Catchmentscape: A Novel Hierarchical Spatial Planning Unit for the Design of Ecologically-based Planning Practice

—

Iresh Jayawardena

Figure 1. View of current residential developments in the Warkworth urban area and the surrounding catchment landscape. © Iresh Jayawardena, 2022

Ecologically-based Design and Land Use Planning

—

Ecologically-based planning is one of the emerging approaches to spatial planning that guide planners in designing and developing urban spaces, adapting to human needs while balancing environmental concerns. Planning is well known to be an integrated process that deals with all aspects of urban development and is an important process for supporting and enhancing biophysical mechanisms. Technologically innovative concepts, such as Smart Cities, are developing alongside changing social and environmental attitudes in urban communities and have drawn increasing attention in modern planning practices in recent years (Rahmayanti et al., 2020). However, such methods and approaches have still to sufficiently address many environmental problems, in particular in the face of rapidly expanding cities. As a result, ecological functioning in urban areas has been degrading in response to incremental impacts created by urban planning practices.

There are arguments that planning practice and policies have not given enough attention to urban ecological systems (Ahern et al., 2014). To date, research on land use planning has mostly focused on development strategies and the need for approaches to respond to potential environmental impacts in cities and contribute to sustainable development. However, it remains unclear if planning and ecologically-based design concepts have been considered as an integrative tool for meeting specific environmental challenges in contemporary urban environment, including, for example, to respond to the current debate on adverse impacts of urbanisation on urban watersheds, ecosystems, terrestrial, freshwater, and coastal environments.

This paper proposes a novel ecologically-based spatial planning unit called 'catchmentscape' that can assist planners on how to integrate ecologically-based planning approaches and work within systems such as catchments to enable land use planning. Empirical evidence from a case study conducted in Auckland, New Zealand has been presented to demonstrate the potential of catchmentscape for broader practical application. The research focuses on investigating the extent to which historic theoretical planning practices have been used to integrate ecological design approaches to land use planning. As it is imperative to explore how catchmentscape can be introduced as a spatial unit for the design of ecologically-based planning to support such integration, the research reviewed theocratical and practical frameworks concerning ecological, landscape and land use planning as a foundation for putting forward the concept of catchmentscape.

A Novel Hierarchical Spatial Unit: Catchmentscape and Ecological Implications

—

Given limited space in our urban environments, planners often prioritise allocating a large amount of urban land for the development of human-made, social and physical infrastructure, including housing. However, planning cannot ultimately improve the quality and resilience of urban environments without taking into account the value of urban ecological resources and ecosystem management.

People enjoy the interaction between the natural and human-made environment offered in urban spaces. The combination of these two elements can make an urban space productive and meaningful for the community. Due to the interdependencies of ecosystems and their relationships with human habitats, under-

Figure 2. An area of greenfield landscape in Warkworth identified as a future urban area under the Auckland Unitary Plan. © Iresh Jayawardena, 2022

standing ecological effects provides opportunities to inform urban planning and design approaches. These ecologically-based approaches are mainly founded on the understanding of the existing character of land use, waterways and ecology in areas where urbanity occurs under changing urban environmental conditions.

This paper shows a potential application of catchmentscape using Warkworth in the Auckland Region of New Zealand as a case study (Figure 1). Warkworth is a rural town located 60 km north of Auckland CBD. Under the Warkworth Structure Plan 2019, an existing greenfield land area of approximately 1,000 ha has been identified as significant potential to accommodate future urban growth and zoned Future Urban Zone under the Auckland Unitary Plan (Figure 2). During conventional urbanisation, disruption of the existing biophysical characteristics of the land are inevitable. The concept of catchmentscape has reinforced the need and ability to change land use processes to improve and support ecological connectivity, biodiversity and water quality outcomes through the planning process.

Catchmentscape: A Framework for Developing Ecologically-based Spatial Planning

—

Theoretical origins of and trends in the integration of natural and human solutions into planning and design

From the Western perspective, the belief that urban nature was integrated into human design, or so-called ecological urbanism, appeared more than two thousand years ago when Hippocrates described the impacts of 'air, water and places' on public health and human society (Spirn, 1985). Much later, the concept of 'conservation' began to gain currency in Western theoretical understandings. In the 19th century, Olmsted, Patrick Geddes, and Lewis Mumford introduced various designs integrating nature into the city. Since the publication of Ian McHarg's *Design with Nature* in 1969, Kevin Lynch and Philip Lewis have also made outstanding contributions to developing the value of integrating natural environments and human objectives in order to achieve the goals of urban design.

Over the past decades, many researchers have reported on the serious impacts of urban growth and increasing interest in integrating urban ecological systems, landscape, and biodiversity into design and development strategies. Despite the enormous importance of these approaches, in the previous practices there was little discussion of planning frameworks and limited availability of tools that adequately measured ecological outcomes within the appropriate integration of spatial planning (Cook, 1991; Corry & Nassauer, 2005). However, theory and methodological frameworks for ecologically-oriented planning approaches later appeared in a range of disciplines, such as landscape planning (Grose, 2014; Hawkins & Selman, 2002), landscape and urban ecology (Naveh, 2001; Corry & Nassauer, 2005), ecosystem management (Cortinovis & Geneletti, 2018; Ahern et al., 2014), and landscape-ecological planning (Cook, 1991; Wu, 2013).

While there is a well-established history within the literature that emphasises the wide range of value and benefits that nature provides in human-created or modified environments, recent trends such as green infrastructure (Walmsley, 1995), nature-based solutions (Bell et al., 2021; Dhyani et al., 2020), Water Sensitive Urban Design (Barton & Argue, 2007; Morison & Brown, 2011), and Low Impact Development (Elliott & Trowsdale, 2007; Fletcher et al., 2015) reflect the integration and application of 'green' and 'blue' elements concepts into urban planning and design. These concepts are also linked to resilience concepts and emphasise the advantages of adaptation to climate risk and vulnerability. Considering growing concerns about climate resilience and impacts in urban systems, if planning incorporates a land use change based on the catchment that involves links between ecological landscape and human-induced development to provide a framework for spatial planning, it could improve resilience of our urban systems. In other words, the design of a holistic and integrated ecological approach will contribute to ensuring that future urban environments will be not only more readily adapt to climate change, but also have the capacity to remain in a healthy and resilient state during the planning process and changes in land use.

The catchment{scape} – based approach: the spatial pattern in landscape

Landscape pattern has a strong influence on its ecological process and the characteristics of urban systems. There is an opportunity to integrate urban ecology into planning and management of urban catchments by devising and applying a

framework that uses a combination of planning and design initiatives. Landscape ecology based understanding emphasizes broad spatial scales and the ecological effects of the spatial patterning of ecosystems, in particular the dynamics of spatial heterogeneity, interactions and exchanges between catchment and landscape (Turner & Gardner, 2015). To understand how the main structural elements in a landscape are crucial for articulating expected ecological impacts, a spatial unit form on the basis of catchment scale needs to be included in a spatially and functionally integrated land use planning process.

It is understood that there is a wider spatial heterogeneity of the landscape, and each natural element is self-dependent in nature (Turner & Gardner, 2015). Therefore, it is appropriate to analyse and evaluate the ecological structure of the landscape, i.e., spatial model and ecological dynamics, assuming the three basic characteristics of the landscape – structure, function and change.

> « 'Structure' refers to the spatial relationships between distinctive ecosystems, that is, the distribution of energy, materials and species in relation to the sizes, shapes, numbers, and kinds of configurations of components. 'Function' refers to the interaction between the spatial elements, that is, the flow of energy, materials, and organisms among the components of ecosystems. 'Change' refers to alteration in the structure and function of the ecological mosaic through time. » (Turner, 1989: 173)

The research emphasises that analysis and evaluation of the dynamic interaction and configuration of structure and function of landscape are important for planners in planning and managing the change of ecology of the urban landscape more effectively. This is because of the focus on maintaining both the natural system and the human-dominated environment of land use. This process might involve work within spatial elements such as streams, wetlands, and aquatic and terrestrial elements and create ecological networks to maintain ecological processes and habitats to accommodate endangered species and safeguard biodiversity. From the planning practice point of view, foreseeing impacts through a process of impact assessment is often beneficial, as the land use change process and its foreseeable environmental implications can either positively or negatively impact on one another's activity.

From the link between the natural and social systems and human settlements, the landscape of the catchment can be seen in its cultural, social and economic dimension and is part of the ecological hierarchy. As urban environments develop, outcomes of dynamic interactions between nature and human settlements appear to be part of the total environment. Therefore, the Total Human Ecosystem (THE) is considered to be the new paradigm of the global ecological hierarchy (Naveh, 2000), because it recognises human dominance as an integral part of the total environment. To achieve better outcomes for the total environment, the research found that the most interesting observation emerging from the catchmentscape approach was to recognise the dynamics of the catchment landscape through spatial and biophysical disciplines. These dynamics can contribute to the sustainable development of urban landscapes. The integration of ecological planning requires a comprehensive understanding of spatial planning processes to establish a comprehensive spatial planning unit for guiding land use changes. It is in response to this need that catchmentscape is proposed.

Defining Catchmentscape

—

According to the Oxford dictionary, catchment is defined as 'the action of collecting water, especially the collection of rainfall over a natural drainage area'. Catchment identifies the pattern of natural water drainage, and comprises both natural, planned and unplanned processes in catchment context (Figure 3). The term landscape has its origins in the late 16th century (denoting a natural scenery) from the Middle Dutch *lantscap*, meaning 'land' + the suffix 'scape' (the English equivalent of '–ship'). Landscape is defined as 'all the visible features of an area of land, often considered in terms of their aesthetical appeal'. Accordingly, catchmentscape is defined as follows:

« Catchmentscape is a spatial unit recognised within hydrological (catchment) constraints, characterised by networks of ecological structures and human-induced forces, and formed by interactions of patterns, functions and connectivity across the landscape. »

This framework provides guidance to planners on what elements to consider in a planning policy framework and methods that provide an opportunity to maintain an ecologically-influenced planning outcome. The combination of these key elements provides important opportunities to identify the role of water and ecological structures of the landscape as central elements within catchments.

The use of a spatial boundary in a catchment context considers various biophysical elements and provides a more locally-specific approach to design and urban development. The interconnected nature of catchments and sub-catchments offers an opportunity to protect and enhance natural environmental values and restore ecological connectivity during the change in land use. For example, as depicted in Figure 4, smaller ecological patches of the landscape of various shapes are important, as are larger patches or corridors (greater than 10 ha) to ensure their long-term survival, facilitating wildlife movement and ecological and biodiversity functioning between patches. However, smaller patches are vulnerable to isolation or disappearance in heavily developing areas. Hence, the catchmentscape approach uses a combination of ecological characteristics through a network of patches and corridors and demonstrates how ecological integrity, value of ecosystems, and functioning can be maintained by restoring ecological connectivity in the urbanising landscape. The principles, policies, and strategies of urban design and development play an important role in enhancing and protecting this connectivity and in preventing further degradation within a catchmentscape of urbanisation. This part has been further discussed in the following section, using the proposed zoning scenario of Warkworth urban area as a case study.

Development and Use of Catchmentscape Concepts

—

As previously discussed, characterisation of the catchmentscape is crucial for the present research study. Therefore, this section summaries the criteria that were used for identifying the determinants of the catchmentscape for ecologically-based planning using the Warkworth case study. As depicted in Figure 4, the spatial pattern of the landscape consists of three basic elements that can be combined to form different landscape structures: a) patches; b) corridors; and c) land metrics that consist of patches and corridors (Forman, 2014). These structures

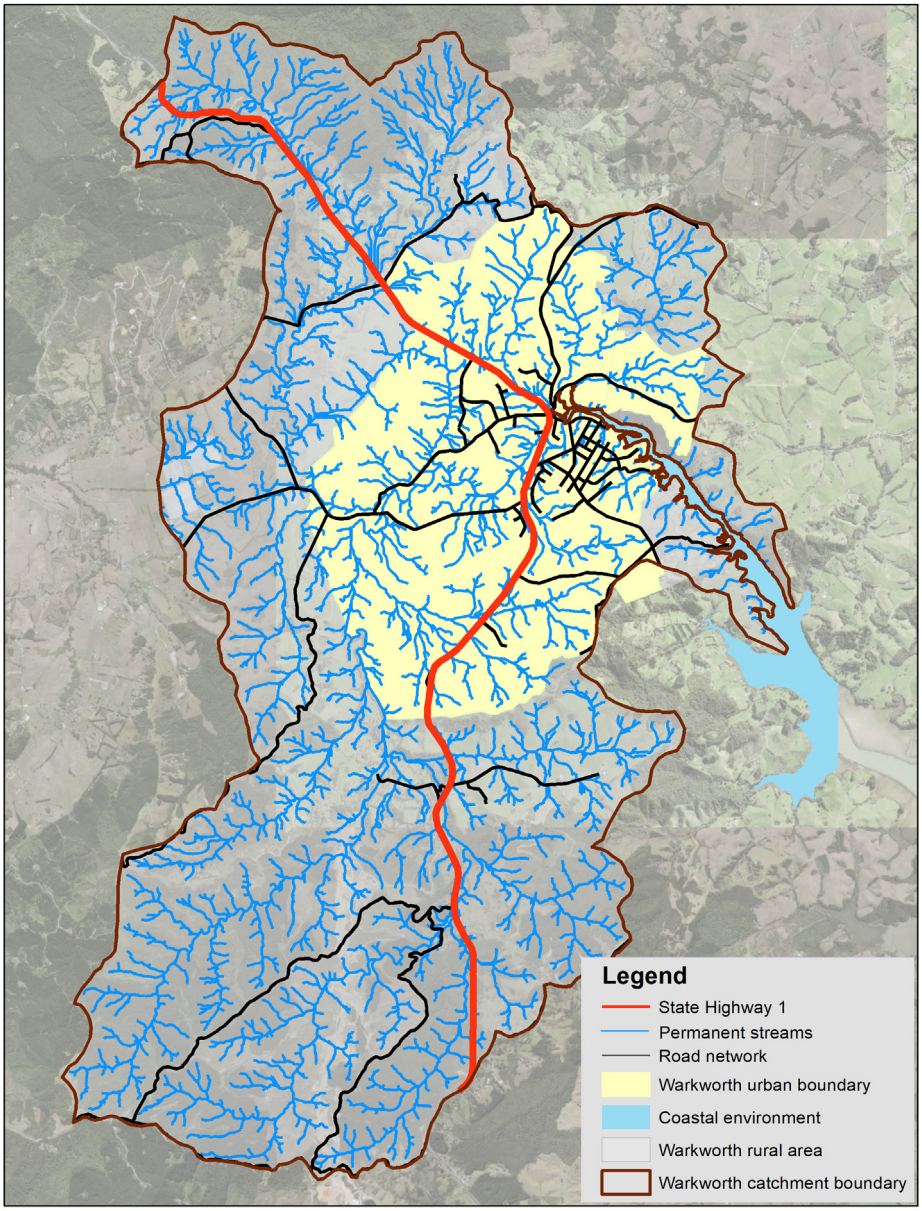


Figure 3. Warkworth catchment boundary. Source: Author, based on LINZ Data Service, Auckland Council

may consist of natural, planned, or unplanned elements in the landscape (Figures 4, 5). Natural structures, in particular, face serious threats and are increasingly becoming vulnerable to fragmentation when urban development modifies the catchment landscape during the planning and construction stages. However, understanding of the spatial relationships within each of these structural elements has become important for planners in arranging urban land uses.

As depicted in Figure 4, ecological processes operate consciously within a range of spatial scales between catchments in the landscape. However, when considering an individual catchment, it sets the pattern of natural structural elements such as *patches* and *corridors* on the catchment landscape. This can also be called the ecological footprint of the catchment. The opportunity to maintain the integrity of that ecological footprint can be obtained through a series of links called the *connectivity* of the catchment context. The existing ecological footprint can be unique between one catchment and another due to its natural existence or damage caused by other anthropogenic reasons, such as farming, agriculture, and urban development.

However, the existing structural footprint of the catchmentscape provides a holistic picture that assists and nudges planners to better understand current issues, and subsequently to search and think about alternative approaches to managing ecological processes during the urbanisation of greenfield environments. Figure 5 shows the proposed land use structure plan for the Warkworth urban area. Understanding the spatial relationships of these structural elements and the form and intensity of development appropriate to the environmental values within the catchment is important for planners in arranging urban land uses. The aim of using the catchmentscape is to help improve the linkages between the ecological landscape and the natural and man-made environments and to address key challenges of land use and the design and development of spatial planning strategies.

The conceptual framework of the development of catchmentscape is to take into account the fundamental aspects of the spatial and hydrological characteristics of the catchment in terms of landscapes and planning. Figure 6 gives a visual representation of the process framework for evaluating the catchmentscape. Protection and restoration of existing natural vegetation patches and corridors; and creating linkages between these ecological footprint through stream riparian buffers and green corridor forms dynamic ecological networks and contributes to the catchmentscape framework developed in the research.

This catchmentscape framework suggests that investigation of urban forms that minimises negative effects of the ecological landscape requires implementation of ecologically-based planning. These planning outcomes aim to achieve water-sensitive planning and design objectives. As Figure 6 shows, catchmentscape requires the aggregation of selected catchments/sub-catchments, taking into account the emphasis on 'connectivity' and other spatial structural elements of patches and corridors. The spatial analysis tools that use ArcGIS software are useful for analysing ecological patches and corridors and connecting those fragmented landscapes to strengthen stream riparian corridors or green belts that provide linkages in the catchmentscape (Figure 7). This contributes to managing long-term ecological integrity and outcomes of the catchmentscape within the catchment and sub-catchments. Investigating spatial elements using the three criteria of patch, corridor, and connectivity that are identified within the existing landscape matrix and defining the catchmentscape as a preferred spatial unit are considered imperative for the potentialities of applying ecologically-based planning and design.

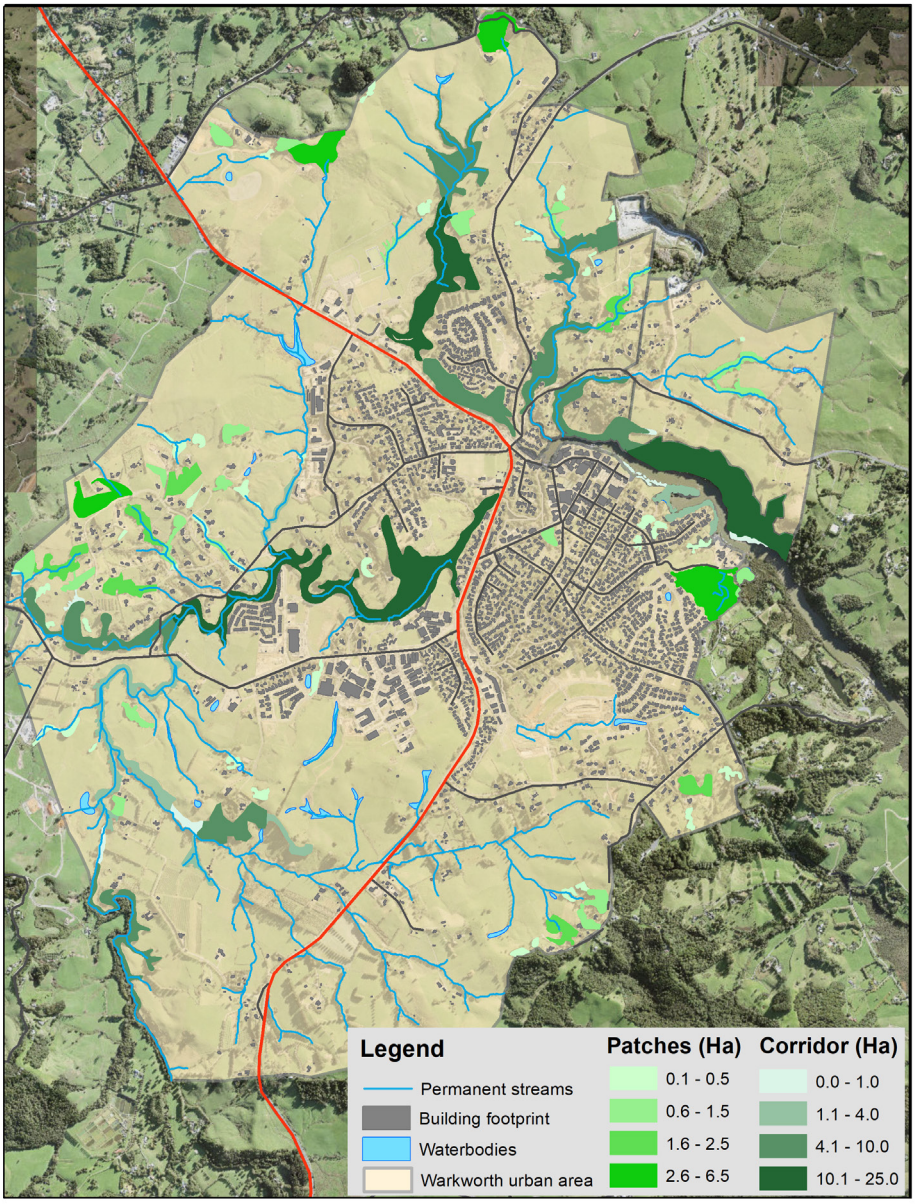


Figure 4. Patch-corridor landscape structures. Source: Author, based on LINZ Data Service, Auckland Council

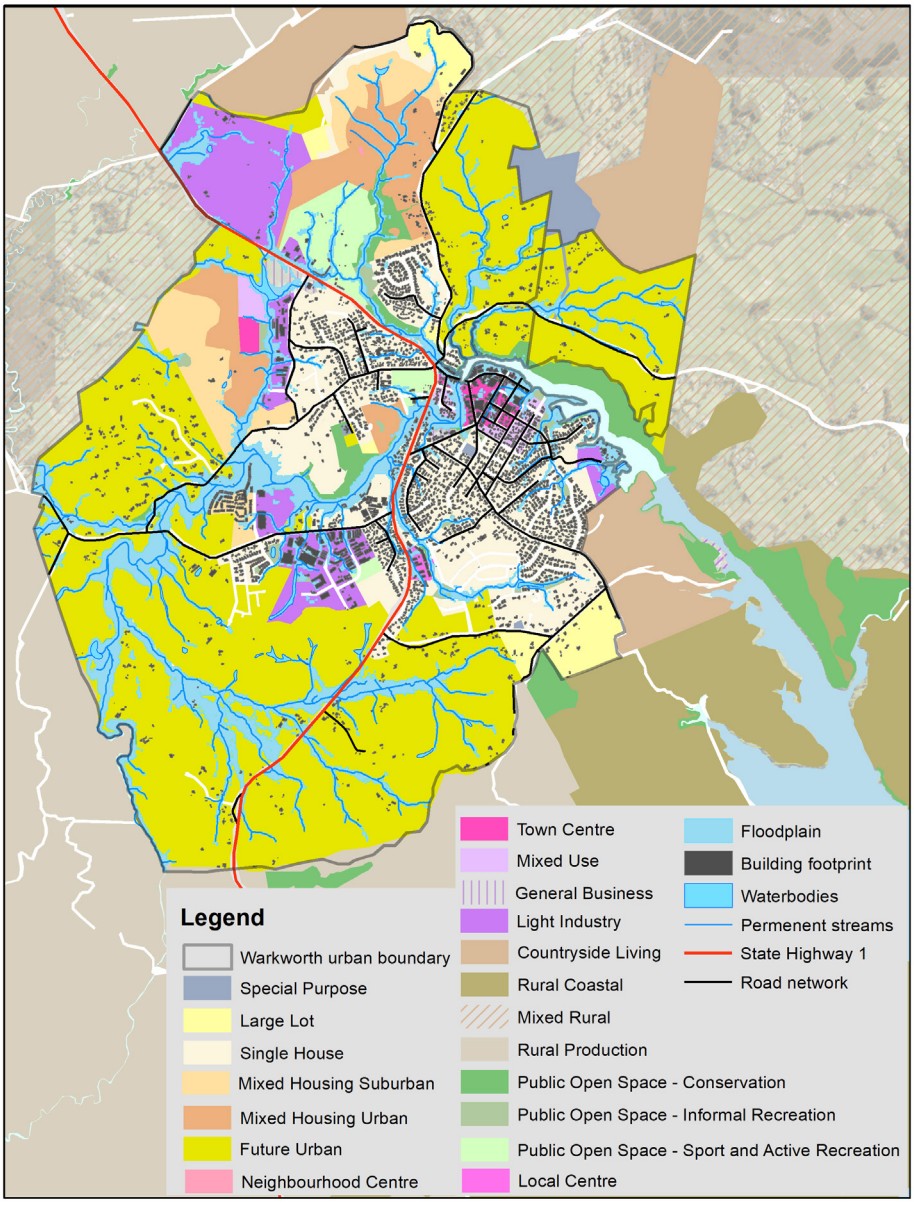
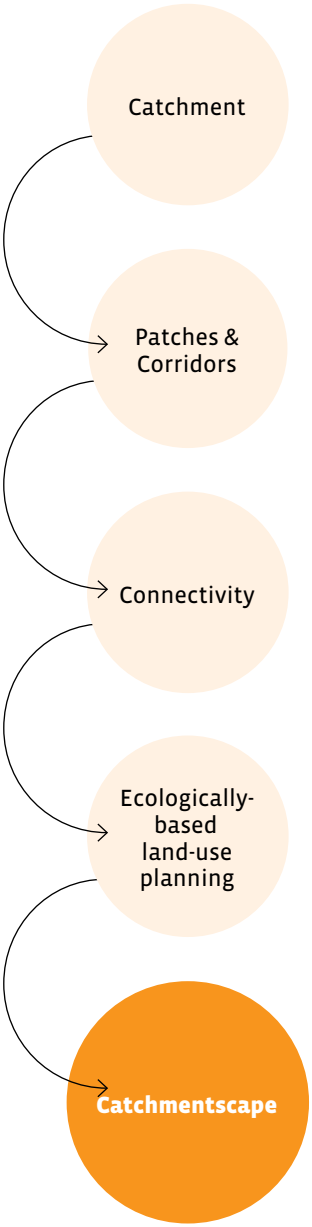


Figure 5. Existing and proposed landscape structures.
Source: Author, based on LINZ Data Service, Auckland Council

Catchmentscape



Spatial planning boundary that works within the catchment that identifies natural water drainage for urban design and development.

Assess the spatial structural elements of the catchment landscape (green areas, reserves, water bodies, green ways at various spatial scales, shapes and sizes) from an ecological optimisation point of view.

Identify linearity and possible linkage of ecological habitats between urban, rural, and natural landscapes and provided support to maintain ecological integrity and functionality.

Identify the interconnected nature of catchments and sub-catchments and provide opportunities to restore, protect, and enhance natural environmental value and ecological connectivity during the process of land-use change.

Demonstrate the spatial relationships of structural and functional elements of catchment landscape in arranging the urban land uses.

Figure 6. Conceptual framework for the new spatial planning unit of catchmentscape. Source: Author

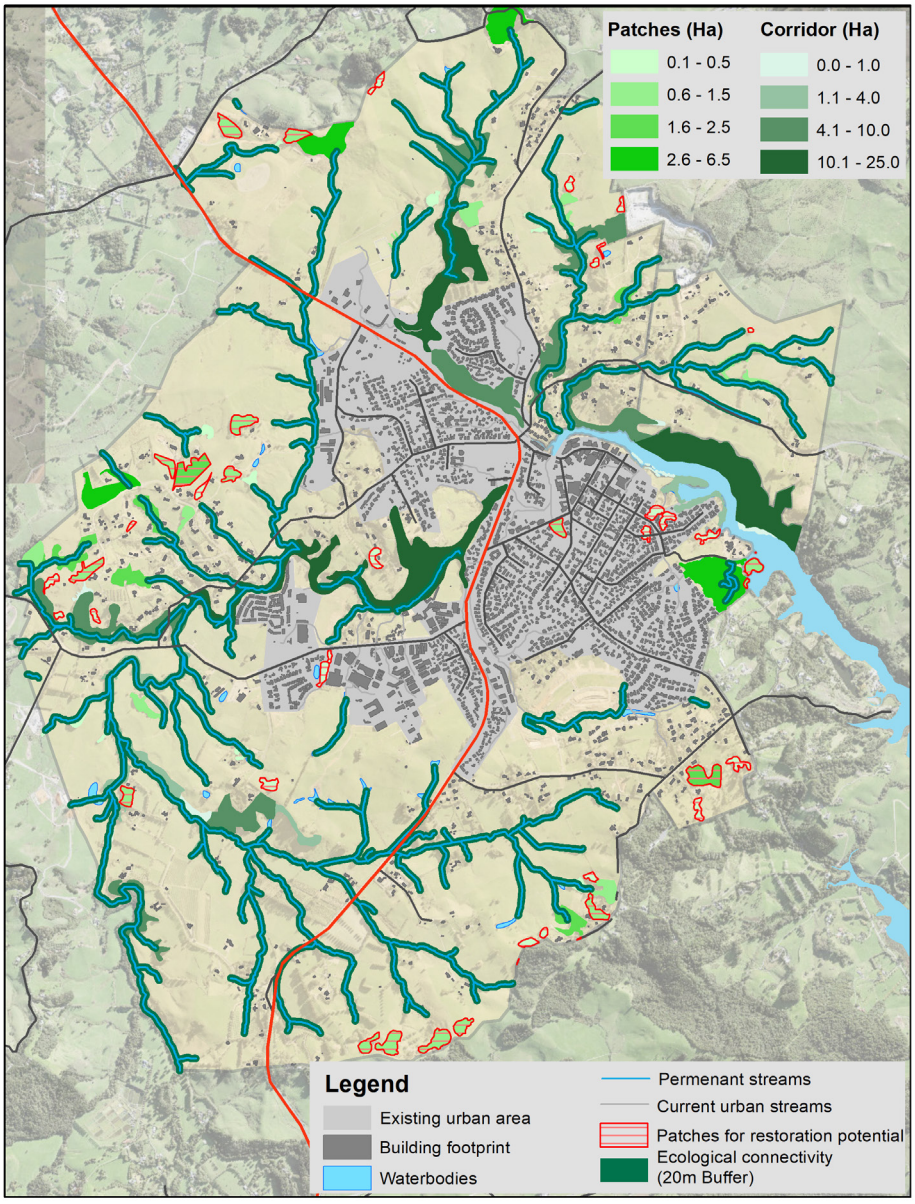


Figure 7. Catchmentscape for ecologically-based planning in the Warkworth urban area.
Source: Author, based on LINZ Data Service, Auckland Council

Conclusion

—

This paper presents important insights into ecological implications in our urban catchments and proposes a novel hierarchical spatial unit called 'catchmentscape' that responds to ecological concerns with the appropriate integration of spatial planning to design and develop urban environments. This paper adopts an approach that considers stream catchment as a central element for developing locally-augmented strategies to integrate the ecological landscape into spatial planning. Considering the catchment basis approach and its relationships and connectivity between structural and functional elements of the landscape, the notion of catchmentscape was presented using the future urban area of Warkworth as a case study. Catchmentscape contributes to the existing knowledge of planning theory and practice and ecologically-inspired planning approaches by integrating patches, corridors, and connectivity of the catchment landscape. The catchmentscape concept can be a useful spatial planning unit and can be effectively explored in other regions or within urban catchments as part of urban planning, design, and management. Application of catchmentscape would improve ecological integrity by facilitating urban growth and thereby enhancing urban environmental quality in greenfield developments.

—

References

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The Concept of Ecosystem Services in Adaptive Urban Planning and Design: A Framework for Supporting Innovation. *Landscape and Urban Planning, 125*, 254–259.

Barton, A.B. & Argue, J.R. (2007). A Review of the Application of Water Sensitive Urban Design (WSUD) to Residential Development in Australia. *Australasian Journal of Water Resources, 11*(1), 31–40.

Bell, S., Fleming, L.E., Grellier, J., Kuhlmann, F., Nieuwenhuijsen, M.J., & White, M.P. (Eds.) (2021). *Urban Blue Spaces: Planning and Desgin for Water, Health and Well-Being*. New York: Routledge.

Cook, E.A. (1991). Urban Landscape Networks: An Ecological Planning Framework. *Landscape Research, 16*(3), 7–15.

Corry, R.C. & Nassauer, J.I. (2005). Limitations of Using Landscape Pattern Indices to Evaluate the Ecological Consequences of Alternative Plans and Designs. *Landscape and Urban Planning*, *72*(4), 265–280.

Cortinovis, C. & Geneletti, D. (2018). Ecosystem Services in Urban Plans: What Is There, and What Is Still Needed for Better Decisions. *Land Use Policy, 70*, 298–312.

Dhyani, S., Gupta, A.K., & Karki, M. (2020). *Nature-Based Solutions for Resilient Ecosystems and Societies*. Singapore: Springer Nature.

Elliott, A.H. & Trowsdale, S. (2007). A Review of Models for Low Impact Urban Stormwater Drainage. *Environmental Modelling & Software, 22*(3), 394–405.

Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.L., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal, 12*(7), 525–542.

Forman, R.T.T. (2014). "Foundations", Land Mosaics: The Ecology of Landscapes and Regions (1995). In F.O. Ndubisi (Ed.), *The Ecological Design and Planning Reader* (pp. 217–234). Washington DC: Island Press.

Grose, M.J. (2014). Gaps and Futures in Working between Ecology and Design for Constructed Ecologies. *Landscape and Urban Planning, 132*, 69–78.

Hawkins, V. & Selman, P. (2002). Landscape Scale Planning: Exploring Alternative Land Use Scenarios. *Landscape and Urban Planning, 60*(4), 211–224.

Morison, P.J. & Brown, R.R. (2011). Understanding the Nature of Publics and Local Policy Commitment to Water Sensitive Urban Design. *Landscape and Urban Planning, 99*(2), 83–92.

Naveh, Z. (2000). What Is Holistic Landscape Ecology? A Conceptual Introduction. *Landscape and Urban Planning, 50*(1–3), 7–26.

Naveh, Z. (2001). Ten Major Premises for a Holistic Conception of Multifunctional Landscapes. *Landscape and Urban Planning, 57*(3–4), 269–284.

Rahmayanti, H., Zajuli Ichsan, I., Oktaviani, V., Syani, Y., Hadi, W., & Marhento, G. (2020). Environmental Attitude for Smart City Technology: Need Assessment to Develop Smart Trash in Environmental Education. *International Journal of Advanced Science and Technology, 29*(3), 8374–8383.

Spirn, A.W. (1985). Urban Nature and Human Design: Renewing the Great Tradition. *Journal of Planning Education and Research, 5*(1), 39–51.

Turner, M.G. (1989). Landscape Ecology: The Effect of Pattern on Process. *Annual Review of Ecology and Systematics, 20*(1), 171–197.

Turner, M.G. & Gardner, R.H. (2015). *Landscape Ecology in Theory and Practice: Pattern and Process*. New York: Springer.

Walmsley, A. (1995). Greenways and the Making of Urban Form. *Landscape and Urban Planning, 33*(1–3), 81–127.

Wu, J. (2013). Key Concepts and Research Topics in Landscape Ecology Revisited: 30 Years after the Allerton Park Workshop. *Landscape Ecology, 28*(1), 1–11.