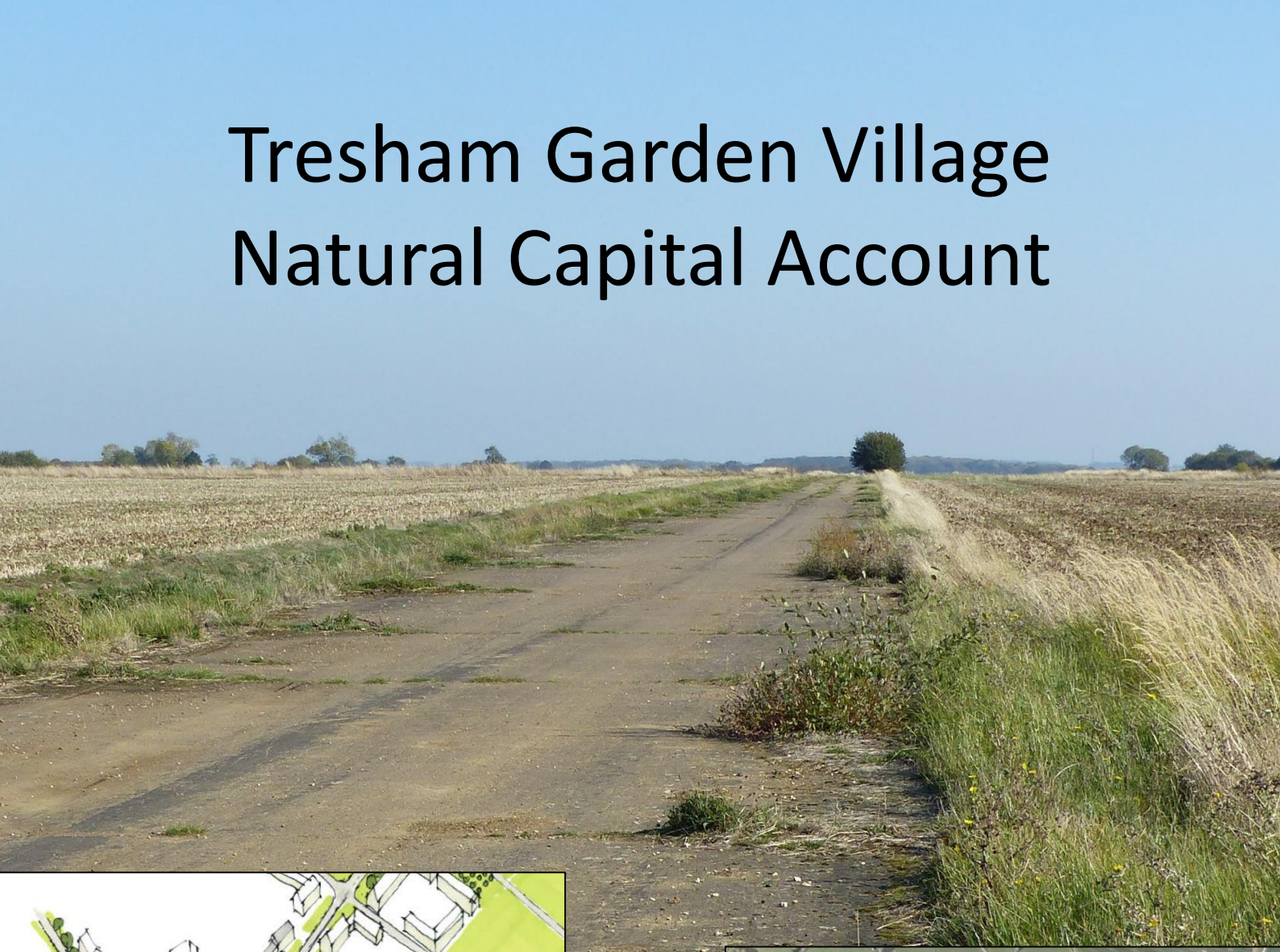
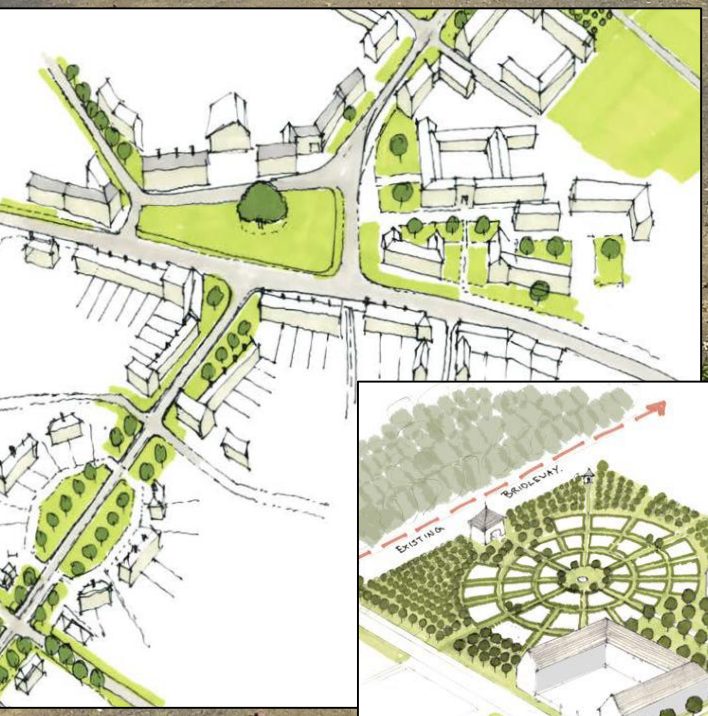
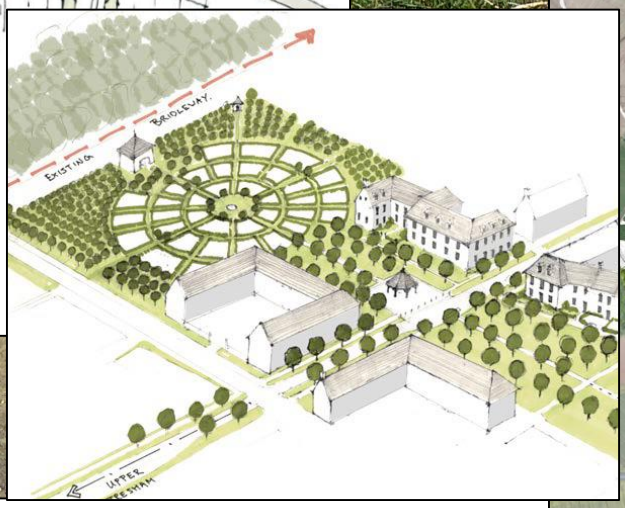
Tresham Garden Village
Natural Capital Account









Natural Capital Solutions

East Northamptonshire Council

North Northamptonshire Joint Planning & Delivery Unit

Tresham Garden Village Natural Capital Account

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Executive summary

This report presents a natural capital account for the proposed Tresham Garden Village development in East Northamptonshire and was commissioned by East Northamptonshire Council. Using a natural capital accounting framework, the assessment aimed to identify and assess natural capital assets (asset register) with and without the development, the flow of services from them (physical flow account), and the monetary value of the resultant benefits (monetary flow account). The net ecosystem service benefits were then established (natural capital balance sheet), taking into account the costs of creating and maintaining the natural capital assets (capital and maintenance costs account). At all stages the assessment compared the site under its current land use, with the site under the proposed Masterplan. This report should be read in conjunction with the previous natural capital impact assessment (Rouquette 2017), which provides a broader (but non-monetary) assessment of impact on ecosystem services, including detailed maps showing the spatial location of service delivery and how this will change following development.

The natural capital asset register revealed that the site (370 ha) is currently dominated by arable land, with smaller patches of improved grassland, semi-natural grassland and broadleaved woodland (see Figure 3). Under the proposed masterplan (Figure 4), the area of arable land will fall considerably (by 143 ha), with smaller losses of improved grassland and semi-natural grassland. Overall woodland cover will increase by 36 ha to 62.4 ha (16.7% of the site), and parkland will occupy 35.4 ha (9.5% of the site). Built-up areas, gardens and infrastructure (roads, pavements and paths) will together make up 105 ha, which is 28.2% of the land area.

The physical and monetary flow accounts show that the services providing the greatest value are recreation and physical health. It is estimated that an average of 70,250 visits (including repeat visits by the same individual) will be made to the greenspaces around Tresham each year over the next 30 years, providing benefits worth an average of £430,000 per annum. An estimated average of 340 visitors to the greenspaces around Tresham will make active visits each week, resulting in an increase of 11.6 Quality Adjusted Life Years (QALYs) for visitors on average each year, worth an estimated £339,000 per annum. Under the proposed masterplan it is estimated that vegetation will absorb an average of 2,704 kg of PM_{10} each year over the first 30 years, an increase of 435 kg or 19% compared to the baseline. This will provide annual benefits worth £166,000, an increase of £107,000 relative to existing uses. However, the capacity of the vegetation to absorb pollution increases significantly over that period and will continue to increase over time. Once mature, it is estimated that the vegetation will absorb 5,252 kg of PM_{10} per year.

Carbon sequestration will increase from 154 to 423 tCO_2e per year, a 174% increase from the baseline to the masterplan. This corresponds to an increase in value of £36,800, rising from £17,600 to £54,300 per annum. At the same time, emissions from agricultural activities will fall from 418 to 297 tCO_2e per year, providing savings worth £13,500 each year. Data on carbon sequestration can be combined with agricultural emissions to calculate the overall carbon budget for land-based activities at the site. Following development, Tresham will

move from being a net emitter of 264 tCO_2e per year, costing £30,000, to being a net absorber of 126 tCO_2e per year, bringing benefits worth £20,200 each year.

Agricultural production is the only ecosystem service measured that will decline following development, with 130 ha of land being taken out of production. This will result in a loss of £20,400 per year compared to the baseline, once all costs and agricultural subsidies have been stripped out. Timber/woodfuel production is predicted to increase slightly but only from 159 to 209 m^3 per year over the first 30 years, worth an additional £950 per annum. Most production would occur beyond the 30-year period of this assessment, and if production is averaged over the full forest cycle, then yield would increase by 247 m^3 each year on average, an annual average increase of £4,330.

Detailed capital and maintenance costs were calculated for all new and existing green spaces and are shown in the capital and maintenance cost account. Total capital costs to create all the green infrastructure at Tresham Garden Village are estimated to come to £0.99M and maintenance costs will amount to £2.63M over 30 years, with a total cost estimate of £3.62M. Note that these figures are given before discounting, hence do not match those in the natural capital balance sheet.

A summary of the natural capital balance sheet for Tresham Garden Village is shown below. Here all costs and benefits have been discounted, as the value of costs and benefits in the future is considered less than the value today, and is a standard approach adopted in project appraisals (as recommended by the UK Government's Green Book).

Summary Natural Capital Balance Sheet for Tresham Garden Village under the baseline and 2018 masterplan and predicted changes. Based on the Present Value of assets and liabilities over 30 years, using the standard UK Government discount rate (3.5%).

Natural Capital Balance Sheet $£_{2018}$ PV	Baseline £'000	Masterplan £'000	Change £'000
Assets			
Natural capital benefits	1,097	15,583	14,486
Rental & grant income	983	764	(219)
Gross asset value (benefits)	**2,080**	**16,348**	**14,267**
Liabilities			
Capital costs	0	(841)	(841)
Maintenance costs	(132)	(1,479)	(1,347)
Total liabilities (costs)	**(132)**	**(2,320)**	**(2,188)**
Net Natural Capital Value	**1,948**	**14,027**	**12,079**

Following standard accounting convention, figures in parentheses (also marked in red) are negative.

The total Present Value (PV) of all natural capital benefits over 30 years, and discounted at the standard government rate of 3.5%, is £15.58M if Tresham Garden Village is to be built. Including rental and grant income of £0.76M, makes a total gross value of £16.35M for the

planned village. This compares to a PV of natural capital benefits of £1.10M under the present situation, and £0.98M in grant income (Basic Farm Payments), totalling £2.08M. Gross benefits therefore increase by £14.27M following development.

The net natural capital asset value (Net Present Value) of the site as currently managed, once liabilities (costs) have been taken into account, is £1.95M. This is driven predominantly by the value of air pollution regulation, agricultural production and agricultural subsidies (Basic Farm Payment), with the latter responsible for 47% of the total value of the site. If the development at Tresham goes ahead, liabilities increase substantially to £2.32M, but the gross value of the natural capital assets would increase dramatically to £16.35M. **Overall, therefore, the net value of the natural capital assets under the masterplan would be £14.03M, an increase of £12.08M compared to the baseline**. Recreation, physical health and air quality regulation provide the greatest benefits, although all natural capital benefits increase, with the exception of agricultural production. However, the vast majority of the benefits delivered by the site would be in the form of public benefits, and will not accrue directly to the landowner, whereas the costs will be borne privately.

The delivery of ecosystem services will change over time as habitats are created and become established, as houses are completed and the population gradually increases, and as the value of certain ecosystem services changes into the future. Hence the benefits and costs were calculated for each individual year over the next 30 years. The value of the natural capital benefits that will be delivered by the site under the baseline (no development), will not change greatly over time, whereas the value of benefits delivered as the Masterplan is implemented changes considerably over the 30-year period. In particular, recreation and physical health benefits will increase as homes are gradually completed and the village population steadily increases. Air quality regulation and carbon sequestration benefits will increase as the trees and woodlands grow. On the other hand, costs are much higher towards the start of the project period, due to the capital costs of establishing habitats. This means that there will be a net cost at the start of the project, but by Year 4 the green elements of the project will be providing net benefits. Net benefits then increase rapidly as the development is continued and eventually completed over the following 13 years, and remain high following completion of building works.

A sensitivity analysis and RAG assessment were performed and showed that the range of potential values was high. However, the vast majority of this uncertainty arose from the calculation of physical health. In all versions of the sensitivity analysis, creating new green infrastructure at Tresham resulted in a substantial positive return on investment. The development of the accounts has shown that methods and data are robust enough to produce meaningful accounts, despite some uncertainties. It is hoped that it can be used to demonstrate best practice to roll out the approach more widely and to communicate and showcase the importance of the natural environment in new developments. Green infrastructure is an essential part of all new developments, and especially within the Garden Village movement, and this approach is useful at highlighting its value, which may otherwise remain hidden. **Quality green spaces deliver a range of benefits that have real value to society, create community well-being, and enhance liveability and sense of place**.

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1. Introduction

1.1 Background

In 2017 Natural Capital Solutions undertook a natural capital impact assessment of the proposed Tresham Garden Village in East Northamptonshire (Rouquette 2017). This assessment mapped and compared the natural capital assets and the ecosystem services (the benefits) that would flow from the site, before and after the proposed development. A stakeholder workshop was then held where stakeholders were engaged with the process and encouraged to adjust site design. The impact of the altered masterplan on natural capital and ecosystem services was then assessed. Key results that emerged were:

- The proposed development broadly increases both supply and demand for most ecosystem services.
- New woodland planting surrounding the core built zone is particularly beneficial.
- Ecosystem service delivery could be increased further – highlighted through the assessment and the stakeholder workshop.
- The approach taken can be used to evaluate environmental net gain, which is becoming increasingly relevant in national planning policy.
- The approach used is applicable elsewhere in the planning and development sector.

Phase 2 of the assessment was commissioned by East Northamptonshire Council (the statutory planning authority for the site) to complete a natural capital account for the proposed development. This involves calculating the monetary value of the natural capital benefits likely to be delivered by the development. These benefits are then compared to the capital costs of creating the green elements of the development and their ongoing maintenance costs, using a natural capital accounting framework. This considers annual costs and benefits over a 30-year period and the overall cost benefit ratio. Much of the background to the site and the ecosystem services that flow are described in detail in the previous report (Rouquette 2017), so are not repeated here.

1.2 The natural capital approach

The natural environment underpins our well-being and economic prosperity, providing multiple benefits to society, and yet it is consistently undervalued in decision-making. Natural capital is defined as "*..elements of nature that directly or indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions"* (Natural Capital Committee 2014). These benefits (often referred to as ecosystem services) include food production, regulation of flooding and climate, pollination of crops, and cultural benefits such as aesthetic value and recreational opportunities (Figure 1).

The concept of natural capital and its associated approaches can be used to understand the natural capital assets of an area or organisation. Through a natural capital assessment, it is possible to understand the extent and condition of those assets, so the number and the flow of ecosystem service benefits from those assets can be established. These benefits can

then be valued. Information on the condition and benefits derived from an asset enables better informed land management decisions to be made because of the transparency gained by recognising an asset's full, long term value. It provides an understanding of the consequences of land management change (whether that be a change from one type of natural habitat to another, or from natural habitats to housing developments) on the range of benefits that can be provided by a landscape. It can also highlight how specific changes can be tailored to enhance certain services or values, and how environmental change (e.g. climate change) may affect natural capital assets, their benefits and values. It can reveal the value of both public and private benefits that come from managing landscapes, and it is key to identifying trade-offs and synergies between different ecosystem services.

By taking a natural capital approach, East Northamptonshire Council and the developers at Tresham will be able to more accurately demonstrate the value of the green infrastructure elements of the proposed development, highlight critical assets that are particularly beneficial or should be enhanced, enable natural capital to be taken in to account more fully in decision making, and start to monitor losses and gains over time.

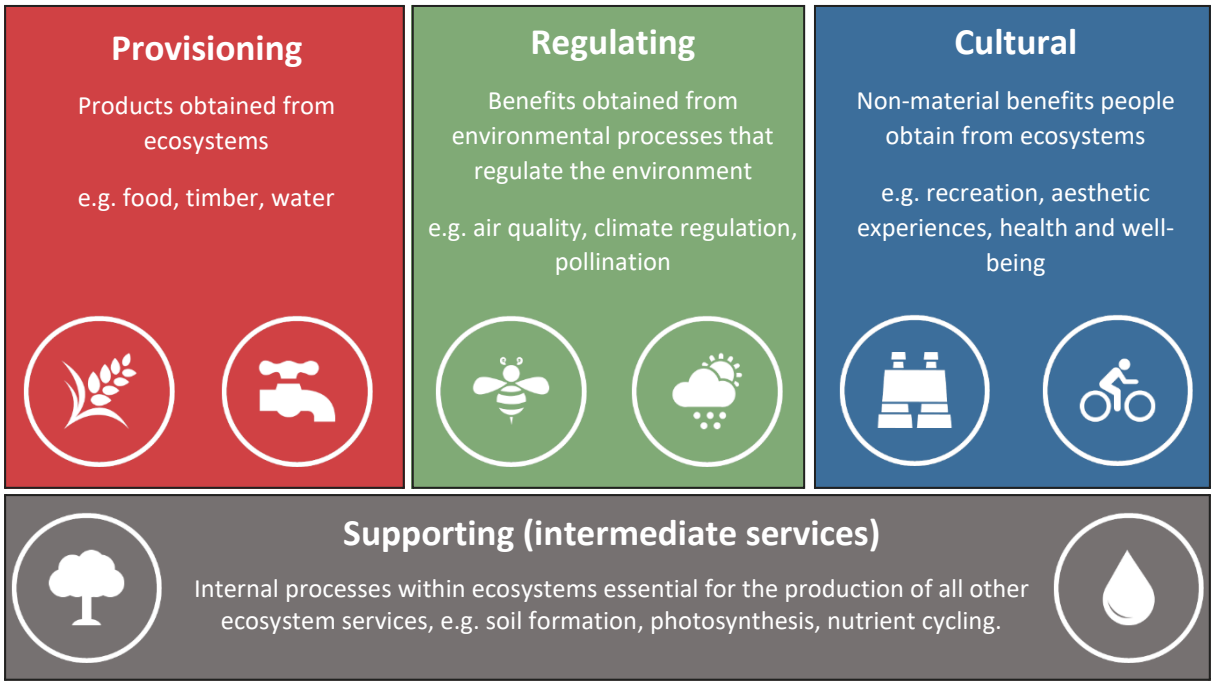


Figure 1: Key types of ecosystem services, based on Millennium Assessment (MA 2005)

1.3 Natural Capital Accounting

A natural capital account measures and values the natural capital assets of an area, based on the flow of ecosystem services and associated benefits from those assets. The benefits are then compared to the costs (capital and operational expenditure), in the form of a balance sheet. General principles and methodology have been developed, such as the Principles of Natural Capital Accounting background paper (ONS 2017) and Corporate Natural Capital Counting Guidelines (Eftec RSPB & PWC 2015). According to ONS (2017): "*natural capital accounts are a series of interconnected accounts that provide a structured*

set of information relating to the stocks of natural capital and flows of services supplied by them". A natural capital account is comprised of a number of different components, outlined below and illustrated in Figure 2:

- An extent and condition account (asset register) – the area, type and condition of natural capital assets.
- Physical flow account – the biophysical annual flow of ecosystem services from the natural capital assets.
- Monetary flow account – the monetary value of these benefits calculated per annum, together with the overall value of the asset over its lifetime (here we calculate this over 30 years).
- Capital and maintenance cost account – the cost of creating new natural capital assets and the cost of current and future natural capital maintenance activities.
- Natural capital balance sheet – the value of the benefits derived from the natural capital assets are compared to the costs of creating and maintaining those assets. Valuations are referred to as 'asset values' and the capital and maintenance requirements as 'liabilities', following standard accounting terminology. In addition, two components of asset value are recognised: private value (benefits to the landowner or organisation) and external value (wider benefits to society).

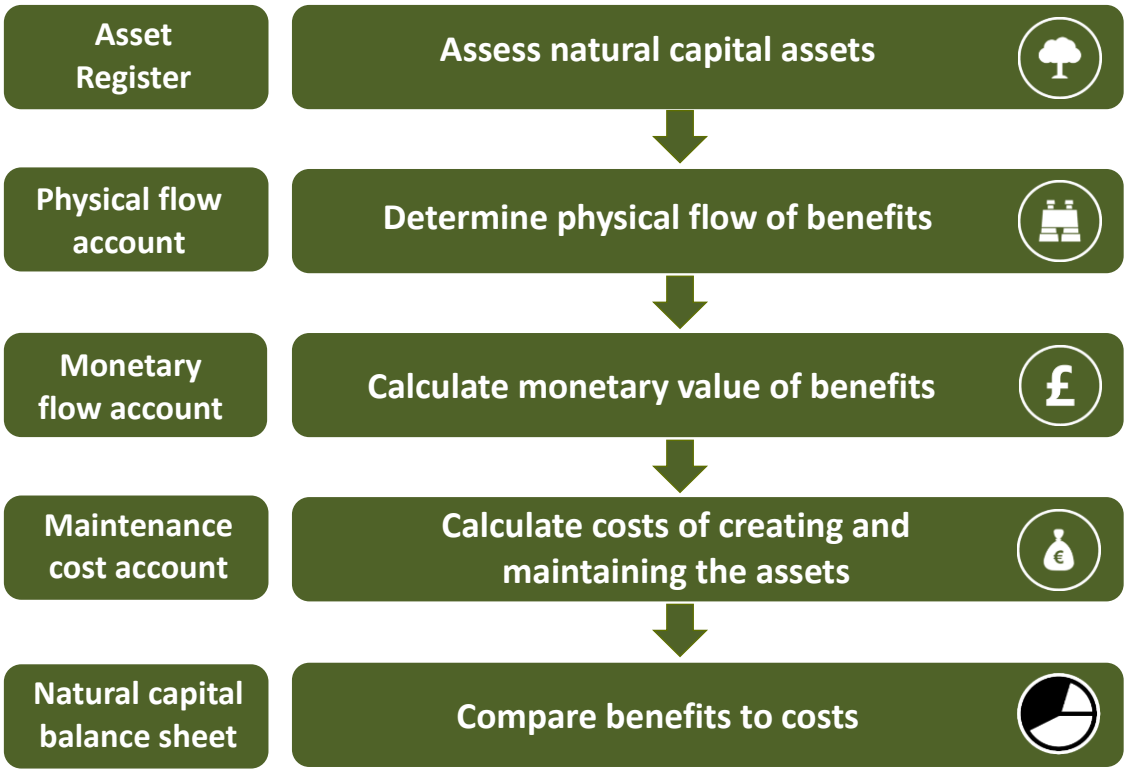


Figure 2: Outline of the assessment approach.

Natural capital accounts can be used to compare the benefits derived from new or existing natural capital assets with the costs required to create and maintain them.

2. Outline of methodological approach

Full details of the methodology are provided in Annex 1, with a brief outline of the approach described here. This was based on the framework for corporate natural capital accounting (CNCA) developed by Eftec et al. (2015) for the Natural Capital Committee, and the ONS (2017) Principles of Natural Capital Accounting. The approach used, therefore, draws on the concepts of natural capital and economic valuation[1]. It also follows the broad approach to natural capital assessment outlined in "*How to do it: a natural capital workbook"* published by the Natural Capital Committee (2017).

The natural capital assets of the site were first mapped and quantified, before and after the proposed development. The pre-development condition is described in the previous report (Rouquette 2017). The masterplan has been modified slightly since that report was written, so the updated final version of the masterplan was used here (Tresham Garden Village Masterplan & Delivery Strategy, October 2018). To incorporate this into the assessment a CAD version of the masterplan was georeferenced in GIS and then all polygons from the previous GIS masterplan were modified to match the new version. In addition, street trees and hedges were manually drawn in GIS based on the Tresham Landscape Framework, and SuDS features were added based on the proposed Blue-Green Infrastructure map (both from the Tresham Garden Village Masterplan & Delivery Strategy, October 2018).

Next, indicators were calculated to measure the physical flow and monetary value of a number of ecosystem services. The services assessed are summarised in Table 1 and the methods used are described in more detail in Annex 1. This is a sub-set of the ecosystem services mapped in Phase 1 of the assessment and the reader should refer to the earlier report (Rouquette 2017) for a more complete picture of ecosystem service flows at the site, their spatial configuration, and the impact of the development. Annual average values were calculated for each service over a 30-year period. In addition, the Present Value (PV) of each service was calculated, which is the overall value of the flow of benefits over the 30-year period, using discount rates from the HM Treasury (2018), and the ONS (2014). This is based on the principle that the value of benefits received in the future is considered less than the value of benefits received today and is a standard approach adopted in project appraisals (HM Treasury 2018). A 30-year time period was used to match the information available on maintenance costs, although please note that benefits will continue to accrue well beyond that time period. All prices used are for 2018, or converted to 2018 prices using the latest HM Treasury GDP deflator series, to allow the comparison of annual flows.

The amount and value of ecosystem services provided by natural capital will change over time as vegetation becomes established, as the number of people living at the site increases, or as the monetary value of a benefit changes over time. To capture these changes, each ecosystem service was quantified and valued over each of the 30 years of the assessment. Further details are provided for each ecosystem service in Annex 1. This differs

[1] Economic valuation quantifies the benefits that people gain as a result of the consumption of goods and services. It is based on welfare or well-being concepts where policy aims to maximise the welfare of society. The economic value of ecosystem services can be measured within the framework of 'total economic value' (TEV) (Defra 2007).

compared to most natural capital accounts which do not consider change over time and merely consider the annual flow and Present Value based on the current condition or assuming all habitats are fully established and mature.

The costs of creating new natural capital assets within the Tresham Garden Village site were calculated following discussion with Robin Truslove from Lockhart-Garratt, who was also able to provide a detailed spreadsheet showing the costs of maintaining these assets for each year over the 30-year period. Although the developers of the site have not yet (February 2019) formally applied for planning permission for the village, they have already planted the new woodland blocks surrounding the main development site. The capital and maintenance costs for these new woodland blocks were provided by Graham Garratt from Isis Forestry Ltd, with capital costs based on actual expenditure when planting these plots in 2017-18.

The estimated value of the benefits provided by the sites and the costs of maintaining them in present value terms were calculated and are summarised in a natural capital balance sheet giving the total net natural capital asset value (Net Present Value).

Local data specific to Tresham were used for the majority of indicators, with English or UK averages used when more local data were not available. A range of assumptions have been made in assessing the physical flows of ecosystem services, in the valuation of those flows as well as when using discounting and calculating present values. These assumptions are outlined when describing the methodology for the assessment and valuation of each ecosystem service in Annex 1 and are summarised in the Conclusions section of the report.

Table 1. Units of measurement of the physical flow and monetary value of the ecosystem services.

Ecosystem service	Physical flow	Valuation
Air quality regulation	Tonnes of PM_{10} and SO_2 absorbed	£/tonne of PM_{10} and SO_2/year
Carbon sequestration	Quantity of CO_2 sequestered	£/tonne of CO_2
Greenhouse gas emissions from agriculture	GHG/ha	£/ha/year
Agricultural production	Ha	£/ha/year
Timber/woodfuel production	m^3/ha	£/m^3/year
Recreation	Number of visits	Recreational value/visit/year
Health & well-being (QALYs)	Quality Adjusted Life Years	£/QALY/year

3. Natural capital account for Tresham Garden Village

3.1 Natural capital asset register

A breakdown of the main habitat types found at Tresham Garden Village before and after the proposed development is provided in the natural capital asset register (Table 2), showing the area and percentage cover of each habitat and the change in habitat area following development. The site maps show the location of these habitats before (Figure 3) and after (Figure 4) the development.

The Tresham Garden Village boundary area is 370 ha in size and is currently dominated by arable land, making up 248 ha or 67% of the area. The remaining area largely consists of improved grassland (36.4 ha, 9.8%), semi-natural grassland (28 ha, 7.5%) and broadleaved woodland (26.8 ha, 7.2%). Much of the improved and semi-natural grassland is located in strips adjacent to the runway and peripheral roads and tracks, which form part of the airfield at the core of the site. The majority of the broadleaved woodland is located to the north-east of the runways, in Langley Coppice, with a few small patches elsewhere.

Table 2. Natural capital asset register for Tresham Garden Village, showing the area and percentage cover of broad habitat types under the baseline and the 2018 masterplan.

Broad habitat type	Baseline		Masterplan		Change
	Area (ha)	% cover	Area (ha)	% cover	Area (ha)
Arable	248.1	67.0	105.3	28.2	-142.8
Improved grassland	36.4	9.8	22.4	6.0	-14.0
Mixed use grassland (amenity)	0.3	0.1	14.4	3.9	14.2
Semi-natural grassland	28.0	7.5	9.3	2.5	-18.6
Marshy grassland	1.2	0.3	4.4	1.2	3.2
Allotments	0.0	0.0	2.9	0.8	2.9
Orchard	0.0	0.0	2.1	0.6	2.1
Parkland	0.0	0.0	35.4	9.5	35.0
Street trees and roadside treelines	0.4	0.1	2.9	0.8	2.5
Scrub	3.8	1.0	1.4	0.4	-2.5
Broadleaved woodland	26.8	7.2	60.1	16.1	33.3
Coniferous woodland	0.0	0.0	2.3	0.6	2.3
Water	0.3	0.1	2.4	0.6	2.1
Built up areas	14.6	4.0	42.6	11.4	27.9
Infrastructure	9.0	2.4	34.6	9.3	25.6
Garden	0.0	0.0	28.0	7.5	28.0
Hedgerows	1.4	0.4	1.5	0.4	0.1
Formal landscaping	0.0	0.0	1.0	0.3	1.0

Figure 3: Key habitats present under the baseline (pre-development) condition at Tresham Garden Village

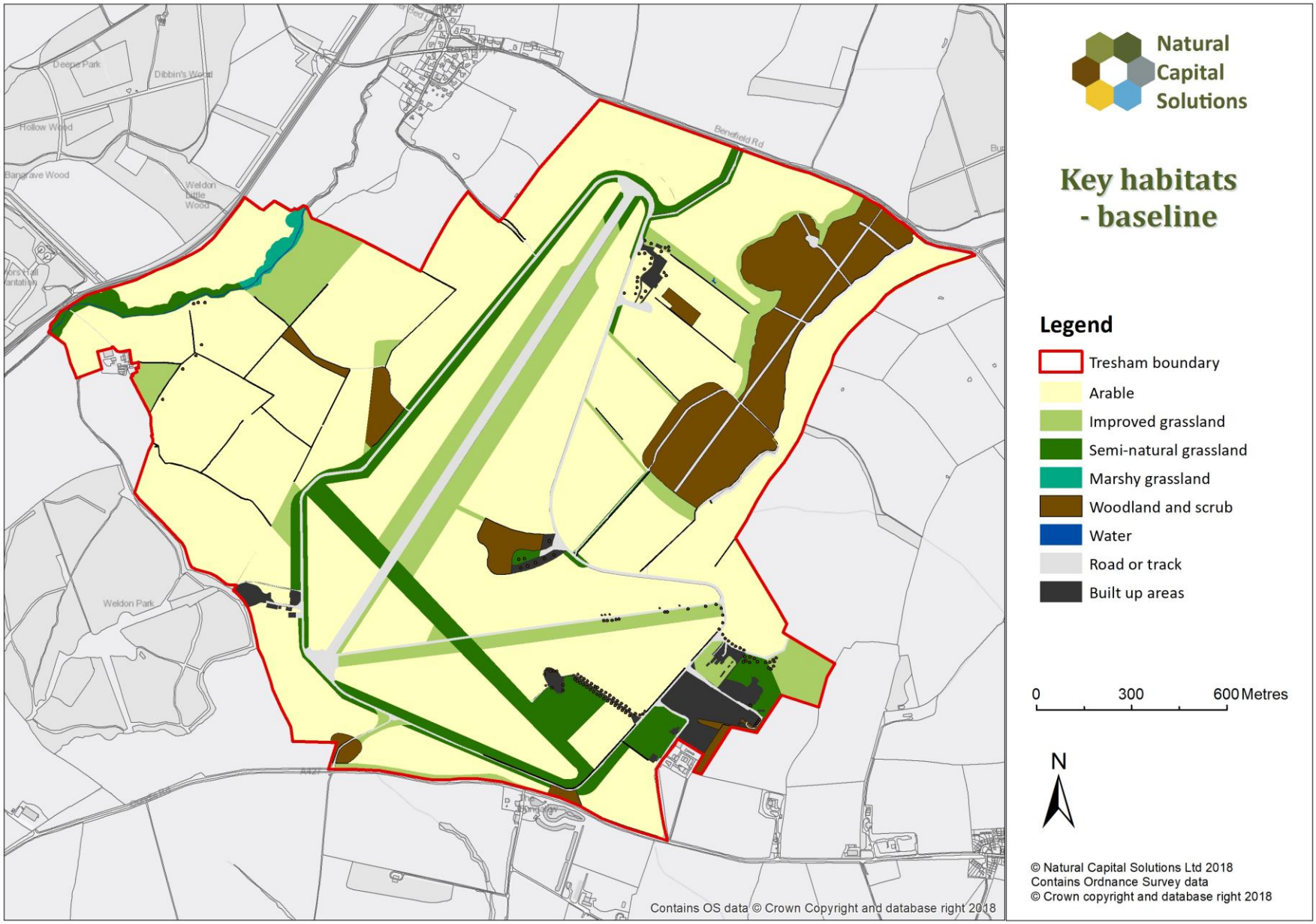
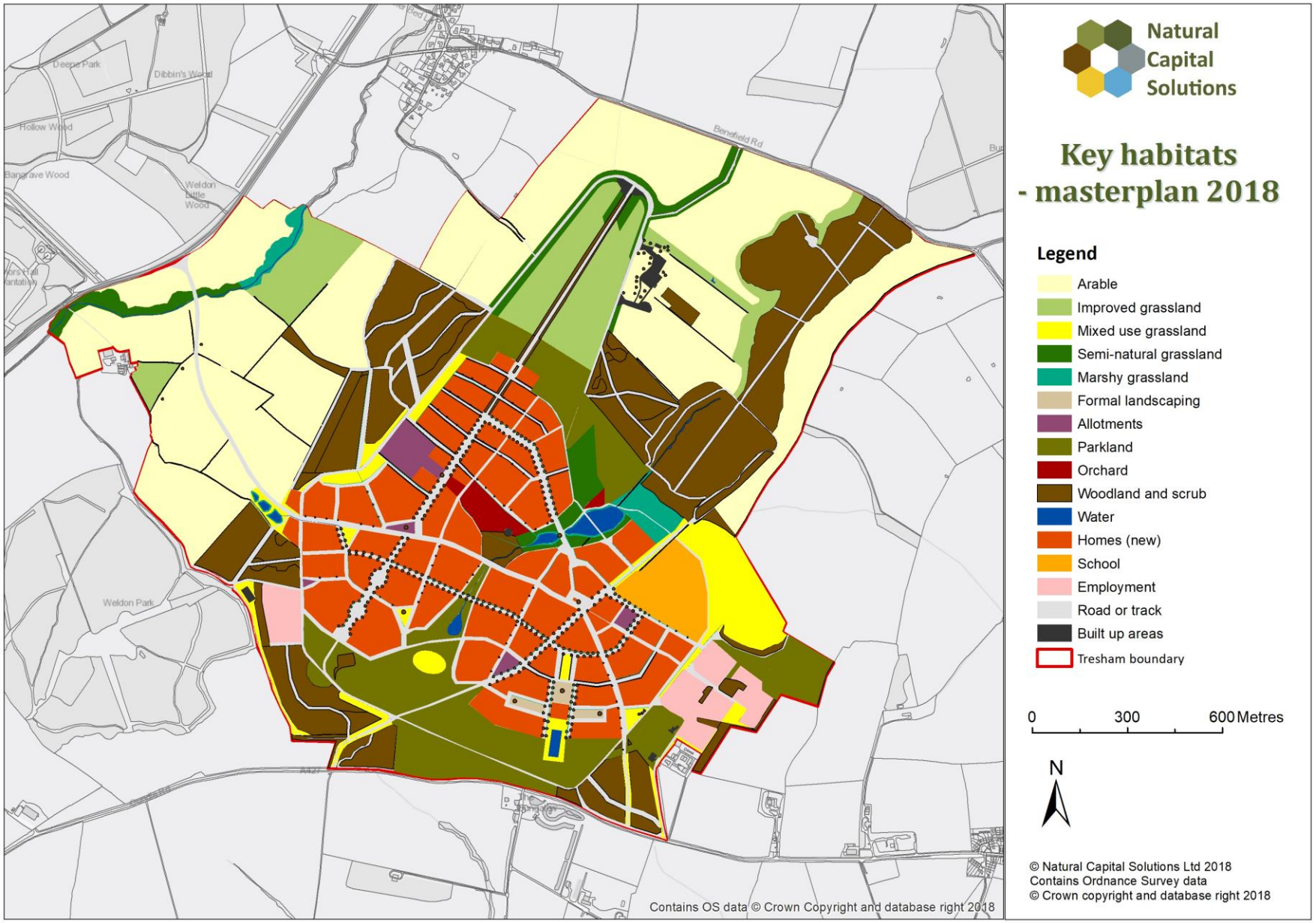


Figure 4: Key habitats present under the 2018 version of the masterplan at Tresham Garden Village



Under the proposed masterplan (2018 version), the area of arable land will fall considerably to 105 ha or 28.2% of the total site area – a loss of 142.8 ha or 58% of the pre-development area. Improved grassland (22.4 ha, 6.0% of the total area) and semi-natural grassland (9.3 ha, 2.5%), also decline, mostly due to loss of the strips adjacent to the airfield runways and roads. Large areas of new woodlands have already been planted in several compartments surrounding the core built zone, and when established these will increase the overall woodland cover by 36 ha to 62.4 ha, or 16.7% of the site. Parkland will also take up 35.4 ha or 9.5% of the area. Built-up areas, gardens and infrastructure (roads, pavements and paths) will together make up 105 ha, which is 28.2% of the land area. Further information on habitats, their condition and their biodiversity value is provided in the Phase 1 report (Rouquette 2017).

3.2 Physical flow account

The estimated annual physical flows of ecosystem services from Tresham under the existing habitats / land use and under the proposed masterplan are outlined in Table 3 and full methods are provided in Annex 1.

Table 3: Annual physical flow account for Tresham Garden Village under the baseline and 2018 masterplan and predicted changes. The physical flows under the masterplan are the annual average over the first 30 years (2018-2047) of the proposed development.

Natural Capital benefit	Units	Baseline	Masterplan	Change	% change
Annual average physical flows					
Carbon sequestration	tCO_2e per year	154	423	269	174.3
**Agricultural emissions	tCO_2e per year	-418	-297	121	28.9
**Carbon budget	tCO_2e per year	-264	126	390	-
Air quality regulation - PM10	kg PM_{10} per year	2269	2704	435	19.2
- SO2	kg SO_2 per year	17.4	21.0	3.6	21.0
Agricultural production	Area (ha) per year	297	167	-130	-43.8
Timber / wood fuel	m^3 per year	159	209	49	30.9
Recreation	No. visits per year	0	70,250	70,250	-
Physical health	QALYs	0	11.6	11.6	-

**A negative figure for agricultural emissions and carbon budget indicates emissions, a positive figure indicates sequestration.

Carbon sequestration is the uptake of carbon by plants as they grow, with woodlands being much the most effective habitat in the Tresham area. The existing woodlands are sequestering (capturing) carbon at a rate of 5.80 tonnes of CO_2 equivalent per hectare per year when averaged over 100 years. The total average carbon sequestered at Tresham under

the baseline condition is calculated to be 154 tCO_2e per year (Table 3), with Langley Coppice the main location of carbon sequestration at present. Under the 2018 version of the masterplan, several new areas of woodland will provide increased carbon sequestration capacity. The majority of these compartments consist of broadleaved woodland, which will sequester carbon at an average rate of 4.08 tCO_2e per hectare per year over 100 years (typical rotation length for broadleaved woodland). One area is due to be planted with productive conifers (principally Douglas Fir), and this area will have the highest average sequestration rate of 7.52 tCO_2e per hectare per year over a typical 60-year coniferous rotation. However, the rate of carbon sequestration in woodlands changes considerably with age, with rates increasing rapidly at first, to a peak when woodlands are around 15-40 years old, and then gradually reducing after that time. When considering only the first 30 years of the development at Tresham, the annual average rate of sequestration will be 8.10 and 8.40 tCO_2e per hectare per year for the newly planted deciduous and coniferous woodlands respectively, providing a total annual average carbon sequestration of 423 tCO_2e per year for the whole site (Table 3). This is a 174% increase compared to the baseline.

The area of land in **agricultural production** at Tresham at present is about 297 ha, or 80% of the total area. Approximately half of the area is farmed for wheat, with the remainder a mixture of oilseed rape, barley, field beans, grass, oats, maize and sugar beet, although the exact amount of each crop varies each year under standard rotation patterns. Under the proposed development, the area of agricultural land would decrease to 131 ha, with an additional 35 ha of grazing on wood pasture and parkland habitats. This means that a total of 45% of the total area would be under some sort of agricultural production, a decline of 44%.

Agricultural emissions of greenhouse gasses (GHG) represent a cost to society that is currently not included in the cost of production (an externality). Emissions from arable farming were estimated to be around 1.50 tCO_2 equivalent/ha/year for the arable areas under both the baseline and masterplan, with slight variation depending on the crop type. This means that a total of 418 tCO_2e is currently emitted per year (Table 3). Under the proposed development, as the area of agricultural land decreases, there would be a concurrent reduction in the GHG emissions associated with agricultural production. However, this reduction is partly offset by the introduction of livestock (beef cattle) onto the site. Emissions associated with livestock farming are higher than arable, due primarily to the release of methane through enteric fermentation, although maintaining a low stocking density will lessen this impact. It is assumed that cattle would graze on most of the parkland areas at a relatively low stocking density of 1.5 head per ha, with emissions from livestock only beginning once the parkland areas have been established in Phases 1 and 2 of the delivery strategy. Overall average emissions over the first 30 years of the development will total 297 tCO_2e per year, an average reduction of 121 tCO_2e per year (or 29%) compared to the baseline.

By comparing emissions from agriculture with the amount of carbon sequestered by woodland, it is possible to calculate an overall **carbon budget**, or greenhouse gas balance for the site. Prior to development, considerably more greenhouse gasses are being emitted than are being captured, resulting in a net emission of 264 tCO_2e on average per year (a cost to

society). However, over the next 30 years, if the proposed development goes ahead, the situation will be reversed, with more greenhouse gases captured by woodland than are being emitted by agriculture. This will result in a net sequestration of 126 tCO_2e on average per year (a benefit to society), an increase of 390 tCO_2e per year. Please note, however, that this carbon budget is for land based activities only and does not take into account the increased emissions due to construction, transport and energy use associated with the development itself.

Vegetation can be effective at contributing to **air quality regulation**, with surface area being the most important determinant of capacity. As such, trees are much more effective than grass, but capacity increases significantly as trees grow and their surface area increases. Vegetation at Tresham under the baseline is estimated to absorb 2269 kg of PM_{10} (particulate matter 10 micrometres or less in diameter) per year. Under the proposed masterplan it is estimated that vegetation will absorb an average of 2704 kg of PM_{10} each year over the first 30 years, an increase of 435 kg or 19%. However, the capacity of the vegetation to absorb pollution increases significantly over that period (from 2305 kg in year 1 to 3388 kg in year 30) and will continue to increase over time. Once mature, it is estimated that the vegetation will absorb 5252 kg of PM10, an increase of 131% on the baseline levels. Though the site also contributes to SO_2 pollution amelioration, the concentration of SO_2 near the site was relatively low and the capacity of vegetation to absorb SO_2 is also low. The site is estimated to absorb 17 kg of SO_2 at baseline, increasing to an average of 21 kg each year over the first 30 years under the proposed masterplan, and eventually to 37 kg per annum on maturity, an increase of 116%.

If the existing woodlands were managed for **timber/woodfuel production**, they would be able to produce approximately 159 m^3 per year averaged over a full woodland production cycle. Note that the estate Woodland Management Plan demonstrates that all the estate woodlands are managed as commercially as possible. Whilst yields will not be as high as for some of the newly planted woodland, there is a harvesting and replanting plan in place for Langley Copse. The large areas of new woodland planted under the masterplan will greatly increase the timber/woodfuel capacity of the site. However, there will be little output in the first 30 years after planting, apart from some thinning. Annual yield, averaged over the first 30 years, is therefore only predicted to increase by 49 m^3 or 31%. If production is averaged over the full forest cycle, then yield would increase by 247 m^3 each year (198 m^3 of broadleaved output and 47 m^3 of coniferous output), or 125% increase compared to the baseline.

One of the most significant impacts of the Tresham development will be in providing new accessible greenspace for the residents and visitors, with considerable **recreational value**. There is currently no publicly accessible greenspace at the site, although a number of Public Rights of Way (PRoW) do cross the site. There are no data on the number of current visits using the PRoW network, although it is likely to be very low as the site is not close to any urban populations or commuter routes and does not contain any well-known landscapes or attractions. Following development, the number of visits to the greenspaces around Tresham will increase in line with the growing population as each phase of the development

is completed. This was modelled to increase from zero at present (an underestimate) to 101,500 visits per year upon occupation of all 1500 houses (likely to be in about 2034). Further details of this calculation are provided in Annex 1. Over the next 30 years, this will average 70,250 visits per year.

A subset of visitors will also receive benefits to their **physical health** through making regular active visits[2]. As with recreation, this will increase as housebuilding progresses. It is estimated that an average of 340 visitors to the greenspaces around Tresham (residents) will make active visits each week, rising from zero in 2018 to 492 active visitors each week on completion. These active visits are associated with an estimated increase of 11.6 Quality Adjusted Life Years (QALYs) on average each year over 30 years (16.8 QALYs each year on completion). Note that the estimate of the number of active visits is based on national averages, but it is quite possible that more people will make active visits than shown here due to the ease of access to the greenspaces that will be available at Tresham.

3.3 Monetary flow account

The monetary flow account is constructed using the data from the physical flow account (above) and shows the economic value of the private and public benefits that flow from the natural capital assets at the site under the current habitats / land use and under the proposed masterplan. A summary of the results is shown in Table 4 (overleaf) and further details of the methods are provided in Annex 1.

The existing woodlands at Tresham will provide **carbon sequestration** benefits worth an average of £17,600 per year over the next 30 years, or £662 per hectare of woodland. New deciduous woodland will provide benefits worth an additional £34,000 per year (£1,118 per hectare) and coniferous woodland will contribute £2,750 worth of additional benefits (£1,037 per hectare) each year over the next 30 years. The value per hectare is higher for the new woodlands as young woodlands sequester carbon at a faster rate than mature woodlands. Overall benefits will therefore increase to £54,300 per year, an increase of 209% and the Present Value (PV) of these benefits will increase from £299,000 to £833,000 (based on standard 3.5% discount rates over 30 years). As noted earlier, this increase would be less if measured over the whole lifetime of the woodland, but would still be an increase of 93%.

Agricultural emissions are currently causing damage estimated at -£47,600 per annum (PV of £809,000), but this will decrease to -£34,200 (PV of -£577,000) under the proposed masterplan, a decrease (improvement) of 28% on the annual value. When combined with carbon sequestration, the site has a **carbon budget** showing net emissions costing -£30,000 each year (PV of -£510,000) if the baseline conditions are continued, but changing to a net sequestration (carbon capture) with benefits worth £20,200 per year (PV of £257,000) if the site is developed under the existing masterplan.

[2] Active visits are defined as those that last for at least 30 minutes and raise the metabolic rate over a certain threshold (moderate intensity or higher). Guidelines recommend at least five active visits per week.

Table 4: Annual monetary flow account for Tresham under the baseline and 2018 masterplan and predicted changes. The monetary flows under the masterplan are the annual average over the first 30 years (2018-2047) of the proposed development.

Natural Capital benefit	Baseline	Masterplan	Change	% change
Annual average monetary flows				
Carbon sequestration	£17,595	£54,345	£36,750	208.9
**Agricultural emissions	-£47,633	-£34,175	£13,458	28.3
**Carbon budget	-£30,038	£20,170	£50,208	-
Air quality regulation - PM10	£58,631	£165,516	£106,885	182.3
- SO2	£49	£61	£11	22.9
Agricultural production	£26,134	£5,703	-£20,430	-78.2
Timber / wood fuel	£2,520	£3,473	£953	37.8
Recreation	0	£430,178	£430,178	-
Physical health	0	£338,852	£338,852	-
TOTAL	**£57,296**	**£963,953**	**£906,657**	**1582**

**A negative figure for agricultural emissions and carbon budget indicates emissions, a positive figure indicates sequestration.

The monetary value of **air quality regulation** is high and increases substantially from £58,700 each year (PV of £1,061,000) under the baseline to £166,000 (PV of £2,896,000) under the masterplan, an increase of 182%. This is a much larger increase than for the physical flow of this benefit (the kg of pollution absorbed), as each unit of pollution that is absorbed is worth more under the masterplan than under the baseline condition due to the presence of many more people following development. In addition, this benefit will continue to increase as the trees and woodland matures, and after 50 years the masterplan will be providing annual benefits worth almost five times as much as under the baseline condition.

Agricultural production at Tresham will be worth an estimated £26,100 per year over the next 30 years if the current land use patterns are continued (PV of £497,000). This estimate gives a return (an economic rent) to the land resource itself after deducting all costs associated with production except for land ownership and rental costs, and excluding Basic Farm Payments (income support subsidies). In several parts of the UK the value of agricultural production is in deficit once farm payments have been stripped out (i.e. it is only profitable when income support for farmers is included). That is not the case at Tresham, although values are low. If the site was developed under the 2018 masterplan, agricultural production would decrease substantially to £5,700 per annum (PV of £109,000), a decrease of 78%. As well as the loss in farmed area, this loss of value is exacerbated by the introduction of beef cattle grazing in the parkland areas, which presently returns a loss once agricultural subsidies are stripped out.

Existing woodlands could produce **timber/woodfuel** with a value of £2,520 per annum (PV of £48,000). New woodlands and trees are projected to produce an additional £953 per annum averaged over the first 30 years, for a total of £3,470 (PV of 60,600), an increase of 38%. There would actually be no income over the first 20 years and then only a small income of woodfuel from early thinnings between years 20-30, which would bring in less than the cost of the forestry operations. More substantial income would only be achieved in the period beyond 30 years. If timber/woodfuel income over the full forestry cycle was considered (rather than just the first 30 years), the new woodlands and trees would be expected to have an average annual value of £4,330, to give a total annual value of £6,850 (PV of £130,000), an increase of 172%.

The value of **recreation** is predicted to rise from zero under the baseline situation to an average of £430,000 each year over the next 30 years (PV of £6.97M) if the development proceeds. This is the benefit with the highest value at Tresham. Similarly, the value of **physical health** is also very high, increasing from zero to an average of £339,000 per annum (PV of £5.29M) over the 30 years. Note that the estimate of zero value for recreation and physical health under the baseline is almost certain to under represent the true value of the site at present, but it is likely that the true value will nevertheless less be very low. Lack of data on present use precludes a value being estimated.

3.4 Capital and maintenance costs account

For the newly planted woodland areas, costs were provided by Graham Garratt from Isis Forestry Ltd, with capital costs based on actual costs incurred (the areas have just been planted) and maintenance costs based on projected estimates for the first 30 years following establishment. For all the remaining types of green infrastructure, capital costs were calculated following discussion with Robin Truslove from Lockhart Garratt and maintenance costs were calculated and supplied by Robin as part of budget planning for the Tresham Garden Village development. For the sensitivity analysis (Section 3.7), low and high estimates were assumed to be 1.33 and 0.9 times the central estimate respectively. The costs of the linear SuDS features, such as roadside swales, are not included in the accounts as details are yet to be decided, although the main balancing ponds are included. Note also that the maintenance costs of agricultural production have not been included as these are not really relevant to the provision of green infrastructure at Tresham and are already accounted for in the agricultural production value.

The capital, maintenance and total costs over 30 years of each major habitat type are shown in Table 5. Ornamental shrub beds to be planted within each housing area are by far the most expensive to create on a per hectare basis (£280,000 per ha), whereas the various types of grassland are vastly cheaper (£500 per ha) and total capital costs remain highest for the ornamental shrub beds, along with newly planted woodland, and lowest for the grasslands. Total maintenance costs are highest for amenity grassland within the housing areas and newly planted woodland, and lowest for the orchards and hedgerows. Total costs per hectare (capital and maintenance costs combined) are highest for the standard trees and

ornamental shrub beds and lowest for parkland and existing areas of woodland. Total capital costs to create all the green infrastructure at Tresham Garden Village are estimated to come to £0.99M and maintenance costs will amount to £2.63M over 30 years, with a total cost estimate of £3.62M.

Table 5: Capital and maintenance cost account over 30 years for natural capital elements of the new developments at Tresham Garden Village and based on real information specific to this project.

Habitat	Capital costs £		Maintenance costs over 30 years £		Total costs £	
	Per ha	Total	Per ha	Total	Per ha	Total
Mixed use grassland (extensive)	500	8,900	13,646	242,904	14,146	251,804
Species rich meadow	500	2,670	11,005	58,767	11,505	61,437
Parkland	1,350	40,460	2,128	63,787	3,478	104,247
Newly planted woodland	6,339	245,401	10,015	387,699	16,354	633,100
Existing Woodland	-	-	7,011	208,451	7,011	208,451
Newly planted hedgerow (semi-natural)	9 per m^2	13,500	213,433	32,015	303,433	45,515
Orchard	8,900	17,978	15,581	31,473	24,481	49,451
Allotment	16,272	36,612	18,300	41,175	34,572	77,787
Ponds & margins	30,000	48,600	48,948	79,296	78,948	127,896
Amenity grassland (village incidental)	500	2,485	141,779	704,642	142,279	707,127
Ornamental shrubs beds	280,000	372,400	221,038	293,980	501,038	666,380
Hedgerows (village incidental)	9 per m^2	18,000	95,470	19,094	185,470	37,094
Standard trees	28,517	49,050	699,400	90,922	727,917	139,972
Noxious & invasive weeds (excluding in woodland)	-	-	663	41,487	663	41,487
Land management fees**	952	129,338	3,075	337,472	4,028	466,810
TOTAL		**985,393**		**2,633,164**		**3,618,558**

**Land management fees covers planning, supervision and management of capital and maintenance works

3.5 Natural capital balance sheet

The natural capital balance sheet for Tresham Garden Village is given in Table 6. The total value (benefits) of the natural capital assets of the site with and without the development are quantified, together with the total liabilities (both reported in present value terms, discounted over 30 years), with the net value of the natural capital assets of the site shown.

The gross asset value of the site as currently managed is £2.08M. This is driven predominantly by the value of air pollution regulation, agricultural production and agricultural subsidies (Basic Farm Payment), with the latter responsible for 47% of the total

value of the site. Note that the maintenance costs appear low as all agricultural costs are already accounted for in the value of agricultural production. **The current net natural capital asset value of the site is £1.95M**.

If the development at Tresham goes ahead, the gross value of the natural capital assets would increase substantially to £16.35M. As noted in the monetary flow account, recreation, physical health and air quality regulation provide the greatest value, although all natural capital benefits increase, with the exception of agricultural production. Rental and grant income declines compared to the current situation, due to the loss of Basic Farm Payment income, although this is partially compensated for through grants for new woodland and allotment and grassland rental. Liabilities (costs) also increase dramatically to £2.32M, but **the net asset value of the site post development would be £14.03M. This is an increase of £12.08M compared to the site without development**. The benefits to cost ratio of the new development is 6.5, which means that for every £1 spent there will be £6.50 worth of benefits delivered.

Table 6: Natural Capital Balance Sheet for Tresham Garden Village under the baseline and 2018 masterplan and predicted changes. Based on the Present Value of assets and liabilities over 30 years.

Natural Capital Balance Sheet $£_{2018}$ PV	Baseline £'000	Masterplan £'000	Change £'000
Assets			
Air purification - PM10	1,061	2,896	1,835
- SO2	0.9	1.1	0.2
Carbon sequestration	299	833	534
Agricultural emissions	(809)	(577)	233
Agricultural production	497	109	(389)
Timber production	49	61	13
Recreation	0	6,966	6,966
Physical health	0	5,294	5,294
Natural capital benefits	**1,097**	**15,583**	**14,486**
Rental & grant income	983	764	(219)
Gross asset value (benefits)	**2,080**	**16,348**	**14,267**
Liabilities			
Capital costs	0	(841)	(841)
Maintenance costs	(132)	(1,479)	(1,347)
Total liabilities (costs)	**(132)**	**(2,320)**	**(2,188)**
Net Natural Capital Value	**1,948**	**14,027**	**12,079**
Benefit: cost ratio			**6.5**

Following standard accounting convention, figures in parentheses (also marked in red) are negative.

It is also interesting to examine the distribution of the benefits; private benefits are those that accrue to the landowner, usually through an existing market, whereas external or public benefits are those that currently don't have a market but provide benefits to society. Agricultural production and timber are considered to generate private value, whereas the other ecosystem services generate external value. Rental and grant income also generate private value and are included in the calculations. Under the current situation, the site provides £1.40M of net private benefits (taking liabilities into account) and £0.55M of net public benefits. Under the proposed masterplan the site would run at a net loss of -1.39M privately, as although the land would accrue market benefits and grants worth £0.93M, this would be outweighed by the significant capital and maintenance costs which are borne by the landowner. The site would, however, generate public benefits worth £15.4M. The change in benefit distribution from baseline to masterplan is shown in Table 7, with an overall loss of -£2.78M in private benefits, but a gain of £14.86M in public benefits. This obviously does not include the benefits that the landowner will receive from the built infrastructure (e.g. the value of the houses), or the increase in value of property due to the presence of high-quality green infrastructure.

Table 7: Change in the distribution of natural capital benefits and costs to beneficiaries following development of Tresham Garden Village.

PV over 30 years at 3.5%	Private value £'000	External value £'000	Total value £'000
Asset value (benefits)	(595)	14,863	14,267
Liabilities (costs)	(2,188)	0	(2,188)
Net natural capital value	(2,783)	14,863	12,079

Following standard accounting convention, figures in parentheses (also marked in red) are negative.

3.6 Changes in costs and benefits over time

The delivery of ecosystem services will change over time as habitats are created and become established, as houses are completed and the population gradually increases, and as the value of certain ecosystem services changes into the future. Hence the benefits and costs were calculated for each individual year over the next 30 years and annual average values (or present values) were shown in the sections above. Exactly how these values change over the 30-year project is now described in more detail, with Figures 5 and 6 (overleaf) showing the values over time for natural capital benefits and capital and maintenance costs respectively. All are shown on the same scale for ease of comparison.

The value of the natural capital benefits that will be delivered by the site under the baseline (no development), will not change greatly over time. The exceptions are air purification, which increases in value over time, based on UK Government guidance to reflect the assumption that willingness to pay for health will rise in line with economic growth, and

carbon sequestration and agricultural emissions, which increase in benefits and costs respectively over time as the value of carbon is projected to rise sharply into the future.

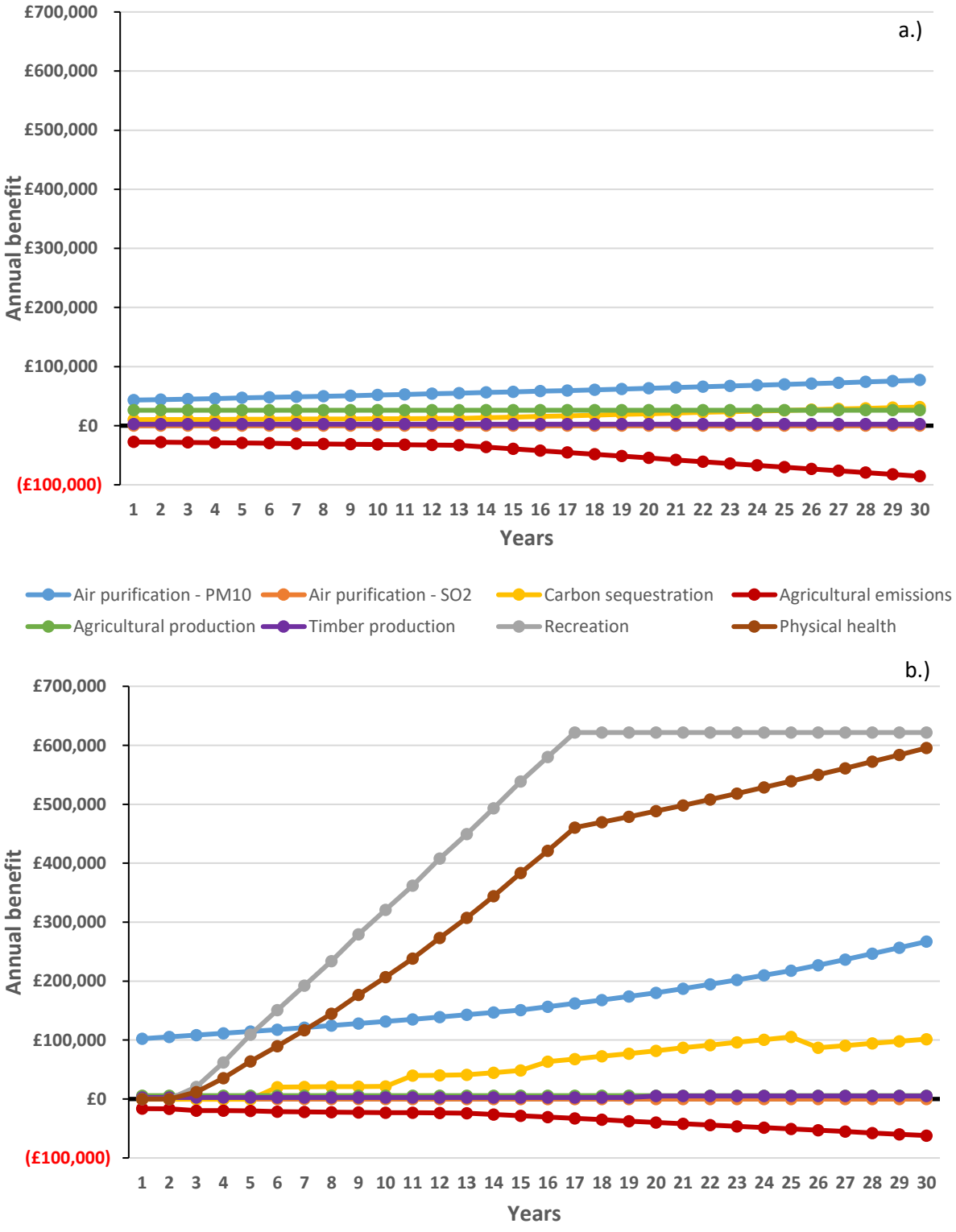


Figure 5: The value of natural capital benefits each year for the next 30 years for a.) the baseline and b.) the Masterplan for Tresham Garden Village. Year 1 is 2018.

The value of benefits delivered as the Masterplan is implemented changes considerably over the 30-year period. The value of recreation and physical health start at zero and increase rapidly from years 3 to 17 as house building is completed over the 5 planned phases of the development. The value of recreation then remains constant, whereas the value of physical health continues to rise more slowly, in line with rising willingness to pay for health benefits. The physical amount of air purification (PM_{10}) increases substantially over time as the trees grow, and this is reflected in the increasing monetary value of this benefit over time. Note that the value of this service would continue to increase substantially beyond the 30-year project period. The value of carbon sequestration increases considerably as the trees grow and sequester increasing amounts of carbon, peaking at around Year 25, although the value of this service would remain approximately constant beyond that period as rising carbon prices would balance the slowing rate of carbon sequestration. Similarly, agricultural emissions cost more over time due to the increasing price of carbon.

Figure 6 shows how costs would change over time. The high capital costs shown in Year 1 relate to the new woodland planting, and the peaks at Years 3 and 6 relate to Phases 1 and 2 of the Tresham Garden Village delivery strategy, when the majority of the larger green spaces will be created. Smaller incidental green spaces in and around the main housing zones will be created in Phases 3-5, as highlighted by the further peaks. Maintenance costs will increase gradually as the new habitats are created, peaking at around Year 15 once all new habitats have been created and will then remain more or less constant.

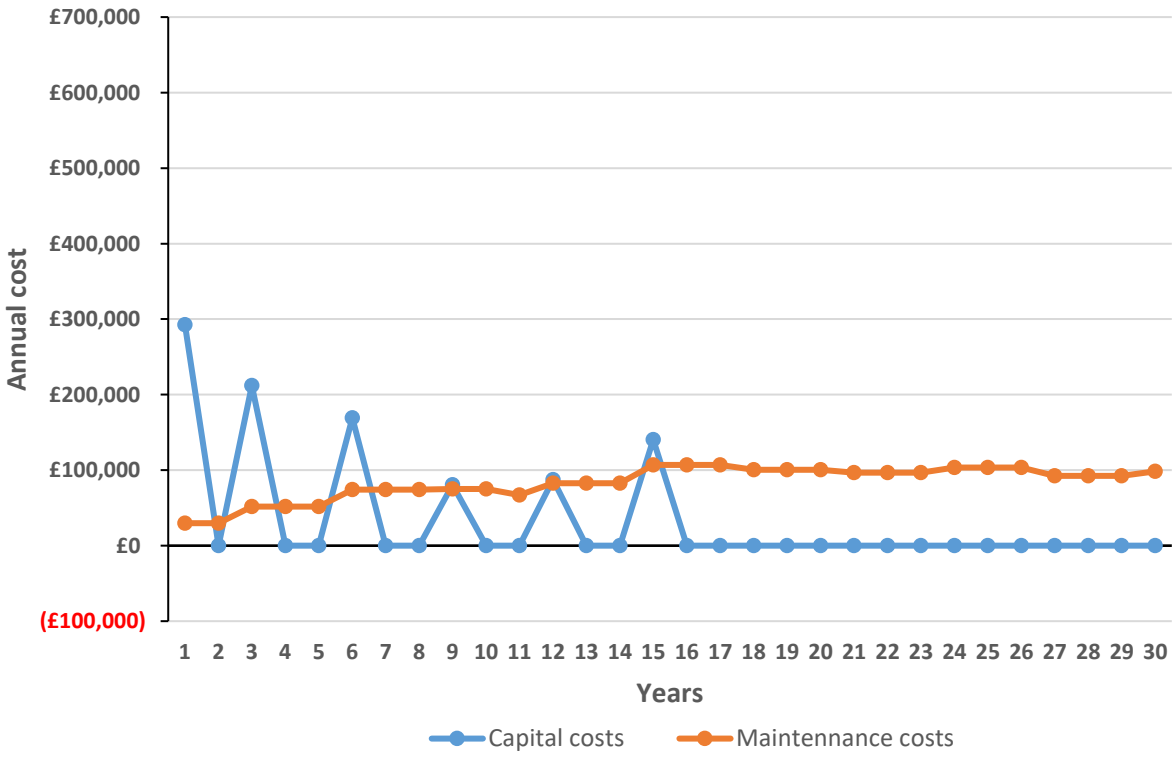


Figure 6: Capital and maintenance costs each year for the next 30 years following implementation of the Masterplan for Tresham Garden Village. Year 1 is 2018. Axes are drawn to the same scale as Figure 5 to enable direct comparison.

Overall, therefore, costs are greater in the first few years of the development, whereas benefits start low but then increase rapidly. The net effect of this is shown on Figure 7, which plots the net annual benefits, taking into account all natural capital benefits, grant and rental income, and all costs (but without discounting). Net annual benefits are predicted to be negative for Years 1 and 3 (2018 and 2020) due to the high initial capital costs and relatively low benefits, but are positive for each of the remaining years of the assessment (and beyond). Net annual benefits will increase rapidly as habitats are established and people move in, up to completion of the development and full occupation at around Year 17, and will then continue to increase, but at a slower rate, for the remainder of the assessment period.

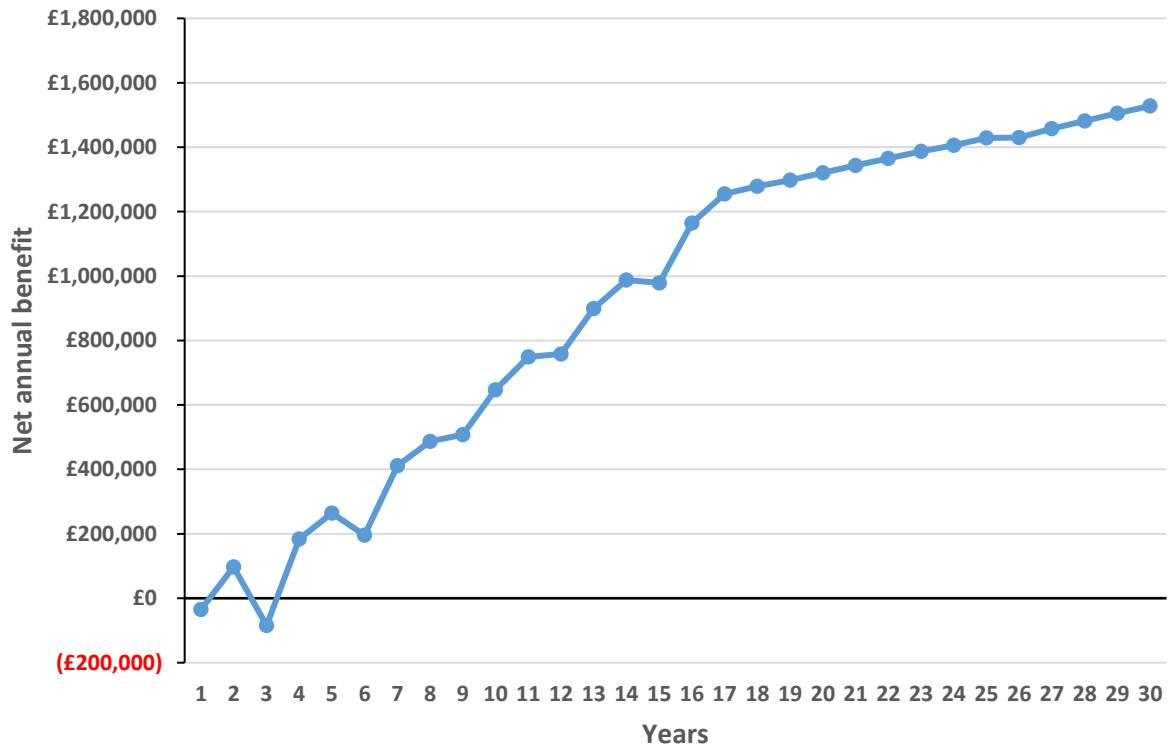


Figure 7: Net annual benefit each year for the next 30 years following implementation of the Masterplan for Tresham Garden Village. Year 1 is 2018.

3.7 Sensitivity analysis

A sensitivity analysis was performed, by examining the low, central and high estimates of all costs and benefits. Table 8 shows these figures under the Masterplan (so the central figure is the same as shown in the "Masterplan" column of Table 6). This shows the overall sensitivity of the net natural capital value and the sensitivity of each cost and benefit. Net natural capital value ranges from £5.7M under the lowest benefits and highest cost estimates, up to £27.9M under the highest benefits and lowest cost estimates. This large difference highlights the challenges of placing a monetary value on some services. A key point, however, is that even under the low estimate, the green infrastructure elements of Tresham Garden Village will deliver a substantial net benefit worth at least £5.7M. Note also, that the range of values

is driven largely by the uncertainty inherent in just one ecosystem service – physical health. The range of benefits provided by that service alone ranges from £2.6M to £15.9M. The net natural capital value is also moderately sensitive to the value of recreation, whereas it is not particularly sensitive to the value of any of the other services or the estimated costs.

Table 8: Sensitivity analysis, showing low, central and high estimates of benefits and costs under the 2018 Masterplan. Based on the Present Value of assets and liabilities over 30 years.

Natural Capital Balance Sheet £$_{2018}$ PV	Low £'000	Central £'000	High £'000
Assets			
Air purification - PM10	2,267	2,896	3,290
- SO2	0.9	1.1	1.2
Carbon sequestration	417	833	1,250
**Agricultural emissions	(288)	(577)	(865)
***Net carbon balance*	*128*	*257*	*385*
Agricultural production	(42)	109	683
Timber production	45	61	76
Recreation	3,171	6,966	8,708
Physical health	2,647	5,294	15,883
Natural capital benefits	**8,218**	**15,583**	**29,026**
Rental & grant income	573	764	955
Gross asset value (benefits)	**8,791**	**16,348**	**29,982**
Liabilities			
Capital costs	(1,121)	(841)	(757)
Maintenance costs	(1,973)	(1,479)	(1,331)
Total liabilities (costs)	**(3,093)**	**(2,320)**	**(2,088)**
Net Natural Capital Value	**5,698**	**14,027**	**27,894**

Following standard accounting convention, figures in parentheses (also marked in red) are negative.

**A negative figure for agricultural emissions and carbon budget indicates emissions, a positive figure indicates sequestration.

4. Conclusions

4.1 Key findings

Natural Capital Accounting has been successfully applied to the proposed development at Tresham Garden Village, comparing the pre-development baseline, with the proposed 2018 Masterplan over a 30-year period. The accounts have shown that the green infrastructure elements of the proposed development will provide significant benefits to society in the form of public goods and services, and these considerably outweigh the costs of habitat creation and maintenance. Overall, net natural capital asset value at the site will increase from £1.95M to £14.03M over 30 years, an increase of £12.08M. **The site is therefore providing net benefits after discounting worth £468,000 on average each year under the masterplan, an increase of £403,000 compared to the baseline**. The development delivers a benefit to cost ratio of 6.5 once all capital and maintenance costs have been taken into account, which means that for each £1 of investment, £6.50 worth of benefits will be delivered

The greatest benefits are derived from the value of recreation and physical health. Air quality regulation and carbon sequestration are also important, with other benefits being relatively insignificant. This is a common finding in natural capital valuation and accounting studies, especially in areas with public access close to where people live. It demonstrates the importance of accessible natural greenspaces for society and the economy, where the impact on health and well-being is substantial. It should be noted, however, that the vast majority of benefits are in the form of external values (public goods) rather than private values that could be gained by the land owners. Private values will actually decrease following development as agricultural incomes will fall (especially single farm payment subsidies) and will not be fully replaced by income related to the new woodland plantings. Benefits through recreation, physical health, air quality regulation and carbon sequestration are public benefits and will not directly provide income for the landowners, although markets are developing for woodland carbon, and some of the other benefits will be reflected in potentially higher selling prices for the houses (RICS 2016).

Benefits will increase substantially over time. In particular, recreation and physical health benefits will increase as homes are gradually completed and the village population steadily increases. Air quality regulation and carbon sequestration benefits will increase as the trees and woodlands grow. On the other hand, costs are much higher towards the start of the project period, due to the capital costs of establishing habitats. This means that there will be a net cost at the start of the project, but by Year 4 (2021) the green elements of the project will be providing net benefits. Net benefits then increase rapidly as the development progresses and is eventually completed over the following 13 years, and will continue to increase more slowly following completion of building works.

This is one of the first natural capital accounts to have been calculated for a proposed development, as far as we are aware, and one of the aims has been to demonstrate if the approach is feasible. The development of the accounts has shown that methods and data are robust enough to produce meaningful accounts, although uncertainties are high for

some services (see below). It is also the first to consider the change in services over the project lifecycle, giving an indication of how costs and benefits change as the development progresses. It is hoped that it can be used to demonstrate best practice to roll out the approach more widely and to communicate and showcase the importance of the natural environment in new developments. Green infrastructure is an essential part of all new development, and especially within the Garden Village movement, and this approach is useful at highlighting its value, which may otherwise remain hidden. Quality green spaces also create community well-being, liveability and sense of place. Indeed, research into various design features in large residential schemes complied by RICS (2016) has shown that community provision, in particular good schools, extensive public parks and play spaces, and community space, were the main influences in creating a positive sense of place and enhancing value. Green infrastructure in and around built areas provide a wide range of benefits, extending beyond those valued here, and a more complete list is provided in Annex 2.

4.2 Data gaps, assumptions and limitations

Work is progressing rapidly on the calculation of physical and monetary flows of ecosystem services from natural capital assets, but it remains a developing area. A number of ecosystem services remain difficult to quantify and value. Some are highly location specific, for example water flow and impact on downstream flood risk. This can be quantified and valued by running detailed hydrological and flood risk modelling, but it is difficult to generalise. Others, such as water quality can be modelled, but are very difficult to value, while there are additional cultural services, such as aesthetic experiences, cultural heritage, and spiritual experience and sense of place are difficult to even quantify. It should, therefore, be borne in mind that the natural capital accounts presented in this report place values on several key benefits, but these are necessarily incomplete. The earlier natural capital impact assessment (Rouquette 2017) provided further information on a number of additional services, including water flow, water quality, noise, pollination and biodiversity and should be referred to for a more complete (but non-monetary) assessment of services and the impact of the proposed development. That assessment also provides maps, showing in detail the spatial location of service delivery and how this will change following development. The two reports should be seen as complimentary, and should be read together, to provide a more complete understanding of the impacts of the proposals and their monetary value.

For the services that have been included in the accounts, a range of assumptions have been made, and these are outlined when describing the methodology (See Annex 1). In addition, a summary of the main uncertainties is provided for each service in Table 9 (below), along with a RAG rating highlighting the overall confidence in each estimate. For most ecosystem services these assumptions are minimal, as established production functions exist, linking natural capital to ecosystem service production, and levels of production to monetary value. For some services, despite fast developing research in relevant areas, broad assumptions have to be made because these links are not clear. This is particularly the case for physical health, and this estimate should, therefore, be used with care.

Table 9: Summary of uncertainties in the calculation of physical flows and monetary values of each natural capital benefit, and an overall assessment of confidence, using a red, amber, green (RAG) rating.

Natural capital benefits	Assessment of uncertainties	RAG rating
Air purification	A lot of uncertainty over change in absorption as trees grow. Also based on averages for broadleaved and coniferous trees and grassland. Valuation follows ONS guidance, but is subject to revision as more evidence on negative impact of air pollution becomes available.	
Carbon sequestration	Well studied, standardised carbon lookup tables available. Valuation uses UK Government carbon price.	
Agricultural emissions	Receiving increasing attention as part of climate change accounting. Valuation uses UK Government carbon price.	
Agricultural production	Based on extensive data collected by Defra annually and market prices.	
Timber production	Well studied over many years as part of forestry management. Valuation uses market prices.	
Recreation	Uncertainty over the number of visits that would be made to the greenspaces following development. Some uncertainty over the value of these visits.	
Physical health	The most uncertain of the services measured. High uncertainty over both the number of visitors who would make active visits to the greenspaces and the monetary value of these benefits.	

The sensitivity analysis highlighted the impact of these uncertainties on natural capital values. Total net natural capital value for the Masterplan ranges from £5.7M under the lowest benefits and highest cost estimates, up to £27.9M under the highest benefits and lowest cost estimates. This shows the high levels of uncertainty inherent in natural capital accounting, but the vast majority of this uncertainty arose from the calculation of physical health. In all versions of the sensitivity analysis, creating new green infrastructure at Tresham resulted in a substantial positive return on investment. Valuation of ecosystem services should therefore be seen as appropriate at indicating the approximate magnitude of benefits, but not their exact values. It has allowed these to be compared across a broad suite of services as it was important to demonstrate the range of benefits that the natural environment can provide in a new development context, and has demonstrated the overall positive impact of the green elements of the new development. However, these results need to be interpreted with care, and in the knowledge that whilst the highest quality and most readily available data and methods were used, there are limitations and assumptions that need to be borne in mind.

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Annex 1: Methodology

This annex provides detailed information regarding the methods used to develop the Natural Capital Accounts for Tresham Garden Village, including sources of data and assumptions made. The methods used to determine physical and monetary flows for each ecosystem service are described in turn. The flows and values of ecosystem services will change over time as habitats become established and the population of Tresham Garden Village builds-up, so figures were calculated for each year over the 30-year assessment period.

A1.1 Carbon sequestration

Carbon sequestration from woodland areas were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2018a,b). For areas of new woodland, sequestration rates were derived for each 5-year period for the first 30 years following establishment. For existing deciduous woodland, sequestration rates were averaged over a 100-year period, as this is the length of a typical forestry cycle for deciduous woodland. Information on species composition, yield, spacing and intended management for each compartment was obtained from the Deenethorpe Airfield Woodland Creation Plan (Broom 2016). The annual sequestration rate for each time period (for new woodland) or the average annual sequestration rates (for existing woodland) were then multiplied by the area of each woodland type and added together to give the total annual sequestration estimate for woodland at the site.

Monetary flows were calculated using the government's non-traded central carbon price for each year for the next 30 years, starting in 2018 (BEIS 2017), to provide the average annual value. The price is expected to rise from £66 per tonne in 2018 to £205 in 2047. We use the non-traded carbon price because it is a better reflection of the 'real' value of carbon sequestration if it were to be exchanged, than market prices. Using the latter reflects the current institutional set up of carbon markets, rather than the true value of carbon sequestration. The present value (PV) of the ability of the woodland to sequester carbon into the future was calculated by summing the values for each year over the 30-year project period, after discounting using the discount rate suggested in HM Treasury (2018) of 3.5%, and the formula within ONS (2016). The government also provides low and high estimates of future carbon prices and these were used in the sensitivity analysis to estimate the range in possible values.

A1.2 Timber/woodfuel production

For existing woodland, annual physical flows of timber/woodfuel production were calculated in terms of average annual yield, by multiplying the yield class of the different species by the area of each woodland type. For areas of new woodland, the expected yield obtained each year over the first 30 years following establishment was obtained from Forest Management Tables for the appropriate species and yield class. Note that new woodlands will not produce any yields for the first 20 years, but limited yields would then arise from thinnings. Yields would increase substantially as the woodlands mature, beyond the scope of this assessment.

Yield class and species composition were obtained from the Deenethorpe Airfield Woodland Creation Plan (Broom 2016).

The monetary flows for the woodland areas were calculated by multiplying the yield (calculated above) by the standing price of timber or woodfuel. The average price for softwood in 2018 was taken from the Forestry Commissions Coniferous Standing Sales Price Index (Forestry Commission 2018). The price for broadleaved timber in 2015 ranged from £15 to high quality timber reaching £250 per m^3 standing (ABC 2015). As commercial forestry is not the sole focus of the woodlands at Tresham, and especially in the early years after planting when thinnings are of small diameter, we have assumed that most output would be in the form of fuelwood and hence use the lower price inflated to 2018 value (£15.80). We also calculated average annual monetary flows over a full woodland cycle (assumed to be 100 years for broadleaved and 60 years for coniferous woodland) and use this figure for the existing woodlands which are of mixed ages. The present/asset value of the ability of the woodland created to provide timber into the future was calculated by multiplying the annual income by the standard government discount rate for each respective year and summing the discounted values over the 30-year period, as outlined in Section A1.1 (above). It was assumed that the area of woodland remains static and the unit price was also assumed to be constant. Low and high estimates were calculated to be 0.75 and 1.25 times the central estimate respectively.

A1.3 Air quality regulation

We measured the ability of the vegetation at the sites to absorb two key pollutants, particulate matter ≤10µm in diameter (PM_{10}) and sulphur dioxide (SO_2). Quantifying the physical flow of the air quality regulation service provided by woodland, street trees and grassland was based on the absorption calculation in Powe & Willis (2004), and Air Quality Damage Cost Guidance from Defra (2011) and ONS (2016). Scrub, hedgerow and orchard were calculated as having half the absorption capacity of deciduous woodland, while 5% of the parkland area was assumed to consist of deciduous trees. The deposition rates for PM_{10} and SO_2 in coniferous woodland, deciduous woodland and grassland were taken from Powe & Willis (2004). Average background pollution concentrations for PM_{10} and SO_2 were calculated using Defra data (Modelled Background Pollution Data, Defra 2016) and resampled in GIS to the Tresham study area boundary.

The surface area index of coniferous and deciduous woodlands in on-leaf and off-leaf periods was taken from Powe & Willis (2004). The proportion of dry days (rainfall <1mm) at Tresham was estimated using MET office regional value data (http://www.metoffice.gov.uk/climate/uk/summaries/datasets) for the Midlands. Data were averaged over 10 years (2008-17). The proportion of on-leaf relative to off-leaf days was estimated at the UK level using the average number of bare leaf days for five of the most common broadleaf tree species (ash, beech, horse chestnut, oak, silver birch) in the UK using the Woodland Trust data averages tool.

The air quality regulation service was valued using guidance from Defra that provides estimates of the damage costs per tonne of emissions across the UK (Defra 2015). These are

social damage costs based on avoided mortality and morbidity. Therefore, it was assumed that the value of each tonne of absorbed pollutant by the tree stock was equal to the average damage cost of that pollutant. The average damage cost for SO_2 across all locations was used (£2,106 per tonne after inflating to 2018 prices). The PM_{10} damage cost estimates depend on the location (urban size or rural) and source of pollution and this will change as the site is developed and hence more people become exposed. Before development Tresham was classed as rural (with an associated central damage cost of £19,112 after inflating to 2018 prices), whereas after development it was classed as urban small (£44,385 in 2018 prices). Following the Air Quality Damage Cost Guidance (Defra 2011), these damage costs were then uplifted by 2% per annum over the 30-year assessment period to reflect economic growth, as it is predicted that willingness to pay for health rises in line with economic growth. The annual values were then discounted by 3.5% to obtain estimates of Present Value. Low and high estimates were based on low and high damage cost estimates provided by Defra (2015).

For existing woodland and trees, it was assumed that the rate of absorption of PM_{10} and SO_2 would be constant over time. However, as pollution absorption depends upon the surface area of the vegetation, new woodland and trees will absorb pollutants at a drastically lower rate and will increase their capacity as they grow. We therefore obtained a sample of 10,000 trees from Peterborough Council's tree database and used the programme *iTree Eco* to determine the surface area of each tree. Forest Management Tables based on the species and yield classes of the trees at Tresham were used to estimate the typical diameter (DBH) of deciduous and coniferous trees at different ages. Trees within the sample were then allocated to appropriate age bands based on their DBH, to determine the typical surface area at each age and this was compared to the typical surface area of mature trees. Finally, these data were used to construct a profile of how the surface area changes with age, and the absorption capacity was adjusted for each year accordingly. For example, 15 year old deciduous trees were calculated to have a surface area that was only 10% of a mature tree, whereas this proportion had risen to 37% for a typical 30 year old deciduous tree. This approach is crude, but we were unable to find any standard estimates showing how surface area changes with age for different species.

A1.4 Agricultural production

The physical annual flow of agricultural production at the sites was simply measured as the area of land under agriculture. Crop areas were also obtained from Rob Wilkinson, representing the Brudenell Estate, for each separate land holding (there were four land holdings within the Tresham Garden Village site boundary), and these were classified to an appropriate Defra farming system based on the proportion of different crops and livestock. The four land holdings actually represented three different farming systems, namely cereal farms, general cropping farms and mixed farms.

The monetary value of agricultural production was calculated as the economic value of land, net of all non-land costs. Net Farm Income (NFI), the return to farm operators once all expenses have been deducted, were obtained from Defra's Farm Accounts in England (Farm Business Survey) for the three different farming systems in the Tresham area. This takes into

account yields and farm gate prices, to give gross output, and subtracts typical variable costs (e.g. fertilizers, husbandry, feed and forage costs) and fixed costs (labour, machinery, fuel, buildings). Annual NFI estimates were obtained over 5 years for the period 2012/13 to 2016/17. These were then adjusted to remove the effects of Basic Farm Payments (income support), to remove any charges for imputed (unpaid) rent, and to include charges for the imputed value of unpaid family labour. This gives a return (an economic rent) to the land resource itself after deducting all costs associated with production except for land ownership and rental costs, and excluding income support subsidies. The annual estimates of adjusted NFI were inflation adjusted to 2018 prices, and a mean estimate per hectare was derived for the period for each of the farming systems. Low and high estimate were also calculated by slightly varying the assumptions of which costs to remove. The per hectare estimates were multiplied by the area of land under each of the farming systems at Tresham under the baseline and Masterplan, to derive the total annual value of agricultural production. Present Value was calculated over 30 years using the standard discount rate and assumes that the mix of crops stays approximately the same.

A1.5 Greenhouse gas emissions from agriculture

Agricultural activities release CO_2 and other greenhouse gasses such as methane and NO_2 into the atmosphere, with emissions highly variable depending on the type of farming practices employed. These emissions can therefore negate the benefits obtained through carbon sequestration of habitats within a site.

The greenhouse gas emissions of the site were calculated by multiplying the area of each crop type and the numbers of livestock by emissions figures for each crop type and livestock type in Bateman et al. (2013). These emission figures are based on three types of agricultural emissions:

1. Emissions from typical farming practices (e.g. tillage, sowing, spraying, harvesting, and the production, storage and transportation of fertilizers and pesticides)
2. Emissions of N_2O from fertilizers
3. Emissions of N_2O and methane from livestock, caused by enteric fermentation and the production of manure

Emissions from the arable crops at Tresham averaged 1.5 tCO_2e per ha per annum. Improved, mixed use (amenity) grassland, and parkland were classed as permanent grassland with associated annual inputs and emissions of 1.24 tCO_2e/ha, whereas semi-natural grassland was assumed to have no inputs (hence zero greenhouse gas emissions). The total physical flow of greenhouse gas emissions was calculated by adding crop type and livestock emissions (in tCO2e). These were monetised using the BEIS (2017) non-traded central carbon price, as described for carbon sequestration in Section A1.1, and discounted at the standard rate to obtain the Present Value. The low and high non-traded carbon prices were used for the sensitivity analysis.

A1.7 Recreation

The importance of access to the natural environment is being increasingly recognised. Visits to natural areas have been shown to enhance physical and mental health and well-being, increase social cohesion and contribute greatly to the local economy. There are various methods for calculating the recreational value of a site including, for example, using visitor spend and contribution to the local economy. Given the likely limited opportunities for spending directly linked to the greenspaces at Tresham Garden Village we instead use recreational value derived by Sen et al. (2014) from a meta-analysis of just under 300 previous assessments of the value of outdoor recreational visits to different habitat types in Great Britain.

The physical flow of the recreation service to greenspaces around Tresham was calculated as the estimated number of visits. As the site has not yet been developed, we have had to make a number of broad assumptions in estimating this figure. Data from 5 years of the Monitor of Engagement with the Natural Environment (MENE) survey (Natural England), covering the period from 2011/12 to 2015/16, were used to calculate the proportional visit rate by members of the public to greenspaces (e.g. 9.1% of people visit greenspaces every day, 19.7% visit once or twice a month etc.). The visit rate was converted into the number of visits per year (Natural England 2017) and this was multiplied by the proportional visit rate to give the average number of visits to greenspace per person per year (83.5). The same MENE data set was also used to calculate the proportion of visits made at different distances from peoples' homes. It was calculated that 41.4% of all visits are within 1 mile of home. As there are few alternative sites very close to Tresham, it is therefore assumed that 41.4% of all visits to greenspaces made by Tresham residents will be to the local Tresham greenspaces, which means that 34.6 visits will be made on average per person to the Tresham greenspaces by residents each year.

The resident population of Tresham was then calculated over the 30-year assessment period. UK census data for Northamptonshire was used to obtain the typical occupancy rate for houses in the county (2.44 people per house) and the proportion of these that will be 16 and over. The Tresham Garden Village Delivery Schedule (2018) provides an estimate of the number of houses planned to be built each year, until eventual completion of 1500 houses after 15 years. The delivery schedule and the census data were therefore used to calculate the likely over 16 population of the village for each year over the next 30 years. Finally, the population each year was multiplied by the average number of visits per person estimated to occur to the local greenspace, to give the total visits each year. On completion it is estimated that 2,934 people aged 16 and over will be living at Tresham, making 101,500 visits to the Tresham greenspaces each year.

The annual monetary flow for recreation was estimated by multiplying the number of visits each year by the per person per trip recreational value for greenbelt and urban fringe farmlands (£6.12 after inflating to 2018 prices) from Sen et al. (2014). This was calculated for each year and averaged to obtain the annual average value and was also discounted at the standard rate to obtain an estimate of Present Value. A low estimate was obtained by using a lower monetary value per trip (£2.79), based on the value of visits to rural grassland and woodland habitats, and a high value was obtained by increasing the central value by 25%.

A1.8 Health and well-being

There is now a growing body of evidence to show the positive effect that the natural environment can have on human health and well-being. Monetising these benefits remains a challenge, with mental health in particular lacking a generic measure that is commonly applied, making it very difficult to value at present (Binner et al. 2017). Physical health is more commonly valued, although methods are still being refined. We measured the physical flow of health benefits delivered by Tresham Garden Village using an approach developed by White et al. (2016), who analysed the implications of recreational physical activity in the natural environment on health in England. The method relies on estimates of visitors to natural environments who meet recommended activity guidelines (based on both duration and intensity of physical activities). These can be translated into Quality Adjusted Life Years (QALYs) scores, with 30 minutes of moderate to intense physical activity (if taken 52 weeks a year) being equal to 0.0107 of a QALY. QALY scores have an associated monetary value through estimated savings in health care costs. We are, therefore, able to value this physical health benefit by calculating the total number of QALYs by active visitors to sites that meet guidelines, and multiplying this by the QALY value. The social value of one QALY has been estimated to be worth £20,000 (White et al. 2016). Note, however, that the HM Treasury has recently published an update to the Green Book (the Government's key guidance document on appraisal and evaluation), in which the value associated with one QALY has been increased to £60,000 (HM Treasury 2018). Given the large monetary benefit that would be assigned if using the higher QALY figure and the large number of assumptions involved in calculating this value, we have taken a conservative approach and used the £20,000 value for our central estimate, as has been used in previous natural capital assessments. We do, however, use the £60,000 estimate for our upper estimate of value, highlighting that the value of physical health could be considered to be much higher.

The first step in these calculations was to estimate the number of visitors to the green areas in and around Tresham over the 30 years of the assessment period. Note that this is focussing on number of visitors (individuals), rather than number of visits (which includes repeat visits by the same individuals), which was used for estimating the value of recreation. The over 16 population of the village for each year over the next 30 years was calculated as for recreation (above). This was then multiplied by the proportion of people who are likely to visit the natural environment at least once. The latter figure was obtained from 5 years of national MENE survey data from Natural England.

The next step was to determine the number of these visitors who are likely to meet physical activity guidelines in the greenspaces around Tresham. Again, as the site has not yet been built, we relied on national average data taken from White et al. (2016), which itself was based on MENE data. This provided estimates of the proportion of visits that are active, and the proportion of those active visits that meet physical activity guidelines. These figures were used to work out estimated number of QALYs and associated monetary value for each year. Based on government guidance (HM Treasury 2018), we uplifted the value of the benefit by 2% each year to reflect the assumption that willingness to pay for health benefits increases with economic growth. The annual value was calculated as the average value over

the 30 year period and the present value (PV) of the site to deliver physical health benefits into the future was the sum of annual values over the 30-year period, after discounting.

A number of assumptions are used in these calculations and the results should therefore be interpreted with caution; it is the ecosystem service with the greatest degree of uncertainty out of all those assessed.

Annex 2: The benefits of green infrastructure

Table A2: The ecosystem service benefits provided by green infrastructure and some of the ecological, economic and social implications of these services.

Natural Capital Benefits	
Regulating services	
Reducing rate and volume of storm water runoff	Providing shade
Reducing flood risk	Reducing summer air temperatures and the urban heat island effect
Enhancing infiltration and recharging ground water	
Reducing soil erosion	Providing shelter from wind
Trapping sediment	Reducing energy use
Enhancing water quality	Reducing glare
Absorbing air pollution – particulate matter (PM), NO_x, SO_3, ozone, carbon monoxide, ammonia	Attenuating noise
	Screening unattractive or noisy places
Removing dust and odour	Supporting pollinators
Producing oxygen	Enhancing pest and disease control
Sequestering and storing carbon – in plants and in soil	
Cultural services	
Providing and enhancing landscape character	Enhancing community cohesion
Contributing to sense of place and identity	Reducing aggression, violence and crime rates
Part of cultural heritage	Increasing security
Enhancing aesthetics	Enhancing driver and pedestrian safety
Benefiting physical health – reducing blood pressure, stress, asthma	Reducing road traffic speeds
	Enhancing privacy
Speeding recovery from surgery and illness	Bringing people closer to nature
Enhancing attention and cognitive function	Providing setting for outdoor learning
Improving mental health and well-being	Improving educational outcomes through improvements in concentration and performance and reduced time off for illness
Improving pregnancy and birth outcomes	
Reducing mortality rates – especially related to cardiovascular and respiratory diseases	Enhancing quality of life
	Providing spiritual value and meaning
Encouraging physical activity	Supporting biodiversity and wildlife viewing
Enhancing connectivity	
Provisioning services	
Source of timber, fuel, fodder, and fibre	Source of biofuels
Location and source of food production	Location for solar, wind and hydro energy
Enhancing water supply	Source of ornamental resources and crafts
Ecological benefits	
Habitat provision, improvement & connectivity	
Economic benefits	
Increasing land and property prices	Increasing property taxes
Reducing 'time on market' for selling property	Enhancing rental income
Attracting business and customers	Increasing tourism and visitor revenues
Reducing health care costs	Reducing screening costs especially next to main roads
Reducing expenditure on air pollution removal	Reducing agricultural costs and enhancing farmer income
Reducing expenditure on storm water infrastructure	
Reducing expenditure on flood defences	Providing potential for carbon offsetting trade
Saving investment in new power supplies	Generating income from sales of food, fibre, biofuels and ornamental / craft produce
Generating income from renewable energy	
Reducing heating and cooling costs	Creating jobs and employment in environmental sector