Land use planning in urban areas – towards an ecosystems approach

Volume 2: Appendices

Peter M. Phillips

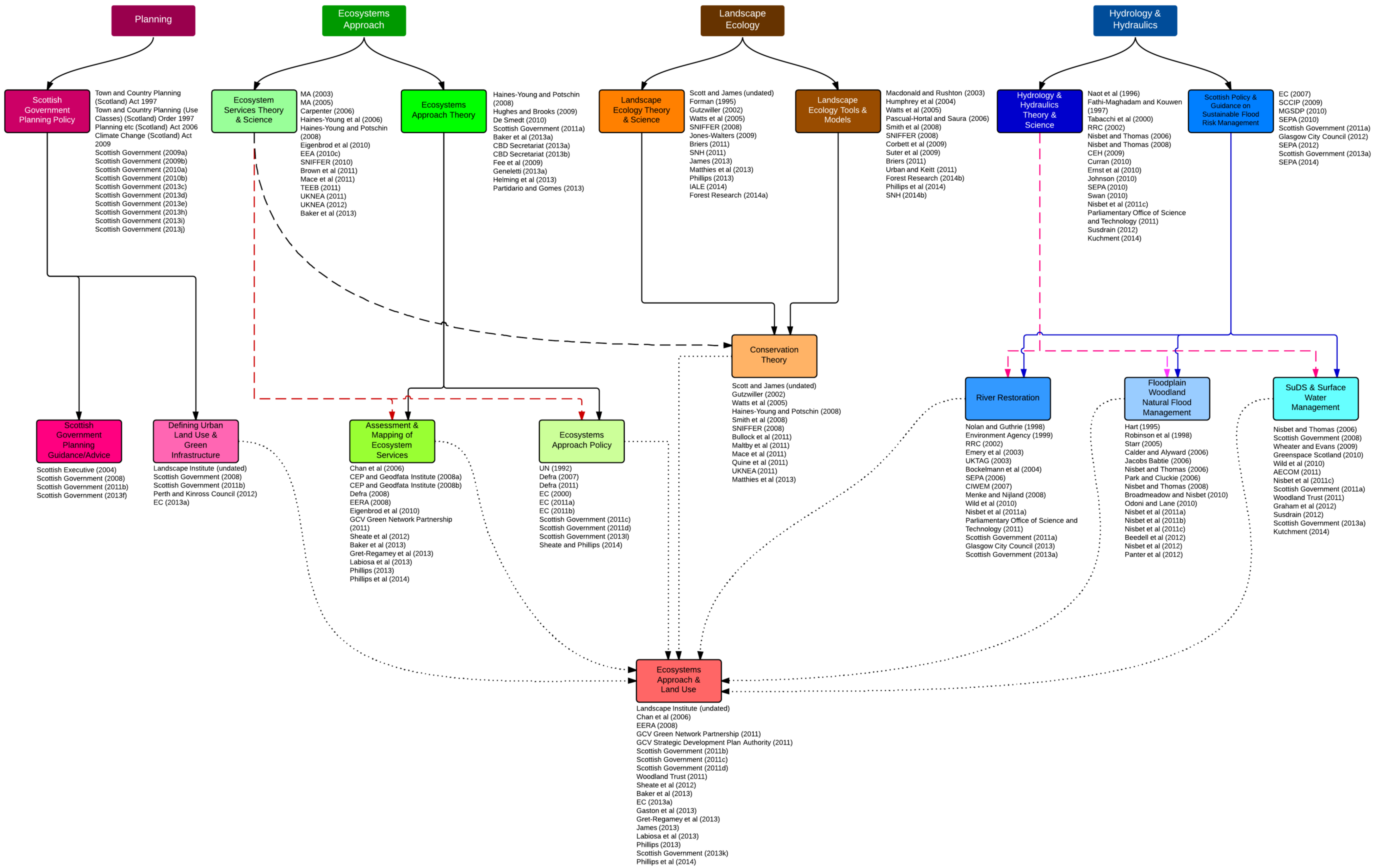
A thesis presented in fulfillment of the requirements for the degree of Doctor of Philosophy

The University of Strathclyde
Department of Civil and Environmental Engineering

2014

Contents

Appendix 1: Literature map


Planning
Ecosystems Approach
Landscape Ecology
Hydrology & Hydraulics
Scottish Government Planning Policy
Town and Country Planning (Scotland) Act 1997
Town and Country Planning (Use Classes) (Scotland) Order 1997
Planning etc (Scotland) Act 2006
Climate Change (Scotland) Act 2009
Scottish Government (2009a)
Scottish Government (2009b)
Scottish Government (2010a)
Scottish Government (2010b)
Scottish Government (2013c)
Scottish Government (2013d)
Scottish Government (2013e)
Scottish Government (2013h)
Scottish Government (2013i)
Scottish Government (2013j)
Ecosystem Services Theory & Science
MA (2003)
MA (2005)
Carpenter (2006)
Haines-Young et al (2006)
Haines-Young and Potschin (2008)
Eigenbrod et al (2010)
EEA (2010c)
SNIFFER (2010)
Brown et al (2011)
Mace et al (2011)
TEEB (2011)
UKNEA (2011)
UKNEA (2012)
Baker et al (2013)
Ecosystems Approach Theory
Haines-Young and Potschin (2008)
Hughes and Brooks (2009)
De Smedt (2010)
Scottish Government (2011a)
Baker et al (2013a)
CBD Secretariat (2013a)
CBD Secretariat (2013b)
Fee et al (2009)
Geneletti (2013a)
Helming et al (2013)
Partidario and Gomes (2013)
Landscape Ecology Theory & Science
Scott and James (undated)
Forman (1995)
Gutzwiller (2002)
Watts et al (2005)
SNIFFER (2008)
Jones-Walters (2009)
Briers (2011)
SNH (2011)
James (2013)
Matthies et al (2013)
Phillips (2013)
IALE (2014)
Forest Research (2014a)
Landscape Ecology Tools & Models
Macdonald and Rushton (2003)
Humphrey et al (2004)
Watts et al (2005)
Pascual-Hortal and Saura (2006)
Smith et al (2008)
SNIFFER (2008)
Corbett et al (2009)
Suter et al (2009)
Briers (2011)
Urban and Keitt (2011)
Forest Research (2014b)
Phillips et al (2014)
SNH (2014b)
Hydrology & Hydraulics Theory & Science
Naot et al (1996)
Fathi-Maghadam and Kouwen (1997)
Tabacchi et al (2000)
RRC (2002)
Nisbet and Thomas (2006)
Nisbet and Thomas (2008)
CEH (2009)
Curran (2010)
Ernst et al (2010)
Johnson (2010)
SEPA (2010)
Swan (2010)
Nisbet et al (2011c)
Parliamentary Office of Science and Technology (2011)
Susdrain (2012)
Kuchment (2014)
Scottish Policy & Guidance on Sustainable Flood Risk Management
EC (2007)
SCCIP (2009)
MGSDP (2010)
SEPA (2010)
Scottish Government (2011a)
Glasgow City Council (2012)
SEPA (2012)
Scottish Government (2013a)
SEPA (2014)
Conservation Theory
Scott and James (undated)
Gutzwiller (2002)
Watts et al (2005)
Haines-Young and Potschin (2008)
Smith et al (2008)
SNIFFER (2008)
Bullock et al (2011)
Maltby et al (2011)
Mace et al (2011)
Quine et al (2011)
UKNEA (2011)
Matthies et al (2013)
Scottish Government Planning Guidance/Advice
Scottish Executive (2004)
Scottish Government (2008)
Scottish Government (2011b)
Scottish Government (2013f)
Defining Urban Land Use & Green Infrastructure
Landscape Institute (undated)
Scottish Government (2008)
Scottish Government (2011b)
Perth and Kinross Council (2012)
EC (2013a)
Assessment & Mapping of Ecosystem Services
Chan et al (2006)
CEP and Geodfata Institute (2008a)
CEP and Geodfata Institute (2008b)
Defra (2008)
EERA (2008)
Eigenbrod et al (2010)
GCV Green Network Partnership (2011)
Sheate et al (2012)
Baker et al (2013)
Gret-Regamey et al (2013)
Labiosa et al (2013)
Phillips (2013)
Phillips et al (2014)
Ecosystems Approach Policy
UN (1992)
Defra (2007)
Defra (2011)
EC (2000)
EC (2011a)
EC (2011b)
Scottish Government (2011c)
Scottish Government (2011d)
Scottish Government (2013l)
Sheate and Phillips (2014)
River Restoration
Nolan and Guthrie (1998)
Environment Agency (1999)
RRC (2002)
Emery et al (2003)
UKTAG (2003)
Bockelmann et al (2004)
SEPA (2006)
CIWEM (2007)
Menke and Nijland (2008)
Wild et al (2010)
Nisbet et al (2011a)
Parliamentary Office of Science and Technology (2011)
Scottish Government (2011a)
Glasgow City Council (2013)
Scottish Government (2013a)
Floodplain Woodland Natural Flood Management
Hart (1995)
Robinson et al (1998)
Starr (2005)
Calder and Alyward (2006)
Jacobs Babtie (2006)
Nisbet and Thomas (2006)
Park and Cluckie (2006)
Nisbet and Thomas (2008)
Broadmeadow and Nisbet (2010)
Odoni and Lane (2010)
Nisbet et al (2011a)
Nisbet et al (2011b)
Nisbet et al (2011c)
Beedell et al (2012)
Nisbet et al (2012)
Panter et al (2012)
SuDS & Surface Water Management
Nisbet and Thomas (2006)
Scottish Government (2008)
Wheater and Evans (2009)
Greenspace Scotland (2010)
Wild et al (2010)
AECOM (2011)
Nisbet et al (2011c)
Scottish Government (2011a)
Woodland Trust (2011)
Graham et al (2012)
Susdrain (2012)
Scottish Government (2013a)
Kutchment (2014)
Ecosystems Approach & Land Use
Landscape Institute (undated)
Chan et al (2006)
EERA (2008)
GCV Green Network Partnership (2011)
GCV Strategic Development Plan Authority (2011)
Scottish Government (2011b)
Scottish Government (2011c)
Scottish Government (2011d)
Woodland Trust (2011)
Sheate et al (2012)
Baker et al (2013)
EC (2013a)
Gaston et al (2013)
Gret-Regamey et al (2013)
James (2013)
Labiosa et al (2013)
Phillips (2013)
Scottish Government (2013k)
Phillips et al (2014)

Appendix 2: Interview schedule and data from expert interviews

Interview schedule

Part 1. Introduction

The following is to be explained/introduced:

- Who I am
- Where I'm from (i.e. the University, Department etc)
- What the objectives of my research are (provide interviewees with a copy of the research framework – title, aim and objectives)
- How this interview and the data collated will be used (i.e. helping to identify key principles for ecosystems approach based urban land use planning – this will inform the development of an evaluation framework that will be used to test/evaluate the new urban planning approaches developed in my research i.e. what are its key strengths and weaknesses)
- All names will be kept confidential but other personal data (e.g. qualifications, professional background etc) will be used in the analysis and may be documented in the thesis. Names will never be used though and therefore these details will never be attributed
- Chatham House rules – no direct quotations unless authorised by the interviewee
- Chatham House rules – no direct quotations unless authorised by the interviewee

---

Part 2. Background questions

The aim of these questions is to get an idea of interviewee background and experience. This may provide important contextual data for cross-referencing with responses to subsequent questions.

2.1 What is your background (i.e. higher education qualifications, chartered status etc)?

2.2 What would you say are your main areas of expertise?

2.4 What type of context would you say you are most comfortable working in (e.g. urban, rural etc)?

2.5 Where else have you worked professionally other than Glasgow/Scotland?

Part 3. Ecosystem services concept questions

The aim of these questions is to gauge interviewee understanding and awareness of the concept of ecosystem services and their opinion of the potential utility of urban ecosystem services providing and/or supporting the delivery of key urban services.

3.1 To your mind, what are the defining characteristics of the urban natural environment?

3.2 To your mind, what are the key components of the urban natural environment?

3.3 At what scale do you think it is most useful to think about, plan for and manage the urban natural environment (e.g. city-wide, neighbourhood, site, multiple scales)?

3.4 To your mind, does the urban natural environment provide and/or support the delivery of key urban services? *If the answer is no, proceed to question 3.8, otherwise proceed to question 3.5*

Yes No

3.5 If the answer to 3.4 is yes – which services from the following list do you think the urban natural environment provides? *Tick all that apply*

- Food (crops, livestock, fish)
- Fibre (timber, pulp)
- Energy
- Drinking water
- Natural medicine
- Recreation/tourism
- Pollution/noise control
- Disease/pest control
- Maintenance of an equable climate
- Flood control
- Erosion control
- Aesthetic/inspiration
- Spiritual/religious
- Other

3.6 Of the services you've identified, which three do you consider to be most important?

3.7 To your mind, are the services provided by the urban natural environment context specific and why? *[question can be skipped if short of time]*

3.8 Are you familiar with the term ecosystem services? *If the answer is no, proceed to part 4, otherwise proceed to question 3.9*

Yes No

3.9 How would you define ecosystem services?

3.10 Is the concept of ecosystem services something that you have come across in your professional work?

Yes No

3.11 On the scale below, how would you judge your knowledge of the ecosystem services concept *(where 1 is limited knowledge and 6 is expert)*?

1 2 3 4 5 6

3.12 On the scale below, how would you judge your use of the ecosystem services concept, implicitly or explicitly, in your professional work (*where 1 is very little and 6 is all the time*)?

1 2 3 4 5 6

3.13 To your mind, what are the most important aspects or processes governing the health and function of the urban natural environment?

4. Land use planning concept questions

The aim of these questions is gather interviewee opinion and suggestions for where and how it is most appropriate and useful to consider ecosystem services and ecosystems approach principles within urban land use planning.

4.1 To your mind, what are the **three** most important policies or regulatory frameworks that affect urban land use planning in Scotland?

4.2 To your mind, what are the most important tools or concepts that can help urban planners, designers and engineers think about, plan for and manage the urban natural environment?

4.3 Which of the following are you familiar with? *Tick all that apply*

- Scottish Planning Policy (SPP)
- Strategic Development Plans (SDP)
- Local Development Plans (LDP)
- Development Management
- River Basin Management Plan (RBMP)
- Climate Change (Scotland) Act 2009
- PAN77 Designing Safer Places
- PAN83 Masterplanning
- PAN44 Fitting Housing Development into the Landscape
- Flood Risk Management Strategies
- Local Flood Risk Management Plans
- PAN65 Planning and Openspace
- Scottish Government Design Guidance – Green Infrastructure: Design and Placemaking
- Getting the best from our land – Scotland's land use strategy
- Scottish Government Surface Water Management Planning (SWMP) Guidance
- Scottish Government Delivering Sustainable Flood Risk Management Guidance

4.4 To your mind, what are the five most important 'items' from the above list for integrating the natural environment and ecosystem services into urban planning and why?

4.5 What types of urban land use are most important for providing ecosystem services and why?

4.6 From what you know about the Local Development Plan (LDP) process, what do you think is the most useful stage to integrate consideration of urban ecosystem services into plan-development?

4.7 Other than LDP policy, what other key mechanisms are there for delivering natural environment and ecosystem service enhancements through urban land use planning/management?

---

5. General questions

5.1 Do you think that the urban natural environment and its role providing and/or supporting the delivery of key urban services is adequately considered in current urban planning practice? *If the answer is yes the interview is finished – proceed to section 6, otherwise proceed to question 5.2*

Yes No

5.2 What are your top **three** priorities for improving urban planning practice in this regard?

5.3 What are the **three** main barriers to improving urban planning practice in this regard?

5.4 What are the **three** main opportunities for improving urban planning practice in this regard?

Data from expert interviews

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
Background questions					
2.1 What is your background (i.e. higher education qualifications, chartered status etc)?	Ecology; Chartered Ecologist (CIEEM); Chartered Environmentalist (Society for the Environment)	BSc Civil Engineering; MSc Environmental Systems	Degree in landscape architecture; Chartered member of the Landscape Institute	Chartered Civil Engineer	Chartered landscape architect and chartered town planner; Honours degree in landscape architecture; Master degree in environmental studies; Member of the academy of urbanism
2.2 What would you say are your main areas of expertise?	Woodland ecology; Land use of all kinds; Practical conservation management (i.e. nature reserves); Practical management of various ecosystems; Access	Land use planning; Ecology	Landscape architecture; Urban design; Working at a range of scales from detailed design and implementation up to masterplan and urban strategy	Management; Flood risk management (FRM); Contaminated land; Environmental management	Landscape scale urban planning; Strategic physical planning; Making projects happen on the ground; People and place – improving peoples' lives by addressing poor landscape quality
2.3 What is your current role?	Woodland and land use advisor at a government natural heritage agency	Regional/strategic land use planning looking specifically at the environmental component of this	Director of a landscape architecture/urban design firm	Group Manager of Environmental Services working for a large urban local authority	Group Manager for a large urban local authority – responsible for input to cross-sector strategic plans including land use, development and drainage plans. Responsible for delivering the new Local Development Plan (LDP). Corporate input. Statutory planning/policy. Remit changes a lot through involvement with strategic projects
2.4 What type of context would you say you are most comfortable working in (e.g. urban, rural etc)?	Any context really. Less familiar with urban. Rural certainly	Comfortable working in rural and urban context but current role is urban	Both. Moth commonly the company's work focuses on urban areas/the urban fringe i.e. where development pressure and change is greatest	Current role is urban though historically I-4 has worked in urban and rural contexts	Urban/peri-urban. Metropolitan
2.5 Where else have you worked professionally other than Glasgow/Scotland?	Philippines. North/South England	N/A	One year in San Francisco as an assistant landscape architect between 1990/91. Taught at universities in the US and Australia (landscape architecture and urban design): University of Oregon and University of South Australia in	England – London, NE and NW. Northern Ireland. Republic of Ireland	Always in central Scotland

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
			Adelaide. Taught in many Scottish universities, most notably the University of Strathclyde where I-3 taught final year urban design. Has worked on projects around the UK		
Ecosystem services concept questions					
3.1 To your mind, what are the defining characteristics of the urban natural environment?	Openspace and greenspace. Watery elements and greenspace next to water (e.g. floodplains). Structural diversity. Three dimensional element incorporating trees etc. Brownfield habitats – not categorised as greenspace but can be important for biodiversity	Degraded and heavily managed. Heavily modified	Question not asked due to time constraints	Question not asked due to time constraints	Question not asked due to time constraints
3.2 To your mind, what are the key components of the urban natural environment?	Structural habitat. Access and functionality – human values are important	River valleys. Fragmented habitats, primarily woodland. Less intensively managed openspaces – grassland meadows, some components of more formal parks. Wouldn't really consider parks and gardens/amenity greenspace as natural environment as their primary function does not mimic the natural environment i.e. their primary function is recreation/aesthetic value	Could be a whole range of things though scale and significance is key. Parks and public openspaces are key in Glasgow. Infrastructure corridors – roads, rail and canals. Water network and river corridors. Public useable space e.g. allotments, cemeteries, school estates. Vacant and derelict land (VDL). Areas of semi-natural habitat will exist within all of the above – especially public openspace. In Glasgow, there is limited use of individual smaller scale green infrastructure (GI) elements such as street trees – bridging scales between land parcels and individual GI elements is a key gap in Glasgow	Green infrastructure – green / blue corridors that provide connectivity for surface water and biodiversity. This is split between retaining natural corridors (this includes canals as a historic feature) and providing new / engineered corridors. Areas of limited human activity – e.g. we try to bring back all of our VDL into use but it does have a value while it is VDL (e.g. natural succession). This also applies to areas of natural / semi-natural greenspace though David commented that the flora and fauna on these sites is under pressure from e.g. dog walkers	What's outside peoples' doorstep/window. What people can interact with immediately e.g. private gardens. Urban landscapes are often not very rich – i.e. they are bland. Some components are richer where development pressure is less e.g. river valleys. Key characteristics are complexity, interconnectedness and tapestry
3.3 At what scale do you think it is most useful to think about, plan for and manage	Depends really. Has to be from a local authority (LA) wide scale down to site/masterplan	Depends what aspects of ecosystem services you are looking at e.g. ecological	Scottish Government policy on urban planning and design issues is good but is not	Across a range of scales. Understanding at the catchment scale is key – i.e. to identify	Big picture – not the red line. Must look at the interconnected nature – too many spaces are

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
the urban natural environment (e.g. city-wide, neighbourhood, site, multiple scales)?	scale. LA-wide is important for understanding the resource, pinch-points and opportunities. Upwards and downwards – scales should inform one another	connectivity will be influenced by patch size and small patches will have a negligible contribution to ecological networks at landscape scale but may be important locally. No hard and fast rule. Neighbourhood scale is useful for identifying sites for specific management intervention – i.e. you wouldn't do this level of detailed planning at more strategic scales. Scale depends on what you are looking for/what your objectives are – all three scales are important in this regard. Wider scales are for the identification of more broad-brush interventions e.g. Strategic Development Plan (SDP). Planning can include more natural management units e.g. catchments/sub-catchments.	influencing delivery on the ground. Because of how planning decisions planning are made and how subsequent action is delivered on the ground, the key scale is somewhere high enough above on the ground (i.e. development management/DM) but not so high that focus, detail and deliverability is lost. In effect there is a gap between the good stuff at the Scottish Government level and the DM level. The IGI/masterplan scale is useful in this regard as it offers a chunk of City that can be considered, planned and where plans and designs can reasonably influence DM. There is a need to actually provide good information to DM planners – LDPs are not detailed enough in this regard. The big problem is that there is a gap in the system at the IGI scale – there isn't the planning 'infrastructure' in place at present to drive this. Planning and design at this scale should be formally integrated with LDPs. Some topics also need to be looked at and planned for at wider scales (e.g. water management at the catchment scale).	intervention where the whole can become greater than the sum of the parts. There is also a need to do something constructive with individual sites even if you don't know or fully understand how it will support the bigger picture. Often it is about leaving space to retrofit at a later stage.	left over after planning. Even just beyond the red line boundary. Also key is the need to look up.
3.4 To your mind, does the urban natural environment provide and/or support the delivery of key urban services? If the answer is no, proceed to question 3.8,	Yes	Yes	Yes – to qualify though, I-3 suggested that it could but more often than not it does not.	Yes	Yes – I-5 also commented that there is huge potential that is currently underused/misunderstood e.g. there is often too much of a focus on individual

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
otherwise proceed to question 3.5					uses/services
3.5 If the answer to 3.4 is yes – which services from the following list do you think the urban natural environment provides? Tick all that apply	All	Food (crops, livestock, fish); Fibre (timber, pulp); Energy; Drinking water; Natural medicine; Recreation/tourism; Pollution/noise control; Maintenance of an equable climate; Flood control; Erosion control; Aesthetic/inspiration; Other - ecological networks and healthier lifestyles	Food (crops, livestock, fish); Fibre (timber, pulp); Energy; Drinking water; Recreation/tourism; Pollution/noise control; Disease/pest control; Maintenance of an equable climate; Flood control; Erosion control; Aesthetic/inspiration; Other - health / activity In I-3's view food and health / activity are one and the same in a Glasgow context	Food (crops, livestock, fish); Fibre (timber, pulp); Energy; Recreation/tourism; Pollution/noise control; Maintenance of an equable climate; Flood control; Aesthetic/inspiration; Spiritual/religious; Other - transport (e.g. water bus) and healthy lifestyles	All Other - cultural/different cultural reactions to landscape and quality of life/health
3.6 Of the services you've identified, which three do you consider to be most important?	Recreation/tourism Flood control Aesthetic/inspiration and spiritual/religious – I-1 regards these as the same thing i.e. sense of place	Food (crops, livestock, fish) Recreation/tourism Flood control	Food and health/activity Aesthetic/inspiration Flood control I-3's prioritisation choices were driven by what the urban natural environment can do as well as need – given the socio-economic context in Glasgow there is a particularly important case for health related services including community growing and other healthy lifestyle type activities. In this regard, I-3 suggested that health/activity and food should be linked in an 'ecosystem service typology' for Glasgow – this is a socially driven issue.	Aesthetic/inspiration Flood control Recreation/tourism	1. Aesthetic/inspiration (including cultural issues as per response to Question 3.5) 2. Flood control 3. Recreation/tourism – I-5 commented that this is a key service though there is currently a lack of integration between this and other services i.e. more multifunctional approaches etc is key for sites, interventions etc for the delivery of multiple ecosystem services
3.7 To your mind, are the services provided by the urban natural environment context specific and why?	Depends on the site/area and its history. Floodplain/flood storage is very context specific. Can depend on climate. Wider catchment issues beyond LA boundaries can be important also. Size of greenspace (patch)	Depends on climate (temperature, rainfall etc) and the interaction of climate with the physical environment (e.g. slope, aspect, altitude etc). Cultural factors also have a key	Socio-economic context is key. The visual/aesthetic value of an urban area can constrain peoples' lives – i.e. there can be barriers to accessing services outwith the City for certain communities. In this context,	Yes – e.g. in the case of drinking water, Hamburg gets all of its drinking water form groundwater below the city. Mobility of the population has an influence – e.g. if people	Question not asked due to time constraints

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
	and soils will also affect service provision.	influence e.g. how people view/interact with the natural environment.	many of the cultural services jump up the pecking order. Climate is key in relation to flooding.	have no access to a car / transport then this makes recreational opportunities within the city more important. Population density, climate and national / local level policies are also key factors.	
3.8 Are you familiar with the term ecosystem services?	Yes	Yes	Yes	Yes	Yes
3.9 How would you define ecosystem services?	The benefits that people receive from nature.	The benefits that can be derived for people from the natural environment.	A landscape or natural element that performs a particular function but is beneficial for other reasons supporting societal wellbeing.	The benefit that the natural environment provides to humankind.	The role that the natural environment can play in the overall quality and health of both people and place.
3.10 Is the concept of ecosystem services something that you have come across in your professional work?	Yes	Yes	Yes	Yes	Yes
3.11 On the scale below, how would you judge your knowledge of the ecosystem services concept (where 1 is limited knowledge and 6 is expert)?	6	4	6	2	5
3.12 On the scale below, how would you judge your use of the ecosystem services concept, implicitly or explicitly, in your professional work (where 1 is very little and 6 is all the time)?	6	3 I-2 commented that use is implicit – some aspects/services they consider all the time (e.g. ecological networks, flood/water management etc) but the concept does not provide an overall framing to their work. However, the use of ecosystem services is increasing all the time.	3 or 6 For the types of work that the practice wants to do, consideration of ecosystem services will be very high (e.g. IGI type projects) though the average across the practice’s whole portfolio will be lower. In essence, it depends on specific briefs and what comes through the door. Some project briefs are just bad – the projects are defined by the knowledge and limitations of the client (i.e. the scope of the	3	5

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
			brief). Ecosystem services are a big emphasis/focus where there is the opportunity and where the client is receptive. There is a massive problem where poor briefs and lack of planning teeth resulting in potential wider benefits of the scheme (e.g. in terms of GI/ecosystem services) just not being considered. Ecosystem services/GI approaches need to be embedded within statute.		
3.13 To your mind, what are the most important aspects or processes governing the health and function of the urban natural environment?	Depends on the context – each greenspace site will fit in in a way. Could potentially support all ecosystem processes. Benefits are derived from all processes.	Land management is key i.e. how we manage the urban natural environment. Also, a lack of understanding of ecosystem processes and benefits influences poor management. The way our land use/management system works means that other issues take precedence over ecosystem services and the natural environment e.g. the drive for economic growth and getting things through planning will trump ecosystem services. The IGI approach helps to show how ecosystem services and economic growth are not mutually exclusive but current approaches to land use/management planning means that they often are.	Question not asked due to time constraints	Question not asked due to time constraints	Embedding natural environment in policy therefore people will have to think about it. Communicating/telling the story. Land use and flood risk management (FRM) planning. This is often seen as 'tree-hugging' – it needs to be honed down to practicalities and issues that people can grasp.
Land use planning concept questions					
4.1 To your mind, what are the three most important policies or regulatory frameworks that affect urban	Strategic Development Plans (SDP) and Local Development Plans (LDP) – the Scottish	Development Plans Development Management	I-3 doesn't think that any of them are having an impact. The types of policies etc that	Strategic Development Plans (SDP) and Local Development Plans (LDP) – the Scottish	The statutory planning system: the National Planning Framework (NPF), Scottish Planning Policy (SPP),

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
land use planning in Scotland?	Planning System in general Scotland's Land Use Strategy (LUS) River Basin Management Plans (RBMPs)	River Basin Management Plans (RBMPs)	most influence the work that I-3's practice is involved are: Strategic Development Plans (SDPs) Local Development Plans (LDPs) Flood risk management plans	Planning System in general The Water Framework Directive (WFD) and River Basin Management Plans (RBMP) Nature Conservation (Scotland) Act 2004 I-4 commented that the first two have a positive impact on land use planning.	Strategic Development Plans (SDP) and Local Development Plans (LDP) I-5 also commented that A key issue/barrier within the above is the degree of influence it can have on transportation planning – i.e. there are lots of separate regulatory powers that can allow transport projects to steam ahead. There is a need to change the mind-set of road engineers.
4.2 To your mind, what are the most important tools or concepts that can help urban planners, designers and engineers think about, plan for and manage the urban natural environment?	Lots of guidance out there – some will be better than others. Integrated Habitat Networks (IHN)/anything that is map based and simple – not lots of text. SNH are developing interactive map based tools that are simple to dip in and out of – doesn't take a lot of time and investment to understand and can be used for specific projects/issues.	Green infrastructure and green network approach – seeks to work with what is already there in terms of the natural environment (i.e. on greenfield sites) or restore it to mimic what was once there. The network aspect of green networks is crucial for connectivity – including water environment connectivity re addressing morphology pressures etc. Landscape scale ecology i.e. to facilitate planning at a scale that reflects how the natural environment actually works. Catchment/sub-catchment scale surface water management planning i.e. to facilitate planning at a scale that reflects how the natural environment actually works. IHN modelling and the use of GIS in general.	Taking the assumption that high level national policy is there and having a positive influence and that mapped/spatial data is there and available as general background stuff that should be there, good policy and data doesn't necessarily mean that things will happen. As a concept, you need good, skilled, multi-disciplinary people to translate policy/data into actual change on the ground – key to this are urban designers and landscape architects as this process requires a creative/design element. Complex problems require elegant solutions that can deliver wider multiple benefits – there is a danger that 'black-box' technical solutions can lose the creativity and design element – i.e. they are just tools. Another key input is identifying areas of anticipated change or	Vision statements and guiding principles as a means of driving an agenda. Local Development Plans (LDP) as tools. Integrated catchment modelling i.e. combined natural/artificial drainage system modelling as a tool. Openspace strategy as a tool. Climate Ready Clyde as a concept – a partnership/linked agenda looking at a problem with a different angle/perspective. Healthy sustainable me – as a tool for developing sustainable communities through a people focussed perspective.	More information. Tools that can help people to act. Guidance and help on what applies (e.g. policies, guidance etc) in a specific circumstance. CPD and professional development e.g. for road engineers. This is a requirement of membership of some institutions. For example IGI is being led by engineers but it needs input from LAs (re bottom line). For clients too – i.e. what to expect, what is good-practice etc.

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
			issues of poor urban condition/deprivation status etc – consideration of these issues in conjunction with more regulating service issues can add value to the approach. The IGI five elements approach is a good reflection of this – it really is key to consider the wider socio-economic development issues as well as regulating services.		
4.3 Which of the following are you familiar with? Tick all that apply	All – I-1 commented that some documents are more familiar than others	Scottish Planning Policy (SPP); Strategic Development Plans (SDP); Local Development Plans (LDP); Development Management; River Basin Management Plan (RBMP); Climate Change (Scotland) Act 2009; PAN77 Designing Safer Places; PAN83 Masterplanning; Flood Risk Management Strategies; Local Flood Risk Management Plans; PAN65 Planning and Openspace; Scottish Government Design Guidance – Green Infrastructure: Design and Placemaking; Getting the best from our land – Scotland's land use strategy. I-2 commented that he has heard of the FRM and SWM guidance documents but has not read them.	Scottish Planning Policy (SPP); Strategic Development Plans (SDP); Local Development Plans (LDP); Development Management; River Basin Management Plan (RBMP); Scottish Government Surface Water Management Planning (SWMP) Guidance; PAN44 Fitting Housing Development into the Landscape; Flood Risk Management Strategies; Local Flood Risk Management Plans; PAN65 Planning and Openspace	Scottish Planning Policy (SPP); Strategic Development Plans (SDP); Local Development Plans (LDP); Development Management; River Basin Management Plan (RBMP); Climate Change (Scotland) Act 2009; Flood Risk Management Strategies; Local Flood Risk Management Plans; Scottish Government Surface Water Management Planning (SWMP) Guidance; Scottish Government Delivering Sustainable Flood Risk Management Guidance	All – I-5 commented that some documents are more familiar than others
4.4 To your mind, what are the five most important 'items' from the above list for integrating the natural environment and ecosystem services into urban planning and why?	The Land Use Strategy (LUS) and Scottish Planning Policy (SPP) – theoretically everything else should hang of these two. River Basin Management Plans (RBMP) – catchment scale is	Local Development Plans (LDP) – provide a holistic view of a sizeable unit and allow for strategic planning over a good time frame and for the full array of land use considerations.	Scottish Planning Policy (SPP) Strategic Development Plans (SDP) Local Development Plans (LDP)	Local Development Plans (LDP) Development Management (DM) Flood Risk Management Strategies	In response to this question I-5 lumped the four planning mechanisms together as the 'statutory planning system' and the two flood risk management mechanisms together. These were considered to be the most important for integrating the

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
	crucial. RBMPs should also cover other issues too including flood risk management. Climate Change (Scotland) Act – gives an overview of mitigation/adaptation and includes provision for the LUS. GI Design and Placemaking – catch all for others e.g. PAN65.	Flood risk management Strategies – new approach that incorporates natural flood management (NFM) – massive opportunity. River Basin Management Plans (RBMP) – identifies where issues are, involves multiple partners with multiple objectives. Measures should be incorporated with LDPs. PAN83 – Masterplanning covers sites of a significant scale such that development can [and should] incorporate big chunks of ecosystem services. In effect, masterplan/neighbourhood scale is ideal for incorporating ecosystem services and the IGI approach. Also, as a PAN there is a strong directive that it should be used. Land Use Strategy (LUS) – ecosystem services are a founding principle, trickle down approach – as an overarching strategy/policy it should be informing all of the above.	• Development Management Same caveat applies as per question 3.5 – the above items have been highlighted with respect to how they could/should perform as opposed to how they are performing currently	Local Flood Risk Management Plans Surface Water Management Planning Guidance	natural environment and ecosystem services into urban planning I-5 also highlighted what were felt to have the least influence – these were the Climate Change (Scotland) Act 2009 and the Land Use Strategy (LUS). PAN44 was also felt to be less relevant in a metropolitan sense.
4.5 What types of urban land use are most important for providing ecosystem services and why?	Case by case and depends on scale. Depends on landform, topography and soils. Depends on which services and how you value them. Very context specific e.g. same bit of woodland in two different places may have different value. Cultural services are generally undervalued in relation to provisioning and regulating services – e.g.	PAN65 land use. River valleys. Scale is important. PAN65 is core of ecosystem services though there are other aspects of urban land use that are important e.g. vacant and derelict land (VDL) and underused land i.e. brownfield land that is not registered VDL. Amenity greenspace offers	Depends on how they are designed – in essence all urban land uses can provide ecosystem services. Public openspace could do nothing at all but it depends on design – e.g. an urban street could be designed to deliver a whole range of outcomes. In the absence of good design however, the green land uses	Parks – aesthetic/inspiration (i.e. good for cultural services), a role in surface water management, pollution/noise control, recreation/tourism and healthy lifestyles. River corridors – aesthetic/inspiration, flood control, recreation/tourism and healthy lifestyles. Allotments – food growing,	All land uses should be providing ecosystem services. The focus is often on residential areas though this is not ideal. Planning greenspace with major development e.g. the Southern General hospital i.e. the need to go beyond amenity. Greenspace.

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
	converting parkland to woodland. These conflicts could potentially be designed out though not everyone will agree.	potential due to scale.	will be the most important.	pollution/noise control, recreation and healthy lifestyles.	All development should provide ES. Formal parks and managed greenspace – this is currently underperforming re ecosystem services.
4.6 From what you know about the Local Development Plan (LDP) process, what do you think is the most useful stage to integrate consideration of urban ecosystem services into plan-development?	Right at the start before the plan is even thought about. Up-front engagement. Main Issues Report (MIR) or even before. Engagement driven with key stakeholders/agencies and possibly community groups/councils and the general public though it may become unwieldy.	Main Issues Report (MIR).	Before i.e. the whole process should be informed by these issues. Area specific guidance is also key in this regard.	Right at the start – the Main Issues Report (MIR).	Right at the beginning and through the Main Issues Report (MIR) i.e. what the vision is e.g. the GCVSDPA have just sent out a vision questionnaire – this would be a good opportunity (noting however that the Glasgow LDP vision is defined by the SDP).
4.7 Other than LDP policy, what other key mechanisms are there for delivering natural environment and ecosystem service enhancements through urban land use planning/management?	The Local Development Plan (LDP) provides the blueprint and is key.	Openspace strategies. Local Biodiversity Action Plan (LBAP). More localised planning frameworks. Flood risk management strategies and plans. Development Management – this is probably the weak link in the chain at the moment i.e. policy folk get it but this is not driven through at planning application/DM.	Question not asked due to time constraints.	Metropolitan Glasgow Strategic Drainage Partnership (MGSDP) – the eight guiding principles align to an ecosystems approach, it has broader objectives than just flood risk management. I-4 commented that Flood Risk Management (Scotland) Act measures might not necessarily be delivered using ecosystem services approach i.e. objectives could be delivered solely with traditional structural measures. The placemaking agenda. Market demand for an enhanced urban landscape (which would also deliver enhanced ecosystem services).	Openspace strategies – i.e. openspace strategies as per PAN65. Local Biodiversity Action Plan (LBAP). Natural Environment Framework (Glasgow City Council specific). Fitting different sectors together e.g. transport and drainage + cycling/walking routes etc.
General questions					
5.1 Do you think that the urban natural environment	Neither - sort of and getting	No	No	Yes	No

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
and its role providing and/or supporting the delivery of key urban services is adequately considered in current urban planning practice?	better.			However, I-4 commented that the statutory planning system has to address multiple objectives and can't be skewed to focus on just ecosystem services – ecosystem services are currently recommended within planning policy explicitly and implicitly.	I-5 commented that this is a huge challenge.
5.2 What are your top three priorities for improving urban planning practice in this regard?	Development of GI concept and awareness raising. Clearer directives or even statute from the Scottish Government on the minimum of what needs to be considered in terms of LDP policy though this would need to be balanced with cost. Improved guidance for what statute regarding ecosystem services means on the ground for planners and developers – must be simple and clear, could involve checklists.	Awareness raising i.e. people don't get it yet. Ecosystem Services/GI as a central pillar of urban planning – more central role within planning policy at various levels. More thorough understanding/audit of what we have already i.e. in terms of ecosystem services and the urban natural environment.		Supplementary Guidance for the public realm – mainly to do with the prevalence of hard landscaping. There is scope for the public realm to deliver a wide range of ecosystem services if designed well including flood control, noise/pollution control, aesthetic/inspiration and biodiversity. Development Management (DM) not being restricted to the red line boundary – e.g. if development is over a threshold size it would have an obligation to, say, reduce flood risk by 2% within that catchment. I-4 also highlighted how such an approach would require a more flexible approach for section 106 agreements i.e. being able to do intervention elsewhere.	Embedding in policy. Facilitating understanding and capacity to deal with policy internally. Increased awareness externally e.g. developers, clients etc.
5.3 What are the three main barriers to improving urban planning practice in this regard?	Resources/money – i.e. what a developer is prepared to deliver cost vs. benefits, keeping shareholders happy etc.	Expediency/other priorities that are easier for politicians to understand. Institutional inertia re adopting new ideas – primarily LAs but government agencies too.		Business as usual – e.g. to achieve the MGSDP 50 year vision will require a real step change in approach. I-4 gave the example of the recent public realm works on George St that is replacing impermeable hard standing with the same and no provision for storm water storage etc	The red line. Focus on immediate sites e.g. parks management.

Question	Interviewee 1 (I-1)	Interviewee 2 (I-2)	Interviewee 3 (I-3)	Interviewee 4 (I-4)	Interviewee 5 (I-5)
				Budget silos – the type of public realm we (i.e. the MGSDP) aspire to will come at a higher management cost. These types of approach have wider multiple benefits but these are not reflected in budgets (e.g. enhanced budget for maintenance). Catchment Masterplanning – to map out blue / green corridors. I-4 commented that this is not currently a requirement of the Flood Risk Management (Scotland) Act. Moving from planning to implementation – relative priority of ecosystem services vs. education vs. NHS vs. elderly care etc.	
5.4 What are the three main opportunities for improving urban planning practice in this regard?	Promote and raise awareness of the wider/multiple benefits of GI etc. Thinking beyond the site e.g. using s106 funds elsewhere, offsetting approaches etc – links to scale issues at Question 3.3.	More stick – i.e. adopting this in central policy.	Knowing what the barriers are is a good start – identifying support to overcome these is then the next step. There is a need for a clear agenda.	North Glasgow integrated water management system including dynamic management with the canal (demonstration project). MGSDP Implementation Plan – being able to articulate what this will look like on the ground. Surface Water Management Plans (SWMP). These are a distinctly urban device i.e. managing water from where it falls to where it eventually ends up. I-4 commented that these are what add value across agendas. Legislation acts to stimulate thinking in this field. Implementation is key.	Big opportunity in Glasgow is the MGSDP. Flood risk management, surface water management and water management generally – this is a tangible issue that people can grasp. Risk – sustainable response to corporate risk management.

Appendix 3: A new suite of guiding principles for ecosystems approach based urban land use planning

Introduction to the principles

The table below provides a suite of guiding principles for ecosystems approach based urban land use/management planning. The principles in the first column are generic and taken verbatim from CBD Secretariat (2013a) i.e. these are ecosystems approach principles as per the Convention on Biological Diversity (CBD). These principles are introduced in the main volume of the thesis at section 3.2.4 and Table 3.8. The CBD ecosystems approach principles shown in the table below have been categorised in line with Scottish policy on land use/management and the ecosystems approach as per Scottish Government (2011c). This is explained further at Table 3.8 in the main volume of the thesis.

The sub-principles in the second column have been developed through this research on the basis of the material collated, analysed and synthesised in the evidence assessment described in Chapters 3, 4, 5 and 6. The analysis approach used to develop the sub-principles is described in Chapter 8 at section 8.1.1. The sub-principles are designed primarily for use in urban land use/management planning though some principles will be of more general relevance.

The third column provides references to indicate the provenance of the new sub-principles within specific parts of the evidence assessment in the main volume of the thesis or specific key references (e.g. journal articles, official reports, government policy etc) that have played a crucial role within the evidence assessment. The references are intended to signpost the reader to more detailed information that can aid the interpretation and translation of the principles in practical urban land use/management planning. In this regard, the principles are intended to provide high level statements of good-practice as opposed to detailed implementation guidance. For specific principles, implementation guidance has been delivered through the tools and models developed in this research – see Chapters 7 and 8 in the main volume of the thesis and Appendices 4, 5 and 6.

A new suite of guiding principles for ecosystems approach based urban land use planning

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	**Details of sub-principle**	
Principles relating to the management of natural systems			
EsA_1: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems	**EsA_1.1**	Spatial delineation of urban ecosystems for management purposes (e.g. on the basis of similar climatic conditions, geophysical conditions, surface cover, resource management systems) should consider how delineation can incorporate multiple ecosystems. Where relevant, this can help to ensure that the functioning of ecosystem processes/intermediate services (e.g. ecological interactions, nutrient cycling etc) are considered both within and between ecosystems. **This sub-principle is also relevant to EsA_2**	Section 3.2.1
	EsA_1.2	Early on in the development of urban land use/management strategies, including Local Development Plans (LDP), consider engaging neighbouring authorities to explore transboundary ecosystem issues as well as opportunities for joint land use/management action that can help to protect and restore ecosystem structure and function. **This sub-principle is also relevant to EsA_2**	Sections 3.1.2 and 5.1.1 Table 3.3 Expert interview data (Appendix 3 and section 5.1.1) Phillips et al (2014)
	EsA_1.3	Integrated land and water management planning (as part of a sustainable approach to Flood Risk Management (FRM) for example) should ideally be undertaken at the whole catchment scale. Working at the catchment scale can require cross-boundary working with neighbouring authorities – urban planning authorities in this situation should consider how catchment scale planning can be developed through partnership working and the use of formalised partnership agreements	Sections 4.1 and 4.2 Figure 4.3 Phillips et al (2014)
	EsA_1.4	Regional scale land use/management plans are likely to incorporate multiple whole ecosystems/landscapes/catchments. Planning at this scale therefore can ensure that the effects of land use/management change on adjacent ecosystems are considered. This could be undertaken as part of a tiered planning system - e.g. regional scale plans establishing a broad framework for more detailed sub-regional and local level plans	Section 6.4.1 Phillips et al (2014)
EsA_2: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the	**EsA_2.1**	Land use/management decisions should be informed by an understanding of the functioning of the ecosystems which they affect in order to maintain the benefits of the ecosystem services which they provide	Section 3.1.4 pp.55 Table 3.5 Scottish Government (2011d p.4)
	EsA_2.2	Consider the implications of land use/management decisions across all aspects of ecosystem function (ecosystem processes/intermediate services). Consider how changing one aspect	Sections 3.2.1, 3.2.2, 3.2.3 and 6.1.1

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	Details of sub-principle	
ecosystem approach		can bring about changes at the ecosystem level, potentially affecting the supply of ecosystem services. **This sub-principle is also relevant to EsA_9 and EsA_10**	Figures 3.6 and 3.8 Mace et al (2011)
	EsA_2.3	For management purposes, ecosystem processes/intermediate services should be considered irreplaceable and un-substitutable. Urban land use/management plans should work towards an overall objective of maintaining ecosystem health and function as well as ecosystem services	Sections 3.2.2, 3.2.4 and 6.2.1 Figures 3.6 and 3.8 Mace et al (2011)
	EsA_2.4	Adopt the principles of landscape ecology in urban land use/management planning to maintain and improve ecological connectivity, thereby facilitating landscape scale ecosystem processes. Ecological connectivity in this regard is essential for the maintenance and enhancement of biodiversity. This sub-principle is also relevant to EsA_8	Section 3.2.1 Figures 3.6 and 3.8 Section 5.1 Figure 5.1
	EsA_2.5	Ensure that all relevant key themes, 'big ideas' and statutory provisions within Local Development Plan (LDP) Main Issues Reports (MIRs) consider how land use/management within the plan area can help to protect and restore ecosystem structure and function	Section 3.1.2 Table 3.3 Expert interview data (Appendix 3 and section 3.1.2)
	EsA_2.6	Urban land use/management plans, including Local Development Plans (LDPs), should integrate and manage the range of demands placed on the urban ecosystem such that it can support essential ecosystem services indefinitely	Section 3.2.4 Table 3.7
	EsA_2.7	Urban land use/management plans, including Local Development Plans (LDPs), should seek to restore and enhance the urban natural environment's role supporting natural drainage processes - interception, evapotranspiration, infiltration, attenuation and conveyance. This can support the more natural functioning of the hydrological cycle in modified urban catchments as well as enhancing key water management related ecosystem services	Section 4.1 Tables 4.1 and 4.6
EsA_3: Ecosystems must be managed within the limits of their functioning	**EsA_3.1**	Environmental limits data (including spatially explicit data) should be used to target restorative land use/management action - i.e. where specific intervention to enhance ecosystem services or restore degraded aspects of ecosystem function should take place. This is in addition to its use defining constraints for land use/management - i.e. environmentally sensitive areas where development should not take place	Section 3.2.1 Figures 3.6 and 3.7

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	Details of sub-principle	
	EsA_3.2	Consider how threshold (biophysical) and non-threshold (social preference) approaches can be used to define environmental limits for land use/management planning. The choice of approach should be informed by data availability, planning context and scale	Section 3.2.1 and 6.2.1 Figures 3.6 and 3.7
	EsA_3.3	Use policy and management interventions to account for data gaps and uncertainty in relation to ecosystem function and the definition of environmental limits e.g. the use of 'buffer zones' around threshold or non-threshold environmental limits	Section 3.2.1 Figures 3.6 and 3.7
	EsA_3.4	Consider how the use of different types of environmental limit indicator (pressure, state and ecosystem service indicators) can help to address data gaps and uncertainty in relation to ecosystem function and the definition of environmental limits	Section 3.2.1 Figures 3.6 and 3.7
EsA_4: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales	**EsA_4.1**	It may be useful to disaggregate the urban natural environment into 'green' and 'natural environment' type land parcels. For planning and management purposes, these can then be construed as the spatial 'building blocks' of urban ecosystems. In Scotland, Planning Advice Note (PAN) 65 provides a useful typology of openspace for this purpose	Sections 3.1.3 and 3.2.1 Figure 3.3 Table 3.4 AECOM (2011) Scottish Government (2008)
	EsA_4.2	Ensure that the approach adopted in the spatial delineation and disaggregation of the urban natural environment sufficiently reflects the heterogeneity of the urban landscape	Section 6.1.2 Phillips et al (2014)
	EsA_4.3	Urban land use/management planning for the restoration of ecosystem structure and function and enhancement of ecosystem services can be undertaken at a range of scales: 1) **landscape or whole ecosystem scale** - key management units could include whole catchments, whole landscapes, river corridors and floodplains, large parks and gardens of city-wide importance, urban forest parks, large areas of natural/semi-natural habitat, large areas of amenity greenspace (e.g. associated with a large housing scheme or business park), regional SuDS and associated habitats, strategic areas of public realm/municipal plazas; 2) **land parcel scale** - discrete areas of amenity greenspace, pocket parks, small patches of natural/semi-natural habitat, collective and/or private gardens, allotments and burial grounds/cemeteries; and 3) **specific green infrastructure intervention <u>within</u> land parcels** - source control SuDS measures (e.g. green roofs, permeable surfaces, rain gardens), site control SuDS (e.g. detention basins), street trees, small ponds, footpaths, signage, street furniture etc	Section 3.1.3 Expert interview data (Appendix 3) Figures 3.4 and 3.5 Tables 3.4 and 4.7
	EsA_4.4	Where possible (e.g. within the framework of relevant legislation and regulation), urban land use/management strategies, including Local Development Plans (LDPs), should set long term objectives for land use/management (including ecosystem and natural environment	Sections 1.5, 3.1 and 3.1.1

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	Details of sub-principle	
		management). **This sub-principle is also relevant to EsA_5**	
EsA_5: Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term	**EsA_5.1**	Consideration of ecosystem services should be integrated with strategic plans that have forward looking visions and set long term objectives. In terms of the statutory planning system in Scotland this could include the National Planning Framework (NPF), Strategic Development Plans (SDPs) and some Local Development Plans (LDPs). **This sub-principle is also relevant to EsA_4**	Section 3.1.1 and 6.3.1 Tables 3.1 and 3.2
	EsA_5.2	Consider how an analysis of ecosystem state indicators and/or ecosystem service indicators can be used to identify key trends and the driving forces behind these trends. This can provide a useful means of setting long term objectives for ecosystem management - e.g. trends help to indicate potential future problems which may need to be addressed by setting management objectives and delivering interventions in the short term. This sub-principle is also relevant to EsA_4	Section 6.2.1 Figures 6.5 and 6.6
	EsA_5.3	Use openspace audits and strategies to establish robust baselines and set long term objectives for the management of the urban natural environment and associated ecosystem services. In Scotland, this type of approach is set out in Planning Advice Note (PAN) 65	Section 3.1.3 Figure 3.3 Table 3.4 AECOM (2011) Scottish Government (2008)
EsA_6: Management must recognise the change is inevitable		No sub-principles identified	
Principles relating to ecosystem services			
EsA_7: Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem	**EsA_7.1**	Ecosystem service values (monetary or non-monetary) can help to cast a different light on complex decisions, especially where there is conflict between economic and environmental objectives. Ecosystem service assessments in this regard can help to demonstrate the full value of the natural environment	Section 3.2.3 Table 3.6
	EsA_7.2	Economic prosperity and wellbeing is dependent on ecosystems providing flows of goods and services. Where appropriate, monetary values for ecosystem services should be	Sections 3.1.3, 3.2.1 and 3.2.3 AECOM (2011)

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	Details of sub-principle	
management programme should: a) reduce those market distortions that adversely affect biological diversity; b) align incentives to promote biodiversity conservation and sustainable use; and c) internalise costs and benefits in the given ecosystem to the extent feasible		considered in decision-making, including urban land use/management decision-making e.g. where proposed land use change may affect the provision of land based ecosystem services	Scottish Government (2008) EC (2011b)
	EsA_7.3	Use statutory policy within Local Development Plans (LDPs), in conjunction with Development Management and Enforcement, as key regulatory drivers to protect and enhance land based ecosystem services. This sub-principle may be particularly important in the absence of economic assessments of ecosystem services i.e. to provide proxy protection for biodiversity and ecosystem services where there is no data available to support consideration of the monetary value of ecosystem services in economic analyses	Sections 3.1.1, 3.1.3 and 6.3.1
EsA_8: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity	**EsA_8.1**	Opportunities for urban land use/management to deliver multiple benefits should be encouraged, within the constraints of defined biodiversity objectives and environmental limits	Sections 3.1.3 and 3.1.4 Table 3.5 Scottish Government (2011d p.4)
	EsA_8.2	Ensure that biodiversity is protected and enhanced as an essential factor underpinning ecosystem function and the supply of ecosystem services. Land use/management stakeholders should adhere to this principle even in the absence of perfect data on the role of biodiversity in ecosystem function and ecosystem services	Section 3.2.1 Figures 3.6 and 3.8
	EsA_8.3	Within the constraints of defined biodiversity objectives and environmental limits, final ecosystem services can be managed, manipulated and engineered to produce the ecosystem goods that are required given the specific urban context. **This sub-principle is also relevant to EsA_9**	Section 3.2.2 Figures 3.6, 3.8 and 3.10
	EsA_8.4	The natural environment in northern European urban centres potentially has the ability to supply all ecosystem services identified within the UKNEA typology, to varying degrees. Urban land use/management strategies, including Local Development Plans (LDPs), should	Section 3.2.2 Expert interview data (Appendix 3 and section

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	**Details of sub-principle**	
		consider how the urban land resource and specific green infrastructure interventions (e.g. SuDS, access networks, street trees) can best be managed to deliver the full range of ecosystem services that may be required, given the specific urban context	3.2.2) Figures 3.8 and 3.9
	EsA_8.5	Within the constraints of defined biodiversity objectives and environmental limits, land use/management decisions should be informed by an understanding of the opportunities and threats brought about by the changing climate. Greenhouse gas emissions associated with land use should be reduced and land should contribute to delivering climate change adaptation and mitigation objectives	Section 3.1.4 Table 3.5 Scottish Government (2011d p.4)
Principles relating to involving people			
EsA_9: The objectives of management of land, water and living resources are a matter of societal choices	**EsA_9.1**	Ecosystems (including urban ecosystems) can be managed for specific objectives, especially by manipulating final ecosystem services to target the provision of specific ecosystem goods. Management objectives in this regard should be a matter of societal choice and the public and affected communities should have the opportunity to influence land use/management decisions that may impact ecosystems and ecosystem services (though there opportunities for the public to influence private land use/management objectives may be limited). **This sub-principle is also relevant to EsA_8 and EsA_12**	Section 3.2.2 Figure 3.8 and 3.10 Phillips et al (2014)
	EsA_9.2	Cultural ecosystem services (e.g. aesthetic, inspiration, recreation, tourism) can be particularly important in urban areas as the value of these services is influenced by factors relating to population size and accessibility (i.e. urban areas are home to large numbers of people that need ready access to cultural services such as outdoor recreation). These factors can increase the importance/value of cultural ecosystem services in urban areas. The same principle applies to hazard regulation services as the significance of natural hazard risks is influenced by the value and vulnerability of the receptors (e.g. people and livelihoods) that are exposed to the risks	Sections 3.2.2 and 4.1 Expert interview data (Appendix 3 and section 3.2.2) Figures 3.9, 3.11, 4.1 and 4.2
EsA_10: Management should be decentralised to the lowest appropriate level	**EsA_10.1**	Ensure effective decentralisation of ecosystem management within the Scottish Planning System's hierarchy of Development Plans - from the National Planning Framework (NPF) down to Local Development Plans (LDPs). **This sub-principle is also relevant to EsA_4**	Section 3.1.1 Tables 3.1 and 3.2
	EsA_10.2	Ensure effective decentralisation of ecosystem management within the remit of individual local planning authorities - from the Local Development Plan (LDP) through Local	Section 3.1.2

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	Details of sub-principle	
		Development Frameworks (LDFs), development briefs and masterplans to community level land use/management initiatives such as community growing projects and community greenspace management etc. This sub-principle is also relevant to EsA_4	
EsA_11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices	**EsA_11.1**	Effective use of ecosystem services data at the science-policy interface to help translate the link between the natural environment/ecological processes and human wellbeing in a manner that is understandable and useful for policy-makers. **This sub-principle is also relevant to EsA_12**	Section 3.2.2
	EsA_11.2	Open up specific steps (e.g. setting model parameters and defining assumptions) in the use of technical methodologies for the ecosystems approach to key stakeholders, the public and affected communities to ensure that all forms of relevant information including scientific/local knowledge, practice and innovation can be incorporated. **This sub-principle is also relevant to EsA_12**	Sections 6.1.1 and 6.2.1
EsA_12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines	**EsA_12.1**	During debates and decisions about land use/management decision-making, use a broad definition of stakeholders (including the public and affected communities) to ensure that all relevant sectors of society and scientific disciplines are involved. **This sub-principle is also relevant to EsA_11**	Section 6.2.2
	EsA_12.2	During debates and decisions about land use/management decision-making, especially with the public and affected communities, frame the natural environment in terms of 'uses/benefits' as opposed to 'things' to help non-technical stakeholders communicate perceptions and uses of the natural environment on their terms. This sort of information can also help decision-makers to understand the full 'value' of the natural environment (over and above market values). **This sub-principle is also relevant to EsA_7**	Sections 3.1.1 and 3.2.3 Table 3.6
	EsA_12.3	During debates and decisions about land use/management decision-making, especially with policy-makers, use ecosystem services to draw attention to the integrated nature of the natural environment and the need for holistic management that moves away from silo or topic based approaches. **This sub-principle is also relevant to EsA_11**	Sections 3.2.2 and 3.2.3 Figures 1.4, 3.6 and 3.8 Table 3.6
	EsA_12.4	Use ecosystem service maps and other visual tools to communicate the human wellbeing benefits provided by existing and/or potential future land use scenarios to stakeholders, the public and affected communities, as a useful means of engaging people in urban land use/management decision-making. **This sub-principle is also relevant to EsA_9 and EsA_11**	Section 6.1.2 Figure 6.2 Phillips et al (2014)
	EsA_12.5	At the Main Issues Report (MIR) stage of the Local Development Plan (LDP) process,	Section 3.1.2

CBD ecosystems approach principle	Sub-principles for ecosystems approach based urban land use/management planning		Reference(s)
	Ref.	Details of sub-principle	
		engage stakeholders with relevant ecosystem, conservation and landscape planning and management skills to ensure that all relevant 'big ideas' and statutory provisions within MIRs are informed by a detailed understanding of ecosystem structure and function issues	Expert interview data (Appendix 3 and section 3.1.2) Table 3.3
	EsA_12.6	Engage with stakeholders, the public and affected communities to validate ecosystem service typologies and assessments developed as part of land use/management planning. **This sub-principle is also relevant to EsA_11**	Section 6.1.2 Figure 6.2

Appendix 4: Guidance for interpreting and acting on flood control model outputs in the development of integrated urban land use/management strategies

Introduction to the flood control model guidance

The tables below provide guidance to support the consideration of flood storage ecosystem services in urban land use/management planning. The guidance in the first table is also applicable to runoff reduction ecosystem services (see Appendix 5). The guidance has been developed through this research on the basis of the material collated, analysed and synthesised in the evidence assessment described in Chapters 3, 4, 5 and 6. The analysis approach used in the development of the guidance is described at section 8.1.1 in the main volume of the thesis.

The tables include references to indicate the provenance of the guidance notes within specific parts of the evidence assessment in the main volume of the thesis or specific key references (e.g. journal articles, official reports, government policy etc) that have played a crucial role within the evidence assessment. The references are intended to signpost the reader to more detailed information that can support consideration of the guidance in practical urban land use/management planning.

The first table provides **overarching guidance** for the **consideration** of flood storage **and** runoff reduction services in urban land use/management planning. In essence, these are key principles that can help stakeholders integrate consideration of flood storage and runoff reduction ecosystem services within urban land use/management plans. This is in addition to the general ecosystems approach principles described at Appendix 3. Further information on the utility of the overarching guidance supporting urban land use/management planning, including worked examples, is provided at sections 8.2 and 8.3 in the main volume of the thesis. The overarching guidance notes are grouped into the following categories:

1. Approaches and concepts;
2. Tools, policy and regulation;
3. Resilience and flexibility; and
4. Planning and intervention.

The second table provides **specific technical guidance** to help practitioners **interpret and act on** flood control model outputs in the development of integrated urban land use/management strategies. In essence, these are practical recommendations describing how flood storage ecosystem services can be enhanced, at sites and locations identified through the flood control model, through targeted land use/management intervention. Further information on the utility of the technical guidance supporting urban land use/management planning, including worked examples, is provided at sections 8.2 and 8.3 in the main volume of the thesis.

The **overarching guidance notes** are distinguished by a number suffix e.g. **Hydro/Flood_1**.

The **technical guidance notes** are distinguished by a letter suffix e.g. **Flood_A**.

Overarching guidance for the consideration of flood storage and runoff reduction ecosystem services in urban land use/management planning

Ref.	Overarching guidance	Reference(s)
Overarching Guidance Category No.1: ***Approaches and Concepts***		
Hydro/Flood_1	Urban landscapes can provide space to store water and slow down the progress of floods. These services can be enhanced through appropriate land use/management intervention that acts to reduce runoff at source (runoff volume reduction) and/or provides increased flood storage (attenuation of peak flows). Designed effectively, these types of intervention can help to reduce flood risk by reducing the likelihood of flooding, mitigating the consequences/impacts of flooding or both. A catchment based approach to Flood Risk Management (FRM) in this regard should consider the use of Natural Flood Management (NFM) measures in the channel, floodplain and wider catchment	Sections 4.2 and 4.7 Figure 4.3 Tables 4.2 and 4.8 Scottish Government (2011a)
Hydro/Flood_2	To deliver an overall reduction in flood risk, catchment based Flood Risk Management (FRM) is likely to require a combination of natural and more traditionally engineered structural measures, in conjunction with non-structural measures such as policy (e.g. planning policy as part of LDPs), advice and flood warnings	Sections 4.2 and 4.7 Table 4.3 Scottish Government (2011a)
Hydro/Flood_3	As a general principle for the purposes of strategic urban land use/management planning; land in the wider catchment, river channels, floodplains etc that exhibit a greater degree of hydraulic 'roughness' can be considered to provide greater flood storage/runoff reduction benefits. However land use/management change that alters the hydraulic properties of land must be undertaken in a planned manner to ensure that change doesn't exacerbate flood risk (e.g. by synchronising peak flow discharge from tributaries or causing the 'backing-up' of flood waters where it is unsafe to do so)	Section 4.4
Hydro/Flood_4	Urban land use/management strategies, including Local Development Plans (LDPs), should seek to address the complex flooding problems that can arise in urban catchments due to the interaction of different sources of flooding, especially fluvial, pluvial and sewer flooding. As a general principle, urban land use/management practice should help to keep surface water out of the sewer system through the use of specific green infrastructure intervention (e.g. source control SuDS) and the enhancement and restoration of natural drainage processes via sustainable land use/management practices	Section 4.7.1 Figure 4.14 Tables 4.1 and 4.6 Scottish Government (2013a)

Ref.	Overarching guidance	Reference(s)
Hydro/Flood_5	An additional key objective for the planning and design of urban land use/management and green infrastructure for the provision of runoff reduction ecosystem services (especially in the wider catchment away from river corridors) should be to reduce pressure on sewer systems, by providing storm water attenuation	Section 4.2 Table 4.2 Scottish Government (2013a)
Overarching Guidance Category No.2: *Tools, Policy and Regulation*		
Hydro/Flood_6	Use Strategic Flood Risk Assessment (SFRA) in conjunction with the statutory planning system (including Local Development Plan (LDP) policy and supplementary guidance, Development Management and Enforcement) to guide new development away from areas where flooding is likely to occur and to protect, enhance and restore existing land use and green infrastructure that provides flood storage and runoff reduction ecosystem services (e.g. stretches of unmodified floodplain, other significant areas of 'green' and 'natural environment' type urban land use). The restorative function is particularly important in highly modified urban catchments to help reverse the effects of historic development pressure e.g. waterbody modification, removal of vegetation and building over of greenspace	Sections 4.3, 4.2, 4.5.1 and 4.7.1 Figure 4.14 Scottish Government (2011a)
Hydro/Flood_7	Consider how the statutory planning system can be used to provide new areas of 'green' and 'natural environment' type urban land use (i.e. appropriately sited and designed multifunctional openspace as per PAN65) and green infrastructure for the provision of runoff reduction and flood storage ecosystem services (e.g. through planning conditions, section 106 agreements etc)	Section 4.2 Table 4.2
Overarching Guidance Category No.3: *Resilience and Flexibility*		
Hydro/Flood_8	Flood Risk Management (FRM) actions should be flexible and resilient in the face of climate change. Natural Flood Management (NFM) based structural measures (e.g. land use/management and green infrastructure) are potentially more flexible than traditionally engineered structural measures (e.g. embankments and culverts) which generally have a finite design capacity that can be costly or impractical to modify (e.g. in the face of more frequent extreme rainfall events and associated higher flows)	Section 4.2 Table 4.2 Scottish Government (2011a)

Ref.	Overarching guidance	Reference(s)
Hydro/Flood_9	Use hydrological and hydraulic modelling to explore the implications of a range of strategic options for reducing overall flood risk. Modelling should consider rainfall event scenarios flows associated for a range of different return periods, including for more extreme events (e.g. 1 in 200 year + climate change event), to explore the efficacy of a range of different strategic options for Flood Risk Management (FRM). Where possible (e.g. given constraints from other land uses etc), modelling should consider how land use/management and green infrastructure based FRM strategies can be used to deliver a substantial reduction in flood risk, in conjunction with wider multiple benefits (e.g. consolidation of existing habitat, enhancement of ecological networks, enhanced amenity etc)	Section 4.3 Table 4.4
Hydro/Flood_10	Urban land use/management planning for the restoration of ecosystem structure and function (e.g. hydrological cycle function) and enhancement of ecosystem services (e.g. runoff reduction) should be undertaken at a range of scales including at the landscape or whole ecosystem scale	Sections 3.1.3 and 5.1.1 Expert interview data (Appendix 3 and section 3.1.3) Figures 3.4 and 3.5 Tables 3.4 and 4.7
Overarching Guidance Category No.4: ***Planning and intervention***		
Hydro/Flood_11	The timing and magnitude of river runoff is dictated by natural drainage processes - interception and depression storage, evapotranspiration, infiltration, attenuation and conveyance. Urban land use/management strategies, including Local Development Plans (LDPs), should work to protect, enhance and restore these processes to support the delivery of sustainable Flood Risk Management (FRM) and water management more generally. Where appropriate (i.e. given existing constraints such as landscape and biodiversity designations), urban land managers should seek to enhance the natural drainage processes supported by all existing 'green' and 'natural environment' type land uses in the urban area through targeted management intervention. In Scotland, this could be undertaken with reference to openspace audits produced as per the requirements of Planning Advice Note (PAN) 65. Equally, the design and management of new areas of openspace should be informed by simple hydraulic criteria to ensure that they contribute to hydrological improvements at the catchment scale	Sections 4.7.1 and 4.7.2 Figure 4.14 Tables 4.1, 4.6 and 4.7 AECOM (2011) Scottish Government (2008) Scottish Government (2011a)
Hydro/Flood_12	Land use/management that enhances attenuation capacity will enhance interception capacity and vice versa as both processes are influenced by the hydraulic roughness of the land. As a general principle, 'green' and 'natural environment' type urban land uses with denser, taller, more structurally diverse vegetation will be hydraulically rougher and have more porous, open structured soils. These properties are beneficial for sustainable Flood Risk Management (FRM) in urban areas by helping to reduce runoff at source as well as attenuating and delaying peak flows	Sections 4.7.1 and 4.7.2 Tables 4.6 and 4.7 Figure 4.14 AECOM (2011) Scottish Government (2008)

Ref.	Overarching guidance	Reference(s)
Hydro/Flood_13	The use of SuDS should be considered even when it is not possible for treated runoff to be discharged to a waterbody (e.g. due to topographical constraints). SuDS use in this regard can provide storm water storage and reduce pressure on sewer systems, till such time that peak discharge associated with the rainfall event has passed. This is in addition to the wider multiple benefits that SuDS can provide in terms of biodiversity and amenity	Section 4.7.3 Figures 4.16 and 4.17 Table 4.8

Technical guidance for interpreting and acting on flood control model outputs in the development of integrated urban land use/management strategies

Ref.	Technical guidance	Reference(s)
Flood_A	Identify possible **synergies and areas of overlap** between LDP related land use/management proposals (as identified through the modelling) and objectives, policies, actions etc from **related land use delivery mechanisms**, especially: 1) Scottish Planning Policy (SPP); 2) Strategic Development Plans; 3) relevant Development Management decisions; 4) River Basin Management Plans (RBMPs); 5) Flood Risk Management Strategies; and 6) Scotland's Land Use Strategy. Where relevant, consider how these opportunities can be developed through partnership working and the use of formalised partnership agreements	Expert interview data (Appendix 3 and section 3.1.1) Figure 3.1 Phillips et al (2014)
Flood_B	The hydraulic properties of **river channels** can be manipulated to increase their roughness, increase turbulence and decrease flow velocities. This can help to delay the passage of flood water downstream and promote out of bank flows, helping to connect watercourses to their floodplains and enhance floodplain storage. Consider how the hydraulic properties of river channels at sites identified through the flood control model can be enhanced for Flood Risk Management (FRM) by: a) Increasing the occurrence of irregularities within the channel b) Restoring the channel to a more natural alignment reflecting the geomorphology of the catchment or specific stretch at hand c) Restoring the channel cross-section to a more natural shape reflecting the geomorphology of the catchment or specific stretch at hand d) Restoring the river bed and banks e.g. by reintroducing native vegetation and eradicating invasive non-native vegetation	Sections 2.5.3 and 4.4 RRC (2002) Nisbet et al (2008) Nisbet et al (2011a)

Ref.	Technical guidance	Reference(s)
Flood_C	The hydraulic properties of **floodplains** can be manipulated to increase their roughness, thereby increasing turbulence/flow disruption and decreasing flow velocities. This can enhance floodplain storage and help to delay the passage of flood waters downstream. Some types of floodplain measure (e.g. floodplain woodland) may also help to reduce runoff volumes (e.g. by increasing the infiltration capacity of floodplain soils). Consider how the hydraulic properties of the floodplain at sites identified through the flood control model can be enhanced for Flood Risk Management (FRM) by: a) Management intervention that alters soil properties thereby increasing infiltration capacity b) Increasing surface irregularities to disrupt flood flows and increase turbulence c) Altering the nature of floodplain vegetation to increase roughness, disrupt flows and increase turbulence **Note:** Measures (b) and (c) can help to increase flood depth and extent (where safe to do so) contributing to increased flood storage	Section 4.4 RRC (2002) Nisbet and Thomas (2008) Nisbet et al (2011a)
Flood_D	Vegetation type can influence the hydraulic properties of **floodplain** and **riparian** land, either promoting out of bank flows and flood storage or acting as a barrier and rushing flood flows downstream. Consider how floodplain and riparian vegetation at sites identified through the flood control model can be designed and managed for the provision of flood storage ecosystem services by: a) Managing vegetation density to ensure that riparian vegetation does not pose a barrier to out of bank flows b) Managing vegetation density to maintain flow routing between the channel and the floodplain whilst also increasing turbulence/flow disruption to the extent that flood storage is enhanced c) Designing any new planting and/or restocking to ensure that the mix of tree, shrub and grass/herb species provide the required degree of structural diversity and stiffness to maintain flow routing whilst also increasing turbulence/flow disruption and flood storage d) Sensitive introduction and management of large woody debris (LWD) dams where appropriate and safe to do so	Section 4.4 Figures 4.6 and 4.9 Tabacchi et al (2000) Nisbet and Thomas (2008)

Ref.	Technical guidance	Reference(s)
Flood_E	Well-designed **river restoration projects** should provide a range of **multiple benefits**. Consider how potential river restoration measures at sites identified through the flood control model can be designed to deliver a range of multiple benefits including: a) Addressing water environment issues (morphology pressures) b) Restoring a more natural morphology (e.g. reinstating meanders, natural channel cross-section etc) and flow regime (especially peak flow response times) to modified watercourses c) Helping to increase capacity in the natural drainage network d) Providing enhanced flood storage where appropriate and safe to do so (by reconnecting the watercourse with its floodplain) e) Consolidating existing aquatic, riparian and floodplain habitats f) Enhancing habitat networks within the river corridor and improving structural and functional connectivity g) Providing a range of amenity benefits to local communities and other users of the water environment	Sections 4.5.2 and 4.5.3 Figures 4.7 and 4.8 RRC (2002)
Flood_F	The **width of woodland planting across the floodplain** can impact the flood storage effect of the woodland. As a general rule, the flood storage effect of floodplain woodland will be greater, the greater the width of planting used. The flood storage efficacy of floodplain woodland will also be influenced by floodplain topography, specifically the effect will be less where the floodplain is steeper. In addition to these general principles, potential floodplain woodland measures at sites identified through the flood control model should consider the following design principles: a) The impact of woodland planting delaying and/or reducing downstream peak flows decreases as floodplain steepness increases. The steeper the floodplain the lesser the effect b) Planting will be most effective at enhancing flood storage when located within the lower lying, wettest part of the floodplain c) Relic side channels can divert flood flows back into the main channel, potentially negating the flood storage benefit provided by the planting – detailed topographical data should be studied to identify relic side channels in the floodplain which can be factored into woodland design e.g. in terms of planting width	Section 4.6 Nisbet and Thomas (2008)
Flood_G	The **length of woodland planting along the floodplain** can impact the flood storage effect of the woodland. As a general rule, the flood storage effect of floodplain woodland will be greater, the greater the length of planting used. Potential floodplain woodland planting measures at sites identified through the flood control model should cover as great a length of the floodplain as possible, given constraints posed by other land uses	Section 4.6 Nisbet and Thomas (2008)

Ref.	Technical guidance	Reference(s)
Flood_H	As a general rule, the flood storage effect of floodplain woodland planting will be greater, the **greater the area of planting** that is used. In addition however, **targeted planting of discrete woodland blocks** in the floodplain can achieve a similar overall flood storage effect with less land take. This approach can be particularly useful helping to desynchronise flows from contributing tributaries. Consider how floodplain woodland planting measures at sites identified through the flood control model can be targeted through the use of discrete woodland blocks. Particular woodland design issues to consider include: a) The flood storage effect of individual woodland blocks will be influenced by site specific issues – this is especially true of topography (i.e. the steepness of the floodplain cross-section) and the presence of relic side channels b) The siting of woodland blocks should be designed around topographical constraints. Key topographical constraints should be mapped and planting scenarios designed around these	Section 4.6 Jacobs Babtie (2006) Nisbet and Thomas (2008)
Flood_I	The choice of **tree species** used in floodplain woodland planting will have a significant impact on the hydraulic properties of the floodplain and therefore the flood storage effect of the planting. The following technical guidance should be considered in the design of floodplain woodland planting measures at sites identified through the flood control model: a) Ensure that the species or mix of species used is appropriate for the site conditions. Given that planting is to take place on the floodplain, the water table is likely to be high and the soil frequently waterlogged. The species used must therefore be appropriate for these conditions (e.g. shallow rooting) or a suitable silvicultural treatment used (e.g. mounding – see below also) b) Broadleaved species that are shallow rooting and/or resilient to frequent waterlogging include: trees from the *Salix* (willow) family, *Betula* (birch) family, *Sorbus aucuparia* (rowan/mountain ash) and *Alnus glutinosa* (alder) c) Conifer species that are shallow rooting and/or resilient to frequent waterlogging include: *Picea sitchensis* (Sitka spruce) and *Picea abies* (Norway spruce) d) Select a tree species that forms low branches (see Figures 4.6 and 4.9) to increase floodplain roughness and turbulence/flow disruption by creating a physical barrier low to the ground e) Select a tree species that forms a low crown (see Figures 4.6 and 4.9) to increase floodplain roughness and turbulence/flow disruption by creating a physical barrier low to the ground	Section 4.6 Figures 4.6 and 4.9 Hart (1991) Nisbet and Thomas (2008)

Ref.	Technical guidance	Reference(s)
Flood_L	The choice of **silvicultural regime** and **woodland management** practice can have a significant impact on the hydraulic and hydrological properties of woodland, potentially affecting both runoff reduction and flood storage ecosystem services. The following technical guidance should be considered in the design and management of floodplain and wider catchment woodland planting measures at sites identified through the flood control and hydrological cycle models: a) Urban woodland should be structurally diverse and incorporate: 1) a closed canopy; 2) an understorey of shrubs and/or shrubby trees such as *Corylus avellana* (hazel) and trees from the *Salix* (willow) family; and 3) the retention of deadwood on the woodland floor b) Where possible (e.g. given landscape and biodiversity constraints), the use of closed canopy conifer stands should be promoted given their year round foliage and strong support for multiple natural drainage processes (especially interception, evapotranspiration and attenuation) c) Adopt continuous cover forestry (CCF) silvicultural practices where possible to increase structural diversity and the area of land under continuous woodland cover d) Adopt a hierarchy of different woodland design and management strategies for different circumstances - the use of closed canopy conifer stands is likely to be the most preferential type of woodland in terms of water management though not appropriate for all sites. Where this strategy is inappropriate, the following alternatives should be considered: i. Native broadleaf with non-native conifer CCF ii. Native broadleaf CCF iii. Native broadleaf CCF with areas of openspace, noting that areas of openspace should ideally be managed in line with Hydro_F (c) and (d) e) Where possible, dead trees and brash from any harvesting and management operations should be retained on site to help maintain hydraulic roughness (see Figure 4.9) f) Mounding can be used to provide increased depth for tree rooting and may facilitate the planting of species that would otherwise not thrive in such wet conditions. Mounding also provides a physical barrier to flood waters and will contribute to increased hydraulic roughness	Section 4.6 Figures 4.6 and 4.9 Hart (1991) Nisbet and Thomas (2008)

Appendix 5: Guidance for interpreting and acting on hydrological cycle model outputs in the development of integrated urban land use/management strategies

Introduction to the hydrological cycle model guidance

The table below provides specific **technical guidance** to help practitioners **interpret and act on** hydrological cycle model outputs in the development of integrated urban land use/management strategies. In essence, these are practical recommendations describing how runoff reduction ecosystem services can be enhanced, at sites and locations identified through the hydrological cycle model, through targeted land use/management intervention.

The guidance has been developed through this research on the basis of the material collated, analysed and synthesised in the evidence assessment described in Chapters 3, 4, 5 and 6. The analysis approach used in the development of the guidance is described at section 8.1.1 in the main volume of the thesis. Further information on the utility of the technical guidance supporting urban land use/management planning, including worked examples, is provided at sections 8.2 and 8.3 in the main volume of the thesis.

The table includes references to indicate the provenance of the guidance notes within specific parts of the evidence assessment in the main volume of the thesis or specific key references (e.g. journal articles, official reports, government policy etc) that have played a crucial role within the evidence assessment. The references are intended to signpost the reader to more detailed information that can support consideration of the guidance in practical urban land use/management planning.

Appendix 4 includes more general **overarching guidance** to support the **consideration** of runoff reduction and flood storage ecosystem services in urban land use/management planning. This is in addition to the general ecosystems approach principles described at Appendix 3. Further information on the utility of the overarching guidance supporting urban land use/management planning, including worked examples, is provided at sections 8.2 and 8.3 in the main volume of the thesis.

Technical guidance for interpreting and acting on hydrological cycle model outputs in the development of integrated urban land use/management strategies

Ref.	Technical guidance	Reference(s)
Hydro_A	Identify possible **synergies and areas of overlap** between LDP related land use/management proposals (as identified through the modelling) and objectives, policies, actions etc from **related land use delivery mechanisms**, especially: 1) Scottish Planning Policy (SPP); 2) Strategic Development Plans; 3) relevant Development Management decisions; 4) River Basin Management Plans (RBMPs); 5) Flood Risk Management Strategies; and 6) Scotland's Land Use Strategy. Where relevant, consider how these opportunities can be developed through partnership working and the use of formalised partnership agreements	Expert interview data (Appendix 3 and section 3.1.1) Figure 3.1 Phillips et al (2014)
Hydro_B	For areas of existing 'green' and 'natural' environment type land use identified through the hydrological cycle model, consider how **interception** and **attenuation** capacity can be enhanced or restored by: a) Increasing tree cover/density on the site - in general terms, trees and woodlands intercept more precipitation than shorter types of vegetation (shrubs and grasses) b) Restructuring sites with significant existing woodland cover (e.g. certain types of natural/semi-natural greenspace and green corridor site in terms of PAN65) to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris* etc) c) Altering the management of existing amenity grassland (e.g. as found within parks and gardens and amenity greenspace) to support the creation of species rich grassland/meadow, noting that interception losses from dense grasses and herbs can be as much as broadleaved tree species. The subsequent change in management regime would see a greater sward height for longer and therefore greater hydraulic roughness and interception losses	Sections 4.7.1 and 4.7.2 Tables 4.6 and 4.7 Figure 4.14 AECOM (2011) Scottish Government (2008)
Hydro_C	For areas of existing 'green' and 'natural' environment type land use identified through the hydrological cycle model, consider how **evapotranspiration** capacity can be enhanced or restored by: f) Increasing the density of all types of vegetation cover on the site including trees, shrubs and grasses g) Restructuring sites with significant existing woodland cover (e.g. certain types of natural/semi-natural greenspace and green corridor site in terms of PAN65) to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris* etc)	Sections 4.7.1 and 4.7.2 Tables 4.6 and 4.7 Figure 4.14 AECOM (2011) Scottish Government (2008)

Ref.	Technical guidance	Reference(s)
Hydro_D	For areas of existing 'green' and 'natural' environment type land use identified through the hydrological cycle model, consider how **infiltration** can be enhanced or restored by: a) Increasing the density of all types of vegetation cover on the site including trees, shrubs and grasses to help protect soil porosity and infiltration capacity b) Where appropriate, changing land use to woodland - woodland soils often have a more open structure and therefore greater porosity and infiltration capacity c) Restructuring sites with significant existing woodland cover (e.g. certain types of natural/semi-natural greenspace and green corridor site in terms of PAN65) to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris* etc)	Sections 4.7.1 and 4.7.2 Tables 4.6 and 4.7 Figure 4.14 AECOM (2011) Scottish Government (2008)
Hydro_E	For existing **natural/semi-natural greenspace** and **green corridor** sites identified through the hydrological cycle model and in **local authority ownership**, consider how drainage function can be enhanced or restored by: a) Increasing tree cover/density on the site - in general terms, trees and woodlands intercept more precipitation than shorter types of vegetation (e.g. shrubs and grasses) b) Restructuring sites with significant existing woodland cover (e.g. certain types of natural/semi-natural greenspace and green corridor site in terms of PAN65) to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris*) c) For sites with significant existing woodland cover, change management regime to continuous cover forestry (CCF) d) Increasing the density of all types of vegetation cover on the site including trees, shrubs and grasses e) Where appropriate, changing land use to woodland (e.g. for grassland sites with low ecological value - i.e. woodland soils tend to have a more open structure and therefore greater porosity and infiltration capacity f) Reverse land drainage and promote the creation of wetland and wet flush areas including wet woodland g) Installing/retrofitting regional control SuDS measures (e.g. retention basins and associated wetland habitat) - the use of regional control SuDS in this regard could be designed to provide part of the surface water management solution for other land uses surrounding the area of natural/semi-natural greenspace (e.g. housing, business, roads etc)	

Ref.	Technical guidance	Reference(s)
Hydro_F	For existing **public park and garden sites** (potentially incorporating areas of **playspace for children and teenagers**) identified through the hydrological cycle model and in **local authority ownership**, consider how drainage function can be enhanced or restored by: a) Increasing tree cover/density on the site - in general terms, trees and woodlands intercept more precipitation than shorter types of vegetation (e.g. shrubs and grasses) b) Restructuring parts of the site with significant existing woodland cover to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris*) c) Increasing the density of all types of vegetation cover on the site including trees, shrubs and grasses (where appropriate given the site's primary use) d) Altering the management of some or all of the site's existing amenity grassland to support the creation of species rich grassland/meadow – these new areas of habitat should be integrated with existing habitat networks where possible e) Installing/retrofitting source control SuDS measures (e.g. green roofs on cafes, permeable surfaces, rain gardens etc) within areas of public realm and civic space (i.e. parts of the site where there are significant areas of hardstanding) f) Installing/retrofitting site control SuDS measures (e.g. detention basins) that are fully integrated with the site's existing use(s) and other surface water management infrastructure (i.e. source and regional control SuDS) g) Installing/retrofitting regional control SuDS measures (e.g. retention basins and associated wetland habitat) - the use of regional control SuDS in this regard could be designed to provide part of the surface water management solution for other land uses surrounding the park (e.g. housing, business, roads etc)	Sections 4.7.1, 4.7.2 and 4.7.3 Tables 4.6, 4.7 and 4.8 Figures 4.14, 4.15 and 4.17 AECOM (2011) Scottish Government (2008) Scottish Government (2011d)
Hydro_G	For existing **allotments and community growing space sites** identified through the hydrological cycle model and in **mixed ownership** (e.g. owned by the local authority, leased/owned by a community group etc), consider how drainage function can be enhanced or restored by: a) Where appropriate, using policy (e.g. planning policy within the LDP) and grants/incentives to increase tree cover/density on the site - in general terms, trees and woodlands intercept more precipitation than shorter types of vegetation (e.g. shrubs and grasses) b) Where appropriate, using policy (e.g. planning policy within the LDP) and grants/incentives to increase the density of all types of vegetation cover on the site including trees, shrubs and grasses c) Where appropriate, using policy (e.g. planning policy within the LDP) and grants/incentives to promote the installation of source control SuDS measures (e.g. green roofs, permeable surfaces, rain gardens etc) on the site	Sections 4.7.1, 4.7.2 and 4.7.3 Tables 4.6, 4.7 and 4.8 Figures 4.14, 4.15 and 4.17 AECOM (2011) Scottish Government (2008)

Ref.	Technical guidance	Reference(s)
Hydro_H	For existing **private gardens and grounds** identified through the hydrological cycle model and in **private ownership**, consider how drainage function can be enhanced or restored by: a) Using policy (e.g. planning policy within the LDP) and grants/incentives to promote the installation of source control SuDS measures (e.g. green roofs, permeable surfaces, rain gardens etc) on the site	Sections 4.7.1, 4.7.2 and 4.7.3 Tables 4.6, 4.7 and 4.8 Figures 4.14, 4.15 and 4.17 AECOM (2011) Scottish Government (2008)
Hydro_I	For existing **sports area sites** identified through the hydrological cycle model and in **local authority ownership**, consider how drainage function can be enhanced or restored by: a) Increasing tree cover/density on the site - in general terms, trees and woodlands intercept more precipitation than shorter types of vegetation (e.g. shrubs and grasses). This could include planting up of discrete woodland blocks across the site where existing primary use would allow - these new areas of habitat should be integrated with existing habitat networks where possible b) Restructuring parts of the site with significant existing woodland cover to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris*) c) Altering the management of some or all of the site's existing amenity grassland to support the creation of species rich grassland/meadow - these new areas of habitat should be integrated with existing habitat networks where possible d) Increasing the density of all types of vegetation cover on the site including trees, shrubs and grasses. This could include the creation of discrete areas of species rich grassland/wildflower meadow where existing use would allow - these new areas of habitat should be integrated with existing habitat networks where possible e) Installing/retrofitting source control SuDS measures (e.g. green roofs on buildings, permeable surfaces, rain gardens etc) within areas of public realm and civic space (i.e. parts of the site where there are significant areas of hardstanding) f) Installing/retrofitting site control SuDS measures (e.g. detention basins) that are fully integrated with the site's existing use(s) and other surface water management infrastructure (i.e. source and regional control SuDS) g) Installing/retrofitting regional control SuDS measures (e.g. retention basins and associated wetland habitat) - the use of regional control SuDS in this regard could be designed to provide part of the surface water management solution for other land uses surrounding the sports area (e.g. housing, business, roads etc)	Sections 4.7.1, 4.7.2 and 4.7.3 Tables 4.6, 4.7 and 4.8 Figures 4.14, 4.15 and 4.17 AECOM (2011) Scottish Government (2008) Scottish Government (2011d)
Hydro_J	For existing **amenity greenspace sites** identified through the hydrological cycle model and in **mixed ownership** (e.g. local authority, housing association, business association etc), consider how drainage function can be enhanced or restored by: a) Increasing tree cover/density on the site - in general terms, trees and woodlands intercept more precipitation than shorter types of vegetation (e.g. shrubs and grasses). This could include planting up of	Sections 4.7.1, 4.7.2 and 4.7.3 Tables 4.6, 4.7 and 4.8 Figures 4.14, 4.15 and 4.17 AECOM (2011) Scottish Government (2008)

Ref.	Technical guidance	Reference(s)
	discrete woodland blocks across the site where existing use would allow - these new areas of habitat should be integrated with existing habitat networks where possible b) Restructure parts of the site with significant existing woodland cover to include a greater proportion of conifer species (e.g. *Picea sitchensis* and *Pinus slyvestris*) c) Altering the management of some or all of the site's existing amenity grassland to support the creation of species rich grassland/meadow - these new areas of habitat should be integrated with existing habitat networks where possible d) Increasing the density of all types of vegetation cover on the site including trees, shrubs and grasses e) Installing/retrofitting source control SuDS measures (e.g. green roofs on housing and offices, permeable surfaces, rain gardens etc) within areas of public realm and civic space (i.e. parts of the site where there are significant areas of hardstanding) f) Installing/retrofitting site control SuDS measures (e.g. detention basins) that are fully integrated with the site's existing use(s) and other surface water management infrastructure (e.g. source control SuDS) g) Installing/retrofitting regional control SuDS measures (e.g. retention basins and associated wetland habitat) - this could be designed to provide part of the surface water management solution for the development (e.g. housing, business, roads etc) associated with the area of amenity greenspace	
Hydro_K	For areas of urban land use identified through the hydrological cycle model that are **not** 'green' and 'natural environment' type land uses (e.g. areas of public realm, roads, buildings, school/hospital estates etc) that are primarily in **public ownership**, consider how drainage function can be enhanced or restored by: a) Installing/retrofitting source control SuDS measures (e.g. green roofs, permeable surfaces, rain gardens) noting that the nature of source control SuDS measures is such that their use can be considered at any location e.g. within areas of public realm, car parks, pavements, roads etc. Source control SuDS may be particularly useful where existing land use constrains the installation/retrofit of site control SuDS (though runoff from source control SuDS may have to be conveyed off-site to site/regional control SuDS assets depending on anticipated runoff volumes and the level of treatment that can be achieved at source) b) Where existing land use allows, installing/retrofitting site control SuDS measures (e.g. detention basins) within developments e.g. housing estates, business parks, school estates etc	Sections 4.7.1, 4.7.2 and 4.7.3 Tables 4.6, 4.7 and 4.8 Figures 4.14, 4.15 and 4.17 AECOM (2011) Scottish Government (2008)
Hydro_L	The choice of **silvicultural regime** and **woodland management** practice can have a significant impact on the hydraulic and hydrological properties of woodland, potentially affecting both runoff reduction and flood storage ecosystem services. The following technical guidance should be considered in the design and management of floodplain and wider catchment woodland planting measures at sites identified through the flood control and hydrological cycle models: g) Urban woodland should be structurally diverse and incorporate: 1) a closed canopy; 2) an understorey of	Section 4.6 Figures 4.6 and 4.9 Hart (1991) Nisbet and Thomas (2008)

Ref.	Technical guidance	Reference(s)
	shrubs and/or shrubby trees such as *Corylus avellana* (hazel) and trees from the *Salix* (willow) family; and 3) the retention of deadwood on the woodland floor h) Where possible (e.g. given landscape and biodiversity constraints), the use of closed canopy conifer stands should be promoted given their year round foliage and strong support for multiple natural drainage processes (especially interception, evapotranspiration and attenuation) i) Adopt continuous cover forestry (CCF) silvicultural practices where possible to increase structural diversity and the area of land under continuous woodland cover j) Adopt a hierarchy of different woodland design and management strategies for different circumstances - the use of closed canopy conifer stands is likely to be the most preferential type of woodland in terms of water management though not appropriate for all sites. Where this strategy is inappropriate, the following alternatives should be considered: i. Native broadleaf with non-native conifer CCF ii. Native broadleaf CCF iii. Native broadleaf CCF with areas of openspace, noting that areas of openspace should ideally be managed in line with Hydro_F (c) and (d) k) Where possible, dead trees and brash from any harvesting and management operations should be retained on site to help maintain hydraulic roughness (see Figure 4.9) l) Mounding can be used to provide increased depth for tree rooting and may facilitate the planting of species that would otherwise not thrive in such wet conditions. Mounding also provides a physical barrier to flood waters and will contribute to increased hydraulic roughness	

Appendix 6: Guidance for interpreting and acting on habitat network model outputs in the development of integrated urban land use/management strategies

Introduction to the habitat network model guidance

The tables below provide guidance to support the consideration of ecological connectivity ecosystem services in urban land use/management planning. The guidance has been developed through this research on the basis of the material collated, analysed and synthesised in the evidence assessment described in Chapters 3, 4, 5 and 6. The analysis approach used in the development of the guidance is described at section 8.1.1 in the main volume of the thesis.

The tables include references to indicate the provenance of the guidance notes within specific parts of the evidence assessment in the main volume of the thesis or specific key references (e.g. journal articles, official reports, government policy etc) that have played a crucial role within the evidence assessment. The references are intended to signpost the reader to more detailed information that can support consideration of the guidance in practical urban land use/management planning.

The first table provides **overarching guidance** for the **consideration** of ecological connectivity services in urban land use/management planning. In essence, these are key principles that can help stakeholders integrate consideration of ecological connectivity ecosystem services within urban land use/management plans. This is in addition to the general ecosystems approach principles described at Appendix 3. Further information on the utility of the overarching guidance supporting urban land use/management planning, including worked examples, is provided at sections 8.2 and 8.3 in the main volume of the thesis. The overarching guidance notes are grouped into the following categories:

1. Approaches and concepts;
2. Tools, policy and regulation;
3. Resilience and flexibility; and
4. Planning and intervention.

The second table provides **specific technical guidance** to help practitioners **interpret and act on** habitat network model outputs in the development of integrated urban land use/management strategies. In essence, these are practical recommendations describing how ecological connectivity ecosystem services can be enhanced, at sites and locations identified through the hydrological cycle model, through targeted land use/management intervention. Further information on the utility of the technical guidance supporting urban land use/management planning, including worked examples, is provided at sections 8.2 and 8.3 in the main volume of the thesis.

The **overarching guidance notes** are distinguished by a number suffix e.g. **Habitat_1**.

The **technical guidance notes** are distinguished by a letter suffix e.g. **Habitat_A**.

Overarching guidance for the consideration of ecological connectivity ecosystem services in urban land use/management planning

Ref.	Overarching guidance	Reference(s)
Overarching Guidance Category No.1: ***Approaches and Concepts***		
Habitat_1	Within the development of urban land use/management strategies, including Local Development Plans (LDPs), stakeholders should approach urban landscapes as entities comprising structural elements of patch, mosaic, corridor and barrier. Thinking in these terms can support better planning for landscape connectivity for species and biodiversity conservation but also for people movements and other ecosystem processes/intermediate services	Section 5.1.1 Figure 5.1
Habitat_2	For land use planning/management purposes, consider how the urban landscape can be measured and evaluated in terms of relevant habitat metrics (e.g. total area of habitat, mean size of habitat patches, mean inter-patch distance etc) to better understand the opportunities and constraints for species movements and ecological connectivity	Section 5.1.2
Overarching Guidance Category No.2: ***Tools, Policy and Regulation***		
Habitat_3	Use the statutory planning system, including Local Development Plan (LDP) policy, Development Management and Enforcement, to protect and enhance land and green infrastructure that provides ecological connectivity ecosystem services	Section 4.2 Table 4.2
Habitat_4	Where relevant, consider how the statutory planning system can be used to provide new areas of 'green' and 'natural environment' type urban land use (i.e. appropriately sited and designed multifunctional openspace as per PAN65) and green infrastructure for the provision of ecological connectivity ecosystem services (e.g. through planning conditions, section 106 agreements etc)	Section 4.2 Table 4.2
Overarching Guidance Category No.3: ***Resilience and Flexibility***		
Habitat_5	Urban land use/management strategies, including Local Development Plans (LDPs), should seek to protect, restore and enhance structural and functional connectivity in habitat networks	Section 5.2.1 Figures 5.2, 5.3 and 5.5
Habitat_6	Urban land use/management planning for the restoration of ecosystem structure and function (e.g. hydrological cycle function) and enhancement of ecosystem services (e.g. runoff reduction) should be undertaken at a range of scales including at the landscape or whole ecosystem scale	Sections 3.1.3 and 5.1.1 Expert interview data (Appendix 3 and section 3.1.3) Figures 3.4 and 3.5

Ref.	Overarching guidance	Reference(s)
		Tables 3.4 and 4.7
Overarching Guidance Category No.4: *Planning and intervention*		
Habitat_7	Where possible, habitat network protection, enhancement and restoration measures should be designed to support as wide a range of native species as possible. In habitat network modelling this can be facilitated through the use of a Generic Focal Species (GFS) designed to capture a broad range of objectives (e.g. conservation, landscape, climate change adaptation). In any event, habitat networks should be designed to support priority species (e.g. those identified in the UKBAP, the relevant LBAP etc)	Section 5.1.1 and 5.2.2
Habitat_8	Use sensitivity analysis in habitat network modelling (e.g. running models using a range of different parameters for patch size and dispersal distance) to reflect the uncertainty inherent to the modelling techniques used (e.g. lack of data on species ecology, over reliance on Generic Focal Species etc). Model outputs produced through analyses using a range of different parameters can then be evaluated before habitat network model data is used to inform urban land use/management strategies, including Local Development Plans (LDPs)	Section 5.2.2

Technical guidance for interpreting and acting on habitat network model outputs in the development of integrated urban land use/management strategies

Ref.	Technical guidance	Reference(s)
Habitat_A	Identify possible **synergies and areas of overlap** between LDP related land use/management proposals (as identified through the modelling) and objectives, policies, actions etc from **related land use delivery mechanisms**, especially: 1) Scottish Planning Policy (SPP); 2) Strategic Development Plans; 3) relevant Development Management decisions; 4) River Basin Management Plans (RBMPs); 5) Flood Risk Management Strategies; and 6) Scotland's Land Use Strategy. Where relevant, consider how these opportunities can be developed through partnership working and the use of formalised partnership agreements	Expert interview data (Appendix 3 and section 3.1.1) Figure 3.1 Phillips et al (2014)

Ref.	Technical guidance	Reference(s)
Habitat_B	**First priority:** Existing **habitat patches** identified through the habitat networks model should be the priority for land use/management intervention that enhances ecological networks. In the first instance, areas of high quality habitat that are not protected or in active management should be improved (e.g. afforded protection through planning policy and brought back into active management). Following this, areas of habitat with restoration potential should be restored and improved. Both of these interventions will require a degree of ground-truthing beyond the outputs of the habitat networks model - e.g. to assess habitat quality and identify required management intervention. Where possible, all habitat network management activities should be fully integrated with water management related land use/management and green infrastructure intervention (see Appendices 7 and 8) and designed to deliver a broad range of other ecosystem services, as required given the specific context	Sections 5.2.2 and 5.3 Tables 5.1 and 5.2 Figures 5.2, 5.3, 5.4 and 5.5 Smith et al (2008)
Habitat_C	**Second priority:** Land use intensity **within existing functional habitat networks** identified through the habitat networks model should be maintained or reduced to improve the landscape matrix (e.g. adoption of specific planning policy to protect existing connectivity). This can have the effect of maintaining or improving ecological connectivity - i.e. areas of 'low-cost' matrix should be maintained where possible. Where possible, all habitat network management activities should be fully integrated with water management related land use/management and green infrastructure intervention (see Appendices 7 and 8) and designed to deliver a broad range of other ecosystem services, as required given the specific context	Sections 5.2.2 and 5.3 Tables 5.1 and 5.2 Figures 5.2, 5.3, 5.4 and 5.5 Smith et al (2008)
Habitat_D	**Third priority:** Land use intensity **adjacent to existing functional habitat networks** identified through the habitat networks model should be reduced to improve the landscape matrix (e.g. adoption of specific planning policy to protect existing connectivity, improving the management of isolated patches that are not functionally connected). This can have the effect of improving ecological connectivity by increasing functional connectivity - i.e. areas of 'low-cost' matrix should be increased where possible. Where possible, all habitat network management activities should be fully integrated with water management related land use/management and green infrastructure intervention (see Appendices 7 and 8) and designed to deliver a broad range of other ecosystem services, as required given the specific context	Sections 5.2.2 and 5.3 Tables 5.1 and 5.2 Figures 5.2, 5.3, 5.4 and 5.5 Smith et al (2008)

Ref.	Technical guidance	Reference(s)
Habitat_E	**Fourth priority:** The **creation/recreation** of new areas of natural/semi-natural habitat should be considered **within existing functional habitat networks** identified through the habitat networks model. This can have the effect of improving ecological connectivity by increasing functional connectivity (i.e. the addition of new patches can have the effect of increasing the total area of functionally connected habitat/contiguous habitat network). Where possible, all habitat network management activities should be fully integrated with water management related land use/management and green infrastructure intervention (see Appendices 7 and 8) and designed to deliver a broad range of other ecosystem services, as required given the specific context	Sections 5.2.2 and 5.3 Tables 5.1 and 5.2 Figures 5.2, 5.3, 5.4 and 5.5 Smith et al (2008)

Appendix 7: Evaluation of existing ecosystems approach based land use planning frameworks

Key to scoring	Case study ecosystems approach based urban land use planning frameworks					
Principle considered / *Considered to a degree* / *Principle not considered*	**THESAURUS**		**EERA**		**Green Network Opportunities Mapping**	
	References: Collingwood Environmental Planning and Geodata Institute, 2008a; Defra, 2008; Sheate et al, 2012		**References:** East of England Regional Assembly, 2007; East of England Regional Assembly, 2008		**References:** GCV Green Network Partnership, 2011; GCV Strategic Development Planning Authority, 2011	
Ecosystems approach principle	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**
EsA 1. Consider effects on ***adjacent ecosystems***		**To a degree** – the ecosystem service typology adopted in the THESAURUS approach considers key ecosystem processes and intermediate services[1] including hydrological cycling and wildlife habitats/networks. Although not stated explicitly, these services are likely to have implications beyond the boundaries of single ecosystems e.g. strategic habitat networks, hydrological cycle impacts of vegetation on adjacent catchments (transpiration and transportation of water) etc		**To a degree** – the EERA approach recommends that additional spatial environmental information is used in conjunction with environmental limits maps for the study area (see EsA 3). The intention is to provide a wider contextual understanding (e.g. in spatial terms) of the implications for spatial planning. The approach also considers broader scale issues beyond the geographical scope of the study area including "opportunities to import, recreate or substitute the services [provided by the study area]" (EERA, 2008 p.20)		**To a degree** – the approach is designed primarily for use in an urban context with a focus on urban greenspace enhancement, access improvements and meeting the greenspace/green infrastructure needs of new development. In this regard, opportunities to think strategically about effects on adjacent ecosystems are limited. However, the approach does include provision for consideration of wider/landscape scale issues through the analysis of individual high scoring cells (i.e. clustered priorities where multiple high scoring cells cluster together are generally focussed around urban areas with multiple green network issues). These cells often represent habitat enhancement opportunities in the wider countryside
EsA 2. Conserve ecosystem ***structure*** *and* ***function***		**Principle considered** – as per the above, the ecosystem service typology incorporates key ecosystem processes/intermediate services, many of which are key for ecosystem structure and function. Crucially, natural succession is also considered, exemplifying the importance of ecosystem structure i.e. maintaining diversity in ecosystem structure by natural processes		**To a degree** – EERA's approach to mapping environmental limits (see EsA 3) is based on state based indicators for discrete environmental topics taken from strategic environmental assessment (SEA) legislation[2]. This sort of topic based approach works against the integrated nature of ecosystems though there is recognition that the approach has been dictated by data availability i.e. the data required to support ecosystem service based indicators wasn't available (see section 3.2.1). Ecosystem function		**To a degree** – the approach includes some consideration of ecosystem structure and function issues though the focus is very much on ecological connectivity (i.e. joining up areas of fragmented habitat) as opposed to wider ecosystem processes/intermediate services such as water cycling and soil formation (see section 3.2.2). Consideration of EsA 2 type issues is facilitated through the use of a biodiversity opportunities layer that "identifies locations where intervention would yield the greatest

[1] The typology and definition of ecosystem services considered in this research is provided at section 3.2.2
[2] See Annex I of the EC SEA Directive: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:197:0030:0037:EN:PDF [accessed 01/02/14]

Key to scoring	Case study ecosystems approach based urban land use planning frameworks					
Principle considered (dark green)	THESAURUS		EERA		Green Network Opportunities Mapping	
Considered to a degree (mid green); *Principle not considered* (light green)	**References:** Collingwood Environmental Planning and Geodata Institute, 2008a; Defra, 2008; Sheate et al, 2012		**References:** East of England Regional Assembly, 2007; East of England Regional Assembly, 2008		**References:** GCV Green Network Partnership, 2011; GCV Strategic Development Planning Authority, 2011	
Ecosystems approach principle	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**
	Principle considered		Considered to a degree	issues are picked up to a degree by some of the topic indicators e.g. land and marine based flora and fauna considers ecosystem resilience and stability issues	Considered to a degree	benefit in terms of improving habitat connectivity" (GCV Green Network Partnership, 2011 p.13)
*EsA 3. Ecosystem management must respect environmental **limits***	Principle not considered	**Principle not considered** (either explicitly or implicitly)	Principle considered	**Principle considered** – consideration of environmental limits and capacity is the key objective of the EERA approach. Environmental limits are defined using state based indicators (see section 3.2.1) for key environmental issues/topics (see EsA 2) drawing on readily available data. A two phase model is used where the issue/topic is described as either within or exceeded in relation to the defined limit. Limits are identified with reference to literature, policy and through stakeholder engagement	Principle not considered	**Principle not considered** (either explicitly or implicitly)
*EsA 4. Adopt the ecosystems approach at appropriate **spatial** and **temporal***	Considered to a degree	**To a degree** – the approach recognises how a "typology of ecosystem services can be developed for any location and at any scale" (Sheate et al, 2012 p.7). There is also consideration of how different stakeholders can help understand the context specific value of ecosystem services at different scales. Crucially	Principle considered	**Principle considered** – the approach is designed to operate at the regional/sub-regional scale. Although this will be defined by administrative boundaries (i.e. the Regional Spatial Strategy area), such a broad scale will likely encompass key natural features e.g. strategic ecological networks, catchments etc. Indeed there is explicit	Principle considered	**Principle considered** – the approach includes extensive consideration of issues relating to spatial scale. The GIS based element is designed for use at the local authority[3] scale though it identifies priorities/opportunity areas at the local scale. For example, the analysis undertaken for the West Dunbartonshire Council (WDC) area

[3] Local authorities in Scotland are responsible for the provision of a range of services such as roads and transport, education, social work, economic development, housing and environment. They are administrative regions that represent Scotland's diversity in population distribution (and therefore other geographical issues by proxy e.g. topography, accessibility, remoteness etc). For example, Dundee City Council is only 26m^2 in area whereas the Highlands Council is 12, 437m^2. Unsurprisingly, the former is also much more densely populated than the latter. As such, although there is no one size fits all definition of local authority spatial scale, local authority areas are likely to be sufficiently broad such that they encompass key natural features like water catchments and strategic ecological networks: http://www.scotland.gov.uk/Topics/Government/local-government/localg [accessed 03/02/14]

Key to scoring			Case study ecosystems approach based urban land use planning frameworks					
Principle considered			THESAURUS		EERA		Green Network Opportunities Mapping	
Considered to a degree			**References:** Collingwood Environmental Planning and Geodata Institute, 2008a; Defra, 2008; Sheate et al, 2012		**References:** East of England Regional Assembly, 2007; East of England Regional Assembly, 2008		**References:** GCV Green Network Partnership, 2011; GCV Strategic Development Planning Authority, 2011	
Principle not considered								
Ecosystems approach principle		**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**	
	scale		the approach has also been tested at different scales – sub-regional (i.e. the whole of the Kent Thameside area) and local (i.e. for a specific settlement within the study area). There is no specific consideration of the ecological rationale for using different scales and neither is there any reference to temporal issues		recognition of how "consideration of environmental limits requires thinking at a broad spatial scale" (EERA, 2008 p.8). Crucially, the EERA approach also considers temporal scale issues including the need to balance land use conflicts in time and space. The consideration of pressures and trends in relation to the environmental issues/topics for which limits have been defined is an additional temporal element		identified four hotspots for green network intervention at either the town and neighbourhood scale. Similarly, outputs are designed to feed into LDP policy at broader scales as well as informing masterplans, design studies and, ultimately, Development Management decisions at the neighbourhood and site scales (see section 3.1.3). Temporal scale issues are considered implicitly as the outputs of the approach are designed to inform LDP green network policy. In this regard, green network policy (as with other areas of policy within the LDP) should focus on proposals up to year 10 from the LDP's adoption (Scottish Government, 2009b)	
	EsA 5. Set ***long term objectives*** *for ecosystem management*		**Principle not considered** (either explicitly or implicitly)		**To a degree** – as per EsA 4 above, the EERA approach incorporates consideration of key temporal scale issues. Specific timescales are not defined however (e.g. quantifying what is meant by long term in relation to environmental pressures and trends as well as objectives for spatial planning)		**To a degree** – as per EsA 4 above, the approach incorporates implicit consideration of key temporal scale issues though specific timescales are not defined. In essence though, this would be the role of the local authority (i.e. the green network opportunities mapping is undertaken by the GCV Green Network Partnership on behalf of the eight local authorities within the GCV region)	
	EsA 6. Ecosystem management must recognise that ***change is inevitable***		**Principle not considered** (either explicitly or implicitly)		**Principle not considered** (either explicitly or implicitly)		**Principle not considered** (either explicitly or implicitly)	

Key to scoring	Case study ecosystems approach based urban land use planning frameworks					
Principle considered (dark green)	**THESAURUS**		**EERA**		**Green Network Opportunities Mapping**	
Considered to a degree (mid green); *Principle not considered* (light green)	**References:** Collingwood Environmental Planning and Geodata Institute, 2008a; Defra, 2008; Sheate et al, 2012		**References:** East of England Regional Assembly, 2007; East of England Regional Assembly, 2008		**References:** GCV Green Network Partnership, 2011; GCV Strategic Development Planning Authority, 2011	
Ecosystems approach principle	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**
*EsA 7. Understand and manage the ecosystem in an **economic context***		**To a degree** – a key part of the rationale for this approach is recognition that ecosystem services are context specific (i.e. ecosystem services are more or less valuable depending on a range of contextual issues such as population density, flood risk, soils etc). Context in this regard can also include consideration of existing planning and management arrangements for ecosystems including key economic issues such as costs associated with land management for a given level of service		**To a degree** – there is a strong emphasis on the value and importance of ecosystem services including recognition that "large sections of the economy are dependent on a high quality natural environment" (EERA, 2008 p.7). Operationally, the approach has been designed to facilitate the transparent consideration of conflicts and trade-offs between different ecosystem services (or aspects of the environment providing the services) including the use of sensitivity analysis in the GIS mapping of environmental limits (e.g. to explore stakeholder preferences for specific services). However there is no specific consideration of costs and benefits		**Principle considered** – the approach has a distinct focus on the need to understand and manage green networks and the urban natural environment in an economic context. In particular, the GIS analysis seeks to answer the question "where are the major areas of land use change" (GCV Green Network Partnership, 2011 p.11) through the use of spatial datasets on development and regeneration sites. In essence, areas of change and investment are regarded as opportunities for the enhancement of ecosystems and ecosystem services (e.g. through the creation of habitat mosaics that are integrated with development to provide key ecosystem services such as water management, climate regulation and environmental settings). There is also a particular focus on the role of the planning system delivering "multiple green network [ecosystem service] benefits through the targeting of resources" (GCV Green Network Partnership, 2011 p.18). Other than ecological connectivity and access networks/recreation however the approach does not include provision for the spatial analysis/targeting of any other ecosystem services
*EsA 8. Ensure an appropriate **balance** between **conservation***		**To a degree** – biodiversity (and other important elements of biodiversity including habitats, semi-natural greenspace and ecological networks) is incorporated within the ecosystem service typology adopted in this approach. However there is no specific method, approach		**Principle not considered** – biodiversity issues are incorporated to a degree within the selection of state indicators for mapping environmental limits (i.e. land and marine based flora and fauna). However there is no specific method, approach or mechanism identified for balancing		**Principle not considered** – biodiversity issues are incorporated to a degree within the biodiversity opportunities dataset though there is no specific method, approach or mechanism identified for balancing conservation with use of biodiversity

Key to scoring	Case study ecosystems approach based urban land use planning frameworks		
Principle considered (dark green)	**THESAURUS**	**EERA**	**Green Network Opportunities Mapping**
Considered to a degree (mid green)	**References:** Collingwood Environmental Planning and Geodata Institute, 2008a; Defra, 2008; Sheate et al, 2012	**References:** East of England Regional Assembly, 2007; East of England Regional Assembly, 2008	**References:** GCV Green Network Partnership, 2011; GCV Strategic Development Planning Authority, 2011
Principle not considered (light green)			

Ecosystems approach principle	Score	Summary comments/rationale	Score	Summary comments/rationale	Score	Summary comments/rationale
*and **use** of biodiversity*		or mechanism identified for balancing conservation with use of biodiversity		conservation with use of biodiversity		
*EsA 9. **Objectives** for ecosystem management are a matter of **societal choice***		**To a degree** – the approach defines stakeholders as "anyone who believes they have a stake/is thought to have a stake in a specific issue or activity relating to the Kent Thameside Green Grid (KTGG). They may be individuals or representatives of organisations, government bodies or groups of interest" (Sheate et al, 2012 p.8). In this regard, the approach includes clear provision for engagement with a broad range of stakeholders (including local communities and other publics) that may facilitate the development of ecosystem management objectives through societal choice. Despite this, the research only engaged with technical stakeholders/agencies so this premise is yet to be tested		**Principle considered** – as per section 3.2.1, the EERA approach recognises that there are two ways in which environmental limits can be determined i.e. scientifically or socially determined. Crucially, the approach recognises that "environmental limits need to be predetermined and supported by stakeholders" and how "the UK's democratic planning process lends itself well to this approach" (EERA, 2008 p.12). The EERA project was only able to engage technical stakeholders, presumably due to available resources as per Sheate et al (2012), but recognises that stakeholder views in this regard can provide a proxy for the views of the wider public. Were the approach to adopted wholesale in spatial planning, it is feasible that the wider public would be engaged in the process of determining environmental limits		**Principle not considered** – the approach provides a technical, GIS-led solution for developing "robust and defensible green network policies for LDPs" (GCV Green Network Partnership, 2011 p.1). Although, in principle, the outputs of the approach will inform proposals within MIRs (which will themselves be subject to extensive public consultation – see section 3.1.2), the approach itself is designed to be undertaken by GIS technicians/planners without wider input from the public or affected communities
*EsA 10. Ecosystem management should be **decentralised** to the **lowest** appropriate level*	**?**	**Unknown** – development of the approach to date has only considered key practical issues concerning identifying the ecosystem services in a given area, linking these to land use/cover using network analysis and mapping ecosystem services using GIS. The approach has not yet informed practical land use/management decision-making		**Principle not considered** (either explicitly or implicitly)		**To a degree** – as described at EsA 4, the approach is designed to identify priority areas for green network/urban natural environment enhancement projects. There is strong recognition of the economic practicalities of such projects (see EsA 7) and the approach accounts for this, to a degree, by promoting the (implicit) decentralisation of management responsibility to developers, landowners and community groups
EsA 11.		**To a degree** – see comments above against EsA		**Principle considered** – see comments above		**Principle not considered** – see comments above

Key to scoring		**Case study ecosystems approach based urban land use planning frameworks**					
Principle considered	(dark green)	**THESAURUS**		**EERA**		**Green Network Opportunities Mapping**	
Considered to a degree	(mid green)	**References:** Collingwood Environmental Planning and Geodata Institute, 2008a; Defra, 2008; Sheate et al, 2012		**References:** East of England Regional Assembly, 2007; East of England Regional Assembly, 2008		**References:** GCV Green Network Partnership, 2011; GCV Strategic Development Planning Authority, 2011	
Principle not considered	(light green)						
Ecosystems approach principle		**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**	**Score**	**Summary comments/rationale**
	Consider all forms of ***relevant information*** *including scientific/local knowledge, practice and innovation*	(To a degree)	9. There is a specific opportunity to incorporate a range of relevant information through the specific GIS methodology adopted: " the assumptions made[when combining spatial data sets in the GIS to evaluate proxy ecosystem services] and their relative weight would be an opportunity for stakeholders to become involved and tailor the process to locally selected criteria" (Sheate et al, 2012 p.18)	(Considered)	against EsA 9. The approach recognises the importance of engaging stakeholders and the wider public in the determination of environmental limits. This approach will allow for the consideration of a range of different information including "local perceptions of the relative value of environmental features or benefits" (EERA, 2008 p.14)	(Not considered)	against EsA 9
	EsA 12. ***Involve*** *all relevant* ***sectors of society*** *and scientific disciplines*	(To a degree)	**To a degree** – see comments above against EsA 9 and 11	(Considered)	**Principle considered** – see comments above against EsA 9 and 11	(Not considered)	**Principle not considered** – see comments above against EsA 9

Appendix 8: Flood control model step-by-step instructions and example outputs

Specific technical guidance for undertaking all geoprocessing operations described in this Appendix is available from the ArcGIS online help resources:

ArcGIS online help for buffer operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//000800000019000000
[accessed 23/11/13]

ArcGIS online help for clip operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//000800000004000000
[accessed 23/11/13]

ArcGIS online help – use of the summary statistics tool:
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00080000001z000000 [accessed 23/11/13]

Distance is measured using the ArcGIS measurement tool. Further information is available from ArcGIS online help:
http://help.arcgis.com/en/arcgisexplorer/help/index.html#//015600000002000000
[accessed 23/11/13]

ArcGIS online help – selecting and extracting data:
http://resources.arcgis.com/en/help/main/10.1/index.html#/Selecting_and_Extracting_data/018p00000005000000/ [accessed 23/11/13]

ArcGIS online help – creating new features:
http://resources.arcgis.com/en/help/main/10.1/index.html#//01m700000022000000
[accessed 23/11/13]

Flood Control Model Step 1: is the catchment subject to significant flood risk?

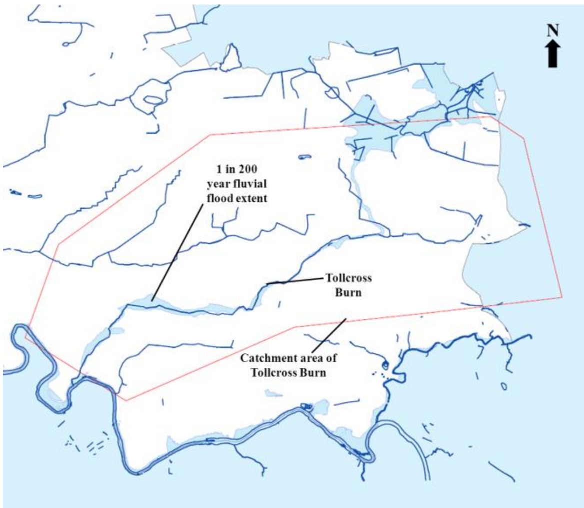
Step-by-step instructions and example outputs

Purpose of Step 1: *to identify whether the catchment being investigated is subject to significant flood risk*

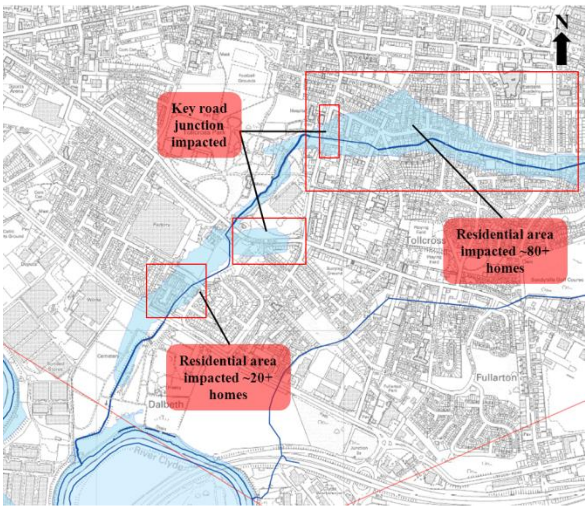
Supporting technical information in Chapter 4 – relevant sections	4.1, 4.2 and 4.3
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.1

Key Tasks to undertake in Step 1 of the flood control model

Task	Instructions
T1.1	• Open ArcMap and add the following data, ensuring that all layers are switched on: ➢ waterbodies ➢ catchment area ➢ 1 in 200 year fluvial flood extent ➢ suitable base mapping • Further information on data is provided at section 2.4.2
T1.2	• Review the data by eye • Are there areas within the catchment that are likely to flood under the 1 in 200 year flood event? If yes proceed to Task 1.3 • It may also be desirable to quantify the area of the catchment that is likely to flood under the 1 in 200 year flood event. This could be presented as a percentage of the total catchment area. Use data in the attribute table and the statistics tool in ArcMap to calculate areas
T1.3	• Identify key areas within the catchment where flooding is likely to occur under the 1 in 200 year flood event • Ensure that the base mapping layer is active and zoom in to the affected areas – are there any receptors that may be impacted by the flood? See the example figure opposite • If yes proceed to Task 1.4
T1.4	• Where the 1 in 200 year flood event is likely to impact receptors, make a broad estimation of the type and number of receptors affected • Record this data (see the example



Flood control model Step 1, T1.1 – example model output: hydrology and fluvial flood extent for the Tollcross Burn catchment



Flood control model Step 1, T1.3 and T1.4 –

	output table below) and move on to Step 2 of the flood control model	***potential flooding impacts at Tollcross and Braidfauld under a 1 in 200 year flood event***

Flood control model Step 1 example data recording sheet

Catchment	Neighbourhood	Residential properties impacted	Major roads impacted
Tollcross Burn	Tollcross	Housing at Ardgay St, Glenalmond St and Amurlee St – circa 80+ homes affected	Wellshot Rd at Shettleston Library and Learning Centre
			Tollcross Rd at junction with Wellshot Rd
	Braidfauld	Housing at Potter St and Rattray St – c 20+ homes potentially affected	London Rd/A74 at Potter St

Flood Control Model Step 3: are there significant areas of openspace within the floodplain?

Step-by-step instructions and example outputs

Purpose of Step 3: *to identify the floodplain openspace resource that may be available for the development of floodplain NFM measures*

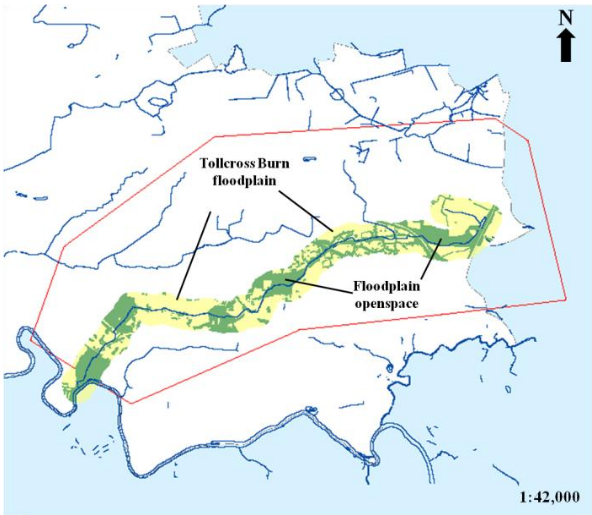
Supporting technical information in Chapter 4 – relevant sections	4.2, 4.3, 4.4, 4.6 and 4.7
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.3

Key Tasks to undertake in Step 3 of the flood control model

Note: Step 3 should use the same ArcGIS project (.mxd file) set-up at Step 1

T3.1
- Buffer the waterbodies layer
- Detailed geoprocessing instructions for carrying out buffering operations in ArcGIS are available from ArcGIS online help. Guidance on selecting an appropriate width for the floodplain cross-section for use in the buffer operation is provided below

T3.2
- Add the PAN65 openspace data to ArcMap
- Clip the PAN65 openspace data to the output from the waterbodies buffer operation (i.e. the modelled approximation of the floodplain generated through Task 3.1)
- Detailed geoprocessing instructions for carrying out clip operations are available from ArcGIS online help



Flood control model Step 3, T3.1 and T3.2 – modelled approximation of the floodplain and identification of the floodplain openspace resource

T3.3
- Calculate the cumulative area of floodplain openspace falling within the study catchment – this is the output from the Task 3.2 clip operation
- Instructions for how this calculation can be carried out in ArcGIS are available from ArcGIS online help

Tollcross Burn floodplain openspace metrics		
Area of catchment (ha)	Total area of floodplain openspace (ha)	Percentage of catchment area comprised of floodplain openspace (%)
2621.5	**133.6**	**5.1**

Flood control model Step 3, T3.1 and T3.2 – floodplain openspace metrics

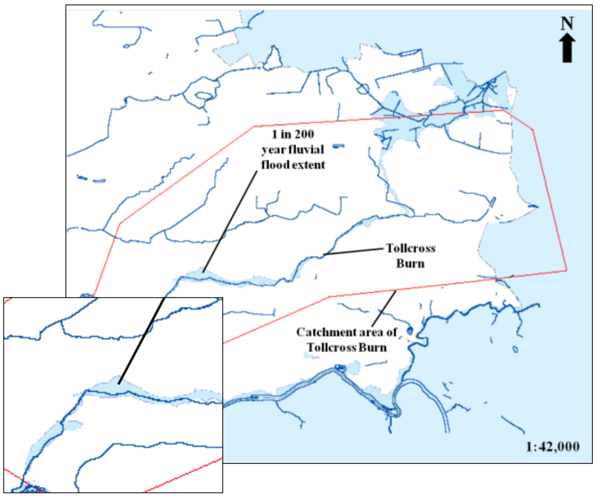
T3.4
- Calculate the percentage area of the study catchment that is comprised of floodplain openspace
- Where this is greater than or equal to 2%, the practitioner may wish to progress to Step 4

Flood control model Step 3 – guidance on the selection of buffer parameters for T3.1

Context

Step 3 of the flood control model is predicated on modelling an approximation of the functional floodplain within the study catchment of interest. The Scottish Government (2010) and SEPA (2012) suggest that in SFRA for land use/development planning purposes, the functional floodplain can be considered as synonymous with the area encompassed by the 0.5% probability (1 in 200 year return period) fluvial flood extent data supplied by SEPA. However this data does not give a true representation of the functional floodplain as it takes account of existing flood defences, anthropogenic geomorphological changes etc in its delineation of flood extent – i.e. stretches of the watercourse that are not currently connected with their floodplain and therefore do not have a natural flooding regime in place. The flood control model developed in this research is intended to provide urban planners with a forward looking planning tool that can support the development of visionary land use plans and projects. Accordingly, Step 3 takes a much broader view of the potential functional floodplain, thereby supporting the identification of restoration options that may be viable in the future (e.g. where land use change is proposed). Further information on FRM planning and approaches is provided at section 2.5

- Step 3 Task 3.1 models an approximation of the floodplain is by buffering the study watercourse in the GIS
- The dimension for the buffering operation (i.e. half the floodplain cross-section) is ascertained by measuring the distance (at right angles to the watercourse) of the width of the fluvial flood risk area at its greatest extent. This exercise uses SEPA's 0.5% probability fluvial flood extent data as indicated on the figure opposite
- This measurement is then inputted to the buffering operation in the GIS when modelling the floodplain
- In adopting the measurement protocol outlined above, the floodplain modelling exercise at T3.1 will always yield a uniform floodplain. This is considered appropriate given the objective of the exercise – see section 5.1.3 for further information



Ascertaining the buffer parameter used at Step 3 T3.1 – identifying the width of the fluvial flood risk area at its greatest extent in the study catchment

Flood Control Model Step 4: is the watercourse subject to morphology pressures?

Step-by-step instructions and example outputs

Purpose of Step 4: *to identify whether the watercourse being investigated is subject to the types of morphology pressure that lend themselves to being addressed as part of land use/management based NFM schemes*

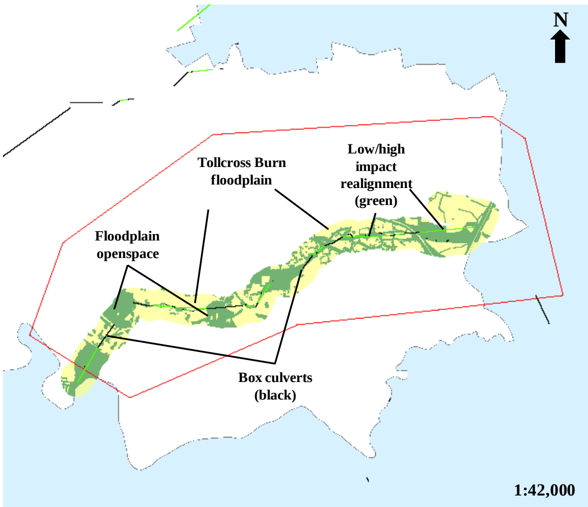
Supporting technical information in Chapter 4 – relevant sections	4.4 and 4.5
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.4

Key Tasks to undertake in Step 4 of the flood control model

Note: Step 4 should use the same ArcGIS project (.mxd file) set-up at Step 1

T4.1

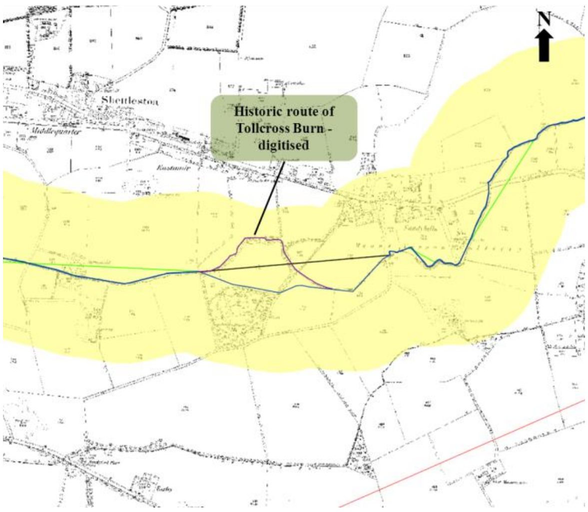
- Add the morphology pressures data to ArcMap, extracting culvert and realignment pressures if necessary. Guidance on data extraction using the select tool in ArcGIS is available from ArcGIS online help
- Overlay the pressures data with the floodplain openspace layer (output from Step 3) and identify (by eye) areas where the two features are coincidental



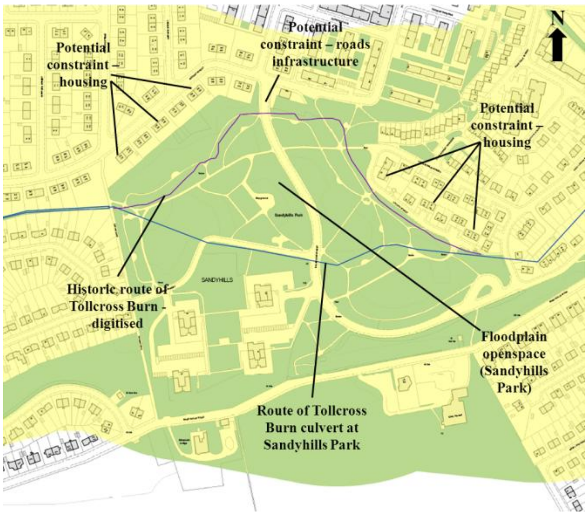
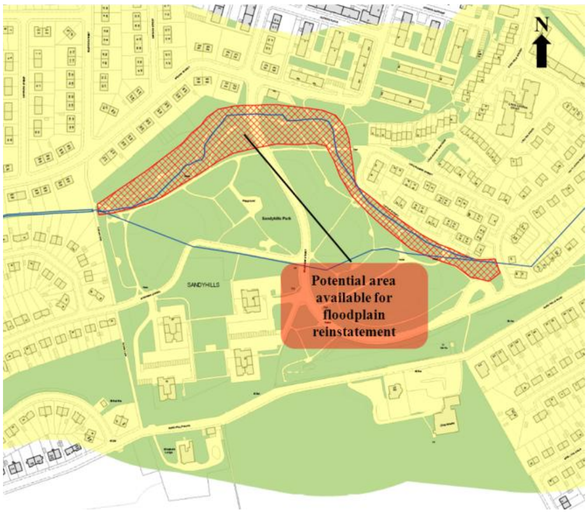
Flood control model Step 4, T4.1 – coincidental floodplain openspace and morphology pressures

T4.2

- Zoom in to a site of interest where floodplain openspace and morphology pressures are coincidental
- Add the historic (1860s) viewing raster to ArcMap
- Identify the historic route of the watercourse and digitise the historic route. Guidance on digitising in ArcGIS is available from ArcGIS online help
- The figure opposite clearly shows how there is a marked difference between the historic route of the watercourse (shown in purple) and the culverted route of the watercourse (shown in blue)



Flood control model Step 4 T4.2 – digitising historic /pre-modification route of the study watercourse

T4.3	• Turn off the historic (1860s) viewing raster and turn on modern base mapping including the 1:10000 viewing raster and OS MasterMap, ensuring that the newly digitised historic watercourse layer is on • View the site at a range of scales using different modern base mapping and identify constraints to restoring the historic route of the watercourse: ➢ housing ➢ other buildings ➢ roads infrastructure • Ideally, the watercourse will be restored as close as possible to its original route though modern constraints may predicate this • This type of restoration approach can help water environment stakeholders access funding for project delivery, such as national funding programmes under the Water Framework Directive	 ***Flood control model Step 4, T4.3 – identifying possible constraints to river restoration***
T4.4	• Based on the constraints identified at Task 4.3, digitise the approximate area within the study site that may be available for floodplain reinstatement. **Note:** this is a broad estimate at this stage and doesn't account for other constraints such and topography or underground infrastructure • Make a note of the potential area of the reinstated floodplain (i.e. the area of the newly digitised polygon – see bullet point above) and the key constraints to floodplain reinstatement • Key constraints to river restoration at the site in the figure opposite are summarised at the end of this table	 ***Flood control model Step 4, T4.4 – digitising the potential reinstated floodplain based on T4.3 constraints***
Note	Tasks 4.2 – 4.4 should be repeated for all sites identified at Task 4.1 where culvert and realignment pressures are coincidental with areas of floodplain openspace. All potential floodplain reinstatement areas identified at T4.4 should be digitised. These are all potential NFM priority areas in their own right and could feasibly be used in the integration of spatial model outputs to identify ecosystem service priority areas (see Chapters 4 and 6)	

The wider multiple benefits of river restoration

- River restoration is one of several land use/management based NFM measures considered in this research. Although restoring a watercourse to its original route will support a range of FRM benefits (e.g. reinstating a meander will increase the overall length of the watercourse, contributing to hydraulic improvements and helping to delay downstream flood flows etc), restoration as part of a wider land use/management based strategy has the potential to enhance FRM benefit whilst also delivering wider multiple benefits

- A key example is the introduction and/or restoration of floodplain woodland as described at section 2.4.5. That said, floodplain measures (such as woodland establishment) can require a sizeable river corridor to provide the physical space necessary for the establishment of sufficiently sized woodland blocks to positively influence downstream flood flows. This is in addition to other local factors such as topography that can influence the magnitude of the woodland's flood storage effect and therefore the viability of the scheme (see Appendix 3)
- As such, the constraints analysis undertaken during T4.3 should also consider how any identified housing and infrastructure constraints may impact the dimensions (including the cross-section) of any reinstated functional floodplain

Summary of constraints and details of potential floodplain reinstatement opportunities

Site details	**Housing and other built environment constraints**	**Transport infrastructure constraints**
• Catchment: Tollcross Burn • Neighbourhood: Sandyhills • Site: Sandyhills Park • Potential floodplain reinstatement area: 1.54ha	Housing at Lochay Street (approximately 20 homes)	Ardgay Street (also a bus route)
	Housing at Ardgay Street (approximately 28 homes)	Balbeggie Street (also a bus route)

Flood Control Model Step 5: is there potential for significant areas of floodplain woodland and wetland?

Step-by-step instructions and example outputs

Purpose of Step 5: *to identify whether existing or potential areas of floodplain woodland and wetland within the study catchment are significant in NFM terms*

Supporting technical information in Chapter 4 – relevant sections	4.4, 4.6 and 4.7
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.5

Key Tasks to undertake in Step 5 of the flood control model

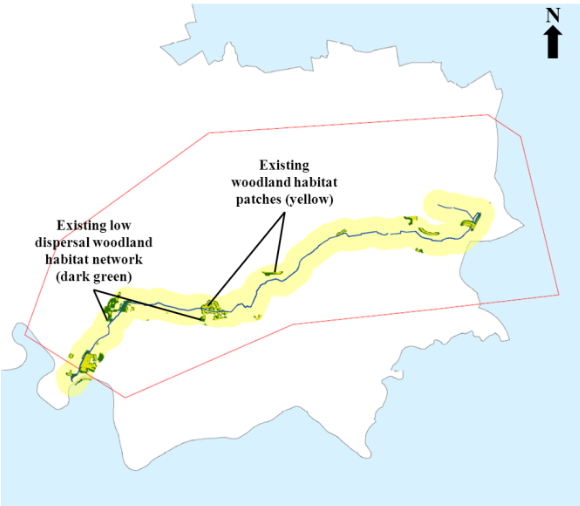
Note: Step 5 should use the same ArcGIS project (.mxd file) set-up at Step 1

T5.1

- Add the woodland and wetland habitat patches, low and high dispersal habitat networks and woodland and wetland opportunities data to ArcMap
- This is six data sets in total. Further information on these data sets can be found at section 2.4.2

T5.2

- Clip the six data sets listed at T5.1 to the output from the waterbodies buffer operation (i.e. the modelled approximation of the floodplain generated through Task 3.1)
- Detailed geoprocessing instructions for carrying out clip operations are available from ArcGIS online help



Flood control model Step 5, T5.2 – floodplain woodland habitat patches and habitat networks

T5.3

- Using the Microsoft Excel model developed through this research (example output opposite), calculate the following five habitat metrics for both floodplain woodland and wetland and record (e.g. see Table 5.3)
  - ➢ Metric 1: total area of habitat **patches** (ha)
  - ➢ Metric 2: total area of habitat **networks** (ha)
  - ➢ Metric 3: potential area available for habitat expansion (ha)
  - ➢ Metric 4: percentage of catchment area **currently comprised** of habitat (%)
  - ➢ Metric 5: percentage of catchment area **potentially comprised** of habitat (%)

Catchment area (m2)	***26215000.00***
Catchment area (ha)	2621.50
1% of catchment area	26.22
Total area of existing woodland habitat patches (m2)	***122991.32***
Total area of existing woodland habitat patches (ha)	12.30
Total area of existing woodland habitat network (m2)	***361423.32***
Total area of existing woodland network (ha)	36.14
Area potentially available for woodland expansion (ha)	23.84
Percentage of catchment area currently comprised of woodland (%)	**0.47**
Percentage of catchment area potentially comprised of woodland (%	**1.38**
Total area of existing wetland habitat patches (m2)	***16800.00***
Total area of existing wetland patches (ha)	1.68
Total area of existing wetland habitat network (m2)	***59800.00***
Total area of existing wetland network (ha)	5.98
Area potentially available for wetland expansion (ha)	4.30
Percentage of catchment area currently comprised of wetland (%)	**0.06**
Percentage of catchment area potentially comprised of wetland (%)	**0.23**

Flood control model Step 5, T5.3 – calculating floodplain habitat metrics

Note	As part of Task 5.3, practitioners should analyse output habitat metrics to help form a view of the viability of floodplain wetland and woodland as 'stand-alone' NFM strategies within the catchment under investigation (i.e. with reference to the quantified thresholds discussed at section 2.4.5). This analysis could also include consideration of sub-optimal habitat expansion sites as an alternative scenario when calculating habitat metrics (see below for further information). Alternatively, where they are not viable as stand-alone NFM strategies, floodplain woodland/wetland could be considered as part of an integrated strategy incorporating other land use/management based NFM measures

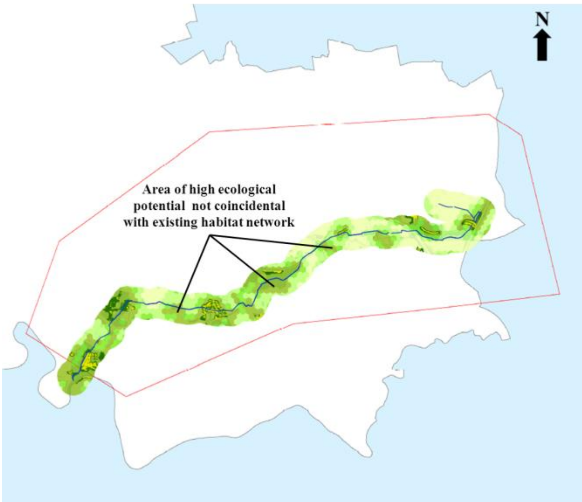
The rationale for habitat metric calculations at flood control model Step 5, T5.3

- In essence, Metric 3 is equivalent to all areas of land that are encompassed by a habitat network but where land cover is not currently classified as habitat. Habitat networks are the areas of land adjacent to habitat patches where existing land use is such that species are able to move freely within this surrounding area (see section 2.6 for further information)
- Accordingly, it is reasonable to consider areas of land within existing habitat networks as optimal sites for habitat establishment. Within the context of the flood control model therefore, these areas of land constitute potential floodplain wetland and woodland expansion areas, hence why Metric 3 is obtained by subtracting Metric 1 from Metric 2
- The ecological potential of areas of land within habitat networks is also a feature of the habitat opportunities data sets. As is evident from an analysis of Figures 5.7 and 5.8, areas of high ecological potential identified on Figure 5.8 are frequently clustered around existing habitat patches and habitat networks on Figure 5.7. This issue is an important issue when considering sub-optimal habitat expansion sites as part of floodplain woodland wetland NFM strategies (see below)

Identifying sub-optimal habitat expansion sites for floodplain habitat NFM strategies

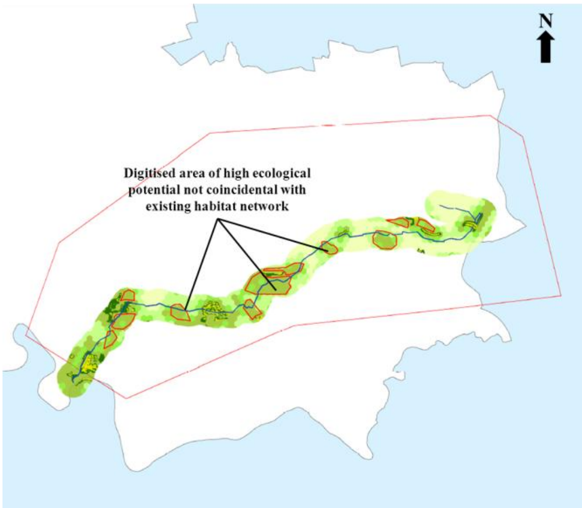
The approach presented through Tasks 5.2 and 5.3 is geared towards the identification of optimal habitat expansion sites (and associated habitat metrics) where ecological potential is particularly high i.e. areas of land within low dispersal habitat networks. Given this, there is also potential to explore habitat expansion opportunities at more marginal sites, particularly where floodplain woodland is being pursued as one element of an integrated NFM strategy (see sections 5.1.5 and 5.1.8)

An overlay of the woodland habitat opportunities data (see Figure 5.8) and the existing woodland habitat patches/networks data (see Figure 5.7) from the Tollcross Burn case study shows how significant areas of land with good ecological potential to support woodland expansion (i.e. data represented on Figure 5.8) do not coincide with existing woodland habitat patches or their habitat networks. This indicated on the figure opposite



Overlay of woodland habitat opportunities data (see Figure 5.8) and existing woodland habitat patches and networks data (see Figure 5.7)

Approximations of these outlying areas can be digitised in the GIS (see figure opposite) and a new metric calculated to give an indication of the total area of potential woodland habitat within the catchment when more marginal, sub-optimal sites are also considered as well. Woodland habitat metrics in this regard for the Tollcross Burn catchment are summarised in the table below. In light of this new calculation, there would be significant potential for floodplain woodland as a stand-alone NFM strategy as the percentage of the catchment area potentially available for woodland is well over the 2% threshold



Sub-optimal sites for floodplain woodland expansion – digitised to calculate habitat metrics under a sub-optimal scenario

Tollcross Burn floodplain woodland habitat metrics under sub-optimal scenario

Potential total area of woodland habitat – **optimal** sites (ha)	Potential total area of woodland habitat – **sub-optimal** sites (ha)	Potential total area of woodland habitat – **all** sites (ha)	Percentage of catchment area potentially comprised of woodland – **all** sites (%)
36.14	68.59	104.73	**3.99**

Flood Control Model Step 6: identify sites where opportunities are greatest and constraints minimal

Step-by-step instructions and example outputs

Purpose of Step 5: *to identify, rank and prioritise floodplain NFM measures that have the potential to deliver the greatest FRM benefit with the minimum of constraint*

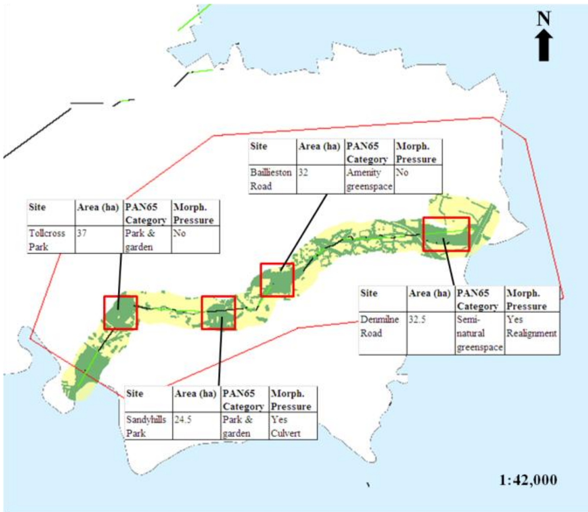
Supporting technical information in Chapter 4 – relevant sections	All sections
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.6

Key Tasks to undertake in Step 6 of the flood control model

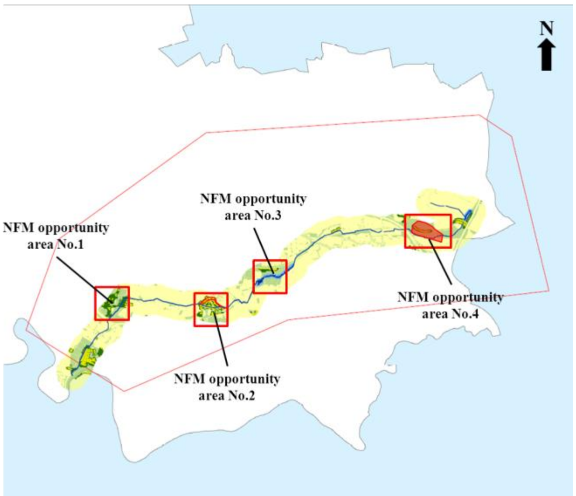
Note: Step 6 should use the same ArcGIS project (.mxd file) set-up at Step 1

T6.1

- Review outputs from Task 4.1 (map detailing the route of the study watercourse, floodplain openspace and location of morphology pressures: Fig 5.4)
- Identify floodplain openspace sites that have a direct hydrological link with the study watercourse – i.e. sites that the watercourse flows through in either a modified or unmodified state
- Review the identified sites and make a note of their area and PAN65 land use categorisation
- Select appropriate sites for further consideration in Step 6, noting whether they are 'high cost' or 'low cost'. Guidance and questions to support site selection are provided below:
  - ➢ what is the average size of floodplain openspace sites within the study catchment?
  - ➢ are there a few large outliers or are all sites of a similar size?
  - ➢ in the case of the former, it may be preferable to select large outliers only where as in the latter, it may be useful to impose a [arbitrary] size threshold e.g. *select all sites >3ha*
  - ➢ where required, PAN65 land use categorisation can be used to refine selection e.g. select sites with a higher degree of existing



Flood control model Step 6, T6.1 – NFM opportunity areas identified for the Tollcross Burn catchment (noting that two 'low cost' and two 'high cost sites' have been identified)

<table>
<tr><td></td><td>‘roughness’ e.g. choosing park & garden sites over amenity greenspace sites for example
Highlight selected sites and key information on a map (see opposite). These sites become the NFM opportunity areas</td><td></td></tr>
<tr><td>T6.2</td><td>Open the existing ArcGIS project (.mxd file) that has been used throughout the flood control model and turn on the following layers:
floodplain openspace
watercourse restoration opportunities
potential floodplain reinstatement areas
optimal sites for floodplain woodland and wetland expansion
Zoom in to NFM opportunity areas identified at Task 6.1 and make a note of NFM measures that may be available e.g. is there scope for significant floodplain reinstatement at ‘high cost’ sites? Are there existing habitat networks and is there the ecological potential to expand these?
Note: At this scale of analysis (i.e. catchment-wide scoping) it is assumed that some degree of engineering/bunding will be possible for all sites scoped in at Task 6.1. This measure should be scoped in for every NFM opportunity area</td><td>

Flood control model Step 6, T6.2 – identification of potential NFM measures and combinations of measures for each scoped in NFM opportunity area</td></tr>
<tr><td>T6.3</td><td>Review analysis undertaken at Task 6.2
Using a table such as that shown opposite (and at Table 5.7), collate a schedule of all potential NFM measures available at each NFM opportunity area
A complete schedule of possible measures (and combinations of measures) at ‘high cost’ and ‘low cost’ sites is provided at Table 5.8
Schedules of potential NFM measures identified for NFM opportunity areas No.3 and</td><td><table>
<tr><th colspan="2">Site details</th><th>Potential NFM measures available</th></tr>
<tr><td>Site</td><td>Baillieston Rd.</td><td rowspan="5">1. Leave the site as is and zone in LDP as flood storage area
2. Engineering/bunding of the site to increase flood storage capacity
3. Expansion of floodplain woodland
4. Expansion of floodplain wetland
5. Fully integrated scheme incorporating LDP zoning, engineering/bunding of the site, floodplain woodland expansion and floodplain wetland expansion</td></tr>
<tr><td>NFM Opportunity No.</td><td>3</td></tr>
<tr><td>PAN65 category</td><td>Amenity greenspace</td></tr>
<tr><td>Area (ha)</td><td>32</td></tr>
<tr><td>High/low cost</td><td>Low cost</td></tr>
<tr><td>Site</td><td>Denmilne Road</td><td rowspan="5">1. Leave the site as is and zone in LDP as flood storage area
2. Restore channel and functional floodplain and reconnect watercourse with floodplain
3. Channel/functional floodplain restoration + engineering/bunding of the site
4. Channel/functional floodplain restoration + floodplain woodland expansion
5. Fully integrated scheme incorporating channel/floodplain restoration, engineering/ bunding of the site and floodplain woodland expansion</td></tr>
<tr><td>NFM Opportunity No.</td><td>4</td></tr>
<tr><td>PAN65 category</td><td>Semi-natural greenspace</td></tr>
<tr><td>Area (ha)</td><td>32.5</td></tr>
<tr><td>High/low cost</td><td>High cost (channelised)</td></tr>
</table>
Flood control model Step 6, T6.3 – example schedules of potential NFM measures</td></tr>
</table>

No.4 from the Tollcross Burn catchment case study are shown opposite

- Ensure that identified NFM measures are ranked on the basis of FRM benefit (see Table 5.8 for guidance)

T6.4

- Review the Microsoft Excel based MCA models for both 'high cost' and 'low cost' sites (available electronically on request)
- Where required, liaise with stakeholders as appropriate (e.g. technical colleagues, members of the public in affected areas etc) and agree cost/performance scores for each measure and MCA weightings
- **Note:** multiple MCA scenarios can be run to explore different issues, drivers and decision-making contexts. Scenarios can be developed using different weights and cost/performance scores
- For each NFM opportunity area identified (see Task 6.1), review the schedule of potential NFM measures from Task 6.3
- For each NFM opportunity area, rank the potential NFM measures on the basis of their MCA score. The higher the MCA score, the higher the FRM sustainability of the NFM measure(s) under that particular configuration of cost/performance scores and weightings. Note that this ranking exercise should be undertaken for each weighting/scoring scenario run in the MCA evaluation process
- Review the outputs of the MCA evaluation process. Where required, discuss outputs with stakeholders and agree which of the potential NFM measures or combinations of measures will be taken forward for further analysis in Steps 7 and 8
- **Note:** the MCA evaluation process described above is intended for use as a decision-

Measure	1. Likely number/total area of potential sites	2. Likely cost of intervention	3. Likely impact on Manning's n/FRM benefit	
1. leave site as is and zone in LDP as a flood storage area	0.15	-0.06	0.14	**0.23**
2. engineering/bunding of the site	0.09	-0.11	0.42	0.40
3. floodplain woodland expansion	0.09	-0.06	0.42	0.45
4. floodplain wetland expansion	0.03	-0.11	0.42	0.34
5. fully integrated NFM scheme	0.06	-0.11	0.60	**0.54**

Flood control model Step 6, T6.4 – example MCA output for 'low cost' site weighted for FRM benefit

Measure	1. Likely number/total area of potential sites	2. Likely cost of intervention	3. Likely impact on Manning's n/FRM benefit	
1. leave site as is and zone in LDP as a flood storage area	0.10	-0.24	0.06	-0.08
2. engineering/bunding of the site	0.06	-0.45	0.18	-0.21
3. floodplain woodland expansion	0.06	-0.24	0.18	**0.00**
4. floodplain wetland expansion	0.02	-0.45	0.18	**-0.25**
5. fully integrated natural FRM scheme	0.04	-0.45	0.26	-0.16

Flood control model Step 6, T6.4 – example MCA output for 'low cost' site weighted for cost

	support tool only for this particular step in the flood control model. Practitioners may just as well choose to progress to Steps 7 and 8 with different measures on the basis of other factors	

Additional information on the MCA approach

- The purpose of the MCA is to help practitioners using the flood control model prioritise NFM measures (or combinations of measures) to take forward to Steps 7 and 8. It is not intended to be an exhaustive approach, rather it is an additional element to aid decision-making
- Each measure considered in the MCA is assigned a qualitative *performance* score against criteria 1 (likely number or area of sites) and 3 (FRM benefit). Quantified *performance* scores used in the MCA are always positive. The range of qualitative and quantitative *performance* scores used in the MCA are as follows: Low (0.20), Low-Med (0.40), Med (0.60), Med-High (0.85) and High (1.0)
- Measures are also assigned a qualitative *cost* score against criterion 2 (likely cost of intervention). Quantified *cost* scores used in the MCA are always negative. The range of qualitative and quantitative *cost* scores used in the MCA are as follows: Low (-0.4), Med (-0.75) and High (-1.0). At ‘high cost’ sites, the *cost* score is always High (-1.0)
- The MCA weights *cost* and *performance* scores before summing to give an overall MCA score for each measure (or combinations of measure) considered. Weightings and the *cost/performance* scores themselves can be adjusted by the practitioner, allowing for different preferences to be expressed for different contexts. For example, if the flood control model was being used to inform the prioritisation of actions in a Surface Water Management Plan (SWMP) in a high risk urban catchment, it may be appropriate to adjust the MCA weighting to put greater emphasis on FRM benefit and less on cost
- In addition to the MCA, practitioners may wish to undertake further prioritisation of potential NFM measures on the basis of metrics produced at Steps 4 and 5 of the flood control model. For example, measures at ‘high cost’ sites (i.e. measures that will always require a degree of channel and floodplain restoration) can be prioritised where restoration would contribute to the greatest potential increase in watercourse length and/or the greatest potential increase in area of reinstated floodplain (see sections 2.4.4 and 5.1.4). Equally, measures involving floodplain woodland and/or wetland expansion (see sections 2.4.5, 2.4.6 and 5.1.5) could be prioritised where the area potentially available for habitat expansion is greatest. Integrated projects could consider a range of different metrics. The full range of metrics produced through Steps 3, 4 and 5 of the flood control model are outlined at Tables 5.3, 5.4 and 5.6 respectively

Flood Control Model Step 7: Review topographical data to identify further constraints and viability of measures

Step-by-step instructions and example outputs

Purpose of Step 7: *to estimate the gradient of the floodplain cross-section at key locations within NFM opportunity areas in order to identify further constraints on the development of NFM schemes*

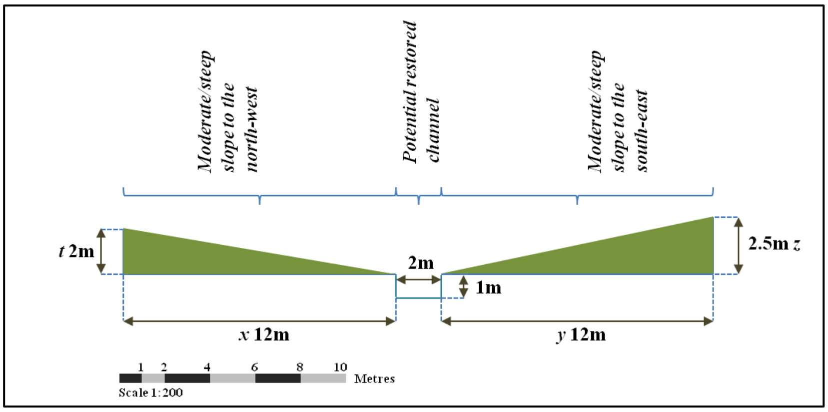
Supporting technical information in Chapter 4 – relevant sections	4.4 and 4.6
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.7

Key Tasks to undertake in Step 7 of the flood control model

Note: Step 7 should use the same ArcGIS project (.mxd file) set-up at Step 1

T7.1

- Open the existing ArcGIS project (.mxd file) and add the most detailed topographical contour data available
- Ensure that the following additional layers are switched on:
  - waterbodies (primary data set)
  - watercourse restoration opportunities
  - floodplain reinstatement area
- Zoom in to an NFM opportunity area of interest and review floodplain topography
- Identify two to three floodplain sections where the gradient is steepest. **Note:** steep gradients occur where topographical contours are closest together i.e. the greatest rate of change in elevation
- The floodplain sections identified through this process become the gradient estimation test sites
- At 'high cost' sites, measurements of 'run' (distances *x* and *y* on the figure below) will depend on the extent of the *proposed* floodplain reinstatement area defined at Task 4.4. 'Run' measurements (*x* and *y* on the figure below) should span the entire width of the proposed floodplain reinstatement area



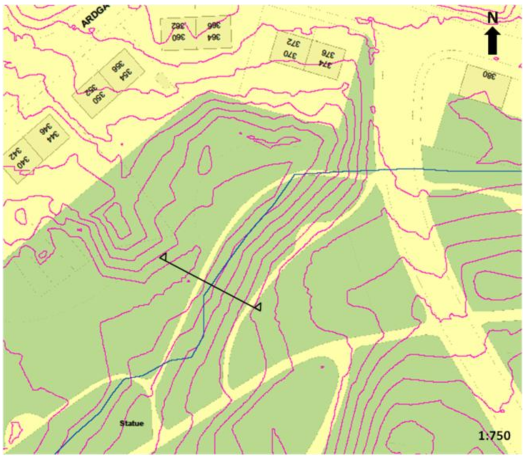
Approximate representation of floodplain cross-section at NFM opportunity area No.2 – Sandyhills Park, test site 2 (looking north-east – see plan below). Note that the four dimensions shown above (t, x, y and z) are the rise and run data that is obtained from the GIS in Task 7.2 in order to calculate gradient

- At 'low cost' sites, measurements of 'run' should correspond to the dimensions of the *existing* floodplain. This can be estimated based on the topographical data or through consultation with other relevant specialists (e.g. geomorphologists, civil engineers etc)
- Practitioners may find it useful to digitise the floodplain cross-section to be measured at each test site and produce a detailed plan of each site as shown on the figure below. This

can be a useful aid for Task 7.2 – obtaining 'rise' and 'run' data from the GIS

T7.2

- Zoom in to the gradient estimation test site
- Using the ArcGIS measure tool, measure the length of both banks of the floodplain (i.e. distances *x* and *y* on the figure above). This is the 'run' data
- With reference to the 'run' distance measured above (i.e. distances *x* and *y* on the figure above), count the number of contours crossed on both banks of the floodplain and multiply this by the contour interval of the topographical data set used. This is the 'rise' data (i.e. distances *t* and *z* on the figure above)
- In the case of the figure opposite, five contour lines are crossed on the south-east bank. The data used here is a LiDAR 0.5m topographical contour data set so the 'rise' is equal to: **5 x 0.5 = 2.5m**
- Make a note of the 'run' and 'rise' data and repeat the above for each test site



Flood control model Step 7, T7.2 – extracting data from the GIS at NFM opportunity area No.2 (Sandyhills Park) test site 2

T7.3

- For each test site, input 'rise' and 'run' data from Task 7.2 to the Microsoft Excel based gradient estimation model (available electronically on request)
- An example output from the gradient estimation model is shown opposite
- For each test site, document 'rise', 'run' and gradient data using a table such as that shown at Table 5.9

SANDYHILLS_TEST_SITE2	
South-East Bank	
Rise_Difference in elevation (m)	2.5
Run_Horizontal distance from the highest elevation to the lowest elevation (m)	12
Percent slope %	20.8
Gradient	5
North-West Bank	
Rise_Difference in elevation (m)	2
Run_Horizontal distance from the highest elevation to the lowest elevation (m)	12
Percent slope %	16.7
Gradient	6

Flood control model Step 7, T7.3 – gradient estimation model example output for NFM opportunity area No.2 (Sandyhills Park) test site 2

T7.4

- Review estimated floodplain cross-section gradients at each test site and compare results with the categorisation of potential gradient constraints (see table below)

Gradient (quantitative)	Gradient (qualitative)	Potential constraint on floodplain NFM measures
2.5% or 1:40	Very gentle	Less constrained
5% or 1:20	Gentle	
10% or 1:10	Moderate	
20% or 1:5	Moderate-steep	
33% or 1:3	Steep-moderate	
50% or 1:2	Steep	
100% or 1:1	Vey steep	Highly constrained

Categorisation of potential gradient constraint on floodplain NFM measures

- Consider the nature of proposed NFM measures (from Task 6.4) and the potential impact

	of floodplain gradients on these measures. For example: ➢ is it a 'high cost' or 'low cost' site? ➢ will earthworks be required regardless i.e. as part of channel/floodplain restoration works at a 'high cost' site? ➢ might there still be a significant FRM benefit of planting floodplain woodland across a steep floodplain? ➢ what are the potential wider benefits of floodplain woodland and wetland expansion? • Review all available information and liaise with other technical specialists as required (e.g. geomorphologists, civil engineers etc) • In light of all available information, make a decision as to the appropriateness of the proposed NFM measures from Task 6.4: ➢ retain proposed NFM measure(s) as is and proceed to scenario development in Step 8 (option for 'high cost' and 'low cost' sites) ➢ revise proposed NFM measure(s) to better account for topographical constraints[4] and proceed to scenario development in Step 8 (primarily an option for 'high cost' sites) ➢ reject proposed NFM measure i.e. no further consideration of the site in the flood control model (option for 'high cost' and 'low cost' sites) Based on the above, collate a revised list of proposed NFM measures to carry forward to the scenario development step of the flood control model (Step 8)
Note: Tasks 7.1 – 7.4 should be repeated for all NFM opportunity areas identified in Step 6. Step 7 tasks have been documented above for NFM opportunity area No.2 at Sandyhills Park. Based on the analysis described above, Sandyhills Park is considered to be relatively unconstrained in terms of floodplain topography and the NFM measure proposed at Step 6.4 has been carried forward to Step 8	

[4] This option is only likely to be viable at 'high cost' sites. It will require practitioners to revisit the analysis in Step 4 to identify alternative routes for river restoration (Task 4.2) and floodplain reinstatement areas (Task 4.4). In essence, it may be the case that restoring the floodplain to its historic/pre-modification route is not viable due to the magnitude of topographical constraints and an alternative, less steep option must be sought (in order to reduce earthworks costs to 'viable' levels – noting however that this research doesn't attempt to quantify viability).

Flood Control Model Step 8: Scenario development

Step-by-step instructions and example outputs

Purpose of Step 8: *to translate the proposed outline NFM measures from Steps 6 and 7 into more detailed scenarios*

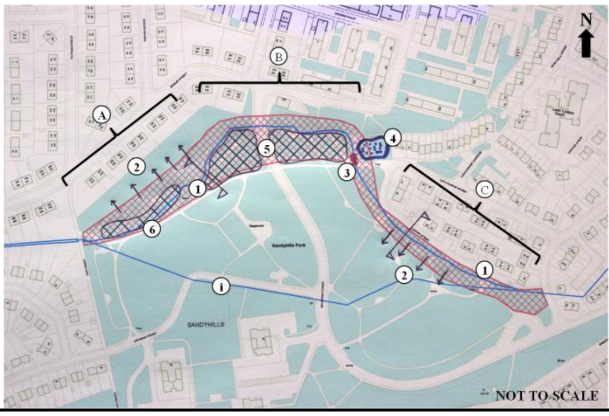
Supporting technical information in Chapter 4 – relevant sections	All sections
Supporting technical information in Appendices – relevant Appendices	3 and 4
Related sections in Chapter 7	7.2.8

Key Tasks to undertake in Step 8 of the flood control model

Note: Step 8 should use the same ArcGIS project (.mxd file) set-up at Step 1

<table>
<tr>
<td>T8.1</td>
<td>• Review key outputs from Steps 6 & 7:
➢ T6.4 – preferred NFM measure(s) as identified through MCA
➢ T7.4 – additional recommendations for preferred NFM measure(s) that may be required in order to account for topographical constraints
• Clarify the scope of the proposed NFM measure(s) and/or suggest alterations, as required, to account for topographical constraints as per T7.4
• Establish clear and ambitious objectives that articulate the vision for the scheme. Example objectives for NFM opportunity area No.2 (Sandyhills Park) are shown opposite</td>
<td>NFM opportunity area No.2: Sandyhills Park
• Proposed scope: channel restoration AND floodplain woodland expansion
• Proposed scheme objectives:
1. To open up the culverted section of the Tollcross Burn running through the park and restore it to its historic route
2. To reinstate a functional floodplain
3. To reconnect the restored burn with its floodplain wherever possible
4. To design the channel, banks and floodplain to provide maximum flood storage ecosystem services and FRM benefit
5. To expand and improve existing floodplain woodland patches to provide maximum flood storage ecosystem services and FRM benefit</td>
</tr>
<tr>
<td>T8.2</td>
<td>• Obtain[5] a high resolution digital elevation model (DEM) raster for the site
• Add this data to the existing ArcGIS project (.mxd file) used throughout the flood control model
• Interrogate the DEM to identify fine scale topographical features:
➢ relic side channels
➢ relic ponds and other depressions in the floodplain
➢ flat areas in the floodplain at a similar or lower elevation to the banks of the watercourse
• Digitise any identified fine scale topographical features, ensuring that a different feature class is used for each of the three different topographical</td>
<td>
Flood control model Step 8, T8.2 – example DEM raster. The darker the cell the lower the elevation and vice versa</td>
</tr>
</table>

[5] Alternatively a DEM can be constructed in the GIS using high resolution LiDAR topographical contour data (such as that shown at Figure 5.14). See ArcGIS online help – topo to raster (spatial analyst): http://resources.arcgis.com/en/help/main/10.1/index.html#//009z0000006s000000 [accessed 30/12/13]

	features listed above. Guidance on digitising in ArcGIS is available from ArcGIS online help	
T8.3	• Review topographical contour data for the site (see T7.1 and T8.2) • Identify steep sections of the *existing* or *proposed* floodplain • With reference to key technical information (see sections 2.4.4/2.4.6 and Appendices 1 and 2), identify where essential earthworks (e.g. to enable complete restoration of the channel and floodplain at high cost sites) and non-essential earthworks (e.g. reducing floodplain gradients in order to enhance the FRM benefit of floodplain woodland at low cost sites) may be required • Highlight recommendations indicating broad locations for essential and non-essential earthworks on a plan to inform T8.4 (see figure opposite) • Further guidance on scoping potential earthworks is provided below	 ***Flood control model Step 8, T8.3 – locations at NFM opportunity area No.2 where earthworks may be required in order to realise a desired floodplain profile*** **Note:** Proposals denoted with the number '1' are likely to be essential due to floodplain gradients at these locations. Proposals denoted with the number '2' are desirable but non-essential.
T8.4	• Review digitised fine scale floodplain topographical features from T8.2 • Review recommendations for essential and non-essential earthworks from T8.3 • Identify areas where major and minor scale earthworks may be required to realise the desired floodplain profile • Identify areas where land engineering works may be required to exploit fine scale floodplain topographical features in order to enhance flood storage ecosystem services: ➢ creation of spillways ➢ creation of floodplain scrapes on areas of flat ground ➢ creation of interconnected floodplain wetland mosaics ➢ engineering of relic side channels to increase flood storage • Mark all of the above on an outline geomorphology and land engineering strategy plan, showing the broad locations and extent of potential earthworks and other key features (see the figure opposite and explanatory key below)  ***Flood control model Step 8, T8.4 – outline geomorphology and land engineering strategy plan (see explanatory key below for further information)***	

Tollcross Burn Catchment NFM Opportunity Area No.2 (Sandyhills Park) - Outline Geomorphology & Land Engineering Strategy Plan: Explanatory Key		
Strategy plan item	**Strategy theme**	**Details**
i	Baseline	Route of existing culvert
A	Strategy zone	The primary function of this zone is FRM. Flood storage is provided by the proposed two stage channel and floodplain woodland expansion/enhancement. The provision of safe access to the water at this location is less critical and the existing topography is less constrained. Accordingly, bank and floodplain gradients can be steeper and earthworks are likely to be less onerous
B	Strategy zone	The primary functions of this zone are split equally between FRM and access/amenity. Flood storage is provided primarily by the two stage channel. Accordingly, bank and floodplain gradients will be as shallow as possible (to facilitate safe access to the water for leisure, educational purposes etc) and earthworks are likely to be onerous. The shallow gradient of the floodplain at this location will ensure that the floodplain is rapidly inundated during high flows, providing FRM benefit
C	Strategy zone	The primary function of this zone is FRM and access to the water is a low priority. Flood storage is provided primarily by the proposed floodplain woodland expansion/enhancement. This zone has the least constrained topography and earthworks are likely to be less onerous
1	Proposed intervention	Approximate location of reinstated main channel
2	Proposed intervention	Potential to increase the limit of the proposed new floodplain if desirable (on the basis of housing and road/path infrastructure constraints only)
3	Proposed intervention	Potential location of spillway to feed the floodplain scrape at Proposed Intervention 4
4	Proposed intervention	Floodplain scrape at area of flat ground to the north-east of proposed reinstated channel. The scrape should be designed to provide flood storage as well as biodiversity/habitat and amenity benefits
5	Proposed intervention	Major earthworks to create desired profile and section of the reinstated channel and floodplain at this location. To include a meandering and relatively wide and shallow main channel (where water will be located during low flows) and wet berm/wetland areas associated with the main channel that will be progressively inundated during medium-high flows. The second stage channel/wet berm area should be designed to accommodate high flows under the 200 year return period event + climate change
6	Proposed intervention	Less major earthworks to create the desired profile and section of the reinstated channel and floodplain at this location. To adopt the same design protocols as Proposed Intervention 5 though the gradient of the channel and floodplain can be steeper at this location as safe access is less critical

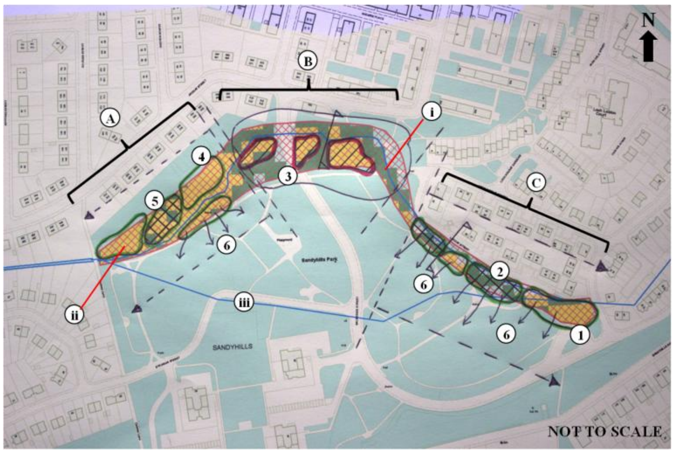
T8.5

- Review key outputs from Steps 1, 4, 5 and 6, ensuring that the following layers are switched on:
  - T1.1 – waterbodies and fluvial flood extent
  - T4.4 – potential floodplain reinstatement area
  - T5.2 – floodplain woodland/wetland habitat patches and habitat networks
  - Step 5 – sub-optimal sites for habitat expansion (where relevant)
- Revisit Step 6 (see T6.4 in particular) and identify all NFM opportunity areas where floodplain woodland/wetland enhancement has been identified as a potentially viable NFM strategy
- With reference to the above, undertake the following:
  - at 'low cost' sites where floodplain woodland and/or wetland enhancement is viable (see T6.4), identify where habitat patches/networks are located within the *existing* floodplain (i.e. the area encompassed by the fluvial flood extent data – see T1.1)
  - at 'high cost' sites where floodplain woodland and/or wetland enhancement is viable (see T6.4), identify where habitat patches/networks are located within the *potential* floodplain (i.e. the potential floodplain reinstatement area – see T4.4)
- **Consolidation of existing habitat patches for FRM benefit:** with reference to section 4.6, Chapter 5 and Appendices 4, 5 and 6, develop recommendations for consolidating

existing floodplain habitat patches to improve FRM performance. At this stage, it may be desirable to refer to any existing management plans[6] to inform the development of recommendations, for example:

- ➢ is the existing species mix suitable for FRM (e.g. are tree species water tolerant)?
- ➢ what is the current/proposed stocking for woodland and could this reasonably be increased to enhance flood storage ecosystem services and FRM benefit?
- ➢ how is dead wood and the understorey managed and could this reasonably be altered to enhance flood storage ecosystem services and FRM benefit?
- ➢ what management (if any) is in place to protect existing wetland (e.g. regular vegetation removal to prevent natural succession)?

- **Creation of new habitat for FRM benefit:** once recommendations have been developed to improve the FRM performance of *existing* habitat patches, it may be appropriate and/or desirable to consider options for creating *new* floodplain habitat features. The creation of new habitat poses a significant opportunity to integrate key FRM design principles from the outset, thus ensuring that flood storage ecosystem services and FRM benefit is maximised:
  - ➢ recommendations for the creation of new floodplain habitat patches should be developed with reference to section 4.6, Chapter 5 and Appendices 4, 5 and 6
  - ➢ consider the topography of the existing (low cost sites – see Step 7 and T8.2) or proposed (high cost sites – see Step 7 and T8.4) floodplain in the design of new habitat features
  - ➢ habitat creation should ideally focus on sites within existing habitat networks (i.e. sites with good ecological connectivity)
  - ➢ suitable sites for habitat creation may also be available outwith existing habitat networks yet within areas of land that have good ecological potential for habitat creation (see the Step 5 guidance above on identifying sub-optimal sites for habitat expansion)
  - ➢ ensure that the spatial configuration of proposed new habitat features is designed to improve connectivity with surrounding habitat networks, including those that are adjacent to the floodplain in the wider landscape
- Based on the above, develop an outline strategy plan for proposed floodplain woodland and wetland habitat enhancement and/or creation (see example below)



Flood control model Step 8, T8.5 – outline floodplain woodland strategy plan (see explanatory key below for further information)

Tollcross Burn Catchment NFM Opportunity Area No.2 (Sandyhills Park) - Outline Floodplain Woodland Strategy Plan: Explanatory Key		
Strategy plan item	**Strategy theme**	**Details**
i	Baseline	Extent of existing floodplain woodland habitat network (dark green)
ii	Baseline	Extent of existing floodplain woodland habitat patches (yellow)
iii	Baseline	Route of existing culvert
A and C	Strategy zone	Primary function of floodplain woodland intervention within these zones is to deliver FRM benefit by increasing values of Manning's n for the bank and floodplain, promoting out of bank flows and increasing the extent and depth of flooding across the floodplain. Zone A is secondary to Zone C in this regard as it is more constrained by topography (the floodplain profile is generally steeper). Floodplain profiling within Zone C is likely to be less onerous hence the rationale for focusing the FRM function of floodplain woodland at this location. Proposed stocking density in Zone A is lower than Zone C and planting strategy should be designed to deliver amenity/landscape benefit as well as the primary FRM benefit
B	Strategy zone	The primary function of floodplain woodland intervention within these zones is to deliver landscape and amenity benefit. Any FRM benefit is secondary
1	Proposed intervention	Interplanting and high density restocking of existing woodland habitat patches to maximise FRM benefit of existing woodland blocks. All new planting should use tree species appropriate to the wet conditions such as trees from the *Salix* (willow) and *Betula* (birch)

[6] The pr[...] authorit[...] manage[...] recreati[...] point – [...] formal f[...] greensp[...] generic

T8.6	• Review outputs from T8.4 and T8.5 • Consider how essential earthworks at 'high cost' sites (see T8.3 and T8.4) may constrain or support other NFM measures: ➢ which stretches of the channel/floodplain are likely to retain steep gradients? ➢ where will newly created stretches of shallow channel/floodplain gradient be located? ➢ marry-up habitat focussed NFM measures with suitable gradients, for example: o wetland features, floodplain scrapes etc will require shallow gradients o woodland features will perform better for FRM on shallower sites but can also planted on steeper sites, delivering wider benefits including landscape, amenity and biodiversity/habitat network • Consider each individual strategy plan from T8.4 and T8.5 in turn to identify potential synergies (practitioners may wish to use a matrix based approach to explore compatibility between each measure). For example: ➢ stocking density and silvicultural treatment (e.g. mounding) for floodplain woodland can be manipulated across the site to provide different Manning's n/roughness values for different parts of the site ➢ habitat based NFM measures can be used to support land engineering measures (e.g. floodplain scrapes) by manipulating (e.g. slowing flows and increasing flood depth) and diverting the flow to flood storage areas • Based on the analysis above, develop an overall strategy plan for the NFM opportunity area that integrates the various discrete measures. The plan should include sufficient information such that relevant specialists (e.g. civil engineers, hydrologists, ecologists, landscape architects, ecologists etc) can engage in the process and agree a finalised outline design for testing FRM benefit in an appropriate hydraulic model. An example overall strategy plan for NFM opportunity area No.2 (Sandyhills Park) is indicated at Figure 5.15
Note: Tasks 8.1 – 8.6 should be repeated for all NFM opportunity areas identified in Step 6. By way of example, Step 8 tasks have been documented above for NFM opportunity area No.2 (Sandyhills Park).	

Additional information/guidance on scoping potential earthworks

- For high cost sites, a degree of earthworks will always be required to create the new channel for the restored watercourse (see section 2.4.4 and Appendices 1 and 2). Where the watercourse is being restored to its historic route, the landform associated with the historic floodplain may still be present. In this case, additional earthworks to engineer the desired floodplain profile may be minor or not required at all
- Where the historic landform has been altered (e.g. through the introduction of made ground), earthworks may be necessary to achieve the desired floodplain profile. Equally, where other land uses (e.g. housing, roads infrastructure etc) have encroached onto land formerly occupied by the floodplain, it will be necessary to realign the reinstated floodplain to account for these constraints. In this case, the configuration of the reinstated floodplain may be such that it is 'pushed' onto an area of high/steep ground, meaning that some degree of earthworks will be required to achieve the desired floodplain profile. In instances such as this, the costs of the earthworks must be balanced against the FRM and wider multiple benefits of the NFM scheme
- Essential earthworks at high cost sites must take cognisance of the dimensions of the potentially available floodplain reinstatement area identified at Step 4, Task 4.4. For example, the available area may be constrained and of insufficient width such that suitably gentle floodplain, bank and channel gradients cannot be achieved, potentially negating/reducing FRM benefit and reducing the overall viability of the scheme – see section 2.4.4 and Appendices 1 and 2

Appendix 9: Hydrological cycle model step-by-step instructions and example outputs

Specific technical guidance for undertaking all geoprocessing operations described in this Appendix is available from the ArcGIS online help resources:

ArcGIS online help for buffer operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//000800000019000000 [accessed 23/11/13]

ArcGIS online help for clip operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//000800000004000000 [accessed 23/11/13]

ArcGIS online help for simplify line operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//007000000010000000 [accessed 03/05/14]

ArcGIS online help – selecting and extracting data:
http://resources.arcgis.com/en/help/main/10.1/index.html#/Selecting_and_Extracting_data/018p00000005000000/ [accessed 23/11/13]

ArcGIS online help for topo to raster operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//009z0000006s000000 [accessed 03/05/14]

ArcGIS online help for reclassify operations:
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z000000sr000000.htm [accessed 03/05/14]

ArcGIS online help for raster to polygon (conversion) operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//001200000008000000 [accessed 03/05/14]

ArcGIS online help for intersect operations:
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00080000000p000000 [accessed 03/05/14]

Hydrological Cycle Model Stage 1: Slope analysis

Geoprocessing instructions and example outputs

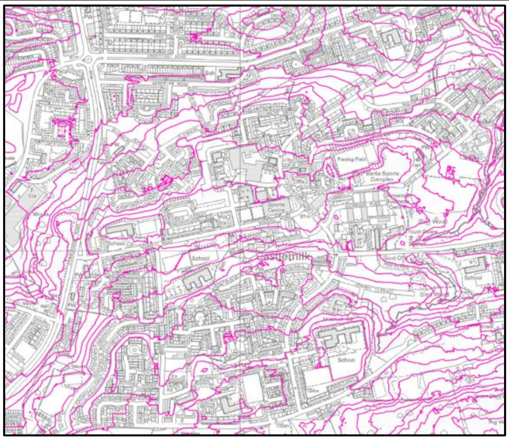
Purpose of Stage 1: *to characterise the study area in terms of slope and to delineate steep, medium and gently sloped areas of land in a vector dataset*

Supporting technical information in Chapter 4 – relevant sections	4.2, 4.3, 4.4 and 4.7
Related section(s) in Chapter 7	7.3.1

Step 1: buffer study area polygon

Purpose of step	[For study areas that aren't defined by natural features] to ensure that opportunities for enhancing ecosystem processes/intermediate services (i.e. runoff reduction ecosystem services) at the peripheries of the study area are captured in the analysis	
ArcGIS geoprocessing tool	**<u>BUFFER</u>** Tool location: Analysis Tools > Proximity > BUFFER	
Input feature class/classes	Study area polygons	
Output feature class	Buffered study area polygons	
Output feature class filename structure	[*study area name*]_[*buffer distance*]_BUFFER	
Parameters	Buffer study area polygons to increase study area size by between 10 and 30%	
Geoprocessing notes	BUFFER: buffer the study area polygons to the required size using linear units. Do not dissolve buffers	

Step 2: clip topographical contours dataset to the study area

Purpose of step	Reduces the amount of data analysed in subsequent modelling steps. This is particularly important for LiDAR topographical contour data which is very rich	 ***LiDAR topographical contours dataset at 5m intervals clipped to the study area***
ArcGIS geoprocessing tool	**<u>CLIP</u>** Tool location: Analysis Tools > Extract > CLIP	
Input feature class/classes	1. Buffered study area polygons [**output from Step 1**] 2. LiDAR topographical contour polylines covering the study area	
Output feature class	LiDAR topographical contour polygons clipped to the study area(s)	
Output feature class filename structure	LiDAR_[*contour interval*]_[*study area name*]_CLIP	
Parameters	N/A	
Geoprocessing notes	CLIP: clip the LiDAR topographical polyline data (input feature) to the buffered study area data (clip feature)	

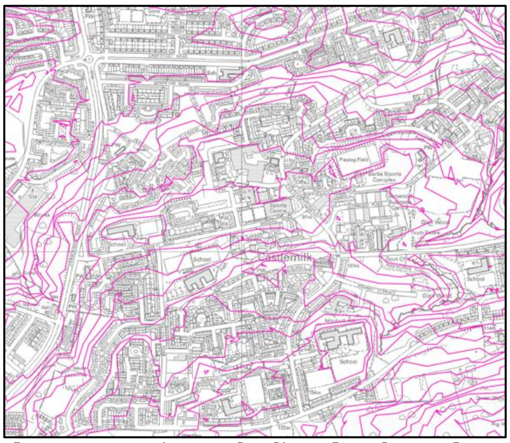
Step 3: simplify the topographical contours dataset

Purpose of	Reduces the complexity of LiDAR	***Simplified LiDAR topographical contours***

Hydrological Cycle Model Stage 1: Slope analysis

Geoprocessing instructions and example outputs

step	topographical polyline data by removing small fluctuations or extraneous bends from it while preserving its essential shape. This step is necessary for study areas with a large spatial extent (e.g. whole urban catchments) due to the volume of data required to be analysed. This step may not be required for smaller spatial extents (e.g. masterplan or neighbourhood areas) or if computer processing power is sufficient
ArcGIS geoprocessing tool	**SIMPLIFY LINE** Tool location: Data Management Tools > Generalisation > SIMPLIFY LINE
Input feature class/classes	LiDAR topographical contour polylines clipped to the study area(s) [**output from Step 2**]
Output feature class	Simplified LiDAR topographical contour polylines clipped to the study area(s)
Output feature class filename structure	LiDAR_[*contour interval*]_[*study area name*]_CLIP_SIMPLIFY
Parameters	• Simplification Algorithm: POINT_REMOVE • Maximum Allowable Offset: 10 metres • Check for topological errors: NO • Keep collapsed points: NO:
Geoprocessing notes	SIMPLIFY LINE: simplify the LiDAR topographical contour polylines using the SIMPLIFY LINE tool and the parameters listed above



dataset at 5m intervals clipped to the study area

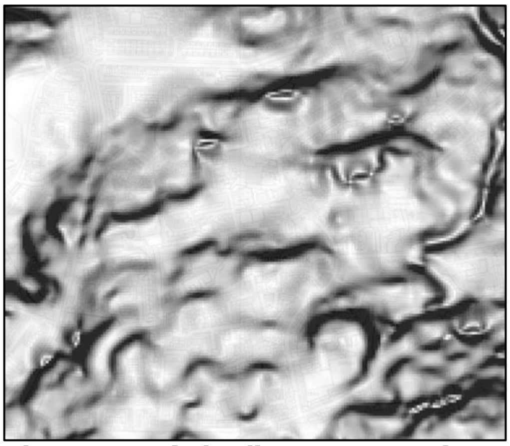
Step 4: construct Digital Elevation Model (DEM) raster

Purpose of step	To create a Digital Elevation Model (DEM) raster. The DEM is the starting point for all subsequent modelling steps that are influenced by slope
ArcGIS geoprocessing tool	**TOPO TO RASTER** Tool location: 3D Analyst Tools > Raster Interpolation > TOPO TO RASTER
Input feature class/classes	Simplified LiDAR topographical contour polylines clipped to the study area(s) [**output from Step 3**]
Output feature class	DEM rasters showing the altitude of study area(s) surface in metres above sea level (msl)
Output feature class filename structure	[*study area name*]_DEM
Parameters	• Input feature data: Simplified

DEM raster – light coloured cells represent higher elevation

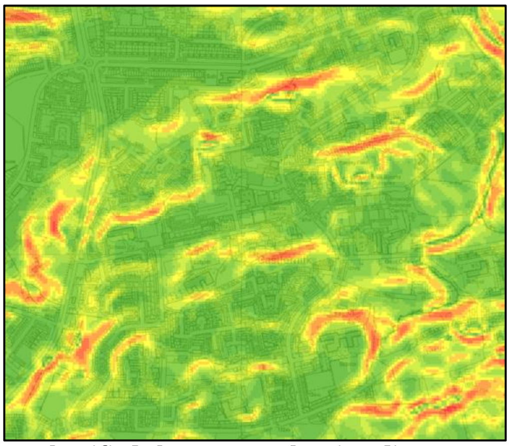
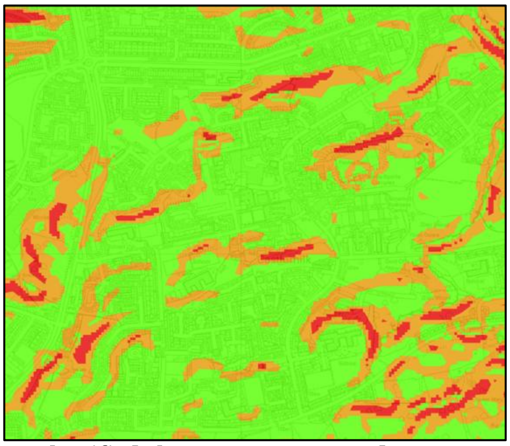
Hydrological Cycle Model Stage 1: Slope analysis

Geoprocessing instructions and example outputs

	LiDAR topographical contour polyline data clipped to the study area(s) • Input feature data field: CONTOUR • Input feature data type: Contour • Output cell size: default • Output extent: same as input feature data (the clipped LiDAR data) • Margin in cells: 10 • Drainage enforcement: no enforce	
Geoprocessing notes	TOPO TO RASTER: interpolate a hydrologically correct surface from the simplified LiDAR topographical polylines using the TOPO TO RASTER tool and the parameters above	
Step 5: construct slope raster		
Purpose of step	Based on the input DEM raster, this step creates a slope raster. The slope raster is used to identify steeply sloped areas of land for use in subsequent modelling steps	 ***Slope raster – dark cells represent steeply sloped areas of land***
ArcGIS geoprocessing tool	**SLOPE** Tool location: 3D Analyst Tools > Raster Surface > Slope	
Input feature class/classes	DEM surface raster covering the study area(s) [**output from Step 4**]	
Output feature class	Slope raster depicting slope angle in degrees based on the interpolated DEM raster	
Output feature class filename structure	[*study area name*]_SLOPE	
Parameters	• Output measurement: degree • Z factor: default	
Geoprocessing notes	SLOPE: the SLOPE tool calculates the rate of maximum change in elevation from each cell to identify slope angle. Calculate slope angle in the study area(s) using the SLOPE tool and the parameters above	
Step 6: reclassify slope raster		
Purpose of step	To classify slopes in the study area based on their steepness	
ArcGIS geoprocessing tool	**RECLASSIFY** Tool location: Spatial Analyst Tools > Reclass > Reclassify	
Input feature class/classes	Slope raster covering the study area(s) [**output from Step 5**]	

Hydrological Cycle Model Stage 1: Slope analysis

Geoprocessing instructions and example outputs

Output feature class	The input slope raster is reclassified to give nine different slope classes, from gentle to steeply sloped, reflecting the topography of the study area(s). The reclassification parameter is set to 'default' (see below) meaning that the nine different slope classes reflect local conditions and are not uniform across multiple study areas	 ***Reclassified slope raster showing discrete slope classes – red cells are steep slopes, yellow cells medium slopes and green cells gentle slopes***
Output feature class filename structure	[*study area name*]_SLOPE_RECLASS	
Parameters	• Reclass field: value • Reclassification: default • Change missing values to NoData: NO	
Geoprocessing notes	RECLASSIFY: use the RECLASSIFY tool to reclassify the slope raster into nine slope classes. Use the default settings as per the parameters above	
Step 7: convert reclassified slope raster to vector format		
Purpose of step	To convert the nine raster based slope classes in the study area(s) into polygons. This step facilitates subsequent stages of the modelling (catchment analysis and integration analysis) which are all vector based	 ***Reclassified slope raster converted to vector format – red polygons are steep slopes, orange polygons medium slopes and green polygons gentle slopes***
ArcGIS geoprocessing tool	**RASTER TO POLYGON** Tool location: Conversion Tools > From Raster > Raster to Polygon	
Input feature class/classes	Slope raster covering the study area(s) reclassified on the basis of slope angle [**output from Step 6**]	
Output feature class	Groups of cells from the reclassified slope raster that share the same slope attribute are converted to polygons of the same slope class. The output dataset is polygons representing a given slope class	
Output feature class filename structure	[*study area* name]_SLOPE_VECTOR	
Parameters	• Field: value • Simplify polygons: YES	
Geoprocessing notes	RASTER TO POLYGON: use the RASTER TO POLYGON tool to convert the reclassified slope raster to polygons of the same slope class	
Step 8: extract different classes of slope polygon from the vector slope dataset		
Purpose of step	To identify and extract polygons representing steep, medium and gently sloped land within the study area(s)	

Hydrological Cycle Model Stage 1: Slope analysis
Geoprocessing instructions and example outputs

ArcGIS geoprocessing tool	**SELECT** Tool location: Analysis Tools > Extract > Select
Input feature class/classes	Slope polygons covering the study area(s) classified on the basis of slope angle [**output from Step 7**]
Output feature class	Discrete polygon feature classes representing steep, medium and gently sloped areas of land within the study area(s)
Output feature class filename structure	[*study area name*]_SLOPE_Steep [*study area name*]_SLOPE_Medium [*study area name*]_SLOPE_Gentle
Parameters	Use SELECT tool and SQL query builder to extract steep, medium and gently sloped polygons. SQL expressions are as follows: STEEP slope polygons SQL query: [GRIDCODE] >= 7 MEDIUM slope polygons SQL query: [GRIDCODE] = 4 OR [GRIDCODE] = 5 OR [GRIDCODE] = 6 GENTLE slope polygons SQL query: [GRIDCODE] < 4
Geoprocessing notes	SELECT (steep slopes): extract 'steep' slope polygons from the slope polygon data (input feature) using the expression above SELECT (medium slopes): extract 'medium' slope polygons from the slope polygon data (input feature) using the expression above SELECT (gentle slopes): extract 'gentle' slope polygons from the slope polygon data (input feature) using the expression above

Polygons representing areas of steeply sloped land within the study area

Polygons representing areas of medium sloped land within the study area

Hydrological Cycle Model Stage 2: Catchment analysis

Geoprocessing instructions and example outputs

Purpose of Stage 2: *to identify the immediate catchment areas of natural and artificial drainage features and to delineate these areas of land in a vector dataset*

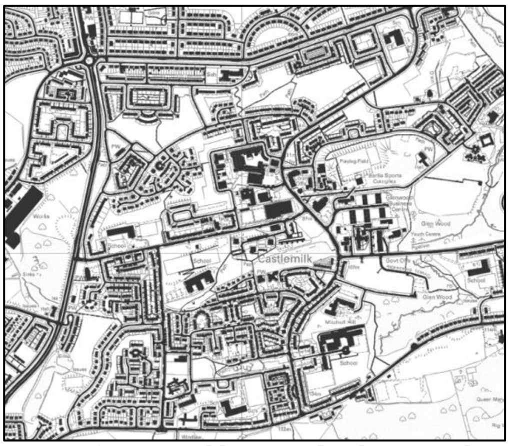
Supporting technical information in Chapter 4 – relevant sections	4.2, 4.3, 4.4 and 4.7
Related section(s) in Chapter 7	7.3.2

Step 9: clip OSMM topography polygons to the study area

Purpose of step	To reduce the amount of data analysed in subsequent modelling steps
ArcGIS geoprocessing tool	<u>**CLIP**</u> Tool location: Analysis Tools > Extract > CLIP
Input feature class/classes	1. Buffered study area polygons [**output from Step 1**] 2. OSMM topography polygons
Output feature class	OSMM polygons clipped to the study area(s)
Output feature class filename structure	OSMM_[*study area name*]_CLIP
Parameters	N/A
Geoprocessing notes	CLIP: clip the OSMM data (input feature) to the buffered study area data (clip feature)

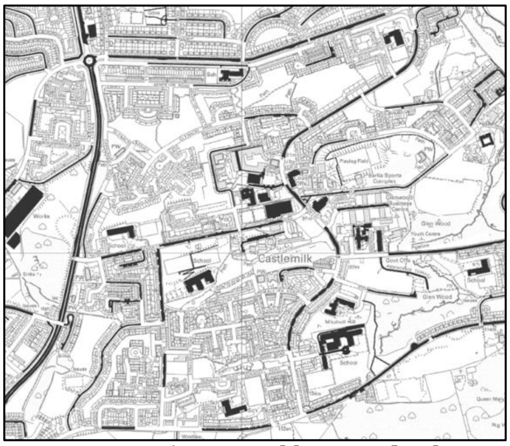
Step 10: identify and extract impermeable ground polygons only from OSMM topography layer

Purpose of step	To extract only those polygons that are likely to comprise impermeable ground. Precipitation falling on or draining to impermeable land parcels will end up either in the underground drainage network or contributing to pluvial flooding. The immediate catchment of an impermeable land parcel may therefore be a candidate for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	<u>**SELECT**</u> Tool location: Analysis Tools > Extract > Select
Input feature class/classes	OSMM polygons covering the study area(s) [**output from Step 9**]
Output feature class	Potentially impermeable OSMM polygons clipped to the study area(s)
Output feature class filename structure	OSMM_Impermeable_SELECT
Parameters	Use SELECT tool and SQL query builder to extract only those polygons that are likely to be impermeable[7] Impermeable polygon SQL query:



OSMM impermeable ground polygons only (black polygons)

[7] Further information on OSMM attributes is available ay Edina MasterMap user guide at: http://edina.ac.uk/mastermap/support/MMUserGuide.shtml [accessed 15/02/14]

Hydrological Cycle Model Stage 2: Catchment analysis *Geoprocessing instructions and example outputs*		
	[DESCGROUP] = 'Building' OR [DESCGROUP] = 'Glasshouse' OR [DESCGROUP] = 'Path' OR [DESCGROUP] = 'Path; Rail' OR [DESCGROUP] = 'Rail' OR [DESCGROUP] = 'Road Or Track' OR [DESCGROUP] = 'Road Or Track; Structure' OR [DESCGROUP] = 'Structure'	
Geoprocessing notes	SELECT: extract impermeable ground polygons from the clipped OSMM dataset (input feature) using the expression above	
Step 11: identify and extract large impermeable ground polygons only from OSMM topography layer		
Purpose of step	To extract large impermeable ground polygons only. This reduces the amount of data analysed in subsequent modelling steps	 ***Large OSMM impermeable ground polygons (black polygons)***
ArcGIS geoprocessing tool	**SELECT** Tool location: Analysis Tools > Extract > Select	
Input feature class/classes	Potentially impermeable OSMM polygons clipped to the study area(s) [**output from Step 10**]	
Output feature class	Large potentially impermeable OSMM poly clipped to the study area(s)	
Output feature class filename structure	OSMM_LargeImpermeable_SELECT	
Parameters	Use SELECT tool and SQL query builder to extract only those impermeable polygons that are also large Example large impermeable polygon SQL query: [SHAPE_Area] >= 1000	
Geoprocessing notes	SELECT: extract large polygons from the impermeable clipped OSMM data (input feature) using the expression above. **Note:** a 1,000m^2 threshold is suggested for the select operation (i.e. for defining what is meant by a 'large' area of impermeable ground). This is a key parameter where sensitivity analysis can be used to explore different outcomes from the modelling	

Hydrological Cycle Model Stage 2: Catchment analysis

Geoprocessing instructions and example outputs

Step 12: identify the immediate catchment area of artificial drainage features by proxy (i.e. large areas of impermeable ground)

Purpose of step	To identify the immediate catchment of large impermeable ground polygons as a proxy for artificial drainage features. The immediate catchment of an impermeable land parcel may therefore be a candidate for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	**BUFFER** Tool location: Analysis Tools > Proximity > BUFFER
Input feature class/classes	Large potentially impermeable OSMM poly clipped to the study area(s) [**output from Step 11**]
Output feature class	Large OSMM polygons likely to be impermeable clipped to the study area(s) and buffered to identify their potential immediate catchment areas
Output feature class filename structure	OSMM_LargeImpermeable_[*buffer distance*]_BUFFER
Parameters	Buffer large OSMM polygons to 30m • Distance: linear unit 30m • Dissolve type: ALL
Geoprocessing notes	BUFFER: buffer the large impermeable OSMM polygons to the required size using linear units. Where the volume of input data and/ or processing power allows, ensure that all buffers are dissolved. This reduces the number of output polygons from the integration analysis. **Note:** a 30m buffer is suggested here. The buffer distance parameter is a key area where sensitivity analysis can be used to explore different outcomes from the modelling

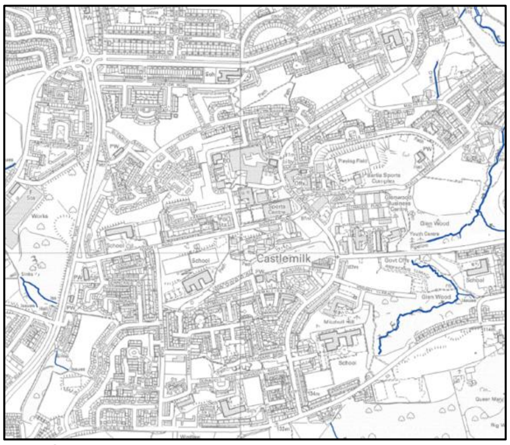
Large areas of impermeable ground buffered to 30m (green polygons) – the buffered area is used as a proxy for the immediate catchment area of artificial drainage features to identify locations where land use/management and/or storm water storage intervention may be required to enhance runoff reduction ecosystem services

Step 13: clip waterbodies polyline to the study area

Purpose of step	To reduce the amount of data analysed in subsequent modelling steps
ArcGIS geoprocessing tool	**CLIP** Tool location: Analysis Tools > Extract > CLIP
Input feature class/classes	1. Buffered study area polygons [**output from Step 1**] 2. Waterbodies polyline
Output feature class	All waterbodies clipped to the study

Hydrological Cycle Model Stage 2: Catchment analysis

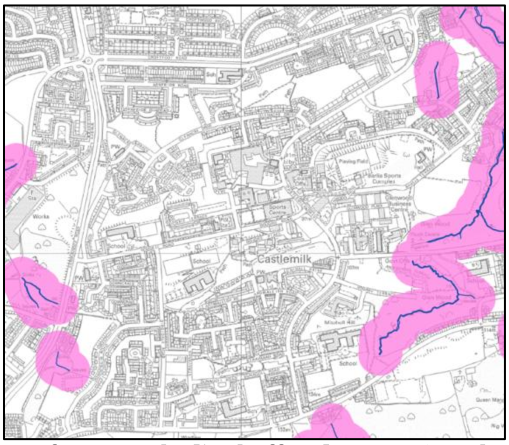
Geoprocessing instructions and example outputs

	area(s)	
Output feature class filename structure	Waterbodies_[*study area name*]_CLIP	
Parameters	N/A	
Geoprocessing notes	CLIP: clip the waterbodies data (input feature) to the buffered study area data (clip feature)	
Step 14: select surface waterbodies only		
Purpose of step	Depending on the nature of the waterbodies dataset it may be necessary to extract **surface** waterbodies only (i.e. the dataset may also contain culverts that are not directly affected by overland flow based runoff generation mechanisms. In practice however there is likely to be a high degree of interaction between different sources of flooding and natural and artificial drainage features – see section 6.2.2)	 ***Surface waterbodies (blue polylines)***
ArcGIS geoprocessing tool	<u>**SELECT**</u> Tool location: Analysis Tools > Extract > Select	
Input feature class/classes	Waterbody polylines in the study area(s) [**output from Step 13**]	
Output feature class	All surface waterbodies within the study area(s)	
Output feature class filename structure	Waterbodies_Surface_SELECT	
Parameters	Use SELECT tool and SQL query builder to extract surface waterbodies only Surface waterbody SQL query: [TYPE] = 'OPEN WATERCOURSE'	
Geoprocessing notes	SELECT: extract surface waterbody polylines from the waterbodies data (input feature) using the expression above. **Note:** the expression above has been developed for use with Glasgow City Council's waterbodies dataset. Other hydrology datasets may be different and Step 14 may not be required	
Step 15: identify the immediate catchment area of natural drainage features		
Purpose of step	To identify the surface waterbody's immediate catchment as a proxy for the immediate catchment area of natural drainage features. These areas may therefore be candidates for land use/management and/or storm water	

Hydrological Cycle Model Stage 2: Catchment analysis

Geoprocessing instructions and example outputs

	storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	**<u>BUFFER</u>** Tool location: Analysis Tools > Proximity > BUFFER
Input feature class/classes	Surface waterbodies within the study area(s) [**output from Step 14**]
Output feature class	Surface waterbodies clipped to the study area(s), buffered to identify their potential immediate catchments
Output feature class filename structure	Waterbodies_Surface_[*buffer distance*]_BUFFER
Parameters	Buffer surface waterbody polylines to 75m • Distance: linear unit 75m • Dissolve type: ALL
Geoprocessing notes	BUFFER: buffer the surface waterbody polylines to the required size using linear units. Where the volume of input data and/ or processing power allows, ensure that all buffers are dissolved. This reduces the number of output polygons from the integration analysis. **Note:** a 75m buffer is suggested here. The buffer distance parameter is a key area where sensitivity analysis can be used to explore different outcomes from the modelling



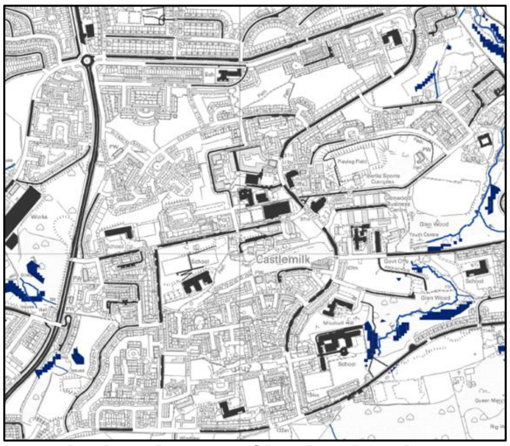
Surface waterbodies buffered to 75m (purple polygons) – the buffered area is used as a proxy for the immediate catchment area of natural drainage features to identify locations where land use/management and/or storm water storage intervention may be required to enhance runoff reduction ecosystem services

Hydrological Cycle Model Stage 3: Integration analysis
Geoprocessing instructions and example outputs

Purpose of Stage 3: *to integrate outputs from Stages 1 and 2 by identifying where various classes of slope fall within the immediate catchment areas of natural and artificial drainage features. These areas of land are then delineated in a vector dataset and may become priorities for runoff reduction ecosystem services*	
Supporting technical information in Chapter 4 – relevant sections	4.2, 4.3, 4.4 and 4.7
Related section(s) in Chapter 7	7.3.3

Step 16: identify where areas of steeply sloped land fall within the immediate catchment area of natural drainage features

Purpose of step	To identify where areas of steeply sloped land are located within the immediate catchment of surface waterbodies (as a proxy for natural drainage features). These areas may be a **high** priority for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	**INTERSECT** Tool location: Analysis Tools > Overlay > Intersect
Input feature class/classes	1. Buffered surface waterbody polylines in the study area(s) [**output from Step 15**] 2. Steep slope polygons in the study area(s) [**output from Step 8**]
Output feature class	Areas of steeply sloped land intersecting the immediate catchments of surface waterbodies in the study area(s)
Output feature class filename structure	STEEPSlopes_Water_INTERSECT
Parameters	N/A
Geoprocessing notes	INTERSECT: intersect the buffered surface waterbodies data with the steeply sloped land data



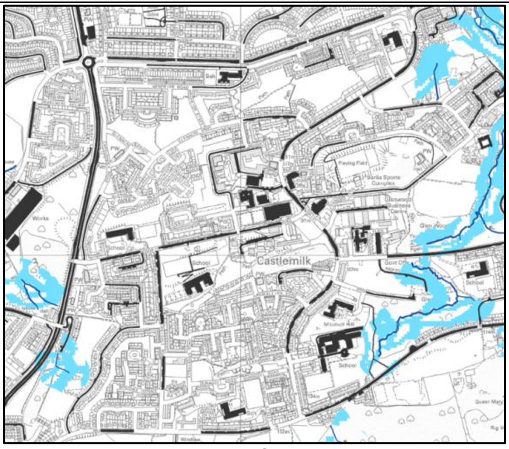
Steeply sloped areas of land within the immediate catchment area of natural drainage features (dark blue polygons). Blue polylines are surface waterbodies, black polygons are large areas of impermeable ground

Step 17: identify where areas of medium sloped land fall within the immediate catchment area of natural drainage features

Purpose of step	To identify where areas of medium sloped land are located within the immediate catchment of surface waterbodies (as a proxy for natural drainage features). These areas may be a **medium** priority for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	**INTERSECT** Tool location: Analysis Tools > Overlay > Intersect
Input feature class/classes	1. Buffered surface waterbody polylines in the study area(s)

Hydrological Cycle Model Stage 3: Integration analysis

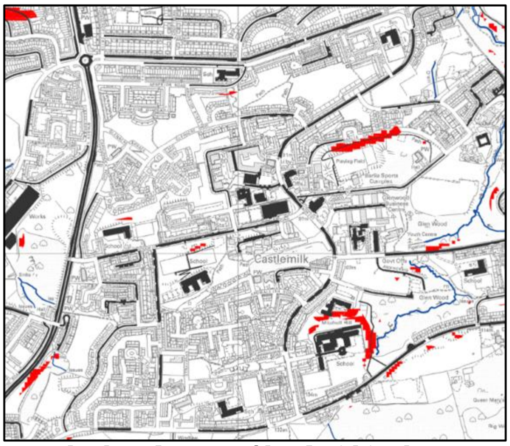
Geoprocessing instructions and example outputs

	[**output from Step 15**] 2. Medium slope polygons in the study area(s) [**output from Step 8**]	***Medium sloped areas of land within the immediate catchment area of natural drainage features (light blue polygons). Blue polylines are surface waterbodies, black polygons are large areas of impermeable ground***
Output feature class	Areas of medium sloped land intersecting the immediate catchments of surface waterbodies in the study area(s)	
Output feature class filename structure	MEDIUMSlopes_Water_INTERSECT	
Parameters	N/A	
Geoprocessing notes	INTERSECT: intersect the buffered surface waterbodies data with the medium sloped land data	
Step 18: identify where areas of gently sloped land fall within the immediate catchment area of natural drainage features		
Purpose of step	To identify where areas of gently sloped land are located within the immediate catchment of surface waterbodies (as a proxy for natural drainage features). These areas may be a **low** priority for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services	
ArcGIS geoprocessing tool	**INTERSECT** Tool location: Analysis Tools > Overlay > Intersect	
Input feature class/classes	1. Buffered surface waterbody polylines in the study area(s) [**output from Step 15**] 2. Medium slope polygons in the study area(s) [**output from Step 8**]	
Output feature class	Areas of gently sloped land intersecting the immediate catchments of surface waterbodies in the study area(s)	
Output feature class filename structure	GENTLESlopes_Water_INTERSECT	
Parameters	N/A	
Geoprocessing notes	INTERSECT: intersect the buffered surface waterbodies data with the gently sloped land data	
Step 19: identify where areas of steeply sloped land fall within the immediate catchment area of artificial drainage features		

Hydrological Cycle Model Stage 3: Integration analysis

Geoprocessing instructions and example outputs

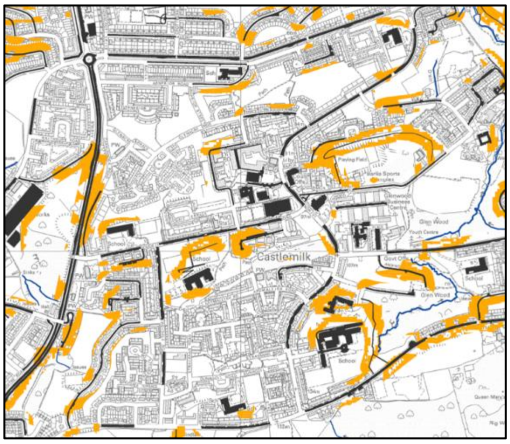
Purpose of step	To identify where areas of steeply sloped land are located within the immediate catchment of large areas of impermeable ground (as a proxy for artificial drainage features). These areas may be a **high** priority for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	**INTERSECT** Tool location: Analysis Tools > Overlay > Intersect
Input feature class/classes	1. Buffered large area of impermeable ground polygons in the study area(s) [**output from Step 12**] 2. Steep slope polygons in the study area(s) [**output from Step 8**]
Output feature class	Areas of steeply sloped land intersecting the immediate catchments of large areas of impermeable ground in the study area(s)
Output feature class filename structure	STEEPSlopes_Imper_INTERSECT
Parameters	N/A
Geoprocessing notes	INTERSECT: intersect the buffered large areas of impermeable ground data with the steeply sloped land data



Steeply sloped areas of land within the immediate catchment area of artificial drainage features (red polygons). Blue polylines are surface waterbodies, black polygons are large areas of impermeable ground

Step 20: identify where areas of medium sloped land fall within the immediate catchment area of artificial drainage features

Purpose of step	To identify where areas of medium sloped land are located within the immediate catchment of large areas of impermeable ground (as a proxy for artificial drainage features). These areas may be a **medium** priority for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services
ArcGIS geoprocessing tool	**INTERSECT** Tool location: Analysis Tools > Overlay > Intersect
Input feature class/classes	1. Buffered large area of impermeable ground polygons in the study area(s) [**output from Step 12**] 2. Medium slope polygons in the study area(s) [**output from Step 8**]
Output feature class	Areas of steeply sloped land intersecting the immediate catchments of large areas of impermeable ground



Medium sloped areas of land within the immediate catchment area of artificial drainage features (orange polygons). Blue polylines are surface waterbodies, black polygons are large areas of impermeable ground

Hydrological Cycle Model Stage 3: Integration analysis
Geoprocessing instructions and example outputs

	in the study area(s)	
Output feature class filename structure	MEDIUMSlopes_Imper_INTERSEC T	
Parameters	N/A	
Geoprocessing notes	INTERSECT: intersect the buffered large areas of impermeable ground data with the medium sloped land data	
Step 21: identify where areas of gently sloped land fall within the immediate catchment area of artificial drainage features		
Purpose of step	To identify where areas of gently sloped land are located within the immediate catchment of large areas of impermeable ground (as a proxy for artificial drainage features). These areas may be a **low** priority for land use/management and/or storm water storage intervention to provide runoff reduction ecosystem services	
ArcGIS geoprocessing tool	**INTERSECT** Tool location: Analysis Tools > Overlay > Intersect	
Input feature class/classes	3. Buffered large area of impermeable ground polygons in the study area(s) [**output from Step 12**] 4. Steep slope polygons in the study area(s) [**output from Step 8**]	
Output feature class	Areas of steeply sloped land intersecting the immediate catchments of large areas of impermeable ground in the study area(s)	
Output feature class filename structure	GENTLESlopes_Imper_INTERSECT	
Parameters	N/A	
Geoprocessing notes	INTERSECT: intersect the buffered large areas of impermeable ground data with the gently sloped land data	

Appendix 10: Habitat network model step-by-step instructions and example outputs

Specific technical guidance for undertaking all geoprocessing operations described in this Appendix is available from the ArcGIS online help resources:

ArcGIS online help for buffer operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//000800000019000000 [accessed 23/11/13]

ArcGIS online help for clip operations:
http://resources.arcgis.com/en/help/main/10.1/index.html#//000800000004000000 [accessed 23/11/13]

ArcGIS online help – selecting and extracting data:
http://resources.arcgis.com/en/help/main/10.1/index.html#/Selecting_and_Extracting_data/018p00000005000000/ [accessed 23/11/13]

ArcGIS online help for intersect operations:
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00080000000p000000 [accessed 03/05/14]

Habitat Network Model Stage 1: Analysis of ecological potential

Geoprocessing instructions and example outputs

Purpose of Stage 1: *to identify areas of land within the study area where ecological potential to support habitat establishment is high*

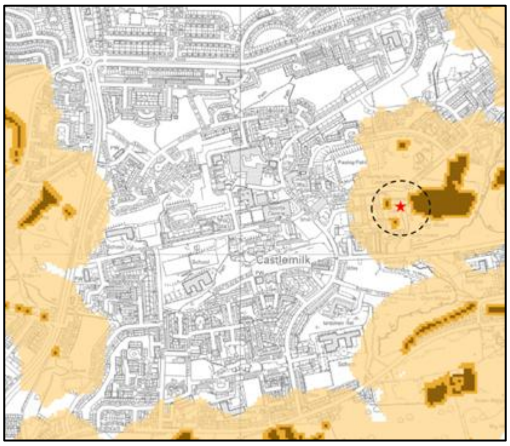
Supporting technical information in Chapter 5 – relevant sections	5.1 and 5.2
Related section(s) in Chapter 7	7.4.1

Step 1: Buffer study area polygon

Purpose of step	[For study areas that aren't defined by natural features] to ensure that opportunities for enhancing ecosystem processes/intermediate services (i.e. ecological connectivity ecosystem services) at the peripheries of the study area are captured in the analysis
ArcGIS geoprocessing tool	**<u>BUFFER</u>** Tool location: Analysis Tools > Proximity > BUFFER
Input feature class/classes	Study area polygons
Output feature class	Buffered study area polygons
Output feature class filename structure	[*study area name*]_[*buffer distance*]_BUFFER
Parameters	Buffer study area polygons to increase study area size by between 10 and 30%
Geoprocessing notes	BUFFER: buffer the study area polygons to the required size using linear units. Do not dissolve buffers

Step 2:Clip the biodiversity opportunities, habitat patches and habitat networks datasets to the study area

Purpose of step	Reduces the amount of data analysed in subsequent modelling steps
ArcGIS geoprocessing tool	**<u>CLIP</u>** Tool location: Analysis Tools > Extract > CLIP
Input feature class/classes	1. Buffered study area polygons [**output from Step 1**] 2. Biodiversity opportunities polygons for woodland, wetland and grassland habitat 3. Existing habitat patch polygons for woodland, wetland and grassland habitat 4. Existing high dispersal habitat network polygons for woodland, wetland and grassland habitats 5. Existing low dispersal habitat network polygons for woodland, wetland and grassland habitats
Output feature class	1. Biodiversity opportunities polygons clipped to the study area 2. Existing habitat patch polygons



Unimproved/ neutral grassland patches (brown polygons), low/0.3km dispersal habitat network (dark orange polygons) and high/2km dispersal habitat network (pale orange polygons) data clipped to the study area

Habitat Network Model Stage 1: Analysis of ecological potential
Geoprocessing instructions and example outputs

	clipped to the study area 3. Existing high dispersal habitat network polygons clipped to the study area 4. Existing low dispersal habitat network polygons clipped to the study area	
Output feature class filename structure	[*habitat type*]_OPPOTUNITIES_[*study area name*]_CLIP [*habitat type*]_HABITAT_[*study area name*]_CLIP [*habitat type*]_highDISPERSE_[*study area name*]_CLIP [*habitat type*]_lowDISPERSE_[*study area name*]_CLIP	
Parameters	N/A	
Geoprocessing notes	CLIP: clip the various habitats data (input features) to the buffered study area data (clip feature)	
Step 3: Extract high ecological potential polygons from the biodiversity opportunities datasets		
Purpose of step	To identify land where there is high ecological potential to support the three priority habitats considered in the analysis	 ***Land where ecological potential to support grassland habitat establishment is high (brown polygons)***
ArcGIS geoprocessing tool	**SELECT** Tool location: Analysis Tools > Extract > Select	
Input feature class/classes	Biodiversity opportunities polygons clipped to the study area [**output from Step 2**]	
Output feature class	Biodiversity opportunity polygons representing land with high ecological potential to support habitat establishment (i.e. an ecological potential value of 3 or more)	
Output feature class filename structure	[*habitat type*]_OPPORTUNITIES_HIGH_SELECT	
Parameters	Use SELECT tool and SQL query builder to extract biodiversity opportunities polygons with high ecological potential only Woodland SQL query: [tbl] >= 3 Wetland SQL query: [twet] >= 3 Grassland SQL query: [tgrs] >= 3	
Geoprocessing notes	SELECT: extract high ecological potential polygons from the three biodiversity opportunities datasets	

Habitat Network Model Stage 1: Analysis of ecological potential *Geoprocessing instructions and example outputs*		
	(input feature) using the expressions above	

Habitat Network Model Stage 2: Identify prime sites *Geoprocessing instructions and example outputs*	
Purpose of Stage 2: *to integrate the ecological potential data from Stage 1 with existing low and high dispersal habitat networks data to identify prime sites for habitat creation/recreation*	
Supporting technical information in Chapter 5 – relevant sections	5.1 and 5.2
Related section(s) in Chapter 7	7.4.2
Step 4: Intersect high ecological potential polygons with existing low and high dispersal habitat networks data to identify prime sites for habitat enhancement works	

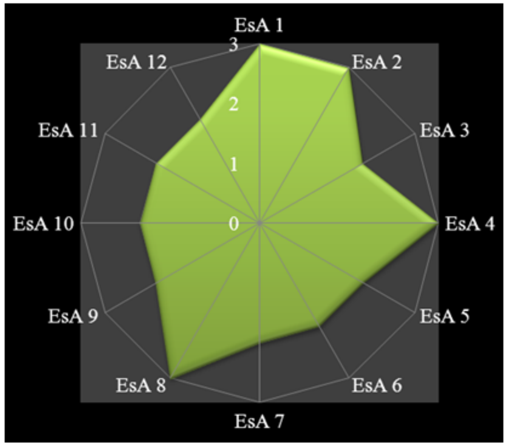
Purpose of step	To identify areas of land encompassed by existing high and low dispersal habitat networks that also have high ecological potential to support the three priority habitats considered in the analysis. The land areas identified may be prime candidates for various habitat enhancement works including improved management, restoration, reducing the intensity of land use in the matrix and creation/recreation of areas of new semi-natural habitat. Habitat enhancement delivered in these areas has the potential to increase the total area of habitat networks and the area of habitat patches within these networks	 ***Output (pale pink polygons) of intersecting land with high ecological potential to support grassland habitat establishment and existing high dispersal grassland habitat networks. The brown polygons show existing grassland habitat patches***
ArcGIS geoprocessing tool	**<u>INTERSECT</u>** Tool location: Analysis Tools > Overlay > Intersect	
Input feature class/classes	1. Biodiversity opportunity polygons representing land with high ecological potential to support habitat establishment [**outputs from Step 3**] 2. Existing high dispersal habitat network polygons clipped to the study area [**outputs from Step 2**] 3. Existing low dispersal habitat network polygons clipped to the study area [**outputs from Step 2**]	
Output feature class	Intersection of high ecological potential habitat opportunity polygons and existing high and low dispersal habitat network polygons within the study area	
Output feature class filename structure	[*habitat type*]_highOPPS_and_highDISPERSE_[*study area name*]_INTERSECT	

Habitat Network Model Stage 2: Identify prime sites ***Geoprocessing instructions and example outputs***		
	[*habitat type*]_highOPPS_and_lowDISPERSE_[*study area name*]_INTERSECT	
Parameters	N/A	
Geoprocessing notes	INTERSECT: intersect the high ecological potential habitat opportunity polygons with existing high and low dispersal habitat network polygons	

Appendix 11: Evaluation of new ecosystems approach based urban land use planning frameworks developed through this research

Key	
Principle considered fully	
Principle considered to a degree	
Principle not considered	
Consideration of principle unknown	

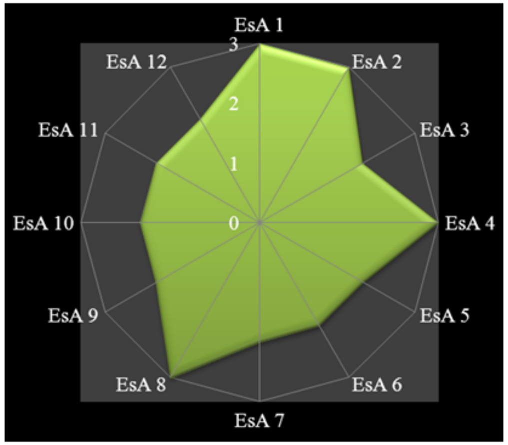
Radar Diagram Code	Ecosystem approach principle	Score	Theme
EsA 1	*Consider effects on adjacent ecosystems* **Evaluation comments:** Designed to work at the catchment/ecosystem scale. Whole city planning would encompass multiple ecosystems. Buffering of study areas captures effects on adjacent ecosystems		***Management of natural systems***
EsA 2	*Conserve ecosystem structure and function* **Evaluation comments:** Spatial models consider key ecosystem processes/intermediate services (hydrological cycle and ecological connectivity). New technical guidance considers ecosystem structure issues		
EsA 3	*Ecosystem management must respect environmental limits* **Evaluation comments:** Consideration mainly implicit. Spatial models identify locations where ecosystem service limits (see section 3.2.1) may be exceeded. Remedial intervention identified through new technical guidance		
EsA 4	*Adopt the ecosystems approach at appropriate spatial and temporal scale* **Evaluation comments:** Spatial models designed to work at the ecosystem scale (especially urban water catchments). Temporal scale aligned to statutory LDP process		
EsA 5	*Set long term objectives for ecosystem management* **Evaluation comments:** New approaches aligned to urban LDP process - i.e. 10 year planning timeframe. Limited consideration of varying temporal scales and lag effects		
EsA 6	*Ecosystem management must recognise that change is inevitable* **Evaluation comments:** Resilience thinking embedded with ecosystems approach guiding principles and technical guidance. No specific consideration of management for inevitable change		



Evaluation of new urban land use planning approaches against the Convention on Biological Diversity (CBD) ecosystems approach principles

Key	
Principle considered fully	
Principle considered to a degree	
Principle not considered	
Consideration of principle unknown	

Radar Diagram Code	Ecosystem approach principle	Score	Theme
EsA 7	*Understand and manage the ecosystem in an economic context* **Evaluation comments:** Practical constraints and opportunities of urban land management for ecosystem services considered to a degree. Use of grants, incentives and regulation integrated with technical guidance		*Ecosystem services*
EsA 8	*Ensure an appropriate balance between conservation and use of biodiversity* **Evaluation comments:** Conservation and sustainable use of biodiversity is central to the whole approach. Spatial models and technical guidance balance conservation and use		
EsA 9	*Objectives for ecosystem management are a matter of societal choice* **Evaluation comments:** New approach designed for integration with statutory LDP process (see section 8.3) including public and stakeholder consultation at the MIR stage		*Involving people*
EsA 10	*Ecosystem management should be decentralised to the lowest appropriate level* **Evaluation comments:** New approach designed to intervene at the neighbourhood scale through multifunctional priority areas (see section 8.3). No specific mechanisms to support decentralised management however		
EsA 11	*Consider all forms of relevant information including scientific/local knowledge, practice and innovation* **Evaluation comments:** Implicit consideration only through integration with statutory LDP process (see section 8.3) and associated consultations		
EsA 12	*Involve all relevant sectors of society and scientific disciplines* **Evaluation comments:** As per EsA11		



Evaluation of new urban land use planning approaches against the Convention on Biological Diversity (CBD) ecosystems approach principles

Appendix 12: Example application of the new approaches in the Glasgow 2014 Multifunctional Greenspace Project (MGP)