3.9 ROADSIDE VERGE MANAGEMENT

Roadside verges do provide valuable habitats (Way, 1977 - see *Table 3.6a* in *Section 3.6*) and some have been classified as SSSIs or identified as local roadside nature reserves. Over the last 20 years there have been changes in the way that verges have been managed and the techniques which are used. Changes include the use of herbicides and growth retardants, flail mowers instead of hay mowers and a reduction in the frequency of cutting, resulting in widespread changes in the structure and species composition of roadside vegetation. Coarse grasses such as common couch (*Elytrigia repens*) and false oat grass (*Arrhenatherum elatius*) and umbellifers (*Anthriscus sylvestris* and *Heracleum sphondylium*) have become more common with species-rich swards declining.

The ITE Countryside Survey of 1990 which recorded roads covering an area of 4,400 km^2 noted that species diversity in road verges decreased significantly in arable landscapes, but not elsewhere and some loss of characteristic meadow species was noted in all areas. An increasing trend towards overgrown verge types dominated by tussocky grasses and tall herbs and sometimes scrub was recorded except in upland areas where grazing of road verges was more common.

An 18 year experiment (Parr & Way, 1988) found that vascular plant species-richness of the vegetation was lowest in the uncut plots and highest in the plots which are cut twice a year. Increased cutting frequency significantly decreased the frequency of ten mainly coarse growing species, including common couch (*Elytrigia repens*), false oat-grass (*Arrhenatherum elatius*) and cow parsley (*Anthriscus sylvestris*). Eleven finer species (mainly grasses) increased in frequency and creeping buttercup (*Ranunculus repens*) and ribwort plantain (*Plantago lanceolata*) reached maximum at two cuts per annum.

Increases in plant-species richness were recorded following removal of the cuttings, as a result of a decrease in extractable potassium in the soil. It was also suggested that the increase was not due to reduced levels of soil nutrients but probably associated with increased disturbance and scarification when the cuttings were removed.

Alexander (undated) describes research based on telephone questionnaires to all Highway Authorities, the DoT and other associated Government agencies, to assess existing management of roadside verges for nature conservation.

The study found that many organisations are actively involved in managing verges or offering advice on management. However, the research identified a number of barriers to increased nature conservation on roadside verges, including lack of funding, lack of information and inadequate allocation of responsibility and authority for promoting conservation.

Laursen (1981) noted that the most important function of the roadside habitat was as a nesting place and that different bird species favoured different parts of the verges although a preference was observed for nesting in the ditch or back edge of the verge. Summer mowing of verges can potentially destroy nests but there were no significant changes in distribution between mown and unmown areas of verge.

Variation in the number of species, density and diversity of butterflies and burnets depended on the range of breeding habitats on verges. The density of adults and number of species was correlated with verge width while diversity was correlated with the abundance of nectar. The amount of traffic did not appear to have an effect on the populations in the verges (Munguira *et al*, 1992).

Road verges are subjected to a number of extreme stresses. The soil structure is usually undeveloped and they are usually poor in terms of essential nutrients. The movement of vehicles creates air turbulence and water, debris and de-icing salt are sprayed onto the verge. Where vehicles occasionally run onto the verge they cause ruts and compaction.

The Highways Agency has commissioned the production of an Advice Note on landscape management for inclusion in Volume 10 of the Design Manual for Roads and Bridges (DMRB, 1993 as amended). This note will cover all aspects of "soft estate" management and will include general advice on managing roadside verges in ways that take account of the needs of nature conservation. Publication of this note is expected by Spring 1996.

3.10 OTHER EFFECTS

Soil Salinity

De-icing salt is likely to cause the greatest hazard to vegetation of all traffic related pollutants. Salt in almost pure form is applied to main roads regularly in winter, at an application rate of 35 g/m^2 (for motorways), although this rate varies across the country (Haddart, 1990; Colwill *et al*, 1982). Salt is transferred to verges by runoff and by spray or along with snow after ploughing and is taken up directly or via the soil.

Salt affects plant growth by altering soil structure and damaging photosynthetic tissue. This can result in the loss of susceptible species and a selection towards salt tolerant species (Ranwell *et al*, 1973; SNH, 1994).

The primary effect of salt on plant growth is thought to be due to water stress and is believed to be dependent on the concentration of salt in the soil solution although the relative rate of rainfall, evaporation and salt application are important. Rainfall in April and May can leach salt from soil, but late applications of salt may be particularly harmful. Colwill *et al* (1982) showed that the most sensitive species would be affected if sodium levels exceeded 700 $\mu g\ g^{-1}$ and chloride about 200 $\mu g\ g^{-1}$ at the start of April.

Most spray is deposited close to the carriageway. At distances of about 10m from the road, the hazard to plants from salt becomes negligible, although a slight browning of leaves may occur. Colwill *et al* (1982) have, however, observed significant damage to the foliage of scot's pine, spruce and gorse at a distance of up to 15 m from the road.

A number of salt tolerant species can thrive at roadside locations and the salt tolerance of 80 species is tabulated by Colwill *et al* (1982), and a similar list indicating the salt tolerance of about 100 species of trees has been completed by Dirr (1976).

Ranwell *et al* (1973) found that levels of accumulated sodium in verges immediately adjacent to principal roads in England at levels comparable with those near the seaward limit of plant growth in coastal sand dunes and locally approached values found at the extreme landward limit of saltmarshes. In heavily salted verges (500 ppm) the species assemblage almost mirrored that found on the seaward limit of land vegetation on Cornish cliffs. The affected zone extended as far as 9.1 m from the road edge and to a depth of 0.15 m whilst at 3.1 m from the road edge the depth effect increased to 0.46 m. Damage to vegetation may occur up to 4 m in height. Similar effects have been noted at a number of inland roadside sites including the A1 in the Midlands. The possibility of alien salt tolerant species being imported with salt and establishing along British roadsides was suggested by Ranwell.

Thompson *et al* (1986a) reviewed the effects of salt applications to roads in the UK. Previous studies suggested that a threshold level of sodium of 15% of exchangeable cations was required before effects occur. Thompson *et al* (1986) sampled 39 points in central reservations throughout the English motorway system (and a few in Scotland) over 2.5 years but found no levels that exceeded 15%. Similar studies by Davidson (1971) found levels of exchangeable sodium of between 20 and 40% at some sites.

Thompson *et al* (1986a) also found that mean concentrations in April (the start of the growing season) were less than 500 ug g^{-1} in most of the Midlands and south. In Lancashire, Yorkshire and northern counties the concentrations were commonly between 500 - 1000 ug g^{-1} and exceeded this at higher altitudes. Concentrations in the soil that have been associated with visible damage to various temperate trees and shrubs range from 100 - 400 ug g^{-1} for sodium.

Experiments on the salt tolerance of some native British trees and shrubs were undertaken and are presented in Thompson & Rutter (1986b).

Thompson *et al* (1986b) sampled the top 50 mm of soil in cental reserves throughout England. Soil sodium concentrations at the centre of 4 m wide central reservations were typically 50-70% of the value 0.5 m from the carriageway. This decreased to as low as 10% where the reservations were 9-10 m wide. Shrub establishment on central reserves increased the soil sodium concentration by 50% and where there was a hard shoulder the sodium concentrations at 2 m were 30 - 40% of those on the central reserve.

A recent press article by the BTO suggests that finches can die due to contamination from de-icing salt (see *Section 3.7.11*).

Metal Contamination

Lead pollution causes the replacement of natural plant communities by lead tolerant species and to genetic selection of lead resistance in certain species (SNH, 1994). English Nature (1994) report that lead levels are highest in central reservation soils and vegetation, with totals reaching 10-20 times normal background on the roadside, with elevated levels recorded up to 120 m from the road.

Musket & Jones (1980) studied the concentrations of lead, cadmium and nickel in air at sites 1, 10, 30 and 100 m from the A40 which is a heavily trafficked road in West London. The results of vegetation sampling found that there was a decline in concentrations of lead and cadmium with increasing distance from the road and no pattern in the levels of nickel. The study did not find any evidence of a general detrimental effect of road traffic pollution on roadside macro-invertebrates, although it could not be discounted.

Warren & Birch (1987) studied concentrations of Cd, Cu, Pb and Zn in atmospheric particulates, roadside dust and soils along a major highway in London. The results showed that soil metal concentrations decline rapidly with distance from the roadside.

Generally soil lead concentrations must exceed 1000 $\mu g\ g^{-1}$ before plant growth is affected. Observations by Colwill *et al* (1976) at 50 motorway central reserve sites gave levels of 100 to 1000 $\mu g\ g^{-1}$. The lead level is likely to fall off rapidly with distance from the road. However, there is little evidence of acute toxic effects in plants, and amongst animals, no differences in species abundance have been recorded which correlate with air pollution levels within the vicinity of road edges (English Nature, 1994).

Atkins *et al* (1982) compared lead tolerance of red fescue (*Festuca rubra*) from a site contaminated with lead mine soil, an M6 motorway verge and a relatively uncontaminated site. The results of the study suggested that the conditions which prevail at the M6 site have resulted in the evolution of a lead tolerant population of *F.rubra*.

Heavy metals have been shown to accumulate in lichens (during transplant experiments) up to 70 m from a road (Angold, 1995). Levels of cadmium, nickel, copper and zinc have all been investigated and no adverse effects on plants have been detected, although the concentration of these metals in the food chain (especially zinc) may be a cause for some concern (English Nature, 1994).

Pollution (for example lead) has caused increased levels of toxic substances in birds, but the levels recorded were well below the toxic level (Lowell *et al*, 1977; Grue *et al*, 1986) and no effects on reproduction and mortality were established (Lowell *et al*, 1977).

Pain *et al* (1995) looked at lead concentrations in birds of prey. Although the study concentrated on the effects of lead shot the author did suggest that high lead levels may result from birds feeding regularly on small feeding sites contaminated with lead *eg* road verges. Invertebrates and small mammals near major roads can have high lead body burdens.

Shore (1995) studied the relationship between certain heavy metals (cadmium and lead) in soil and those found as residues in small mammals. The results showed that residues in soils could be used to predict their concentrations in small mammals.

Temporary Roadways

Rose & Webb (1994) noted that if heathland was disturbed early in the growing season by temporary roadways it regenerated more rapidly than when disturbed later in the year. No species were lost or severely reduced and changes in abundance of some species were similar to those changes produced by standard heathland vegetation management *eg* cutting the vegetation prior to laying ballast.

Ten invading species were recorded after the treatment but they did not become established in numbers large enough to threaten change to the original vegetation. Rose & Webb (1994) stressed that care should be taken not to introduce new species on imported ballast.

Cutting the vegetation was found to open up the existing structure and enable seedlings to establish. The damaged surface provided a range of suitable microclimates and more seedlings were recorded on these sites. Wet heath plots recovered more rapidly than the dry heath plots because they contained a greater proportion of fast growing species such as purple moor-grass (*Molinia caerulea*).

Variations in disturbance to birds on temporary coastal roadways across sandflats have been noted (*pers observ*, ERM). Large trucks passing relatively quickly along the road at regular intervals appear to disturb birds less than slow moving vehicles, which occasionally stop.

Visual Impacts

In open areas Reijnen *et al* (1995) suggest that the visual impacts of roads may be effective over long distances and disturb birds, however, such effects are greatly reduced in wooded areas. Henderson & Clark (1993), reported that estuarine roads screened by embankments incorporating shrubby vegetation helped alleviate the problem of visual disturbance to birds (see also *Section 5.2.9*).

Human Presence

A number of studies have already shown that human presence is a common causal factor in the disturbance of wintering and breeding coastal bird populations (Davidson & Rothwell, 1993). However, it is difficult to define exactly the type and scale of response by for example different waterfowl species as their response is very variable and even the same species of bird can react in different ways at different times and in different places (Davidson & Rothwell, 1993). A number of factors are involved in determining the overall effect including state of the tide, time of the year, weather conditions, flock size, feeding success, type of disturbance and the bird's own past history of disturbance (Davidson & Rothwell, 1993).

Such effects on waterfowl from human presence are typically an issue for consideration when roads are constructed close to or across rivers and estuaries. Henderson & Clark (1993) studied the effects of existing roads near estuaries and recorded no obvious signs of disturbance to birds at any of the sites, although they noted that at one site, pedestrians using the footpath disturbed feeding and roosting birds if they stopped near to them.

For terrestrial habitat such as woodland, in general larger woodland birds are more vulnerable to disturbance with great spotted woodpecker, kestrel and buzzard sometimes deserting a nest if regularly disturbed, however, blue tit and robin will often ignore human presence even close to a nest (Smart & Andrews, 1985).

3.11 SUMMARY

In summary the review of impacts has noted the following (although there appear to be many gaps in the literature (see *Section 6*)):

Air Quality

- Vehicles emissions contribute to the creation of ground level ozone. Experimental evidence suggests that existing levels of ozone in the UK, do in certain summers, affect crop yield, tree physiology and growth and the species composition of plant communities. A north-south gradient occurs and increases are known to occur with altitude. Critical levels have been recommended by WHO.

- The relative importance of sulphur dioxide as a phytotoxic pollutant in Europe has diminished to some extent since 1987. The WHO has produced guidelines for gaseous and deposited SO_2.

- Atmospheric nitrogen compounds have a varied impact on plant growth. High concentrations of NO_2 are known to retard plant growth and cause visible damage to plants, although low concentrations may promote growth, especially on nitrogen-deficient soil. Nitrogen from vehicle exhausts in heathland areas may cause a gradient of change in vegetation extending from the road at least 200 m into heathland habitat on either side of the road. Such edge effects are closely correlated with traffic volumes.

- Transport-related emissions of nitrogen oxides increased by 59% during the 1980s. The introduction of 3-way catalytic convertors to all petrol fuelled vehicles will lead to a reduction in emissions to atmosphere although the impacts on air quality will to some extent be offset eventually by expected growth in traffic.

- The effects of acid deposition from oxides of nitrogen on vegetation, soils and waterbodies are well documented.

- The impacts of dust and particulates on plants appear to be variable, and data is insufficiently comprehensive to draw any firm conclusions on the effects of road traffic particles on nature conservation.

- Indirect effects of atmospheric pollution include increased drought or frost sensitivity and increased susceptibility to pests and pathogens.

Noise Disturbance

- Recent studies have indicated that the effects of road traffic on some species of breeding bird densities in woodlands are due to noise rather than other environmental factors such as visual impact or air pollution. The distance from the motorway at which breeding bird densities were affected in a Dutch study was influenced by the intensity and speed of traffic.

- Reijnen *et al* (1995a) suggest that noise load is the main causal factor in the reduction of bird densities adjacent to roads and that in woodland, only noise pollution was considered relevant to reduced densities at distances greater than 200 m from the road.

- Disturbance to meadow nesting birds in the Netherlands was recorded (van der Zande, 1980) and to birds near to the E18 in Finland (Hirvonen, 1995).

- Hill (1992) suggests noise disturbance to waterfowl may potentially result in a reduction of feeding time, reduced feeding area and interference with breeding, although there is great variation between species and many different factors may be involved.

Artificial Lighting

- Campbell (1990) suggests that the potential implications for plants of artificial lighting are considerable and harmful effects of sodium vapour lighting on plants through disruption of photoperiodic regulation of growth and development have been shown by several workers.

- Birds, particularly nocturnal species are likely to be disturbed by the presence of bright illumination and seabirds in particular may be drawn to artificial light sources. Artificial lighting may also provide waterfowl with more feeding time although a decrease in prey populations may result.

- The occurrence of badgers and foxes in cities lit by artificial lights at night suggests that habituation is possible. Additionally badgers are frequently the subject of TV programmes which illuminate the animals.

- It is thought that moths and other night-flying insects attracted to lights have experienced altered populations and there is a perception among some entomologists that urban locations in Britain support a far lower density of moth species than they did 30-40 years ago even when there has been little change in the composition of vegetation and thus their food availability.

Aquatic Impacts

- Routine highway runoff discharges to watercourses appear to have few acute effects on downstream biota, and the most significant ecological effects occur from chronic exposure and bioaccumulation from trunk roads and motorways carrying high traffic volumes.

- Accidental spillages have the potential for significant ecological damage to watercourses, though the effects vary according to the substance released and the pollution containment measures in place.

- Hydrogeological impacts should be considered especially when deep cuttings or tunnels are part of the proposed scheme. Protection of groundwater aquifers is important as impacts can be difficult to rectify.

Fragmentation and Species Movement

- Linear infrastructure developments may be a minor cause of habitat loss, but they can often present more serious habitat fragmentation problems and there is a risk that future road widening may further increase the effect of the barrier.

- The greatest impacts resulting from habitat fragmentation by roads are likely to be in landscapes where sufficient natural and semi-natural habitat exists that all routes are likely to involve some damage to sites and also where fragmentation has already put many species close to their limits and where the relative benefits from mitigation are likely to be small.

- Conflicting studies on the barrier effects of roads to animals have been reported. Quantitative indications using computer models of the extent of habitat loss, disturbance and collisions are being advanced, however, the extent of the effects of barrier action cannot yet be reliably determined.

- The effects of roads and rail bridges as barriers to bird movement have been studied in Scotland which no major impacts noted. Low bridges were, however, likely to reduce the usage of the mudflats beneath them.

Wildlife Casualties

- Roads and road transport do result in wildlife casualties ranging from insects to large mammals. The extent of the problem varies considerably between species and between countries although the overall effects on wider populations are not known. Significant local effects particularly on badgers and amphibians have been recorded and roads have been highlighted as a major factor in the decline of the barn owl.

- Recent increases in otter casualty numbers appear to be related to a simple increase in the numbers of otters in many areas.

Litter

- The scarcity of references to litter in the literature indicate that it may not be a major issue with regards to roads and wildlife.

- However, the Mammal Society refer to a press article suggesting that millions of small mammals die in bottles and cans, with up to 28 in one bottle.

Roadside Verge Management

- Roadside verges do provide valuable habitats and some have been classified as SSSIs or identified as local roadside nature reserves.

- Many organisations are involved in the nature conservation management of roadside verges. However, it is considered that the full potential of verges typically remains unrealised due to lack of funding, information and allocation of responsibility (Alexander, undated).

Other Effects

- The primary effect of salt on plant growth is thought to be due to water stress and is believed to be dependent on the concentration of salt in the soil solution although the relative rate of rainfall, evaporation and salt application are important.

- Recently the BTO has suggested some fatalities in finches may be due to contamination of food supplies by de-icing salt.

- There is little evidence of acute toxic effects caused in plants from lead, and amongst animals, no differences in species abundance have been recorded which correlate with air pollution levels within the vicinity of road edges.

- It is possible that plant populations have developed adjacent to motorways which are lead tolerant.

- Pollution from roads has caused increased levels of toxic substances in birds but levels were typically below the toxic level and no effects on reproduction or morality were established.

- The rate of regeneration of disturbed heathland by temporary roadways was dependent upon the time of year of the disturbance.

- Large trucks travelling relatively fast on temporary coastal roadways appeared to disturb birds less than slower moving vehicles which stopped.

- Visual impacts of roads may disturb birds although this is considered to be reduced in woodland and in coastal areas where roads are screened by embankments.

- Human presence can disturb wildlife although the effects are determined by many different factors including location, species, time of the year, weather conditions, flock size, feeding success, state of tide (if estuarine) and the bird's own past history of disturbance. Some small woodland species are known to ignore humans whilst larger birds may desert nests.

- Birds of prey may be indirectly affected if they feed on small mammals with high levels of lead adjacent to main roads.

4 CUMULATIVE IMPACTS

4.1 INTRODUCTION

Cumulative impacts can take several forms including the following:

- impacts arising from more than one development affecting the same resource;
- the accumulation of different impacts at one location;
- the accumulation of impacts over a period of time;
- induced and indirect impacts where secondary development is stimulated as a result of a particular project (see *Section 2.4*).

4.2 REVIEW

EC Directive 85/337 *"The assessment of the effects of certain public and private projects on the environment"* requires cumulative impacts to be addressed in environmental assessments however in practice this is rarely done (Therivel *et al*, 1992). The lack of assessment of the cumulative impacts of development on lowland heath in environmental statements is cited as an example.

Similarly the OECD (1994) state:

"EIAs for road projects are often criticised for ignoring issues like cumulative effects of multiple projects and global and long-term effects. These are examples of issues that should be dealt with at a strategic level of systems planning".

It is suggested (Therivel *et al*, 1992) that the lack of knowledge concerning other development proposals and lack of control over these proposals may be significant factors contributing to the limited assessment of cumulative impacts.

Therivel *et al* also considered that more environmental assessment at the strategic level would allow cumulative impacts to be better addressed because such assessment takes place earlier in the decision-making and considers implications of a wider range of development proposals over a much larger area.

The lack of monitoring of impacts of road schemes makes prediction of the cumulative impacts of the secondary effects particularly difficult. Some recent assessments, however, have considered cumulative impacts in some detail. For the proposed Channel Tunnel Rail Link (URL, 1995) the cumulative impacts of the scheme have been addressed including for example the cumulative loss of ancient woodland along the length of the railway.

The SACTRA report (DoT, 1992) also used impacts on woodland as an example of what could lead to a significant cumulative effect:

"One road may cause the destruction of a wood which when taken by itself might not be a serious loss. If, however, the Government is promoting concurrently one hundred road schemes, each one of which involves the loss of some woodland, then the impact of

those schemes on the stock of trees may have to be looked at not simply in isolation but in the national context too. In such cases the total effect of the Government's road policy nationally might be greater then the sum of effects of its constituent parts."

The species composition of roadside verges may be affected by a number of cumulative effects including management changes, mowing regimes, road salting and herbicide usage. Verges are also vulnerable to disturbance from road works, ditch clearance works and vehicles which may result in bare patches allowing the invasion of colonising species (Barr *et al*, 1994).

Some studies have proposed that an accumulation of factors may be responsible for impacts such as the barrier effect. Mader (1984) considers the following factors may affect forest dwelling carabid beetles and woodmice in west Germany:

- breaks in the microclimatic conditions at the edge of the road resulting in a savanna or rocky habitat rather than a moist wood;
- a variety of emissions and disturbance such as noise, dust, lighting, exhaust fumes and increased salinity in the soil, vegetation and ditches;
- verges comprising zones of environmental instability due to periodic cutting and spraying;
- intensified competition for resources and a broadening of the zone of disturbance; and
- danger of mortality as a result of traffic.

In addition the edge conditions resulting from roads have been attributed to a combination of pollutants, noise and increased human access leading to more trampling or the leaving of rubbish (Kirby, 1995).

Vehicle usage effects on terrestrial and aquatic environments are highly sensitive to traffic density (Forman, 1995; Langevelde & Jaarsma, 1995). The impacts of contributory factors such as for example noise and air pollution will vary with traffic density. Reijnen *et al* (1995a) have compiled tables for the determination of noise effect distances for woodland and hay meadow bird species, at various traffic intensities and speeds, for various woodland fractions in grassland.

Cumulative impacts may seriously degrade important habitats. Langbroek (1955) suggests that dramatically decreased quality of habitat in the Paterwolde district of north Netherlands has resulted from significant fragmentation from development and mean lowering of polder waters from abstraction.

Comprehensive and successful methods, including predictive techniques, of integrating the overall impact of one or more proposed scheme upon a range of species and habitats are thus, still required to more fully understand cumulative impacts. Such techniques should also be capable of considering the success or otherwise of mitigation measures (see *Section 5*).

Attention is now focusing on cumulative impacts with the *DMRB* (1993 as amended) now suggesting that a cumulative assessment may be appropriate in certain circumstances. Strategic Environmental Assessment (SEA) is, therefore, now beginning to be undertaken on roads projects with a recent example including that for the proposed Second Forth Road Crossing for the Scottish Office (ERM/MCB/MVA/OFTPA, 1994). Assessing cumulative impacts has also been the subject of recent conferences including the Fourth Annual Conference of the Institute of Environmental Assessment (IEA) (Purnell, 1995).

5 MITIGATION MEASURES

5.1 INTRODUCTION

English Nature's approach to mitigation is that it should be consistent with the concept of sustainable development. Nature conservation interests should be preserved by avoiding impacts wherever possible and where mitigation measures are required to reduce impacts they themselves should not create adverse impacts (English Nature, 1994).

It is realised that because of other conflicting constraints it is not always possible to eliminate all detrimental effects on wildlife. In these cases English Nature seek to minimise the impacts and in addition will seek to ensure that the scheme includes an equivalent area of similar new habitat elsewhere if that is agreed to be necessary. The concept behind this is English Nature's aim to maintain a constant stock of 'natural capital' (Forbes & Heath, 1990).

In considering the impacts of any scheme it is important that the approach should assess a scheme with agreed mitigation measures included in the final design. Appropriate measures will vary between schemes.

The following sections describe the range of mitigation measures which are commonly employed to reduce or minimise secondary impacts from roads and road transport on nature conservation. They should not, however, be viewed as measures which can replace the need for initial changes in the road scheme design which could avoid impacts in the first place.

In the design of any scheme the potential impacts on nature conservation of both construction routes and slip roads should be taken into account.

A major issue raised during the consultations for this review was the success of such measures and whether the cost of their implementation was matched by their success rate.

5.2 PREVENTATIVE MEASURES

5.2.1 Policy

To reduce the impact of the transport sector government policy is required that incorporates economic, regulatory and institutional measures. The RSPB are currently examining the possibilities of achieving a reduction in transport impacts through improving site and habitat protection and encouraging the reduction of overall pollution (Briggs *et al*, 1993). Briggs *et al* (1993) also propose the possibility of switching of transport modes, however, this is considered outside the scope of this report.

Heap (1995) suggests that in seeking to implement sustainable development, the concepts of critical natural capital and constant natural assets offer a practical approach which sets out a framework for environmental compensation. Fundamental to their application is the technical feasibility of replacing semi-natural habitats. A strategic approach to this, using a natural areas framework, could ensure contributions to this through planning agreements targeting priority areas for action. Development Plan Appraisals and Environmental Assessments also offer mechanisms for avoiding the loss of semi-natural habitat.

5.2.2 *Air Pollution*

Reductions in air pollution arising from transport and its secondary effects are likely to depend largely on policy decisions (see *Section 5.2.1* above) especially if they result from reduced traffic intensity, emissions of air pollutants (for example through the use of three-way catalytic converters *etc* (Woodin, 1989).

On a more local level, adjacent to roads, English Nature (1994) has identified two effective strategies for mitigating air pollution namely the use of buffer zones (preferably 200 m in width) and shelterbelts.

Roadside air pollution shelterbelts should comprise species tolerant to, yet effective interceptors of, prevailing air pollutants. It is also important that the species are able to tolerate, especially when young, the additional adversities of the roadside environment including salt spray and the increased dryness of air near roads. Madders & Lawrence (1981) suggest a mix of the following species may be suitable on a range of soil types as air pollution interceptors:

- Lombardy poplar *Populus nigra* 'Italica';
- Japanese larch *Larix kaempferi;*
- Hawthorn *Crataegus monogyna;*
- Whitebeam *Sorbus aria;*
- Holly *Ilex aquifolium;*
- Lime *Tilia X europaea;*
- Oak *Quercus sp*; and
- Ash *Fraxinus excelsior.*

It should be noted, however, that it is preferential to use species appropriate to the particular Natural Area, avoiding the use of both native and non-native species likely to be invasive on habitats of importance for nature conservation in that Natural Area.

5.2.3 *Noise Disturbance*

Until relatively recently, there was little published work on the impacts of road noise on wildlife and hence mitigation options were also limited. Much of the previous work on mitigation was based on the measurements of noise reduction resulting from screening by vegetation.

Research has found that noise attenuation by vegetation shows maxima at both low and high frequencies. Between the low and high frequency maxima is an acoustic window. Unfortunately the traffic noise spectrum peaks at about 1000 to 2000 Hz, which is within this window, so high rates of attenuation by vegetation may be unattainable. However, vegetation may make traffic noise less annoying to humans and wildlife by filtering both high and low frequencies (Huddart, 1990).

Dense spruce was identified as providing the greatest attenuation, although broadleafs may also be effective and vegetation up to 30 m depth provided up to 6 dB(A) L_{10} greater attenuation than that over the same depth of grassland. The effectiveness of vegetation in attenuating traffic noise is also noted to be greatest close to the road and diminishes with distance (Huddart, 1990).

The latest studies by Reijnen *et al* (1995a) considered that reductions in the quality of breeding bird habitats were primarily due to noise (see *Section 3.4*) and the studies suggested that only two mitigation options resulted in major reductions in noise impacts to breeding birds [(1)]:

- *major reduction in traffic intensity* which resulted in significant reductions in the noise effect distances;

- *noise barriers* - the greatest reductions were with barriers at least 4 m high with the screened fraction [(2)] amounting to 1. However, this would require the construction of very long barriers which in themselves may affect breeding birds in open areas for approximately 200m. Their use was suggested as being suitable only in reducing very long distance effects. In general the construction of noise barriers in the form of "green screens", for example from willows and planted embankments, was still recommended.

5.2.4 *Artificial Lighting*

The extent of knowledge concerning the effects of artificial road lighting on fauna and flora is limited (see *Section 3.4*) and thus the extent of mitigation measures typically proposed for road schemes is also minimal.

It is also possible that mitigation measures for different species of fauna for example may have conflicting effects. For example lighting may provide a deterrent to deer crossing the road, but it may also result in declines in some insect species, affect feeding areas for some nocturnal animals, alter breeding behavioural patterns and attract birds and bats to the road which may then become wildlife casualties.

Preliminary mitigation measures with regard to the effect of lighting on insect populations have been proposed by Outen (undated):

- avoid installation of lighting near potentially vulnerable sites;
- use of low-pressure sodium lamps and lamps with as low brightness as legally permissible;
- fit shades to restrict light to where it is needed only;
- fit ultra-violet filters to mercury lamps (sodium lamps emit negligibly in the UV) or change to low-pressure sodium lamps;
- turn off lamps close to vulnerable sites outside key periods of human activity if this does not put people at risk.

Hill (1992) also suggests shielding of street lights should be incorporated into construction of new roads which are close to bird breeding areas.

Further research work into the impacts of artificial lighting is required before more detailed general mitigation measures can be proposed.

5.2.5 *Aquatic Impacts*

As noted in *Section 3.5* the secondary aquatic impacts from roads and road transport have been more extensively studied and a fuller understanding and

(1) Noise screens for example may be less desirable to other animal groups, therefore, careful consideration should be given to their use.

(2) Proportion of a road section along which noise barriers have been installed expressed as a fraction between 0 and 1.

documentation of potential impacts exists. Not surprisingly, therefore, greater consideration has also been given to mitigation options.

As these options are well documented (*eg* English Nature, 1994; Luker & Montague, 1994; Colwill *et al*, 1984; Ellis & Revitt, 1991) a summary of generally accepted measures only is included in this report.

Noted mitigation options include:

- **Street sweeping** is currently not carried out in Britain as a pollution control measure, rather for aesthetic reasons and on roads and motorways as a road safety measure (DoT lays down sweeping frequencies). US studies have shown only small reductions in pollutant runoff from unswept roads, mainly because sweepers are inefficient at removing small particles which become suspended in liquid (Luker & Montague, 1994).

  Trials in Sweden and the UK have shown improvements in the quality of urban runoff as a result of sweeping. Ellis (1986) concludes that the cleaning interval is the dominant influence on effectiveness and that achievement of the optimum effectiveness requires a sweeping frequency of at least the average time between storms.

- **Street flushing** (or washing) is not common in Britain but is used in some areas for aesthetic purposes. Flushing does not remove particles from the catchment but merely relocates them. The effect of flushing on pollution reduction is marginal to negligible in areas served by sewers since most of the flush is collected by surface water sewers and conveyed to the receiving body of water.

- **Sewer and drain cleaning.** Sediment deposition within sewers and drains has been implicated to a greater or lesser extent in the first flush phenomenon observed in stormwater (and combined sewer) discharges. To ameliorate this problem one option is to control the level of sewer deposits by cleaning. Butler & Clark (1993) reviewed the various methods available and found it to be an expensive option with little or no experience of the use of cleaning as a pollution control measure in storm sewers.

- **Reduction of salt application.** In recent years the introduction of advanced meteorological forecasting, weather radar, thermal mapping and ice prediction techniques has resulted in a reduction in the number of occasions on which salt is used. In addition the measurement of residual salt on the road surface now enables salt to be spread as a top-up so reducing the quantities that are used. The use of salt for snow removal is also being reduced by improved highway design, including more efficient snow fences.

- **Gully pots.** The design of the gully pot as an instrument for pollution control is still in its infancy and there are no established procedures at present. In principle the gully pot should be chosen for its solids capture efficiency and the sump should provide sufficient sediment storage space given the actual cleaning regime. Unless gully pots are cleaned regularly and thoroughly their benefit will be much reduced.

- **Filter drains** have historically been used for draining surface runoff from carriageways, verges, cutting and embankment slopes and adjacent land, particularly in cuttings. The DoT has made recommendations that their use should be limited to instances where resultant economies can clearly be identified, and they are not at present generally advocated by the DoT. However, there is a good case for the wider application of filter drains particularly in view of their good removal performance for sediments and associated pollutants.

- The **informal verge system** has its main application in rural locations. Verges can enhance runoff water quality by providing pollutant-reduction mechanisms similar to those encountered in swales. It has recognised shortcomings but these are principally related to over-running by vehicles and it can be overcome by the use of geotextiles to provide reinforcement.

- **Swales.** Current British design approaches for swales are based principally on optimising the hydraulic efficiency of surface runoff flows (ie high flow velocities and minimisation of erosion). However, to achieve water quality improvement (by bio-filtration, sedimentation *etc*) sufficient contact time must be provided and this means basing the swale capacity on an upper limit of flow velocity.

- **Soakaways and infiltration trenches.** The use of these methods for the disposal of highway runoff to ground is being increasingly called into question. Where some form of infiltration is unavoidable, on roads carrying little traffic, and where risks of groundwater contamination are minimal, filtration trenches may offer a more effective means of disposal, because of the larger surface area available for infiltration.

- **Storage ponds and detention tanks.** In general, flow detention in storage ponds and detention tanks will lead to particle settling and removal, together with its associated contaminant load, and some bacterial die-off and soluble contaminant reduction may occur. The extent of the treatment achieved will depend on the type of storage pond, the mean flow detention time and the pond design.

- **Oil separation** from highway runoff is more important for heavily-trafficked roads that drain to sensitive surface or groundwaters. Consequently, oil separators are being increasingly recommended for new major road developments (urban and rural) although their use is at present limited.

- **Sedimentation tanks.** In a comparative study of a filter drain, sedimentation tank and lagoon, the sedimentation tank was found to be the least effective treatment system. In most circumstances, similar solids removal efficiency could probably be achieved by a grit trap/oil separator combination albeit at higher cost.

- **Wetlands.** Limited research to date suggests that a moderate to high degree of water quality improvement can be achieved particularly for suspended solids and metals, and an even greater treatment is possible by combining wetland systems with other treatment or flow control stages.

- **Lagoons** appear to provide an effective approach to treatment of potential value in rural or semi-rural locations in which space constraints preclude a formal wetland or storage pond development, but still permit construction of a narrow linear lagoon which can lend itself naturally to fitting within the highway land boundary.

The NRA have published guidance on the environmental assessment of road schemes in relation to the water environment (NRA, 1995). An example of some of the measures to be considered are summarised below:

Table 5.2a *NRA Suggested Mitigation Measures*

Issue	Mitigation
Minimise pollution risk	• use of oil separators with cut off valves, silt traps, wet balancing ponds, open ditches, soakaways, reedbeds and grass swales.
Conservation of river corridors	• maintain a river corridor between the road and river of approximately 50 m;
	• a minimum width of at least 9 m on each bank should be provided beneath bridges and river crossings;
	• culverting should be minimised and diverted river channels carefully designed
Other measures include	• using bridges and tunnels rather than cuttings and embankments;
	• installing appropriately designed tunnels for safe passage of amphibians, badgers *etc.* at known crossing points;
	• formulation and adoption of a sensitive management plan.

With regard to protection of groundwater resources, guidance is provided in NRA (1992) and ADRIS (1995).

5.2.6 *Fragmentation and Wildlife Casualties*

Many European countries are in the process of designing and implementing national or regional ecological networks to meet the challenges of habitat fragmentation, whilst providing sufficient scope for appropriate economic and agricultural development (Bennett, 1995). Ecological networks typically comprise four main components:

- *core areas* that ensure the conservation of the main habitat types;
- *corridors* or *stepping stones* that allow species to disperse and migrate between core areas;
- *restoration areas (or nature development areas)* that expand the network to an optimum size and provide an appropriate diversity of habitats;
- *buffer zones* that protect the network from potentially damaging external influences, such as pollution or land drainage.

Where fragmentation, disturbance and barrier effects are predicted to be severe for high value habitats (*ie* core areas) then the only acceptable mitigation option is to avoid such areas (English Nature, 1994). In other areas, several options are typically proposed including tunnels, bridges and habitat creation (English Nature, 1994; Kaule, 1995).

The fragmentation of habitats used by species protected by law is the principal area where mitigation is required (Peel *et al*, 1995). The level of response regarding the impacts of fragmentation is, however, usually determined by the perceived rather than the real level of impact to wildlife and by the cheapness of the solution (Kirby, 1995).

Conservation buffer zones need to be considered routinely in planning procedures (Angold, 1995), the important aspects being:

- the area of the affected habitat, and its conservation importance;
- the predicted long term edge effect of the proposed development;
- the area of land required to absorb this edge effect and thus prevent degradation of the habitat.

Durham Wildlife Trust suggest that improved identification and signposting of potential animal casualty sites could produce some benefits (*pers comm*, 1995).

A recent article in The Times highlighted the idea of the Animal Warning Device. It is a concept from the USA but is now available in the UK. It is essentially a horn that sends out a high frequency tone inaudible to the human ear. In a trial by Nebraska State Patrol, collisions with deer fell 50%. Animals with forward facing ears react well, however, there are concerns on it's effect on horses being ridden along roads (Ballard & Hacker, 1996).

Specific measures may be required to mitigate impacts on different animal species and these are discussed in turn below.

Badgers

- **Underpasses/tunnels** are commonly used to allow the passage of badgers beneath roads. Underpasses and their construction are well documented in Ratcliffe (1984), Neal (1986) and RSPCA (1994). They should be approximately 5 m wide and low enough to minimise human disturbance (RSPCA, 1994). The importance of badger tunnels and road fences in reducing badger road casualties is widely acknowledged (Lankester *et al*, 1991; Bekker, 1995; Keller & Pfister, 1995; also see *Box 5.2.6a*).

  In the Netherlands tunnels were previously 30 - 40 cm in diameter and made of concrete for durability (Vereniging Das & Boom, 1990; Douwel, 1995) although more recently wider pipes have been favoured. In the UK, concrete drain pipes of 60 cm diameter are now commonly used under roads with embankments (RSPCA, 1994). In areas where flatter road systems are introduced, culverts are often required and these allow the use of galvanised corrugated steel culvert pipes ($\geq$ 1 m diameter) and a raised badger path may be incorporated along the sides (RSPCA, 1994). In the Netherlands badger tunnels are typically a maximum of 150 m in length (Douwel, 1995).

  The National Federation of Badger Groups has indicated that pipelines in mid air over cuttings may provide suitable safe tunnels. These have been used in Shropshire (*pers comm*, 1995).

  Where tunnels are constructed beneath roads at ground level, a tunnel in the shape of a "V" or "U" is required with gentle slopes and a drainage section in the middle (RSPCA, 1994).

  All of these options should be combined with appropriate fencing (see below) and should be located along the line of existing pathways (Douwel, 1995). In places, planked entrances to tunnels may be required, to guide animals into the tunnels.

Box 5.2.6a *Species to Benefit from Wildlife Passages (Source: Keller & Pfister, 1995)*

Species to benefit from wildlife passages including bridges, tunnels, underpasses *etc* are those that:

- **suffer from high mortality due to collision with vehicles;**
- **show strong migratory behaviour;**
- **require a lot of space (at the individual and population level);**
- **are retained by infrastructure in their dispersal.**

The concept of wildlife passages is still in the early stages and it is important that their ecological function should be defined at the planning stages to ensure that they are both well placed and well designed.

- **Fencing** is typically required to guide animals to the required entrance points of tunnels, culverts *etc* and also to reduce the likelihood of them attempting to cross roads (Yanes *et al*, 1995). Various fence types including those used by DoT (Eastern Division) and produced by the TWIL Group (light weight, easy to install and relatively cheap) are discussed further in the RSPCA document (1994). In the Netherlands badger tunnels were built under the A50 motorway between Arnhem and Apeldorn, badgers were led to the entrances by reinforced wire netting dug 50 cm into the ground (Sluiter, 1995).

  No fencing is completely badger proof and the relative effectiveness of different types of fencing is poorly understood (RSPCA, 1994). Following erection of badger fencing on the M40 Waterstock - Wendlebury additional fencing was required and electric fencing was used to deter badgers temporarily (Bickmore, 1992).

  The use of one-way swing gates in fencing to permit badgers to escape should they get onto the road has been suggested, however, they need regular maintenance and because of this *"their use is best discouraged"* (RSPCA, 1994).

- **Road side reflectors** about 30 cm from the ground have been used to deter badgers crossing roads. Two main types are available, either a stainless steel dimpled mirror or a "Swareflex" reflector. These are staggered along the road at 15 m intervals and reflect light from car headlamps thereby providing a warning to badgers near the road. They do, however, require a lot of maintenance including regular cleaning and clearance of surrounding vegetation and they are prone to vandalism (RSPCA, 1994).

- **Wire netting** has previously been used in embankment repair work for roads on areas of flat ground. Badgers have sometimes dug into the road embankment and caused subsequent subsidence (RSPCA, 1994). In such areas it may be advisable to incorporate wire netting into the embankment construction if badgers are known in the surrounding area. Badgers are reported not to be able to easily dig under spot-welded casanet wire (Douwel, 1995).

- **Other** measures which contribute to a reduction in badger casualties include the reduction of the maximum speed on specific roads, the use of roadsigns, or more extremely, the nightly closure of roads and the limitation of access to certain areas. Roads running through the Maasheggen in Vierlingsbeek in the Netherlands are closed between sunset and dawn (Vereniging Das & Boom, 1990). Other requirements for badgers include bushes and hedges that serve as corridors for movement and pasture for foraging and upgrading of remaining foraging grounds following construction should be considered to maintain the food supply (Lankester *et al*, 1991; Douwel, 1995). In the Heuman/A73 area of the Netherlands a 6 km section of motorway was fenced off completely and 5 tunnels built with over 11 km of hedgerows and wooded banks planted between the badger setts and badger tunnels (Douwel, 1995).

  Mitigation measures proposed for badgers associated with the M6 widening, Junctions 16-20 included specific soil storage instructions. Soils removed from the construction site would be stored in such a way that, upon its return, the re-establishment of a healthy population of earthworms would be facilitated (Anthony Walker & Partners, 1994).

Research which has been undertaken for the Highways Agency during 1994/95 is currently being used to produce a new guidance note on protecting badgers. This is being developed in conjunction with the Roads Working Party of the National Federation of Badger Groups and will be included eventually in *Volume 10* of the *Design Manual for Roads and Bridges* (DMRB).

Otters

- **Underpasses/culverts** are regularly used by otters, although the inclusion of ledges above the high water mark is important. Otters do not like sharp bends or fast water movements (English Nature, 1994; *pers comm* Otter Trust, 1995).

- **Fencing** with a maximum mesh size of 8 cm should be installed for at least 200 m either side of streams and rivers and further if the road runs parallel to them (English Nature, 1994). A trench of compacted sub-base material is recommended under the fence to prevent otters digging their way through.

- **Walls** up to 1 m in height and 30 cm wide with flush mortar joints to prevent otters from climbing the wall are recommended.

- **Habitat creation** can involve the creation of freshwater pools to encourage otters (see *Section 5.3*).

Deer and Other Mammals

- **Bridges/Underpasses** have been constructed and in the UK three scheme structures were modified on the M40 (Waterstock - Wendlebury) to provide deer with a safe crossing including one wide underpass with plenty of light and two overbridges with grass-covered surfaces (Bickmore, 1992). In the Netherlands bridges known as "ecoducts" have been constructed comprising wide viaducts (often 50 m long) with 1.5 m high walls, topsoil/sand surface cover and enlarged entrances which end in areas of natural vegetation or provide cover (Berris, 1995; Lichtendahl & Stam, 1995; Sluiter, 1995;). An example includes the ecoduct over the A50 between Arnhem and Apeldoorn. Elsewhere in the Netherlands underpasses have been constructed which allow dry as well as wet fauna migration and link in with a network of connecting zones such as ditches (10 m wide and at least 1 m deep) with shallow banks (slopes 1:10-20) of 10-15 m width (Langbroek, 1995).

The British Deer Society (*pers comm*, 1995) has indicated that deer may use underpasses more readily than bridges.

Such techniques have obvious ecological benefits, as well as some considerable short-term economic drawbacks (Bekker, 1995; Kaule, 1995; Keller & Pfister, 1995).

- **Other wildlife passages** include a tree stump corridor which has been constructed in the Netherlands under the Zandheuvel viaduct (A27 motorway) between the woods on both sides of the motorway. It is disproportionately wide and underlain by a bare stretch of sand adjacent to a grade separated road. The wall of tree stumps also provide:

  - cover between the two sections of forest;
  - a hibernating place for bank vole and white-toothed shrew;
  - an addition to the biotopes of mice, voles and shrews and probably also for martens.

  Disturbance effects of the adjacent road were also minimised by placing a screen beside the road which deterred vandalism and fly tipping onto the sandy area (van der Linden, 1995).

Use of passages can be augmented by increasing vegetation cover near the entrances, eliminating the use of detritus pits and by providing ramps to modify the access.

Different taxonomic groups display different requirements for wildlife passages (see *Box 5.2.6b*).

Box 5.2.6b *Taxonomic Group Preferences for Wildlife Passages (Source: Rosell et al, 1995)*

- **Ungulates were the most selective with deer species and wild boar requiring structures with high dimensions and specific crossing structures.**
- **Amongst the carnivora a selection of structures located in points where the entrance is found at a topographical height similar to the surroundings is required, enhanced by woodland or shrubby vegetation near the entrances. Unobstructed views of the opposite entrance are also important to some carnivore species.**
- **Lagomorphs select the structures with a natural substrate base and a good view of the far side of the underpass.**
- **Amphibian crossings are enhanced by the presence of water inside or at the entrance of the structure and the presence of abundant vegetation at the entrances.**

- **Fencing** is also used, even in conjunction with ecoducts (Sluiter, 1995) and further information on high quality, well designed and secure fencing can be obtained from the British Deer Society (*pers comm* British Deer Society, 1995). To prevent bear collisions in Slovenia, the construction of additional high tensile electric fence along the motorway section has been recommended (Rotar & Adamic, 1995). On the M40 (Waterstock - Wendlebury) 18 km of deer fencing has been erected (Bickmore, 1992).
- **Reflectors** (*eg* Swareflex) mounted along the roadway were developed in Austria and have been used in the USA (Schafer & Penland, 1985) and elsewhere including the UK (*pers comm* British Deer Society, 1995). They are currently being used by the Forestry Commission in forests in this country who are also running tests of their effectiveness as part of a DoE, MAFF Deer Initiative (which also involves the Highways Agency) (*pers comm* Forestry Commission, 1995; *pers comm* Highways Agency, 1995).

Box 5.2.6c overleaf presents an example of a mitigation package from the Netherlands.

Box 5.2.6c *Case Study: A1 Motorway (Source: Stegehuis, 1995)*

- **Tunnels for small mammals were created at 200-300 m intervals.**
- **A combined fence with mesh to guide amphibians, small animals and larger animals.**
- **Three dry brooks were constructed (50 cm wide) on both sides of the culvert under the road.**
- **A hibernation facility for bats was constructed.**
- **An ecoduct was constructed and positioned at-grade with a span of 60 m and the ends are 30 m wide and the centre 15 m wide. Experience from France has shown that ends wider than the central part is beneficial.**
- **Part of the duct is sown and another planted with forest plants to guide and provide shelter. Wooden screens were installed at the edges to hide traffic from the view of animals and also to lower traffic noise.**
- **The green area is managed by the Netherlands Society for the Conservation of Nature Reserves which also manages the areas on either side of the road.**
- **Construction cost = 2.5 M Guilders (approximately £1 M).**

Amphibians and Reptiles

At present there are no precise guidelines for safeguarding amphibians and reptiles on sites which are to be developed (Urban Wildlife News, 1995). Some preliminary guidelines have been provided by English Nature (1994), however, the gaps in existing knowledge of the impacts of secondary effects from road schemes on amphibians and reptiles makes exact mitigation very difficult. Even where measures have been proposed for road schemes monitoring of their success has not always been undertaken. Some of the more commonly used measures are described in *Text Box 5.2.6d* including a case study from the A34 Wilmslow and Handford Bypass.

- Tunnels under the road comprising a tube of 400 mm to 600 mm diameter can be used along with a collection gutter that runs parallel with the road (Galet, 1995).
- Fencing around road edges particularly adjacent to hibernation ponds are important (English Nature, 1994; Galet, 1995).

Box 5.2.6d *Case Study: A34 Wilmslow and Handford Bypass (Marshall et al, 1995)*

The amphibian interest of the proposed route included a number of ponds and pond clusters along the route which were important for a range of amphibians. In particular, 15 ponds would be destroyed some of which supported great-crested newts which are protected under *Schedule 5* of the *Wildlife and Countryside Act 1981.* Two other ponds with the most varied 'species assemblage' would also be destroyed and other pond clusters fragmented as a result of the proposed road.

The mitigation measures which were proposed aimed to:

- **replace lost ponds and terrestrial habitats;**
- **maintain and where possible enhance the existing ecological value of retained ponds and terrestrial habitat; and**
- **minimise the losses of amphibians of all species both during and after engineering works.**

These aims were achieved by:

- **creating 15 new ponds and planting each with vegetation from ponds which would be lost and from other local sources - additional egg-laying substrates such as small branches and plastic strips were also provided;**

- **improving twelve existing ponds in the area through de-silting, deepening and extending, regrading to create shallow margins, removing overhanging branches and scrub to prevent shading and removal of invasive marginals and fish;**

- **translocation of amphibians to new ponds and suitable terrestrial habitat which were fenced to provide a 'safe compound'.**

Proposals for monitoring the success of the measures are currently being considered (*pers comm* Marshall, 1995).

- Signs where amphibians migrate across roads in the spring. The DoT approves a list of registered sites each year which have formal approval for Highways Authorities to place signs at migration sites (HCIL, 1995).

5.2.7 *Litter*

Limited information on the impacts of litter has been recorded during this review. However, the provision of appropriate facilities, regular emptying of them and education of the public are considered key issues in respect to minimising litter generation.

5.2.8 *Roadside Verge Management*

Way (1977) suggested that the long term aim with regard to management should be to identify the potential of different areas using road maps of highway divisional areas marked as follows:

- with sites of special biological interest, sometimes requiring individual management;
- lengths of roadside requiring seasonal management to prevent encroachment of scrub in order to preserve or encourage herb-rich grassland communities;
- lengths of roadside where scrub might be allowed to develop; and
- lengths of roadside where there is no known biological interest.

Following research conducted by telephone questionnaires Alexander (undated) suggested the following two solutions regarding the nature conservation of road verges:

- a comprehensive survey of roadside verges should be undertaken to establish their existing or potential value for nature conservation, and the information used as a basis for management decisions; and
- authorities involved with roadside verge management should have a duty to further nature conservation.

Management advice could then be determined. Several studies of road side verges have been undertaken (*eg* Alexander, undated), however, many still remain unsurveyed.

5.2.9 *Visual Impacts*

A BTO study conducted by Henderson & Clark (1993) investigated the effects of roads near estuaries and embankment design on shorebirds. The study found that direct disturbance to birds from traffic to birds was minimal and that the superficial construction of embankments which were studied had no obvious effects on birds. However, the report suggests that embankments which can incorporate shrubby vegetation will help to screen a road and path from the shore and any form of screening would help to alleviate the potential problem of visual disturbance by traffic and people.

5.3 HABITAT CREATION

Many road schemes include provisions for scheme enhancement (English Nature, 1994). An element of this is habitat creation which typically results from one of the following:

- as compensation for habitat lost directly as a result of the scheme;
- in the form of road verges which can be of potential nature conservation value;

- as supplementary habitat to improve surrounding areas and therefore, lessen the affect of some secondary impacts *eg* fragmentation and isolation.

In addition many of the new wildlife passages themselves are now being planted with vegetation to create protective corridors. Thus habitat creation as a result of road development can produce some nature conservation benefits.

Measures to enhance butterfly richness on new road verges include the following:

- **Wide verges and central reservations** should be encouraged except where areas are of high nature conservation value already (Munguira & Thomas, 1992). The DoT commissioned the ITE to produce a flexible set of guidelines for the revegetation of roadside verges entitled the Wildflower Handbook (DoT, 1993) after recognising the need for greater flexibility and more appropriate use of seed mixes. Where a special flora is present verge replacement can be achieved through hydroseeding and the restoration of the original topsoil (Bakker, 1995).

  Vermeulen (1995) demonstrated that broad verges can act as a corridor between habitat fragments thereby lowering the chance of extinction of species.

- **Management** of verges can be enhanced using a mix of fine-leaved native grasses rather than by using fertiliser, only applying top soil sparingly and maintaining a mosaic of mown and unmown habitats.

- **Create irregular topography** to provide a greater range of breeding habitats for a range of species *eg* ditches may be added to narrow flat verges, sheltered indentations in the side of large cuttings may be excavated and steep slopes may be designed to descend in steps (Munguira & Thomas, 1992).

- **Compensatory habitat** may be provided as in the case of the M40 between Waterstock and Wendlebury where the route passed through Shabbington Wood SSSI affecting the black hairstreak butterfly (Bickmore, 1992). An area of over 4 ha was planted and managed for nature conservation purposes to encourage the black hairstreak including planting of irregular bands of trees and shrubs to provide shelter and feeding areas. In addition blackthorn bushes on which the butterfly pupae were attached in Shabbington Wood SSSI were removed and planted in the habitat creation area. The butterflies subsequently hatched and the majority of bushes survived.

  Creation of woodland, grassland and wetland sites are typical recommendations in environmental assessments (see M6 widening proposals Thomlinson, 1994). The habitat most likely to establish a reasonably rich community within a few years is probably a pond, as many aquatic species are adapted to ephemeral conditions (Edmunds, 1995).

  Some compensatory habitat and linking habitat has been established around road schemes, for example in the Netherlands, through compulsory purchase of land to provide an ecological corridor (Bakker, 1995).

- **Linking Habitat** for example a wildlife corridor was created between two woodland SSSIs by sowing a corridor within the motorway fenceline with a wildflower seed mix (Bickmore, 1992). The seed mix was chosen to comprise species attractive to invertebrates typically found in the local area. Trees and shrubs were also planted and two existing hedgerows enhanced to complete the corridor link. The full nature conservation benefits could take 50 years to achieve but in the short term the link also has a screening effect.

Small nature areas in between, for example, isolated wetland areas can function as stepping stones because they enable species to overcome the distance between the isolated habitats (Lichtendahl & Stam, 1995). Proximity of new woodland to established woodland comprising similar species could encourage immigrations or reduce exposure to the weather (Dennis, 1992).

For woodland areas several issues are important (Hinsley *et al*, 1992):

- where larger woodlands are fragmented, then the largest possible area should be planted (up to about 2 ha) to provide the greatest gains per additional unit of area for both breeding species and population stability;
- planting woods in groups creates a larger woodland for those species able to cross open ground;
- smaller woodlands and scrub patches can provide stepping stones between larger woods;
- a reservoir of large woods must be maintained to allow stability and sustainability at a landscape scale.

5.4 CASE STUDIES

This section includes two case studies as examples of current practice and outlines the mitigation and enhancement measures which have been provided.

5.4.1 Realignment of the Blackwater Valley Road (Source: pers comm Alfred McAlpine Construction Ltd)

The main ecological issues associated with the project and the mitigation provided is presented in *Table 5.4a* below.

Table 5.4a ***Blackwater Valley Road Mitigation***

Issue	Mitigation Proposed
River diversion	Reintroduce meandering sections of previously straightened river
	Banks dressed with soil excavated from redundant parts of the river to encourage natural regeneration of river bank vegetation
Protection of river from scour	Use of rock filled gabion baskets, loose rock fill and willow spiling to form natural bank protection
	Regrading of specially graded fill material to create deep ponds and shallows providing ideal river bed for fish to breed
Highway drainage	Directed to river via balancing ponds with outlet controls and roadside ditches
Amphibians and reptiles	Rescue operations capturing 2500 animals of 7 species which were held in enclosures

Issue	Mitigation Proposed
	Remaining captures were released at remote sites in the valley
	Small ponds were excavated for colonisation once enclosures removed and culverts and special fencing provided at crossing points
	Heathland habitat was transplanted from the line of the new road to the western side to conserve the habitat and also allow recolonisation by reptiles
Badgers	Badger proof fencing was erected alongside the road and lengths of the electrified railway line remote from the site
	Short lengths of line were to be de-electrified to allow badger crossings
	Offsite planting of plum trees and crab apple to increase foraging habitat and regular grassland management
Bats	Bat cave constructed in accordance with Surrey County Council design specifications and is only accessible by boat
	12" of water inside cave to allow for a natural environment (previously in brick river culvert) and a solar panel was installed in the roof
Fish	Affected gravel pits were, with help of NRA, destocked by netting and electro-fishing and catches transferred to other lakes in the valley
Noise and Visual Impact	Low design of road with earth mounds and noise fencing at sensitive sites
	Protection of existing vegetation and infill planting using native species

5.4.2 *Case Study: M6 Widening Junctions 16-20 (Source: Anthony Walkers & Partners, 1994)*

The main objectives of the proposed ecological mitigation are:

- to prevent any damage to sites or species of value for nature conservation; where adverse effects are unavoidable, to ensure that they are more than offset by mitigation measures;
- to enhance retained areas within the motorway curtilage by undertaking sympathetic management;
- to increase the total area of habitats of value to local wildlife.

Damage to sites or species would be prevented by identifying important sites on constraints maps, fencing working areas and the consideration of the appointment of an Environmental Manager during construction.

Further details of the measures proposed are presented in *Table 5.4b* below.

Table 5.4b *Case Study: Mitigation Measures M6 Junctions 16-20 (Source: Anthony Walker & Partners (1994)*

Key Issue	Mitigation
Existing woodland	Enrich by the control of competitive grasses, introduce shrub and herb species, progressive introduction of native trees and thinning out of non-natives.
	Identification of NVC plant community types and development of management plans.
	Erection of bird and bat boxes and retention of thinned timber to provide dead-wood habitats for invertebrates and fungi.
	Where practicable, areas of woodland and scrub likely to support nesting birds will be cleared outside the nesting season.
	Judicious tree surgery of retained trees during the construction period to reduce the risk of wind blow.
Existing hedges	Lost hedges will be replaced by tree and shrub planting.
	Offsite hedgerow planting offered to local landowners.
Existing grasslands	Approximately 50% of the retained grass verge to be diversified.
	Locations of species rich areas would be pin pointed. On species poor areas, top soils and grassy thatch would be removed and possibly used elsewhere. Consideration to creating shallow pools or wetland areas would be given for low lying areas. Sowing and planting of appropriate wildflower species would follow. Occasional mowing (annually or less) with periodic removal of cuttings every 4-5 years would be required to maintain floristic diversity.
Woodland creation	Landscape planting would be made up of native species.
	NVC would be used as a guide and natural regeneration would be encouraged at sites adjacent to semi-natural woodland.
	In selected areas trees would be planted into well-structured subsoil.
	The provision of contiguous woodland habitats would encourage the spread of woodland species which are slow to colonise.
	Open ground would be provided to form a total of 20% of the woodland area.
Scrub and tree planting	Scrub would be planted to provide further habitat and dense ground cover, particularly for breeding song birds.
Grassland creation	Existing unimproved, semi-improved pastures and appropriate NVC communities would be used as a model for new verges. Seed mixes from local sources would be used wherever possible and British seed sources elsewhere. The resulting sward would be managed in order to maintain the diversity (as for existing grasslands).
	Orchid habitats could be created if suitable substrates are exposed.
Heathland creation	Soils exposed for embankment and verge construction would be assessed for the suitability for heathland creation.
	Where possible, areas of bare sand would be left amongst the heathland vegetation to enable colonisation by bees and wasps and to provide suitable basking sites for reptiles.

Key Issue	Mitigation
Badger habitats	Badger mitigation works would be in accordance with detailed specifications prepared from guidelines agreed with English Nature and supervised by an ecologist or an Environmental Manager if one is appointed to the scheme. Where a main sett would be lost or risked abandonment due to disturbance a replacement sett would be constructed. Badger proof fencing would be erected where traditional badger paths would be severed by the new road, and close to certain setts. Where badger paths cross busy side roads which would be realigned for new bridges across the motorway, tunnels with associated fencing would be built to enable badgers to cross safely. Badgers would be encouraged to re-use land which they had previously frequented whenever it is safe to do so. Rabbit proof fencing used to protect new trees would have badger gates inserted wherever traditional paths were crossed. Soil removed from the construction sites in badger frequented areas would be stored in uncompacted low mounds to facilitate recovery of an earthworm population when re-spread.
Wetland creation	Approximately 30 ponds to be created, including 8 balancing ponds. The ponds would be created to maximise their value for wildlife *eg* varied depths, edges, gradients, extent of shrub, tree and herbaceous planting and by using suitable plants and mud from existing waterbodies nearby to 'inoculate' new ponds.
Amphibian habitats	Details of any mitigation for great crested newts would be agreed with English Nature and supervised by an ecologist or Environmental Manager if one is appointed on the scheme. Replacement ponds would be created close to each original lost. Replacement planting would provide suitable terrestrial habitat around the new ponds. Amphibians would be excluded from the habitat to be lost and an intensive trapping programme would be undertaken in March. A proportion of the additional ponds would be made less suitable for fish to reduce the risk of predation on amphibians. Ponds considered to be at risk of hydrological changes would be subject to a hydrological survey and protective measures carried out where necessary.
Balancing pond design	Detailed mitigation measures would ensure that the quality of surface water runoff would be within guidelines set by the NRA. The scheme would include the construction of 8 wet balancing facilities/retention pools and 2 pollution ponds. Reedbeds would be incorporated within the balancing ponds where this is practicable to further improve the water quality of the inflow. The balancing pool would be inoculated with marginal, aquatic and emergent vegetation. Trees would only be planted on the northern side and habitats such as willow and alder carr would be established to provide shelter and screening.

Key Issue	Mitigation
Alterations to watercourses	Where stream to be realigned there would be a minimal reduction in channel length and bankside vegetation. Banks would be replanted with native trees, shrubs and plants and rocks placed in the stream bed to mimic previous conditions. The pool and rifle sequence of a natural stream would be preserved or recreated. Bed and bank protection during realignment would be undertaken and works carried out in winter. Linings of cobble or rubble, gabions, gravel armouring, grasses and woody vegetation would be preferred as they provide some habitat for aquatic plants and macro-invertebrates. Suitable bed materials would be used to increase the diversity and deflectors used where appropriate to create a pool and riffle sequence. Small weirs and sills would be inserted to further diversify the habitat.
Engineering works and structures	Stone filled gabion baskets would be diversified by using willow logs in the front space of the baskets. Once sprouted the willows provide cover and secure the gabions. Measures to enable bats to colonise new structures would be included wherever possible.

5.5 SUCCESS OF MITIGATION MEASURES

5.5.1 *General*

Techniques for monitoring actual environmental impacts are not well developed and the predictions made in EAs are rarely tested against what actually happens when the project is built and operated (Therivel *et al*, 1992). The costs of monitoring are high and thus only relatively rarely will a developer monitor the success of implemented mitigation measures.

However, some examples reviewing the success of mitigation measures have been identified in the literature or from consultation and these are described below.

5.6 EFFECTIVENESS OF MITIGATION MEASURES

Badgers

Between 1969-1993 at least 193 underpasses for badgers were constructed in the Netherlands, however, about 65% of those examined were poorly designed. In most cases the quality of the wire netting fences guiding the badgers and the drainage of the underpasses were inadequate. Despite this at least 74% proved to be effective ecological corridors for badgers with only a few casualties along the fenced section of the underpass. In 71% of cases the procedures for planning, management and maintenance were not satisfactory in every respect. Insufficient budget for replacement materials, a lack of regular inspections and evaluation and insufficient collaboration between land owners and the road maintenance authorities were all highlighted as casual factors for lack of effectiveness (Janssen *et al*, 1995).

The population size of badgers in the Heuman/A73 area in the Netherlands has increased from six setts in 1985 to twelve in 1995. The main reason for this growth is probably due to the success of some of the mitigation measures which have been implemented (Douwel, 1995). Badger tunnels were well used by badgers (and other mammals) before the road opened to traffic. Fences were lengthened, however, following road kills of badgers around the ends of the original fencing. Despite this badger kills still occur on the road and regular inspection of the fences remains a priority.

In this country monitoring of the success of badger mitigation is poor although a recent report has been produced for the Highways Agency on the success of mitigation in the south west (*pers comm*, Cresswell, 1995). Such commitment from the statutory agencies has not always occurred as for example in the case of the Derby Bypass where DoT declined to monitor the success of badger mitigation measures (*pers comm*,-Penny Anderson Associates, 1995).

RSPCA (1994) suggests that although badgers do use tunnels they may require encouragement to begin with. Fencing, which is typically required with tunnels is expensive and there is no agreement on the effectiveness of the different types (*pers comm*, NFBG, 1995). Badgers regularly cause holes and lots of casualties are still recorded near to holes in fencing or where fencing ends (*pers comm*, English Nature Thames and Chiltern Team, 1995).

An assessment of the effectiveness of badger protection measures on ten road schemes in the south west was undertaken by Bristol Ecological Consultants (BEC) on behalf of the Highways Agency. Of the badger provisions on the ten schemes reviewed only one, the A35 Yellowham Hill Improvement appeared to be almost successful. In this case all of the purpose-built badger tunnels were being used and no other regularly used crossing points were found. Apart from one other scheme the measures to avoid or minimise badger road mortality have typically been unsuccessful. The lack of success can be largely attributed to the lengths of badger fencing installed being insufficient and fencing being installed without the provision of a crossing point (BEC, 1994).

Some effectiveness in reducing casualties in Cornwall and the Forest of Dean is claimed using reflectors (*pers comm*, NFBG, 1995), however, from the Netherlands Vereniging Das & Boom (1990) state that *"Badgers cannot be stopped by reflectors alongside the road"*.

Reflectors were used along a 1.5 km stretch of road in Grave and road mortality did not decrease over a four year period. The Northumberland Badger Group (*pers comm*, 1995) note that reflectors become muddy and because they are sited at a low level are easily covered with vegetation which, without regular maintenance, renders them ineffective.

The use of artificial lighting (and reflectors) as a deterrent to badgers is, apparently, not readily acknowledged, although there has been no research to date as far as we are aware. However, the fact that badgers are frequently filmed for television under bright lights would suggest that they can become accustomed to them. It may be possible that selective use throughout the year may be more appropriate (*pers comm*, NFBG, 1995).

As regards the effectiveness of other measures, roadsigns were considered to raise awareness, but not considered to be particularly effective (*pers comm*, NFBG, 1995) and badgers are "*more than capable of crossing grids, even at full speed*" (Vereniging Das & Boom, 1990).

Other review work on the effectiveness of mitigation measures for badgers includes a 5 year study (for the Highways Agency) of the badger measures provided on the M40 between Oxford and Birmingham. A report is expected by spring 1996 (*pers comm* Highways Agency, 1995).

Other Mammals

The use of wildlife passages for overcoming fragmentation problems has been used on a more grand scale abroad and especially in the Netherlands, where several ecoducts have been successfully constructed.

Six years after construction of the A50 motorway between Arnhem and Apeldorn mammals were apparently making intensive use of ecoducts and tunnels (the cost of these structures was 9M guilders - approximately £3.5M).

Animals have been recorded crossing every night and during the first year more than a thousand crossings of roe deer, red deer and wild boar alone were counted and numbers are rising. The ecoducts should, though, not be seen as complete solutions (Berris, 1995; Sluiter, 1995).

Preliminary findings regarding the effectiveness of wildlife overpasses indicate that passages can fulfil their purpose if designed and placed correctly by wildlife specialists. The dimensions of the wildlife passages have to fulfil the requirements of the most sensitive species occurring in the area as well as providing a suitable corridor for a range of affected species with diverse habitat requirements (Keller & Pfister, 1995).

A variation using a wildlife passage comprising a wall of tree stumps (also in the Netherlands) was in regular use after a few months (van der Linden (1995).

In the UK, the success of other measures varies for example:

- reflectors are reported to be effective in deterring deer from roads, however, they are frequently stolen and therefore, their long term use is questionable (*pers comm*, British Deer Society, 1995);

- otters are known to climb well and have scaled fences and walls and will frequently travel hundreds of metres to the end of a fence and then continue in the original direction (*pers comm*, Otter Trust, 1995);

- the installation of an underpass beneath a road on the edge of the Tonbridge Estuary near Brideford (which was a known animal blackspot) was successful as the underpass was used immediately and there have been no deaths since (*pers comm*, NRA South West, 1995);

- in contrast on the A39 an underpass was installed and an otter casualty was recorded following installation (*pers comm*, NRA South West, 1995).

Reptiles and Amphibians

- Very little is known about the impacts on reptiles and therefore mitigation success is uncertain to date.

- Successes of amphibian mitigation measures are also poorly monitored (*pers comm*, HCIL, 1995). Some initial successes are apparent from relocations of ponds etc (see Marshall *et al*, 1995 and below).

Marshall *et al* (1995) concludes that as part of the mitigation scheme for the A34 Wilmslow and Handforth Bypass (see *Box 3.6a*) the amphibian populations have been maintained or enhanced with the exception of one site.

This suggests that amphibian populations can be sustained and even increased as long as programmes are planned in advance and careful attention is given to detail. It is also important that there is sufficient flexibility in the scheme to modify specific conservation measures in light of monitoring results and changes in circumstances. The total cost of the amphibian mitigation scheme was estimated to be £205,500.

General

Three ecological and landscape appraisals of existing trunk roads and motorways (M5, A303 and A30) were undertaken for the Highways Agency in 1994/95 and a further ten studies are ongoing. These are aimed at determining hotspots and providing further management/maintenance regimes which seek to benefit these areas.