Biodiversity and climate change assessment for the NHS Lothian estate

March 2021

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Citation

Holt, A.R., Dempsey, N., Henneberry, J.M., Ashby, M. and Lush, C. (2021) Biodiversity and climate change assessment for the NHS Lothian estate. Report to the NHS Lothian, Natural Capital Solutions Ltd, February 2021.

About the authors

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Executive summary

Background: The NHS Lothian commissioned Natural Capital Solutions and collaborators to deliver a biodiversity, climate change and nature-based health benefits assessment of the natural capital assets (habitats) of their estate. The NHS in Scotland has a duty as a public body to further the conservation of biodiversity (Nature Conservation (Scotland) Act) and meet the ambitious climate change target of net zero by 2045 (The Climate Change (Scotland) Act). At the same time, the importance of biodiversity and natural capital in delivering health benefits is increasingly recognised within the NHS. This document reports on an assessment of the natural capital assets (biodiversity, carbon sequestration, air quality regulation and health) of the NHS Lothian estate. This sets a biodiversity and benefits baseline for the estate and five case study sites, so NHS Lothian is able to adapt the management of its estate to meet its policy responsibilities and to increase the provision of multiple ecosystem service benefits.

Baseline natural capital asset map: A Geographic Information System (GIS) basemap was created containing information on habitat type, extent and condition at each of the 94 estate sites of the NHS Lothian estate. This spatial asset register shows the area of the estate is 174 ha, 81 ha (46%) of which is greenspace. Estate sites range in size from 0.02 to 33.89 ha. The area of greenspace on each site also varies considerably, some of the smaller GP surgeries or dentists not having any greenspace at all, with larger hospital sites supporting up to 13 ha. The habitats on the site range from semi-natural habitats such as woodland, parkland, native hedging and rough grassland, to typical urban landscaped habitats such as individual tree planting, introduced shrub borders, gardens and amenity grassland. However, the habitats that comprise the greatest proportion of the green estate are broadleaved parkland and woodland (20%), followed by amenity grassland (8%). The larger sites tend to have a greater range of habitats present within them (e.g. Royal Victoria Hospital, Ellen's Glen House, Midlothian Community Hospital), and have significant areas of woodland and parkland habitats. The smaller estate sites tend to be dominated by sealed surfaces, have less variety in habitats, and are more likely to comprise of garden planting and introduced shrub.

Biodiversity baseline: A biodiversity metric was used to quantify the level of biodiversity across the estate, based on area, distinctiveness of habitat and its condition. The condition of each habitat within the GIS basemap was assessed, 71.5% were in poor condition and 28.3% were moderate, with only 0.2% in good condition. As a consequence, the overall biodiversity units for the estate was 484, a score which leaves opportunities for improvement.

Ecosystem service baseline: The flows of carbon sequestration and air pollution regulation were quantified across the estate and their monetary value estimated. The woodland, trees and hedges across the estate capture 283 tCO_2e per year, with an annual value of £19,501 and a present value (over 50 years) of £1.14 million. The estate natural capital assets also absorb 0.98 $tPM_{2.5}$ per year, with an annual value of £255,993 and a present value of £8.36 million. The health benefits delivered by the natural capital of the estate focused on green interventions such as therapeutic gardening and outdoor activities. These activities improve people's mental and/or physical health and wellbeing, reducing their demands on the NHS, saving it money. A cost-benefit analysis of two existing therapeutic gardening activities run by NHS Lothian, that have 350 participants annually, showed a Net Present Value (NPV) of the QALYs produced by this nature-based health intervention over a period of 50 years of £4.65 million. This is a return on investment (RoI) of 2.00. That is, every £1.00 spent on therapeutic gardening results in benefits to health with a value of £2.00. This demonstrates that

therapeutic gardening delivers health benefits the value of which significantly exceed the costs of running them. The combined annual value of the carbon sequestration, air quality regulation and health benefits is £508,700, with a present value of £14.15 million over 50 years. However, this natural capital account is partial, the value of all of the benefits provided by the natural capital of the estate (e.g. including flood alleviation, water quality and noise regulation) are likely to increase this total value.

Site scale baselines: The baselines for biodiversity, and the provision of the carbon sequestration and air quality regulation services have also been presented at the site scale. Five sites that represent different types of NHS service, e.g. city and community hospitals, medical centres and care homes were included. There is a great deal of variation in the proportion of greenspace at these sites and the type of habitat within it, and as a consequence the level of provision and value of the two ecosystem services. The opportunities for connecting on-site habitats to off-site ones to create habitat networks, also vary depending on the location of the site. Each site offers different opportunities for increasing services, although we outline general recommendations that will help NHS Lothian increase provision.

Key recommendations

Improve greenspace quality - Focus on improving poor condition habitats through better management, and replacing low value biodiversity habitats (e.g. amenity grassland) will result in an increase of at least 179 biodiversity units. The provision of carbon sequestration and air quality regulation could be improved, and the first step is to focus on increasing the condition of the woodland, parkland and hedgerow habitats in poor condition. The second is to increase areas of woodland, individual trees and hedges on sites. There are opportunities to transform the low biodiversity value habitats in this way, using more hedging around roads and car parks, and to consider green roofs and walls. Species that are efficient at providing these services have been outlined.

Improve greenspace quantity - Further gains in biodiversity and ecosystem service provision can only be achieved through increasing the greenspace provision at sites within the NHS Lothian estate. The green assets are a finite space, any loss of greenspace will have to be compensated for if the biodiversity and climate change policy responsibilities of the NHS Lothian are to be upheld, and for the estate to continue to promote health benefits from its green assets. Adding greenspace may be possible when sites are renovated, and should be considered in masterplans, or acquired.

Connect with surrounding green infrastructure - Connecting on-site natural capital assets with surrounding greenspace may increase the level of on-site biodiversity and health benefits, without expanding them. Nature-based health interventions hosted on-site can also use greenspaces (parks and woodlands) adjacent to the site that could enable an increased number and diversity of programmes.

Encouraging more nature-based health activities - Opportunities for nature-based health interventions on sites with existing community gardens could immediately be increased by 50% with no detrimental impact on them. For sites without gardens, creating a new community garden at a site with one programme of therapeutic gardening for 180 patients per year would deliver benefits to the value of £2.28m over 50 years, with an RoI of 1.92. Creating a reasonable sized greenspace on the estate to run one programme of outdoor activity involving 180 patients per year would deliver benefits that value £2.38m over 50 years

with an RoI of 2.0. Expanding the NHS nature-based interventions would be a cost effective way of supporting the provision of considerable public health benefits.

Promote the use of the estate as a health asset - The use of estate sites by patients, staff and the local community could be promoted by improving signage of walking routes on-site, and routes to adjacent parks and greenspaces. To achieve increased use, promote community gardens that offer opportunities for social 'green' prescribing using local delivery partners, and greenspaces through staff well-being programmes.

Develop a co-ordinated strategic approach to managing the natural capital assets - Use the spatial asset register map and the linked biodiversity and natural capital accounting tool (developed as part of this project) to assess changes at sites and their impact on the whole estate and use it to create and assess the meeting of targets and policy responsibilities (biodiversity and net zero carbon). Regular habitat and habitat condition surveys (using volunteers) will underpin biennial audits of biodiversity and ecosystem service provision. Create greenspace site management plans to increase the condition of habitats for biodiversity, and to create new habitats. Green asset management skills need to be embedded into the delivery of these plans. Use a monitoring approach to collect data and evaluate nature-based health interventions.

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1. Introduction

The NHS in Scotland has a duty as a public body to further the conservation of biodiversity (Nature Conservation (Scotland) Act) and meet the ambitious climate change target of net zero by 2045 (The Climate Change (Scotland) Act). At the same time, the importance of biodiversity and natural capital in delivering health benefits is increasingly recognised within the NHS. It is clear that contact with nature, and specific nature-based or green health interventions can help deliver health benefits to people, with the potential for significant cost savings to the NHS. Indeed, the Sustainable Development Strategy for NHS Scotland outlines the need to manage the NHS' greenspace and outdoor estate as a healthcare facility. Regional strategies[1,2,3] also outline the need to maximise the use of the NHS Lothian green estate to deliver health and biodiversity benefits.

The NHS Lothian estate, as currently documented, comprises 94 sites (hospitals, community hospitals, health centres and care homes) across an area of 174 ha, 81 ha of which is natural habitat / greenspace. The greenspace provision at each of the estate sites varies. Some of the hospitals have sizeable areas of greenspace within their sites, but smaller sites, such as health centres or dentists, may have a square of grass or no greenspace at all. In an NHS context the greenspace can be important to patients, staff, visitors and the wider community. Despite this variety in greenspace provision across the estate, it has the potential to be managed to deliver multiple benefits across a range of ecosystem services. For example, carbon sequestration, air quality regulation, flood alleviation, local climate change and noise regulation, as well as increasing physical and mental wellbeing and providing habitat for biodiversity. These benefits will aid NHS Lothian in climate mitigation and adaptation, in its duty to conserve and enhance biodiversity, at the same time as meeting the key targets that centre on the management of the greenspace provision laid out in the NHS Lothian Greenspace and Health Strategy.

This report is a roadmap for the NHS Lothian so it can manage its estate to meet its policy commitments in relation to climate change and biodiversity, also identifying where other public natural capital benefits, particularly related to heath, can be enhanced. It outlines an assessment of the natural capital assets (habitats) of the NHS Lothian estate. From this the level of biodiversity and ecosystem service provision (carbon sequestration, air quality regulation and well-being) has been assessed, and the benefits that flow from them valued. This sets a biodiversity and benefits baseline for the estate. This will allow NHS Lothian to track the changes to both the green and built estate, to assess whether they will meet their policy responsibilities. It will also allow them to weigh the costs of managing the green estate against the benefits provided. We provide recommendations on how to improve the quality and type of greenspace at estate sites, while identifying sites across the estate that offer the greatest opportunities for increasing the delivery of benefits across the whole estate. We also highlight critical steps that the NHS Lothian need to take, both strategic level processes and

[1] Strategic Plan 2014-2024: Our Health, Our Care, Our Future. Available at: https://org.nhslothian.scot/OurHealthOurCareOurFuture/Documents/OurHealthOurCareOurFuture-NHSLothianStrategicPlan2014-2024.pdf on 20th January 2021.
[2] Greenspace for Health: NHS Lothian Grounds – the way forward
[3] Greenspace and Health, the strategic framework for Edinburgh & Lothians (2019) Available at: https://www.greenspacescotland.org.uk/Handlers/Download.ashx?IDMF=209ea0c4-82e7-4bea-8854-fb6be2522dce on 20th January 2021.

site level practicalities, to transform the estate into a well-used and significant health and environmental asset.

1.1 Aims

NHS Lothian commissioned Natural Capital Solutions and collaborators to deliver a biodiversity and climate change assessment of the NHS Lothian estate. The aims were to:

(i) Map the natural capital assets of the estate to provide a spatial asset register.

(ii) Deliver an assessment of the biodiversity and the natural capital benefits provided by the estate with a focus on carbon sequestration and air quality regulation, including an in-depth analysis of health and wellbeing benefits with a focus on two nature-based health interventions.

(iii) Provide recommendations on improvements that could be made to the estate sites to increase the provision of biodiversity and ecosystem services.

(iv) Create a spatial biodiversity and natural capital accounting tool linked to the spatial asset register that will allow the NHS Lothian to re-run the biodiversity and ecosystem services assessment based on past or future changes to greenspaces of the estate.

(v) Deliver a biodiversity and climate change assessment technical report with in-depth case studies of some of the priority sites, along with a shorter glossy report that will communicate the main headlines of the report to a wider audience, using non-technical language and infographics.

We briefly outline the methods used to achieve these aims in the main report, but the technical detail of these is documented in the annexes at the end of the report. We present the results of the spatial asset register and the natural capital accounting at both the estate and the site scales. Due to the large number of sites, and their broad geographic spread, the results for five case study sites are summarised in the main body of the report (Section 4) and detailed in Annex 1:

- Royal Infirmary Edinburgh
- St John's Hospital
- Western General Hospital
- Musselburgh Primary Care Centre
- Ellen's Glen House

We outline results and provide maps for a further five sites in an Annex 2 at the end of the report:

- Royal Edinburgh Hospital
- Astley Ainslie Hospital
- Mid Lothian Community Hospital
- East Lothian Community Hospital
- Comely Bank Centre (NHS Lothian Training Centre)

These ten sites were considered a priority by the NHS Lothian and they span the different categories of site within the estate e.g. large hospitals, community hospitals, health centres and care homes.

The recommendations for how the green infrastructure of the estate can be improved to enhance biodiversity and ecosystem services will also be presented in this format. The cost-benefit analysis of the nature-based health interventions will be reported on according to the two intervention types that were its focus; therapeutic gardening/horticulture and conservation/outdoor activities.

A key part of this project was to develop a spatial natural capital accounting tool that links to the spatial asset register ((iv) above). We do not describe this tool in the main body of the report but have dedicated a section to it in Annex 2. However, we do refer to the tool in the report, and it is integral to some of the recommendations we make for the future management of the NHS Lothian green estate.

1.2 The natural capital concept

Presently, the NHS Lothian consider the role and value of the built assets within the estate, but do not account for the green assets and the benefits that they can provide. It is important to consider the estate greenspaces because the natural environment underpins our wellbeing and economic prosperity, providing multiple benefits to society. 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[4]). It is the stock of natural assets (e.g. soils, water, biodiversity) that produces a wide range of ecosystem services that provide benefits to people. These benefits include food production, regulation of flooding and climate, pollination of crops, and cultural benefits such as aesthetic value and recreational opportunities (Fig. 2.1).

[4] Natural Capital Committee (2014) The state of natural capital: Restoring our natural assets. Second report to the Economi Affairs Committee. Natural Capital Committee, March 2014.

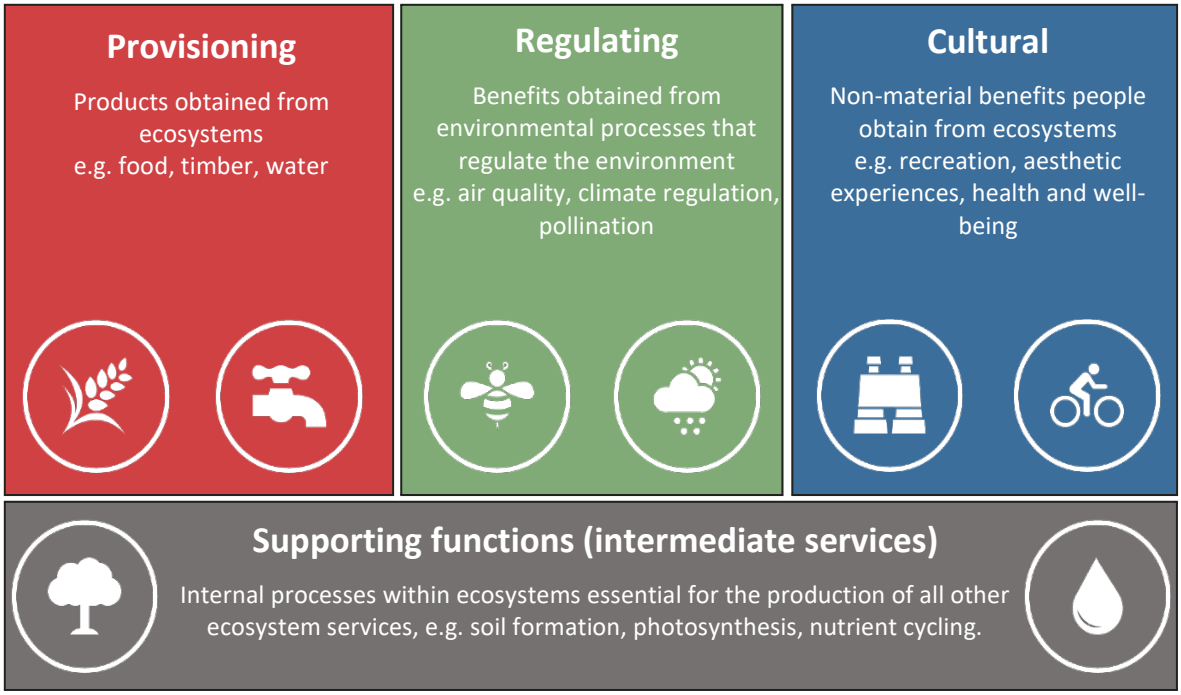


Figure 1 Key types of ecosystem services (based on MA 2005[5]). Note that supporting or intermediate services are now categorised as ecological functions (CICES[6]), they are the underpinning structures and processes that give rise to ecosystem services.

It is important to incorporate natural capital into decision-making within NHS Lothian to understand the provision of benefits from the green assets of the estate, so they can be enhanced to support policy responsibilities and the health and wellbeing of patients, staff, visitors and the local communities. Much work is progressing on how to deliver the natural capital and ecosystem services approach on the ground and how to use it to inform and influence management and decision-making. The first important step is to map the natural capital assets of the site of interest and to create an asset register (habitat type, quantity and quality). The next step is to quantify ecosystem service delivery (the physical flow of services derived from natural capital). Additional insight can be gained by taking a spatial perspective on the variation in ecosystem service supply across a study area using a Geographic Information System (GIS). Maps can highlight hotspots and coldspots of ecosystem service delivery, highlight important spatial patterns that provide much additional detail, and are inherently more user friendly than non-spatial approaches. The next step is to estimate the monetary value of the benefits that are delivered by these services.

In this context, a natural capital assessment will provide the NHS Lothian with a mapped natural capital baseline of habitat type, condition, level of biodiversity and level of provision of 3 ecosystem services (carbon sequestration, air pollution regulation and human health/well-being). This will allow the NHS Lothian to track progress from that baseline and assess whether policy responsibilities, for example, a net gain in biodiversity and contributing to net zero carbon, are being met. A baseline will also show the areas of the estate that are performing well and areas where opportunities for improvement lie (e.g. opportunities for expanding nature-based health interventions). It will allow NHS Lothian to work out how best to off-set the biodiversity and services lost through site disposals or site acquisition and design

[5] Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: Synthesis. Island Press, Washington D.C. https://www.millenniumassessment.org/en/index.html
[6] Haines-Young, R. & Potschin, M. (2018) Common International Classification of Ecosystem Services (CICES) V5.1. Guidance on the application of the revised structure. Fabis Consulting.

in the relevant greenspace requirement into developments on existing sites. Natural capital valuation is key to providing full cost-benefit analyses of changes to the built estate, which may reduce or expand and improve the area or quality of the green estate, and allows the assessment of new grounds maintenance practices.

2. NHS Lothian estate natural capital

2.1 How the NHS Lothian sites were identified

NHS Lothian has a large and varied property portfolio which means that there is a range of tenure under which the land is owned or occupied. Some sites are whole owned and occupied by the board, others are occupied by tenants or are rented by NHS Lothian. All sites for which the NHS Lothian has responsibility for the management and maintenance (including those that managed by a third party) have been included in this analysis. Details of these sites were provided by the Head of Business Services and Asset Management as part of an ongoing process of categorisation and cataloguing of site ownership.

Prior to this project no spatial database existed of the boundary of the entire NHS estate. With the support of Greenspace Scotland, we have estimated the estate boundaries from available information. Each site was located using aerial photography to validate the general location. Available information was then used to estimate the boundary of the site, this brought together information from OpenStreetMap, OS Mastermap, published maps of sites, planning applications and local knowledge. Aerial photography was then used to create approximate polygon boundaries in QGIS2 and a 'Boundary Confidence' attribute was created giving each site a score of 1 to 5 (1 = low confidence, 5 = high).

2.2 Estate scale natural capital assets

A Geographic Information System (GIS) basemap was created containing information on habitat type, extent and condition at each of the 94 estate sites of the NHS Lothian estate[7]. This information was derived from site survey data collected in the field, and existing spatial environmental data (see Annex 2.5). The estate sites range in size from 0.02 to 33.89 ha, with a median of 0.39 (Table 1). The area of greenspace on site also varies considerably (Table 1, Figure 2a&b), some sites not having any greenspace at all, and some with 13 ha. The proportion of the site that is greenspace (Table 1) is, therefore, broad, ranging from 0% to sites that are 94% greenspace. Further statistics can be seen in Annex 1.1.

Table 1 Key statistics for the NHS Lothian estate and sites.

	Estate	Site median	Site min	Site max
Estate/site area (ha)	173.82	0.39	0.02	33.89
Greenspace area (ha)	80.50	0.11	0	13.35
Proportion of site that is greenspace (%)	46.31	32.30	0	94.19

[7] This map is the basis of the biodiversity and natural capital accounting tool that has been created as part of this project and is outlined in a separate document.

An asset register for the estate (Table 2) was created from this map. The asset register shows that the NHS Lothian Estate covers 174 ha, 81 ha (46%) of which has been identified as natural habitat/greenspace (also see Table 1). There are a wide range of habitat types (Table 2) across the green estate, ranging from semi-natural habitats to habitats associated with urban landscaping. In and around some sites there are areas of brownfield and disturbed ground. The habitats that cover the greatest area of the estate are broadleaved parkland (19 ha) and broadleaved woodland (16 ha), and amenity grassland (13 ha).

The asset register (Table 2 below) presents an overview of the type of habitats that comprise the estate, but it is more revealing and practically relevant to understand how these habitats are dispersed across the sites (which we are unable to illustrate by map in this report because the estate is dispersed over a wide geographic region).

Figures 2a & b show the proportion of each habitat that occurs at each of the 94 hospital sites. The larger hospital sites feature in (a) and tend to have a greater range of habitats present within them. Some of the sites, for example, the Royal Victoria Hospital (RVH), Tippethill Hospital (TH), Ellen's Glen House (EGH), Midlothian Community Hospital (MCH), Bellhaven Hospital (Bell H), ATOS and the Milestone House site (MHS) are not as dominated by sealed surfaces and have significant areas of woodland and parkland habitats within them (see Table A1.1 for the site codes and Table A1.2 in Annex 1 for a list of the ten hospitals with the highest proportion of greenspace).

The smaller estate sites Figure 2(b) tend to be more dominated by sealed surfaces, have less variety in habitats, and are more likely to comprise of garden planting and introduced shrub. There are sites in both groups (Figure2a & b) that have a higher proportion of amenity grassland than any other habitat (21 sites in total). There are 5 sites that have no greenspace at all.

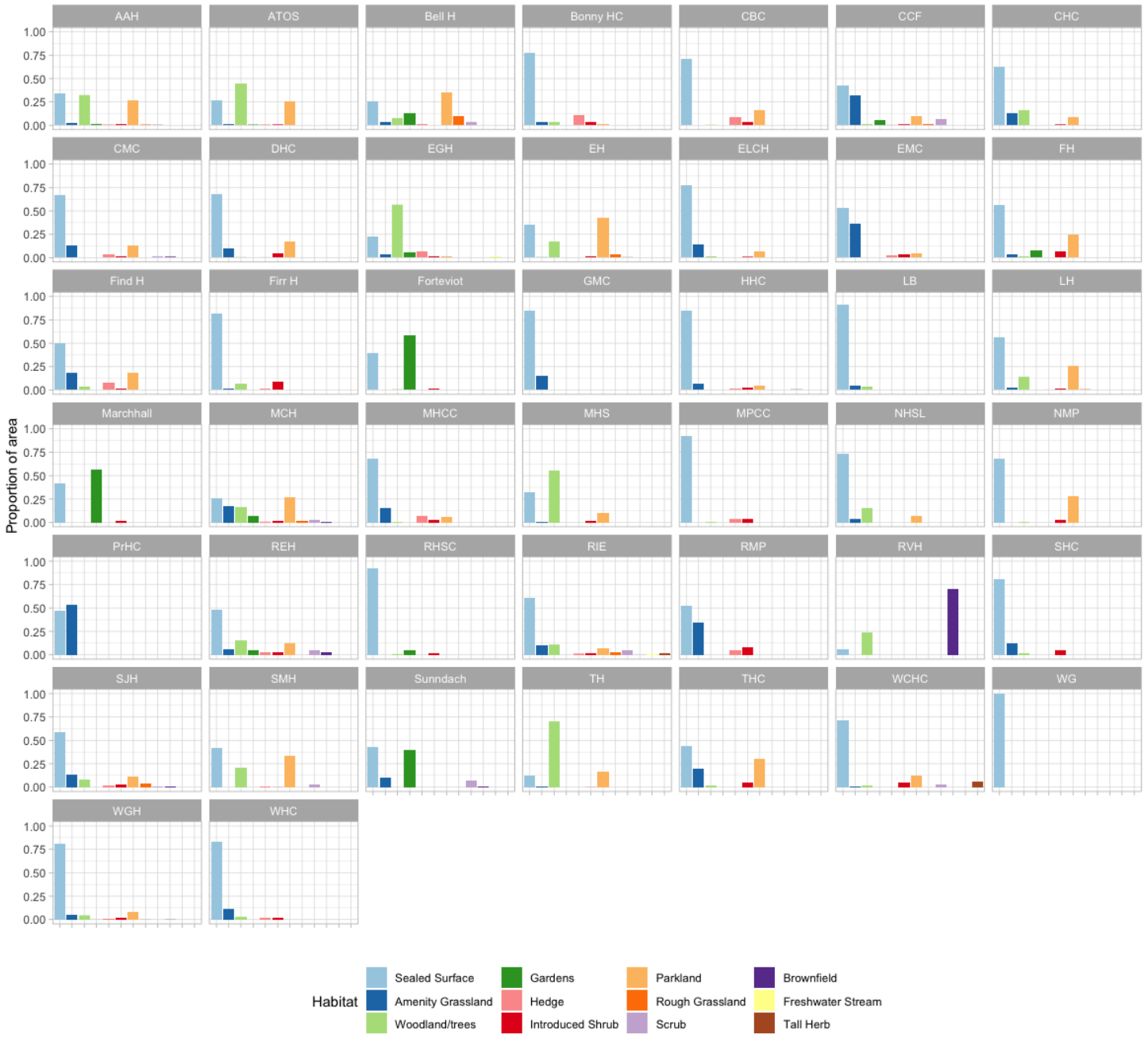
The woodland, parkland and rough grasslands tend to occur around the outskirts of larger hospital sites, although there are exceptions to this. For example, the Astley Ainsley Hospital buildings are set within a relatively large area of parkland and woodland. Amenity grasslands are widespread, probably as it is practical habitat to maintain, allows clear sightlines around car parks and is generally considered 'neat'. It occurs across all site categories (city hospitals, community hospitals, care homes and health centres). It is often a feature of the parkland under and around the trees. Hedges, lines of trees and flower/shrub borders are generally used in and around the buildings and car parks, and in courtyard gardens within some hospital sites.

Table 2 Asset register (derived from spatial asset register) for the NHS Lothian Estate showing the area of each habitat type in hectares and the percent cover of the total area of the estate (including buildings and sealed surfaces).

Habitat Type	Area (ha)	Area (%)
Amenity grassland	13.07	7.52
Broadleaved planting	2.20	1.27
Broadleaved woodland	15.93	9.17
Brownfield site	4.36	2.51
Coniferous planting	0.04	0.02
Coniferous woodland	0.62	0.36
Defunct hedge	0.03	0.01
Disturbed ground	0.57	0.33
Ditch	0.05	0.03
Freshwater stream	0.39	0.22
Gardens	3.36	1.93
Hedge	2.01	1.16
Introduced shrub	3.16	1.82
Mixed planting	0.15	0.09
Mixed woodland	5.89	3.39
Parkland (broadleaved)	18.89	10.87
Parkland (coniferous)	0.16	0.09
Parkland (mixed)	3.82	2.20
Rough grassland	2.09	1.20
Scrub	3.21	1.85
Tall herb	0.48	0.28
Sealed surface (buildings, roads)	93.32	53.69
Total	**173.82**	**100**

N.B. Woodland, parkland (broadleaved, coniferous and mixed categories), scrub, tall herb, and rough grassland are all considered to be semi-natural habitats in this project. Planting of individual or rows of trees in borders, gardens and car parks (defined as broadleaved, coniferous and mixed planting), hedging, and hedging with trees inter-dispersed, shrub borders (introduced shrub), gardens (within which the various habitats have also been classified), and amenity grassland, are considered to be modified habitats and those associated with urban landscaping.

(a)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WHC
Proportion of area
1.00
0.75
0.50
0.25
0.00
Habitat
Sealed Surface
Amenity Grassland
Woodland/trees
Gardens
Hedge
Introduced Shrub
Parkland
Rough Grassland
Scrub
Brownfield
Freshwater Stream
Tall Herb

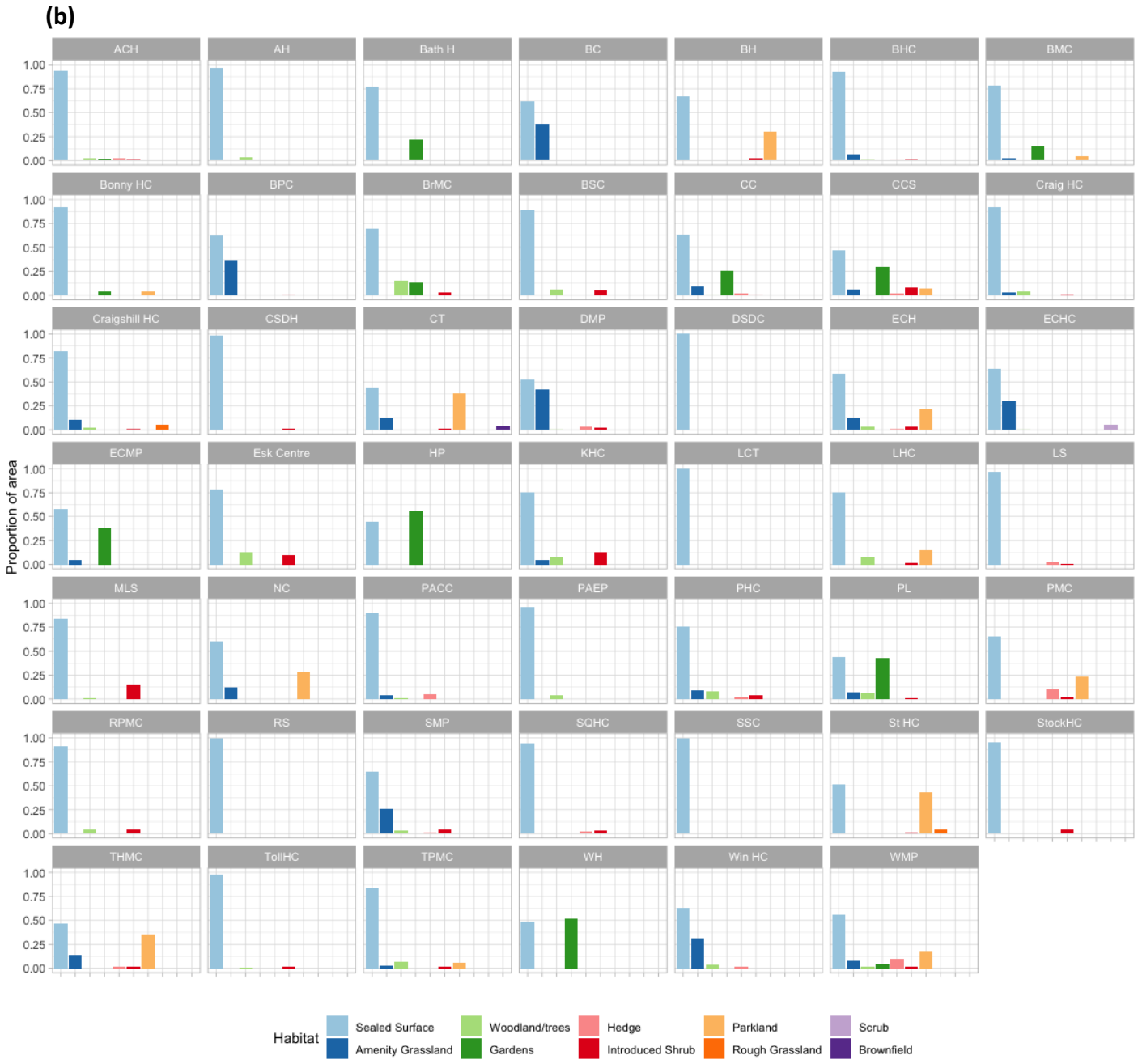


Figure 2 The proportion of sealed surface and each habitat type at the NHS Lothian estate sites (see figure legends for the habitat categories). The site names have been coded and the list of site codes is in Annex 2, Table A2.1. The sites have been grouped according to area, largest first. **(a)** Sites between 33-0.42 ha, this includes the hospitals, larger care homes and medical centres. **(b)** Sites from 0.4-0.02 ha which includes mainly medical centres and surgeries.

3. Estate scale biodiversity and ecosystem service provision

3.1 Biodiversity

It is possible to track changes (increases and decreases) in biodiversity across the NHS Lothian estate if the current baseline for biodiversity can be quantified. The NHS Lothian has a commitment to further the conservation of biodiversity as part of the Nature Conservation (Scotland) Act. Changes in biodiversity may occur due to the loss of sites from the estate, from developments to the built estate that take up greenspace or create additional greenspace, or from changes in the management of specific habitats within the sites due to, for example, health and safety requirements. All of these may affect the habitat types on the site, but also the condition or quality of those habitats. The level of biodiversity across the NHS Lothian estate was quantified using a relatively simple metric (Biodiversity Metric 2, Natural England 2019, see Annex 2.5.2 for an outline of the tool) that is increasingly being used in the development sector in England to check for biodiversity net gain[8], which calculates a measure of biodiversity (biodiversity units) for each habitat based on the area of the habitat, its distinctiveness and condition. Habitats that have a high distinctiveness, are in good condition and cover a greater area will achieve a higher biodiversity unit score. We applied this metric to every NHS Lothian estate habitat polygon in the spatial asset register.

The overall biodiversity units for the estate total 484 ranging across the sites from 0 to 78 (see Table A2.3 in Annex 2.1). As a standalone value this has little meaning, its power comes from comparisons when changes have been made to the estate habitats. However, by looking further into the condition of the estate habitats, the score can be construed as relatively low. This is because 71.5% of the total estate habitat polygons in the spatial asset register were assessed as poor condition, 28.3% were moderate and only 0.2% were assessed as being in good condition, following the condition assessment guidelines of the Biodiversity Metric 2[9].

When focussing on the condition of the habitats across the estate, it is useful to distinguish between habitats that are considered valuable in terms of biodiversity (e.g. semi-natural habitats) and those that are of low biodiversity value (e.g. amenity grassland). The former can be in poor quality but be managed to achieve medium or good condition. The latter will always be assessed as poor-quality habitats.

The habitats considered to be in 'good' condition tend to be the well managed gardens of the Royal Edinburgh and Midlothian Community Hospitals. These gardens are well used and maintained, supporting a diversity of semi-natural habitats such as rough grassland and broadleaved trees, habitats considered of higher biodiversity value than the allotments, lawns and borders that are also part of the gardens (Table 3).

The habitats that tend to be in a moderate condition (Table 3) are broadleaved planting and woodland, brownfield sites, coniferous planting, gardens, hedges and hedges with trees, mixed tree planting and mixed woodland, rough grassland, scrub and tall herb.

The poor condition habitats (Table 3) are a mix of poorly managed habitats and habitats that are considered of low biodiversity value. Amenity grassland, introduced shrub and disturbed

[8] Biodiversity net gain is often referred to as 'securing positive effects for biodiversity' in Scottish policy documents.
[9] Biodiversity Metric 2. (Natural England 2019). Available at: http://publications.naturalengland.org.uk/publication/5850908674228224 on 20th January 2021.

ground, however they are managed, will be classified as poor condition because ecologically they are not valuable for biodiversity.

Alternative habitats to amenity grassland, like rough grassland or native woody shrubs should be considered, native shrubs would also be preferable. Other habitats, such as hedges, gardens, parkland, woodland and scrub could be managed more positively. For example, replacing old hedges and pruning trees, ensuring continuous canopy cover in woodland, maintaining a diverse range of trees with species that are better for biodiversity (see Table 10 for a list), limiting tree damage, leaving dead wood and limiting non-native plant species.

Sites that could benefit from improved management of these habitats are the Astley Ainslie Hospital, ATOS, Ballenden House, Bellhaven Hospital, Bonnyrigg Health Centre (new), Edenhall Hospital, Ellen's Glen House, Findlay House, Midlothian Community Hospital, Royal Edinburgh Hospital, Royal Infirmary of Edinburgh, St John's hospital, St Michael's Hospital and the Western General Hospital. Disturbed ground at Western General Hospital, St John's Hospital, Royal Edinburgh Hospital, Howden Health Centre, Craigmillar Medical Centre and Camus Tigh Care Home could be used to create new semi-natural habitats (e.g. woodland, parkland, rough grassland).

The habitats at sites in poor condition can be targeted for improvement to make relatively quick wins increasing the baseline biodiversity of the site, and also slightly increasing the carbon sequestration and air purification. If management measures to improve condition, as outlined above, were employed in the poor condition habitats (e.g. woodland, parkland scrub, hedges etc) increasing them to medium condition, it would be possible to increase the overall biodiversity unit score by 145. The biodiversity units of the estate could also be increased by at least 34[10] if the habitats considered low biodiversity value, e.g. amenity grassland, introduced shrub and disturbed land, were replaced by habitats that have more biodiversity value. Given that the large majority of sites have amenity grassland in their greenspace profile, this would be a good place to start, increasing biodiversity units at the site and the estate scales.

Biodiversity is important as the foundation for the provision of a wide range of ecosystem services. It is also considered that increasing biodiversity in turn increases the resilience of natural systems to deal with climate change. There are likely to be trade-offs between the practicality of maintaining habitats for biodiversity in the grounds of hospital sites, for example, the costs of maintenance need to be kept to a minimum, habitats need to look pleasing at the same time as being practical where there are many people driving and moving about. There is certainly scope to increase biodiversity across the estate. Finding the balance here is key, and this assessment aids an understanding of the value of the benefits that can also be delivered from an enhanced biodiversity. It is also possible to increase the value of the biodiversity on the estate by connecting onsite habitats with offsite greenspaces. This creates networks for wildlife to move through. We have looked at how these connections can be made at the site scale (Section 4 and Annex 1).

[10] This is assuming the distinctiveness score (2) stays the same, but that the condition moves from poor to moderate, but, for example, if woodland was planted the distinctiveness score would increase to 6, raising the score further.

Table 3 NHS Lothian estate site habitats that appear in each Biodiversity Metric 2 condition category.

NHS Lothian estate habitats in each condition category		
Good	**Moderate**	**Poor**
Gardens (community gardens with a diversity of habitats within them particularly allotments with lawns and border that also include broadleaf trees and rough grassland).	Broadleaved planting Broadleaved woodland Brownfield (with broadleaved or mixed trees) Coniferous planting Freshwater stream Gardens with broadleaved trees, allotments, lawns and borders Hedges and hedges with trees Mixed planting and woodland Rough grassland Parkland (broadleaved) Scrub Tall herb	Amenity grassland Brownfield Coniferous woodland Disturbed ground Freshwater stream Gardens Hedges and hedges with trees Introduced shrub Parkland (broadleaved, coniferous and mixed) Scrub

3.2 Carbon sequestration and air quality regulation

It is also possible to track changes in ecosystem service provision across the estate by quantifying their provision. A policy priority for the NHS Lothian are achieving net zero carbon by 2045 in relation to The Climate Change (Scotland) Act, and increasing the health and well-being of the patients, staff and local communities in and around the sites of the estate. As a result, the flow of carbon sequestration, air pollution regulation and physical and mental health benefits have been quantified across the estate and their monetary value estimated. We have used well established techniques and best practice, for details of these see Annex 2, 3 and 4 at the end of the report. The greenspaces of the estate will supply other services, for example, climate regulation, noise regulation, water quality and flood regulation services at the same time. We were not able to quantify those for this project, but we show how these can also be considered in the estate scale recommendations below (Section 3.4). Changes to the estate, as outlined for biodiversity above, also impact on the ecosystem service provision of the greenspaces of the estate. The quantification and valuation of these services allows an understanding of how estate changes impact on the provision of these benefits and reveal the value that should be considered in any cost-benefit analyses (from assessing business cases for new buildings or car parks, to how the greenspace is maintained).

The natural capital assets of the NHS Lothian estate have the capacity to supply a wide range of important benefits. The woodland, trees and hedges across the estate capture 282 tCO_2e per year, with an annual value of £19,501 and a present value (over 50 years) of £1.14 million (Table 4). The estate woodland, trees, grassland and shrubs absorb 0.98 $tPM_{2.5}$ per year, with an annual value of £255,993 and a present value of £8.36 million. This value is a cost saving to the NHS from avoiding air pollution related illness.

Table 4 Biodiversity units, annual physical and monetary flows and Present Value (over 50 years) of carbon sequestration and air quality regulation across the whole of the NHS Lothian estate.

	Annual physical flow	Annual monetary flow £(2020)	Present Value £(50 years)
Carbon sequestration tCO_2e/year	281.5	19,501	1.14 million
Air quality regulation $tPM_{2.5}$/year	0.98	225,993	8.36 million
Biodiversity units	484		

These results suggest that the natural capital assets of the NHS Lothian estate play a role in taking up carbon emissions. Increasing the capacity of greenspaces to sequester carbon is one important component in the path to achieving net zero carbon emissions, along with policies to deliver emissions reduction (e.g. promoting green transport). This sequestration capacity needs to be seen in the context of the NHS Lothian emissions. The average yearly emissions across the NHS Lothian estate over the last 5 years is 77,516 tCO_2e[11].

Clearly the green estate can sequester carbon, but even if all green areas on the NHS Lothian Estate were planted with trees it would not be enough to off-set the emissions of the estate (a rough estimate is that this would sequester 400 tCO_2e per year). However, the green areas of the estate could be managed further to increase the delivery of this service. The first step is increasing the condition of woodland, parkland and hedgerow habitats, as discussed in Section 3.1. The second is to increase areas of woodland, individual trees and hedges on the site. There are likely to be opportunities for this on all sites (we touch on some of these in our recommendations for specific sites in Section 4 and Annex 1). How much it could be increased by is very difficult to estimate, as opportunities are site specific, planting on other quality habitats (e.g. semi-natural grasslands) should be avoided, and planting trees in and around car parks could interfere with sight lines.

Air pollution is likely to be an issue on the hospital sites with many of them being near busy roads, and site car parks becoming congested in-patient visiting hours. Green areas on the hospital sites, therefore, play an important role in increasing local air quality. Hedges and trees have been shown to be particularly effective at providing this service, so both improving the maintenance of hedging where it is in poor condition and increasing these habitats across the estate (particularly around roads and car parks) would increase the ability of the estate's natural capital assets to provide this service. Interventions for increasing the provision of this service will generally also increase the carbon sequestration service.

As the estate is somewhat constrained in the improvements that can be made, it is important to also consider green infrastructure interventions that do not take up ground space, for example green walls and roofs. Depending on the habitats used, these could increase biodiversity, but also the provision of both carbon and air quality regulation services. There are some green roofs already on some sites within the estate, but we were not able to include these in the analyses due to lack of data.

[11] Figure from the Public Sector Climate Change Duties 2019, Summary Report, NHS Lothian.

The quantification and natural capital accounting sets the baseline against which future estate changes can be compared. The spatial natural capital accounting tool (Annex 2.4) that has been created as part of this project can be used to alter the size and condition of habitat across the NHS Lothian estate, to understand what the impact on biodiversity and ecosystem services will be of interventions such as increasing the condition of habitats, adding hedges or trees, and removing sites or habitats due to increasing of the built estate assets.

3.3 Physical and mental health benefits

3.3.1 Baseline benefits

NHS Scotland now recognises the importance of its green estate for promoting the health and well-being of patients and staff. In order for NHS Lothian to manage its greenspaces for the provision of increased physical and mental health benefits, it is important to understand, at least partially, how the estate currently supports the provision of this service, and what the monetary value of the benefits might be.

Quantifying and valuing this service is not as straightforward as for the carbon sequestration and air pollution regulation services. This is because in addition to natural asset data, local data is required on the type of nature-based health interventions (activity and number of patients participating) as well as studies that have quantified the changes to participants' health of those specific activities (see Annex 3 for details of the approach). Two main nature-based health interventions are currently offered on the NHS Lothian estate - gardening and walking. The former is delivered through community gardens (at Midlothian Community Hospital and Royal Edinburgh Hospital) and a mix of ward, courtyard and other types of smaller gardens (at Astley Ainslie Hospital, Midlothian Community Hospital, Royal Edinburgh Hospital, St John's Hospital Livingston and Western General Hospital). The latter is provided through walking routes at Astley Ainslie Hospital, Edinburgh Royal Infirmary, Midlothian Community Hospital, Royal Edinburgh Hospital, St John's Hospital Livingston and Western General Hospital. Participation in green interventions such as therapeutic gardening improves people's mental and/or physical health and wellbeing. In turn, this reduces their demands on the NHS, saving it money.

There were no data available on the use of the walking routes on the estate. Consequently, it was not possible to estimate their health impact. Information on the use of the smaller gardens is related to the programmes of activity and those delivering and participating in them. Those programmes commonly span several smaller gardens, making the estimation of the latter's specific health impacts problematic. A similar difficulty affects the analysis of the health impacts of the community gardens but to a less marked degree. Consequently, the larger gardens were one of the two foci of a cost-benefit analysis (CBA). The other green health intervention that was the subject of CBA was that of outdoor nature-based programmes of activity. There is considerable potential for establishing this type of intervention on suitable sites on the NHS Lothian estate, we report on the results of this in Section 3.3.2 below.

Two approaches were used to assess the costs and benefits of therapeutic gardening:

(i) Quality adjusted life year (QALY)[12] approach, which uses the change in all participants' QALYs to derive estimates of the value of the health benefits resulting from the intervention. In this study one QALY was valued at £15,180.

(ii) A case study approach focused on how an individual might benefit from participation in the nature-based interventions.

It was not possible to get data on a participant's experience of therapeutic gardening offered by NHS Lothian. Instead, the experiences of a participant in a similar programme run in Gartnaval community garden in Glasgow was used, to gain an understanding of the cost savings to the NHS Lothian from such interventions.

The two existing therapeutic gardening activities run by the NHS Lothian have 350 participants annually. The Net Present Value (NPV) of the QALYs produced by this nature-based health intervention over a period of 50 years is estimated to be £4.65m (Table 5), producing a return on investment (RoI) of 2.00. That is, every £1.00 spent on therapeutic gardening results in benefits to health with a value of £2.00. Over a period of 10 years, the NPV is £0.80m and the RoI is 1.49. This demonstrates that the interventions produce estimated health benefits the value of which significantly exceed the costs of running them.

Table 5 Physical flows and annual monetary flows with net present values (NPV)* and return on investment (RoI), over 10- and 50-year discounting periods, of the therapeutic gardening intervention on the NHS Lothian estate.

Physical flow	Annual monetary flow	NPV		RoI	
		10 years	50 years	10 years	50 years
350 participants 17.34 QALYs	263,206	802,594	4,645,444	1.49	2.00

*Please note these are gross annual monetary flows but present values are presented net of the related costs for running the gardening programmes.

The annual economic benefits of a participant in a therapeutic gardening activity are outlined in Table 6. These benefits arise from the improvements to the participant's (Robin) health (see Annex 3.1.3). The estimated direct net avoided costs to the NHS are itemised in Table 6 and amount to £1,954 per annum. Due to of the lack of evidence of the long-term health and economic effects of therapeutic gardening, the benefits are assumed to last for one year only. This is a conservative assumption that is likely to understate the value of the benefits.

Table 6 Summary of net annual economic benefits from one participant involved in therapeutic gardening.

Benefits	Value
Increased prescription costs	-£130
Avoided psychiatric consultation costs	£888
Avoided use of community psychiatric nurse services	£1,196
Total	**£1,954**

[12] A QALY is a measure of the state of health of a person or group in which the benefits, in terms of length of life, are adjusted to reflect the quality of life. One QALY is equal to 1 year of life in perfect health. QALYs are calculated by estimating the years of life remaining for a patient following a particular treatment or intervention and weighting each year with a quality-of-life score (on a 0 to 1 scale). It is often measured in terms of the person's ability to carry out the activities of daily life, and freedom from pain and mental disturbance.

This delivers a net saving to the NHS that significantly exceeds the unit cost of these types of intervention compared with an indicative cost of £557 per patient per annum.

This analysis demonstrates the value of the health benefits from interventions that depend upon the green assets of the NHS Lothian estate. It would be possible to increase the therapeutic gardening intervention on the NHS Lothian by using existing gardens more intensively, or by creating one or more community gardens (we discuss the costs involved in this in Section 3.3.2 below). There are also reasonable areas of woodland on the NHS Lothian site to run conservation/outdoor activities. Hence, there is considerable potential to begin to run these activities on the NHS Lothian Estate while incurring little or no up-front costs.

3.3.2 Expanding nature-based health interventions

We outline the value of the benefits, and the return on investment that is gained from delivering therapeutic gardening opportunities on the NHS Lothian estate above. It demonstrated that the benefits from running this activity are considerably higher than the costs. This cost-benefit analysis was extended to explore the additional benefits from therapeutic gardening and from outdoor nature-based activities:

(i) CBA of creating a new garden at a site on the NHS Lothian estate with one programme of gardening courses for 180 patients per year.
(ii) CBA of using one reasonable sized greenspace on the NHS Lothian estate to run one programme of outdoor activity involving 180 patients per year.

The CBA used the same two approaches – QALY and the case study approach. In this section the case study approach was used as an alternative measure of the benefits from outdoor nature-based conservation activities. This uses a participant from the Edinburgh and Lothians Greenspace Trust Branching Out programme as an example of the benefits that running a similar programme on the NHS Lothian estate could bring. The details of the methods and the case study are in the Annex 3.

Table 7 Physical flows, annual monetary flows, net present values (NPV) and return on investment (RoI), over 10- and 50-year discounting periods, of (i) setting up a new garden site on the NHS Lothian estate for therapeutic gardening and (ii) to run one nature-based conservation activity programme using the natural capital assets of the NHS Lothian estate.

Physical flow	Annual monetary flow	NPV		RoI	
		10 years	50 years	10 years	50 years
(i) New garden site 180 participants 8.92 QALYs	135,363	356,153	2,283,278	1.40	1.92
(ii) New nature-based conservation programme 180 participants 8.92 QALYs	135,363	411,102	2,384,356	1.49	2.00

*Please note these are gross annual monetary flows but present values are presented net of the related costs for running the interventions.

Table 8 Summary of the net annual economic benefits from one participant involved in Branching Out, and outdoor nature-based conservation activity programme.

Benefits	Value
Avoided prescription costs	£32
Avoided psychiatric consultation costs	£111
Avoided use of community psychiatric nurse services	£2,392
Avoided use of support worker	£1,248
Total	**£3,783**

Table 7 shows that a programme of therapeutic gardening on a new community garden will deliver benefits that value £2.28m over 50 years and £0.36m over 10 years, with RoIs of 1.92 and 1.40, respectively. A programme of outdoor activities will deliver benefits that value £2.38m over 50 years and £0.41m over 10 years, with RoIs of 2.00 and 1.49, respectively.

The case study approach demonstrates that the estimated direct avoided costs to the NHS from an individual participating in an outdoor nature-based conservation activity amount to £3,783 per annum (Table 8). Due to the lack of evidence of the long-term health and economic effects of Branching Out, the benefits are assumed to last for one year only. This is a conservative assumption that is likely to understate the value of the benefits.

As with the CBA results for the current therapeutic gardening activity on the NHS Lothian Estate (Section 3.3.1), the value of the benefits significantly exceed the costs of running the activities. The RoI from setting up a new garden on the NHS Estate for therapeutic gardening (Table 7) is slightly lower than the RoI of the existing activities (Table 5), but is the same as the existing therapeutic gardening for creating a programme akin to 'Branching Out' based on the green assets of the NHS Lothian estate.

The results from two approaches to the CBA demonstrate that creating more nature-based activities on the NHS Lothian estate would deliver significant health and well-being benefits, the values of which exceed the costs of running the programmes, and that the green assets of the estate would allow this to be rolled out across a number of sites (see case study site recommendations for opportunities Section 4 and Annex 1).

3.4 Estate scale recommendations – green interventions

The estate, and site scale (Section 4, Annex 1), recommendations were informed by a literature review as well as site visits (for details see Annex 4.1.4).

Provide **bigger, better**, and **better-connected** greenspaces in the NHS Lothian estate for biodiversity, carbon sequestration and air quality.

BIGGER GREENSPACES

- Increase the extent of greenspace across the NHS Lothian estate by
  - Reducing car parking provision (e.g. by 25%, which will involve improving active travel infrastructure for staff and visitors).
  - Ensuring that site-scale changes follow the principles of biodiversity net gain so there is only ever an increase, and no net loss, of biodiversity across the estate.

BETTER GREENSPACES

- Improve the quality of existing greenspace on the estate to support biodiversity, sequester carbon and mitigate air pollution by:
    - Increasing the biodiversity units across the estate from 484 to at least 629 in the short term.
    - Maximising continuous tree canopies through and across sites.
    - Planting new trees following existing research and guidance for pest and disease resilience and optimising biodiversity and carbon sequestration – see recommended list of tree species for planting below.
    - Increasing and improving the extent of mixed hedges within the site – see recommended list of hedge species and cultivars below.
    - Examine capacity of green roofs to be planted with shrubs and vegetation.
    - Creating community gardens, allotments and/or growing spaces on all NHS Lothian sites.

BETTER-CONNECTED GREENSPACES

- Improve the connectedness of existing and future greenspace across the estate by:
    - Working in partnership with neighbouring landowners and land managers to increase tree canopy cover in communities beyond the boundaries of NHS Lothian sites.

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Maintain the quality of future, improved greenspaces on the estate by:
    - Carrying out greenspace site management plans with local experts to increase tree canopy and hedge cover, introduce scrub and, where parkland is retained, incorporate more relaxed mowing regimes.
    - Ensuring that necessary skills (e.g. in arboriculture) are embedded into the delivery of management plans and specified in management contracts
- Incorporate the Natural Capital Asset Register and Accounting tool into decision-making, e.g.
    - NHS Lothian property/ asset systems
    - NHS Lothian strategies such as net zero carbon; estate acquisitions and disposals; car parking.
- Regularly collect and maintain datasets to maximise the usefulness of the Natural Capital Accounting tool, including tree surveys, greenspace audit, assessment of condition of greenspace in new/ developed sites, biennial biodiversity audit
- Work strategically with existing partners, such as NHS Forest, to share knowledge, expertise, data and capacity

WELL-USED HEALTHY GREENSPACES

- For all hospital site users (patients, staff, local community):
    - improve signage on all sites to improve awareness of walking opportunities, link to existing routes and greenspaces/ parks adjacent to the hospital sites
    - reinstate/ update site walking routes and maps for all hospital sites, coordinating with local partners (e.g. ELGT, The Ramblers).
- For patients: increase the use of community gardens and social ‘green’ prescribing to all sites, coordinating with local delivery partners to increase prescribed activities (e.g. Cyrenians, Branching Out programme)

    - Make regular evaluation of prescribed activities to show changes in primarily mental health, in 'before and after' format with formalised indicators to measure benefits over time (e.g. to measure QALYs).
- For staff: regularly communicate the potential use of greenspaces through staff wellbeing programmes.
    - Designate a coordinator to work across the NHS estate with local partners to organise, deliver and publicise staff wellbeing programmes.

Prioritising the recommendations: what are the low-cost quick returns that could start now?

0. Increase the use of existing community gardens: this could immediately be increased by 50% with no detrimental impact on resourcing/ staffing.
1. Ensure the evaluation of ongoing prescribed activities is in a 'before and after' format and agree on formalised indicators to measure health benefits over time (e.g. to measure QALYs).
2. Identify locations for more relaxed mowing regimes to be introduced into grounds maintenance – e.g. leaving sections where grass grows tall (which could later be planted up with trees and/ or hedges) and incorporate into existing management plans.
3. Publicise findings from the report and Natural Capital Asset Register with staff, via staff wellbeing programmes.
4. Incorporate the Natural Capital Asset Register and Accounting tool into decision-making: the tool is ready to use for modelling different 'what if?' scenarios – this would help start a debate about reducing car parking.
5. Identify areas on sites for future community gardens/ allotments/ growing spaces (using the Cyrenians (2011) feasibility study as a starting point).
6. Identify (gaps in) existing datasets including, tree surveys, greenspace audit, assessment of condition of greenspace in new/ developed sites, biennial biodiversity audit.
7. Assess existing signage across the site and test the 'walkability' of existing routes and maps, reinstating those that are valid.

Table 9 Indicative list of tree species for consideration on site. Specific recommendations for each site are made below.

Small trees	Medium trees	Large trees
Cherry (e.g. *Prunus Umineko*) Apple Woodland Hawthorn (*Crataegus laevigata*)	Hawthorn (*Crataegus monogyna*) Rowan hybrid (*Sorbus x arnoldiana*) Field maple Goat and Crack willow Callery Pear Swedish Whitebeam	Birch species, including Silver Birch* Scots Pine** Beech** Oak (Sessile and English)** Mountain Ash Sweet/wild cherry (*Prunus avium*) Sycamore*** Common holly*** Lime (common, large-leaved, small-leaved)** Norway spruce** Aspen*/ **/ *** Alder*** Turkish hazel* White willow Common Hornbeam* London Plane */ **

* caveat: these trees produce pollen when flowering.

** caveat: these trees can grow to a very large size (30m+)

*** In Edinburgh, Sycamore (12.1%) and common holly (11.1%) are currently over the recommended guidance that no species should exceed 10% of the tree population (Doick et al., 2017[12]) so should be planted in line with this guidance.

Table 10 Indicative list of species and cultivars to be included in hedges on site, which should be mixed wherever possible to gain multiple ecosystems services for air quality, biodiversity, carbon sequestration (and health/ wellbeing).

Species/ cultivar	Air quality	Biodiversity	Carbon sequestration	Other notes
Juneberry/ shadbush *Amelanchier lamarckii*		✔		Potentially invasive
Darwin's barberry *Berberis darwinii*		✔		Potentially invasive
Barberry *Berberis thunbergii*	✔			Good for noise mitigation with other species; Potentially invasive
Common box *Buxus sempervirens*	✔	✔		Also good for noise mitigation; tolerates heavy metals, good for water management
Camellia japonica	✔			May provide some human restoration potential due to mid-deep green leaves and range of flower colours, where limited pruning encourages flowers.
Camellia sansanqua	✔			
Hornbeam *Carpinus betulus*	✔	✔		Considered useful at providing psychological 'refuge', e.g. used in stress restoration gardens
Japanese quince *Chaenomeles japonica*		✔		No species recorded in NBNAS
Mexican orange blossom *Choisya ternata*		✔		Species/cultivars have restorative effects i.e. promoting feelings of serenity, refuge and sense activation.
Common hazel *Corylus avellana*		✔		Capacity to release allergenic pollen
Cotoneaster spp. various		✔		Potentially invasive
Hawthorn *Crataegus monogyna*	✔	✔		Has potential for noise mitigation
Silverberry/ oleaster *Elaeagnus × ebbingei*	✔			
Red cascade *Euonymus europaeus*		✔		Potentially invasive

Japanese spindle tree *Euonymus japonicus*	✓			Good for noise mitigation with other species
Beech *Fagus sylvatica*		✓		Used as hedge spp. in therapeutic gardens; Relatively minor noise mitigation
Forsythia spp. and cultivars		✓		
Hebe spp. and cultivars		✓		
Hypericum × hidcoteense 'Hidcote' *St John's Wort*		✓		
Holly *Ilex aquifolium*	✓		✓	Has potential for noise mitigation; Potentially invasive
Bay laurel *Laurus nobilis*	✓			Has potential for noise mitigation
Lavender *Lavandula angustifolia*		✓		Considered to have mental health / restorative properties in humans due to hue and aromatics
Common privet *Ligustrum ovalifolium*	✓	✓		
Red robin tree *Photinia fraseri*	✓			Has potential for noise mitigation. No species recorded in NBNAS
Golden bamboo *Phyllostachys aurea*	✓		✓	Potentially invasive
Firethorn *Pyracantha coccinea and cultivars*	✓	✓		Potential for noise mitigation with other species; Potentially invasive
Flowering currant *Ribes sanguinium*		✓		Potentially invasive
Rosa rugosa *Rugosa rose*	✓			Tolerance to sulphur dioxide and lead, but not particularly effective at removing particulate matter
Skimmia japonica *Skimmia*	✓			
Snowberry *Symphoricarpos albus*		✓		Potentially invasive
Common yew *Taxus baccata*	✓	✓		Most parts of the plant are poisonous
Western red cedar *Thuja plicata*		✓		Some potential for carbon sequestration; Species has allergenic properties
Viburnum tinus *Viburnum*	✓	✓	✓	
Weigela florida *Weigela*	✓			

This information has been extracted from peer-reviewed journal articles and reports (see Annex 4.1.4).

4. Site level case studies

The previous sections have described the assessment of natural capital at the estate scale. It has been established that the estate is made up of 94 sites that vary in their greenspace type, quality, biodiversity and capacity to provide carbon sequestration and air quality regulation benefits. This section provides a summary of the natural capital assessments of five of the estate sites - Royal Infirmary Edinburgh, St John's Hospital, Western General Hospital, Musselburgh Primary Care Centre and Ellen's Glen House. These sites were considered priority sites for assessment and represent different types of NHS service, e.g. city and community hospitals, medical centres and care homes were included. The same methods are used at the site scale as for the whole estate, but with the addition of maps of the natural capital assets, the provision of the two services, the condition score assigned to each habitat and a map showing the connectivity of the sites to surrounding green infrastructure. The detailed results and maps for these sites are in Annex 1. These assessments are useful for understanding site baselines, so that the general interventions (Section 3.4) can be tailored to the suit the context of the site. Maps for a further 5 priority sites have been produced and feature in Annex 2.3.

4.1 Summary of case study results

The individual site natural capital assessments each contain a summary description of the grounds, a breakdown of the natural capital assets, the ecosystem service provision and value, the condition and biodiversity units of the site, followed by an assessment of their connectivity to off-site greenspaces. This is followed by site specific recommendations on how to increase the quality and the size of the greenspaces, how to better connect them, and manage to enhance biodiversity, carbon sequestration, air quality regulation and health benefits.

The sites differ significantly in size, with the Royal Infirmary Edinburgh being the largest hospital site (Table 11). St John's and the Western General Hospital are similar sizes (15 and 17 ha), with Musselburgh Primary Care Centre and Ellen's Glen House being 1 and 2 ha (Table 11). The proportion of the site that is greenspace varies across these sites, the Royal Infirmary Edinburgh and St John's Hospital, despite their differences in size, both having around 40% greenspace. The two smaller sites show how the proportion of greenspace can vary considerably even in sites of a similar size (Table 11).

Table 11 Total site area, area and proportion of greenspace, and area and proportion of sealed surface at each of the five case study sites.

Site	Area of Site	Area of greenspace (ha)	Greenspace (%)	Area of Sealed surfaces (ha)	Sealed surface (%)
St John's Hospital	16.79	6.55	38.99	10.24	61.01
Royal Infirmary Edinburgh	33.88	13.36	39.42	20.53	60.58
Western General Hospital	15.20	2.94	19.35	12.26	80.65
Musselburgh Primary Care Centre	1.04	0.08	8.02	0.96	91.98
Ellen's Glen House	1.64	1.27	77.35	0.37	22.65

The types of habitats at the sites do not vary significantly, in that there is a mix of semi-natural habitats (woodland, parkland, scrub) with urban landscaped type habitats (amenity grassland, introduced shrubs). The three largest sites have a predominance of amenity grassland, with woodland and parkland. The smallest site is mainly shrub borders, hedges and tree planting.

However, the assets of Ellen's Glen House are quite different with a predominance of broadleaved woodland (57% of the site). This is reflected in the biodiversity unit score where Ellen's Glen house may not have the highest total units (Table 12), but certainly has the highest number of units per hectare.

Table 12 The biodiversity units, annual physical and monetary flows of the carbon sequestration and air quality regulation services at each of the five case study sites.

Site	Biodiversity units	Carbon sequestration		Air quality regulation	
		Annual physical flow (tCO_2e/year)	Annual monetary flow £(2020)	Annual physical flow ($tPM_{2.5}$/year)	Annual monetary flow £(2020)
St John's Hospital	31.72	15.5	1,076	0.04	6,441
Royal Infirmary Edinburgh	78.18	43.1	2,986	0.13	32,400
Western General Hospital	13.71	7.4	512	0.03	7,674
Musselburgh Primary Care Centre	0.22	0.3	17	0.0006	91
Ellen's Glen House	8.50	8.8	613	0.02	5,448

Note that the annual monetary flow values will vary not only with the level of physical flow but also with the geographic location of the site (see methods Annex 2.5.2).

At all sites the condition of the habitats are either moderate or poor, leaving plenty of opportunities for improving the overall biodiversity scores by replacing the habitats of low biodiversity value (e.g. amenity grassland and introduced shrub), and by managing the semi-natural habitats into moderate or good condition. For example, the biodiversity units for St John's Hospital could be increased from 31.72 to 42.30 by managing the parkland broadleaved trees, hedges and hedges with trees to moderate condition. If amenity grassland and introduced shrub habitats that are not ecologically valuable habitats and can only achieve poor condition, were replaced with semi-natural grassland habitats or even trees or native shrubs, the biodiversity score could be increased further by at least 4.84.

Due to the variation in habitat type and extent across the sites, the annual physical and monetary flows of the carbon sequestration and air quality regulation services vary (Table 12). However, the sites that have the highest area of woodland, parkland, scrub and hedges will have the highest physical flow and monetary value. Ellen's Glen House has a high value for these services compared to its size, due to its large area of woodland.

All of the sites have opportunities to connect to greenspaces outside of the site. This will increase the biodiversity value of the sites themselves through the creation of habitat networks. It also may allow increased capacity for nature-based health activities, if local landowners were amenable.

4.2 Site scale recommendations

BIGGER GREENSPACES

- Reduce the amount of car parking.
- Remove under-used infrastructure (e.g. storage units and planters).

BETTER GREENSPACES

- Increase tree planting.
- Increase the extent of mixed hedges within the site.

- Reduce mowing regimes and introduce perennial wildflower planting to attract pollinators and invertebrates.
- Consider the creation of small community gardens/ growing spaces.

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Carry out a greenspace site management plan with local experts and partners.
- Work with local community groups to create a shared vision for the community garden/ growing spaces.
- Work in partnership with neighbouring landowners to explore potential woodland expansion and use of land for nature-based health activities.

WELL-USED HEALTHY GREENSPACES

- For all primary care centre site users (patients, staff, local community):
    - Publicise the new community garden/ growing space via local groups
    - Create walking routes from the site towards the River Esk with accompanying signage connecting outside the site.
- For patients:
    - Incorporate the community garden/ growing space into social prescribing programmes.
- For staff:
    - Use the greenspace (or future community garden/ growing space) for outdoor meetings and staff wellbeing programmes.

5. Conclusions

The value of NHS Lothian's natural capital assets

The greenspaces of the NHS Lothian estate cover 81 ha, and support a reasonably broad range of habitats, both semi-natural (woodland, scrub, rough grassland) and landscaped (amenity grassland, introduced shrub, tree planting and hedging). This study has measured just three of a number of ecosystem services that will be provided by the NHS Lothian estate natural capital assets. Whilst the provision of carbon sequestration, air quality regulation and health benefits are limited in terms of the natural capital that provides them, and in the number of nature-based health interventions that are currently run from the estate, the annual value of these benefits is £508,700, with a present value of £14.15 million over 50 years. This natural capital account is partial and the value of all the benefits provided by the natural capital of the estate are likely to increase this total value substantially. We have shown how the site scale natural capital assets vary considerably across the sites, and consequently, how the provision and value of these services changes across the estate.

Improve greenspace quality

At the estate scale 71.5% of the habitat polygons in the spatial asset register were assessed as poor condition. This is just over half of the estate greenspace area (43 ha). This offers opportunities and reasonably quick wins for increasing the biodiversity value of the site from its current baseline of 484 biodiversity units. The first target should be to increase the condition of the semi-natural habitats that have biodiversity value to moderate condition through more positive management. The second should be to convert the low biodiversity value habitats (amenity grassland, introduced shrub) to habitats that can achieve at least a moderate condition. This will also increase carbon sequestration and air quality regulation slightly (condition is not captured in these ecosystem service models, so the baseline results assume reasonable habitat condition). A target should be to increase the biodiversity unit baseline score at least to 629 in the short term.

Where the opportunities exist to increase the condition of habitats through both improved management, habitat restoration or and habitat replacement, habitats that are effective at sequestering carbon and regulating air quality should be the focus. These are habitats such as native mixed hedges, hedges with trees, tree planting and woodland. We have outlined particular species that perform well for these services and biodiversity. Rough grassland habitats also sequester carbon and take up pollutants, but to a lesser degree than woody species, but should also be considered for diversity and where it is not possible to plant trees. The use of green infrastructure like green roofs and walls would also increase the provision of these services and biodiversity. All of these approaches will increase the ability of the estate's natural capital assets to regulate water quality, alleviate flooding, regulate local climate and noise.

Increase greenspace quantity

Further gains in biodiversity and ecosystem service provision can only be achieved through increasing the greenspace provision at sites within the NHS Lothian estate. As outlined in the recommendations, this can be done by reducing car parking provision. It will be important to use the natural capital and biodiversity accounting tool (developed as part of this project) to track the consequences of site masterplans, any change to the sealed surface component of the estate (e.g. the addition of buildings, roads and car parks), and site disposals. The assets of the estate are a finite space. This makes compensation of any loss of greenspace tricky, but

it is necessary if the biodiversity and climate change policy responsibilities of the NHS Lothian are to be upheld, and for the estate to continue to promote health benefits from its green assets. Adding greenspace may be possible when sites are renovated, and should be considered in masterplans, or through acquisitions. The spatial tool can also be used to assess whether masterplans are likely to deliver biodiversity and ecosystem services net gain.

Connect with surrounding green infrastructure

As the creation of greenspace on the estate is limited, connectivity with surrounding greenspace may deliver an increase in biodiversity and health benefits. Connecting habitats and creating networks, particularly to habitats of strategic importance locally, can increase biodiversity. We have demonstrated the considerable benefits associated with nature-based health interventions that are hosted outside (e.g. conservation activity), and the use of greenspaces adjacent to estate sites can offer ways of delivering an increased number and diversity of programmes. Connecting woodland and providing a more continuous tree cover will also be beneficial for carbon sequestration, air quality regulation, local climate regulation and for increasing water quality and flood alleviation services. Working with local landowners and conservation organisations could help.

Encouraging more nature-based health activities

There are opportunities to increase nature-based health interventions on sites with existing community gardens (Western General Hospital and Midlothian Community Hospital): the use of these gardens could immediately be increased by 50% with no detrimental impact on them. For sites without gardens, creating a new community garden with one programme of therapeutic gardening courses for 180 patients per year would deliver benefits to the value of £2.28m over 50 years and with a return on investment (RoI) of 1.92. Creating a reasonably sized greenspace on the estate to run one programme of outdoor activities involving 180 patients per year would deliver benefits to the value of £2.38m over 50 years with an RoI of 2.0. Expanding the NHS nature-based interventions would be a cost-effective way of supporting the provision of considerable public health benefits. There is existing greenspace at larger sites such as St John's Hospital, Astley Ainslie and Royal Infirmary Edinburgh which could be converted to community gardens.

Promote the use of the estate as a health asset

To promote the use of the estate sites by patients, staff and the local community, improvements such as better signage of walking routes on-site, and routes to adjacent parks and greenspaces would be beneficial. To achieve increased use, promote community gardens that offer opportunities for social 'green' prescribing using local delivery partners, and greenspaces through staff wellbeing programmes.

Embed monitoring and evaluation

Take a more strategic approach to managing the natural capital assets of the NHS Lothian estate. Use the spatial asset register map and the linked natural capital and biodiversity accounting tool to assess changes at sites and their impact on the whole estate and use it to create and assess the meeting of targets and policy responsibilities (biodiversity and net zero carbon). Regular habitat and habitat condition surveys (using volunteers) will underpin biennial audits of biodiversity and ecosystem service provision. Create greenspace site management plans, perhaps with local environmental organisations, to increase the condition of habitats for biodiversity, and to create new habitats. Green asset management

skills need to be embedded into the delivery of these plans. Use a monitoring approach to collect data and evaluate nature-based health interventions.

Annex 1 Site level case studies

1.1 St John's Hospital

1.1.1 Grounds summary

The site has extensive parking with visitor parking at the north of the site and additional staff parking in the south of the site. The car park paving is not permeable. Around the site entrance and at spots around the car parks, there is ***space for more tree planting and replacement/enhancement of shrub and hedge planting***, and potential removal of planters. There are extensive and well-established hedges around the car parks (beech, laurel, rose) and some of the hedging could be improved and filled in as there are some gaps. There are heavy-duty planters acting as barriers which – if the access route is not needed, could be replaced with permanent tree and hedge planting. ***The vegetation is found mostly around the edge of the site and concentrated at the south***.

Figure 3 Extensive lawns and non-native shrub borders at St John's Hospital.

There are ***numerous banks of mown grass*** *(see Figure 3)*, some of which are bounded by established hedges (e.g. near Howden Health Centre) planted with individual trees (one a memorial tree). There is some ***forgotten space at the Health Centre*** (within the space of the H shaped building). It does not look to be accessible from indoors but is overlooked from the windows.

At the Outpatients building, there is a lone cherry tree in a grassed bank and vegetation that has recently been cut back. There is ***potential for additional and replacement planting***, such as a second line of (birch) trees could be planted along the main drive towards A&E with scope for continuing the hedging round the corner towards A&E on this bank of lawn.

The ***maternity buildings are dominated by parking*** and there is scope to improve the shrub planting around the maternity building. The two planters on raised gravel surfacing (not parking) could be replaced by tree planting if utilities allow. Additional planting could be included at the entrance barriers where there is a bank of grass (evidence of desire lines cutting across grass to car park). At the east of the site, there is a long strip of snowberry and gorse (adjacent to Howden Park).

There is ***no formal path along the eastern edge of the site*** but there are desire lines indicating that it is used by pedestrians, and consequently the shrubbery (cotoneaster) is getting damaged. There are many self-seeded trees around the east round to the south of the site

which could be removed and replaced with planted trees. At the east, there is evidence that people are accessing Howden Park from the site but ***there is no formal path between the Park and the hospital site***.

At the south end of the site, there is a ***copse of self-seeded trees*** which could be thinned out. There is a ***large expanse of grass*** with trees/ hedge mostly at the site edges and around the car parks. Within the grass at the south-west edge, there are some individual trees and ***a break in the hedge provides access off-site*** near the housing and the B7015 road. This indicates that people are using this greenspace at the south of the site as a cut through between the B7015 and Howden Park.

There is an ***extensive mix of tree species*** at the south of the site, including Swedish white beam, field maple, grey alder, pines, Portuguese laurel, cotoneaster, hawthorn. There are laurel hedges around this part of the site which also includes cotoneaster and barnet rose. Historic maps show that some of this woodland has existed here since at least the 1850s. Alongside the south – staff – car park, there is a gully of trees with Scots pine, hawthorn, lime, oak, willow. The Scots pine is a popular spot for smokers.

Moving from the south westwards around the site, there another ***very large, grassed area***, on a raised bank overlooking the hospital. 4 hawthorn trees have been recently planted and are struggling. ***Seating opportunities are limited,*** and people were seen immediately outside the hospital walking along the car park pavement to get exercise/ fresh air or sitting immediately outside in a walled space attached to the building. The bench outside the MacMillan Centre (different planting palate to elsewhere on site with grasses and silver birches subspecies) was being used.

Dotted around the west of the site, there are desire lines across small, grassed areas and scope for increased and improved planting which currently have scrubby shrubs and space for additional trees. This is also the case immediately alongside the main building (northwest corner) where there is some scrubby lawn which is lined with disabled signposts and hence rendered inaccessible.

In front of the main building, there is a ***gravel patch with planters*** which could be replaced/ enhanced with trees/planting. The central island at the hospital's main entrance is colourful with 4 well-established trees. The number of trees could be increased and ***lawned areas around the main entrance*** and A&E could be removed completely. ***When the annual planting needs replacing***, this could be replaced with perennial pollinator-attracting species. There are ***two old storage units*** outside the main facade of the building (between main entrance and A&E) which could be removed and replaced with tree planting. Visitors were seen meandering around here to make phone calls, chat and smoke.

1.1.2 Habitats, biodiversity and ecosystem services

St John's Hospital in Livingston, West Lothian, is 16.8 hectares in size, with 6.6 hectares of natural habitats. The asset register (Table A1.1) shows the natural capital assets are dominated by amenity grassland (2.1 ha) which covers 13% of the total area of the site. The amenity grassland occurs at the south-west edge of the site (Map A1.1), and in and around the buildings in the north-east of the site and throughout. Broadleaved parkland (1.8 ha) occurs mainly around the eastern edges and broadleaved woodland (1.2 ha) on the south-west and eastern edges. There is a large patch of rough grassland (0.6 ha) on the eastern edge

of the site, where it backs on to Howden Park. The rest of the natural areas are comprised of scrub, hedges and urban tree planting.

Map A1.1 Natural capital asset map of St John's Hospital.

Table A1.1 Asset register for St John's Hospital showing the area of each habitat type in hectares and the percent cover of the total area of the estate (including buildings and sealed surfaces).

Habitat	Area (ha)	% of area
Amenity grassland	2.1	12.7
Broadleaved planting	0.1	0.5
Broadleaved woodland	1.2	6.9
Parkland (broadleaved)	1.8	10.7
Rough grassland	0.6	3.3
Scrub	0.1	0.8
Hedge	0.1	0.4
Hedges including trees	0.2	1.0
Introduced shrub	0.5	2.6
Ditch	0.02	0.10
Disturbed land	0.01	0.08
Sealed surface	10.3	61.0
Total habitat:	**17.0**	**100.1**

The woodland, trees and hedges of St John's Hospital sequester a total of 15.5 tCO_2e per year, with an annual value of £1,076 and a present value (over 50 years) of £58,944 (Table A1.2). The area of woodland in the southwest corner of the site is sequestering carbon at a higher level than the parkland habitat and the urban tree planting (Map A1.2). The natural capital assets also absorb 0.04 $tPM_{2.5}$ per year, with an annual value of £6,441 and a present value of £233,389. The woodland in the south-west of the site is absorbing particular matter at a higher level than the parkland habitats and hedges. The condition of the habitats at this site were assessed as largely poor (81% of the habitat polygons) (Map A1.3). This is due in part to the amenity grassland and introduced shrub habitats which are of low biodiversity value. However, are hedges, hedges with trees and broadleaved parkland that are considered to be in poor condition, that with restoration could be a higher quality habitat. The moderate condition habitats tended to be broadleaved woodland and planting native hedgerows, scrub and rough grassland. There were no habitats considered to be in good condition at this site. The overall biodiversity units for the site are therefore relatively low (31.7), but these present opportunities for improvement. The biodiversity units for St John's Hospital could be increased from 31.72 to 42.30 by managing the parkland broadleaved trees, hedges and hedges with trees to moderate condition. If amenity grassland and introduced shrub habitats that are not ecologically valuable habitats and can only achieve poor condition, were replaced with semi-natural grassland habitats or even trees or native shrubs, the biodiversity score could be increased further by at least 4.84. This would also increase the provision of carbon sequestration and air quality regulation.

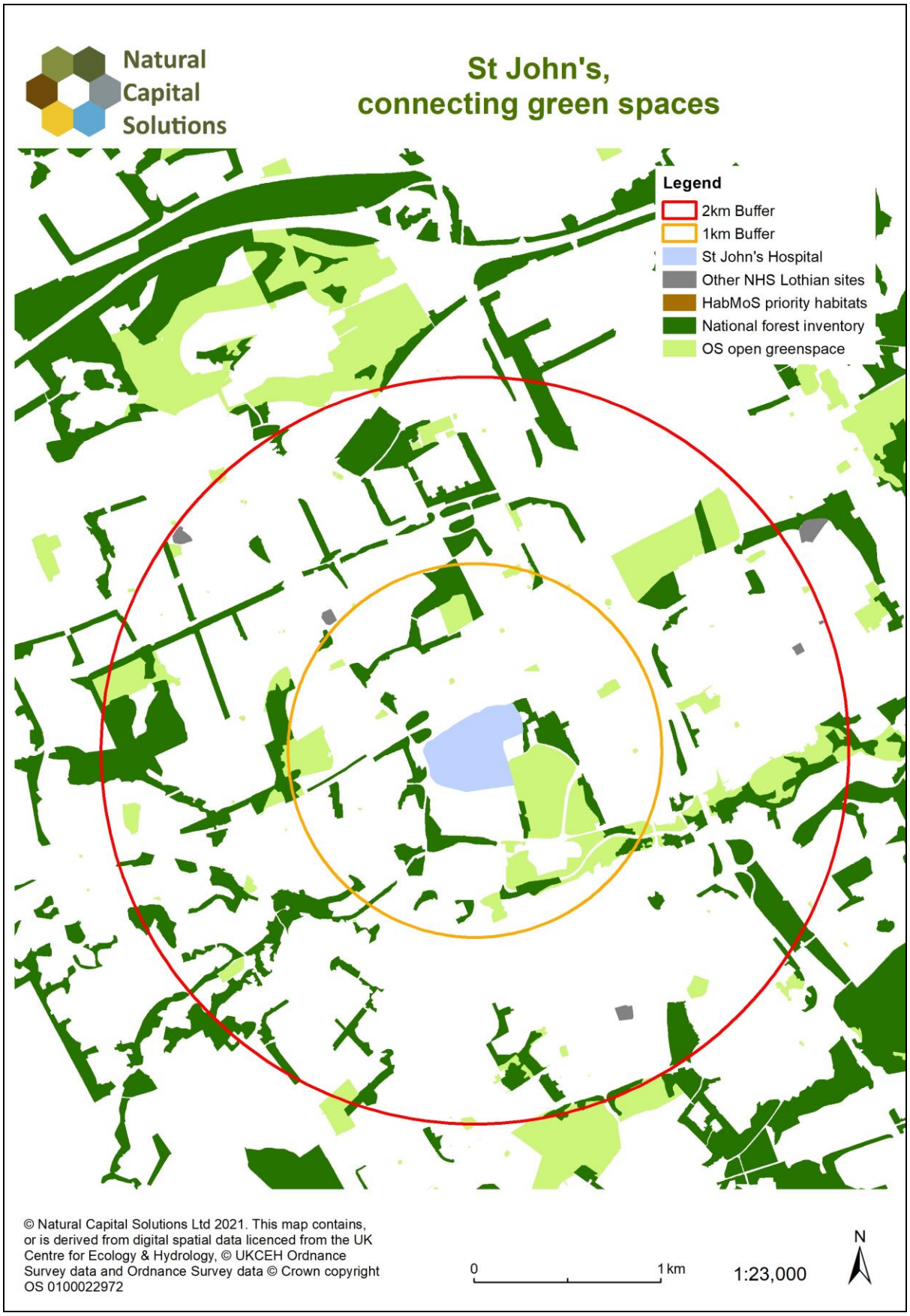
Table A1.2 Biodiversity units, annual physical and monetary flows and Present Value (over 50 years) of carbon sequestration and air quality regulation at St John's Hospital.

	Annual physical flow	Annual monetary flow £(2020)	Present Value (£) (50 years)
Carbon sequestration tCO_2e/year	15.5	1,076	58,944
Air quality regulation $tPM_{2.5}$/year	0.04	6,441	233,389
Biodiversity units	31.7		

Map A1.2 Carbon sequestration and air pollution regulation capacity of the natural capital assets St John's Hospital

Map A1.3 The condition of habitats at St John's Hospital.

Map A1.4 Greenspace connectivity of St John's Hospital habitats with priority habitats for biodiversity (Habitat Map of Scotland (HabMoS)), woodland and publicly accessible greenspaces within 2km of the site.



St John's hospital is surrounded by small fragments of woodland and greenspaces, for example, Howden Park and Almondvale Park to the east and southeast of the site (Map A1.4). This offers opportunities to connect the site with the surrounding habitats, maybe through planting trees at the edge of the grassland to join onto and expand existing woodland. The Parks also offer opportunities for expanding outdoor nature-based activities offsite.

1.1.3 Recommendations

BIGGER GREENSPACES

- Reduce the amount of car parking. Visitor parking at the north of the site as well as staff parking at the northwest and the south of the site should be removed, and trees/hedges planted to connect up existing deciduous woodland outside the site boundary.
- Remove the old storage units between the main entrance and A&E and replace with (tree) planting.
- Replace gravel patch and planters in front of the main building (ref. disabled parking) with trees/planting.

BETTER GREENSPACES

- Increasing the biodiversity units across the estate from 31.72 to at least 42.30 in the short term by considering the changes below:
- When the main entrance annual planting needs replacing, plant perennial pollinator-attracting species.
- Introduce less intensive mowing regimes on grassed lawns around the site (a move away from amenity grassland), particularly at the south end.
- Plant more trees within the site, including at the Outpatients building and along the main drive to A&E. Extend the existing woodland (some of which could be over 170 yrs old) at the south-west the site at the current (raised) lawn.
- Plant additional mixed hedges (e.g. hawthorn, cotoneaster, beech) to continue the existing hedge planting towards the A&E building and attend to gaps in the hedges around the north car park. This could also apply to where vegetation has recently been cut back at the Outpatients building.
- In line with the Cyrenians feasibility study (2011), create a community garden in the south of the site.
- At Howden Health Centre (east flank), introduce mixed spring-autumn pollinator-friendly flower planting as this greenspace is looked out onto and currently is bare.

BETTER-CONNECTED GREENSPACES

- Work with neighbouring landowners and land managers (e.g. West Lothian Council who recently published their Blue/Green Network Masterplan Report (2019)) to increase tree canopy and green cover beyond the site boundaries: with tree planting along Cousland Road (north), Howden Park (east) St Margaret's Academy and the River Almond (south) and tree planting along Alderstone Road (west).

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Carry out greenspace site management plan with local experts (e.g. West Lothian Council and Woodland Trust Scotland) to increase tree canopy and hedge cover, introduce scrub and, where parkland is retained, incorporate more relaxed mowing regimes.

WELL-USED HEALTHY GREENSPACES

- For all hospital site users (patients, staff, local community):
    - Introduce a path into the existing south lawn and signposts for routes through the site, e.g. to an accessible entrance to Howden Park and surroundings
    - Increase the number of seating opportunities within the site.
- For patients:
    - Incorporate the community garden and walking routes into social prescribing programmes
    - Consult with patients about whether existing (poor quality) trim trail would be used if repaired and signed (if not, the remove the broken equipment).
- For staff:
    - Regularly communicate the activities and potential use of greenspaces around the site through staff wellbeing programmes.

1.2 Royal Infirmary of Edinburgh

1.2.1 Grounds summary

Royal Infirmary Hospital is an extensive site surrounded by a ***large amount of parking***. On the edges of the site are significant tracts of greenspace including Craigmillar Park and Little France Park. While there is pedestrian and cycle routes and signage around the site, ***the signage does not connect up well with surrounding greenspaces***. The #newroyalmile QR links for the walking route on signs around the site were not working.

The walk between Gates 1 and 2 along the Niddrie Burn is at points a well-planted and pleasant walk which takes you away from the parking and the general hubbub around the hospital buildings. However, it is striking how ***few seating opportunities*** there are despite the almost continuous waist/chest-high handrail for people to put their drinks and lean against. The black gravel is striking against the green grass and seems to retain its edge well but may put off some people who are less steady on their feet.

Figure 4 Extensive mown lawns and high maintenance planting at Royal Infirmary Edinburgh.

There is *debris in the Niddrie Burn* **which needs clearing and some self-seeded vegetation which needs clearing.**

There is a ***very large swathe of mown grass*** at Gate 1 (alongside the A7/ Old Dalkeith Road. See Figure 4) with 17 trees planted in the lawn, of which 5 ***trees are dead or dying***.

At Little France Crescent, there ***are two incongruous, designed spaces at the entrance at Gate 1***: one ('modern') has small beds of naturalistic planting and young, struggling trees in tree pits. The other ('older') side of the road has ten well-established oak trees, low-level shrubs and ornamental lawn. Looking at historic maps, the 'modern' part was similar to the 'older' part of the entrance, but the vegetation has been completely stripped and it now feels like a hard-surfaced showcase entrance, but which has very little relationship to existing vegetation. Given the layout, it's not clear why the existing trees were removed. The ***parking at this part of the site is not in keeping with the pedestrianised nature of this particular area***.

Heading into the site along Little France Crescent, the site plan shows how at Gate 1, dedicated footpaths are harder to locate and one has to follow the road network. There is limited seating at the Royal Hospital for Children and Young People building entrance. The trees are mostly columnar in tree pits or in shrub beds. Hedges (hornbeam) are being trained up but in spots ***are dead or dying,*** like some (3/8) of the birch trees. This failing planting is nearest the building entrance (there are idling taxis around this area too). The hornbeam hedge improves as we move away from the parking leading to herbed edge planting beds alongside the building. The planting changes at the Anne Rowling Regenerative Neurology Clinic - a swathe of naturalistic planting (with lots of possibly unplanned for grasses) opposite more formalised planting that looks like it has been retained (beech hedge, lavender among them). There is one bench outside the Clinic on the crazy paving and planting at this entrance is close to the buildings.

Walking along Little France Crescent to the bus stop, the signs become confusing on the pavement for cyclists/ pedestrians and when buses are operating, are ***potentially unsafe***. There are some ***gaps in shrub planting*** outside the Chancellor's building. There is ***poor threshold connection up to Craigmillar Park***. There is a clear desire line which is disconnected from the footpath which has fencing designed to slow down cyclists. There are two picnic tables alongside a tall wire fence which is quite off-putting. People outside the Queens Medical Research Institute opting to sit on a low wall next to the road rather than at the nearby picnic tables. The signage should be updated to include Craigmillar Park and Little France Park (with hill) - currently ***they are not marked on the site plan or via signs around the hospital site***.

There is ***extensive grassed (sloping) space here*** around the Queens Medical Research Institute and opposite the Chancellor's building which is unused. The path up towards Craigmillar Park is good quality and linking up some way with both the views and the extensive woodland behind the hospital could be very useful to help people who want to make a walk of it, indicating the potential for ***reinstating the Ramblers Medal Route walks (or equivalent)***. On the north-east side of the site, the exit towards Little France has a small bank of woodland which is used extensively by smokers. One piece of trim trail equipment was found – it is not clear if this was well-used (there was no wear and tear on the surrounding grass). It seemed to be in a strange place, alongside the road. Could it be relocated and reunited with the rest of it, if it is surviving. It might be better used if it were set back further from the road or elsewhere on the site.

There is extensive parking on the site, alongside significant public transport provision, which would suggest that there is ***scope for reducing the scale of parking required***. This should be

considered alongside the ***scope for increased planting on the grassed areas*** around the site, and for water tolerant planting along the Niddrie Burn further along Little France Drive.

1.2.2 Habitats, biodiversity and ecosystem services

The Royal Infirmary of Edinburgh, situated in the southeast of the city, is the largest hospital site of the NHS Lothian estate at 34 hectares. The natural assets of the site cover 13 hectares. The main habitats on site are amenity grassland (3.3 ha), broadleaved woodland (2.7 ha), broadleaved parkland (2.1 ha), scrub (1.5 ha), rough grassland (1.2 ha) and broadleaved planting (see Table A1.3 and Map A1.5). The woodland, parkland and rough grassland habitat occur around the edges of the site. The amenity grassland is throughout the site, with hedges and scrub occurring in the north-east of the site in the car park area, with shrub and urban tree planting in the courtyard gardens.

Table A1.3 Asset register for the Royal Infirmary Edinburgh showing the area of each habitat type in hectares and the percent cover of the total area of the estate (including buildings and sealed surfaces).

Habitat	Area (ha)	% of area
Amenity grassland	3.3	9.6
Broadleaved planting	0.6	1.7
Broadleaved woodland	2.7	7.9
Mixed woodland	0.3	0.9
Parkland (broadleaved)	2.1	6.1
Parkland (mixed)	0.4	1.4
Rough grassland	1.2	1.3
Scrub	1.5	4.5
Hedge	0.1	0.3
Hedges including trees	0.2	0.7
Tall herb	0.4	1.3
Introduced shrub	0.5	1.5
Freshwater stream	0.4	1.1
Ditch	0.02	0.07
Sealed surface	20.5	60.6
Total habitat:	**34.2**	**99.0**

The woodland, trees and hedges of the Royal Infirmary sequester a total of 43 tCO_2e per year, with an annual value of £2,986, and a present value (over 50 years) of £163,559 (Table A1.4). Most of the sequestration is from the broadleaved woodland along the edges for the site, with the scrub habitats, parkland and urban planting also contributing, but to a lesser degree (Map A1.5). The natural capital assets also absorb 0.1 $tPM_{2.5}$ per year, with an annual value of £32,400 and a present value of £1.17 million (Table A1.4 Map A1.6). As with carbon sequestration, the woodland and scrub absorb the most pollutant, but the grassland also plays a role in delivering this service, albeit to a lesser degree.

Map A1.5 Natural capital asset map of the Royal Infirmary Edinburgh.

A little over half of the habitat polygons in the spatial asset register are estimated to be in poor condition (53.9%) but 46.1% are in moderate condition (Map A1.7). The large percentage of poor condition habitat is due to the presence of amenity grassland and introduced shrub. However, there are also hedge, parkland and scrub habitats that are in poor condition and, therefore, could be improved. The moderate habitats range from rough grassland, tall herb and hedges to scrub, broadleaved woodland, and broadleaved planting. The biodiversity unit baseline is 78.2.

Table A1.4 Biodiversity units, annual physical and monetary flows and Present Value (over 50 years) of carbon sequestration and air quality regulation at the Royal Infirmary Edinburgh.

	Annual physical flow	Annual monetary flow £(2020)	Present Value (£) (50 years)
Carbon sequestration tCO_2e/year	43.1	2,986	163,559
Air quality regulation $tPM_{2.5}$/year	0.1	32,400	1,174,012
Biodiversity units	78.2		

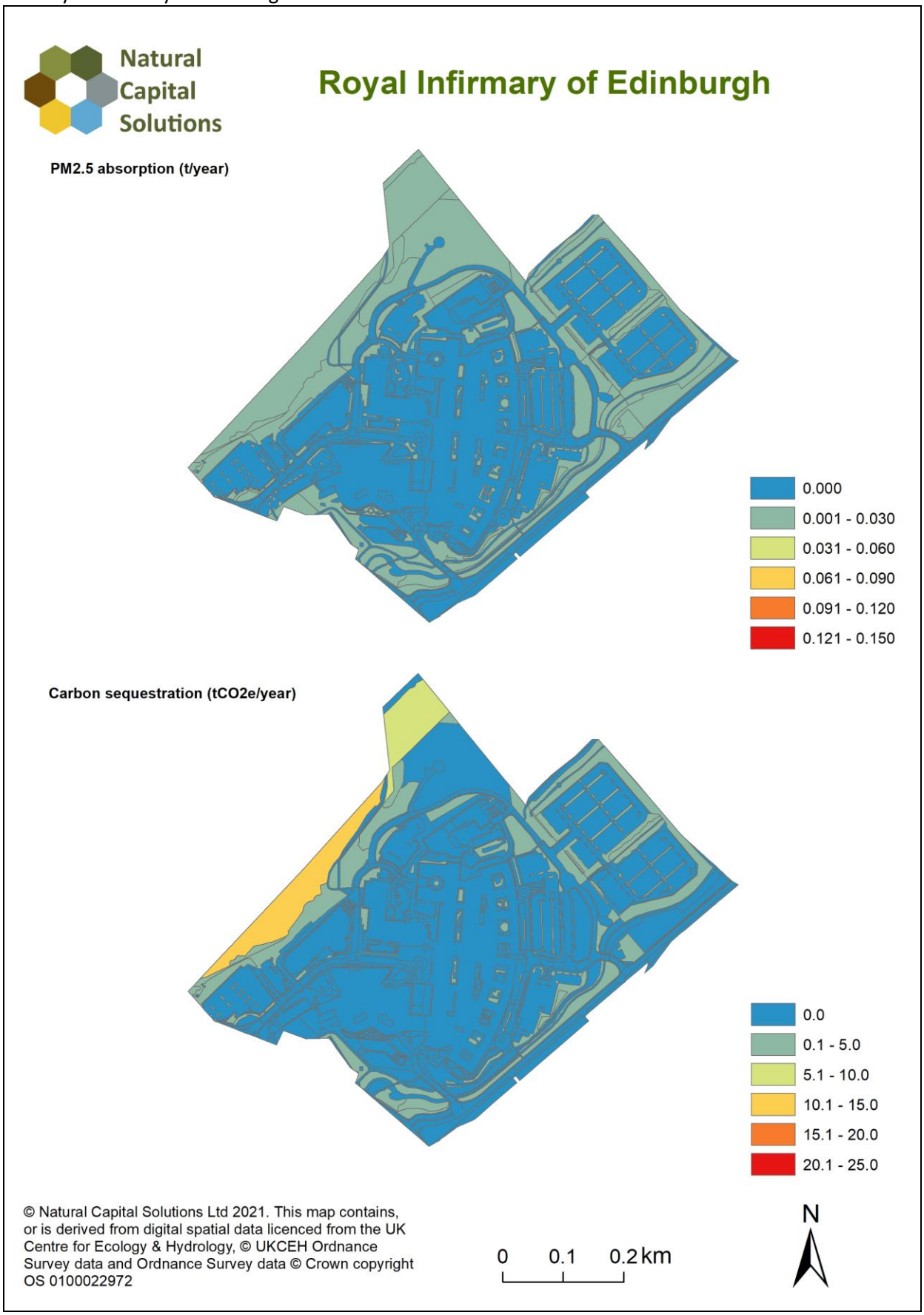
The greenspace connectivity map (Map A1.8) shows good connection of the site to a network of existing woodland and greenspaces, that eventually meet with priority habitat north-west of the site just outside the 2km boundary around Duddingston Loch, Arthur's Seat and Salisbury Crags. This is worth maintaining into the future as it will increase the biodiversity value. Expanding nature-based health activities onto the neighbouring Craigmillar Castle Park may possible.

1.2.3 Recommendations

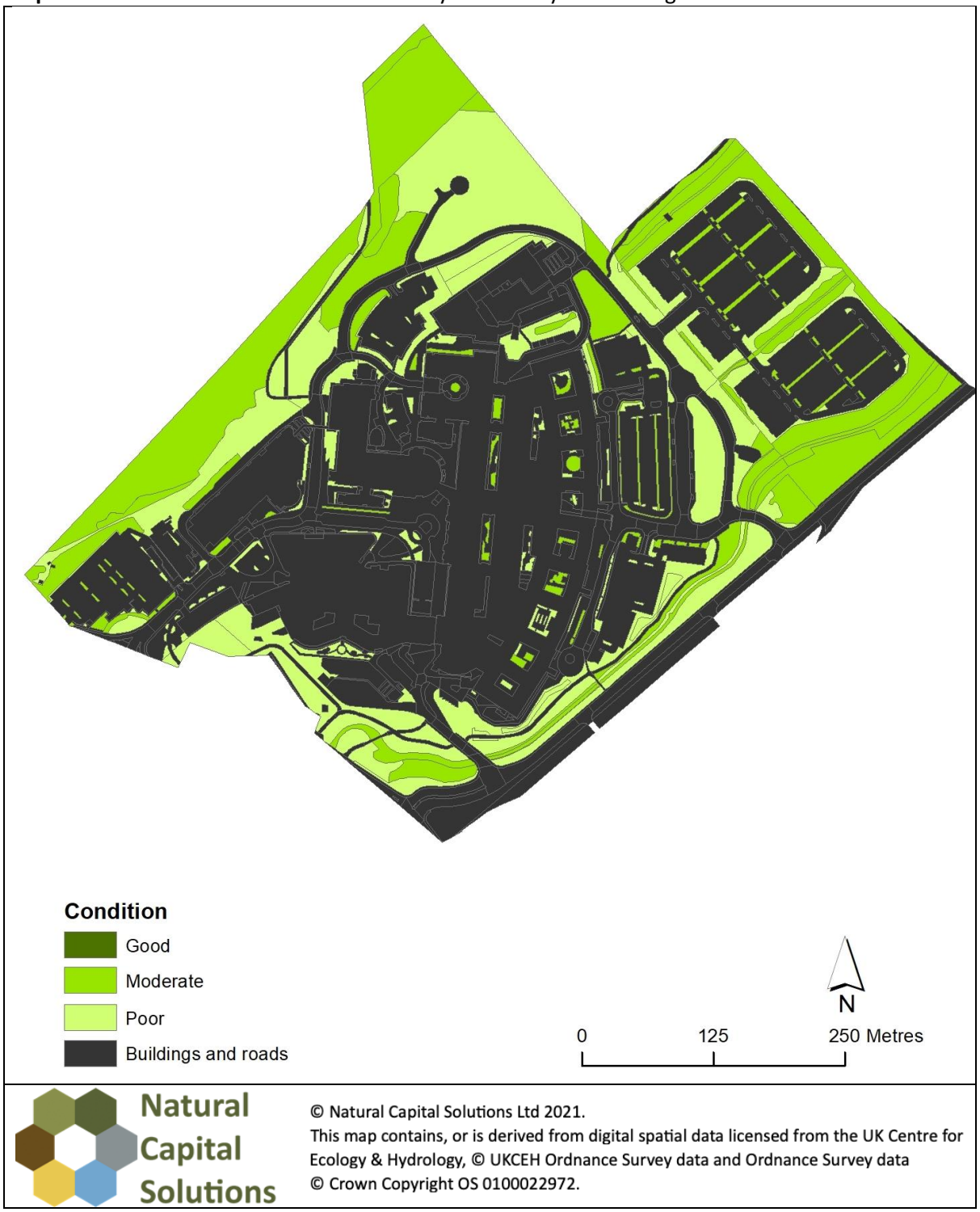
BIGGER GREENSPACES

- ***Reduce the amount of car parking.*** Peripheral parking on the western edge of the site as well as parking at Gate 1 (west of the site) should be removed and trees/ shrubs planted to connect up with Little France Park and woodland beyond Gate 3. The trees in this area could enhance the existing patches of deciduous woodland involving the planting of large trees such as Birch, Scots Pine, Beech, Oak, Mountain Ash and Cherry.
    - This will necessarily involve, e.g. improving the incentives for patients, staff and visitors to use existing public and non-motorised transport.

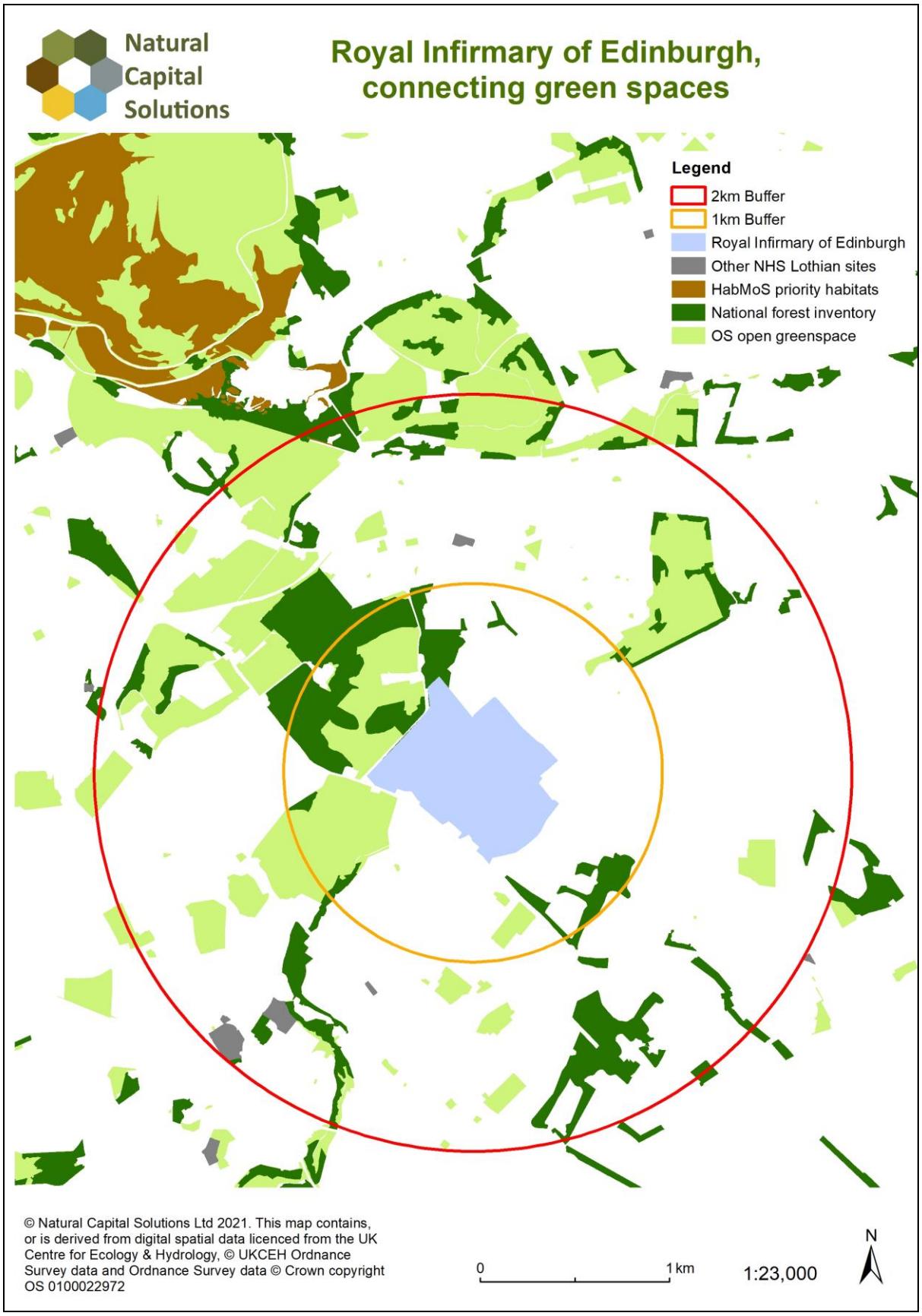
Map A1.6 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the Royal Infirmary of Edinburgh.



Map A1.7 The condition of habitats at the Royal Infirmary of Edinburgh.



Map A1.8 Greenspace connectivity of the Royal Infirmary Edinburgh habitats with priority habitats for biodiversity (Habitat Map of Scotland (HabMoS)), woodland and publicly accessible greenspaces within 2km of the site.



BETTER GREENSPACES

- Increase and improve tree planting on the grassed areas within the site. This will involve replacing the dead or dying trees in the grassed area around Gate 1. The trees in this area could enhance the existing patches of deciduous woodland and greenspaces.
- Increase water tolerant planting along the Niddrie Burn further along Little France Drive. Trees here might include: Willow (e.g. crack willow), Cherry (e.g. bird cherry) and Alder (e.g. common alder). This will involve clearing the debris in Niddrie Burn and possibly self-seeded vegetation.
- Increase and improve the extent of mixed hedges within the site. This will involve replacing dead or dying hedges and mixing hedges where one species currently exists. The choice of species will depend on the location, the function of the space (e.g. existing species in question).
- In line with the Cyrenians feasibility report (2011), create a community garden north-west of the site near the exit up towards Craigmillar Park.
- Introduce less intensive mowing regimes where lawns are not used by the public.

BETTER-CONNECTED GREENSPACES

- Work with neighbouring landowners and land managers (e.g. ELGT) to increase tree canopy and green cover beyond the site boundaries: with Craigmillar Park (north), Little French Park (east) the Bioquarter (south) and Liverton Golf Course (west).

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Carry out greenspace site management plan with local experts (e.g. ELGT, Friends of Craigmillar Park) to increase tree canopy and hedge cover, introduce scrub and, where parkland is retained, incorporate more relaxed mowing regimes.

WELL-USED HEALTHY GREENSPACES

- For all hospital site users (patients, staff, local community):
    - Create on-site signage which includes Craigmillar and Little France parks, providing a choice of routes (e.g. Medal Routes).
    - Increase the number of seating opportunities within the site.
- For patients:
    - Incorporate the community garden and walking routes into social prescribing programmes.
    - Consult with patients about whether existing (poor quality) trim trail would be used if repaired and signed (if not, the remove the broken equipment).
- For staff:

Regularly communicate the activities and potential use of greenspaces around the site through staff wellbeing programmes.

1.3 Western General Hospital

1.3.1 Grounds summary

This site has limited greenspace with **most of the outdoor space comprised of hard surfacing** such as car parking, roads and pedestrian walkways. There are lots of mature trees (around the boundary edges), shrub beds, bedding plants and freestanding planters. There is amenity planting on-site such as lavender shrub beds to ornamental hedges and more formal flower beds around Royal Victoria Buildings. In some places, the **planting is not well-maintained** and is blocking out natural light, particularly in the Anne Ferguson courtyards as well as on the southern side of the Royal Victoria Building (see Figure 5). There is colourful planting adjacent

to the visitor Car Park 1, including **a large bed of annual planting** that needs replanting (currently its largely full of pelargonium geraniums) which are not favoured by pollinating insects.

Figure 5 Planting at Anne Ferguson Building and overgrown planting in a courtyard garden at the Western General Hospital.

The map outside the visitor car park is not very easy to understand. The pavements/**pedestrian infrastructure around the site is at times not easy to navigate,** e.g. on Porterfield Road, the bus stop, grit bin and barrier clutter up the pavement. Desire lines show that people are walking on the other side of the road which is **adversely affecting the planting** (lavender and the bed of wildflowers opposite the visitor car park) along the route. Alongside the car park, **some of the beds are in need of replanting**. To the east of the visitor car park, along Crewe Road South, there is an access path (technically open to the public but not obvious or particularly welcoming) which is lined with trees and shrubs. The other end of this path takes you to a small stretch of grass at the staff car park behind the Anne Ferguson building and a solitary picnic table which blocks the path. This arrangement is replicated along Crewe Road South with lawn, trees and locked gates (for security). In essence, **the lawns and trees can be seen but not accessed**.

Accessible only from within Royal Victoria Buildings, there is **a large formal garden with seating area and steps**. The steps are for occupational therapy patients. According to the on-site Head Gardener, this garden is very well-used. The original planting was retained (mixed shrubs including cotoneaster) which is low maintenance, with new flowerbeds as well as established low beech, box and cotoneaster hedges. The **recent new benches** that have been introduced as a result of the popularity of the garden with staff. The **initial entrance to the garden is currently bare** earth and unappealing – this could be planted up. There is **scope for planting trees and extending hedges** alongside the Crewe Road South edge of the garden to enhance privacy and potentially help biodiversity.

There are seven courtyards in the Anne Ferguson building which are never used by patients or non-gardening staff because of fire safety issues. Three of the courtyards have no planting in them, instead housing fans and skylights; the third can't realistically be overlooked by internal rooms which are surgery spaces. This sensitive location makes it very difficult to maintain this space.

Where there is planting in the courtyards, these range from being a planting/ growing/ greenhouse space used by gardening staff (C3) to providing some planting visible through the window. However there are **problems with pigeons roosting** (C3) meaning windows have to remain closed (in a Glasgow hospital, a patient died of infection when a pigeon got inside). Office staff apparently regularly complain about the **lack of natural light** (C3, 5, 6). The suitability and **low quality of the courtyard planting** which is part of commissioning contracts is called into question by gardening staff.

There are some wildflower beds (e.g. adjacent to Anne Ferguson building) which are a little incongruous next to the formal 'beehives' (pelargoniums which do not attract pollinators) and low-key evergreen shrub planting. Elsewhere on the hospital site there are beds of wildflower planting alongside the roadways. The **wildflowers are cut back, sprayed off and resown annually**.

There are **shrub beds (herbs) in need of maintenance** which have been damaged because of footfall. Planting which is in raised beds (so people don't stand on the soil) is faring better than those planted flush to the ground.

As one walks up Hospital Main Drive where lots of construction is happening, the **number of large, mature trees** increases and it feel like an older, more established part of the site - very different from the north of the site. Walking through the car park to the Maggie's Centre (not currently accessible from elsewhere due to construction) was through thick box hedging (at least 3-4 feet wide) and more mature, overhanging trees. The Head gardener pointed out that there was more hedging around the site but issues around claims for hand and arm vibration-related injuries had informed a decision to half all the hedging on site. Some of the neighbours have apparently complained about lack of natural light and shading into their properties from these large trees. **Amanda's Garden** is a secluded garden with benches and mixed shrub and tree planting. The maintenance is provided by the brother of a patient who died at the hospital. The garden is used as a place to east (with litter around the space), and is in **need of maintenance** including low-scale repairs to the stone sculpture.

The planting in **Maggie's Centre** is very distinct from what is seen elsewhere on site, although there is a sense of being in a highly managed and controlled space. Materials (stone and resin pathways) are different from elsewhere on site, as is the planting throughout. Planting is still taking so there are some gaps and longer term, it looks like there will be tall beech planting for privacy.

NB. The **FACE Garden** on this site was not accessed (due to construction activity). Immediately outside the Edinburgh Cancer Centre, it was very well-used by patients and staff, but it does not appear on the 2045 masterplan.

Around the hospital site, there are patches of amenity grass, some of which have picnic tables. One picnic table installed on Hospital Main Drive near the adjacent run of houses resulted in a high fence and hedge being erected at the residents' request. While others are used, **these particular picnic tables show little/ no evidence of use** (e.g. no desire lines).

1.3.2 Habitats, biodiversity and ecosystem services

The Western General Hospital, situated in the north-west of the city is 15 hectares in size. The natural assets of the site cover 2.9 hectares. The main habitats on site are mixed pakland (0.9

ha), amenity grassland (0.7 ha), broadleaved parkland (0.4 ha), broadleaved woodland (0.3 ha), and broadleaved planting and introduced shrub (0.2 ha), and mixed tree planting (0.1 ha) (see Table A1.5 and Map A1.9).

Map A1.9 Natural capital asset map of the Western General Hospital.

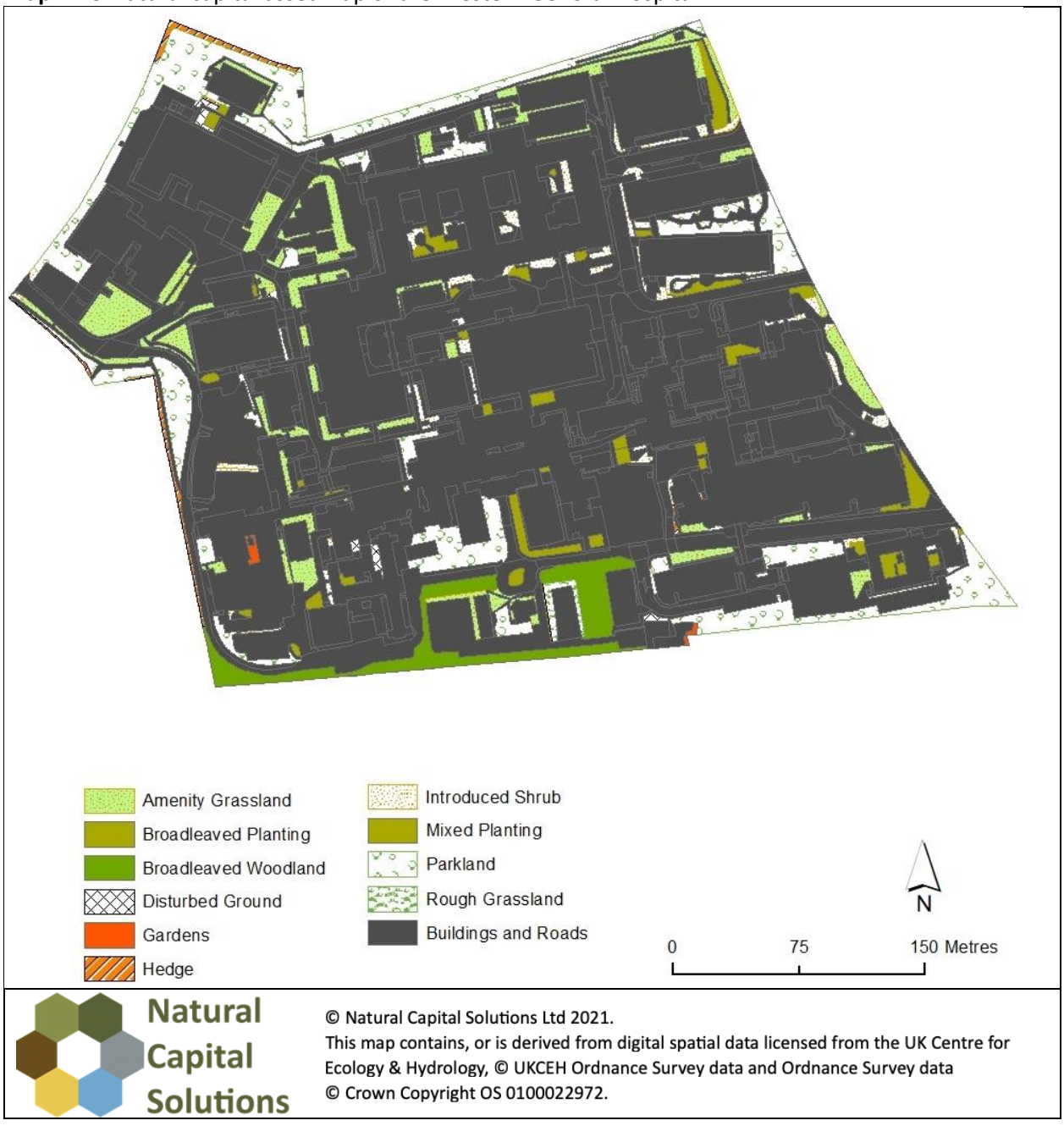


Table A1.5 Asset register for the Western General Hospital showing the area of each habitat type in hectares and the percent cover of the total area of the estate (including buildings and sealed surfaces).

Habitat	Area (ha)	% of area
Amenity grassland	0.7	4.5
Broadleaved planting	0.2	1.4
Broadleaved woodland	0.3	2.2
Disturbed ground	0.02	0.2
Gardens (lawns and broadleaved trees)	0.01	0.08
Hedge	0.02	0.1
Hedges including trees	0.06	0.4
Introduced shrub	0.2	1.6
Mixed (tree) planting	0.1	0.5
Parkland (broadleaved)	0.4	2.6
Parkland (mixed)	0.9	5.6
Rough grassland	0.03	0.2
Sealed surface	12.3	80.7
Total habitat:	**15.2**	**100.1**

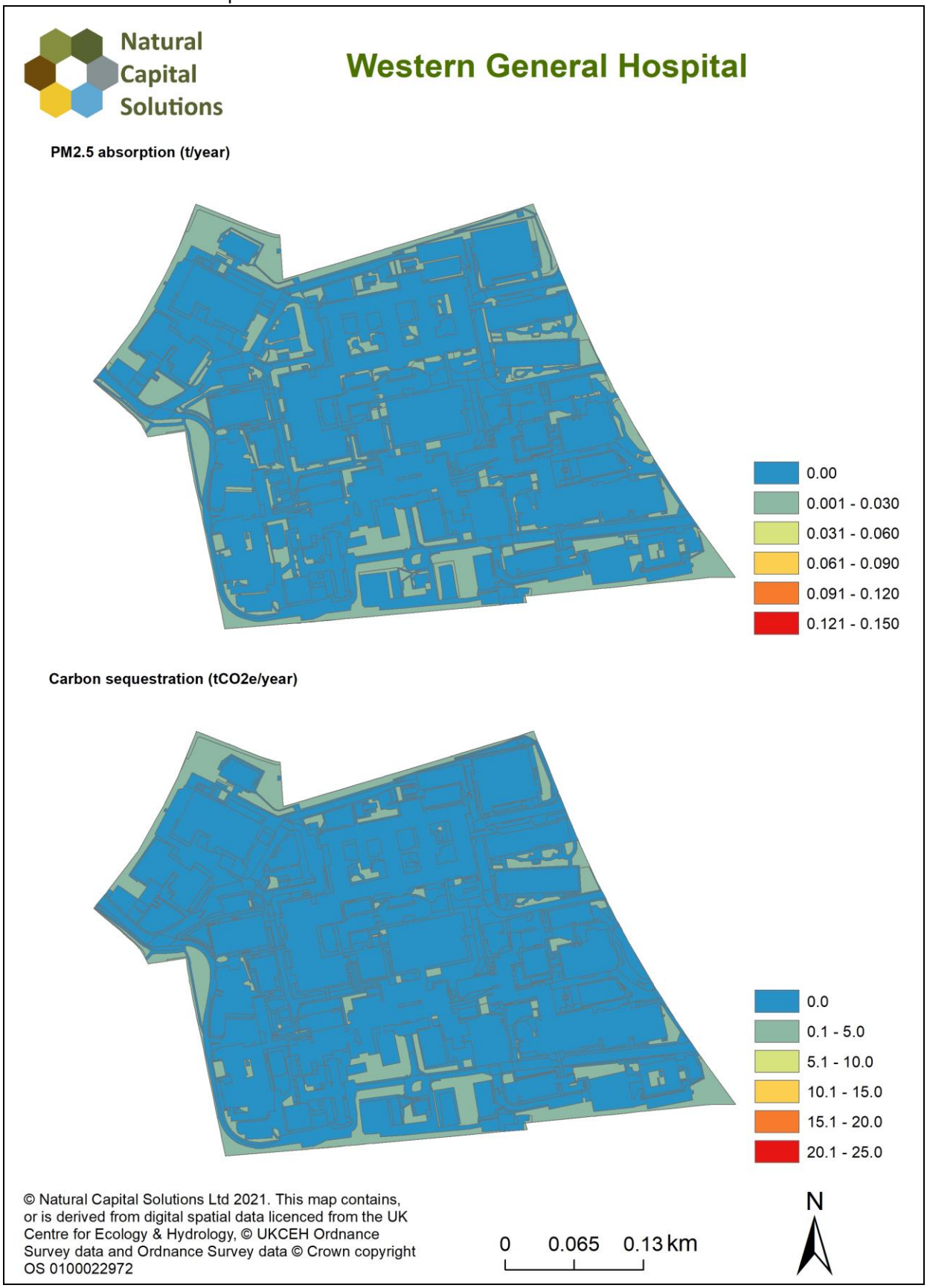
The woodland, trees and hedges of the Western General sequester a total of 7.4 tCO_2e per year, with an annual value of £512, and a present value (over 50 years) of £28,054 (Table A1.6). Most of the sequestration is from the vegetation on the outskirts of the site (broadleaved planning, hedges and parkland) (Map A1.10). The natural capital assets also absorb 0.03 $tPM_{2.5}$ per year, with an annual value of £7,674 and a present value of £278,054 (Table A1.6 Map A1.10). As with carbon sequestration the woodland and scrub absorb the most pollutant, but the grassland also plays a role in delivering this service, albeit to a lesser degree.

Eighty percent of the site's habitat polygons in the spatial asset register are estimated to be in poor condition (Map A1.11). Amenity grassland, disturbed ground and introduced shrub will always be categorised as poor condition, as mentioned above, these are considered to have little biodiversity value. However, hedges, hedges with trees, the garden tree and lawn habitats, mixed and broadleaved parkland are also in poor condition, which offers opportunities for restoration and an increase in biodiversity value. The broadleaved woodland and planting, mixed planting, some of the hedges with trees and rough grassland are considered to be in moderate condition (20% of site habitat polygons). The biodiversity unit baseline is 13.7.

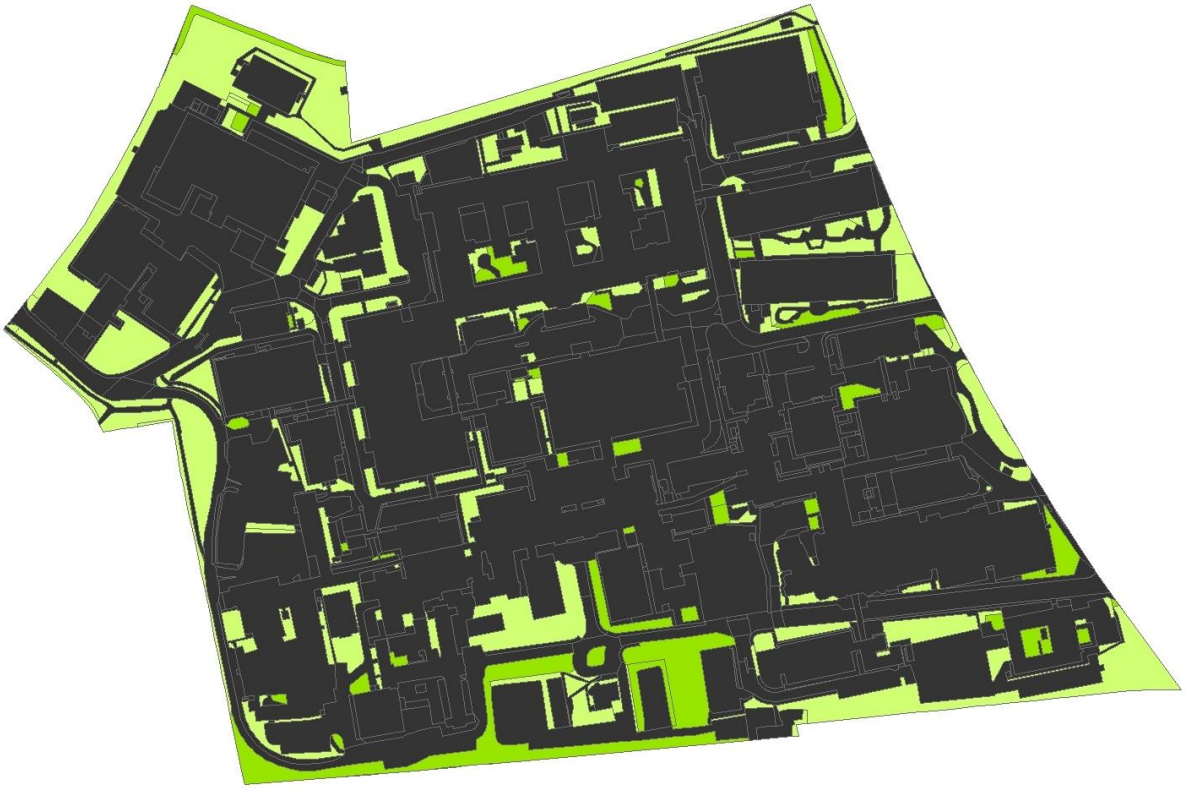
Table A1.6 Biodiversity units, annual physical and monetary flows and Present Value (over 50 years) of carbon sequestration and air quality regulation at the Western General Hospital.

	Annual physical flow	Annual monetary flow £(2020)	Present Value (£) (50 years)
Carbon sequestration tCO_2e/year	7.4	512	28,054
Air quality regulation $tPM_{2.5}$/year	0.03	7,674	278,054
Biodiversity units	13.7		

Map A1.10 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the Western General Hospital.



Map A1.11 The condition of habitats at the Western General Hospital.



Condition

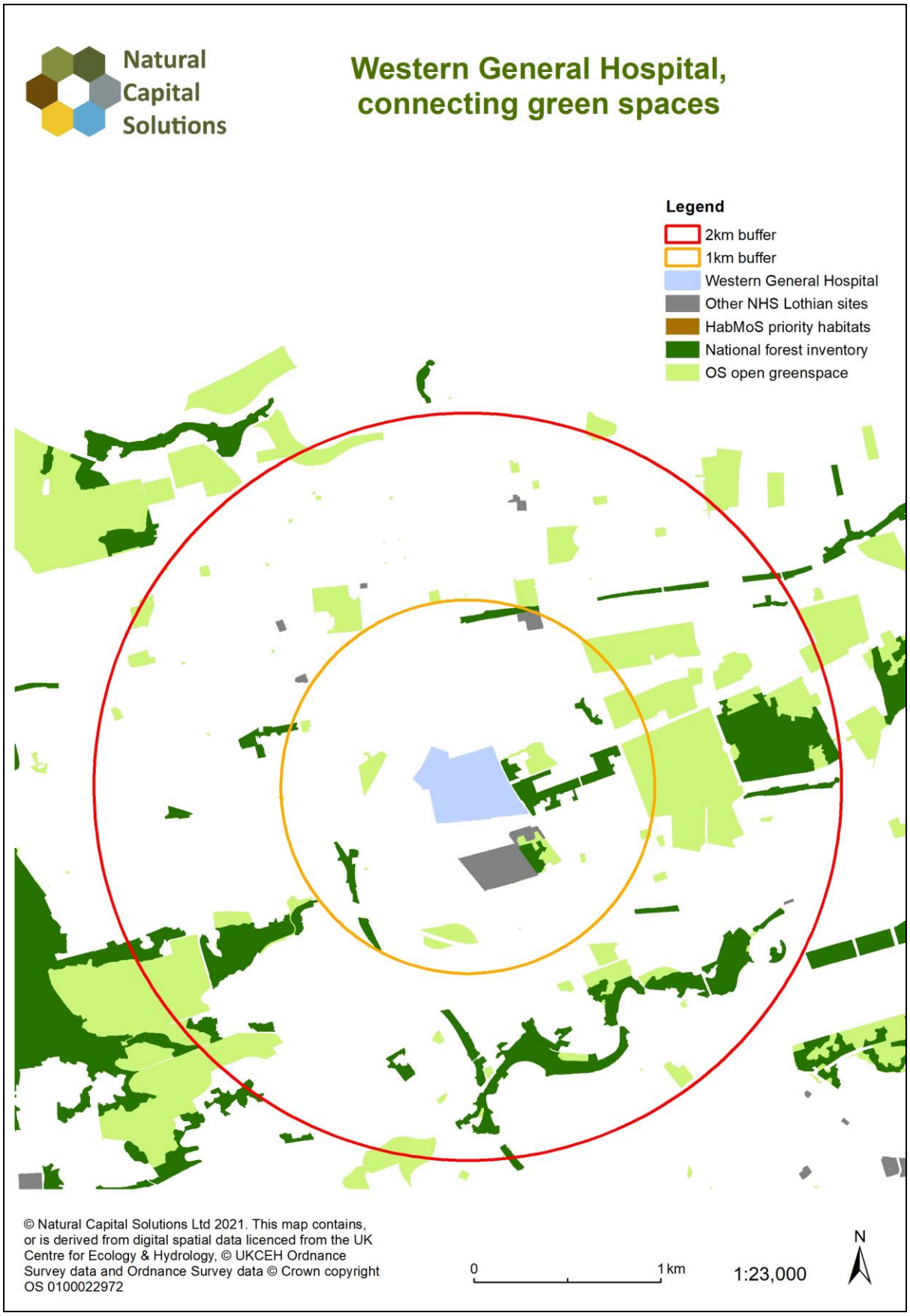
- Good
- Moderate
- Poor
- Buildings and roads

N

0 75 150 Metres

Natural Capital Solutions

Map A1.12 Greenspace connectivity of Western General Hospital habitats with priority habitats for biodiversity (Habitat Map of Scotland (HabMoS)), woodland and publicly accessible greenspaces within 2km of the site.



There are opportunities to connect to other habitats in the areas surrounding the Western General Hospital (Map A1.12). There are woodlands and greenspaces to the east of the site where the on-site habitats at the edge of the site could connect to increase opportunities for biodiversity. Some woodland planting on the east side of the Hospital could encourage such connectivity. Just outside the 1km from the Western General, again to the east, is Inverleith Park and the Royal Botanic Garden Edinburgh. These sites can be used as part of walking routes from the hospital, and to think about joint activities with other organisations outside of NHS Lothian.

1.3.3 Recommendations

These recommendations have been made with reference to the site masterplan which will see the amount of green cover increase and car parking decrease. The masterplan does not indicate the extent of tree and hedge planting nor if it will provide continuous canopy cover, which the recommendations below are aiming for.

BIGGER GREENSPACES

- Reduce the amount of car parking even further, e.g. at Amanda's Garden/ Maggie's Centre. By 2045, the masterplan shows car parking on the roofs of buildings. These could be converted to green roofs, and with forward planning, with sufficient load-bearing capacity to take trees as well as shrubs and other vegetation.

BETTER GREENSPACES

- Increase tree planting in existing and new greenspaces to maximise the continuous tree canopy cover around and through the site. This new planting (e.g. to north of the Anne Ferguson building, to the west of Amanda's garden) should connect up with the existing mature tree canopies through the site.
- Increase and improve the extent of mixed hedges within the site. The information about the removal of hedges in the past means that they could essentially be replanted in situ. The choice of species will depend on the location and existing species in question (e.g. common box, holly and bay laurel along roads; lavender camellia, beech and Mexican orange blossom in spaces where patients/ staff spend time).
- Explore the potential for creating a community garden in the new south-eastern greenspace as per the masterplan.
- Introduce perennial wildflower planting rather than having to spray off annually.
- Remove the 'beehives' and replace with 'pollinator-friendly' perennials. Where possible these should be in raised beds to avoid edge damage from footfall.
- Replace the ash tree(s) that may be affected by Ash Dieback (e.g. on Hospital Main Drive).

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Carry out greenspace site management plan with local experts and partners (e.g. Maggie's Centre, Amanda's Garden, grounds maintenance staff with knowledge of previous hedges) to increase tree canopy and hedge cover, introduce scrub and, if/ where new parkland is created, incorporate relaxed mowing regimes.

WELL-USED HEALTHY GREENSPACES

- For all hospital site users (patients, staff, local community):
    - Create walking routes through the site with accompanying signage connecting outside the site, e.g. to an accessible entrance to Howden Park and surroundings, and including Amanda's Garden.

- Increase the number of seating opportunities within the site (along the walking routes).
- For patients:
  - Incorporate the community garden and walking routes into social prescribing programmes.
- For staff:
  - Regularly communicate the activities and potential use of greenspaces around the site through staff wellbeing programmes.

1.4 Musselburgh Primary Care Centre

1.4.1 Grounds summary

There is only one way into the site for vehicles, cyclists and pedestrians past a large Tesco from the north west, through the extensive car park area (which uses permeable paving) surrounding the building to the north and east. There is a second, pedestrian-only entrance to the building from a high-walled path between Inveresk Road and St Michael's Church and graveyard. This is gated and locked at night.

There is **clear signage for pedestrians** and there are numerous places for cycle parking, both in front and behind the building (for staff). There is **not a lot of evidence that cycle parking is used**. There is **one bench at the front of the building** but nowhere to sit in the immediate vicinity of the building entrance.

Figure 6 Lawn and car park at Musselburgh Primary Care Centre.

There are **hedges of mixed species** around the car parking which includes beech, oleaster (thorny olive), buddleia, dogwood, Darwin's barberry and trees within the hedging including alder and oak (see Figure 6). To the north of the site, the car park is adjacent (separated by a high wall) to back gardens of a row of houses on Inveresk Road, some of which have trees.

Immediately around the north façade of the building, there is a fence behind which there is some planting which is not clearly visible to the visitor. The fence is for privacy and a visible barrier because people are able to access the lawn at the north of the building if one follows the fencing (there is a bin located near here). There is **no permanent seating at the lawn area** or immediately outside the building. There is a birch tree in a tree pit set in the paving next to the lawn.

The mixed hedging (beech mainly, with hawthorn) with trees (birch) continues around the building – at times broken up by bike racks and where the access path becomes narrow. At the south-east corner of the building, immediately south of the pedestrian entrance and through a fenced gate (and therefore not immediately visible), there are two benches. At the south of the site, there is some linear planting which is not maintained meaning the low wall, which might have been for sitting, is not accessible. There are two portable chairs which have been placed outside the building near the wall. This side of the building is adjacent to a bank of inaccessible woodland/ scrub which is why **ivy, Japanese knotweed, buddleia are invading the planted beds**.

This **bank of inaccessible woodland/scrub** continues along the south edge of the parking, and in the south-west corner, there is a small but thick bank of hedge which could be expanded. This woodland/ scrub could be on land owned by Tesco. There is some planting alongside the fence lining the building, with some evidence of wear and tear (due to an access gate) and two birch trees in tree pits. There is some **struggling beech hedge within the car parking** at the west of the building, suffering partly because people have used it as a cut through.

It was not possible to access the building but within there are **courtyards and green roofs**. Satellite imagery indicates these are sedum roofs which have limited habitat or plant diversity (Gedge et al., n.d). There is therefore **scope for replacement shrub planting to attract pollinators and invertebrates** on the sedum roofs.

1.4.2 Habitats, biodiversity and ecosystem services

The Musselburgh Primary Care Centre, in Musselburgh, East Lothian, is a small 1-hectare estate site that is 92% sealed surface. The natural assets of the site cover 0.08 hectares. The habitats on site are introduced shrub (0.04 ha), hedge and hedge with trees (0.04 ha) and some broadleaved trees (0.01) (see Table A1.7 and Map A1.13).

Map A1.13 Natural capital asset map of the Musselburgh Primary Care Centre.

Natural Capital Solutions

Table A1.7 Asset register for the Musselburgh Primary Care Centre showing the area of each habitat type in hectares and the percent cover of the total area of the estate (including buildings and sealed surfaces).

Habitat	Area (ha)	% of area
Broadleaved planting	0.01	1.04
Hedge	0.02	1.8
Hedge with trees	0.02	1.7
Introduced shrub	0.04	3.5
Sealed surface	0.96	92.0
Total habitat:	**1.05**	**100.0**

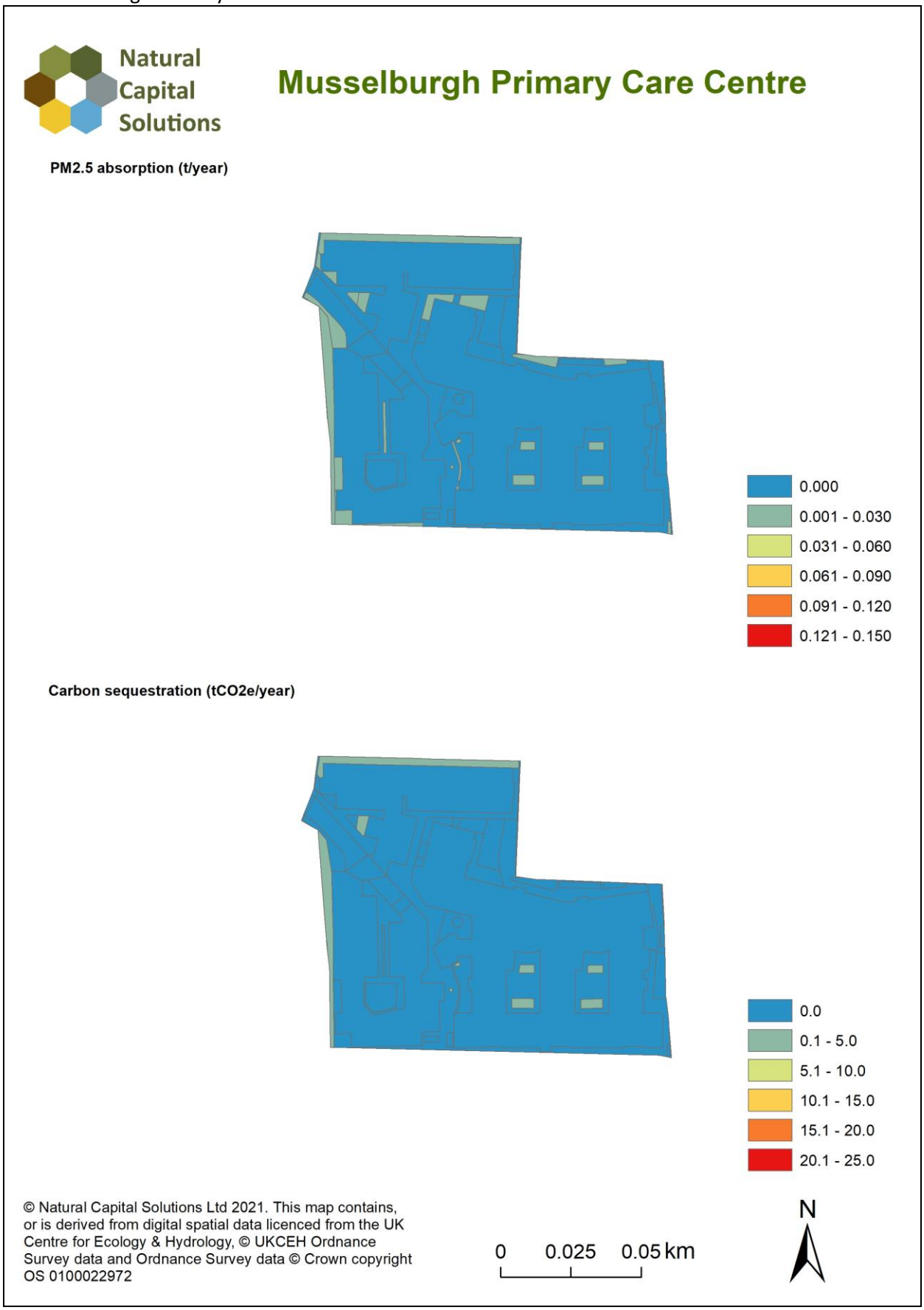
The woody species of the Musselburgh Primary Care Centre do sequester some carbon, albeit at a very low level (0.3 tCO_2e per year, with an annual value of £17, and a present value (over 50 years) of £949 (Table A1.8). This is from the broadleaved planting and hedging (Map A1.14). The natural capital assets also absorb 0.0006 $tPM_{2.5}$ per year, with an annual value of £91 and a present value of £3,282 (Table A1.8 Map A1.14). As with carbon sequestration the woody habitats are the most effective of taking up the fine particles of $PM_{2.5}$, but the grassland also plays a role in delivering this service, albeit to a lesser degree.

Seventy percent of the habitat polygons at this site in the spatial asset register are estimated to be in poor condition (Map A1.15). This is due mainly to introduced shrub, which as a habitat is of low value for biodiversity, although the hedging is in poor condition. This could be improved which would increase biodiversity units and be better at carbon sequestration and capturing small air pollutant particles. The rest of the habitat polygons are of medium condition (broadleaved planting and hedges with trees). The biodiversity unit baseline is 0.2.

Table A1.8 Biodiversity units, annual physical and monetary flows and Present Value (over 50 years) of carbon sequestration and air quality regulation of Musselburgh Primary Care Centre.

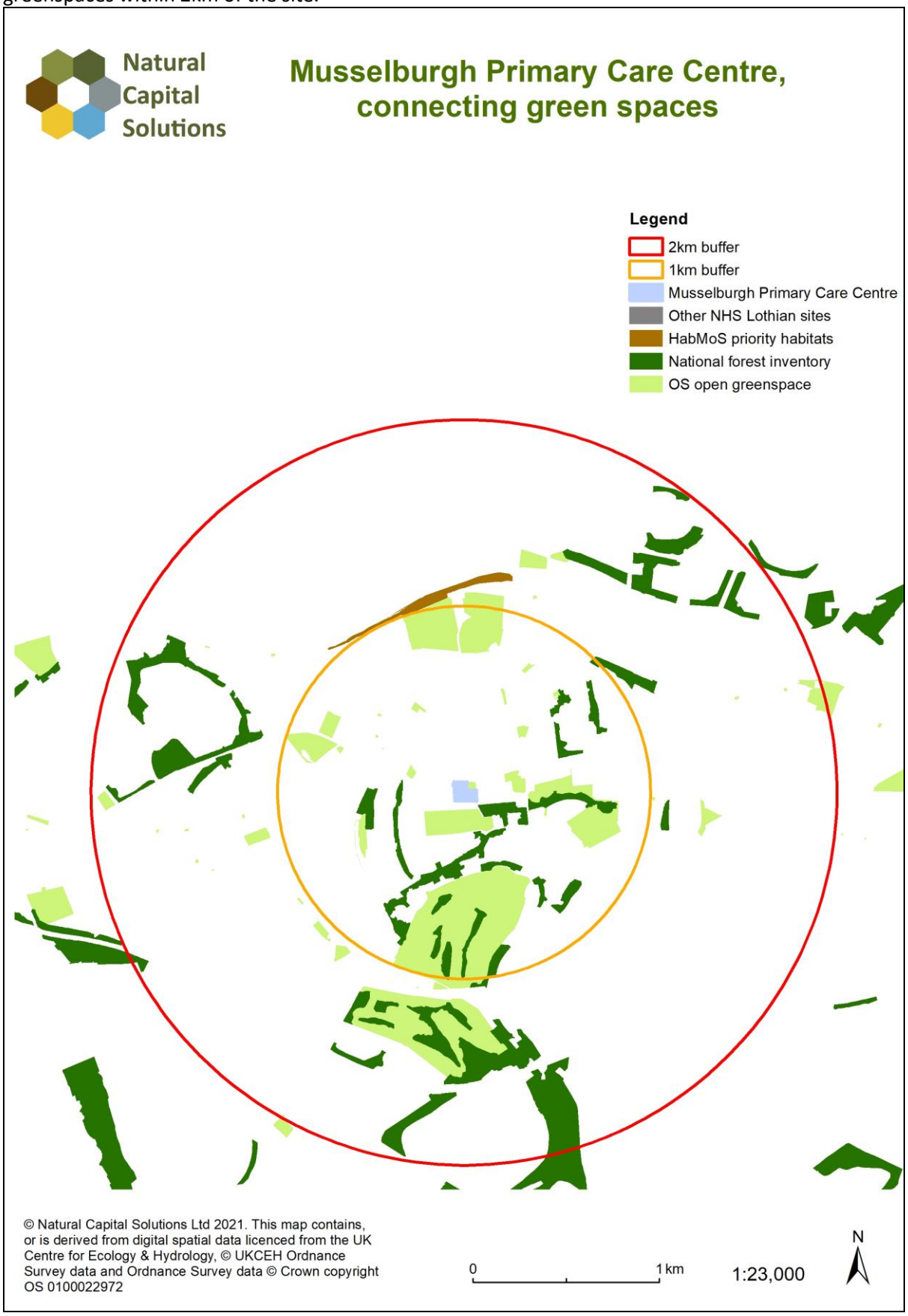
	Annual physical flow	Annual monetary flow £(2020)	Present Value (£) (50 years)
Carbon sequestration tCO_2e/year	0.3	17	949
Air quality regulation $tPM_{2.5}$/year	0.0006	91	3,282
Biodiversity units	0.2		

Map A1.14 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the Musselburgh Primary Care Centre.



Map A1.15 Condition of habitats at the Musselburgh Primary Care Centre.

Map A1.16 Greenspace connectivity of Musselburgh Primary Care Centre habitats with priority habitats for biodiversity (Habitat Map of Scotland (HabMoS)), woodland and publicly accessible greenspaces within 2km of the site.



There are a good deal of woodlands and greenspaces close by to the Musselburgh Primary Care Centre (Map A1.16). Opportunities for connecting habitats on site mainly lie in the south, where woodland on site could connect to other woodland. This would increase the biodiversity value of the site. These greenspaces also offer walking routes from the site, opening up opportunities for green prescribing and walking activities. There are footpaths from the south of the site, down to and along the River Esk.

1.4.3 Recommendations

BIGGER GREENSPACES

- Reduce the amount of car parking, by removing it along the entire perimeter of the site and at the immediate entrance to the site.
- If it is not regularly used, remove one of the cycle shelters.

BETTER GREENSPACES

- Increase tree planting where car parking is removed to connect with the existing mature tree canopies outside the site, i.e. with the bank of woodland/ scrub and Inveresk Cemetery to the south, the woodland at Musselburgh Grammar School and beyond to the east and extending planting in the north and west of the site
- Increase the extent of mixed hedges within the site (including where car parking and cycle shelter are removed)
- Supplement the sedum on the roof garden with shrub planting to attract pollinators and invertebrates, with an indicative aim of sedum constituting less than 30% of species composition (Gedge et al., n.d).
- Consider the creation of a small community garden/ growing space which extends from the existing lawn space and replaces some of the parking at the north-east of the site.

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Work with local community groups to create a shared vision for the community garden/ growing space, with advice from Cyrenians, and the Scottish Green Roof Forum for advice on green roof adaptation.
- Work in partnership with neighbouring landowner (Tesco?) to explore potential woodland expansion to the south and west of the site, as well as with Inveresk Cemetery.

WELL-USED HEALTHY GREENSPACES

- For all primary care centre site users (patients, staff, local community):
    - Publicise the new community garden/ growing space via local groups.
    - Create walking routes from the site towards the River Esk with accompanying signage connecting outside the site.
- For patients:
    - Incorporate the community garden/ growing space into social prescribing programmes.
- For staff:
    - Use the greenspace (or future community garden/ growing space) for outdoor meetings and staff wellbeing programmes.

1.5 Ellen's Glen House

1.5.1 Grounds summary

This site was not visited so the summary and recommendations are derived from a desk study. Ellen's Glen House is accessed via one vehicular entrance (which is shared with Southfield House) at the south of the site with no other pedestrian access routes. The site is bordered to the north by mixed woodland which extends down to Stenhouse Burn, Ellen's Glen and Burdiehouse Burn Valley Park. However, there is no direct access from Ellen's Glen House from the Burns, which would involve a circuitous walk.

At the entrance, there is a footpath and greenspace between Carnbee Avenue and Carnbee Park which lie outside the site but allow views into the site among the mature trees, giving the impression of managed parkland. Only the low metal fence indicates the site boundary.

There is **extensive mown grass** with mature, mostly deciduous trees (including birch, cherry, spruce and magnolia). Some of these trees are planted with colourful flowers at their base. There is **mixed herbaceous border shrub and flower planting** immediately outside the building, amongst which is some **mixed seating on an outdoor patio space**. There looks to be two further small garden spaces at the north of the site with seating.

Parking is provided for approximately 36 cars, half of which is permeably surfaced. On the two available satellite images of the car parks, over half of the spaces were empty (although this is purely indicative).

With reference to satellite imagery, **the tree canopy is varied** – dense alongside the neighbouring site of Southfield House (to the west) and the Glen (northwest) and far more sparse and patchy in the south of the site. There is therefore **scope for more tree planting** at the south of the site.

At the site entrance at Carnbee Avenue, the pavement to Southfield House is hedge-lined, and between Southfield and the site, there is laurel hedging. However, the road into Ellen's Glen House is lined with bollards. There is arguably **scope for mixed hedge planting** along this road entrance (certainly on the non-pavement side).

1.5.2 Habitats, biodiversity and ecosystem services

Ellen's Glen House is a hospital in the south-east of Edinburgh. The site is 1.7 ha with greenspace occupying 1.3 ha, 77% of the site. It is relatively unusual for estate sites to have such a high proportion of greenspace. Broadleaved woodland is the dominant habitat (0.9 ha, 56.5% of the site). There are gardens with trees, lawns and flower borders (0.1 ha) and hedging (0.1 ha), and small areas of amenity grassland, mixed parkland and introduced shrub (see Table A1.9 and Map A1.17).

Map A1.17 Natural capital asset map of the Ellen's Glen House.

Table A1.9 Asset register for Ellen's Glen House showing the area of each habitat type in hectares and the percent cover of the total area of the estate (including buildings and sealed surfaces).

Habitat	Area (ha)	% of area
Amenity grassland	0.06	3.6
Broadleaved woodland	0.9	56.5
Coniferous planting	0.01	0.3
Freshwater stream	0.03	1.5
Gardens (lawns, borders, broadleaved planting)	0.1	5.9
Hedge	0.1	6.6
Introduced shrub	0.02	1.7
Parkland (mixed)	0.03	1.7
Sealed surface	0.4	22.7
Total habitat:	**1.7**	**100.5**

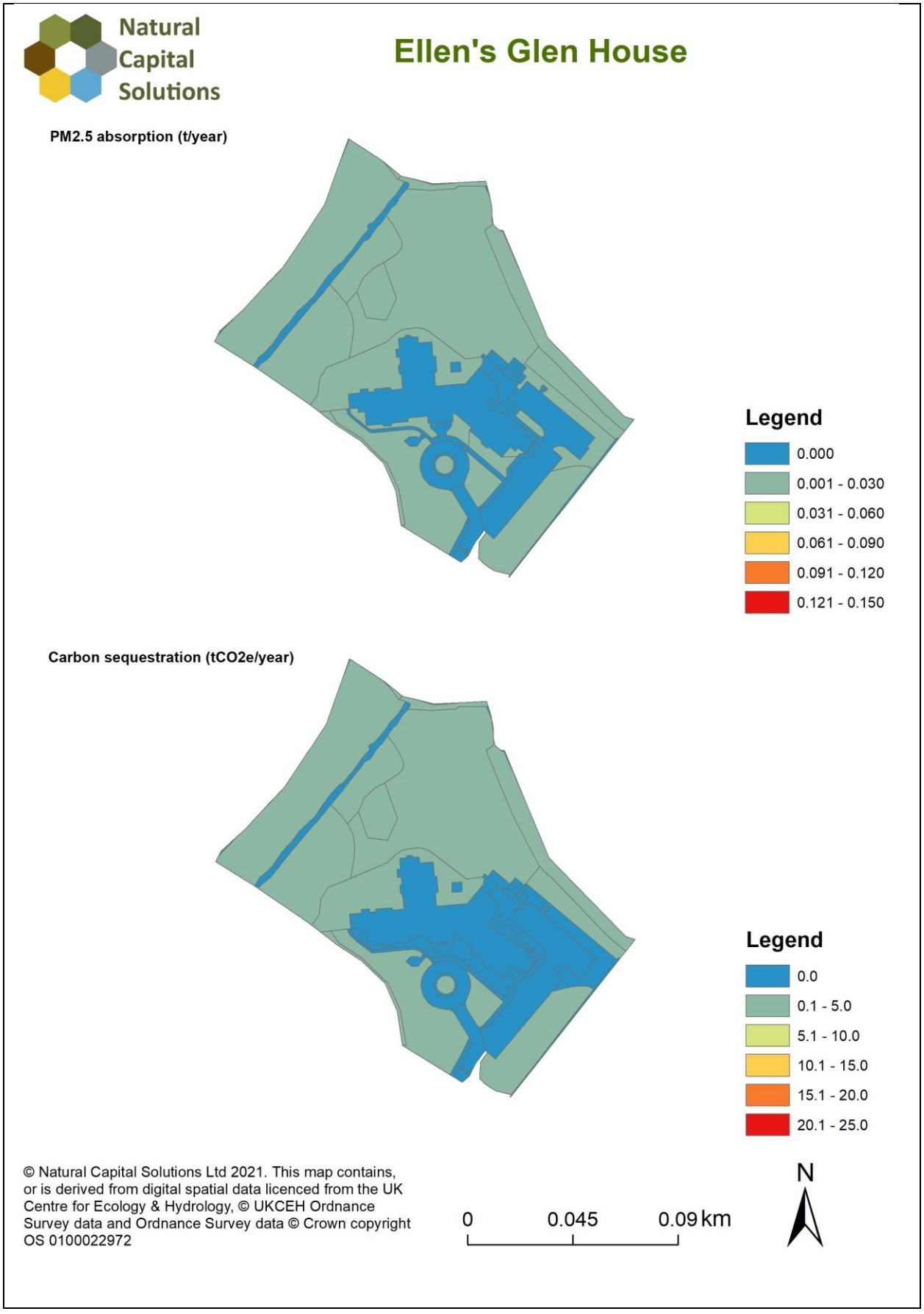
The woodland and parkland in the grounds of Ellen's Glen House sequester carbon at a rate of 8.8 tCO_2e per year, with an annual value of £613, and a present value (over 50 years) of £33,560 (Table A1.10). The natural capital assets also absorb 0.02 $tPM_{2.5}$ per year, with an annual value of £5,448 and a present value of £197,400 (Table A1.10 Map A1.14). As with carbon sequestration the woody habitats are the most effective of taking up the fine particles of $PM_{2.5}$, but the grassland also plays a role in delivering this service, albeit to a lesser degree.

Fifty-five percent of the habitat polygons at this site are estimated to be in moderate condition (Map A1.15). This due to the broadleaved woodland, coniferous planting and the freshwater stream. Forty five percent of the polygons are recorded as being poor condition habitats. This is due to the amenity grassland and introduced shrub habitats, that are of little biodiversity value, and due to the gardens and hedges. The latter two habitats could be better managed to increase the condition, therefore increasing biodiversity units, and the ability of the site to efficiently sequester carbon and take up $PM_{2.5}$. The biodiversity unit baseline is 8.5, which is a reasonable score for a relatively small estate site.

Table A1.10 Biodiversity units, annual physical and monetary flows and Present Value (over 50 years) of carbon sequestration and air quality regulation at Ellen's Glen House.

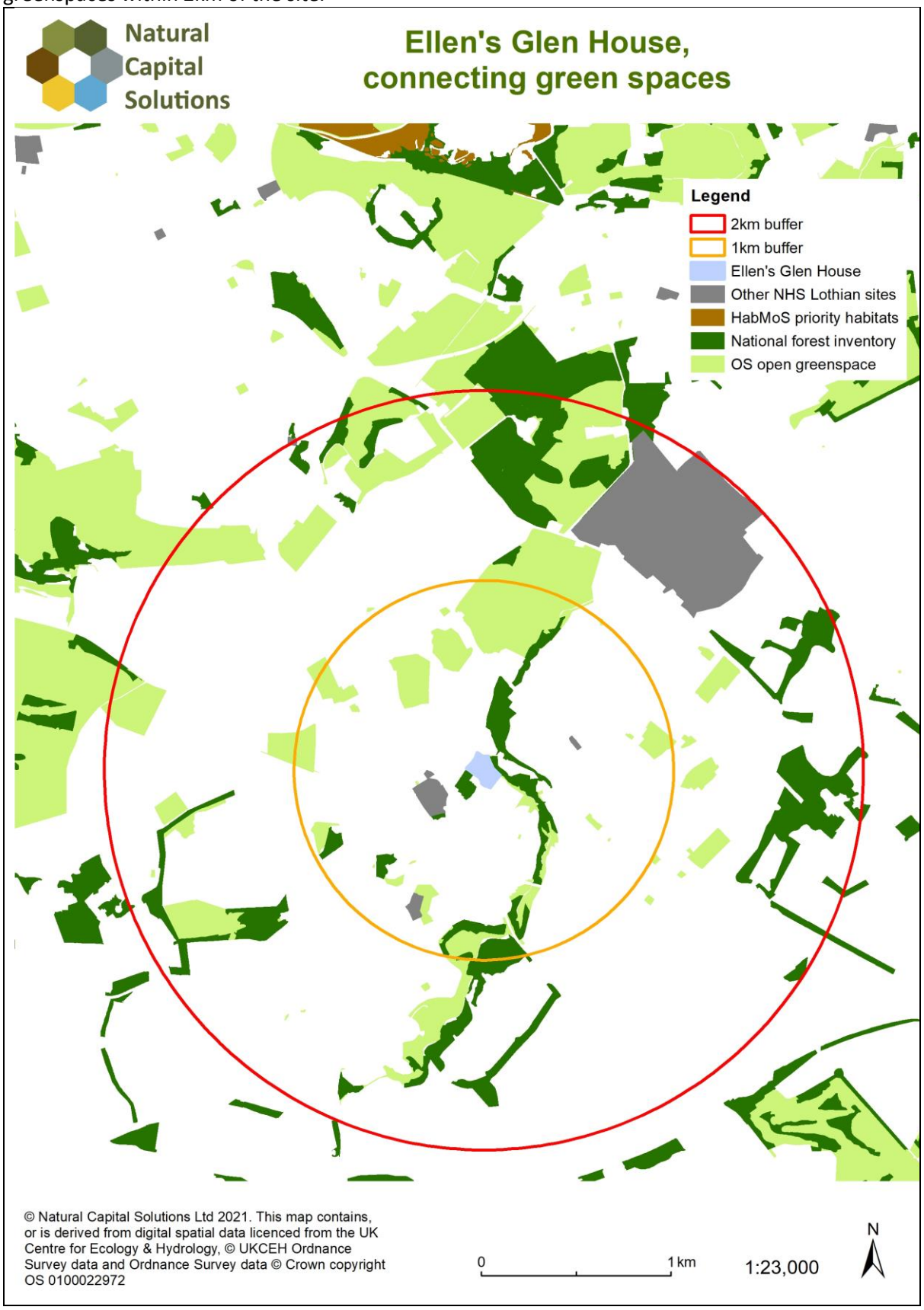
	Annual physical flow	Annual monetary flow £ (2020)	Present Value £ (50 years)
Carbon sequestration tCO_2e/year	8.8	613	33,560
Air quality regulation $tPM_{2.5}$/year	0.02	5,448	197,400
Biodiversity units	8.5		

Map A1.14 Carbon sequestration and air pollution regulation capacity of the natural capital assets of Ellen's Glen House.



Map A1.15 Condition of the habitats at Ellen's Glen House.

Map A1.16 Greenspace connectivity of Musselburgh Primary Care Centre habitats with priority habitats for biodiversity (Habitat Map of Scotland (HabMoS)), woodland and publicly accessible greenspaces within 2km of the site.



Ellen's Glen House is situated in parkland and woodland and next to the Burdiehouse Burn corridor, which is surrounded by woodland, especially to the north of the site (Map A1.16). The woodland at the site already connects quite well to this corridor. The site and its surrounds lends itself well to nature-based-health interventions such as established walking routes.

1.5.3 Recommendations

BIGGER GREENSPACES

- Remove the non-permeable car parking at the northeast of the site.

BETTER GREENSPACES

- Increase tree planting along the lawned area to provide a continuous canopy connecting with existing mature tree canopies outside and in the north of the site, i.e. with Southbank House to the west and trees off Carnbee End and flanking the footpath between Carnbee Avenue and Carnbee Park.
- Remove the bollards and plant mixed hedges along the entrance into the site.
- Consider the creation of a small community garden/ growing space on the existing lawn, e.g. flanking the hedge with Southfield House.

WELL-MANAGED, MAINTAINED AND COORDINATED GREENSPACES

- Work with local community groups to create a shared vision for the community garden/ growing space, e.g. with advice from Cyrenians and other local partners.

WELL-USED HEALTHY GREENSPACES

- For all primary care centre site users (patients, staff, local community):
    - Publicise the new community garden/ growing space via local groups.
- For patients and staff:
    - Explore the feasibility of a walking route with accompanying map from the site to Burdiehouse Burn as part of social prescribing and staff wellbeing programmes.
- For patients
    - Incorporate the community garden/ growing space into social prescribing programmes.
- For staff:
    - Use the existing seating spaces (and future community garden/ growing space) for outdoor meetings and staff wellbeing programmes.

Annex 2 Natural capital and biodiversity assessment

A2.1 Additional tables

Table A2.1 Figure 2a and 2b site codes.

Site	Site code
10 Chalmers Cresent -Childrens Service	CC
25 Hatton Place	HP
Allander House	AH
Armadale Community Health	ACH
Astley Ainslie Hospital	AAH
ATOS Origin- SEMA ..Building (old)	ATOS
Ballenden House	BH
Bathgate House	Bath H
Bellhaven Hospital	Bell H
Blackburn Partnership Centre	BPC
Blackridge Health Centre	BHC
Boghall Clinic	BC
Bonnyrigg Health Centre (New)	Bonny HC
Braids Medical Centre (Practice)	BrMC
Breast Screening Centre	BSC
Bruntsfield Medical Centre (Practice)	BMC
Calareidh - Childrens Services	CCS
Cambridge Street Day Hospital	CSDH
Camus Tigh - Care Home	CT
Carmondean Health Centre	CHC
Comely Bank Centre	CBC
Craigmillar Medical Centre	CMC
Craigroyston Health Centre	Craig HC
Craigshill Care Facility (Maple Vila)	CCF
Craigshill Health Centre	Craigshill HC
Dalkeith Health Centre	DHC
Danderhall Medical Practice	DMP
Dedridge Health Centre	DHC
Duncan Street Dental Centre	DSDC
East Calder Health Centre	ECHC
East Craigs Medical Practice	ECMP
East Lothain Community Hospital	ELCH
Eastfield Medical Centre : CAMHS Dept.	EMC
Edenhall Hospital	EH
Edington Cottage Hospital	ECH
Ellen's Glen House (PFI)	EGH
Esk centre	Esk Centre
Ferryfield House (PFI) : nhs Trust	FH

Findlay House PFI	Find H
Firrhill House	Firr H
Forteviot	Forteviot
Gracemount Medical Centre	GMC
Howden Health Centre	HHC
Kirkliston Health Centre	KHC
Lauriston Building	LB
Leith Community Treatment Ctr - Leith CTC	LCT
Leithmount Surgery	LS
Liberton Hospital	LH
Linlithgow Health Centre	LHC
Longhouse surgery	LS
Marchhall	Marchhall
Midlothian Community Hospital	MCH
Milestone House Site	MHS
Mill Lane Surgery	MLS
Mountcastle Health Care Centre	MHCC
Musselburgh Primary Care Centre	MPCC
Newbattle Medical Practice	NMP
Newtongrange Clinic	NC
NHSL Sexual Health & Reproductive Health Service	NHSL
Parkgrove Medical Centre	PMC
Penicuik Health Centre	PHC
Pennywell All Care Centre	PACC
Prestonpans Health Centre	PrHC
Primrose Lodge (Care House)	PL
Princess Alexandra Eye Pavilion	PAEP
Ratho Surgery (NEW)	RS
Restalrig Park Medical Centre	RPMC
Roslin Medical Practice	RMP
Royal Edinburgh Hospital	REH
Royal Hospital for Sick Children	RHSC
Royal Infirmary of Edinburgh (PFI)	RIE
Royal Victoria Hospital	RVH
Sighthill Health Centre	SHC
Slateford Medical Practice	SMP
South Queensferry Health Centre	SQHC
Spittal Street Clinic	SSC
St John's Hospital	SJH
St Michael's Hospital	SMH
Stockbridge Health Centre	StockHC
Stoneyburn Health Centre	St HC
Sunndach : Care Home	Sunndach

The Harbours Medical Centre	THMC
The Pentland Medical Centre	TPMC
Tippethill Hospital (PFI)	TH
Tollcross Health Centre	TollHC
Tranent Health Centre	THC
Waverley Gate	WG
West Calder Health Centre	WCHC
Western General Hospital	WGH
Whinpark Medical Practice	WMP
Whitburn Health Centre	WHC
Willowgrove House	WH
Winchburgh Health Centre	Win HC

Table A2.2 Hospitals with the highest areas of greenspace, proportion of site as greenspace, habitat units, carbon sequestration rates and air pollution regulation rates.

Area of greenspace	**Ha**
Royal Infirmary of Edinburgh (PFI)	13.36
Astley Ainslie Hospital	12.38
Royal Edinburgh Hospital	10.63
St Johns Hospital	6.29
Royal Victoria Hospital	5.64
Midlothian Community Hospital	4.65
Edenhall Hospital	3.49
Tippethill Hospital (PFI)	3.45
Western General Hospital	2.94
ATOS Origin SEMA Building (old)	1.73
Proportion of greenspace on site	**Ha**
Royal Victoria Hospital	94.19
Tippethill Hospital (PFI)	88.11
Ellens Glen House (PFI)	77.35
Midlothian Community Hospital	74.25
Bellhaven Hospital	73.91
ATOS Origin SEMA Building (old)	72.89
Milestone House Site	67.33
Astley Ainslie Hospital	65.37
Edenhall Hospital	65.03
Forteviot	60.47
Biodiversity level	**Biodiversity units**
Royal Infirmary of Edinburgh (PFI)	78.18
Astley Ainslie Hospital	77.74
Royal Victoria Hospital	62.07
Royal Edinburgh Hospital	58.39
St Johns Hospital	30.92
Midlothian Community Hospital	29.76
Tippethill Hospital (PFI)	26.01
Edenhall Hospital	22.25

Western General Hospital	13.71
ATOS Origin SEMA Building (old)	12.12
Carbon sequestration	**tCO_2e**
Astley Ainslie Hospital	61.34
Royal Infirmary of Edinburgh (PFI)	43.10
Royal Edinburgh Hospital	40.17
Tippethill Hospital (PFI)	23.40
Royal Victoria Hospital	16.29
St Johns Hospital	15.32
Midlothian Community Hospital	13.23
Edenhall Hospital	11.19
ATOS Origin SEMA Building (old)	10.10
Ellen's Glen House (PFI)	8.84
Air quality regulation	**$PM_{2.5}$**
Astley Ainslie Hospital	0.19
Tippethill Hospital (PFI)	0.13
Royal Infirmary of Edinburgh (PFI)	0.13
Royal Edinburgh Hospital	0.12
Royal Victoria Hospital	0.12
Edenhall Hospital	0.04
St Johns Hospital	0.04
Midlothian Community Hospital	0.03
Milestone House Site	0.03
Western General Hospital	0.03

Table A2.3 Key statistics across the NHS Lothian Estate.

	Median	Min	Max
Area (ha)	0.39	0.02	33.89
Greenspace area (ha)	0.11	0	13.35
Biodiversity Metric habitat units	0.29	0	78.18
Proportion of site that is greenspace (%)	32.30	0	94.19
Carbon sequestration	0.17	0	61.34
Air quality regulation	0.0006	0	0.19

A2.2 Sensitivity analysis

The present values in the report are reported as the central values provided by the government. A sensitivity analyses on these figures (Table A1.4) demonstrates the variation around the central estimates, especially for the air quality regulation service.

Table A2.4 Sensitivity analysis showing low, central and high estimates of benefits from the natural capital assets of the NHS Lothian estate. Based on the Present Value of assets over 50 years.

Ecosystem service benefits **£2019 PV (50 years)**	Low **£2020 PV (50 years)**	Central **£2020 PV (50 years)**	High **£2020 PV (50 years)**
Carbon sequestration (tCO_2e)	511,507	1.14m	1.63m
Air quality regulation ($PM_{2.5}$)	1.72m	8.36m	25.21m

For the services that have been included in this study, a range of assumptions have been made, and these are outlined when describing the methodology (see A2.5 below). In addition, a summary of the main uncertainties is provided for each service in Table A2.4, along with a RAG rating highlighting the overall confidence in each estimate. These ecosystem services have minimal assumptions compared to other services, and established production functions exist, linking natural capital to ecosystem service production, and levels of production to monetary value.

Table A2.5 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.

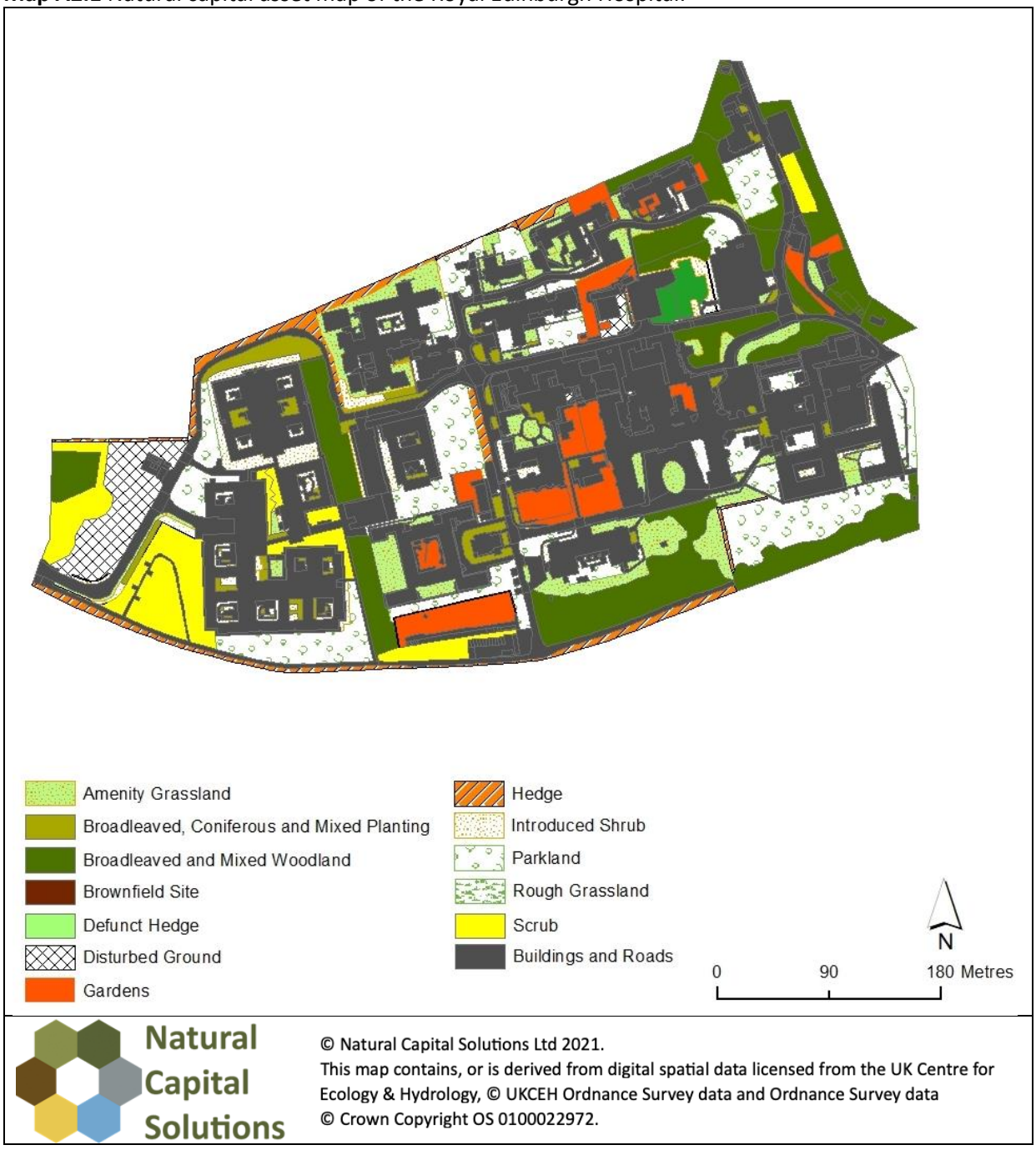
Natural capital benefits	**Assessment of uncertainties**	**RAG rating**
Air purification	A lot of uncertainty over change in absorption as trees grow. Also based on averages for broadleaved and coniferous trees and grassland. Valuation follows ONS guidance.	
Carbon sequestration	Well studied, standardised carbon lookup tables available. Valuation uses UK Government carbon price.	

A2.3 Additional priority site maps

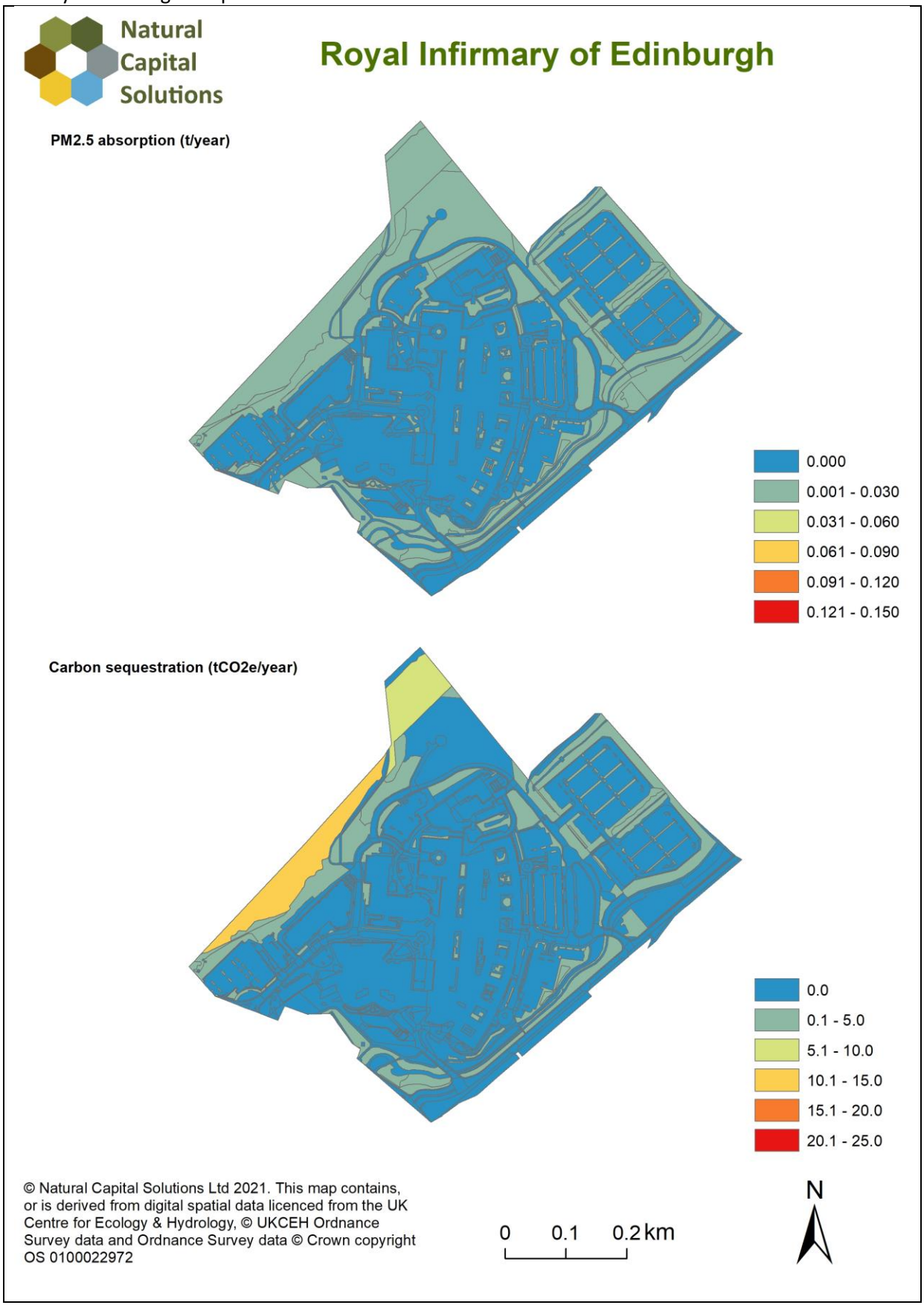
Below are natural capital asset maps, carbon sequestration and air quality regulation maps for the other 5 priority NHS Lothian estate sites.

A2.3.1 Royal Edinburgh Hospital

Map A2.1 Natural capital asset map of the Royal Edinburgh Hospital.



Map A2.2 Carbon sequestration ad air pollution regulation capacity of the natural capital assets of the Royal Edinburgh Hospital.

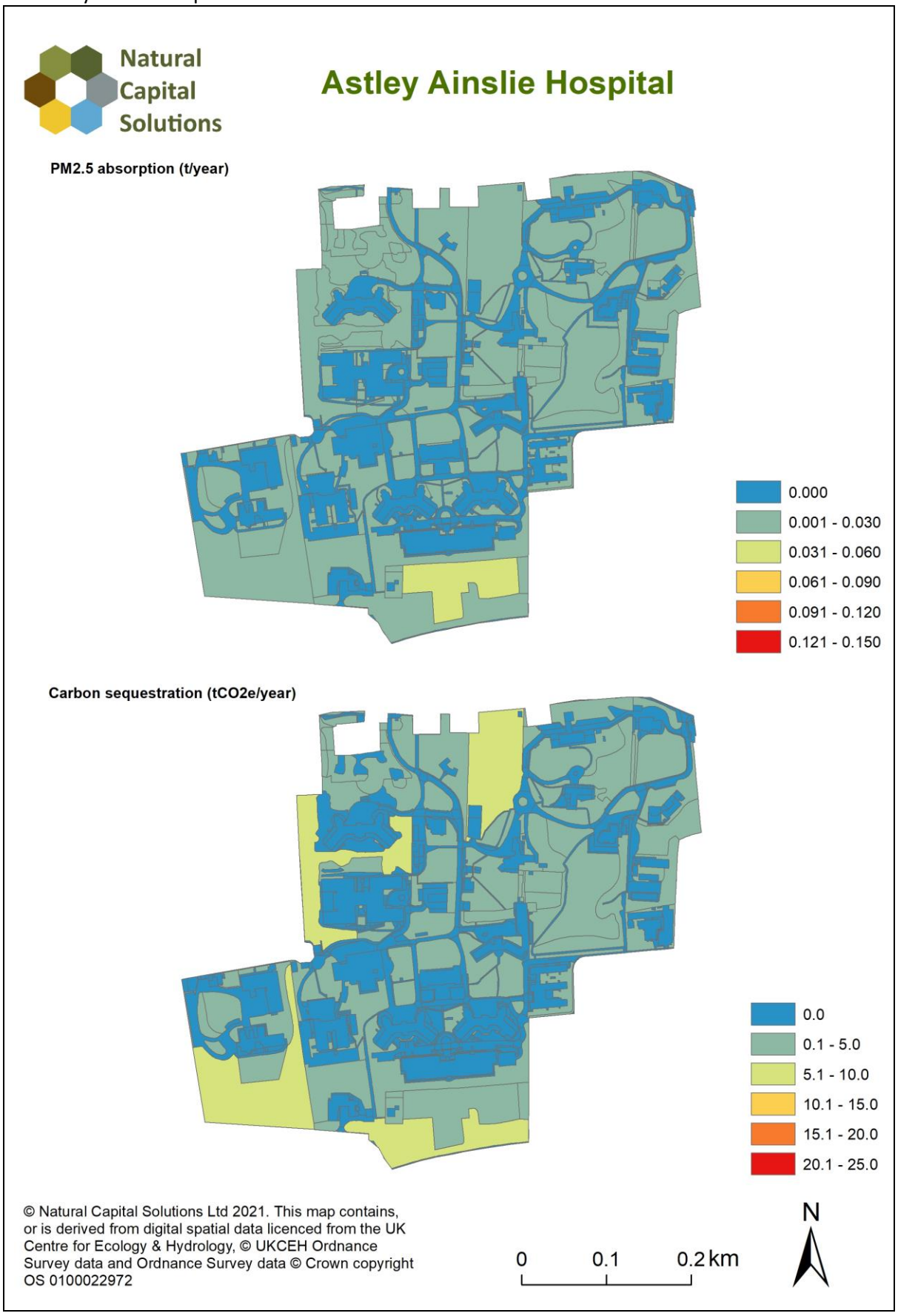


Map A2.3 Habitat condition at the Royal Edinburgh Hospital.

A2.3.2 Astley Ainslie Hospital

Map A2.4 Natural capital asset map of the Astley Ainslie Hospital.

Map A2.5 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the Astley Ainslie Hospital.



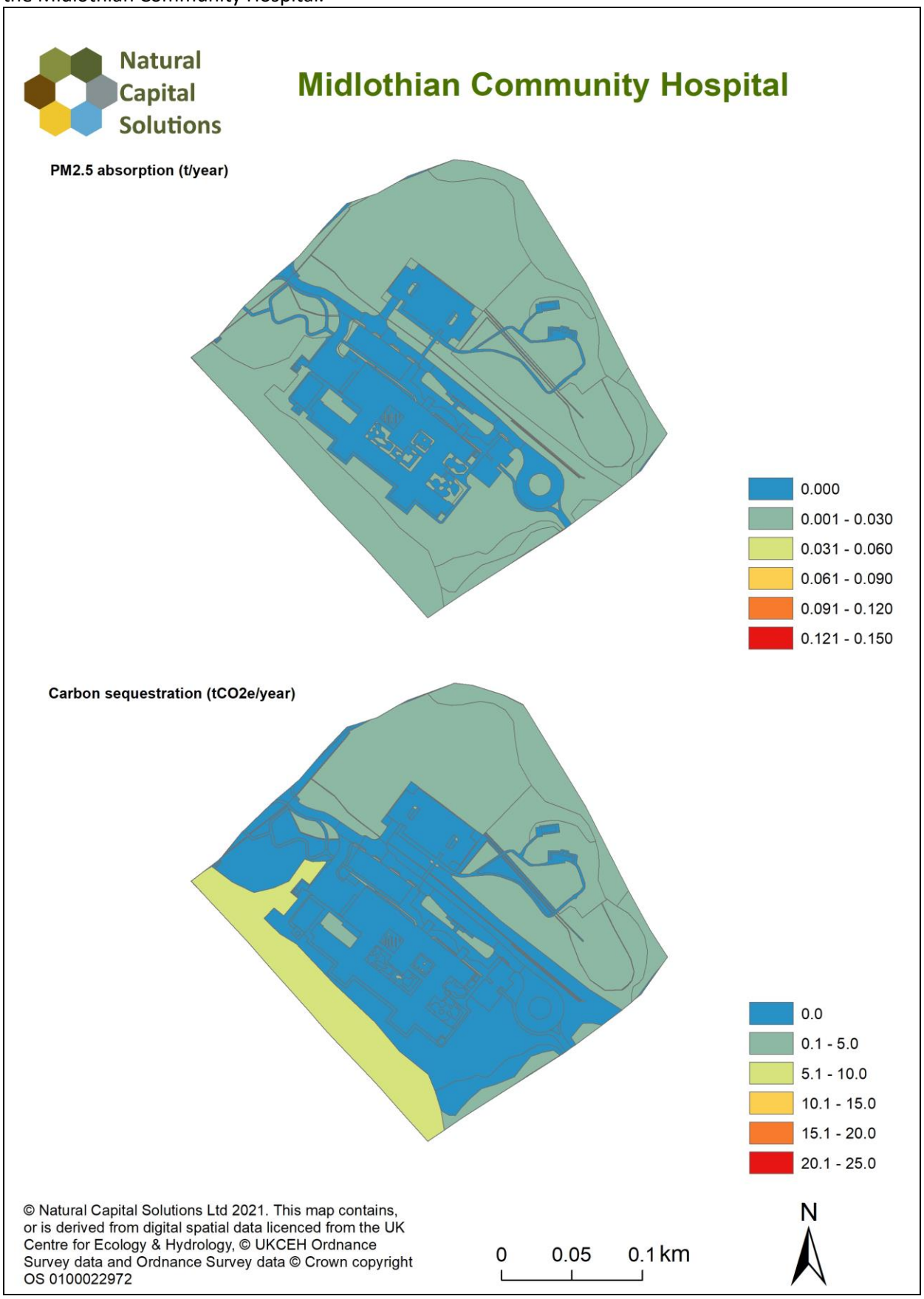
Map A2.6 Condition of habitats at the Astley Ainslie Hospital.

Natural Capital Solutions

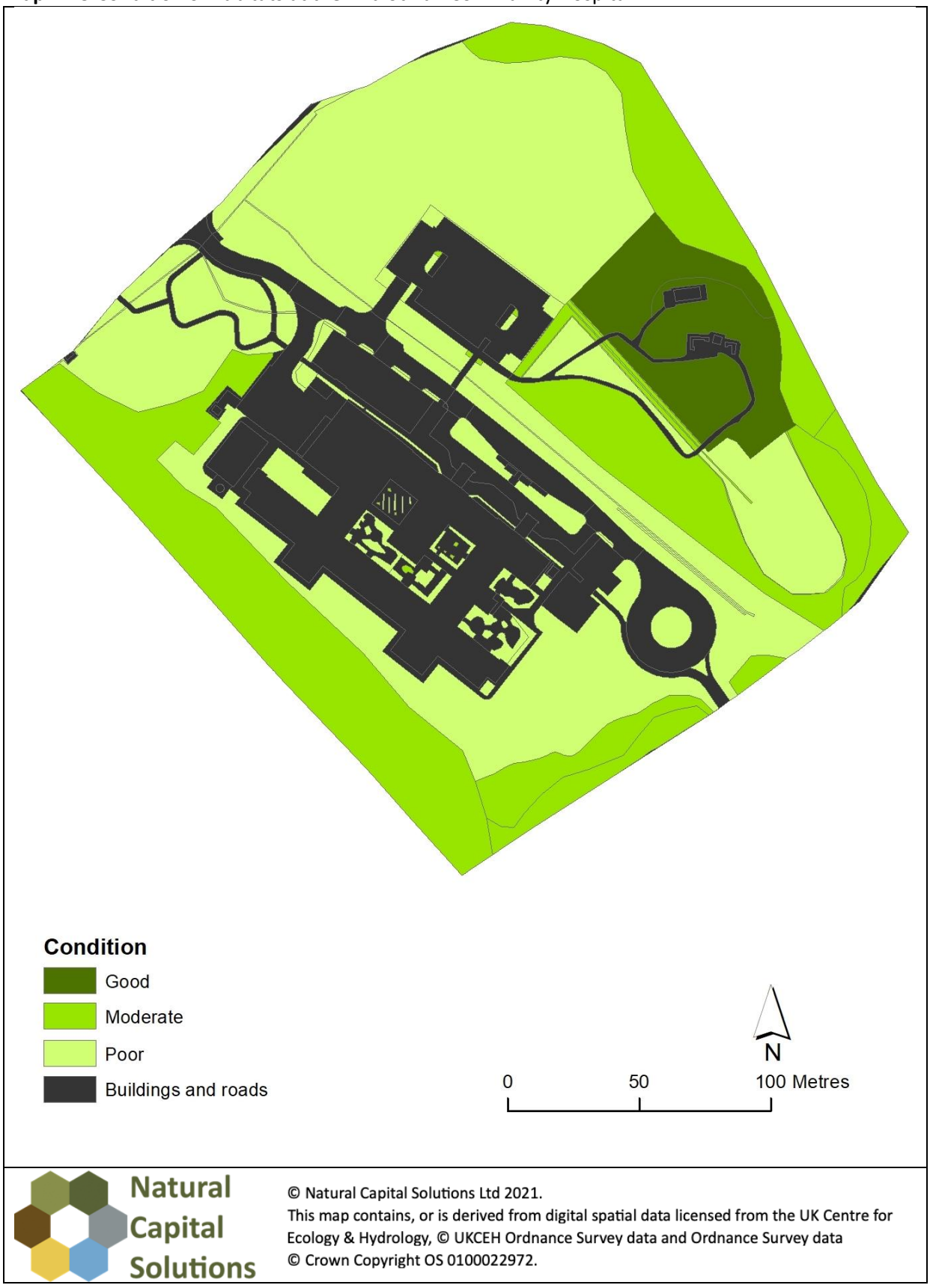
A2.3.3 Midlothian Community Hospital

Map A2.7 Natural capital asset map of the Midlothian Community Hospital.

Map A2.8 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the Midlothian Community Hospital.

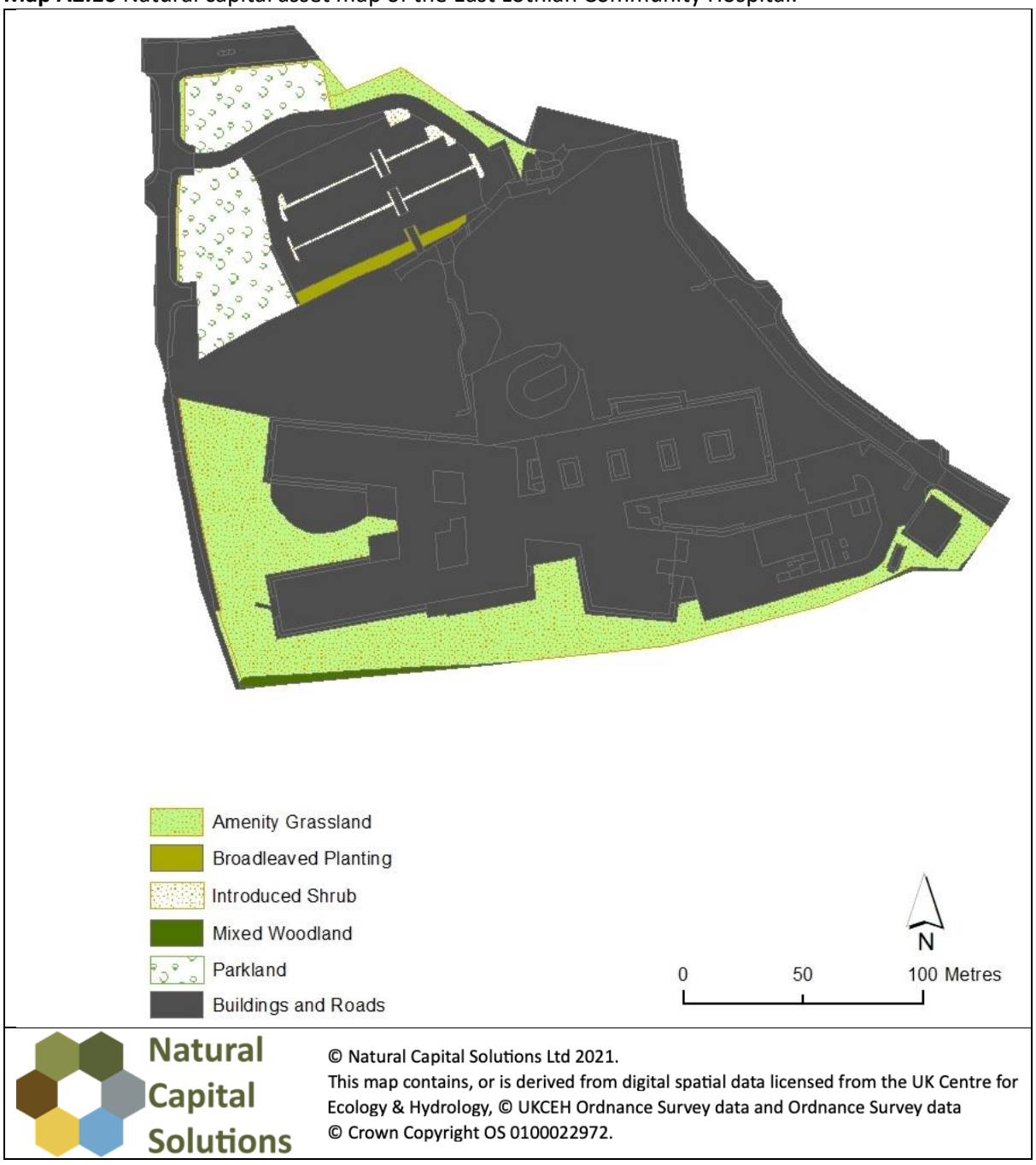


Map A2.9 Condition of habitats at the Midlothian Community Hospital.

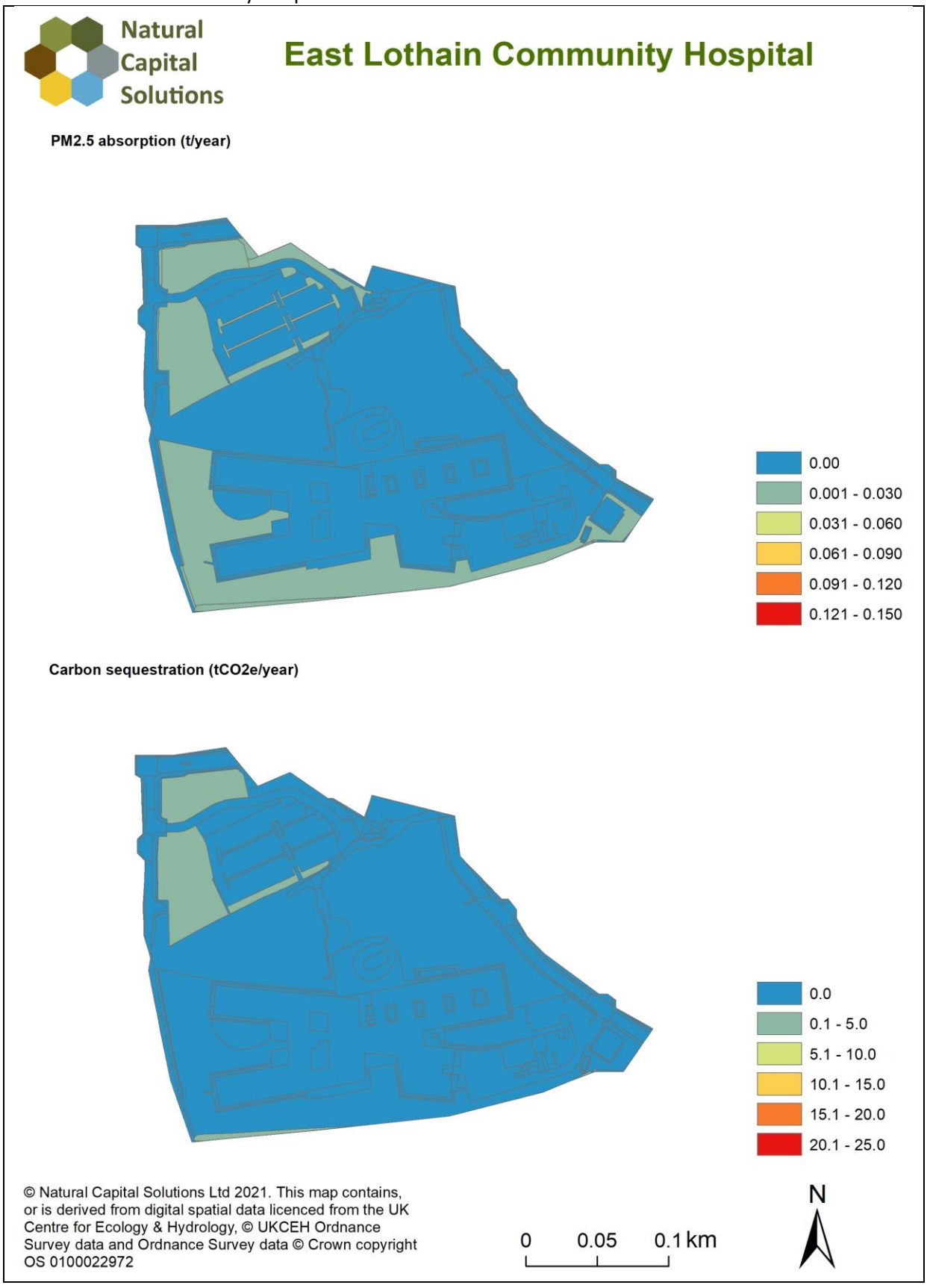


A2.3.4 East Lothian Community Hospital

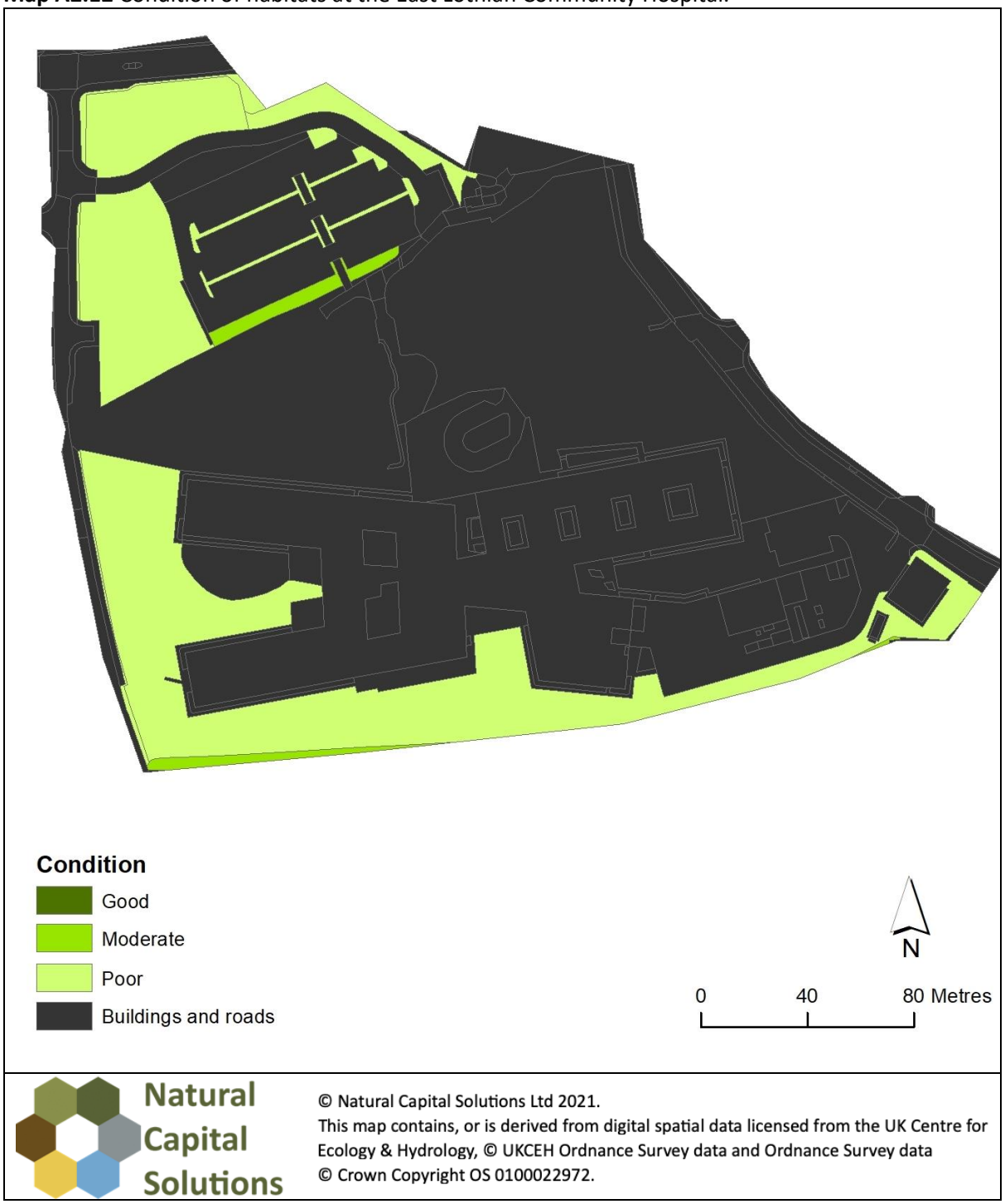
Map A2.10 Natural capital asset map of the East Lothian Community Hospital.



Map A2.11 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the East Lothian Community Hospital.



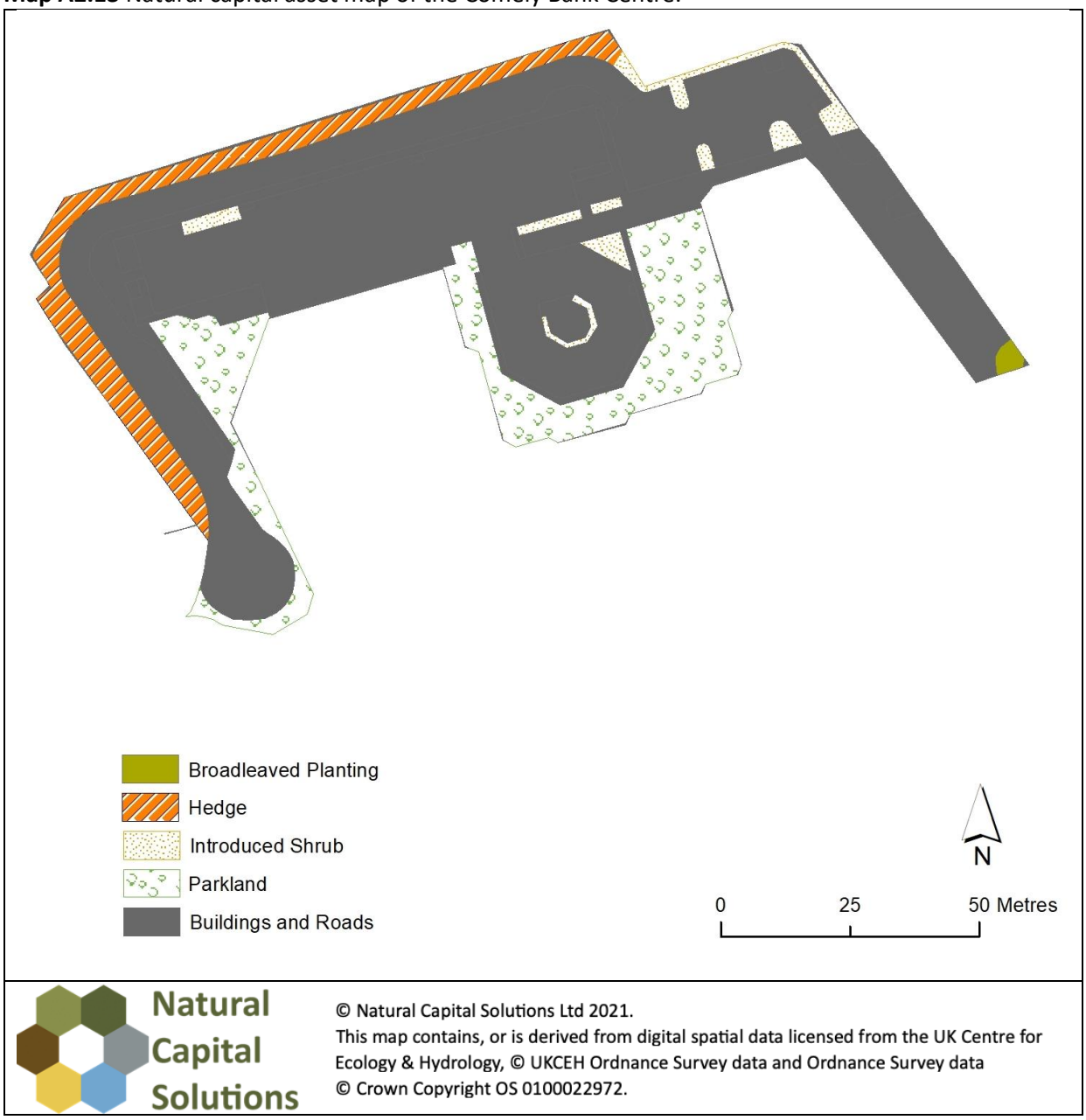
Map A2.12 Condition of habitats at the East Lothian Community Hospital.



Natural Capital Solutions

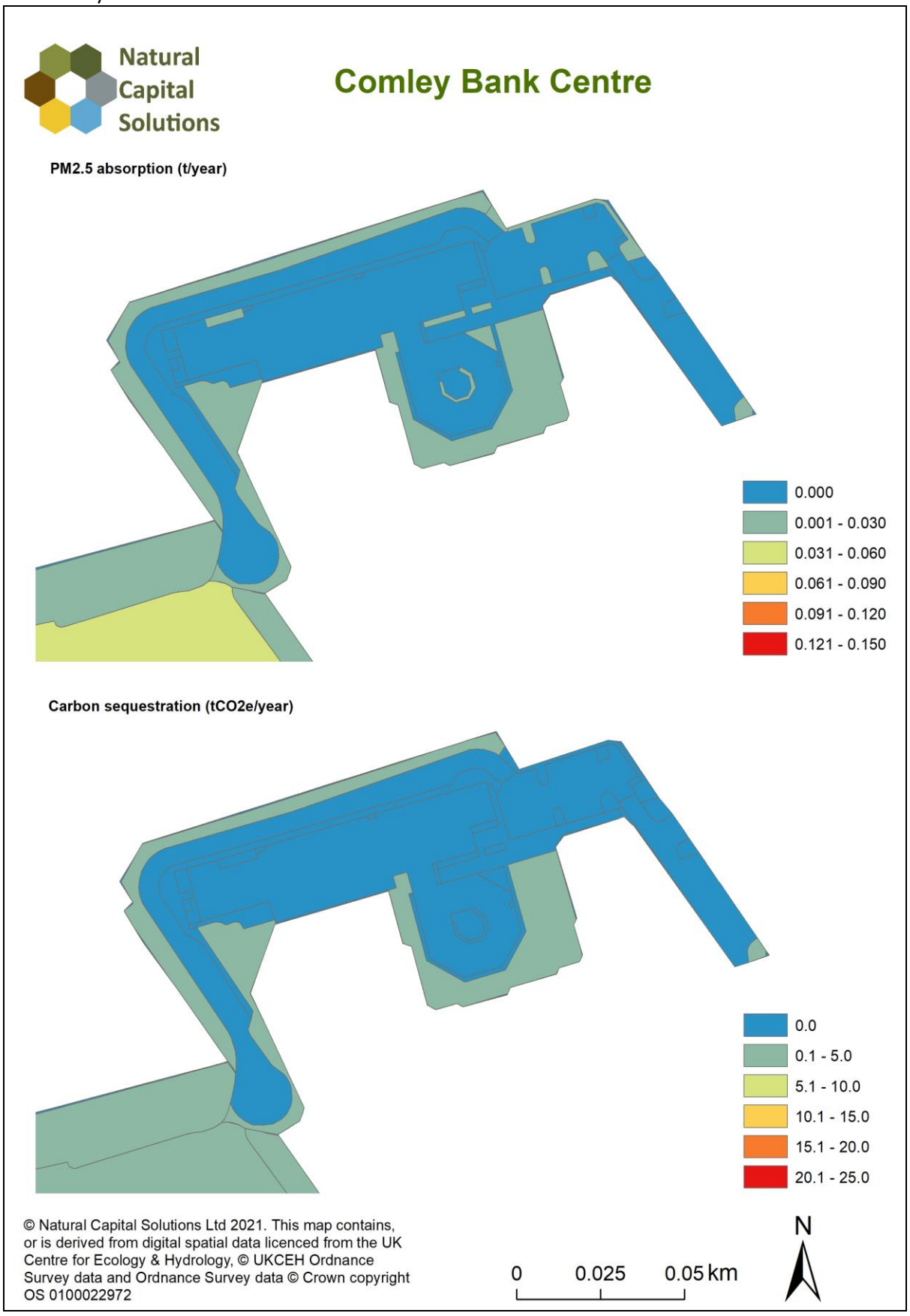
A2.3.5 Comely Bank Centre

Map A2.13 Natural capital asset map of the Comely Bank Centre.

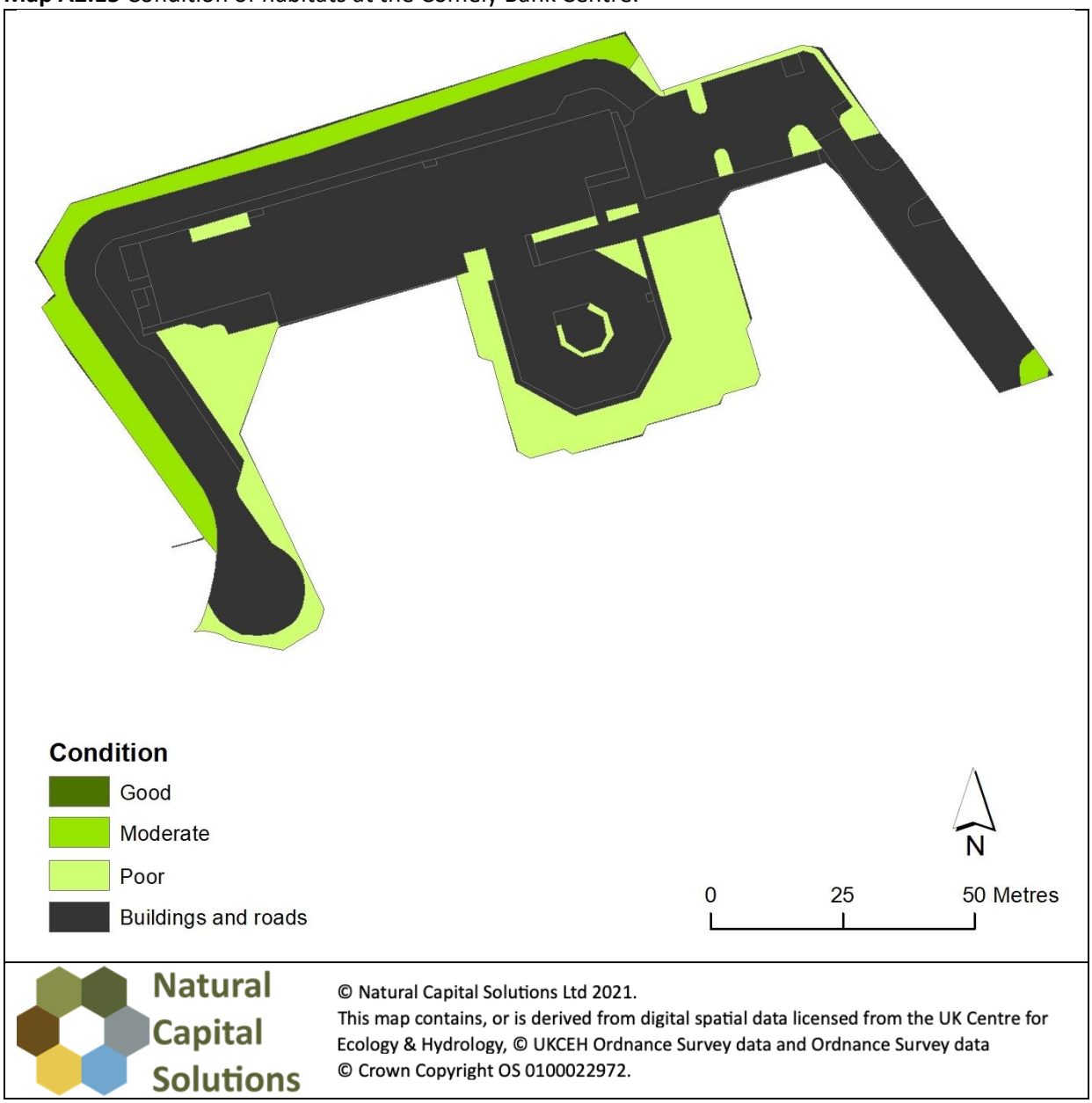


Natural Capital Solutions

Map A2.14 Carbon sequestration and air pollution regulation capacity of the natural capital assets of the Comely Bank Centre.



Map A2.15 Condition of habitats at the Comely Bank Centre.



A2.4 Spatial natural capital accounting tool

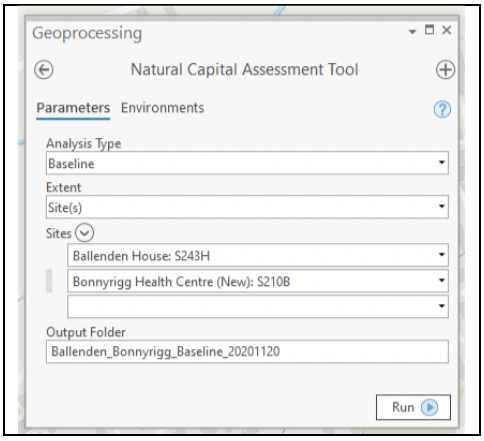
The spatial asset resister will exist as a GIS layer for use by NHS Lothian. It can be edited as changes to the estate occur. For example, when habitats within the estate change from natural habitats to sealed services (or *vice versa*) due to new building works or grounds maintenance, or a site is no longer owned by NHS Lothian.

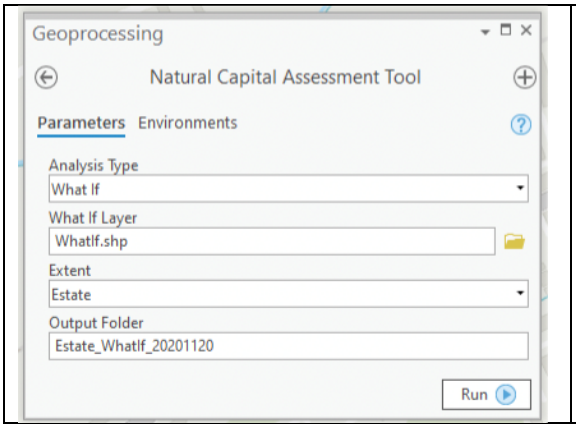
We have created a tool in ArcGIS Pro in which the spatial asset register can be edited by the NHS Lothain. This allows future and past scenarios of habitat/land use change to be explored, along with the implications for biodiversity and ecosystem service provision and value. The user can create one or a series of 'what if' layers for different scenarios, which could be a copy of the whole basemap or polygons of specific sites. These will be saved as a feature class in a geodatabase. The annual physical and monetary flows and present value (value discounted over 50 years) will be re-calculated for the carbon sequestration and air pollution regulation services. The biodiversity units for the specified scenario will also be recalculated. The results will be displayed for the site and the whole estate and outputs will be in .csv format. Mapped output can also be produced as desired.

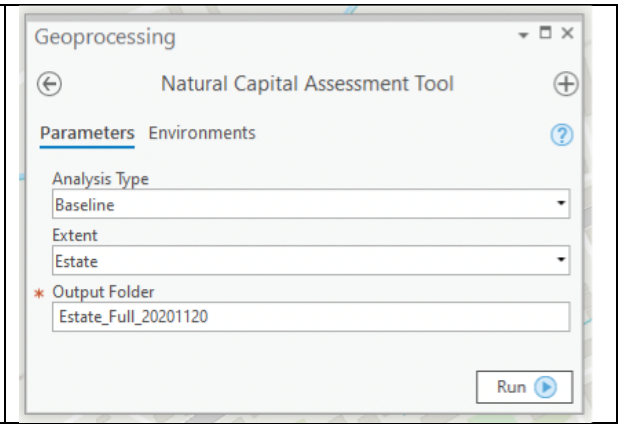
The parameters required for these calculations sit within the tool as look up tables. The only table that will need to be updated when changes are made is the condition and distinctiveness of the habitat. Annual updates will also need to be made to the prices of non-traded carbon and air pollution damage costs, altered in line with inflation. These are straightforward to implement, and we will provide the relevant guidance information.

The accounting tool will not include the valuation for health and wellbeing in relation to gardening/horticultural activities and conservation/outdoor activities. This is because this service is not only linked to the provision and type of greenspace but is also a function of the type of nature-based intervention, the number of people that take part in the activity, and whether there is an interest in how the intervention impacts on specific medical conditions. It will, therefore, not be possible to make generalisations about the provision and value of this service across the whole of the NHS Lothian estate, in the same way as carbon sequestration and air quality regulation. A separate spreadsheet has been created that the NHS Lothian can edit to explore the impacts of increasing the size of, or creating new, nature-based health interventions. The spatial asset register and tool can be used to find out whether the appropriate size and type of greenspace exists to support the desired nature-based health interventions.

Figure 2.1 Screenshots of the ArcGIS Pro natural capital accounting tool configured for different options.







A2.5 Methods

A2.5.1 Natural capital asset mapping

The first step was to create a spatial natural capital asset register for the Lothian Estate. The spatial asset register contains information on the habitat type, extent and condition of the habitats within the estate. We created a Geographic Information System (GIS) basemap covering all of the 94 NHS estate sites across the Lothian region. We used OS MasterMap polygons as the underlying mapping unit and then added a series of additional data sets to classify each polygon to a land-use / habitat type (CEH Woody Linear Feature Framework, the Habitat Map of Scotland (HabMoS), National Forest Inventory Scotland, OS Open and OS MasterMap Greenspace). Due to the fragmented nature and small size of the habitats (single trees, short hedges in car parks, patches of grass, flower beds) on the estate sites, these data sets were not able to provide data with which to classify many of the habitats. We, therefore, used field visits and satellite imagery to classify these habitats. Ten hospital sites considered as a priority by the client were visited over 4 days in September 2020:

- Edinburgh BioQuarter (Royal Infirmary Edinburgh)
- Royal Edinburgh Hospital
- Western General Hospital
- St John's Hospital
- Astley Ainslie Hospital
- Mid Lothian Community Hospital
- East Lothian Community Hospital

- Comely Bank Centre (NHS Lothian Training Centre)
- Musselburgh Primary Care Centre (Heath Centre)
- Ellens Glen House (Care Home)

The priority sites covered the different types of estate sites, e.g. large hospitals, community hospitals, health centres and care homes. This was so we could get a general idea of the type of habitats that were maintained across the various site categories and sizes. The habitats at all of these sites were recorded and used to classify the spatial asset register. The remaining habitats were classified using satellite imagery (Google Earth). Having visited the sites it became clear that there were a limited range of habitats that appeared within the estate, and it was easier to then identify habitats from satellite imagery.

This process produced a reasonably accurate basemap of the NHS Lothian Estate. The ten main hospital sites are the most accurate, the other sites are subject to some error, but this should be minimal.

The condition (poor, fairly poor, moderate, fairly good, good) of each habitat polygon within the spatial asset register was also estimated, following the guidelines for the application of the Biodiversity Metric 2.0 (Natural England 2019). This condition assessment is the basis for calculating the habitat level biodiversity units. Condition was assessed in the field for the ten priority sites. The condition of the remaining sites was estimated. As with the habitat classification, this was easier having visited a range of sites on the estate, and for the types of habitats commonly occurring within estate condition was wither moderate or poor.

Note that this spatial asset register is based on the NHS Lothian's most up to date understanding of the NHS Lothian estate. It will be possible in the future to incorporate into the asset register new sites that are identified or remove sites that are found to no longer be part of the estate.

A2.5.2 Biodiversity and climate change assessment

Biodiversity underpins the natural capital that provides benefits to people. Maintaining and enhancing biodiversity is an important part of building resilience to the environmental impacts of climate change. Key to mitigating the effects of climate change is to devise ways of reducing and capturing emissions on the NHS Lothian estate. The NHS Lothian, and indeed Scotland, have ambitious net-zero carbon targets, and it will be possible to use the green estate to contribute to these targets through carbon sequestration. Climate adaptation is also important and green assets can be used to increase flood mitigation, regulate the local climate by provision of cooling, and to produce sustainable fuel. The natural capital assets of the estate will also deliver significant health and wellbeing benefits. Green areas will contribute to the uptake of air pollutants that can have significant health impacts, and they provide opportunities for physical exercise. There is increasing evidence that access to the natural environment can increase aspects of mental health.

The spatial asset register was used to assess biodiversity and two main ecosystem services: carbon sequestration and air quality regulation. The green estate is the foundation for providing health and wellbeing benefits, but no generic production functions exist that can describe this complex relationship. Further data and analysis were necessary to understand how the NHS Lothian estate supports nature-based health and wellbeing benefits, and to estimate the costs and benefits associated with them. The spatial asset register can be used

to understand whether there is sufficient green provision (in terms of area and habitat type) on the estate to support expansion of nature-based health interventions in the future. We outline our approach to the targeted assessment below.

Biodiversity

The Biodiversity Metric 2 (Natural England 2019)[9] was used to calculate the baseline biodiversity units for the NHS Lothian estate. This relatively simple metric measures biodiversity at the level of habitats (it does not take into account populations of species). The metric scores different habitat types (e.g. woodland) according to their relative biodiversity value and adjusts this according to its size, distinctiveness and condition.

Carbon sequestration and air quality regulation

We used a natural capital accounting approach to measure the annual physical and monetary flows of carbon sequestration and air quality regulation across the whole estate, and, therefore, at individual sites within it. The overall value of the natural capital assets over their lifetime (usually estimated over 50 years) was also calculated.

Carbon sequestration

Carbon is sequestered (captured) by growing plants. We focus on sequestration by woody species (trees, hedges and scrub). There is very little information about sequestration in other habitats, but these are likely to be very low. The carbon sequestration was calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2018[13]). Coniferous woodland sequestration rates were averaged over a 60-year period and deciduous woodland sequestration rates were averaged over a 100-year period, as this is the length of a typical forestry cycle for these woodland types. Information on species composition was derived from field visits and from the Valuing Edinburgh's Urban Trees report [14]. Yield classes for each tree species were derived from Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/). The annual sequestration rate for each tree species present in the woody habitat polygon was then multiplied by its area. These were added together to give the total annual sequestration estimate for each site, and for across the whole estate in tonnes of carbon equivalent.

Monetary flows were calculated using the Government's non-traded central carbon price for 2020 (DBEIS 2019[15]). 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 a 50-year period, after discounting using the discount rate suggested in HM Treasury (2019[16]) of 3.5%. The HM Treasury also provides low and high estimates of current and future non-traded carbon prices. These were used to provide a sensitivity analysis to the economic valuation of this ecosystem service.

[13] Woodland Carbon Code (2018) Carbon calculation guidance v2. March 2018. Forestry Commission.
[14] Doick et al. (2017) Valuing Edinburgh's Urban Trees. An update to the 2011 i-Tree Eco survey – a report of Edinburgh City Council and Forestry Commission Scotland. Forest Research. https://www.forestry/fr/itree
[15] DBEIS (2019) Carbon priced and sensitivities 2010-2100 for appraisal in HM Treasury (2018) The Green Book. Central Government guidance on appraisal and evaluation, version 3. London.
[16] HM Treasury (2019) The Green Book. Crown Copyright.

Air quality regulation

The ability of the woodland, hedges, grassland and shrub vegetation across the estate to absorb particulate matter ≤2.5µm in diameter ($PM_{2.5}$) was measured. Quantifying the physical flow of the air quality regulation service was based on the absorption calculation in Powe & Willis (2004[17]) and the method in ONS (2016[18]). The deposition rates for $PM_{2.5}$ in these habitats were taken from Powe & Willis (2004). Average background pollution concentrations for $PM_{2.5}$ were calculated using Defra data (UK Air background mapping data for local authorities). 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 in 2020 (rainfall <1mm) for the Lothian region was estimated using MET office regional value data (http://www.metoffice.gov.uk/climate/uk/summaries/datasets). 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 2019[19]). 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 habitats was equal to the average damage cost of that pollutant. The $PM_{2.5}$ damage cost estimates depend on the location (urban or rural) and source of pollution. The four local authority areas of the Lothian region were considered to fall into urban large (City of Edinburgh), and urban small (East and West Lothian, and Mid Lothian) according to the Scottish Urban Rural Classification[20], and an understanding of where the sites were located within each local authority.

[17] Powe, N., A., & Willis, K.G. (2004) Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. *Journal of Environmental Management,* 70, 119-128.
[18] ONS (2016) Annex 1: Background and methods for experimental pollution removal estimates. UK National Accounts.
[19] Defra (2019) Air quality damage costs guidance. Crown Copyright.
[20] Scottish Government (2018) Scottish Government urban rural classification.

Annex 3 Nature-based health interventions

A3.1 Methods and detailed results of nature-based interventions Cost-Benefit Analysis (CBA)

A.3.1.1 Selection of green health interventions to be the subject of Cost-Benefit Analysis (CBA)

The two main nature-based health interventions that are currently offered on the NHS Lothian estate are gardening and walking. The former is delivered through community gardens (at Midlothian Community Hospital and Royal Edinburgh Hospital) and a mix of ward, courtyard and other types of smaller gardens (at Astley Ainslie Hospital, Midlothian Community Hospital, Royal Edinburgh Hospital, St John's Hospital Livingston and Western General Hospital). The latter is provided through walking routes at Astley Ainslie Hospital, Edinburgh Royal Infirmary, Midlothian Community Hospital, Royal Edinburgh Hospital, St John's Hospital Livingston and Western General Hospital.

There are no data on the use of the walking routes. Consequently, it is not possible to estimate their health impact. Information on the use of the smaller gardens is related to the programmes of activity and those delivering and participating in them. Those programmes commonly span several smaller gardens, making the estimation of the latter's specific health impacts problematic. A similar difficulty affects the analysis of the health impacts of the community gardens but to a less marked degree. Consequently, the larger gardens were one of the two foci of the CBAs. The other green health intervention that was the subject of CBA was that of outdoor nature-based programmes of activity. There is considerable potential for establishing this type of intervention on suitable sites on the NHS Lothian estate.

A3.1.2 Estimating the value to NHS Lothian of the selected green health interventions using CBA

CBAs of therapeutic gardening and of outdoor activities were undertaken, drawing on as much local data as possible. The forms of the interventions, the values of the costs and benefits, and the details of the application of discounting, together with the source of each element of the CBAs, are presented in Table A3.1 (over) and in section A3.2.3. A range of possible elements and related values might be examined. In this analysis, the following interventions were evaluated:

- the therapeutic programmes operated in the two existing community gardens on the NHS Lothian estate (elements 1 and 2) and that form part of its natural capital account; and

- potential additional green health interventions that might be pursued on suitable sites on the NHS Lothian estate, in the form of: (a) the development and operation of new community gardens (elements 3 and 4); and (b) the introduction and operation of programmes of outdoor activities similar to Branching Out (elements 5 and 6).

Table A3.1 Coverage and Contents of CBAs

	Element of CBA	Value	Source
	Subject interventions		
1	Therapeutic gardening: courses in the two existing community gardens at Midlothian Community Hospital and Royal Edinburgh Hospital, 2019-20.	2 programmes per annum	The Cyrenians, 2020
2	Therapeutic gardening, participants: recent cohort of patients (accompanying supporters/carers not accounted)	350 patients per annum	The Cyrenians, 2020
3	Therapeutic gardening: programme of courses in new community garden	1 programme per annum	The Cyrenians, 2020; Edinburgh & Lothian Greenspace Trust, 2020; The Conservation Volunteers, 2020
4	Therapeutic gardening, participants: patients (accompanying supporters/carers not accounted)	180 patients per annum	
5	Outdoor activities: Branching Out programme of 20 courses, each of one 3-hour session per week for 12 weeks	1 programme per annum	
6	Outdoor activities, participants: 9 patients per session (accompanying supporters/carers not accounted)	180 patients per annum	
	Costs		
7	Therapeutic gardening: total operating costs of delivery agent	£557 per patient per annum	The Cyrenians, 2020; Edinburgh & Lothian Greenspace Trust, 2020; The Conservation Volunteers, 2020
8	Outdoor activities: total operating costs of delivery agent	£557 per patient per annum	
9	Therapeutic gardening: NHS related costs	£411 per annum	NHS Lothian, 2020
10	Outdoor activities: NHS related costs	£411 per annum	
11	Therapeutic gardening (existing): construction of garden	£0	The Cyrenians, 2020
12	Therapeutic gardening (potential): construction of garden	£30,000 plus 10% / £3,000 per annum maintenance costs	HMST, 2014 (updated)[21]
	Benefits		

[21] HMST, Helen Macpherson Smith Trust (2014) *Community Gardens Manual*, HMST, Victoria, Australia.

13	Therapeutic gardening: change in QALYs before/after course	+0.04954 QALYs per patient	Willis et al, 2016[22]
14	Therapeutic gardening: value of a QALY	£15,180	Claxton et al, 2015 (updated)[23]
15	Outdoor activities: change in QALYs before/after course	+0.04954 QALYs per patient	Willis et al, 2016[19]
16	Outdoor activities: value of a QALY	£15,180	Claxton et al, 2015 (updated)[20]
	Discounting (Therapeutic gardening and outdoor activities)		
17	Discounting periods	50 years and 10 years	
18	Discount rate, standard, years 1-30	3.50% pa	HMT, 2020[24]
19	Discount rate, standard, years 31-50	3.00% pa	HMT, 2020[21]
20	Discount rate, health, years 1-30	1.50% pa	HMT, 2020[21]
21	Discount rate, health, years 31-50	1.29% pa	HMT, 2020[21]

[22] Willis, K., Crabtree, B., Osman, L. and Cathrine, K. (2016) Greenspace and health benefits: a QALY and CEA of a mental health programme, *Journal of Environmental Economics and Policy*, 5(2), 163-180. DOI: 10.1080/21606544.2015.1058195

[23] Claxton K, Martin S, Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC, Sculpher M (2015) Methods for the estimation of the NICE cost effectiveness threshold, *Health Technology Assessment,* 19(14): doi10.3310/hta19140.

[24] HMT, HM Treasury (2020) *The Green Book: Central Government Guidance on Appraisal and Evaluation*, HMT, London.

The CBAs indicate that both types of intervention produce estimated health benefits the value of which significantly exceed their costs (see Table A3.2). The Net Present Value (NPV) of the QALYs produced by the existing therapeutic gardening activities over a period of 50 years is estimated to be £4.65m, producing a return on investment (RoI) of 2.00. That is, every £1.00 spent on therapeutic gardening results in benefits to health with a value of £2.00. Over a period of 10 years the NPV is £0.80m and the RoI is 1.49. The equivalent figures for potential additional interventions are as follows: a programme of therapeutic gardening on a new community garden, £2.28m over 50 years and £0.36m over 10 years, with RoIs of 1.92 and 1.40, respectively; a programme of outdoor activities, £2.38m over 50 years and £0.41m over 10 years, with RoIs of 2.00 and 1.49, respectively.

Table A3.2 Estimated financial performance of interventions

		Financial Data		
Intervention		Discount	NPV of	RoI of
Type	Status	period	QALYs (£s)	QALYs
Therapeutic Gardening	Existing	50 years	4,645,444	2.00
350 patients pa		10 years	802,594	1.49
Therapeutic Gardening	Potential	50 years	2,283,278	1.92
180 patients pa		10 years	356,153	1.40
Outdoor Activities	Potential	50 years	2,384,356	2.00
180 patients pa		10 years	411,102	1.49

The financial performance of the interventions is better over longer periods because of the increasing difference between the present values of contemporaneous costs and values arising from the application of the standard and health discount rates, respectively. While significant and positive, the RoIs here are relatively modest compared with those reported in other evaluations. For example, Bagnall et al (2019)[25] calculated a return on investment of 6.88 for wildlife conservation activities run by the Wildlife Trust that were aimed at improving health and wellbeing. However, this is a social return on investment that includes the wider personal and public benefits arising from green health interventions. The current analysis covers only the direct costs and benefits of the interventions to NHS Lothian and uses these to estimate a private return on investment.

A2.1.3 Illustrating the impact of green health interventions: individual case studies

Participation in green interventions such as therapeutic gardening and outdoor activities improves people's mental and/or physical health and wellbeing. In turn, this reduces their demands on the NHS, saving it money. The ways that this process operates may be illustrated by case studies of individuals' experiences (after Vardakoulias, 2013[26]). Both produce net savings to the NHS that significantly exceed the unit cost of these types of intervention (savings of £1,954 per annum and £3,783 per annum compared with an indicative cost of £557 per patient per annum).

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[25] Bagnall, A-M., Freemand, C., Southby, K. and Brymer, E. (2019) *Social Return on Investment analysis of the health and wellbeing impacts of the Wildlife Trust programmes*, Leeds Beckett University.

[26] Vardakoulias, O. (2013) *The Economic Benefits of Ecominds: A case study approach*, New Economics Foundation, London. https://www.mind.org.uk/media-a/4424/the-economic-benefits-of-ecominds-report.pdf

How gardening helped Robin

At home in spring 2017, following a week in a high dependency unit and a month in a psychiatric ward, Robin was having monthly appointments with a psychiatrist and meeting a Community Psychiatric Nurse (CPN) every two weeks. On a 'good' day Robin expressed an interest in volunteering at the Gartnaval gardens and soon after registered as a volunteer with The Conservation Volunteers (TCV) and through the NHS.

"The first afternoon I went to the gardens … I was a very quiet and timid version of myself. I was guarded and had no confidence in myself whatsoever. I felt uncomfortable in my skin and being around other people. Despite this, and thanks to … gentle encouragement, I stayed, and I returned week after week. In the first year my attendance was erratic and depended on the depths of my lows, which were still frequent. […] Every time I missed a session, I was so ashamed and embarrassed; I didn't think I could go back. To my surprise, every time I did feel a little brighter and did manage to go back, I felt genuinely welcomed back. Unlike my experiences when I was unwell at work, there was no judgement if I showed up late. It was always reinforced that I could do as little or as much as I liked, there were no demands. I was more than welcome to just show up to a session for a cup of tea. This lack of pressure to do or achieve gave me a feeling of choice and control and this had a knock-on effect on my confidence.

I believe wholeheartedly in the healing effects of being outdoors and in nature. The resilience of plants has taught me to have faith and hope when things aren't going so well in life. Everything will be OK with time. Plants can bounce back and so can I! Gardening is such a multisensory experience it is the perfect tool to ease you into mindfulness; you can't help but start to notice the sounds of the different birds or the leaves rustling, the feeling of the cool soil on your fingertips, the scent and taste of the herbs, the iridescent colours on the back of a beetle, the smell of wet leaves. Gardening has taught me to be patient, to be hopeful, to accept myself as I am.

In the last few months, I referred myself to a program designed to help people with mental health problems get back to work. This is run by the Scottish Association for Mental Health (SAMH) and already I have been offered a part-time job as an assistant to a very successful garden designer that is due to start in the new year. This wouldn't have happened had I not discovered my passion for gardening and without the skills and knowledge that I've developed over the past three and a half years as a volunteer. Clearly the project has been hugely beneficial to me on a personal level, but I also think it could have a ripple effect in a more complex and wider sense. For example, thanks to my progress and confidence gained at the gardens, I co-facilitated an 8-week course called, 'Action for Happiness' which was a free course and was attended by 15 individuals who also wanted to connect and explore the determinants of our own happiness. I am now far enough in my recovery that I feel comfortable talking openly about my own experiences."

Robin now has an appointment with a psychiatrist every three months and no longer has meetings with a CPN, although Robin's level of medication has been increased.

Source: anonymous volunteer, via Rebecca Strofton (Team Leader, The Conservation Volunteers) acting as an intermediary.

Outcomes
The avoided costs of the intervention to the NHS are the following:

- Increased prescription costs
- Avoided psychiatric consultation costs
- Avoided use of community psychiatric nurse services

Table A3.3 summarises the economic benefits arising from the improvements to Robin's health (see A3.2.3 for details). The estimated direct net avoided costs to the NHS amount to £1,954 per annum. Because of the lack of evidence of the long-term health and economic effects of therapeutic gardening, the benefits are assumed to last for one year only. This is a conservative assumption that is likely to understate the value of the benefits.

Table A3.3 Summary of annual economic benefits from Robin and gardening

Benefits	**Value**
Increased prescription costs	-£130
Avoided psychiatric consultation costs	£888
Avoided use of community psychiatric nurse services	£1,196
Total	**£1,954**

Gemma's experience of Branching Out

Gemma has a diagnosis of bipolar affective disorder and has received treatment over the last 30 years in inpatient and community settings involving detention under the Mental Health Act. Branching Out was offered to Gemma by her support worker who had a good working relationship with Gemma and knew she enjoyed the outdoors. Branching Out is offered to service users who are under the care of the community mental health team (CMHT). Users' participation is facilitated by staff from Edinburgh & Lothians Greenspace Trust and by support workers from the CMHT.

Gemma was keen to have a new experience, commit to weekly attendance and contribute to the group. She participated in the Branching Out project on two occasions. In the summer of 2015, Gemma attended weekly and completed three out of a possible 12 sessions. Gemma was unable to continue with the group because of a decline in her mental health. She joined the course again the following summer and completed it in October 2016.

Gemma initially struggled to contribute her thoughts and speak up during activities. However, over the course her confidence grew and Gemma often took the lead in activities and supported other group members. Out with the group, Gemma continued to have one-to-one support from her support worker. Gemma said that attending the group helped structure her week and provided some normality for her. Gemma acknowledged that her second attempt at the group was successful due to timing. She was coming out of a period of depression and felt "in a better place". Being able to focus on a physical task, doing something different and not being indoors all day were areas identified by Gemma as contributing to her enjoyment of the group. Gemma felt at that time that she was well enough to know what helped to

improve her mood. She identified the following factors that enabled her to attend the group each week and to complete the course.

- Social contact under her control;
- Feeling safe in the group;
- Being around others with similar conditions;
- Non-clinical setting;
- Supportive staff; and
- Not feeling judged.

After completing the course, over the following 2 years until late summer 2018, Gemma's contact with the CMHT gradually reduced from weekly contact with her community psychiatric nurse (CPN) and her support worker and 6-monthly psychiatrist's appointment, to discharge from her CPN and support worker and a yearly review by a psychiatrist. During this time Gemma completed a further outdoor activities-based group course (Good Woods, 2017-18) as well as volunteering in a florist. The volunteering led to a paid post that Gemma still holds. Gemma continues to use medication but her dose has been halved. She has not had a relapse in her mental health.

Source: Julie Bagbakan, Community Mental Health Team, NHS Lothian.

Outcomes

The avoided costs of the intervention to NHS Lothian are the following:

- Avoided prescription costs
- Avoided psychiatric consultation costs
- Avoided use of community psychiatric nurse services
- Avoided use of support worker

Table A3.4 summarises the economic benefits arising from the improvements to Gemma's health (see Section A2.5 for details). The estimated direct avoided costs to the NHS amount to £3,783 per annum. Because of the lack of evidence of the long-term health and economic effects of Branching Out, the benefits are assumed to last for one year only. This is a conservative assumption that is likely to understate the value of the benefits.

Table A3.4 Summary of annual economic benefits from Gemma and Branching Out

Benefits	**Value**
Avoided prescription costs	£32
Avoided psychiatric consultation costs	£111
Avoided use of community psychiatric nurse services	£2,392
Avoided use of support worker	£1,248
Total	**£3,783**

A3.2 The cost-benefit analysis (CBA) of nature-based health interventions

A3.2.1 The NHS Lothian context

The strategic framework for greenspace and health developed by the Edinburgh & Lothians Health Foundation (ELHF, 2019[27]) identifies the health benefits that are associated with greenspace and how these might be realized. However, there is no detailed consideration of the costs involved in such activities or of the monetary value of the health benefits that result from them. The studies covered by the evidence review (ELHF, 2019[24], Appendix 2) that informed the strategic framework were analysed to identify what consideration was given to the financial costs and benefits of activities and/or investments in greenspaces.

- The WHO (2016[28], 2017a[29] and 2017b[30]) studies contained only one detailed reference to the cost-effectiveness of greenspace activities/investments. This covered investments in parks and in physical activity-based interventions such as walking and cycling trails. The latter were associated with benefit cost ratios in a range (>4-1):1 (WHO, 2017a[26], Appendix 1: 22-23).

- The DEFRA review, reported in Maxwell and Lovell (2017)[31] and Lovell et al (2018)[32], covered the estimation of the monetised health values of the natural environment. Many of the studies related to the general health effects of nature or to green activities or investments of a form or in a context different from the NHS Lothian Estate. However, estimates of the cost-effectiveness of health walks and nature-based health interventions for mental health were given in terms of unit monetary values and in QALYs.

- The EU-funded INHERIT report (Staatsen et al, 2017[33]; Chapter 4) focused on the health benefits of urban nature. Consideration of the associated financial costs and benefits was limited to population level estimates (White et al, 2016)[34] and to a single detailed example: Green Gyms (nef Consulting, 2016)[35].

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[27] ELHF, Edinburgh & Lothians Health Foundation (2019) *Greenspace and Health: Strategic Framework for Edinburgh & Lothians*, Edinburgh and Lothians Health Foundation, Edinburgh.

[28] WHO, World Health Organization, Regional Office for Europe (2016) *Urban Greenspaces and Health: A Review of Evidence*, WHO, Copenhagen.

[29] WHO, World Health Organization, Regional Office for Europe (2017a) *Urban Greenspace Interventions and Health: A Review of Impacts and Effectiveness*, WHO, Copenhagen.

[30] WHO, World Health Organization, Regional Office for Europe (2017b) *Urban Greenspaces: a brief for action,* WHO, Copenhagen.

[31] Maxwell, S. and Lovell, R. (2017) *Evidence Statement on the links between natural environments and human health*, DEFRA, London.

[32] Lovell, R., Depledge, M. and Maxwell, S. (2018) *Health and the natural environment: A review of evidence, policy, practice and opportunities for the future*, DEFRA, London.

[33] Staatsen, B., van der Vliet, N., Kruize, H., Hall, L., Morris, G., Bell, R. and Stegeman, I. (2017) *INHERIT: Exploring triple-win solutions for living, moving and consuming that encourage behavioural change, protect the environment, promote health and health equity*, EuroHealthNet, Brussels.

[34] White, M., Elliott, L., Taylor, T., Wheeler, B., Spencer, A., Bone, A., Depledge, M. and Fleming, L. (2016) Recreational physical activity in natural environments and implications for health: A population based cross-sectional study in England, *Preventive Medicine*, 91, 383-388.

[35] nef Consulting (2016) *Green Gym Evaluation Report 2016*, The Conservation Volunteers, https://www.tcv.org.uk/wp-content/uploads/2012/04/green-gym-evaluation-report-2016.pdf

- The NICE review (Bennie et al, 2017)[36] considered the role of park, neighbourhood and multicomponent interventions in raising levels of physical activity to produce health benefits. It identified just two studies that "included small amounts of data on cost effectiveness of park locations" (ibid: 37) in the form of average costs per MET-hour (Metabolic Equivalent Task) arising from park refurbishment and from the development of new pocket parks in the USA.

- Natural England commissioned a review of nature-based interventions for mental health care (Bragg and Atkins, 2016[37]; Bragg and Leck, 2017[38]). The reports made general references to the cost-effectiveness of nature-based interventions for mental health care but did not present any detailed evidence on the matter.

The above findings support Lovell et al's (2018: 44)[29] view that "There are few studies ... which have sought to specifically value direct health benefits of exposure to, or use of, natural environments on health outcomes. [...] This is predominantly related to the quality of the existing evidence base and extent of datasets." The latter are both limited. A particular problem is posed by the very varied, highly specific combinations of the particular characteristics of the subjects of the interventions, of the interventions themselves and of the effects of the interventions, intended or otherwise.

A3.2.2 Approaches to the cost-benefit analysis (CBA) of nature-based health interventions

It was agreed with NHS Lothian that the therapeutic interventions that would be the subject of CBA would be (i) gardening/horticultural activities and (ii) conservation/outdoor activities. A review of the academic and practice/policy literature on the analysis of the financial performance of these interventions was undertaken using Google, Google Scholar, the National Center for Health Research (NCHR), the National Institute for Health Research (NIHR), the National Institute for Health and Care Excellence (NICE), OVID Medline, Pubmed and Web of Science. It focused on review papers to maximise coverage in the limited time available.

(i) The literature on the cost-effectiveness of therapeutic gardening/horticulture

The focus of the academic reviews and meta-analyses of gardening and horticulture was on their impact on health and wellbeing (Gonzalez and Kirkevold, 2013[39]; Kamioka et al, 2014[40];

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[36] Bennie, J., Crane, O., Cullum, A., Levay, P., O'Rourke, D., Murray, A., Peploe, K., Wohlgemuth, C. and McGuire, H. (2017) *NICE Physical activity and the environment update: Evidence Review 3: Park, Neighbourhood and Multicomponent Interventions*, NICE. https://www.nice.org.uk/guidance/ng90/documents/evidence-review-3

[37] Bragg, R. and Atkins, G. (2016) *A review of nature-based interventions for mental health care*, Natural England Commissioned Report Number 204, York. http://publications.naturalengland.org.uk/publication/4513819616346112

[38] Bragg, R. and Leck, C. (2017) *Good practice in social prescribing for mental health: The role of nature-based interventions*, Natural England Commissioned Report Number 228, York. http://publications.naturalengland.org.uk/publication/5134438692814848

[39] Gonzalez, M. and Kirkevold, M. (2013) Benefits of sensory garden and horticultural activities in dementia care: a modified scoping review, *Journal of Clinical Nursing*, 23, 2698-2715.

[40] Kamioka, H., Tsutani, K., Yamada, M., Park, H., Okuizumi, H., Honda, T., Okada, S., Park, S-J, Kitayuguchi, J., Abe, T., Handa, S. and Mutoh, Y. (2014) Effectiveness of horticultural therapy: a systematic review of randomized controlled trials, *Complementary Therapies in Medicine*, 22, 930-943.

Soga et al, 2017[41]; Thaneshwari et al, 2018[42]; Whear et al, 2014[43]). None of these papers presented any evidence on the costs or cost-effectiveness of the reviewed interventions. In a practice/policy report, Buck (2016: 40-41) considered "The business case for gardens, gardening and health". This was limited to references to other studies that used analyses based on large populations to estimate the value of the treatment costs to the NHS that were avoided because of the beneficial impact of parks, greenspaces, trees and activities related to them on physical and people's mental health and wellbeing. The two specific studies identified by Buck (2016)[44] were not related to gardening/horticulture.

(ii) The literature on the cost-effectiveness of conservation and related outdoor activities/ therapies

Three studies were found that examined the cost-effectiveness of conservation and other outdoor activities/therapies. They adopted different methodologies to address the issue.

A case study approach

Vardakoulias (2013)[23] used case studies of individuals pursuing a range of managed activities on the Ecominds scheme – including conservation, wildlife, horticulture and gardening – to estimate the economic benefits of these activities. These were equated to the estimated avoided costs to the public sector plus additional income accruing to the public sector as a result of the interventions. Examples of the former included avoided prescription, medical consultation and treatment costs.

A quality adjusted life year (QALY) and cost effectiveness analysis (CEA) approach

Willis et al (2016)[19] undertook a before-and-after analysis of the mental health benefits arising from the Branching Out programme. Patients, together with therapists and service organisers, pursued group-based woodland activities tailored to their needs for three hours each week for a 12-week period. The resulting change in patients' QALYs was calculated from before and after SF-12 scores. Cost per QALY was then estimated, based on the staffing, facilities and other costs of the programme.

A social return on investment (SROI) approach using wellbeing valuation

Rogerson et al (2017)[45] used a before-and-after method to assess the impact of involvement in Wildlife Trust activities on the health and wellbeing of participants. Questionnaires embodying WEMWBS, elements of the International Physical Activity Questionnaire (IPAQ) and bespoke questions were administered to estimate the changes in health and wellbeing. Bagnall et al (2019)[22] identified proxy measures for these changes and attributed financial values to them that reflected their social worth to the individual. These social values were obtained from the HACT social value calculator (hact.org.uk/value-calculator; see Trotter et

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[41] Soga, M., Gaston, K. and Yamaura, Y. (2017) Gardening is beneficial for health: a meta-analysis, *Preventive Medicine Reports*, 5, 92-99.

[42] Thaneshwari, Kumari, P., Sharma, R. and Sahare, H. (2018) Therapeutic Gardens in Healthcare: a Review, *Annals of Biology*, 34(2), 162-166.

[43] Whear, R., Thompson Coon, J., Bethel, A., Abbott, R., Stein, K. and Garside, R. (2014) What is the impact of using outdoor spaces such as gardens on the physical and mental well-being of those with dementia? A systematic review of quantitative and qualitative evidence, *JAMDA*, 15, 697-705.

[44] Buck, D. (2016) *Gardens and Health: Implications for policy and practice*, The King's Fund, London.

[45] Rogerson, M., Barton, J., Bragg, R. and Pretty, J. (2017) *The health and wellbeing impacts of volunteering with the Wildlife Trusts*, University of Essex, Essex.

al, 2014)[46], from the global value exchange tool (globalvalueexchange.org) and from Collins (2014)[47] and Trotter and Rallings (2017)[48].

Comparison of the alternative approaches to CBA

The three approaches use different measures of value: avoided costs and arising incomes (case studies); QALY combined with CEA relative to the NICE threshold (Willis et al, 2016)[19]; and the value of any increase in health and wellbeing to the individual (SROI approach). The case study approach is technically the most straightforward but, because it relates to individual participants, provides the weakest basis for generalisation. The QALY and SROI approaches are more methodologically rigorous but resource and time constraints mean that the application of either would require extensive use of the benefits transfer technique. This results in less specificity but it has a firmer general empirical basis.

A3.2.3 Further details of the selected approaches to CBA

It was agreed with NHS Lothian that the two approaches to CBA that best met its requirements were: (i) the QALY/CEA approach that uses the change in participants' QALYs to derive estimates of the value of the health benefits resulting from the intervention; and (ii) the case study approach adapted to the needs of NHS Lothian by equating the economic benefits of a therapeutic intervention to the estimated resulting avoided health costs.

The QALY/CEA approach to CBA

Willis et al (2016)[19] analysed the results of two surveys of participants in the Branching Out programme in Scotland (2007-08, n=74 and 2011-12 n=76; pooled n=150). The programme engages adults with severe and enduring mental health problems in a range of woodland group activities for three hours a week over a 12-week period. The mean changes in the QALY scores of the participants in the Branching Out programme were as follows:

2007-08 cohort: -0.00902; not statistically significant.
2011-12 cohort: +0.04954; statistically significant.
Pooled data for both cohorts: +0.01948; statistically significant.

The estimation of the value of the health benefits resulting from Branching Out are dependent on the value attributed to a QALY. Willis et al (2016)[19] use £30,000 as the value of a QALY but do not provide any justification for this figure. HMT (2020)[21] suggests that the welfare benefit of an additional QALY is £60,000. In contrast, the NICE threshold based on White et al (2016)[19] and Eftec (2017)[49] was £20,000 per QALY. More recently, the Department of Health has advised that an indicative threshold of £15,000 per QALY (2018 prices) be used (based on Claxton et al's (2015)[20] estimate of averted costs). Given NHS Lothian's concern

[46] Trotter, L., Vine, J., Leach, M. and Fujiwara, D. (2014) *Measuring the Social Impact of Community Investment: a Guide to Using the Wellbeing Valuation Approach*, HACT, London.
[47] Collins, B. (2014) *How do we value wellbeing? Combining data to put an economic value on the change in Short Warwick Edinburgh Wellbeing Scale (SWEMWBS) scores*, SSRN.
[48] Trotter, L. and Rallings Adams, M-K. (2017) *Valuing improvements in mental health: applying the wellbeing valuation method to WEMWBS*, HACT, London.
[49] Eftec (2017) *Scoping UK Urban Natural Capital Accounts*, Report for Defra, eftec, London.
Gonzalez, M. and Kirkevold, M. (2013) Benefits of sensory garden and horticultural activities in dementia care: a modified scoping review, *Journal of Clinical Nursing*, 23, 2698-2715.

with cost savings, the latter threshold (updated to 2019 prices) is applied to Willis et al's (2016)[19] results.

Using £15,180 per QALY, the average economic value of these changes for each person completing the course are:

2007-08 cohort: £0 (no observable change in QALY).
2011-12 cohort: 0.04954 x 15,180 = £752.02
Pooled data for both cohorts: 0.01948 x 15,180 = £295.71

These estimates are based on the assumption that the health improvement resulting from the intervention lasts one year (a similar assumption is made by Vardakoulias, 2013[23]). If the health improvements are not as lasting, then their QALY and money values will be reduced commensurately. In the absence of any similar study, the health improvement resulting from the completion of a programme of gardening activities, measured by change in QALYs, was assumed to be the same as that for conservation/outdoor activities.

The estimated cost of the Branching Out programme related to 2012-13 (£142,695 for 335 people: an average cost of £426 per user per year). The equivalent figures for 2019, adjusted for inflation using the Consumer Price Index (CPI; ONS, 2020), are: £158,631 and £474.

The case study approach to CBA

Vardakoulias (2013)[23] adopted a before-and-after approach to the estimation of the impact of interventions on five individual participants. He compared, *inter alia*, the change in the cost of various aspects of healthcare that resulted from the activities. The savings were estimated using a wide range of NHS unit cost data. The results are summarised in Table A2.5. Vardakoulias (2013)[23] made no estimate of the unit or aggregate costs of setting up and running the relevant activities, so it was not possible to estimate their cost-effectiveness.

Table A3.5 Annual economic benefits arising from specified therapeutic interventions

	Therapeutic interventions				
Economic benefits	1. Joanne Horticulture	2. John Conservation	3. Wayne Conservation	4. Jack Conservation	5. Gary Gardening
Avoided prescription costs	£258.27	£258.27	£258.27	£258.27	
Avoided medical consulation costs	£408.92	£408.92	£408.92	£408.92	
Avoided community psychiatric nurse costs	£6,968.00		£3,484.00		
Avoided OCD treatment and medication costs					£440.07
Avoided diabetes complication costs		£1,815.00			
Avoided alcohol outpatient treatment		£4,888.00			
Benefits to NHS	£7,635.19	£7,370.19	£4,151.19	£667.19	£440.07
Avoided Jobseeker's Allowance	£2,953.60			£3,728.40	£2,953.60
Avoided Disability Living Allowance	£1,092.00			£1,092.00	£1,092.00
Increased tax contribution	£572.90			£572.90	
Increased NI contribution	£545.94			£545.94	
Other public sector benefits	£5,164.44			£5,939.24	£4,045.60
All benefits	£12,799.63	£7,370.19	£4,151.19	£6,606.43	£4,485.67

Source: Vardakoulias (2013)

A3.2.4 Coverage and contents of the QALY/CEA CBAs for NHS Lothian

Subject interventions

1 & 2. Therapeutic gardening courses were run in the two existing community gardens at Midlothian Community Hospital and Royal Edinburgh Hospital by the Cyrenians. 350 patients participated in these courses in 2019-2020.

3 & 4. A standard programme of therapeutic gardening courses, similar to the Branching Out programme of outdoor activities, operating in a new community garden would involve 180 patients each year.

5 & 6. A standard Branching Out programme of outdoor activities consisting of 20 courses, each of one 3-hour session per week for 12 weeks, involving 9 patients. 180 patients would participate in the programme each year.

Costs

It is assumed that any carers/supporters accompanying the patients would have been so occupied if the patients had been pursuing other activities. The cost of such carers / supporters is not, therefore, taken into account.

7 & 8. Three delivery agents (The Cyrenians, ELGT and TCV) provided details of the costs of running a programme. These include direct staff costs (salary, pension, NIC), staff insurance, a materials budget, event costs, volunteer expenses (for travel) and staff and volunteer personal protective equipment (boots, waterproofs, work gloves, etc). They also cover a proportion of the deliver agent's overheads including staff recruitment and training, IT, Health & Safety and safeguarding support, finance, payroll, laptops/mobile phones, management costs and office costs.

The cost per patient of a programme varies with: the state of health of the participants; the staff/patient ratio; the type and intensity of the activities that are pursued; and the number of sessions in / duration of the course. Delivery agents' costs for programmes of shorter, less

intense courses were estimated to be £278, £301 and £343 per patient per annum. The estimated costs for programmes of longer, more intense courses were £505, £556 and £557 per patient per annum. The costs of running therapeutic gardening courses were similar to those for courses of outdoor activities. Branching Out courses are relatively long and intensive. It is assumed that a therapeutic gardening course would need to be of a similar character to have the same impact on participants' health. Consequently, £557 per patient per annum (the highest and most conservative estimate) was the overall unit operating cost selected for use in the CBAs.

9 & 10. The NHS costs incurred in relation to a programme of courses run by one delivery agent include the following. Due diligence checks on delivery agent: 4.5 hours of NHS administrator staff time per organisation. The checks are undertaken at the start of a project and are reviewed annually, with the full cost incurred in year 1 and then 0.25 of the cost each subsequent year of the programme. Services provision (water, gas and electricity) is assumed to be negligible by NHS Lothian and therefore is not accounted. Commissioning costs involved in entering into a service level agreement with the provider: 1.5 days of NHS administrator staff time to agree terms and draft a contract. Co-ordination and promotion of programmes are general duties. Assume, say, 1 day per annum of staff time attributed to each specific programme. Applying mid-point Band 4 gross salary (£21,892-£24,157 = £23,025) plus employer's overheads results in a (working) day rate of £130. Making the conservative assumption that each programme is of one year's duration, NHS costs are: 3.14 days @ £130 = £411.

11. Because the existing community gardens were developed piecemeal over a significant period, the cost of constructing these gardens is not included in the related CBA.

12. Information on the cost of constructing a community garden is very limited. Most guidance covers the design of such gardens and advice on how to go about raising funding to pay for their development. An exception is HMST (2014)[18]. This outlines a construction budget for a 'typical' community garden that covers design and planning, site preparation, structures (shed, greenhouse, polytunnel, pergola, etc), garden works (raised beds, compost bays, water butts, etc) and tools and equipment. It excludes the cost of the site, as does the CBA because the required land is already part of the NHS Lothian estate. The current cost is £30,000. This is a high, conservative estimate because the HMST (2014)[18] garden specification includes more features than those contained in the two existing community gardens at Midlothian Community Hospital and Royal Edinburgh Hospital. Repairs, maintenance and depreciation of garden structures, works and tools is covered by an allowance of 10% / £3,000 per annum.

Benefits

13 – 16. The benefits of the green health interventions, measured in QALYs, are based on Willis et al (2016)[19]. Because no assessment could be found of the health benefits of gardening that reported results in a form that allowed their monetary value to be derived, such benefits were assumed to be the same as those arising from outdoor activities. The change in QALYs resulting from participating in a course (elements 13 and 15) is given in Willis et al (2016)[19]. The Department of Health advises that the value of a QALY (elements 14 and 16) be based on Claxton et al's (2015) estimate of averted costs. See Appendix 3 for a more detailed discussion of these points.

Discounting

17-21. The costs and benefits relating to the two interventions were estimated for periods of 50 years and 10 years (element 17), using the standard and health discount rates specified by HM Treasury (2020)[21] (elements 18-21).

Data quality

Table A3.6 (below) provides an indication of the quality and calculative significance of the data used in the CBAs. By far the largest cost of nature-based health interventions is that of the delivery agents (elements 7 and 8). Three such agents (The Cyrenians, ELGT and TCV) provided estimates of the cost of programmes of courses of gardening and outdoor activities. They have extensive experience of operating such courses in Central Scotland and their estimates – particularly those for the more intensive courses – were similar. These cost data were therefore considered to be of high quality. The information on NHS Lothian's related costs (elements 9 and 10) were similarly rated, although they constitute a small proportion of overall costs. Data on the costs of the construction and maintenance of a therapeutic garden (element 11) were derived from secondary sources. This led to their medium quality rating. They constitute a significant but modest proportion of the overall costs.

The value of the health benefits generated by the selected green health interventions is the product of the change in the QALYs (elements 13 and 15) and the value of a QALY (elements 14 and 15). The latter was based on Department of Health advice and was rated highly for this reason. The former, as far as outdoor activities are concerned, was based on relatively recent, rigorous research and was therefore also rated highly. No such evidence existed for therapeutic gardening, the value of whose benefits was based on the assumption that it had the same effect on patient's health as outdoor activities. It was for this reason that the quality of this datum was rated much lower.

The data 'gap' that has had the greatest impact on the robustness of the CBA results is the lack of rigorous evidence of the health impact of therapeutic gardening in a form that allows a monetary value of that impact to be estimated. It is recommended that an evaluation of a 'standard' or 'typical' programme of therapeutic gardening (defined according to the needs of NHS Lothian) be undertaken to fill this gap.

Table A3.6: Estimation of Quality of Data used in the CBAs

	Element of CBA	Value	Sources	Data quality	Significance in calculation
	Costs				
7	Therapeutic gardening: total operating costs of delivery agent	£557 per patient per annum	The Cyrenians, 2020; Edinburgh & Lothian Greenspace Trust, 2020; The Conservation Volunteers, 2020	**7**	**8**
8	Outdoor activities: total operating costs of delivery agent	£557 per patient per annum		**7**	**8**
9	Therapeutic gardening: NHS related costs	£411 per annum	NHS Lothian, 2020	**7**	**2**
10	Outdoor activities: NHS related costs	£411 per annum		**7**	**2**
12	Therapeutic gardening (potential): construction of garden	£30,000 plus 10% / £3,000 per annum maintenance costs	HMST, 2014[18] (updated)	**5**	**4**
	Benefits				
13	Therapeutic gardening: change in QALYs before/after course	+0.04954 QALYs	Willis et al, 2016[19] (updated)	**4**	**9**
14	Therapeutic gardening: value of a QALY	£15,180	Claxton et al,[20] 2015 (updated)	**8**	**9**
15	Outdoor activities: change in QALYs before/after course	+0.04954 QALYs	Willis et al, 2016[19] (updated)	**8**	**9**
16	Outdoor activities: value of a QALY	£15,180	Claxton et al, [20]2015 (updated)	**8**	**9**

Scale: Low (1-3); Medium (4-6); High (7-9)

A3.2.5 Estimation of the avoided health costs in the individual case studies

Robin and gardening

Increased prescription costs

Prescriptions in 2017: Fluoxetine, 20mg per day; Quetiapine, 50mg per day. Prescriptions in 2020: Fluoxetine, 60mg per day; Quetiapine, 300mg per day; Lamotrigine, 300mg per day.

The current minimum cost (drug tariff price) of 30 Fluoxetine 20mg capsules is £1.12 (£1.12 x 12.17 = £13.63 pa) and of 30 Fluoxetine 60mg capsules is £7.46 (£7.46 x 12.17 = £90.79 pa). Source: BNF https://bnf.nice.org.uk/medicinal-forms/fluoxetine.html, accessed 11/01/21. Additional cost over one year: £77.16.

The current minimum cost of 60 Quetiapine 25mg tablets is £2.11 (£2.11 x 2 x 6.083 = £25.67 pa for 50mg per day) and of 60 Quetiapine 300mg tablets is £6.44 (£6.44 x 6.083 = £39.17 pa). Source: BNF https://bnf.nice.org.uk/medicinal-forms/quetiapine.html, accessed 11/01/21. Additional cost over one year: £13.50.

The current minimum cost of 56 Lamotrigine 100mg tablets is £2.98 (£2.98 x 6.52 = £19.43 pa) and of 56 Lamotrigine 200mg tablets is £3.07 (£3.07 x 6.52 = £20.02 pa). Source: BNF https://bnf.nice.org.uk/medicinal-forms/lamotrigine.html, accessed 11/01/21. Additional cost over one year: £39.45.

Total additional prescription costs over one year: £130.11.

The conservative assumption is made that this disbenefit lasts for one year.

Avoided psychiatric consultation costs

Change from monthly psychiatrist's appointments to appointments every three months. Hospital based doctors, consultant psychiatric, cost per hour, 48-hour week, 2018-19 values: £111.00. Source: Curtis, L. and Burns, A. (2019) *Unit Costs of Health and Social Care 2019*, PSSRU, University of Kent; <https://www.pssru.ac.uk/project-pages/unit-costs/unit-costs-2019/>, accessed 15/12/20. Savings over one year: £888.00. These are based on costs per hour rather than costs per consultation. The latter may be higher or lower than the former, depending on circumstances. The conservative assumption is made that this benefit lasts for one year.

Avoided use of community psychiatric nurse services

Change from meeting a community psychiatric nurse (CPN) every two weeks to no meetings with a CPN. Community-based nurses, Band 6, nurse specialist (community), cost per hour, 2018-19 values: £46.00. Source: Curtis, L. and Burns, A. (2019) *Unit Costs of Health and Social Care 2019*, PSSRU, University of Kent; <https://www.pssru.ac.uk/project-pages/unit-costs/unit-costs-2019/>, accessed 15/12/20. Savings over one year: £1,196.00. These are based on costs per hour rather than costs per contact. The latter may be higher or lower than the former, depending on circumstances. The conservative assumption is made that this benefit lasts for one year.

Gemma and Branching Out

Avoided prescription costs

Use of Quetiapine reduced from 400mg per day to 200mg per day. The current minimum cost (drug tariff price) of 60 Quetiapine 200mg tablets is £5.26 (£5.26 x 6.083 = £32.00). Source: BNF https://bnf.nice.org.uk/medicinal-forms/quetiapine.html, accessed 14/12/20. Savings over one year: £32.00. The conservative assumption is made that this benefit lasts for one year.

Avoided psychiatric consultation costs

Change from biannual psychiatrist's appointment to annual review by a psychiatrist. Hospital based doctors, consultant psychiatric, cost per hour, 48-hour week, 2018-19 values: £111.00. Source: Curtis, L. and Burns, A. (2019) *Unit Costs of Health and Social Care 2019*, PSSRU, University of Kent; <https://www.pssru.ac.uk/project-pages/unit-costs/unit-costs-2019/>, accessed 15/12/20. Savings over one year: £111.00. These are based on costs per hour rather than costs per consultation. The latter may be higher or lower than the former, depending on circumstances. The conservative assumption is made that this benefit lasts for one year.

Avoided use of community psychiatric nurse services

Change from weekly contact with community psychiatric nurse (CPN) to discharge from CPN. Community-based nurses, Band 6, nurse specialist (community), cost per hour, 2018-19 values: £46.00. Source: Curtis, L. and Burns, A. (2019) *Unit Costs of Health and Social Care 2019*, PSSRU, University of Kent; <https://www.pssru.ac.uk/project-pages/unit-costs/unit-costs-2019/>, accessed 15/12/20. Savings over one year: £2,392.00. These are based on costs per hour rather than costs per contact. The latter may be higher or lower than the former, depending on circumstances. The conservative assumption is made that this benefit lasts for one year.

Avoided use of support worker

Change from weekly contact with support worker to discharge from support worker. Support and outreach worker, cost per hour, 2018-19 values: £24.00. Source: Curtis, L. and Burns, A. (2019) *Unit Costs of Health and Social Care 2019*, PSSRU, University of Kent; <https://www.pssru.ac.uk/project-pages/unit-costs/unit-costs-2019/>, accessed 15/12/20. Savings over one year: £1,248.00. These are based on costs per hour rather than costs per contact. The latter may be higher or lower than the former, depending on circumstances. The conservative assumption is made that this benefit lasts for one year.

Annex 4 Benefits of greenspaces and recommendations at estate and site scales

A4.1 Aims and literature review

A4.1.1 Aims

The aims of this section are to summarise the:

1. characteristics of greenspace associated with health and wellbeing benefits (e.g. type/ size/ facilities within/ tree cover etc./ locations of nearby green/ open space)
2. types of (physical) activities that can help improve patients' mental health and wellbeing
3. focus on biodiversity and carbon sequestration and relevant NHS Lothian sites greenspace characteristics
4. specific interventions recommended which both contribute to enhancing biodiversity and improving carbon sequestration, in line with on-site health and wellbeing benefits

A4.1.2 The health and wellbeing benefits of greenspace: introduction.

There is extensive evidence of the overall health and wellbeing benefits of urban greenspace (e.g. Lovell, 2018[50]; Public Health England, 2020[51]; Douglas et al., 2017[52]). Within a hospital context, it is important to examine how specific characteristics of an estate can maximise the contribution that greenspace can make to health and wellbeing outcomes (Shackell and Walter, 2012[53]) and where potential improvements can be made. There are, however, limitations to our current understanding of the health and wellbeing benefits of specific characteristics of greenspace in that we can refer only to those that have been tested by empirical researchers (and by default deemed worthy of examination). For example, recent research conducted in Sheffield (Dobson and Dempsey, 2019[54]) asked health and greenspace practitioners and professionals which interventions in greenspaces were considered to be healthiest. *Cafés* emerged as an important and feasible intervention in parks and greenspaces, despite there being no current empirical evidence to support their specific contribution to health and wellbeing.

In this way, the following section cannot provide an exhaustive review of all health and wellbeing benefits of particular greenspace characteristics. However, the literature reviewed which highlights the health and wellbeing benefits of greenspace tends to fall into two broad categories: ***physical interventions*** and ***programmed activities***. A further category around ***management and maintenance*** also emerged, which are important for health and wellbeing benefits, but tend not to have been examined in detail in research.

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[50] Lovell, R. (2018) *Research Briefing: Health and the natural environment. A review of evidence, policy, practice and opportunities for the future*, Defra, London.

[51] Public Health England (2020) *Improving access to greenspace: A new review for 2020*, PHE, London.

[52] Douglas, O. Lennon, M. and Scott, M. (2017) Greenspace benefits for health and wellbeing: A life-course approach for urban planning, design and management. *Cities,* 66, 53–62.

[53] Shackell, A. and Walter, R. (2012). *Greenspace design for health and well-being.* Forestry Commission Practice Guide. Forestry Commission, Edinburgh.

[54] Dobson, J. and Dempsey N. (2019) Working out What Works: The Role of Tacit Knowledge Where Urban Greenspace Research, Policy and Practice Intersect, Sustainability, 11(18), 5029; https://www.mdpi.com/2071-1050/11/18/5029

The characteristics of greenspace associated with health and wellbeing benefits.

The presence of nearby greenspace is a well-examined characteristic by researchers, often in terms of more being positively associated with health benefits. Having ***easy access to nature*** is associated with positive physical and mental health outcomes (ELHF, 2019[55]; Taylor et al., 2017[56]). Access to nature can contribute to better physical health (e.g. Gladwell et al., 2013[57]; Almanza et al., 2012[58]) and mental health outcomes by improving patient stress (WHO, 2016[25]); attentional fatigue (INHERIT, 2017[59]), levels of depression and anxiety (DEFRA, 2017[60]). It therefore follows that ***perceived greenness of a neighbourhood*** is associated with better physical and mental health – greener neighbourhoods are correlated with recreational walking and social engagement (WHO, 2016[25]; Douglas et al., 2017[61]). Positive health outcomes have been found when research participants did their physical activity in wooded areas around water features and places with pleasant views (WHO, 2016[25]). ***Enhancing the greenery*** in a given area, including the greening of derelict/ vacant spaces, is associated with positive physical and mental health and wellbeing outcomes for people at different points in the life course (Douglas et al., 2017[53]; Hystad et al., 2014[62]; Agay et al., 2014[63]).

When in greenspaces, there is some evidence that the ***specific equipment/ facilities*** are correlated with improved health outcomes, particularly with older age groups. This includes toilets and seating (DEFRA, 2017[52]) but also includes walking and cycling paths as well as bike racks and parking (WHO, 2016[25]; Gardsjord et al., 2014[64]). Trim trails and exercise equipment were associated with increased greenspace use, however the evidence does not always measure specific health and well-being outcomes (e.g. Cranney et al, 2016[65]).

While it is not always possible to unpick the specific effects of particular features in the greenspace, it is widely accepted that ***trees*** form part of greenspace and therefore are associated with health and wellbeing benefits (e.g. Chawla, 2015[66]; Astell-burt, 2014[67]). Some

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[55] Edinburgh and Lothians Health Foundation (2019) Greenspace and Health Strategic Framework for Edinburgh & Lothians, ELHF, Edinburgh. https://www.elhf.co.uk/greenspace-and-health/

[56] Taylor, L., Hahs, A.K and Hochuli, D.F. (2018) Wellbeing and urban living: nurtured by nature, *Urban Ecosystems*, 21, 197-208.

[57] Gladwell VF, Brown DK, Wood CJ, Sandercock GR and Barton JL (2013). The great outdoors: how a green environment can benefit all. *Extreme Physiology and Medicine*, 2: 3.

[58] Almanza, E., Jerrett, M., Dunton, G., Seto, E. & Ann Pentz, M. (2012) A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data, *Health & Place*, 18, pp. 46–54.

[59] Staatsen, B, Van der Vliet, N, Kruize, H., Hall, L. Morris, G., Bell, R. and Stegeman, I. (2017) *Exploring triple-win solutions for living, moving and consuming that encourage behaviour change, protect the environment, promote health and health equity*, EuroHealthNet, Brussels. http://inherit.eu/wp-content/uploads/2017/06/INHERIT-Report-A4-Low-res_s.pdf

[60] Defra (2017) Evidence Statement on the links between natural environments and human health, Defra, London. http://randd.defra.gov.uk/Document.aspx?Document=14042_EvidenceStatementonnaturalenvironmentsandhealth.pdf

[60] WHO, World Health Organization, Regional Office for Europe (2017b) *Urban Greenspaces: a brief for action,* WHO, Copenhagen.

[61] Douglas, O. Lennon, M. and Scott, M. (2017) Greenspace benefits for health and wellbeing: A life-course approach for urban planning, design and management. *Cities,* 66, 53–62.

[62] Hystad, P., Davies, H. W., Frank, L., Van Loon, J., Gehring, U., Tamburic, L., & Brauer, M. (2014). Residential greenness and birth outcomes: Evaluating the influence of spatially correlated built-environment factors. Environmental Health Perspectives, 122, 1095-102. doi: 10.1289/ehp.1308049

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[64] Gardsjord, H., Tveit, M., and Nordh, H. (2014). Promoting youth's physical activity through park design: Linking theory and practice in a public health perspective. Landscape Research, 39, 70–81.

[65] Cranney, L., Phongsavan, P., Kariuki, M., Stride, V., Scott, A., Hua, M. et al. (2016) Impact of an outdoor gym on park users' physical activity: A natural experiment. *Health and Place,* 37, 26-34. doi: 10.1016/j.healthplace.2015.11.002.

[66] Chawla, L. (2014) Children's engagement with the natural world as a ground for healing. In: Krasny ME and Tidball KG (eds.), *Greening in the red zone: Disaster, resilience and community greening*. Dordrecht: Springer, pp.111–124.

[67] Astell-burt, T., Feng, X., & Kolt, G. S. (2014a). Is neighborhood greenspace associated with a lower risk of type 2 diabetes? Evidence from 267,072 Australians. *Diabetes Care*, 37, 197–201.

research focuses specifically on woodland (e.g. Ward Thompson et al (2013)[68]) finding positive associations with quality of life outcomes when the woodland was perceived to be safe. Other positive health and wellbeing outcomes relate to doing physical activity in places with trees such as ***woodlands*** (e.g. Morris and O'Brien, 2011[69]; Kerr and Schneider, 2008[70]). However, as will be referred to below, people who access forest and woodland must feel safe and comfortable in doing so, which is not the case for everyone in an urban population (O'Brien et al., 2010[71]).

Other evidence points to the positive benefits of greenspaces which provide ***quiet areas for relaxation***, for different groups in the life course (e.g. pregnant women (Douglas et al., 2017[49]) and children (Chawla, 2014[55])). While difficult to measure in terms of physical characteristics, for greenspaces to be used, they must feel ***safe*** (Bennie et al, 2017[72]). This is related to the management and maintenance to ensure that existing and potential users feel safe in new and already familiar paths, parks and other greenspaces, but is often not the subject of empirical research (Dempsey and Dobson, 2019[73]).

Positive relationships have been found between the subjective wellbeing of urban residents and ***higher plant species richness*** (Carrus et al., 2015[74]). The idea of 'nature connectedness' – being tied to, or belonging in, nature – is one positively associated with promoting wellbeing (Lumber et al., 2017[75]). Research shows how nature-connected people enjoyed more physical and psychological health benefits when walking through woodland, shrubs and herbaceous borders than less nature-connected people (Hoyle et al., 2019[76]; also related research by Southon et al, 2017[77]; Fischer et al., 2018[78]).

One physical characteristic closely related to the gardening activity which happens therein is ***allotments and community gardens***. For this reason, it is discussed in the following section.

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[68] Ward Thompson, C., Roeb, J. and Aspinall, P. (2013) Woodland improvements in deprived urban communities: What impact do they have on people's activities and quality of life? *Landscape and Urban Planning*, 118: 79– 89.

[69] Morris, J. and O'Brien, L. (2011) Encouraging healthy outdoor activity amongst under-represented groups: An evaluation of the Active England woodland projects, *Urban Forestry & Urban Greening,* 10, 4, 323-333.

[70] Kerr, M.A. and Schneider, B.H. (2008), Anger expression in children and adolescents: a review of the empirical literature, *Clinical Psychology Review*, 28(4):559-77.

[71] O'Brien, L., Williams, K. and Stewart, A. (2010) *Urban health and health inequalities and the role of urban forestry in Britain: A review*, Forest Research, Farnham.

[72] Bennie, J., Crane, O., Cullum, A., Levay, P., O'Rourke, D., Murray, A., Peploe, K., Wohlgemuth, C. and McGuire, H. (2017) Physical activity and the environment update: Evidence Review 3: Park, Neighbourhood 5 and Multicomponent Interventions, National Institute for Health and Care Excellence, London. https://www.nice.org.uk/guidance/ng90/documents/evidence-review-3

[73] Dempsey, N. and Dobson, J. (2019) Identifying healthy greenspace interventions – what works in practice? *Town and Country Planning*, 88, 2, 52-56.

[74] Carrus, G.; Scopelliti, M.; Lafortezza, R.; Colangelo, G.; Ferrini, F.; Salbitano, F.; Agrimi, M.; Portoghesi, L.; Semenzato, P.; Sanesi, G. (2015) Go Greener, Feel Better? The Positive Effects of Biodiversity on the Well-being of Individuals Visiting Urban and Peri-urban Green Areas. *Landsc. Urban Plan. 2015*, *1*, 221–228.

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[76] Hoyle, H., Jorgensen, A. and Hitchmough, J.D. (2019) What determines how we see nature? Perceptions of naturalness in designed urban greenspaces, People and Nature, 00: 1-14.

[77] Southon, G.E., Jorgensen, A., Dunnett, N., Hoyle, H. & Evans, K. L. (2017). Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. *Landscape and Urban Planning,* 158*,* 105-118. Doi.org/10.1016/j.landurbplan.2016.08.003

[78] Fischer, L.K., Honolda,J., Cvejićd, R., Delshammare, T., Hilbert,S., Lafortezzah,R., Nastrand, M., Nielsenj, A.B., Pintard,M. van der Jagt, A.P.N., Kowarika,I., (2018b). Beyond green: Broad support for biodiversity in multicultural European Cities. *Global Environmental Change* 49 35-45.

A4.1.3 Types of (physical) activities that can help improve patients' mental health and wellbeing

An extensive review by Bragg and Atkins (2016[79]) concluded that ***social and therapeutic horticulture*** which necessarily takes place in settings such as allotments and community gardens are associated with significant mental health benefits (also Kings Fund, 2016[80]). These include reduction in depression, anxiety and stress-related symptoms and improvements in dementia-related symptoms.

While it has already been highlighted that management and maintenance of greenspaces is not often measured in relation to health and wellbeing outcomes, there is one notable exception. ***Environmental conservation*** activities are inherently related to the long-term management of natural spaces and Bragg and Atkins (2016[77]) found numerous positive health and wellbeing outcomes. These benefits overlap those from social and therapeutic horticulture and also ***care farming*** which they identify as a specific type of activity that can help improve patients' mental health and wellbeing. Bragg and Atkins highlight that because all three inherently involve a deep interaction with nature, the benefits of *social and therapeutic horticulture, environmental conservation* and *care farming* are very similar. They include*:*

- Psychological restoration and increased general mental wellbeing
- Reduction in depression, anxiety and stress related symptoms
- Improvement in dementia-related symptoms
- Improved self-esteem, confidence and mood
- Increased attentional capacity and cognition
- Improved happiness, satisfaction and quality of life
- Sense of peace, calm or relaxation
- Feelings of safety and security
- Increased social contact, inclusion and sense of belonging
- Increase in work skills, meaningful activity and personal achievement

(from Bragg and Atkins, 2016[77], p. 45).

Such activities above may also be considered ***volunteering activities***, which is associated with positive health and wellbeing outcomes (Pillemer et al., 2010[81]). This is linked to the ***sense of contact with other people*** and being part of an organised group which were significant health benefits found by Morris and O'Brien (2011)[58] when assessing healthy outdoor activities in England. For example, ***Green Gyms*** encourage participation in local nature conservation activities specifically to improve health and well-being which are endorsed by health practitioners (Bragg and Atkins, 2016[77]).

Other activities in greenspaces associated with positive health and wellbeing outcomes which have been examined by researchers include: ***spending time in nature*** (e.g. Jakubec et al.,

[79] Bragg, R. and Atkins, G. (2016) 'A review of nature-based interventions for mental health care', *Natural England Commissioned Reports*, 204. http://publications.naturalengland.org.uk/publication/4513819616346112

[80] The Kings Fund (2016) *Gardens and health Implications for policy and practice, National Gardens Scheme*, London.

[81] Pillemer K., Fuller-Rowell, T.E., Reid, M.C. and Wells, N.M. (2010) Environmental volunteering and health outcomes over a 20-year period. *Gerontologist*. 50, 5, 594–602. https://pubmed.ncbi.nlm.nih.gov/20172902/

2016[82]), ***walking in natural settings*** (Hoyle et al., 2017[83]), ***arts-based activities*** (Birch et al., 2020[84]) and ***mindfulness-based stress reduction*** (Choe et al., 2020[85]).

Engaging in physical activity in an urban greenspace can facilitate long term physical health benefits (White at al., 2016[31]), and also help stress relief more immediately (White et al., 2017[86]) and foster social benefits of exercising with friends (e.g. Sugiyama et al. 2008[87]; Maas et al. 2009[88]). It is important to remember that underlying feelings of confidence and security can affect whether people feel comfortable in greenspaces. Therefore where such feelings don't exist, this can constitute significant barriers to using greenspace (Morris and O'Brien, 2011[58]).

The way in physical interventions and activities in a greenspace are ***communicated and marketed*** has been found to lead to increased usage of greenspace (Cohen et al., 2013[89]). Finally, the curation and overall organisation and management of programmes of greenspace usage – be they social prescribing, care farming, community gardening or accompanied health walks – all need a coordinator of some sort which needs to be resourced (Morris and O'Brien, 2011[58]). This is not something that is evaluated or examined empirically by researchers, indicating a gap in knowledge. It is something that is examined by practitioners, although can be subject to funding limits – when a project and a coordinator can no longer be funded. The NHS Greenspace Demonstration Project (Green Exercise Partnership, 2020[90]) was established 'to show how improvements to these outdoor spaces around existing and new hospitals and health centres could be delivered in practice and to assess the benefits of…investment for health and wellbeing, biodiversity and climate change' (Green Exercise Partnership, 2020[73], p. 1). A number of conclusions were not directly related to the physical interventions made in the greenspace nor the activities that could be delivered. They were around ***curation, coordination and management***: 'promoting the use of NHS greenspace in clinical interventions', 'linking greenspace, active travel and art strategies to provide more opportunities to engage with staff, patients and community' and 'managing the assets in ways which support and encourage use for health and wellbeing, and which also contribute to action on biodiversity and climate change' (Green Exercise Partnership, 2020[73], p. 2).

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[82] Jakubec, S. L., Carruthers Den Hoed, D., Ray, H., & Krishnamurthy, A. (2016). Mental well- being and quality-of-life benefits of inclusion in nature for adults with disabilities and their caregivers. *Landscape Research*, 41, 616–627.

[83] Hoyle, H., Hitchmough, J.D., & Jorgensen, A. (2017). All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting. *Landscape and Urban Planning,* 164, 109-123 Doi.org/10.1016/j.landurbplan.2017.03.011

[84] Birch, J., Rishbeth, C. and Payne, S.R. (2020) Nature doesn't judge you – how urban nature supports young people's mental health and wellbeing in a diverse UK city, *Health & Place*, 62 (2020) 102296

[85] Choe, E.Y., Jorgensen, A. and Sheffield. D. (2020) Does a natural environment enhance the effectiveness of Mindfulness-Based T Stress Reduction (MBSR)? Examining the mental health and wellbeing, and nature connectedness benefits, *Landscape and Urban Planning,* 202, 103886.

[86] White, M. P., Pahla, S., Wheeler, B.W., Depledge, M.H. and Fleming, L.E. (2017) Natural environments and subjective wellbeing: Different types of exposure are associated with different aspects of wellbeing, *Health & Place*, 45, 77-84

[87] Sugiyama, T., Leslie, E., Giles-Corti, B. and Owen, N. (2008) Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology and Community Health*, 62, e9, doi:10.1136/jech.2007.064287

[88] Maas, J., van Dillen, S.M.E., Verheij, R.A., and Groenewegen, P.P. (2009) Social contacts as a possible mechanism behind the relation between greenspace and health. *Health & Place*, 15, 2, 586–595. doi: 10.1016/j.healthplace.2008.09.006.

[89] Cohen, D.A., Han, B., Derose, K.P., Williamson, S., Marsh, T. and McKenzie, T.L. (2013) Physical Activity in Parks: A Randomized Controlled Trial Using Community Engagement, *American Journal of Preventive Medicine*, 45(5), 590–597.

[90] Green Exercise Partnership (2020) Unlocking the Potential of NHS Greenspace for health and wellbeing: the NHS Greenspace Demonstration Project, NHS Scotland and Scottish Forestry, Edinburgh.

A4.1.4 Focus on biodiversity and carbon sequestration and relevant NHS Lothian sites greenspace characteristics

The *NHS Greenspace Demonstration Project* and the *Greenspace and Health Strategic Framework for Edinburgh & Lothians* (2019)[3] provided invaluable starting points for this report. They have allowed for an exploration of other activities and interventions not already mentioned or empirically examined in the literature (e.g. less intensive mowing regimes as conducted at the Ailsa Hospital and University Hospital Ayr) to explore a wide gamut of potential interventions.

With our underpinning focus on carbon sequestration and biodiversity in this review of potential interventions, this naturally brings us to consider vegetation: namely, trees, hedges and woodland. However, as the preceding discussion suggests, how patients, staff and site visitors can 'get' the health and wellbeing benefits from trees, hedges and woodland involves a wider range of non-physical interventions, which are discussed later.

In addition, we also considered potential indirect changes to the landscape that can improve carbon sequestration, as well as those that go beyond the boundaries of the sites. We are mindful that on their own, 'urban forests make fairly modest contributions to the global challenge of reducing carbon emissions' (Hirons and Sjöman, 2019[91], p. 39). However, if high-quality green infrastructure is provided on-site, this can help to change or stop carbon-intensive behaviours. In this way, we take a holistic approach to each site, and its environs, to assess their full potential for carbon sequestration and biodiversity.

The on-site health and well-being benefits and green intervention recommendations were informed by site visits conducted in September 2020 . These site visits were important to gain an understanding of how accessible these green areas within the hospital and clinic grounds are, and how they are currently used. They involved map-based survey work in and around the sites, including the mapping of vegetation types by species as well as locating features/ furniture such as benches, picnic tables, gym equipment and signage for walks. Where possible, the research team met with site managers on site. However, the study took place during the Covid-19 pandemic which severely limited access to NHS site management personnel. Internal courtyards could not be accessed at all the sites due to access restrictions, however the team did gain access to those at the Royal Infirmary Edinburgh and Western General Hospital.

In providing ***recommendations for tree species*** to be planted, the following texts were consulted alongside the site visit and mapped data. O'Sullivan et al. (2017)[92] provide data on specific ecosystems services provided by over 50 tree species found along road verges, this is cross-referenced with Hirons and Sjöman (2019)[74] database, detailing size, crown characteristics and their potential in sites such as parks or gardens. This is then informed by the Doick et al. (2017)[12] report which provides data on the i-Tree survey of trees in Edinburgh. While a large number of tree species are identified, other tree species (e.g. *Acer campestre*/ Field maple) were seen on the site visits but do not feature in the Doick et al. report. While the site visits did not provide an exhaustive tree survey, it does mean that tree species seen on site that O'Sullivan identify as providing ecosystems services pertinent to carbon

[91] Hirons, A. and Sjöman, H. (2019) *Tree Species Selection for Green Infrastructure: a guide for specifiers, Issue 1.3*, Trees & Design Action Group.

[92] O'Sullivan, O., Holt, A.R., Warren, P.H. and Evans, K.L. (2017) Optimising UK urban road verge contributions to biodiversity and ecosystem services with cost-effective management, *Journal of Environmental Management*, 191, 162-171. http://dx.doi.org/10.1016/j.jenvman.2016.12.062

sequestration and biodiversity (but do not feature in the Doick et al. report) are included in the recommendations.

The ***recommendations around hedges*** are derived from Blanusa et al. (2019)[93] who provide an overview of plant species and cultivars used in urban hedges. As a review of 'the role of urban hedges within NW Europe', Blanusa et al.'s paper reviews the available literature detailing the ecosystems services and disservices provided by different plant species and cultivars when used as hedge plants. These species and cultivars were then checked to ensure they are found/ planted in Scotland using the National Biodiversity Network Atlas Scotland (NBNAS) online database https://scotland-species.nbnatlas.org/ and cross-referenced with the Doick et al. (2017)[12] report and the non-exhaustive survey conducted on-site in September 2020.

The ***recommendations around biodiversity net gain*** are in recognition that development on NHS sites is an ongoing and inevitable activity. To make meaningful improvements in carbon sequestration and biodiversity, the debate is moving beyond ideas of *offsetting* and *no net loss* to the principle of *biodiversity net gain* (CIEEM Scotland Policy Group, 2019[94]). This acknowledges that – at best – *no net loss* can only sustain the well-documented downward trajectory of biodiversity decline (Simmonds et al., 2019[95]). The Scottish policy context arguably reflects this in its position of supporting positive action to protect and enhance the natural environment (e.g. Edinburgh Biodiversity Action Plan, 2019[96]), identifying the need to go further in 'securing positive effects for biodiversity' by 'ensuring well-designed, high quality provision and long term maintenance of natural infrastructure in new development, recognising its contribution to goals for *climate change mitigation and adaptation*, *biodiversity* and *health and wellbeing*' (emphasis added) (Scottish Government, 2020[97]). There are no specific targets in place for biodiversity net gain as yet, but recent consultation exercises for Scotland's National Planning Framework 4 (NPF4) indicate that biodiversity net gain will be mandated in Scotland by 2022. It is expected that the required 'gain' will be at least 10% increase in biodiversity and the need for addressing this at a landscape, rather than a site, scale informs our recommendations for working beyond and across NHS Lothian site boundaries (McKain, 2020[98]).

Facilitating the ability of the NHS estate to meaningfully support biodiversity and sequester carbon, involves the reduction of CO2 emissions which requires consideration of the reduction of on-site car parking. It is beyond the scope of this report to present viable options for reducing the need for car parking on the NHS Lothian estate as this would require a joined-up cross-sector approach to reducing car use.

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[93] Blanusa, T., Garratt, M., Cathcart-James, M., Hunt, L. and Cameron, R.W.F. (2019) Urban hedges: A review of plant species and cultivars for ecosystem service delivery in north-west Europe, *Urban Forestry & Urban Greening*, 44 (2019) 126931.

[94] Chartered Institute of Ecology and Environmental Management (CIEEM) Scotland Policy Group (2019) *Biodiversity Net Gain in Scotland: briefing note*, https://cieem.net/wp-content/uploads/2019/06/Biodiversity-Net-Gain-in-Scotland-CIEEM-Scotland-Policy-Group.pdf

[95] Simmonds, J.S., Sonter, L.J, Watson, J.E.M. et al. (2019) Moving from biodiversity offsets to a target-based approach for ecological compensation, *Conservation Letters*, 13, e12695, https://doi.org/10.1111/conl.12695

[96] City of Edinburgh Council (2019) *Edinburgh Biodiversity Action Plan 2019-2021*, Edinburgh, City of Edinburgh Council, https://www.edinburgh.gov.uk/downloads/file/26216/edinburgh-biodiversity-action-plan-2019-2021

[97] Scottish Government (2020) Fourth National Planning Framework: position statement, https://www.transformingplanning.scot/national-planning-framework/

[98] McKain, S. (2020) Opportunities for Implementing Biodiversity Net Gain in Scotland, *British Ecological Society blog*, https://www.britishecologicalsociety.org/spg-biodiversity-net-gain-event/

In developing the site-specific interventions, Annex 6 of the *Greenspace and Health Strategic Framework for Edinburgh & Lothians* (2019)[3] was the starting point. Unsurprisingly, there is considerable overlap in the recommendations made below with the 'future opportunities and actions' found in Annex 6.