Falkirk Council

Falkirk Council Carbon Sequestration Scoping Study

Final report

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LUC

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Contents

Chapter 1
Introduction

This carbon sequestration scoping study is an important part of supporting Falkirk Council's urgent progress to achieve net zero emissions by 2030

1.1 Within Scotland, key policy context for the study includes the climate emergency and biodiversity crisis, both of which were declared in May 2019. The Scottish Government have set ambitious targets for achieving net zero emissions to address the climate emergency, supported within the Climate Change Plan Update (2020) which sets out key ambitions to increase woodland creation to 18,000 hectares a year in 2024/25 and increase levels of peatland restoration. Likewise, there are national, EU and global targets to address the biodiversity crisis, including the Scottish Biodiversity Strategy post-2020 (published December 2020), EU Biodiversity Strategy for 2030 and the updated post-2020 Global Biodiversity Framework.

Climate emergency

1.2 Falkirk Council declared a climate emergency in 2019 and committed itself to achieve Net Zero emissions by 2030, and '*agreed to push towards increasing our efforts to reduce our carbon emissions to net zero by 2030 while making Grangemouth our first carbon neutral town*. In line with the ambitions set out within the Scottish Government Climate Change Plan, carbon sequestration will form a key part of meeting this target.

Edinburgh Declaration

1.3 Falkirk Council has also signed the Edinburgh Declaration on the post – 2020 global biodiversity framework. This is an international agreement between subnational, regional and local governments across the world to take bold action to halt biodiversity loss. This recognises the importance of healthy biodiversity and ecosystem services to livelihoods and communities.

Scope of the study

1.4 The focus of the study is on the potential for creation of carbon sequestering habitats (woodland, grassland & wetland) on Council owned land. The study requires the following main stages:

- Geographical Information System (GIS) based assessment of current carbon sequestration on Council owned land;
- GIS based assessment of carbon sequestration potential through habitat creation (woodland, grassland, wetland);
- Desk top assessment of the potential for retrofitting green roofs onto existing Council properties.

1.5 It is anticipated that the final report will facilitate a second phase of the project to:

- Develop detailed proposals for a number of priority sites;
- Carry out community consultation exercise to inform recommendations;
- Identify potential funding streams for carbon sequestering habitat/ green roof creation; and
- Develop appropriate plans to access those funding streams.

Carbon stock and flow

1.6 Carbon is stored in vegetation or soil stocks and the carbon sequestration provided by a vegetation type is generally referred to as the annual flow of carbon. The annual flow of carbon provided by a vegetation type is the quantity that can be sequestered.

1.7 The existing carbon value of soil stock is relevant to land use change, as management interventions or development may release carbon from the soil. Different levels of carbon storage in soils are important when considering land use change, but not for considering carbon flow. For example, woodland cover can significantly increase the carbon stock within soils, compared to a previous arable land use.

It is recommended that Falkirk Council understand the carbon stock of their existing land area, in order to identify locations where land use change may result in net carbon loss. The focus of this study is however on increasing carbon flows.

Data caveats

1.8 The study is based on digital data of Falkirk Council owned land and Phase 1 habitat survey (dated 2008). Due to a number of issues with the completeness and accuracy of the available digital data, the report findings are based on the best available data but there are a number of known issues which must be taken into account when interpreting the report findings which are high level and indicative. These data issues underline the importance of Phase 2 of the study which will verify opportunities and constraints at a site specific level.

Study context

COVID-19 Green Recovery

1.9 COVID-19 has led to an unprecedented shutdown of large parts of the global economy. As a result, it has also facilitated a substantial shift in our behaviours. A large proportion of the population have been working remotely from home for several months, as well as engaging more in active travel, and minimising travel beyond their local area. This has had a significant effect on the environment, with a dramatic reduction in air pollution and the release of greenhouse gasses, globally, compared to pre-COVID levels.

1.10 The Committee on Climate Change (CCC) has highlighted the opportunity to turn the COVID-19 crisis into a defining moment in the fight against climate change, and has provided advice on delivering economic recovery that accelerates the transition to a cleaner, net-zero emissions economy, whilst strengthening resilience to the impacts of climate change.

1.11 The CCC have set out the principles to building a resilient economy in the 'Reducing UK emissions: 2020 Progress Report to Parliament'. One of the key principles relates to increasing tree planting, peatland restoration and green infrastructure. The report acknowledges that there may be significant benefits for the climate, biodiversity, air quality and flood prevention, as a result of making substantial changes to land use.

1.12 Enabling a shift toward positive, long-term behaviour patterns may also provide opportunities to support economic recovery. There is a need to continue to reinforce the ‘climatepositive’ behaviours that have emerged during the lockdown, including increased remote working, cycling and walking.

1.13 Promoting new tree planting, habitat connectivity and the creation and enhancement of green infrastructure will encourage greater use of the natural environment for active travel and recreation. In addition, it will enable greater rates of carbon sequestration whilst providing sustainable adaptation measures for the predicted effects of climate change.

Natural flood management

1.14 SEPA’s handbook for natural flood management outlines that climate change, population growth, economics and environmental legislation such as the Floods Directive and Water Framework Directive all necessitate a move towards a more integrated catchment-based approach to the management of land and water. A key component of this integrated catchment-based approach is the recognition that working with natural processes to manage the sources and pathways of flood waters can benefit flood risk in other parts of the catchment and is known as natural flood management. Woodland and trees reduce the rate at which precipitation reaches the ground, and also the rate of lateral transport across the ground into watercourses. Land management practices such as those associated with agriculture and forestry also bring about changes to soils which affect water holding and the rate of infiltration. Well sited and well-managed floodplain, riparian and catchment woodlands can contribute to a suite of nature-based solutions.

Structure of the report

1.15 The remainder of the report includes:

- Chapter 2: Current and potential carbon sequestration values of council owned land
- Chapter 3: Green roof and green wall potential
- Chapter 4: Conclusions and recommendations for Phase 2.

1.16 The report is supported by a number of Appendices:

- Appendix A: Methodology
- Appendix B: GIS data index
- Appendix C: Phase 1 habitat conversion to carbon sequestration habitats
- Appendix D: Habitats most suitable for change
- Appendix E: Data caveats
- Appendix F: List of Abbreviations
- Appendix G: References
- Appendix H: Map figures.

Chapter 2

Current and potential carbon sequestration values of council owned land

This chapter sets out the current and potential carbon sequestration values for Falkirk Council owned land, alongside key recommendations.

Introduction

2.1 The calculation of carbon sequestration values of council owned land and the calculation of the carbon sequestration potential value of council owned land has been calculated for the whole ownership area and also broken down by site typology.

It is important to caveat the values included in this chapter with the data issues identified in the methodology set out in Appendix A and data caveats in Appendix E.

2.2 The carbon sequestration values are calculated based on:

- the carbon sequestration values assigned by Phase 1 habitat survey habitat code for all Falkirk Council owned land (Appendix C)
- the Phase 1 habitat codes identified as habitats most suitable for change, and the potential conversion habitats and associated assigned carbon sequestration values (Appendix D).

Current approximate carbon sequestration value of council owned land

2.3 The current approximate carbon sequestration value of all Falkirk Council owned land (an area of approximately 3,588ha) is estimated as[1] **4,628 tCO_2e per annum.** This represents a current carbon sequestration value of approximately 1.3 tCO_2e/ha/annum. The council owned land and carbon sequestration habitats are illustrated in Appendix H, Figure 2.

[1] Note that this figure is caveated by the data inaccuracies within the Phase 1 and council land ownership datasets.

Current carbon sequestration value by site typology

2.4 Table 2.1 below illustrates the average current carbon sequestration value by site typology. The distribution of land typology within council owned land is illustrated in Appendix F, Figure 1. Table 2.1 illustrates that Natural, semi-natural greenspace and green corridor and public parks and gardens sequester the highest amount of carbon per ha per annum. These figures should be treated with caution due to the limitations of the typology assignment.

Table 2.1: Average current carbon sequestration value by typology

Site typology	Area (ha)	Total current carbon sequestration tCO_2e	Average current carbon sequestration per ha tCO_2e
Agricultural land	267.91	66.28	0.25
Allotments	0.37	0.9	2.43
Amenity open space	111.37	182.77	1.64
Churchyard / cemetery	43.19	57.82	1.34
Golf course	57.44	162.85	2.84
Industrial / commercial[2]	65.06	20.38	0.31
Inland water	35.55	0.02	0.00
Natural, semi-natural greenspace & green corridor	639.02	2279.03	3.57
Play space	8.41	9.3	1.11
Private house grounds (including institutional)	706.86	1.94	0.00
Public building complex	24.94	17.06	0.68
Public park & garden	423.92	1490.66	3.52
Quarry	29.73	38.44	1.29
Railway	7.37	2.18	0.30
Road	209.47	1.9	0.01
Roadside	173.04	68.41	0.40
School grounds	125.94	57.56	0.46
Sports area	132.28	88.44	0.67
Tidal water	462.19	42.02	0.09
Undetermined	64.45	40.41	0.63
TOTAL	**3588.51**	**4628.37**	**1.29**

Area of habitats most suitable for change by site typology

2.5 Based on the total area of Falkirk Council owned land, areas with habitat most suitable change have been identified, using the process set out in Appendix A, Methodology. The total area of habitat most suitable for change, with the potential for conversion to a higher carbon sequestration value habitat is estimated as **1,648 ha (46% of Council owned land)**. This figure includes all site typologies where habitat change may not be appropriate/achievable due to their function, e.g. quarry. Further explanation on these typologies is provided in Appendix A. The inclusion of all site typologies is in order to provide context for future decisions on potential additional typologies which could be subject to habitat change. The area of habitat most suitable for change by all site typologies is summarised in Table 2.2 below, and illustrated in Appendix H, Figure 3.

[2] Includes land identified as bus station

Table 2.2: Area of habitat most suitable for change by all site typologies and average current carbon sequestration value

Site typology	Area (ha) of habitat most suitable for change	Average current carbon sequestration per ha tCO_2e
Agricultural land	260.93	0.10
Allotments	0.28	0.39
Amenity open space	64.03	0.12
Churchyard / cemetery	32.11	0.35
Golf course	38.69	0.39
Industrial / commercial	12.67	0.33
Inland water	0.04	1.00
Natural, semi-natural greenspace & green corridor	284.61	0.46
Play space	6.65	0.25
Private house grounds[3] (institutional)	3.33	0.37
Public building complex	7.36	0.44
Public park & garden	210.42	0.24
Quarry	3	4.97
Railway	0.56	0.39
Road	2.6	0.38
Roadside	79.56	0.39
School grounds	59.82	0.28
Sports area	106.95	0.01
Tidal water[4]	448.92	0.00
Undetermined[5]	25.39	0.36
TOTAL	1657.99	**0.20**

2.6 Table 2.3: Habitats most suitable for change and current carbon sequestration value is similar to Table 2.2, but illustrates the current carbon sequestration value by Phase 1 habitat and not site typology. The current Phase 1 habitat typology of habitats most suitable for change is illustrated in Appendix H, Figure 4. The Phase 1 habitat codes of habitats most suitable for change were converted into broad habitat codes which relate to identified carbon sequestration values. The values for habitats most suitable for change are illustrated in Table 2.3, and listed in full for all habitats in Appendix C.

[3] Due to errors in the assignment of typology a proportion of land with the typology 'private house grounds' has an assigned Phase 1 habitat value. This figure does not reflect the majority of private house grounds (534 ha) for which no Phase 1 habitat code was assigned.
[4] Tidal water includes H1 habitats which are located below mean high water springs
[5] Note that not all habitat areas are assigned a typology and that there are inaccuracies within the site typologies. Includes the are (this sentence appears incomplete)

Table 2.3: Habitats most suitable for change and current carbon sequestration value

Phase 1 habitat name (of habitats most suitable for change)	Phase 1 habitat code	Current Carbon Sequestration Average Value tCO_2e/ha per annum (based on carbon sequestration value of both named habitats where two are listed)	Total Area (Ha)	Carbon Sequestration Total Value tCO_2e per annum
Amenity grassland	J1.2	0	380.01	0
Amenity grassland / Broadleaved scattered trees	J1.2 / A3.1	2.485	1.33	3.3
Arable	J1.1	0.107	136.1	14.56
Broadleaved scattered trees	A3.1	2.6835	14.76	39.61
Improved grassland	B4	0.0535	23.38	1.25
Improved grassland / Arable	B4 / J1.1	0.0535	112.82	6.04
Intertidal	H1	*Assumed zero*	91.84	*Assumed zero*
Intertidal - boulders/rocks	H1.3	*Assumed zero*	1.73	*Assumed zero*
Intertidal - mud/sand	H1.1	*Assumed zero*	369.25	*Assumed zero*
Intertidal - shingles/cobbles	H1.2	*Assumed zero*	2.88	*Assumed zero*
Marshy grassland	B5	0.5485	11.27	6.18
Mixed scattered trees / Amenity grassland	A3.3 / J1.2	4.4075	3.45	15.19
Mixed scattered trees / Improved grassland	A3.3 / B4	4.606	1.02	4.69
Mixed scattered trees / Poor grassland (semi-improved)	A3.3 / B6	4.606	2.65	12.22
Other tall herb and fern (ruderal)	C3.1	0.397	1.57	0.62
Other tall herb and fern (ruderal) / Arable	C3.1 / J1.1	0.252	2.91	0.73
Poor grassland (semi-improved)	B6	0.397	477.39	189.52
Poor grassland (semi-improved) / Arable	B6 / J1.1	0.252	2.08	0.52
Poor grassland (semi-improved) / Broadleaved scattered trees	B6 / A3.1	0.397	15.34	6.09
Scrub (scattered)	A2.2	4.97	6.19	30.77
		Total area of habitats most suitable for change (ha)	**1657.97**	
		Total current annual carbon sequestration value (tCO_2e per annum)		**331.29**

2.7 A range of potential carbon sequestration values based on conversion of habitats most suitable for change is grouped by site typology in Table 2.4. This illustrates potential carbon sequestration values based on different habitat change assumptions. Table 2.5 includes typologies to which the standard assumptions for habitat change do not apply. These include private gardens, inter-tidal zone and green roofs. Appendix H, Figure 5 illustrates the potential habitat conversion to higher carbon sequestration habitat types.

2.8 Following these tables a number of scenarios are set out which explore the potential total carbon sequestration gains based on different combinations of change.

Table 2.4: Potential average carbon sequestration value of habitat most suitable for change by all site typologies

Site typology	Total area (ha) of habitat most suitable for change	Carbon sequestration value tCO2e per annum as 50% deciduous and 50% semi natural grassland	Carbon sequestration value tCO2e per annum as 50% mixed woodland and 50% semi natural grassland	Carbon sequestration value tCO2e per annum grassland habitat[6] only	Carbon sequestration value tCO2e per annum Inland wetland[7] only	Carbon sequestration value tCO2e per annum Saltmarsh only	Carbon sequestration value tCO2e per annum Coastal wetland[8]	Conversion limitations	Conversion opportunities
Agricultural land	260.93	698.72	1199.30	103.37	0.39	0	0	Loss of agricultural rental income for council Current land use may provide supporting habitat for SPA species Existing agricultural leases may preclude short term habitat change	Significant area of land with conversion potential. This could provide opportunities for creation of significant new recreational space as part of habitat conversion. Opportunities to increase carbon sequestration on buffer strips etc.
Allotments	0.28	0.74	1.27	0.11	0	0	0	Loss of food growing space. Limited area for conversion.	Inclusion of permanent fruit trees or planting for wind breaks could increase carbon sequestration and biodiversity value at a limited scale
Amenity open space	64.03	164.15	281.76	24.29	2.00	0	0	Includes small and fragmented areas	This typology can have limited

6 Phase 1 habitat code B2.2
7 Phase 1 habitat code F1
8 Phase 1 habitat code B5 / H2

Site typology	Total area (ha) of habitat most suitable for change	Carbon sequestration value tCO2e per annum as 50% deciduous and 50% semi natural grassland	Carbon sequestration value tCO2e per annum as 50% mixed woodland and 50% semi natural grassland	Carbon sequestration value tCO2e per annum grassland habitat[6] only	Carbon sequestration value tCO2e per annum Inland wetland[7] only	Carbon sequestration value tCO2e per annum Saltmarsh only	Carbon sequestration value tCO2e per annum Coastal wetland[8]	Conversion limitations	Conversion opportunities
								Larger areas may provide supporting habitat for SPA species	recreational or biodiversity value
Churchyard / cemetery	32.11	86.18	147.92	12.75	0	0	0	Available land area limited by functional space for graves/memorials	Potential for creation of natural burial grounds to combine carbon sequestration, biodiversity and burial requirements
Golf course	38.69	103.83	178.22	15.36	0	0	0	Loss of income, loss of recreational spaces	Significant land area
Industrial / commercial	12.67	30.83	52.92	4.56	0	0.3	3.13	Space may be used for vehicle parking or turning	Improved amenity and climate change adaptation
Inland water	0.01	0.04	0.07	0.01	0	0	0	Marginal locations only suitable for change	
Natural, semi-natural greenspace & green corridor	284.61	378.47	649.62	55.99	0.33	94.78	348.59		Significant area with opportunity to improve habitat connectivity
Play space	6.65	16.60	28.49	2.46	0.32	0	0	Loss of play space	Creation of natural play areas

Site typology	Total area (ha) of habitat most suitable for change	Carbon sequestration value tCO2e per annum as 50% deciduous and 50% semi natural grassland	Carbon sequestration value tCO2e per annum as 50% mixed woodland and 50% semi natural grassland	Carbon sequestration value tCO2e per annum grassland habitat[6] only	Carbon sequestration value tCO2e per annum Inland wetland[7] only	Carbon sequestration value tCO2e per annum Saltmarsh only	Carbon sequestration value tCO2e per annum Coastal wetland[8]	Conversion limitations	Conversion opportunities
Private house grounds (institutional)	3.33	8.89	15.25	1.31	0	0	0	Space may be used for vehicle parking or turning	Improved amenity and climate change adaptation
Public building complex	7.36	19.74	33.89	2.92	0	0	0	Space may be used for vehicle parking or turning	Improved amenity and climate change adaptation
Public park & garden	210.42	558.49	958.60	82.62	1.61	0	0	Loss of space for outdoor functions or other activities which rely on current habitat type	Habitat change highlights the significance of the council commitment in high profile spaces
Quarry	3	8.06	13.83	1.19	0	0	0	Future mineral extraction	Additional landscaping
Railway	0.56	1.19	2.04	0.18	0	0	0.33	Functional use as a railway	Typology may be a data error
Road	2.6	6.73	11.56	1.0	0	0	0.25	Functional use as a road	Typology may be a data error
Roadside	79.56	211.06	362.27	31.22	0.01		2.49	Sight lines and safety considerations in some locations may limit woodland conversion potential	Broad verges offer greater potential. Continuous roadside habitat improvements could provide biodiversity corridors

Site typology	Total area (ha) of habitat most suitable for change	Carbon sequestration value tCO2e per annum as 50% deciduous and 50% semi natural grassland	Carbon sequestration value tCO2e per annum as 50% mixed woodland and 50% semi natural grassland	Carbon sequestration value tCO2e per annum grassland habitat[6] only	Carbon sequestration value tCO2e per annum Inland wetland[7] only	Carbon sequestration value tCO2e per annum Saltmarsh only	Carbon sequestration value tCO2e per annum Coastal wetland[8]	Conversion limitations	Conversion opportunities
School grounds	59.82	160.52	275.51	23.75	0	0	0	Retention of play space	Educational benefits
Sports area	106.95	283.82	487.15	41.99	0.83	0	0	Loss of sports facilities	Falkirk Council review of sports pitches will facilitate habitat conversion of a larger area of land
Undetermined[9]	25.39	65.80	112.94	9.73	0.35	1.24	0.36	Unknown	Unknown
TOTALS	**1198.97**	**2803.88**	**4812.63**	**414.81**	**5.85**	**96.32**	**355.19**		

Table 2.5: Other typologies with alternative carbon sequestration potential assumptions

	Area (ha) identified with potential for change	Lower range carbon sequestration value tCO2e per annum	Upper range carbon sequestration value tCO2e per annum	Mean	Conversion limitations	Conversion opportunities
Private house grounds	11[10]	55[11]	-	-	Tenant preferences for use of garden ground may limit scope and longevity of planted trees.	Tree planting in urban gardens could significantly improve biodiversity value and climate change adaptation through shading

[9] Note that not all habitat areas are assigned a typology and that there are inaccuracies within the site typologies.
[10] Based on 2% of 534ha area, on the assumption that carbon sequestration improvement will be possible on only a small proportion of private gardens. See Appendix A, Table 4.1 for carbon sequestration values of private gardens. Further more detailed study may establish a more accurate figure for Falkirk Council owned private gardens.
[11] Based on planting 2% of total garden area with deciduous woodland

	Area (ha) identified with potential for change	Lower range carbon sequestration value tCO2e per annum	Upper range carbon sequestration value tCO2e per annum	Mean	Conversion limitations	Conversion opportunities
					No data on current carbon sequestration value of garden ground.	and cooling. Positive impacts on resident amenity.
Tidal water[12]	449	232[13]	581[14]	407	Conversion would be complex and potentially costly and require additional work in relation to the SPA. Practical challenges of saltmarsh creation below mean high water	Habitat benefits for the SPA species.
Green roofs	5	18	58	38[15]		
TOTALS	**465**	**305**	**639**			

[12] Tidal water includes H1 habitats located below mean high water springs
[13] Based on 10% area saltmarsh conversion
[14] based on 25% area saltmarsh conversion
[15] Average of 18 tCO_2e/annum and 58 tCO_2e/annum based on 0.375kg CO2e/m^2 and 1.22kg CO2e/m^2 respectively

Scenarios for increasing carbon sequestration

Current and potential carbon sequestration value of total habitats most suitable for change

2.9 The project specification requires the identification of the area of potential habitat conversion to the three broad habitat types of woodland, grassland and wetland. As set out in Table 2.4, the potential for conversion to deciduous woodland with grassland, mixed woodland with grassland, grassland only and wetland (coastal or inland, where suitable) is set out.

2.10 Options for potential carbon sequestration scenarios based on varying combinations of the content of Table 2.4: *Potential average carbon sequestration value of habitat most suitable for change by all site typologies* are outlined in the following paragraphs.

2.11 Three scenarios have been identified based on the anticipated level of constraint associated with different site types, and differing approaches to woodland creation (deciduous or mixed):

- Scenario 1 is the lower estimation, based on less constrained typologies and creation of deciduous woodland.
- Scenario 2 is the mid estimate based on less constrained typologies set out under Scenario 1 and creation of mixed woodland.
- Scenario 3 is an ambitious scenario based on conversion of more challenging typologies and creation of deciduous woodland.

2.12 Each scenario is explained in more detail below and sets out the associated potential carbon sequestration value.

Scenario 1

2.13 Scenario 1 includes habitat conversion of habitats most suitable for change for the following typologies, identified as offering lower levels of inherent constraint for habitat change. Where woodland is created the figures are based on deciduous woodland

- Agricultural land
- Amenity open space
- Natural/semi natural
- Public park and garden
- School grounds
- Sports area

2.14 Total with the above listed typologies only using the values in Table 2.4 gives a value of 2,244 tCO_2e per annum, less the current carbon sequestration value of 238 tCO_2e per annum, gives a **potential net gain of 2,006 tCO_2e per annum**. This involves habitat change of 987ha.

2.15 Total with the above listed typologies also with cemeteries using the values in Table 2.4 gives a value of 2,330 tCO_2e per annum, less the current carbon sequestration value of 249 tCO_2e per annum, gives a **potential net gain of 2,081 tCO_2e per annum**. This involves habitat change of 1,109ha.

2.16 Total with the above listed typologies also with roadside using the values in Table 2.4 gives a value of 2,455 tCO_2e per annum, less the current carbon sequestration value of 269 tCO_2e per annum, gives a **potential net gain of 2,186 tCO_2e per annum**. This involves habitat change of 1,066ha.

2.17 Total with the above listed typologies with BOTH cemeteries and roadside using the values in Table 2.4 gives a value of 2,541 tCO_2e, less the current carbon sequestration value of 280 tCO_2e per annum, gives a **potential net gain of 2,261 tCO_2e per annum**. This involves habitat change of 1,098ha.

Scenario 2

2.18 Scenario 2 includes habitat conversion of habitats most suitable for change for the same typologies as Scenario 1 but based on mixed woodland.

2.19 Total with the above listed typologies only and the values in Table 2.4 gives a value of 3,852 tCO_2e per annum, less the current carbon sequestration value of 238 tCO_2e per annum, gives a gives a **potential net gain of 3,641 tCO_2e per annum** for this scenario. This involves habitat change of 987ha.

2.20 Total with the above listed typologies also with cemeteries using the values in Table 2.4 gives a value of 4,000 tCO_2e per annum, less the current carbon sequestration value of 249 tCO_2e per annum, gives a **potential net gain of 3,751 tCO_2e per annum.** This involves habitat change of 1,109ha

2.21 Total with the above listed typologies also with roadside using the values in Table 2.4 gives a value of 4,214 tCO_2e per annum, less the current carbon sequestration value of 269 tCO_2e per annum, gives a **potential net gain of 3,945 tCO_2e per annum.** This involves habitat change of 1,066ha.

2.22 Total with the above listed typologies with BOTH cemeteries and roadside using the values in Table 2.4 gives a value of 4,362 tCO_2e per annum, less the current carbon sequestration value of 280 tCO_2e per annum, gives a

potential net gain of 4,082 tCO_2e per annum. This involves habitat change of 1,098ha.

Scenario 3

2.23 Scenario 3 includes all habitat conversion of all habitats most suitable for change for all typologies. Where woodland is created the figures are based on deciduous woodland. This scenario must be caveated that it includes a number of typologies for which there may be significant limitations on the potential for conversion. This scenario includes potential contribution of the site typologies of private house grounds, inter tidal zone and green roofs and is based on the mean values from Table 2.5.

2.24 Based on the total potential carbon sequestration values from Table 2.4, for all typologies (using the values for deciduous woodland) and the mean values from Table 2.5, this gives a potential 3,303 tCO_2e per annum. Less the current carbon sequestration value of 331 tCO2e per annum, gives a **potential net gain of 2,972 tCO2e per annum for this scenario**. This involves habitat change of in the region of 1,500ha.

Other considerations for carbon sequestration value of habitats most suitable for change

2.25 A number of factors need to be taken into account when taking the carbon sequestration conversion values forward which may influence the carbon sequestration value of the changed habitat. These include:

- Type of habitat chosen for conversion, including wetland (see below)
- Maturity of habitat
- Site typology constraints
- Other site constraints such as cultural heritage.

Habitats most suitable for change and flood risk

2.26 Of the total habitats most suitable for change (irrespective of typology), 466 ha[16] overlaps with SEPA 1:10 years (high probability) coastal flood risk. This includes 449ha of inter tidal zone below mean high water. SEPA 1:10 years (high probability) flooding from rivers was overlapped with the areas of habitats most suitable for change 8ha of habitats most suitable for change overlaps with SEPA 1:10 years (high probability) fluvial flood risk. There are also a number of highly fragmented areas of overlap between the two datasets, which may offer potential for wetland creation through a more detailed phase of work, but have not been identified as a strategic carbon sequestration opportunity within the scope of this study.

Habitats most suitable for change and cultural heritage

2.27 Of the total habitats most suitable for change (irrespective of typology) 100 ha[17] overlap with either the Antonine WHS boundary or buffer zone. This overlap is highlighted, but does not mean that habitat conversion should not or could not take place, only that additional site specific considerations may exist.

[16] Excluding the 1.15ha of not convertible habitat defined as habitats most suitable for change which should not be converted since they are adjacent to habitats they can naturally turn into (e.g. B5 next to H1-H3 or B6 / A3.1 adjacent to B1.2-B3.3)

[17] Excluding 1.83 of not convertible habitat which should not be converted since they are adjacent to habitats they can naturally turn into (e.g. B5 next to H1-H3 or B6 / A3.1 adjacent to B1.2-B3.3)

2.28 The map figures in Appendix H illustrate the following:

- Figure 1: Land Typology within Council Owned Land
- Figure 2: Carbon Sequestration Habitats Within Council Owned Land
- Figure 3: Habitats most suitable for change and by Land typology Within Council Owned Land
- Figure 4: Habitats most suitable for change Within Council Owned Land
- Figure 5: Habitats most suitable for change Converted into Carbon Sequestration Habitats Within Council Owned Land.

Conclusions and recommendations

2.29 Falkirk Council has identified that 13,000 tonnes of carbon per year is the carbon deficit of Falkirk Council services and activities to achieving net zero by 2030. Other planned infrastructure work will add further pressures on carbon budget.

2.30 The scenarios indicate that Falkirk Council owned land has the potential to sequester between an additional 2,006 tCO_2e per annum and 4,082 tCO_2e per annum, as a result of current habitats and resulting from habitat change (mature habitat) in addition to the baseline current 4,628 t/CO2e/annum from existing council owned land. This figure must be caveated within the data limitations of the study. This represents an approximate shortfall of between 4,290t/CO_2e per annum and 6,366t/CO_2e per annum in 2030 against the target of 13,000 tonnes of carbon. The figure is based on the mature carbon sequestration rates of converted habitats to maximise carbon sequestration. This is the new carbon sequestration value based on the replacement of the former habitats. It does not take into account other site-specific constraints or opportunities.

How quickly can Falkirk Council sequester more?

2.31 The largest and most rapid carbon gains can be achieved by the conversion of habitats with the lowest current carbon sequestration value. Those which are assigned a carbon sequestration value of zero include amenity grassland, improved grassland and arable land. Amenity grassland is particularly important for habitat change, due to the additional carbon inputs of mowing and maintenance. It is recognised that areas of agricultural land will be subject to leasing arrangements which may affect the potential for change. Any habitat change which increases carbon sequestration by reducing management inputs will bring about short term gains.

2.32 Longer term, increasing areas of mixed woodland on habitats most suitable for change where it is appropriate to do so, will achieve the greatest carbon sequestration. It is recognised that grant funding for woodland may impact on the type of woodland planted.

In addition to the habitats most suitable for change identified, no assessment of the habitat value of private gardens (534ha) was possible through the data. The literature review suggests that a large proportion of private gardens is of minimal carbon sequestration value. Although it is recognised that private gardens fulfill a range of functions which require open character and are within tenant control, there may be opportunity to achieve carbon sequestration gains in these areas.

Expected co-benefits in terms of surface water management.

2.33 The proposed habitat conversion for carbon sequestration would deliver additional benefits for surface water management through increased levels of vegetation intercepting water, stabilising banks, and reducing erosion and the amount of water and pollutants reaching the watercourse, while also improving biodiversity.

2.34 Woodland can attenuate rapid run off at a local scale and the greater hydraulic roughness associated with riparian and floodplain woodland can aid the retention and delay the passage of flood waters[18].

Due to the significant proportion of potential habitat change which is identified as potentially suitable for woodland conversion, this would result in reduced run off from an additional approximate 1,199ha of land within Falkirk Council area.

[18] Nisbet, T. R. & Thomas, H., (2006) The role of woodland in flood control: a landscape perspective. [online] Available at: https://www.forestresearch.gov.uk/documents/1756/woodland_flood_control_iale_paper_2006.pdf [Accessed on 08/03/2021]

Chapter 3
Green roof and green wall potential

This chapter explores the potential for green roof and wall creation on council owned buildings

3.1 As outlined in the methodology, the study has also considered the potential for the creation of green roofs and walls on council owned buildings and their contribution to carbon sequestration.

Considerations for installation of Green Roofs

3.2 Every structure will have a maximum weight it can support, and an installation needs to allow for snow loading and unseasonal rainfall in weight calculations, as the green roof could hold/absorb considerable additional weight during high precipitation[19].

3.3 Roof pitch needs to be taken into consideration, as it needs to allow for free drainage, some modern green roof solutions can be installed on roofs pitched at an angle up to 15 degrees[20], some other sources suggest that structures can be delivered to slopes as steep as 35 degrees[21].

3.4 Light availability and wind prevalence will impact on the suitability of a green roof. Most sedum plants require direct sunlight, or at least being in only semi-shaded conditions, however they will not survive in very shaded areas for a long time. Strong wind or saline conditions will affect the types of plants that can be used[22].

3.5 Benefits of green roofs are widely known, and they include reduced energy costs due to improved insulation and cooling, cleaner air, regulated temperature and reduced water run-off and potential flooding[23].

[19] Wallbarn (2020) Green Roof Installation – Planning Considerations. [online] Available at: https://www.wallbarn.com/green-roof-installation-the-key-pre-planning-decisions/ [Accessed on 08/03/2021]
[20] Ibid.
[21] Foster, R. (2018) Choosing a Green Roof System: Weight, Maintenance and More. BuildIt. [online] Available at: https://www.self-build.co.uk/green-roof-designs/ [Accessed on 08/03/2021]
[22] Wallbarn (2020) Green Roof Installation – Planning Considerations. [online] Available at: https://www.wallbarn.com/green-roof-installation-the-key-pre-planning-decisions/ [Accessed on 08/03/2021]
[23] ANS GLOBAL (2019) The Best Locations for a Green Roof. ANS GLOBAL. [online] Available at: https://www.ansgroupglobal.com/news/best-locations-green-roof [Accessed on 08/03/2021]

3.6 There may be some adverse effects related with green roofs such as more costly building insurance, the weight of the green roof may result in liability issues if the pressure of it causes sagging, and potential damage caused by plants and their roots[24].

3.7 There are two broad categories of green roofs – intensive and extensive. The former is a flat roof garden planted with a deep layer of soil while the latter compromises a thinner substrate and is more suitable as a finish for pitched structures. An extensive system can flourish best on a slope 35 degrees or less[25].

3.8 Waterproofing of roof deck is a key part of protecting the structure. This could be a bitumen membrane or coating, asphalt on a shed, or some form of liquid waterproofing[26].

3.9 Root barrier to prevent any roots causing damage to the structure. In intensive roofs, root barriers are essential due to the potentially more wood-like and vigorous roots of the vegetation[27].

Carbon sequestration

3.10 Carbon sequestration 6 – 16 years of CO_2 payback time[28]. A typical figure for carbon sequestered by an extensive green roof (both below ground in substrate and above ground in perennial vegetation) is 375g of carbon per square metre. Researchers are investigating the possibility of integrating charcoal and materials that chemically absorb carbon dioxide in green roofs in order to store carbon. Other research is also underway, looking at how the uptake of carbon dioxide in green roofs could be increased by inoculating mychorrizhal fungi[29]. Other resources identify that there can be up to 1.22 kg of carbon sequestered by a m^2 of a green roof under optimal conditions[30].

3.11 A more recent study focused on the carbon sequestering differences between a green roof plant community and ground landscape, considering 13 different landscapes over a three year period, (Whittinghill, et al, 2014). After a two year period, the sedum and grass green roof sequestered 4.67 C kg/m^2, suggesting the greater substrate depth, increased complexity of the plant system and more advanced irrigation system, enhanced the carbon sequestering significantly. Although this approach increased the cost of a green roof project (discussed later), it was necessary to install irrigation mats in conjunction with deeper soil depth to maximize carbon sequestering. Applying these results to a seven square meter roof, approximately 168.48 kg of carbon dioxide would be sequestered per year. If a green roof were used to grow vegetables, the carbon sequestering would be approximately 20 per cent lower. (Michigan State University, 2009)[31]

3.12 It was found that vegetation and soil properties are the key factors affecting the performance of building energy consumption reduction and CO_2 sequestration[32].

Green walls

3.13 Green walls give enormous visual pleasure, and can help to 'humanise' long stretches of wall that may otherwise be blank. They can take the eye from the mega-scale of a giant construction down to a much more intimate scale[33].

3.14 Research highlights the superior ability of living walls to benefit air quality. The nature of city landscapes creates 'street canyons' which trap pollution at street level, living walls can increase the deposition rate of harmful particulate matter by as much as 40% of nitrogen dioxide and 60% when planted correctly[34].

3.15 High urban temperatures are caused by the increased capacity of the urban land surface (eg. roads, buildings, pavements) to absorb and trap heat. This causes our city temperatures to be up to 10c higher than rural areas, resulting in the Urban Heat Island effect. Adding living walls and green roofs to urban structures mimics the conditions presented in rural surroundings, evapo-transpiration from plants mitigates the urban heat island effect and makes cities more comfortable places to live in the summer months by both

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[24] Climate Action Business Association (2018) Green Roofing: everything you need to know. CABA. [online] Available at: https://cabaus.org/2018/04/20/green-roofing-everything-need-know/ [Accessed on 08/03/2021]

[25] Foster, R. (2018) Choosing a Green Roof System: Weight, Maintenance and More. Buildlt. [online] Available at: https://www.self-build.co.uk/green-roof-designs/ [Accessed on 08/03/2021]

[26] Permagard (undated) Green Roof construction – How to Guide. Permagard. [online] Available at: https://www.permagard.co.uk/advice/green-roof-construction [Accessed on 08/03/2021]

[27] Ibid.

[28] Kuronuma, T., Wantanabe, H., Ishihara, T., Kou, D., Toushima, K., Ando, M., and Shindo, S., (2018) CO2 Payoff of Extensive Green Roofs with Different Vegetation Species. Sustainability, 10, 2256. [online] Available at: https://www.mdpi.com/2071-1050/10/7/2256/pdf

[29] Designing Buildings (2020) Green Roofs. [online] Available at: https://www.designingbuildings.co.uk/wiki/Green_roofs [Accessed on 08/03/2021]

[30] Scotscape (undated) Living Walls. [online] Available at: https://www.scotscape.co.uk/services/living-walls#types [Accessed on 08/03/2021]

[31] Ibid.

[32] Shafique, M.; Xue, X.; Luo, X. (2020) An overview of carbon sequestration of green roofs in urban areas. Urban Forestry & Urban Greening. 47. [online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S1618866719303668#:~:text=The%20field%20study%20results%20(Luo,13.15%20kg%2Fcm2%20respectively. [Accessed on 08/03/2021]

[33] Designing Buildings (2020) Green Roofs. [online] Available at: https://www.designingbuildings.co.uk/wiki/Green_roofs [Accessed on 08/03/2021]

[34] Scotscape (undated) Living Walls. [online] Available at: https://www.scotscape.co.uk/services/living-walls#types [Accessed on 08/03/2021]

reducing temperatures and dust in the air. 'Green facades effectively remove 50% of solar radiation. In summer vegetated roofs can be up to 50c cooler than conventional roofs.' – Arup Green Buildings[35].

Installing green roof and walls

3.16 Green roofs and walls are typically bespoke projects. Green roof and wall providers suggest that there are opportunities to find a suitable solution, be it a green roof or a green wall for any building, although cost will vary. The specifications of each project will be designed and adjusted to the character and construction of a building. Generic costs are difficult to provide per m^2 of a green roof or a green wall as it will depend on the thickness of the roof, types of plants, and materials required.

3.17 One reference resource indicates that an extensive turf roof can be fully installed for £50-100 per m^2, or £130-140 per m^2 for an intensive green roof. (The wide variation depends on how close you are to the supplier.)[36]

3.18 Additionally, it is suggested that green walls are often built as a separate structure for the green wall which is then attached to the building. Such approach allows for green walls on most types of buildings, however it may require additional planning permission.

Green wall and roof potential for Falkirk Council owned buildings

3.19 An evaluation of the green roof and green wall potential of Falkirk Council owned buildings identified the following considerations. Based on the assumption that flat roofs most readily lend themselves to green roof installation we have taken the high level assumption that if 50% of the roof area of all flat roofed buildings being retained in Falkirk could theoretically be suitable for green roof installation, this gives an area of 47,884m^2[37]:

Table 3.1: Green roof and green wall potential of Falkirk Council owned buildings

Property characteristic	Number of properties
Existing flat roof (full or partial)	33 properties (one with existing green roof)
Number with flat roof and indicative structural capacity	18
Number with some potential for green wall installation	32

- Based on maximum carbon sequestration values for green roofs from the literature of 1.22kg CO_2e/m^2, this level of green roof installation would result in approximately 58 tonnes of CO_2 sequestration per year. This is equivalent to the CO_2e of approximately 12ha of broadleaved woodland.
- Based on the lower carbon sequestration value given of 0.375kg CO_2e/m^2 this level of green roof installation would result in approximately 18 tonnes of CO_2 sequestration per year. This is equivalent to the carbon sequestration of approximately 4 ha of broadleaved woodland.
- Based on the literature resources, neither of these values of sequestration would be achieved until 6 – 16 years after installation.

3.20 As noted above, due to a number of the buildings included in the above calculations only having partial areas of flat roof, and multiple storeys, these figures are likely to be a significant overestimate.

3.21 A more detailed review of a sample of five properties was undertaken to provide an indication of potential green roof and green wall installation. This draws on the information provided by Falkirk Council and aerial and Google Streetview images, and internal floor areas have been adjusted to reflect the number of storeys.

Bonnybridge Primary School

3.22 The school was built in 1960's as a two-storey building with a flat roof. The approximate roof area is 1,886 sq m. Considering the age of the building any significant roof installation may not be suitable for this building. However, there are green wall opportunities to be explored on the sides of the buildings where there are fewer windows.

Langlees Primary School

3.23 Langlees Primary School is located in the north of Falkirk. The school consists of two two-storey buildings and four one storey connecting and additional facilities which were built in 1950's. The roof area is approximately 2,770 sq m. The

[35] Ibid.
[36] Foster, R. (2018) Choosing a Green Roof System: Weight, Maintenance and More. BuildIt. [online] Available at: https://www.self-build.co.uk/green-roof-designs/ [Accessed on 08/03/2021]
[37] Based buildings with all or some flat roof, potential structural suitability and 50% of the floor area which may be for buildings with more than one storey, therefore this figure is likely to be an overestimate.

roof is with a slope on parts of the building, and has flat roofed areas, considering the age of the building green roof may not be a suitable solution. There is a scope for green walls installations on the sides of the buildings.

Mariner Leisure Centre

3.24 Mariner Leisure centre is located in Camelon. The approximate roof area is 2,893 sq m. This is a single storey building from the 1980's and has windows on the walls only at the entrance. Additional windows are in the roof of tallest part of the building over the swimming pool, which accounts for approximately 50% of the roof area. Green roofs could potentially be installed on the lower parts of the roofs. All building walls provide opportunities for the green walls, those that are more exposed to sunlight could be prioritised for the installation.

Falkirk High School

3.25 Falkirk High School is located in South West Falkirk, near Summerford Park. It is a modern 2-3 storey building with a flat roof above the main entrance and the building to the left of the main entrance. The rest of the roof is under a minimal slope. Part of the flat roof above the main entrance may not be suitable for a green roof, however the remaining part of the roof could be explored as a potential location of a green roof. The total roof area is approximately 8,976.17 sq m, and the area of the roof unlikely to be suitable for a green roof is 229.78 sq m. There are some opportunities for green walls to be installed on this building by the entrance and also on a wall along Westburn Avenue, however this would be limited by the narrow gap between the building and perimeter fence. It is a north-facing wall, therefore plant species should be carefully selected so that they can thrive in more shadowed conditions. There are green wall opportunities along the wall to the east, which would be suitable for more heat resistant types of plants.

Earls Road Depot

3.26 Earls Road Depot is located on the outskirts of Grangemouth in an industrial area. The building has a flat roof, however it is a one storey only. Approximate roof area 864 sq m. As this building was built in 1960's the structure may not be strong enough to hold the additional weight of a green roof. There may be a potential for an extensive green roof with a very thin layer of substrate (e.g. 5 -10 cm). Such a solution could help with cooling of the building in the summer months considering that the roof is black and it absorbs the heat and directly warms the units underneath. However, there is a need for a specialist evaluation of specific opportunities. There is no blank wall that could support a green wall construction, however there are columns of wall between windows that are approximately 2 meters wide that could serve as a support from a mini green wall installation. It will be important to ensure that pavement space is not taken away as disabled parking spaces are located close to that wall.

Alternative recommendations for council owned roofs

3.27 Photovoltaic panels may provide an alternative use for the roof area of Council owned buildings, providing annual CO_2 savings, although it is also recognised that photovoltaic panels have a carbon footprint. Key limitations for the potential for photovoltaic panels for council owned buildings would be the additional spacing and mounting for installing on flat roofs, limitations of any asbestos roofs, listed buildings or buildings located in conservation areas, in addition to shading considerations from surrounding buildings.

3.28 Consideration of green roofs on the construction of new council owned buildings should be taken forward, in addition a further available option is to combine both solar panels and green roof development.

Chapter 4

Conclusions and next steps for Phase 2

This project represents the first stage of a two stage project, which will take forward more detailed project proposals.

Conclusions

4.1 The study has highlighted that there is a degree of uncertainty over the current and potential carbon sequestration values due to data limitations, however council owned land is estimated to currently sequester in the region of 4,628 tCO_2e per annum, with the potential to increase this between an additional 2,006 tCO_2e per annum and 4,082 tCO_2e per annum through habitat change in areas identified as 'habitats most suitable for change'. This will require habitat change on a minimum of 1,000ha of land. In order to achieve the higher levels of carbon sequestration this would require creation of areas of mixed woodland and implementation of habitat change within some site typologies which present greater challenges to conversion such as roadside verges, or by influencing the management of private house grounds.

4.2 The timescales for achieving these levels of carbon sequestration vary with the habitat change, although it is anticipated that achieving maximum levels of carbon sequestration may take approximately a decade for grassland habitats and up to 60 years for broadleaved woodland to achieve maximum carbon sequestration, although mixed woodland will see more rapid gains if faster growing species are included. Specific data has not been identified on the carbon sequestration values of different ages of woodland. It is important to note that site specific characteristics are a key consideration in these figures. Resilience to future climate change, including pests and disease and wildfire risk must be taken into account in order to ensure that carbon sequestered remains within soils and vegetation.

4.3 This highlights the importance of other actions to reduce carbon emissions through reducing management inputs for areas of land, including through both chemical and physical means.

4.4 This study has not included the value of carbon stock held in soils, therefore management of existing soils is also highlighted as an important consideration as loss and damage to existing soil resources will further reduce future carbon sequestration potential.

4.5 The study has highlighted that there is a high degree of uncertainty over the potential for green roofs and walls (based on data limitations), however this could make a minor positive contribution to carbon sequestration beyond the next 6 – 16 years in the region of 16-50 tCO_2e per annum.

4.6 It is recommended that Falkirk Council should explore the feasibility for other carbon saving uses of roofs, such as photovoltaic panels and the relative cost benefits of these.

Considerations for Phase 2

4.7 The first phase of the study has highlighted the data limitations of the existing Phase 1 habitat data (dated 2008) and the limitations of the Council owned land dataset which includes inaccuracies and a lack of consistent application of site typology categories.

4.8 As such, the study conclusions as highlighted through this report are subject to these caveats. However, they provide an important starting point for taking forward the more detailed actions for Phase 2 which should be based on site specific and verified data.

4.9 Potential stages for Phase 2 were noted in the project specification as:

- Develop detailed proposals for a number of priority sites;
- Carry out community consultation exercise to inform recommendations;
- Identify potential funding streams for carbon sequestering habitat/ green roof creation; and
- Develop appropriate plans to access those funding streams.

4.10 The outputs from the first phase of the study provide a clear indication of the areas within Falkirk which should be prioritised for habitat change, based on the identification of the habitats most suitable for change.

> An option to be carried out alongside the progression of Phase 2 would be to update the Phase 1 habitat survey to allow accurate identification of all habitats most suitable for change and address data errors.

4.11 Recognising that there is urgency in implementing habitat change for carbon sequestration, it is recommended that the next steps for Phase 2 should include:

- Verification of all areas of habitats most suitable for change over an agreed size threshold with ecological site survey.
- Identify adjacent areas of council owned land which may also have habitat types suitable for change with a view to identifying contiguous areas for habitat change.
- Identify other constraints onsite which limit the area of land suitable for habitat change such as site typology, paths/roads, wayleave for services, archaeological sites, riparian corridors.
- Consider linkages to other policy areas and the potential contribution of the habitat change to these.

4.12 Wider considerations for taking habitat change forward in Phase 2 also include:

- The requirement for forestry EIA (for planting over 20ha or in environmentally sensitive locations):
- Alignment of woodland creation with grant funding requirements, including species choice (conifer/deciduous) tree density and biodiversity value.
- The impacts of habitat change on soil carbon stock.

Appendix A
Methodology

Introduction

A.1 The study is based on two main stages, the identification of existing carbon sequestration value and potential habitat change for carbon sequestration purposes, and the identification of green roof potential. The methodology for each of these stages is described below.

Carbon sequestration value and potential habitat change

A.2 The methodology for the carbon sequestration value and potential habitat change is based around the following main steps:

- Literature review to identify carbon sequestration values of different habitats
- GIS data cleaning and organisation
- Assigning carbon sequestration values to all Phase 1 habitats
- Identifying habitats suitable for change to habitats with higher carbon sequestration value, whilst conserving existing biodiversity value and recognising the constraints of different site typologies
- Identifying options for change.

Literature review

A.3 Research suggests that carbon sequestration and storage vary considerably within given habitat types, reflecting characteristic such as soil conditions, climate, latitude and altitude. Habitat age and condition also have a significant bearing on the rate of sequestration and storage. It is critical, therefore, to adopt a suite of sequestration factors that are appropriate to Falkirk and its existing and potential habitats.

A.4 A range of literature (See Appendix G) has formed the basis of the review to identify carbon sequestration values to apply to different habitat types.

A.5 Technical advice published by SNH[38] provides a useful starting point and references a 2011 UK-based literature

[38] NatureScot (2018) EcoServ – GIS v3.3 Technical Report: "Carbon Storage Service". [online] Available at: https://www.nature.scot/sites/default/files/2018-06/Publication%202018%20-%20SNH%20Research%20Report%20954%20-%20Technical%20Report%20-%20ES2%20Carbon%20storage.pdf [Accessed 08/03/2021]

review[39] which compared measurements of carbon storage within eleven different habitat types recorded in the scientific literature. These were categories designed to correspond to EU Corine Land Cover mapping[40] but represent fairly broad habitat types. The study also referred to work in Wales which ranked habitats by their importance for carbon storage in soils, vegetation and combined, and research at city scale which confirmed that urban habitats and soils can store significant amounts of carbon.

A.6 Natural England[41] has also published research drawing together data on carbon storage by habitat type and, where relevant, soil type. The Natural England research also highlights some useful management considerations, including the suggestion that the transition from one habitat to another (e.g. to improve sequestration) should be undertaken steadily rather than suddenly, and soil disturbance should be kept to a minimum.

A.7 The initial review of existing literature resulted in the selection of a hybrid approach based on a number of literature sources and bringing together habitat types and carbon sequestration value.

A.8 There is some variation in the evidence on the rates on sequestration from urban greenspace, although this typically relates to urban trees, and not amenity grassland. The European Commission has published estimates of carbon storage – which range widely, while research carried out in Florida provides sequestration figures for a variety of different types of greenspace. While the latter may not be directly transferable to Central Scotland, the relative importance of different types of greenspace may be useful in calibrating the approach.

A.9 A key challenge for urban greenspace is the carbon sequestration value to attribute to amenity grassland. As noted in the research in Florida, the carbon inputs from mowing and management are not taken into account in the calculations.

A.10 Trees are widely recognised as a key means of absorbing and storing carbon from the atmosphere. Forestry Commission research[42] provides information on the carbon stored by different tree species including Scots Pine, Birch, Oak, Sitka Spruce and within soils and forest litter. The research also underlines the importance of good woodland management, indicating that sequestration rates are higher for thinned than for unthinned woodlands, reflecting the more vigorous growth that results.

A.11 The Forestry Commission research also provides information on the carbon stored in different types of soils, an important consideration in understanding the baseline position and the scope to change management to increase sequestration rates.

A.12 Most existing studies provide a range of potential carbon storage value (min-mean-max) for different habitat types. Due to the issues identified with the Phase 1 habitat data for Falkirk Council, for consistency the study uses relevant mean values, but the study caveats that there is a difference in carbon storage capacity between young and mature trees, or drained wetland, for example. Full vigour growing woodland will have higher carbon sequestration rates, and this levels off at maturity where natural losses due to decay and deadwood occur.

A.13 As broader context for increasing carbon sequestration, research[43] undertaken for The Committee on Climate Change has identified the approaches which can be taken to maximise carbon sequestration based on case study analysis of four large scale locations in England. The findings are summarised as:

- Increase the woodland and forest land cover.
- Preferentially plant new woodland on mineral soils rather than high carbon (peaty) soils.
- Wet woodland has a high capacity for sequestration (providing a high water table can be maintained).
- Convert cultivated lands to managed permanent grasslands.
- Convert marginal cropland to native vegetation, grasslands or forest.
- Reduce agricultural grazing intensity on grasslands.
- Reduce the level of mechanical disturbance and cultivation of soils.

[39] Cantarello, E., Newton, A.C. & Hill, R. a., 2011. Potential effects of future land-use change on regional carbon stocks
in the UK. Environmental Science & Policy, 14(1), pp.40–52. Available at: http://linkinghub.elsevier.com/retrieve/pii/S146290111000122X [Accessed 08/03/2021]
[40] Copernicus & Land Monitoring Service (undated) CORINE Land Cover. [online] Available at: https://land.copernicus.eu/pan-european/corine-land-cover [Accessed 08/03/2021]
[41] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources (NERR043). [online] Available at: http://publications.naturalengland.org.uk/publication/1412347 [Accessed 08/03/2021]
[42] Forestry Commission (2012) Understanding the carbon and greenhouse gas balance of forests in Britain. [online] Available at: https://www.forestresearch.gov.uk/research/understanding-the-carbon-and-greenhouse-gas-balance-of-forests-in-britain/ [Accessed 08/03/2021]
[43] JBA consulting (2018) Exploring the economics of land use change for increasing resilience to climate change in England. The Committee on Climate Change. Available at: https://www.theccc.org.uk/wp-content/uploads/2018/12/JBA-Consulting-Exploring-the-economics-of-land-use-change-for-increasing-resilience-to-climate-change-in-England.pdf [Accessed 08/03/2021]

- Manage sustainably currently functioning wetlands and peatlands.
- Restore wetland soils and damaged peatlands.
- Minimise controlled burning for managing vegetation.

A.14 These principles are relevant to the present study.

GIS Data

A.15 The study is a data led study and a full list of spatial datasets identified as being of relevance for the project is provided in Appendix B. The list provides high level metadata for each dataset (e.g. date, originator), as well as any identified licensing restriction or dataset limitations.

Land Ownership Data

A.16 Falkirk Council digitised the majority of its land ownership record as listed below (July 2020):

- Complete: Airth, Bonnybridge, Banknock, Denny, Grangemouth and Braes (including Polmont, Laurieston & Redding, and rural villages).
- Partially complete: Braes (including Brightons Maddiston, Reddingmuirhead and Muiravonside) 99% complete, Falkirk North and Falkirk South are 90-95% complete.
- Incomplete: Bo'ness.

A.17 The land ownership polygon data is available at the level of individual title deeds and it does not include information on site type (e.g. building, road, verge, park, sport facility, school).

A.18 Considering the difficulties of digitising the outstanding land ownership boundary paper maps by the Council due to the Covid-19 pandemic, it was agreed to progress the project with the existing digital data.

A.19 The land ownership data provided by the Council included:

- Land ownership – extent of land owned by the Council, as available on the Council's Location Centre GIS system;
- Titles – extent of land owned by the Council captured from existing title deed paper maps;
- Sales – extent of land sold by the Council.

A.20 In order to create one unique land ownership dataset for the purpose of this project, the provided Land ownership and Titles datasets were merged and the extent of the Sales dataset removed. Boundary alignment has not been checked against Ordnance Survey MasterMap (OSMM), since it is assumed they have been captured at this scale in line with the current mapping requirement for land registration of the Registry of Scotland.

A.21 It was found that the resulting land ownership dataset had overlapping records (e.g. multi-storey building with flats in Council ownership, data errors / duplicates due to using data from different sources (e.g. sales, titles)), therefore the full dataset had to be dissolved into dis/continuous areas.

A.22 Since the data provided by the Council does not include unique identifiers nor information on site typology, LUC created two datasets:

- Extent of land parcels owned by the Council. Each continuous parcel was assigned a **unique identifier** to allow their unique referencing.
- Break down of land parcels owned by the Council into **site type** / typology to allow their categorisation required for the assessment of their habitat and carbon sequestration.

A.23 The site type has been indicatively assigned based on other spatial datasets, including OSMM, OSMM Greenspace, Forest Estate Plan, focusing on broad typology classes. Due to data quality the focus was on assigning typologies for larger areas, while for smaller areas whose typology was not possible to be easily determined based on available datasets, the site type 'Undetermined' has been assigned. Within the scope of the study it was not possible to assign typologies to all polygons, which task would have required manual checking of each land parcel against available aerial imagery and other base mapping.

A.24 The applied site typology includes the following categories:

- Agricultural land
- Allotments
- Amenity open space
- Churchyard/cemetery
- Golf course
- Industrial/commercial
- Natural, semi-natural greenspace
- Play space
- Private house grounds
- Public building complex
- Public park/garden
- Quarry
- Railway

- Road
- Roadside
- School grounds
- Sports area
- Inter tidal zone
- Undetermined

A.25 The site type 'Private house grounds' was assigned to all land parcels over private houses and their grounds / gardens, since based on the available spatial data it was not possible to determine the extent of the built up and green areas / gardens.

A.26 Due to the identified numerous data accuracy issues the assigned site typology should be treated as indicative only.

A.27 The following disclaimer is attached to all GIS and map outputs derived from the Falkirk Council land ownership data:

> "The information provided is to the best of the Council's knowledge and belief, accurate. The Council does not however, warrant the information and it should not be relied upon. Clarification should be sought by contacting the Council's Asset Management Unit".

Phase 1 Habitat Data

A.28 The original Phase 1 habitat survey of Falkirk Council is from 2008 based on JNCC habitat classification. A subsequent revision of the dataset has been undertaken by Falkirk Council to ensure it aligned to OSMM mapping.

A.29 After the initial review of the Falkirk Council habitat datasets it became apparent that a large percentage did not have a valid JNCC Phase 1 habitat code, but stated only 'Other habitat' or did not provide a habitat code. Therefore, an additional task of populating the missing habitat codes from other sources, as a desk-based exercise, had to be undertaken for areas within the ownership of Falkirk Council only.

A.30 A significant number of polygons were missing the Phase 1 habitat codes but were classified only as general surface / multi surface / private garden in OSMM Greenspace. A desk-based check against available aerial imagery proved that these included a wide range of surfaces, lawns, gardens, hardstanding and bare earth. It was outwith the scope of this project to undertake a habitat survey of all these areas with missing habitat codes, therefore the value PG – Private house grounds was assigned to them all. These PG habitats were excluded from further assessment.

A.31 It was also observed that where habitats from 2008 were now within settlement extensions, for most of these OSMM did not provide any detailed information which would have allowed the assignment of valid habitats, therefore these were assigned PG – Private house grounds as well.

> 49,894 areas were identified which had no Phase 1 habitat code assigned in the provided Phase 1 dataset and for which the only other information available was that they were private house grounds.
>
> **There is an opportunity for Falkirk Council to seek to influence residents' management of private grounds and gardens within Council owned land to inform garden and planting management practices to achieve maximum carbon sequestration potential and biodiversity resilience.**

A.32 It was also noted that the Phase 1 habitats dataset did not include smaller habitats within wider areas (e.g. paths, canals through amenity grassland were shown as amenity grassland). This means there will be a margin of error in carbon sequestration calculations and conversion potential.

A.33 It was also noted that the Phase 1 habitats dataset had a large number of overlapping areas, with different habitat values in places. In total, 7,436 areas had overlapping habitat values, of which just over 4,000 are within Council owned land. It was outwith the scope of this project to reconcile this data duplication and it must be highlighted that due to the GIS–led method of populating missing habitats it is possible that for some areas the incorrect habitat code has been assigned.

A.34 In order to ensure currency and completeness of the Phase 1 dataset, and due to the very large number of issues in the provided Phase 1 dataset, it was decided to recreate an indicative Phase 1 habitats dataset based on available current datasets:

- Current OSMM and OSMM Greenspace datasets were used as the base of the new Phase 1 dataset, to ensure currency of the main habitats, including built-up and water areas.
- Phase 1 habitats from the original dataset, where available, were compared against the current land cover as defined in OSMM. Where there was a clear match (e.g. 'A1.3.2 Mixed woodland (plantation)' habitat in the original Phase 1 dataset and 'Non-coniferous trees' in the current OSMM dataset), the more detailed habitat code from the original Phase 1 dataset was kept.
- A check against Forestry Commission National Forest Inventory (NFI) 2018 dataset has been undertaken to ensure existing wooded areas are correctly shown. It was established that many smaller patches of woodland

throughout the Council owned land were not included in NFI. These were preserved from OSMM.

- A check against FC Woodland compartments dataset has been undertaken, however it was established that this dataset was coarser than OSMM and its inclusion would have introduced further data simplification.
- Visual check of a sample of habitat types where changes are most likely to have occurred (e.g. changes to some of the parks and open spaces through reduced mowing and creation of new meadows, settlement extensions) against the most recent aerial imagery available for the study area. Since Falkirk Council was not able to provide current aerial imagery for the project, the freely available ESRI aerial imagery was used, though it should be noted that this can be up to five years out of date. Since OSMM data provided by the Council was more current than the ESRI aerial, OSMM was used as the definitive source for assigning missing habitats (e.g. if the original Phase 1 habitat dataset and the aerial showed a land parcel as amenity grassland but OSMM showed it as manmade general surface, it was assumed it was manmade general surface / hardstanding).
- It was ensured that all areas were assigned a valid JNCC Phase 1 habitat code and name within land owned by Falkirk Council.

Due to the identified issues with the provided Phase 1 dataset and the different scale of data used to patch it, the resulting data can be treated as indicative only.

We recommended that a new and detailed Phase 1 habitat survey of all Council owned land including private house grounds is undertaken at OSMM scale and the developed carbon sequestration method applied to it to ensure improved accuracy.

A.35 The diagram overleaf provides an overview of the key stages of the methodology.


Council owned land
Council owned land with valid JNCC Phase 1 habitat code
Council owned land without valid JNCC Phase 1 habitat code
Phase 1 habitat types
High level habitat types assigned from OSMM
Assignment of site type (school, road verge etc) from available data (OSMM, OSMM Greenspace)
Field visit verification of Phase 1/open space data/Mastermap habitat types and verification of site types
Carbon sequestration types assigned to current habitat type
Current carbon sequestration value of council owned land
Development of rules to assign potential habitat conversion type to current habitat most suitable for change taking into account data on flood risk
Application of conversion scenarios
Potential carbon sequestration value of disposable habitats based on conversion scenarios
Council owned buildings
Buildings with existing green roofs
Categorisation of buildings and identification of suitability
Buildings with potential for green roofs/walls
Current carbon sequestration value of existing green roofs
Potential carbon sequestration value of buildings if fitted with green roofs/walls

Carbon Calculator Model Development and Carbon sequestration values

A.36 A review of carbon sequestration values in literature has identified a number of key references. Different studies have drawn upon a variety of sources to inform the carbon sequestration values by habitat type. Data sources used for estimated carbon sequestration values applied to this study are as follows:

- White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland: Technical Appendix', Department for Food, Environment & Rural Affairs/ The Scottish Government.
- Christie, M., Hyde, T., Cooper, R. Fazey, I., Dennis, P., Warren, J., Colombo, S., and Hanley, N.,(2010). Economic Valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan. Final report to Defra[44].
- Alonso, I., Weston, K., Gregg, R., Morecroft, M., 2012. Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources (Natural England Research Report No. NERR043). Natural England https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12561

A.37 Through the process of assigning carbon sequestration habitats to Phase 1 habitat types it became apparent that values would be required for the additional habitat types of:

- parkland and scattered trees
- scrub
- private gardens
- marginal and inundation vegetation.

A.38 This requirement is due to these habitat types not fitting easily within any of the existing carbon sequestration habitat types identified from the literature.

A.39 Based on the review of literature the approach to assigning carbon sequestration rates by habitat type used as the basis for this study is set out in Table 4.1 below.

[44] Christie, M., Hyde, T., Cooper, R. Fazey, I., Dennis, P., Warren, J., Colombo, S., and Hanley, N.,(2010). . 2010. Economic Valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan. Final report to Defra. [online] Available at: https://users.aber.ac.uk/mec/Publications/Reports/Value%20UK%20BAP%20FINAL%20published%20report%20v2.pdf [Accessed 08/03/2021]

Table 4.1: Carbon sequestration rates by habitat type as applied in the Falkirk Council Carbon Sequestration Scoping Study

Habitat	Carbon sequestration t/CO2/ha/yr	Comment	Source
Amenity grass (mown)	0.000	Value of zero assigned reflecting literature source variations in value from negative to positive values, and minimal positive contribution where this was indicated. Note that carbon sequestration value does not include inputs to maintenance through mowing etc.	Alonso et al (2012) '*Taking all factors into account Ostle and others (2009), citing the IPCC LULUCF reports, concluded that grasslands remaining as such were net emitters of 0.2-0.3 Mt C yr1'*.
Amenity grass with broadleaved scattered trees	2.485	LUC assigned value.	LUC assigned value based on 50% of broadleaved woodland value, plus zero amenity grassland value
Broadleaved woodland	4.970	-	White et al. (2015), sourced from Christie et al (2010)
Coniferous woodland	12.660	-	White et al. (2015), sourced from Christie et al (2010)
Enclosed farmland	0.107	-	White et al. (2015), sourced from Christie et al (2010)
Fen, marsh and swamp	0.700	-	White et al. (2015), sourced from Christie et al (2010)
Freshwater	0.000	Assuming no vegetation cover	White et al. (2015), sourced from Christie et al (2010)
Lowland bog[45]	0.700	-	White et al. (2015), sourced from Christie et al (2010)
Marginal and inundation	0.549	LUC assigned value.	LUC assigned value based on 50% semi natural grassland value and 50% fen, marsh and swamp
Mixed woodland	8.815	Noted as mean of broadleaved and coniferous carbon sequestration values	Christie et al.(2010)[pg. 106]
Mixed woodland and semi natural grassland	4.606	LUC assigned value	LUC assigned value based on 50% mixed woodland value and 50% semi natural grassland value
Private house grounds	0.000	Value of zero assigned reflecting amenity grass value alongside key trends of increased hard standing.	Cameron et al (2012)[46] cite Gaston et al., (2005) that within UK domestic gardens lawns constitute 60% of the area.
Saltmarsh	5.188	-	White et al. (2015), sourced from Christie et al (2010)

[45] Not identified as a habitat within Falkirk Council owned land
[46] Cameron, R.W.F.,, Blanusa, T., Taylor J.E., Salisbury, A., Halstead, A.,J. Henricot, B. and Thompson, K. (2012) The Domestic Garden - Its contribution to Urban Green Infrastructure. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1618866712000076 {Accessed 08/03/2021]

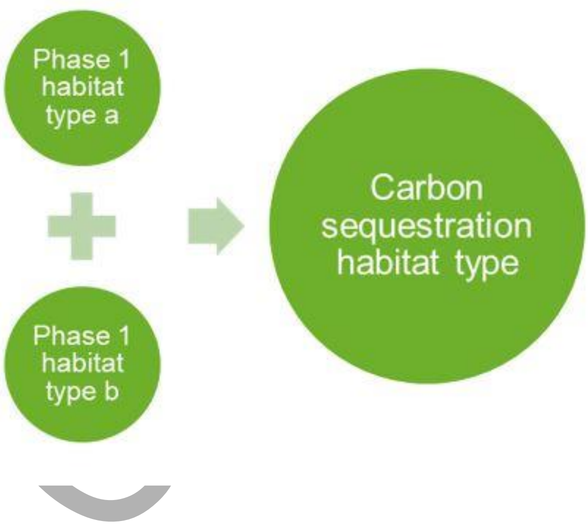
Habitat	Carbon sequestration t/CO2/ha/yr	Comment	Source
Scrub	2.684	LUC assigned value	LUC derived value based on 50% of broadleaved woodland value and 50% semi-natural grassland value.
Semi natural grassland	0.397	-	White et al. (2015), sourced from Christie et al (2010)

Habitats and Carbon Sequestration Habitat Alignment

A.40 Available carbon sequestration models are available only for high level habitats, so it was necessary to simplify the more detailed Phase 1 habitats identified within Council owned land to align with these. Multiple Phase 1 habitats are assigned the same carbon sequestration habitat type in order to provide an associated value of t/CO_2/ha/annum.

A.41 A list of all Phase 1 habitats identified within Council landholdings was compiled and each Phase 1 habitat has been assigned a broader carbon sequestration habitat type by the project team ecologist, (Appendix C). This allows the calculation of the current carbon sequestration value of council owned land. Where standard carbon sequestration values were not identified from literature, variations on the standard rates were applied. For example, the value for scrub is based on a 50% split between broadleaved woodland and semi natural grassland carbon sequestration values. Assumptions are recorded in the table in Appendix C. It should be noted that in order for the calculations to reflect other site based constraints for woodland planting that the carbon sequestration value assigned for woodland in the calculations is based on achieving 50% woodland cover and 50% semi natural grassland cover.

Figure 4.1: Schematic overview of habitat conversion



Prioritising biodiversity: Habitat conversion to increase biodiversity through carbon sequestering habitat intervention/enhancements

A.42 It was clearly set out by the project steering group that the project should prioritise protecting and enhancing biodiversity value, and in line with legislation and policy. Following on from this, the approach to identifying potential habitat conversion was based on identifying habitats which would be likely to have the lowest intrinsic habitat value.

A.43 In relation to the Nature Conservation (Scotland) Act 2004, "It is the duty of every public body and office-holder, in exercising any functions, to further the conservation of biodiversity so far as is consistent with the proper exercise of those functions." Biodiversity is therefore at the front of Scottish Government priorities and this is devolved to the Local Authorities.

A.44 In addition to the biodiversity priority, the Scottish Government is committed to addressing climate change, aiming to meet the targets set out in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. In response to these priorities, Falkirk Council is focussing on enhancing and maintaining biodiversity while simultaneously examining ways in which they can use biodiversity to sequester carbon. Carbon sequestration and biodiversity do not always go 'hand in hand', there is often a conflict of interest between these two categories most commonly resulting in a trade-off/comprises being made.

A.45 To support Falkirk Council in making informed decisions on appropriate land management for the future, guiding principles are required. These principles will allow the council to prioritise and target areas that will yield the greatest results to meet targets.

Considerations for habitat conversion

A.46 Before considering whether a potential site is a viable option for intervention, the council must first understand what the proposed intervention area (or habitat proposed for modification) currently supports. When examining a site for potential conversion, the council should consider the following:

- Is the site offered or likely to be offered any protection and if so, what is the status of the designation? i.e. are there any statutory or non-statutory designations either forming part of or falling within close proximity to the proposed area.
- Is it possible for the site to be a candidate for a designation? Designated areas should be retained and enhanced for their qualifying features.
- Will the proposed intervention support the Scottish Biodiversity List and Local Biodiversity Action Plan? i.e. are existing habitats, or the fauna they support, considered nature conservation priorities?
- How will any proposed intervention affect the functional and structural connectivity of existing habitat networks? What are the likely biodiversity impacts of the proposed intervention? i.e. will any proposed interventions

positively/ negatively affect the existing flora or fauna present. If so, are these effects permanent or temporary, reversible or irreversible etc.

- What are the long-term land management plans for the area? i.e. will any proposed interventions be retained for a long enough time period to establish and produce results which meet the requirements.
- Are there any existing proposals for the area including (but not limited to) development plans/allocations, tenancy agreements, and Woodland felling plans which could result in the intervention option having low efficacy?

A.47 Falkirk Council should consider the longevity of any intervention options through consultation with planning policy, public engagement, and stakeholder involvement as required. Any potential interventions that could benefit both biodiversity and or carbon sequestration need to have a level of permanence in order to function viably. Increasing the ability to store carbon and habitats through a range of management techniques will be possible through various mechanisms as described below.

A.48 Generally, there is a lack of empirical data informing many of these proposals/mechanisms, and so careful consideration of selected species, target location, and efficacy/longevity must be considered at the site level. As a general 'rule of thumb' increasing habitat diversity and connectivity will lead to increased biodiversity.

Woodland

A.49 Falkirk Council should be aware of the value held in the retention of carbon sequestering habitats particularly those of woodland habitat. Typically, woodland provides high biodiversity value and is often ecologically diverse. Management of woodlands should be a priority for the council. Creation of new woodland habitat and woodland corridors reconnecting fragmented landscapes will be an important and a relatively simple way off increasing the carbon sequestration potential within the area as well indirectly benefiting nature. In areas of existing broadleaf woodland either of semi-natural or plantation origin should be increased for their biodiversity and carbon sequestration value by addition of native conifer trees.

A.50 Existing conifer plantation woodland can be improved for biodiversity through management strategies and diversification of stock species.

Grassland

A.51 Increasing carbon storage through planting a mixture of native broad leaved and coniferous trees on areas currently of low carbon sequestering value habitat (e.g. amenity, semi-natural, or agricultural land) is a potential method to increase carbon storage in the long term. It should be noted that species rich grasslands are important habitats in their own right and so interventions on good quality grassland are not always appropriate.

Enclosed farmland

A.52 Enclosed farmland can be managed to increase biodiversity and carbon sequestration through creation of hedgerows and short rotation coppice plantation within field margins and boundaries. Hedgerow management through increasing species diversity and connectivity between adjacent land parcels will help increase biodiversity, while having the simultaneous effect of increasing the areas ability to store carbon [47,48]. It may be possible for enclosed farmland to be released and converted to woodland habitat or a change in management practice e.g. from traditional open grazing pasture to silvo-pastoral systems or other agroforestry[49] methods.

Flood risk

A.53 One of the key adaptation challenges facing central Scotland is the growing risk of flooding, particularly during wetter winters and extreme rainfall events. It is widely recognised that the way land is managed can influence the speed and volume of flood water within a catchment. Frequently measures to improve sustainable flood management, such as woodland planting, restoration of peatlands and wetlands also deliver benefits in terms of carbon sequestration so options have been explored to realise this synergy.

A.54 In areas susceptible to flooding, management options to consider may be through creation of natural flood resilience. Increasing bank stability through vegetation planting will provide multiple benefits. Biodiversity will be increased through increased habitat creation and decreased soil/ bank

[47] Thiel, B. & Smukler, Sean & Krzic, Maja & Gergel, Sarah & Terpsma, C. (2015). Using hedgerow biodiversity to enhance the carbon storage of farmland in the Fraser River delta of British Columbia. Journal of Soil and Water Conservation. 70. 247-256. 10.2489/jswc.70.4.247.

[48] Perks et al. (2018) Agroforestry in Scotland – potential benefits in a changing climate. ClimateXChange. [online] Available at: https://www.climatexchange.org.uk/media/3312/agroforestry-in-scotland-potential-benefits-in-a-changing-climate.pdf [Accessed 08/03/2021]

[49] Saunders *et al.* (2016). Can Silvo-pastoral agroforestry systems contribute to Scotland's emission reduction targets? The James Hutton Institute on behalf of ClimateXChange.

erosion[50,51]. Coastal areas at risk of flooding could be enhanced by active management and increase in salt marsh habitat. There is growing evidence of multiple benefits provided from well managed saltmarsh habitat ranging from flood resilience[52] to increased biodiversity and, carbon storage[53]. Intervention options should consider conversion of urbanised landscapes with inclusion of green infrastructure. Examples should consider maximising the carbon storage potential of an otherwise carbon source environment are: Investment in tree/ hedgerow planting. Careful selection of certain species[54] will provide better carbon storage however, the benefits of urban trees acting as carbon sinks are considerable and recently recognised[55].

Habitats most suitable for change or habitats typically with lower intrinsic biodiversity value

A.55 Based on the agreed approach to prioritising biodiversity above carbon sequestration value, the approach was taken to identify Phase 1 habitats with lowest intrinsic biodiversity value, as identified by the team ecologist. This was based on opinion from examining the habitats (aerial imagery) within Falkirk Council owned land and applying their knowledge of protected habitats and species which would be expected to be present within the area, their knowledge of the ecology of the species, and how the network of habitats are likely to change over time with typical succession patterns (assuming no interreference).

Habitats most suitable for change within flood risk areas

A.56 Areas of habitats most suitable for change which when cross referenced with the SEPA flood risk data were identified as being at "high risk" of 1 in 10 years flooding were then examined against the Central Scotland Green Network-Integrated Habitat Network. Where the habitats most suitable for change overlapped with both the SEPA and the CSGN dispersal network data, these areas have been assigned as potential for new wetland habitat. Falkirk Council should note the following before implementing the changes in these areas.

- The above considerations in paragraph A.45 'Considerations for habitat conversion' will apply.
- Flood management through natural mechanisms is site specific and will need to be further examined with input from various specialist contractors including but not limited to: Landscape architects, Hydrologists, and Ecologists
- Creation of marsh habitat or other wetlands can provide a natural flood defence system and will aid in increasing FCC's diversity of habitat networks. However, it may not provide the most effective solution to prevent future flooding. Depending on the advice from the specialist contractors, it may be more appropriate to convert these areas to mixed woodland.

A.57 Phase 1 habitats most suitable for change which were identified as having the least potential constraints to habitat change in terms of biodiversity value, and the potential habitat conversion types identified for these within the Falkirk context are set out in Appendix D. This appendix also sets out general rules to be applied at this strategic level of study, but also highlights the role of site-specific considerations.

Ground Truthing

A.58 Initial site visits were undertaken to a sample of sites to verify the Phase 1 habitat data and site typology and to identify potential constraints to assumed habitat conversion.

A.59 The development of the methodology around habitats most suitable for change also utilised a degree of cross checking with aerial imagery, which has enabled verification across a wider area. However, Phase 2 of the project should incorporate a sufficient level of ground truthing, which can now be undertaken in a focused manner based on the habitats most suitable for change Habitats most suitable for change conversion and site typology

A.60 We developed a number of potential habitat conversion scenarios based on site typology and habitat type which were presented and discussed with the project steering group. The scenarios take into consideration of limitations within different site typologies and generic constraints for example in terms of wayleaves.

A.61 This was used to indicate the more realistic areas of habitat conversion for a particular site, based on the requirements of different typologies.

A.62 However, following the steering group meeting and the steer towards a 'biodiversity first' approach to the project, it then became clear that the site typology is secondary to the identification of areas of potential habitat change.

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[50] Ran, Lishan et al. "Effective soil erosion control represents a significant net carbon sequestration." Scientific reports vol. 8,1 12018. 13 Aug. 2018, doi:10.1038/s41598-018-30497-4.
[51] Rickson, R.J., Baggaley, N., Deeks, L.K., Graves, A., Hannam, J., Keay, C and
Scottish Government (2020). Developing a method to estimate the costs of soil erosion in high-risk Scottish catchments. Report to the Scottish Government. Available at: https://www.gov.scot/ISBN/978-1-83960-754-7 [Accessed 08/03/2021]
[52] Adnit *et al.* (2007) Saltmarsh management manual, Environment Agency, Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. R&D Technical Report SC030220.
[53] Forest Research (2010). Benefits of green infrastructure. Report to Defra and CLG. Forest Research, Farnham.
[54] Scharenbroch, B. C., (2011) Carbon Sequestration in Urban Ecosystems, pp121-138.
[55] Wilkes et al. (2018) Estimating urban above ground biomass with multi-scale LiDAR, Carbon Balance Manage 13:10

A.63 The scenarios developed and discussed at the steering group meeting are therefore effectively superseded by the revised approach. Furthermore, due to the nature of the site typology polygons (which is disaggregated in many instances), it has not been possible to identify the proportion of habitats most suitable for change types by site typology.

A.64 Therefore, the specific limitations of different site typologies has not been applied to the carbon sequestration calculations.

Site typology and inclusion for habitat conversion calculations

A.65 From review of site typologies, some site types which are more limited for habitat change are identified, on the assumed basis of their key requirement to retain their current habitat to fulfil their function. These are reflected in the typologies included in the scenarios in Chapter 2, which also sets out assumptions on limitations for habitat conversion of e.g. the inter tidal zone.

A.66 . Sites typologies with lease constraints for change included in the scenario assessment are identified as:

- Agricultural land.
- Amenity open spaces
- Natural, semi-natural greenspaces and green corridors
- Public parks and gardens
- School and institutional grounds
- Sports areas.

A.67 The calculations for carbon sequestration value and potential for change reflect the area of habitats most suitable for change within the above typologies and not the total area of the typology.

Data caveats

A.68 The assignment of site typology is based on a number of datasets as described in Chapter 2. It is identified that there are likely to be errors within the assignment of these typologies. Additionally, there are sites for which no typology has been assigned, as this process was outside of the scope of this project. These are recorded as 'undetermined'.

A.69 A caveat is included about the potential conversion for these uncategorised areas within Chapter 3.

A.70 Within all of the included typologies is a proportion of hardstanding including surfaced paths, parking areas etc which will reduce the overall area of habitat conversion potential.

A.71 The following typologies have been included within calculations for carbon sequestration.

1. Natural, semi-natural greenspaces and green corridors (approx. 640 ha)
2. Public parks and gardens (approx. 425 ha)
3. Amenity open spaces (approx. 110 ha)
4. Agricultural land (approx. 270 ha)
5. School and institutional grounds (approx. 125 ha)
6. Sports areas (approx. 130 ha)
7. Cemeteries and graveyards (approx. 45 ha)

Flood risk

A.72 Flooding is a key issue for Falkirk, especially towards Grangemouth. GIS analysis identified the overlap between habitats most suitable for change and SEPA's coastal and river flooding dataset. This was then reflected in the recommendations for habitat conversion to wetland for these areas.

Other impacts on habitat conversion

A.73 A review of the below datasets was also undertaken, however due to the urban nature of the council owned land, these datasets did not influence the recommendations or calculations.

- JHI's Soils of Scotland 1:25,000 dataset (built-up area, which encompasses most of Council owned land, is categorised as 'Non-soil' in the dataset).
- BGS's Superficial geology 1:50,000 dataset.
- SNH's carbon and peatland, as well as deep peat, dataset (e.g. no Category 1 and 2 peatland within council owned land).
- Falkirk Council's existing Woodland and Forestry Strategy and Forest Plans, for information on proposed woodland expansion.
- JHI's Land Capability for Forestry 1:50,000 dataset. (built-up area, which encompasses most of Council owned land, is categorised as 'Built-up' in the dataset).

Antonine Wall WHS

4.13 The GIS analysis also took into account the Antonine WHS boundary and buffer zone, to identify the area of habitats most suitable for change within these boundaries. This highlights the area where additional site specific considerations may exist.

Time period for habitat change and carbon sequestration

A.74 Implementing habitat change may result in carbon expenditure. For example for tree planting, this includes the growth of the nursery stock, transport of trees and staff, tree guards and other maintenance activities during the establishment phase. This aspect of the carbon impact of habitat change has not been included in the calculations. Additionally, there is a time lag in achieving the levels of carbon sequestration applied in the calculations to different habitats.

A.75 The aim is to provide sufficient background information to Falkirk Council to be able to count benefits from carbon sequestration in 10-30 years' time and how the outputs could be tied in with other long term local plans of the Council (e.g. land allocated for housing, infrastructure).

A.76 Implementing a habitat change to achieve a change in carbon sequestration will take time for the establishment of that new habitat. As outlined previously, the carbon sequestration value of woodland varies over time, with the greatest carbon sequestration within the period of rapid growth, but also dependent on tree species. Over time, woodland also increases soil carbon stocks, but the period of rapid growth is likely to be between 20 - 60 years.

A.77 The carbon sequestration value of grassland is indicated as dependent on species diversity, and it is indicated by research that soil carbon storage increases over time, and may be greater within the second decade (based on conversion of arable to grassland). However, the rate of change is dependent on the characteristics of the original habitat.

A.78 Therefore for all habitat changes, the benefits for carbon sequestration may be significantly lower within the first decade, however this emphasises the need to implement change within a rapid timescale in order to achieve maximum benefits within the shortest timeframe.

Green roofs and vertical gardens methodology

Green roofs and vertical gardens

A.79 Green roofs and vertical gardens offer carbon storage and indirect benefits from eventual long-term effects such as reduced energy consumption[56], resulting in a reduction of fossil fuel usage[57]. This is further explored in Chapter 4.

A.80 Green roofs can achieve significant energy, carbon and biodiversity benefits. They can improve buildings' energy efficiency, absorb carbon from the atmosphere and lock it up in vegetation and the soil substrate, and can provide new habitats in otherwise urbanised areas. By absorbing and slowing run-off, they can contribute to sustainable flood management.

A.81 The Council's Strategic Asset and Property team has provided basic information on buildings that have not been identified for closure, including age and floor area. These buildings are to be priorities for consideration for green roof potential.

A.82 Due to the limitations of the information provided for the buildings the assessment has focused on providing high level advice on existing potential as baseline information for future projects.

A.83 A high level assessment using internet resources was undertaken to identify if a flat roof was present. A review of potential structural constraint based primarily on building age was carried out, assuming that older buildings (pre 1950s) are more likely to be suitable. Finally, web based mapping and images were used to identify where buildings appeared to have sizeable, largely blank walls that might have potential for green wall installation.

A.84 Research suggests that sequestration can be maximised by designing a deeper substrate and selecting plant species, such as some grasses, that are particularly efficient at absorbing carbon. Literature on the carbon sequestration value of green roofs suggests that due to the carbon emitted during production and maintenance that the CO_2 payback time of the extensive green roofs was between 5.8 and 15.9 years, which indicates that extensive green roofs contribute to CO_2 reduction within their lifespan[58].

A.85 Of course, much depends on the suitability and structural integrity of potential host buildings. Our experience suggests that later 20C, flat roofed buildings are often too weak to carry green roofs and the most suitable tend to be those from the 1930s-1950s. In all cases, structural advice will be required to determine technical feasibility.

[56] Hui, S. C. M. & Yan, L. T., (2016). Energy Saving potential of green roofs in University buildings, Joint Symposium 2016: Building a Smarter City via Latest Technologies.
[57] Shafique, M. *et al.* (2020) An overview of carbon sequestration of green roofs in urban areas, Urban Forestry & Urban Greening, Volume 47, 126515.
[58] Kuronuma, T., Wantanabe, H., Ishihara, T., Kou, D., Toushima, K., Ando, M., and Shindo, S., (2018) CO2 Payoff of Extensive Green Roofs with Different Vegetation Species. Available at: https://www.researchgate.net/publication/326134431_CO2_Payoff_of_Extensive_Green_Roofs_with_Different_Vegetation_Species [Accessed on 08/03/2021]

Appendix B

GIS data index

Table B.1: GIS Data Index[59]

GIS Dataset	Source	Notes
Land ownership boundary	Falkirk Council	Issues with data accuracy, overlaps, lack of typology / classification
OS Explorer 1:25,000	Falkirk Council	
OS MasterMap	Falkirk Council	
OS MasterMap Greenspace	Falkirk Council	
5m DTM	*Falkirk Council*	*Not part of PSGA, FC unable to provide*
Aerial imagery	*Falkirk Council*	*No FC data identified. Will use free ESRI*
Flood map (river, surface water, groundwater, coastal)	Falkirk Council / SEPA	
Existing / proposed flood defences and areas benefiting from flood defences	Falkirk Council / SEPA	
Public Rights of Way	Falkirk Council	
Local cycle routes	*Falkirk Council*	*No FC data identified*
Core paths and local trails	Falkirk Council	
National Cycle Network	Sustrans	
Scottish Trails	SNH	
Overhead power lines	SPEN	
World Heritage Site and buffer zone	Historic Environment Scotland	
Registered Battlefield	Historic Environment Scotland	
Registered Parks and Gardens	Historic Environment Scotland	
Phase 1 habitat survey	Falkirk Council	Data old from 2008. Large % of polygons missing valid JNCC phase 1 habitat code within FC owned land. Patched from OSMM.
Forest Estate plans	Falkirk Council	Received only compartment boundaries. No data on proposed management (e.g. removal, planting)
Forest Estate plan – woodland compartment	Falkirk Council	Data scale coarser than OSMM. Used to fill in P1 habitat codes where possible.
Woodland and Forestry Strategy	Falkirk Council	
Green roofs	*Falkirk Council*	
Green network LDP	Falkirk Council	
Local designated wildlife sites	Falkirk Council	

[59] Data in grey / italic is not available from the source

GIS Dataset	Source	Notes
Open Space Strategy 2015 Audit Update	Falkirk Council	
Tree Preservation Order LDP	Falkirk Council	
National Forest Inventory 2018	Forest Research	
Native Woodland – Integrated Habitat Network	Forest Research	
Ancient Woodland Inventory	SNH	
Integrated Habitat Networks	SNH	
Local Nature Reserves (LNR)	SNH	
Special Protection Area (SPA)	SNH	
Ramsar	SNH	
Sites of Special Scientific Interest (SSSI)	SNH	
SWT Reserves	SWT	
RSPB Reserves	RSPB	
IBA Reserves	RSPB	
Landscape Character Areas	Falkirk Council	
Special Landscape Areas	Falkirk Council	
BGS Geology 50K / Superficial geology	Falkirk Council	
Carbon and peatland 2016 map	SNH	
Peatland ACTION – Peat depth	SNH	
Bare peat areas	SNH	
Soil 1:25,000	JHI	No coverage for built-up areas.
Land Capability for Forestry 1:250,000	JHI	

Appendix C

Phase 1 habitat conversion to carbon sequestration habitats

Table C.1: Falkirk Phase 1 habitats and equivalent habitats with a defined carbon sequestration value

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value $t/CO_2/ha/yr$	Carbon sequestration habitat 2	Assigned carbon sequestration value $t/CO_2/ha/yr$	Average assigned carbon sequestration value $t/CO_2/ha/yr$	Justification
A1.1	Broadleaved woodland (semi-natural)	Broadleaved woodland	4.97	n/a		4.97	Broadleaved woodland value
A1.1 / A2.2	Broadleaved woodland (semi-natural) / Scrub (scattered)	Broadleaved woodland	4.97	n/a		4.97	Broadleaved woodland value
A1.1.2	Broadleaved woodland (plantation)	Broadleaved woodland	4.97	n/a		4.97	Broadleaved woodland value
A1.2	Coniferous woodland	Coniferous woodland	12.66	n/a		12.66	Coniferous woodland value
A1.2.2	Coniferous woodland (plantation)	Coniferous woodland	12.66	n/a		12.66	Coniferous woodland value
A1.3	Mixed woodland	Mixed woodland	8.815	n/a		8.815	Mixed woodland value
A1.3.2	Mixed woodland (plantation)	Mixed woodland	4.97	n/a		8.815	Mixed woodland value
A2	Scrub	Broadleaved woodland	4.97	Semi natural grassland	0.397	2.68	Presume the scrub is a mix of all possible types of scrub vegetation. Value is 50% split between broadleaved woodland and semi natural grassland values.
A2.1	Scrub (dense/continuous)	Broadleaved woodland	4.97	n/a		4.97	Assume scrub forms part of woodland ecosystem and assigned broadleaved woodland value
A2.1 / J1.1	Scrub (dense/continuous) / Arable	Broadleaved woodland	4.97	Semi natural grassland	0.397	2.68	Assume part of woodland ecosystem; assigned part as b6 so included semi-natural. Value is 50% split between broadleaved woodland and semi natural grassland values.
A2.2	Scrub (scattered)	Broadleaved woodland	4.97	n/a		4.97	Assume scrub forms part of woodland ecosystem and assigned broadleaved woodland value

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value $t/CO_2/ha/yr$	Carbon sequestration habitat 2	Assigned carbon sequestration value $t/CO_2/ha/yr$	Average assigned carbon sequestration value $t/CO_2/ha/yr$	Justification
A2.2 / A3.1	Scrub (scattered) / Broadleaved scattered trees	Broadleaved woodland	4.97	n/a		4.97	Assume scrub forms part of woodland ecosystem and assigned broadleaved woodland value
A2.2 / J1.1	Scrub (scattered) / Arable	Broadleaved woodland	4.97	Semi natural grassland	0.397	2.68	Assume part of woodland ecosystem. With grassy patches. Value is 50% split between broadleaved woodland and semi natural grassland values.
A3.1	Broadleaved scattered trees	Broadleaved woodland	4.97	Semi natural grassland	0.397	2.68	Assume equal split. Value is 50% split between broadleaved woodland and semi natural grassland values.
A3.1 / B1.2	Broadleaved scattered trees / Acid grassland (semi-improved)	Broadleaved woodland	4.97	n/a		4.97	Grassland element a minor slither of land, and discounted. Based on broadleaved woodland value
A3.2	Coniferous scattered trees	Mixed woodland	8.815	n/a		8.815	Reclassed as mixed woodland. Based on mixed woodland value
A3.3	Mixed scattered trees	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / A2.2	Mixed scattered trees / Scrub (scattered)	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / B2.1	Mixed scattered trees / Neutral grassland (unimproved)	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / B2.2	Mixed scattered trees / Neutral grassland (semi-improved)	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / B4	Mixed scattered trees / Improved grassland	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / B5	Mixed scattered trees / Marshy grassland	Fen, marsh and swamp	0.7	n/a		0.7	Checked and changed to only marshy grass. Based on fen, marsh and swamp value

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value t/CO_2/ha/yr	Carbon sequestration habitat 2	Assigned carbon sequestration value t/CO_2/ha/yr	Average assigned carbon sequestration value t/CO_2/ha/yr	Justification
A3.3 / B6	Mixed scattered trees / Poor grassland (semi-improved)	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / C3.1	Mixed scattered trees / Other tall herb and fern (ruderal)	Mixed woodland	8.815	Semi natural grassland	0.397	4.606	Assume equal split. Value is 50% split between mixed woodland value and semi natural grassland value
A3.3 / J1.2	Mixed scattered trees / Amenity grassland	Mixed woodland	8.815	Amenity grass (mown)		4.408	Assume equal split mixed woodland and amenity grassland. 50% mixed woodland value (as amenity grass value is 0)
A4.3	Mixed woodland (recently felled)	Mixed woodland	8.815	n/a		8.815	Assume areas usually restocked after felling
B1.1	Acid grassland (unimproved)	Semi natural grassland	0.397	n/a		0.397	Based on semi natural grassland value
B2	Neutral grassland	Semi natural grassland	0.397	n/a		0.397	Based on semi natural grassland value
B2.1	Neutral grassland (unimproved)	Semi natural grassland	0.397	n/a		0.397	Based on semi natural grassland value
B2.2	Neutral grassland (semi-improved)	Semi natural grassland	0.397	n/a		0.397	Based on semi natural grassland value
B2.2 / J1.1	Neutral grassland (semi-improved) / Arable	Semi natural grassland	0.397	n/a		0.397	Appeared to be grassland rather than arable. Based on semi natural grassland value
B4	Improved grassland	Amenity grass (mown)	0	Enclosed farmland	0	0	Improved is usually poor species and low productivity / maintained by heavy grazing. Assigned amenity grassland value.
B4 / J1.1	Improved grassland / Arable	Amenity grass (mown)	0	Enclosed farmland	0	0	Improved is usually poor species and low productivity / maintained by heavy grazing. Assigned amenity grassland value.

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value $t/CO_2/ha/yr$	Carbon sequestration habitat 2	Assigned carbon sequestration value $t/CO_2/ha/yr$	Average assigned carbon sequestration value $t/CO_2/ha/yr$	Justification
B5	Marshy grassland	Fen, marsh and swamp	0.7	Semi natural grassland		0.7	Based on fen, marsh and swamp value
B5 / J1.1	Marshy grassland / Arable	Fen, marsh and swamp	0.7	Semi natural grassland		0.7	Appears to be marshy grass over pasture. Based on fen, marsh and swamp value
B6	Poor grassland (semi-improved)	Semi natural grassland	0.397			0.397	Based on semi natural grassland value
B6 / A3.1	Poor grassland (semi-improved) / Broadleaved scattered trees	Semi natural grassland	0.397			0.397	Based on semi natural grassland value
B6 / J1.1	Poor grassland (semi-improved) / Arable	Semi natural grassland	0.397	Enclosed farmland	0.107	0.252	Assume even split. Based on 50% enclosed farmland value and 50% semi natural grassland value.
C3.1	Other tall herb and fern (ruderal)	Semi natural grassland	0.397			0.397	presumably similar value for semi natural grasslands. Theses are non-woody habitats and likely a range of forbs
C3.1 / J1.1	Other tall herb and fern (ruderal) / Arable	Semi natural grassland	0.397	Enclosed farmland	0.107	0.252	Assume even split. Based on 50% enclosed farmland value and 50% semi natural grassland value.
D1.1	Dry dwarf shrub heath (acid)	Semi natural grassland	0.397			0.397	Aerial image appear to be on edge of grassland, assigned semi natural grassland value
D5	Dry heath/acid grassland	Semi natural grassland	0.397			0.397	Assumed similar to semi natural grass from imaging and it fits this category more than others.
F1	Swamp	Fen, marsh and swamp	0.7			0.7	Based on fen, marsh and swamp value
F2.2	Marginal and inundation - inundation vegetation	Fen, marsh and swamp	0.7	Semi natural grassland		0.7	Assumed likely a combination of both habitats. Assigned fen, marsh and swamp value
G1	Standing water	Freshwater	0			0	

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value t/CO_2/ha/yr	Carbon sequestration habitat 2	Assigned carbon sequestration value t/CO_2/ha/yr	Average assigned carbon sequestration value t/CO_2/ha/yr	Justification
G1	Standing water (reservoir)	Freshwater	0			0	
G1.1	Standing water - eutrophic	Freshwater	0			0	
G2	Running water	Freshwater	0			0	
G2	Running water (canal)	Freshwater	0			0	
G2	Running water (drain)	Freshwater	0			0	
G2	Running water (spring)	Mixed woodland				8.815	Within mixed woodland changed this as insignificant amount of land / no evidence of water. Mixed wood is supra category
H1	Intertidal	n/a	0			0	
H1.1	Intertidal - mud/sand	n/a	0			0	
H1.2	Intertidal - shingles/cobbles	n/a	0			0	
H1.3	Intertidal - boulders/rocks	n/a	0			0	
H2.6	Saltmarsh - dense/continuous	Saltmarsh	5.188			5.188	Assigned saltmarsh value
H2.6 / J1.1	Saltmarsh - dense/continuous / Arable	Semi natural grassland				0.397	Changed from salt marsh to B6. Assigned semi-natural grassland value.
H3.2	Shingle/gravel above mean high water	n/a				0	
HS	Hardstanding	n/a				0	
HS	Hardstanding (bridge)	n/a				0	
HS	Hardstanding (misc)	n/a				0	

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value t/CO_2/ha/yr	Carbon sequestration habitat 2	Assigned carbon sequestration value t/CO_2/ha/yr	Average assigned carbon sequestration value t/CO_2/ha/yr	Justification
HS	Hardstanding (path)	n/a				0	
HS	Hardstanding (railway)	n/a				0	
HS	Hardstanding (road)	n/a				0	
HS	Hardstanding (roadside)	n/a				0	
HS	Hardstanding (slipway/masonry)	n/a				0	
HS	Hardstanding (structure)	n/a				0	
HS	Hardstanding (sub station)	n/a				0	
HS	Hardstanding (weir)	n/a				0	
I1.4	Other rock exposure	n/a				0	
I2.1	Quarry	n/a				0	
I2.4	Refuse tip	n/a				0	
J1.1	Arable	Enclosed farmland	0.107			0.107	Assigned enclosed farmland value
J1.2	Amenity grassland	Amenity grass (mown)				0	
J1.2 / A3.1	Amenity grassland / Broadleaved scattered trees	Amenity grass (mown)	0	Broadleaved woodland	4.97	2.485	Assume even split. Based on 50% broadleaved woodland value

JNCC P1 CODE	JNCC P1 Name	Carbon sequestration habitat 1	Assigned carbon sequestration value $t/CO_2/ha/yr$	Carbon sequestration habitat 2	Assigned carbon sequestration value $t/CO_2/ha/yr$	Average assigned carbon sequestration value $t/CO_2/ha/yr$	Justification
J3.5	Artificial sea wall	n/a	0	n/a		0	
J3.6	Buildings	n/a	0	n/a		0	
J3.7	Tracks	n/a	0	n/a		0	
ok	Tracks / Arable	n/a	0	n/a		0	
J4	Bare ground	n/a	0	n/a		0	
PG	Private house grounds	n/a	0	n/a		0	Areas of hardstanding and amenity grass have a value of 0.

Appendix D

Habitats most suitable for change and potential conversion habitats

Table D.1: Habitats most suitable for change and potential conversion habitats[60]

Phase 1 classification	Phase 1 habitat code	Phase 1 habitat code description	Carbon sequestration potential conversion habitat 1	Carbon sequestration potential conversion habitat 2	Carbon sequestration potential conversion habitat 3	Carbon sequestration potential conversion habitat 4	Notes *Caveats to conversion
Woodland and Scrub:	A2.2	Scrub (scattered)	A1.3 (Mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		For carbon sequestration purposes this is assigned values of mixed and broadleaved woodland with grassland. Retaining as scrub and scattered trees would maintain/ increase the diversity of available habitats. However this habitat is also likely to change over time to A1.3 (mixed woodland).
	A3.1	Broadleaved scattered trees	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)			
	A3.3/B4	Parkland scattered trees/Improved grassland	A1.3 (Mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		
	A3.3/B6	Parkland scattered trees/Poor semi-improved grassland	A1.3 (Mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		B6* site dependent, this may be important depending on local circumstances i.e. if it is the only grassland habitat or is functionally connected to better examples, and likely to overtime improve to B1.2, 2.2, or 3.2
	A3.3/J1.2	Parkland scattered trees/Amenity grassland	A1.3 (Mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		

[60] The Phase 1 habitats were processed for the extent of council owned land only. There will potentially be edge effects due to adjacent habitats in non-council owned land.

Phase 1 classification	Phase 1 habitat code	Phase 1 habitat code description	Carbon sequestration potential conversion habitat 1	Carbon sequestration potential conversion habitat 2	Carbon sequestration potential conversion habitat 3	Carbon sequestration potential conversion habitat 4	Notes *Caveats to conversion
Grassland and marsh	B4 and any combination including B4	Improved grassland	A1.3 (Mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		Where B4, B6, J1.1 (arable) J1.2 (Amenity grassland) and combination/mosaics with any of these habitats most suitable for change codes sit within the habitats most suitable for change within 1:10 years (high) river flooding" layer AND the CSGN IHN wetland network, these could be converted to wetland typology i.e. Fen, marsh and swamp (Phase1: B5) rather than mixed woodland. This may not be appropriate depending on the geology/ hydrology which would need to be based on detailed assessment.
	B5*	Marshy grassland	H2 (Saltmarsh)	D5 (Dry heath/acid grassland)	D6 (wet heath/acidic grassland mosaic)	E (Mire)	B5* Extremely site dependent, this can be an important habitat and is often of conservation value in its own right Convert to H2 only if adjacent to estuarine habitat H1-H3. If functionally connected with any D (heathland) or E (mire)codes can be feasibly changed to a D5/D6 or an E code.[61]
	B6*	Poor grassland	A1.3 (mixed woodland)	B1.2 (semi-improved	B2.2 (neutral grassland	B2 and H5 (neutral	B6* site dependent, this may be important

[61] Note: There are no E habitats within FC. There are no B5 habitats next to D5 habitat in FC (there are no other D habitats in FC). Converted one to H2 next to estuarian habitat. The remaining B5 habitats (31) were excluded from the habitats most suitable for change conversion.

Phase 1 classification	Phase 1 habitat code	Phase 1 habitat code description	Carbon sequestration potential conversion habitat 1	Carbon sequestration potential conversion habitat 2	Carbon sequestration potential conversion habitat 3	Carbon sequestration potential conversion habitat 4	Notes *Caveats to conversion
		(semi-improved)		acid grassland)	(semi improved))	grassland/strandline vegetation)	depending on local circumstances i.e. if it is the only grassland habitat or is functionally connected to better examples, and likely to overtime improve to B1.2, 2.2, or 3.2. Cross - reference with the CSGN data for connectivity. Convert to B5/H2 only if habitat next to Grangemouth water / flood risk areas (H2 would be on the outermost edges transitioning in land to B5- marshy grass). The B2/H2 habitat will likely benefit the SPA/Ramsar species but this would be subject to HRA. Where B4, B6, J1.1 (arable) J1.2 (Amenity grassland) and combination/mosaics with any of these habitats most suitable for change codes sit within the habitats most suitable for change within 1:10 years (high) river flooding" layer AND the CSGN IHN wetland network, these could be converted to wetland typology i.e. Fen, marsh and swamp (Phase1: B5) rather than mixed woodland. This may not be appropriate depending on the geology/ hydrology which would need to be

Phase 1 classification	Phase 1 habitat code	Phase 1 habitat code description	Carbon sequestration potential conversion habitat 1	Carbon sequestration potential conversion habitat 2	Carbon sequestration potential conversion habitat 3	Carbon sequestration potential conversion habitat 4	Notes *Caveats to conversion
							based on detailed assessment.
Tall herb and fern	C3.1 and any combinations of C3.1	Other tall herb and fern (ruderal)	A1.3 (mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		
Open water	G1* and G2* codes	Standing water, running water	Potential to be partially changed to include Fen (E3), Marsh (B5) and Swamp (F1) codes around the edges of the watercourse/body				G1 & G2* site dependent cross reference the carbon and soil map with areas of G1 or G2, if on peat >0.5m then can be changed to E3. If less than 0.5m of peat then should be B5 unless the water table is permanently high (in relation to flooding maps) then this could be F1
Coastal	H1* and all variations of H1 e.g. H1.3 codes	Intertidal	Some areas may have potential for change to H2 (Saltmarsh)				H1* changes to these codes are potentially extremely difficult to implement due to these areas typically being extremely important for birds.
Cultivated/disturbed lands	J1.1	Arable	A1.3 (mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)	F1 (Swamp)	Convert to F1 - Swamp where it overlaps 1:10 years of flooding from rivers
	J1.2	Amenity grassland	A1.3 (mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)	F1 (Swamp)	Convert to F1 - Swamp where it overlaps 1:10 years of flooding from rivers
	J1.2 /A3.1	Amenity grassland and broadleaved scattered trees	A1.3 (mixed woodland)	A1.1 (Broadleaved woodland)	B2.2 (Semi-improved neutral grassland)		
Rock exposure and waste, miscellaneous	HS, I codes & J codes	Hardstanding, quarry, refuse tip, arable,	HS, I codes & J codes* Potentially the largest implementation strategy to increase carbon storage within FCC land will be to increase the planting in the urban environment within				*this will be extremely site dependent and due to the nature

Phase 1 classification	Phase 1 habitat code	Phase 1 habitat code description	Carbon sequestration potential conversion habitat 1	Carbon sequestrati on potential conversion habitat 2	Carbon sequestrati on potential conversion habitat 3	Carbon sequestration potential conversion habitat 4	Notes *Caveats to conversion
		amenity grassland, artificial sea wall, buildings, tracks	(habitats coded as: HS, I, J) and in rural/agricultural areas planting of trees/ hedgerows. Cross reference these areas with CSGN maps for adjacent/ or potential for functional connectivity to decide on most appropriate habitat These areas could feasibly be changed to a variety of habitats from grasslands to woodland.				of this study and limitations discussed, these habitat types have not been converted. Where B4, B6, J1.1 (arable) J1.2 (Amenity grassland) and combination/mosaics with any of these habitats most suitable for change codes sit within the habitats most suitable for change within 1:10 years (high) river flooding" layer AND the CSGN IHN wetland network, these could be converted to wetland typology i.e. Fen, marsh and swamp (Phase1: B5) rather than mixed woodland. This may not be appropriate depending on the geology/ hydrology which would need to be based on detailed assessment.

Appendix E

Data caveats

E.1 The Falkirk Council P1 habitat dataset had a significant number of issues in it:

- it was from 2008 therefore outdated
- it was not completely aligned to OSMM
- it didn't include smaller habitats within larger areas (e.g. streams, tracks within bigger grassland areas)
- it had the P1 code missing for a significant number of records (e.g. provided only 'Other habitat' or nothing)
- it had a large number of overlapping polygons

E.2 In order to create an updated base P1 habitat dataset for the purpose of this project:

- the original 2008 P1 survey was intersected with OSMM and OSMM greenscape datasets to get current land use types
- it was also intersected with the FC Forest Estate Plan woodland extents, but it transpired that dataset was at much smaller scale, therefore not as beneficial for the project
- built up areas (e.g. roads, hardstanding, all that was 'manmade') was assigned from OSMM
- for hardstanding, the type of it was assigned, where possible from OSMM to the habitat name (e.g weir, bridge, structure)
- water features were assigned from OSMM (G1 and G2). For some the type was appended in bracket from the original 2008 P1 survey - these were later converted back to simple G1 and G2, since this was suitable considering the accuracy of data and the scope of the project
- most of the other habitats were assigned from OSMM
- 2008 P1 habitats were kept only if the current OSMM implied that they were still the same type of habitat (e.g. grassland, woodland)
- if the OSMM description_term had the value 'Agricultural land' this was assigned as the secondary habitat to

whatever other code the area already had (e.g. grassland, woodland)

- when OSMM implied the cover is grassland, and there was no further info from the 2008 P1 code what type of grassland it might be, B6 was assigned.
- it is expected B6 and amenity grassland are not consistently used within and outside settlements
- PG Private house grounds (initially Private gardens) - these are vast expanses of land, whole housing estates, for which there was no habitat code from FC and there was no info in OSMM. Therefore these were assigned Private house grounds. It was out with the scope of this project to undertake a review of all of these).

Appendix F

List of Abbreviations

- BGS – British Geological Survey
- CCC - Committee on Climate Change
- CEH - Centre for Ecology & Hydrology
- DEFRA - Department for Environment, Food & Rural Affairs
- EU - European Union
- FAO – Food and Agriculture Organization of the United Nations
- GIS - Geographic Information System
- IHN - Integrated Habitat Network
- IPCC - Intergovernmental Panel on Climate Change
- IUCN - The International Union for the Conservation of Nature
- NE - Natural England
- ONS - Office of National Statistics
- OS – Ordnance Survey
- OSMM – Ordnance Survey MasterMap
- RHS - The Royal Horticultural Society

Appendix G

References

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Appendix H

Map Figures