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Justifying Water Sensitive Development: Science Informing Policy and Practice

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Abstract
This New Zealand research focuses on providing evidence that a specified residential land use layout plus 'at source' stormwater management results in higher aquatic ecosystem health. The evidence provides justification for changes in statutory plans, policies and practice rules that direct urban development. The surveyed sites are within river basins clustered by similar residential land use density. Each cluster includes one river basin with conventional urban form and drainage. Other comparative basins in the cluster typify a 'water sensitive' urban form and infrastructure. An index of biotic integrity (indicating river health) is determined for each waterway at annual intervals over years. Current plan requirements, policies and practice guidelines for urban development are critiqued in relation to survey results. The cumulative influence of defined residential river basin characteristics (drivers) are related to the holistic biotic indices. Combined drivers determine the cumulative aquatic health outcome. Research methods typically don't target the effects of a single driver. Policy, plan and practice requirements need to guide urban design and construction to incorporate the elements of urban form that are together necessary for aquatic health. This will ensure an order of magnitude improvement in the functionality and recreational appeal of streams, wetlands, lakes and recipient harbours.

Keywords: Water sensitive urban design; biotic integrity; urban planning

1. Introduction

There has been progress in recent years with the uptake of a concept for, and style of, urban development that is sensitive to the consequences for water and its efficient use. Common names given to variants of these concepts and practices include Water Sensitive Urban Design (WSUD) from Australia (DEWNR, 2013), Low Impact Development (LID) from the United States of America (Coffman, 1999), Sustainable Urban Drainage (SUDs) from the United Kingdom (Environment Agency, 2008), and Low Impact Urban Design and Development (LIUDD) from New Zealand (van Roon and van Roon, 2009). All of these practices have a common origin that questions traditional western approaches to stormwater management (or mismanagement). The degree to which each practice has deviated or evolved from this common origin is very variable. In some cases such as LIUDD, there is a strong focus on making changes to urban design, in order to optimise avoidance of negative consequences for water, rather than just providing an alternative drainage service. In other cases the practice has evolved to respond to country-specific needs, such as local water shortage (WSUD) or severe flooding (SUDs). As the concepts spread across the globe and become adapted to local needs, practice diversifies and participation spreads to a broader range of professions. Another important issue that can be addressed by these practices is the condition of natural waterways in terms of water quality, biodiversity, ecosystem services, adaptation

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to climate change, recreational usability and aesthetics. All of these are closely linked to the liveability of a city. Across most of New Zealand, an island nation where most of the population live very close to natural waters and adequate rainfall usually falls, it is the degradation of receiving water health that is the priority concern.

The health of urban waterways is determined by a multitude of influences predominantly from river basin biogeophysical processes (including climate) and land uses plus ground water exfiltration and air pollutant fall out. Most of these determinants (including climate change) are either a product of, or influenced by human decision-making and actions. The Resource Management Act 1991 (RMA) (New Zealand Government, 1991), along with local government and transport statutes, largely determine the planning and policy contexts of urbanisation in New Zealand (van Roon et al., 2016). It is mostly the directives and implementation of the RMA through plan making, policy formulation, objective setting, rule making, and consent granting that lead to the conditions that determine degradation of waterway health away from a reference (forested river basin) condition. Effects are cumulative both spatially and temporally and the RMA requires such cumulative effects to be avoided, remedied or mitigated (RMA Section 5 (2)(C)). "The RMA allows councils to develop their own approach to sustainable management on the basis of avoiding or mitigating adverse environmental effects, such as benthic ecosystem degradation" (van Roon et al., 2016 p6). The difficulties and complexity of unravelling the cause and effect relationships within a river basin leads to the conclusion that this is a 'wicked problem' as defined by Rittel & Webber (1973 as cited in Lazarus, 2009 p1159) "that defies resolution because of the enormous interdependencies, uncertainties, circularities, and conflicting stakeholders implicated by any effort to develop a solution".

The traditional response to such complexity has been for isolated professions to examine single drivers of waterway degradation, such as changes to hydrological and sedimentary regimes. This reductionist approach to problem solving within river basins frequently leads to the solution of one problem and the creation of others (such as through stormwater pond installation as will be demonstrated later in this paper). However, sufficient evidence has been accumulated to itemise a short list of urban river basin characteristics that are known to contribute to the health of streams in urban New Zealand. These understood characteristics are the minimum 'building blocks' for defining the urban form and infrastructure that is believed to be necessary to achieve a stream health equivalent to, or close to, reference condition within the urban environment. The 'building blocks' include but are not limited to: design each urban development using the river basin as the design unit, design with regard to connections between linked waterways and between land and water, minimise reconfiguration of the topography, keep streams natural and not piped, riparian native vegetation along the edges of waterways, the clustering or concentration of housing to free up open space in riparian and steep parts of the river basin, the minimisation of impervious surfaces, the maximisation of vegetation, reticulated sewage collection and treatment separated from stormwater, and at-source stormwater management. These minimum requirements have subsequently contributed to the New Zealand practice of Low Impact Urban Design and Development (LIUDD)(defined in Appendix 1 of van Roon and van Roon, 2009) and the Auckland Council guidance on Water Sensitive Design (WSD) manual (Auckland

Council, 2015a). It is with this in mind, that this research sets out to observe indicators of stream ecological health as it exists within comparative river basins, of traditional urban form and infrastructure (including separated sewer and stormwater networks) versus those river basins where urban form and infrastructure conform to the 'building blocks' referred to above for LIUDD and WSD. This research has been designed to generate scientific evidence, of the efficacy of the whole LIUDD approach, to residential neighbourhood design and management in delivering receiving water outcomes desired by residents. The accumulation of such evidence, from this and other sources, provides justification for politicians and government employees to support changes in policies, regulations and practice guidelines related to urban design and construction.

2. A Method for Collecting Some Evidence

All characteristics, of both human and natural origin, of a river basin cumulatively give rise to aquatic ecosystem health. These characteristics can be described, but their individual contribution to river health is much more difficult to differentiate. Fourteen streams/river basins have been sampled over varying lengths of time. Table 1 identifies which LIUDD 'building blocks' each river basin contains.

Table 1: Sampling sites defined by LIUDD building blocks complied with (✔) or not (**X**). Shaded sites are controls. Note: Septic tanks and stormwater ponds are not LIUDD building blocks but are included to record their presence or absence.

Building blocks of LIUDD/ WSD River basin	Urban density	River basin as design unit	Design connects nature	Riparian tree cover as % of river basin	Maximise vegetation	Design to topography	Streams natural	Houses clustered	Minimise imperviousness	Separate sewer & stormwater network	Stormwater biofiltration	Septic tanks	Ponds & wetlands
Norwood Upper	med	✔	✔	20	✔	✔	✔	✔	X	✔	X	X	X
Norwood Lower	med	✔	✔	11	✔	✔	✔	✔	X	✔	X	X	✔
Sullivans	med	✔	✔	22	✔	✔	✔	✔	X	✔	X	X	✔
Point View	med	X	X	3	X	X	X	X	X	✔	X	X	X
Regis North	low	✔	✔	60	✔	✔	✔	✔	✔	✔	✔	X	X
Regis South	low	✔	✔	60	✔	✔	✔	✔	✔	✔	✔	X	X
Regis Sth-east	low	✔	✔	60	✔	✔	✔	✔	✔	✔	✔	X	X
Regis West	low	✔	✔	60	✔	✔	✔	✔	✔	✔	✔	X	X
Redoubt	low	X	X	10	X	X	X	X	X	X	X	✔	X
Tiffany	low	✔	✔	30	✔	✔	✔	✔	X	X	X	✔	X
New Dawn	low	✔	✔	>30	✔	✔	✔	X	✔	X	X	✔	X
Silver Moon	med	✔	✔	>20	✔	✔	✔	✔	X	✔	X	X	✔
Carol Lee	med	✔	✔	20	✔	✔	✔	✔	X	✔	X	X	✔
Rangitoto	med	✔	✔	30	✔	✔	✔	✔	X	✔	✔	X	X
Oteha Para	med	✔	✔	>20	✔	✔	✔	✔	X	✔	✔	X	X
Oteha Ilam	med	✔	✔	>20	✔	✔	✔	✔	X	✔	✔	X	✔
Cranston	med	X	X	>20	X	X	X	X	X	✔	X	X	X

No single parameter can be measured to indicate river health. An indicator is required that reflects variability in river conditions over extended periods and the effects of that variability upon a representative and relatively stationary component(s) of the river ecosystem. For this reason a biotic index is measured for the invertebrate benthic organisms that live a relatively stationary existence on the river floor. Such a biotic index is specifically developed in relation to local species types and sensitivities and for a specific river type. The index used in this research was developed in New Zealand (Stark, 2004) and is known as the Macroinvertebrate Community Index for soft-bottomed streams (MCIsb), plus its quantitative (QMCIsb) variant. MCIsb gives a cumulative score that results from applying a sensitivity weighting to individual species, then adding the scores for all species found within a river sample. The QMCIsb incorporates further information into the total score on the number of individuals of each species. Information on a third index is generated as part of the calculation of QMCIsb. That is, the percentage of all taxa in the sample that belong to the pollution sensitive groups of mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) insects otherwise known as EPT. Further details on the methods for sampling of rivers using Protocol C2 and calculating the indices are available from (Stark, 2004).

For three of the streams in Table 1, samples have been taken and analysed upstream and downstream of differing stormwater treatment devices and methods. In one case only, the intensity of residential use was higher downstream than upstream, otherwise residential density has been held constant between streams compared.

The initial group of 9 streams/river basins (Figure 1) was first surveyed in 2005.

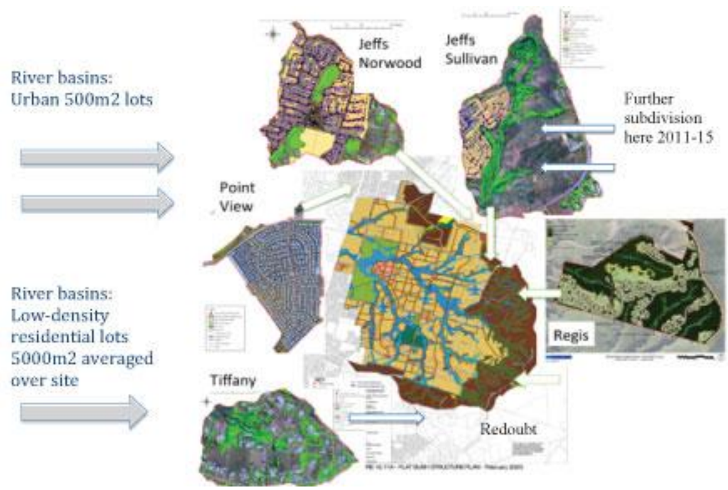

Figure 1: Location and character of the initial 9 streams and river basins. Sources: The Flat Bush Structure Plan (centre of Figure) Manukau City Council; Regis concept plan - DJScott Associates. Remaining images were prepared for van Roon (2010) by Tamsin Rigold.

These 9 river basins were grouped in two clusters according to residential density. Each cluster included a 'control' river basin so that alternative urban form and drainage infrastructure management (river basins with the building blocks) could be compared with conventional urban form and drainage infrastructure management. These 9 streams were usually sampled in early summer each year during two periods, that is 2005-2008 inclusive and 2012-2016 inclusive. An additional 5 streams were added to the research project in 2015 at a different location. The latter 5 streams were chosen to replicate the river basin land uses, vegetation, and treatment methods for stormwater and sewage that were present in the initial stream/basin series. Note however that no two river basins are ever identical so the replication was close but not perfect. Two of the latest 5 streams had 2 sampling reaches each. Again river basins were chosen so that a cluster of basins in conventional residential use could be compared with the alternative residential use typified by LIUDD or WSD.

3. Some Evidence of the Effects of Residential Land Development and Infrastructure on Stream Ecosystem Health

Figure 2 shows results for all streams that have been plotted on one graph. This figure plots 'QMCIsb' against '% EPT taxa'. Proximity or similarities in catchment land use and infrastructure have been used to cluster sampling sites by similar colour in Figure 2.

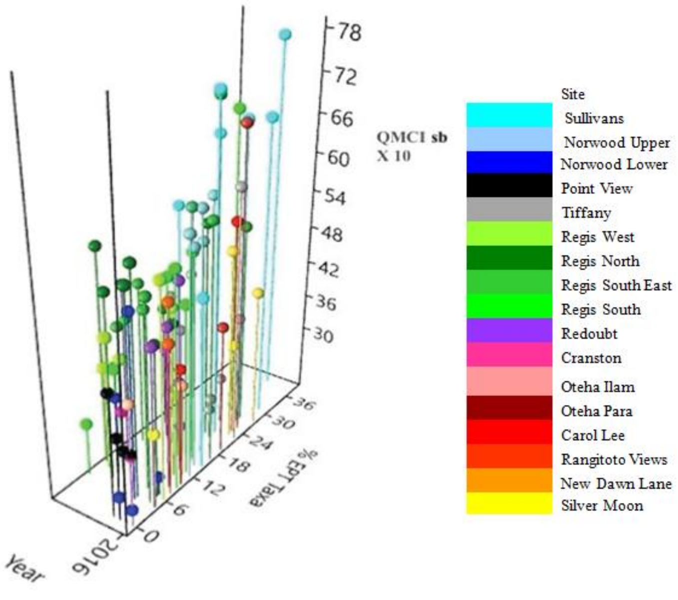

Figure 2: Two biotic indices are plotted 'QMCIsb' versus '% EPT taxa'. The year axis extends from 2005 (at rear) to 2016. The sites refer to those described in Table 1.

The following observations result from the interpretation of Figure 2 and demonstrate the consequences for receiving water ecosystem health, of varying degrees of inclusion of the 'building blocks' of LIUDD or WSD described above.

- The plotting of the two biotic indices against each other creates separation of river basins with similar characteristics.
- Streams in residential river basins with the most mature and wide riparian forest that also have reticulated offsite sewage treatment and at-source stormwater treatment have the highest (excellent) stream ecosystem health as measured by both QMCIsb and %EPT taxa. Streams with riparian vegetation replanted a decade ago have good stream ecosystem health and

further research will be needed to determine whether this continues to improve as the forests mature.

- Six streams in residential river basins with raingardens and no ponds but with immature or exotic weed infested riparian (re)vegetation have a good (not excellent) aquatic ecosystem health.
- A comparison of three streams in residential river basins with septic tanks and 5000m² grid subdivision shows high numbers of EPT species only in the 2 basins with mature & wide riparian forest and not in the basin with immature & narrow riparian vegetation.
- One stream in a clustered (4-500m²) residential development with a mature riparian native forest and no sewage or piped stormwater inputs has over a 9 year period demonstrated high to excellent stream ecosystem health.
- Five streams in residential river basins with very mature native riparian forests have high numbers of sensitive EPT species. (EPT species have pollution sensitive juveniles in streams and the adults inhabit the riparian forest, showing co-dependency on both stream and forest.) However, of these 5 basins those with septic tank seepage (rather than reticulated sewage treatment) and no stormwater treatment have only poor to moderate aquatic stream health as measured by QMCIsb.
- One stream subject to overflows from several stormwater ponds upslope of the forested riparian corridor has maintained excellent reference quality aquatic ecosystem health before and during subdivision of its river basin over a 10-year period. A recent drop in stream health is noted following limited vegetation stripping and earth disturbance on a point where a planned road will cross the stream.
- One natural stream within a mature native riparian forest in a river basin with 500m2 house lots but downstream of a stormwater pond and stream diversion has aquatic ecosystem health as poor as each of two piped streams in basins with 500m² grid residential subdivisions plus no forest or stormwater treatment.
- Three unrelated stream reaches downstream of stormwater ponds (within the riparian corridor but not online) have notably inferior stream ecosystem health relative to upstream reaches on the same waterways that receive no pond overflows.
- Two (out of two) piped streams (stream reach sampled at pipe exit point) in river basins with 500m² conventional grid subdivision have the lowest aquatic ecosystem health of all streams monitored.
- Six out of eight streams with stream ecosystem health ranging from good to excellent (as measured by QMCIsb) have either very low summer flows or would be classified as ephemeral.

4. How this Evidence Links to Plans, Policies and Guidelines in Auckland

Under the planning hierarchy of the RMA, lower-level plans shall give effect to, and must not be inconsistent with higher-level plans (Sections 62(3), 67 (2) and 75(2)). National Policy Statements inform regional plans, which inform district plans (van Roon et al., 2016). The National Policy Statement for Freshwater Management (NPSFWM) (MfE, 2014) and the New Zealand Coastal Policy Statement are relevant to this research. For each region preparation of a Regional Policy Statement, a Regional Coastal Plan and District Plans is mandatory under the RMA. In the Auckland case the districts and region have been merged in 2010 into a single Unitary Authority, which has recently made operative (in part) the Auckland Unitary Plan (AUP) (Auckland Council, 2016) within which are embedded the Regional Policy Statement (RPS), Regional Coastal Plan, other non-mandatory regional plans, and the District Plan.

Objective A1 of the NPSFWM (MfE, 2014 p9) reads: "To safeguard a) the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems, of fresh water in sustainably managing the use and development of land, and of discharges of contaminants." This is directly relevant to the management of subdivision and stormwater discharges and the degree to which they impact streams and aquatic life, as highlighted in this research. Councils are required to set freshwater quality limits, having regard to climate change and the connections between water bodies, and to impose conditions on discharge permits to meet limits (Policy A3). Further, the NPSFWM requires improvement "in integrated management of freshwater and the use and development of land in whole catchments, including the interactions between fresh water, land, associated ecosystems and the coastal environment" (Objective C1, p13). Every regional council must change its RPS to provide for the integrated management of the effects of the use and development of land on fresh water, including encouraging the co-ordination and sequencing of regional and/or urban growth, land use and development and the provision of infrastructure (Policy C2(a). Under Compulsory National Values it states that:

> *In a healthy freshwater ecosystem ecological processes are maintained, there is a range and diversity of indigenous flora and fauna, and there is resilience to change. Matters to take into account for a healthy freshwater ecosystem include the management of adverse effects on flora and fauna of contaminants, changes in freshwater chemistry, excessive nutrients, algal blooms, high sediment levels, high temperatures, low oxygen, invasive species, and changes in flow regime. Other matters to take into account include the essential habitat needs of flora and fauna and the connections between water bodies* (NPSFWM Appendix 1, p20).

All of the above Compulsory National Values of Freshwater bodies are under threat in streams, the river basins of which have been subject to conventional approaches to urban development, including the use of online stormwater ponds, as previously undertaken throughout the Auckland region. The NPSFWM Appendix 1 also states that measures of macroinvertebrates may be used, as in this research, for measurement of the health of stream flora and fauna. Both the NPSFWM and the NZCPS seek to improve the integrated management of freshwater and the use and development of land.

Auckland Council's regional predecessor the Auckland Regional Council has been involved in 'low impact' approaches to stormwater management to an increasing degree since the late 1990s. Until recently, however, a strong engineering focus on an alternative drainage approach has dominated over consideration of simultaneous changes to urban layout and revegetation. Research until recently has been aimed at ensuring optimal efficiency of ecologically engineered devices for mitigating hydrological changes and minimising contaminant losses to waterways.

Meanwhile throughout 2003-09 a major government funded national research programme, between a crown research institute and the University of Auckland, investigated the means to 'make mainstream' the practice of Low Impact Urban Design and Development. The outputs of this programme, included a definition of LIUDD (van Roon and van Roon, 2009, Appendix 1) as an alternative holistic approach to urban design and development to avoid multiple adverse effects (including hydrological effects)

of traditional development. The extensive published outputs drew attention to the complexity of implementation actions, methods, barriers and needed incentives.
Council's progression towards requiring a 'low impact' or WSD approach through its plans, policies and guidance documents has been slowly unfolding over the past decade (Table 2) as staff, council consultants and political awareness of the need has risen.

Table 2: requirements within the Auckland Unitary Plan (Auckland Council, 2016) that contribute to the achievement of the 'building blocks' of LIUDD or WSD.

Building block	Section/ policy	Purpose
Design development using the river basin as the design unit	AUP RPS: Policy 7.3.2(b)	Ensure catchment management plans form part of the structure planning process.
Design with regard to connections between linked waterways and between land and water	E1.3(1) & (2)	Relevant for water quality and integrated management these policies manage discharges, subdivision, use and development that affect freshwater having regard to NPSFWM National Bottom Lines and MCI as a guideline for freshwater ecosystem health.
Reconfiguration of the topography	E11	Region-wide overlays and rules for land disturbance.
Un-piped natural streams Riparian native vegetation along the edges of waterways	AUP: D4; D4.3(4) page 1	Natural Stream Management Areas Overlay which identifies "river and stream reaches with high natural character and high ecological values. They generally have an unmodified river or streambed with existing indigenous riparian vegetation on both sides." Instream values and riparian vegetation on both sides are to be protected. Construction of infrastructure is permitted if there is no practicable alternative.
Maximisation and protection of vegetation	D9.1.1 page 1	Provides for the identification of Significant Ecological Areas - Terrestrial as "identified areas of significant indigenous vegetation or significant habitats of indigenous fauna located either on land or in freshwater environments. In order to maintain indigenous biodiversity these areas are protected from the adverse effects of subdivision, use and development."
	E15 provides for biodiversity management not covered by D9.1.1.	Policy E15.3. page 1 "Protect areas of contiguous indigenous vegetation cover and vegetation in sensitive environments including the coastal environment, riparian margins, wetlands, and areas prone to natural hazards'.
Reticulated sewage collection & treatment separate from stormwater	E26	Region-wide rules for infrastructure
At-source stormwater management + Minimisation or disconnection of impervious surfaces	E1.3(8) to E1.3(16)	Policies provide for the implementation of all of the most desirable WSD/LIUDD stormwater management techniques to be applied during greenfield urban development. These techniques relate to the avoidance of effects on fresh water systems from discharge of contaminants, hydrological changes, loss of infiltration, erosion, increased stormwater temperature and loss of catchment pervious surfaces. Urban intensification is required to be "supported by appropriate stormwater infrastructure, including natural assets that are utilised for stormwater conveyance and overland flow paths" (E1.3(9)(e) p6.

Evidence of the ecological and economic benefits of such an approach has been essential to motivate staff and political decision makers to provide leadership. A section of the Auckland State of the Environment Report (Auckland Council, 2015b) entitled 'Better Urban Design' included a section on the Water Sensitive Design case study of Flat Bush where the current author's earlier evidence of stream ecosystem health gains were reported.

Council has been aware of, and receptive to acting on, local research evidence when crafting policies and guidance. During the development of the AUP (2011-2016) and the non-statutory guidance manual on WSD (Auckland Council, 2015a) Council and its consultants have provided the public and developers with guidance, on how to implement urban development that is more broadly 'water sensitive'. They have done this by demonstrating the need for change in the wider urban landscape and urban form to complement an alternative at-source stormwater control drainage system. Many provisions of the AUP that contribute to achievement of WSD within the Auckland region are summarised in Table 2 in relation to the 'building blocks' for LIUDD/WSD described above. Changes of language in the final editing of the AUP resulted in the loss of the identifiable names for WSD practice, but the practices remain embedded in the plan.

Conclusion

The results from this research do not prove or disprove the effectiveness of at-source stormwater devices alone, but rather they give an indication that a definable collection of river basin characteristics lead to positive outcomes for river health. Some characteristics are 'game breakers', in other words if they are absent no amount of tinkering with other components will compensate for their absence e.g. mature and wide riparian forest or a near to natural hydrological regime. Other components frequently lead to downstream ecological degradation e.g. stormwater ponds in the riparian corridor. Riparian forest alone will not protect or restore river health because urban river basin hydrological change is highly influential and is a result of many river basin characteristics both inside and outside of the riparian corridor. All forest, including riparian forest, within the urban area will, like a rain garden or other engineered biofiltration device, make a contribution to at-source management and minimisation of stormwater thereby improving hydrological neutrality of urbanisation and reducing contaminant accumulation in waterways. Offline stormwater ponds may also make a contribution but their effectiveness depends on their location, shading, and the method of conveyance, infiltration or surface spreading of the pond overflow before it reaches the stream/river. Within this research some stormwater ponds constructed offline but in close proximity to the stream or where pond construction caused damage to the original stream path have been shown to consistently depress stream ecosystem health as measured by QMCIsb upstream compared with downstream of the pond overflow. Ongoing monitoring will be needed to show whether stream health improves with time after water sensitive development, as replanted riparian vegetation matures and the damage to the landform from urban earthworks heals.

Many of the most ecologically healthy streams are either ephemeral or have very low summer flows. Ephemeral streams are vulnerable to destruction or damage during urban development and are deserving of greater protection through policies and development rules.

This research has demonstrated the growing body of scientific evidence in support of a form of urban development that incorporates the 'building blocks' of LIUDD or WSD. The results show the stream ecosystem health gains from this alternative approach in contrast to poor stream ecosystem health outcomes frequently recorded for water bodies downstream of conventional developments and piped infrastructure. Plans, policies and rules for urban development in Auckland, New Zealand are evolving in response to this evidence.

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References

Auckland Council (2015a) *Water Sensitive Design for Stormwater*. Guideline Document 2015/004. Auckland Council, Auckland. Retrieved from Auckland Council (2015b) *The Health of Auckland's Natural Environment in 2015*. Retrieved from www.aucklandcouncil.govt.nz.

Auckland Council (2016) *Auckland Unitary Plan – Operative in part*. Auckland, New Zealand. Retrieved from http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/unitaryplan/Pages/unitaryplanoperative.aspx.

Coffman, L. (1999) *Low-Impact Development Design Strategies; An Integrated Design Approach* (Report). Washington, D.C.: U.S. Environmental Protection Agency (EPA). EPA 841-B-00-003.

DEWNR (2013) *Water Sensitive Urban Design: creating more liveable and water sensitive cities in South Australia.* Department of Environment, Water and Natural Resources, South Australia: State Government. Retrieved from https://www.google.co.nz/search?q=wsud+australia&ie=utf-8&oe=utf-8&client=firefox-b&gfe_rd=cr&ei=BxHnWNahIIbr8wfivZyQBg.

Environment Agency (2008) *Sustainable Urban Drainage: a guide for developers.* United Kingdom: Environment Agency, Retrieved from www.rtpi.org.uk/media/12399/suds_a5_booklet_final_080408.pdf

Lazarus, Richard J.(2009) *Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future,* 94 Cornell L. Rev. Retrieved from http://nrs.harvard.edu/urn-3:HUL.InstRepos:12967877.

MfE, (2014) *National Policy Statement for Freshwater Management.* New Zealand: Ministry for the Environment, Retrieved from www.mfe.govt.nz. New Zealand Government (1991) Resource Management Act. Retrieved from www.legislation.govt.nz.

Rittel, H.W.J., & Webber, M.M. (1973) Dilemmas in a General Theory of Planning, *Policy Sciences* 4, 155-169

Stark, J.D. and Maxted, J.R. (2004) *Macroinvertebrate Community Indices for Auckland's Soft-bottomed Streams,* Technical Publication 303, Auckland: Auckland Council. Retrieved from http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/reports/technicalpublications/Pages/technicalpublications301-350.aspx.

van Roon, M. and van Roon, H. (2009) *Low Impact Urban Design and Development the big picture: an introduction to LIUDD principles and methods framework.* Landcare Research Science Series No. 37. Lincoln, New Zealand: Manaaki Whenua Press. Retrieved from http://www.mwpress.co.nz/store/viewItem.asp?idProduct1⁄4871 van Roon, M. R. (2010) *Low Impact Urban Design and Development: ecological efficacy as a basis for strategic planning and its implementation.* PhD thesis (Planning), University of Auckland, Auckland, New Zealand.

van Roon, M., Dixon, J. and Rigold, T. (2016) SEA Planning Responses to Estuarine Cumulative Effects of Urbanisation. *Journal of Environmental Assessment Policy and Management* 18 (3) 1-30