Natural England Commissioned Report NECR168

NEWP32 Transport green corridors: literature review, options appraisal and opportunity mapping

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

This project report and accompanying literature review were commissioned as part of the commitment to deliver the Natural Environment White Papers (NEWP) commitment 32 which states;

'*The Government will work with its transport agencies and key delivery partners to contribute to the creation of coherent and resilient ecological networks, supported, where appropriate, by organisation-specific Biodiversity Action Plans. We will host a forum with environmental stakeholders to inform future priorities for the enhancement of these green corridors'*

Developed in partnership with Network Rail, the Highways Agency, Morecambe Bay Nature Improvement Area (NIA) and Humberhead Levels NIA this report looks at how the management of transport soft estate (the land owned by the transport operators that is neither road nor railway) can be better integrated and linked with adjacent land management. Doing so could deliver wider benefits not limited to the estate within Network Rail and Highways Agency boundaries themselves but which help better connect that estate to the wider landscape.

The aims of the project were to:

- Carry out a literature review in relation to the role of the transport soft estate for biodiversity, ecological connectivity, ecosystems services provision and transport infrastructure resilience, (NECR169).
- Apply the findings to the transport network within two Nature Improvement Area (NIA) locations: at Humberhead Levels and Morecambe Bay (this report).

The project outputs are being used to inform a three year programme of work within each NIA. This next stage will be piloting different approaches to land management of the transport soft estate and neighbouring land holdings with a view to developing and informing best practice that can be employed more widely.

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Further information
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NEWP32 Transport green corridors: literature review, options appraisal and opportunity mapping

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Our grateful thanks go to Natural England (NE), the transport operators of Network Rail (NR) and the Highways Agency (HA) (including regional staff from the Humberhead Levels and Morecambe Bay areas), and the Nature Improvement Area (NIA) Partnerships for the Humberhead Levels NIA and Morecambe Bay NIA.

Executive Summary

Background to the project

Transport networks are critical components of a nation's economic success, but the infrastructure and operations associated with roads and railways can also have adverse effects on biodiversity and landscape, as well as being a major source of pollution. In addition, transport networks are particularly vulnerable to the impacts of changing climatic factors.

Within the transport network there is a significant area of 'soft estate'. This term essentially refers to the natural habitats along the sides of motorways, trunk roads, and railway tracks. There is a growing evidence base to suggest that the soft estate can mitigate many of the adverse impacts of transport networks, and even deliver biodiversity gain, improve ecological connectivity and provide ecosystem services. Furthermore, by using a green infrastructure approach, the soft estate also has the potential to improve the resilience of transport networks towards future climate change.

Purpose and aims of the project

Following the publication of the UK Government's Natural Environment White Paper (NEWP) in 2011, a project was initiated with the aim of maximising the ecological connectivity, ecosystem services provision and infrastructure resilience of the UK's transport soft estate. This project (NEWP 32) was led by Natural England in partnership with the Highways Agency and Network Rail. The project has looked for the first time at how the management of soft estate can be better integrated and linked to adjacent land management to deliver wider benefits, not limited to the Network Rail and Highways Agency estate, with better connection to the wider landscape. The aims of the project were to carry out a literature review in relation to the role of the transport soft estate for biodiversity, ecological connectivity, ecosystems services provision and infrastructure resilience, and then to apply the findings to the transport network at two pilot Nature Improvement Area (NIA) locations: at Humberhead Levels and Morecambe Bay.

Literature review

The literature review comprised a methodological search of peer-reviewed journal articles and grey literature with the aim to answer two key research questions:

a. How has land within or adjacent to the transport corridor been used or enhanced for green infrastructure that delivers biodiversity gain, ecological connectivity, and ecosystem services?

b. How has green infrastructure been used or enhanced to deliver ecosystem services both within and adjacent to the transport corridors to increase transport infrastructure resilience to climate change (i.e. green solutions to network resilience)?

The key findings in relation to these questions were that transport soft estate does have potential to deliver biodiversity gain and ecological connectivity but that this depends very much on the species and landscape context, as well as the management regime. The evidence for ecosystem service delivery showed the transport soft estate has potential for biomass provision, air quality and climate regulation, noise and wind regulation, carbon sequestration, water quality improvement, flood risk mitigation, visual amenity, as well as habitat provision for pollinators. Some of these services, for example wind shields, flood risk mitigation, and local heat effect reduction alongside the soil stability provided by vegetation could also be valuable in improving the resilience of the network to future climate change. There are already some green infrastructure solutions in place along transport corridors, but their deployment has been somewhat limited especially in a UK context. Lack of research to investigate their applicability in a transport context (especially for rail) as well as health and safety concerns are the main obstacles. The literature review concluded with a number of recommendations for different management regimes along the transport soft estate; these recommendations have been used to inform the pilot studies. There were also recommendations for further research, in particular into the applicability of green infrastructure to transport networks. In this regard the pilot studies at Humberhead Levels and Morecambe Bay will also prove to be valuable additions to the literature.

Consultation with the Nature Improvement Areas partnerships

The two NIAs chosen for the pilot represent different habitat types and management opportunities and challenges. Humberhead Levels is an intensively arable farmed, heavily drained lowland landscape. The objective is to develop a major multi-functional wetland landscape in a largely unrecognised biodiversity hotspot. Morecambe Bay includes iconic lowland and upland landscapes, existing mosaics of high quality grass and woodland habitats and predominantly pastoral farmland. The objective is to enhance and restore one of UK's most important biodiversity hotspots including in particular limestone pavement and wetland habitats.

A number of key issues were revealed at the Humberhead Levels NIA workshop, including water management, earthwork stability and drainage, tree and leaf fall, and invasive species for both transport operators. Cost and time were also major constraints for carrying out roadside vegetation maintenance. However, there are also opportunities to create mosaic and species rich habitats in the soft estate including scrub, grassland, and woodland which would provide a range of ecosystem services.

Invasive species, flooding, and run-off were raised as concerns at the Morecambe Bay workshop. There are potential opportunities to manage woodland and trees more effectively and economically, as well as to improve connectivity of the key habitats. The opportunities for the rail network are more constrained than for the road network, as the lines are electrified and the banks relatively steep. Biomass production was seen to be potentially viable at certain locations along the road and rail network, although there are constraints around access and transport costs, particularly in relation to rail, which limit the removal of biomass from the estate. The consultation also revealed that opportunities exist to enhance hedgerow cover, and to install Sustainable Drainage Systems (SuDS), ponds and wetland habitats along rail and road networks and the adjacent land.

Consultation with the transport operators

Through this project, both Network Rail and the Highways Agency are committed to understanding how their estate can be better managed to deliver wider biodiversity and ecosystem service outcomes, reduce their operating risk and increase resilience. Stakeholder consultation was conducted with the Highways Agency and Network Rail regarding their overall habitat and vegetation management approach, as well as any specific constraints and opportunities unique to the two pilot sites.

Both organisations recognise the potential for habitat enhancement and ecosystem service delivery at the local level. However, the existing habitat and vegetation management approach prioritises health and safety as well as cost control. For the Highways Agency previous activities carried out for biodiversity and amenity benefit, such as annual cutting of roadside vegetation have been replaced with less frequent, lower cost management. Meanwhile the opportunity along the rail network is limited to that part of the soft estate furthest from the track. Both organisations have developed their own Biodiversity Action Plans (BAP) and land management around protected sites is carried out in conjunction with Natural England. However, at time of writing both BAPs were out of date and due for renewal.

Opportunity mapping

A mapping exercise was then conducted to identify the opportunities for biodiversity gain, ecological connectivity, ecosystem services, and network resilience within the transport corridor of the two NIAs, in order to better link the soft estate with the wider landscape. The first stage mapped out priority habitats and designated sites, flood risk areas, water quality status and ecosystem services potential within a 200m buffer of the transport soft estate. The locations of Higher Level Stewardship schemes were also mapped to identify potential synergies with adjacent landholders. A scoring methodology was then applied; this rated the land on a scale of 0 to 13 according to its potential to deliver biodiversity, ecosystem services, and network resilience.

Hotspots were identified along the transport corridors of both NIAs where there was potential to deliver these services at key locations. Morecambe Bay had relatively more hotspots, with 11% of its rail transport corridor scoring 10 or higher. Humberhead Levels had relatively fewer hotspots with just 3% of the rail network scoring 10 or higher and more than half the total transport corridor scoring 3 or less (54%, compared to 27.5% in Morecambe Bay). This is likely to be because of differences in the area of priority habitats / designated sites and habitats supporting key ecosystem services within the 200m transport corridor buffer in the two NIAs, with Morecambe Bay having comparatively more of these habitats than Humberhead Levels.

Vegetation management options

The final stage of the project sought to identify potential management options and then apply them to different spatial locations along the transport corridor. The findings of the literature review and the stakeholder consultation led to five potential management options being selected. These management options varied according to their target habitat and the existing soft estate and surrounding land use.

Management Option A aims to support woodland habitats with a focus on retention, management via coppicing and thinning and potentially planting. This option is potentially suitable where more than 50% of the soft estate is already woodland or scrub, and the surrounding 200m contains woodland priority habitat or habitats with a high potential for delivering woodland ecosystem services. This could be applied to a total of 23km of the NIA transport corridor.

Management Options B and D both aim to support water management with a focus on enhancing priority wetland and freshwater sites. Option B is potentially suitable where there is already a high scrub or tree cover on the soft estate. Option D is potentially suitable where there is low scrub or tree cover on the soft estate. Both options prioritise flood risk mitigation including retaining trees to reduce runoff, and using surrounding land as flood storage, subject to land management agreements, with use of SuDS on the soft estate where width allows. Option B is potentially applicable for 23km of the corridor, whilst Option D could be used on 58km of the corridor.

Management Options C and E both aim to support species rich grassland and grass/scrub mosaic habitats. This includes the thinning of tree cover and subsequent management as appropriate to the specific grassland habitat. The two management regimes differ mainly based on the existing tree and shrub cover in the soft estate. Option E is potentially suitable where there are relatively few trees or shrubs and no flood risk issues, thus allowing a more ambitious grassland creation objective. Option C is potentially suitable where there is already a high tree and shrub cover and thus aggressive tree removal and management change may not be advisable. Option C and E could be applied to 17km and 52km of the corridor respectively.

Future work

Subsequent localised project work (to be undertaken in follow up stages of this work over period 2014-2017) will include a consideration of the implications of the management regime for the landscape character of the area affected. The management approaches will also be checked against the priority species identified in the Local Biodiversity Action Plans, and will seek to tie in, where possible, with neighbouring Higher Level Stewardship schemes. Finally, Highways Agency and Network Rail will review the local applicability of the management plans to identify any health, safety, and cost considerations which may require the management plan to differ. Subject to any locally applicable changes derived from the additional work described above, the management regimes will be applied within the two NIAs for a period of 3 years under the supervision of Natural England, Highways Agency, Network Rail and the NIA partnerships and the results monitored.

In addition to groundtruthing, further work may be required to improve the accuracy of ecosystem services mapping at the local level. If more information was available on the condition of the ecosystem service provided by each habitat in each location, or perhaps if the conservation status of the sites and species and the severity of the flooding etc was taken into account, then more complex scoring could be used allowing a broader buffer zone to be chosen.

Depending on the outcome of the pilot studies, the approach could be extended to the other ten NIA pilot areas, or perhaps to the transport estate within sites with nature conservation designations, protected landscapes, urban areas or the wider countryside. The project could also potentially be extended to other linear corridors, such as canals and rivers, cycle networks and national grid networks.

1. Introduction

The existing transport network includes a significant area of 'soft estate', ie the natural habitats that have emerged along motorways, trunk roads and railways (verges and linesides). The Highways Agency (HA) manages approximately 30,000 hectares of land, supporting a wide range of habitats, including over 40 million trees (HA website). Network Rail (NR) manages over 32,000 km of track (NR website) and has an interest in over 200 SSSIs in England covering over 650 hectares of land (NR SSSI register).

Whilst it is recognised that transport infrastructure and its operations can have significant adverse effects on biodiversity and landscape, transport's soft estate also has the potential to deliver a range of environmental benefits, whilst simultaneously enhancing network resilience, through its green infrastructure (GI). This project is seeking to develop the evidence base to identify where there is greatest potential for delivering biodiversity, ecosystems services and network resilience gains from the soft estate.

With appropriate design and management the soft estate has the potential to deliver multiple benefits such as increasing biodiversity value and improving transport infrastructure resilience to the impacts of climate change. For example transport corridors can provide a valuable semi-natural habitat, acting as a linear dispersal corridor facilitating the migration of some plant and animal species, providing important connecting corridors between ecological sites (Cost Action 341), and with the potential to aid migration of species as they seek to adapt to climate change. In some instances, transport corridors pass through designated areas such as Natura 2000 sites and may include sections of priority habitat within the estate boundary.

Transport's soft estate also has the potential to deliver a range of ecosystems services through its green infrastructure (GI). With appropriate design and management, the soft estate and its green infrastructure has the potential to deliver multiple ecosystem services which could benefit biodiversity and ecological connectivity as well as increasing transport infrastructure's resilience to climate change. For example there is potential for transport corridors to provide sustainable drainage to help manage surface water runoff and improve water quality, or to improve air quality, capturing or acting as a barrier to dispersal of pollutants produced by vehicles. This project seeks to explore further the potential for enhancing the transport's green infrastructure and the ecosystem services it provides for the benefit of biodiversity and transport infrastructure resilience.

Enhancing the soft estate could make an important contribution towards the delivery of outcomes as set out in Biodiversity 2020 (Defra, 2011a). It could also contribute towards local social and economic developments and make an important contribution to the debate around short and long term resilience of the nation's transport infrastructure (DfT, 2014).

1.1. Background to the NEWP 32 transport corridors project

The Natural Environment White Paper (NEWP) was published by HM Government in 2011, with a particular aim of protecting and improving the natural environment across England, moving to a net gain in the value of nature. 34 commitments are set out to help achieve this, of which commitment 32 says:

'The Government will work with its transport agencies and key delivery partners to contribute to the creation of coherent and resilient ecological networks, supported,

where appropriate, by organisation-specific Biodiversity Action Plans. We will host a forum with environmental stakeholders to inform future priorities for the enhancement of these green corridors.' [32].

In order to take forward this commitment, a working group was established in November 2012 comprising Defra, Natural England (NE), NR and HA, along with representatives of the Humberhead Levels and Morecambe Bay NIA partnerships. The aim of the "NEWP 32" project is to maximise the ecological connectivity and ecosystem services provision from transport's soft estate in a way that:

- Is cost effective;
- Helps transport networks increase resilience and enhance their ability to adapt to the effects of climate change, including the effects of more frequent and intense extreme weather events, and incremental seasonal changes;
- Delivers new or enhanced green infrastructure that delivers ecosystem services, and/or priority habitat that is species rich and appropriate to the character of the landscape;
- Enhances ecological connectivity and reduces fragmentation;
- Results in landscape-scale benefits;
- Secures enhanced landscape-character and value;
- Enhances indirect experience of biodiversity and contact with the natural environment for people and communities; and
- Contributes towards other local social and economic enhancements.

Natural England is the lead partner in this project, and is working to achieve this aim and objectives by:

- Bringing together in partnership the key organisations responsible for the management of transport's soft estate.
- Piggybacking on work that partners are already doing e.g. utilising existing transport soft estate management plans, such as HA and NR Biodiversity Action Plans (BAPs).
- Piloting a new approach to joined up working in two Nature Improvement Areas (NIAs) - Morecambe Bay NIA and Humberhead Levels NIA. Both have a mix of road, rail (and waterway) infrastructure.
- Linking with other existing ecosystem service and biodiversity enhancement work already underway within these NIAs e.g. ecosystem service pilots and the NIAs and key partners planned delivery activity.
- Incorporating best practice and learning from similar linear connectivity projects, disseminating outcomes through the Department for Transport (DfT), Department for Environment, Food and Rural Affairs (Defra), Defra 'family' organisations and industry bodies.

This project forms part of a wider (multi-phase) transport project working with these two NIAS, NR and the HA. One component of this wider project is to trial new approaches to managing the soft estate to maximise the delivery of GI that provides ecosystem services and ecological connectivity. These new approaches will be informed by the outcomes of this literature review, options appraisal and opportunity mapping. It is intended that the information gathered and approaches utilised could potentially be incorporated into current or future operational decision-making tools in order to inform and optimise future network resilience and ecosystem service and environmental delivery.

The initial aims of this project were to:

a) Robustly review the existing literature to find out how transport's soft estate (and adjacent land) has been used to enhance green infrastructure that delivers ecosystem services (including ecological connectivity and climate change adaptation) and increases transport infrastructure resilience across the UK and EU.

b) Use the findings of the review to:

    - Identify the range of potential land management options that could be employed in the two NIAs.

    - Undertake a Multi-Criteria Analysis of these land management options to identify preferred approaches based upon considerations such as cost, ease of implementation, environmental benefits achieved, timeframes etc. and develop a ranking system for each criteria.

c) Identify the data needed and any key data gaps that exist (based on currently available data) to baseline current ecological connectivity, ecosystem service provision and network resilience provided by each land management option.

d) Develop an outline decision-making tool that could be trialled within the two NIAs which is informed by the above.

e) Develop opportunity maps for the two NIAs, informed by the above.

Multi-Criteria Analysis (MCA) and the decision making tool have not been progressed as part of this project, as workshops held with representatives from the NIAs, NR and HA revealed that this approach was perhaps too complex. The work has thus been refocused on the opportunity mapping as the primary output. However, further consideration will be given to the possible use of MCA and the decision making tool in the next stages of the project (which lie beyond the scope of this report).

A key purpose of the project is to assist the transport corridors' role in enhancing ecological (habitat) connectivity across the landscape, whilst also seeking to maximise beneficial ecosystems services provision and developing management solutions that will increase transport resilience to climate change and reduce operational risks for the transport network operators.

1.2. Transport corridor context

Network Rail's approach to habitat and vegetation management

The aim of NR vegetation management, as set out in the Management of Lineside Vegetation document (NR, 2012), is to manage the grassland within the 'cess strip' (the ground area between 3m and 5m from the running rail) and scrub vegetation beyond this. Trees are discouraged within a zone between 5m from the track and the boundary (generally 12m from the track) to reduce risk of falling trees onto the track and overhead power lines and to control leaf and branch fall on the track. NR estimate that 80% of tree fall is attributable to healthy trees blown over by strong winds, and this results in disruption to services and associated compensation to train operators (circa. £2 million per year for the northern section of the London North West (LNW) line).

Vegetation management regimes vary according to the risk posed by the lineside vegetation (leaf and tree fall and other hazards such as impaired sight lines) and the characteristics of the railway. In general vegetation clearance is carried out in order to achieve a structure of vegetation that reduces the risk posed by that vegetation to as low as reasonably practicable. Vegetation operations and activities are planned in such a way as to avoid contravening environmental legislation, but do not specifically seek to enhance the environment.

Currently the management practice within the 'cess' (the area closest to the track, typically 3m wide) and the cess strip is to spray the vegetation once annually during early to mid-summer. Spraying is carried out using a regular programme of applications of total herbicides using specialist rail vehicles, known as Multi-Purpose Vehicles. In some cases herbicides are applied only to the ballast area, but they often drift to cover other areas. Spraying along road and rail corridors could have an impact on water quality; coastal authorities have shown concern on the impact on blue flag beaches. The objective is not to reduce everything to bare earth, which as well as impacting on biodiversity and aesthetic value would increase the risk of soil erosion in cuttings and on embankments, but to maintain a grassy strip with no large trees or bushes within 5m of the line.

NR proactively manage the strip of land beyond 5m distance from the track as scrub, coppicing trees that have exceeded 150mm dbh in girth. If trees are coppiced before they reach maturity, before they start to become a hazard (hazardous trees are felled under the current maintenance regime), there could be cost savings. Additionally there is a demand for coppiced wood which could provide a modest income. (Note that coppiced sycamore presents a major leaf fall problem so coppicing is limited to non-leaf fall problem species).

Where railways pass through SSSIs, Site Management Statements are drawn up agreeing actions by both NR and NE. These typically include the following objectives:

- To manage NR land to permit the safe and easy passage of trains through the site.
- To comply with statutory conservation requirements.
- To manage protected heritage features and habitats within NR's care.
- To work with Natural England at a local level to agree management required to maintain the SSSI in a favourable/recovering condition.
- To conserve and where possible enhance the interest features for which the SSSI has been notified by maintaining or restoring them to a favourable condition.
- Where the SSSI also forms part of a European Special Protection Area (SPA)

to avoid the deterioration of the habitats of the SPA's qualifying features, and the significant disturbance of its qualifying features, ensuring the integrity of the site is maintained and the site makes a full contribution to the aims of the Wild Birds Directive.

- Where the SSSI forms part of a European Special Area of Conservation (SAC), to avoid the deterioration of the SAC's qualifying natural habitats and the habitats of its qualifying species (if appropriate), and the significant disturbance of any qualifying species, ensuring the integrity of the site is maintained and the site makes a full contribution to achieving Favourable Conservation Status of each of the qualifying features.

The Highways Agency's approach to habitat and vegetation management

Following the publication of the Natural Environment White Paper (HM Government, 2011) and England's Biodiversity Strategy (Defra, 2011) HA is giving further consideration to its approach to Biodiversity and Nature Conservation. In 2002 HA published its own Biodiversity Action Plan (BAP) which set out actions and targets to enhance the value of the estate and to maximise HA's contribution to biodiversity. This expired in 2012. A revised BAP is currently in the process of being developed and is due to be completed in 2014. HA has also published its own guidance on nature conservation and biodiversity issues, which is included with the Design Manual for Roads & Bridges. This guidance is maintained and supplemented through continued research on aspects of environmental best practice relevant to HA's activities.

In terms of managing roadside vegetation, HA used to perform a 2m swathe cut twice annually in early and late summer (May/June and September). However, in 2009 the HA decided to cease amenity and swathe cuts and to continue only with safety / visibility cuts (e.g. cutting vegetation in front of road signs) in order to reduce expenditure on grass cutting. However, scrub encroachment has since occurred in various locations in the Humberhead Levels area which is likely to require more expensive management to address in future, whilst it is thought that grassland species diversity may have declined due to the change in management.

As revealed in a report by Ground Control Ltd (2013), woodland forms a significant area of the road network in Area 12 (this Area covers 326 miles of motorway and trunk roads throughout Yorkshire and North Lincolnshire, including within the Humberhead Levels) amounting to approximately 70 hectares. Historically the tree asset has undergone a managed regime of thinning operations as part of the routine maintenance works. This work has been based on a range of requirements, including aesthetics, health and safety, and enhancing species diversity. Thinning or coppicing operations have ranged from 15% to 50% removal dependent on the managed regime prescribed for a tree plot, with some of this targeting specific species. For example Alder and Sycamore are short term species and have as such been thinned to favour long term species such as Oak, Beech and Ash. Willow and Poplar species have been targeted for 100% coppice in order to manage their rapid growth rates. Trees are felled and processed by chainsaw and put through a chipper unit with the chippings spread out back onto the ground.

The Highways Agency's Area 12 Environmental Management Plan contains the following relevant objectives:

- Adopting a stewardship approach involving both the network and design teams creating an overall teamwork approach when undertaking works that affect the soft estate.

- Undertake environmental Local Network Management Schemes (LNMS) surveys of the Area 12 network to meet the requirements of the Highways Agency Biodiversity Action Plan (HABAP). This will determine increased awareness of protected species and habitats within the network and help add a wider knowledge of biodiversity within EnvIS (HA's environmental database).

- Implementing and maintaining an environmental training programme to ensure that all managers, planners, designers and site operatives are aware of their responsibilities with regard to environmental issues.

- Identifying, exploring and developing partnership opportunities with other agencies and landowners.

- Review annually the maintenance operations undertaken on the soft estate taking into consideration information identified from local network management schemes (LNMS) studies and other sources.

1.3. Pilot study area context: Humberhead Levels

The Humberhead Levels Nature Improvement Area (NIA) is part of the predominantly low lying, flat landscape of the 2,000 sq km Humberhead Levels National Character Area (NCA) covered by the Humberhead Levels Partnership (see Figure 1.1 below). Following centuries of land drainage, the peaty soils now produce good arable land. Criss-crossed with canalised rivers, ditches and dykes, these waterways provide opportunities for habitat connectivity. To protect farmland and settlements from flooding, complex pump drainage systems are managed by several Internal Drainage Boards and the Environment Agency. The remaining wetlands of this former marshland are mostly nature reserves and a focus of NIA activity. One of these wetlands is the Humberhead Peatlands National Nature Reserve. At 3,300 hectares, it is the UK's largest lowland raised peat bogs as well as being a Special Protection Area, Special Area of Conservation and SSSI. Improving its hydrological integrity is a NIA priority as this will also store carbon as well as create a fully functioning peat bog.

The NIA also extends into the Humber Estuary National Character Area (NCA) where it drains the major rivers found in the Humberhead Levels NCA. In this area, washlands provide habitat for wetland bird species but the area also contains managed re-alignment to protect settlements from coastal flooding. Spanning the counties Yorkshire, Lincolnshire and Nottinghamshire, the NIA covers 49,700 hectares. The lead partner for the NIA is the Yorkshire Wildlife Trust and the NIA is part of the wider Humberhead Levels Partnership (HLP) which was established in 2001.

The wetland habitats in Humberhead Levels are intimately interspersed within some of the most productive arable land in the UK, mostly below sea-level and vulnerable to climate change effects. The area offers the best opportunity in England to develop a major multi-functional wetland landscape in a largely unrecognised biodiversity hotspot. The main aim for the NIA is to contribute towards the Vision of the HLP:

- To create an internationally renowned, unique wetland landscape, supporting thriving communities, economy and wildlife.

The NIA has identified five themes that will help achieve the HLP vision:

1. Creating key habitats in the inner part of the Humber Estuary;
2. Achieving sustainable water management in an arable landscape through enhancement of riparian habitats along connecting rivers, ditches and dykes';
3. Increasing the hydrological integrity of England's largest lowland raised mire (the Humberhead Peatlands);
4. Delivering sustainable management of existing biodiversity assets through the development of the local green economy; and
5. Increase community links to biodiversity sites to increase volunteer support for site management, heritage conservation and interpretation.

Figure 1.1: Humberhead Levels NIA within the wider Partnership Area

By operating at landscape-scale, the NIA partnership aims to enhance existing, internationally important wetlands (the Humberhead Peatlands and Humber Estuary), other SSSIs and Local Wildlife Sites; reconnecting sites by working with local farmers to create ribbons of habitat on unproductive drain-sides, headlands and wet field corners associated with the important rivers and dykes that traverse the area. The aim is that wildlife will be free to move through adjacent farmland whilst maintaining food production and increasing resilience to climate change. At the end of the NIA funding period, it is anticipated that 1,427 hectares of wetland habitat will have been created or restored.

A key aspect of the NIA partnership will be to progress towards reinstatement of England's largest lowland mire system. Achieving this long term goal will increase the amount of carbon sequestered into newly forming peat and wetland soils; a vital ecosystem service. The NIA will develop community capacity to get involved with wildlife sites. This will include targeted volunteer development and training, resulting in an extra 3,910 hours of volunteer time.

Other aims include better integrated land management, which in the long term will improve resilience to climate change. Closer partnership working will align farming with more sustainable flood defence, water supply and enhance biodiversity. The impetus provided to the local green economy through, for example, work on developing innovative biomass to energy products. Operating within the National Character Area (NCA) as the wider 'landscape-scale' framework for local delivery, the NIA will be developing future ideas with new partners and seeking further funding opportunities. In particular the 'ecosystems approach' will be embedded within the Business Plan when it undergoes its next revision in the near future. This will also align with the Statements of Environmental Opportunity identified in the Humberhead Levels NCA profile to:

- Safeguard, manage and expand the wetland habitats, including the internationally important lowland raised bogs, the floodplain grazing marsh, reedbeds, wet pastures and watercourses, to protect and enhance biodiversity, contribute to landscape character, address climate change and reduce flood risks.

- Manage the agricultural landscape to retain its distinctive character and its productivity, whilst improving its contribution to biodiversity, the protection of vulnerable soils and palaeo-environmental evidence, and the water resource.

- Manage the landscape features such as semi-natural habitats and historic field patterns that reveal local variations in landscape character, often arising from underlying soils and history of drainage, to enhance people's understanding and enjoyment of the landscape.

- Protect the open and expansive character of the landscape, its cultural features and sense of remoteness, by ensuring that new development is sensitively located, accommodates green infrastructure, retains long views and makes a positive contribution to biodiversity.

1.4. Pilot study area context: Morecambe Bay

The Morecambe Bay Limestones and Wetlands NIA area is one of the UK's most important biodiversity hotspots with a unique transition of priority limestone pavements, grasslands and woodlands and coastal and freshwater wetlands. The diverse geology and landscape features and coastal and climatic influences have created an extraordinary diversity of habitats, which are home to internationally important populations of birds, flora and invertebrates.

The NIA is based on the Morecambe Bay Limestones and Morecambe Bay Coast and Lune Estuary National Character Areas but also extends into the neighbouring South Cumbria Low Fells and Lancashire & Amounderness Plain National Character Areas. The NIA follows the distribution of priority habitats and species and provides linkages into adjoining areas. The NIA contains Arnside & Silverdale Area of Outstanding Natural Beauty and parts of the Lake District National Park as well as new areas recently recommended as National Park extensions.

The steering group of the NIA partnership is drawn from the members of the Morecambe Bay Local Nature Partnership (LNP) with the NIA programme being one of the landscape-scale projects the partnership is delivering to deliver the LNP's vision for the wider Morecambe Bay area (see Figure 1.2 below).

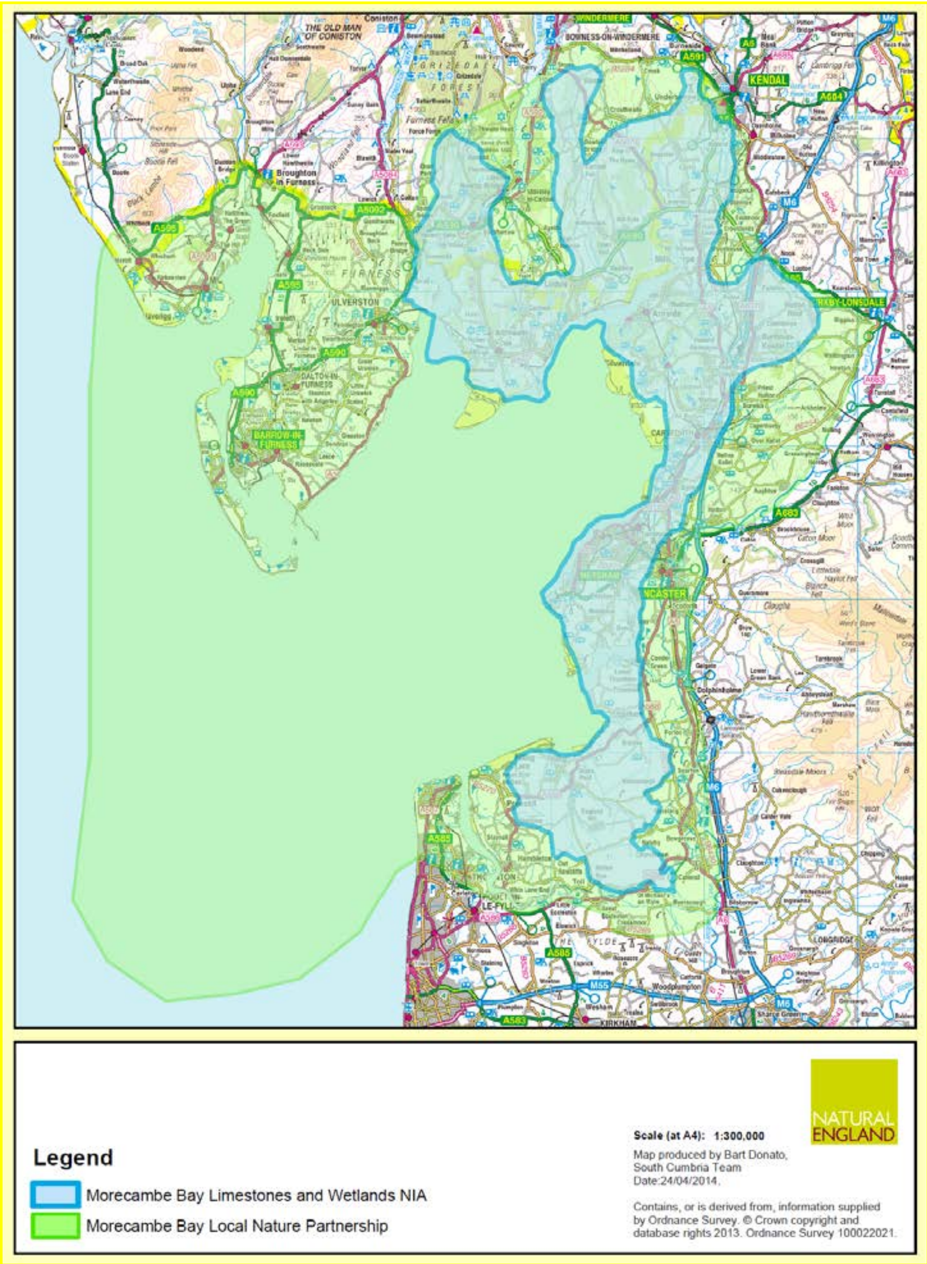

Figure 1.2: Morecambe Bay NIA within the wider Partnership Area

In the northern part of the project area the landscape is characterised by its geology of steep limestone escarpments, capped by limestone grasslands and pavements with wooded flanks. Between these escarpments the land is flat and low lying with broad valleys dominated by lowland mosses, agriculture on the peaty soils of former floodplains and reclaimed saltmarsh. Where drainage has not been practical in the valley bottoms lowland raised bogs survive, including some of the largest intact sites in England. From here the valleys grade into the saltmarshes and extensive intertidal areas of Morecambe Bay. In places the limestone escarpments descend directly into the intertidal area adding variety to the communities present. To the south the urban landscape of Morecambe itself and the low lying character of reclaimed grazing marshes, saltmarshes and raised bogs dominate.

Overall the NIA contains 30 habitats from the S41 (NERC Act) national list of habitats of principal importance. Notably the NIA holds a globally significant resource of lowland raised bogs and limestone pavements.

The NIA contains a wealth of designated sites with over 30% of the area internationally, nationally or locally designated for its biodiversity interest. This includes the internationally designated sites of Witherslack Mosses Special Area of Conservation (SAC), Morecambe Bay Pavements SAC, Morecambe Bay SAC & SPA, Morecambe Bay Ramsar, Leighton Moss Special Protection Area (SPA) and Leighton Moss Ramsar site. There are 46 Sites of Special Scientific Interest covering 10,669ha (21.7 %) of the NIA and a further 256 Local Wildlife Sites that are recognised to be of regional importance for their biodiversity covering 4,219.5 ha (8.6%) of the NIA. There are also large areas of undesignated priority habitat.

The diversity of habitats in close proximity is a key feature of this landscape. This variety is key to the area’s identity as a biodiversity hotspot for a range of taxa including vascular plants, birds and Lepidoptera. It supports nationally significant endemic and/or rare and declining flora such as maidenhair fern, Teesdale violet, autumn lady’s tresses and spiked speedwell. It is the only area in the world where the Lancastrian whitebeam occurs. It is a national hotspot for breeding waders and still supports good populations of farmland and woodland birds. Morecambe Bay has one of the biggest over-wintering and passage populations of wading birds and wildfowl in Britain and the area is the national stronghold for high brown and pearl-bordered fritillary butterflies and the belted beauty moth.

Overall at least 195 species on the S41 national list of species of principal importance have been recorded in the NIA6, more than 20% of the list. This is a key area nationally for such flagship priority species as bittern, high-brown fritillary, duke-of-burgundy and hawfinch; species-recovery programme species such as lady’s-slipper orchid and habitat specialists such as dark-red helleborine, white-faced darter, large heath and marsh tit.

The principal land use is livestock farming including both cattle (beef and dairy) and sheep, with some arable mainly in the south of the area. Some active quarrying and commercially managed coniferous woodland remain. The area is dominated by private land ownership including a number of large landowning estates, and numerous private and tenant farms and landholdings. Conservation organisations own and/or manage some of the most distinctive semi-natural areas such as Leighton Moss, Foulshaw and Gaitbarrows NNR amounting to almost 6,000ha or about 12% of the NIA.

Morecambe is the main centre of population and small towns and villages such as Milnthorpe, Arnside and Grange-over-Sands act as key service centres in a predominantly rural landscape. The area is a popular destination for quiet outdoor recreation, short stay, caravanning and day visitors. The 2007 Census data reveals that 14% of the population in Morecambe report their health to be not good, significantly higher than the national average.

A 20-year Vision is shared by a committed and well supported NIA partnership:

"The Morecambe Bay NIA is an exceptionally high quality landscape that is rich in wildlife, resilient to climate change and provides a range of valued ecosystem services to local communities, the economy and visitors. Joint local action is delivering nationally significant benefits for wildlife and people contributing to a sustainable future for the area. Landowners, famers, communities and businesses are at the heart of this success."

The objectives of the Morecambe Bay Limestones and Wetlands NIA are to:

- Work with over 100 local communities and businesses by 2015 to promote the growth of a sustainable low carbon economy linked to the natural environment;

- Work closely with land managers to enhance and restore over 1000ha of priority limestone and wetland habitat by 2015, creating a robust network of high quality sites that deliver a range of ecosystem services;

- Within sustainable land management systems, buffer, connect and create 'stepping stones' between high quality sites to allow development of a coherent ecological network that is resilient to climate change;

- Leave a legacy for future enhancements to the natural environment through improved and effective integration with the planning system and sharing lessons learnt; and

- Connect people with nature by involving local communities in shaping habitat restoration schemes and providing a series of inspiring opportunities for people to experience and get involved with the natural world.

Statements of Environmental Opportunity for the Morecambe Bay Limestones National Character Area are:

- Protect and enhance the extensive mosaic of high-quality limestone habitats, including pavement, woodland, scrub and grassland, to create a coherent and resilient ecological network, retain a sense of place and maintain the strong relationship between the landscape and its underlying geology.

- Ensure the long-term sustainable management of the nationally and internationally designated coastal zone by conserving and managing its habitats, including the extensive sand flats, salt marshes, estuarine landscapes and limestone cliffs, for their wildlife, strong sense of place, inspiration and tranquillity, their diverse range of species, their traditional fisheries, and for their ability to mitigate the effects of climate change through carbon sequestration and coastal flood mitigation.

- Ensure the long-term sustainable management of the nationally and internationally designated wetland landscape and its linking, non-designated, habitats by conserving and restoring the lowland raised bogs, fens, rivers and reedbeds for their strong sense of inspiration and tranquillity, their diverse range of species, and for their ability to mitigate the effects of climate change through carbon sequestration.

- Conserve and enhance the wider landscape of the NCA as the supporting framework to its distinctive attributes, including features of the drumlin landscape, the settlement character, orchards, recreational identity and heritage features, for their individual importance and the complementary role they play in supporting the local visitor economy and providing enjoyment and education to visitors and residents alike.

2. Literature Review

The objectives of the review were to address the following research questions:

a. How has land within or adjacent to the transport corridor been used/enhanced for green infrastructure that delivers biodiversity gain, ecological connectivity and ecosystem services?

b. How has green infrastructure been used or enhanced to deliver ecosystem services both within and adjacent to the transport corridors to increase transport infrastructure resilience to climate change (i.e. green solutions to network resilience)?

The review of literature aimed to investigate the evidence base for the above research questions in order to make recommendations for land management options for the transport soft estate within the two selected study areas, Humberhead Levels Nature Improvement Area (NIA) and Morecambe Bay NIA.

A summary of the potential for ecosystem service provision by green infrastructure within or adjacent to transport corridors, and the literature to support this, is summarised in Table 2.1 at the end of this chapter. The full literature review is available as a separate publication (see Annex 1), and the key findings are summarised in the following sections.

2.1. Objective 1: Transport soft estate delivering biodiversity and ecosystem services

Objective 1 of the literature review covers the very broad topic area of how transport soft estate can deliver ecosystem services, as defined above. This section of the review investigates the evidence for how land within or adjacent to the transport corridor has been used/enhanced for green infrastructure that delivers biodiversity gain, ecological connectivity and ecosystem services.

Biodiversity

The literature review identified two main conclusions. Firstly, the transport soft estate has the potential to support high levels of biodiversity interest, though this varies by species and depends on the surrounding landscape context. Secondly, the management of transport verges plays a key role in the maintenance and enhancement of biodiversity value.

There are opportunities to create species rich grassland and shrubland within transport corridors. Techniques to enhance the species richness of grassland verges include seed sowing, hay transfer and the use of existing seed banks (Nordbakken *et al*, 2010). Management practices such as early and late cuts with or without hay removal were also effective in establishing vulnerable grassland species (Auestad *et al*, 2010; Hambrey, 2013). There is also potential to make use of seed dispersing fauna common to transport soft estate to increase dispersal of certain types of shrub (Suarez-Estaban *et al*, 2013).

Road verges can also provide a shelter for certain bird species, though this often occurs when they are a complementary habitat to the dominant surrounding habitats. For example, if the surrounding habitat is highly fragmented by intensive cropping, a contrasting verge habitat would be most favourable (Meunier et al, 1999). However, roads also represent a considerable bird mortality risk especially during certain seasons and weather conditions. In the UK, barn owls are most severely affected by road traffic strikes (Ramsden, 2003). General design considerations for roads to reduce bird mortality include the planting of dense and continuous bush, hedge or tree cover, as well as avoiding the close proximity of vegetation to elevated roads (Erritzoe et al, 2003).

Road verges can be a valuable refuge for some fauna such as small mammals including wood mouse, common shrew, bank voles and field vole (Ruiz-Capillas et al, 2013). They also provide ecological corridors for many mammals, though this increases road strike risk, which can represent up to 60% of overall mortality of sensitive species such as badger, otter, and hedgehog (EC, 2013). Amphibian road mortality is also a potential concern though this is an under-researched area and current mitigation measures (under-road tunnels, culverts) may not be entirely effective (Elzanowski et al, 2009; Beebee, 2013).

Insects and pollinators can benefit from well managed verges, especially where the habitat created is large and species rich (Vermuelen and Opdam, 1995; Saarinen et al, 2005; Le Viol et al, 2008; Skorka et al, 2013). Careful scheduling of mowing is important. Twice-yearly cuts result in greater plant species richness which benefits pollinators especially later in the summer, but too much disturbance can encourage wider foraging which increases the road kill risk (Noordijk et al, 2009; Skorka et al, 2013).

The Mosaic Approach, although untested in the transport sector, could offer a potential approach to managing the soft estate in a way that is beneficial for a range of species.

Ecological connectivity

Transport corridors play a dual role in ecological connectivity. In some circumstances, they can act as ecological corridors to connect otherwise isolated habitat patches, with both animals and vehicles acting as dispersal vectors (Zwanepoel et al, 2006; Penone et al, 2012; Hambrey Consulting, 2013). However, for certain species in other circumstances they create a barrier and are associated with increased mortality and fragmentation (EC, 2003). Spatial breaks caused by road overpasses are particularly significant connectivity barriers (Penone et al, 2012). Moreover, there is evidence that transport corridors also promote the spread of invasive species though the wider landscape context is also an important factor (Hansen and Clevenger, 2005; Garnier et al, 2006; Sullivan et al, 2009; Penone et al, 2012).

Both project level and strategic level solutions are important in improving the ecological quality of transport soft estate and thus enhance its connectivity role. At the project level this involves putting in place infrastructure solutions such tunnels, wildlife underpasses, culverts, bat gantries, green bridges and hop-overs. However, the use of these has not been addressed in detail in this review. This is an area that would benefit from further investigation. At a strategic level this requires institutional and political commitment and resources to develop and carry out restoration programmes. The literature review was able to identify examples of this across the EU and beyond (van der Grift *et al*. 2008).

In addition, GIS methodologies can be effective methods to identify the best places to locate ecological networks as well as prioritise connecting areas for conservation (Gurrutxaga et al, 2011; Chang et al, 2012). A GIS site selection tool which estimates connectivity of habitat patches by measuring distance between source and local species populations shows great potential to enhance the ecological value of transport corridors (Nikolakaki, 2004).

Ecosystem services

Biomass

There could be potential in some locations on the road and rail network to utilise verge vegetation for biomass for energy generation (Ground Control, 2013). Experience form the Netherlands shows that there are opportunities to use verge grass as biofuel (Elbersen et al, n.d.). A trial is also currently being undertaken in Wales to test a new German technology to process biomass before transport to biomass plants (ClickGreen, 2013). Opportunities to cultivate willow for biofuel on road verges have been explored in a Dutch study and found to be theoretically viable (Qin, 2011).

Air quality

The effectiveness of vegetative barriers along roadsides for removing pollutants has been found to be variable. Vegetation is generally regarded as effective at removing ozone, particulate matter, and some gaseous pollutants although has been found to depend on the particulate size as well as the vegetation species and characteristics, such as crown density, leaf area density and tree size (Steffens *et al*, 2012; Vos *et al*, 2013; Brantley *et al*, 2014; Rogers *et al.*, 2011; Forest Research, 2012). More specifically, there is significant variation in pollutant removal due to the amount of hair and wax cover on the leaves (Sæbø *et al*., 2012). A Natural England report (Bignal *et al*., 2004) revealed that wooded shelterbelts effectively capture particulates, including their metal component, thereby reducing transport to sites further away from the road. However, their role in preventing the spread of gaseous pollutants such as NO_2 is less clear. There is some evidence to suggest that they act as a physical barrier to NO_2 transport, changing dispersal patterns rather than taking up the pollutant. The report suggests that it may be better to view vegetative buffer zones as providing a physical distance between the road and air quality sensitive ecological receptors, rather than an area of vegetation that is able to remove pollutants from the atmosphere (Bignal *et al*., 2004).

Carbon sequestration

The promotion of green infrastructure and especially tree cover brings beneficial carbon sequestration properties (Rogers et al., 2011; Forest Research, 2012). In the absence of trees, the literature suggesting that wetland swales are preferable to dry swales as roadside carbon stores (Bouchard et al, 2013). Afforestation along transport corridors may be useful in providing a visual screen and/or sequestering roadside carbon, however, consideration should be given to the value of the existing habitat which may be of greater ecological value (Chisholm, 2010).

Water management

Although there is little literature that is specific to the transport sector, surface water management techniques used in urban areas could be applied in this context. SuDS such as filter strips, swales and balancing ponds can act as multifunctional structures which have the potential to provide an opportunity to manage water quality, mitigate flood risk, enhance transport infrastructure resilience and also sequester carbon (Dickie et al, 2010; Defra, 2013). The literature has shown opportunity to use vegetation filter strips to reduce the pollutant content in road runoff (Piguet et al, 2008; Jin et al, 2011). SuDS solutions are already in place at certain locations on Highways Agency land in the UK (Highways Agency, 2006; Susdrain, 2014). There is great potential for transport operators to engage with land managers and other partners to identify land that could be used to reduce the flood risk to transport estate. Payment for ecosystems services could be one way to develop such a relationship.

Noise

Vegetation is often used to mitigate the visual impact of grey engineered acoustic barriers, and has also been used as a barrier in its own right. Some studies show vegetated barriers to be as effective as their grey equivalents under certain circumstances of size, shape, layout and density (van Renterghem and Botteldooren, 2012; van Renterghem et al, 2012). In addition they are often viewed as preferable by residents (Arenas, 2008). Although transport noise has adverse effects on animal communication and reproductive success, it is not known if the implementation of acoustic barriers (vegetated or otherwise) has net positive or negative effects on biodiversity due to other factors.

Pollination

The potential and management regimes necessary for transport soft estate to provide good quality habitat for insects has been discussed above. Some of the findings such as plant species richness and twice-yearly rotational mowing with hay removal can also be applied to pollinating insects such as bees (Noordijk et al, 2009). Breadth of verge and volume of traffic did not affect bee abundance (Hopwood, 2008), although we know from other literature that wider and more strategically managed verges can benefit other pollinators e.g. butterflies and moths (Saarinen et al*,* 2005). In addition, the management of adjacent habitats can have a significant effect on density of flowering plants in the corridors, and hence on pollinators (Henriksen and Langer, 2013).

Landscape / sense of place and visual amenity

There is evidence that green infrastructure can play an important role in enhancing the aesthetics of transportation corridors. People are willing to pay for green street infrastructure, where the amount they are willing to pay increases with the size and greenness of the structure (Mell et al, 2013). Studies show that integration with the surrounding environment, creating a sense of place and the use of natural materials and vegetated areas are all important to aesthetically enhance the design of road and transport networks (Blumentraht and Tveit, 2014). Residents also show a preference for green barriers in reducing visual and acoustic impacts of neighbouring transport networks (Arenas, 2008; Maffei et al, 2013).

Visual screening and driver/resident stress

The presence of vegetation along the sides of roads plays a role in driver stress and behaviour. In urban contexts, vegetation helps screen adjacent built-up and commercial land use which improves driver experience and lowers stress level (Cackowski and Nasar, 2003; Wolf, 2003). However, in a rural context, when the surrounding landscape is densely vegetated with no open space, drivers experience less calm and drive less safely than when there are fully or partially open landscapes (Antonson et al, 2009).

Access

There is potential for designing and managing the transport soft estate to provide enhanced facilities for non-motorised users. The literature, though not specific to the transport soft estate, identifies the importance of gateways being visually attractive (Beunen et al, 2007).

2.2. Objective 2: Transport soft estate delivering infrastructure resilience to climate change

This objective again looks into ecosystem services, but with a focus on network resilience rather than biodiversity. Climate change presents a complex management challenge where the resilience of transport infrastructure will be an important factor in adapting to future uncertainty (Jarozsweski et al, 2010; Defra, 2011b). Green infrastructure and 'Ecosystem-based Adaptation' offer a range of potential solutions to specific problems which will be created by climate change (EbA Flagship, 2004; Gill et al, 2007; Defra, 2010).

Storm water and wind damage

There is little literature to suggest how green infrastructure could be used to mitigate wind damage resulting from extreme weather events. There are studies showing the extent to which vegetated buffer strips can slow wind speeds in urban and rural contexts, but these have not been studied in a transport context (Zhou et al, 2005; Penone et al, 2012b; Taranaki Regional Council, n.d.).

It is clear that the active management of woodland to remove weak or diseased trees that may be vulnerable to high winds is required for safety reasons (Network Rail, 2011; 2012). Further research is needed into the potential to use shelterbelts in the wider landscape to provide shelter for exposed sections of the transport network.

Temperature effects on road and rail track

Information on the direct and indirect heat effects on road and rail track were well documented (Eddowes et al, 2003; Hunt et al, 2006; Standley et al, 2009; Network Rail, 2011; Hooper and Chapman, 2012). However, solutions offered for rail buckling and melting of tarmac were engineered ones and no evidence of the mitigating effect of vegetation was found. One study did find that that trees and vegetation can significantly reduce the surrounding air temperature and provide shade for road and rail surfaces (Gill et al, 2007). It will be important to balance benefits with potential risks such as fire risk if summer temperatures increase (Dunn and Robson, 2013), and issues of leaf and branch fall during storms.

Subsidence and landslides

Much of the UK's rail network is on or in earthworks (embankments and cuttings) and therefore slope stability is a key concern. The problem of landslides is particularly serious in areas where the underlying geology is clay, such as in the south of England (Network Rail, 2011).

Effective land management and the use of green infrastructure can assist in mitigating the impacts of slope instability associated with a climate change. In particular, trees can be used along transport corridors to improve soil stability, prevent embankments being swept away during heavy precipitation events and intercept and infiltrate runoff.

Bank moisture content is an important factor in bank stability, which is strongly influenced by heavy precipitation events, dry summer periods and vegetation type and cover. The possibility that changes in climate may also lead to adverse change in vegetation presence along railway networks is of concern (Dunnett et al, 1998; Manning et al, 2008).

In order to maintain the important functions of vegetation along transport corridors, the response of existing vegetation to increases in temperature, drought and changes in precipitation should be monitored (Hooper and Chapman, 2012).

Briggs et al. (2013) showed that high water demand species (e.g. Oak, Poplar, Willow) located within the threshold ratio of the track, were shown to cause track movement greater than 10mm. Moderate and low water demand tree species (e.g. Ash, Sycamore, Birch) were not associated with track movements. Adapting planting and woodland management by moving towards lower water demand species such as ash, sycamore and birch could help with this, although it should be noted that ash and sycamore are actively discouraged on the lineside as their large leaves cause leaf litter problems on the track (Network Rail, 2012).

Flood risk and sea levels

The literature highlights green infrastructure as a method of flood risk mitigation that has a high potential. Gill et al. (2007) see green infrastructure as one of the most promising ways opportunities for adaptation and that it needs to be recognised in the planning process at all scales. The use of Sustainable Drainage Systems (SuDS) to increase the lag time of storm water reaching rivers will be an important factor to reduce the occurrence of flooding. There were no examples in the literature review of studies that monitored the success of SuDS schemes undertaken by rail and highways authorities, although SUDs are identified in the Highways Agency's Design Manual for Roads and Bridges (Volume 11) as a pollution control measure that can be used to mitigate the impact of road-runoff pollution. SuDS solutions are already in place at certain locations on Highways Agency land in the UK (Highways Agency, 2006; Susdrain, 2014).

Coastal defences currently rely on hard engineered, short term solutions. But there is potential for soft defences to be employed to reduce the power of storm surges such as coastal marshes, sand dunes, and beaches (National Trust, 2014). This area needs more consideration, potentially through the Shoreline Management Plan process.

Leaf and branch fall

Leaf and branch fall is a recognised issue especially along rail corridors (Network Rail, 2011). Climate change may result in stronger autumn winds which has the potential to cause more concentrated leaf fall as well as a longer season with leaf fall extending into December (Hooper and Chapman, 2014). Adaptation measures to changes in leaf fall impacts include cutting back of vegetation and planting of different species (Eddowes et al, 2013). These can work in tandem with existing Network Rail health and safety guidance on which tree species are suitable in proximity to rail tracks (Network Rail, 2012).

2.3. Summary of findings

The review identified a number of studies which related to role of transport soft estate in delivering biodiversity gain, ecological connectivity, ecosystem services, resilience to climate change, and as a serious alternative to grey-engineered solutions. The distribution of research and guidance was not evenly distributed. A far greater proportion of the papers identified covered road as opposed to rail networks. In addition there was a considerable bias towards studies discussing the impacts of transport on biodiversity, ecological connectivity, ecosystem services and the impacts of climate change on transport. There were relatively few studies of existing or proposed green infrastructure solutions in a transport soft estate context, so many of the suggestions have been transposed from comparable situations.

Overall, the review has found that transport soft estate has the potential to provide biodiversity gain for a variety of flora and fauna though this is highly species and context dependent. This could occur through well managed and maintained grassland i.e. with two cuts per year, or woodland that is coppiced and has open glades or rides. The main beneficiaries would be vulnerable grassland species restored to roadside verges as well as the insects which rely on them. Its impact on other fauna is more mixed with some birds and mammals benefiting from the soft estate whilst posing a significant risk to others such as barn owl. The management of verges and design of vegetation cover are important factors in enhancing species richness as well as minimising safely and operational risk such as risk of vehicle collisions and leaf and branch fall. Recommendations have been made to take into account these factors.

Similarly, transport soft estate can both enhance and reduce ecological connectivity depending on the species and context. At the same time they can also be a factor in the spread of certain invasive species. Project level solutions to these problems include green bridges and other wildlife crossings. In addition, bridges and overpasses are often a major barrier feature and ecological considerations should be factored into their design. GIS methods offer a means for transport planners to take a strategic approach, taking landscape-level factors into consideration when designing and modifying infrastructure networks.

There is considerable evidence that transport soft estate can provide a range of ecosystem services which would benefit communities. Provisioning services include the use of road or trackside biomass for fuel. Regulating services include the use of vegetation strips to improve local air quality, reduce local heat effects, provide a wind and noise shield and sequester carbon. The use of SuDS along transport corridors could also improve water quality and mitigate flood risk. In addition, the restoration of transport soft estate can provide important habitat for pollinators. Well managed vegetation strips can improve the visual amenity of the road for local residents, and in some instances reduce driver stress.

Transport networks will be severely affected by climate change, though the extent, location and frequency of its impacts will be hard to predict at this juncture. The evidence suggests that green infrastructure can provide a resilient adaptation to some of these effects, such as increased storm and wind damage, summer heat effects, subsidence and landslides, flood risk and sea level rise, as well as increased leaf and branch fall. Vegetation strips and SuDS would appear to offer the best potential. However, many of the studies of green infrastructure application were carried out in a non-transport context and there is a need for further work to investigate their applicability to road and rail networks. Management of vegetation will also be important, especially as transport operators will also need to consider health and safety factors.

A summary of the benefits and challenges of green infrastructure associated with transport corridors is presented in Table 2.1 below.

Table 2.1: The importance of transport soft estate (green infrastructure) for final ecosystem services

The quantity of research was rated as follows: 1-5 studies (Low), 5-10 studies (Moderate), 10-15 studies (High), 15+ studies (Very High). The extent to which research was supportive was rated as follows: 85%+ supportive (Very Supportive), 75-85% supportive (Supportive), 65-75% (Moderately Supportive), 35-65% (Inconclusive), 25-35% (Moderately Unsupportive), 15-25% (Unsupportive), <15% (Very Unsupportive)

Benefits to ecosystem services	Benefits to transport infrastructure	Challenges	Addressing challenges	Literature supporting or refuting benefits
Wild species diversity and habitat provision		**Extent of Research: Very High (23 studies)**		**Supportivity: Very Supportive (91%)**
Soft estate can act as linear ecological corridors, connecting habitats and increasing ecological coherence (but transport infrastructure can also be a significant barrier to movement of some species). Increase species diversity and adaptation to climate change. Soft estate can also provide habitat in its own right, including shelter and food.	See benefits listed under individual ecosystem services: - Biomass harvesting - Air quality regulation - Carbon sequestration - Water management - Water quality - Bank stability and erosion control - Wind shelter - Pollination - Noise abatement - Sense of place/Visual amenity	Leaf and tree fall and other fallen down vegetation can cause disturbance to transport infrastructure. Risk of spread of invasive species. Risk to wildlife from road and rail traffic e.g. fragmentation, barrier and mortality effects	Active management of track and roadside verges may be required including application of the Mosaic Approach. Planting of native species must be encouraged along with management of existing invasive species. Monitoring sensitive species e.g. barn owl to observe population trends. Trial new management approaches in priority locations.	✓ Akbar et al. (2010) ✓ Auestad et al. (2010) ✓ Chang et al. (2012) ✓ EC (2003) ✗ Erritzoe *et al.* (2003) ✓ Foy (1980) ✓ van der Grift et al. (2008) ✓ Gurrutzaga et al. (2011) ✓ Gurrutxaga et al. (2010) ✓ von Haaren and Reich (2006) ✓ Hambrey Consulting (2013) ✓ Meunier et al. (1999) ✓ Nordbakken et al. (2010) ✓ Penone et al. (2012) ✗ Ramsden (2003) ✓ Ruiz-Capillas et al.

Benefits to ecosystem services	Benefits to transport infrastructure	Challenges	Addressing challenges	Literature supporting or refuting benefits
				(2013) ✓ Saarinen et al. (2005) ✓ Skórka et al. (2013) ✓ Suárez-Esteban et al. (2013) ✓ Szita et al. (n.d) ✓ Vermeulen and Opdam, (1995) ✓ Le Viol et al. (2009) ✓ Zwaenpoel et al. (2006)
Fuel provision		**Extent of Research: Moderate (6 studies)**		**Supportivity: Very Supportive (100%)**
Trees and scrub can be managed as a source of biomass. Highways Agency land harvest 861,000 tonnes per year.	Income for transport estate owners from sale of biomass (e.g. wood fuel) and potential energy security.	Production of large enough quantities for biomass production from road and rail sides may be a challenge in terms of access and safety.	Consider planting on neighbouring land or in areas where the transport corridors are wide so as to keep trees and access points away from the road/rail. Consider accessing soft estate via adjacent landowners rather than road/rail side.	✓ ClickGreen (2013) ✓ Elbersen et al. (n.d.) ✓ Forestry Commission (2005) ✓ Ground Control (2013) ✓ Qin (2011) ✓ Salter et al. (2007)
Air quality maintenance		**Extent of Research: Moderate (9 studies)**		**Supportivity: Supportive (78%)**
Vegetation, particularly trees, can intercept air pollutants and play an important buffering role where habitats sensitive to air pollution (e.g. NOx) lie	Through buffering and intercepting air pollutants, trees can reduce the number of complaints made about transport networks.	Performance of vegetation in intercepting air pollutants is variable depending on factors such as species, time of day and time of year.	Consider choice of species.	✓ Bignal et al. (2004) ✗ Brantley et al. (2014) ✓ Cooter et al. (2013) ✓ Forest Research (2012) ✓ Hwang (n.d.) ✓ Rogers et al. (2011)

Benefits to ecosystem services	**Benefits to transport infrastructure**	**Challenges**	**Addressing challenges**	**Literature supporting or refuting benefits**
close to transport networks. Vegetation can provide a buffer distance between air pollution source and receptor with benefits for public health.				✓ Sæbø et al. (2012) ✓ Steffens et al. (2012) ✗ Vos et al. (2013)
Climate regulation, resilience and adaptation		**Extent of Research: High (11 studies)**		**Supportivity: Very Supportive (100%)**
Trees provide carbon sequestration leading to mitigation of climate change. Soft estate can act as linear ecological corridors connecting habitat patches and providing opportunities for species migration to adapt to climate change, particularly for low mobility species. Climate resilient species of flora must be used, however.	Trees can provide shading and can have a cooling effect on infrastructure, particularly as summer temperatures increase due to climate change.	Branch debris/tree fall on road/track from high winds. Leaf fall in autumn depending on species (rail). Risk to highly mobile migrating wildlife e.g. fragmentation, barrier and mortality effects	Management of lineside trees in order to prevent risk to transport operations through frequent cutting back of vegetation, removing dead and diseased trees and producing leaf fall timetables. Monitoring sensitive species to observe population trends. Trial new management approaches in priority locations.	Carbon sequestration: ✓ Bouchard et al. (2013) ✓ Davies et al. (2011) ✓ Forest Research (2012) ✓ O'Donoghue and Shackleton (2013) ✓ Radford and James (2013) ✓ Rogers et al. (2011) Found no evidence of a cooling effect on transport infrastructure caused by green infrastructure, but there is more general evidence on resilience and adaptation: ✓ Defra (2010) ✓ Dunnett et al. (1998)

Benefits to ecosystem services	Benefits to transport infrastructure	Challenges	Addressing challenges	Literature supporting or refuting benefits
				✓ EbA Flagship (2004) ✓ Gill et al. (2007) ✓ Hwang (n.d.)
Water purification and flood regulation	**Extent of Research: Moderate (9 studies)**		**Supportivity: Very Supportive (100%)**	
Use of vegetated SUDs can and improve water quality by removing pollutants and sediments. Biodiversity improvements to wetland habitats such as reduced amount of sediment entering watercourses.	Use of vegetated SUDs for drainage from roads/rail can improve drainage, reduce flooding and improve water quality by removing pollutants and sediments. Runoff mitigation – interception of rainfall by trees and other vegetation can slow down flooding. This can reduced occurrence of flooding events that affect road/rail infrastructure	Invasive vegetation can enter watercourses and grow rapidly. This can lead to eutrophication as a result of reduced oxygen levels. Vegetation can fall into drainage channels causing blockages and flooding.	Planting of native species is encouraged. Management and maintenance to remove dead, diseased or storm damaged vegetation to prevent it causing damage to infrastructure or ecosystems.	✓ Dickie et al. (2010) ✓ Graham et al. (n.d.) ✓ Highways Agency et al. (2006) ✓ Nisbet and Broadmeadow (2003) ✓ Piguet et al. (2008) ✓ Sahu and Gu (2009) ✓ Susdrain (2014) ✓ Le Viol et al. (2009) – high pollutant concentrations in water storage ponds ✓ Wilson et al. (n.d.)
Natural hazard protection	**Extent of Research: High (12 studies)**		**Supportivity: Supportive (83%)**	
Trees and other vegetation can help to prevent landslides which can be damaging to both plant and animal species e.g. the silting of aquatic ecosystems.	Trees and other vegetation can help to stabilise banks through mechanical root reinforcement and prevent landslides in severe weather. Shelterbelts in wider	Branch debris/tree fall on road/track from high winds. Leaf fall in autumn depending on species (rail). Tree roots can cause	Scrub vegetation can help to catch leaf fall and reduce the establishment of undesirable tree species. Trees should be planted in appropriate locations and	✓ Briggs et al. (2013) ✓ Clarke et al. (2002) ✓ Eddowes et al. (2003) ✓ Gill et al. (2007) × Hooper and Chapman (2012) – leaf fall × Department for Transport (2005) – leaf

Benefits to ecosystem services	Benefits to transport infrastructure	Challenges	Addressing challenges	Literature supporting or refuting benefits
Vegetation has the potential to provide wind shelter to other habitats, including cropland.	landscape have the potential to provide wind shelter. Runoff mitigation – interception of rainfall by trees and other vegetation can slow down flooding. This can reduced occurrence of flooding events that affect road/rail infrastructure	damage to infrastructure such as roads, rails and pedestrian pavements. Shrink and swell caused by vegetation, particularly in clay soils causing movement of track in some circumstances (rail). Vegetation can fall into drainage channels causing blockages and flooding.	managed accordingly. Moving towards lower water demand species to reduce shrink and swell in clay soils (rail)	fall ✓ Highways Agency (2006) – SuDS ✓ Network Rail (2011) ✓ Northern Territory Government (n.d.) ✓ Susdrain (2014) ✓ Le Viol et al. (2009) ✓ Wilson et al. (n.d.) – SuDS
Erosion control		**Extent of Research: Low (1 study)**		**Supportivity: Very Supportive (100%)**
Vegetative cover plays an important role in soil retention. Erosion control by vegetation reduces the amount of sediment and pollutants that enter watercourses which preserves water quality.	Trees can help to stabilise cuttings and embankments to prevent erosion.	Branch debris/tree fall on road/track from high winds. Leaf fall in autumn depending on species (rail).	Management of lineside trees in order to prevent risk to transport operations through frequent cutting back of vegetation, removing dead and diseased trees and producing leaf fall timetables.	✓ Northern Territory Government (n.d.)

Benefits to ecosystem services	Benefits to transport infrastructure	Challenges	Addressing challenges	Literature supporting or refuting benefits
Noise abatement		**Extent of Research: Moderate (7 study)**		**Supportivity: Very Supportive (100%)**
Public health and quality of life benefits. Benefits for species diversity and wildlife if appropriate species mix and well managed.	Trees can provide a useful barrier to noise pollution (and perception of noise through visual screening) from transport networks, reducing complaints.	Branch debris/tree fall on road/track from high winds. Leaf fall in autumn depending on species (rail). No evidence that green barriers have biodiversity benefits.	Management of lineside trees in order to prevent risk to transport operations through frequent cutting back of vegetation, removing dead and diseased trees and producing leaf fall timetables. Research into effects of green barriers on biodiversity.	✓ Arenas (2008) ✓ Maffei et al. (2013) ✓ Radford and James (2013) × Reijnen and Foppen (2006) ✓ Reijnen and Foppen (2006) × Reijnen et al (1997) ✓ van Renterghem et al. (2013) ✓ van Renterghem et al. (2012) ✓ van Renterghem and Botteldooren (2012) ✓ Tyagi et al. (2009)
Regulation of pests, diseases and invasive species		**Extent of Research: Low (4 studies)**		**Supportivity: Inconclusive (50%)**
Green infrastructure can improve the health of the landscape. Pests and diseases tend to occur more in stressed ecosystems than healthy ones. Trees and other vegetation planted in the vicinity of		Care needed to ensure linear corridors don't aid dispersion of invasive species or diseases which could potentially cause a decline in native species, damage to tracks/roads or blocked sightlines.	Avoiding the planting of species prone to disease or the facilitating of conditions which encourage pests, diseases and invasive species to spread. Avoid disturbance where possible. Healthy, diverse	× Garnier et al. (2006) – escape of oilseed rape crops to natural habitats via roadside verges × Hansen and Clevenger (2005) – invasives more abundant along transport corridors than

<table>
<tr><th>Benefits to ecosystem services</th><th>Benefits to transport infrastructure</th><th>Challenges</th><th>Addressing challenges</th><th>Literature supporting or refuting benefits</th></tr>
<tr><td>cropland can increase the prevalence of pest predators.</td><td></td><td></td><td>and well managed estate and adjacent land can reduce the risk of spread of invasives.</td><td>control sites
✓ Penone et al. (2012) – invasives more prevalent in urban areas than railway edges
✓ Sullivan et al. (2009) – roadside verges had little effect on spread of invasives</td></tr>
<tr><td colspan="2">Pollination</td><td colspan="2">Extent of Research: Moderate (6 studies)</td><td>Supportivity: Very Supportive (100%)</td></tr>
<tr><td>Can provide species-rich grassland to aid pollination.

Mowing verges up to twice a year and removing arisings will allow them to flower and thereby provide pollen and valuable nectar sources for bumble bees, butterflies and other invertebrates.

Increased yield for pollination-dependent agricultural crops.</td><td>Possible financial benefits to transport operators if cutting/mowing of soft estate is carried out once or twice per year and scrub encroachment reduced.</td><td>Road and trackside verges may need to be actively managed to ensure new species are able to establish and invasive plants and weeds do not dominate.</td><td>Establishment of best management guidelines for trackside and road verges.</td><td>✓ Henriksen and Langer (2013)
✓ Hopwood (2008)
✓ Noordijk et al. (2009)
✓ Saarinen et al. (2005)
✓ Skórka et al. (2013)
✓ Townsend and Levey (2005)</td></tr>
</table>

Benefits to ecosystem services	Benefits to transport infrastructure	Challenges	Addressing challenges	Literature supporting or refuting benefits
Cultural services – access	**Extent of Research: Low (4 studies)**		**Supportivity: Very Supportive (100%)**	
Potential to provide pedestrian/ cycle access with associated benefits for human health. Railways and roads provide access to visitor destinations, promoting green growth/ ecotourism.	Network accessible to a wider range of users	Pedestrian/ cycle access may result in safety risks or increased expenditure on security	Hedges on boundary can prevent trespassers on the transport network.	✓ Garré et al. (2009) ✓ von Haaren and Reich (2006) ✓ Natural Economy North West (n.d.) ✓ Beunen et al. (2007)
Cultural services – landscape and sense of place	**Extent of Research: Low (4 studies)**		**Supportivity: Very Supportive (100%)**	
Soft estate can be designed to reflect the local landscape character e.g. open landscape and can provide the setting for access gateways, benefitting the wider landscape and people’s enjoyment of it.	Soft estate can provide visual screening of the transport corridor in both urban and rural areas, reducing complaints.	Trees, though providing screening, can also block the view of more open landscapes.	Neighbouring landscapes must be taken into account.	✓ Blumentrath and Tveit (2014) ✓ Garré et al. (2009) ✓ Maffei et al. (2013) ✓ Mell et al. (2013)
Cultural services – visual screening / stress	**Extent of Research: Low (5 studies)**		**Supportivity: Supportive (83%)**	
Soft estate can provide a visual screen which is more favourable to residents. Roadside vegetation	Fewer complaints from residents about transport infrastructure. Greater road safety and	Vegetated screens may be more visually appealing, but it may not be possible to make them dense enough to provide other services due to space	Appropriate site selection, but even a moderate amount of vegetation may improve experience for drivers at least.	✓ Antonson et al. (2009) × Antonson et al. (2009) ✓ Arenas (2008) ✓ Cacowski and Nasar (2003)

Benefits to ecosystem services	**Benefits to transport infrastructure**	**Challenges**	**Addressing challenges**	**Literature supporting or refuting benefits**
reduces stress and frustration of drivers.	fewer "road rage" incidents	limitations. The stress/ behaviour/ safety effect is only found in an urban context. In a rural context open or varying landscape is better.	Importance of varying landscape in rural context – avoiding long stretches of dense forest/shrub.	✓ Maffei et al. (2013) ✓ Wolf (2003)

2.4. Recommendations

Biodiversity Gain, Ecological Connectivity, and Ecosystem Services

The literature review has identified some specific recommendations for biodiversity gain, ecological connectivity, and ecosystem services within transport soft estate:

- Greater use could be made of the transport soft estate for pollinators, with reintroduction of appropriate grassland management for species-rich grass verges to promote plant and pollinator species diversity.

- There is potential for a mosaic approach to be applied to the management of the soft estate to increase biodiversity, with greater levels of thinning, coppicing and removal of trees to create glades and to increase the variety of habitats on the soft estate. Where width allows using ecotones (i.e. gradual blending between two habitats) to transition from one habitat to another.

- Take greater account of the land use immediately adjacent to the transport corridor in management decisions for the soft estate and maximise the potential for linkages with the surrounding landscape.

- Consider the design of roadside vegetation strips to reduce the mortality of individual species. Balancing conflicting needs of different species may present challenges in relation to the soft estate management and will need to be addressed at the local level.

- Consider solutions which deliver multiple ecosystem services, such as wetland swales and balancing ponds which can act as carbon stores and wildlife habitat as well as water flow and quality regulators.

- New approaches to the management of the soft estate could bring multifunctional benefits for the natural environment and people, as well as the operation and resilience of the network. For example managing woody vegetation through coppicing and restoring areas of grassland could benefit pollinators and reduce the hazards associated with tree and leaf fall, as well as potentially providing a sustainable source of woodfuel for local communities.

Transport Resilience and Green Infrastructure

The literature review has identified some specific recommendations for using green infrastructure to build a more resilient transport infrastructure:

- Greater recognition should be given to the relationship between transport and the natural environment and consideration of the impacts of transport resilience solutions on the natural environment, which in turn could affect the long term operation of transport systems.

- There should be more consideration of soft as well as hard solutions and further investigation into the role of green infrastructure in developing climate resilient transport infrastructure.

- The collaboration between academic institutions, road and rail operators and other bodies such as Natural England on the Natural Environment White Paper (NEWP) 32 commitment is a positive development and should be encouraged and expanded for future work.

- Long term adaptation/resilience strategies need to be developed that look at the potential synergies between transport infrastructure climate change resilience goals and other environmental goals where there is potential for multiple benefits.

Further Research

The literature review uncovered considerable evidence regarding the role that transport soft estate plays in biodiversity, ecological connectivity, ecosystem services, climate change resilience and green infrastructure solutions. However, there were also some significant gaps in certain key areas where knowledge would greatly inform and improve the delivery of these features.

As discussed above, there were considerably more studies related to road as opposed to rail networks. Whilst there are similarities in the environmental impacts of both types of transportation, there are material differences in terms of vehicle type and frequency, as well as the accessibility of the verges. Management regimes proposed for roadside verges may not be applicable to track because of these differences. In particular, studying the animal mortality data for rail would be informative as has proved with the roadside verge studies.

Another general area of relative information scarcity regards the applicability of green infrastructure and climate change resilience solutions to transport soft estate. The majority of applications discussed in the review derive their legitimacy from other contexts, such as urban or rural projects. Further work should investigate the success of SuDS in relation to the transport soft estate in general. Vegetation strips are better understood, but there are still gaps in the literature. More work is needed to investigate the design features of vegetation strips alongside roads and rail that would be necessary to provide wind shelters, reduce localised temperatures and reduce subsidence (on tracksides), whilst at the same time not compromising public safety from treefall.

As mentioned earlier, this review did originally have a third objective, which was to investigate the opportunities and challenges facing transport operators in transitioning from grey engineered to green ecosystems-based solutions. However, the review found a scarcity of literature concerning this topic. For example, further research is needed to explore the role of shelter belts as part of the wider landscape; whilst there is little evidence to demonstrate the effectiveness of SuDS being applied to transport soft-estate. Given the potential of transport soft estate to provide ecosystem services and climate change adaptation solutions, the lack of information in guiding the transition process presents an opportunity for continued research and investigation. Green bridges were also considered with respect to the greening of grey infrastructure; these are more common overseas than in the UK where small scale solutions to connectivity have been prioritised. More work is required to better understand the contexts in which these features are most effective and to look for opportunities to include them within the network in the future.

Otherwise, the literature review did identify some more specific areas for future research. For example, the role of transport corridors in ecological connectivity appears to be very complex and context dependent and would benefit from further elucidation to understand the risks and maximise the benefits for biodiversity. Particular attention should be focussed on the nature of the relationship between the positive and negative corridor effects and how these can be balanced to benefit wildlife. In addition, a better of understanding is required for how transport infrastructure should be integrated into ecological networks to maximise biodiversity benefits without increasing the risk of animal-vehicle collisions. In this regard, identifying pinch points for wildlife mortality is important, as is understanding the role of crossing points and how best to manage vegetation to deter animals from riskier zones. A greater knowledge of the species that benefit from transport corridors and those than are challenged by it would also be useful, and where there are known risks for species such as barn owls, further work is needed to find solutions that will benefit the species whilst also reducing safety and operational risk to the network, for example from tree or leaf fall.

Further work could also explore the potential for commercial benefits from the harvesting of wood or other biomass products from the transport soft estate in ways that could also benefit biodiversity such as the thinning or coppicing of trees to create glades and rides. There are also neighbourhood considerations here, for instance how to enter into agreements with adjacent landholders to use their land to access the vegetation to be harvested for biomass. However, this could also lead to further opportunities to work with neighbours to improve and enhance land management practices at a landscape scale and not just immediately on the soft estate itself. There could be mutual benefits, in particular to provide flood attenuation and pollination services which could be potentially funded through payment for ecosystem services schemes.

3. Stakeholder Consultation

3.1. Methodology

Meetings were held with representatives of the Humberhead Levels and Morecambe Bay NIAs at Yorkshire Wildlife Trust nature reserve, Potteric Carr on 16th January 2014 and at the Natural England office in Kendal on 17th January 2014. The purpose was to discuss existing habitat management/ maintenance operations, ecological, and climate related issues in the two areas that relate to transport corridors. This included potential opportunities to work with NR and HA to address these issues including enhancing the provision of ecosystem services. As well as NIA, ADAS, Natural England and NIA partners, these meetings were attended by representatives of NR and HA. This was crucial in making the workshops a success as it enabled face-to-face discussion of conflicts and opportunities between the aspirations of NIA partners and the practicalities of delivering habitat improvements with limited the funding and safety and operational constraints of NR and HA.

Following these workshops, four separate teleconferences were held with regional HA and NR staff for both Humberhead Levels and Morecambe Bay. Again existing ecological and climate related issues and opportunities for enhancement were discussed, along with current track/road-side vegetation management and maintenance operations. These meetings involved staff who have a local knowledge of the highways and railways that run through the two NIAs, including managing agents who carry out vegetation management on HA's behalf. Teleconferences with NR staff were conducted on 20th and 21st January 2014, representing Humberhead Levels and Morecambe Bay respectively. Teleconferences with HA staff representing the two NIAs followed on 30th and 31st January 2014.

3.2. Humberhead Levels NIA workshop

Key issues surrounding management and maintenance of the transport soft estate in the Humberhead Levels along with the key opportunities identified by the workshop participants for enhancing the management and maintenance of the transport soft estate for biodiversity benefit include the following.

Table 3.1: Key issues and opportunities identified at the Humberhead Levels NIA workshop

Humberhead Levels NIA Workshop	
Key issues	• HA highlighted that health and safety legislation and the need to gain permission for all maintenance work is a significant constraint and significant cost of any maintenance operation. It takes 12 weeks to get permission to stop on the hard shoulder with traffic cones etc. to carry out any work, including surveys. • Tree and leaf fall is a particular challenge for NR. • Water management and drainage is a significant issue in this low lying area. HA are identifying flood risk areas around the network. NR added that changing ground water levels is a challenge as it affects earthwork stability. • Himalayan Balsam is widespread in the study area. Control of non-native Himalayan Balsam and Japanese Knotweed is required.

Key opportunities	• Use biodiversity opportunity mapping, as the benefit of a habitat will depend on where it is and how it fits into a network. • Promote a mosaic approach[1] to habitat management and provide ecotone habitats. • Consider not just linear connectivity but also how the soft estate can function in terms of landscape scale conservation (bigger, better, connected – outward from soft estate). • Manage habitats for keystone species, such as Barn Owl which often has benefits for other species. • Ensure habitat is complimentary to neighbouring habitat, for example avoid trees/woodland next to wet grassland sites for breeding waders, as trees can be used as perches for predator species. Scrub and species rich grassland act as complimentary habitat in agricultural landscapes. • Avoid clear felling for biodiversity and visual amenity benefits (HA following this approach). • Timing of works – avoid the bird breeding season, especially for tree works. • Increase frequency of verge cutting to twice annually, in early and late summer. • Create or encourage scrub habitat (defined as vegetation that is not grassland and is below 2m in height) to benefit key species, especially Willow Tit. It would benefit this red listed species if 1.5m high trunks were left when trees are felled. NR stated that scrub rather than climax (tree) species would be suitable as lineside vegetation, including gorse, hawthorn, willow and dog rose.
	• Carry out coppicing instead of felling. Coppicing is cheaper than removing stumps and saves on the cost of replanting. Cut branches could be chipped and left on site, used as hibernacula (HA has tried this but people removed the logs posing a safety risk), or removed and sold. • Design drainage features, such as balancing ponds, to benefit biodiversity rather than simply being functional engineering features (HA increasingly following this approach). • Create SUDS along new stretches of track and road or on land adjacent to existing routes as there is limited opportunity along existing routes. Management responsibility would be an issue on third party land. • On larger sites, create woodland for carbon sequestration. • HA are undertaking some pilot work on biomass and the potential for providing biomass material from the soft estate for energy generation e.g. for combined heat and power (CHP) generators. • There are examples of LAs managing roundabouts particularly at 'Gateways' where visual appearance is a priority. HA highlighted safety concerns of this.

[1] See Annex 3 for detail on the mosaic approach.

3.3. Morecambe Bay NIA workshop

Key issues surrounding management and maintenance of the transport soft estate in Morecambe Bay along with the key opportunities identified by the workshop participants for enhancing the management and maintenance of the transport soft estate for biodiversity benefit include the following.

Table 3.2: Key issues and opportunities identified at the Morecambe Bay NIA workshop

Morecambe Bay NIA Workshop	
Key issues	• Cotoneaster is a problem within some parts of the NIA, particularly in the top of the Bay. There is concern about the presence of cotoneaster and buddleia in some parts of the rail network. Summer chemical removal is needed. • Spraying the off-track area with herbicides is causing water quality issues - coastal local authorities are concerned about the impact of water quality on blue flag beaches. Similarly, run-off from roads generally goes straight into rivers unless there is a big scheme improvement. • HA advised that the A590 has flooding hotspots.
Key opportunities	• Potential to remove trees along rail network and link this with local initiatives. The possibility was also raised of HA and NR staff volunteering for local projects to promote links between their management works and local initiatives. • Link with Butterfly Conservation initiative to develop a community woodland hub to sell/give away wood generated by better woodland management i.e. to alleviate fuel poverty etc. Can get access to NR land via contacts with local estate managers, HLS agreement holders etc. NR also interested in looking at ways other people could manage some of their estate for them. Letting voluntary groups do this in some places is tricky but is not an insurmountable issue for NR and could also be possible for HA. • The NIA has a target to get 1000ha of land brought into management during the lifetime of the funded NIA and in particular the partnership is focusing on opportunities to enhance connectivity between sites. Habitats of particular focus are woodland, limestone grassland and wetland; the Lancashire Record Centre has produced opportunity maps highlighting ecological networks of these habitats. It is felt that the greatest biodiversity gains could be secured via a focus on habitats and species associated with limestone. There is potential for current soft estate management to link into existing limestone grassland management projects. • There is potential to manage the soft estate to reflect/enhance the visual appeal of an area and examples where LAs have paid for and taken on additional maintenance to do this. The idea of ‘Gateways’ is established but none are located in the NIA area.

3.4. NR teleconferences

NR advised that the typical width of the lineside from track to boundary is 12m, but can reduce to 5m and increase to overall width of 50m. The lineside does not contain many trees; typical species are sycamore, birch and ash, with additional scrub species. Grassland and farmland are the most typical surrounding land uses in the study areas, separated from the lineside by post and wire fencing. In the Humberhead Levels there are also some brick wall and ditch or dyke boundaries, and in Morecambe Bay some rail corridors are bounded by hedgerows or drystone wall.

The main objective of management and maintenance for NR is safety, followed by operational issues. Current management operations undertaken in the study areas are:

- Vegetation inspections, drainage inspections and fencing repairs.
- Annual weed spray of track ballast in March – April.
- Annual spraying of grassland within 5m cess strip to control woody vegetation, carried out in June – early August.
- 3 yearly flail of 5m cess strip from end of October to end of March, to avoid bird nesting season.
- Targeted invasive plant spray by hand.
- Every five years a lineside tree survey is undertaken.
- The area outside the 5m cess strip (typically scrub) is not maintained except for safety reasons.

NR has a Biodiversity Action Plan (BAP), however, it is not used for daily maintenance operations and is additionally out of date. Enhancing the management and maintenance of the transport soft estate for biodiversity benefit is not a priority for NR due to financial, safety and space constraints.

Key issues surrounding management and maintenance of the lineside along with the key opportunities identified by regional NR staff for enhancing the management and maintenance of the transport soft estate for biodiversity benefit include the following.

Table 3.3: Key issues and opportunities identified at the NR teleconferences

Network Rail Teleconferences	
Key issues	• Vegetation along electrified and high speed lines can be particularly problematic, so for lines such as the West Coast Main Line, minimal vegetation is preferred. • A change of vegetation can cause destabilisation of slope or track. For example, removal of trees allows increase of soil pore water pressure and decrease in factor of safety against slope failure. Presence of trees on clay soil can lead to shrink swell problems and undesirable track movements. • Slope stability - storms have caused some damage to earthworks, whilst landslides have been caused during periods of heavy rain, particularly during 2012 which was a wet year. • Land adjacent to the Humber is prone to flooding, especially from Tidal surges. Tidal erosion and failure of flood defences is an issue in Morecambe Bay, but no tracks have been submerged. There is flooding at Grange over Sands, however. • Occasional hotspots of Japanese Knotweed and other invasive weeds, however kept under control by (annual) spray treatment and removal, so not a significant problem. • The rail corridors are generally too narrow for environmental enhancements, and generally railway slopes are too steep for green engineering.
Key opportunities	• Grassland improvements to increase species richness. • Felling / coppicing of trees large enough to fall on the track and establishing scrub vegetation to catch leaf fall. • Creation of SuDS, ponds and wetland habitats may be possible on third party land as there is limited land availability within the rail corridor, and water can cause stability problems to earthworks. • There are opportunities for hedgerows in place of post and wire fencing in appropriate circumstances. The cost of hedge laying is similar to the cost of fence maintenance, however, NR are obliged to maintain all boundaries to prevent trespass, and hedges take time to establish. • Biomass production has been investigated, and has been found not to be feasible due to transportation costs. It might be possible but would require additional funding to implement and manage correctly and safely within a railway environment. • Creation of allotments on wider parts of the lineside, with the boundary fence moved closer.

3.5. HA teleconferences

HA advised that the typical width of each verge is 10m in the Humberhead Levels and 2-10m in Morecambe Bay. There are additional large plots of woodland alongside the M6. HA owns plots of land beyond the operational boundary; these are managed centrally rather than by regional teams, so their locations were not known. Roadside habitats include drainage ditches, grassland, scrubland and some wetland habitats in the Humberhead Levels, and in Morecambe Bay, grassland (including high quality grassland areas with high species count), scattered trees and belts of shrubs. Boundaries comprise post and rail fencing throughout the Humberhead Levels and along the M6 in Morecambe Bay, but along the A590 there are some sections of drystone wall or hedgerow owned by neighbouring landowners. Adjacent land use is predominantly farmland (especially pasture) with some urban areas and in Morecambe Bay some areas of woodland.

The main objective of management and maintenance for HA is safety and operational issues; aesthetics are considered but not a driver. Biodiversity is considered and sometimes a key driver for many projects in certain locations. Additional funding is available from HA for conservation work; the HA BAP determines what improvements can be bid for. Current management operations undertaken in the study areas are:

- New planting alongside highways in Morecambe Bay comprises native, local species for the function of screening. Local plant species are also planted in Humberhead Levels.

- Works to drainage ditches is carried out in both NIAs, typically in March. In Humberhead Levels this is driven by conservation of water voles and linking up suitable habitat. In Morecambe Bay, ditches are cleared out one side at a time to maintain habitat and reduce disturbance.

- Grass is cut in May/June and September, but only where required for safety and sightlines. Clippings are generally left on site, but removed (at the end of the season) if within a sensitive nature site.

- Vegetation is retained between ditches and fences to screen farms and match the landscape pattern of trees and scrub.

Key issues surrounding management and maintenance of the roadside along with the key opportunities identified by regional HA staff for continuing to enhance the management and maintenance of the transport soft estate for biodiversity benefit include the following.

Table 3.4: Key issues and opportunities identified at the HA teleconferences

Highways Agency Teleconferences	
Key issues	• Motorway planting in Morecambe Bay is mature and has succession issues with unwanted species such as larch, ash and rhododendron encroaching. • Invasive species such as Japanese knotweed and giant hogweed are present but not causing a problem. • Maintenance problems associated with boundaries owned by land owners along A590 in Morecambe Bay, as walls can fall over and hedges can grow too big. • Deer and other animal collisions are a problem in some areas, e.g. where M18 meets M62 (Humberhead Levels) and at Meathop Moss (Morecambe Bay). • The Humberhead Levels has experienced some flooding and branch fall during storms, e.g. in 2012, though weather events are not a significant concern. In Morecambe Bay the Newby Bridge area of the A590 that is level with the adjacent land and was submerged two years ago. • There is a need to slow traffic/close lane when Public Service Agreement (PSA) is required. The cost of PSA is a significant constraint so HA try to access from adjacent land if possible and tend to do chunks of roads in one go, e.g. the M18 in the Humberhead Levels.
Key opportunities	• There is potential for HA to work with land owners to improve vegetation management, e.g. partnership working using the new BAP. • HA in the Humberhead Levels is keen to mimic actions carried out on land under Higher Level Stewardship schemes (HLS) on neighbouring HA land. • HA in both NIAs is keen to bring back managing for wildlife rather than just managing for safety, e.g. cutting 20% of grass every year to reduce scrub encroachment.
	• Opportunities around water voles and improving species rich grasslands in the Humberhead Levels e.g. extend work done to improve calcareous grassland and woodland at J1-2 of M18 to other areas. • Potential collaboration with Butterfly Conservation by J36 of the M6, and an opportunity to increase butterfly populations along the bypass between Lindale and Newby Bridge (Morecambe Bay). • Wildflowers were planted on embankments at High Low Newton, whilst scrub species with berries were also planted to provide a source of food for wildlife (Morecambe Bay) – this could be carried out elsewhere, e.g. extending species rich grassland along the M62 (J37-38), M18 (J6-7) and M180 (J1-2) in Humberhead Levels. • Achievement of the HA BAP is related to the delivery of 15

	priority targets, or key performance indicators (KPIs). One of these KPIs (ancient woodland links) was to undertake tree and shrub planting/ management to extend the area of existing semi-natural ancient woodland, and increase connectivity between valuable woodland sites. Ancient woodland links have been established in Morecambe Bay. • Hedgerows are also a HA BAP KPI, with the target of creating 100km of species-rich hedgerows within new road schemes towards known biodiversity needs in the local area (e.g. fruit- and nut-bearing trees of value to dormice or badgers; linking existing features affected by severance; encouraging commuting or foraging bats away from, rather than onto, the carriageway). HA will consider hedge planting in Morecambe Bay, especially where they can link existing habitats, though they are constrained by A590 boundaries not being owned by HA. Could introduce secondary, inner boundaries to specifically link two areas of woodland. • Potential to maintain wet ditches and balancing ponds and to link fragmented habitats in both NIAs, as previously carried out at Bottersford Beck (J3-4 of M180), Meathop, High Low Newton, Newby Bridge and Backburrow. Creation of new wetland habitats in Humberhead Levels will need agreement with neighbouring land owners as HA has steep embankments. • Could be opportunities for SuDS in Morecambe Bay as an alternative to hard engineering depending on specific location. • Biomass has good prospects in the Humberhead Levels (current opportunities at J23, 27, 28 and 35 of M62, whilst the M180-M181 junction is also potentially suitable). The lack of thinning work in the last 30 years means biomass would be a good driver to reduce the cost of thinning. In Morecambe Bay there are possible constraints regarding access issues for retrieving wood and small size of woodland plots.

3.6. Identified constraints on vegetation management

NR are facing considerable constraints regarding management of lineside vegetation. At present the overriding criteria are safety, cost and operational considerations. Limited consideration is given to the natural environment e.g. SSSI sites, where NR have a duty to manage land according to the site management plans that are agreed with NE. The approach is generally reactive rather than proactive, with cost constraints limiting works to essential maintenance to allow the safe operation of the network.

The main problem related to lineside vegetation management is the control of woody species (trees) within 5m of the track, and most resources are directed towards this. Species are mostly sycamore, ash and birch which are pioneer species and self-seed readily especially on disturbed ground. Maintenance operations are focused on the 2-5m cess strip, and vegetation beyond this distance is generally not managed unless there are trees that have grown large enough to become a hazard. Areas close to stations and overpasses are also particularly sensitive areas.

In contrast, HA is more proactive with regards to managing the soft estate for biodiversity, for example HA survey and identify environmental improvement areas in some parts of the network for more specialised habitat management. The improvement areas on the estate are based on ecological surveys undertaken on the site – attempts are also made during these to look at how neighbouring land is managed. A new Biodiversity Action Plan (BAP) is currently being developed to follow on from the previous BAP, which expired in 2012. The emerging BAP is focused on outcomes rather than targets, which reduces geographical bias. This is a very significant change as it means that more areas can apply for funding, not only areas with priority habitats and species.

However, the policy on grassland cutting along road verges was changed in 2009. Up to 2009, 20% of grassland was cut each year. Now the frequency of cutting is much less and relates only to safety and sightlines. This has caused problems with protected species such as Great Crested Newts coming right up to the road. As a result of this management change, many road verges are neglected, with large area of scrub invasion, and there is an opportunity for these to be restored to grassland. In addition, HA is spending less on biodiversity now the BAP has expired and there is generally less money available to spend on management. Spending money on non-essential land management works is considered inappropriate when resources are needed for essential maintenance work such as fixing potholes etc.

The main constraint for HA is health and safety legislation and the need to gain permission for all maintenance work which adds a significant cost to any maintenance operation. It takes 12 weeks to get permission to stop on the hard shoulder with traffic cones etc. to carry out any work, including survey work.

3.7. Potential opportunities for enhancing vegetation management

Network Rail

As no spatial information on the habitats present within the NIA rail corridors was available at the time of the NR teleconferences, so discussion of opportunities was at a strategic level rather than looking at specific sections of lineside. For NR as a whole there are different vegetation management options depending on the distance from the track; these are detailed below.

1. 3 – 5m from track: Grassland
    a. Spraying annually with total herbicides using specialist rail vehicles, known as Multi-Purpose Vehicles (MPVs).
    b. Seeding with wildflower or tussocky grass mix using MPVs.
    c. Cutting and collecting arisings annually using MPVs.
2. 5m – 12m from track: Scrub
    a. Minimum management. Only felling of trees when these pose a risk to safety and operations.
    b. Coppicing of trees, cutting some trunks at 1.5m to provide Willow Tit habitat.
    c. Control of tress using tree injection method. Standing dead stems provide biodiversity benefits. Cost effective method.

d. Planting desirable low maintenance scrub species with biodiversity benefits, such as dog wood, dog rose, hawthorn, blackthorn (add). This also reduces the ability of undesirable tree species to establish.

3. Beyond 12m from track: More options exist in this zone further away from the track. Within the study areas there are, however, few stretches of lineside wider than 12m.

    a. Minimum management. Only felling of trees when these pose a risk to safety and operations.

    b. Coppicing of trees, cutting some trunks at 1.5m to provide scrub habitat, for example for Willow Tit habitat in the Humberhead Levels.

    c. Planting desirable low maintenance scrub species with biodiversity benefits, such as dog wood, dog rose, hawthorn, blackthorn. This also reduces the ability of undesirable tree species to establish.

    d. Establishment of allotment gardens.

    e. Biofuel production.

    f. Maintain as grassland and enhance the species diversity, e.g. by planting a mix of pollen rich or tussocky grass species.

    g. Bee keeping.

The NR and NIA consultations showed that there is agreement on the habitat type most favoured along rail corridors ie In terms of rail operation and safety and biodiversity benefit, the two habitats most highly favoured are grassland and scrub. The do minimum approach of NR can have benefits for biodiversity, by limiting disturbance to wildlife. However it also means that significant opportunities for the enhancement of the network for biodiversity, ecosystem services and network resilience are being missed under the current management regimes. There is potential to develop new approaches that benefit rail operation/resilience, biodiversity and ecosystem services. This is explored further in the opportunity mapping and management options sections of this report.

Highways Agency

The consultation events revealed agreement between HA and NIA participants on the priority habitats on which to focus within highway corridors – with grassland and scrub being favoured by both. HA takes a proactive approach with regards to promoting biodiversity, although in recent years this has significantly reduced due to declining budgets and changing priorities. HA staff are aware of the use of the HA BAP at a local level as well as strategically.

Prior to the teleconferences, HA provided detailed spatial information of vegetation present within the highway corridors (EnvIS data). This enabled HA staff to identify specific areas where wildlife conservation is already taking place, e.g. dormouse and bat boxes and otter ledges installed along the A590, as well as areas with potential for habitat and ecosystem service improvements, e.g. extending species rich grassland along the M62 (J37-38), M18 (J6-7) and M180 (J1-2), and producing biomass along the M62 and at the M180-M181 junction.

A report investigating the feasibility of biomass production on HA land in Area 12 was provided following the teleconference with HA staff in Humberhead Levels (Ground Control Ltd, 2013). This suggested that, under the correct remit and management, woody biomass has the potential to provide a revenue stream to aid funding the management of the HA soft estate. The potential to produce biomass was investigated at M62 Junctions 23, 27, 28 and 35 and M18 J5, and the report concluded that: "*tree felling and the extraction of trees to a processing point, and the chip processing of trees can be easily undertaken, and overall will be a swift operation. Over the course of the survey it has become increasingly apparent that the logistics of collecting and moving chip off the Network is the single biggest problematic area. This is only due to the working space available in certain aspects of the network and availability times to access live running lanes by installing traffic management*."

4. Opportunity Mapping

4.1. Summary of the methodology

The methodology for the selection of strategic opportunity areas and management options is divided into the following stages:

1. Baseline mapping – identification of relevant baseline data layers and mapping of these;

2. Mapping of strategic hotspots – identification of primary management aim, i.e. biodiversity, other ecosystem services (note that only the most relevant ecosystem services have been mapped, and this is constrained by data availability) or network resilience, and analysis of these spatial datasets in relation to their proximity to transport corridors;

3. Identification of management options – identification of potential management options based on management aim and surrounding priority habitat; and

4. Selection of preferred local management options – this stage will be based on local proofing and ground truthing (including integration with management options within adjacent HLS schemes, as well as relevant tree, leaf fall and landslip hazards) and thus carried out at a later stage.

Further detail on methodology and results can be found in the following sections.

This approach has resulted in the identification of a number of strategic opportunity areas. These will then be discussed and prioritised by NIA, NR and HA representatives at forthcoming stakeholder workshops. In addition to and supporting the opportunity areas we will also recommend generic management principles which could be applied anywhere across both HA and NR network (i.e. adoption of the mosaic approach[2] to habitat management, leaving dead wood in situ, leaving large standing stumps, removing invasive non-natives etc.) as well as generic management recommendations for the role of the soft estate in connecting urban and per-urban areas.

All new baseline and opportunity plans were uploaded to a sharepoint site made available to the NEWP32 stakeholder group and all previous participants of the stakeholder consultation events. Finalised plans are now publicly available via the NEWP 32 project site on the ADAS website.

These plans are subject to copyright. Detail on the copyright that applies to each of the data layers used in the analysis and shown on the maps is provided in Annex 4.

4.2. Stage 1 - Baseline mapping

The datasets collected for both Humberhead Levels and Morecambe Bay NIAs are as follows:

- NIA boundaries (NE);

- Road and rail infrastructure (OS open data);

[2] See Annex 3 for detail on the mosaic approach.

- Ecological designations including Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites, Sites of Special Scientific Interest (SSSIs) and National Nature Reserves (NNRs);

- Priority habitats (PH) and ancient woodland sites (NE);

- Land Cover Map 2007 (Centre for Ecology and Hydrology);

- Flood warning areas (Environment Agency);

- Water Framework Directive (WFD) river ecological status (Environment Agency);

- Higher Level Stewardship (HLS) boundaries and options (NE):

- Ecosystem services potential (NE);

- Highways Agency EnvIS data; and

- Network Rail leaf fall tree survey data.

The GIS data used in this project comprises 60.9km of railway owned/managed by Network Rail in the Humberhead Levels NIA and 67.5km in Morecambe Bay NIA. In terms of roads owned/managed by the Highways Agency, the GIS data comprises 25.2km in the Humberhead Levels NIA and 33.8km in Morecambe Bay NIA.

HA were able to provide detailed information about the soft estate in GIS format (EnvIS data), including the detailed classification of vegetation types along the highway verges. NR do not have data on the soft estate in GIS format, but as an Asset Register, which is an Excel spreadsheet. This contains information on percentage of land within each 1/8th mile segment of the lineside that is classed as open space, scrub or trees. This data has been geo-referenced and used to create a GIS layer showing the dominant vegetative cover for each lineside segment.

Ecosystem Services Baseline

Spatial data on potential ecosystem services provision has been provided by Natural England. These datasets use an interpretation of the Centre of Ecology and Hydrology's (CEH) Landcover Map 2007 (LCM2007) to describe the potential for areas to deliver individual ecosystem services. Not all services are mapped due to the weak evidence base linking habitats to some services (principally regulating services). Limitations of the data include the lack of consideration of flows and demand for ecosystem services and the location of beneficiaries. The habitat data used does not provide an indication of habitat condition, consequently the condition of ecosystem service provision cannot be inferred. The potential to deliver an ecosystem service is based on an assessment of the importance of the broad habitat – for each ecosystem service, each habitat is therefore classed as having high importance for the service, medium importance, low importance or no importance. For the purposes of this NEWP32 project, only habitats classed as having high importance for the service were included.

Of the ten ecosystem services included in the Natural England database, only five ecosystem services have been deemed appropriate for analysis through this project on transport corridors; these are as follows:

- Pollination – only habitats with a high potential to provide this service have been selected, ie Fen, Marsh & Swamp, Acid grassland, Calcareous grassland, and Rough low-productivity grassland.

- Water quality – this data shows the habitats (and underlying soils) that could contribute to the regulation of water quality. Only habitats with high potential to provide this service have been selected, i.e. freshwater, coastal and woodland habitats.

- Wood provision – only existing woodland habitats have the highest level of potential to deliver this service. This data was used as a proxy for areas that could also provide:

    - air quality services (due to the role that trees can play as a buffer for air quality impacts and in absorbing some pollutants); and

    - climate regulation services (due to the role that trees can play in carbon sequestration and in local climate cooling).

The priority habitats dataset can be used in a similar way to the landcover maps to provide proxy information on potential for ecosystem services, with the additional benefit of providing information on the quality of that habitat. This project has focused on the broad priority habitat categories of 'woodland', 'wetland' and 'other' priority habitats. In terms of the ecosystems services that these broad categories of habitats can deliver, it has been assumed for the purposes of this project that:

- woodland priority habitat sites have the potential for wood provision, air quality services and climate regulation services,

- wetland priority habitat sites have the potential to deliver water quality services; and

- 'other' sites have the potential to deliver pollinating services.

The baseline datasets are displayed as interactive maps, produced at a scale of 1:20,600 at A3 size and are available from Natural England on request. For Humberhead Levels, 9 plans have been produced covering the rail network, and 7 plans covering the highways network. For Morecambe Bay, 8 plans have been produced for the rail network, and 5 plans for the highways network. This is the most meaningful scale, allowing us to show sufficient detail along the transport corridors, key baseline data including designations and flood risk, vegetation types within the highway verges and landscape features shown on 50k OS mapping. Layers can be turned on and off as required.

The baseline data gathering and mapping formed the basis for the decision making process carried out to inform the various stages of opportunity mapping. This is detailed in the following section.

4.3. Stage 2 - Mapping of strategic hotspots

The stages undertaken for this initial GIS analysis were as follows:

1. Separately for NR and HA in each NIA, create a layer of continuous lines for rail or highway corridors.

2. Divide the HA/NR lines up into equal 100m segments (+/- 5m) and identify the

indicators (e.g. priority habitat, flood warning area etc) that fall within a 200m buffer of the transport corridor (see Figure 4.1 below). Justification for the 200m buffer is provided later in this section.

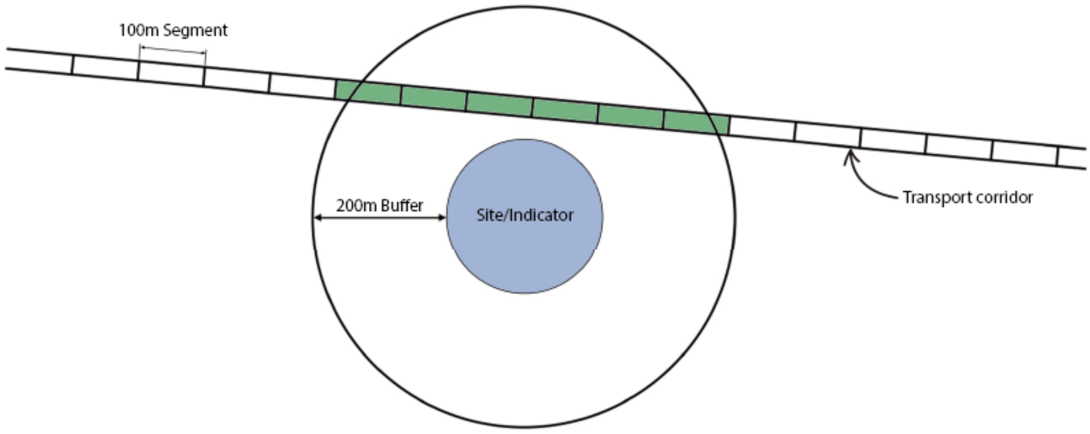

Figure 4.1: GIS mapping methodology

3. Create fields for the different sections of analysis (i.e. biodiversity, ecosystem services and network resilience) with specific indicators. The analysis will identify whether a certain l indicator (e.g. woodland priority habitat or flood warning areas) is present within 200m of the transport corridor and scored.
4. The fields, indicators and scores are as follows:
   - Biodiversity field
     - Woodland priority habitat indicator (PH_wood) [2 = yes, 0 = no]
     - Wetland priority habitat indicator (PH_wet) [2 = yes, 0 = no]
     - Other priority habitat indicator (PH_other) [2 = yes, 0 = no]
     - National designation indicator (Des_nat) [1 = yes, 0 = no]
     - International designation indicator (Des_int) [1 = yes, 0 = no]
   - Ecosystem services field
     - Pollination indicator (pollicrops) [1 = yes, 0 = no]
     - Water quality indicator (waterqual) [1 = yes, 0 = no]
     - Wood provision indicator (woodprov) [1 = yes, 0 = no]
     - WFD river condition indicator (WFD_qual) [1 = bad/poor, 0 = other]
   - Network resilience
     - Flood warning areas indicator (Flood) [1 = yes, 0 = no]
5. For the majority of indicators (excluding priority habitats, WFD river condition and flood warning areas) a score of 1 is given to each 100m stretch of line if it falls within **200m** of that indicator layer, or 0 otherwise.

6. Priority habitats have been deemed to be of greater importance than the other indicators, as they provide information on the value of habitats in terms of their importance for biodiversity and, by proxy, their potential for ecosystem services. Thus for these indicators , a score of 2 is given to each 100m stretch of line if it falls within 200m of that indicator layer, or 0 otherwise.
7. For WFD river condition, a score of 1 is given if the 100m stretch of line falls within the catchment where the river for the given catchment has a status of bad / poor, or 0 otherwise. No buffer distances are applicable.
8. The score for the flood warning areas is given based on a buffer distance of 30m, rather than 200m. Beyond this distance the layer becomes quite meaningless as most of the Humberhead Levels and a large part of Morecambe Bay have flood warnings in place due to their low lying nature. For this analysis we are only concerned with flood risk in the immediate vicinity (within 30m) of the transport corridor as it relates to the resilience of the network.
9. Total scores are then calculated for biodiversity (0-8), ecosystem services (0-4), network resilience (0-1) and the grand total (0-13) for each 100m stretch of line. The higher the score the more significant the opportunity for habitat creation and/or vegetation management.
10. Hotspot maps have then been produced for each NIA with sections of transport corridor with low overall scores shaded in dark to light green, medium scores in yellow to orange, and the highest overall scores coloured red.

The initial opportunity area analysis has been undertaken at a whole-NIA level; plans have therefore been produced at 1:170,000 at A3 for Humberhead Levels and at 1:200,000 at A3 for Morecambe Bay. This scale allows immediate identification of ‘hotspots’, i.e. sections of the rail or highway networks that have the greatest potential for concerted action.

A summary of the results from the mapping of strategic hotspots for each of the four corridors is shown in Table 4.1 below, whilst the maps themselves are provided in Annex 5.

Table 4.1: Summary of strategic hotspots analysis

Overall score for each 100m stretch of line	Humberhead Levels NIA: Proportion of transport corridor with each overall score		Morecambe Bay NIA: Proportion of transport corridor with each overall score	
	Rail corridor	Road corridor	Rail corridor	Road corridor
0	11.3%	17.8%	5.7%	6.8%
1	9.5%	12.7%	4.0%	3.3%
2	16.7%	21.8%	2.4%	6.2%
3	6.2%	11.1%	11.6%	7.1%
4	8.9%	14.6%	9.2%	8.3%
5	10.2%	6.0%	10.7%	24.3%
6	8.9%	8.3%	18.6%	6.2%
7	10.2%	1.6%	11.1%	19.3%
8	10.2%	4.0%	6.4%	8.9%
9	4.9%	1.6%	9.3%	9.5%
10	1.7%	0.4%	4.2%	0.0%
11	0.8%	0.0%	2.5%	0.0%
12	0.5%	0.0%	4.3%	0.0%
13	0.0%	0.0%	0.0%	0.0%

As can be seen from the summary table, more than half of the total length of transport corridor in the Humberhead Levels NIA has a score of 3 or lower, whilst for Morecambe Bay NIA the equivalent proportion of transport corridor has a score of 5 or lower. This means that Morecambe Bay has a greater proportion of land with nature conservation interest or which may provide ecosystem services within 200m of its transport corridors than the Humberhead Levels. Morecambe Bay's rail corridor in particular is in close proximity to land with multiple and/or overlapping nature conservation / ecosystem services potential, with 11% of this particular corridor scoring 10 or higher.

Justification for the choice of 200m buffer distance

Our principle aim in this work was to enhance the value of the transport network for biodiversity and to maximise the services from ecosystems which help to increase the resilience of transport infrastructure to variables such as climate change. The literature review, whilst identifying many areas for further research, provides pointers which suggest that enhancing both biodiversity and ecosystems services can be achieved by enhancing the corridor function of transport networks. This can be done by making these corridors as wide and continuous as possible to maximise habitat areas and minimise risk, as well as being providing as diverse in vegetation composition and age structure as possible. Taking account of the character of the habitats in the surrounding landscape so that transport corridors can provide complimentary habitats is also important for many species and ecosystem services.

We know that different species have different dispersal strategies and distances. Nature after Minerals report, published in 2006, suggests all priority habitat types can be (re)created up to 1km away from an existing patch of that priority habitat and still benefit many species. However, some species are far less mobile and benefit most from improvements within or in close proximity to their current site. Equally, we know that enhancing habitat close to or against existing sites, thereby buffering that site, also helps protect that site from external impacts such as pollution or fire.

Different habitats also provide different ecosystem services and the spatial configuration over which such services function will also vary. For example air pollution impacts from transport networks tends to be most significant within 200m, so any buffering of impacts using green infrastructure would be most beneficial within this distance. Water pollution impacts tend to be related to catchments, but interception at or close to source is highly beneficial. Pollination function is highly dependent on the plant diversity of the verge and adjacent habitats.

To take account of all variables we initially considered a 1km buffer distance. However a 1km buffer for a linear corridor covers an extensive area and the initial mapping results showed it to be too indiscriminate to effectively inform management approaches. We therefore revised the approach to focus on the land in close proximity to the transport corridor, since proximity to species rich habitats was deemed as being a key component in enhancing the biodiversity value of the transport soft estate. Many of the regulating ecosystem services provided by the soft estate operate most effectively when they are close to the source of the impacts (e.g. air quality and water quality functions of green infrastructure) and other services such as pollinating services are highly dependent on the immediate surrounding land; 30m and 200m buffer distances were therefore considered. 30m was discounted as there is little in the way of priority habitat, designated sites or ecosystem service potential adjacent to the transport corridors. We chose 200m either side of the road/track as the area of land that we considered could reasonably inform the management of the soft estate, and this distance provided a good mix of priority habitat, designated sites and ecosystem services potential. The resulting opportunity areas identified using this 200m buffer were cross-checked by local ecologists and land managers who advised that the opportunity areas identified utilising this approach appeared to correspond to their on the ground experience. The same buffer was used for biodiversity, ecosystem services and for network resilience, to provide a consistent spatial boundary.

Further work could be done on defining spatial buffers for individual habitats and ecosystem services, e.g. evidence is available to identify selected species-specific bespoke buffer sizes. It would be possible to repeat the exercise with a broader buffer, but the scoring would need to be more complex and take into account distance from the corridor, as well as other factors such as quality of the habitat and spatial configuration. However, the 200m buffer applied provides a robust approach for identifying a broad range of biodiversity, ecosystem service and transport network resilience enhancement opportunity areas.

4.4. Stage 3 - Identification of management options

Detailed methodology for stage 3

As mentioned in Section 4.2, the available habitat data for HA verges (EnvIS data) is far more detailed than for NR linesides (leaf fall tree audit data). To enable useful comparison between the habitat adjacent to railways and highways, the respective HA and NR datasets have been simplified to show, for each 100m stretch of line, whether the habitat is predominantly woodland (i.e. greater than 50% tree cover) or a mixture of other habitats (ie. less than 50% tree cover).

Where the mapping of strategic hotspots has revealed 100m sections of line with medium to high scores (the cut-off point for these higher scores differs for each corridor, as can be seen by the shaded cells in Table 4.1 above, as in each case these cover approximately 50% of the corridor), further GIS analysis has been undertaken based on the priority habitats and potential for ecosystem services for those sections.

Five management options (A, B, C, D and E) have been defined for opportunity areas identified on the transport soft estate. The aims of each management option are based on the vegetation composition of the existing soft estate and the composition of habitats found within a 200m buffer of the transport corridor (justification for selection of the 200m buffer is provided in the preceding Section 4.3).

The management aims draw on the findings of the literature review and discussions with the transport operators which suggest that there are opportunities to make greater use of the transport soft estate for pollinators, with reintroduction of grassland management to promote plant and pollinator species diversity. The active management of woodland, with the creation of glades, and where appropriate the reversion of wooded areas to grassland could also help manage safety risks around leaf and tree fall that were identified during the workshop sessions with transport operators. The management options also pick up on the findings of the literature review that there is scope for greater use of SUDs on the soft estate, as well as the use of land beyond the boundaries of the soft estate for wetland management that could be beneficial for reducing the flood risk.

The five management options are summarised in Table 4.2 below.

Table 4.2: Management options for the transport soft estate

Existing soft estate	Land in surrounding buffer contains:	Broad management aim for the transport soft estate	Management Option
≥ 50% woodland	• woodland priority habitat, and/or • habitats with a high potential for delivering woodland ecosystem services (e.g. woodfuel/ air quality/ climate regulation) i.e. shrub, hedgerows	Woodland retention / management / enhancement / planting on soft estate. N.B. This **could** include tree thinning/ coppicing (and removal of non-native species) with the managed creation of rides and glades to enhance existing woodland structure and quality.	A Woodland
	• wetland priority habitat and/or • habitats with a high potential for delivering water management ecosystem services (e.g. water quality), i.e. ditches, fen, marsh, wet grasslands etc	Sympathetic management of wooded soft estate and adjacent wetland and/or woodland/ wet woodland/ scrub/ grassland to control surface water run-off and pollution. Where the corridor is wide enough (and particularly if watercourse is below good ecological quality), also consider creation of SUDS e.g. soakaways and swales. Where transport network is within a flood risk area,	B Wetland

		management could involve the provision of additional flood storage areas (e.g. retention ponds, wet grassland/meadow) on adjacent land.	
	• grassland priority habitats or other habitats that are not woodland and wetland, e.g. heathland etc, and/or • habitats with a high potential for delivering pollinating ecosystem services	Tree removal / thinning / coppicing on soft estate (but retain trees that are veteran/ancient or support key local ecosystem services) and managed reversion of site to appropriate grassland / grass scrub mosaic type management.	C Grassland
<50% woodland	• wetland priority habitat and/or • habitats with a high potential for delivering water management ecosystem services (e.g. water quality), i.e. ditches, fen, marsh, wet grasslands etc.	Sympathetic management of soft estate to buffer and protect adjacent wetland and/or enhance water ecosystem services through the control of surface water runoff and pollution. Where the corridor is wide enough (and particularly if watercourse is below good ecological quality), also consider creation of SUDS e.g. soakaways and swales. Where soft estate lies in flood risk area, management could involve the provision of additional flood storage areas (e.g. retention ponds, wet grassland/meadow) on adjacent land or tree/woodland planting on or off the transport network estate in order to reduce run-off (and filter out pollutants) – particularly where slope stability is a concern. Wet grassland/grassland management / creation / enhancement and scrub mosaic type management on soft estate and land adjacent to soft estate where appropriate.	D Wetland

	• grassland and/or woodland priority habitats (not wetland) and/or • habitats with a high potential for delivering pollinating ecosystem services	Tree removal / thinning / coppicing on soft estate (but retain trees that are veteran/ancient or support key local ecosystem services) and managed reversion of site to appropriate grassland / grass scrub mosaic type management. Grassland management / creation / enhancement on soft estate. Where near woodland priority habitat, a transitional mosaic habitat of scrub may be more desirable than grassland.	E Grassland

Most opportunity areas will trigger multiple management options due to the presence of multiple priority habitats or ecosystem services in the 200m buffer. Decisions on which options to apply should be taken at the local level, based on local priorities.

Management Option A: Aim is to support woodland habitats
Management of the transport corridors where existing soft estate is predominantly woodland/scrub (≥ 50% woodland) and where land in the surrounding 200m buffer: • Supports priority woodland habitat; *and/or* • Provides an ecosystem service for which woodland is a habitat of high importance (e.g. climate change regulation, air quality and wood provision).

Where soft estate width allows, management ambition of the soft estate opportunity area should focus on, **managing or enhancing existing native woodland** (N.B. this could include tree removal to facilitate the creation of rides and glades where this would enhance the woodland structure), and options available to better buffer and/or connect the site through either tree planting on the soft estate or adjacent land and/or provision of transitional scrub and herb layers in line with the mosaic approach (see Annex 3 for more details on mosaic approach interactive guides e.g. trees and woodland).

Management of site to be done in sympathy with adjacent land holding management plans (if known), appropriate agri-environment management options or known appropriate management techniques for that priority habitat type (include consideration of Local Biodiversity Action Plan (LBAP) species, e.g. birds, reptiles and pollinators). Management to be informed by appropriate surveys to identify presence / absence of priority habitats / species on site.

Management will depend on whether the opportunity area has been identified for biodiversity reasons (woodland priority habitat within surrounding area) or for ecosystem services (climate change, air quality and wood provision).

Management is characterised by:

- Management of any existing woodland/tree cover on site, where track/road width allows potentially increase native tree cover if appropriate (such that the transport corridor land will retain or increase to circa 50% native tree cover) within transport corridor estate in order to link/ maintain link to existing woodland sites and contribute to carbon sequestration. But, tree felling/removal (not ancient/veteran trees) could be appropriate if existing woodland structure would be enhanced by creation of rides and glades and opening up of canopy.

- Trees should not encroach within 5m of track/road. Trees in 5-12m section should be regularly thinned/coppiced with some large dead wood left in situ and potential retention of some standards. Native tree planting can take place if appropriate where width of track/road > 12m.

- Where tree cover increase is not viable for safety reasons emphasis placed instead on increasing scrub cover (e.g. to benefit species such as Willow Tit), albeit with retention of some open grass areas in addition to the herb layer immediately adjacent to trackside/road.

- Tree/scrub as a boundary in areas as pseudo-hedge with good structure and can act as provider of fruit/berries/corridor/windbreak/microclimate/mosaic generator.

- Removal of non-native trees and identification and management of veteran/ancient trees, dead wood left in situ.

- If surrounding habitats are sensitive to air pollution (e.g. bogs, heathlands, sand dunes, acid grassland), management should look to enhance role of woodland as a buffer.

Management Option B: Aim is to support water management
Management of the transport corridors where existing soft estate is predominantly woodland (≥ 50% woodland) and where land in the surrounding 200m buffer: • Supports priority wetland/freshwater sites; *and/or* • Provides an ecosystem service for which wetland is a habitat of high importance (e.g. water quality); *and/or* • Is susceptible to flooding which could affect transport infrastructure resilience.

Management is characterised by:

- **Supporting water management** with emphasis away from transport network soft estate and onto the sympathetic management of neighbouring/adjacent sites and landowners to minimise risk to the network and maximise benefits for biodiversity.

- Where waterbodies are a feature of adjacent habitats, the soft estate focus is on pollution control (run-offs/pesticides etc) through retention/management of the existing woodland/tree cover on site, potentially increasing tree cover where track/road width and bank stability allow (refer to note 1), and sympathetic management of any grass/scrub i.e. manual cuts over spraying, extension of catchment sensitive farming practices. Where the corridor is wide enough (and particularly if watercourse is below good ecological quality), also consider creation of vegetated Sustainable Drainage Systems (SUDs) e.g. soakaways and swales.

- Where soft estate lies in or adjacent to flood warning area, management could involve the provision of additional flood storage areas (e.g. retention ponds) on adjacent land combined with retention/management of the existing woodland/tree cover on site (or the creation of wet woodland), potentially increasing tree cover where track/road width and bank stability allow (refer to note 1), in order to maintain/enhance role of trees in intercepting rainwater and slowing flow of rainwater. This will require agreement with neighbouring land-owners possibly via HLS or Payment for Ecosystem Services (PES).

- **Note 1:** Trees should not encroach within 5m of track/road. Trees in 5-12m section should be regularly thinned / coppiced with some large dead wood left in situ and potential retention of some standards. Native tree planting can take place if appropriate where width of track/road > 12m.

Management Option C: Aim is to support more open species rich grassland/grass/scrub mosaic habitats
Management of the transport corridors where existing soft estate is predominantly woodland (≥ 50% woodland) and where land in the surrounding 200m buffer: • Supports other priority habitats that are not woodland and/or wetland/freshwater; • Supports habitats that are identified as having a high potential for the pollination ecosystem service; *and/or* • Where flooding of transport infrastructure is not a risk; *and/or* • Where bank stability is not a risk (this should be noted, but is beyond the scope of this project).

Management ambition focusses on:

- Appropriate and managed reduction/thinning of any existing tree cover (with exception of any identified as utilised by bats (surveys) or where the tree is a recognised veteran/ancient tree, or where trees could be supporting a locally important ecosystem service, such as a buffer for adjacent habitats sensitive to air pollution such as bogs, heaths, sand dunes or acid grassland) and **managed reversion of site to appropriate grassland** i.e. if abutting calcareous grassland aim to establish calcareous grassland communities.

- Emphasis placed on utilisation of principles in mosaic approach to establish mosaic features i.e. transitional habitat zones i.e. scattered shrub/scrub, sword length variability, creation of areas of bare ground (see Annex 3 for mosaic approach interactive guides, e.g. lowland grassland).

- Selected native standards can be retained but non-natives removed – having an eye to helping trees change distribution with respect to climate change. Removal of any non-ancient/veteran trees where these could represent a risk of falling onto the network/network equipment or collision risk for road vehicles.

- For areas requiring thinning of tree cover and where access permits (consider use of access from adjacent land holdings to remove wood - agri-environment schemes may offer opportunities for this), consider coppicing and/or biofuel / timber production for economic gain.

- Management to be informed by survey evidence of presence/absence of priority habitats and species.

- Management of soft estate to be done in sympathy with adjacent land holding management plans (if known – Higher Level Stewardship scheme data is publicly accessible via Biodiversity Action Reporting System – BARS - website[3]), appropriate agri-environment management options or known appropriate management techniques for that priority habitat type (include consideration of LBAP species, e.g. birds, reptiles and pollinators).

Management Option D: Aim is to support water management

Management of the transport corridors where existing soft estate is predominantly a mix of grassland/scrubland (where tree cover less is less than 50%) and where land in the surrounding 200m buffer:

- Supports priority wetland/freshwater sites; *and/or*

- Provides an ecosystem service for which wetland is a habitat of high importance (e.g. water quality); *and/or*

- Is susceptible to flooding which could affect transport infrastructure resilience.

Management is characterised by:

- **Supporting water management** with emphasis away from transport network soft estate and onto the sympathetic management of neighbouring/adjacent sites and landowners to minimise risk to the network and maximise benefits for biodiversity.

- Where waterbodies are a feature of adjacent habitats, the soft estate focus is on pollution control (run-offs/pesticides etc) through sympathetic management of grass/scrub ie manual cuts over spraying, extension of catchment sensitive farming practices. Where the corridor is wide enough (and particularly if watercourse is below good ecological quality), also consider creation of SUDS e.g. soakaways and swales

- Where soft estate lies in or adjacent to flood warning area, management could involve the provision of additional flood storage areas (e.g. retention ponds, wet grassland/meadow) on adjacent land or tree/woodland planting off the transport network estate in order to reduce run-off (and filter out pollutants) – particularly where slope stability is a concern. This will require

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3 http://ukbars.defra.gov.uk/

agreement with neighbouring land-owners and provision via agri-environment scheme or Payment for Ecosystem Services (PES).

- On the soft estate retain existing low levels of tree cover if this provides benefits for surface water runoff or pollution control. Otherwise managed enhancement of soft estate to appropriate species rich grassland / grass scrub mosaic type management i.e. if abutting calcareous grassland aim to establish calcareous grassland communities. Sowing native wildflower seed mix to promote nectar and pollen rich grassland, or an appropriate tussocky grass mix, which may be beneficial for reptiles and invertebrates (see Annex 3 for mosaic approach interactive guides, e.g. lowland grassland).

- Look to reduce spraying in these areas, and instead replace with early (May) and late (August) or just late summer (late August) cuts with removal of arisings. If practicable a rotational scheme might further promote insect diversity and abundance, as verges will be flower-less immediately after mowing.

- Investigate the potential for turning verge cuttings (e.g. soft rush, gorse and bracken) into viable biomass fuel.

Management Option E: Aim is to support more open species rich grassland/ grass/scrub mosaic habitats
Management of the transport corridors where existing soft estate is predominantly a mix of grassland/scrubland (where tree cover less is less than 50%) and where land in the surrounding 200m buffer: • Supports other priority habitats (grassland/woodland and other non-wetland); • Supports habitats that are identified as having a high potential for the pollination ecosystem service; *and/or* • Where flooding of transport infrastructure is not a risk; *and/or* • Where bank stability is not a risk (this should be noted, but is beyond the scope of this project).

Management is characterised by:

- Appropriate and managed reduction/thinning of any existing tree cover (with exception of any identified as utilised by bats (surveys) or where the tree is a recognised veteran/ancient tree, or where trees could be supporting a locally important ecosystem service, such as providing a buffer for adjacent habitats sensitive to air pollution such as bogs, heaths, sand dunes or acid grassland) and **managed reversion of site to appropriate species rich grassland**. Management to be informed by appropriate mosaic management principles and adjacent land, i.e.:

    - If abutting calcareous grassland aim to establish calcareous grassland communities and appropriate mosaic type management i.e. variable sword heights, creation of bare ground. Sowing native wildflower seed mix to promote nectar and pollen rich grassland, or an appropriate tussocky grass mix, which may be beneficial for reptiles and invertebrates. Look to reduce spraying in these areas, and instead replace with early (May) and late (August), or just late summer (late August) cuts with removal of arisings. If practicable a rotational scheme might further promote insect diversity and abundance, as verges will be flower-less immediately after mowing (see Annex 3 for mosaic approach interactive guides, e.g. lowland grassland).

    - If abutting priority woodland habitat, a transitional mosaic habitat of shrubs/scrub will be more desirable than transition straight to grassland, with retention of existing trees where possible and creation of rides/glades (see Annex 3 for mosaic approach interactive guides e.g. trees and woodland).

- Investigate the potential for turning verge cuttings (e.g. soft rush, gorse and bracken) into viable biomass fuel.

Analysis and mapping for stage 3

The management options defined above are displayed as interactive maps. For each NIA, one overarching opportunity layer map has been produced for the rail network and another for the road network. These have been produced at A3 size with the following broad scales: 1:130,000 for both the road and rail maps for Humberhead Levels; 1:110,000 for the Morecambe Bay rail map; and 1:100,000 for the Morecambe Bay road map). These broad scales are the most meaningful for this strategic stage of analysis. More detailed maps (at a scale of 1:40,000 at A3 size) have been produced which show the opportunity areas and the underlying GIS layers that were used to inform the development of the opportunity areas, showing locations of:

- Ecological designations including Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites, Sites of Special Scientific Interest (SSSIs) and National Nature Reserves (NNRs);

- Priority habitats and ancient woodland sites (NE);

- Flood warning areas (Environment Agency);

- Water Framework Directive river ecological status (Environment Agency);

- Higher Level Stewardship boundaries and options (NE); and

- Ecosystem services potential (NE).

Though not included in the analysis so far, these maps include an additional layer that shows land under agri-environment Higher Level Stewardship (HLS) schemes (along with the specific HLS options chosen where these are relevant to the project). This is useful as it is likely that habitat enhancement and especially creation of woodland or wetland habitats will need to be carried out on adjacent (agricultural) land rather than within the transport corridors themselves. These management option maps will form the basis for discussion with NIA, NR and HA representatives at forthcoming workshops over which options to prioritise in which areas.

A summary of the results from the opportunity mapping for each of the four corridors is shown in Table 4.3 below. Maps to show the identified areas of opportunity and the suggested management options for these areas can be found in Annex 6 and 7 respectively. Interactive maps showing the strategic opportunity areas, detailed management options and all of the baseline data are available on request from Natural England. For each of these maps, data layers can be turned on and off as required.

Table 4.3: Summary of opportunity mapping analysis

Management Option	Humberhead Levels NIA: Length of transport corridor within each management option (km)		Morecambe Bay NIA: Length of transport corridor within each management option (km)	
	Rail corridor	Road corridor	Rail corridor	Road corridor
A. Woodland	9.21	3.31	2.41	7.72
B Wetland	9.31	3.81	2.41	7.72
C Grassland	5.58	2.41	2.41	6.92
D Wetland	19.51	8.00	23.14	7.11
E Grassland	16.82	6.31	22.04	7.01

The summary table and maps reveal that roadside and lineside habitats are predominantly a mix of grassland/scrubland (where tree cover less is less than 50%). This is especially the case for rail corridors in Morecambe Bay where almost all of the opportunity areas have been identified for existing grassland/scrubland habitats, whereas for road corridors in Morecambe Bay there is a more even spread between opportunity areas in woodland and non-woodland habitats.

In theory, a total of 23km of the transport corridors across the two NIAs may be suitable for increased support of woodland habitats (Option A); 23km may be suitable for increased support of water management where tree cover is currently greater than 50% (Option B); 17km may be suitable for support for more open species rich grassland/grass/scrub mosaic habitats where tree cover is currently greater than 50% (Option C); 58km may be suitable for increased support of water management where tree cover is currently less than 50% (Option D); and 52km may be suitable for support for more open species rich grassland/grass/scrub mosaic habitats where tree cover is currently less than 50% (Option E).

It must be noted that due to the presence of multiple priority habitats and/or ecosystem services in the 200m buffer around each of the four transport corridors, often two or three of the management options are applicable in each identified opportunity area. Consequently there are overlaps in the lengths of corridor shown in Table 4.3 above, particularly between Options A, B and C, and between Options D and E.

4.5. Stage 4 - Selection of preferred local management options

This stage will involve liaising with the relevant local NIA or LNP to discuss, amend and finesse the relevant opportunity area maps and prioritise the various opportunity areas and overlapping management options based on local priorities. Partnership based management approaches to the opportunity areas identified in conjunction with relevant partners/ stakeholders and land managers will also be worked up.

Specifically the stage will consider:

- Agri-environment scheme / habitat proofing
    - This step will involve consultation with neighbouring land owners, particularly those with land in HLS schemes, to ensure that management of the soft estate is done in sympathy with adjacent land holding management plans (if known), appropriate agri-environment management options or known appropriate management techniques for that priority habitat type.

- Geodiversity and landscape character / sense of place proofing
    - This step will help to ensure that the management options chosen for each opportunity area do not conflict with and where possible enhance geodiversity and landscape character/ sense of place of the NIAs, as set out in the National Character Area (NCA) profiles. An example would be in the Humberhead levels where consideration should be given to keeping long open views.

- Priority species proofing
    - This step will provide a similar sense check in terms of the priority species identified in the Local BAPs and the NCA profiles. It will ensure that consideration is given to whether there are specific management requirements of key species which could be incorporated into the management option for that opportunity area whilst still allowing viable operations of the transport network.

- Tree hazard / leaf fall / landslip hazard proofing
    - This step will involve consultation with local HA and NR staff in order to identify sections of the opportunity areas which currently have issues related to leaf fall, branch fall, hazardous trees, unstable banks or landslips. Where a particular management option would help to reduce this risk to the transport network, appropriate management in these areas should be prioritised.

5. Summary and Conclusions

5.1. Strategic opportunities and management options

This project has used a review of the literature, consultation with NIA, HA and NR stakeholders from the Humberhead Levels and Morecambe Bay areas, and spatial data analysis to identify hotspots and opportunity areas for enhancing biodiversity, ecosystem services and network resilience along the transport corridors within the two NIAs.

The project has used the information gathered in the workshops and consultations to develop options for the management of vegetation within the opportunity areas, based upon the existing habitat within the corridors and the use and management of adjoining land.

The mapped outputs can be found in Annexes 5, 6 and 7. These show the progression from hotspots, to opportunity areas, to management options for the road and rail soft estate in the two NIAs. An example of the progression for the rail network in Morecambe Bay is shown in Figures 5.1, 5.2 and 5.3 below.

The project has looked for the first time at how the management of soft estate can be better integrated and linked to adjacent land management to deliver wider benefits, not limited to the Network Rail and Highways Agency estate, with better connection to the wider landscape. Specifically, there is a key opportunity to make greater use of the transport soft estate for pollinators, with reintroduction of grassland management to promote plant and pollinator species diversity. Such management also has potential for reduced safety risks around leaf and tree fall, particularly for rail corridors.

For existing soft estate with greater than (or equal to) 50% tree cover (i.e. predominantly woodland/scrub habitats), three management options were developed. These are as shown in Table 5.1 below. For existing soft estate of less than 50% tree cover (i.e. predominantly a mix of grassland/ scrubland), two management options were developed. These are shown in Table 5.2 below.

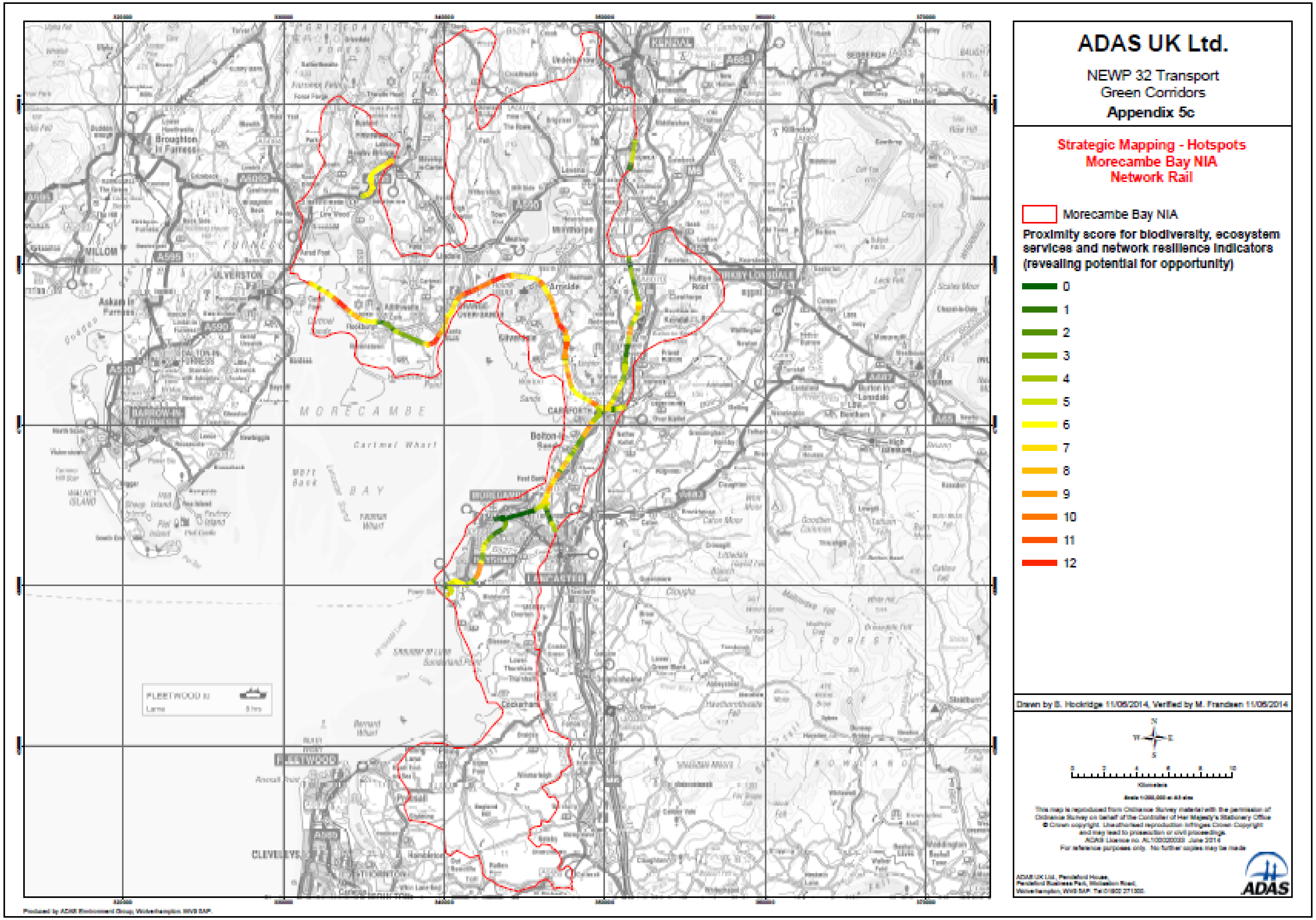

Figure 5.1: Hotspots map for rail soft estate within the Morecambe Bay NIA

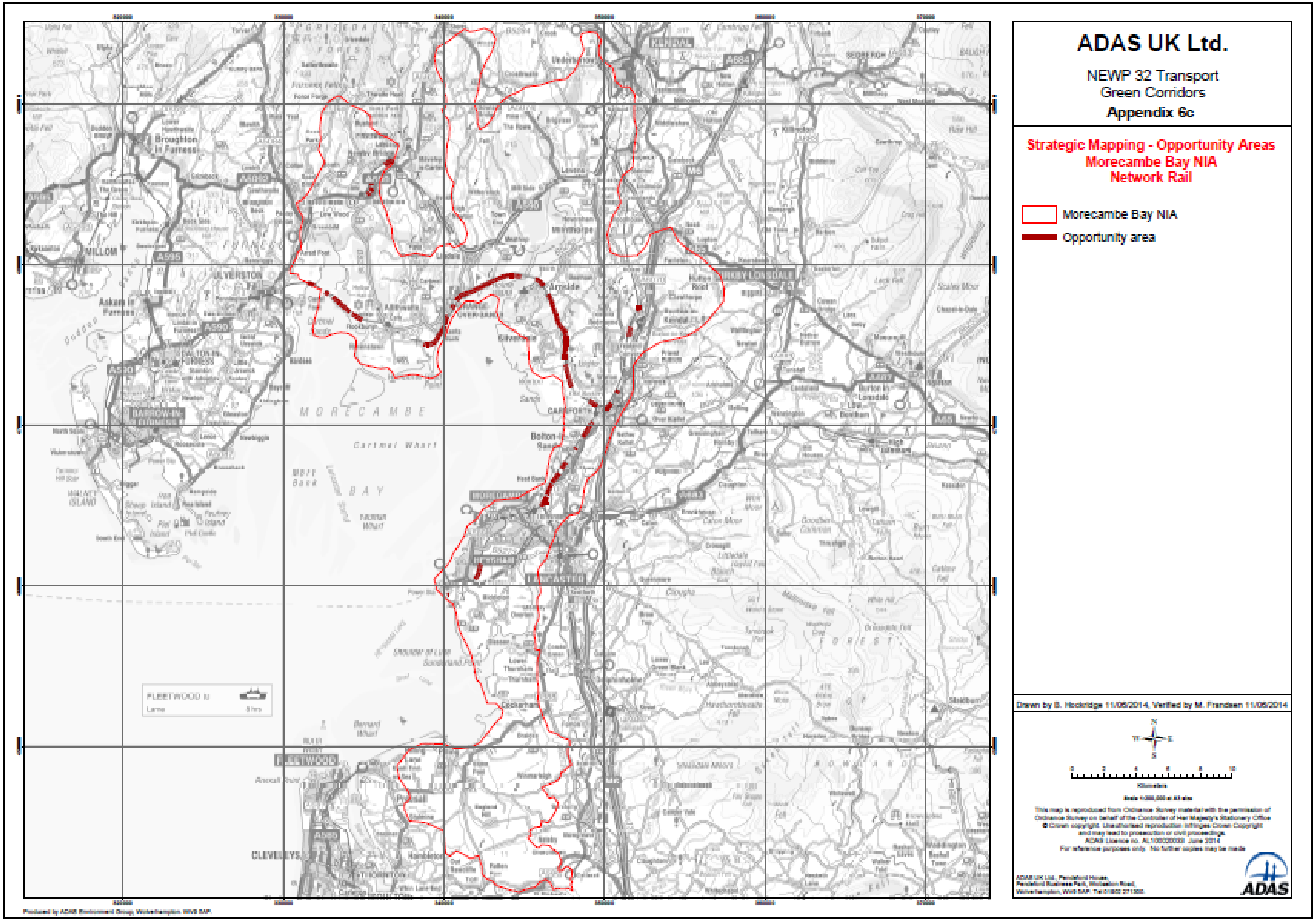

Figure 5.2: Opportunity Areas for the rail soft estate within Morecambe Bay NIA

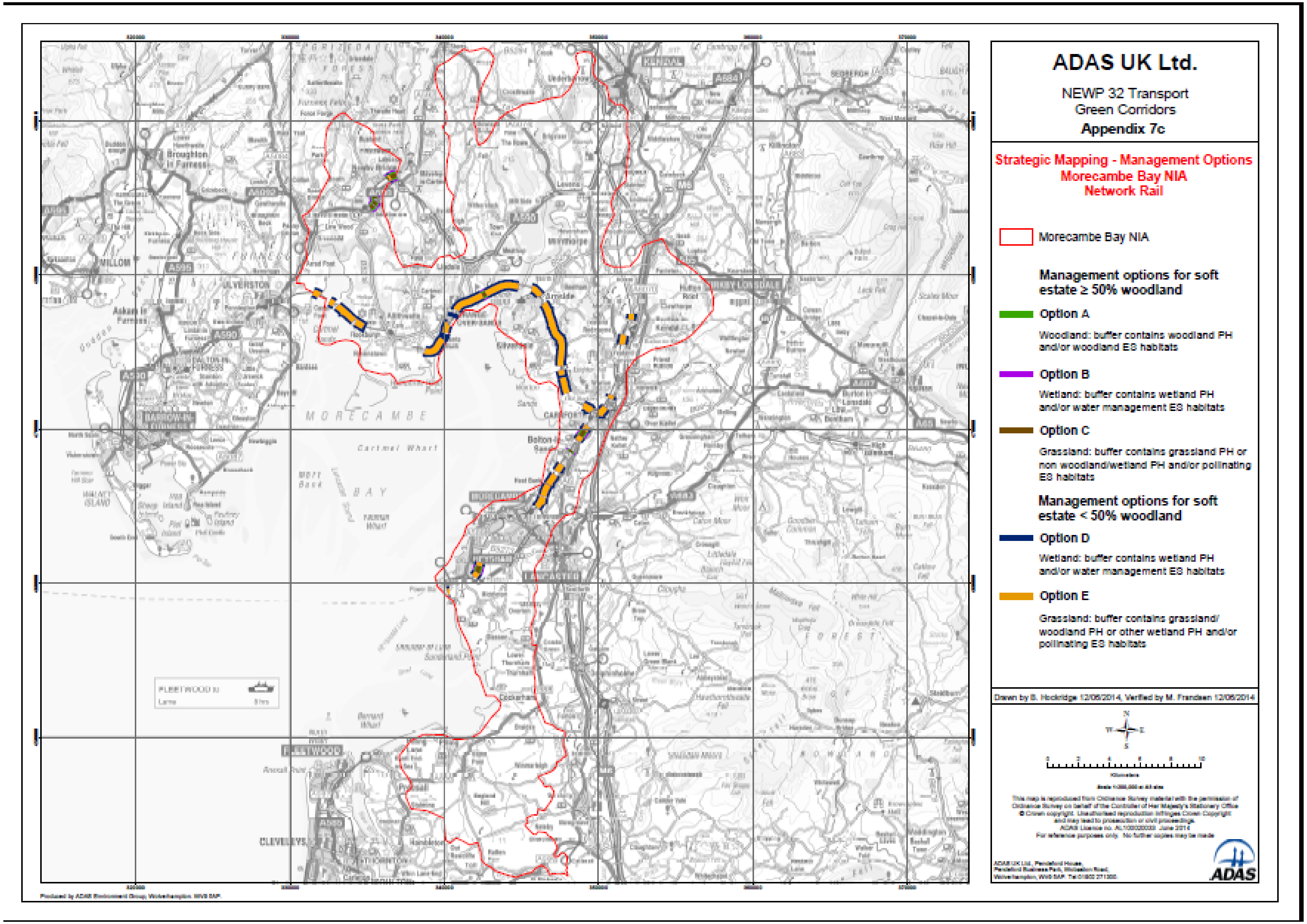

Figure 5.3: Management Options for rail soft estate within Morecambe Bay NIA

Table 5.1: Summary of strategic opportunities for predominantly woodland transport corridors

Management Option	Land in surrounding buffer contains:	Broad management aim:	Applicable to:
A Woodland	• woodland priority habitat, and/or • habitats with a high potential for delivering woodland ecosystem services (e.g. woodfuel/ air quality/ climate regulation)	Woodland retention / management / enhancement / planting on soft estate. N.B. This **could** include tree thinning/ coppicing (and removal of non-native species) with the managed creation of rides and glades to enhance existing woodland structure and quality.	15% of rail corridor in HL (9km) 13% of road corridor in HL (3km) 4% of rail corridor in MB (2km) 23% of road corridor in MB (8km)
B Wetland	• wetland priority habitat and/or • habitats with a high potential for delivering water management ecosystem services (e.g. water quality).	Sympathetic management of wooded soft estate and adjacent wetland and/or woodland/scrub/grassland to control surface water run-off and pollution. Where the corridor is wide enough (and particularly if watercourse is below good ecological quality), also consider creation of SUDS e.g. soakaways and swales Where transport network is within a flood risk area, management could involve the provision of additional flood storage areas (e.g. retention ponds, wet grassland/meadow) on adjacent land.	15% of rail corridor in HL (9km) 15% of road corridor in HL (4km) 4% of rail corridor in MB (2km) 23% of road corridor in MB (8km)
C Grassland	• grassland priority habitats or other habitats that are not woodland and wetland and/or • habitats with a high potential for delivering pollinating ecosystem services	Tree removal / thinning / coppicing on soft estate (but retain trees that are veteran/ancient or support key local ecosystem services) and managed reversion of site to appropriate grassland / grass scrub mosaic type management.	9% of rail corridor in HL (6km) 10% of road corridor in HL (2km) 4% of rail corridor in MB (2km) 20% of road corridor in MB (7km)

Table 5.2: Summary of strategic opportunities for predominantly grassland transport corridors

Management Option	Land in surrounding buffer contains:	Broad management aim:	Applicable to:
D Wetland	• wetland priority habitat and/or • habitats with a high potential for delivering water management ecosystem services (e.g. water quality).	Sympathetic management of grass / scrub soft estate and adjacent wetland and / or grassland / scrub to control surface water runoff and pollution. Where the corridor is wide enough (and particularly if watercourse is below good ecological quality), also consider creation of SUDS e.g. soakaways and swales Grassland management / creation / enhancement on soft estate where appropriate. Where soft estate lies in flood risk area, management could involve the provision of additional flood storage areas (e.g. retention ponds, wet grassland/meadow) on adjacent land or tree/woodland planting on or off the transport network estate in order to reduce run-off (and filter out pollutants) – particularly where slope stability is a concern.	32% of rail corridor in HL (20km) 32% of road corridor in HL (8km) 34% of rail corridor in MB (23km) 21% of road corridor in MB (7km)
E Grassland	• grassland and/or woodland priority habitats (not wetland) and/or • habitats with a high potential for delivering pollinating ecosystem services	Grassland management / creation / enhancement on soft estate. Where trees or scrub present removal / thinning / coppicing on soft estate (but retain trees that are veteran/ancient or support key local ecosystem services) and managed reversion of site to appropriate grassland or grass scrub mosaic type management. Where near woodland priority habitat, a transitional mosaic habitat of scrub may be more desirable than grassland.	28% of rail corridor in HL (17km) 25% of road corridor in HL (6km) 33% of rail corridor in MB (22km) 21% of road corridor in MB (7km)

5.2. Identification of data needs and data gaps

The literature review and spatial data analysis revealed that there are currently some gaps in knowledge. The availability of literature is noticeably scarcer for railways than it is for roads whilst spatial habitat data for NR land is also far less detailed than the equivalent for HA land. There is an opportunity for both organisations to update their Biodiversity Action Plans (BAP) and to increase awareness of its content and practical application across the organisation.

The literature review identified several areas where further work is needed into the role of transport corridors, including:

- A better of understanding is required for how transport infrastructure should be integrated into ecological networks to maximise biodiversity benefits without increasing the risk. In this regard, identifying pinch points for wildlife mortality is important, as is understanding the role of crossing points and how best to manage vegetation to deter animals from riskier zones. A greater understanding of the species that benefit from transport corridors and those than are challenged by them is needed, as well as the structures that can be used to reduce risk, such as green bridges, culverts, bat gantries, underpasses and hop-overs.

- Further work could also explore the potential for commercial benefits from the harvesting of wood or other biomass products from the transport soft estate in ways that could also benefit biodiversity such as the thinning or coppicing of trees to create glades and rides.

- Further work to explore how to work better with transport's neighbours to improve and enhance land management practices at a landscape scale and not just within the soft estate. For instance how to enter into agreements with adjacent landholders to use their land to access the vegetation to be harvested for biomass, or to coordinate weed control. There could be other mutual benefits, such as providing flood attenuation and pollination services which could be potentially funded through payment for ecosystem services schemes.

In relation to the opportunity mapping, additional work could be undertaken to improve the mapping of local ecosystem services. The approach used in this project is based on an approach trialled by Natural England whereby existing spatial habitat data is used as a proxy for ecosystem services provision. The advantages of this approach are that it is quick and simple to use and provides national maps of habitats that are important in the provision of ecosystem services. Limitations include low accuracy (additional datasets are required for each ecosystem service to provide a more accurate and meaningful depiction), the lack of consideration of flows and demand for ecosystem services and the location of beneficiaries. Furthermore, not all services are mapped due to the weak evidence base linking habitats to some services (principally regulating services). The Natural England approach only shows the *potential* of a particular area to deliver a particular ecosystem service. This is based on existing habitat type – and without any reference to the quality of that habitat in any given area. It does not, therefore show where ecosystem services are actually being delivered, and further work to refine these at the local level could be undertaken.

5.3. Next steps for the transport corridors project

The opportunity maps provide a strategic analysis of the transport soft estate and surrounding land (up to 200m) and provide suggested options for future management of the soft estate. They are innovative in that they take account, not only of the land within the transport estate itself, but also the adjacent land corridor, and how the management of the soft estate can be designed to complement and maximise the biodiversity and ecosystem services potential of the combined resource, whilst delivering benefits for the operation and resilience of the transport network.

However the maps are based on national data sets and as such have caveats and limitations in terms of their accuracy and applicability at the local level. Further work is therefore required to ground truth the opportunity maps and management options, using local knowledge and understanding to help refine priorities for action. This will need to draw on the experience and expertise of transport operators as well as that of the local NIA partners.

Specifically this next stage will consider:

- agri-environment scheme / habitat proofing e.g. to ensure that management is in sympathy with neighbouring HLS objectives;

- geodiversity and landscape character / sense of place proofing, e.g. to ensure that the management options chosen for each opportunity area align with National Character Area (NCA) profiles and where possible enhance landscape character;

- priority species proofing, e.g. to ensure that consideration is given to whether there are specific management requirements of key species which could be incorporated into the management options for that opportunity area; and

- tree hazard / leaf fall / landslip hazard proofing, e.g. to identify sections of the opportunity areas which currently have issues related to leaf fall, branch fall, hazardous trees, unstable banks or landslips.

The financial cost of carrying out particular management options will also be a consideration at this stage.

Further work is then required to trial new approaches to management of the soft estate and to monitor the effectiveness of these new approaches. This work will be managed by Natural England, Network Rail, Highways Agency and NIA partners over the next three years through the employment of two project officers who will be hosted by Yorkshire and Cumbria Wildlife Trusts.

5.4. Suggestions for further work

Roll-out to other areas

Depending on the success of the next stages of the project at local level, this approach could be rolled out in some of the other ten NIA pilot areas. Railways and/or highways pass through or adjacent to Dark Peak NIA, Dearne Valley Green Heart NIA, Meres and Mosses NIA, Nene Valley NIA, Northern Devon NIA, South Downs Way Ahead NIA and Wild Purbeck NIA, with Birmingham and the Black Country NIA being a prime candidate for similar work on transport corridors (albeit with a more urban focus).

Improved accuracy at local level

To improve the accuracy of this study at local level, further research will be required regarding the mapping of ecosystem services. Currently there are limitations in relation to the national approach taken (as detailed above), and there is potential to link into other local projects being carried out by various organisations on ecosystem services mapping.

A more complex scoring system could be used to identify hotspots, perhaps with a greater variety of indicators, or with scores that vary depending on the quality/ conservation status/ severity/ prevalence of that indicator, or with the distance from the transport corridor. Different habitats provide different ecosystem services and the spatial configuration over which such services function will also vary. It is likely that a more complex scoring system would enable a broader buffer zone to be chosen, which would tie in with other similar studies. For example, the Nature after Minerals report, published in 2006, suggests all priority habitat types can be (re)created up to 1km away from an existing patch of that priority habitat and still benefit many species. It was not possible to use a 1km buffer with the simple scoring system used in this report, as the initial mapping results showed it to be too indiscriminate to effectively inform management approaches. Further work could be done on defining spatial buffers for individual habitats, ecosystem services, or species.

To aid data gathering, the mapping was limited to the boundaries of the NIAs. A further refinement would be to broaden the mapping to cover key transport routes within the general NIA area, rather than to focus specifically on the routes within the NIA.

Alternative applications

Through the development of the project it has become clear that there is potential to apply the methodology in different ways:

- **Focus on non-priority habitat / urban areas:** The two NIAs used in this study are in rural areas and particular importance has been placed on connectivity with priority habitats. An extension of this study could be to benefit the wider countryside by focusing on improving the management of vegetation in non-priority habitat areas, particularly giving greater consideration to the importance of transport corridors in providing habitat connectivity through urban areas where there is limited greenspace. An alternative focus could thus be on the ecosystem services provided by the soft estate (particularly rail and non-highway roads) in urban areas. Such a study could also consider the recreation potential of soft estate, linking urban greenspace to the wider countryside, with visual amenity and screening also potentially playing a more important role.

- **Focus on links with neighbouring agri-environment schemes:** There is potential to replicate the actions carried out on neighbouring land under agri-environment schemes on the transport soft estate; the focus could thus be on collaborations between adjacent landowners and transport corridors.

- **Focus on protected sites and landscapes:** This project has focused on two NIAs, but there would be scope to extend and tailor the work to enhance the soft estate where it passes through protected landscapes (e.g. National Parks and AONBs) or other sites designated for their nature conservation interest (either at local or national level).

- **Focus on individual species or species groups:** The literature review identified the potential for greater use to be made of the transport soft estate for certain species groups such as pollinators, and there is scope to identify specific management requirements of key species that could be adapted to the soft estate, where cost, operational and safety constraints allow.

- **Focus on ecosystem service delivery:** There is scope to tailor the application of the methodology to focus on delivering benefits from the soft estate for individual or multiple ecosystem services depending on local priorities.

- **Focus on other linear corridors:** The project could be extended to other transport/linear corridors, such as local road networks, canals and rivers, cycleways, and potentially other linear infrastructure networks such as the national grid network.

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