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A framework for assessing the quality of green infrastructure in the built environment in the UK☆

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ABSTRACT

The advocacy argument for green infrastructure has largely been won. Policy and statutory guidance for green infrastructure planning and development exists at international, national and regional/local levels and the functions and benefits of green infrastructure interventions are well evidenced in academic literature. To support this, professional bodies and experts from the built and natural environment have produced a multitude of practice guidance on the delivery of individual green infrastructure features. And yet, examples of high quality green infrastructure in new development schemes remain difficult to find, and the success of statutory guidance to accelerate this phenomenon surprisingly ineffective to manage change within the development sector. This paper presents a new framework for the delivery of high quality green infrastructure. Consultation with stakeholders in the UK suggested that a key factor affecting the translation of green infrastructure evidence, and policy and practice guidance, into delivery through planning and development is a lack of confidence amongst practitioners regarding the qualities and characteristics of high quality green infrastructure in the built environment. The key characteristics of high quality green infrastructure, based on a review of both academic and grey literature, and extensive work with stakeholders are grouped into principles that underpin high quality green infrastructure (including the presence of a multifunctional network, and provision for long-term management), and principles related to health and wellbeing, water management and nature conservation. The resulting framework is presented as twenty three principles for delivering green infrastructure. This can be used internationally as a set of standards to assess the quality of green infrastructure to ensure that it contributes to quality of life, health and wellbeing of individuals and communities, flood resilient towns and cities, and places where nature can flourish and be more viable as a result of development.

1. Introduction

There is a substantial body of evidence from research and practice that green infrastructure provides benefits to people and society. For example, green infrastructure can support health and wellbeing (e.g. Frumkin et al., 2017; Hunter et al., 2015; Jeanjean et al., 2016); protect and enhance urban biodiversity (Sadler et al., 2010); contribute to a high quality built environment (Payne and Barker, 2015); reduce the urban heat island (UHI); and support environmental quality and adaptation to climate change (Demuzere et al., 2014; Zölch et al., 2016). This evidence has been important in making the economic case for green infrastructure investment, demonstrating its value to policy makers, planners, the property development sector and others responsible for the form and quality of the built environment (Sinnett et al., 2018a).

This guidance is clear in its advocacy for green infrastructure as the preferred mechanism to deliver multiple benefits for people and wildlife through the planning and development system. As such, green infrastructure is widely articulated as being defined by its *multifunctionality, continuous network* and *quality*. In the context of this paper, green infrastructue is understood as a delivery mechanism for ecosystem services and benefits in urban environments. Much has been written about the requirements of green infrastructure to deliver co-benefits through multifunctional features, and for these features to be interconnected (Kambites and Owen, 2006) and integrated (Roe and Mell, 2013) to provide optimal functionality for people and nature. For example, sustainable drainage (SuDS) features such as ponds and swales provide for water attenuation, contribute to enhancing water

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quality, and make provision for increasing biodiversity and recreational opportunities. Less has been written however about the need and requirements for the quality of green infrastructure, and the constituent elements of high quality green infrastructure. This is in spite of an established acknowledgement in the literature that use of green space, effectiveness of water management and habitat creation is quality-dependent (e.g. Schipperijn et al., 2010; Salomaa et al., 2016).

This paper is, therefore, concerned with establishing a framework for more effectively identifying high quality green infrastructrue. The purpose of the framework is to provide clarity for those seeking to deliver green infrastructure in the built environment. Ultimately, the aim is a higher, more consistent quality of green infrastructure in our towns and cities.

2. Defining quality in green infrastructure planning and delivery

Globally, green infrastructure literature and guidance recognise the need to define the characteristics of a green infrastructure planning approach (Bowen and Parry, 2015). O'Neil and Gallagher (2014) principles to identify a 'good quality green network' are useful in this context, in particular their consideration of which aspects of the quality of the green network are most important to deliver a functional network. Although fourteen 'quality categories' (2014: 208) were identified, including, quantity of green infrastructure, ability to mitigate flood risk and provide cooling, and provision of management, the critical categories for determining quality were indicated as *proximity* to people, *biodiversity* and *linkage* between green infrastructure features. O'Neil and Gallagher (2014) frame *proximity* in terms of 'ease of access', the need for 'access close to people's homes', and green infrastructure 'within walking distance'; *biodiversity* as 'habitats being part of an ecological network' and features for people to 'experience nature'; and *linkage* as 'physical' and 'functional' connections and opportunities for a 'variety of experiences' within a 'network of spaces and routes' (2014: 209). These findings echo evidence across the academic and practitioner literature relating to the importance of *proximity* (e.g. Ward Thompson et al., 2012; Mårtensson et al., 2014), *biodiversity* (e.g. Speak et al., 2015; Wood et al., 2016) and *linkage* (e.g. Roe and Mell, 2013; Kambites and Owen, 2006) for the provision of green infrastructure functionality and quality.

As such, the evidence identifies agreement that these elements of proximity, biodiversity and linkage are critical to delivering high quality green infrastructure. However, this does not convey a complete picture as to *how* to deliver high quality green infrastructure. Roe and Mell (2013) go some distance to establish a number of *principles* that ought to underpin a green infrastructure planning approach as a distinct approach to design, implementation, and long-term management and maintenance of the natural environment to secure benefits for human and non-human actors. Significantly, Roe and Mell (2013) highlight the role played by policy making in the delivery of green infrastructure, in particular the nature of 'green infrastructure strategy development options' (2014: 655). This is useful for the wider consideration of the role of policy in the delivery of quality in green infrastructure.

3. The role of the green infrastructure strategy in influencing quality

Many countries and cities globally now have strategic commitments to deliver high quality green infrastructure. For example, in the UK, this commitment is present in national planning policy, for example the Revised National Planning Policy Framework (2018) and Scottish Planning Policy (2014) prioritise green infrastructure as the preferred approach to delivering multifunctional benefits through supporting a functional natural environment. Similarly, the European Union have developed a strategy for green infrastructure, primarily as a means to ensure that the natural environment delivers a range of ecosystem services via policy areas including agriculture and forestry, land use, climate change adaptation and water management (European Commission, 2016), although European cities have often prioritised biodiversity and recreation outcomes in their policies (Davies and Lafortezza, 2017). However, although there are good examples of clear and evidence-based green infrastructure planning policy, there remains a lack of certainty amongst practitioners about how to deliver this green infrastructure (Albert and von Haaren, 2017; Sinnett et al., 2018a).

And finally, the role of built environment professionals (e.g. landscape architects, engineers, ecologists, surveyors, and house builders) engaged in the design, implementation and maintenance of green infrastructure has a significant impact on the ways in which green infrastructure is brought forward through the planning and development system (i.e. skills, knowledge, risk aversion, land and property values, responding to consumer demand). Therefore, clarity on the characteristics of high quality green infrastructure could play a critical knowledge transfer role between academic understanding and professional practice. In fact, it may be argued that it is this operational stage of green infrastructure planning that presents the highest potential for securing quality and inversely the highest risk for failing to secure long-term services and benefits (Sinnett et al., 2018b).

More recently, critique has focused on the implementation and post-construction stages of green infrastructure delivery. In particular long-term management and maintenance have been highlighted as presenting the greatest challenge for delivering sustainable and multifunctional landscapes (Jerome et al., 2017; Jerome, 2016). The importance of sustaining green infrastructure functionality through maintenance appropriate to the scale, type and local context of an individual feature is given emphasis across the practitioner guidance (e.g. Science for Environment Policy, 2012; UK-GBC, 2015).

In light of this gap between policy and practice in green infrastructure planning this paper more effectively articulates the key characteristics of high quality green infrastructure. Ultimately this will support the delivery of *multifunctional* green infrastructure that satisfies the principles outlined in the literature, and meets *local need*, in order to deliver ecosystem services that support liveable, sustainable and healthy places (Albert and von Haaren, 2017; Sinnett et al., 2018a).

Here we argue that to provide some clarity for those responsible for creating and interpreting planning policy, and developing planning proposals for new places, it is necessary to create a framework for high quality green infrastructure. The framework builds on existing green infrastructure principles such as those defined by O'Neil and Gallagher (2014) and Roe and Mell (2013), by creating a series of objective-led principles for high quality green infrastructure.

The focus of this paper is the development of this framework. It explains how the framework was devised, and outlines its usefulness, including a brief summary of the research method before presenting the framework itself. The purpose of this paper is to illustrate the thinking behind the framework and sets out how a more nuanced understanding of what constitutes high quality green infrastructure was developed.

4. Method

The framework was developed through a review of current guidance and standards, academic literature, and national and local policies related to green infrastructure from across the UK. Although the policy review and stakeholder work is focussed on the UK, the literature and guidance used to develop the framework is international, and the framework has been developed for broad applicability to an international context. This was supplemented with a consultation exercise with key stakeholders from England and Scotland. Together these identified the key themes for a framework, associated with securing high quality green infrastructure. The framework was developed in three stages (Fig. 1) as follows.

The first stage consisted of stakeholder consultation through individual meetings and a series of six events (reported in Calvert et al.,

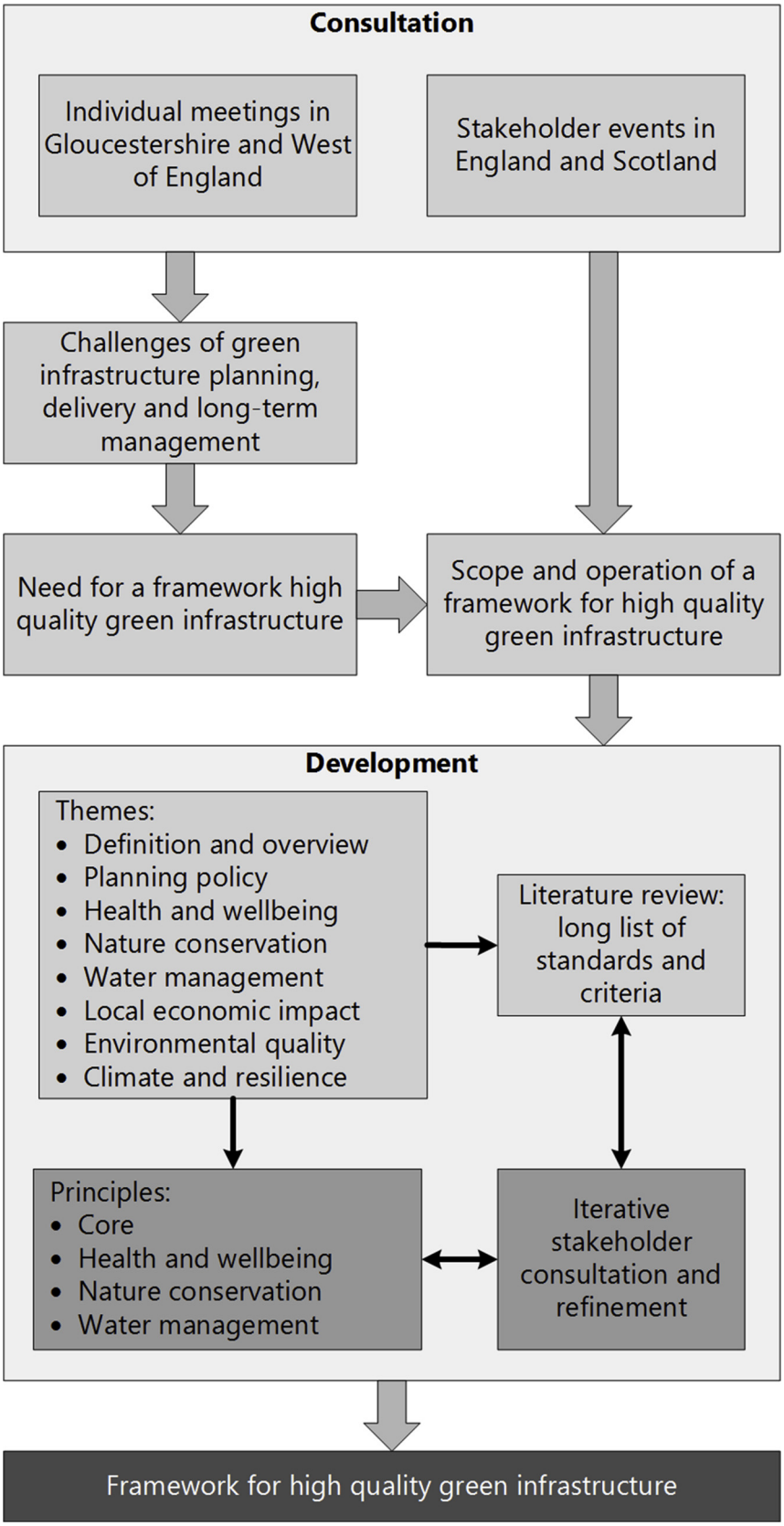

Fig. 1. Development of a framework for high quality green infrastructure (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

2018) with practitioners engaged in the planning and development process, including planners and policy makers; landowners, developers and volume housebuilders; ecologists and landscape architects. The events were hosted by the three professional bodies primarily responsible for green infrastructure planning and delivery in the UK (Royal Town Planning Institute, Royal Institute of Chartered Surveyors and Landscape Institute), four organisations influential in green infrastructure advocacy and delivery (Town and Country Planning Association jointly with Forest Research, Royal Society of Wildlife Trusts, and Central Scotland Green Network Trust). Each hosting organisation targeted delegates to represent their particular interests, or who had a specific expertise in green infrastructure from a policy or practitioner perspective. This early consultation revealed a number of critical challenges associated with better communicating priorities relating to the creation of new green infrastructure, as well as protecting and enhancing existing green infrastructure features to meet local need. The principal challenge for practitioners engaged in the long-term delivery of green infrastructure was a need to understand *what* are the expectations related to green infrastructure in the planning system. The categorisation of four distinct stages of development was therefore defined to frame the challenges associated with delivering high quality green infrastructure more effectively through planning: 1) policy and plan-making; 2) design and feasibility; 3) implementation and construction; and 4) long-term management and maintenance.

This stakeholder consultation also revealed the objectives for green infrastructure in terms of the expected outcomes (e.g. flood risk management, biodiversity gain). This was used to define the broad thematic areas of the framework (see below). It was decided that the framework would be objectives led, rather than 'prescribing the action needed to achieve those objectives' (Williams and Dair, 2007: 28) as this introduced an essential level of flexibility for the range of practitioners who may utilise the framework and the different contexts in which they are working.

The second stage consisted of a review of the current guidance relating to green infrastructure. This review included a consideration of empirical findings from academic research as to the constituent parts of a multifunctional green infrastructure network, and the critical factors affecting the successful delivery of green infrastructure. Key words and themes searched for in scientific papers and practitioner literature focused partly on the services and benefits provided by green infrastructure (e.g. green infrastructure biodiversity; green infrastructure flood), across different green infrastructure features (e.g. street trees temperature; green space access) and the stages of planning and development process (e.g. green infrastructure management; green infrastructure governance). Standard academic databases were interrogated including Science Direct, Sage, Scopus, Taylor and Francis, Google Scholar and Google. The Green Infrastructure Resource Library, managed by the Green Infrastructure Partnership was also searched for relevant grey literature, and the technical guidance of existing built environment assessment systems (Calvert et al., 2018) and other areas of design guidance were included. Additional sources were found from the references of the publications reviewed. This review resulted in a large number of standards and criteria that characterise high quality green infrastructure. These were then grouped thematically, initially around seven broad themes: *definition and overview* and *planning policy* which cover the underpinning characteristics for green infrastructure; and *nature conservation*, *health and wellbeing, local economic impact*, *water management*, *environmental quality,* and, *climate and resilience*, which are focussed on the objectives for green infrastructure.

The third stage refined the framework and created a suite of principles for high quality green infrastructure. This stage was an in-depth and iterative process conducted collaboratively with the stakeholders based in Gloucestershire and the West of England. This area includes nine local authorities, and encompasses the cities of Bristol, Bath and Gloucester, the towns of Stroud and Tewkesbury as well as number of smaller towns and parishes. Gloucestershire and the West of England are experiencing a high demand for new housing and employment growth, with 17,022 homes planned for Gloucester, Tewkesbury and Cheltenham by 2031, and 105,500 homes planned for the West of England by 2036.

First, the seven themes were rationalised to reflect feedback from stakeholders who wanted a simple, flexible framework presented as a series of principles or standards as opposed to a large number of detailed or rigid criteria that may not be appropriate in every scenario. Essentially, three groups of criteria were formed. The first set was drawn from the evidence grouped in the first stage of analysis under *definition and overview*. The second set describes *thematic principles* that effectively summarises three key objectives for green infrastructure (*nature conservation, water management, health and wellbeing*). The third set of criteria informed the understanding of how each of these principles is approached by the delivery agents of green infrastructure at each stage of planning and development. Subsequently, this final set of criteria were combined with the first set to form the five *core principles* that articulate the fundamental qualities of high quality green infrastructure. Throughout this process, corroboration was undertaken through a series of consultation exercises with the stakeholders. This allowed an interrogation of any assumptions made within the literature about both practical and technical challenges associated with delivering high quality green infrastructure, whether perceived or actual, based on the experiences of those responsible for the planning, delivery and long-term management of green infrastructure.

5. A framework for high quality green infrastructure

The framework itself provides 23 principles to aid those involved in the development of new places in achieving high quality green infrastructure. The objectives-led approach allowed for the creation of a discrete number of green infrastructure principles (see Table 1). For the framework to be effective, the principles are flexible enough to be applicable to different local contexts. This will ensure that the green infrastructure within any one development or strategic area expresses the most appropriate ecosystem services and benefits in response to the needs of the area, and existing landscape-scale features and networks. Table 1 sets out the 23 principles. These are grouped around four main areas of focus: core principles, principles to enhance health and wellbeing, principles for sustainable water management, and principles to enhance nature conservation. The table describes each principle and defines its purpose. In addition, examples are provided as to how each principle could be delivered within the context of planning and development of green infrastructure.

The next sections will detail the focus of each principle and explain its purpose in contributing to consistently, and flexibly, delivering high quality green infrastructure. The framework includes two levels across the thematic principles. Whilst it was acknowledged that the 23 principles all represent high quality green infrastructure a distinction was drawn between those that are *essential* and those that are *desirable*. Essential principles have therefore been translated into a set of core principles, and the first level across each of the thematic principles. In contrast, desirable principles describe those that indicate an exemplary quality of green infrastructure, and although examples from each can be found across the policy, practice and academic literature, a consensus across the stakeholder consultees was that these were negotiable and were more dependent on the wider priorities, contexts and constraints of a given development. It is important to understand that the desirable principles are set for UK practice and it may be the case that other countries, with a more advanced understanding of how to implement green infrastructure, interpret the desirable principles as essential. It is critical to understand that the aim of the framework is to raise the quality of the green infrastructure, and as such the framework can be adapted to take into account differentiations in the 'baseline' quality or expectations of green infrastructure in different countries. We now turn to a summary of the principles themselves (Table 1).

Table 1
Framework for high quality green infrastructure.

	Purpose	Examples of how this could be delivered
CORE PRINCIPLES		
Green infrastructure forms a multifunctional network.	Ensures that individual features form, and contribute to, a multifunctional network of green infrastructure operating at a landscape scale.	Green infrastructure components within SuDS provide functionality for water retention during heavy rainfall, and an area for play and recreation at other times.
Green infrastructure reflects and enhances the character of the local environment.	Ensures that the green infrastructure reflects the character of the local environment and positively contributes to local identity, landscape character and vernacular, and a sense of place.	Green infrastructure is designed with sensitivity and reference to the character of the local environment, including existing habitat types (e.g. woodland) or features (e.g. species of street tree).
The type, quality and function of green infrastructure responds to the local context.	Ensures green infrastructure effectively meets local priorities and needs as articulated in local policy or through consultation with local stakeholders.	Local policies and evidence, stakeholders and communities have informed the design of the green infrastructure and the individual features.
Green infrastructure is resilient to climate change and enhances environmental quality.	Ensures that green infrastructure is resilient to climate change, and opportunities for shade provision, carbon storage, improved soil and air quality, and reduced noise and light pollution are maximised.	Green infrastructure is designed to provide resilience to climate change, for example, by balancing native and resilient species, mixed species to reduce pest and disease risk or the creation of 'stepping stones' of habitat.
Provision is made for long-term management and maintenance of green infrastructure.	Ensures that adequate provision is made for how the green infrastructure will be managed and maintained including the responsibility for these activities and their funding.	Voluntary environmental stewardship is encouraged to enhance a sense of belonging through communities taking an active role in the management and maintenance of green infrastructure.
PRINCIPLES TO ENHANCE HEALTH AND WELLBEING		
Essential		
Green infrastructure is accessible and is situated close to where people live.	Ensures that all people can use, enjoy and positively contribute to green infrastructure, recognising that the greatest benefits occur when green infrastructure is situated close to where people live.	A range of green infrastructure features are provided at an appropriate distance from homes (e.g. smaller green spaces and play areas within a walkable distance) with linkages between them.
All people are encouraged to use and enjoy green infrastructure.	Ensures that the green infrastructure is usable and attractive for different user groups, recognising the needs and strengths of local people and how these may change over time.	The facilities, seating and other furniture, lighting and play equipment provided as part of the green infrastructure facilitate access by people with differing needs and abilities.
Green infrastructure is designed to be accessible at all times of year.	Ensures that green infrastructure features can be used and enjoyed at all times of year, maximising the beneficial outcomes from green infrastructure.	Green infrastructure is designed to work with changes in seasons, such as situating trees to provide shading and urban cooling to buildings, play areas and active travel routes.
Desirable		
Green infrastructure supports the reduction and/or prevention of health inequalities.	Ensures that green infrastructure can contribute to reducing health inequalities by optimising its therapeutic role for vulnerable and excluded groups.	Green infrastructure and associated street furniture has been designed to be dementia-friendly or children's play areas include equipment for wheelchair users.
Green infrastructure promotes socially sustainable communities and community cohesion.	Ensures that green infrastructure creates a sense of social cohesion and inclusion, thereby improving community wellbeing and increasing the likelihood of social sustainability.	Green infrastructure is designed to accommodate the needs of groups who are particularly vulnerable to social exclusion, including ethnic minorities or those at an economic disadvantage.
Green infrastructure is integral to the distinctiveness of place.	Ensures that green infrastructure contributes to place distinctiveness, with the aim of creating a place where people feel a sense of belonging and pride in their neighbourhood.	Green infrastructure features add value to existing heritage assets, use local materials, or protect or enhance valuable views.
PRINCIPLES FOR SUSTAINABLE WATER MANAGEMENT		
Essential		
Green infrastructure is integral to sustainable drainage.	Ensures that green infrastructure controls the quantity of runoff, which in turn supports the management of flood risk, and maintains and protects the natural water cycle.	Water quantity is controlled and managed through the integration of an interconnected system of individual SuDS components, unless site conditions suggest that SuDS are inappropriate.
Green infrastructure has been used to improve water quality on site.	Ensures green infrastructure and associated components, deliver a controlled flow of clean water downstream and into the ground.	Green infrastructure features are designed and managed to contribute to managing water quality and are created or enhanced to be managed as standard landscape features.
Green infrastructure related to water management also creates and sustains better places for people and nature.	Ensures that, in addition to managing water quantity and quality, green infrastructure features enhance benefits for people and nature.	SuDS components are designed to contribute to a high quality environment for people, by providing amenity value, and for nature, by creating new habitats, linkages and enhancing ecological connectivity.
Desirable		
Green infrastructure responds innovatively to the local policy context in terms of water management.	Ensures green infrastructure features respond to local policy priorities for water management going beyond the statutory minimum.	Green infrastructure has been designed to minimise water demand in landscaping including that in the private and public realm.
Green infrastructure is used to improve water quality off site and downstream of its location.	Ensures that, where possible and appropriate, a catchment-based approach to water management is used through creating or restoring links to green infrastructure at a landscape scale.	Natural flood management schemes that contribute to improved water quality at a catchment scale.
Green infrastructure related to water management is used to enhance local distinctiveness and the overall design.	Ensures that the design of green infrastructure features enhances the physical connectivity between them both increasing their contribution to water management and sense of place.	Use the flow of water to create dynamic and interesting landscapes that offer an unusual level of beauty, biodiversity, usability and local distinctiveness.
PRINCIPLES TO ENHANCE NATURE CONSERVATION		
Essential		
Green infrastructure delivers long-term ecological enhancement in line with local priorities.	Ensures that over time green infrastructure contributes positively to reversing the long-term decline in biodiversity, including on-going monitoring, remediation where necessary and management.	The design of green infrastructure considers local biodiversity priorities and prioritisation is given to features with a high biodiversity value (e.g. retained mature trees and hedgerows, established wildflower meadow).

(*continued on next page*)

Table 1 (*continued*)

Purpose		Examples of how this could be delivered
Green infrastructure creates, restores and enhances habitats and the linkages between them.	Ensures that habitats and linkage of habitats are expanded to restore ecosystem function, contributing positively to reversing the long-term decline in biodiversity.	Green infrastructure features have been designed to incorporate native species of local provenance both in creating new habitats and providing connectivity between them and existing habitats.
Populations of key species are more viable as a result of the green infrastructure.	Ensures that the site layout, and habitat creation and restoration, provide optimal conditions to satisfy the requirements of target species, improving connectivity between green infrastructure features.	Green infrastructure is used to avoid and repair habitat fragmentation and create more suitable habitat allowing movement of key species, which are more viable as a result.
Desirable		
Creation and conservation of high-quality habitat, fully integrated with the built environment.	Ensures that space is provided for wildlife to flourish throughout the built environment in order to sustain and increase target species and use land as efficiently as possible.	Buildings (roofs, terraces, facades, etc.) provide high-quality wildlife habitat benefiting quality and function of local priority habitats.
Green infrastructure plays a role in restoring and sustaining wider ecological networks.	Ensure that the green infrastructure operates at the landscape scale to enhance local ecological networks by maximising opportunities to make the wider ecological network more viable.	Green infrastructure includes habitats that are connected to, and reflect, the wider ecological network.
Green infrastructure secures biodiversity enhancement at each stage and in all phases of implementation.	Ensures that opportunities to protect and enhance biodiversity are taken at each stage of the process, particularly during delivery and construction.	Mechanisms exist to ensure that existing and new green infrastructure features are successfully protected through delivery, construction, and when in use.

5.1. Core principles underpinning high quality green infrastructure

The core principles are *essential* components in the planning and delivery of green infrastructure. They encompass characteristics highlighted in the literature as defining qualities of green infrastructure, namely *multifunctional* features organised in a *connected network* to ensure that individual features optimise benefits for urban populations and the surrounding countryside (e.g. Mell, 2010; Sinnett et al., 2018a). The core principles also seek to overcome a number of challenges that are highlighted across the literature and in the stakeholder consultation as key to securing the benefits of green infrastructure. For example, it is *essential* that green infrastructure reflects and enhances the character of the local environment, so that it positively contributes to local identity, landscape character and vernacular, and a sense of place (Williams and Dair, 2007). It is also *essential* that the type, quality and ecosystem services provided by individual green infrastructure features responds to the local context in terms of policy priorities and needs, including those relating to the physical environment and society (e.g. Perth and Kinross Council, 2014; Blakely and Leigh, 2017). Ensuring that green infrastructure is resilient to climate change and enhances environmental quality (e.g. Gill et al., 2007), including mitigating the impacts of UHI (Zölch et al., 2016) and poor air quality (Tallis et al., 2011; Jeanjean et al., 2016), and therefore responds to the strategic context of local environmental and societal pressures, is a core principle. This is recognised as a critical factor to ensure the delivery of ecosystem services are sustainable in the long term (e.g. TDAG, 2014). And finally, in reflection of the practitioner-focused literature and stakeholder consultation relating to the perpetual frustration for delivery agents, there is a principle that ensures that provision is made for the long-term management and maintenance of green infrastructure features (e.g. UK-GBC, 2015; BRE, 2012). These five core principles cover the underpinning definition and planning approaches to high quality green infrastructure. We now turn to the thematic principles, organised as those focussed on enhancing health and wellbeing, sustainable water management and nature conservation.

5.2. Principles to enhance health and wellbeing

There is now strong evidence that green infrastructure can influence health and wellbeing outcomes (WHO, 2017). This set of principles sets out the characteristic of green infrastructure that enhances positive health and wellbeing outcomes, in line with the World Health Organization's definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO, 1946). Clearly, many other characteristics of the built environment are also related to health and wellbeing and these principles seek to ensure that the contribution of green infrastructure is maximised as opposed to implying importance in comparison to other endeavours (e.g. to provide safe and secure housing). The presence of health and wellbeing in the framework reflects the growing evidence related to the physical and mental health benefits of access to green infrastructure, and the prioritisation of these benefits across a number of countries (e.g. TCPA and The Wildlife Trusts, 2012; Frumkin et al., 2017; van den Berg et al., 2016v; Hunter et al., 2015).

The *essential* principles within the health and wellbeing theme reflect the findings across the literature and stakeholder consultation that ensuring high quality green infrastructure features are accessible for all and situated close to where people live can enhance use and enjoyment (e.g. Sinnett et al., 2015; CIWEM, 2010; Hunter et al., 2015). The first principle, associated with *proximity* of green infrastructure to where people live and spend their time, was therefore highlighted as an *essential* principle for ensuring health and wellbeing outcomes of green infrastructure for all users (Ward Thompson et al., 2012, 2010; RICS, 2011). The second *essential* principle focusing on access encompasses nuances highlighted within the literature, for example, in how design of green infrastructure can facilitate use a by different groups including vulnerable and excluded groups (CABE Space, 2010; Schipperijn et al., 2010; Ward Thompson et al., 2010, 2012). This principle ensures that all people are encouraged to use and enjoy green infrastructure, regardless of, for example, the demographic needs of existing or future communities (e.g. gender, age, ethnic group, socio-economic group, and ability) (Gidlow et al., 2012: 354). This particularly recognises that values and perceptions have an important role in determining individual and societal wellbeing, and quality of life and that this can change over time, and between different population groups (Pacione, 2003; Armitage et al., 2012), thus there is a need to provide green infrastructure that meets the needs and expectations of the existing or intended community. The final *essential* health and wellbeing principle ensures green infrastructure contributes to place making, which requires that green infrastructure features are designed to be accessible at all times of year to encourage optimal use, for example by employing hard features (e.g. seating, shelter, cycle parking) and soft features (e.g. vegetation, wildlife areas). This principle has been created to reflect the findings in the literature related to the link between usability, enjoyment and quality in green infrastructure features (Gidlow et al., 2012) and builds on the core principle relating to environmental quality. This aims to ensure optimal use at all times of year, green infrastructure features need to be usable in varying climate conditions and

temperatures, which is particularly important in urban areas where parks and greenspaces should include areas that provide shade and cooling in periods of extreme heat. This principle also captures the feedback from stakeholders that the quality of green infrastructure is nuanced, for example, being dependent on the capacity of green infrastructure features to adapt to changing conditions, and to be integral to the built environment to optimise opportunities for regular engagement.

The *desirable* principles build on these three *essential* principles and aim to further maximise positive health and well-being outcomes. Although they are all recognised as important in the planning and delivery of high quality green infrastructure they are areas for which the evidence is emergent or are dependent on policy detail that is context-specific. The principle that describes how green infrastructure can support the reduction and/or prevention of health inequalities (Bragg and Atkins, 2016; Coutts, 2016) was defined by stakeholders as *desirable* as the link between health inequalities and green infrastructure is not always reflected in local policy. The second *desirable* principle requires green infrastructure to promote socially sustainable communities and community cohesion reflecting the capacity of green infrastructure provision to improve community wellbeing and increase the likelihood of social sustainability (Ward Thompson et al., 2012). The final *desirable* principle ensures that green infrastructure is integral to the distinctiveness of place, drawing on evidence that the natural environment can contribute to a sense of place, and support feelings of pride and community identity (HM Government, 2010; Keller and Stirling, 2011).

5.3. Principles for sustainable water management

It is widely recognised across policy and practice guidance that the delivery of green infrastructure in the built environment is critical to sustainable water management. Green infrastructure can reduce surface water runoff, improve water quality, and contribute to flood resilience by reducing the economic, social and environmental costs of flooding (e.g. CIRIA, 2015). However, sustainable water management requires more than simply increasing the quantum of green infrastructure (Ellis, 2013). The design and integration of SuDS, and their constituent components (e.g. swales, infiltration strips, detention and retention ponds) into a wider green infrastructure network is essential to optimise the role of green infrastructure in surface water management. The importance of *water quantity, water quality,* and delivering enhancements for *amenity and biodiversity*, are emphasised across the academic and practice literature, as well as by our stakeholder engagement. Thus, these form *essential* principles in the delivery of sustainable water management in the framework. The principle relating to *water quantity*, which describes the assessment and management of flood risk (e.g. OECD, 2016; Offermans et al., 2011), ensures that green infrastructure is integral to sustainable drainage to control the quantity of surface water runoff and the management of flood risk. The principle relating to *water quality,* which describes the prevention and management of water pollution (e.g. BRE, 2014; EPA, 2009), ensures green infrastructure has been used to improve water quality within the boundary of the scheme, to deliver a controlled flow of clean water into the ground and downstream.

A strategic approach to sustainable urban water management has been a principle focus for sustainable development for the past two decades. For example, in considering the opportunity for SuDS to contribute to wider objectives for society and nature conservation (e.g. Haasnoot et al., 2012; Frey et al., 2015). Arguably, it is this additional factor of delivering co-benefits for amenity and biodiversity through a SuDS approach which differentiates sustainable water management, with integral green infrastructure features, from a highly engineered approach; which may just as effectively ensure management of water quantity and water quality. Therefore, the framework includes an *essential* principle relating to the role of water management in provision for *amenity and biodiversity enhancements*. This principle ensures SuDS are also used to create and sustain better places for people and nature through the provision of integral green infrastructure features that contribute additional habitat, linkages and high quality recreational space.

The *desirable* principles for the delivery of sustainable water management are representative of high quality green infrastructure but are contingent on local context. First, in the UK the local policy context relating to water management may require a development scheme to show that any negative impact on water quality and water quantity can be mitigated through a SuDS or natural flood management approach. Therefore, where appropriate a development scheme should use green infrastructure to improve water quality off site and downstream of its location. In this regard, the design of SuDS should also demonstrate innovation to move beyond the statutory minimum with regards management of water quantity and quality. Finally, the *desirable* principles recognise that an exemplary scheme may utilise green infrastructure related to water management to enhance local distinctiveness and the overall design (e.g. blue roofs for water storage and biodiversity benefit; swales within a natural play area which accommodate water storage in less frequent but heavy downpours) (e.g. CIRIA, 2015).

5.4. Principles to enhance nature conservation

Green infrastructure is the primary mechanism through which nature is protected and enhanced in cities (Sinnett, 2015). There is consensus across the literature and guidance that green infrastructure can contribute to the protection and enhancement of biodiversity to make existing habitats and populations of species more viable (e.g. Feinberg et al., 2015; Kowarik, 2011). The other services, provided by green infrastructure are at least in part dependent on well-functioning ecosystems, and cities are now seen as critical in protecting and reconnecting habitats (e.g. Hayhow et al., 2016; Lawton et al., 2010). In addition, contact with nature is seen as important in environmental education, for example, through developing an understanding of environmental processes (Breuste and Artmann, 2014). The focus on ecological enhancement and improving linkages between habitats, both spatially and in terms of focus on local priority species, is repeated across the literature (e.g. Berthon et al., 2015; Madre et al., 2015) and is highlighted by stakeholders as an important objective of green infrastructure. Therefore, the framework identifies three *essential* principles for nature conservation. First, green infrastructure should deliver long-term ecological enhancement in line with local priorities (e.g. biodiversity targets) to ensure that the built environment positively contributes to reversing the long-term decline in biodiversity. Second, the framework highlights the *essential* role of green infrastructure in creating, restoring and enhancing habitats and linkages between them. This is to reflect the importance of connectivity for habitat and species viability, for example through the provision of green infrastructure features, such as wildlife corridors, which can assist with the mobility of key species (e.g. bats) across the built environment. Finally, a third *essential* principle sets the expectation that green infrastructure is supportive of populations of key species, for example, by creating and restoring optimal conditions to satisfy the requirements of species identified in local biodiversity targets.

Additional principles that reflect current understanding and good practice (Table 1) were identified as *desirable* within the framework to reflect their dependence on the local context and constraints in some development schemes. The first *desirable* principle recognises that green infrastructure that is integral to the built environment can ensure that space is provided for wildlife to flourish within the footprint of the built environment and individual buildings. For example, recognising that integral green infrastructure features, such as bird bricks and bat boxes for roosting, can be designed to support target species (Madre et al., 2015; Andersson and Colding, 2014). The second *desirable* principle promotes the opportunity for green infrastructure to contribute to landscape-scale ecological enhancement, building on the *essential*

principle relating to connectivity and linkages. This could include, for example, overcoming fragmentation of an environmental corridor through creation of new or enhancement of existing green infrastructure features. As such, the framework recognises that green infrastructure has a role in restoring and sustaining wider ecological networks. Finally, the third *desirable* principle relates to the role green infrastructure can have in securing biodiversity enhancement in all phases of implementation, including planning, construction and in use. This principle, although supported by practice guidance (e.g. British Standards, 2013 – Biodiversity Code of practice for planning and development) and recognised as the 'ideal' scenario by stakeholders, is challenging to deliver often due to constraints in the development process. There are a number of mechanisms to ensure existing and new green infrastructure features are successfully protected through delivery, construction and when in use (e.g. Ecological Clerk of Works), although green infrastructure can be perceived as an ambiguous concept in spite of policy expectations and good practice guidance (Salomaa et al., 2016).

6. Conclusions

The framework for high quality green infrastructure has been developed to provide clarity for those engaged in the delivery of green infrastructure across the built environment sector. It is organised across four areas: *core principles*, and principles related to *health and wellbeing, sustainable water management* and *nature conservation* outcomes. In addition, two types of principle were identified – *essential* and *desirable* – to differentiate between those that are fundamental to ensuring green infrastructure services and those that contribute additional benefits to health and wellbeing, water management and nature conservation. The *essential* principles are those that should be designed and implemented through the planning and development system resulting in high quality green infrastructure that can be managed and maintained in a sustainable and cost-effective way. The *desirable* principles are less likely to be outlined in planning policy, at least in the UK, and are not necessarily appropriate in every context but are commonly understood to represent existing exemplary practice. Taken together the principles respond to the various challenges, highlighted in the literature and by stakeholders, in the design, implementation and long-term management and maintenance of green infrastructure.

In summary, through the process of reviewing academic literature, and policy and practice guidance, a framework of principles has been developed to answer the question of what constitutes high quality green infrastructure. However, the task of creating a framework also raised additional questions that are outstanding and warrant further research. For example, although there are increasing levels of evidence to both quantify and qualify the benefits of green infrastructure for health and wellbeing outcomes, there remains a lack of evidence regarding the preferences of residents and other users in terms of the characteristics of green infrastructure. This was highlighted by stakeholders as particularly important considering the challenges connected to building advocacy and support across the built environment sector. Another challenge highlighted in the literature and by stakeholders is the lack of robust evidence on the most cost effective and sustainable models and mechanisms for long-term management and maintenance of high quality green infrastructure. This was emphasised in particular in the context of UK public sector funding cuts, which have reduced funding for the management of green infrastructure assets (Jerome, 2016; Jerome et al., 2017). As a consequence, new funding mechanisms, such as public-voluntary sector partnerships and private sector contractor arrangements, particularly in relation to parks and recreational areas delivered as part of new development, are the subject of much discussion amongst academics, policy makers and practitioners (Dempsey et al., 2012, 2016; DCLG, 2017).

In conclusion, this paper presents a framework that defines the characteristics of high quality green infrastructure at each stage of the planning and development process set out as a series of 23 principles. This contributes a refreshed understanding of the knowledge-practice gap between evidence for the benefits of green infrastructure planning and development, and provides a consistent approach to delivery through the market mechanisms of new development. The framework, developed collaboratively with stakeholders (see also Calvert et al., 2018) found that although there is an understanding about what characteristics provide benefits for people and nature, uncertainty persists across the built environment sector internationally regarding the delivery of high quality green infrastructure. As such, the principles presented here provide more clarity around *how* to deliver high quality green infrastructure through the planning and development process. These principles can be effectively translated into strategy and design criteria by policy makers and practitioners to more consistently and reliably secure the delivery of high quality green infrastructure. Considering the scope of the principles set out in the framework, and their background in literature and policy guidance from a number of countries, the principles could be readily applied globally, including by strategic stakeholders and practitioners engaged in the design, delivery and long-term management and maintenance of high quality green infrastructure. Ultimately, the framework can be used by all those involved in green infrastructure to enable the delivery of high quality green infrastructure to improve the health, wellbeing and climate resilience of people and wildlife.

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