# An Ecosystem Approach assessing the impacts of the construction and operation of the Mersey Gateway Crossing on the Upper Mersey Estuary


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# Glossary

**Adaptive management:**

Adaptive management reacts to changes in order to respond to changes. It involves an element of learning-by-doing. Ecosystem processes are often not linear and in order to manage ecosystems under a long-term approach, the management has to be adapted. Adaptive management should consider differences between short-term benefits and long-term goals and generate new knowledge to allow decision-makers to adjust management techniques (Secretariat of the Convention on Biological Diversity, 2004).

**Complex and dynamic ecosystem:**

A complex and dynamic system is characterised by non-linearity, including feedback loops, and time lags (Limburg, O'Neill, & Costanza, 2002). Complex and dynamic ecosystems are not confined to an individual temporal or spatial scale and adapt to changes influencing the system.

**Cross-habitat scale/landscape scale:**

In this thesis, cross-habitat scale/landscape scale describes a spatial scale which incorporates a variety of habitats and/or different land uses/covers.

**Green Belt:**

The policy of green belts was introduced in the UK with the aim to reduce and restrict urban sprawl into countryside. Of the total land area of the UK (13,040,000 ha), nine percent are classified as developed land. One third of the land area is protected against development through a designation such as Area of Outstanding Natural Beauty, National Park, or Green Belt (Garland, 2014). The Green Belt area can be estimated to be around 13% of the total UK land area (1,638,610 ha). The aims and purpose of Green Belt are: i) restriction of sprawl of large built-up areas; ii) prevention of merging towns and cities; iii) safeguarding the countryside against encroachment; iv) preservation of the setting and special character of historical towns; and v) assistance in urban regeneration.

**Natural:**

In the context of this thesis, natural means the non-built environment. This includes areas which have previously been used differently, e.g. landfill, industry. These areas may be under management, but their main attribute remains as a green space.

**Natural Capital:**

Natural Capital is defined as 'the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people' (Natural Capital Coalition, 2016). Natural Capital has the capacity to provide essential goods and services to humans. The term was introduced to support better decision-making by including natural resources (Natural Capital Committee, 2017a).

**Operational period**:

The operational period is described as the time period in which the Mersey Gateway Crossing is in operation by Halton Borough Council until 2044.

**Short-term/medium-term/long-term:**

This thesis covers a time interval of 30 years – from the beginning of the construction of the Mersey Gateway (and the start of data collection) in autumn 2014, to the end of the operational period of the Mersey Gateway Crossing in 2044. Short-term describes a time period up to five years; medium-term describes a time period up to 15 years; long-term describes a time period over 15 years and extending over the operational period to 2044.

**Socio-ecological system:**

The theory behind socio-ecological systems adopts the concept of coupled natural and social systems. The systems interact between human subsystems (i.e. cultural, economic, socio-political) and bio-physical subsystems on multiple temporal and spatial scales (Berkes, Colding, & Folke, 2003; Dawson, Rounsevell, Kluvánková-Oravská, Chobotová, & Stirling, 2010).

**Stakeholder:**

In this thesis, a stakeholder is defined as an individual or entity that can be represented by an individual, active and/or interested in the study site, and known to the Mersey Gateway Crossings Board.

## Acknowledgements

First and foremost, I need to express my gratitude to my supervisor Philip James, who offered endless support, inspiration and enthusiasm throughout the last years, who always asked those questions that needed asking, and who always had an open ear for all my problems.

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## Abstract

The ecosystem approach, introduced by the Convention on Biological Diversity, identifies the need to recognise the benefits nature provides to humans. More recently, the concept of natural capital has boarded the range of issues considered to include natural stocks such as geology, soil, air, water, and all living things. The use of ecosystem services to achieve sustainable management of natural capital has been endorsed in international and national literature, although there remain operational gaps. The research reported here explores how the use of ecosystem services can be used in long-term management of socio-ecological systems.

Expert opinion and consultation in form of a Delphi technique were used to identify triggers of change and relevant ecosystem services of the Upper Mersey Estuary. Alongside this, a critical review of planning documents was used to develop three scenarios: Business as Usual 2044; Development Boom 2044, and Nature is Key 2044; projecting different aspects of the future until 2044. These were used in a model to indicate the provision of ecosystem services in the estuary.

Eighteen ecosystem services were identified, with biodiversity being rated the most important, followed by regulating and cultural services. Distinct changes in the provision of these ecosystem services can be observed at sites within the estuary under the three scenarios. Changes are especially noticeable in the case of increased development in and around the estuary, as well as in the case of focus on nature conservation and long-term approaches to habitat management.

Methods to monitor the provision of ecosystem services as part of an adaptive management are proposed, which can be integrated into an adaptive management system for the estuary. Such an approach facilitates decision-making by local stakeholders and offers transferable methods for the long-term management of dynamic systems such as estuaries, using an ecosystem approach.

*Nature hides her secret because of her essential loftiness,*

*but not by means of ruse.*

– Albert Einstein

# 1. Introduction

## 1.1. Research Context

Humans and nature are inseparable – since the early evolution of *Homo sapiens,* as early as 2.5 million years ago, humans have used nature for food and drink, shelter, clothing, communication, and tools (Ambrose, 2001). The use of natural resources has, however, changed significantly, leading to depletion and over-exploitation of these resources in many areas (Neumayer, 2001). Today's era, the Anthropocene, is highlighted by the unsustainable use of resources, climate change, and a human population exceeding any known records (Crutzen, 2006). Changes in land use and conversion of natural habitats such as forests and grasslands for human activities like agriculture and pastures, together with an increased need of resources like water and energy, have accelerated the loss of habitats (Foley et al., 2005). This perceived environmental crisis of the 21$^{st}$ century (Ceballos et al., 2015; Glaser, 2012) sees species disappearing, and humans lacking a connection with nature (RSPB, 2013).

Fragmentation of ecosystems is one of the main drivers of biodiversity loss, as highlighted in the Making Space for Nature reports, published in 2011 (Lawton et al., 2010). The most recent report on the UK's state of nature (RSPB, 2016) shows that the country has lost significantly more nature than the global average, indicating that the UK is one of the most nature-deprived countries worldwide. Natural resources are often taken for granted, and the risk of loss of ecosystems and biodiversity is not taken into consideration on a large scale. Consequently, steps need to be taken to acknowledge the dependency and need to protect ecosystems around the world, while considering the part nature plays in the provision of benefits to society.

Based on the global initiatives and efforts to acknowledge and contest global biodiversity decline, international and national treaties, directives and strategies came into place, for example the Convention on Biological Diversity, a multilateral treaty aiming to conserve global biodiversity, which was implemented on a European level by the Habitats directive (formally known as Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora), and translated into national strategies such as Biodiversity 2020 – A strategy for England’s wildlife and ecosystems (Defra, 2011a). The documents convey one core message: to halt net biodiversity loss, to invest into the conservation of habitats, and to explore strategies to improve nature conservation from a fragmented approach towards integrated solutions. Both the Natural Environment White Paper (Defra, 2011b) and the Biodiversity 2020 – A strategy for England’s wildlife and ecosystem services (Defra, 2011a) acknowledge the need to integrate a large-scale approach for nature conservation and to reconnect society with the natural environment.

The ecosystem approach, introduced by the Convention on Biological Diversity (Convention on Biological Diversity, 2005), attempts to integrate management of natural resources in a sustainable way. Within its twelve principles, the ecosystem approach focuses on the integral part of human knowledge in the management of ecosystems and supports a decentralised approach to govern natural resource management (Secretariat of the Convention of Biological Diversity, 2004). This approach forms a central part in the assessment and management of ecosystem services. Ecosystem services are described as the direct and indirect benefits nature provides to humans, and form an integral part in the understanding of ecosystem management and assessment (Millennium Ecosystem Assessment, 2005a). Ecosystem services were first introduced in 1981 as a metaphor to describe the interaction between nature and humans (Gómez-Baggethun, de Groot, Lomas, & Montes, 2010). It has since been used as a means to understand the value of nature to humans.

Frameworks such as the Millennium Ecosystem Assessment made substantial contributions in understanding the interactions between nature and humans (Millennium Ecosystem Assessment, 2005a). The Millennium Ecosystem Assessment provides a structure for ecosystem assessments by identifying direct and indirect drivers of change, and suggesting a classification of ecosystem services into supporting (e.g. primary production), regulating (e.g. water regulation), provisioning (e.g. food), and cultural services (e.g. recreation) (Millennium Ecosystem Assessment, 2005a). Based on the initial assessment in 2005, several others followed, investigating the provision of ecosystem services from different perspectives, e.g. the UK National Ecosystem Assessment on the provision of services on a national scale (UK National Ecosystem Assessment, 2012), or The Economics of Ecosystems and Biodiversity, assessing ecosystem services from an economic perspective (TEEB, 2010a).

In order to receive natural benefits such as ecosystem services, the Natural Capital Committee argues that the natural capital (natural assets that form the basis of ecosystem services such as clean air, clean water, forests, etc.) of the planet has to be sustainably managed (Natural Capital Committee, 2017b). To be able to incorporate ecosystem services into policy planning and decision-making, the committee suggest the development of a 25-year plan. Within these suggestions, a long-term approach is set out to support planners, communities and landowners to protect and improve the local environment.

Two major elements have to be considered in all assessments and discussions around ecosystem services: the relation between the natural environment and the social environment. The theory of socio-ecological systems helps to approach these interactions and the complexity of these systems, by combining scientific disciplines (Carter et al., 2014; Liu, 2014). In recent years, research utilised the socio-ecological systems approach to understand the provision of ecosystem services (Cord et al., 2017; James et al., 2009; Zia et al., 2011). Through the ecosystem approach, the understanding of interaction between humans and nature and the benefits humans receive from ecosystems can be translated into management actions and decision-making (García-Llorente, Martin-Lopez, & Montes, 2011). Although the ecosystem approach is not yet fully translated into policy (Ecosystems Knowledge Network, 2016a), the integration of aspects of socio-ecological systems become apparent in, for example, the strategies suggested for the UK biodiversity 2020 (Defra, 2011a).

Ecosystem services and the associated management of landscapes under an ecosystem approach have led to a substantial body of literature in the last decades (Guerry et al., 2015; Olander et al., 2017; Ruckelshaus et al., 2015; Tammi, Mustajärvi, & Rasinmäki, 2017). However, challenges remain in the application of ecosystem approaches throughout socio-ecological systems. Socio-ecological systems are exposed to consistent change from a variety of factors (Cote & Nightingale, 2011). These changes to the system have ultimately lead to changes in the provision of ecosystem services. With people being the cornerstone of the socio-ecological system and the ecosystem service approach, a further challenge involves the appropriate involvement of people in the decision-making processes on the natural environment. As suggested by the Natural Capital Committee (2017b), a long-term approach to the management of ecosystem services is favourable for socio-ecological systems, in order to manage resources sustainably.

The research reported in this thesis explores the socio-ecological system of an estuary in the North West of England, the Upper Mersey Estuary. In order to reach those who are most active in the study site, the study involves a participatory element in the form of a Delphi technique. Based on the data collection from local stakeholders and the review of existing planning documents, the research develops three scenarios. Those scenarios explore how the future can unfold for the provision of ecosystem services in the estuary, depending on the different foci of the scenarios (e.g. business as usual, increased development, and nature conservation). The study site has been identified because of its potential to be managed as a socio-ecological system under the guidance of the Mersey Gateway Environmental Trust, which will be involved in the management of the study site until 2044.

## 1.2. Research Aim and Objectives

The aim of the research is to critically evaluate the assessment of ecosystem services in a complex socio-ecological system, which is under constant direct and indirect change. By using an ecosystem approach, the research aims to facilitate environmental management in decision-making processes, leading to improvements of future planning processes.

In order to fulfil the aim, a number of objectives have to be addressed:

**Objective 1: To identify key ecosystem services and their role in socio-ecological systems.**

a) To critically evaluate the relevance of ecosystem services in socio-ecological systems.

b) To identify key ecosystem services by using relevant documentation and knowledge of local stakeholders.

c) To develop a map of relevant ecosystem service locations.

**Objective 2: To critically evaluate changes impacting the socio-ecological system.**

a) To identify triggers of change.

b) To identify scenarios of change by analysing relevant documents and consulting local experts.

c) To critically analyse how change affects the resilience of the socio-ecological system.

**Objective 3: To produce a model that shows gains and losses of ecosystem services associated with future actions.**

a) To combine the knowledge from objective 1 and 2 to provide sound conclusions and recommendations regarding the provision of ecosystem services under different scenarios and their inclusion into socio-ecological systems to improve environmental management and decision making.

The objectives have to be translated into a research framework. This framework is shown in Figure 1. Beside the flow of information between the objectives (solid lines), further knowledge is created by analysis and evaluation of the individual objectives. The data collection that informs the individual objectives also creates a second flow of information that has an influence on the overall evaluation and synthesis of the thesis, based on additional information that comes out of every data collection, but is not necessarily processed as part of the objective. The use of this information as part of a reflective process will contribute to a comprehensive thesis.

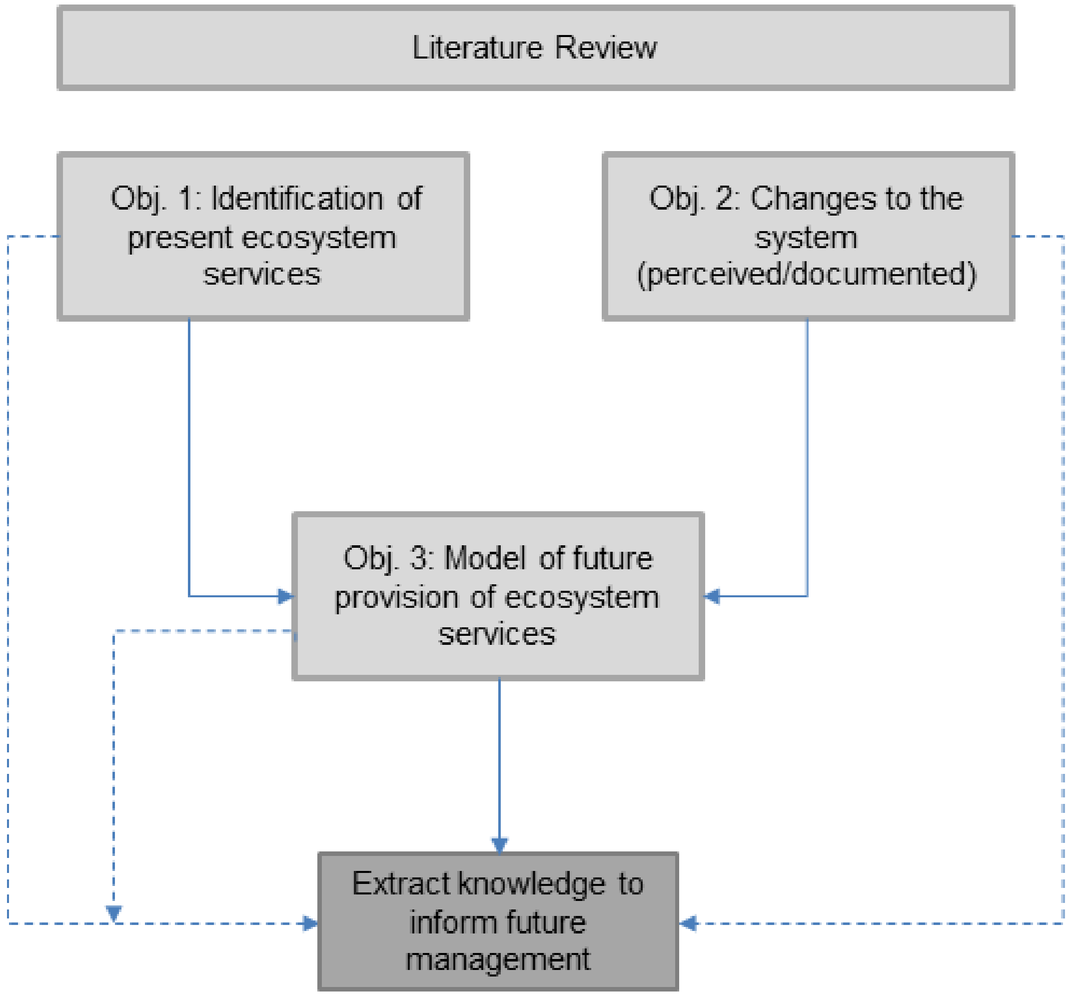


**Figure 1 Conceptual framework of the research project. Solid lines indicate a direct flow of information between the data collected as part of the individual objectives. Dashed lines indicate an additional flow of information which contributes to the evaluation of the research questions and synthesis of the thesis. Solid boxed around the objectives show the main method of investigation.**

Objective 1 highlights the need to involve local stakeholders of the study site to identify and evaluate ecosystem services. Equally, strategic documents have to be evaluated regarding the presence and current assessment of ecosystem services in the study site. Through these activities, key ecosystem services and their potential location can be identified.

The same need for analysis is required for objective 2. Changes in socio-ecological systems will be evaluated through stakeholders and local strategic documents. By assessing triggers of change, as well as areas of change, scenarios can be developed to inform later objectives.

Objective 3 is based on data collected within objectives 1 and 2. By developing a model which informs on future provision of ecosystem services, new knowledge is formed for the study site. Here, the transferability of the research becomes apparent: although the individual objectives are based on known and tested methods, the combination of these methods can create a model which can be applied locally and presents an advanced step in the application of the ecosystem approach.

Based on the newly created data, specific recommendations for the management of the study site can be formulated. The data are reflected on and the contribution to knowledge discussed. Through this synthesis, researchers, practitioners as well as decision-makers are enabled to draw information and insights with a view on the provision of ecosystem services under different futures.

This research framework (Figure 1) takes into account elements of the concept of information hierarchy (Cooper, 2014), which introduces five categories of knowledge management, important for the use and evaluation of data: raw data are transformed into information by making use of these data, which is then followed by the creation of knowledge as a deterministic process. The aim of research projects includes the first three steps (data, information, knowledge) mentioned by Cooper (2014) to ultimately contribute to the understanding of a process.

By formulating research objectives and developing a framework, the project's backbone is established. All elements of the thesis are based on the objectives and framework, to form a consistent piece of research that contributes to science, closes gaps in knowledge, and offers new thoughts to the scientific community. The researcher complies with the Academic Ethics Policy (University of Salford, 2017), introduced by the host university and acknowledges the ethical standard described in the framework.

## 1.3. Study Area

### 1.3.1. General Information

The Upper Mersey Estuary was identified as a study site for this research project. The estuary is located in the North West of England, within the county borders of Cheshire. It stretches from the Runcorn Gap (Point A in Figure 2; British National Grid SJ511835) to the end of the tidal range at Howley Weir (Point B in Figure 2; British National Grid SJ616876). The study area lies in the administrative area of Halton Borough Council and Warrington Borough Council.

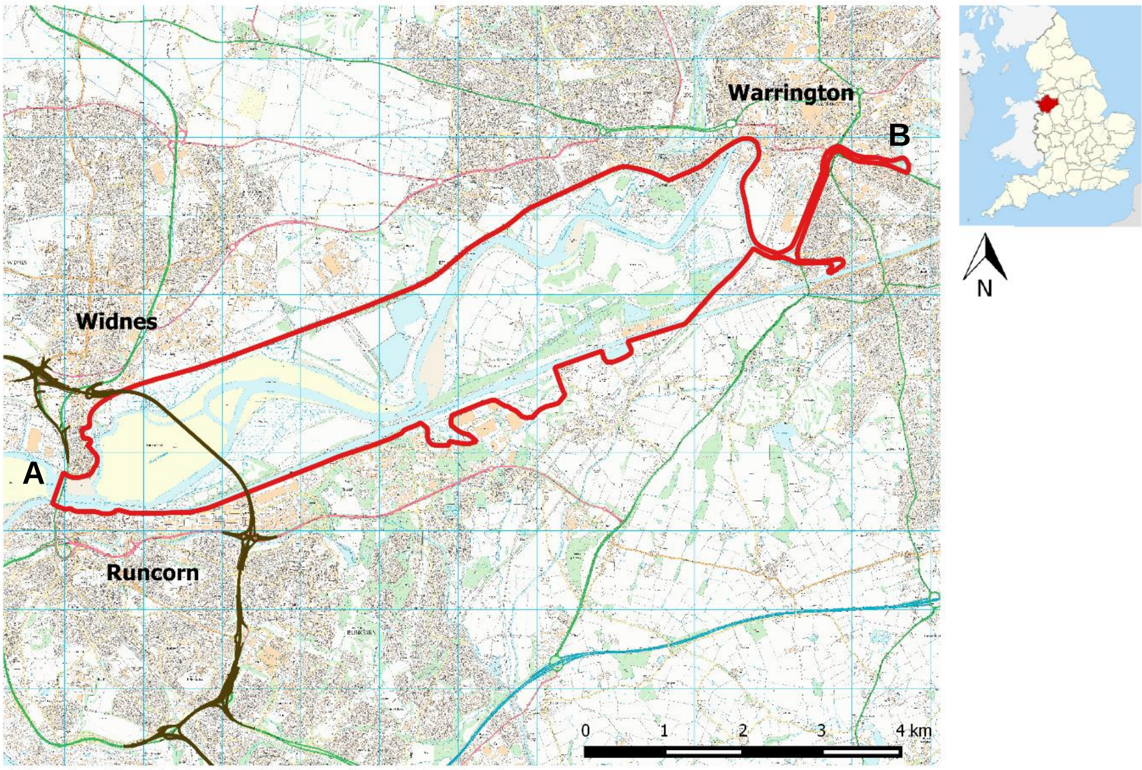




**Figure 2 OS map of the study area. Red lines indicate the boundary of the area managed by the Mersey Gateway Environmental Trust from 2014-2044, with the approximate position of the Upper Mersey Estuary in the UK. Point A shows the most western point of the Upper Mersey Estuary, the Runcorn Gap; Point B shows the most eastern point of the estuary at Howley Weir.**

The 1653 ha area of interest is characterised by tidal mudflats, saltmarsh, reed beds, neutral and rough grassland, woodlands, farmland, freshwater lakes, canals, (active and non-active) industrial areas, landfill sites and is surrounded by urban areas. Figure 3 and Figure 4 show examples of the saltmarsh on the north side as well as a grassland on the south of the river. Within the UK National Ecosystem Assessment Technical Report, the area can be classified as a coastal margin (Jones, 2011) and/or urban habitat (Davies, 2011). The area is under mixed public and private ownership.

**Figure 3 View over the saltmarsh at Widnes Warth with Fiddlers Ferry Power Station in the background, taken in February 2016.**

**Figure 4 Grassland in the Upper Mersey Estuary; taken in summer 2016.**

The estuary is embedded in an urban setting, of which the towns of Widnes and Runcorn have especially iconic positions in the historical development of the chemical industry during the industrial revolution, leading to significant rises in population and development of infrastructure in the area (National Rivers Authority, 1995). Even though the chemical industry is not as present as it was in the 19$^{th}$ and 20$^{th}$ century, refineries and other industries such as power generation remain in close vicinity. On the western site of the Runcorn Gap, beyond the boundaries of the study site, the estuary is designated as a Ramsar Site and a SSSI.

The Upper Mersey Estuary is framed by the Manchester Ship Canal in the south and by the disused St. Helens Canal in the north. Both canals played an important role during the height of the industrial revolution, with the Manchester Ship Canal continuing to be used as an operational canal in the ownership of The Peel Group (commonly known as Peel Holdings) (UK Ports Directory, 2017). The artificial structures in close vicinity of the estuary contribute to the coastal squeeze.

An estuary's environment is a dynamic system which is under constant natural change (Meire et al., 2005). The movement of an estuary's channels is a natural phenomenon which leads to saltmarsh erosion and accretion and, despite short-term changes, either natural or anthropogenic, changes within its system are absorbed and functionality remains (McLusky & Elliott, 2004). The Upper Mersey Estuary has two main channels, both of which are changing over the course of time with no indication of changes due to anthropogenic influence in the last years (Merseylink, 2016a).

The study site is governed by two local authorities: Halton Borough Council and Warrington Borough Council. As of 2010, 119,600 people lived in Halton Borough Council (Halton Borough Council, 2013). Two urban settlements, Widnes (population of 58 300 (2010)) and Runcorn (population of 61 000 (2010)), are in close proximity to the study site. The 1970s saw many facilities of the chemical industry close down, often leaving behind polluted and despoiled land (Fox, Johnson, Jones, Leah, & Copplestone, 1999). Industrial and former industrial land still dominates the water front of Widnes. The infrastructure is well developed in the borough, although the area suffers from deprived areas in places (Halton Borough Council, 2013). The Silver Jubilee Bridge (Figure 5) is the current means to cross the Runcorn Gap between Widnes and Runcorn for vehicles, and the Runcorn Railway Bridge for freight by train.

**Figure 5 View over the estuary towards Silver Jubilee Bridge, taken from viewing platform at the Catalyst Museum, Widnes.**

The urban settlement in closest proximity to the study site in Warrington Borough Council is the town of Warrington (population of 202 200 (2011) (Warrington Borough Council, n.d.)). With the industrial revolution, Warrington expanded, becoming a manufacturing area for steel production, textiles, and tanning. This industrial heritage is still visible, especially within Warrington town and around the River Mersey. The area now attracts major national and international companies as a result of the strategic position of the town and the connectivity to other major cities in the country.

Major infrastructural changes were taking place over the period of this study in the Upper Mersey Estuary. The construction of a second crossing over the River Mersey, releasing pressure off the current bridge (the Silver Jubilee Bridge), has been taking place between 2014 and 2017 (for illustration of the construction site, see Figure 6). Additional to the crossing, supporting road networks will relieve the existing infrastructure after completion in 2017 (Mersey Gateway Project & Halton Borough Council, 2011). A map of the planned route of the Mersey Gateway Crossing and the existing crossing is shown in Figure 7 (Mersey Gateway Environmental Trust, n.d.). After the construction phase, the operation of the bridge and the associated economic changes will present challenges to the natural and social environment in the area, motivating regular monitoring efforts and consequential management options being explored as part of a long-term strategy.

**Figure 6 Construction of the Mersey Gateway Crossing, photographed in June 2017 from the north pylon.**

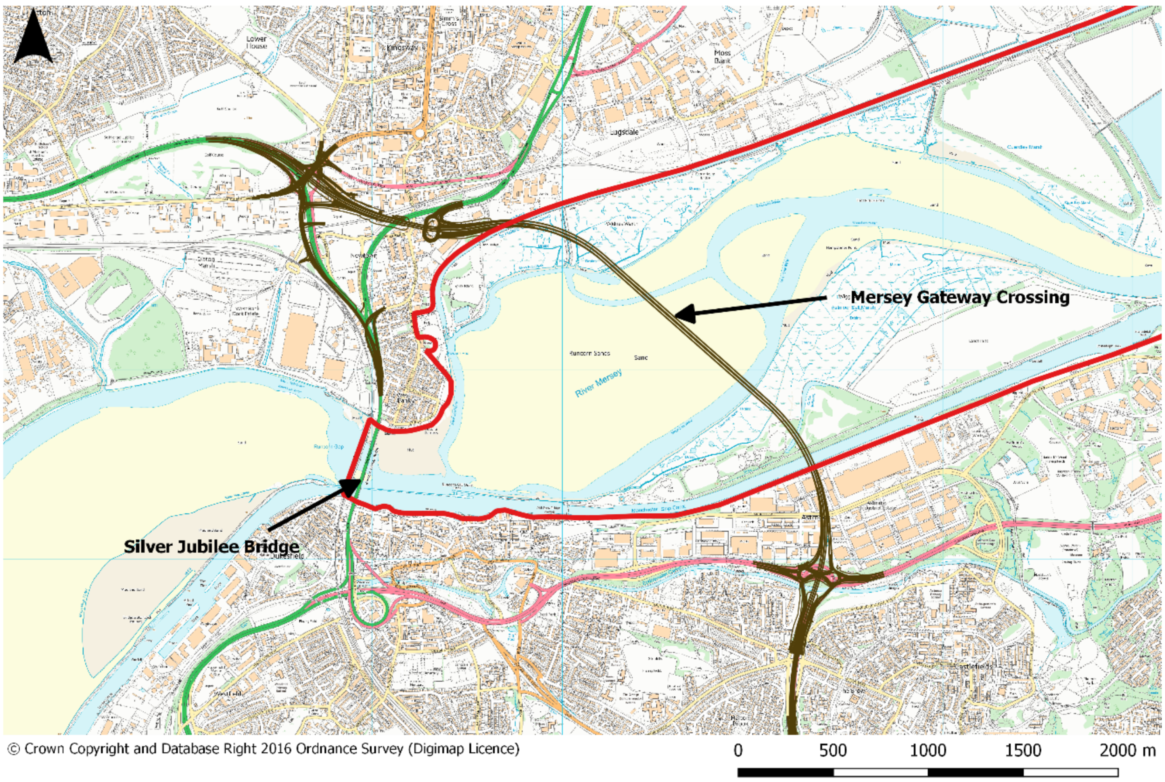


**Figure 7 Route of the new Mersey Gateway bridge.**

During the construction period of the Mersey Gateway Crossing a charitable trust, the Mersey Gateway Environmental Trust, was established. The Trust will govern the environmental legacy of the study area as part of the planning conditions attached with the bridge construction and its operation (Mersey Gateway Environmental Trust, n.d.). The Trust's work began in 2014, establishing its organisation and governance structure prior to the opening of the Mersey Gateway Crossing. After completion of the bridge, the Trust begins its operation in 2017. It aims to provide management options and to improve the natural environment around the bridge and within the Upper Mersey Estuary, until the end of the operational period (agreed operation by Halton Borough Council) in 2044.

### 1.3.2. Site Compartments

The Upper Mersey Estuary is divided into 22 compartments (Figure 8) – geographical units that were previously identified by the Mersey Gateway Crossings Board (personal communication Paul Oldfield) and adapted to the project. Units that were just outside the area such as the compartment of Tan House Lane (compartment C in Figure 8) were added as part of this research, due to their potential impact as a development site and expected change in ecosystem services over the coming years. The other site which is under consideration, although partially outside the red line boundary, is Fiddlers Ferry Power Station (compartment E in Figure 8), which is operated by SSE and who own an area of saltmarsh that is part of the Upper Mersey Estuary (compartment D in Figure 8).

The site compartments are under mixed public and private ownership. As seen in Figure 8, the river itself, including its mudflats, are not included as a site compartment. These habitats will not be considered in this study. The site compartments differ in their land uses and land cover types; therefore, the composition of ecosystem services will vary within each individual compartment. For ease of management and the understanding of the bigger picture, it is important to consider areas that are under the same management/ownership, even though the site compartments may comprise mixed land covers and land uses, decision-making processes are more likely to be effective if impacts to the area of management/ownership are described (Scottish Government, 2016).

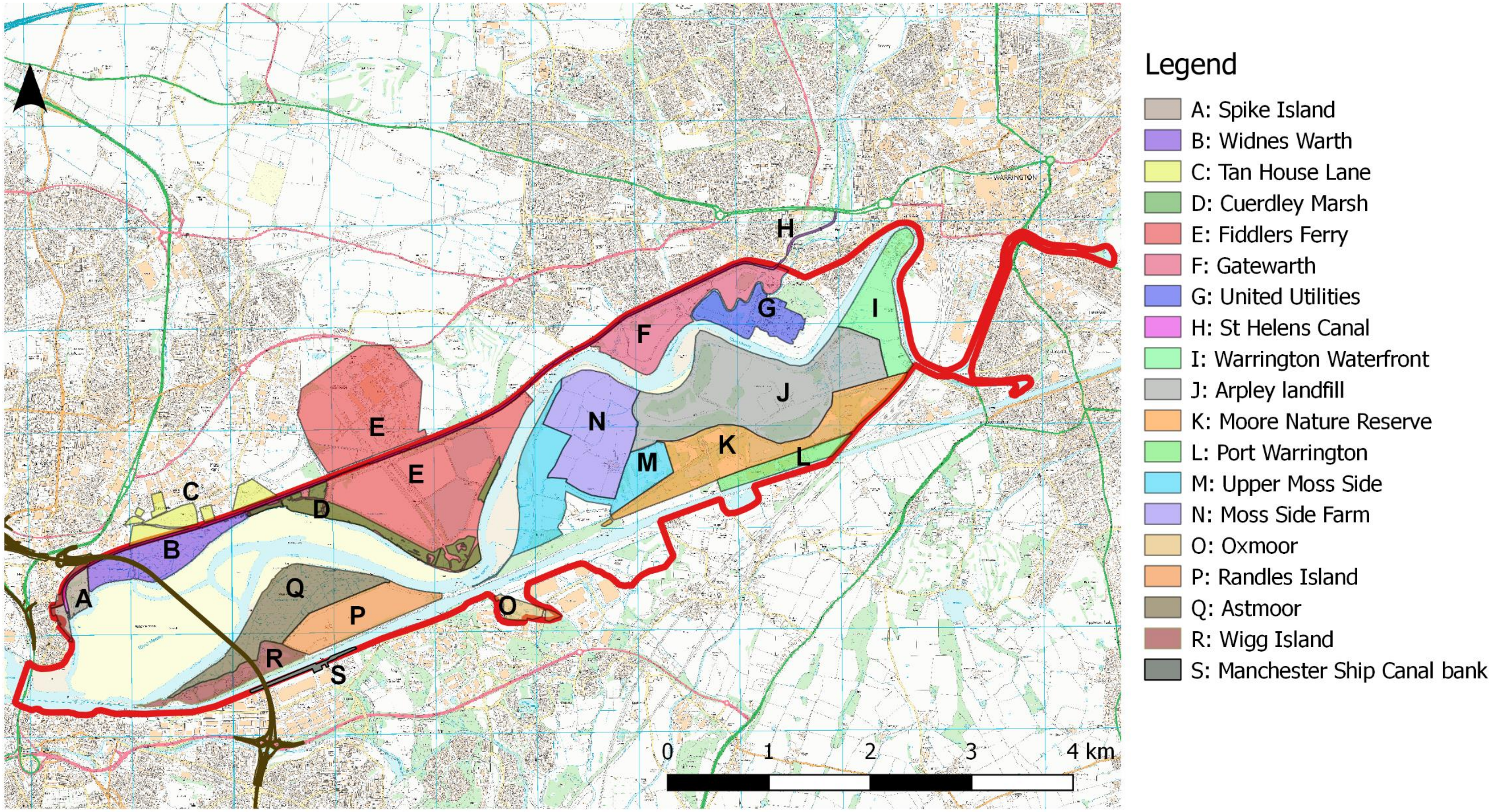




**Figure 8 Map of site compartments that were considered in the stud**

## 1.4. Thesis Structure

In this chapter, a brief context overview of the topic was given. The aims and objectives of the research were introduced and a detailed description of the study site was presented.

In the literature review (chapter 2) relevant literature is critically analysed and discussed. This analysis concludes with emerging questions which are developed to identify gaps in scientific knowledge. The body of the thesis is developed around these questions, and answers are provided in the concluding chapter.

Chapter 3 contains a description of the methods and methodology of the research. By establishing the ontology and etymology of the research, the methodology can be constructed – a anti-foundationalist ontology position and post-positivistic etymology position, enable the author to develop methods within the theoretical realm.

Chapter 4 is dedicated to the results of the applied methods. The chapter describes the results from objective 1 to objective 3.

Following the description of the results, the findings are discussed in chapter 5. Similar to chapter 3 and 4, the discussion is organised around the objectives. Where appropriate, the discussion relates to aspects outside the respective objective and makes connections to related elements of the study. In this chapter, the answers to the questions presented in the literature review are answered. Two recommendations to the framing of the research in a management context are made.

Finally, chapter 6 contains a presentation of the conclusions and puts the research into a wider context, by describing the impact of the research on a specific (study site) level, as well as on a general level. Recommendations for future research opportunities are made.

# 2. Literature Review

In this chapter, a critical analysis of the relevant literature is presented in the form of a literature review. Within this review, primary and secondary literature are analysed and discussed regarding relevant aspects of the research. The literature review explores the current state of research and concludes with emerging questions, supporting the objectives that were formulated in section 1.2. The literature review channels the knowledge of the relevant topics, discussing existing concepts and identifying gaps in the knowledge.

## 2.1. Socio-ecological Systems

Science has, for some years now, acknowledged that natural systems are not linear or predictable (Dawson et al., 2010). Systems' processes include attributes such as uncertainty, nonlinearity, emergence, and self-organisation (Berkes et al., 2003), which are complex and dynamic at any given time. The historic separation of human systems and natural systems into social science and natural science has made a full understanding of the complexity difficult (Liu et al., 2007). Looked at through the lens of the 21st century with the perspective of a human ecologist, the link between humans and ecology (i.e. natural systems) is clear, though this has not always been the case (Glaeser, Bruckmeier, Glaser, & Krause, 2009; Glaser, Krause, Ratter, & Welp, 2008). Humans continuously engage with nature, constructing a world which depends upon cultural and historic human realities that determine the social status in a natural system (Glaser et al., 2008). Since humans have an immense impact on the natural environment (Millennium Ecosystem Assessment, 2005b), the need arises to understand this complexity and the feedback loops between resources, actors, and institutions across temporal and spatial scales (Schlüter et al., 2012).

In order to grasp some of the complexity, the term socio-ecological system was introduced, describing a spatial unit which can be used for research and management purposes (Berkes, Folke, & Colding, 2000). Complex socio-ecological systems measure not only social or ecological variables, but draw information from a variety of sources, including variables that link human – nature interactions such as ecosystem services (Liu et al., 2007), combining scientific disciplines that are regularly studied separately. By combining the disciplines, an analysis of socio-ecological systems can be attempted. Therefore, the need for a joint, interdisciplinary approach that incorporates both natural and social sciences arises. Tretter & Halliday (2012, p.61) developed a list of information required for this assessment:

- ‘The state of the natural environment – and the validity of data we use to measure it;
- The speed and scale of nature’s response to human disturbance;
- The robustness of natural systems – and its limits – in the face of human induced environmental change;
- The feedback mechanisms which enable social systems to perceive, conceptualise and respond to ecological changes;
- The nature of this response, through changes in behaviour of critical subsystems (e.g. science, industry, politics, law) and subpopulations (e.g. consumers, farmers, tourists, industrialists).’

Following an assessment of a socio-ecological system, management options can be formulated, which aim to improve the connection between social and ecological components in the system (Cord et al., 2017). A socio-ecological system is not a fixed system of interaction between nature and humans; instead it depends on the type of question we ask to understand the underlying system dynamics that affect landscape structures in any management or research context (Eigenbrod, 2016). Navabi & Daniell (2016) argue that socio-ecological systems are not simply constructed between the environment and humans, but there are other passive actors that construct the reality of a socio-ecological system such as new technology, discourses, even research, can contribute to the shaping of a system. This aspect becomes especially relevant when considering the spatial and temporal dynamics of a socio-ecological system. It becomes clear that an attempt to manage interdisciplinary systems requires management techniques that allow interdisciplinary approaches, adapting to new realities as they arise.

## 2.2. Resilience – Definitions and Meanings

When considering socio-ecological systems as research units, the concept of resilience plays a crucial role as changes on multiple scales (e.g. ecological/habitat, social, landscape) can be expected (Brondizio et al., 2016; Lacitignola, Petrosillo, & Zurlini, 2010; Wang et al., 2014). It is, therefore, important to consider the concept of resilience in a context that embraces the social and natural drivers that shape a system.

The term resilience is found in many publications across different fields, especially in environmental sciences (e.g. Nelson, Adger, & Brown, 2007), disaster management (e.g. Cutter, Burton, & Emrich, 2010) and governance (e.g. Biesbroek, Dupuis, & Wellstead, 2017), but also health systems and management (Costella, Saurin, & de Macedo Guimarães, 2009; McAllister & McKinnon, 2009), economic/financial management (Augustine, Wolman, Wial, & McMillen, 2013; Markman & Venzin, 2014), information systems (Lengnick-Hall, Beck, & Lengnick-Hall, 2011; Riolli & Savicki, 2003), and poverty abatement and health (Pendall, Weir, & Narducci, 2013; Seccombe, 2002).

The term 'resilience' was shaped by the works of Holling (1973) and later further defined by influential works such as Walker & Salt (2006) and Folke et al. (2010). Since those early definitions, scientists and practitioners have tried to understand what constitutes a resilient system, how resilience can be measured, and what resilience means for the development of a particular system. Today, the concept's wide range of definitions and applicability makes it inherently difficult to be implemented as a concept that fits all situations and problems in the same way. As Walker & Salt (2006) point out, the concept falls into the same category as 'justice' and 'well-being', which are used differently, depending on the user's understanding and interpretation. However, the general term can best be defined as 'the ability of a system to absorb disturbances and still retain its basic function and structure' (Walker & Salt, 2006, p.1) or slightly altered by Folke et al. (2010, p.3) as 'the capacity to change in order to maintain the same identity'. Three different resilience concepts are presented in Table 1, showing the variation in main characteristics between engineering, ecological and socio-ecological resilience. As Pisano (2012) states, resilience thinking is inevitably linked to systems thinking and will form part of the system discussion within the socio-ecological system concept, i.e. the interactions of nature and humans are considered.

**Table 1 Three resilience concepts, based on Pisano (2012).**

| **Resilience concept** | **Characteristics** | **Focus on** |
|---|---|---|
| Engineering resilience | Return time, efficiency | Recovery, constancy |
| Ecological resilience | Buffer capacity, withstand shock, maintain function | Persistence, robustness |
| Socio-ecological resilience | Interplay disturbance and reorganisation, sustaining and developing | Adaptive capacity, transformability, learning, innovation |

In the context of this thesis, it is especially important to note that the socio-ecological resilience focuses on the adaptability of a system. The concept moves away from the idea of constant recovery, which would not require the system to change, but to go back to its original state and its equilibrium (engineering resilience). Socio-ecological systems are not linear, instead they are connected and intertwined and, therefore, do not follow a straightforward process of disturbance to recovery. Although it can be assumed that the adaptive cycle described by Holling (1973) is also applicable to socio-ecological systems (Dennis, 2015), the stages of the processes could take place at different rates at different times, in several parts of the system. Also, the system is not necessarily going back to its original state. The ability to recover and to learn and innovate (adaptive capacity) sets it apart from the other resilience systems mentioned in Table 1; not relying on a return to an equilibrium, but using change as an experience through which improvement is possible, taking the resilience concept a step forward.

## 2.3. Approaching Resilience in Socio-ecological Systems

The concept to incorporate adaptive capacity into the resilience concept comes down to the capacity of humans to influence resilience in socio-ecological systems (Walker, Holling, Carpenter, & Kinzig, 2004). As Walker et al. (2004, p.2) describe, the adaptability of the system is 'mainly a function of the social component – the individuals and groups acting to manage the system'. As human actors have the capacity of knowing and managing system states, they have the ability to use thresholds describing the desirable and undesirable states of a system and have major influence upon determining the success of resilience and adaptation through the appropriate setting of thresholds (Walker et al., 2004).

In an adaptive management approach, humans systematically explore possibilities to improve management strategies and increase the adaptive capacity of the system in question (Pahl-Wostl et al., 2007). It is, therefore, crucial to include the social component when assessing the resilience of systems, as well as acknowledging that humans can alter the adaptive capacity of socio-ecological systems through their management and implementations of policies and new approaches. It is suggested in the literature, that research is moving away from a sectorial perspective (forestry, fisheries, etc.) towards a more integrated perspective, including ecological processes and functions across multiple spatio-temporal scales (Brunckhorst, 2002; Grimm, Grove, Pickett, & Redman, 2000; Uhde et al., 2017; Zurlini et al., 2006). The understanding of individual ecosystems, their processes and functions fostered the expansion of knowledge towards the connections between the individual systems. The questions scientists asked changed from a perspective of separate human and nature interaction to an inclusion of both elements (see next section 2.4).

Besides an integrated perspective, the importance of the orientation towards a transdisciplinary ecosystem management and socially integrated management is also highlighted (Convention on Biological Diversity, 2005; Weinstein, 2008). It is also indicated in the literature that there is a need to develop ways to combine the two closely related elements of ecosystem services and human well-being in future approaches (Cumming, Olsson, Chapin, & Holling, 2013).

McPhearson, Andersson, Elmqvist, & Frantzeskaki (2014) point out that 'resilience is a multidisciplinary concept that encompasses persistence, recovery, and the adaptive and transformative capacities of socio-ecological systems and subsystems'. By incorporating the idea of resilience in socio-ecological systems, the adaptive capacity of the systems is strengthened and, therefore, less prone to vulnerabilities (Bailey & Buck, 2016). Erixon, Borgström, & Andersson (2013) also identify three ways in which the science of resilience can help in the process of planning and decision making:

- Socio-ecological integration: acknowledgement of interconnectedness and interdependence of humans and nature; taking into account that the presence of humans should not always be seen as a disturbance to the ecosystem.
- Cross-scale interactions: the need to understand spatial and temporal effects, change processes, and features in a socio-ecological system.
- Change is part of a complex system dynamics: high adaptive capacity can handle changes better; thus, diversity is one of the prerequisites to influence the adaptive capacity of a system.

Currently, little is known about how long-term planning processes are linked with and impacted by complex system interactions (Frantzeskaki & Tilie, 2014; McPhearson et al., 2014). The understanding of the link between socio-ecological systems and how these interactions and pressures influence the resilience of a socio-ecological system should be explored, as this allows the planning of future management under the aspect of integrating social and ecological systems in a sustainable manner.

## 2.4. Ecosystems in Today's Thinking

With the world population growing, a changing climate, and continuing biodiversity loss, which is predicted to accelerate in the 21st century (Leadley et al., 2010), conservation management and long-term environmental management become more prevailing in today's thinking. Ecosystems are a basic entity that is considered and understood as a vital part of understanding socio-ecological systems (Ostrom, 2009). Beginning as a highly conceptualized technical term, the idea of an ecosystem was quickly translated into a concept which had great theoretical and applied importance (Golley, 1996).

Ecosystems and their functioning have long been evaluated against the backdrop of nature conservation and continue to be so (Jongman, 1995). Arguably, conservation plays an important role in every aspect of dealing with nature itself; however, the development of concepts regarding ecosystem functioning and ecosystem services has attracted multiple disciplines such as economists, landscape planners, and engineers. In an inspiring talk given at the INTECOL Plenary Session in London in 2013, Georgina Mace identified four stages which frame biodiversity conservation (British Ecological Society, 2013; Mace, 2014). These stages are informed by the understanding of the pressures on ecosystems, which finally form pressures that are recognised by humans.

The first stage of nature conservation, in the 1960s and 70s and before, saw the development of ideas around ‘nature itself’. It mainly took into account species, remote areas and their protection, and did not yet include people in its systems’ thinking. Stage 2 (1980s and 90s), ‘nature despite people’, turns towards the understanding of increased pressures by people, for example, drivers of species decline such as pollution, destruction, or pathogens, which initiated new thoughts among scientists to begin the inclusion of humans in understanding of systems. Following the discussion surrounding humans, and their damaging impact on ecosystems, stage 3 recognises people from a distinct perspective around the first decade of the new century. The thinking develops towards ‘nature for people’, from which the concept of ecosystem services emerges. Research moved away from species-thinking, towards a more holistic perspective: the one of ecosystem approaches. Finally, in stage 4, from 2010 onwards, the most modern approach, ‘people and nature’ fully includes people into natural systems, forming socio-ecological systems.

These stages, although being classed into temporal periods in the last fifty to sixty years, are not isolated from each other entirely, but form a network of information on which each successive stage was built. Nevertheless, the stages still play a role in today’s thinking and research. For example, research on species extinction (Pimm et al., 2014) and protected areas and conservation monitoring (Geldmann et al., 2013; He, Zhang, Li, Li, & Shi, 2005; Nagendra et al., 2013) have been published in recent years, picking up the keywords from stages 1 and/or 2, but connecting them with achievements of the 21st century such as Geographical Information Systems and remote sensing. The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005c) is one of the key publications in which integrated management came into focus (Mace, 2014), beginning the process of integrating humans into ecosystem thinking, and building on the evidence of ecosystem service values that had been described around the turn of the millennium by several authors (Kreuter, Harris, Matlock, & Lacey, 2001; Sutton & Costanza, 2002; Zhao et al., 2004). It has been recognised as important to understand ecosystems and the place humans have in these systems (Costanza et al., 2014; Fu, Wang, Xu, Yan, & Li, 2014; Richardson, Loomis, Kroeger, & Casey, 2015). Based on the findings from all previous stages, stage 4 intends to move a step further to integrate people and ecosystems, seeing beyond the fact that humans are 'simply' using nature for their benefit, but intend to understand the complex dynamics between people and the environment. It becomes clear that this stage, similar to the other stages, is not separated from the others, but instead looks at the issue from a different perspective, adding more detail to the scientific discourse. Even though this discourse emerged from a conservation perspective, it is important to take the main message from it – nature is no longer a stand-alone research object, but is seen to be merged with social aspects and human needs and well-being.

Understanding the process of development within the field raises the question of whether we have reached stage 4, or if not, which stage are we currently at? As previously mentioned, research regarding ecosystems and their impact on humans has been continuously developing over the last decades with a fluent transition from one into the next stage. The most recent stage builds on the knowledge from other stages which are still being explored today. However, it is important to recognise the use of ecosystem services for human well-being and the approach to manage ecosystems based on the services they provide for human well-being in recent years. Critically assessing the state of the research in ecosystem services shows that many recent publications recognise socio-ecological systems and their importance in the ecosystem services research. Examples can be found across the globe in de Juan, Gelcich, Ospina-Alvarez, Perez-Matus, & Fernandez (2015), Estoque & Murayama (2013) and García-Llorente et al. (2015) in which the social component of the research is emphasised. Although research is often concentrated around the need for humans, as suggested in stage 3 (e.g. food production, timber production, etc.), recent literature indicates a shift towards the integration of human-nature interactions as socio-ecological systems, and, therefore, moving towards the fourth stage (Aretano, Parlagreco, Semeraro, Zurlini, & Petrosillo, 2017; Uhde et al., 2017).

Regarding this project, it is interesting to explore a way of assessing socio-ecological systems and ecosystem services to create a more thorough understanding of the socio-ecological components, as well as the influence of a changing world on the resilience (section 2.2) of socio-ecological systems. It remains important to address a variety of topics in social and natural sciences with an open mind to create synergies and work towards mutual understanding of the disciplines (Derry, Schunn, & Gernsbacher, 2013).

## 2.5. From Ecosystems to Ecosystem Services and Changing Definitions

The third and fourth stage of ecosystem thinking (Mace, 2014) requires a concept that takes into account the mutual connection between society and the natural environment. The concept of ecosystem services has been a major success in attempting to bridge the gap between the two elements. The idea of ecosystem services as a concept in today's thinking has been developed over years of academic and applied work and gained recognition in management policies in the public and private sectors (Waage & Kester, 2013), as well as on the societal level (Beery et al., 2016). The understanding of the pressures and drivers in and on the environment has increased and the impacts of nature on humans, and vice versa, has led to a much better understanding of the goods and services required and provided by the environment.

The concept of ecosystem services has, as Gómez-Baggethun et al. (2010) point out, developed from a mainly pedagogical concept, which aimed to raise public interest for biodiversity conservation. The term, coined by Ehrlich & Ehrlich (2008) and further developed in Ehrlich & Mooney (1983) for the use in the context of species disappearance.

Despite this limited initial ambition, the concept has widened in its use, and is also used for economic purposes with an emphasis on the commodities associated with ecosystem services and their influence on markets (Gómez-Baggethun et al., 2010; Peterson, Hall, Feldpausch-Parker, & Peterson, 2010), and in the field of Natural Capital (Costanza et al., 2006; Natural Capital Committee, 2017b).

Ecosystem services can be understood as aspects of ecosystems, that through their active or passive use, produce direct or indirect contributions to human well-being (Fisher, Turner, & Morling, 2009; TEEB, 2010a). This supports the idea to combine the assessment of ecosystem services in recognition of human activity, because humans as beneficiaries of these services play a crucial role in the perception of the received services.

While the term ‘ecosystem service’ has been used in different contexts and by different assessment approaches (e.g. Millennium Ecosystem Assessment, UK National Ecosystem Assessment, The Economics of Ecosystems and Biodiversity), its use remained largely similar: organising and conceptualising science and knowledge of ecosystems into a social context (Danley & Widmark, 2016). With regard to the use of the ecosystem approach and the idea of ecosystem services in the light of socio-ecological systems, it is relevant to discuss the change in definitions of the term to be able to use a definition that is relevant to this research project and the intended methodology.

The term ‘ecosystem service’ has been defined multiple times. In the Millennium Ecosystem Assessment (2005b, p. 78) it is described as ‘the benefit humans obtain from ecosystems’. As described in the previous section, the term emerged around the millennium, when the connection between humans and the environment became a focus in environmental management. The ‘service’ that the environment provides is always linked to humans, through direct or indirect services to form a socio-ecological system (Costanza et al., 1997). Generally, four categories are recognised when classifying ecosystem services. Supporting services form the basis of all other ecosystem services by providing the essential elements of natural processes and the basic elements for all other ecosystem services. Provisioning, regulating, and cultural services are those services that form final ecosystem services, and which can finally be translated into benefits.

An example of the structure of ecosystem services derivation from structures and processes is shown in Figure 9 for an industrialised estuarine environment (Jacobs et al., 2015). The figure gives an impression of how processes in a particular habitat impact the reception of benefits for humans through interactions with other functions. Several structures and processes form intermediate service, which again translated into final services, or are directly related to benefits for humans. It becomes clear that every process is highly site-specific regarding its final ecosystem services and benefits rely highly on site-specific conditions.

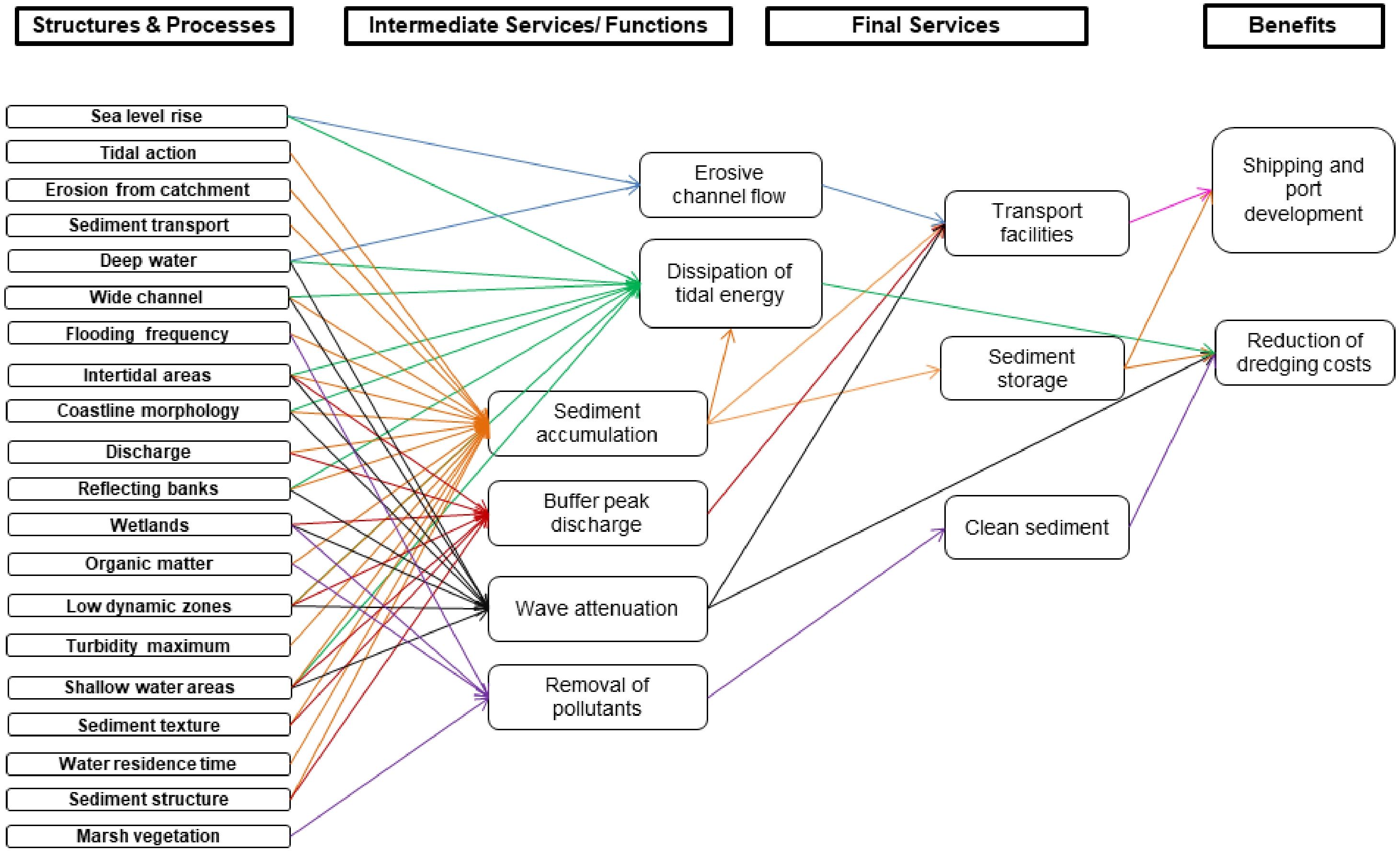


**Figure 9 From structures and processes to ecosystem benefits of ecosystem services in industrialised estuaries, based on Jacobs et al. (2015). The coloured arrows are used for improved readability to show the process from structures and processes to benefits.**

In the last decades, the definition of ecosystem services has been evolving and changing. In the previous sections, the term ‘ecosystem services’ has been used regularly, without the need of commitment to one particular definition. This alone shows that the concept of ecosystem services is a versatile approach and tool that can be used in multiple conceptions (Lele, Springate-Baginski, Lakerveld, Deb, & Dash, 2013), that allows a general understanding, based on a basic definition. Danley & Widmark (2016) highlight that the debate regarding a definition of ecosystem services is based around three overlapping ideas: i) the physical component (structure), ii) the functioning and interaction of the physical components (process), and iii) the resulting contribution to human well-being from the ecosystem (benefit).

Different definitions are listed in Table 2. Originating from a natural science background, the initial definitions of ecosystem services were based on the functions and processes that were observed to influence and sustain human life (e.g. Daily (1997)). Around the same time, the approach of economic valuation created new ideas of how ecosystem services were perceived by the scientific community. Costanza et al. (1997) described goods and services which could be used as a means to represent and calculate the benefits humans receive from functions. This takes the definition of ecosystem services a step further than Daily (1997), but relates it to functions and processes in an ecosystem.

Possibly the most commonly used definitions are those originating from the Millennium Ecosystem Assessment (2005) and TEEB (2010b). Even though not mentioned in the Millennium Ecosystem Assessment definition of ecosystem services directly, both definitions incorporate direct as well as indirect services, therefore, including underlying supporting services. Those, in turn, can be defined as the functions and processes, and structures behind the final benefit of the nature’s provision of services. The consideration and use of underlying structures and processes is important when these aspects are the focus point of a research project. As discussed previously, the focus on the explicit functions and processes in a system relates to the idea of understanding the system to either improve it, or maximise its value for resource abstraction. In research which focused on the final ecosystem services and well-being, supporting services are not necessarily always directly considered in the assessment, but recognised as underlying functions (Atkinson, Bateman, & Mourato, 2012; Downing et al., 2014). The idea of socio-ecological systems and the incorporated human well-being aspect is not yet included in those definitions.

**Table 2 Definitions of 'Ecosystem Services' ordered chronologically.**

| Author | Definition | Source |
|---|---|---|
| Daily | 'Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life.' | Daily (1997, p. 3) |
| Costanza et al. | 'Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions.' | Costanza et al. (1997, p. 253) |
| Millennium Ecosystem Assessment | 'Ecosystem services are the benefits people obtain from ecosystems.' | Millennium Ecosystem Assessment, (2005d, p.53) |
| Boyd and Banzhaf | 'Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being.' | Boyd & Banzhaf, (2007, p. 619) |
| TEEB | 'The direct and indirect contributions of ecosystems to human well-being.' | TEEB (2010b, p. 19) |
| UK National Ecosystem Assessment | 'The benefits people obtain from ecosystems.' | UK National Ecosystem Assessment, (2011, p. 84) |
| CICES | '[Final ecosystem services are] the *contributions* that ecosystems make to human well-being.' | Haines-Young & Potschin, (2013, p. 8) |

The most recent definition (Haines-Young & Potschin, 2013) concentrates on the final ecosystem services, not taking into account the intermediate services that may or may not occur in a system as they are dependent upon specific site conditions. As Danley & Widmark (2016) point out, this makes it possible to include a range of non-tangible ecosystem services, instead of concentrating on the physical environment. However, after years of research and debate surrounding the definition of ecosystem services, even the most recent research is not able to create consistent answers or definitions, as Saarikoski et al. (2015) describe with the example of cultural ecosystem services within the CICES approach or Costanza et al. (2017), reviewing the ecosystem service definitions of the past twenty years.

It is apparent that it is ultimately the decision of the respective researcher which ecosystem services are included in the research, depending on the socio-ecological composition of the system in question. Therefore, in this context, it is 'more useful to express that nature is important to human welfare than it is useful to carefully and deliberately specify how one identifies ecosystem services among nature's structures, processes, and benefits' (Danley & Widmark, 2016, p. 136). It emerges that it is important not to get carried away defining all elements in the ecosystem, if the ecosystem service assessment is aimed at making ecosystems more manageable, as otherwise the system's complexity is overwhelming and manageable portions not possible to be identified.

## 2.6. Ecosystem Approach and Ecosystem Assessment – International Approaches and the Relevance for the UK

The ecosystem approach has been considered a strategy to incorporate a holistic and sustainable management of landscape, including social, economic, and scientific aspects (Smith, 2013). The approach incorporates the principle that decisions are made on all levels, taking into account as many factors and stakeholders as possible, enabling all parts of the ecosystem to be managed (Secretariat of the Convention of Biological Diversity, 2004). The ecosystem approach is based on the adaptation of management policies into the existing management context of a socio-ecological system, enabling the maximisation of ecosystem services for a respective system (Haines-Young & Potschin, 2013).

The concept of an ecosystem approach was first mentioned in the Convention on Biological Diversity (Convention on Biological Diversity, 2000) and led to several ideas regarding how best to work with this approach. The main aim of the ecosystem approach is to form ‘a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way’ (Convention on Biological Diversity, 2000, paragraph 1). The ecosystem approach recognises the need for adaptive management, as it aims to reach a balance of conservation, sustainable use, and the fair and equitable sharing of resources (Convention on Biological Diversity, 2000, paragraph 1), as well as the complexity and dynamic nature of ecosystems (Convention on Biological Diversity, 2000, paragraph 4). Its objectives are described in twelve guiding principles on the Convention of Biological Diversity (in Appendix 1), which are complementary for adopting an ecosystem approach and clearly combine the need of society to be part of ecosystem management (Convention on Biological Diversity, 2005).

The ecosystem approach is a tool which is based on the socio-ecological approach, and is not designed to work in isolation. It requires an integration of the three pillars of sustainability: environmental protection, economic development, and social equity. Abson et al. (2014) demonstrate that the ecosystem approach has great potential as a transformative concept, which engages in integrating different ideas from scientific and non-scientific disciplines. If, through this approach, the integration of different aspects can be managed, taking into account governance, ethics and social processes, and intra- and inter-generational principles, it will prove a valuable asset for biological conservation, natural resource management, and environmental policy making (Glotzbach & Baumgärtner, 2009; Jax et al., 2013).

It has been the goal of several studies to assess and map the global value of ecosystem services, as for example by Costanza et al. (1997) and Grêt-Regamey et al. (2014). Costanza et al. (2017) discussed that the attempt to establish a value for all global ecosystem services was an exercise that was not expected to be accurate, but intended to show the potential of the concept. However, studies assessing and mapping ecosystem services are often limited in scale and are concentrated on a specific ecosystem or habitat type (Baral, Keenan, Sharma, Stork, & Kasel, 2014; Grêt-Regamey et al., 2014). In order to study ecosystems and society holistically, an approach which considers multiple ecosystem services on a cross-habitat scale can be recognised as a valuable contribution to knowledge. To use the full potential of the approach, it would also be necessary to integrate it into long-term planning, using the iterative nature of natural resource management (Talley, Schneider, & Lindquist, 2016).

In England, ten broad ecosystem types of principal importance[1] have been identified (Natural England, 2010). These broad ecosystem types are broken down into habitats which focus upon the country's Biodiversity Action Plan (Natural Environment and Rural Communities Act, 2006). Research and policy should aim for a detailed understanding of all of those habitat types, as they are not yet sufficiently considered in decision making and/or economic analyses (Ecosystems Knowledge Network, 2016a). With an increased understanding of the habitats, management can be directed towards an ecosystem approach and an improved valuation of ecosystem services.

The assessment of ecosystem services is based on conceptual frameworks which have been developed throughout the last two decades, focusing on different perspectives, i.e. global, national, and economic. The development began with the Millennium Ecosystem Assessment, which resulted in global recognition of the topic among the scientific community and sparked an interest into researching the topic. The idea of assessing ecosystems such as in the Millennium Ecosystem Assessment was followed, further developed and advanced by other research groups of which the UK National Ecosystem Assessment and its follow-on in 2014 are of particular relevance to the UK.

The Millennium Ecosystem Assessment was initiated by the UN in 2001, and published its findings of a global assessment of ecosystem services in 2005 (Millennium Ecosystem Assessment, 2005a). The aim of the Millennium Ecosystem Assessment was to establish a scientific basis for actions, which support ecosystems in their contribution to (human) well-being without infringing upon their long-term productivity (Millennium Ecosystem Assessment, 2005e). The approach did not aim to create new knowledge about the ecosystems in question, but instead attempted a thorough analysis of available data and information to

[1] Arable and horticulture, boundary, coastal, freshwater, grassland, heathland, inland rock, marine, wetland, woodland, as listed in the Natural Environment and Rural Communities Act 2006 (Section 41) are ecosystems of principal importance in the UK.

assess interrelations and connection between ecosystems, humans, and the benefits humans gain from these ecosystems, as well as the related direct and indirect drivers (Haines-Young et al., 2008).

To assess ecosystem services, the Millennium Ecosystem Assessment developed a conceptual framework (Figure 10), which covers the range of assessment and the influencing drivers of change (direct and indirect) that can lead to alteration of ecosystems and the consequential change in provision of ecosystem services (Millennium Ecosystem Assessment, 2005e).

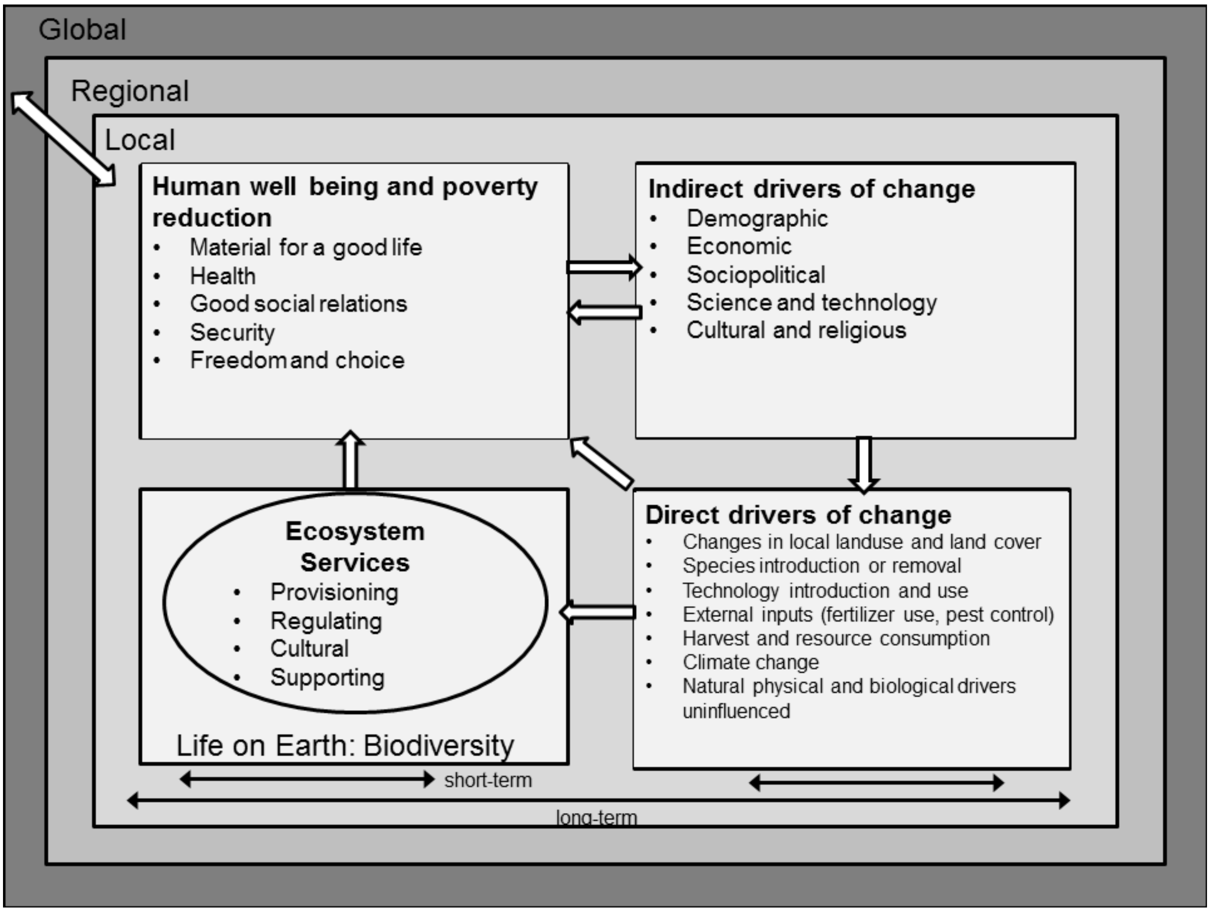


**Figure 10 Simplified conceptual framework of Millennium Ecosystem Assessment, adapted from Millennium Ecosystem Assessment (2005b).**

Through the assessment of ecosystem services, i.e. their identification and categorisation, the consequential step is to analyse their impact on human well-being. This offers the possibility to assess future development of ecosystem services (Figure 11) and opens up new research areas, considering the basis established by the Millennium Ecosystem Assessment, by identifying relevant ecosystem services (step 1), assessing the changes over a period of time (step 2), and developing scenarios, explaining how these changes can affect the provision of ecosystem services in the future. This aspect of ecosystem service assessment will be evaluated in section 2.8. Important in the context of this research is the aspect that the Millennium Ecosystem Assessment offers a framework through which it is possible to understand how changes can influence ecosystem service provision over a short and long-term basis.


**Figure 11 Assessment stages of the Millennium Ecosystem Assessment (author's representation).**

The Millennium Ecosystem Assessment has been successful in its approach to assess the global ecosystem services and has sparked wide interest in the field of ecosystem service assessment. By combining spatial, temporal, socio-political, economic and environmental data, as well finding a way to connect the human-nature interface through the categorisation of ecosystem services, the Millennium Ecosystem Assessment developed a system that can offer a way to improve the social-ecological understanding.

The influence of the Millennium Ecosystem Assessment has had a substantial impact on other approaches that aim to assess ecosystem services (Haines-Young & Potschin, 2013; UK National Ecosystem Assessment, 2011). Development and advancement of the approach resulted in assessments on different scales, e.g. with a focus on economic valuation (Natural Capital Coalition, 2016; TEEB, 2010a) and other ideas and means of structuring the ecosystem service categories (CICES, 2017). A national approach which is of interest for this study, is the UK National Ecosystem Approach (UK National Ecosystem Assessment, 2011) and its Follow-On (UK National Ecosystem Assessment, 2014).

The UK National Ecosystem Assessment and its follow-on were the first ecosystem assessments of the UK’s natural environment (UK National Ecosystem Assessment, 2012). The assessment was introduced in 2009 and identified four key objectives: i) to produce an independent and reviewed assessment of UK’s natural environment and ecosystem services; ii) to identify drivers of change of the environment, and potentials of change in the future; iii) to encourage interdisciplinary cooperation between natural and social scientists as well as policy making; and iv), to facilitate communication and interaction of the relevant stakeholders, raising awareness for the importance of protection of the natural environment and human well-being (UK National Ecosystem Assessment, 2011).

Using a national scale for the assessment of ecosystem services comes with several advantages that are beneficial to the assessment: it narrows down the habitats that can be found, particularly in the case of the UK as an island, and it also makes it approachable for practitioners and managers in the country for direct comparison and application. This approach can also directly inform policy and aid decision making on a national scale. The assessment includes ten work packages. Their reports are combined in a key-findings report (UK National Ecosystem Assessment, 2014) (Table 3). The topics of the work packages reflect the key areas for environmental management important in the UK. Several of these topics have been followed-up by regulating bodies and the government in England (Creedy, Doran, Duffield, George, & Kass, 2009; Defra, 2011a; Natural England, 2013a). The UK National Ecosystem Assessment Follow-on also focuses on the implementation (work package 7–10) and application for further policies and applicability to practitioners in the UK, which is crucial when considering further application of elements from the assessment. The work packages reflect the assessment stages of the Millennium Ecosystem Assessment: i) identification of ecosystem services (packages 2-6); ii) conditions and trends of ecosystem services (package 8); and iii) developing scenarios (package 7).

**Table 3 Work packages of the UK National Ecosystem Assessment Follow-On.**

| Work package | Topic |
|---|---|
| Work package 1 | Natural Capital Asset Check |
| Work package 2 | Ecosystem Services and the macroeconomy |
| Work package 3 | Economic value of ecosystem services |
| Work package 4 | Coastal and marine ecosystem services |
| Work package 5 | Cultural ecosystem services and indicators |
| Work package 6 | Shared, plural and cultural values of ecosystem services |
| Work package 7 | Operationalising scenarios |
| Work package 8 | Robust response options – what response options might be used to improve policy and practice for the sustainable delivery of ecosystem services? |
| Work package 9 | Embedding the Ecosystem Service Framework into appraisal |
| Work package 10 | Tools, application, benefits and linkages for ecosystem services |

The work on the assessment of ecosystem services and the importance and value in policies has also been considered by Natural England (2016), the Environment Agency (2009), and Defra (2007b, 2011a). The economic valuation and assessment of the natural capital was substantially advanced by the report published by the Natural Capital Committee (2017b). The value of nature in the UK in economic and social terms has been acknowledged in the White Paper on the value of the natural environment in the UK (Defra 2011b). Based on the findings of the Millennium Ecosystem Assessment and Lawton et al. (2010), it concludes that nature and humans are highly interconnected, and to secure ecosystem services and their benefits/value to society, action is required to include ecosystem services in decision-making processes.

Beside the need to assess and value ecosystem services, as highlighted in the previously mentioned publications, the work packages of the UK National Ecosystem Assessment also reveal the importance of coastal and marine ecosystems (Jones, 2011). These ecosystems contribute various ecosystem services for the UK due to the country's island character. This can be considered an important point in the selection of study sites.

The ecosystem assessments provide a suitable base for establishing a discussion for the chosen study site. Providing a framework that is recognised on an international level, the provision of an approach to grasp socio-ecological systems is considered to be a valuable point of reference. Acknowledging the factors that interact with a system and influence the provision of ecosystem services is a crucial aspect for this research. In order to use the fundamentals of these approaches in a case study, a variety of aspects has to be considered. Conclusions from the reviewed literature on the assessment of ecosystem services within socio-ecological systems are presented in the following section.

## 2.7. How Socio-ecological Systems fit in with the Assessment of Ecosystem Services – Drawing Conclusions from the Literature

Ecosystem services give us humans the possibility to assess what benefits are received from nature. This assessment has been developed over the last decade and multiple methods have been researched investigating systems to account for ecosystem services, their synergies and trade-offs (Bennett, Peterson, & Gordon, 2009; Rodriguez et al., 2006). The value of ecosystem services plays an important role in environmental management as it can justify decision making processes, as described in Chee (2004) and Ma et al. (2016). Several factors have to be considered because, as pointed out previously, a socio-ecological system is a complex and highly dynamic entity, which is subject to many direct and indirect influencing factors.

Ideally, the importance of ecosystem services is displayed in a unit that is globally understandable and does not require any specialist knowledge. A valuation of ecosystem services facilitates the communication of the benefits and can be incorporated into decision-making more easily (de Groot et al., 2012). As Farber, Constanza, & Wilson (2002) point out, a specific value of an action or object (the valued unit) depends largely on the understanding of the user's value system, i.e.

the user's perceptions of norms which influence and guide human judgement and action. This understanding will ultimately influence the relative importance directed to the valued unit.

The quantification of ecosystem services is a major aim for researchers and decision-makers, as it offers a way to account for nature in projects that require, for example, land use and land cover changes. The increasing demand in natural resources has, therefore, led to an increase in studies that investigated values of ecosystem services in specific habitats and/or under specific conditions (Baral et al., 2014; D'Amato, Rekola, Li, & Toppinen, 2016; de Groot et al., 2012; Luisetti et al., 2014; Sen, 2012; Torres & Hanley, 2016). However, despite numerous studies relating to the value and quantification of ecosystem services, no consensus has been reached regarding the validity and implications of these valuations (Morse-Jones, Luisetti, Turner, & Fisher, 2011).

The quantification of ecosystem services in monetary terms has to be considered a major exercise, which has been trailed several times in the past. Probably the most famous valuation of ecosystem services is the publication 'The value of the world's ecosystem services and natural capital' by Costanza et al. (1997), with over 18000 citations alone on Google Scholar (21/08/2017). In this paper, the economic value has been estimated, giving the global ecosystem services a value in monetary terms. Beery et al. (2016) illustrate in their study that the description of ecosystem services in quantitative, and especially monetary terms, makes the concept useful for decision making processes. However, they also point out that among the participants of the study, only a few had a critical understanding of the idea of monetisation of ecosystem services. Schröter et al. (2014) highlight that even though the monetary valuation of ecosystem services can lead to more informed decisions, it does not replace the biophysical assessment and socio-cultural indicators, which are based on non-market instruments. Also, the economic valuation of ecosystem services requires an advanced collaboration between disciplines, as the valuation of those services is largely dependent on the results emerging from science (Atkinson, Bateman, & Mourato, 2012). This is not an easy task to fulfil in a highly complex setting such as socio-ecological systems (van Zanten, Koetse, & Verburg, 2016). The perceived persuasiveness of the economic language is a driving factor in the decision-making process (Laurans &

Mermet, 2014), but should not be put at the centre of decision making, let alone science. Given the limitations of the quantitative valuation of ecosystem services, it has to be considered on an individual basis whether it is a viable approach or not.

In the context of socio-ecological systems and the consideration of ecosystem services in managing those systems, economic valuation is, therefore, a limiting and/or restricting factor. As van Zanten et al. (2016) acknowledge, other factors need to be recognised when approaching socio-ecological systems: for example, the cultural and recreational value of landscapes are often not sufficiently considered in the valuation of ecosystem services. These are often context specific, complicating comparisons between sites (Pinto-Correia & Carvalho-Ribeiro, 2012; Soini, Vaarala, & Pouta, 2012).

The economic valuation of cultural ecosystem services is difficult, but their consideration in the overall assessment of ecosystem services should not be omitted. Unlike other ecosystem services, cultural ecosystem services are not linked to a specific ecosystem or habitat, and can depend upon the presence of other ecosystem services (Ecosystems Knowledge Network, 2016b). However, they are important when considering the dynamic systems in which humans are interacting and using the environment alongside its regulating and provisioning aspects. Cultural ecosystem services are also described as 'life-fulfilling functions' (Daily, 1999), 'cultural and amenity functions' (de Groot, Alkemade, Braat, Hein, & Willemen, 2010), or 'socio-cultural fulfilment' (Wallace, 2007).

These services often seem intuitive in nature and are often poorly quantified and integrated into management plans (Milcu, Hanspach, Abson, & Fischer, 2013). Although research is looking into the aspect of a full integration of cultural ecosystem services into the valuation of benefits of ecosystems, a full integration into governance structures and policy making has not yet been achieved (Ecosystems Knowledge Network, 2016a; Milcu et al., 2013).

Cultural services often depend on intermediate services, which lead to final cultural ecosystem services (Milcu et al., 2013). They 'can be used as a way of binding together and exploring the relationship between provisioning, regulating and supporting services' (Ecosystems Knowledge Network, 2016a, p.11).

However, even though a linkage between cultural services and other ecosystem services can be found, cultural services are often independent of specific habitat types or individual ecosystems (Ecosystems Knowledge Network, 2016a).

The discussion of cultural ecosystem services is also important because it shows the difficulty of defining ecosystem services, and their direct connection to society becomes apparent. Recently, the value of cultural services to health care and mental, as well as physical well-being has been recognised and is shaping awareness towards the importance of assessing of cultural ecosystem services (Chief Cultural & Leisure Officers Association, 2014; Wigan Council, 2014).

It becomes clear that an assessment of benefits from nature to humans needs to include a variety of factors in order to fully establish an understanding of the well-being that is provided. A representation of a conceptual model, demonstrating how ecosystem services fit into socio-ecological systems and how well-being is perceived on different levels is shown in Figure 12. Beginning with initial functions and processes, services are recognised and translated into individual and shared well-being. Here, the connection is clearly depicted of how ecosystems can support humans on an individual as well as on a community basis. Consequently, through management of ecosystems human well-being can be influenced, ultimately shaping the future of individuals and groups. It can also be concluded that through assessing ecosystem services in a socio-ecological system, and recognising the underlying ecosystems, as well as managing landscapes adaptively and holistically, could have an influence on the future development of a socio-ecological system, and, therefore, its resilience to change.

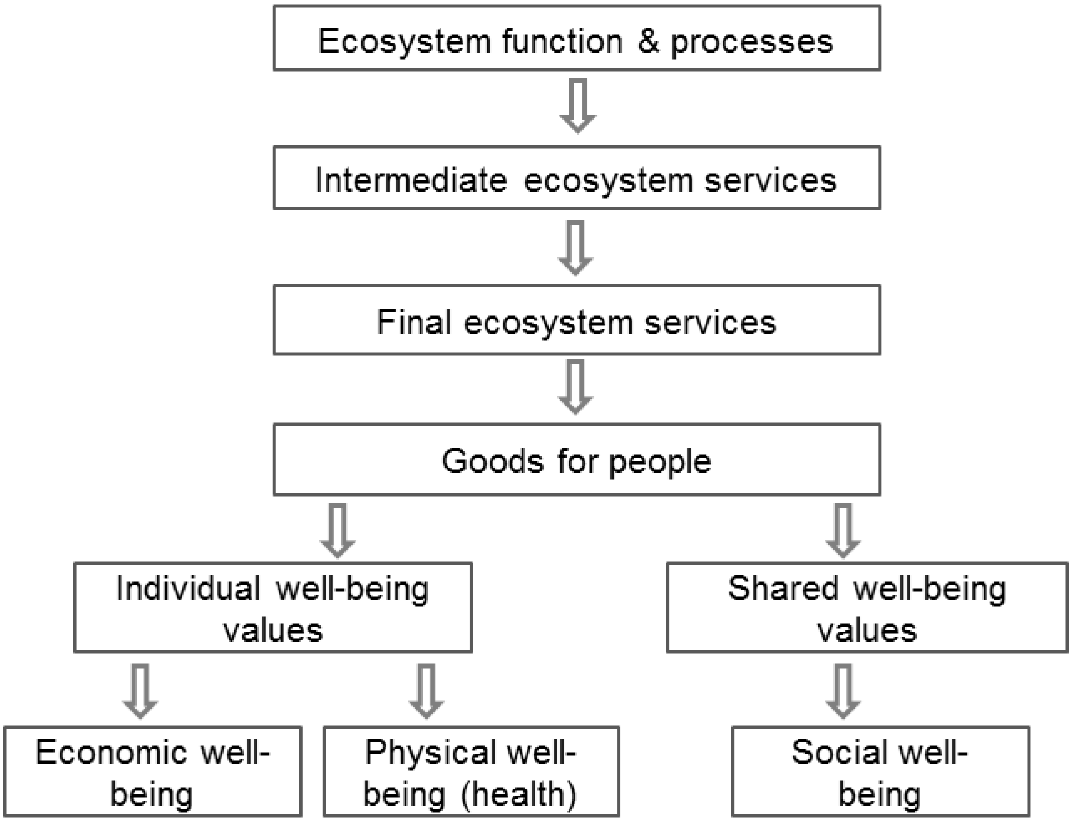


**Figure 12 From ecosystem functions to well-being, adapted from Smith (2013).**

Despite increasing research in the field of ecosystem services, the concept continues to be criticised (Olander et al., 2017; Schröter et al., 2014). Although plenty of research pursues the aim to achieve a socio-ecological description of their work, researchers still struggle to meet practitioners' requirements (Baveye, 2017; Primmer & Furman, 2012; Schägner, Brander, Maes, & Hartje, 2013). The integration of ecosystem services is sought after for governing landscapes and people. For example, the Natural Capital Committee recommended a long-term strategy for the management of the UK's natural resources. Jäppinen and Heliölä (2015) report the need to integrate knowledge of ecosystem location with their value to strengthen the validity of the use of concept. Bagstad, Semmens, Waage, & Winthrop (2013) reviewed seventeen decision support tools, concluding that the tools' applicability widely depend on the location and context applied.

Two points can be identified that lead to a successful translation from science into practice. One of the necessary requirements is the integration of stakeholders into the process (Bryson, 2004; Ianni & Geneletti, 2010; Jacobs et al., 2015; Krueger, Page, Hubacek, Smith, & Hiscock, 2012; Vierikko & Niemelä, 2016)). Link et al. (2017) identify the issue that stakeholders are needed to identify what information is needed in ecosystem service management. Spangenberg et al. (2015) say that stakeholders must be directly involved in ecosystem service assessment to create an awareness and willingness to participate in the governance of those services. The challenge is to capture the perceptions and worldviews of the stakeholders to achieve robust results that can inform management and planning (Görg et al., 2014).

The need arises to move from primarily scientific and, therefore, complex approaches to ones that can be adopted and carried out by stakeholders themselves (Levin & Mollmann, 2015). Several studies review approaches on integrating stakeholders in ecosystem service research (Cebrián-Piqueras, Karrasch, & Kleyer, 2017; Galler, Albert, & von Haaren, 2016; Kaczorowska, Kain, Kronenberg, & Haase, 2016; Spangenberg et al., 2015), identifying strengths and weaknesses of those approaches that can be adapted for local circumstances.

The second requirement is the appropriate selection of ecosystem services within each socio-ecological system. Hanspach et al. (2014) highlight that when assessing diverse and complex systems with multiple habitat types, it is necessary to adopt an area-based approach rather than restricting the assessment to a sub-set of habitats or ecosystem services. The selection of tools and methods for ecosystem service assessment is wide and broad (Grêt-Regamey, Altwegg, Sirén, van Strien, & Weibel, 2017). There is, however, often little to no indication of how the studied ecosystem services were selected (Grêt-Regamey et al., 2017; Wang, Tang, & Xu, 2017), other than based on availability of data, modelling techniques or suitability of the study site (Mascarenhas, Ramos, Haase, & Santos, 2016). Reviewing the literature, the selection of ecosystem services is not documented widely – exceptions can be found in Jacobs et al. (2015) and Mascarenhas et al. (2016). Other studies model the provision of biophysical aspects of ecosystem service provision, but the link to the stakeholders and beneficiaries of the services is not apparent (Keeler et al., 2012; Remme, Schröter, & Hein, 2014).

Stakeholders, decision-makers, and practitioners need methods which are not overwhelmingly complicated, expensive or data-intensive (Baveye, 2017; Pandeya et al., 2016). Despite the fact that many success stories of applications of ecosystem service assessments and subsequent use of research in policy and decision-making are documented (Ruckelshaus et al., 2015), a simplification of the process should be considered.

Long-term vision and adaptive management are two key aspects of an ecosystem approach (Bailey and Buck, 2016). Embedding an ecosystem approach for long-term planning, as reflected in the suggestion to the Department for Food and Rural Affair's 25-year plan by the Natural Capital Committee (2017a), requires tailoring of the approach to the local context of a socio-ecological system. Therefore, the selection of ecosystem services to consider should be context-specific and driven by local stakeholders. By drawing on this local knowledge, it will be possible to ensure that all ecosystem services of relevance are identified, especially within complex socio-ecological systems.

## 2.8. Learning for the Future

Based on the reviewed literature, the question arises of how the ecosystem services of socio-ecological systems can be integrated into decision-making processes, leading to a resilient system that is capable of adapting to change. Using environmental foresight in environmental management can inform the management approaches for adaptive systems and can, therefore, influence the ecosystem condition and the provision of ecosystem services (Ravetz, 2015). The integration of ecosystem services into decision-making can be a challenging task, but the need to include the assessment of ecosystem services into governance systems and policy making has already been identified (Frantzeskaki & Tilie, 2014; Salomaa et al., 2016). This means that environmental foresight needs to be developed in order to address challenges and environmental issues using a variety of tools (Bengston, Kubik, & Bishop, 2012).

However, the major challenge with which science is presented is that the future is uncertain and estimates of how the future will unfold are often imprecise. Furthermore, the emergent nature of socio-ecological systems makes it impossible to successfully forecast a systems' future (de Haan, 2006; Kass, Shaw, Tew, & Macdonald, 2011). However careful an exercise that considers the future is carried out, it will not represent the actual future, but instead can explore challenges and opportunities of times to come. If we are intending a holistic and complete understanding of a problem, it is useful to consider as many perspectives as possible (Floyd & Zubevich, 2010), ergo using a combination of techniques that allows researchers to include several sources of information in order to model possible futures.

### 2.8.1. Using Stakeholder Knowledge to Understand the Future

The stakeholder, 'anyone significantly affecting or affected by someone else's decision-making activity' (Chevalier, 2001, p.1), is consulted in most managerial projects, which aim to influence decision-making. The concept of using stakeholder analysis is now used in several fields, ranging from political sciences to international relations, and conflict resolution (Chevalier, 2001), as well as business administration and project management (Fletcher, Guthrie, Steane, Roos, & Pike, 2003).

Stakeholders are an essential element in project planning and management (Cleland, 1997). It is important to consider a stakeholder position, view and vision within any project to form a holistic picture of the impact of the project on stakeholders and the environment in which the stakeholders are active. The definition of a stakeholder is broad and has to be adapted to the individual project (Fassin, 2009). Every socio-ecological system has various stakeholders, some of which might have sufficient expertise to be able to provide information on how possible futures could appear. An involvement of stakeholders that are experts in the particular field in question can create new knowledge and offer insights into complex problems that could not be addressed without the knowledge provided by expert opinion (Clayton, 1997; Cooke, 1991).

One method to include experts in learning for the future is the Delphi method. The Delphi method[2] is a forecasting technique developed in the 1950s and '60s by the

[2] The Delphi method is also known as 'Delphi technique' and 'Delphi approach', with the terms being used interchangeably.

American RAND Corporation (Sackman, 1974). It first found use in technological forecasting and was intended to be used to forecast likely inventions, new technologies, and the social and economic impact of such developments (Adler & Ziglio, 2002). During its early development, the technique was used in a variety of disciplines such as forecasting social phenomena (human attitudes and values) and quality of life (Sackman, 1974), the impact of new land use policies, and other impacts in health, environmental, economic, and social policies (Adler & Ziglio, 2002). The aim of a Delphi method is the facilitation of a group communication process, mainly through the voice of experts.

‘Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem’ (Linstone & Turoff, 1975, p. 3). A Delphi technique is structured as a multistage system of questionnaires, based on informed judgement. The original technique requires anonymity of the participants (instead of direct confrontation in a group), who are usually a group of selected experts. The avoidance of face-to-face interaction is seen as a key advantage of the approach. Controlled interaction appears more conducive in the formation of independent opinions, as compared to direct confrontation, which often results in the impulsive formulation of statements (Dalkey & Helmer, 1962). The questionnaires are answered in written form by the group of experts who are considered to have deep knowledge of their field and are, therefore, able to give valuable estimates regarding future developments (Vorgrimler & Wübben, 2003). The series of questionnaires can be interspersed with feedback rounds of the intermediate results, which give the participants the opportunity to adjust and refine their previous answers, when compared to the answers of the other experts (Brown, 1968; Vorgrimler & Wübben, 2003).

It is argued that the method is also suitable for situations in which uncertainties and imperfect knowledge are an inevitable part of the data collection (Kaynak, Bloom, & Leibold, 1994). It provides a chance to move forward in complex situations, which are often not easily dealt with through lack of data, or hard proof. It is, therefore, a valuable tool in qualitative research, chiefly because of its potential in problem solving, decision making, and group consensus (Häder & Häder, 1998).

The critical evaluation of the literature has demonstrated that the Delphi method is an effective tool to learn about the future from experts (i.e. stakeholders) of a socio-ecological system. This can also be concluded from the study published by Rowe & Wright (1999), who summarised several Delphi studies according to their group size, number of rounds, nature of feedback, and nature of subjects. Okoli & Pawlowsi (2004) also compared the Delphi method to conventional surveys in an information system environment.

Besides the broad application potential of the Delphi technique, it has also been applied in studies, assessing ecosystem service value changes to support spatial planning (Navrud & Strand, 2017; Scolozzi, Morri, & Santolini, 2012), as well as investigating governance of protected areas (Mehnen, Mose, & Strijker, 2012) and ecosystem services for education (Ruppert & Duncan, 2017). All studies conclude that the Delphi is a suitable method when assessing factors that influence ecosystems.

The inclusion of stakeholders in the process of learning for the future requires suitable methods such as the Delphi technique. Exploring the wide range of applications of the technique reveals options and opportunities to include stakeholders in the research. Limiting factors such as limited opportunities for discussion and open exchange of information can be addressed through modifications (section 3.6.4). Exploring ecosystem service provision within a socio-ecological system benefits from external input of stakeholders (Uhde et al., 2017) and allows the researcher to integrate the newly found knowledge into other methods to investigate the socio-ecological system.

### 2.8.2. Scenarios for an Ecosystem Service Assessment

Scenarios and their analysis are tools which have been used in a variety of ways to investigate aspects of environmental change. In the field of climate change, scenario thinking has been well established (Parry, Canziani, Palutikof, van der Linden, & Hanson, 2007), and other authors have been working with scenarios to establish possible outcomes of the future under specific assumptions of the development of the world’s climate (Hyytiäinen et al., 2016). Creedy et al. (2009) look at scenarios of the natural environment in the UK from now until 2060. These scenarios consider land use changes and changing socio-political aspects, although due to their broadness, they cannot draw conclusion to particular areas. They do, however, provide a helpful insight in potential developments that might affect the UK. The use of scenarios in conservation practice has also been explored by Peterson, Cumming, & Carpenter (2003). The group argues that scenario planning offers a useful tool to explore more resilient options for the management of unpredictable environments and can have a significant input in adaptive management (Walters, 1986). By using scenarios in management decisions, the resilience of landscapes towards particular changes can be investigated. The use of scenarios, as structured accounts of possible futures, (Walters, 1986) offers the possibility to capture diverse aspects of particular areas through a variety of qualitative and quantitative means (Kass et al., 2011).

‘A scenario is a coherent, internally consistent, and plausible description of a possible future state of the world’ (Carter & La Rovere, 2001, p. 147). Scenarios give the possibility to provide alternative views regarding the future and future conditions and can be used for implementing adaptive management, or the management for a specific purpose such as the management for conservation (Peterson, Beard, et al., 2003). Using scenario planning allows focus on options available in the future and helps to identify strategies that can be implemented now. They can be based both on participatory methods and expert opinion, and often use a combination of the two (McKenzie et al., 2012).

A scenario has to be developed with enough detail to be useful for strategic planning. The use of scenarios allows managers, policy makers, and strategic thinkers to adapt their planning according to the preferred outcome of the scenarios (OECD, 2015). If, in the future, the management and/or conditions change, the scenarios can be helpful to revise the initial planning objectives and allow adjustments to be made. It is, therefore, a useful exercise for areas that are under adaptive management.

Scenarios are not employed to act as a model and to predict detailed changes (Creedy, Doran, Duffield, George, & Kass, 2009). The use of scenarios as a planning tool is limited by the identification and incorporation of pressures that affect the future and influence the balance between the natural, social, and economic environment. Although all scenarios have the same aim, several types of scenarios exist (Table 4), which use different questions and storylines to reach their aim. McKenzie et al. (2012) point out that there is no single recipe to develop scenarios, and often not one type of scenario is right to use, but a combination of at least two types which are overlapping in some respects, can create those aspects that are important in the respective context.

Looking at scenarios in a socio-ecological system context, it becomes clear that not just one type of scenario can be applied. Determining the extent of each of the types is impossible, due to people's own and individual perceptions of the question asked within each scenario. It can be assumed that the more people are asked to contribute to a scenario, the more ideas and worldviews are incorporated into it. However, as previously noted, the types of scenarios have the same aim. It is, therefore, not necessary to define which type is best used, but to appreciate the diversity of questions that can be answered through the application of this tool.

The development of scenarios is often based on the identification of drivers of change, that can be identified as influences on the system in the future. These are often based around population dynamics and climate change (Millennium Ecosystem Assessment, 2005f). The variety of scenarios can be seen in Table 5.

**Table 4 Types of scenarios, user goals, questions asked and storylines. Adapted from McKenzie et al. (2012).**

| Scenario | User Goals | Question asked | Scenario Storyline |
|---|---|---|---|
| Intervention | • Choose among alternative interventions.<br>• Identify effective and equitable interventions that meet policy goals. | What are the best ways to achieve the future we want? | Designs for real policies, plans, and projects. |
| Exploratory | • Anticipate uncertain future circumstances.<br>• Test how policies cope with unexpected change. | Where might the future take us? What can we do to prepare? | Possible but unexpected futures. |
| Vision | • Reach a shared vision.<br>• Determine how to reach a desired future.<br>• Resolve stakeholder conflicts. | What future do we desire? | Stakeholders' concepts of desirable or undesirable futures. |
| Future projection | • Evaluate consequences of current policies.<br>• Compare scenarios against future baselines.<br>• Identify likely risks or opportunities. | What future do we expect? | Depictions of the expected future with no new interventions. |

**Table 5 Use of scenarios by different authors. The scenario descriptions are taken from the relevant source document and shortened to give an overview and a brief summary of the scenario.**

| Author | Scenarios | Analysing | Method | Temporal/ spatial extend |
|---|---|---|---|---|
| Millennium Ecosystem Assessment, (2005f) | • Global Orchestration: globally connected society, focus on global trade and liberalization of trade.<br>• Order from Strength: regionalized and fragmented world with an emphasis on primary regional markets and little attention to common goods.<br>• Adapting Mosaic: rise of local ecosystem management strengthening and local institutions.<br>• TechnoGarden: globally connected world which relies strongly on technology and often engineered ecosystems to deliver ecosystem services. | Ecosystem Services identified by the Millennium Ecosystem Assessment. | matrix, indication of direction of ecosystem services provision by arrows. | 2050/ Global (developing countries/ industrial countries) |
| Bateman, (2011), based on UK NEA | • Go with the flow: follows today's socio-political and economic trends.<br>• Green and pleasant land: conservation of biodiversity and landscape are the dominant driving forces.<br>• Local stewardship: localism as a dominant driving force.<br>• National security: UK industry is protected from foreign investors and imports. | Selected ecosystem services | Numerical, based on collected data on the selected ecosystem services. | 2060/ UK |

**Table 5 (cont.)**

| Author | Scenarios | Analysing | Method | Temporal/ spatial extend |
|---|---|---|---|---|
| | • Nature@work: Maintaining and enhancing the output of ecosystem services.<br>• World Markets: unlimited economic growth through complete liberalisation. | | | |
| Creedy et al. (2009), for Natural England | • Connect for Life: major focus on using information and communication technologies.<br>• Go for Growth: Trends dominant in the 21st century continue, focusing on consumption-based society.<br>• Keep it local: slow move towards a slowing globalisation, focusing on local protection.<br>• Succeed through science: development of long-term, forward-looking approaches in order to have a competitive advantage to safeguard social and human capital. | State of the natural environment in 2060 | theoretical analysis, written text. | 2060/ UK |
| Teague et al. (2016) | • Business as usual: current growth patterns continue.<br>• Revitalization: improved infrastructure, especially rail and transit options.<br>• Mass transit: minimised use of automobiles, increased public transport.<br>• Natural Resource Protection: emphasized protection of water resources and wildlife habitat. | Selected ecosystem services | Spatial analysis/ graphic modelling | 2060/ US Tampa Bay region |

The identified studies range until 2060 (2050 for the Millennium Ecosystem Assessment) and explore a varying spatial range for the application of the scenarios, from global (Millennium Ecosystem Assessment), to national (UK National Ecosystem Assessment, Natural England) to regional (Teague et al. (2016)). All studies included one scenario that concentrated on improved ecosystem management. The focus on a more globalised world, which would increase the pressure on environmental resources, is also present. As the presented scenarios are peer-reviewed and accepted by the scientific community, the development of new scenarios can be based on ideas from these scenarios, but incorporate local, as well as newly identified drivers of change, that are relevant for the respective study area.

The analysis of scenarios for ecosystem changes has been attempted by several researchers. Apart from the Millennium Ecosystem Assessment, other studies (Table 5) have selected ecosystem services to be used within the scenario analysis. Provisioning and regulating services are selected by two of the studies, as data for these services can often be accessed and used to provide a numerical analysis of the provision of ecosystem services in the future. However, a gap can be identified here – studies that have identified a wider range of ecosystem services on a local scale are scarce. As previously discussed, ecosystem services are highly site specific, and should be selected on a context basis when assessed.

The analysis of scenarios of ecosystem service provision in the future can be done in a variety of ways. However, the use of a matrix in which the direction of development of the ecosystem service provision can be indicated, is seen as a successful concept to display the information gained from a scenario analysis. The use of a matrix system with either colours, arrows, numbers, or signs indicating the direction of ecosystem service provision can be understood by practitioners as well as academics, and can be informed by different data sources, and presented in a user-friendly manner. The use in the Millennium Ecosystem Assessment indicates a practical use of the tools, which was further developed by Burkhard, Kroll, Müller, & Windhorst (2009) and Jacobs, Burkhard, Van Daele, Staes, & Schneiders, (2014) to incorporate supply and demand capacities of ecosystem service provision.

From the reflection on the use of scenarios, it can be concluded that the use is of high value for a socio-ecological system which is managed through an ecosystem approach. The adaption of management to changes requires an approach which focuses on creating a resilient system. This can be achieved using environmental foresight and the development of scenarios which explore the provision of ecosystem services in the socio-ecological system.

## 2.9. Context and Emerging Questions

Appreciating the great volume of information found in the literature regarding the assessment of ecosystem services in socio-ecological systems, resilience issues, and scenario analysis, questions emerge from this critical review of the literature. These questions inform the methodology and will be answered through the use of the objectives.

In general, ecosystem service approaches are conceptually based on the Millennium Ecosystem Assessment. The core idea of the Millennium Ecosystem Assessment was further developed, including new and individual ideas, which put an individual focus on the respective approaches. Besides differences in definitions, the ecosystem service assessment has been successful in bridging the gap between social and natural science, approaching an improved understanding of socio-ecological systems.

However, it can be argued that ecosystem services assessment is site-specific and it has been evaluated that most ecosystem assessments are based on selected habitats instead of a landscape scale. Here, the question emerges of **how ecosystem services are best assessed in a complex socio-ecological system under constant change?**

Changes are an inevitable part of a system which is influenced by several direct and indirect factors. As human-induced changes influence the ecological part of the socio-ecological system, the provision of ecosystem services can be assumed to be affected. Therefore, the question arises if **the assessment of ecosystem services and the development of scenarios can inform long-term**

**management that aims to provide a resilient provision of ecosystem services in a dynamic socio-ecological system?**

Finally, it has been evaluated that the participation of local stakeholders is a valuable addition to inform the assessment of ecosystem services and the decision-making process. Here, the question arises of **how the knowledge of local stakeholders can be incorporated into ecosystem service assessment and of this can contribute to a model of ecosystem service provision, which aims to further an understanding of the provision of ecosystem services in the future of a socio-ecological system?**

It becomes clear that there is a connection between the emerging questions from the literature review and the objectives by which this research is led. There is a clear need for assessments of ecosystem services that takes local circumstances in consideration that enables a specific understanding and subsequent assessment of ecosystem services for an area, as identified in the first question. This is taken up by objective 1 in which key ecosystem services will be identified and located. The first question also includes the need to address changes within a system. This is linked to objective 2 in which the triggers of changes are identified and further incorporated in a long-term assessment of ecosystem service provision. Objective 2 is further connected to the second emerging question, as the need to inform long-term changes is approached through the development of scenarios. Finally, the incorporation of stakeholder knowledge, identified in question 3 is covered in objective 3 which will enable a modelling of a long-term provision of ecosystem services under different scenarios.

In order to answer the outlined questions, it is appropriate to use a case study approach. This will give the researcher the possibility to develop an approach which is tested in the field, making the transferability to other areas possible. The research model can inspire managers and decision-makers to include the assessment of ecosystem services in the long-term planning of areas. Furthermore, the case study approach gives an insight into the naturally occurring dynamics of a system, which can reveal important aspects for the stakeholders within a particular system (Bassey, 2003). A case study approach presents a powerful method to investigate a dynamic system in a context that is close to reality. By developing a methodology, a rationale, as well as appropriate methods for the application of a case study approach, this research aims to fill gaps in current knowledge and contribute to the understanding of ecosystem services in socio-ecological system.

# 3. Methodology

In this chapter, the developed methodology is presented. Building onto the presented objectives, the theoretical approach is outlined and the use of a case study approach is explained and justified. As part of the methodology, the methods, i.e. tools to conduct the research, are presented in detail.

## 3.1. Rationale

Ecosystems and human systems are strongly interlinked (Liu et al., 2007). As discussed in the previous chapter, these links are incorporated within the concept of an ecosystem approach. This approach can be used in conjunction with other management approaches, taking into account local ecosystems and their management. To do that, however, the ecosystems need to be analysed and understood. This includes the socio-ecological components, which need to be identified before a management system can be established under an ecosystem approach. Development projects that have direct and indirect implications for changes in a study area can also lead to future changes on social and ecological levels (Bateman, 2011). This will, consequently, have implications on the future ecosystems and their management.

This rationale is applied and tested through a case study in the Upper Mersey Estuary (see section 1.3), and aims to inform an ecosystem approach as a means of a future management option. By analysing how future changes in and around the estuary might shape the socio-ecological system of the Upper Mersey Estuary, the long-term provision of the benefits that the area provides to humans can be understood. This analysis has to be based on documents such as policies and strategies of local authorities, in addition to the knowledge and expertise of local stakeholders. The information, that is pulled together from various sources, will be analysed with regard to the objective to produce a scientifically sound approach to assess a long-term management option for the Upper Mersey Estuary. This analysis, although case-specific, can be transferred to other socio-ecological systems through the application of the methods described in this document.

## 3.2. Theoretical Approach and Research Paradigms

In order to develop a sound research approach and corresponding methods, research paradigms have to be established. These will frame the research by theorising the way this project is approached. The ontological position of research describes the researchers view on reality, which expresses what the researcher believes constitutes reality (Grix, 2010). By recognising this, the epistemological position will then build on that, describing the possible method of gaining knowledge for the project (Crotty, 1998; Grix, 2010). Both of these positions have implications for the methodology, the choice of analytical strategy and research design (Hay, 2002), and the techniques to gain knowledge (Grix, 2010). The ontological and epistemological positions are closely connected and frame the (social) context of the research and the approaches taken by the researcher.

Through a critical analysis of the literature, it has been established that by using a study site approach, it is possible to explore the socio-ecological system of the study area. By considering the dynamics of this system, it is acknowledged that the reality is socially and discursively constructed by human actors (Bryman, 2004). The ontological approach to the research is, therefore, of an anti-foundationalist nature (Grix, 2010) , arguing that the world is subjective to the world view of the researcher and the study objects. Within the network of actors and their ideas and perceptions, structures might not be directly observable. This only provides the researcher with a view through a looking glass, but recognises that there is a reality which can be captured by observation. Hence, the researcher is taking part in the construction of this reality (Grix, 2010). Therefore, part of the reality is the inevitable influence on the participants by the researcher. By asking questions, the researcher affects the individuals thinking and opinion, regardless of attempts of an objective setting. This forms part of the research and the researcher's bias should be addressed whenever needed. This bias will be part of the process, but is acceptable due to the reality that is formed via the information gathered through the individuals participating in the study.

Having established an ontological position of anti-foundationalism, the epistemological position will be post-positivistic, looking beyond the realm of explaining phenomena. Instead, interpretation of social phenomena will form the basis of the research with elements of attempts to understand those phenomena.

Aiming to fully understand social phenomena would already fall into an interpretivist epistemological position, as indicated in Figure 13. It has to be acknowledged that the epistemological positions are not self-contained, but can be influenced by other positions (as illustrated by the connecting lines in Figure 13).

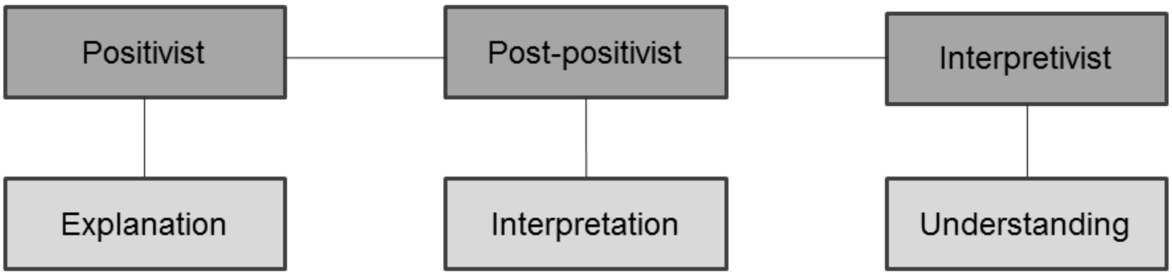


**Figure 13 Research paradigms (epistemology) and their associated type of action, adapted from Grix (2010).**

For this research, the paradigm of critical realism is of interest. Critical realism is the most commonly used epistemological position within interpretivism, which intends to combine the extremes of the 'how', asked for in positivism, and the 'why', studied in interpretivism (Grix, 2010). This research will look at those processes of the natural environment that can be identified as beneficial for humans, by exploring beyond the surface of 'just' the quantitative aspects of the natural environment and humans. A further supporting aspect of a critical realist position for this research is the belief in 'causes' as a dynamic action, which is dependent on changes in mechanisms and conditions – opposed to a purely positivistic view, which would determine causes simply as action (Grix, 2010). However, the aim of the research is not the understanding of the social processes in general, but rather the inclusion and interpretation of social components through the assessment of the perception of benefits gained from ecosystem services at the study site.

Critical realism gives the opportunity to look 'right and left' towards the extremes of positivism and interpretivism. Positivism has a focus on quantitative methods, whereas interpretivism is often concentrated on qualitative methods. Generally, in critical realism the research methods can be both quantitative and qualitative. In this research project, the socio-ecological nature with the focus on the benefit provided by the estuary has a focus on social realities. However, Trochim (2006) stated that critical realism also supports a triangulation of methods to eliminate errors in measures and observation in the research. As mentioned above, the socio-ecological component of the research frames the necessity for an actor's perspective, recognising the diversity of worldviews. However, the data collected on ecosystem services, i.e. their indicators, can also include quantitative data which have to be combined with the information gathered in the 'social' portion of the research. Therefore, the methodology will follow an inductive approach, with the aim to formulate its observations as part of recommendations and theories.

## 3.3. Translating Theory into Practice

This research will explore a small part of a social-ecological system which is part of a larger environment. This wider environment, enclosing the study area, is both directly and indirectly influencing the study area. There are an unknown number of factors that are potentially influencing any system – their importance and impact, however, is often difficult to assess (Liu et al., 2007). Hence, the researcher has to be aware that the constructed reality cannot display the whole and true reality, as there will be unknown and unaccounted factors which impact the system.

Instead, an inclusion of as many sources as possible allow the researcher to form her reality as realistically as possible. Within this study, this is done through the inclusion of stakeholders in the study, who are able to add their knowledge and views to the research (Edelenbos, van Buuren, & van Schie, 2011; Martin et al., 2012; Rigillo & Majello, 2014). The researcher will experience the work with the stakeholders from her own eyes, and will not only and inevitably influence the stakeholders, but will perceive the information as part of a reality that is formed through the collection of information.

Using a combination of methods enables the researcher to look at the research objectives from different perspectives. It includes a perspective that is based on the perception of the stakeholders, but also includes sources from strategic documents and other literature. As the research aims to answer questions about the future of the estuary, the use of different angles and perspectives can be considered a way forward, as through these different perspectives, new ideas and visions of the estuary can be discussed. As the researcher, it is important to keep an open mind to the potential changes, visions, and views of the estuary, avoiding excessively imposing their own perspective onto the research (Chenail, 2011). This is a complex exercise in itself, as the future is an unknown aspect to all parties involved in the project. However, the researcher must be aware of the mentioned research paradigms, to be an observer rather than a participant in the study.

With the theoretical approach and paradigm established, the research design will be used as a foundation to understand the participants' worlds. Qualitative research is especially suitable when the questions to be answered are too complex to be answered by 'simple' hypotheses (Shuttleworth, 2008.). It tries to go beyond straightforward understanding of a situation, by using process-oriented elements (Maxwell, 2013), aiming to analyse situations and their influence on events and people, compared to an analysis of statistical relationships of various parameters.

Beside answering the individual objectives, the study has the overall aim to contribute to science and knowledge creation. Through the selection of different methods, the project is able to combine knowledge that will add to the overall discussion of environmental management. Applying the elements that were identified as the research paradigms, enables the project to use different methods to answer the complex questions which have not been answered in this manner before.

## 3.4. Justification of a Case Study Approach

Management for ecosystem services is, despite not being a new idea to science, difficult to realise in real-world environments (Haase et al., 2014; Ruckelshaus et al., 2015). Due to the limits of resource availability, mainly financial and human resources, a full exploration of the potentials that the ecosystem approach can offer is often constrained. Many applications of the approach and the assessment of ecosystem services have had limited ecosystem services in mind (Ruckelshaus et al., 2015) and despite success stories (Bateman et al., 2013; Kushner, Jungwiwattanaporn, Waite, & Burke, 2012), incorporation into real life decision making has been slow (Guerry et al., 2015; Ruckelshaus et al., 2015). The use of ecosystem services for environmental management is necessarily bound to socio-ecological systems, which come with their own dynamics and complex interactions, and are crucial to consider for both the researcher and manager of any given area.

By adapting a case study approach, it is possible to consider one socio-ecological system in detail with the advantage of real-world experiences in a real-life context (Yin, 2003). Using the case study approach also enables the researcher to answer the questions of ‘how’ and ‘why’ targeted at a ‘contemporary set of events, over which the investigator has little or no control’ (Yin, 2003, p. 9). The researcher is able to use the social and ecological environment to create their case and is not only able to secure data on the uniqueness of a case study, but also prepare the data for a wider generalisation from which other studies can benefit (Hammersley & Gomm, 2002). The issue of generalisation of results produced in a case study has to be considered carefully (Hammersley & Gomm, 2002): naturally, each case has its own details that make the case special and individual, however, based on methods that are established and repeatable, each case study provides a degree of generalisability, which allows other researchers to attempt new conclusions based on different cases.

In any case study, decisions have to be made by the researcher regarding which questions to ask and where to draw the boundary of investigation, physically, theoretically and methodologically. This implies a paradigm challenge: if one of these decisions were made differently, the case study results would be altered altogether as the researcher analyses the data. As Danmoyer (2002, p.63) argues ‘case studies allow us to look at the world through the researcher’s eyes and, in the process, to see things that we otherwise might not have seen’. This point can be applied to most research projects, but it is important to realise that the subjectivity of the researcher is influencing the outcome and conclusions of any project. This should not be seen as a negative aspect of case study work, but rather an inevitable issue that can add important and interesting notions to a project.

## 3.5. Establishing the Socio-Ecological System of the Upper Mersey Estuary

The study site description and stakeholder analysis form a basis to establish the socio-ecological system of the Upper Mersey Estuary. However, a major aspect of the project is not the present condition, or status quo, but the future provision of ecosystem services and recommendations for future management. Changes that will influence the Upper Mersey Estuary will include natural and anthropogenic ones, both shaping the future of the area. In order to establish changes within the socio-ecological system of the estuary, scenarios are employed to make possible changes apparent and to set them into context with the development in the Upper Mersey Estuary. These scenarios are described in section 4.4.8.

Before the establishment of the methods suitable for this project, a decision has to be made regarding which ecosystem services should be included in the analysis of the socio-ecological system. An important basis for the research project in the Upper Mersey Estuary is the work by Natural England (2013b). Their categorisation and identification of ecosystem services in the Mersey Valley will give an indication of the predominant ecosystem services in the wider area. The location of the study area in a coastal and urban environment has to be taken into account. The coastal and urban zones form the transition between water and land interface and are among the most productive biomes (Adnitt et al., 2007). It becomes clear that the concept of ecosystem services, which bridges the difference between the social and natural systems (Glaser, 2012), is particularly applicable to the Upper Mersey Estuary, due to the high natural and anthropogenic values of this natural transition zone. Also, the variety of different habitats will support a wide range of ecosystem services (Jackson et al., 2013).

Jacobs et al. (2014) identified a list of ecosystem services which are potentially important for industrialised estuaries. A comprehensive list was developed through expert judgement in four countries in north-west Europe. The authors also argue that the supporting services were included as 'total amount of abiotic and biotic diversity at all levels, regardless of rarity and vulnerability' (Jacobs et al., 2014, p. 3). This argument is employed for the Upper Mersey Estuary and the assessment of ecosystem services in the context. This gives the research the advantage of concentrating on provisioning, regulating, habitat, and cultural ecosystem services. The inclusion of biodiversity as an ecosystem service is supported by the importance of the estuary as a wildlife site (Natural England, 2013b, Mersey Gateway Environmental Trust, personal communication, various dates).

## 3.6. Methods

### 3.6.1. Assessment of Land Use and Land Cover in the Estuary

In order to assist the understanding of the provision of ecosystem services in the Upper Mersey Estuary, an assessment of land use and land cover was conducted. The assessment was based on UK National Land Use Database and adapted to the specific local context. Both land use and land cover were assessed through consultation with experts, as well as field visits. Maps were produced in a Geographical Information System as part of a summer internship of a Masters student in summer 2016.

### 3.6.2. The Stakeholder in the Upper Mersey Estuary

In order to understand a network of stakeholders, the tool of 'stakeholder mapping' can be used (Freeman, 2010). Even though the tool is based on the subjective perception of the user, it can deliver a good qualitative assessment of the stakeholders in a system (Bourne & Weaver, 2010). The mapping tool most commonly used, uses a schematic representation of a grid, using the relationship of 'influence' (or also called power) to 'interest' that a stakeholder has in a subject matter or project, as for example used by the Imperial College London (2016). The development of a stakeholder matrix was an essential exercise to understand the stakeholders of the Upper Mersey Estuary. The example of a grid structure, using interest versus influence is adopted (Bryson, 2004). Four major grid positions were identified to display the stakeholders of the Upper Mersey Estuary, describing their stake at present and their possible position in the future:

- High influence, high interest: these stakeholders are important stakeholders who influence the decision-making process and without whom the implementation of change can fail, e.g. landowners. These stakeholders are important to keep engaged and informed about all management processes and planning stages.

- High influence, low interest: these stakeholders might be difficult to reach and communicate with. However, every effort should be made to inform the stakeholder of plans and projects, without overwhelming them with information.
- Low influence, high interest: even though these stakeholders might not have a high influence in the decision making, they are important partners in the planning process of projects. These parties should be well-informed about major steps and actions. They have ideas and visions which should not be neglected in the decision-making process. An example of this category are NGOs.
- Low influence, low interest: these stakeholders are least affected by the decision-making process. Information flow can be minimal, as no major interest in the decision-making process or change in influence can be expected.

The classifications of the stakeholders into six categories (landowner, nature NGO/trust, science/education, leisure/recreation, business/company, and administrative/government) was adopted, according to their position and work within the context of the Upper Mersey Estuary. It was, therefore, important to notice that some stakeholders were classed depending on their position in the Upper Mersey Estuary, despite the possibility that stakeholders could be classed into different categories for other sites. An example was the classification of the Cheshire Wildlife Trust as a NGO/Trust, due to its activity in the Upper Mersey Estuary. However, the Cheshire Wildlife Trust also owns land in the UK, and might therefore, be classed in this category in other studies.

Stakeholders grouping offered a tool to identify those stakeholders that have an impact on the project that is going to be investigated. As Olander & Landin (2005) concluded in their study, a matrix based on the categories listed above, give a good overview for the project manager, here researcher, to understand the dynamics of a stakeholder group. Including this analysis in the research, the validity of the project was strengthened, by distinguishing the different elements of the group and recognising that a group of stakeholders is not static.

### 3.6.3. Review of Strategic Documents

To understand the future development of the Upper Mersey Estuary, the plans and visions made by stakeholders had to be critically evaluated. Part of this critical analysis was a review of the strategic documents developed and published by the planning departments of Halton Borough Council and Warrington Borough Council. The identification and anticipation of problems and opportunities was carried out for the Upper Mersey Estuary, as these elements can be considered to be important in the development of future management plans.

This analysis aimed to generate new knowledge regarding three main topics that are recognised in Objectives 1 and 2:

1) The areas of core change: the thematic areas that have been identified in the core strategies, which form the basis of the future development plans in the boroughs. This information helped to establish an idea of how the borough might develop in the long-term.
2) The triggers of change that influence the future of the estuary: The collection of triggers of change were identified and analysed regarding their applicability in the Upper Mersey Estuary.
3) The environmental concerns and management of the boroughs: The aim was to review the documents with a focus on the natural environment. This included the perception of environmental key terms such as climate change, sustainability, green spaces, any mentioning of ecosystem services and their location in the boroughs.

The critical evaluation of the documents was carried out with the following criteria in mind:

- The core strategies were the main strategic documents regarding future changes and planning for Halton Borough Council and Warrington Borough Council. Supplement documentation is listed as appropriate.

- The documents were analysed to identify areas of change and core topics which might influence developments in the Upper Mersey Estuary. It was not the aim to list the strategies and objectives of the councils, but rather to identify how this information can be incorporated into different futures of the study site.
- The administrative area was recognised to go beyond the study area of the Upper Mersey Estuary: changes that were recognised around the estuary were included in the analysis to a certain extent on a case-by-case basis. The spatial extent of the analysis covered the town centres of Runcorn, Widnes and Warrington.
- The provision and change of ecosystem services was considered in the analysis although no direct use of the term 'ecosystem service' could be identified. For example, the increase of recreational area through land use changes was considered to describe an ecosystem service.

In order to validate the results of the review of the strategic documents, the criteria listed above provided transparency in this element of the research, which was based on case-specific data. In coherence with the theory of post-positivism outlined in section 3.2, the researcher had to appreciate the construction of different aspects of this socio-ecological system, in order to understand the complexity of it (Noor, 2008). The formulation of core topics and criteria enabled a consistent review of the literature and provides the necessary guidance on which elements can be included in the analysis.

#### 3.6.3.1. A SWOT Analysis as part of the review of strategic documents

A SWOT analysis as carried out for both boroughs as part of the view of their respective strategic documents. It identified the strengths (S), weaknesses (W), opportunities (O), and threats (T) of the respective borough. SWOT analyses were first developed in a business context (Hill & Westbrook, 1997) and have remained popular as a tool for planning, as well as policy and decision-making (Marilyn & Judy, 2010).

The analysis was based on the status quo of the boroughs, i.e. the borough's reality, which is described in the strategic document. This information supported the understanding of the boroughs' future and the possibilities that arise from the core topics. Referring to the main topics identified for the analysis of the core documents described in the previous section, the SWOT analysis was used to collect information on the core areas and triggers of change that can be identified for the two boroughs.

#### 3.6.3.2. Environmental Management within the Boroughs

The review of strategic documents aimed to identify a variety of potential triggers of change that will influence the environmental management of the Upper Mersey Estuary in the future. The issues and elements of environmental management addressed in the planning documents were identified to give an idea about how the natural environment is captured in the core strategies of the boroughs.

Six keywords were identified, covering the natural environment and its management in the borough. The identified keywords were counted in the text of the core strategy documents of Halton and Warrington Borough Council and enabled an identification of potential foci of environmental management within the study area. The keywords were defined in Table 6.

The environmental management aspirations, highlighted in the core strategy documents, gave insights in the future management ideas of the boroughs. Therefore, information could be collected to inform future scenarios of the estuary. The identified keywords created a thorough overview of the elements addressed in the management of the natural environment in the estuary.

**Table 6 Keywords used in the analysis of aspects of environmental management in Halton Borough Council and Warrington Borough Council.**

| **Keyword** | **Description** |
|---|---|
| Climate Change | The effects of climate change are varied and can include challenges in water management, e.g. flood water management; landscape management, e.g. arrival of new species; land management, e.g. land loss due to sea level rise. Other aspects such as energy provision with renewable energies are also considered. |
| Ecosystem Services | The term ecosystem service has not been used in the documents. However, references were made to specific ecosystem services such as recreation, sense of place, flood protection, etc. Supporting services were not included. |
| Environment | This term was defined as the natural environment. |
| Green Belt | The Green Belt land is an important feature of the boroughs and was included due to its importance regarding land development for housing and commercial purposes. |
| Green Infrastructure | The keyword included green infrastructure throughout the borough, e.g. parks and nature reserves as well as the natural element, e.g. trees, in landscaping. |
| Sustainability | Sustainable development was included as a term depending on the context of the sentence – the documents included economic sustainability, which were not included in the search. Only when the term was used according to the definition of Goodland (1995), the term was included to explore the attempt of the borough to become environmentally sustainable in the future. |

### 3.6.4. The Design and Application of the Delphi Method in the Upper Mersey Estuary

It was suggested in the literature review, that the application of a Delphi method would aid the understanding of environmental foresight, by offering a possibility to understand stakeholders' visions and views on a certain topic. Considering these benefits, a Delphi method was applied in the Upper Mersey Estuary. Delbecq, van de Ven, & Gustafson (1975) base the success of a Delphi on three criteria:

1) The process should not take longer than 45 days,
2) Participants are skilled in written communication, and
3) The motivation of the participants is high.

Since there was not a large group of researchers available to work on the implementation of the method, the process was expected to take longer than the suggested 45 days, although the time spent on the data collection was kept as short as possible. Delbecq's et al. (1975) second criterion, the participants' skill in written communication, was assumed to be fulfilled without any doubt, as this project was based in an area of high literacy. The last point to successfully conduct a Delphi method, the high motivation of the participants, was ensured through the hand-out of participant information sheets and, where possible, personal communication between the researcher and the participant before and during the Delphi process. As some authors point out, the drop-out rate is expected to rise after the first round, especially if the first round of questions is not well understood by the participants (Adler & Ziglio, 2002; Delbecq et al., 1975). To keep the participation rate high, the intentions of the method and the relevance to the research had to be understood by the participant.

It is suggested in the literature that the identification of experts is often based on existing networks which get extended by the snowball principle (Nahuelhual, Carmora, Lozada, & Jaramillo, 2013; Scolozzi et al., 2012). The experts for participation in the Delphi method were identified mainly in co-operation with the Mersey Gateway Crossings Board and the Mersey Gateway Environmental Trust, which operate a joint database of contacts available in the Upper Mersey Estuary.

The design of the survey was tailored to the study area. The survey had been developed over several months at the University of Salford and received ethical approval by the university (approved 30/03/2015, Appendix 2). This Delphi technique used a questionnaire to collect first results in a non-intrusive and anonymous way for the participants, which was followed up with a workshop

(Figure 14). To keep the motivation of the participants high, a site visit to the estuary and the construction site was arranged as part of the workshop.

Due to its altered process, the Delphi can be considered to be a modified Delphi. The traditional elements of the Delphi were extended to fit the purpose of the project, but continued to include the aspects that are expected as part of this method (see section 2.8.1 and this section).

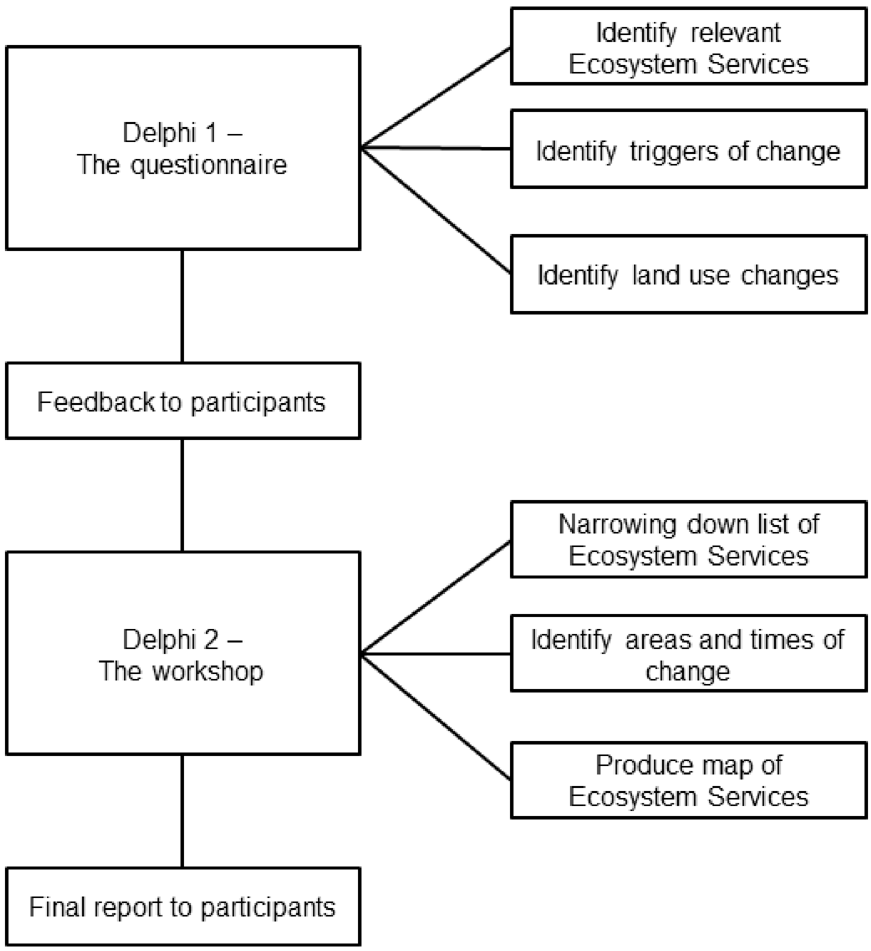


**Figure 14 Conceptual presentation of the modified Delphi method used in this project.**

The modifications were justified by a number of reasons which are important with regard to the success of the research project:

**Consensus**: Following the original idea of the Delphi, a continuous iteration process is employed to reach consensus in one or more topics. However, for this research project, the consensus of the group was not the thematic focus – the collection of ideas and gathering of knowledge in a semi-anonymous way was valued as more important than reaching consensus at the end of the exercise.

**Anonymity**: the first round of the Delphi was conducted anonymously. This was important in order to capture the individual viewpoints of the participants. With no one interfering with more dominant opinions, the participants could submit their answers at their own pace, without the pressure of other participants or an interviewer.

In the workshop, a more open environment was created. However, in two of the three exercises of the workshop the results were collected anonymously, with only the researcher being able to access the full results, including names. The third exercise (developing an ecosystem services map), an open working environment was supported, enabling the participants to work alone or in small groups.

**Response rate:** Generally speaking, a high response rate is preferable. The rate, however, is influenced by several factors; in case of internal surveys among a known group of respondents, for example, the response rate is expected to be higher than in external surveys distributed among an unknown group of people. It has been established that internal surveys can receive a response rate of 30–40 % on average, whereas external surveys obtain a 10–15 % response rate (Fryrear, 2015). A response rate between the minimum and maximum values was expected for the Upper Mersey Estuary.

#### 3.6.4.1. The Questionnaire

The questionnaire was developed through literature studies and working together with the Mersey Gateway Crossings Board and the Mersey Gateway Environmental Trust. A pilot was run within the University of Salford and the Mersey Gateway Crossing Board, and feedback was given regarding the comprehensibility and technical issues of the questionnaire.

The questionnaire was distributed to the stakeholders of the Upper Mersey Estuary at the beginning of summer 2015. The participants were initially contacted by a member of the Mersey Gateway Crossings Board by e-mail, to introduce the research project and its objectives. This seemed to be an appropriate step to engage the participants' interest in a project they were not aware of. Following this, the participants received an e-mail including the questionnaire, participant information sheet, and a consent form. The first round of data collection ended in October 2015.

The questionnaire comprised four questions. The aim within this round of the Delphi was to collect information about the relevant ecosystem services, the triggers of change and information regarding possible land use changes within the Upper Mersey Estuary (Figure 14). The questionnaire can be found in Appendix 3. All answers were collected in excel spreadsheets, protected by passwords, as set out in the ethical approval.

Regarding the identification of relevant ecosystem services in the Upper Mersey Estuary, an ordinal Likert scale from 'very important' to 'not important at all' (5 = very important, 4 = important, 3 = neither important, nor unimportant, 2 = of little importance, 1 = unimportant, 0 = I don't know) was used. The 75% mark was used to indicate a majority decision. Stevenson, Campbell, & Kielmann (2003) use a mark of 80% as a cut-off point in their study. However, it can be argued that in the case of the Delphi technique of this project, the majority did not need to exceed a three-quarter majority. The objective was to identify the most relevant ecosystem services for the Upper Mersey Estuary, which was achieved by this cut-off point and indicated the overall direction of thinking of the experts asked to adapt their management, so that it supported an ecosystem approach.

#### 3.6.4.2. The workshop

The second stage of the Delphi was conducted as a workshop. This workshop had the objective to collect further data, to look at the previously collected information from the questionnaire in more detail, and to widen the knowledge regarding the ecosystem services and possible changes in the Upper Mersey Estuary (Figure

14). The participants who took part in the questionnaire were invited to take part in a one-day workshop on the 7th June 2016. The aims of this workshop were:

1) To confirm and/or narrow down the list of relevant ecosystem services relevant for the Upper Mersey Estuary.

2) To discuss where and when changes within the Upper Mersey Estuary are most likely to occur.

3) To present and extend the list of triggers that might affect the Upper Mersey Estuary.

4) To produce a map of ecosystem service locations in the estuary.

5) To experience the knowledge of the people, who know the estuary, from different perspectives.

The participants were mainly identified from the respondents of the first Delphi round. All participants who submitted the questionnaire were invited to the workshop. Additional participants were suggested by the Mersey Gateway Environmental Trust.

To answer the questions relevant for the data collection, two techniques were employed:

1) Kahoot (Kahoot, 2017): This online educational platform was used to design voting exercises. It was utilised for the two main activities of the workshop. The tool provided an opportunity to collect anonymous[3] and spontaneous answers.

   The first part of the exercise worked with the previously identified list of relevant ecosystem services. The ecosystem services were to be ranked according to their importance in the ecosystem services. As they were all considered to be relevant, the participants were asked to rate between '+++', '++'. '+', and 'I don't know'.

[3] The answers were submitted anonymously at the time of the exercise. The results were downloaded in form of an excel sheet after the exercise, including a breakdown of answers by name.

The second part of the exercise collected information about when the participants expected change in the individual site compartments to happen. The options given in the Kahoot were: ‘within the next 5 years’, ‘within the next 15 years’, ‘within the next 26 years (end of 2043)’, or ‘not before 2044’. This was based on several assumptions:

- Change within the next 5 years: this is a short-term change. The participants will be able to picture the future to some extent.
- Within the next 15 years: this is mid-point of the operational period of the Mersey Gateway Environmental Trust. Changes occurring between year 6 and 15 can be understood to be medium-term changes, which can be predicted by the participants with knowledge of the area and specific information.
- Within the next 26 years: these changes will fall between year 16 and 26, until the end of 2043, which marks the end of the operational period. These are long-term changes and are difficult to predict, but their documentation provides an indication and a vision of the future of the study site.
- Not until 2044: change is unlikely, especially in the operational period. Changes might still take place, but are not likely to fall into the operational period.

2) Mapping Exercise: A mapping exercise was used to identify the location of ecosystem services in the Upper Mersey Estuary. The participants identified the occurrence of ecosystem services by using coloured dots and could note specifications on post-it notes. These maps were later digitalised in QGIS (QGIS Development Team, 2009).

It was ensured that all participants were aware that they could ask questions in case of uncertainties (email or telephone, during the first round, or in person at the workshop).

Using a Likert-type scale in the questionnaire, facilitated an understanding of the agreement of the participants on the relevance of ecosystem services. Data such as Likert-type data are inherently difficult to analyse, due to its characteristic as ordinal data (Allen & Seaman, 2007). However, it allowed extraction of the information needed for the purpose. The interpretation of the data aimed to construct a list of ecosystem services which could be achieved with this questionnaire and rating system. As no further statistical analysis was intended, the use of ordinal data can be justified for this case, as it is the commonly used scale in a Delphi method and offered a user-friendly approach for the participants (Murry Jr & Hammons, 1995).

The second round of the Delphi, aimed to rate the importance of the identified ecosystem services, used a Likert-like scale, employing the ‘+’-symbol. The plus-sign is commonly associated with positivity and, therefore, was an appropriate symbol to describe the importance of the selected ecosystem services. At this point in the data collection, the participants had already selected the relevant ecosystem services in the Upper Mersey Estuary. By using a positive scale, the connection between the relevant ecosystem services and the importance rating could be denoted.

The bias of participants towards certain ecosystem services had to be recognised and is discussed in the analysis of the responses. By using a modified Delphi technique, the informant bias could be kept low, as the data were collected anonymously in both rounds.

### 3.6.5. Scenarios for the Upper Mersey Estuary

The scenarios for the Upper Mersey Estuary were used to describe possible futures of the Upper Mersey Estuary until 2044, the time period in which the Mersey Gateway Environmental Trust is committed to work with the management of the land area. Therefore, the development of scenarios will be beneficial for the work of the Trust, the landowners operating in the areas, as well as policy-makers, by offering a tool to assess the future of the estuary.

The scenarios for the Upper Mersey Estuary were derived from different sources. First, through interaction with stakeholders of the Upper Mersey Estuary, ideas and visions were documented, delivering an idea about what the stakeholders expect to happen in the future of the Upper Mersey Estuary. Second, planning documents published by the relevant borough councils were reviewed with the aim of identifying the area's development. The scenarios were mainly of the 'future projection' type (section 2.8.2). A certain exploratory element was also included in the scenarios to explore the future of the study site and potential areas of change.

Three scenarios were identified for the Upper Mersey Estuary (section 4.4.8). These scenarios helped to identify opportunities for the provision of ecosystem services and possibly contributed to the identification of risks. The scenarios of the Upper Mersey Estuary focued upon the natural environment as an essential element, as this focus is considered vital in the attempt to provide information regarding the provision of ecosystem services. The changes that will take place in the Upper Mersey Estuary will change the natural, social, or economic environment, allowing a wide range of possibilities until 2044.

### 3.6.6. A Model for the Evaluation of the Future Provision of Ecosystem Services

As part of objective 3, the project sets out to develop a model that indicates the future provision of ecosystem services. The model was based on qualitative assessment and combined expert opinion with literature-based findings. The extent and characteristics of the study site demanded a comprehensive model, which was able to combine information based on land use, land cover, local boundaries, socio-political and socio-ecological changes within the area. It was, therefore, not relevant to provide a detailed quantitative model of provided ecosystem services, but to be able to produce an insight of the holistic development of ecosystem services in the study area, with the aim to develop new, and adapt existing, management options. The model was Excel-based and translated into a Word format for readability. Assumptions that were made in order to clarify factors/condition of the provision of the service were included in the documentation of the model.

The model played through all three scenarios, looking at each identified relevant ecosystem service on a site compartment level. For each spatial unit, the change for each ecosystem service was determined. The model discriminated between no change (0), positive change (+), and negative change (-) in the provision of an ecosystem service for a particular site compartment. Other means of describing the change could have been through arrows (e.g. Millennium Ecosystem Assessment, 2005e), or shades of colours (e.g. UK National Ecosystem Assessment, 2011). However, the use of three symbols that have positive (+), negative (-), and neutral (0) attributes were considered straightforward for application and understanding.

The decisions of the direction of change were based on the knowledge gained throughout the project, by joining several site visits, working in the offices of the Mersey Gateway Crossings Board, and continuous communication with the stakeholders, in particular with the Environment and Biodiversity Officer of the Mersey Gateway Crossings Board. The rating of change in provision of ecosystem services was supported by assumptions and by references, wherever possible.

Based on the model tables, maps were developed to visualise areas of positive and negative change in individual site compartments. This was achieved by weighting the ecosystem services at each site against their importance (+++, ++, +), and dividing it with the total number of available ecosystem services at this site. By weighting the ecosystem services against their importance, a consistent scale could be defined for the elements of the data. Used regularly in Multi-Criteria-Analysis, weighting is a means to assign a value, reflecting the relative importance of the item and to be able to create a meaningful process for decision-making (Department for Communities and Local Government, 2009).

The model of the future provision of ecosystem services in the Upper Mersey Estuary formed a vital part of the research and draws on the data that was collected in previous steps of the research. By including a representation of change, a detailed description of the expected change and graphic presentation of the change through maps, the model delivered valuable insights into potential ecosystem services and offered a means of delivering recommendations for future management.

# 4. Results

Two dependent sets of results are presented within this chapter. Firstly, a set of supplementary results are shown in section 4.1 and 4.2, and secondly the main results, addressing the objectives of the research. The organisation of the results chapter is conceptualised in Figure 15. The supplementary results explore the land use and land cover of the Upper Mersey Estuary, as well as the presence and participation of the estuary's stakeholders. The supplementary results are independent of each other, therefore, shown next to each other in the flow diagram, whereas the main results are organised by objectives, following a logical order from objective 1 to 3.

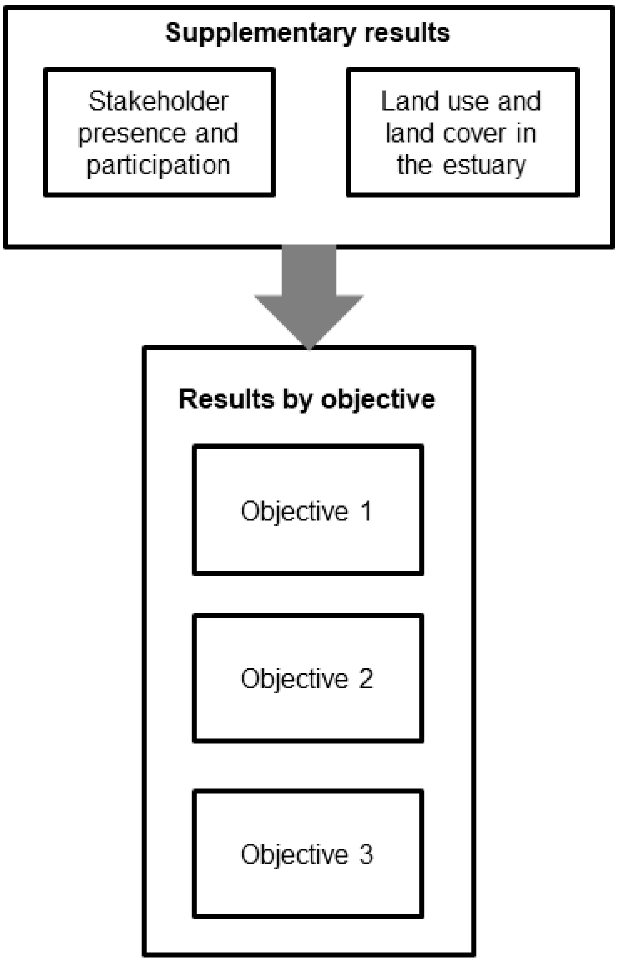


**Figure 15 Flow diagram of the results, indicating the supplementary results which feed into the results that directly inform objectives 1-3.**

## 4.1. Land Use and Land Cover of the Estuary

The analysis of the land cover and use of the Upper Mersey Estuary was carried out in order to produce maps that show the distribution of the land categories in the estuary[4], using the National Land Use Database (Harrison, 2006). Land cover and land use maps on the scale presented in this section are currently not available within the UK, and present a valuable tool for land managers in order to have a holistic view on the estuary. Land use and land cover were classified at least on an order level, but if possible, a group level was assigned. Detailed descriptions can be found in Appendices 4 and 5.

Land use can be defined as the activity or socio-economic function for which land is used, whereas land cover describes the physical nature or form of the land surface (Harrison, 2006). The present land use of the Upper Mersey Estuary is diverse and represents the semi-urban environment in which the Upper Mersey Estuary is embedded (Figure 16). The land use and land cover of sites can be influenced by historic land use, restricting the present land use and cover through, for example, landfilling or chemical industry and subsequent pollution of soils (Harrison, 2006). Within the estuary, examples of sites that have restricted land use at present are now converted to Local Nature Reserves, e.g. Wigg Island, Upper Moss Side Local Nature Reserve, and Oxmoor Local Nature Reserve. Domestic and industrial landfilling took place in the area known as Gatewarth, which is now classified as an open and amenity space. Arpley, a landfill site for residual municipal waste, which stopped operating in 2017, will fall under restricted land use, with plans in place to develop the site into a recreational site for the public (Warrington Borough Council, 2014).

[4] The exercise was conducted in conjunction with a post-graduate student on a summer internship at the University of Salford.

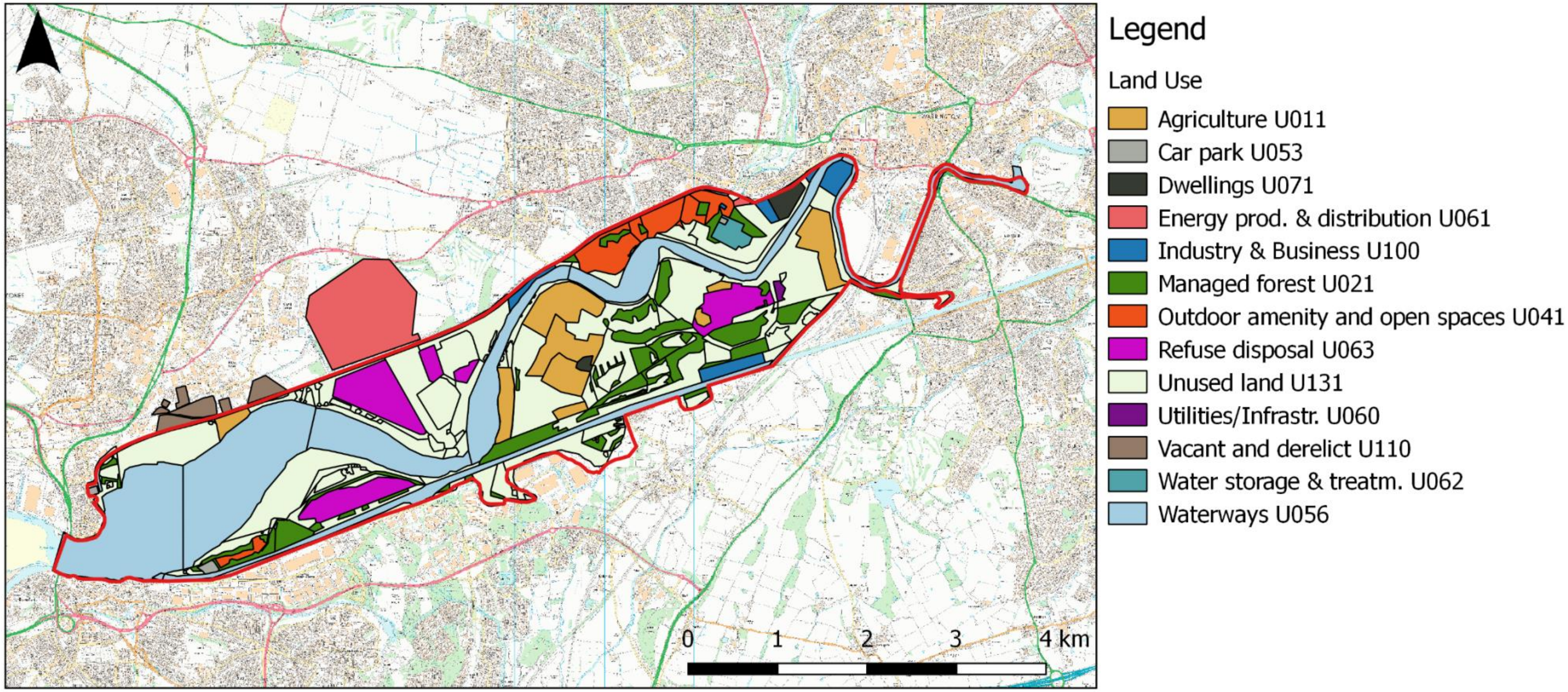




**Figure 16 Land use map of the Upper Mersey Estuary, including National Land Use Database classification; based on Gely (2015).**

Large parts of the Upper Mersey Estuary fall into the land use category ‘unused land’[5], even though there is public access to some of the areas, making it more appropriate to classify the areas as open and amenity spaces. However, the National Land Use Database defines amenity and open space as, for example, ‘gardens, parks, zoos, picnic areas and play areas’, ‘civic spaces e.g. civic squares, plazas, sea fronts’, or ‘heritage sites and monuments’ (Harrison, 2006, p. 36), whereas the land in the Upper Mersey Estuary can be better described as open land used for walking, cycling, or other outdoor activities, that are not dependent on existing infrastructure. Despite not fully representing the land use of the Upper Mersey Estuary, the land use category adds valuable information regarding the infrastructural elements of the estuary, and in combination with the land cover provides data on the natural and anthropogenic infrastructure in the Upper Mersey Estuary.

The land cover in the Upper Mersey Estuary is varied. The map in Figure 17 shows the distribution of land cover within the study site. Within the western part of the estuary, the land near the river is dominated by saltmarshes and permanent surfaces. In the eastern side of the study area, the land cover is dominated by grassland and woodland. The land cover category includes additional detail regarding the natural elements of the estuary and provides an overview of the habitats of the study site. The National Land Use Database does not include reed beds as a land cover type, but due to the importance of reed beds and the active management of several reed beds in the estuary, these were included as a separate category.

[5] Unused land (U130): 1) Semi-natural areas which are not part of routine cultivations or being grazed and which have never been used for development, including scree, cliff, dunes, marsh and beach, reclaimed land which has not been grazed or developed.
2) land or water bodies for which no specific primary use can be determined
3) excludes vacant land (U111)
4) excludes low-intensity agricultural use (U011)

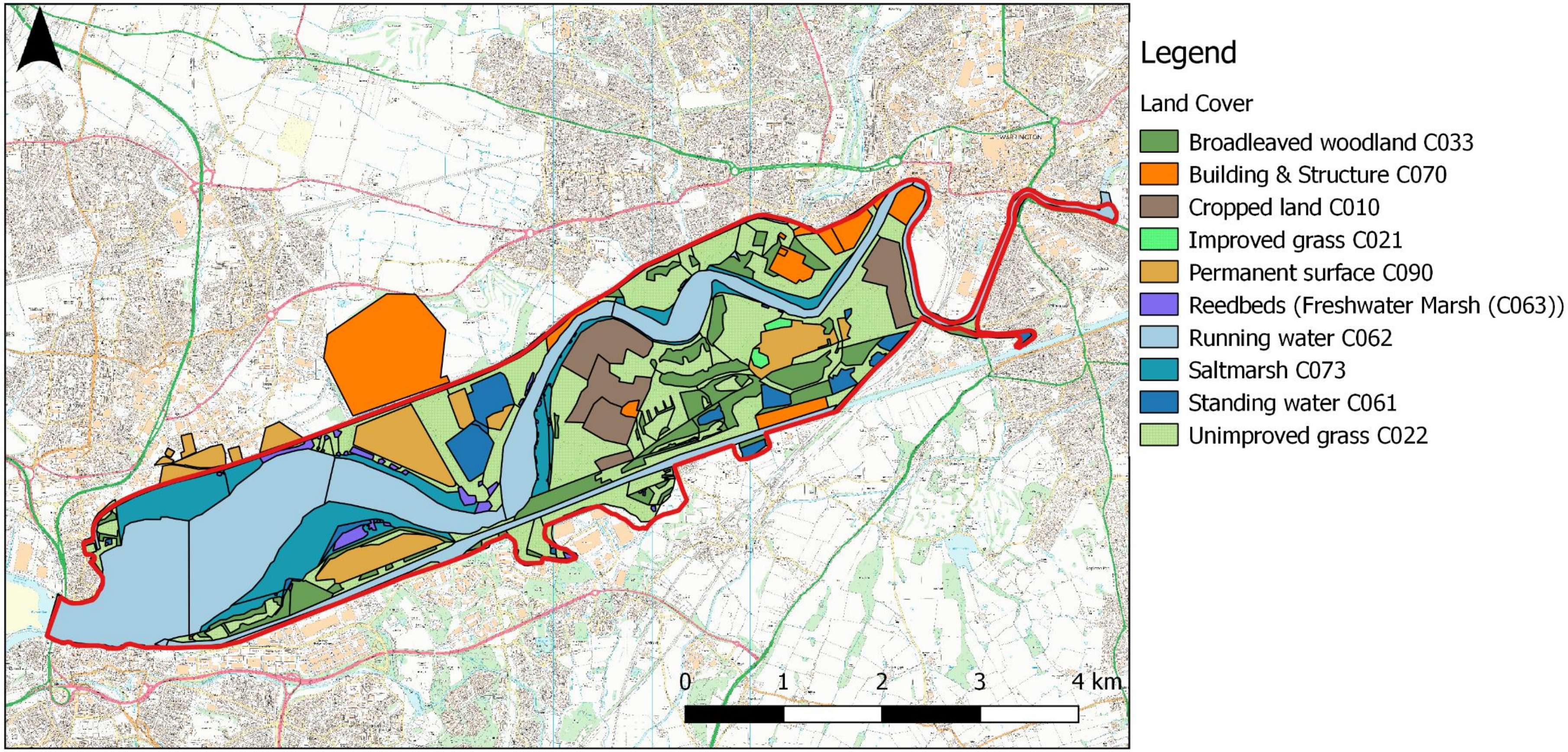




**Figure 17 Land cover map of the Upper Mersey Estuary, including National Land Use Database classification; based on Gely (2015).**

Another notable characteristic is the classification of large parts of the Upper Mersey Estuary as 'Green Belt' (Figure 18). Planning regulations and building development are restricted on this land, with the aim of preventing the sprawl of towns and cities. This will have major implications on the future development of the Upper Mersey Estuary, as changes in regulation can lead to increase in use for development purposes.

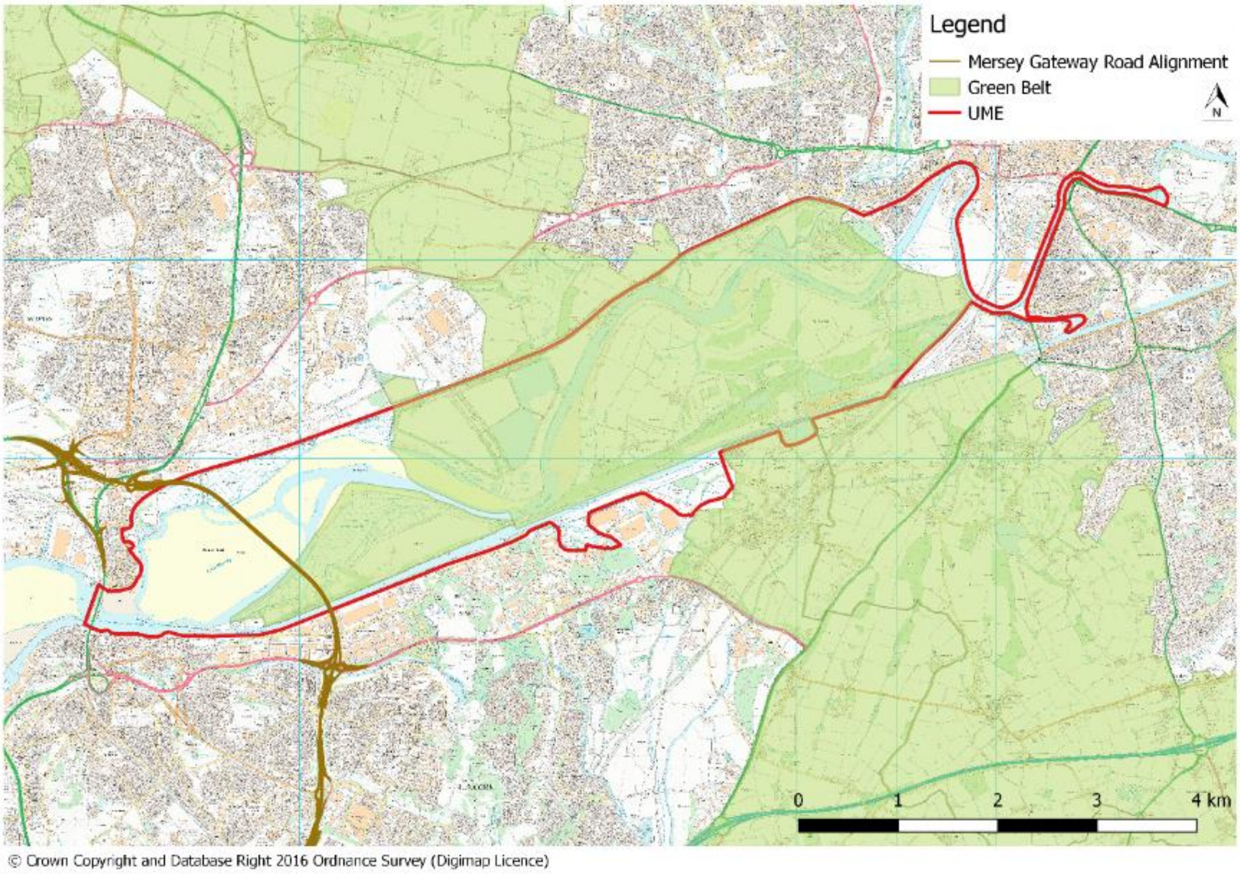


**Figure 18 Extent of Green Belt in Halton Borough Council and Warrington Borough Council, sourced from data.gov.uk (2015).**

The future land use and land cover depends on a variety of factors, which will directly and indirectly shape the land use and land cover of the estuary. Analysing the status quo of the estuary regarding its land use and land cover, enables decision-makers and planners to see the estuary as a whole. This information can facilitate discussion among stakeholders and decision-makers, who acknowledge the socio-ecological system and who want to draw conclusions from data that capture aspects of a socio-ecological system. The results of this section directly feed into the analysis of the objectives. Hence, a discussion of the land use and land cover is not included, but integrated into the discussion of the respective objectives.

## 4.2. The Presence and Participation of Stakeholders in the Upper Mersey Estuary

The stakeholders that were identified in the Upper Mersey Estuary are grouped in the previously described matrix (section 3.6.2). This was achieved by using the knowledge that had been acquired working in the offices of the Mersey Gateway Crossings Board, as well as through the professional opinion of Paul Oldfield and Elaine Newall, who both have several years of professional experience with the stakeholders of the Upper Mersey Estuary. Thus, the matrix is constructed from the perspective of the researcher herself and the information given by the Mersey Gateway Crossings Board.

The positions of the stakeholders are shown according to their role in the Upper Mersey Estuary in Figure 19. It was not expected that all identified stakeholders would participate in the study, however, it is important to assess the stakeholders' position, in order to ultimately draw conclusions on the actual participation of stakeholders.

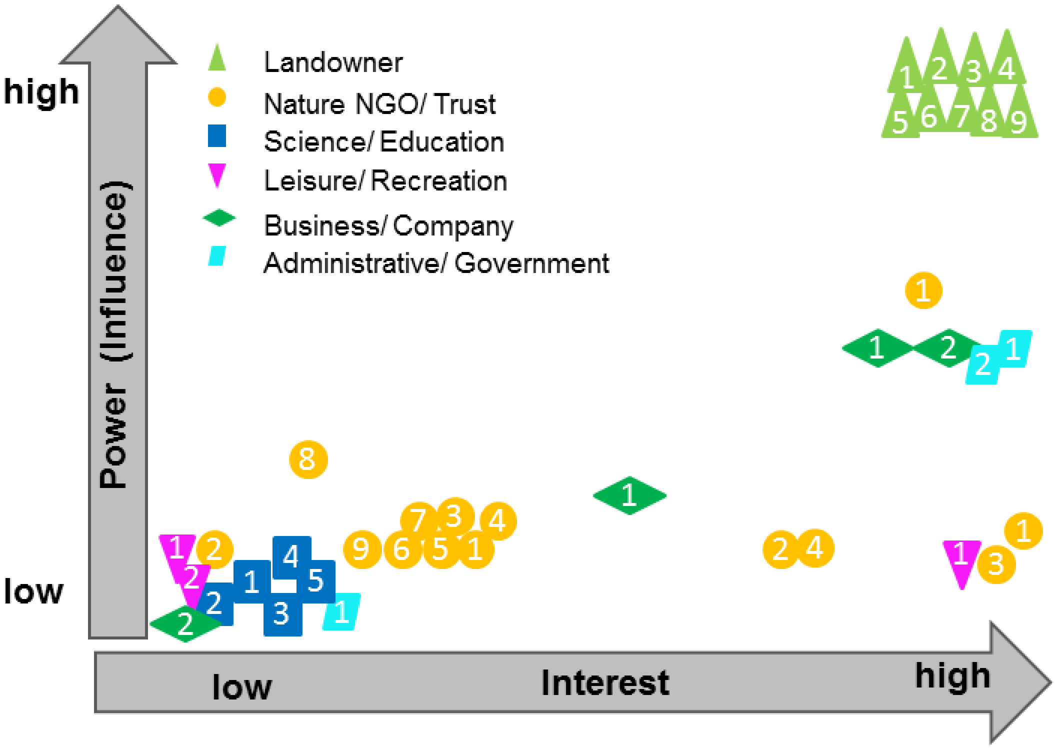


**Figure 19 Dynamic Stakeholder Matrix displaying the Upper Mersey Estuary stakeholders that were contacted, classed by their role in the Upper Mersey Estuary, regarding their interest and influence in the study area.**

The stakeholders with the most influence in the Upper Mersey Estuary are the landowners[6], who have sole control over their property and need to be informed about any action that involves their land. Their decision-making power affects actions taken in the area. The landowners also generally show high interest, as their land would be directly affected by the management of the area. The Mersey Gateway Environmental Trust is also listed among the parties which have a high interest and a high influence in the area. This arises from the Trust's particular position as a charity, that has been set up for the management of the area's environment, following the construction of the Mersey Gateway Crossing.

[6] Two land owners were not contacted in the study (Duchy of Lancaster, The Crown Estates). The stakeholders own the mudflats and access routes to those. In later management works, these two stakeholders will have to be considered as they, for example, hold the shooting rights for wildfowl in the estuary.

The category of high interest – low influence, includes governmental and regulatory bodies such as Natural England and the Environment Agency. A reason for the classification of Natural England in this category, despite its overall high influence in the British environmental sector, is the lack of designation in the study area and, therefore, limited influence on the management of the estuary. The Environment Agency, although generally interested in the management of the Upper Mersey Estuary, is currently prioritising other areas of interest and resources are not currently diverted to the Upper Mersey Estuary (personal communication, date unknown, P. Oldfield). It is, therefore, also classed into the high interest – low influence group. Several NGOs and trusts can be found in this category, due to their specific activity in the study area (e.g. biodiversity monitoring). These stakeholders might have an interest in the Upper Mersey Estuary, because of their geographical location, previous projects or activity, or use of the estuary for their purposes. The stakeholders can be contacted easily and communication with the representatives is based on a good understanding of each other's interests.

About half of the stakeholders are grouped into the low interest – low influence group. These stakeholders will most likely play a less dominant role in the management of the Upper Mersey Estuary, but nevertheless contribute to the complete picture of the study area.

The effective participation of the stakeholder is shown in Table 7. The participation in the first round of the Delphi (questionnaire) delivered a response rate of 50 %. The participation in the workshop resulted in 31% of the initially contacted stakeholders taking part. The majority of participants in both rounds were representatives of NGOs or trusts active in the estuary. Four representatives of landowners were present, which reduced to two in the workshop.

With regard to the influence – interest relation of the group of stakeholders it can be noted, that in the first Delphi round, five high influence – high interest stakeholders were reached (four landowners, one NGO/trust) (Table 8). The most stable participation of stakeholders came from the low influence – high interest category, in which six and five stakeholders participated in the questionnaire and workshop, respectively. The highest participation in the questionnaire came from the category of low influence – low interest with seven participants, reducing to three participants in the workshop.

**Table 7 Category and number of stakeholder: contacted and responded.**

| Classification | Contacted | No. participants Questionnaire | No. participants Workshop |
|---|---|---|---|
| Landowner | 7 | 4 | 2 |
| Nature NGO/Trust | 15 | 7 | 5 |
| Science/Education | 6 | 2 | 1 |
| Leisure/Recreation | 2 | 1 | 1 |
| Business/Company | 3 | 3 | 1 |
| Administrative/Government | 3 | 1 | 1 |
| **Total** | **36** | **18** | **11**[7] |

**Table 8 Influence-interest relationships of participants in the Delphi technique, both questionnaire and workshop.**

| Influence-interest relation | No. participants Questionnaire | No. participants Workshop |
|---|---|---|
| High influence-high interest | 5 | 3 |
| Low influence-high interest | 6 | 5 |
| Low influence-low interest | 7 | 3 |

The participants were generally well-informed about the concept of ecosystem services, with 65% of the respondents having worked with the idea before; only one participant considered the concept as new (Table 9). Most of the participants representing the landowners claimed they had not worked with the concept before (data not presented to keep anonymity of participants) even though they are of

[7] In total 12 workshop participants were present, but one stakeholder was present with two participants.

high influence and interest in the estuary and have ultimate decision power over their land, whereas the majority of NGO/trusts had experience with the concept.

**Table 9 Experience with the concept of ecosystem services**

| Statement | No. participants |
|---|---|
| Yes, I worked with the idea before. | 11 |
| Yes, I read about it. | 2 |
| Yes, I have heard about it. | 3 |
| No, this concept is new to me. | 1 |
| Other | 0 |
| total | 17* |

* one participant did not answer the question.

## 4.3. Objective 1: Identification of Ecosystem Services in the Upper Mersey Estuary

### 4.3.1. Identification of Present Ecosystem Services

This section contains the results that form part of objective one: to identify the present ecosystem services in the Upper Mersey Estuary. This exercise was based on the results of the Delphi technique, collecting data from the stakeholders that acted as local experts and contributed to the research through their knowledge of the Upper Mersey Estuary.

The identification of present ecosystem services is important from two aspects: i) to be able to identify relevant ecosystem services and their importance in the estuary; and ii) to be able to formulate recommendations for the management of the Upper Mersey Estuary within the period until 2044. Based on a list of estuarine ecosystem services by Jacobs et al. (2015), the participants selected 18 relevant ecosystem services. The results are presented in Table 10.

**Table 10 Relevant Ecosystem Services identified by Delphi participants (>75% of agreement).**

| Service category | Ecosystem Service | Relevance (%) [1st Round] | Importance [2nd round] |
|---|---|---|---|
| Provisioning | Ornamental resources | 100 | + |
| Habitat | Biodiversity | 100 | +++ |
| Regulating | Carbon sequestration and burial | 94 | +++ |
| Regulating | Flood water storage | 94 | +++ |
| Regulating | Removing harmful particles, air water exchange, biogeochemical reaction | 89 | ++ |
| Regulating | Water thermodynamic regulation | 89 | ++ |
| Regulating | Peak discharge buffering | 89 | +++ |
| Regulating | Landscape maintenance | 88 | +++ |
| Regulating | Erosion and sedimentation regulation by water bodies | 83 | +++ |
| Regulating | Pollination | 83 | ++ |
| Regulating | Wave reduction | 78 | ++ |
| Regulating | Biological regulation of soil processes and soil formation | 78 | ++ |
| Regulating | Heat exchange regulation | 77 | ++ |
| Cultural | Aesthetic appreciation | 100 | +++ |
| Cultural | Opportunities for recreation & tourism | 100 | +++ |
| Cultural | Sense of place | 89 | ++ |
| Cultural | Inspiration for culture, art & design | 83 | + |
| Cultural | Inspiration for cognitive development | 78 | +++ |

The most important ecosystem service in the Upper Mersey Estuary, as indicated by the Delphi panel, are habitat services (biodiversity) and two cultural services on which all stakeholders agreed within both rounds of the Delphi technique (all 100 % relevance in the first round, and +++ importance rating in the second round). The results by ecosystem service category are described in the following sections.

#### 4.3.2. Provisioning Services

From a list of 15 potential provisioning ecosystem services in estuarine environments, one service was selected: ornamental resources[8]. Although the stakeholders initially agreed on ornamental resources as an important service (100 % of the stakeholders found it important), the second round revealed a much lower rating. Despite this service being listed as a provisional service, it has to be considered that this provision influences another final service such as the aesthetic appreciation of the landscape, which received a high importance rating. The provisioning services were marked and mentioned less than the other services (Figure 20), with four comments, indicating services at four locations in the estuary. The mapping exercise shows that the local experts were able to locate provisioning services (provisioning services were marked eleven times). Not all markings of ecosystem services were accompanied with notes, however, the comments (Table 11) included the importance of water provision for the local power station (Point A in Figure 20), as well as the provision of land for dwellings and development.

[8] Explanation of the service: presence and use of organisms for decorative purposes

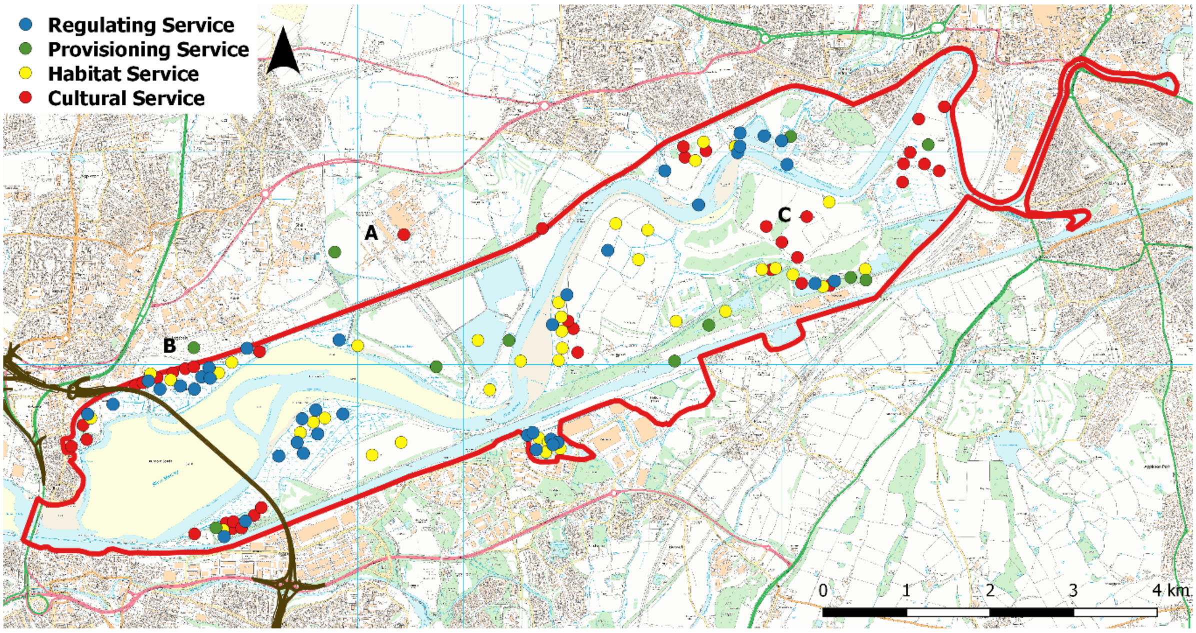



**Figure 20 Map of Upper Mersey Estuary, with identified locations of ecosystem services as a product of the Delphi workshop. Points A = Fiddlers Ferry, point B = Tan House Lane, Point C = Arpley landfill.**

**Table 11 Notes on provisioning ecosystem services, collected from the mapping exercise; brackets [ ] indicate exclusion of respective part from the statement by the author; parentheses () are used when participant included them him/herself.**

| | Comment | Site |
|---|---|---|
| **Provisioning services** | 'Water for industrial use' | Fiddlers Ferry & Cuerdley Marsh |
| | 'Potential flood 'relief' area [+ biodiversity'] | Moore Nature Reserve |
| | ''Safe' land for building out of flood plain' | Tan House Lane |
| | 'Building land on flood plain' | Warrington Waterfront |

### 4.3.3. Habitat Services

Biodiversity was rated 100 % relevant in the first round and its importance was indicated as '+++' in the second Delphi round. Despite localisation of biodiversity in most parts of the estuary (Figure 20), the highest density of biodiversity is located at sites which have public access and supporting elements for the observation of wildlife, for example, bird hides or good views over the estuary and its mudflats. The habitat service was mentioned mainly in conjunction with cultural ecosystem services (Table 12) such as recreation, sense of place, and well-being. Six locations were identified in the mapping exercise.

**Table 12 Notes on habitat ecosystem services, collected from the mapping exercise; brackets [ ] indicate exclusion of respective part from the statement by the author; parentheses () are used when participant included them him/herself.**

| | Comment | Site |
|---|---|---|
| Habitat services | 'Eel passage issues into brooks' | Arpley Landfill |
| | '[Recreation] and biodiversity' | Gatewarth |
| | 'Biodiversity [+well-being]' | Moore Nature Reserve |
| | 'Important for biodiversity [and sense of place] | Moore Nature Reserve |
| | '[Potential flood 'relief' area] + biodiversity' | Moss Side Farm agricultural land |
| | 'Biodiversity, [recreation + flood control carbon sequestration on marsh (+trees)]' | Moss Side Farm |
| | '[Flood control +] biodiversity' | Oxmoor |
| | 'Oxmoor LNR probably most …biodiversity' | Oxmoor |

### 4.3.4. Regulating Services

Eleven regulating services were identified. Five of the eleven regulating services received a '+++' rating in the second round of the Delphi. The comments collected in the mapping exercise mention the ecosystem services that were previously identified as relevant (Table 13). Carbon sequestration was mentioned seven times in comments for a variety of sites. Furthermore, issues relating to water quality and quantity (flood water discharge) were frequently mentioned (n=13). Pollination is mentioned three times, identifying three locations for which the ecosystem service is likely to be particularly relevant (Oxmoor, Wigg Island, Widnes Warth).

The comments on regulating ecosystem services could be attributed to ten sites in the Upper Mersey Estuary. Arpley landfill is mentioned four times. The implications are discussed in section 5.2.6. The saltmarsh habitats of Astmoor and Widnes Warth, Oxmoor Nature Reserve, and the United Utilities site were mentioned four times, respectively.

**Table 13 Notes on regulating ecosystem services, collected from the mapping exercise; brackets [ ] indicate exclusion of respective part from the statement by the author; parentheses () are used when participant included them him/herself. Note from author: unsure of spelling; ** Note from author: TPT= Trans Pennine Trail.**

| | Comment | Site |
|---|---|---|
| Regulating Services | 'Carbon sequestration with trees' | Arpley Landfill |
| | 'N/P binding' | Arpley Landfill |
| | 'Eel passage issues into brooks' | Arpley Landfill |
| | 'Water quantity drainage of river water (Sankey + Whittle Brooks)' | Arpley Landfill |
| | 'Carbon sequestration' | Astmoor Saltmarsh |
| | 'Flood control + water quality' | Astmoor Saltmarsh |
| | 'Improved water quality from expanse of reedbed' | Astmoor Saltmarsh |
| | 'Water quantity regulation, dissipation of tidal energy' | Astmoor Saltmarsh |
| | 'Climate regulation thermodynamic regulation' | Gatewarth |
| | '[Biodiversity, recreation] + flood control, carbon sequestration on marsh (+trees)' | Moss Side Farm |
| | 'Water quantity drainage of river water' | Oxmoor |
| | 'Pollination (meadow)' | Oxmoor |
| | 'Flood water storage' | Oxmoor |
| | 'Reducing extreme weather event impact balancing outflow of Leekwick* brook + tidal events' | Oxmoor |
| | 'Air quality - woodland' | Port Warrington |

**Table 13 (cont.)**

| Comment | Site |
|---|---|
| 'water regulation [+ recreation (TPT) habitat]' | St Helens Canal |
| 'Canal water quantity, drainage, storage' | St Helens Canal |
| 'Ground water levels prevent/reduce saline intrusion' | United Utilities |
| 'Water quantity drainage of river water' | United Utilities |
| 'Water quality, transport of pollutants/nutrients' | United Utilities |
| 'Climate regulation, heat exchange + thermodynamic regulation on water bodies' | United Utilities |
| 'Carbon sequestration' | Widnes Warth |
| 'Pollination' | Widnes Warth |
| 'Carbon sequestration; flood control + sedimentation etc etc.' | Widnes Warth |
| 'C sequestration of saltmarsh' | Widnes Warth |
| 'Carbon sequestration' | Widnes Warth |
| 'Pollination' | Wigg Island |

### 4.3.5. Cultural Services

The cultural ecosystem services of the Upper Mersey Estuary were generally perceived of high importance in the Upper Mersey Estuary with five of six ecosystem services selected from the initial list. Two of the cultural services were rated 100% and received '+++', highlighting the cultural importance of the estuary to the local experts. Cultural ecosystem services were marked especially in areas with public access for walking, dog walking, and bird watching (Figure 20). Cultural services were recognised at nine separate locations. Wigg Island and Warrington Waterfront were mentioned four times, St. Helens Canal and Arpley landfill were mentioned three times, respectively, with the remaining locations being mentioned fewer times. Cultural services are frequently (n=7) mentioned in conjunction with biodiversity (Table 14).

**Table 14 Notes on cultural ecosystem services, collected from the mapping exercise; brackets [ ] indicate exclusion of respective part from the statement by the author; parentheses () are used when participant included them him/herself.**

| | Comment | Site |
|---|---|---|
| Cultural Services | 'Future opportunities recreation' | Arpley Landfill |
| | 'Recreation – Trans Pennine Trail' | Arpley Landfill |
| | 'Conservation & recreation' | Arpley Landfill |
| | 'Recreation and (biodiversity)' | Gatewarth |
| | '[Biodiversity] + well-being' | Moore Nature Reserve |
| | 'Important for [biodiversity and] sense of place' | Moore Nature Reserve |
| | '[Biodiversity,] recreation + [flood control, carbon sequestration on marsh (+trees)]' | Moss Side Farm |
| | 'Flood control [+ biodiversity]' | Oxmoor |
| | '[water regulation +] recreation (TPT) [habitat]' | St Helens Canal |
| | 'Fishing amenity Trans Pennine way, green route' | St Helens Canal |
| | 'Sense of place, first canal in the country' | St Helens Canal |
| | 'Museum and public space in close proximity to urban area. Increased use when Jubilee use -80%' | Spike Island |
| | 'Recreation and well-being' | Spike Island |
| | 'Sense of place – Transponder Bridge' | Warrington waterfront |
| | 'Recreation & tourism – Trans Pennine' | Warrington waterfront |
| | 'Sense of place' | Warrington waterfront |
| | 'Transponder Bridge' | Warrington waterfront |
| | 'Recreation' | Wigg Island |
| | 'Access to nature + sense of place, historic industry' | Wigg Island |
| | 'Appreciation of nature and industry heritage (3 bridges)' | Wigg Island |
| | 'Accessibility' | Wigg Island |

## 4.4. Objective 2: Changes to the Socio-ecological System of the Upper Mersey Estuary

Changes that are going to influence the socio-ecological system of the Upper Mersey Estuary in the future (until 2044) were identified via two different methods: the Delphi technique and a review of strategic documents that were published by Halton Borough Council and Warrington Borough Council. Objective 2 aims to identify triggers of change in the estuary and conduct an analysis of change in the context of the Upper Mersey Estuary. In this section, the strategies, initiatives, and visions that are pertinent for the future of the Upper Mersey Estuary are described.

### 4.4.1. Areas of Core Change in Halton Borough Council

The Halton Borough Council core strategy was published in 2013 and covers a period of 15 years, from the year of publication until 2028. It was published as a guidance document for future development in the borough. The document is linked with the National Planning Policy Framework (Department for Communities and Local Government, 2012) and adds to the planning policies laid out on a national level. The core strategy is considered to be the main strategic planning document for the borough. An overview of the core topics that are discussed in the core strategy, including the supplementary information available, are shown in Figure 21. The complexity of the documents can be narrowed down to the core strategy and its core topics. The strategic documents are revised with a focus on those areas that are in proximity to the study area, therefore not including the wider area of Halton Borough Council.

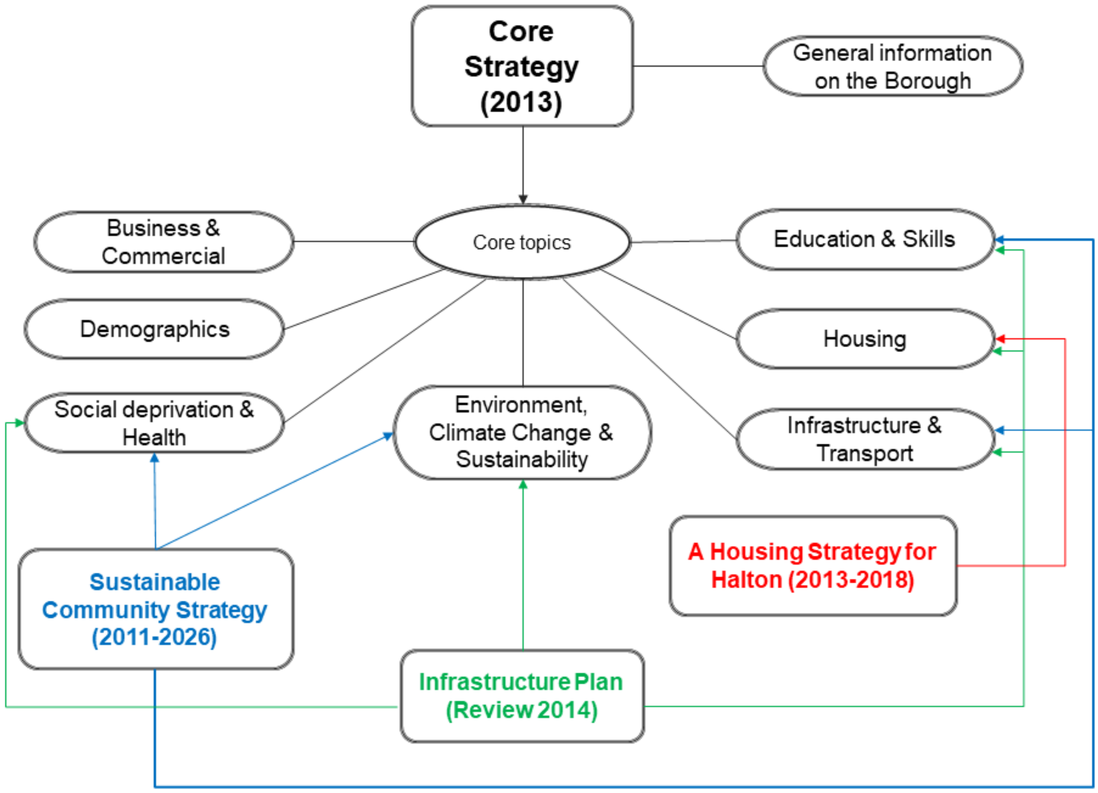


**Figure 21 Core policy topics of the Halton Borough Council. Supplementing documents that can provide additional information on individual topics are indicated through arrows to the respective topic.**

The main topics of the review that could impact possible futures of the Upper Mersey Estuary are described in this section and are used to understand the wider and changing picture that influences the future of the Upper Mersey Estuary. The status quo along with the vision of the borough council were identified for Halton Borough Council (Table 15).

**Table 15 Halton Borough Council core areas of change, based on the information provided in the core strategy document of Halton Borough Council**

| Issue | Status quo | Objective |
|---|---|---|
| **Commercial development** | The supply of land for the development of commercial properties has become difficult in recent years. The commercial sector has been suffering from recent economic downfalls. There are a number of strategic projects which aim to bring commercial development to the area. | • To maintain a five-year supply of employment land.<br>• To make approx. 313 ha of land available for economic growth until 2028. |
| **Housing** | Compared to the national average the borough has a lower proportion of owner-occupied and private rented dwelling stock, and a significantly higher proportion of population renting housing from Registered Social Landlords. The need for lower income houses for new forming households and affordable housing are increasingly not being met. The borough also suffers from a deficiency in large family houses. The housing strategy for Halton for the years 2013 – 2028 describe the vision, objectives, and priorities that Halton Borough Council has laid out regarding this issue. | • Achieve a good housing mix, with easy access to facilities.<br>• Maintain a five-year housing supply.<br>• At least 40% of new houses are delivered on brownfield land. |
| **Infrastructure and transport** | The infrastructure and transport network in Halton Borough Council is well developed and benefits from a central location between the near cities of Liverpool and Manchester. It can provide good links to major motorways (M56, M62), as well as good railway connections to Liverpool and the South. A further transport link is provided by the proximity to Liverpool's John Lennon Airport. A future infrastructural improvement is the completion of the Mersey Gateway Crossing, which will provide an additional transport route over the estuary, with an intentional design to attract long-distance travel, e.g. between the motorways, improving residential transport networks. | • Maximise benefits of existing structures<br>• Minimise the need for new infrastructure<br>• Facilitate access to waterfront and other recreational spaces |

**Table 15 (cont.)**

| Issue | Status quo | Objective |
|---|---|---|
| **Education, skills and employment** | A large proportion of workers are employed in manufacturing industries, along with distribution, information and communication sectors. However, the borough suffers from high rates of unemployment and worklessness. The workforce has generally low levels of education and skills. | • Provide employment by strengthening commercial development. |
| **Health and Wellbeing** | Halton Borough Council is performing poorly in the overall ranking of deprivation. A further concern of the borough is the poor health outcome of the population in recent years. | • Improvements of walking and cycling opportunities.<br>• Widening of cultural, sport and recreational amenities. |
| **Natural Environment and climate change** | The borough has a historic legacy of obsolete and poor-quality land, housing, commercial buildings, physical infrastructure and contaminated land. Its physical appearance improved significantly, but challenges remain to integrate the landscape into a green environment. The borough has a tightly drawn Green Belt and benefits from a substantial green infrastructure such as parks, recreational grounds, and open spaces. One Ramsar Site, one Special Protection Area, three Sites of Special Scientific Interest, ten Local Nature Reserves and 47 Local Wildlife Sites can be found in Halton Borough Council. | • All development is sustainable.<br>• A reduction in carbon dioxide emissions.<br>• Developments should include climate change resilient and carbon management measures.<br>• Decentralised low carbon energy scheme which do not harm the natural environment without appropriate mitigation measures. |

**Table 15 (cont.)**

| Issue | Status quo | Objective |
|---|---|---|
| | Also, 12 Open Spaces of Green Flag awards have been awarded to the borough. Other natural character sites include the waterfront environments along the Mersey Estuary, the Manchester Ship Canal, the Bridgewater Canal, St Helens Canal and the Weaver Navigation. Approximately one third of the borough is designated Green Belt land. Regarding climate change, effects on Halton's natural and built environment are identified which might be affected through increased chances of flooding. Several sites have been identified as at risk to flooding due to their close proximity to the estuary and the number of brooks flowing into the estuary. | • Where appropriate, opportunities are taken to restore, add to or create habitats.<br>• A hierarchical approach will be given to protection, conservation and improvement of biodiversity.<br>• Improving Green Infrastructure networks |

Considering the short to medium term future, it can be established that the borough's key ideas of change manifests themselves in commercial and residential development, in order to strengthen the economy, together with providing sufficient housing for its residents. The commercial development of Halton Borough Council is likely to extend into the boundary of the Upper Mersey Estuary (Halton Borough Council, 2013, p.8). Furthermore, the strategy recognised the use of previously developed land (e.g. brownfields) for use as either commercial and/or residential development. Along the boundary of the Upper Mersey Estuary, land south of Widnes (Widnes Waterfront) has been identified as suitable land.

Residential development planned in the borough is not expected to take place inside the boundary of the Upper Mersey Estuary, due to flood risk and Green Belt obligations (Halton Borough Council, 2013, p.128, 130). Outside the boundaries of the Upper Mersey Estuary, the site compartment Tan House Lane is identified as a potential location for future mixed residential and commercial development (Halton Borough Council, 2013, 2016).

Infrastructure and transport is mainly influenced by the construction and operation of the Mersey Gateway Crossing. This is expected to promote other infrastructural developments in the area, as the new crossing will enable movement across the estuary for local traffic (using the Silver Jubilee Bridge) and guide through-traffic, destined for locations outside the borough, over the new crossing (Halton Borough Counci, 2011, Mersey Gateway Project & Halton Borough Council, 2011).

Due to the low level of education as well as health and well-being, the borough also identified these aspects as core areas of change. The strategic documents highlight the need to invest in these aspects to ensure a healthy work force (Halton Borough Council, 2013, p.125).

The core strategy does not propose any changes to the natural environment directly, but supports a general principle of conservation and protection. However, the location of the Upper Mersey Estuary within the Green Belt and the operation of the Mersey Gateway Environmental Trust within the area, support the aims to structurally enhance the natural environment of the estuary. The construction of the Mersey Gateway Crossing initiated planning regarding the futures of the natural environment within the boundary (Halton Borough Council, 2013, p.49/50).

#### 4.4.2. SWOT Analysis – Halton Borough Council

A SWOT analysis was used to provide further background information on the status quo of the borough council. The SWOTs listed in Table 16 are summarised from the core strategy document and are deliberately kept broad to enable a discussion on possible futures at a later stage.

The SWOT analysis identifies Halton Borough Council's strengths within the fields of its infrastructure, due to its location in the country, between Manchester and Liverpool. Within the borough, the benefits are an extended network of retail and network centres, due to several urban centres within the borough. The further identified strength is the natural and industrial heritage of the borough. This addresses the natural environment and the opportunities that result from the history, presenting it as an opportunity to protect these environments. The identified weaknesses are on a societal level and address the quality of life of the residents, whereas the threats are addressing the non-provision of benefits that are created from the borough's environment, e.g. flood protection, climate control, and sense of place.

**Table 16 SWOT Analysis drawn from Halton Borough Council's policy documents.**

| | Beneficial | Harmful |
|---|---|---|
| **Internal** | **Strength**<br>• Infrastructural hotspot (motorways, airports)<br>• Network of retail & leisure centres (Widnes town centre, Halton Lea, Runcorn Old Town)<br>• Natural and industrial heritage | **Weaknesses**<br>• Weak economy<br>• Housing deficit<br>• Low investment<br>• Poor health<br>• Unemployment/worklessness<br>• Poor quality land |
| **External** | **Opportunities**<br>• Mitigation and adaptation measures to deal with climate change<br>• Sustainable use of resources<br>• Protect, enhance, expand Halton Borough Council's green infrastructure network<br>• High quality of development<br>• Development in various sectors: science & technology, logistics & distribution | **Threats**<br>• Changing population structure<br>• Deprivation<br>• Flooding<br>• Pollution, contamination<br>• Loss of character (due to major developments) |

### 4.4.3. The Natural Environment in the Strategic Documents of Halton Borough Council

The analysis of environmental keywords shows the focus of the core strategies of the borough regarding the environment. The analysis is later incorporated into the scenario development. The Green Belt was mentioned most with 25 comments, followed by sustainability and environment. Green infrastructure was mentioned 19 times. The fewest comments were collected for climate change (n=11). The natural environment is incorporated into the core strategy document of the borough council; however, it is recognised that the social aspects of the borough are targeted more than the natural aspects of the system. This seems appropriate for the aim of the document, nevertheless, a connection between social and natural aspects is not apparent and the natural environment is often perceived to be an external factor which is not seen as an integral part of the borough.

**Table 17 Sum of keywords on the natural environment identified from the Halton Borough Council core strategy.**

| Keyword | References |
|---|---|
| Climate Change | 11 |
| Environment | 22 |
| Green Belt | 25 |
| Green Infrastructure | 19 |
| Sustainability | 23 |

### 4.4.4. Areas of Core Change in Warrington Borough Council

The core strategy of Warrington Borough Council was published in 2012 and undertakes an analysis of the core topics and visions of the borough until 2027. Similar to the core strategy of Halton Borough Council, it is incorporated into local and national planning policy. It forms one of the major documents on which other local plans are based (Warrington Borough Council, 2014).

An overview of the core topics that are discussed in the core strategy, including the supplementary information available, is shown in Figure 22. The complexity of the documents can be narrowed down to the core strategy and its core topics. The strategic documents are analysed with a focus on those areas that are in proximity to the study area, omitting those parts of the documents that are dealing with the eastern parts of Warrington Borough Council.

Similar to Halton Borough Council, Warrington Borough Council has set their core strategy to focus upon structural developments, i.e. housing and commercial development through the provision of appropriate areas (Table 18). Non-structural aspects such as well-being and health are also discussed, intending to cover the boroughs main aspects for a medium-term planning period. The status quo, as well as the vision of the borough council, are used to identify possible developments.

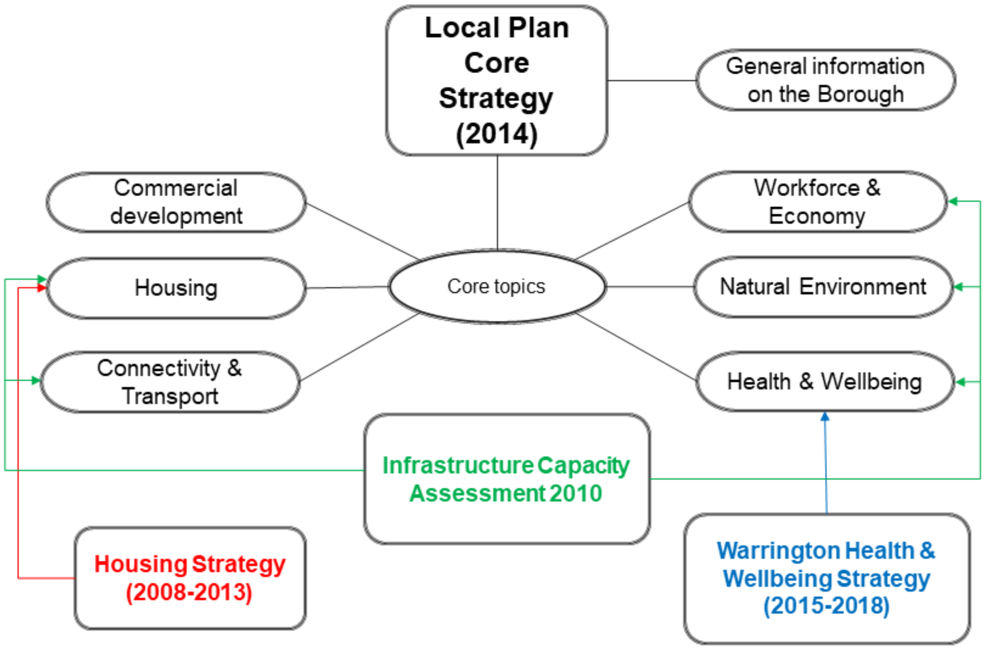


**Figure 22 Core policy topics of the Warrington Borough Council. Supplementing documents that can provide additional information on individual topics are indicated through arrows to the respective topic.**

**Table 18 Warrington Borough Council core areas of change, based on the information provided in the core strategy document of Warrington Borough Council.**

| Issue | Status quo | Objective |
|---|---|---|
| **Commercial development** | **Port Warrington**: Planning permission was granted in 2011 to extend the existing distribution centre (warehouse complex) by 4.5 ha. The construction of refurbishment of the site, extension of the canal side berth and re-instalment of the rail freight connection will be completed in 2017. This development will take place in the context of Port Warrington and Atlantic Gateway. The location is entirely in Green Belt land, but there might be special circumstances permitted for further development. | • Supporting growth and local economic activity.<br>• Provision of 277 ha of employment land until 2027.<br>• Identify locations for development in or on the edge of Warrington Town Centre. |
| **Housing** | The borough has a shortage of houses. Over 400 additional affordable houses need to be supplied, additional to the so far completed ones (aiming for 90% on previous developed land).<br><br>**Inner Warrington**: new homes, accessible employment and training opportunities, enhance the quality of Green Infrastructure and biodiversity.<br><br>**Waterfront & Arpley Meadows**: This is brownfield land which has been considered for residential development. Due to the nature of the site, there are constraints regarding flooding issues in the area. Despite the potential of the site itself, it is unlikely that the site will be developed in the next 20 years. This area will most likely stay in its current state until after the end of the operational period. | • Maintaining a 10 year forward plan of housing land<br>• Provide a balanced mix of houses (type, size, tenure)<br>• The majority of newly developed houses to be built on previously developed land (30% on greenfield sites) |

**Table 18 (cont.)**

| Issue | Status quo | Objective |
|---|---|---|
| **Infrastructure and Transport** | The area is a hub of the region's communications network. Vehicle access is available through the M6, M56, and M62 motorways. Rail connectivity is given through the north-south West Coast Main Line, and the east-west Trans Pennine rail routes. The Manchester Ship Canal connects the Mersey with the Port of Manchester. The town is car dependent and the use of private vehicles is high compared to the national average. | • Support the development of non-car models for travel, including walking, cycling and public transport routes.<br>• Support economic activity generated and sustained by the Manchester Ship Canal.<br>• Maintain and improve railway system for freight transport.<br>• Improve links between residential areas and employment areas. |
| **Education, skills and employment** | In general Warrington Borough Council has a strong labour market and a strong growth in workplace earnings and high skills. However, Inner Warrington and the town centre are especially known for high level of deprivation. The town centre is the main area for retail and leisure facilities. The retail is strong but has little diversity. The town centre is affected by the decentralisation through the New Town development. | • Create accessible employment and training opportunities.<br>• Aim for lower worklessness and unemployment. |
| **Health and Wellbeing** | The health situation in Warrington Borough Council is below national average and concentrated to Inner Warrington and the town centre. The health deprivation is high. | • To have people as healthy as the national health standard.<br>• Provide sport, recreational, and cultural facilities. |

**Table 18 (cont.)**

| Issue | Status quo | Objective |
|---|---|---|
| **Natural Environment and climate change** | Warrington lies within the Mersey Valley corridor and the Sankey Valley Linear Park. The Mersey Valley corridor, exceeding 2 km in some places, is an area of land which extends from Fiddlers Ferry Power Station in the west, to Hollins Green and the flood plains of the River Bollin in the east. The Sankey Valley Park is a six-kilometre-long corridor, running north to south through Warrington, linking the Green Belt to the north, to the River Mersey in the south. It is an important area for flora and fauna, as well as leisure and recreation. | • Maintain the Green Belt.<br>• Minimise the impact on the environment, ensuring development to be energy efficient and resilient to climate change, as well as avoid environmental problems through developments.<br>• Enhance quality of Green Infrastructure and biodiversity.<br>• Mitigate and adapt to flood risks in the borough.<br>• Improve air quality. |

The commercial development and investment in economy and workforce is incorporated into the core strategy by proposing development in the town centre, as well as other commercially active sites outside the Upper Mersey Estuary. The Atlantic Gateway project (Atlantic Gateway, 2012) intends to invest in the development of strategic development sites within the borough (Port Warrington and the Manchester Ship Canal). However, the site identified for the development of Port Warrington is entirely within the Green Belt boundary (Warrington Borough Council, 2014, p. 39), implying that changes to that boundary would be necessary.

Residential development in the borough is a core issue for Warrington Borough Council and new development is outlined within the vicinity of the town centre, within the bend of the river Mersey (Arpley meadows), with the potential to develop previously developed land for mixed development. Due to certain areas such as Warrington Waterfront being located at the waterfront of the river, flooding issues have been identified which can restrict the implementation of the development plans (Warrington Borough Council, 2014, p. 37).

Infrastructure and transport has been described as a core issue of the borough, as the transport routes need to be attractive for businesses and residents, i.e. links between residential and business areas. Besides improvement to the road networks, Warrington Borough Council identified the Manchester Ship Canal as a route to create economic advantages.

The core strategy focuses on the improvement of the borough's green infrastructure and biodiversity, and the connectivity of those elements for the wider area. This aspect is important for the consideration of the Upper Mersey Estuary as a corridor for wildlife, and the Upper Mersey Estuary as a nature reserve (Mersey Gateway Environmental Trust, n.a.). With regard to the natural environment, climate change and sustainability, the core strategy highlights the need to provide sustainable energy and the reduction of emissions. The assessment of flood risks is noted in the core strategy and the need to provide flood plains is incorporated into the planning document (Warrington Borough Council, 2014, p. 86). The Upper Mersey Estuary is recognised as a local wildlife site (Warrington Borough Council, 2014, p. 169) which is an important aspect regarding the vision of the borough council – to protect the natural environment where possible (Warrington Borough Council, 2014, p. 88).

### 4.4.5. SWOT Analysis – Warrington Borough Council

A SWOT analysis provides further background information on the status quo of Warrington Borough Council. The SWOTs listed in Table 19 are summarised from the core strategy document and are deliberately kept broad to enable a discussion on possible futures.

Warrington benefits from a good infrastructure and a strong and resilient economy throughout the borough. Green corridors link a varied landscape, which also contributes to the strength of the borough. Opportunities have been identified in possible development projects such as Atlantic Gateway (Atlantic Gateway, 2012), improvements to infrastructural networks, and promotion of green infrastructure. Warrington's identified weaknesses are based on social components (health, life-style choices). These weaknesses have been translated into threats that might affect the future of the borough, as the poor quality of life in some areas will lead to increased deprivation, as will the increased use of cars impact air quality, and the effects of climate change impact flooding through extreme weather events.

**Table 19 SWOT analysis of Warrington Borough Council core strategy.**

| | Beneficial | Harmful |
|---|---|---|
| **Internal** | **Strength**<br>• Good infrastructure (communication) network<br>• Strong, resilient economy<br>• Varied landscape character with green corridors linking environmental assets | **Weaknesses**<br>• Differences in prosperity and quality in life/ inequality<br>• Poor health in some areas<br>• Pressure from traffic/ car usage |
| **External** | **Opportunities**<br>• Liverpool City Region and Atlantic Gateway as influential development projects<br>• Provide housing, service, health, and well-being to residents<br>• Improve infrastructural networks<br>• Sustainable use of natural resources | **Threats**<br>• Climate change<br>• Poor air quality<br>• Flooding<br>• Raising levels of deprivation in some areas |

### 4.4.6. The Natural Environment in the Strategic Documents of Warrington Borough Council

The analysis of environmental keywords shows the focus of the core strategies of the borough with regard to the environment. The analysis is later incorporated into the scenario development. Keywords connected to the natural environment were identified from the core strategy document. The green infrastructure was mentioned most with 26 comments, followed by environment (n=19) and climate change (n=17). The Green Belt was mentioned 19 times. The fewest comments were collected for sustainability (n=12).

Comparable to Halton Borough Council, the natural environment seems not to be fully integrated into the strategy. Although aspects of the environment are considered, the connection between social and natural aspects is often lacking. However, green infrastructure has been mentioned 26 times and an attempt to integrate the natural environment into the borough's future is recognised here.

**Table 20 Sum of keywords on the natural environment identified from the Warrington Borough Council core strategy.**

| **Keyword** | **References** |
|---|---|
| Climate Change | 17 |
| Environment | 19 |
| Green Belt | 16 |
| Green Infrastructure | 26 |
| Sustainability | 12 |

### 4.4.7. Assessment of Changes Identified by the Stakeholders of the Upper Mersey Estuary

As part of the Delphi questionnaire, the participants were asked about their thoughts regarding triggers of change, together with the time period when those changes would become apparent in the Upper Mersey Estuary until 2044. The analysis identified seven major triggers (Table 21). The majority of the Delphi participants (n=16) agreed that the Upper Mersey Estuary will be subject to building and development. This was followed by frequent mentioning of climate change and political changes. Biodiversity and water quality were mentioned by two participants. The work of the Mersey Gateway Environmental Trust was identified by one participant as a potential trigger of change in the Upper Mersey Estuary.

**Table 21 Triggers of change identified from the Delphi questionnaire.**

| Trigger | References |
|---|---|
| Biodiversity | 2 |
| Building & development | 16 |
| Climate change | 5 |
| Politics | 5 |
| Tourism & Recreation | 3 |
| Use of resources | 3 |
| Water quality | 2 |
| Work of Mersey Gateway Environmental Trust | 1 |

Regarding the time period in which the Upper Mersey Estuary is expected to change, the participants contributed their expertise on potential time intervals of change for the individual site compartments (Figure 23). Most compartments are expected to change within the next 15 years (medium-term). Reasons for these changes were stated as changes to land use and land cover, in particular changes to the Green Belt and Arpley landfill, as well as Fiddlers Ferry Power Station (communication at the workshop). Two saltmarshes, Astmoor saltmarsh and Widnes Warth, that are in close vicinity to the Mersey Gateway Crossing are considered to be changing within the next 5 years. Moore Nature Reserve is also considered to be changing within the next 5 years. One site is not expected to change within the operational period, as the continuation of this site compartment as a landfill can be expected.

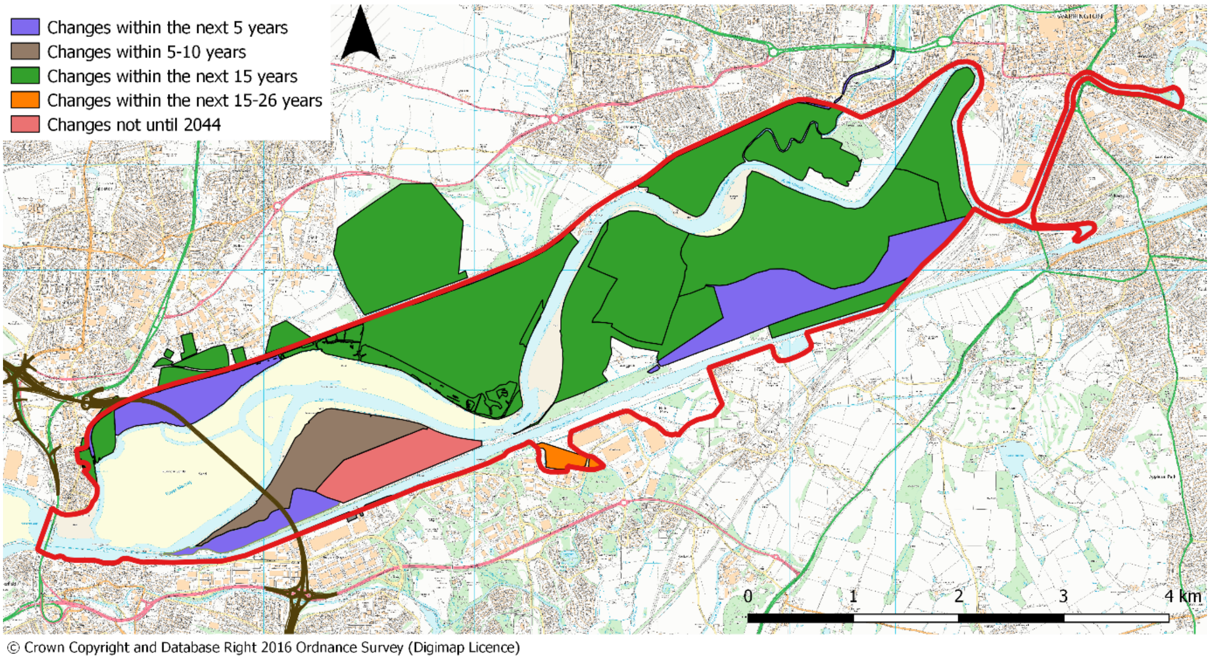


**Figure 23 Changes of the estuary anticipated by the participants of the Delphi workshop per site compartment. Intervals of change were given as i) changes within the next 5 years; ii) changes within the next 15 years; ii) changes within the next 26 years; iv) no changes until 2044.**

### 4.4.8. Scenarios

As part of objective 2, which aims to evaluate changes impacting the socio-ecological system of the Upper Mersey Estuary, scenarios were developed to explore possible futures of the estuary throughout the operational period. The information that was collected in section 4.4.1 – 4.4.7, as well as knowledge developed as part of the research process, has informed these scenarios. The intention behind these scenarios is the option to assess the future provision of ecosystem services (objective 3), allowing conclusions to be drawn, and recommendations to be made for future management of the Upper Mersey Estuary (section 5.4.3). The selected scenarios only depict a small range of possible futures, but intend to show the best possible idea of certain aspects of the future, leading to the identification of the provision of future ecosystem services in the Upper Mersey Estuary.

The scenarios cover the remaining time of the construction and operational period until 2044. As part of the scenario formation, several assumptions were formulated. All scenarios are based on these assumptions:

- Population growth is normal, i.e. increases slightly but without significant migration to the area or out of the area, following the principal projections for population growth, with an increase in people over the age of 65 (Office for National Statistics, 2016). The strategy documents from Halton and Warrington support this assumption (Halton Borough Council, 2013; Warrington Borough Council, 2014).
- Climate change is happening, i.e. a higher annual temperature, more extreme weather events and subsequent floods (Burgess, Deschenes, Donaldson, & Greenstone, 2014; Hulme, 2017). Some effects might be noticeable within the operational period such as more frequent storm events. Sea level rise will also have an impact on the estuary – the extent to which sea level rise affects changes in inundation, more frequent flooding, and changes in habitat within the Upper Mersey Estuary is currently assessed by Alexander (PhD in preparation, University of Salford). The impact of climate change, in particular sea level rise, is difficult to assess in general, as every estuary is highly individual and presents unique conditions. However, it can be assumed that sea level rise has no

significant impact on the Mersey Estuary within the operational period (Kirwan, Temmerman, Skeehan, Guntenspergen, & Fagherazzi, 2016; Stagg et al., 2016)

- Erosion and sedimentation influence the saltmarshes and impact their size. It will be assumed that erosion and sedimentation is part of the natural dynamics of the estuary, as both processes are dependent on the main channels formed in the estuary. It will be assumed that the amount of sediment remains stable in the estuary, but might be transported within it. This assumption is supported by the hydrodynamic surveys undertaken as part of the monitoring work, e.g. Merseylink (2016a).
- Many brownfield sites in the boroughs are contaminated development sites and are, therefore, restricted in their development for residential or commercial purposes. This decreases the attractiveness of the sites to investors compared to sites without contamination issues at present, due to requirements of risk assessments and potential remediation (Department for International Trade, 2015).
- Political factors that are of national importance and which could influence national and local policies (i.e. Brexit) cannot be considered within the scenarios.
- The provision of ecosystem services is a complex and continuously changing process. Aspects of changes in the short-, medium-, or long-term can, therefore, not easily be considered, but an overall expectation is used to indicate the direction of change. Wherever possible, a clarification is made regarding the change of ecosystem service provision over time.

Three scenarios were developed for the Upper Mersey Estuary, all focusing on different thematic aspects of the future. This ensures that the elements which were identified in the first part of objective 2 are covered by the scenarios and a variety of triggers of change are incorporated into the research. For each scenario, a rationale was formulated which set the context for the wider perspective of the scenario. A general description, as well as a specific description for each site compartment, suggesting a possible development under the respective scenario, is outlined.

The first scenario, Business as Usual 2044, is based on aspects that were core issues in the strategic documents. It describes a future in which all core aspects are considered as much as they are now. The second scenario, Development Boom 2044, concentrates on a future in which the need for development is a stronger aspect than other identified core topics. Nature is Key 2044, the third scenario, explores a future in which the identified environmental aspects of the boroughs play a substantial role in the future of the estuary.

#### 4.4.8.1. Business as Usual 2044

**Rationale**

The 21st century is a highly-connected place which benefits from well-developed infrastructure, as well as local development. The economy is still recovering from the difficulties experienced at the beginning of the 21st century – uncertainties for investments remain in the short – to medium-term. However, the North West of Britain requires housing and employment possibilities, which will initiate some development.

**Description**

This scenario explores how the estuary could appear, if the status quo is maintained. Under this scenario, the visions in the policy and planning documents will be realised. Land use plans remain in place and contemporary trends are still viable in 2044. The political environment remains similar, with no major changes to how the boroughs are run (i.e. the boroughs' core strategies will have a similar outline to the ones running until the late 2020s). It is illustrated in Table 22 how the scenario might affect the estuary. Housing and development is taking place at the rate that has been outlined in the core strategies, with restricted use of the Green Belt land in and around the Upper Mersey Estuary. Limited commercial development is expected within the Upper Mersey Estuary (i.e. Port Warrington, Warrington Waterfront), but might take place outside the boundaries. The natural environment within the Upper Mersey Estuary will not change considerably, with local designation being kept in place. Some new development of natural space is expected around Arpley landfill. The work of the Mersey Gateway Environmental

Trust implements nature-focused projects. The infrastructure and transport is strengthened through the heightened capacity of the road networks across the river Mersey. The accessibility for locals remains stable and the area is used for recreational purposes. The connection between the big cities of Liverpool and Manchester is improving, but smaller places like Widnes, Runcorn, and Warrington can thrive through local infrastructure. Science and technology advance at a moderate speed, offering more possibilities for developers and building sites. Overall, the world would not look too dissimilar to todays. However, changes will also have direct effects on individual site compartments. These are described in Table 23.

**Table 22 The scenario Business as Usual 2044 described by core areas of change.**

| | Business as Usual 2044 |
|---|---|
| **Housing/Urban development** | • The provision of housing is a priority for the boroughs. By 2044, most of the housing that is proposed in the local authorities' core strategies has been delivered. Planning permissions for further housing development could be granted, but will be subject to Green Belt boundaries and other binding legal obligations.<br>• The use of Green Belt land will only be permitted in exceptional circumstances which will keep the use of land for development in the Upper Mersey Estuary to a minimum.<br>• People living around the Upper Mersey Estuary can continue to use it the way they used to. |
| **Commercial/ Business development** | • The commercial development has continued as it is laid out in the plans of the boroughs.<br>• The operation of all commercial sites continues as today.<br>• The main constraint for new development is the remediation of contaminated sites. Financial and technical factors restrict the advancement in building.<br>• Commercial development within the boundary of the Upper Mersey Estuary is limited, though might take place outside the boundaries. This might have some effect of coastal squeeze.<br>• Sites that have been identified for development (Port Warrington, Warrington Waterfront) have an impact on the natural environment through reduction of available green space. |

**Table 22 (cont.)**

| | Business as Usual 2044 |
|---|---|
| **Natural Environment** | • Some changes are made to the Green Belt in and around the Upper Mersey Estuary. All nature designations have been kept and the Arpley landfill site has been developed as per plan into a recreational nature site. Moore Nature Reserve is kept as a designated Local Nature Reserve. Initiatives like the Mersey Gateway Environmental Trust support the continuous management of the natural environment in the Upper Mersey Estuary and help to acquire funding for future projects.<br>• Funding for natural sites and designated sites might not be readily available.<br>• The work of the Mersey Gateway Environmental Trust might increase the projects for conservation, leading to better connected sites within the Upper Mersey Estuary.<br>• Sites with high conservation potential can be supported. |
| **Infrastructure and Transport** | • The Mersey Gateway Crossing is operating at its estimated capacity. The infrastructure network of Halton Borough Council and Warrington Borough Council is strengthened, which enables people to travel through the area. The roads will mainly be used to access workplaces and travel longer distances. The Trans Pennine Trail is an accessible route for locals and people coming from neighbouring areas.<br>• The use of the Mersey Gateway Crossing might attract fewer people due to its impact on the views/noise levels. This might decrease the use of areas such as Wigg Island.<br>• The Upper Mersey Estuary remains accessible for locals. |
| **Education, skills & employment** | • There are no major changes in the education, skills and employment of people.<br>• The area surrounding the Upper Mersey Estuary remains an area in which low skilled work is predominant. |
| **Health and Well-being** | • The Upper Mersey Estuary becomes a more popular place for leisure activities. Besides the maintenance of the existing sites, businesses will be attracted to offer activities.<br>• Recreational activities continue to grow, but they might not be concentrated on the creation of natural areas, but allowing commercial areas to build up. This impacts the immediate environment around those areas. |

**Table 23 Business as Usual 2044 scenario: description of site compartments.**

| Site compartment | Description |
|---|---|
| Astmoor | Little management of saltmarsh vegetation. Implementation of saltmarsh restoration plan (Merseylink, 2016b) over the operational period, including the creation of scrapes and ponds for the benefit of biodiversity. |
| Arpley landfill | Development of country park after closure and capping of existing landfill after 2017. Subsequent impact on bird numbers, especially gulls which are feeding on landfill, resting in the estuary's mudflats and surrounding areas. |
| Cuerdley Marsh | Site remains as saltmarsh without major management due to restriction with landowner. Reed bed management (cutting) is taking place on a seven-year basis through the Mersey Gateway Environmental Trust. |
| Fiddlers Ferry | Site will remain operational for electricity production. |
| Gatewarth | Little active management due to lack of available funding. Natural succession throughout the operational period is expected. |
| Manchester Ship Canal Bank | No change in management expected. |
| Moore Nature Reserve | Less funding/management due to closure of Arpley landfill (area leased by operator of landfill). Long-term natural succession can be expected; temporary management works through the Mersey Gateway Environmental Trust likely. |
| Moss Side Farm | Used as floodplain in the near future, due to withdrawal of Environment Agency to maintain bunds. Long-term interest to manage site for biodiversity (estuary and farmland birds) i.e. maintaining agricultural land. |
| Oxmoor | Remains a local nature reserve. |

**Table 23 (cont.)**

| Site compartment | Description |
|---|---|
| Port Warrington | Further developed in the medium-term expected. The use of the Manchester Ship Canal will increase. |
| Spike Island | Will remain similar to present site. |
| St Helens Canal | No major change to the use of the canal. The Trans Pennine Trail will continue as a connection between Warrington and Widnes. |
| Tan House Lane | Partial development of brownfield site for mixed use (similar to planning permission submitted to Halton Borough Council, case no.: 05/00057/OUTEIA). |
| United Utilities | Management of site will continue as expected. Green areas mainly under natural succession (habitat without dog walkers/feral cats) (personal communication with Brian Tollitt), Himalayan balsam remains a problem. |
| Upper Moss Side | Continuous management of the site, but no priority management by Forestry Commission. Saltmarsh is grazed with appropriate cattle numbers. Visitor management is attempted. |
| Randles Island | No changes expected. Future plans of operation unknown. |
| Warrington Waterfront | Development for residential housing. Installation of flood defence mechanisms. |
| Widnes Warth | Implementation of saltmarsh restoration plan (Merseylink, 2016b). Light grazing throughout the operational period. |
| Wigg Island | Management in accordance with the Wigg Island Management Plan (Merseylink, 2015a); small projects to be implemented by the Mersey Gateway Environmental Trust within the operational period. |

The Business as Usual 2044 scenario describes a future in which the local core strategies are implemented. The main aspects that describe this scenario regarding the impact on the natural environment in the Upper Mersey Estuary are:

- In addition to the mitigation proposals that are subject to planning of the Mersey Gateway Crossing, several projects are realised along the objectives of management plans, as part of the work carried out by the Mersey Gateway Environmental Trust.
- The mitigation measures have been delivered according to the proposal of the saltmarsh management plan (Merseylink, 2016b).
- Some natural green areas are lost to development, Arpley landfill is gained as a nature site.

#### 4.4.8.2. Development Boom 2044

**Rationale**

A focus on economic status and high use of natural resources continue from the beginning of the 21st century. The plans to strengthen the North West of the UK to bring economic growth showed fruition. Large scale investment programmes (i.e. Atlantic Gateway) accelerate the movement. Businesses and trade are successful in the area, contributing to its economic prosperity. Green space becomes more valuable, as Green Belt land is increasingly developed.

**Description**

Economic development is the key aspect of the operational period. Economic development is driven by a consumption-oriented society, which devotes a lot of resources on the production of goods. The central position of the Upper Mersey Estuary in the North West is recognised as a hub for regional and national development. The core areas of change are summarised in Table 24. Changes in land use regulations (i.e. Green Belt) increase the availability of land for commercial development and residential land use in and around the Upper Mersey Estuary. The opening of the Green Belt for further development will decrease natural corridors and there is no major focus on nature protection. Through the advancement in technology, brownfield sites become more available for development through improved techniques dealing with contaminated soils. The Mersey Gateway Crossing is an essential infrastructural link and will attract development to the area. The scenario is described in more detail in Table 25, looking at the changes within the individual site compartments.

**Table 24 The scenario Development Boom 2044 described by core areas of change.**

| | Development Boom 2044 |
|---|---|
| **Housing/Urban development** | • The provision of housing is a priority for the boroughs. By 2044, most of the housing that has been proposed in the local authorities' core strategies has been delivered. Due to economic prosperity of the area, the demand for housing in and around the Upper Mersey Estuary increases. Land is required for these developments, leading to opening of Green Belt land. Natural green space is often converted for residential housing and commercial development.<br>• Land might be developed for housing and urban development. Post development, this land might lose its value for conservation, but gain urban ecosystem services.<br>• The estuary might be affected by a more intense coastal squeeze. |
| **Commercial/ Business development** | • Business development is a key focus in the area. Investments in the area are successful and companies expand their operation to the Upper Mersey Estuary area. Brownfield land, as well as unused land, can be used for new developments and expansion of industrial areas.<br>• The same applies for residential housing development, business development influences the coastal squeeze.<br>• Use of the Upper Mersey Estuary for business and commercial operations negatively influences the biodiversity of affected areas. |

**Table 24 (cont.)**

| | Development Boom 2044 |
|---|---|
| **Natural Environment** | • The natural environment plays a subliminal role in society and the development towards an economically thriving society. Natural areas will be underfunded due to other priorities. A long-lasting vision of the incorporation of the natural environment into the future of the Upper Mersey Estuary is not realised. Natural areas such as Green Belt land and sites associated with nature conservation are more easily given up.<br>• Management of natural sites becomes more difficult due to restricted funding and the progressive fragmentation of habitats.<br>• Increased development leads to coastal squeeze and less flood plains, increasing the flood risks.<br>• Development of technology leads to safer ways to remove contamination.<br>• A tidal barrage located down-stream of the Upper Mersey Estuary has significant effects on the natural environment. Renewable energy is produced. |
| **Infrastructure and Transport** | • Infrastructure and transport are important issues. In order to achieve a strong economic region, infrastructural improvements and investment in transport will take place. The Mersey Gateway Crossing will have contributed to the initiation of the expansion of infrastructure in and around the Upper Mersey Estuary.<br>• The area will become a hub for people and goods and, therefore, more often frequented.<br>• The water routes of the Upper Mersey Estuary (Manchester Ship Canal) are frequently used. |

**Table 24 (cont.)**

| | **Development Boom 2044** |
|---|---|
| **Education, skills & employment** | • Trends of the 21st century continue towards a highly technologically dependent society, leading to changes in required skills.<br>• The education of children and young adults is not focused on the long-term thinking of sustainability.<br>• The employment rate might increase due to more business activity in the area. |
| **Health and well-being** | • Due to advances in technology, leisure may develop around indoor activities such as virtual realities, resulting in decreasing outdoor activities.<br>• The Upper Mersey Estuary remains a recreational ground which can be used by locals. Access to areas such as Wigg Island remains. |

**Table 25 Development Boom 2044 scenario: description of site compartments.**

| Site compartment | Description |
|---|---|
| Astmoor | The saltmarsh restoration plan (Merseylink, 2016b) is implemented. Minimum work is carried out due to unavailability of funding. Implications of tidal barrage on saltmarsh are expected in the medium to long-term. The tidal barrage might lead to loss of saltmarsh habitat. |
| Arpley landfill | Site is development into country park, however a low maintenance design of park is implemented to avoid high cost. |
| Cuerdley Marsh | Rotational cutting of reed beds is taking place. The saltmarsh is monitored for birds in the medium-term, but no other work carried out during the operational period. Tidal barrage might lead to loss of saltmarsh habitat. |
| Fiddlers Ferry | Continued energy production, potentially continued use of non-renewable energy production to support the grid in times of high demand. |
| Gatewarth | Natural succession of current habitats is expected, with little to no management due to lack of resources. The area will remain a local site for residents for activities such as (dog) walking. The tidal barrage might lead to loss of saltmarsh habitat. |
| Moore Nature Reserve | Loss of eastern area of site to development of Port Warrington is expected. The remaining area is under pressure for funding for the implementation of projects. |
| Manchester Ship Canal Bank | No change in management expected. |
| Moss Side Farm | Agricultural production is continued with use of the area as a flood plain. |
| Oxmoor | Low maintenance management through the overall difficult allocation of resources is applied. |
| Port Warrington | Full use of site, including an increased use of the Manchester Ship Canal, is likely. |
| Spike Island | No change in management. Tidal barrage might lead to loss of habitat (saltmarsh). |

**Table 25 (cont.)**

| Site compartment | Description |
|---|---|
| St Helens Canal | Continues to be a disused canal which will be under the same management. |
| Tan House Lane | Full development of site for mixed development is expected. |
| United Utilities | No change in management of site. Tidal barrage might lead to loss of saltmarsh habitat. |
| Upper Moss Side | No priority site for land owner regarding management and implementation of projects. Implementation of small projects through the support of the Mersey Gateway Environmental Trust. Small scale conservation grazing on the saltmarsh is continued. The tidal barrage might lead to loss of habitat, in particular, saltmarsh. |
| Randles Island | Continued operation of the site. No change is anticipated. |
| Warrington Waterfront | Site expected to be developed for residential housing, and flood defences to be installed to protect against potential flooding. |
| Widnes Warth | Implementation of the saltmarsh restoration plan (Merseylink, 2016b) according to planning permissions of the Mersey Gateway Crossing. Additional resources are difficult to obtain for the maintenance of projects. Continued small scale conservation grazing on the saltmarsh. The tidal barrage might lead to loss of saltmarsh habitat. |
| Wigg Island | No change in management of site. Site is managed as a local green space for residents but without the incentive to create new projects. |

The Development Boom 2044 scenario focuses on the implementation of housing and commercial plans, as well as on an immediate strengthening of the economy through business development. The main aspects of the scenario are:

- There is less money available for environmental purposes nationwide.
- Exceptions for the development of Green Belt land are more likely to enable development.
- Other developments are made possible through change in legislation that simplifies the use of previously developed land.
- A tidal barrage is build downstream of the Upper Mersey Estuary as part of the development in the North West to produce energy from a reliable source to businesses and households in the medium to long-term. Possible habitat loss is addressed in the assumptions and partially translated into the model of future provision of ecosystem services. See Appendix 6 for an explanation why a tidal barrage was included in the scenario.
- In addition to the mitigation proposals that are subject to planning of the Mersey Gateway Crossing, small projects are realised along the management objectives of the Mersey Gateway Environmental Trust.
- Designation such as Local Nature Reserves are not necessarily kept by the councils, due to change of environmental policies.

#### 4.4.8.3. Nature is the Key 2044

**Rationale**

Business and society explore sustainable and long-term options for production of goods and services. The realisation that resources are finite and that the climate is changing due to anthropogenic actions have triggered an understanding of society that natural capital is important to sustain high living standards in the UK. In and around the Upper Mersey Estuary, the work of the Mersey Gateway Environmental Trust has been recognised and efforts are made to continue the work.

**Description**

Nature is a key point in local and national development. Policies recognise environmental protection as a key issue and a focus on conservation and protection is an essential part of the legislation. Designations for areas of environmental importance are easier to obtain and act as a protection for the respective sites. Nature networks and corridors are likely to develop. It has been recognised by policy makers that green infrastructure is essential for human well-being and, as a consequence, the investment is promoted. This includes easier access to funding and long-term planning opportunities. Advancement in technology facilitate the sustainable use of resources. The opinions of local people are important to decision-making. Residential housing is delivered as expected in the core strategies, but landscaping and green corridors are considered in the planning. Businesses are aware of the need for sustainable resource use. The natural environment is a key factor in this scenario, with a high importance of green spaces in and around the Upper Mersey Estuary. The transport and infrastructure undergo a change towards more sustainable solutions. People are interested in green spaces and enjoy being outside, using available green space and protecting and conserving nature in the Upper Mersey Estuary through volunteer action and environmental education. The scenario is described in more detail in Table 26. The changes expected within the individual site compartments are described in Table 27.

**Table 26 The scenario Nature is Key 2044 described by core areas of change.**

| | **Nature is Key 2044** |
|---|---|
| **Housing/Urban development** | • The housing that has been proposed in the core strategies of the boroughs has been delivered. However, access to green spaces plays a role in the development of new sites.<br>• A green corridor is maintained, and/or extended. Through active involvement of people into projects in the Upper Mersey Estuary, awareness is created and volunteers are recruited.<br>• With more people living in the vicinity, more people are likely to use the Upper Mersey Estuary for local recreational purposes. |
| **Commercial/ Business development** | • Most of the commercial and business development around the Upper Mersey Estuary has been delivered. However, no new land is being used for the development. Brownfield and other previously developed sites are used for the necessary site development. Businesses' corporate responsibility for any effects on the environment are strictly addressed and regulated in local and national policies.<br>• Business owners are encouraged to partake in green projects.<br>• Local businesses think and act more sustainably, supporting the idea of 'act local, think global'. |
| **Natural Environment** | • The natural environment is a key point in this scenario. The management of green spaces and the sustainable use of natural resources are incorporated into local and national policies.<br>• The land that is currently Green Belt, and/or designated is more likely to be protected. This increases the chances for long-term management for conservation and management of key species.<br>• Further designations can be obtained. The Mersey Gateway Environmental Trust will play an important role to reach all landowners as well as developing appropriate management strategies.<br>• A development towards a more sustainable use of nature will also affect areas outside the Upper Mersey Estuary boundaries, therefore opening the possibility of creating a bigger, greener network. |

**Table 26 (cont.)**

| | Nature is Key 2044 |
|---|---|
| **Infrastructure and Transport** | • Infrastructure and transport is an important issue. Transport modes become more sustainable and travel distances are optimised. The Mersey Gateway Crossing is working within its capacity. A main contribution to changes in infrastructure and transport will the conscious decision to use society for more sustainable modes of transport and the available technology.<br>• A change in transport modes might increase the Upper Mersey Estuary's use as a network for cycling/walking (on the Trans Pennine Trail).<br>• Changes to infrastructure that are not based on carbon-fuelled transport could have the effects on climate change pattern and influence the local climate. |
| **Education, Skills & Education** | • Environmental education is taking place from a young age.<br>• Skills are required in the area to enable businesses to operate.<br>• The employment rate has not changed significantly.<br>• Volunteers are in demand to help with the management of the Upper Mersey Estuary. |
| **Health and well-being** | • People enjoy nature and appreciate green spaces. The use of local green spaces has become a valuable resource for society to spend free time. Outdoor activities and environmental education are encouraged.<br>• Use of the Upper Mersey Estuary increases. The amount of 'local' tourism increases.<br>• Habitats have to be managed for a higher number of people.<br>• Leisure activities increase local knowledge of the area. |

**Table 27 Nature is Key 2044 scenario: description of site compartments.**

| Site Compartment | Description |
|---|---|
| Astmoor | The site is expected to be partially under management. The saltmarsh restoration plan (Merseylink, 2016b) will be implemented throughout operational period. Conservation grazing to be implemented on the saltmarsh. |
| Arpley landfill | The expected country park development is realised. Funding and initiative are available to manage site for local residents and create a point to experience a view over large parts of the estuary, including biodiversity experiences and environmental education opportunities. |
| Cuerdley Marsh | Management of reed beds for biodiversity through rotational cutting and management of water flow on the saltmarsh is implemented. Other management is difficult due to limited access to site. |
| Fiddlers Ferry | Continued energy production. |
| Gatewarth | Continued management to maintain present habitats. |
| Moore Nature Reserve | Management of the reserve will continue. Successful funding will be availability for long-term management. |
| Moss Side Farm | Management of floodplains in conjunction with the neighbouring sites, e.g. for estuarine and farmland birds. |
| Manchester Ship Canal Bank | No change in management expected. |
| Oxmoor | Continued management to maintain present habitats. |
| Port Warrington | Partial development of the site is expected. Cooperation and involvement in the work carried out in the Upper Mersey Estuary for nature benefits, e.g. work with the Mersey Gateway Environmental Trust (off-setting of construction works within the Upper Mersey Estuary). |

**Table 27 (cont.)**

| Site Compartment | Description |
|---|---|
| Spike Island | No major change in land use expected. The site is strengthened as visitor site within the Upper Mersey Estuary. Communication of environmental actions and environmental education is made possible. |
| St Helens Canal | Work with Canal and River Trust is intensified. Projects are implemented to improve the site for wildlife. |
| Tan House Lane | No development of brownfield site for mixed use. Brownfield site under natural succession and initiation of projects to manage biodiversity. |
| United Utilities | Management of site will continue as expected. Green areas are mainly under natural succession (habitat without dog walkers/feral cats). Mersey Gateway Environmental Trust and United Utilities are working together regarding monitoring of biodiversity (e.g. birds, Himalayan balsam). |
| Upper Moss Side | Continued, active management of a variety of habitats is taking place. Long-term management plans for biodiversity aims such as the management of improved grassland, wet woodland for willow tits, and the continued grazing of saltmarsh for estuarine birds is carried out. |
| Randles Island | No changes are expected. |
| Warrington Waterfront | No development of site for housing, i.e. no change in Green Belt land. Land can be used as floodplain. |
| Widnes Warth | Continued light grazing for biodiversity benefits. |
| Wigg Island | Continued management in accordance with the Wigg Island Management Plan (Merseylink, 2015a), and incentives for new projects that comply with the key messages of the Mersey Gateway Environmental Trust. |

The Nature is Key scenario focuses on the long-term management of natural resources within the borough. Environmental concerns are addressed in the core topics, as well as in the management of the individual sites. Considering those two elements, the main aspects of the scenario are:

- The Upper Mersey Estuary is managed as one site that is connected through the management of the individual site compartments. Exchange of information among the stakeholders is crucial and taking place. Access to sites for management works and monitoring is possible. Data collected in the Upper Mersey Estuary is stored in one central location.
- Funding of projects is available over the operational period.
- In addition to the mitigation proposals that are subject to planning of the Mersey Gateway Crossing, several projects are realised along the management objectives of the Mersey Gateway Environmental Trust.

## 4.5. Objective 3: Model of the Future Provision of Ecosystem Services

The developed model pulls together the information that was collected in the previous steps and provides information about the future provision of ecosystem service under different scenarios. Based on this, the changes of ecosystem service provision can be assessed and an estimate on the future provision can be made.

The data collected in the model is presented in two ways: i) maps, reflecting an overall change in the provision of ecosystem service within the Upper Mersey Estuary, enabling a presentation of those areas that are especially prone to change under the scenarios; and ii) tables, showing detailed changes of the individual ecosystem services at site level for all three scenarios, with accompanying explanations and references where appropriate. By presenting the data in these ways, the following aspects are covered: i) representing possible changes within the whole of the study area, providing a comprehensive overview of the expected direction of change in the provision of ecosystem services within the site compartments, and ii) a site-specific, as well as ecosystem service specific, account of change, indicating the direction of change through the use of symbols.

Positive changes are represented from blue (no changes in the provision of ecosystem services) to green (distinct positive change in the provision of ecosystem services). Negative changes are shown on a scale from blue (no negative changes in the provision of ecosystem services) to red (distinct negative change expected in the provision of ecosystem services). The scale indicating the change is used to understand no to little change (0-0.92), medium change (0.92-1.38), considerable change (1.38-2.30 for positive changes, 1.38-2.40 for negative changes).

### 4.5.1. Business as Usual 2044: Changes in the Estuary

This scenario is based on the continued status quo of the study area and takes into account the changes that are presented in section 4.4.8.1. The results of this scenario are presented in Figure 24 in form of maps, which display the positive change under the scenario in map 1) and the negative changes in map 2). A detailed explanation can be found in the tables, which show first the expected direction of change (Table 28), followed by an explanation for the change.

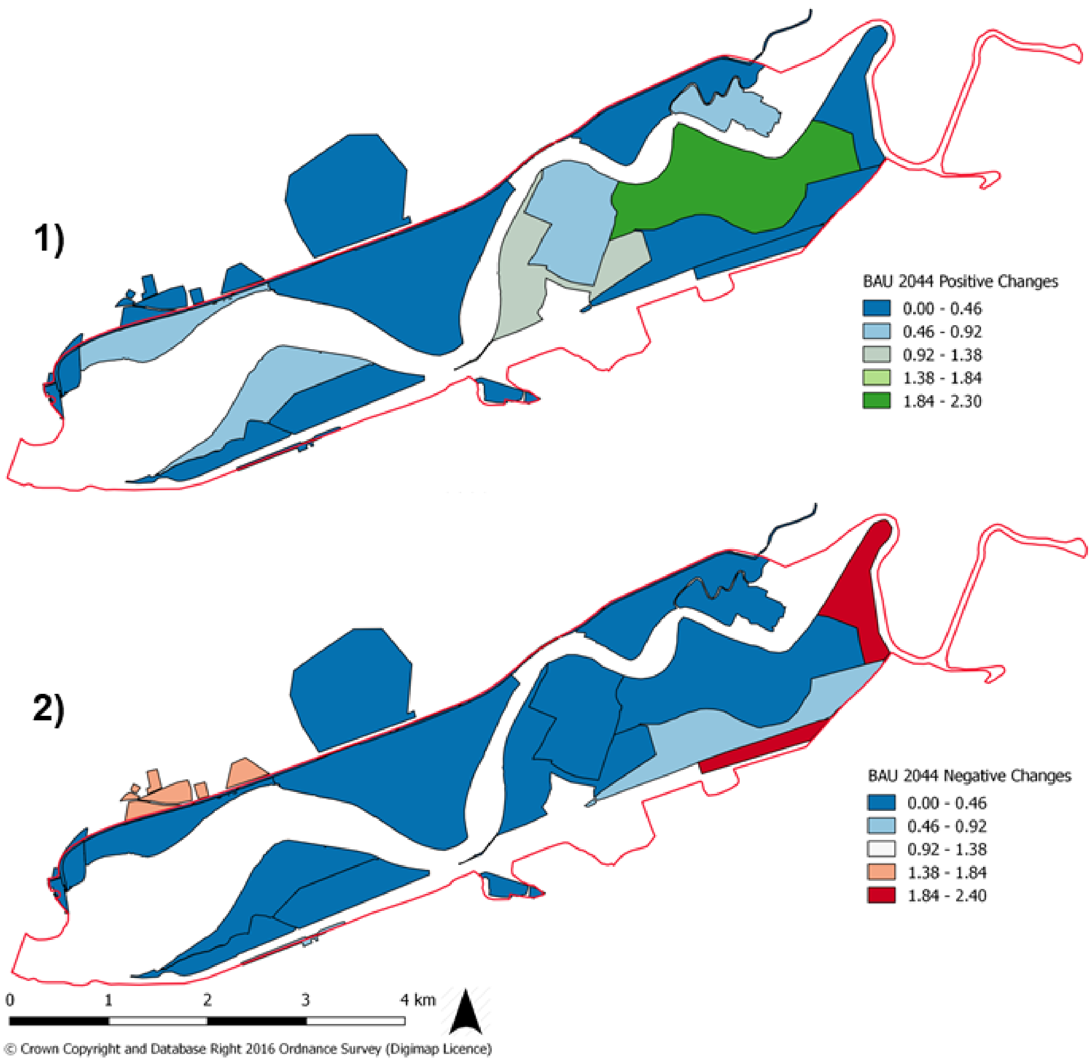


**Figure 24 Changes to the provision of ecosystem services under the Business as Usual 2044 scenario for the Upper Mersey Estuary. Map 1) shows the positive changes of ecosystem service provision in each site compartment. Map 2) shows negative changes within each site compartment.**

**Table 28 Business as Usual 2044: Ecosystem Service Provision by site compartment (0 = no change in provision of service; + = positive change in provision of service; - = negative change in provision of service; x = no provision of the service.**

| | Astmoor | Arpley landfill | Cuerdley saltmarsh | Fiddlers Ferry | Gatewarth | Manchester Ship Canal Bank | Moore Nature Reserve | Upper Moss Side | Moss Side Farm |
|---|---|---|---|---|---|---|---|---|---|
| **Ornamental resources** | 0[1] | +[19] | 0[37] | 0[55] | 0[73] | 0[91] | 0[109] | 0[127] | 0[145] |
| **Biodiversity** | +[2] | +[20] | +[38] | 0[56] | 0[74] | -[92] | -[110] | +[128] | 0[146] |
| **Removing harmful particles, air water exchange, biogeochemical reaction** | 0[3] | +[21] | 0[39] | 0[57] | +[75] | -[93] | +[111] | 0[129] | 0[147] |
| **Carbon sequestration and burial** | +[4] | +[22] | +[40] | 0[58] | 0[76] | 0[94] | 0[112] | +[130] | +[148] |
| **Water thermodynamic regulation** | 0[5] | +[23] | 0[41] | 0[59] | +[77] | 0[95] | +[113] | 0[131] | 0[149] |
| **Heat exchange regulation** | 0[6] | +[24] | 0[42] | 0[60] | +[78] | 0[96] | +[114] | 0[132] | 0[150] |
| **Flood water storage** | +[7] | x[25] | 0[43] | x[61] | 0[79] | x[97] | x[115] | 0[133] | +[151] |
| **Peak discharge buffering** | +[8] | x[26] | 0[44] | x[62] | 0[80] | x[98] | x[116] | 0[134] | +[152] |
| **Wave reduction** | 0[9] | x[27] | 0[45] | x[63] | 0[81] | x[99] | x[117] | 0[135] | 0[153] |
| **Landscape maintenance** | 0[10] | +[28] | 0[46] | 0[64] | 0[82] | 0[100] | 0[118] | 0[136] | 0[154] |
| **Erosion and sedimentation regulation by water bodies** | 0[11] | x[29] | 0[47] | x[65] | 0[83] | x[101] | x[119] | +[137] | 0[155] |
| **Biological regulation of soil processes and soil formation** | 0[12] | +[30] | 0[48] | 0[66] | 0[84] | 0[102] | 0[120] | +[138] | 0[156] |
| **Pollination** | 0[13] | +[31] | 0[49] | 0[67] | +[85] | 0[103] | 0[121] | +[139] | 0[157] |
| **Aesthetic appreciation** | -[14] | +[32] | 0[50] | 0[68] | 0[86] | x[104] | 0[122] | +[140] | 0[158] |
| **Opportunities for recreation & tourism** | x[15] | +[33] | x[51] | x[69] | 0[87] | x[105] | 0[123] | +[141] | x[159] |
| **Inspiration for culture, art & design** | 0[16] | +[34] | x[52] | x[70] | 0[88] | x[106] | 0[124] | 0[142] | x[160] |
| **Inspiration for cognitive development** | 0[17] | +[35] | x[53] | x[71] | 0[89] | x[107] | +[125] | +[143] | x[161] |
| **Sense of place** | -[18] | +[36] | x[54] | x[72] | 0[90] | 0[108] | 0[126] | +[144] | x[162] |

**Table 28 (cont.)**

| | Oxmoor | Port Warrington | Spike Island | St Helens Canal | Tan House Lane | United Utilities | Randles Island | Warrington Waterfront | Widnes Warth | Wigg Island |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ornamental resources** | 0[163] | -[181] | 0[199] | 0[217] | -[235] | 0[253] | x[271] | -[289] | 0[307] | 0[325] |
| **Biodiversity** | 0[164] | -[182] | 0[200] | 0[218] | -[236] | 0[254] | 0[272] | -[290] | +[308] | 0[326] |
| **Removing harmful particles, air water exchange, biogeochemical reaction** | 0[165] | -[183] | 0[201] | 0[219] | -[237] | +[255] | 0[273] | -[291] | -[309] | 0[327] |
| **Carbon sequestration and burial** | 0[166] | -[184] | 0[202] | 0[220] | -[238] | 0[256] | 0[274] | -[292] | +[310] | 0[328] |
| **Water thermodynamic regulation** | 0[167] | -[185] | 0[203] | 0[221] | -[239] | +[257] | 0[275] | -[293] | 0[311] | 0[329] |
| **Heat exchange regulation** | 0[168] | -[186] | 0[204] | 0[222] | -[240] | +[258] | 0[276] | -[294] | -[312] | 0[330] |
| **Flood water storage** | x[169] | x[187] | 0[205] | x[223] | x[241] | 0[259] | x[277] | -[295] | 0[313] | x[331] |
| **Peak discharge buffering** | x[170] | x[188] | 0[206] | 0[224] | x[242] | 0[260] | x[278] | -[296] | 0[314] | x[332] |
| **Wave reduction** | x[171] | x[189] | 0[207] | x[225] | x[243] | 0[261] | x[279] | -[297] | 0[315] | x[333] |
| **Landscape maintenance** | 0[172] | -[190] | 0[208] | 0[226] | -[244] | 0[262] | 0[280] | -[298] | +[316] | 0[334] |
| **Erosion and sedimentation regulation by water bodies** | x[173] | x[191] | 0[209] | x[227] | x[245] | 0[263] | x[281] | -[299] | +[317] | x[335] |
| **Biological regulation of soil processes and soil formation** | 0[174] | -[192] | 0[210] | x[228] | -[246] | 0[264] | 0[282] | -[300] | +[318] | 0[336] |
| **Pollination** | 0[175] | -[193] | 0[211] | 0[229] | -[247] | +[265] | 0[283] | -[301] | 0[319] | 0[337] |
| **Aesthetic appreciation** | 0[176] | -[194] | 0[212] | 0[230] | -[248] | 0[266] | x[284] | -[302] | 0[320] | -[338] |
| **Opportunities for recreation & tourism** | 0[177] | x[195] | 0[213] | 0[231] | -[249] | x[267] | x[285] | -[303] | x[321] | 0[339] |
| **Inspiration for culture, art & design** | 0[178] | x[196] | 0[214] | 0[232] | -[250] | x[268] | x[286] | -[304] | 0[322] | 0[340] |
| **Inspiration for cognitive development** | 0[179] | x[197] | 0[215] | 0[233] | -[251] | x[269] | x[287] | -[305] | 0[323] | +[341] |
| **Sense of place** | 0[180] | -[198] | 0[216] | 0[234] | -[252] | x[270] | x[288] | -[306] | 0[324] | -[342] |

**Table 29 Description of provision of change of ecosystem services provision under the Business as Usual 2044 scenario, based on the footnotes of Table 28.**

| | Description | Reference |
|---|---|---|
| 1 | No major change in land cover, also no public access through which people could reach ornamental resources. | |
| 2 | Potential long-term positive effect of current management of saltmarsh, in particular birds, as this is the objective of the management efforts of the Mersey Gateway Environmental Trust at present. | Adnitt et al. (2007) |
| 3 | No major changes in the provision of the service. Potentially, slightly less vegetation present through the creation of scrapes and ponds. The effect can be assumed to be negligible. | |
| 4 | Frequent tidal inundations affect the amount of carbon stored on the saltmarsh through plant debris deposited on the marshes in the long term, additional to the natural sequestration of carbon on saltmarshes. | Olsen et al. (2011) |
| 5 | No major change anticipated for the site. | |
| 6 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 7 | Astmoor saltmarsh will be inundated depending on the height of the tides. Management and maintenance of pools and scrapes can increase the flood water storage capacity of the saltmarsh. | Natural England (2014) |
| 8 | Astmoor saltmarsh will be inundated depending on the height of the tides. Management and maintenance of pools and scrapes can increase the flood water storage capacity of the saltmarsh. | Natural England (2014) |
| 9 | The provision of this service is dependent on sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision | |

| | | |
|---|---|---|
| | of the service. | |
| 10 | It can be assumed that the service remains mostly stable once the saltmarsh is restored to previous conditions. | |
| 11 | No changes anticipated that go beyond the natural erosion and sedimentation of the saltmarsh. | |
| 12 | As this process is considered to be highly dependent on time, it can be assumed that there will not be any considerable changes to the biological regulation of soil processes throughout the operational period. | Jenny (1994) |
| 13 | No major changes are anticipated regarding the provision of the saltmarsh as the vegetation cover is not assumed to be changing. | |
| 14 | Due to the Mersey Gateway Crossing the views on the saltmarsh might be diminished. | |
| 15 | Not directly accessible to the public. | |
| 16, 17 | As it is not directly accessible to the public, the cultural and art potential will not change from the status quo. | |
| 18 | Very close to the new bridge and likely to not be attractive as a site for residents. | |
| 19 | In the long-term, ornamental resources might be found in the area of the new country park. | |
| 20 | New habitat that will add to the network of green areas and will act as a provider of new habitat structures. | Camerini & Groppali (2014) |
| 21 | Increase through more vegetation at Arpley country park. | Hill (1971) |
| 22 | Increase of this service over the operational period through development of the country park and accumulation of soil and biomass over the operational period. | Post & Kwon (2000) |
| 23 | Increase of this service over the operational period through development of the country park and build-up of vegetation. | |

| | | |
|---|---|---|
| 24 | New formation of soil and vegetation over the operational period, increasing the provision of the service. | |
| 25-27 | Not located in floodplain | |
| 28 | Formation of new site that will form typical landscape. | |
| 29 | Not located near the river bed. | |
| 30 | Through development of country park, provision of the service will increase over the operational period. | |
| 31 | Build-up of resilient species possible over the operational period with new communities establishing at the site. | |
| 32-36 | The change from landfill to country park in the short-term future will increase the provision of this service. | |
| 37 | No major change in land cover, also no public access through which people could reach ornamental resources. | |
| 38 | Active management of the reed beds, in particular, can be assumed to have a positive impact on biodiversity | Fisher et al. (2011) |
| 39 | No major changes on saltmarsh as no major changes to vegetation cover are anticipated at this site. | |
| 40 | Slow accumulation of carbon through tidal inundation and seasonal breakdown of biomass without disturbance. | Alonso, Weston, Gregg, & Morecroft (2012) |
| 41, 42 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 43, 44 | Cuerdley saltmarsh will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. | |
| 45 | The provision of this service is dependent on sedimentation and erosion processes and | |

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| | consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service. | |
| 46 | No changes anticipated. | |
| 47 | No changes anticipated that go beyond the natural erosion and sedimentation of the saltmarsh. | |
| 48 | No changes anticipated, due to the vegetation cover not anticipated to change. | |
| 49 | No changes to the vegetation and plant communities anticipated. | |
| 50 | No changes anticipated. | |
| 51-54 | No public access. | |
| 55 | No major change in land cover, also no public access through which people could reach ornamental resources. | |
| 56 | Continued energy production that will require business access to the site and no active management for biodiversity. | |
| 57-59 | No change to the vegetation cover on the site is anticipated. | |
| 60 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 61-63 | Not located in floodplain. | |
| 64 | Site will likely remain an energy production site, with the site as it is not changing significantly, therefore, the impact on the provision of this service will remain stable. | |
| 65 | Not located near the river bed. | |
| 66, 67 | No changes anticipated. | |
| 68 | Site will remain an electricity producing site within the operational period and will not gain any | |

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| | aesthetic appreciation within the near future. If energy production by coal is ceased in the medium- to long-term future, it can be assumed that the power plant structures remain. | |
| 69-72 | No public access. | |
| 73 | This service will remain stable, even though the land cover might change over time (due to lack of active management), i.e. the type of ornamental resource might change as well. | |
| 74 | It is likely that the area remains the same over the operational period. The species composition will change due to natural succession of the site. | Pielou (1966) |
| 75 | Natural succession will increase the number of shrubs and trees that will be able to move pollutants from air flow through interception and influence evaporation and respiration. | Nowak & Heisler (2010) |
| 76 | Natural succession from grassland to wooded areas, generally similar sequestration rates as other broad habitats, as defined by Natural England. | Alonso, Weston, Gregg, & Morecroft (2012) |
| 77 | Natural succession from grassland to wooded areas, i.e. better retention of water, cooling of surrounding air higher. | Wang, Fu, Gao, Yao, & Zhou (2012) |
| 78 | Natural succession from grassland to wooded areas, i.e. better uptake of solar energy. | Baldocchi (2013) |
| 79, 80 | No change in provision of the service due to unchanged land cover which would affect the service. | |
| 81 | The provision of this service is dependent on sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service. | |
| 82-84 | No changes due to no anticipated change in vegetation cover. | |
| 85 | Possibly more flowering plants available for pollination through natural succession and | Horsley (2013) |

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| | presence of Himalayan balsam. | |
| 86 | Due to lack of funding it can be assumed that the site is not going to receive active management in the near to medium future. The aesthetic appreciation will remain the same even though changes in land cover might take place. | |
| 87 | Due to lack of funding it can be assumed that the site is not going to receive active management in the near to medium future. However, it can be assumed that the site will remain popular for local residents (dog-walkers etc.) | |
| 88-91 | No change in the provision of this service is anticipated. | |
| 92 | Potential impact of shading from bridge for some orchid species. | McKendrick, Dixie, & Heywood (n.d.) |
| 93 | Covering by the new bridge will increase shading, therefore, reducing potential evapotranspiration and photosynthesis, and removal of harmful particles. | Fischer (1975)<br>Woledge (1978)<br>Amiri, Ariapour, & Fadai (2008) |
| 94 | No major impact on vegetation. The shading of the new bridge will be negligible. | Merseylink (2015b) |
| 95 | No major change anticipated for the site. | |
| 96 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 97, 98 | Not located in floodplain | |
| 99 | Canal system - no waves to be expected. | |
| 100 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 101 | Canal system - no physical features to provide erosion and sedimentation control. | |
| 102 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 103 | No major changes are anticipated regarding the provision of the saltmarsh as the vegetation cover is not assumed to be changing. | |

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| 104-107 | No public access. | |
| 108 | No change in the provision of the service due to the same appreciation of the canal as a historic feature of the estuary. | |
| 109 | This service will remain stable, even though the composition of land cover might change over time, e.g. natural succession (due to lack of active management), i.e. the type of ornamental resource might change as well. | |
| 110 | The site is actively managed for biodiversity at the current state, but due to the reserves funding by the operators of the Arpley landfill and its subsequent closure, the active management is likely to reduce over the next years. | Workshop participant, personal communication, 7 June 2016 |
| 111 | Slight increase in tree and shrub cover due to reduction of management and continuing of natural succession, which are able to remove particulate matter from air flow through interception and increase evaporation. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 112 | Natural succession from grassland to wooded areas, generally similar sequestration rates as other broad habitats, as defined by Natural England. | Alonso, Weston, Gregg, & Morecroft (2012) |
| 113 | Slight increase in tree and shrub cover due to reduction of management and continuing of natural succession, which results in more shaded areas and a more stable water uptake for evapotranspiration. | Wang, Fu, Gao, Yao, & Zhou (2012)<br>Shashua-Bar & Hoffman (2000) |
| 114 | Slight increase in tree and shrub cover due to reduction of management and continuing of natural succession, which results in more shaded areas and better heat exchange regulation. | Baldocchi (2013) |
| 115-117 | Not located in floodplain. | |
| 118 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 119 | Not located near the river bed. | |
| 120 | No changes anticipated due to the vegetation cover not anticipated to change. | |

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| 121 | Slight increase expected due to limited management possibilities at site which will result in more availability in flowering shrubs. | |
| 122 | Although changes in land cover might occur due to change in management availability, the site is likely to remain aesthetically appreciated by locals as a green pocket. | |
| 123 | Although changes in land cover might occur due to change in management availability, the site is likely to remain used by local residents for recreation purposes. | |
| 124 | It is assumed that this service remains stable as no incentives to actively encourage culture, art and design are anticipated. | |
| 125 | With the Mersey Gateway Environmental Trust to use the site as a living laboratory, the provision of this service seems likely. | Mersey Gateway (2017) |
| 126 | Although changes in land cover might occur due to change in management availability, the site is likely to remain an important place for locals as a green pocket. | |
| 127 | This service will remain stable, even though the land cover might change over time, e.g. natural succession, i.e. the type of ornamental resource might change as well. | |
| 128 | Through grazing of the saltmarsh and general active management of the habitats at the site, an increase in biodiversity (species diversity) can be assumed. | Smith (2013) |
| 129 | Management of shrubs on site to improve grassland, i.e. shrubs are taken out; decrease in leaf surface area to remove particulate matter from air flow through interception and improve evaporation; management of developing woodland would improve provision. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 130 | Saltmarsh under light grazing and frequent tidal inundation likely to accumulate carbon. Maintenance of the grassland will improve carbon sequestration as well. | Olsen et al. (2011)<br>Morris & Jensen (1998)<br>E. Osim, personal communication, 1 December 2016 |

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| 131 | Management of shrubs on site to improve grassland, i.e. shrubs are taken out, resulting in decreased water thermodynamic regulation, whereas management of developing woodland could improve conditions through increased cooling effects of vegetation. | Wang, Fu, Gao, Yao, & Zhou (2012)<br>Shashua-Bar & Hoffman (2000) |
| 132 | Management of shrubs on site to improve grassland, i.e. shrubs are taken out, resulting in decreased heat exchange regulation; management of developing woodland to improve conditions. | Baldocchi (2013) |
| 133-134 | The saltmarsh will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. | |
| 135 | The provision of this service is dependent on sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service. | |
| 136 | Through active management of the Forestry Commission and the Mersey Gateway Environmental Trust, the landscape maintenance can be improved over the operational period, by active management of the different habitat types. | |
| 137 | It can be assumed that through active management of the saltmarsh in the medium to long-term future, trapping of sediments in gullies and creaks might increase. However, the edge of the saltmarsh is subject to changes of the river dynamics and as part of the natural processes, the extent of saltmarsh accretion or loss cannot be anticipated. | |
| 138 | It can be assumed that through active management of the saltmarsh in the medium to long-term future, e.g. through cattle grazing, the provision of this service improves. | Andresen, Bakker, Brongers, Heydemann, & Irmler (1990) |
| 139 | Grazing of the saltmarsh at medium density will result in peak pollinator densities. Small projects through the Forestry Commission and the Mersey Gateway Environmental Trust could address the | Lazaro, Tscheulin, Devalez, Nakas, & Petanidou (2016) |

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| | provision of wildflowers on the site. | |
| 140 | Through management of the saltmarsh with cattle, the saltmarsh habitat could become more appreciated. Also, with management ideas provided by the Mersey Gateway Environmental Trust, the appreciation could increase throughout the operational period. | |
| 141 | The site will continue to be used by local residents. The improvement of access and additions to the paths network would have a positive impact on the provision of this service. | |
| 142 | It is assumed that this service remains stable as no incentives to actively encourage culture, art and design are anticipated. | |
| 143 | With the Mersey Gateway Environmental Trust to use the site as a living laboratory, the provision of this service seems likely | The Mersey Gateway Environmental Trust (2017) |
| 144 | With adjacent Moore Nature Reserve under potential minimal management, the site at Moss Side Farm will be more appreciated. | |
| 145 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 146 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 147 | No overall change of vegetation cover. | |
| 148 | Potential flooding of agricultural land, depositing biomass available for carbon sequestration. | Forbes, Ball, & McLay (2015) |
| 149 | No overall change of vegetation cover. | |
| 150 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Workshop participant, personal communication, 7 June 2016 |
| 151, 152 | Proposed use of the site for flood water storage through the Environment Agency. | Workshop participant, personal communication, 7 June 2016 |

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| 153 | The provision of this service is dependent on sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service. | |
| 154 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 155 | Changes will occur with the use of the land as flood plain, it is, however, not certain if that involves sedimentation or erosion of land at the site. | |
| 156, 157 | No changes due to no anticipated change in vegetation cover. | |
| 158 | No direct public access available, but appreciation of the land through other viewpoints in the area. | |
| 159-162 | Privately owned agricultural land that will be floodplain, public access is unlikely to be available. | |
| 163-167 | No change in land cover. | |
| 168 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 169-171 | Not located in floodplain | |
| 172 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 173 | Not located near the river bed. | |
| 174-180 | No changes due to no anticipated change in vegetation cover. | |
| 181, 182 | Development of the area, reducing the area available to provide ES. | |
| 183 | Less vegetation cover, due to development of site. | |
| 184-186 | Loss of vegetated areas. | |

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| 187-189 | Not located in floodplain. | |
| 190 | Development of the area for commercial reasons will have an impact on the provision of the service. | |
| 191 | Not located near the river bed. | |
| 192 | Development of the site will have a negative on the provision of the service due to less area available for soil processes. | |
| 193 | Development of the site will have a negative on the provision of the service due to less area available for plants. | |
| 194 | Most likely more development in the area, reducing the area available to provide ES. | |
| 195-197 | Site not used for recreational purposes (industrial/ commercial site). | |
| 198 | Most likely more development in the area, reducing the area available to provide ES. | |
| 199-203 | No change in land cover anticipated. | |
| 204 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 205, 206 | The saltmarsh will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. | |
| 207 | The provision of this service is dependent on sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service. | |
| 208 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 209 | It can be assumed that the river edge will be subject to change in the medium to long-term future. However, the river dynamics are part of the | |

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| | natural processes, the extent of saltmarsh accretion or loss cannot be anticipated. | |
| 210-221 | No change in the provision of the service anticipated. | |
| 222 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 223 | Not located in floodplain. | |
| 224 | Will receive run-off and discharge from surrounding areas. | |
| 225 | Not located near the river bed. | |
| 226 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 227 | No erosion and sedimentation by water body as such due to site being part of a canal system. | |
| 228 | No soil processes or soil formation as such due to site being part of a canal system. | |
| 229-234 | No change in the provision of the service anticipated. | |
| 235 | Housing development likely: removing present vegetation means negative impact following the construction. Through appropriate landscaping, newly installed ornamental resources might be providing this service in the long-term. | |
| 236 | Area likely to be partly or fully developed in the future, negatively impacting the provision of the service. | |
| 237-240 | Less vegetation cover, due to partial development. If landscaping is appropriate, long-term benefits might be observed. | |
| 241-244 | Not located in floodplain. | |
| 244 | Development of the area will have an impact on the provision of the service. | |
| 245 | Not located near the river bed. | |
| 246 | Development of the site will have a negative on | |

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| | the provision of the service due to less area available for soil processes. | |
| 247 | Development of the site will have a negative on the provision of the service due to less area available for plants. | |
| 248-252 | Most likely more development in the area, reducing the area available to provide ES. | |
| 253 | This service will remain stable, even though the composition of the land cover might change over time, e.g. natural succession, i.e. the type of ornamental resource might change as well. | |
| 254 | In line with many other sites in the estuary, the site will remain stable over the operational period, as no active management for biodiversity is taking place. | |
| 255 | Slight increase in tree and shrub cover due to reduction of management and continuing of natural succession, which are able to move particulate matter from air flow through interception and increase evaporation due to an increased surface area. | Wang, Fu, Gao, Yao, & Zhou (2012)<br>Shashua-Bar & Hoffman (2000) |
| 256 | Natural succession from grassland to wooded areas, generally similar sequestration rates as other broad habitats, as defined by Natural England. | Alonso, Weston, Gregg, & Morecroft (2012) |
| 257 | Slight increase in tree and shrub cover due to reduction of management and continuing of natural succession, which are able to retain more water as well as provide air regulation and solar energy uptake. | Wang, Fu, Gao, Yao, & Zhou (2012)<br>Shashua-Bar & Hoffman (2000) |
| 258 | Slight increase in tree and shrub cover due to reduction of management and continuing of natural succession, which are able to provide better heat exchange regulation. | Baldocchi (2013) |
| 259, 260 | The site will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. Flood defences are installed in appropriate places to protect the infrastructure of the site. | |
| 261 | The provision of this service is dependent on | |

sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service.

262 No changes anticipated that would change the landscape maintenance in a significant way.

263 It can be assumed that the river edge will be subject to change in the medium to long-term future. However, the river dynamics are part of the natural processes, the extent of saltmarsh accretion or loss cannot be anticipated.

264 No changes due to no anticipated change in vegetation cover.

265 Provision of more flowering plants such as shrubs due to slow, managed natural succession.

266 No change in appearance of the site. No public access, but visible from other points in the estuary.

267-271 No public access.

272 Active landfill site, unlikely to change in the operational period.

273-275 No overall change of vegetation cover.

276 No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected.

277-279 Not located in floodplain

280 No changes anticipated that would change the landscape maintenance in a significant way.

281 Not located near the river bed.

282, 283 No changes due to no anticipated change in vegetation cover.

284- 288 No public access.

289, 290 Likely to be developed for housing over the

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| | operational period, reducing area available for ecosystem service provision. | |
| 291 | Less vegetation cover, due to development. If landscaping is appropriate, long-term benefits might be observed. | |
| 292 | Less vegetation cover, due to development. | |
| 293, 294 | Less vegetation cover, due to development. If landscaping is appropriate, long-term benefits might be observed. | |
| 295, 296 | Through development, the floodplain will be taken away. Flood defences will have to be installed. | |
| 297 | With development on adjacent land, flood protection would most likely prevent wave reduction from physical features and vegetation. | |
| 298 | Development of the area for mixed use will have an impact on the provision of the service. | |
| 299 | If developed for housing, flood defences are likely to be installed which will make the provision of the service not possible. | |
| 300, 301 | Development of the site will have a negative on the provision of the service due to less area available for soil processes. | |
| 302-306 | Most likely more development in the area, reducing the area available to provide ES. | |
| 307 | The provision of ornamental resources is likely to stay the same over the operational period as the land cover will not change. | |
| 308 | Through active management (grazing) for biodiversity (species diversity), the provision of the service is likely to increase. | Smith (2013) |
| 309 | Grazing has negative impact on vegetation cover, reducing the remove particulate matter from air flow through interception and increasing the amount of exposed soil. | Amiri, Ariapour, & Fadai (2008) |
| 310 | Through grazing with appropriate livestock units, the carbon sequestration is likely to be increased. Also, frequent tidal inundations affect the amount of carbon stored on the saltmarsh. | Olsen et al. (2011) |

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| 311 | No major change anticipated for the site. | |
| 312 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 313, 314 | The saltmarsh will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. | |
| 315 | The provision of this service is dependent on sedimentation and erosion processes and consequently the area available as saltmarsh. These are dynamic and natural in the estuary; therefore, the provision of wave reduction will change over time, but it cannot be assumed that there will be a significant change to the provision of the service. | |
| 316 | It can be assumed that through active management of the saltmarsh in the medium to long-term future, e.g. through cattle grazing, the provision of this service improves. | Andresen, Bakker, Brongers, Heydemann, & Irmler (1990) |
| 317 | It can be assumed that through active management of the saltmarsh in the medium to long-term future, trapping of sediments in gullies and creaks might increase. However, the edge of the saltmarsh is subject to changes of the river dynamics and as part of the natural processes, the extent of saltmarsh accretion or loss cannot be anticipated. | |
| 318 | It can be assumed that through active management of the saltmarsh in the medium to long-term future, e.g. through cattle grazing, the provision of this service improves. | Andresen, Bakker, Brongers, Heydemann, & Irmler (1990) |
| 319 | No changes due to no anticipated change in vegetation cover. | |
| 320 | The bridge might impact the aesthetics of the saltmarsh; however, continued grazing will improve the aesthetics of the saltmarsh. | |
| 321 | No public access. | |
| 322, 323 | Some provision of the service especially through use of the estuary as Living Laboratory by Mersey | The Mersey Gateway |

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| | Gateway Environmental Trust. | Environmental Trust (2017) |
| 324 | With continued grazing of saltmarsh, provision of this service will remain stable. | |
| 325-329 | No change in land cover anticipated. | |
| 330 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 331-333 | Not located in floodplain. | |
| 334 | No changes anticipated that would change the landscape maintenance in a significant way. | |
| 335 | Not located near the river bed. | |
| 336, 337 | No changes anticipated due to the vegetation cover not anticipated to change. | |
| 338 | The bridge might have impact on the aesthetics of the site. | |
| 339 | No change in recreational services, as the site is still used as a local green area. | |
| 340 | No change in the provision of this service. Projects such as the woodland trail will continue throughout the operational period. | |
| 341 | With the Mersey Gateway Environmental Trust to use the site as a living laboratory, the provision of this service seems likely | The Mersey Gateway Environmental Trust (2017) |
| 342 | The site suffers from the presence of the bridge which will impact the sense of place. | |

This scenario shows a varied positive response to changes in the provision of ecosystem services (Figure 24). The site with an expected high positive change of provision of ecosystem services is Arpley landfill. All relevant ecosystem services are expected to change positively, due to the change in land cover from a landfill to an amenity space. Upper Moss Side would benefit from management of habitats under this scenario which would positively influence the provision of ecosystem services. Further high positive changes can be expected at Widnes Warth, a site which is currently under management by the Mersey Gateway Environmental Trust, with expectations that the continued grazing of the marsh influences the provision of ecosystem services positively, e.g. biodiversity, landscape maintenance, and biological regulation of soil processes. Astmoor saltmarsh is expected to change positively under this scenario because the provision of four very important (+++) ecosystem services is expected to change under this scenario: biodiversity, carbon sequestration, flood water control, and peak discharge buffering. Moss Side Farm is also expected to have a medium positive response under this scenario, which is mainly due to the provision of the site as a flood plain, hence the provision of flood water storage and discharge buffering capacity. The medium positive change in provision of services at the United Utilities site originates from the natural succession of vegetation that is expected at the site.

Negative changes with the highest impact within the Business as Usual 2044 scenario are expected at three sites (Tan House Lane, Moore Nature Reserve, and Manchester Ship Canal Bank) (Figure 24). All three sites are expected to undergo development for residential and/or commercial purposes, which will see a reduction in ecosystem services. However, the changes at Tan House Lane are expected to include some visual improvements to the area. Hence, the negative changes are not as strongly perceived as on other development sites, which provided a more visually appealing site compared to the brownfield site before development. Some slight changes are expected at Moore Nature Reserve, due to reduced funding and the consequent management reductions at the site. This will affect biodiversity in particular, which is managed and conserved at the site. Wigg Island and the Manchester Ship Canal site will see some negative changes due to a reduction in the provision of cultural services at Wigg Island, due to the presence of the new bridge and the impact on vegetation at the Manchester Ship Canal site. All other sites are expected to not show a negative change in the provision of ecosystem services.

#### 4.5.2. Development Boom 2044

This scenario focused on an increased economic development of the boroughs and the consequences for the study site regarding the provision of ecosystem services. The results of this scenario are presented in Figure 25 in form of maps which display the positive change under the scenario in map 1) and the negative changes in map 2). The changes are analysed in detail and presented in tables, showing the expected direction of change (Table 30), as well as the underlying explanation for the change.

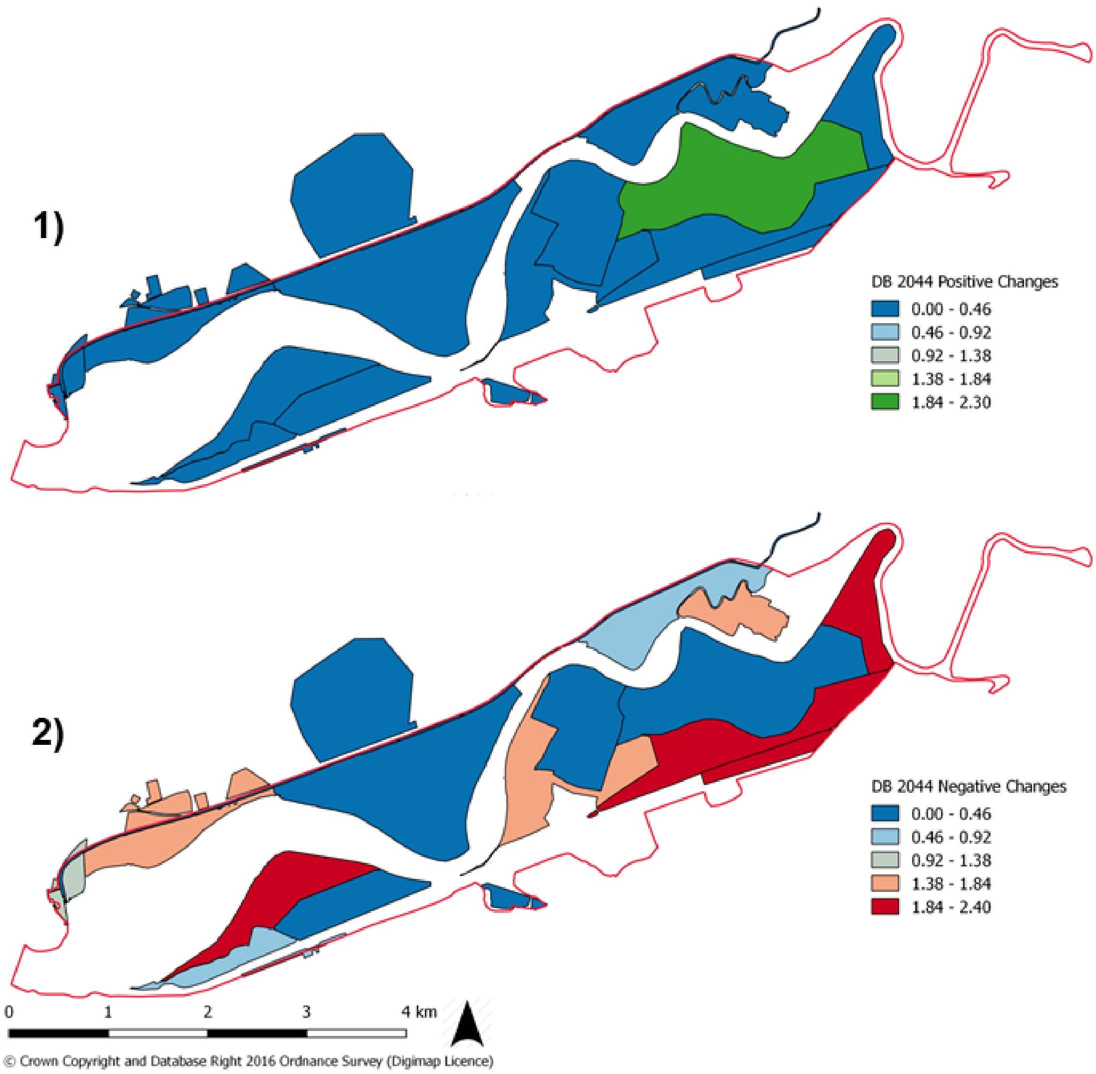


**Figure 25 Changes to the provision of ecosystem services under the Development Boom 2044 scenario for the Upper Mersey Estuary. Map 1) shows the positive changes of ecosystem service provision in each site compartment. Map 2) shows negative changes within each site compartment.**

**Table 30 Development Boom 2044: Ecosystem Service Provision by site compartment (0 = no change in provision of service; + = positive change in provision of service; - = negative change in provision of service; x = no provision of the service.**

| | Astmoor | Arpley landfill | Cuerdley saltmarsh | Fiddlers Ferry | Gatewarth | Manchester Ship Canal Bank | Moore Nature Reserve | Upper Moss Side | Moss Side Farm |
|---|---|---|---|---|---|---|---|---|---|
| **Ornamental resources** | 0[343] | +[362] | 0[380] | 0[398] | 0[416] | 0[434] | -[452] | 0[470] | 0[488] |
| **Biodiversity** | -[345] | +[363] | -[381] | 0[399] | -[417] | -[435] | -[453] | -[471] | 0[489] |
| **Removing harmful particles, air water exchange, biogeochemical reaction** | -[346] | +[364] | -[382] | 0[400] | +[418] | -[436] | -[454] | 0[472] | 0[490] |
| **Carbon sequestration and burial** | -[347] | +[365] | -[383] | 0[401] | 0[419] | 0[437] | -[455] | -[473] | 0[491] |
| **Water thermodynamic regulation** | -[348] | +[366] | 0[384] | 0[402] | +[420] | 0[438] | -[456] | -[474] | 0[492] |
| **Heat exchange regulation** | -[349] | +[367] | -[385] | 0[403] | +[421] | -[439] | -[457] | +[475] | 0[493] |
| **Flood water storage** | -[350] | x[368] | -[386] | x[404] | -[422] | x[440] | x[458] | -[476] | +[494] |
| **Peak discharge buffering** | -[351] | x[369] | -[387] | x[405] | -[423] | x[441] | x[459] | -[477] | +[495] |
| **Wave reduction** | -[352] | x[370] | -[388] | x[406] | -[424] | x[442] | x[460] | -[478] | 0[496] |
| **Landscape maintenance** | -[353] | +[371] | -389 | 0[407] | 0[425] | 0[443] | -[461] | -[479] | 0[497] |
| **Erosion and sedimentation regulation by water bodies** | -[354] | x[372] | -[390] | x[408] | -[426] | x[444] | x[462] | -[480] | -[498] |
| **Biological regulation of soil processes and soil formation** | -[355] | +[373] | -[391] | 0[409] | 0[427] | 0[445] | -[463] | -[481] | 0[499] |
| **Pollination** | 0[356] | +[374] | 0[392] | 0[410] | +[428] | 0[446] | -[464] | 0[482] | 0[500] |
| **Aesthetic appreciation** | -[357] | +[375] | 0[393] | 0[411] | -[429] | x[447] | -[465] | -[483] | 0[501] |
| **Opportunities for recreation & tourism** | x[358] | +[376] | x[394] | x[412] | 0[430] | x[448] | -[466] | -[484] | x[502] |
| **Inspiration for culture, art & design** | 0[359] | +[377] | x[395] | x[413] | 0[431] | x[449] | -[467] | 0[485] | x[503] |
| **Inspiration for cognitive development** | 0[360] | +[378] | x[396] | x[414] | 0[432] | x[450] | -[468] | 0[486] | x[504] |
| **Sense of place** | -[361] | +[379] | x[397] | x[415] | 0[433] | 0[451] | -[469] | 0[487] | x[505] |

**Table 30 (cont.)**

| | Oxmoor | Port Warrington | Spike Island | St Helens Canal | Tan House Lane | United Utilities | Randles Island | Warrington Waterfront | Widnes Warth | Wigg Island |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ornamental resources** | 0[506] | -[524] | 0[542] | 0[560] | -[578] | 0[596] | x[614] | -[632] | 0[650] | 0[668] |
| **Biodiversity** | -[507] | -[525] | -[543] | 0[561] | -[579] | -[597] | 0[615] | -[633] | -[651] | -[669] |
| **Removing harmful particles, air water exchange, biogeochemical reaction** | +[508] | -[526] | 0[544] | 0[562] | -[580] | -[598] | 0[616] | -[634] | 0[652] | 0[670] |
| **Carbon sequestration and burial** | -[509] | -[527] | 0[545] | 0[563] | -[581] | -[599] | 0[617] | -[635] | -[653] | -[671] |
| **Water thermodynamic regulation** | +[510] | -[528] | -[546] | 0[564] | -[582] | -[600] | 0[618] | -[636] | -[654] | 0[672] |
| **Heat exchange regulation** | 0[511] | -[529] | -[547] | 0[565] | -[583] | -[601] | 0[619] | -[637] | -[655] | -[673] |
| **Flood water storage** | x[512] | x[530] | -[548] | x[566] | x[584] | -[602] | x[620] | -[638] | -[656] | x[674] |
| **Peak discharge buffering** | x[513] | x[531] | -[549] | 0[567] | x[585] | -[603] | x[621] | -[639] | -[657] | x[675] |
| **Wave reduction** | x[514] | x[532] | -[550] | x[568] | x[586] | -[604] | x[622] | -[640] | -[658] | x[676] |
| **Landscape maintenance** | 0[515] | -[533] | -[551] | 0[569] | -[587] | -[605] | 0[623] | -[641] | -[659] | 0[677] |
| **Erosion and sedimentation regulation by water bodies** | x[516] | x[534] | -[552] | x[570] | x[588] | -[606] | x[624] | -[642] | -[660] | x[678] |
| **Biological regulation of soil processes and soil formation** | 0[517] | -[535] | -[553] | x[571] | -[589] | -[607] | 0[625] | -[643] | -[661] | 0[679] |
| **Pollination** | +[518] | -[536] | 0[554] | 0[572] | -[590] | 0[608] | 0[626] | -[644] | 0[662] | 0[680] |
| **Aesthetic appreciation** | -[519] | -[537] | 0[555] | 0[573] | +[591] | 0[609] | x[627] | -[645] | 0[663] | 0[681] |
| **Opportunities for recreation & tourism** | -[520] | x[538] | 0[556] | 0[574] | -[592] | x[610] | x[628] | -[646] | x[664] | 0[682] |
| **Inspiration for culture, art & design** | 0[521] | x[539] | 0[557] | 0[575] | 0[593] | x[611] | x[629] | -[647] | 0[665] | 0[683] |
| **Inspiration for cognitive development** | 0[522] | x[540] | 0[558] | 0[576] | 0[594] | x[612] | x[630] | -[648] | 0[666] | 0[684] |
| **Sense of place** | 0[523] | -[541] | 0[559] | 0[577] | +[595] | x[613] | x[631] | -[649] | 0[667] | 0[685] |

**Table 31 Description of provision of change of ecosystem services provision under the Development Boom 2044 scenario, based on the footnotes of Table 30.**

| | Description | Reference |
|---|---|---|
| 343 | No major change in land cover. No public access to the public to the site. | |
| 345 | With the presence of a tidal barrage, the biodiversity would decrease for a considerable amount of time due to changing environments (i.e. loss of intertidal areas, salinity, water flow, trophic relationships). These would need to find a new balance. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 346-352 | Loss of intertidal habitat will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 353-355 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 356 | With a tidal barrage in place, the saltmarsh will see different vegetation communities on the saltmarsh due to changes in water flow regimes and physio-chemical factors, however, the potential to provide the service are not likely to be affected, as the area available for flowering plants will remain the same. | |
| 357 | New bridge over the saltmarsh will obstruct the view towards the estuary. | |
| 358 | Not directly accessible to the public. | |
| 359 | As it is not directly accessible to the public, the cultural and art potential will not change from the status quo. | |
| 360 | Incentives such as the environmental trail on Wigg Island can cover part of Astmoor saltmarsh as well and offer information on the site. | |
| 361 | Very close to the new bridge and likely to not be so attractive as a site for residents. | |
| 362 | Establishment as a country park. Flora and fauna | |

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| | provide ornamental resources over the operational period. | |
| 363 | Green space will provide habitat for biodiversity in the long-term. | |
| 364 | Increase through more vegetation at Arpley country park. | |
| 365 | Build-up of biomass sequestering carbon over the long-term. | |
| 366 | Increase of this service over the operational period through development of the country park and build-up of vegetation. | |
| 367 | New formation of soil and vegetation over the operational period, increasing the provision of the service. | |
| 368-370 | Not located in floodplain. | |
| 371 | Improvement through land use change. Development of a green area will create landscapes and habitats typical for the region. | |
| 372 | Not located near the river bed. | |
| 373 | Through development of country park, provision of the service will increase over the operational period. | |
| 374 | Country park will add to the visual appeal of the landscape. | |
| 375 | Conversion from landfill to green space will see an improvement in the provision of the service. | |
| 376 | Additional space for recreation that can be used by the public. | |
| 377-379 | Additional space for that can be utilised by the public as an inspiration. | |
| 380 | No change in vegetation cover. | |
| 381 | With the presence of a tidal barrage, the biodiversity would decrease for a considerable amount of time due to changing environments (i.e. loss of intertidal areas, salinity, water flow, trophic relationships). These would need to find a new balance. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 382 | Loss of intertidal habitat will lead to less available | Houses of Parliament |

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| | area for provision of the service. | (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 383 | The tidal barrage effects the inundation patterns and tidal range of the site negatively in the long-term, leading to less biomass deposits on the marsh and loss of intertidal saltmarsh in general. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 384 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 385-388 | Loss of intertidal habitat due to tidal barrier will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 389-391 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 392 | With a tidal barrage in place, the saltmarsh will see different vegetation communities on the saltmarsh due to changes in water flow regimes and physio-chemical factors, however, the potential to provide the service is stated here to be stable, as it cannot be assessed how the plant communities would change under a different tidal regime. | |
| 393 | No change in the provision of the service. Site is only visible from other points in the estuary. | |
| 394-397 | No public access. | |
| 398 | No change in vegetation cover. | |
| 399 | Continued energy production that will require business access to the site and no active management for biodiversity. | |
| 400-402 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 403 | No change to the vegetation cover on the site is anticipated. | |

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| 404-406 | Not located in floodplain. | |
| 407 | No change in provision of the service due to unchanged land cover. | |
| 408 | Not located near the river bed. | |
| 409, 410 | No changes anticipated due to the vegetation cover not expected to change. | |
| 411 | Site will remain an electricity producing site within the operational period and will not gain any aesthetic appreciation within the near future. If energy production by coal is ceased in the medium-term future, it can be assumed that the power plant structures remain. | |
| 412-415 | No public access. | |
| 416 | This service will remain stable, even though the land cover might change over time (due to lack of active management), i.e. the type of ornamental resource might change as well. | |
| 417 | Less management at site will see natural succession changing habitats. Dominant flora and fauna will limit biodiversity. | |
| 418 | Natural succession will increase the number of shrubs and trees that will be able to reduce particulate matter and influence evaporation and respiration. | |
| 419 | No major change in land cover that would change the provision of this service. Low maintenance and leaving the site to natural succession would imply a decrease of carbon sequestration in the long-term due to build-up of shrub and woodland. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 420 | Low maintenance and leaving the site to natural succession could imply an increase in the service due to more shrubs and trees present on site that have an effect on the micro-climate and water regulation in terms of more increased cooling and surface area. | Wang, Fu, Gao, Yao, & Zhou (2012) |
| 421 | Natural succession from grassland to wooded areas, i.e. better uptake of solar energy. | Baldocchi (2013) |

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| 422-424 | Loss of intertidal habitat due to tidal barrier will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 425 | No change in the provision of the service over the operational period as no change in land cover assumed. | |
| 426 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 427 | No changes anticipated due to the vegetation cover not anticipated to change. | |
| 428 | Provision of more flowering plants such as shrubs due to natural succession and low management of present grass habitats. Regular management on site could include clearance of shrubs, from which grass habitats would benefit. | P. Oldfield, personal communication, date unknown |
| 429 | With little to no management of the site regarding the maintenance of land cover, shrubs and woods will appear, reducing the visual appeal of the site in the long-term. This includes the provision of a good viewpoint over the estuary. | |
| 430-433 | No change in the provision of the service. | |
| 434 | No major change in land cover, also no public access through which people could reach ornamental resources. | |
| 435 | Potential impact of shading from bridge (reason for relocation of orchids before construction) | McKendrick, Dixie and Heywood (n.d.) |
| 436 | Covering by the new bridge will increase shading, therefore, reducing potential evapotranspiration and photosynthesis, and removal of harmful particles. | Fischer (1975)<br>Woledge (1978) |
| 437 | No major impact on vegetation. The shading of the new bridge will be negligible. | |
| 438 | No major change anticipated for the site. | |

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| 439 | Shading effect of bridge reduces vegetation cover, therefore, reducing potential of water thermodynamic regulation. | Baldocchi (2013) |
| 440, 441 | Not located in floodplain. | |
| 442 | Canal system - no physical features for potential waves | |
| 443 | No major change anticipated for the site. | |
| 444 | Canal system - no physical features to provide erosion and sedimentation control. | |
| 445, 446 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 447-450 | No public access. | |
| 451 | No change in the provision of the service due to the same appreciation of the canal as a historic feature of the estuary. | |
| 452 | Loss of area to development. Less available resources to provide the service. | |
| 453 | Loss of area to development. Remaining area under pressure for funding for the implementation of projects. | |
| 454 | Loss of area to development. | |
| 455 | Loss of area with available biomass to sequester carbon. | |
| 456 | Loss of area will have an impact on the provision of the service due to less area and vegetation available for cooling, photosynthesis and evapotranspiration etc. | |
| 457 | Loss of intertidal habitat due to tidal barrier will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 458-460 | Not located in floodplain | |
| 461 | Loss of area to development. Less available | |

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| | resources to provide the service. | |
| 462 | Not located near the river bed. | |
| 463-469 | Loss of area to development. Less available resources to provide the service. | |
| 470 | No change in provision of the service due to unchanged site conditions. | |
| 471 | With the presence of a tidal barrage, the biodiversity would decrease for a considerable amount of time due to changing environments (i.e. loss of intertidal areas, salinity, water flow, trophic relationships). These would need to find a new balance. Services outside the tidal range remain stable. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 472 | Increase in shrub and woodland in places for former grassland will increase the provision of the service, whereas loss of intertidal areas will decrease the provision. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 473 | Loss of saltmarsh area for provision of the service due to tidal barrage. Slower carbon sequestration in areas through natural succession from grassland to shrub. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 474 | Loss of intertidal habitat due to tidal barrier will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 475 | Natural succession from grassland to wooded areas, i.e. better uptake of solar energy. | Baldocchi (2013) |
| 476-478 | Loss of intertidal habitat due to tidal barrier will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 479 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |

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| 480 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 481 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts on the saltmarshes. Other habitats remain unchanged. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 482 | With a tidal barrage in place, the saltmarsh will see different vegetation communities on the saltmarsh due to changes in water flow regimes and physio-chemical factors, however, the potential to provide the service is stated here to be stable, as it cannot be assessed how the plant communities would change under a different tidal regime. | |
| 483, 484 | With little to no management of the site regarding the maintenance of its land cover, shrubs and woods will appear in the medium term, reducing the visual appeal of the site in the long-term. | |
| 485-493 | No change in the provision of the service. | |
| 494, 495 | Use of the site for flood water storage by removal of flood protection on saltmarsh. | |
| 496 | The potential to provide this service would continue to be stable. However, with a tidal barrage, the effects on the saltmarsh composition would need to be evaluated. | |
| 497 | No change in the provision of the service over the operational period. | |
| 498 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 499, 500 | No change in the provision of the service. | |
| 501 | No direct public access available, but appreciation of the land through other viewpoints in the area. | |
| 502-505 | Privately owned agricultural land that will be floodplain, public access is unlikely to be available. | |

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| 506 | No change in provision of the service due to unchanged site conditions. | |
| 507 | No major change in land cover that would change the provision of this service in the short term. Low maintenance and leaving the site to natural succession could imply a decrease in biodiversity over the medium to long-term by spread of Himalayan Balsam or other dominant plants. | The Inland Waterways Association (n.d.) |
| 508 | Natural succession and build-up of trees, forming a larger surface for the provision of the service. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 509 | No major change in land cover that would change the provision of this service in the short to medium term. Low maintenance and leaving the site to natural succession could imply a decrease of carbon sequestration in the long-term due to build-up of shrub and trees. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 510 | Less grassland areas available through establishment of shrubs and woods through natural succession. In the long-term this could indicate an increase in potential to provide water thermodynamic regulation due to increased tree cover and leaf surface area | Wang, Fu, Gao, Yao, & Zhou (2012) |
| 511 | No overall change of vegetation cover. | |
| 512-514 | Not located in floodplain | |
| 515 | No change in the provision of the service over the operational period. | |
| 516 | Not located near the river bed. | |
| 517 | No changes due to no anticipated change in vegetation cover. | |
| 518 | Provision of more flowering plants such as shrubs due to natural succession and low management of present grass habitats. Regular management on site could include clearance of shrubs, from which grass habitats would benefit. | |

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| 519, 520 | With little to no management of the site regarding the maintenance of land cover, shrubs and woods will appear in the medium term, reducing the appeal of the site in the long-term. | |
| 521-523 | No change in the provision of the service. | |
| 524 | Most likely more development in the area, reducing the area available to provide ES. | |
| 525 | More development, reducing the provision of the service. | |
| 526-529 | Due to development, less area available for the provision of the service. | |
| 530-532 | Not located in floodplain. | |
| 533 | More development, reducing the provision of the service. | |
| 534 | Not close to river. | |
| 535-537 | Due to development, less area available for the provision of the service. | |
| 538-540 | Site not used for recreational purposes (industrial/ commercial site). | |
| 541 | Due to development, less area available for the provision of the service. | |
| 542 | No major change in land cover that provide ornamental resources. | |
| 543 | Reduction of intertidal saltmarsh with tidal barrier. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 544 | No major change in land cover that would change the provision of this service over the operational period. | |
| 545 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 546-550 | Loss of intertidal habitat due to tidal barrier will lead | Houses of Parliament |

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| | to less available area for provision of the service. | (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 551-553 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 554-565 | No change in the provision of the service. | |
| 566 | Not located in floodplain. | |
| 567 | Will receive run-off and discharge from surrounding areas. | |
| 568 | Not located by the river. | |
| 569 | No change in the provision of the service over the operational period. | |
| 570 | No erosion and sedimentation by water body as such due to site being part of a canal system. | |
| 571 | No soil processes or soil formation as such due to site being part of a canal system. | |
| 572 | No change in the provision of the service over the operational period. | |
| 573-577 | No change in the provision of the service. | |
| 578 | Housing development, removing present vegetation means negative impact following the construction. Through appropriate landscaping, newly installed ornamental resources might be providing this service in the long-term. | |
| 579-583 | More development, reducing the provision of the service. | |
| 584-586 | Not located in floodplain. | |
| 587 | More development, reducing the provision of the service. | |
| 588 | Not located by the river. | |

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| 589, 590 | More development, reducing the provision of the service. | |
| 591 | Change from derelict land to mixed use development increases the visual appeal of the site. | |
| 592 | The site is currently used by bikers and dog-walkers, which will not be possible with housing development in place. | |
| 593, 594 | No change in the provision of the service. | |
| 595 | Development from derelict land to housing will give residents and visitors a sense of place, supported by the proximity of the estuary and its views. | |
| 596 | This service will remain stable, even though the land cover might change over time, e.g. natural succession, i.e. the type of ornamental resource might change as well. | |
| 597 | Reduction of intertidal saltmarsh with tidal barrier. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 598-604 | Loss of intertidal habitat will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 605 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 606 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 607 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |

608 No change in provision of the service due to unchanged site conditions.

609 No change in appearance of the site. No public access, but visible from other points in the estuary.

610-614 No public access.

615-619 No change in provision of the service due to unchanged site conditions which would affect the service.

620-622 Not located in floodplain.

623 No change in provision of the service due to unchanged land cover.

624 Not close to river.

625, 626 No change in provision of the service due to unchanged land cover.

627-631 No public access.

632 Housing development, removing present vegetation means negative impact following the construction. Through appropriate landscaping, newly installed ornamental resources might be providing this service in the long-term.

633-639 More development, reducing the provision of the service.

640 With development on adjacent land, flood protection would most likely prevent wave reduction from physical features and vegetation.

641-644 More development, reducing the provision of the service.

645 Change to housing development will see Green Belt land removed, leading to a reduced aesthetic appreciation.

646-649 Development from Green Belt land to housing development will reduce space for the provision of the service.

650 No major change in land cover. No public access to

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| | the site. | |
| 651 | With the presence of a tidal barrage, the biodiversity would decrease for a considerable amount of time due to changing environments (i.e. loss of intertidal areas, salinity, water flow, trophic relationships). These would need to find a new balance. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 652 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 653-659 | Loss of intertidal habitat due to tidal barrier will lead to less available area for provision of the service. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 660, 661 | With different flooding regimes, due to the tidal barrier, the saltmarsh landscape will change over the long-term, with potential long-term negative impacts. | Houses of Parliament (2013)<br>Wolf, Walkington, Holt, & Burrows( 2009) |
| 662 | With a tidal barrage in place, the saltmarsh will see different vegetation communities on the saltmarsh due to changes in water flow regimes and physio-chemical factors, however, the potential to provide the service is stated here to be stable, as it cannot be assessed how the plant communities would change under a different tidal regime. | |
| 663 | The bridge might impact the aesthetics of the saltmarsh; however, continued grazing will improve the aesthetics of the saltmarsh. | |
| 664 | No public access. | |
| 665, 666 | Some provision of the service especially through use of the Mersey Gateway Environmental Trust Living Laboratory. | The Mersey Gateway Environmental Trust (2017) |
| 667 | With continued grazing of saltmarsh, provision of this service will remain stable. | |
| 668 | No major change in land cover that provide ornamental resources. | |
| 669 | No major change in land cover that would change the provision of this service in the short term. Low | The Inland Waterways |

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| | maintenance and leaving the site to natural succession could imply a decrease in biodiversity over the medium to long-term by spread of Himalayan Balsam or other dominant plants. | Association (n.d.) |
| 670 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 671 | No major change in land cover that would change the provision of this service in the short to medium term. Low maintenance and leaving the site to natural succession could imply a decrease of carbon sequestration in the long-term due to build-up of shrub and trees. | Nowak & Heisler (2010)<br>Speak, Rothwell, Lindley, & Smith (2012) |
| 672 | No change in provision of the service due to unchanged land cover which would affect the service. | |
| 673 | Shading effect of bridge reduces vegetation cover, therefore, reducing potential of water thermodynamic regulation. | Baldocchi (2013) |
| 674, 676 | Not located in floodplain. | |
| 677 | No change in the provision of the service over the operational period. | |
| 678 | Not close to the river. | |
| 679 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 680, 681 | Management of habitats on site will see some changes in vegetation cover, but no significant change in the provision of the service can be anticipated. | |
| 682-685 | No change in the provision of the service. | |

Within this scenario not many positive changes to the provision of ecosystem services can be expected. The reasons are laid out in previous sections, but are in general due to low priorities regarding nature conservation and environmental management. Positive changes can be expected at the Arpley landfill site – the closure of the landfill will initiate change towards a more natural land use, hence, a positive change in the provision of ecosystem services.

Some minor positive changes in the provision of ecosystem services can be expected in five other site compartments. Those changes are due to natural succession and the associated positive provision of regulating ecosystem services. At Moss Side Farm, the use of the site as a flood plain enhances the provision of the services associated with this land use. The changes at the brownfield site of Tan House Lane are associated with improvements in the aesthetic appreciation of the site – from a brownfield site that is not widely used by the public, to buildings and associated landscaping that frame the estuary and make it visually appealing.

Negative changes to the provision of ecosystem services can be expected at those sites that are due to be developed (Port Warrington, Warrington Waterfront, and to some extent Tan House Lane). Astmoor saltmarsh, like all saltmarsh habitats in the estuary, is expected to have a decreased provision of ecosystem services due to several important ecosystem services not being provided. This is due to the effects of a tidal barrage further down-stream in the estuary. The tidal barrage would have an effect on regulating services such as carbon sequestration, erosion and sedimentation regulation by water bodies, flood water storage, and peak discharge buffering (Wolf, Walkington, Holt, & Burrows, 2009).

### 4.5.3. Nature is Key 2044

This scenario focuses on long-term sustainable development within and around the Upper Mersey Estuary. The results of this scenario are presented in Figure 26 in form of maps, as well as tables, showing expected direction of change (Table 32), and the underlying explanation for the change (Table 33).

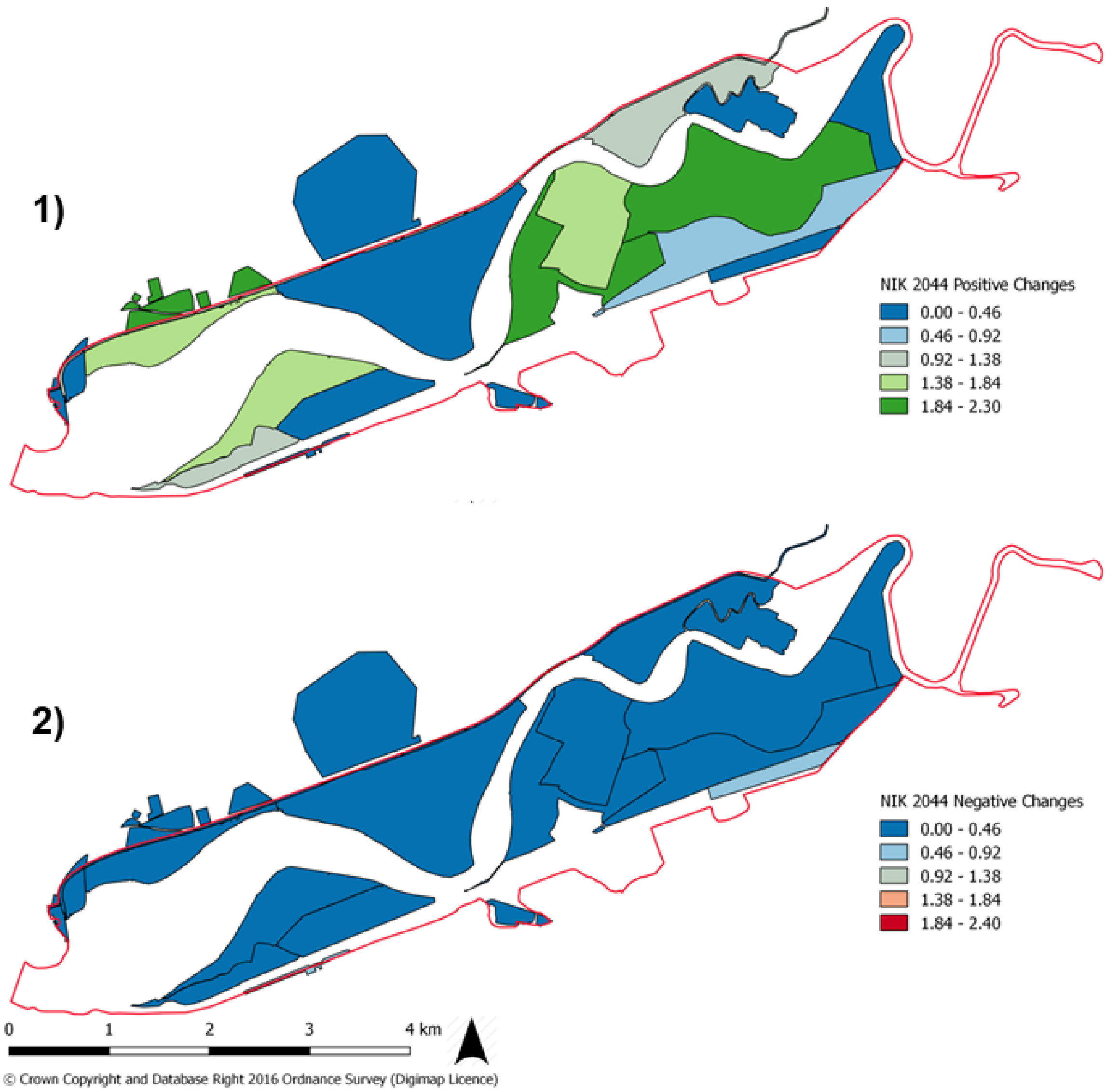


**Figure 26 Changes to the provision of ecosystem services under the Nature is Key 2044 scenario for the Upper Mersey Estuary. Map 1) shows the positive changes of ecosystem service provision in each site compartment. Map 2) shows negative changes within each site compartment.**

**Table 32 Nature is Key 2044: Ecosystem Service Provision by site compartment (0 = no change in provision of service; + = positive change in provision of service; - = negative change in provision of service; x = no provision of the service.**

| | Astmoor | Arpley landfill | Cuerdley saltmarsh | Fiddlers Ferry | Gatewarth | Manchester Ship Canal Bank | Moore Nature Reserve | Upper Moss Side | Moss Side Farm |
|---|---|---|---|---|---|---|---|---|---|
| **Ornamental resources** | 0[686] | +[704] | 0[722] | 0[740] | +[758] | 0[776] | 0[794] | 0[812] | 0[830] |
| **Biodiversity** | +[687] | +[705] | +[723] | 0[741] | +[759] | -[777] | 0[795] | +[813] | +[831] |
| **Removing harmful particles, air water exchange, biogeochemical reaction** | 0[688] | +[706] | +[724] | 0[742] | -[760] | -[778] | 0[796] | 0[814] | 0[832] |
| **Carbon sequestration and burial** | +[689] | +[707] | +[725] | 0[743] | +[761] | 0[779] | 0[797] | +[815] | +[833] |
| **Water thermodynamic regulation** | +[690] | +[708] | 0[726] | 0[744] | -[762] | 0[780] | 0[798] | +[816] | 0[834] |
| **Heat exchange regulation** | 0[691] | +[709] | 0[727] | 0[745] | 0[763] | 0[781] | 0[799] | 0[817] | 0[835] |
| **Flood water storage** | +[692] | x[710] | +[728] | x[746] | 0[764] | x[782] | x[800] | +[818] | +[836] |
| **Peak discharge buffering** | +[693] | x[711] | +[729] | x[747] | 0[765] | x[783] | x[801] | +[819] | +[837] |
| **Wave reduction** | 0[694] | x[712] | 0[730] | x[748] | 0[766] | x[784] | x[802] | 0[820] | 0[838] |
| **Landscape maintenance** | +[695] | +[713] | +[731] | 0[749] | +[767] | 0[785] | 0[803] | +[821] | +[839] |
| **Erosion and sedimentation regulation by water bodies** | +[696] | x[714] | +[732] | x[750] | 0[768] | x[786] | x[804] | +[822] | +[840] |
| **Biological regulation of soil processes and soil formation** | +[697] | +[715] | 0[733] | 0[751] | 0[769] | 0[787] | 0[805] | +[823] | +[841] |
| **Pollination** | +[698] | +[716] | 0[734] | 0[752] | +[770] | 0[788] | 0[806] | 0[824] | +[842] |
| **Aesthetic appreciation** | 0[699] | +[717] | 0[735] | 0[753] | +[771] | x[789] | +[807] | +[825] | 0[843] |
| **Opportunities for recreation & tourism** | x[700] | +[718] | x[736] | x[754] | +[772] | x[790] | 0[808] | +[826] | x[844] |
| **Inspiration for culture, art & design** | +[701] | +[719] | x[737] | x[755] | 0[773] | x[791] | 0[809] | +[827] | x[845] |
| **Inspiration for cognitive development** | +[702] | +[720] | x[738] | x[756] | 0[774] | x[792] | +[810] | +[828] | x[846] |
| **Sense of place** | 0[703] | +[721] | x[739] | x[757] | +[775] | 0[793] | +[811] | +[829] | x[847] |

**Table 32 (cont.)**

| | Oxmoor | Port Warrington | Spike Island | St Helens Canal | Tan House Lane | United Utilities | Randles Island | Warrington Waterfront | Widnes Warth | Wigg Island |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ornamental resources** | 0[848] | -[866] | 0[884] | 0[902] | +[920] | 0[938] | x[956] | 0[974] | 0[992] | +[1010] |
| **Biodiversity** | 0[849] | -[867] | 0[885] | +[903] | +[921] | 0[939] | 0[957] | 0[975] | +[993] | +[1011] |
| **Removing harmful particles, air water exchange, biogeochemical reaction** | 0[850] | 0[868] | 0[886] | 0[904] | +[922] | 0[940] | 0[958] | 0[976] | -[994] | 0[1012] |
| **Carbon sequestration and burial** | 0[851] | 0[869] | 0[887] | 0[905] | +[923] | 0[941] | 0[959] | 0[977] | +[995] | 0[1013] |
| **Water thermodynamic regulation** | 0[852] | 0[870] | 0[888] | 0[906] | +[924] | 0[942] | 0[960] | 0[978] | -[996] | 0[1014] |
| **Heat exchange regulation** | 0[853] | 0[871] | 0[889] | 0[907] | +[925] | 0[943] | 0[961] | 0[979] | 0[997] | 0[1015] |
| **Flood water storage** | x[854] | x[872] | 0[890] | x[908] | x[926] | 0[944] | x[962] | 0[980] | +[998] | x[1016] |
| **Peak discharge buffering** | x[855] | x[873] | 0[891] | 0[909] | x[927] | 0[945] | x[963] | 0[981] | +[999] | x[1017] |
| **Wave reduction** | x[856] | x[874] | 0[892] | x[910] | x[928] | 0[946] | x[964] | 0[982] | 0[1000] | x[1018] |
| **Landscape maintenance** | 0[857] | 0[875] | 0[893] | +[911] | +[929] | 0[947] | 0[965] | 0[983] | +[1001] | 0[1019] |
| **Erosion and sedimentation regulation by water bodies** | x[858] | x[876] | 0[894] | x[912] | x[930] | 0[948] | x[966] | 0[984] | +[1002] | x[1020] |
| **Biological regulation of soil processes and soil formation** | 0[859] | 0[877] | 0[895] | x[913] | +[931] | 0[949] | 0[967] | 0[985] | +[1003] | 0[1021] |
| **Pollination** | 0[860] | 0878 | 0[896] | 0[914] | +[932] | 0[950] | 0[968] | 0[986] | +[1004] | +[1022] |
| **Aesthetic appreciation** | 0[861] | -[879] | 0[897] | +[915] | +[933] | 0[951] | x[969] | 0[987] | 0[1005] | +[1023] |
| **Opportunities for recreation & tourism** | 0[862] | x[880] | +[898] | +[916] | +[934] | x[952] | x[970] | 0[988] | x[1006] | 0[1024] |
| **Inspiration for culture, art & design** | 0[863] | x[881] | 0[899] | 0[917] | +[935] | x[953] | x[971] | 0[989] | +[1007] | +[1025] |
| **Inspiration for cognitive development** | 0[864] | x[882] | 0[900] | +[918] | +[936] | x[954] | x[972] | 0[990] | +[1008] | +[1026] |
| **Sense of place** | 0[865] | -[883] | 0[901] | +[919] | +[937] | x[955] | x[973] | 0[991] | 0[1009] | +[1027] |

**Table 33 Description of provision of change of ecosystem services provision under the 'Nature is key 2044' scenario, based on the footnotes of Table 32.**

| | Explanation | Reference |
|---|---|---|
| 686 | No major change to land cover. No public access to the site. | |
| 687 | Long-term restoration of the saltmarsh with continuous investment into maintenance of biodiversity measures such as pools, creeks, reed bed management. | Adnitt et al. (2007) |
| 688 | No major changes in the provision of the service. Potentially, slightly less vegetation present through the creation of scrapes and ponds, the effect can be assumed to be negligible. | |
| 689 | Through grazing with appropriate livestock units, carbon sequestration is likely to be increased. Also, frequent tidal inundations affect the amount of carbon stored on the saltmarsh. | Olsen et al. (2011)<br>Morris & Jensen (1998) |
| 690 | Changes of vegetation structure due to grazing which encourages a varied canopy, enhancing the provision of the service. | Bakker (1985)<br>Bakker & de Vries (1992) |
| 691 | No major change in vegetation cover anticipated for the site. Unless a major vegetation change occurs, the changes in provision of the service can be neglected. | Baldocchi (2013) |
| 692, 693 | Improvements to the provision of the service through continued work of the saltmarsh restoration plan which includes the creation and maintenance of creeks and ponds on the saltmarsh, which can take up flood water. | Natural England (2014)<br>(Merseylink, 2016b) |
| 694 | Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area. | |
| 695 | Grazing is supporting the development of typical saltmarsh vegetation. Water management on saltmarsh supports typical saltmarsh vegetation, creating a typical landscape and hydrology. | |
| 696 | Apart from natural sedimentation and erosion processes at the edge of the saltmarsh, sediment | |

| | | |
|---|---|---|
| | trapping occurs on the installed features such as ponds, sluices, creeks and in managed reed beds. | |
| 697 | Increase of soil microbial activities due to grazing on saltmarsh and break down of organic material present on the marsh. | Andresen, Bakker, Brongers, Heydemann, & Irmler (1990) |
| 698 | Through presence of grazing cattle, different plant communities will colonise the saltmarsh, supporting a diversity of plants and pollinators. Grazing densities have to be considered. | Lazaro, Tscheulin, Devalez, Nakas, & Petanidou (2016) |
| 699 | Continued grazing and other management efforts improve the provision of the service against the presence of the bridge close by. | |
| 700 | No public access. | |
| 701, 702 | More inspiration through grazing of saltmarsh and presence of new bridge. | |
| 703 | Although there is no public access to the site, the view of the traditional grazing of the saltmarsh, balances the fact that the bridge impacts the view and sense of place of the site. | |
| 704 | Country park source of ornamental resources. | |
| 705 | Old landfill managed as country park for biodiversity and wildlife. | |
| 706 | Increase of vegetation through Arpley country park. | |
| 707, 708 | Country park will contribute to carbon sequestration through increase of vegetation cover. | |
| 709 | Improvements of provision of service through introduction of vegetation on Arpley landfill site. | Baldocchi (2013) |
| 710-712 | Not on a flood plain. | |
| 713 | Adding to green corridor through country park. | |
| 714 | Not close to river | |
| 715 | Slow increase in soil processes during operational period through capping with earth material. Processes will be slow and might not be observable until the end of the operational period. | |
| 716 | Establishment of vegetation and habitats for pollinators in country park. | |

| | | |
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| 717 | Country park will add to the visual appeal of the landscape. | |
| 718 | More locals expected through opening of country park, local view point. | |
| 719 | Incentives can be set to promote the new landscape as an inspiration of culture and art projects. | |
| 720 | Site with good potential to install educational paths, signs, visitor information. | |
| 721 | Good view point over the estuary, gives locals the possibility to enjoy local nature on old industrial site. | |
| 722 | No change in vegetation cover. | |
| 723 | Increase in biodiversity through long-term management of reed beds and water flow on the saltmarsh. | Fisher et al. (2011) |
| 724 | Long-term management of reed beds improves the provision of the service through bio-chemical reactions, i.e. filtration processes. | Greenway (2004) |
| 725 | Slow accumulation of carbon through tidal inundation and seasonal breakdown of biomass without disturbance. | Alonso, Weston, Gregg, & Morecroft (2012) |
| 726, 727 | No major changes on saltmarsh as no major changes to vegetation cover are anticipated at this site. | Baldocchi (2013) |
| 728, 729 | Slight improvement of provision of service through creation and maintenance of creeks and sluices, as well as reed bed management on saltmarsh. | Natural England (2014)<br>(Merseylink, 2016b) |
| 730 | Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area. | |
| 731 | Water management on saltmarsh supports typical saltmarsh vegetation, creating a typical landscape and hydrology. | |
| 732 | Apart from natural sedimentation and erosion processes at the edge of the saltmarsh, sediment | |

| | | |
|---|---|---|
| | trapping occurs on the installed features such as ponds, sluices, creeks and in managed reed beds. | |
| 733 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 734 | No change in vegetation which would have an impact on the provision of the service. | |
| 735 | No change. Site cannot be directly accessed by people and is only visible from a distance. | |
| 736-739 | No public access. | |
| 740 | No change in vegetation cover. | |
| 741 | Continued energy production that will require business access to the site and no active management for biodiversity. | |
| 742 | No change in vegetation cover. | |
| 743 | No major sequestration due to mainly build up area. Green areas are mainly wooded areas (slower sequestration rate). | |
| 744 | No change to the vegetation cover on the site is anticipated. | |
| 745 | No change to the vegetation cover on the site is anticipated. | Baldocchi (2013) |
| 746-748 | Not located in flood plain. | |
| 749 | No change in vegetation cover that would influence the provision of the service. | |
| 750 | Not close to river. | |
| 751 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 752 | No change in vegetation which would have an impact on the provision of the service. | |
| 753 | Will remain an electricity producing site within the operational period and will not gain any aesthetic appreciation within the near future. If energy production by coal is ceased in the medium-term future, it can be assumed that the power plant structures remain. | |

| | | |
|---|---|---|
| [754-757] | No public access. | |
| [758] | Increased management of habitats producing a wider variety of plants. | |
| [759] | Increased management of site and maintenance/improvement of current habitats will result in benefits for biodiversity, supporting a diversity of habitats. | Sinnett (2014) |
| [760] | Removal of shrubs and wooded areas for the benefit of other habitat types which will reduce the amount of leave surfaces. However, site will remain its capacity for evapotranspiration and degradation of chemicals. | Nowak & Heisler (2010) |
| [761] | Active management will prevent natural succession, enabling faster sequestration of carbon by grassland, compared to wooded areas. | Alonso, Weston, Gregg, & Morecroft (2012) |
| [762] | Active management reduces wooded areas which contribute more to water thermodynamic regulation than grassland. | Wang, Fu, Gao, Yao, & Zhou (2012)<br>Shashua-Bar & Hoffman (2000) |
| [763-765] | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| [766] | The present features of the saltmarsh will provide the service over the operational period. Natural dynamics might change the extent of physical features or vegetation, but this will have no significant effect on the provision of the service over the long-term. | |
| [767] | Active management supports a variety of habitats and biodiversity which is typical for an estuarine landscape, based on the history of the site as a landfill. | |
| [768, 769] | No change in the provision of the service over the operational period. | |
| [770] | A variety of habitats will support pollinator communities throughout the site during the operational period with the potential to introduce native flowering plants to the site, increasing the provision of the service. | |

| | | |
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| [771] | Continued management which will improve and create a variety of habitats, with good views over the estuary. | |
| [772] | Improved access and path network make site more accessible for local visitors and users of the Trans Pennine Trail. | |
| [773, 774] | No major change in the provision of the service. | |
| [775] | Through active management and improved access to the site, the public can overview the estuary from the site and experience a sense of place. | |
| [776] | No major change in land cover, also no public access through which people could reach ornamental resources. | |
| [777] | Potential impact of shading from bridge for some orchid species. | McKendrick, Dixie, & Heywood (n.d.) |
| [778] | Covering by the new bridge will increase shading, therefore, reducing potential evapotranspiration and photosynthesis, and removal of harmful particles. | Fischer (1975)<br>Woledge (1978)<br>Amiri, Ariapour, & Fadai (2008) |
| [779, 780] | No major impact on vegetation. The shading of the new bridge will be negligible. | |
| [781] | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| [782, 783] | Not located in floodplain. | |
| [784] | Canal system – no physical features for potential waves. | |
| [785] | No change in vegetation cover that would influence the provision of the service. | |
| [786] | Canal system – no physical features to provide erosion and sedimentation control. | |
| [787, 788] | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| [789-792] | No public access. | |
| [793] | No change in the provision of the service due to the same appreciation of the canal as a historic feature | |

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|---|---|---|
| | of the estuary. | |
| 794 | This service will remain stable, even though the land cover might change over time, e.g. natural succession, i.e. the type of ornamental resource might change as well. | |
| 795 | Moore Nature Reserve will be managed on the same scale as status quo, remaining the current level of biodiversity. In the long-term over spilling effects from other surrounding areas might result in increased biodiversity. | |
| 796 | No major change in the provision of the service due to no major change in vegetation cover which could influence the provision of this service. | |
| 797, 798 | No change in the overall vegetation cover. | |
| 799 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 800-802 | Not located in flood plain. | |
| 803 | The management of the site already supports a high standard of landscape maintenance, using historic features such as old sand quarries as natural spaces. | |
| 804 | Not close to river | |
| 805 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 806 | A variety of habitats will support pollinator communities throughout the site during the operational period. | |
| 807 | Through cooperation with the Mersey Gateway Environmental Trust and other neighbouring areas, the site will become a connected site which visitors will appreciate. | |
| 808 | Already good opportunities for recreation, connectivity to other sites, e.g. Upper Moss Side, might improve the provision of the service in the long-term. | |
| 809 | No major change in the provision of the service. | |

| | | |
|---|---|---|
| 810 | Through cooperation with the Mersey Gateway Environmental Trust and other neighbouring areas, the site can be used for education and cognitive development. | |
| 811 | Through cooperation with the Mersey Gateway Environmental Trust and other neighbouring areas, the site contributes to the provision of the service in the long-term by creating a green space that can be enjoyed close to urban environments. | |
| 812 | This service will remain stable, even though the land cover might change over time, e.g. natural succession, i.e. the type of ornamental resource might change as well. | |
| 813 | Management of a variety of habitats, which attract species over the long-term. | |
| 814 | No major change in the provision of the service due to no major change in vegetation cover which could influence the provision of this service. | |
| 815 | Saltmarsh under light grazing and frequent tidal inundation likely to accumulate carbon. Maintenance of the grassland will improve carbon sequestration as well. | Olsen et al. (2011)<br>Morris & Jensen (1998)<br>E. Osim, personal communication, 1 December 2016 |
| 816 | Management of wooded areas increase provision of service. Grazing will contribute to the development of a varied saltmarsh canopy, supporting the provision of the service. | Wang, Fu, Gao, Yao, & Zhou (2012)<br>Bakker (1985) |
| 817 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 818, 819 | Slight improvement of provision of service through creation and maintenance of creeks and sluices, as well as reed bed management on saltmarsh. | Natural England (2014)<br>(Merseylink, 2016b) |
| 820 | Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area. | |

| | | |
|---|---|---|
| 821 | Grazing of the saltmarsh support the formation of typical saltmarsh vegetation and respective landscape and hydrology. The management of other habitat on site such as wet woodlands and improved grasslands, support the provision of the service as well. | |
| 822 | The saltmarsh habitat will contribute to the provision of the service, especially through the creation of pool and creeks, which are created by cattle on the saltmarsh. | |
| 823 | Increase of soil microbial activities due to grazing on saltmarsh and break down of organic material present on the marsh. | Andresen, Bakker, Brongers, Heydemann, & Irmler (1990) |
| 824 | Active management of habitats such as saltmarsh (grazing) and improved grassland (wildflower meadows) will see an increase in the provision of the service. | |
| 825 | Grazing on the saltmarsh as well as active management of habitats and path network will be appreciated by the visitors. | |
| 826 | Improved path networks, visitor management and connectivity with other sites, as well as habitat management can improve the provision of the site in the long-term. | |
| 827, 828 | Improved visitor and path management will increase use of site and provision of the service. | |
| 829 | Through cooperation with the Mersey Gateway Environmental Trust and other neighbouring areas, the site contributes to the provision of the service in the long-term by creating a green space that can be enjoyed close to urban environments. | |
| 830 | Management of the floodplain will not result in an increase of the provision of ornamental resources at the site. | |
| 831 | Active management of flood plains (agricultural land) for farmland birds. | Wretenberg, Lindstroem, Svensson, & Paert (2007) |
| 832 | No overall change of vegetation cover. | |
| 833 | Through use of floodplain, biomass is deposited on land. | Kane (2015) |

| | | |
|---|---|---|
| 834 | No change in overall vegetation cover. | |
| 835 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 836, 837 | Use of the site for flood water storage by removal of flood protection on saltmarsh. | |
| 838 | Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area. | |
| 839 | Use of the site as a floodplain will support the provision of the service as a typical service in the estuary. | |
| 840 | Land available for sedimentation and erosion during floods. | |
| 841 | Deposits on saltmarsh after floods might increase the soil microbial activity. | Jenny (1994) |
| 842 | Use of the buffer strips adjacent to agricultural land for the introduction of wildflowers and native flowering plants could see an increase in the provision of the service. | |
| 843 | No direct public access available, but appreciation of the land through other viewpoints in the area. | |
| 844-847 | Privately owned agricultural land that will be floodplain, public access is unlikely to be available. | |
| 848, 849 | The provision of the service is assumed to be stable. | |
| 850-852 | No overall change of vegetation cover. | |
| 853 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 854-856 | Not located in flood plain. | |
| 857 | No change at site anticipated that would have an impact on the provision of the service. | |
| 858 | Not close to river. | |

| | | |
|---|---|---|
| 859, 860 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 861-865 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 866, 867 | Most likely more development in the area, reducing the area available to provide ES. | |
| 868 | No overall change of vegetation cover, due to no further development at site. | |
| 869, 870 | No change in overall vegetation cover. | |
| 871 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 872-874 | Not located in flood plain. | |
| 875 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 876 | Not close to river. | |
| 877, 878 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 879 | Most likely more development in the area, reducing the area available to provide ES. | |
| 880-882 | Site not used for recreational purposes. | |
| 883 | Most likely more development in the area, reducing the area available to provide ES. | |
| 884 | This service will remain stable with no changes to the access and management of the site. | |
| 885 | This service will remain stable with no changes to the access and management of the site. | |
| 886 | No overall change of vegetation cover. | |
| 887 | No change in overall vegetation cover. | |
| 888 | No change in overall vegetation cover. | |
| 889 | No change in provision of the service due to unchanged site conditions which would affect the | |

| | | |
|---|---|---|
| | service. | |
| 890, 891 | The saltmarsh will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. | |
| 892 | Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area. | |
| 893-895 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 896 | Introduction of wildflower meadows and management of grassland could see an increase in pollinator communities. | |
| 897 | No change in appearance of the site. | |
| 898 | Projects with local stakeholders, e.g. the Catalyst Museum can introduce opportunities for recreation, i.e. in connection with the new bridge and the work of the Mersey Gateway Environmental Trust. | |
| 899-902 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 903 | Inclusion of the canal in the active management and create a wildlife corridor for it within the wider area. | Lawton et al. (2010) |
| 904-907 | No change in provision of the service due to unchanged site conditions which would affect the service. | |
| 908 | Not located in flood plain. | |
| 909 | Will receive run-off and discharge from surrounding areas. | |
| 910 | Not located near the river bed. | |
| 911 | Through active management, the canal can become active landscape network that supports the hydrology and other functions. | |

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| 912 | No erosion and sedimentation by water body as such due to site being part of a canal system. | |
| 913 | No soil processes or soil formation as such due to site being part of a canal system. | |
| 914 | No change in vegetation which would have an impact on the provision of the service. | |
| 915 | Active management for nature improves the aesthetics of the canal by e.g. more biodiversity. | |
| 916 | As part of the scenario, the management will see a rise in use of green areas e.g. the Trans Pennine Trail | |
| 917 | No change in provision of the service. | |
| 918 | Environmental education is part of the scenario, i.e. using the Trans Pennine Trail as a way to promote nature conservation. | |
| 919 | The canal is part of the history of the area and valued by residents. The investment into nature and the wildlife is adding to the cultural value of the site. | |
| 920 | Use of the brownfield site for nature conservation, i.e. higher variety of plants and ornamental resources. | |
| 921 | Brownfields develop into natural site and attract biodiversity. | Buglife (2009) |
| 922-924 | Increase in vegetation through use of brownfield site as green space. | |
| 925 | More vegetation will increase the provision of the service. | Baldocchi (2013) |
| 926-928 | Not located in flood plain. | |
| 929 | Use of site as green space will support typical landscapes which is highly influenced by human use, but reclaimed by nature. | |
| 930 | Not close to river. | |
| 931 | Formation of soil on derelict site due to new vegetation cover and management of habitat as green space. | |

932 Increase in vegetation cover over operational period through use as green space will benefit the provision of the service.

933 Through active use of the brownfield site, including active management, the aesthetics of the place are improved in the long-term.

934 Through active use of the brownfield site, a local recreation site can be created that is close to the Trans Pennine Trail and can, therefore, be enjoyed by visitors passing through the area.

935 Changed use of the site as a green area improves the provision of the service.

936, 937 Changed use of the site as a green area improves the provision of the service.

938 This service will remain stable, even though the land cover might change over time, e.g. natural succession, i.e. the type of ornamental resource might change as well.

939 No change in management at site and change of land cover through natural succession, therefore, no change in provision of this service.

940-943 No change in provision of the service, due to unchanged site conditions which would affect the service.

944, 945 The site will be inundated depending on the height of the tides. Assuming that sea level rise is not affecting the height of the tides in the operational period, no changes are expected. Flood defences are installed in appropriate places to protect the infrastructure of the site.

946 Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area.

947 No change at site anticipated that would have an impact on the provision of the service.

948 Flood protection measures installed to protect infrastructure on site.

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| 949, 950 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 951 | No change in appearance of the site. No public access, but visible from other points in the estuary. | |
| 952-956 | No public access. | |
| 957-960 | No overall change of vegetation cover that would have an impact on the provision of the service | |
| 961 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 962-964 | Not located in flood plain. | |
| 965 | No change at site anticipated that would have an impact on the provision of the service. | |
| 966 | Not close to river. | |
| 967, 968 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 969-973 | No public access. | |
| 974, 975 | No change to status quo, as no development will take place. | |
| 976-978 | No overall change of vegetation cover that would have an impact on the provision of the service. | |
| 979 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 980-982 | No change to the use of the site as a floodplain. | |
| 983-986 | No change at site anticipated that would have an impact on the provision of the service. | |
| 987, 988 | No change in appearance of the site. | |
| 989-992 | No change in provision of the service. | |
| 993 | General upward trend through management of the saltmarsh by grazing. | Adnitt et al. (2007) |
| 994 | Shading of the new bridge will reduce the amount of vegetation in total which could provide the service. Grazing will also have a negative impact | Fischer (1975)<br>Woledge (1978) |

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| | on the ability to provide this service due to reduction of vegetation cover, reducing the interference with air pollutants and the removal from the system. | Amiri, Ariapour, & Fadai (2008) |
| 995 | Through grazing with appropriate livestock units, the carbon sequestration is likely to be increased. Also, frequent tidal inundations affect the amount of carbon stored on the saltmarsh. | Olsen et al. (2011)<br>Morris & Jensen (1998)<br>E. Osim, personal communication, 1 December 2016 |
| 996 | Less vegetation in total due to poaching effect by cattle grazing. | |
| 997 | Although changes in vegetation/soil cover, no significant effects of change. | Baldocchi (2013) |
| 998, 999 | Improvements to the provision of the service through continued work of the saltmarsh restoration plan which includes the creation and maintenance of creeks and ponds on the saltmarsh, which can take up flood water. | Natural England (2014)<br>(Merseylink, 2016b) |
| 1000 | Depending on sedimentation and erosion processes that are dynamic and natural in the estuary the provision of wave reduction will change over time, but have no significant impact on the area. | |
| 1001 | Grazing is supporting the development of typical saltmarsh vegetation. Water management on saltmarsh supports typical saltmarsh vegetation, creating a typical landscape and hydrology. | |
| 1002 | Landscape changes through the presence of cattle. | |
| 1003 | Increase of soil microbial activities due to grazing on saltmarsh and break down of organic material present on the marsh. | Andresen, Bakker, Brongers, Heydemann, & Irmler (1990) |
| 1004 | Through presence of grazing cattle, different plant communities will colonise the saltmarsh, supporting a diversity of plants and pollinators. Grazing densities have to be considered. | |
| 1005 | The bridge might impact the aesthetics of the saltmarsh; however, continued grazing will improve the aesthetics of the saltmarsh. | |

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| 1006 | No direct public access. | |
| 1007, 1008 | Provision of the service especially through continuous and regular use of the Mersey Gateway Environmental Trust Living Laboratory. | The Mersey Gateway Environmental Trust (2017) |
| 1009 | With continued grazing of saltmarsh, provision of this service will remain stable. | |
| 1010, 1011 | Increased management of the site and introduction of new habitats by the Mersey Gateway Environmental Trust which will provide more ornamental resources. | Merseylink (2015a) |
| 1012-1014 | Management of habitats on site will see some changes in vegetation cover, but no significant change in the provision of the service can be anticipated. | |
| 1015 | No change in provision of the service due to unchanged site conditions which would affect the service. | Baldocchi (2013) |
| 1016-1018 | Not located in flood plain. | |
| 1019 | Management of habitats on site will see some changes in vegetation cover, but no significant change in the provision of the service can be anticipated. | |
| 1020 | Not close to river. | |
| 1021 | No change in vegetation or soil cover which would have an impact on the provision of the service. | |
| 1022 | Introduction of wildflower meadows and management of grassland could see an increase in pollinator communities. | |
| 1023 | Improvement of the provision of the service through active management and introduction of new habitats and projects on site which will be appreciated by visitors. | |
| 1024 | The already good opportunity for recreation can be improved in the long-term by improved visitor management, i.e. advertisement of the site. | |
| 1025, 1026 | Good management of site and presence of new bridge provides incentives to use the site as an inspiration. | |

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| 1027 | Good management of site and presence of new bridge provides a sense of place that can be used by local residents. |

Changes are recognised in several areas, a majority of which are positive changes. Areas of high positive change in the provision of ecosystem services are Arpley landfill, Astmoor saltmarsh, Moss Side Farm, Upper Moss Side, Tan House Lane, and Widnes Warth. The changes are due to variation in management with a view to long-term protection of natural areas. The exact changes are described in section 0. Arpley landfill is converted into a country park, as in the other scenarios, and will provide a number of positive changes to the provision of ecosystem services, due to land cover and land use change. The saltmarsh at Astmoor is expected to improve provision of eight regulating services, biodiversity, and two cultural services. The high positive impact of the provision of ecosystem services at Upper Moss Side and Moss Side Farm results from change in focus on managing the sites for nature. The development of Tan House Lane from a brownfield site to a managed green space, increases the provision of ecosystem services under this scenario, through the change of land use and the possibility for the public to experience cultural ecosystem services. Widnes Warth would be under continued management, including grazing with appropriate livestock numbers, which is expected to positively improve the provision of a number of ecosystem services. Sites such as Spike Island and Moore Nature Reserve are managed under the same approach and are not expected to change to a high degree under this scenario.

No positive change is expected at those sites with commercial land use such as the power station (Fiddlers Ferry), waste water treatment works (United Utilities), landfill (Randles Island) and commercial areas (Port Warrington). Communication and project initiation with the land owners and operators of the site could improve this result and lead to a positive change in the provision of ecosystem services.

Negative changes are only expected at Port Warrington, and the Manchester Ship Canal site, due to partial development and the consequential reduction in the provision of ornamental resources, biodiversity, and aesthetic appreciation. The slight reduction in ecosystem service provision at Gatewarth and Widnes Warth is due to slight changes in vegetation cover, which decreases the provision of the regulating services to remove harmful particles and water thermodynamic regulation.

# 5. Discussion

Due to the consecutive nature of the objectives (section 1.2), the discussion will continue to address the objectives individually, considering the implications of the results, contributions to knowledge, and limitations of the research. Alongside a discussion of the results and general recommendations regarding research issues, specific recommendations for the implementation of the objectives and research approach in the study area are presented.

## 5.1. Discussion of the Participation of Stakeholders

The data for all objectives were partially based on the Delphi technique that was carried out with selected stakeholders in 2015 and 2016. It is, therefore, essential to analyse the participation of the stakeholders and to establish their influence on the respective data beforehand. As highlighted in section 3.6.4, a response rate can be acceptable between 10–40% (Fryrear, 2015). Reaching a response rate of 50% in the questionnaire can, therefore, be considered successful, as the respondents did not know the researcher or the project before being contacted. A higher response rate for the questionnaire, compared to the workshop can also be accepted – the effort to partake in the workshop is considered to be the main reason for non-participation. Several participants indicated in their response to the invitation that their workload would not allow time taken off to contribute. However, one reason for the success of the workshop is attributed to the organisation of a ‘field trip’ with the participants onto the construction site of the Mersey Gateway Crossing, which sparked additional interest. As Irvin & Stansbury (2004) point out, participation in data collection events such as workshops can be frustrating and unsuccessful, but this project benefitted from a pre-existing frame of stakeholder interaction, based on several years of stakeholder management by members of the Mersey Gateway Crossings Board and Mersey Gateway Environmental Trust.

Most participants involved in the questionnaire round of the Delphi came from the low influence – low interest group. The majority of the NGO/trust stakeholders were initially placed in this category, due to their niche field of activity in the estuary or their infrequent contact with the Mersey Gateway Crossings Board.

However, they were interested in ecosystem services, resulting in a high number of participants from that group. This highlights the necessity of stakeholder analysis before and after data collection to be able to draw new conclusions from the results. The participation of the NGO/Trust group dropped in the workshop, whereas the other two groups, high influence – high interest and low influence – high interest remained more stable throughout the process, despite an overall reduced rate of participation.

As the Delphi method did not intend to produce decisions, but asked for the knowledge and vision of the stakeholders, the issues ‘at stake’ might have led to less interest in the project towards the second round, which was also combined with the need to attend a place away from the usual workplace. The aim of the study could have led to increased participation of the NGO/Trust group, as they are often leading change in environmental thinking and sustainable decision making (Kong, Salzmann, Steger, & Ionescu-Somers, 2002).

The majority of the participants indicated previous experience with the ecosystem service concept and were able to express their local knowledge. The fact that several landowners did not work with the concept before shows that the study and implementation of an ecosystem approach in the Upper Mersey Estuary is not only new, but would introduce the landowners to a new way of managing their land. NGOs and trusts, of which many work in the local and/or regional area, have claimed to have previous work experience with the concept.

## 5.2. Discussion of Objective 1: Identification of Ecosystem Services in the Upper Mersey Estuary

A process of identification of relevant ecosystem services for the Upper Mersey Estuary was carried out as part of this objective. The participation of local stakeholders in the identification of those relevant ecosystem services was an essential part of the research, also mentioned by several principles of the ecosystem approach (principles 1, 11, 12) (Convention on Biological Diversity, 2005). The inclusion of local expertise and the simple rating system of ‘importance’ allowed stakeholders to make their own value judgments without the requirements for a common metric and the associated challenges in quantifying that metric (e.g. economic value). The approach can be considered as a powerful tool and method for communication for land managers and decision-makers, as well as an example for the application of an ecosystem approach with the aim to provide long-term management to an area.

The identification of 18 site-specific relevant ecosystem services that are provided by the Upper Mersey Estuary has revealed that regulating, habitat and cultural ecosystem services are particularly prominent. Jacobs et al. (2015) study of four different estuaries across northern Europe showed similar results regarding the general demand for the provision of ecosystem services, with biodiversity having the highest demand, followed by (in decreasing order of importance) regulating, cultural and provisioning services. Unlike other studies, where estuarine ecosystem services were identified for economic valuation (Barbier et al., 2010) or trade-offs and synergies (Jacobs et al., 2015), this study concentrated on the identification of ecosystem services for future use in long-term management, which is in conjunction with the current governmental plans for the UK (Defra, 2016), which encourage the use of the ecosystem approach.

The two Delphi rounds produced a coherent set of results, in which the local experts fully agreed on the importance of three ecosystem services. This indicates the potential to use those services in management decisions for the estuary, as well as the potential to research them in further detail. By applying a Delphi technique, it was shown that the inclusion of local experts can be used to create new knowledge that is: i) site-specific for the estuary and can, therefore, be used by the local land management, and ii) a method to assess any socio-ecological system and its relevant ecosystem services. The participation of local experts indicated that an array of ecosystem services should be considered in the future management of the area. This knowledge and expertise can now be translated into a management context (García-Llorente et al., 2016), considering a cross-habitat scale.

### 5.2.1. Provisioning Services

One provisioning ecosystem service was selected as relevant by the stakeholders of the Upper Mersey Estuary. The stakeholders clearly prioritised other services, which indicates that the landscape in the estuary is not predominately seen as a provisioning asset. Rasmussen et al. (2016) point out that the land cover/land use is not always a good indication of the provision of certain ecosystem services; this supports the presented approach to use local knowledge to gather this information, in combination with other appropriate data such as maps.

The selected provisioning service, ornamental resources, was rated highly relevant in the questionnaire (100%), and received a '+' importance rating in the workshop. The discrepancy between those two selections might be explained through the fact that, although 'ornamental resources' are classed as a provisioning service, the implication of this particular provisioning service can be understood to contribute to, for example, aesthetic appreciation of the area by providing of material that is appealing to people. The placement/inclusion of the service in the category of provisioning service needs to be re-considered to achieve consistent results in the future for which importance of this service needs to be studied in more detail.

### 5.2.2. Habitat Services

The status of biodiversity as an ecosystem service has been discussed from the very start of the emergence of the concept (Mace, Norris, & Fitter, 2012). In the case of the Upper Mersey Estuary, it was decided to include biodiversity as a potential ecosystem service, due to its location upstream of a SSSI/Ramsar site, indicating the importance of estuarine wildlife in the area, and the subsequent expected value of biodiversity in this location.

The high rating (100% in questionnaire, '+++' in workshop) might have been influenced by a relatively high proportion of participants that participated from local NGOs concerned with environmental matters. Nevertheless, the rating suggests that the appreciation of biodiversity is high in the estuary, and conservation of habitats is an important issue recognised by the local experts.

The mapping of habitat services indicated that local stakeholders marked biodiversity mainly in publicly accessible locations, with access to bird hides or good views over the estuary. It can, therefore, be expected that the experts mainly included bird diversity in their assessment of ecosystem services in the Upper Mersey Estuary, although no indication of this has been made by the stakeholders, e.g. through comments. However, birds can be used as an indicator for biodiversity (Herrando et al., 2016). The presence of birds is also known to indicate other regulating ecosystem services (e.g. pest control) or cultural ecosystem services (e.g. recreation through bird watching) (Wenny et al., 2011). This highlights the aspect of interactions between ecosystem services and the fact that ecosystem services can often be intermediate and final ecosystem services (Boyd & Banzhaf, 2007), contributing to multiple aspects of the system. In case of the Upper Mersey Estuary, the monitoring of bird biodiversity can form a first step in biodiversity monitoring.

### 5.2.3. Regulating Services

The high value of an estuary as a regulating unit is mirrored in the selection of eleven out of 23 proposed regulating services. Several ecosystem services that are not easily provided by other habitats can be found in estuaries; for example, carbon sequestration in estuaries is expected to have a higher carbon storage per unit area than other terrestrial vegetation (Ashley, 2014), as well as regulating water flow and regulation of water quality. The focus on carbon sequestration has also been identified in this study, as the service was attributed to all major saltmarsh habitats in the Upper Mersey Estuary. The importance of saltmarsh habitats in the sequestration of carbon has been and still is intensively studied (Li et al., 2010; Mueller et al., 2017; Taylor & Paterson, 2017) and is currently under investigation for the Upper Mersey Estuary (Osim, PhD in preparation, University of Salford).

### 5.2.4. Cultural Services

Cultural ecosystem services are often considered to be straightforward, but difficult to assess, monitor, and value (Davies, 2011; Willcock et al. 2016). The participants of the Delphi study clearly recognised the importance of cultural ecosystem services for the estuary. Both historic, as well as cultural aspects, for example local bridges and canal networks, have been recognised, as well as future potential of cultural services, in the form of an expected country park after closure and final capping of Arpley landfill.

Cultural ecosystem services have been described as intangible, mutable and intuitive (Willcock, Camp, & Peh, 2016), therefore, their perception of the provision is dependent on the individual and their assessment (Milcu et al., 2013). However, when considering the mapping of ecosystem services provision, it appears that the stakeholders were confident in identifying cultural ecosystem services. This supports the assumption that the direct valuation/rating of cultural ecosystem services is achievable for a group of stakeholders with limited knowledge of ecosystem services. Due to the challenging nature of the assessment of cultural ecosystem services, stakeholder perception offers an indicator which is otherwise difficult to capture and can form an important element within the socio-ecological system (Darvill & Lindo, 2016; Hutchison, Montagna, Yoskowitz, Scholz, & Tunnell, 2015).

Cultural ecosystem services were often mentioned in conjunction with biodiversity. The connection of the two elements of ecosystem services is recognised in other studies (Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013; Raymond et al., 2009) and shows that an integrated approach to ecosystem services is valuable in order to assess ecosystem services. However, the experience of ecosystem services is often related to activities within habitats, creating a challenge for managers, to conserve valuable habitats, but enabling visitors to enjoy nature and its provisions (Chan, Satterfield, & Goldstein, 2012; Plieninger & Bieling, 2012; Hutton & Leader-Williams, 2003).

### 5.2.5. The Mapping of Ecosystem Services

Brown (2012) describes the participatory mapping of ecosystem services as the most challenging cognitive part when identifying ecosystem services for a particular area, as particular expert knowledge is required. This study concentrated on local experts from the outset to be able to capture specific expertise. The local competence gives valuable insights on the perception of ecosystem services – in combination with a written explanation, this can support identifying, monitoring and securing the provision of particular ecosystem services in specified areas.

Mapping is often used to create large scale maps of one or more particular ecosystem services and it has been suggested that mapping should only be done if reliable data are present (Burkhard & Maes, 2017). However, before a particular ecosystem service is mapped through advanced models, an overview of where those services can be found is a valuable communications tool to perceive ecosystem services before more substantial efforts are made (Martínez-Harms & Balvanera, 2012). Two aspects need to be scrutinised: i) the accuracy of maps that are developed from readily available data, and ii) the usefulness for planning in a local context. As discussed by Willcock et al. (2016), there is a need for results that are useful for practitioners outside the academic realm, who often do not have access to scientific data, therefore, complicating the production of maps, as well as jeopardising the accuracy of the results. Uncertainties, especially on a larger scale, arise from differences in the definition of indicators, level of understanding, and the mapping methodology (Schulp, Burkhard, Maes, Van Vliet, & Verburg, 2014). Those two aspects indicate that a simple method, without the need to quantify ecosystem services, gives land owners and decision-makers a communication tool, informing the presence of ecosystem services and perception of the landscape. Due to its practicality, it can be easily used by those practitioners, who have not assessed ecosystem services before and who are working in areas for which scientific data might be problematic to access. It can, therefore, be established that the straightforward mapping of the ecosystem services in the Upper Mersey Estuary contributes to local knowledge creation, which can be replicated in other socio-ecological systems.

The results show that the participants were able to extrapolate their views and visions into the future. The assignment of ecosystem services to Arpley landfill shows that the participants are expecting a range of services that are currently not provided. As the land use is expected to change from landfill to a country park (Warrington Borough Council, 2014), the provision of ecosystem services will take effect in the future. In order to understand these data, the researcher must be aware of the changes in the study site, and interpret the data accordingly.

The map of ecosystem service locations does not claim to be inclusive of all ecosystem services, nor does it offer a means of quantification. What it does show is how stakeholder knowledge can be used to prioritise certain areas and use this information for planning and management of projects (Egoh et al., 2008). As Brown & Raymond (2014) discuss, mapping of ecosystem services provides a general idea of the location of ecosystem services and their area of service provision (Lopes & Videira, 2017). The research has shown that local experts are aware of possible locations of these ecosystem services, but it has to be kept in mind that the mapping exercise did not reveal whether the distribution of ecosystem services in the Upper Mersey Estuary was done arbitrarily or if all the stakeholders put the same emphasis on it, to achieve a holistic picture of the ecosystem services location. This remains a challenge of studies (Hauck et al., 2013), but it offers a good indication as to where management should focus, to maintain or provide the located ecosystem services.

### 5.2.6. Reflection on the Inclusion of Stakeholders in the Study

The participants of the study were selected from a pool of stakeholders that were known to be active in the Upper Mersey Estuary. This has positive as well as negative implications for the reliability of the study: i) the participating stakeholders are considered to be viable experts in their field, which implies a good understanding of the study site. If additional, less knowledgeable, stakeholders were invited to participate in the study, the results could not be considered to be reliable for this particular case study; ii) the selection of stakeholder from a known pool excludes views and opinions from other sectors, which, with specialist training, might have been able to participate successfully in the study. This would apply to, in particular, the private sector and the general public.

The participants had limited experience with research methods such as questionnaires and workshops. However, through communication and feedback processes, the confidence and, therefore, reliability of the results can be assumed. However, despite a thorough invitation process, several stakeholders were reluctant to participate because they were uncertain how to distinguish between professional and personal opinion. Although the researcher assured that their opinion as a selected expert could be considered their personal opinion as a professional, hence no differentiation between the two types could be made, several individuals felt uncomfortable to participate.

A further aspect to consider in the analysis and use of the results is that the participants were using their knowledge and, therefore, extrapolated change of the area to project the provision of ecosystem services. This lead to the indication of ecosystem services of an area that will undergo a substantial land use change in the near future. It becomes clear that the researchers need to be aware of potential discrepancies between the actual land use/land cover of a site, the expected land use/land cover by the stakeholders, and the expected land use/land cover that is brought forward through planning permissions.

Through the entire data collection and analysis, the researcher has made provisions to collect the data in the most reliable way. During this process, the researcher was also aware of her own potential bias within the research project and attempted to increase the validity of the research by i) making sure that all participants were aware of the implications of the research, ii) keeping an organised database, iii) providing the participants with the opportunity to comment on the results collected from the first and second Delphi rounds, and iv) being consciously aware of her own behaviour during data collection (Brink, 1993).

The inclusion of stakeholders into a research process bears challenges and limitations (Glicken, 2000; Reed, 2008), but also provides a wealth of qualitative data which cannot be replaced by quantitative equivalents. The inclusion of stakeholders in this project is considered to be an essential quality, in order to assess socio-ecological systems. Furthermore, this approach ensures the points addressed in the literature review, that stakeholders are essential in the provision of information in relevant ecosystem services. The research around ecosystem service provision should be driven by stakeholder interaction in order to ensure a holistic understanding of the system. This is considered to be achieved in this study.

## 5.3. Discussion of Objective 2: Changes to the Socio-ecological System of the Upper Mersey Estuary

### 5.3.1. Triggers of Change

Changes to the socio-ecological system of the Upper Mersey Estuary were identified through reviews of core strategic documents and expert knowledge. The English Oxford Living Dictionaries (2017) defines a strategy as ‘a plan of action designed to achieve a long-term or overall aim’ – a definition which leaves sufficient room of interpretation to allow for changes and alterations to the plan of action. The political landscape has changed since 2013 (the year of publication of the core strategy documents) and will inevitably change further until 2028 (final year of Warrington’s core strategy). Hence, a plan for large areas can only give an indication of the change that will happen and needs to be substituted by other means such as expert knowledge throughout the planning period. There is no absolute certainty about how the Upper Mersey Estuary will develop and the established scenarios based on these reviews, are a best guess of expressing how the Upper Mersey Estuary and the provision of ecosystem services could develop in the future.

Direct changes such as climate change can be associated with long-term implications, which is expected to play a major role in future ecosystems throughout the UK (Winn & Tierney, 2011), affecting both ecosystems and consequently the provision of ecosystem services. Local direct changes, for example, changes to habitats through the alteration of land use, have been an identified key driver of change to ecosystems and their associated services in the UK (Winn & Tierney, 2011). The core strategies relate to this aspect with the identified threat of flooding (through increased weather events) and potential loss of Green Belt land for development.

The extracted information shows that there are expected changes in the medium-term future within the boroughs. The implementation of these changes does not only depend on the policies set out in the borough, but also on external factors such as the political environment and private investments available to the area. To maintain the status quo, the borough would follow all their planned developments, which is mirrored in one of the scenarios (Business as Usual 2044).

The findings of the review suggest that only limited areas of Upper Mersey Estuary could be subject to commercial and residential development under current policies (Warrington Waterfront, Port Warrington, Tan House Lane). However, the aim to promote development is clearly articulated in the core strategies of Halton Borough Council and Warrington Borough Council (Halton Borough Council, 2013; Warrington Borough Council, 2014), and also recognised by the local experts. The issue of the Green Belt plays an important role in the identification of potential development sites, and can be considered the limiting element in the provision of space for present development. This aspect has been translated into the Development Boom 2044 scenario, in which the Green Belt land is opened up for development.

Regarding the natural environment and the implementation of an ecosystem approach in the estuary, the strategy documents indicate the ambition to protect and enhance natural green space and biodiversity, together with the sustainable use of resources. However, it is not considered to be the focus of the policies. The concept of ecosystem services was not incorporated in the strategies, indicating a lack of translation of ecosystem service thinking in policy and decision-making, as identified in the literature review (Ecosystem Knowledge Network 2016a).

As part of the operation of the Mersey Gateway Crossing, the Mersey Gateway Environmental Trust will manage the area of the Upper Mersey Estuary. Apart from its role in the management of the estuary, it is also considered to be vital in the communication process with other stakeholders (Mersey Gateway Environmental Tust, 2015; WREN, 2015). Further, development schemes such as the Atlantic Gateway (Atlantic Gateway, 2012) are crucial for considering the future policy and planning because of their influence for investment and development in the area, which is already indicated in the strategic documents of the boroughs. Incentives such as the Mersey Forest (The Mersey Forest, 2014) work alongside Halton Borough Council and Warrington Borough Council to improve the natural environment of the estuary and are expected to become active stakeholders in the future (P. Oldfield, personal communication, date unknown).

Environmental factors identified by the review of the core strategic documents and Delphi participants were named as flooding, pollution, and loss of character. These aspects relate to the provision of ecosystem services that can be provided by the estuarine landscape. However, these factors can also be classified as external threats, indicating an insufficient provision of these services in the Upper Mersey Estuary. Although the term ecosystem service was not mentioned in the core strategies, the concept is communicated through the identification of benefits that can be expected in the estuary, i.e. flood plains, recreation, regulation of weather events.

The knowledge of the experts consulted in the Delphi process regarding possible changes in the Upper Mersey Estuary added value to the research by contributing to the identification of triggers and expectations. The results show that the participants expect substantial changes in the estuary within the operational period of the Mersey Gateway Crossing. These changes are based on a combination of direct and indirect factors. The participants covered several triggers of change that were also identified by the Millennium Ecosystem Assessment (2005b) such as climate change and political aspects. Generally, the experts identified more specific triggers than mentioned in the global assessment, for example identifying a land use change through building and development of areas in and around the Upper Mersey Estuary. The UK National Ecosystem Assessment (2012) uses the same triggers as the Millennium Ecosystem Assessment, but an adaptation to local circumstances should be considered. For the socio-ecological system of the Upper Mersey Estuary the identified triggers and changes have incorporated local particularities, which are characteristic for the area and those that can be attributed to a general change on a wider scale (e.g. climate change). Triggers that are comparable to the aspects identified in the core strategy documents of the borough councils such as ‘tourism and recreation’ (Delphi) and ‘visitor economy’ (core strategy), ‘housing and development’ (Delphi) and ‘housing’ (core strategy), and ‘climate change’ (same in both) have also been described. This shows that, although the often-quoted ecosystem assessments (Millennium Ecosystem Assessment and UK National Ecosystem Assessment) can provide an initial indication regarding potential changes, the use of local expertise is needed for prediction of changes in local areas. A direct assessment of the respective area will reveal more precise triggers of change that can be used in subsequent analyses. For the Upper Mersey Estuary, these results can be used in the scenario analysis and provide detailed insight in possible futures of the estuary. Beside the use of this analysis as part of the scenarios, the changes in the estuary can indicate the provision of ecosystem services. The monitoring of the identified triggers, will allow managers and decision-makers to make informed decisions for the management of the estuary. An approach for its application is discussed in section 5.4.3.

As mentioned before, the core strategies were limited in their projection time. The Delphi participants, however, were asked to project changes onto the operational period. The participants recognised those areas that are currently under change due to the construction of the bridge, and the area that had been subject to discussion regarding limitations of funding (Moore Nature Reserve) around the time of the workshop. Due to the closure of nearby landfill Arpley, whose operators are responsible for the management of Moore Nature Reserve, the future of the area is currently unknown. The stakeholders are expecting changes in the short-term, a consideration which is taken up in the scenarios. The landfill at Arpley is considered a changing habitat under all scenarios, due to the closure of the site and subsequent land use change.

The development of the scenarios was based on the ideas that were communicated in the first element of objective 2 – the possible changes. Comparable scenarios to the ones developed for the Upper Mersey Estuary can be found in Creedy et al. (2009). However, similar to the triggers of change, the scenarios by Creedy et al. (2009) are exploring a national scale, which is insufficient for management on a local scale such as the Upper Mersey Estuary. As more detailed information is available through the use of local experts, the scenarios can be tailored to the study area. Local knowledge and attempts of local management of natural areas need to balance the national obligations versus the local interest in nature conservation and environmental management (Hovik & Hongslo, 2017), which is achievable through a bigger, better, more connected network of socio-ecological systems (Lawton et al., 2010) in which future changes are an integral part of the management.

### 5.3.2. The Scenarios

The three scenarios developed for the Upper Mersey Estuary display three different futures until 2044. The scenarios reflect the triggers that were identified in section 4.4 to different extents. All scenarios concentrate on different elements of the estuary's future.

The Business as Usual 2044 scenario focuses on a future, similar to today's and is based on the core elements that are illustrated in the strategy documents. Not many changes in the approach to development, nature conservation, and science and technology are made. This scenario includes the fewest changes to the Upper Mersey Estuary. When applied to the model of ecosystem service provision (objective 3), the scenario provides information as to how the ecosystem service provision in the estuary changes if no major managerial changes are implemented.

Including the scenario Development Boom 2044 made it possible to include changes to residential and commercial development, impacting the area by changes in land use and land cover, as well as Green Belt boundaries. This scenario includes a number of changes to the study site, based on the aspects that were raised by the Delphi participants such as additional development at Port Warrington and the installation of a tidal barrage downstream of the river Mersey.

The third scenario Nature is Key 2044 can act as a counterpart to the development scenario. The focus on nature conservation sees changes in the estuary without further residential or commercial development within its boundary. It further focuses on a long-term vision and considers the creation of new habitats, e.g. on brownfield sites.

All three scenarios can be compared to the scenarios developed by Creedy et al. (2009) for Natural England, which identified long-term national scenarios for the UK. These scenarios can, together with local triggers and identified changes, act as a guideline for local scenarios. However, an adaptation to local circumstances is necessary and adds to the accuracy of the scenarios and subsequent use of them as part of the research. Due to the qualitative nature of the scenarios, the connection to stakeholders can be tightened (Kass et al., 2011), using their knowledge to plan for a future that might unfold.

However, data used to inform the scenarios are often changing within a project timeframe. For example, the decision to leave the European Union through the referendum in June 2016 is expected to have an impact on the policies governing the natural environment in the UK[9] (Cowell, 2017; Winkel & Derks, 2016; CIEEM 2016, 2017). Other issues, although already partially identified through the data collection of objective 2 such as additional development of housing areas and the potential installation of a tidal barrage in the estuary, have since the end of the data collection been announced in local media (Liverpool City Region, 2017). Further development projects that were published in the final stages of the thesis, for example, the proposed routes for the Warrington Western Link (Warrington Borough Council, 2017) have not been considered in the scenario development.

Although these announcements do not confirm the actual changes to the natural environment in the Upper Mersey Estuary, they show how the scenarios can be an effective means of assessing what impact changes might have on the area. The local changes mentioned would fall into the second scenario (Development Boom 2044) and could already give an indication regarding the provision of ecosystem services. Being able to identify changes in the estuary enables management planning and decision-making with a view into the future.

## 5.4. Discussion of Objective 3: Model of the Future Provision of Ecosystem Services

Land use changes can be considered the most likely factor in changes to the provision of ecosystem services (Nelson et al., 2010). Exploring the provision of ecosystem services under different futures is a useful tool for long-term management planning, that creates new knowledge for managers and decision-makers and presents a new way of combining methods to use in long-term nature conservation under an ecosystem approach.

[9] Whether these are positive impacts through the adaptation of current policies to achieve a ‘greener’ UK, or negative impacts through less focus on environmental issues, is not of importance at this point.

### 5.4.1. The Resilience of the Socio-ecological System

As mentioned by Pisano (2012), the resilience of a socio-ecological system is not necessarily bound to bounce back to its original state (as in the definition of resilience of Holling (1973)), but can engage in changes and adaptation. Through the analysis of the provision of ecosystem services in the Upper Mersey Estuary, and the incorporation of an ecosystem approach into the management of the site, the adaptation to new situations can be facilitated. By exploring the future and the implications of changes to habitats through e.g. land use changes, the management can incorporate the implications of change of the provision of ecosystem services. Ultimately, management decisions can be informed and the potential of ecosystem service loss directed by i) directly approaching developers to mitigate loss of ecosystem service provision on site, or ii) investing into ecosystem services and habitat creation as a means of off-setting against loss of provision of ecosystem services (Jacob, Vaissiere, Bas, & Calvet, 2016; Quétier & Lavorel, 2011).

In this study, the construction of the Mersey Gateway Crossing acts as an initiator of change. The construction and operation of the bridge can be considered as one element to the ‘disturbance’ of the system, to which it needs to find a new equilibrium, by adapting and innovating itself to fit the new situation. In order to facilitate the adaptation of the socio-ecological system, the model’s indications for the provision of ecosystem services is an approach to ensure the resilience of the system to subsequent changes.

Although no precise predictions on the development of ecosystem services can be done on this scale, the model indicates how the scenarios influence the provision of the services. Positive and negative changes are registered under all scenarios. However, depending on the assumptions made in the model regarding the management and development of the estuary, changes in provision to either side might be predominant. The model and its results are site-specific and individual, therefore, not directly comparable, limiting the scope for discussion and comparison with other sites. However, the application of the model facilitates an understanding in the following areas: i) the expected change in provision of ecosystem services under scenarios for one specific study site (section 4.5); ii) recommendations for the management of the identified ecosystem services (section 5.4.3.1); and iii) recommendations for the general applicability of the model in an ecosystem approach (section 5.4.3.2).

### 5.4.2. The Provision of Ecosystem Services

The general positive response of ecosystems service provision in the Business as Usual 2044 scenario is attributed to the influence of the Mersey Gateway Environmental Trust, which is active in large parts of the estuary, in particular in Halton Borough Council. The idea of the Trust to manage the Upper Mersey Estuary for nature is embedded in its business plan, which comes into operation with the opening of the Mersey Gateway Crossing (Mersey Gateway Environmental Trust, 2017 (unpublished)). Under the Business as Usual 2044 scenario, the Trust will initiate projects in those areas that are currently managed for nature. Despite some changes to the land use, most areas remain unchanged. This highlights the influence that a particular stakeholder, in this case the Mersey Gateway Environmental Trust, can have through a long-term planning approach.

Within the Development Boom 2044 scenario, changes to land use through increased development and less incentive to support local nature conservation leads to an overall negative change in provision of ecosystem services. The modelling of the provision of ecosystem services under this scenario facilitates the understanding of how the change of land use from natural areas to build-up areas can change the provision of the services. However, in conjunction with urban development, urban ecosystem services have to be considered, and can be incorporated into planning once the development has taken place (Kattel, Elkadi, & Meikle, 2013). A repetition of the initial assessment can then consider these additional ecosystem services and allow for additional positive changes in the provision of urban ecosystem services.

Following the assumptions from the Nature is Key 2044 scenario, the provision of ecosystem services would be positively affected at many site compartments. This is based on an implementation of nature conservation projects throughout the operation period, which would see stakeholders of the area investing in the environmental protection of the estuary. In this scenario, the socio-ecological system benefits from an overall change in perception regarding environmental issues, and provides incentives and space for the implementation of management practices that sustain ecosystem service provision.

It becomes clear that under the scenarios changing spatial patterns emerge. Whereas under the Business as Usual 2044 scenario most changes, both positive and negative, can be located in eastern part of the estuary. This is due to potential development sites as well as land use changes at Arpley landfill, from an active landfill to a green space. However, under the Development Boom 2044 scenario, the spatial pattern is wide spread across the estuary under regarding the negative changes, as development, reduced investment in nature conservation and management of existing sites is reduced. This results in the reduction of provision of ecosystem services, but also gives a good indication on potential sites that need support in the future to maintain ecosystem service provision. Under the Nature is Key 2044 scenario, the majority of the changes is expected to be positive throughout the estuary. In particular those sites that are currently managed as natural green spaces will benefit from a more focused management and, therefore, an increased provision of ecosystem services.

When it comes to the provision of ecosystem services, feedback loops, synergies and trade-offs play a role in the provision of ecosystem services (García-Llorente et al., 2015; Howe, Suich, Vira, & Mace, 2014; Zia et al., 2011). However, these have not been considered in this study, instead every identified ecosystem service has been considered individually. This is considered to be an appropriate approach for the study site and addresses the questions elaborated in section 2.9. An assessment of interactions is recommended once the management decisions have been made regarding the extent of management for ecosystem services.

### 5.4.3. Informing the Future Management of the Upper Mersey Estuary Through the Information Gathered in the Research

Through the analysis of the data described in the previous sections, conclusions can be drawn on the resilience of the provision of ecosystem services in the estuary and how these can be managed in the future. Under all three scenarios, positive and negative changes can be observed. However, it can be assumed that for the implementation of an ecosystem approach, generally, the positive changes are favoured over the negative ones. Although feedback loops, synergies and trade-offs between ecosystem services have not been examined in this study, recommendations can be made regarding the use of the data analysed in objective 1–3, to support an ecosystem approach and management of socio-ecological systems under change. The following recommendations are site specific for the Upper Mersey Estuary – however, they can be adapted to other sites and form part of an investigation of socio-ecological systems elsewhere after successful identification of the relevant ecosystem services.

#### 5.4.3.1. Recommendation 1 – To Measure the Provision of Ecosystem Services

The diversity of ecosystem services will influence the resilience of the socio-ecological system to change (Biggs et al., 2012). The provision of ecosystem services in the Upper Mersey Estuary depends on the changes that the system undergoes as well as the management of the habitats. It can be assumed that the intention of the management of any natural site is to encourage the maintenance, or improvement of the provision of ecosystem services. As suggested, the diversity and absence of ecosystem services influences the resilience of the provision of ecosystem services: by assessing and monitoring a variety of ecosystem services, their provision can be maintained, as an entire system is supported and adaptations to management practices are possible (Ma et al., 2016). However, that requires a diverse system that supports a variety of services. This diversity in a socio-ecological system encompasses elements of social and governance strategies, biodiversity, spatial heterogeneity and institutional diversity (Biggs et al., 2012).

After the initial assessment of the relevance of ecosystem services in the Upper Mersey Estuary, the quantification/valuation of those services forms the next step in order to ensure the maintenance of a diverse provision of ecosystem services and to further the understanding of the system’s reaction to changes. This research forms a first step in what can be expected to be an iterative process, continued over a long-term management period. For each identified ecosystem service, suggestions are made how to assess and measure the identified service

(Table 34). These suggestions have been identified in the literature and site-specific indicators are identified. The methods are mainly quantitative for provisioning and regulating services, and qualitative for cultural services. When measuring ecosystem services, the trade-offs and synergies with other ecosystem services should be considered to achieve results that estimate the provision of ecosystem services (Tomscha & Gergel, 2016). The identified methods can provide a rough estimate of the provision of ecosystem service, which can be used in decision-making for future management. The identified methods are not exclusive – however, several of the methods can be incorporated into existing schemes that are currently in use to monitor the development around the construction of the Mersey Gateway Crossing.

**Table 34 Methods and indicators for assessing ecosystem service provision in the Upper Mersey Estuary, based on the ecosystem services that were identified through stakeholder participation.**

| Ecosystem Service | Method | Indicator | Selected references |
|---|---|---|---|
| Ornamental resources | • Assessment of use of resources such as driftwood, plants etc.<br>• Questionnaires | • No. of items<br>• Mentioning by users of the area. | SEQ Ecosystem Framework (n.d.) |
| Biodiversity | • Field surveys<br>• Hotspot analysis<br>• Scoring | • Species richness<br>• Species abundance<br>• Habitat conservation value/ species conservation value | Gotelli & Colwell (2001), Purvis & Hector (2000) Myers, Mittermeier, Mittermeier, da Fonseca, & Kent (2000), Posthumus, Rouquette, Morris, Gowing, & Hess (2010) |
| Removing harmful particles, air water exchange, biogeochemical reaction | • Long-term monitoring of harmful particles (e.g. heavy metals, PVCs) | • Concentration of harmful particles | Andrews et al. 2006 Mcclain et al. 2003 |
| Carbon sequestration and burial | • Soil organic carbon analysis | • Vegetation type<br>• Soil organic matter | Chmura, Anisfeld, Cahoon, & Lynch (2003), Goulden, Munger, Fan, Daube, & Wofsy (1996), Blanco-Canqui & Lal (2008) |

**Table 34 (cont.)**

| Ecosystem Service | Method | Indicator | Selected references |
|---|---|---|---|
| Water thermodynamic regulation | • Thermodynamic modelling<br>• Databases | • Hydrological data | Todorov, Rabadjieva, & Tepavitcharova (2006) |
| Heat exchange regulation | • Heat exchange modelling | • Habitat composition (leaf area, photosynthetic capacity, surface conductance, aerodynamic conductance) | Baldocchi (2013)<br>Hungate & Hampton (2012) |
| Flood water storage | • Field surveys<br>• Aerial photographs<br>• GIS models | • Area available for flood water storage<br>• Hydrological data (water levels) | Posthumus et al. (2010), Grygoruk, Miroslaw-Swiatek, Chrzanowska, & Ignar (2013), Stürck, Poortinga, & Verburg (2014) |
| Peak discharge buffering | • Hydrological modelling | • Precipitation<br>• Increased water flow | Stürck et al. (2014) |
| Wave reduction | • Pressure sensors<br>• Vegetation surveys | • Inundation area<br>• Speed of water flow | Ysebaert et al. (2011), Moller et al. (2014) |
| Landscape maintenance | • Aerial photographs<br>• Habitat mapping | • Long-term trends of habitat's ratio<br>• Formation/ erosion of saltmarsh | Jacobs et al. (n.d.) |

**Table 34 (cont.)**

| Ecosystem Service | Method | Indicator | Selected references |
|---|---|---|---|
| Erosion and sedimentation regulation by water bodies | • Field surveys<br>• Aerial photographs | • Loss/gain of saltmarsh<br>• Establishment of vegetation on saltmarsh accretion | van der Wal & Pye (2004),<br>Harmsworth & Long (1986),<br>Feagin et al. (2009) |
| Biological regulation of soil processes and soil formation | • Modelling of soil properties | • Physical, chemical, biological indicators | Vereecken et al. (2016) |
| Pollination | • Field surveys – Quantification of pollinators and flowering plants | • No. of pollinators<br>• No. of flowers per plant<br>• No. of seed per plant | SEQ Ecosystem Framework (n.d.),<br>Snow (1982) |
| Aesthetic appreciation | • Changes in land cover/ land use<br>• Surveys/ public opinion | • Area available as green space<br>• Mentioning of area in media and social media | SEQ Ecosystem Framework (n.d.) |
| Opportunities for recreation & tourism | • Questionnaires<br>• Changes in land cover/ land use<br>• Economic valuation | • Local recreational sites<br>• Area available as green space<br>• £ spent on recreation | Clough (2013)<br>Kreitler, Papenfus, Byrd, & Labiosa (2013) |
| Inspiration for culture, art & design | • Integrative methods, e.g. DIVE-Analysis<br>• Review of Mersey Gateway Environmental Trust project data | • Projects initiated through the Mersey Gateway Environmental Trust involving schools, artists, volunteers | Reinar & Westerlind (2010) |

**Table 34 (cont.)**

| Ecosystem Service | Method | Indicator | Selected references |
|---|---|---|---|
| Inspiration for cognitive development | • Questionnaires<br>• Review of Mersey Gateway Environmental Trust project data | • Number of projects involving schools<br>• Number of events organised for members of the public<br>• Information boards | Dadvand et al. (2015) |
| Sense of place | • Integrative methods, e.g. DIVE-Analysis<br>• Questionnaires/ Interviews | • Interpretation of interview data | Reinar & Westerlind (2010) |

The identified provisioning ecosystem service, ornamental resources, can be monitored through field survey and assessment of available items, as well as questionnaires, investigating what resources are used by users (SEQ Ecosystem Framework). There is limited information and research on the presence and use of ornamental resources in the literature.

Biodiversity has been measured in several sites of the estuary, in particular, birds (see section 5.2.2). An assessment of the biodiversity throughout the estuary will lead to increased knowledge regarding the provision of the ecosystem service and where management can improve the service. Data already collected by, for example, the Mersey Gateway Environmental Trust, can be the basis to start, and new data can be added to the established database.

Regulating services are mainly subject to quantitative modelling and long-term observation to assess and measure the provision of the provided services. Aerial photographs and site surveys can help to establish a monitoring scheme. However, expert knowledge and sophisticated methods such as laboratory analysis are often required to measure and monitor the provision of ecosystem services in the Upper Mersey Estuary.

Cultural services in estuaries are difficult to quantify and measure (Hansen-Møller, 2009; Kumar & Kumar, 2008). However, through stakeholder interaction and the use of local knowledge the provision of cultural ecosystem services can be achieved. Certain ecosystem services, e.g. opportunities for recreation and tourism, can be valued (Clough, 2013; Kreitler et al., 2013) and support decision-making in the Upper Mersey Estuary regarding management decisions about natural areas.

A key element of the ecosystem approach framework is the inclusion of social elements in the management of ecosystems (Convention on Biological Diversity, 2005). The communication and work with stakeholders should be included on all levels of management and implementation (Coughlan, Lycett, & Macredie, 2003). Therefore, the measuring and monitoring of ecosystem services should be taking place across the estuary, ideally at all sites in which the respective ecosystem service is provided. The location of the perceived ecosystem services (objective 1) can be used to form a baseline of monitoring locations.

#### 5.4.3.2. Recommendation 2 – How the Research Supports an Ecosystem Approach

In order to implement an ecosystem approach in the Upper Mersey Estuary, a long-term commitment has to be made. With the data collected through the study, a second recommendation can be made to support the implementation of the management for a sustainable use of resources under a long-term management approach.

The model (objective 3) suggests that changes to the provision of ecosystem services can be expected. These changes are assumed to take place over a period of time (objective 2). As the ecosystem approach is designed to adapt to new situations, this approach is a valuable addition to the management of the socio-ecological system of the Upper Mersey Estuary.

Data regarding changes within the estuary suggest that the majority of the sites will changes within the next 15 years. However, changes can already be observed from the beginning of the research, ranging from direct changes such as new projects being implemented in the project areas of the Mersey Gateway Environmental Trust, to commercial development on identified brownfield sites. With a direct application of the ecosystem approach and the presented method to monitor the identified ecosystem services, these data could immediately be used to inform the management of the relevant sites. An approach to integrate the research, management, and adaptation to change in the Upper Mersey Estuary is outlined in Figure 27.

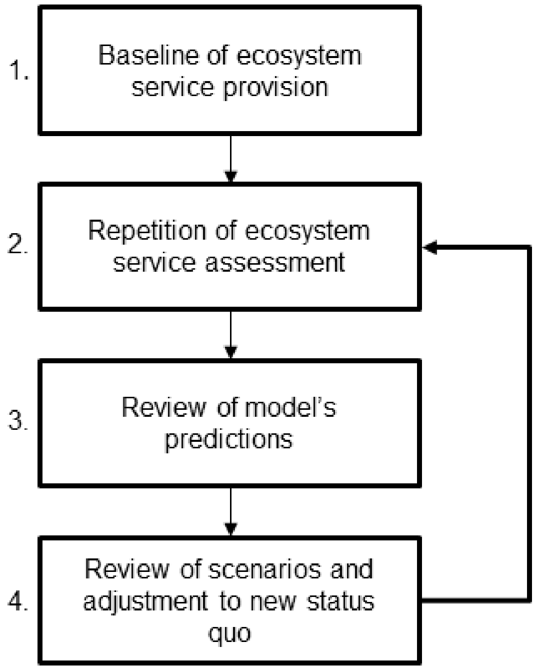


**Figure 27 Framework for the recommendations of the management approach of the implementation of an ecosystem approach in the Upper Mersey Estuary.**

Using a set of appropriate methods (section 5.4.3.1) an assessment of the identified ecosystem services can be carried out with completion of the construction and the commencement of the operational period. Due to the sophisticated nature of the project, the measurement of ecosystem services will require expertise, together with a set-up of long-term monitoring schemes for, in particular, regulating ecosystem services such as carbon sequestration or removal of air pollutants. Other ecosystem services such as biodiversity or erosion and sedimentation of sediments will have been investigated as part of the construction period (e.g. Merseylink, 2014, 2015a, 2015c, 2015d), hence the assessment of a baseline value is facilitated. Ecosystem services that require a qualitative assessment can be assessed throughout a year to account for seasonal variability in order to formulate a baseline value. The iteration of the process throughout the operational period facilitates the reliability of the results obtained in the first attempt.

After initial assessment of a baseline value, repetition is recommended to follow up on changes in the provision of ecosystem services (Chan, Satterfield, &

Goldstein, 2012; Felipe-Lucia, Comín, & Escalera-Reyes, 2015). The literature does not suggest an appropriate interval of repetition, allowing the respective decision-maker to integrate the iterative process into existing management structures. Through the iterative process, a trend can be established, indicating the direction of change in the provision of the studied ecosystem service. In a next step, the assessment can be compared to the predictions made in the model. By comparing and analysing the predictions of the model with the assessment of ecosystem services, adaptations to the management can be made. This will ensure that changes are taken into account within the long-term management of the socio-ecological system, including opportunities to involve stakeholders in the revision process, but which still reflects the different perspectives of the future (Swart, Raskin, & Robinson, 2004). Repetitions of steps 2 to 4 (Figure 27) ensure that new and updated policies are incorporated into the long-term management. The weakness of scenario analysis of not being able to include as many factors as possible to depict a plausible future (Bennett et al., 2009) is avoided through the use of repeated stakeholder interactions and adaption of the model.

By using the data collected in objective 1 to 3, methods and frameworks for the future management of the Upper Mersey Estuary can be recommended. These recommendations not only show that the research follows a logical path from identification of ecosystem services, expected changes in the estuary to a model that gives concrete information on the provision of ecosystem services, it also provides a framework of how to use the methods applied in this research in the future, to address changes through a conceptual framework, ensuring the implementation of an ecosystem approach in a socio-ecological system.

## 5.5. Application of the Research and its Findings

This project explores a new way of integrating long-term planning of an ecosystem approach, based on local knowledge across a socio-ecological system. The need to focus on landscape scales instead of habitats has been elaborated in the literature review and has resulted in the application of the three objectives that were discussed in this chapter. Applying the method as part of an ecosystem approach can facilitate the management planning and decision-making in individual areas. The complexity of socio-ecological systems is broken down into parts, which are supported by local knowledge and expertise – a vital aspect of the ecosystem approach (Convention on Biological Diversity, 2005). The developed method can be applied as a tool in local management planning and decision-making, as it can be used in communication with stakeholders, by including their views and visions, as well as creating a concept that visualises changes in the landscape. By applying further steps, i.e. the recommendations set out in section 5.4.3, the method can be incorporated into existing management structures.

Using the resources of estuarine socio-ecological systems, to create a sustainable approach to nature conservation, can be supported by concepts such as the natural capital approach. The research method and its application forms a valuable starting point to a natural capital assessment (Natural Capital Committee, 2017a). Current research suggests that an integrative approach should be applied when accounting for the management of ecosystems, i.e. a focus on organised collective action (Feger & Mermet, 2017), to which this research contributes. The initiation of a coherent method of establishing a holistic understanding of ecosystems and their provision of services in any socio-ecological system is important, with the view to make environmental management approachable for a wide range of disciplines. Hence, the incorporation of integrative methods into the concept of natural capital and accounting should be considered.

As discussed in section 5.4.3.2, a repetition of the assessment of change and adjustment of the model to include changes within the study site is recommended. Adaptation to change is not only an element of the ecosystem approach, it is also considered to be pivotal in establishing a resilient management (Berkes et al., 2003). Other research acknowledges the need to consider work on socio-ecological systems, as well as on a landscape-scale to allow interdisciplinary and participatory work from stakeholders and experts (Bailey & Buck, 2016; McPhearson et al., 2014). The use of the ecosystem service concept provides the link between societal and natural elements and can, therefore, also be used as a concept to explore the resilience of socio-ecological systems (Zaucha, Conides, Klaoudatos, & Norén, 2016).

A further application of the research is the incorporation of the method in assessments of human well-being in natural green spaces for which the need was indicated in the literature review (section 2.3). A study by Natural England suggests that the increase in health cost through inadequate access to natural green space can be estimated at £23.6 million per year (Rolls, 2016). The connection between physical, as well as mental well-being and ecosystem services (e.g. through biodiversity) was established (Lees & Evans, 2003) and can be carried forward into this study. Through active monitoring and modelling of the provision of ecosystem services, a long-term estimation of this provision can be carried out by planners and managers.

The research acknowledges that methods need to be adaptive and dynamic (Swart et al., 2004), a characteristic that methods presented in this thesis fulfil. An application of the method developed in this study can facilitate elements of environmental management such as nature conservation and planning, by addressing identified aspects of the literature review: i) the need to find a method that is offering new ways to implement an ecosystem approach; ii) to support resilient ecosystems, and iii) the adaptation to change of socio-ecological systems. The application of the method in the Upper Mersey Estuary shows that the steps are coherent and results are obtained to inform the future management of the area. As discussed in this chapter, the results of the study are case-specific and will require adaptation to local circumstances and existing management systems. It is a flexible method that can be used in various socio-ecological settings, allowing managers and decision-makers to include future provision of ecosystem services in management set-ups.

# 6. Conclusions

Looking at long-term approaches that take into account socio-ecological system interactions such as the ecosystem approach and the 25-year plan recommended to the UK government by the Natural Capital Committee (Natural Capital Committee, 2017a), suggests that there is a need for integrative approaches that consider long-term management planning across landscape scales. The three questions that were developed by reviewing the literature can be answered after the synthesis of the results:

1. The ecosystem services of any complex socio-ecological system are varied and site-dependent. Therefore, a local identification of ecosystem services and their assessment is pivotal, if they are to be used for the implementation of an ecosystem approach. Although the use of qualitative data can be challenging, the results that are gathered from stakeholder participation contribute to the understanding of a socio-ecological system and help to identify those ecosystem services that are relevant for a particular system, focusing on those services that provide benefits that are most appreciated by people.
2. The identification of possible futures, as done within this study, is a suitable way to inform long-term management planning, aiming to provide a resilient provision of ecosystem services. By generating an understanding of how the provision of services can change over time, adaptation to management can result in improved decision-making and limit the disturbances to the provision of ecosystem services, i.e. by creating a more resilient landscape. This can be translated into existing management practices and can be integrated into policy planning.
3. Using a model to estimate the provision of ecosystem services under different futures, enabled the understanding of the provision of those services in the long-term and provided a means for decision-makers to be able to focus their management planning on particular areas of change. This can contribute to a sustainable provision of ecosystem services. A repetition of the assessment is recommended in order to fully appreciate

the changes within a system, as they cannot be assessed confidently over several decades.

As called for by researchers and policy-makers (Guerry et al., 2015; Mouchet et al., 2014; Zaucha et al., 2016), the study uses an interdisciplinary approach to combine social and environmental aspects. The need to consider a system holistically and over a long-term, in order to be able to use its resources sustainably has been identified (e.g. Hansen et al., 2015; Hanspach et al., 2014; Rivera-Ferre, Ortega-Cerda, & Baumgartner, 2013) and was addressed in this study.

The 12 principles of the ecosystem approach (Convention on Biological Diversity, 2005) were acknowledged in the literature review and new insights to the application of those principles can be drawn from this research. These are addressed below and indicate how the research contributed to the concept.

Principle 1 *The objectives of environmental management are a societal choice*: This principle was addressed by engaging with local stakeholders from different disciplines to identify relevant ecosystem services. Through these societal choices, management can be adapted to those services that are perceived as relevant by a representative group of society.

Principle 2 *Management should be decentralised to the lowest appropriate level*: The study site is managed by local stakeholders. The lowest appropriate level is assumed to be a joined management approach by the relevant stakeholders, i.e. landowners, exceeding individual site boundaries. Through this research the implementation of a joined management approach is facilitated by considering the socio-ecological system of the Upper Mersey Estuary.

Principle 3 *Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems*: This principle was intensively addressed in this research, as the study suggests an approach that goes beyond individual ecosystem service boundaries and considers the socio-ecological system, i.e. an area that is geographically and socially distinct, in this case an estuary, including different ecosystems, different land uses and land cover types.

Principle 4 *Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context:* Before being able to manage a natural system in an economic context, the need arises to learn which environmental factors, i.e. ecosystem services, play a role in the provision of the services that contribute to the economy. In order to create a holistic picture of those contributors, the relevant ecosystem services were identified for this study site. Also, in order to use the natural capital of the area in a sustainable way, a long-term estimation of change has been established.

Principle 5 *Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach:* This principle has been addressed throughout the study, by providing a method of assessment of change. Through the gained understanding and adaptation to change, nature conservation and ecosystem functioning and structure can be taken into account for future management planning.

Principle 6 *Ecosystems must be managed within the limits of their functioning*: Through the method applied in this study, a selection of ecosystem functions can be explored and the limits of the functions can be incorporated into the management of the Upper Mersey Estuary.

Principle 7 *The ecosystem approach should be taken at the appropriate spatial and temporal scales*: The ecosystem approach for the Upper Mersey Estuary takes into account the boundaries of a distinct geographical area. The spatial scale of the study includes the area of the estuary which will be under the management of the Mersey Gateway Environmental Trust during the operational period of the Mersey Gateway Crossing. This is considered to be an appropriate scale, as it considers a distinct socio-ecological system. The temporal scale of the ecosystem approach is set to be long-term – until the operational period of the Mersey Gateway Crossing expires in 2044. This time scale is considered to be efficient for a long-term adaptive management system in which the management can be adapted to changes throughout the time period. A repetition of the assessment has been recommended and will give more accurate estimations of the provision of ecosystem services for long-term management.

Principle 8 *Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term*: As described in Principle 7, the project is set out for a long-term approach. By developing scenarios, showing possible futures of the study area, the long-term approach is considered a pivotal element of the research. The identified method in this project recognised the temporal changes that can occur in a system over time. The assessment of interactions between ecosystem services and the impact on the provision was not studied here, but offers potential for future research.

Principle 9 *Management must recognise that change is inevitable*: This is an essential part of this research. The identification of triggers of change for the Upper Mersey Estuary and the establishment of potential futures, support the fact that the area is inevitably changing. Through the development of scenarios (objective 2), the change can be recognised and incorporated into management planning.

Principle 10 *The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity*: This principle is covered through different elements of the research. The study considers a socio-ecological system and acknowledges a range of changes in the scenarios of possible futures of the estuary. By assessing the potential provision of ecosystem services, the research seeks to develop a method which is inclusive of the integration and conservation of biological diversity, but takes changes to society and land use into consideration.

Principle 11 *The ecosystem approach should consider all forms of relevant information, including scientific and indigenous, and local knowledge, innovations and practices*: The research project has made considerable effort to include as much relevant information as possible, in an attempt to facilitate an ecosystem approach for the Upper Mersey Estuary. Scientific knowledge has been a primary element to inform the methods described and applied in this project. Local knowledge was incorporated by consultation with local experts and the inclusion of local core strategies, to be able to adapt the method to the local circumstances.

Principle 12 *The ecosystem approach should consider all relevant sectors of society and scientific disciplines*: To be as inclusive as possible, the research suggests that all relevant ecosystem services are identified as one of the first steps within an ecosystem assessment. By concentrating on the relevant ecosystem services, resources and expertise can be used efficiently to manage the socio-ecological system to which the services are provided. By taking into account the socio-ecological system of the Upper Mersey Estuary, the research attempts to incorporate social and environmental factors that are influenced and are influencing the estuary's provision of ecosystem services.

Additional to an increased scientific understanding of the socio-ecological system, the research and engagement with the topic can create an increased personal value of the site (Kyle, Graefe, Manning, & Bacon, 2004) by simplifying the complexity and dynamics of the system to a level that is comprehensible to a wider audience. By widening the approach from narrow, single habitat, to a broader, socio-ecological, cross-habitat scale, the holistic aspect of the ecosystem approach is addressed. As Liu et al. (2007) suggest in their research, human and natural systems should be studied together to be able to reflect the need of resources by society, but at the same time, to ensure that the natural environment is not exploited. The knowledge of the presence and provision of ecosystem services is, therefore, an essential tool to foster the need to address this issue.

Despite the fact that the ecosystem service concept has been criticised for its complexity and intangibility (Baveye, 2017; Primmer & Furman, 2012), it provides a useful framework for researchers and decision-makers, and can be translated and/or simplified for other uses, i.e. stakeholder engagement. It became clear during the research that the concept is challenging for some (section 5.2.6) and that there is a clear need to comprehensively communicate the concept, as well as to listen and record diverse worldviews, opinions, and expressions that will be used by participants and stakeholders.

## 6.1. The Impact of the Research

The construction of the Mersey Gateway Crossing will have been completed by the time this document is submitted. As part of the planning process, it was agreed by Halton Borough Council that the resilience of ecosystem services and their potential future management had to be assessed. This research will form the basis of a report to the Department of Transport of the UK government.

The beginning of the bridge operation is also the starting point of the operation of the Mersey Gateway Environmental Trust. The Trust will be active within the study area, pursuing nature conservation and research in the estuary. The research can inform the management of the study site from the beginning of the operation of the Trust and can inform the communication with the stakeholders that are active in the estuary. Therefore, the direct application of the research and its findings can be expected.

The research intends to contribute to a long-term vision and adaptive management plan within ecosystem management in the UK, as reflected by the Natural Capital Committee (2017a), which can be extended to an international level. The application of the method described in this research, and the attempt to include the ecosystem approach into current management practices, can lead to advances in the establishment of such a long-term vision for the UK ecosystem management.

## 6.2. Opportunities for Future Research

The research is placed in a dynamic and complex socio-ecological system of which not all aspects could be covered in this research. Hence, there is ample opportunity to research alongside the findings of this study. Some recommendations were already given in section 5.4.3 as part of the discussion to strengthen the monitoring and long-term application of the project. Three main topics are identified and are summarised in Table 35.

**Table 35 Areas of possible further research.**

| | Topic | Description |
|---|---|---|
| 1 | Interactions, feedback loops, synergies, trade-offs of ecosystem services | To be able to quantify ecosystem services more precisely, interactions between the present ecosystem services should be considered. As these are site-dependent, this represents an important area of research for the Upper Mersey Estuary. |
| 2 | Stakeholder participation | To be able to cover more aspects of the socio-ecological system, stakeholder participation can be extended to the general public and other stakeholders using the estuary. |
| 3 | Actual change and the impact on ecosystem service provision | In order to make predictions for the provision of ecosystem services, it needs to be researched how particular changes influence the provision of ecosystem services more precisely. Although estimations are made within the model, these offer the opportunity to be investigated further. |

# Appendices

## Appendix 1 The Twelve Principles of the Convention on Biological Diversity

Principle 1: The objectives of management of land, water and living resources are a matter of societal choices.

Principle 2: Management should be decentralized to the lowest appropriate level.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems

Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Principle 6: Ecosystem must be managed within the limits of their functioning.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

Principle 9: Management must recognize the change is inevitable.

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

# Appendix 2 Ethical Approval Letter

**Academic Audit and Governance Committee**

**College of Science and Technology Research Ethics Panel (CST)**

University of Salford MANCHESTER

**MEMORANDUM**

**To** **Andrea Perz (and Dr Philip James)**

**cc:**

**From** **Nathalie Audren Howarth, College Research Support Officer**

**Date** **30/03/2015**

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**Subject:** **Approval of your Project by CST**

**Project Title:** **An ecosystem approach to assess the impacts of the construction and operation of the Mersey Gateway Crossing on the Upper Mersey Estuary**

**REP Reference:** **CST 15/09**

Following your responses to the Panel's queries, based on the information you provided, I can confirm that they have no objections on ethical grounds to your project.

If there are any changes to the project and/or its methodology, please inform the Panel as soon as possible.

Regards,

Nathalie Audren Howarth
College Research Support Officer

**For enquiries please contact:**
**College of Science and Technology**
**College Research Support Officer**
**The University of Salford**
**Maxwell building, (7th floor, room 721)**
**Telephone: 0161 295 5278**
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## Appendix 3 Delphi Questionnaire


University of Salford MANCHESTER

**School of Environment and Life Sciences**

University of Salford
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Salford, M5 4WT
http://www.salford.ac.uk/

the mersey gateway


29/04/2015

ID

### Questionnaire 1

Please note that there no right or wrong answers to the questions! Also remember that no identifying details will be published at any point!

#### Question 1a

The Upper Mersey Estuary is the provider of multiple Ecosystem Services. Ecosystem Services are those services provided by nature from which humans benefit and which enhance our well-being. **The list below contains details of services and benefits associated with the Upper Mersey Estuary. How important are these services and benefits today?** Please choose from the list, or complement the list with your own keywords in the comment box.

| SERVICES | BENEFITS | IMPORTANCE | | | | | |
|---|---|---|---|---|---|---|---|
| | | Very Important | Important | Neutral | Of little Importance | Unimportant | I don't know |
| Water for navigation | shipping | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for industrial use | improved industrial production | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for agricultural use | improved agricultural production | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for energy use | renewable energy production | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for household use | drinking water | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Raw materials (sand, clay) | building material | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Raw materials: surface | building platform for housing, roads, infrastructure, etc. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Raw materials: Plants | building material, fibre, fuel | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Raw materials: Animals | building material, fibre, fuel | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Genetic resources | various improved provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

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| | | Very important | Important | Neutral | Of little importance | Unimportant | I don't know |
|---|---|---|---|---|---|---|---|
| Plants | Food from plants | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Animals | Food from animals | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Medicinal resources | human health | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ornamental resources | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Biodiversity | Insurance for all services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Air quality regulation: Removing harmful particles, air water exchange, biogeochemical reactions | human health | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Climate regulation: Carbon sequestration and burial | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Climate regulation: Water thermodynamic regulation | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Climate regulation: Heat exchange regulation | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regulation of extreme events: Flood water storage | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regulation of extreme events: Peak discharge buffering | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regulation of extreme events: Water current reduction | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regulation of extreme events: Wave reduction | human health, saving potential repair costs caused by extreme events or disturbance, ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regulation of extreme events: Sound buffering | human health | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water quantity regulation: drainage of river water | surface, food, water, other provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water quantity regulation: prevention of saline intrusion | various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| Service | Benefits | Very important | Important | Neutral | Of little importance | Unimportant | I don't know |
|---|---|---|---|---|---|---|---|
| Water quantity regulation: dissipation of tidal and river energy | various ensured provisioning services, avoided maintenance costs | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water quantity regulation: landscape maintenance | various ensured services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water quantity regulation: transportation | Shipping | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water quality regulation: transport of pollutants and excess nutrients | improved water quality, various ensured services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water quality regulation: reduction of excess loads coming from the catchment | improved water quality, various ensured services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Erosion and sedimentation regulation by water bodies | avoided damage or maintenance costs, various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Erosion and sedimentation regulation by biological mediation | avoided damage or maintenance costs, various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Biological regulation of soil processes and soil formation | various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Prevention of establishment of harmful invasive species | various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reduced spread of diseases | various ensured provisioning services, human health | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Pollination | various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Biological pest and disease control | various ensured provisioning services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Aesthetic appreciation | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Opportunities for recreation & tourism | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Inspiration for culture, art and design | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Spiritual experience | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Inspiration for cognitive development | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Sense of place | Wellbeing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Do you have additional services and benefits in mind?

**Question 2a**

Do you think that the services and benefits provided by the Upper Mersey Estuary will change in the next 30 years?

☐ Yes ☐ No ☐ I do not know

**Question 2b**

**If yes:** What do you think are the triggers for future changes of the services and benefits provided in the Upper Mersey Estuary?

**If no:** What do you believe are the reasons that the Upper Mersey Estuary is going to be stable in the provision of services and benefits over the next 30 years?

**Question 3**

Which land use forms will be the ones to change most likely in the next 30 years in the Upper Mersey Estuary?

*

| Land use Type | Yes | No | I do not know |
|---|---|---|---|
| Agriculture | ☐ | ☐ | ☐ |
| Brownfields | ☐ | ☐ | ☐ |
| Forest | ☐ | ☐ | ☐ |
| Grassland | ☐ | ☐ | ☐ |
| Industrial | ☐ | ☐ | ☐ |
| Residential | ☐ | ☐ | ☐ |
| Woodland | ☐ | ☐ | ☐ |

**Question 4**

Have you got experience with the concept of Ecosystem Services?

Yes, I worked with the idea before. ☐
Yes, I read about it. ☐
Yes, I have heard about it. ☐
No, this concept is new to me. ☐
Other: ☐

**Your name*:**

**Your company/organisation*:**

* for internal use only

**Thank you very much for your participation!**

Any questions or concerns? Please contact:
Andrea Perz
a.perz@edu.salford.ac.uk

**Appendix 4 Land use Categories found in the Upper Mersey Estuary compared through their NLUD indices, after Harrison (2006).**

| Land use order | Order | Land use group | Group | Comment |
|---|---|---|---|---|
| Agriculture and Fisheries | U010 | Agriculture | U011 | Agricultural fields and low intensity grazing |
| Forestry | U020 | Managed forest | U021 | Includes woods and shrubs |
| Utilities and infrastructure | U060 | Energy production and distribution | U061 | Fiddlers Ferry Power station |
| Utilities and infrastructure | U060 | Water storage and treatment | U062 | Land owned by United Utilities |
| Utilities and infrastructure | U060 | Refuse disposal | U063 | Arpley, Randall's, Ash heaps at Fiddlers Ferry |
| Unused land | U130 | | | This order comprises all natural and semi- natural land which are described in the land cover as grass, saltmarsh, reed beds. River Mersey also classed in this order because there no use of water for transport purposes. |

**Appendix 4 (cont.)**

| Land use order | Order | Land use group | Group | Comment |
|---|---|---|---|---|
| Industry and Business | U100 | Not specified | Not specified | Offices and storage |
| Vacant and derelict | U110 | | | Brownfields |
| Transport | U050 | Waterways | U056 | Manchester Ship Canal |
| Transport | U050 | Car park | U053 | |
| Residential | U070 | Dwellings | U071 | |
| Recreation and Leisure | U040 | Outdoor amenity and open space | U041 | |

**Appendix 5 Land cover categories found in the Upper Mersey Estuary compared through their NLUD indices, after Harrison (2006).**

| Land cover order | Order | Land cover group | Group | Comment |
|---|---|---|---|---|
| Cropped land | C010 | Not specified | Not specified | |
| Woodland and shrub | C030 | Broadleaved forest | C033 | |
| Permanent made surface | C090 | Other made surface | C094 | Landfill sites, power station, brownfields |
| Grass | C020 | Improved grass | C021 | |
| Grass | C020 | Unimproved grass | C022 | Neutral and rough grassland |
| Water and wetland | C060 | Freshwater marsh | C063 | Reed beds, inundated by mainly high tides, at the shore of river. Estuarine conditions, therefore, mix of salt and fresh water |
| Coastal features | C070 | Saltmarsh | C073 | Inundated on high tides throughout the year. |
| Buildings and structure | C080 | Not specified | Not specified | Buildings and other built structure |
| Water and wetland | C060 | Running water | C062 | River Mersey |
| Water and wetland | C060 | Standing water | C061 | Lakes |

## Appendix 6 A tidal barrage in the Mersey Estuary

A tidal barrage for energy production was considered for the Mersey Estuary as a scheme that could be implemented within the first half of the 21st century in order to provide the area with renewable energy. The suggestion to assume the construction of tidal power generation plant seems fitting for the Development Boom 2044 scenario as it describes a major construction project. Initial plans for the project were abandoned in 2011 due to financial feasibility (BBC News, 2011); however, the need for energy in the UK and independence from external energy providers as well as limitations on fossil fuels, might renew the interest in the scheme. Despite generation of renewable energy based on tidal energy (harvested through turbine generated power production), the operation generates long-term environmental effects on the estuary and surrounding areas.

Studies on the effects of a tidal barrage are scarce, but few point out the mainly negative effects on the natural environment (e.g. siltation, reduced flow of water, salinity issues, effects on biodiversity, erosion and sedimentation) (Ahmadian, Falconer, & Bockelmann-Evans, 2012; Hooper & Austen, 2013; Neill, Jordan, & Couch, 2012). It is important to notice that the studies can only assess the effects in limited ways, as detailed data are not always available (House of Parliament 2013). To fully assess the effects a tidal barrage would have on the wider Mersey Estuary and the Upper Mersey Estuary, a detailed study would have to be carried out to appreciate the uniqueness of the estuary over other estuaries from which information can be compiled due to the presence of a barrage, e.g. La Rance (France) Annapolis Royal (Canada) and Eastern Scheldt (The Netherlands).

Through the operation of a barrage, impacts on the water movement and the amount of suspended solids within the water have to be expected. This will, therefore, have impacts on the composition of plant and animal communities which can be found in the estuary. Dependent on the mode of operation (ebb generation only, or ebb-flood generation) impacts on the natural environment differ (ebb generation having a more severe effect on the estuary in terms of habitat loss and changes to the morphology of the estuary) (Neill, Jordan, & Couch, 2012). Changes in tidal range have prolonged effects on the tidal range of a barraged site (Wolf, Walkington, Burrows, 2009). Wolf et al. (2009) summarised the effects that a tidal barrage would have on an estuary, which further would lead to changes in the provision of ecosystem services in the particular area (Table A1).

Even though there are some indications as to how an estuary will change under the operation of a tidal barrage, these can only be seen as predictions as every estuary will react differently to changes. However, the identified impacts can act as indicators for the Upper Mersey Estuary and the future provision of ecosystem services. The development of a tidal barrage is included in the model for those areas that are connected to the water flow of the river Mersey – the wider impact on areas that are not directly by the water has not been covered.

**Table A 1 Impacts and effects of a tidal barrage on an estuary, adapted from Wolf et al. (2009)**

| | Impact | Effect |
|---|---|---|
| **Physical changes** | Reduced vertical mixing | • Drop of level of suspended matter, leading to increased light penetration. |
| | Reduction of mixing of water | • Increase in density stratification. |
| | Reduced saline penetration | • More brackish water |
| | Reduced flushing rates | • Possible build-up of contaminants<br>• Increase of nutrient availability, leading to increased primary production (eutrophication) |
| | Increase in average water levels | • Decrease in groundwater flows, leading to impacts on drainage of surrounding land. |
| **Environmental and ecological impacts** | Change in water flow | • Loss saltmarsh and mudflats, leading to loss of biodiversity, especially birds (waders) |
| | Modified currents and wave patterns | • Stress on benthic habitats |
| | Structural changes to the estuary | • Migratory routes of fish<br>• Disorientation and damage to aquatic mammals and fish |
| **Human, economic, aesthetics and amenity impacts** | Structural changes | • Visual intrusion<br>• Loss of historic sites in intertidal areas<br>• Increase in tourism and recreational activity |

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