	Slight / Negligible	10	Negligible	Slight / Negligible
2yr	5	Negligible	Slight / Negligible	5	Negligible	Slight / Negligible	5	Negligible	Slight / Negligible

6.2 Construction Mitigation

6.2.1 In addition to the mitigation detailed in Section 5, the following best practice guidance is also recommended:

- one mainline approach road (North or South) should be constructed at a time, if possible;
- areas cleared of vegetation and ground disturbance will be kept to a minimum;
- silt fences or gravel bags will be erected around all stockpiles;
- stockpiles of materials will be located away from watercourses;
- upslope silt fences or catch drains would be used where there is more significant risk from polluted runoff, in order to divert clean runoff away from work areas;
- erection of exclusion fencing to prevent damage to adjacent areas;
- inspection of all erosion controls on a weekly basis and after rainfall events, and these should be cleaned out when necessary. Erosion control devices will be maintained and regularly inspected regularly and cleaned of silt as necessary;
- progressive rehabilitation of exposed areas throughout the construction period. Restoration will take place as soon as possible after the work has been completed.
- Adherence to mitigation measures as detailed in Appendix A24.1 (Surface Water Hydrology), Appendix A24.2 (Hydrodynamic Modelling), Appendix A24.3 (Fluvial Geomorphology), Appendix A24.4 (Water Quality) and Appendix A25.9 (Freshwater Ecology).

6.2.2 Pollution control through best practice on site would be in liaison with SEPA, following the Pollution Prevention Guidelines (PPGs) listed below:

- PPG01 General Guide to the Prevention of Water Pollution;
- PPG04 Disposal of Sewage Where No Foul Sewer is Available;
- PPG05 Works In Near or Liable to Affect Watercourses;
- PPG06 Working at Construction and Demolition Sites;
- PPG07 Refuelling Facilities;
- PPG08 Storage and Disposal of Used Oils;
- PPG10 Highway Depots;
- PPG13 High Pressure Water and Steam Cleaners;
- PPG18 Control of Spillages and Fire Fighting Runoff; and,
- PPG21 Pollution Incident Response Planning.

6.3 Summary

6.3.1 The River Dee is considered to be an ecologically sensitive river with the presence of freshwater pearl mussels and migratory fish. The significance of potential impacts at the location of the freshwater pearl mussel beds, incorporating mitigation for various return periods, is presented in Tables 17-19.

Table 17: Overall Residual Impacts for Combined Construction Sites

		Sensitivity	Magnitude	Period of Impact	Significance
River Dee North (3TPs) and South (2TPs) combined					
Sediment Impact	Construction site short term sediment impacts with mitigation measures				
	200yr	High	Negligible	Short-term/long-term	Slight/Negligible
	100yr	High	Negligible	Short-term/long-term	Slight/Negligible
	10yr	High	Negligible	Short-term/long-term	Slight/Negligible
	2yr	High	Negligible	Short-term/long-term	Slight/Negligible

Table 18: Residual Impacts for Construction Site 'North'

		Sensitivity	Magnitude	Period of Impact	Significance
River Dee North (3TPs)					
Sediment Impact	Construction site short term sediment impacts with mitigation measures				
	200yr	High	Negligible	Short-term/long-term	Slight/Negligible
	100yr	High	Negligible	Short-term/long-term	Slight/Negligible
	10yr	High	Negligible	Short-term/long-term	Slight/Negligible
	2yr	High	Negligible	Short-term/long-term	Slight/Negligible

Table 19: Residual Impacts for Construction Site 'South'

		Sensitivity	Magnitude	Period of Impact	Significance
River Dee South (2TPs)					
Sediment Impact	Construction site short term sediment impacts with mitigation measures				
	200yr	High	Negligible	Short-term/long-term	Slight/Negligible
	100yr	High	Negligible	Short-term/long-term	Slight/negligible
	10yr	High	Negligible	Short-term/long-term	Slight/Negligible
	2yr	High	Negligible	Short-term/long-term	Slight/Negligible

6.3.2 In summary, the impacts of the short-term and long-term sediment impacts on water quality from each construction site, and when combined, is assessed as Slight/Negligible. This assumes that the mitigation measures described in this report are effectively implemented.

6.3.3 The indirect, long-term impact significance upon aquatic ecology in the River Dee is considered to be Slight/Negligible for all return period events.

7 References

Alabaster, J.S. and Lloyd, R. (1982) Water Quality Criteria for Freshwater Fish. Butterworths, London.

CIRIA, (2004) Sustainable Drainage Systems – Hydraulic, Structural and Water Quality Advice CIRIA C609 Wilson, S., Bray, R. and Cooper, P.

CIRIA,(2007) The SUDS Manual CIRIA C697 Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R. and Shaffer, P.

DFO, (2000) Effects of Sediment on Fish and Their Habitat. DFO Pacific Region Habitat Status Report 2000/01.

Mouchel (November 2002) Western Peripheral Route (Southern Leg) Stage 2 Environmental Assessment Volume 1 – Written Report.

Norwest Holst Soil Engineering Ltd. (2006) Borehole data – Particle Size Distributions and Trial Pit Logs, Livingston Laboratory.

Personal communication, (2004) Professor Brian Willets Aberdeen University.

SEPA, (2005) Water Quality Monitoring Data 1984-2005 www.sepa.org.uk/data/classification/index.htm

SEPA, (2007) The Water Environment (Controlled Activities) (Scotland) Regulations 2005: A Practical Guide, Version 3.

SEPA PPG01 General Guide to the Prevention of Water Pollution

SEPA PPG04 Disposal of Sewage Where No Foul Sewer is Available

SEPA PPG05 Works In, Near or Liable to Affect Watercourses

SEPA PPG06 Working at Construction and Demolition Sites

SEPA PPG07 Refuelling Facilities

SEPA PPG08 Storage and Disposal of Used Oils

SEPA PPG10 Highway Depots

SEPA PPG13 High Pressure Water and Steam Cleaners

SEPA PPG18 Control of Spillages and Fire Fighting Run-off

SEPA PPG21 Pollution Incident Response Planning

Skinner, A., Young, M. and Hastie, L. (2003) Ecology of the Freshwater Pearl Mussel. Conserving Natura 2000 Rivers, Ecology Series No. 2 English Nature, Peterborough.

Wallingford, H.R. (1999) ISIS Sediment User Manual. Halcrow.