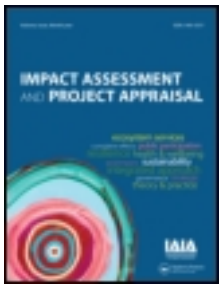

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Network analysis in CEA, ecosystem services assessment and green space planning

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Network analysis in CEA, ecosystem services assessment and green space planning

Lourdes M Cooper

Network analysis is a technique that has been used in cumulative effects assessment (CEA). In a research project for the Department for Environment, Food and Rural Affairs in the UK, network analysis was used in the context of ecosystem services assessment by defining the services provided by green spaces in Kent Thameside. This paper discusses the results of applying the technique to understand relationships between land uses and ecosystem services and to engage stakeholders. Network analysis can also provide a means to identify key issues and assess cumulative effects in green space planning, sustainability appraisals and strategic environmental assessment (SEA).

Keywords: network analysis, ecosystem services approach, green grids, green infrastructure, SEA, sustainability appraisal

NETWORK ANALYSIS (often used for identifying interactions and cumulative effects of development) was applied in the context of ecosystem services, by analysing the potential effects of proposed developments and management scenarios on those services. Network analysis proved to be a useful technique to engage with stakeholders and to understand the relationships between land use/land cover categories and ecosystem services provided by particular land uses.

This paper explores the use of network analysis in a research project funded by the Department for Environment, Food and Rural Affairs (Defra) in the UK. The research project, carried out from October 2006 to April 2008 by Collingwood Environmental Planning and the GeoData Institute, evaluated the value and appropriateness of using an ecosystem services approach within planning frameworks, particularly its application through a range of decision support tools — network analysis, STELLA modelling and Geographic Information Systems (GISs). The case study area selected was Kent Thameside, a key development area of the Thames Gateway Growth Area within the UK Government's Sustainable Communities Plan.

Network analysis has the potential to be applied more widely at strategic levels, such as in planning green spaces and spatial frameworks. It can help us organise thoughts and gain a better understanding of relationships between land uses and proposals. Some recommendations are made to improve the use of this technique.

Network analysis

The network analysis method is based on the concept that there are links and interaction pathways between individual components of the environment and when one component is affected this will also have an effect on other components that interact with it. Network analysis identifies the pathway of an impact or interaction through a series of chains (network) or webs (systems diagrams) between the cause and the receptor. These network diagrams provide the mechanism for linking first and higher

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order impacts. Analysing the response of a receptor to a particular action and identifying the effects on other receptors allows consideration of indirect and cumulative impacts. It clearly illustrates the interaction pathways between the elements of the environment (Hyder, 1999). This method has been applied to analyse the cumulative effects relating to a regional airport in the Victorian Alps in Australia (Testoni, 2002) and hydroelectric dams in various countries (Brismar, 2004). Network analysis has also been used to understand cumulative environmental effects within the context of SEA (e.g. Cooper, 2004).

This research, however, provided an opportunity to apply network analysis in a different context by exploring cumulative effects through ecosystem services interactions. It was used to explore potential cumulative effects through ecosystem interactions and identify links between ecosystem services provided by the Green Grid.[1]

Initially, network analysis was used to identify ecosystem services provided by particular land uses. Potential changes to these services because of development and different management scenarios were established. As a result of these changes, potential effects, which included cumulative effects on the ecosystem services themselves and on key receptors, were identified. Network diagrams were prepared at local and strategic levels.

Ecosystem services assessment

Ecosystem services are the benefits that humans obtain from ecosystems, and they are produced by interactions within the ecosystem. They include ***provisioning***, ***regulating*** and ***cultural*** services that directly affect people. They also include ***supporting*** services needed to maintain all other services. Ecosystem services affect human well-being and all its components, including basic material needs such as food and shelter (World Resources Institute, 2005).

Ecosystems are natural resources that provide people with many essential goods and services, including, for example, air, food, drinking water, landscape and recreational space. The concept of ecosystem services has been developed internationally by the Millennium Ecosystems Assessment, supported by the global Environment Facility and the United Nations Environment Programme, among others. Defra has undertaken research in this area, such as developing inventories of ecosystem services, understanding environmental limits and valuation of ecosystem services. The aim of this research, however, was to assess the types of ecosystem services provided within a particular case study area undergoing extensive urban regeneration and how best they can be evaluated within current land use planning and decision making frameworks.

Case study: Kent Thameside

The case study, Kent Thameside, covers an area of around 40 km^2 and is one of the growth areas in the Thames Gateway, which is the largest regeneration area in the UK. Kent Thameside covers parts of two local authorities, Dartford and Gravesham Boroughs.

The area is already under some considerable constraints, for instance in terms of water resource availability, flood risk, air quality, transportation and biodiversity issues. However, there are extensive areas of brownfield (previously developed) land available in North Kent for new development, particularly resulting from historical quarry and cement works activity in the area. The Channel Tunnel Rail Link (CTRL) passes through Kent Thameside and the new CTRL station at Ebbsfleet is also located within the area. Within Kent Thameside, the project focused on the Green Grid initiative. The Green Grid initiative is an important planning concept designed to improve the environmental perception of the Thames Gateway, enhance environmental assets with a network of green spaces and corridors, recognise the importance of multifunctional green spaces for community life and help ensure that green spaces can also provide important adaptation tools (e.g. in relation to helping with flood relief and improving the quality of life).

The case study enabled the exploration of different geographical scales within Kent Thameside and for different types of analyses (e.g. impacts of different policy options on ecosystem services and the impact of development in local ecosystem services). This provided a much better understanding of the nature of ecosystem services provided by the Green Grid and their interactions. Figure 1 shows Kent Thameside, which covers the area south of the River Thames, the towns of Dartford and Gravesend and the communities of Stone, Greenhithe, Swanscombe and Northfleet located north of the A2.

Methodology

The project sought to understand and assess the ecosystem services function provided by the Green Grid to the local area and to local communities. The research was highly participative, including local people and stakeholder interests from the early stages, in identifying the uses to which the Green Grid network is put, what benefits people derive from it and their own perceptions of the Green Grid concept in practice. The project then evaluated the interrelationships between these ecosystem services and between ecosystem services and potential development impacts, through a sequential approach to the use of dynamic models and GISs.

The overall methodology for the project consisted of the following:

- Literature review: ecosystem services, planning, the Thames Gateway, green grids, GIS, STELLA

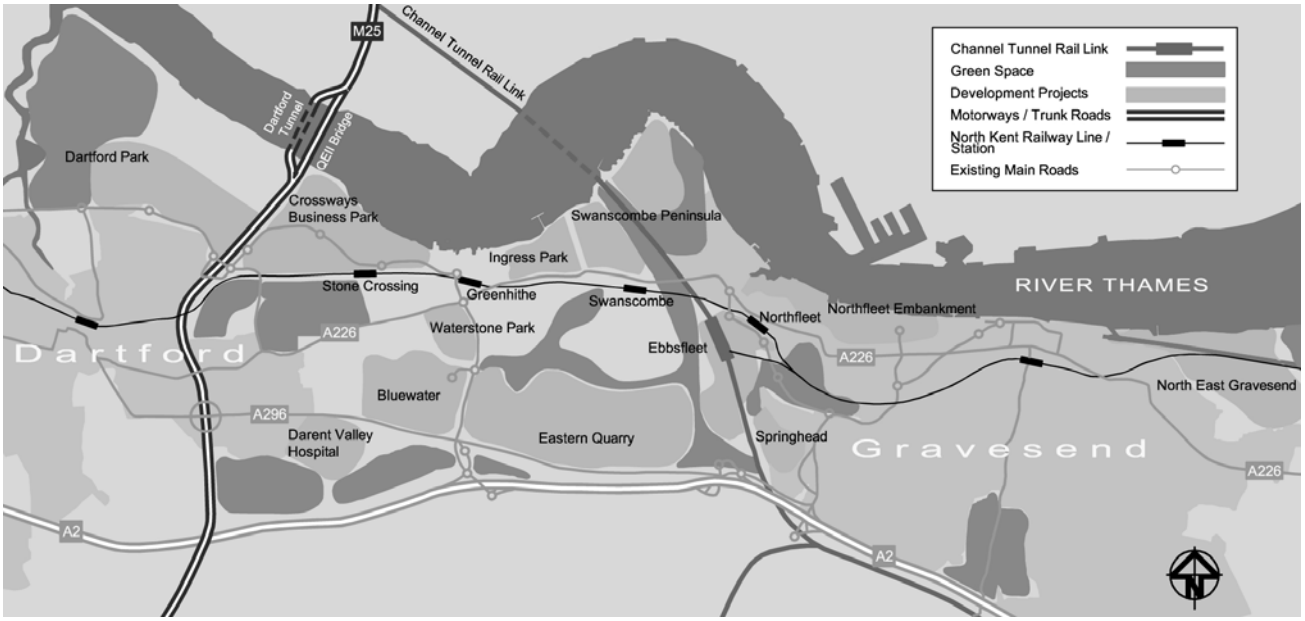

Figure 1. Kent Thameside area
Source: adapted from Kent Thameside (2002)

modelling and network analysis.
- Development of typology of ecosystem services with stakeholders and through a pilot study.
- Undertaking studies at the strategic and local levels to test the use of the decision support tools.
- Analysis and reporting.

A diagram of the approach taken is included in Figure 2. This paper only discusses the application of network analysis. Network analysis diagrams were prepared during the pilot study, the strategic study and the local study. Network diagrams showed the ecosystem services provided under the current situation for each study and how the ecosystem services provided would change under the different management scenarios. Direct, indirect and cumulative effects were indicated in the diagrams as well as interactions between services. To illustrate, the next section will describe how network diagrams were developed and applied in the pilot case study.

Application of network analysis

As indicated in Figure 2, network analysis was applied during the different stages of the project. This paper will focus on the application of network analysis during the pilot study and strategic study stages.

Pilot study

Dartford Marshes, which are located in the north-eastern corner of Kent Thameside cover an area of 370 hectares (Bexley Council, 2006). The marshes are used mostly for horse and livestock grazing, passive enjoyment of nature, cycling and walking. The main habitat type in Dartford Marshes is wet neutral grassland with some woodland and scrub. Other habitat types include tidal mudflats, salt marshes, grazing marsh, ditches, scrub and ancient woodland. Dartford Marshes lies at the confluence of the River Darent with the River Thames with the River Cray flowing on the south. The area is currently protected from both fluvial and tidal inundation through a system of earth embankments but a flood risk strategy for the tidal Thames has established that the area has a potential for flood storage. The marshes are important locally as green space; regionally, it is one of the few remaining marshes along the Thames. However, there is pressure to develop parts of the marshes for housing (The Bridge, 2006).

Exploring ecosystem services Network diagrams were used to explore and define relationships between land uses and the ecosystem services provided in Dartford Marshes. Network analysis models of ecosystem services were developed using the typology developed for Kent Thameside for the following situations and management options:

- Ecosystem services currently provided by Dartford Marshes.
- Ecosystem services affected by 'The Bridge' housing development.
- Ecosystem services affected by maximising flood risk management.
- Ecosystem services affected by maximising biodiversity.
- Ecosystem services affected by maximising access and recreation.

Potential ecosystem services currently provided by Dartford Marshes were identified based on current land uses and land cover. A network analysis diagram of ecosystem services in Dartford Marshes is shown in Figure 3. For clarity, the relationship between particular land uses and potential ecosystem

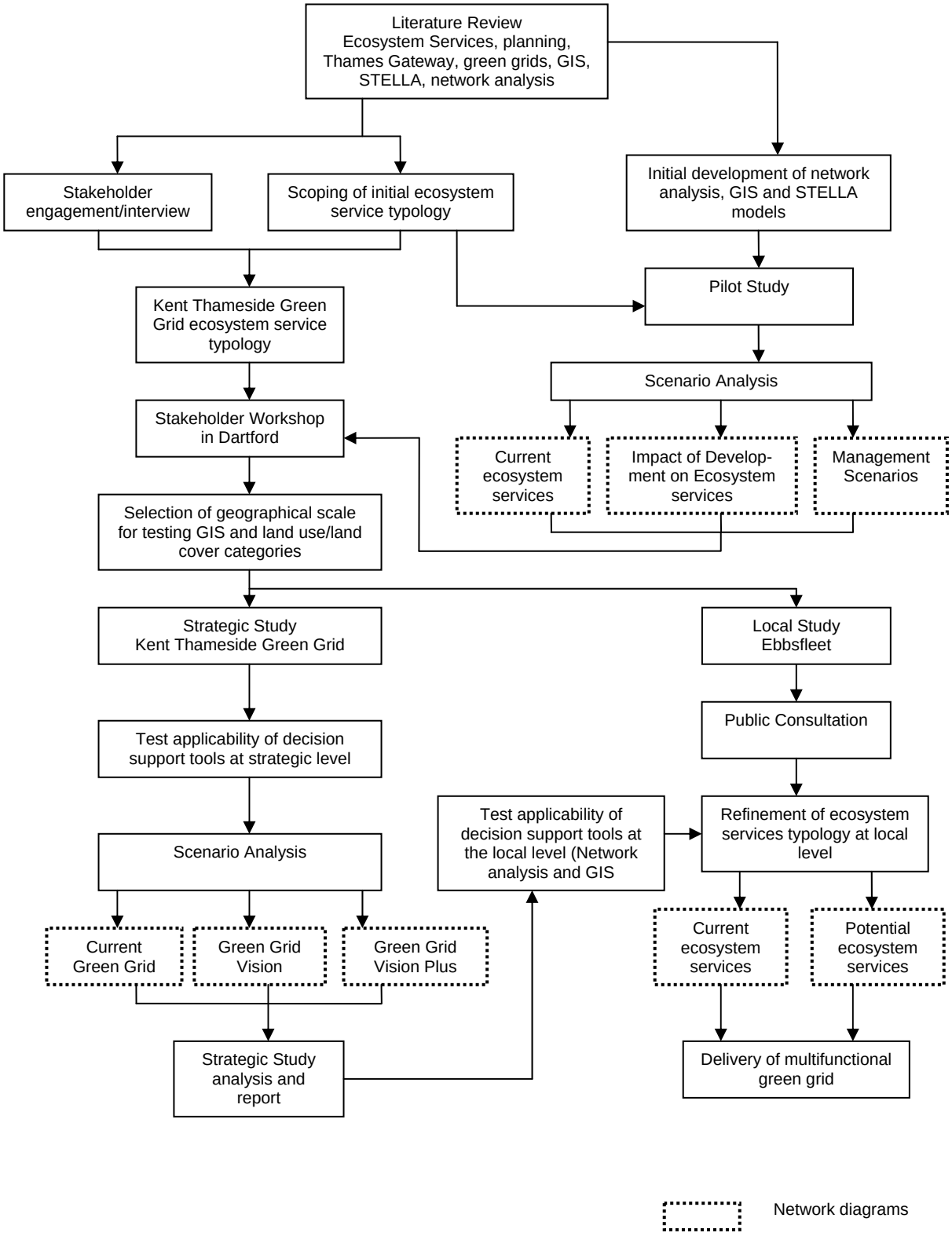

Figure 2. Research approach for Kent Thameside case study
Source: adapted from CEP (2008)

services are indicated by different line weights and patterns.

In constructing the diagrams, open space categories based on Planning Policy Guidance (PPG) Note 17 and the green infrastructure[2] classification were used to classify spaces. These are classifications which are used in spatial/open spaces planning. Other categories such as habitat types could have been used in preparing the diagrams, but it was felt that a land use and land cover categorisation would be better for identifying ecosystem services because the ecosystem services approach being evaluated in this research relates to land use planning frameworks. In addition, habitat and land cover data may not include certain land uses, such as brownfield sites, which were a major feature in the pilot study area.

Another diagram was constructed which allowed analyses of the potential impacts on ecosystem

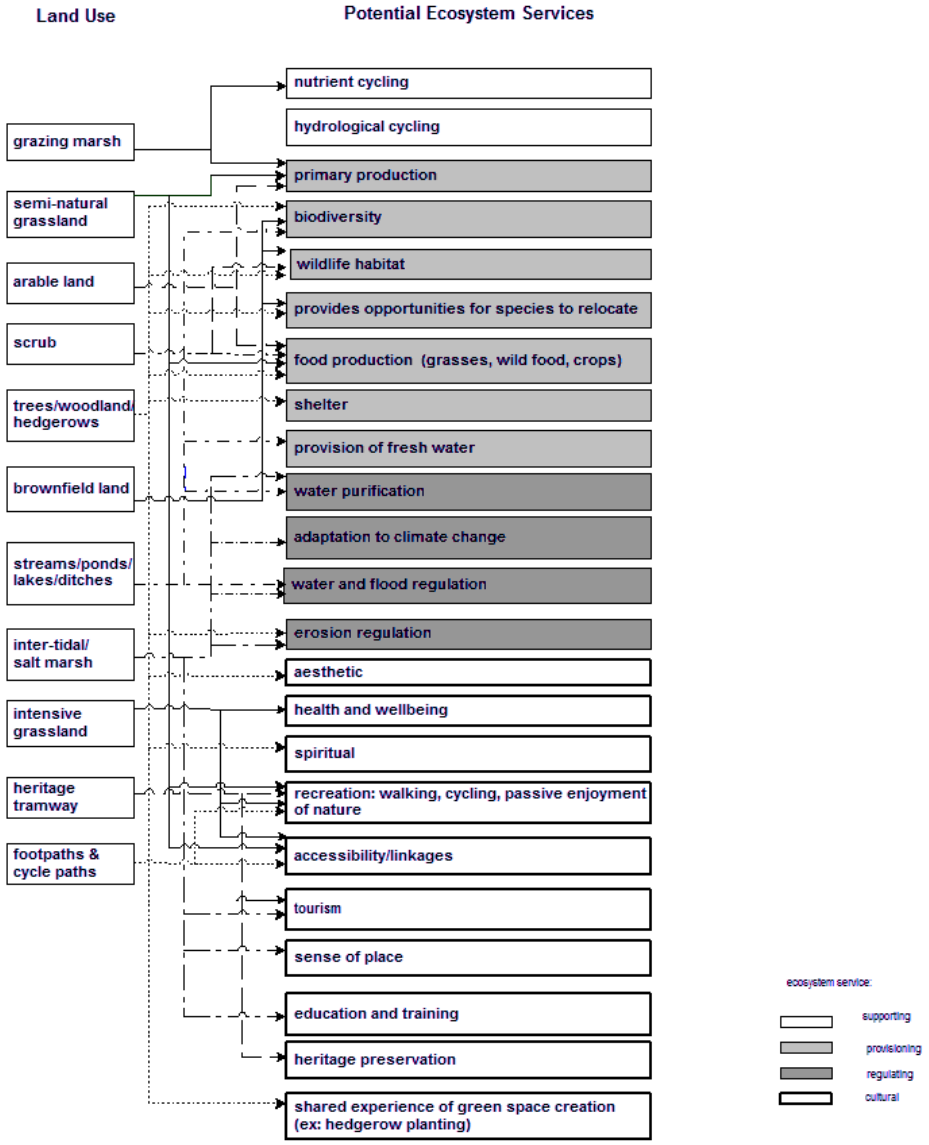

Figure 3. Network analysis diagram showing ecosystem services currently provided by Dartford Marshes

services from 'The Bridge' housing development. The potential direct impacts during construction and operation, the impacts of these activities on ecosystem services and the ecosystem services affected were identified. Potential indirect and cumulative impacts on the environment were indicated in the diagrams as well as the interactions which could result in cumulative impacts. The network diagram showing the impacts of housing development is presented in Figure 4. This diagram indicates positive and negative impacts.

The network analysis model for maximising flood risk management explored the impacts on the provision of ecosystem services as a result of periodic inundation, limited maintenance of defences and using the marshes for flood storage. In identifying potential impacts (e.g. increased tidal flood storage capacity may impact on freshwater biodiversity), research on previous studies was undertaken to find out the potential impacts from particular management decisions. For example, in determining the likely impacts of periodic inundation, studies on the effects of inundation in the Essex salt marshes (Essex Estuarine Strategies, undated) were examined.

The network model for maximising biodiversity showed potential impacts of creating, restoring and managing habitats on ecosystem services. Similarly, the network model on maximising access and recreation traced potential impacts on ecosystem services and identified where increasing access might conflict with another service, such as biodiversity.

In all the diagrams, direct, indirect and cumulative impacts (whether positive or negative), the ecosystem service affected by the policy options and the impact of one ecosystem service on another ecosystem service were indicated.

Stakeholder workshop A stakeholder workshop was held on 2 July 2007 to help focus the research on relevant policy and priority issues and areas within Kent Thameside Green Grid (CEP with Geo Data Institute, 2007a). Participants were introduced to the decision support tools. Examples of network diagrams already prepared were used to investigate how

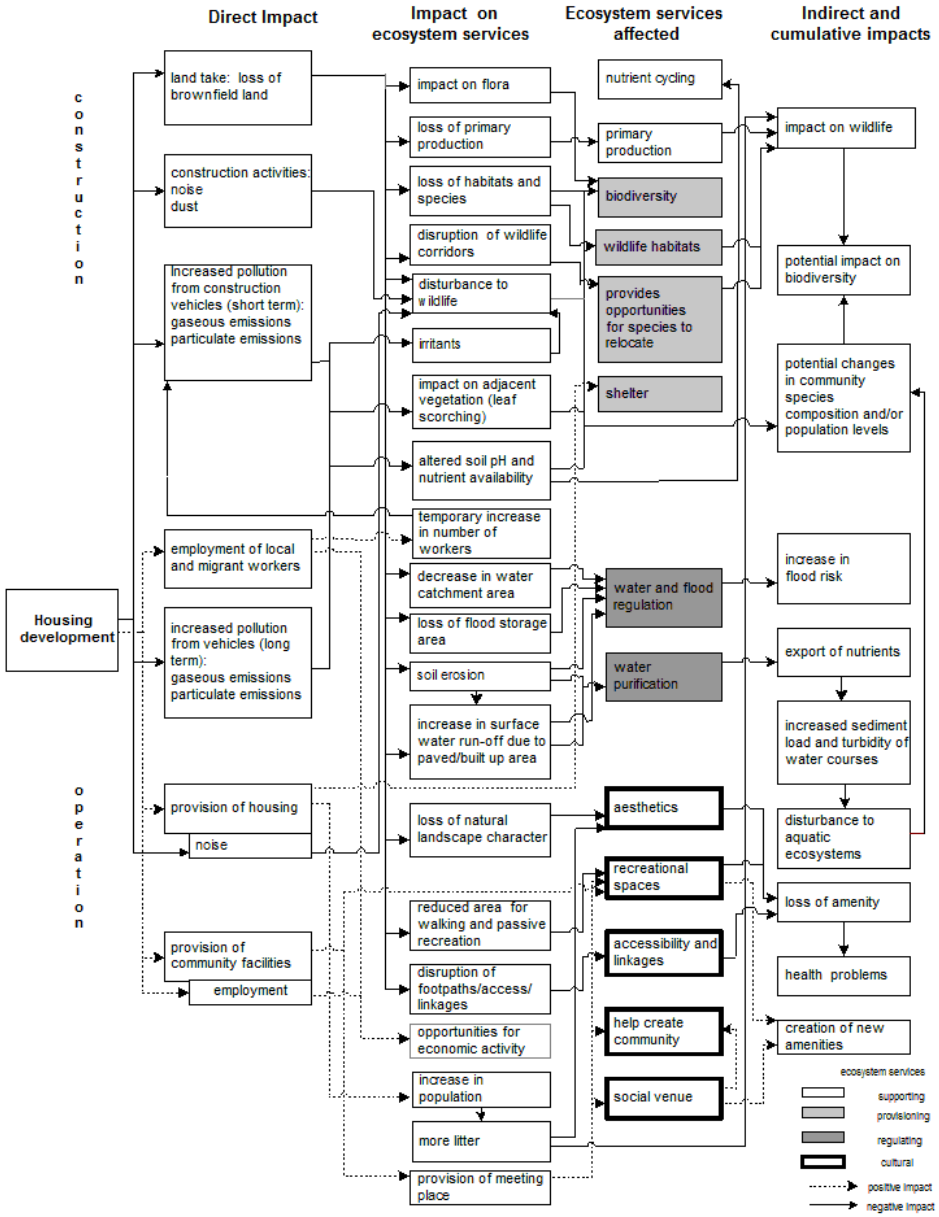

Figure 4. Network analysis diagram showing impact of housing development on Dartford Marshes with indications of negative and positive impacts

ecosystem services would be affected by development at Dartford Marshes. Participants were asked:

- What are the ecosystem services currently provided by Dartford Marshes?
- How might these change following housing development?

The participants were then asked to annotate the network diagrams to reflect their discussions. The views of participants were also sought on how ecosystem services provided may change under the three management options. Participants were provided with network diagrams illustrating the changes each management system might have on the marshes and were asked:

- What changes in ecosystem service provisioning might occur under the hypothetical management option?

In light of the above, participants were asked to annotate the network diagrams to reflect their discussions, and an example is provided in Figure 5. The comments are indicated in shaded boxes with broken outlines in the diagram and additions or changes suggested by the stakeholders have been included in the diagram. This diagram also shows positive and negative impacts and impacts on other services.

Key findings from the pilot study Some important conclusions were drawn from the pilot study that informed the selection of further study areas (CEP with Geo Data Institute, 2007b). The findings which were particularly relevant to network analysis were:

- The ecosystem services typology developed earlier in the research proved helpful in the preparation of the network diagrams.
- The use of network analysis proved effective in communicating the concept of ecosystem services

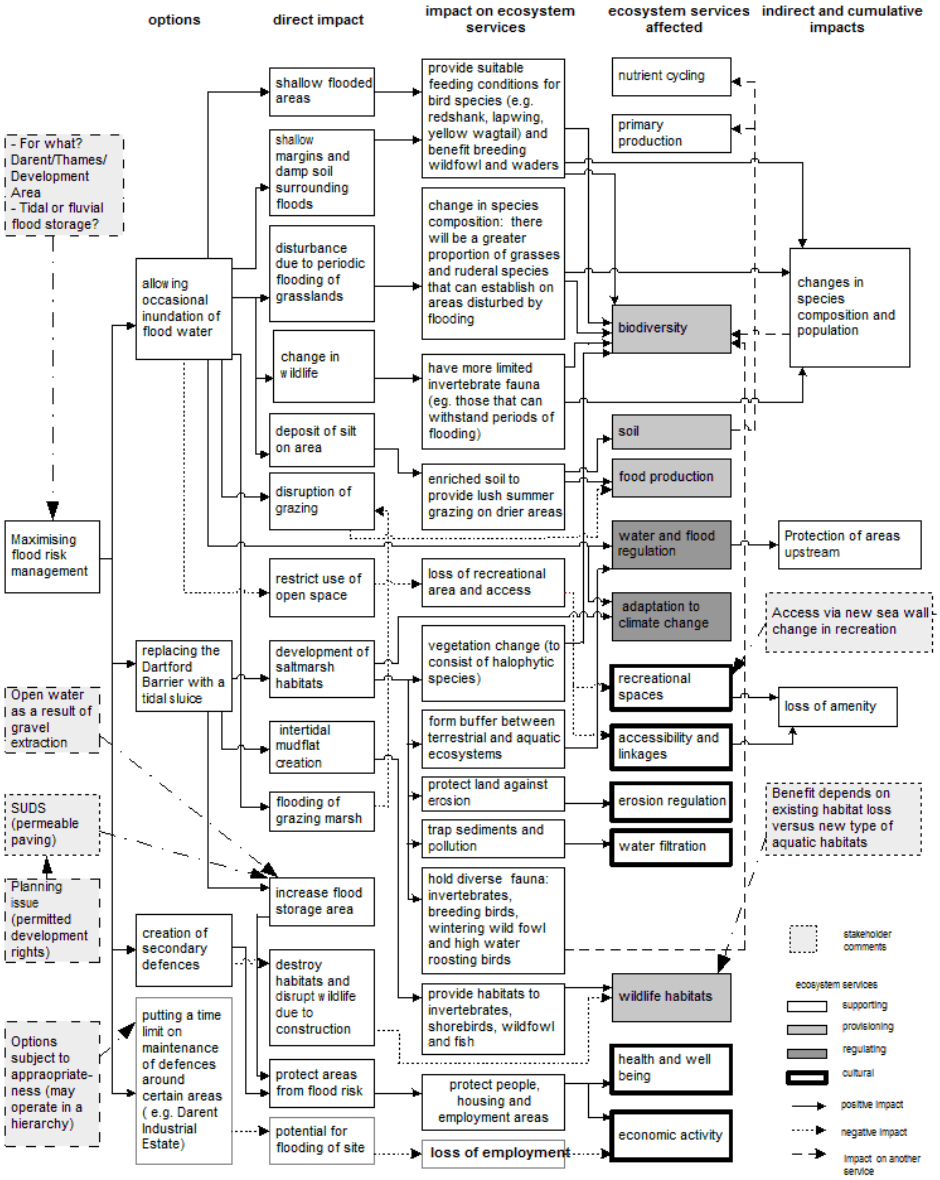

Figure 5. Network analysis diagram for maximising flood risk management, including comments by stakeholders

at the workshop, where participants were able to provide feedback and ideas. The network diagrams were useful in exploring ecosystem services in Dartford Marshes and tracing potential impacts (direct, indirect and cumulative) as well as impact relationships under different management scenarios.

- Network analysis provides a practical way to engage with stakeholders about the type and nature of ecosystem services in the area.

Strategic study

The aim of the strategic study was to explore how ecosystem services may help support the development of the strategy for the Kent Thameside Green Grid and other planning frameworks. As in the pilot study, network analysis diagrams were constructed for the following Green Grid scenarios:

- Current Green Grid;
- Green Grid 'Vision';
- Multifunctional Green Grid based on maximising ecosystem services.

The models used the typology of ecosystem services developed earlier in this research, which were found to be useful when tested in the pilot study. The ecosystem units employed were land use/land cover categories selected earlier to identify the ecosystem services provided by the Kent Thameside Green Grid. In identifying these services, land use/land cover units were characterised based on the study of baseline conditions.

For the *'Current Green Grid'*, land use/land cover categories were based on the information provided by the *Kent Thameside Green Grid Design Strategy and Guidelines* (Landscape Design Associates, 2004) and the *Green Grid Green Links Project, Draft Final Report* (Land Use Consultants, 2004). Site visits of Kent Thameside were also undertaken. Figure 6 illustrates the potential ecosystem services provided by each of the land use/land cover categories

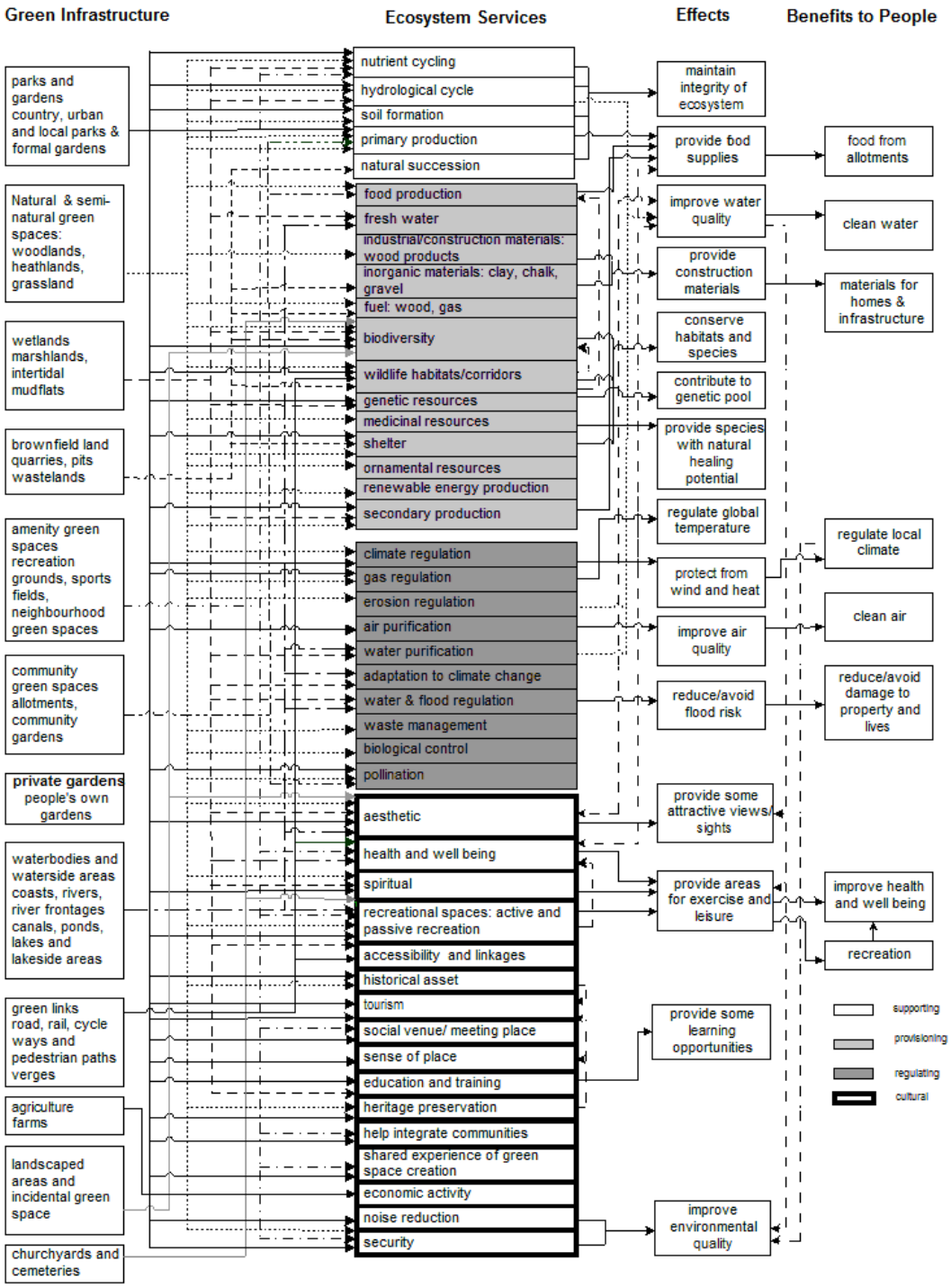

Figure 6. Ecosystem services currently provided by the Kent Thameside Green Grid

or green infrastructure, the effects of providing certain services on the environment and society, and the benefits to people and society. Although some green infrastructure elements contribute to a number of ecosystem services, only the main ones are shown here for clarity. To show the relationship between green infrastructure, ecosystem services and effects more clearly, different line weights and patterns have been used. However, due to the number of elements and relationships shown in the diagram, it was not possible to indicate positive and negative impacts as in Figures 4 and 5 and still maintain clarity.

The Current Green Grid of the Kent Thameside consists of pockets of generally disconnected green spaces that provide a relatively limited range of ecosystem services. In some instances what currently exist as green spaces do not link up and so undermine a number of services that could be provided.

The *Green Grid 'Vision'* is described in the Kent Thameside document *The Green Grid: Conserving and Enhancing Our Natural Heritage* (Kent Thameside, 2006). The vision proposed parks and a number of strategic links. However, where links have been provided as set out in the vision, they are often of a poor quality with limited green characteristics.

A Multifunctional Green Grid should therefore seek to map the green infrastructure and associated ecosystem services that already exist in an area and plan future built development around the Green Grid

The *Multifunctional Green Grid* is a hypothetical scenario based on maximising ecosystem services. This scenario is built upon the existing vision and explored synergies between services, although it acknowledged that some services may be mutually exclusive/potentially in conflict. For example, private gardens could not provide public access opportunities but could still provide multiple ecosystem services (e.g. biodiversity, flood storage, air quality and landscape services). A Multifunctional Green Grid should therefore seek to map the green infrastructure and associated ecosystem services that already exist in an area and plan future built development around the Green Grid.

Key findings from the strategic study Some findings from the strategic study which relate to network analysis are:

- Land use/land cover classifications used to construct network diagrams help us to understand the type and nature of ecosystem services provided by the whole of the Kent Thameside Green Grid.
- Network analysis is a useful and practical tool which can help us understand the ecosystem services provided in an area and the relationship between these services.
- The network analysis technique, combined with consultation, provides a means of understanding local conditions which can be used to generate and refine data sets or identify gaps to be filled.
- Network analysis can show the combined or cumulative effects of ecosystem services.

Conclusions

Network analysis provides a systematic way of organising ideas and variables and defining relationships. In particular, the technique is useful in understanding the relationship between spatial units (land use/land cover units/categories as used in this project) and the ecosystem services they provide. Network analysis can be used by planners during the early stage of the planning process when developing strategies or plans, such as green space strategies to identify the impacts of development or pressures on green spaces. In terms of the sustainability appraisals or SEA, network models could be employed during the option selection process by exploring the potential effects of various options during plan preparation. The technique is particularly helpful in identifying impacts that could result in cumulative effects. Furthermore, network analysis can be valuable during stakeholder workshops or the consultation stage as an interactive tool where participants can comment on and amend paper copies of the diagrams.

On the network analysis technique itself, some observations include the following:

- Developing network diagrams requires some understanding of the relationships between the variables (in this case, between land use/land cover categories and the ecosystem services provided).
- Direct, indirect and cumulative impacts can be explored through a network analysis diagram.
- Network diagrams can be used at varying scales (e.g. in this research, at sub-regional and local scales).
- Positive and negative impacts on ecosystem provision can be differentiated (e.g. through the use of different colours or line patterns) and important impacts can be highlighted.
- Significant impacts can be highlighted (e.g. by varying the width of lines).
- Network diagrams can be a medium for communicating ideas and relationships.
- A shortcoming of network analysis is that there is a limit to the information that can be shown in black and white when there are a number of elements and impact relationships involved (e.g. in Figure 6, where the relationships between green infrastructure and ecosystem services are indicated by different line weights and patterns, indicating positive and negative impacts as well by using line patterns would have resulted in the loss of clarity); the range of line patterns that can be used is rather limited but this problem could be addressed by the use of different colours for positive and negative impacts.
- Another limitation of the method is the lack of quantification or spatial dimension.

In conclusion, network analysis can be a useful decision making tool in planning green spaces and other spatial frameworks. In terms of the ecosystem services assessment, this approach can have wider application in sustainability appraisals and SEAs. Ecosystem services can be used as sustainability appraisal/SEA objectives against which plans are assessed or as criteria for appraising options.

Notes

1. Green Grids are 'locally distinct open spaces connected by footpaths and cycle routes — greenways — that extend from

people's doorsteps in urban areas into the countryside and to the river, to schools, amenities, people's workplaces and to public transport' (Greening the Gateway Partnership, 2005).
2. Green infrastructure is defined as a functional network of green spaces, green links and riverside spaces that can provide many benefits to the communities. From ODPM (2003).

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