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Living suburbs for Living Streams: how urban design strategies can enhance the amenity provided by Living Stream orientated Public Open Space

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ABSTRACT

Perth, the capital city of Western Australia, is a city which is urbanizing into seasonally waterlogged land on two major development fronts. One result of this is that many new greenfield developments are adopting Living Stream orientated Public Open Space systems to cope with the related drainage issues. With respect to this situation this paper scopes the twin research questions, to what degree can Perth Living Stream reserves be considered high amenity Public Open Space, and how can Living Streams be optimized, from an urban design perspective, to provide greater amenity?' These questions are explored in relation to a taxonomy of recently constructed greenfield Living Stream projects in Perth. The paper concludes that a number of urban design strategies could be deployed in relation to urban density and structure, which could increase the amenity Living Streams provide.

Introduction

Wetlands comprise approximately 6% of the Earth's surface and act as sinks for carbon, important buffers in the landscape's hydrology, and support a large part of the Earth's biodiversity (Junk et al. 2013). Regardless of these vital ecosystem services provided by wetlands, their destruction continues in most countries of the world (Junk et al. 2013), generally because of land reclamation and wetland drainage 'required' for feeding and housing increasing population densities (Junk et al. 2013). Indeed, if existing trends in population density continue it is calculated that by 2030, 'urban land cover will increase by 1.2 million km^2, nearly tripling the global urban land area ca. 2000 (Seto, Guneralp, and Hutyra 2012, 16,083) – an increase that is likely to have significant effects on wetlands globally.

The Swan Coastal Plain, upon which the Western Australian capital city of Perth is sited, has up until comparatively recently been symptomatic of this continuing global situation (Department of Conservation and Land Management 1997). The Swan Coastal Plain geological unit is characterized by a complex system of rivers, estuaries, lakes, swamps and geomorphic wetlands. Since European colonization in the early nineteenth century, more

than 200,000 hectares of wetlands have been drained for agriculture and urban development on the coastal plain (Seddon 1972).

In more recent times this practice has been largely curtailed, and in 2008 the wetlands on the Swan Coastal Plain were evaluated and assigned a management category. These categories include Conservation Category Wetlands (CCWs) which support a high level of attributes and functions and are protected from development, clearing or degradation; Resource Enhancement Wetlands (REW) which may have been partially modified but still support substantial ecological functions and are managed so as to restore their conservation value; and finally, Multiple Use Wetlands (MUW) which are highly degraded and have few remaining important ecological attributes and functions (Department of Biodiversity, Conservation and Attractions 2014).

It is into this typically Multiple Use geomorphic wetland[1] category that Perth's suburban form is pushing along the south-eastern and north-eastern development fronts (Figures 1 and 2). As a result of this situation suburban projects are being designed and delivered to deal with the issues posed by high groundwater levels. This is typically expressed through the importation of large amounts of fill to lift urban form above water levels, and through Water Sensitive Urban Design (WSUD) informed 'Living Stream' Public Open Space (POS) models which allow for the drainage of broad suburban areas.

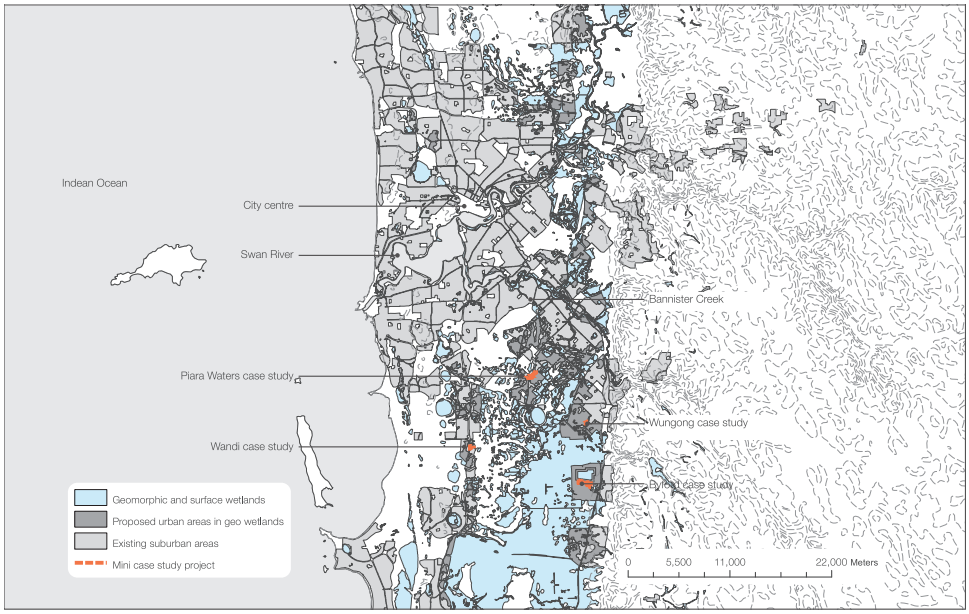

Figure 1. Suburban development and geomorphic (groundwater dependent) wetlands. Perth's new outer suburbs are in many cases being developed in geomorphic wetlands – such wetlands comprise seasonally waterlogged land which is generally highly degraded and considered Multiple Use Wetlands (MUWs). New suburban developments constructed in such areas are likely to require their own Living Stream POS and drainage systems to manage the issues posed by high groundwater levels.

Figure 2. Geomorphic wetlands. Typical geomorphic (groundwater dependent) wetlands in Perth's south-eastern growth corridor.

Water sensitive urban design

The Living Stream concept has emerged out of WSUD, a planning, urban design and engineering approach, which involves the 'integration of urban planning with the management, protection and conservation of the urban water cycle, that ensures that urban water management is sensitive to natural hydrological and ecological processes' (Wong 2006, 214; see also Polyakov et al. 2016). WSUD planning is regarded as being complex because it aims to 'protect, maintain and enhance the multiple benefits and services of the total urban water cycle' (Wong and Brown 2009, 674). These include 'supply security, public health protection, flood protection, waterway health protection, amenity and recreation, greenhouse neutrality, economic vitality, intra and inter-generational equity; and demonstrable long-term environmental sustainability' (Wong and Brown 2009, 674).

Living streams

Living Streams, which arguably represent one of the most visible WSUD trademarks, are typically retrofitted open drains in urbanized or urbanizing, areas, which aim to deliver the multiple benefits of the water cycle described (Figure 3). In this respect the principal functions of Living Streams are considered to be:

(1) To provide flood control and conveyance; in Western Australia Living Streams networks are required by the state government regulator (Water Corporation) "to contain 50% AEP[2] at a 1.5-year ARI[3] flows within a bankfull channel and contain 20% AEP at 5-year ARI flows within the drainage reserve and adjoining POS" (Water Corporation 2016, 1).

Figure 3. Living Streams. Living Streams, which arguably represent one of the most visible WSUD trademarks, are typically retrofitted drains in urbanised or urbanising areas, which aim to deliver the multiple benefits of the water cycle. This is image shows a recently completed Living Stream section in the Wungong development, on Perth's south-eastern growth corridor.

(2) Beyond such drainage related requirements, Living Streams should function as a biological filter in which fringing and aquatic vegetation provides 'a biological filter sieving out both organic and inorganic material and assimilating a portion of the nutrients flushed from the catchment' (Pen and Majer 1994, 197).
(3) Living Streams should function to provide a habitat and food web for a variety of plants and animals and to provide a corridor of land and water along which many animals can move (Pen and Majer 1994).
(4) Living Streams should enhance the amenity of the area – the function that is the explicit focus of this paper. Indeed, through providing POS, planting vegetation along streamlines or incorporating it into new drains the resulting Living Stream. Pen and Majer (1994) exhort that Living Streams 'may become a living feature of the urban or rural environment, rather than just an essential, and often unattractive, part of their infrastructure' (194).

While Living Streams are an essential component of WSUD theory, their lineage can be traced to the greenway and parkway movements (Ignatieva, Stewart, and Meurk 2011), and more contemporarily green infrastructure planning (Scott Shafer et al. 2013). In these movements a 'system of parks, greenways and undeveloped open spaces' were and are considered 'integral components of urban environments' (Scott Shafer et al. 2013, 478), thinking which resonates with the Living Stream concept.

Controversy regarding Living Streams as POS in Perth

Despite the widely held belief that Living Streams enhance the amenity of an urban area (Pen and Majer 1994) there remains some controversy about their role as POS in the Perth

greenfield context. In Western Australia, a greenfield development must also allocate 10% of its developable area to POS. This figure was derived from the mid-twentieth century, a time in which POS was configured with the explicit aim of giving 'recreational opportunities to the masses' and typically consisted of 'playing fields, with little ornamental vegetation, large expenses of grass, places for people to sit, clubrooms for sporting teams, and facilities like goal posts, basketball hoops and cricket pitches' (Sipe and Byrne 2010, 6). These were to be complimented by a system of Regional Open Space (ROS) often incorporating sport fields, incorporated in the planning framework (West Australian Planning Commission, & Department of Planning 2007). However, in the last few decades in Perth POS has increasingly been required to provide for ecological roles, such as stormwater infiltration and retention, providing habitat and maintaining remnant vegetation (Sipe and Byrne 2010; Middle and Tye 2011). In part, as a result a tension exists between the various ecological or recreational uses of POS in Perth (Middle and Tye 2011).

These tensions have been most clearly expressed in the Wungong project, an aspirational suburban development on Perth's south-east fringe (Figure 4). The Wungong project encompasses an area of over 1400 hectares and it is projected it will yield 16,000 homes at a compact density (by suburban standards), accommodating an anticipated population of 40,000 people (Brett Wood-Gush in Weller 2009). The design philosophy of the Wungong project stems

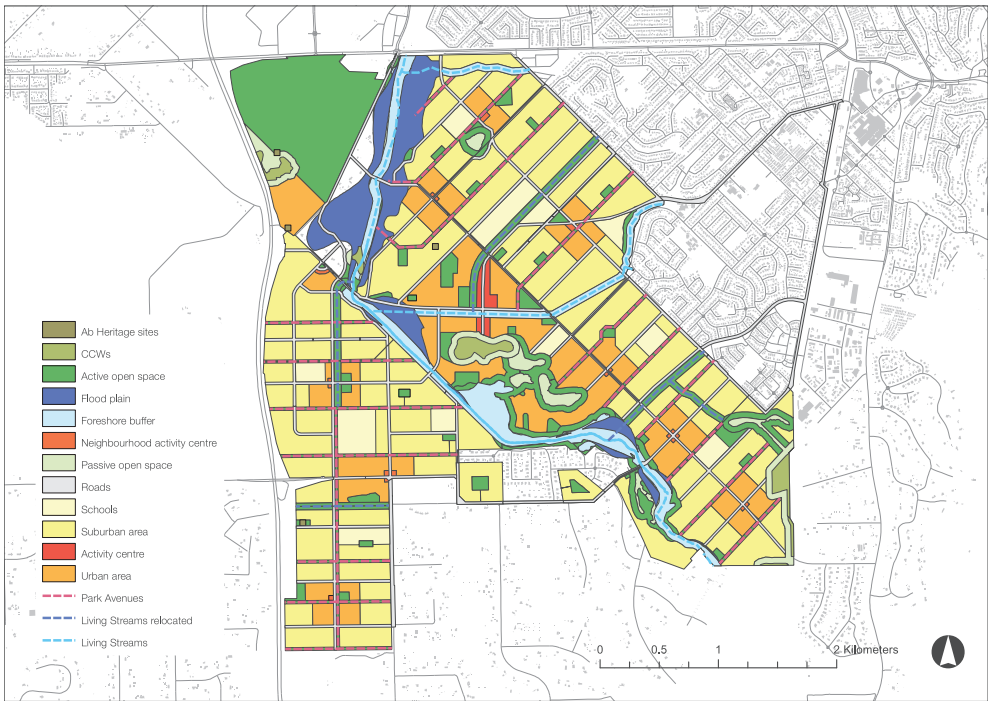

Figure 4. Wungong masterplan. The Wungong project encompasses an area of over 1,400 hectares and it is projected it will yield 16,000 homes at a compact density accommodating an anticipated population of 40,000 people. The Wungong masterplan proposed an urban development with an 'integrated urban water management system (in green) structured around an interconnected matrix of Park Avenues (linear swales with framing avenues of trees) and Living Streams, pictured.

from an initial provocation by the client, the Armadale Redevelopment Authority (ARA), for the designers to produce a 'concept masterplan as if the landscape really mattered' (Brett Wood-Gush, in Weller 2009, 239). Testament to this landscape orientated philosophy, the initial Wungong masterplan proposed an urban development with an 'integrated urban water management system structured around an interconnected matrix of Park Avenues (linear swales with framing avenues of trees) and Living Streams to be 'part of the ecology of the site and educate people about the ecosystem' (Interview with project director, 9 September, 2016) to manage water quality to avoid excessive water and nutrient run off into a CCW and the Wungong River, as well as being a place for nearby residents to meet and ambulate (Brett Wood-Gush in Weller 2009).[4] In 2010 a review of the Wungong project by a peer review panel raised fundamental concerns about the structure of the POS system. In their report it was concluded that there was an 'inadequate provision and distribution of appropriately useable public open space' and 'an over-provision of narrow linear open spaces' (Jones et al. 2010, 3). Moreover, it was considered that the nexus between the Park Avenues and Living Streams and surface water management did not have to be so 'tightly bound' (Jones et al. 2010).

Such criticisms relate to a 2011 Department of Sport and Recreation Commission research paper which argued that both WSUD and Bush Forever[5] have caused a reduced supply of active open space (i.e., sports fields) in the new fringe suburbs studied (Middle and Tye 2011). In part, this has led to an expectation from local governments that the mandated 10% POS figure will be configured in the form of district open space in the form of sporting fields. As a result of this, in areas with hydrological and ecological constraints this creates pressure for planners and developers to increase the overall amount of open space provided above 10%. While there may indeed by a shortage of sporting fields in Perth[6] (Middle and Tye 2011), the controversy about POS types does raise the question as to what degree Living Streams should be considered as POS which offers amenity to surrounding communities, and indeed how this provision of this amenity could be maximized.

Method

Given the likely ongoing proliferation of suburban developments in geomorphic MUW areas adjacent to CCWs and REWs in Perth,[7] and the likelihood such developments will adopt Living Stream orientated POS systems, this paper first examines the amenity offered by a series of Living Stream case study projects, second, and asks how the amenity[8] offered by these projects could be maximized. The questions which structured this research are as follows:

> To what degree does Living Stream POS being delivered in new suburban developments in Perth provide amenity to surrounding communities?
>
> How can Living Streams be optimized, from an urban design perspective, to provide amenity to surrounding communities?

To answer the former question, an 'evaluative' research methodology (Swaffield and Deming 2011) was employed to evaluate a taxonomy of Perth Living Stream mini case study projects against a credible Perth based matrix for assessing public open space attractiveness (Sugiyama et al. 2010). This was augmented by a Perth-focused analysis of the effects of

Living Streams on the real estate values of adjacent properties, and an analysis of wetland visitation data.

To respond to the latter question, a 'design research' method was employed through which urban design strategies were systematically proposed (Swaffield and Deming 2011) that 'explore the space of possibility embodied in a particular urban assemblage' (Dovey 2016, 259). While there is some controversy as to whether a design research method can be considered legitimate research, Swaffield and Deming (2010) argue that if it is conducted systematically, with a clear framework and research questions, that it indeed does constitute research.

In this paper the design research exercise was carried out with reference to a clear research question (as set out above) and in relation to a comprehensive literature review of relevant subjects, review of constructed mini case study projects and knowledge garnered from a range of interviews with sustainability engineers,[9] urban designers, landscape architects and hydrologists, all of whom have delivered Living Stream related projects, state government representatives who regulate the design and operation of Living Streams, redevelopment authority directors who have been responsible for the delivery of Living Stream structured suburban developments, project directors responsible for facilitating the design of WSUD developments, and academics who have conducted research into water and psychological economics. Through this rigorous review it was intended that the design research exercise would produce novel and constructive urban design strategies (Swaffield and Deming 2010), which are generalizable to other sites in Perth, and elsewhere, where seasonally waterlogged geomorphic wetlands and suburban development coincide.

The significance of this research

While there is a substantial body of literature on Living Streams written from an ecological, hydrological, regulatory or economic perspective (Pen and Majer 1994; Bernhardt and Palmer 2007; Polyakov et al. 2016), there is a lacuna of literature which scopes how urban design can maximize the amenity provided by Living Streams while simultaneously allowing for the important ecological and hydrological functions of Living Streams to flourish. Moreover, while the literature argues 'WSUD solutions should engage the city, respond to the environment, and invite use and attention' (Hoyer et al. 2011, 37), this is often not the case. As Hoyer et.al attest:

> There are a lot of planners working with swales and drains for decentralised stormwater management. Too often the implemented techniques are boring-because the surrounding area and context is not taken into consideration. (Hoyer et al. 2011, 89)

Clearly there is progress to be made in this area generally, and in relation to Living Streams in particular.

An assessment of whether Perth Living Streams constitute high amenity Public Open Space

This following section reviews mini case study Living Stream projects to determine to what degree they can be considered to constitute high amenity POS. This review is conducted in

relation to a credible POS 'attractiveness' matrix developed by the University of Western Australia (UWA) School of Population Health, data around wetland visitation – wetlands having many shared attributes as Living Streams, and house price data for residential properties adjoining drains which have been reconfigured as Living Streams.

Mini case study Living Stream projects

The four mini case studies that are examined in this section are parks containing Living Streams including 'Veterans Park' in Byford and 'William Lockard Park' in Piara Waters, 'Honeywood Park' in Wandi and the linear POS adjacent to Burdekin Turn in Wungong (Figures 5–8, Table 1).[10] These parks vary in size from 2 to 24 hectares and contain, in addition to the Living Streams, areas of retained bushland, turfed expanses, walking paths and some other assorted recreational infrastructure. These mini case study projects have been selected because they all form part of recently completed (or still underway) greenfield developments and as such have relevance to the contemporary development conditions. They are located in Perth's south-eastern growth corridor in areas which are identified as geomorphic wetlands, and they are developments which are ostensibly suburban, being characterized by smaller lots sizes of 500 m^2 (and less) and generally single storey suburban form.

Figure 5. The Byford mini case study project. Like the other mini case study projects the Byford project rates highly because it is generally well-equipped, furnished and planted.

Figure 6. The Piara Waters mini case study project.

Figure 7. The Wandi mini case study project.

Figure 8. The Wungong mini case study project.

Table 1. Weights assigned based on the presence of each attribute to measure the 'attractiveness' of the Living Stream case study projects.

Attributes/ Weight assigned	Piara Waters	Wandi	Wungong	Byford
Shade along paths (%)				
Very good			17	
Good		14		14
Medium	10			
Poor				
Very poor				
No paths				
Lawns irrigated (%)	15	15	15	15
Walking paths present (%)	14	14	14	14
Sporting facilities present (%)	10	0	0	13
Adjacent ocean or river (%)	0	0	0	0
Water feature present (%)	8	8	8	8
Quiet surrounding roads (i.e., cul de sac or minor road only)	4	8	8	4
Lighting present (%)				
Along paths				
In some areas			5	
In barbecue/play equipment areas only	3			
No lighting		0		0
Birdlife present (%)	4	4	4	4
Scores for case studies (out of 100)	**69**	**63**	**71**	**74**

Note: This table uses weights assigned based on the presence of each attribute (E.g. walking paths) to measure the 'attractiveness' of the Living Stream case study projects. Using this method the Living Stream projects scored an average of 70 out of 100. In the original project conducted by the School of Population Health, which evaluated 2,500 parks, recreational grounds, sports fields, commons, esplanades, and buffer strips the average score was 47.5. Please note these figures have been evaluated with respect to the Living Streams sections which have been constructed to date. As such, some of these assessments are likely to change overtime.

Measuring the attractiveness of Living Stream POS

Research into POS tells us that users have varying preferences for POS characteristics such as 'undulating topography, water, diverse vegetation and the presence or absence of tree cover' (Sipe and Byrne 2010, 22). Notwithstanding such subjectivity, researchers at the School of Population Health at the University of Western Australia in 2005 developed a method for estimation of the 'attractiveness' of parks to a set of potential users (Giles-Corti et al. 2005). Attractiveness was calculated as a weighted mean score of nine attributes, including the presence of walking paths, shade along walking paths, water features, irrigated lawn, lighting, sporting facilities and birdlife; type of surrounding roads; and being adjacent to a beach or river (Sugiyama et al. 2010). These attributes and their weightings were determined on the recommendations of expert panel members, a focus group, a comprehensive literature review and a second expert panel consisting of urban planners from 13 local government authorities (Giles-Corti et al. 2005).

Significantly, when the four Living Stream mini case study projects being examined in this research were evaluated against these criteria, the Living Stream projects scored an average of 70 out of 100 (Table 1). In the original project conducted by the School of Population Health, which evaluated 2500 parks, recreational grounds, sports fields, commons, esplanades and buffer strips, the average score was 47.5 (Giles-Corti et al. 2005). The Living Stream projects tended to rate highly because, other than sporting facilities, lighting and adjacencies to a beach or river, they were generally well-equipped and furnished spaces. Thus the most reliable quantitative measure of POS attractiveness yet developed in Perth indicates that the Living Streams mini case study projects should be considered attractive POS, at least when 'attractiveness' is calculated by this method.

Living streams and property prices

Confirmation that Living Streams in Perth are regarded as attractive to residents – and presumably are offering significant amenity – can be found in the effect of Living Streams on property prices in the adjacent urban area. The Bannister Creek Living Stream, located in the south of Perth's middle suburbs (Figure 1), provides one example of this. In 2001 Bannister Creek, a trapezoidal drain, was reconfigured as a Living Stream to both be able to filter the water running off a large urbanized catchment but also to simultaneously allow for regular recreational activities such as jogging, dog walking or bird-watching (Polyakov et al. 2016). The effects of upgrading of Bannister Creek to the level of a Living Stream on house prices, calculated using the 'hedonic price approach', showed that within about seven or eight years there was a substantial, statistically significant amenity benefit that reflected itself in increased property values in the adjacent areas (Polyakov et al. 2016).

Wetland visitation

Further to the effect of Living Streams on adjacent property values there is some evidence to suggest that in some situations they may also be more heavily utilized than conventional parks. In a 2001 study of residents in comparatively new suburban areas in Perth with small lot sizes (typically less than 500 m^2), it was found that it is wetlands and not parks which receive the greater visitation – in contrast with suburban areas with 'normal' lots of 700 m^2

and more. The attractiveness of water bodies in urban landscapes is well attested and may partly explain this result (Syme, Fenton, and Coakes 2001); however, it may also be that residents in smaller lots development are seeking a connection with 'nature' to compensate for the lack of greenspace on their smaller residential lot. This dynamic generally is referred to as the 'compensation hypothesis' in which residents compensate poor access to private greenspace by using public greenspaces such as parks which offer this in a well vegetated form (Byrne, Sipe, and Searle 2010).

While the wetlands studied (Syme, Fenton, and Coakes 2001) are less linear than typical Living Stream orientated POS, it could be presumed that the increased visitation of wetlands in small lot developments could also extend to Living Streams. Indeed, the descriptions of wetlands employed in the 2001 study describe a space very much like that of Living Streams, the wetlands constituting 'relatively open park space for active and passive recreation surrounding them. Bird life abounds. Each of the lakes has some natural vegetation at the lakeside through which visitors can walk' (Syme, Fenton, and Coakes 2001, 163).

By way of conclusion to this section of the paper, the literature and economic data about Living Streams in Perth, and (related) visitation figures for wetlands, suggests Living Streams are likely to be considered attractive, high amenity environments by surrounding residents, indicating that they should be considered as amenable POS, regardless of their linearity, overlapping ecological, hydrological and recreational roles. As such, Living Streams could form part of the mandated 10% POS requirement, although ultimately a 'needs based' assessment which considers the likely socio-demographic and bio-physical characteristics of the area (Sipe and Byrne 2010) is required to establish this with confidence. Regardless, urban projects successful or otherwise always entail lessons (Interview with redevelopment authority director, 26 October, 2016), and arguably the urban design aspects of Living Streams in Perth and elsewhere can be further developed. In this spirit, the following section of this paper examines how urban design strategies developed in relation to Living Stream POS could increase the amenity they offer.

Enhancing the amenity of Living Streams through urban design strategies

While the previous section examined the various cases for a characterization of Living Streams as generally high amenity POS, this section develops urban design strategies for how the amenity of Living Streams could be enhanced. The strategies include how Living Streams could be integrated with regional destinations, different types of POS, e.g., neighbourhood open space, adjacent street networks and zones of significant residential density, as well as how Living Streams could provide a 'natural' experience within otherwise manicured suburban areas. These strategies are set out in relation to their approximate scale of application, from the regional scale to the site scale.

Integrate Living Streams with regional destinations

Living Streams are potentially important elements to encourage active modes of transport, in part because 'flowing water … leads you into a landscape as it flows from here to there …' (Interview with water and psychological economics academic, 21 October, 2016). Moreover, compared to streets, with their attendant vehicles, Living Streams are seen by bicyclists and walkers as a more user-friendly connection than streets or even sidewalks

(Scott Shafer et al. 2013). However, the degree to which Living Streams are used for active modes of transport, such as walking and cycling, is also determined by the destinations to which they connect.

As a result of Living Streams being retrofitted drains they often do not provide direct connection to existing destinations such as Regional Open Spaces (ROS), district and neighbourhood centres and primary or high schools, largely because their original alignment is governed by hydrological not cultural factors. Indeed, regional mapping of the emerging Living Stream mini case study projects shows that the emerging Living Streams appear to be generally not well coordinated with regional destinations, in the form of urban centres, schools and ROS, and movement systems such as bike paths[11] (Figure 9). One possible result of this failure to not provide broader regional connections via Living Streams is that neighbouring residents consider the linear parks as their 'personal backyard', and increased use of urban wilderness by outsiders represents an invasion of their home territory (Hester, Blazej, and Moore 1999).

However, developed to its fullest, the integration of Living Streams with destinations could result in a high amenity, regional scale active transport network in which hydrological systems are used to connect 'diverse land uses'[12] (Lindsey et al. 2008), including places of activity such as schools and commercial areas (Buckman 2016) that are woven together into one connected matrix (Figure 10). In this respect Living Streams could be considered as a

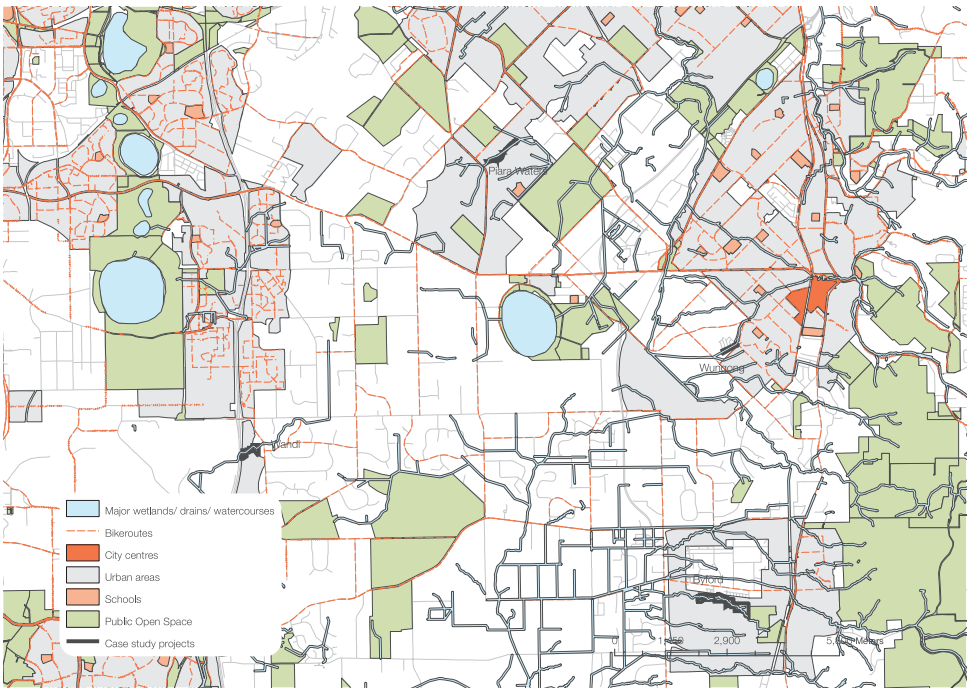

Figure 9. Existing coordination of emerging Living Streams with regional destinations. Regional mapping of the emerging Living Stream case study projects shows that the Living Streams appear to be generally not coordinated with regional destinations, in the form of urban centers, schools, and POS, and movement systems such as bike paths. Given the area is still under construction, such an assessment should change over time. This connection is certainly a feature of the Wungong masterplan.

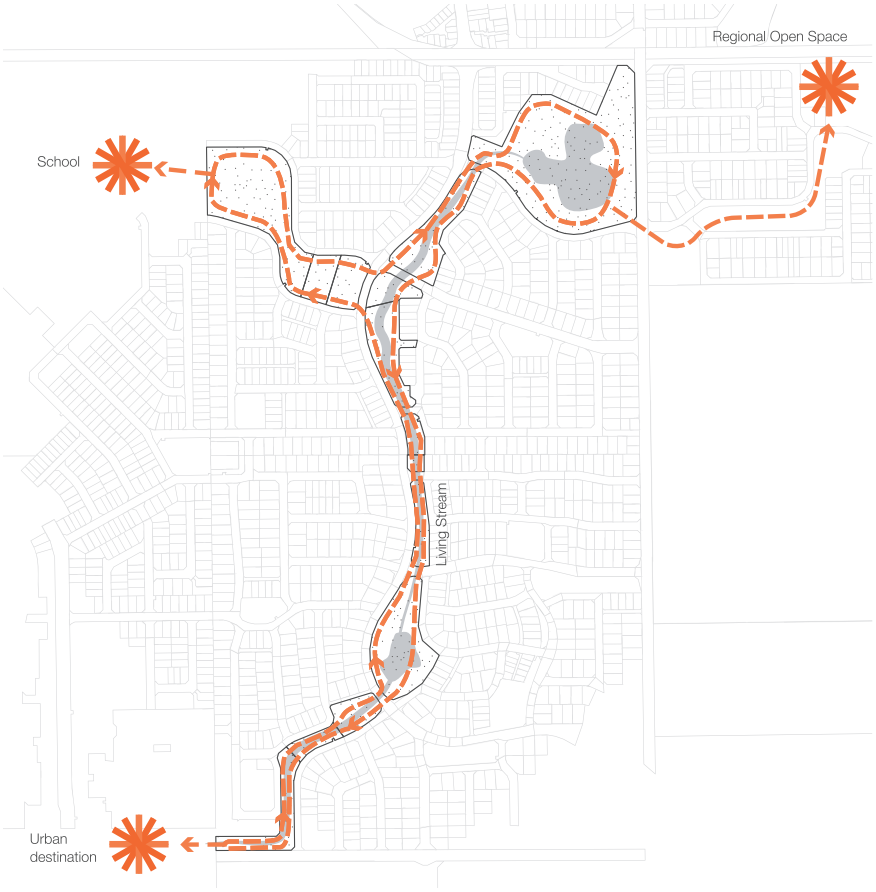

Figure 10. Coordinate Living Streams with destinations. Developed to its fullest however, the integration of Living Streams could result in a high amenity regional scale active transport network in which hydrology, ROS, schools and urban destinations are woven together into one connected matrix. Please note this diagram (and subsequent diagrams) are based on an adapted version of the Piara Waters Living Stream.

structuring principle for entire greenfield developments and the destinations which it contains (Kullmann 2011).

One existing example of connecting Living Streams to destinations is the Wungong project landscape masterplan which employed the linearity of the Living Streams and Park Avenues to encourage people to move along their length, to the Wungong River, the community parks situated at the heart of each neighbourhood and each of the schools proposed in the development area (Weller 2009). As a Wungong engineer explains, 'the Living Streams were considered a bicycle and pedestrian thoroughfare that would go somewhere. The idea of having density around the Living Streams was that they would be the destinations that you would be going to' (Interview with sustainability engineer, 21 November, 2016).

Integrate Living Streams with local, neighbourhood, district and regional POS types

One aspect of Living Streams that is particularly important is the degree to which they form part of an integrated POS system at the local, district and ideally regional scale. To achieve

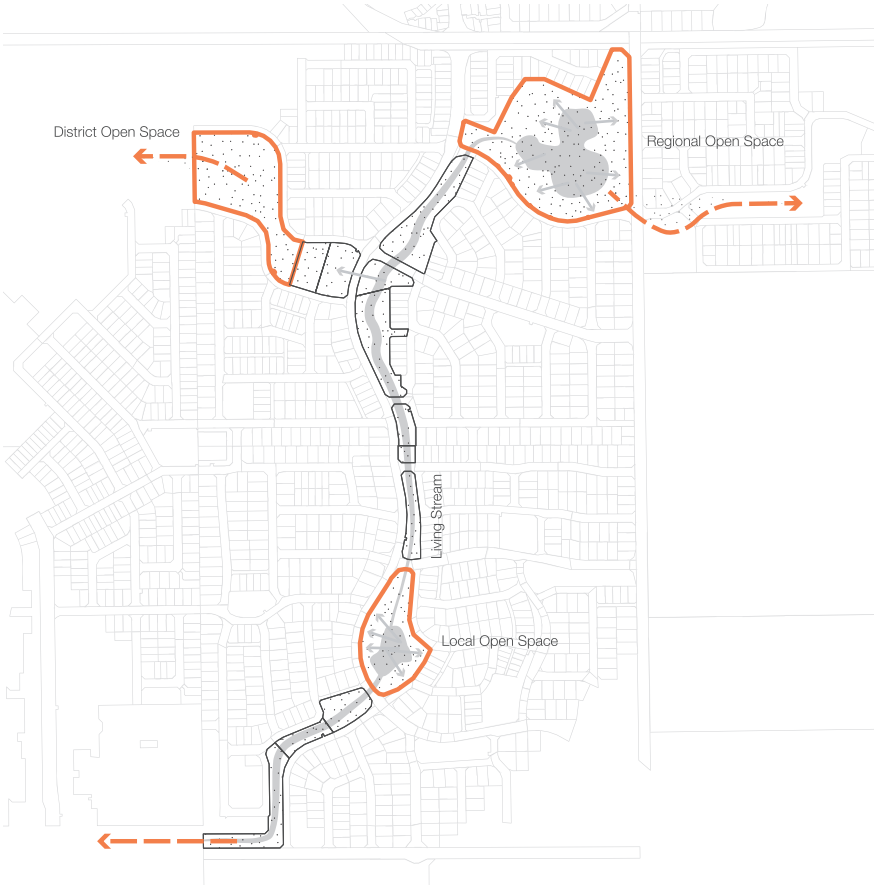

Figure 11. Integrate Living Streams with other POS types. It is particularly important that Living Streams form part of an integrated POS system at the local, district and ideally regional scale. One example of this is that the burden of dealing with major flood events can be shifted from the Living Stream to a broader area of POS which in turn means the Living Stream banks can be less steep, less reinforced with walls, and subsequently more useable and often more attractive.

such an integrated POS system means thinking of POS units not as an isolated component (be it a Living Stream, street or local park) but as a 'vital part of urban landscape with its own specific set of functions' (Richard Rogers, in Thompson 2002, 61). With respect to Living Streams this could be, in part, achieved by co-locating traditional neighbourhood local, neighbourhood and district parks with Living Stream POS (Figure 11). This approach provides a number of benefits with respect to the provision of amenity.

First, when other POS types are co-located with Living Streams some of the burden of dealing with major flood events can be shifted from the Living Stream to a broader area of POS, which in turn means the Living Stream banks can be less steep, less reinforced with walls and subsequently more useable and often more attractive. As a hydrologist explains, an explicit focus on dealing with drainage just within a constrained linear drainage reserve tends to result in a situation in which the Living Stream is 'too steep to be useable, but not vegetated enough to be of environmental value, it's nothing …' (Interview with hydrologist, 13 October, 2016).

Moreover the integration of other forms of POS with Living Streams means that the spatial dimension of the Living Stream is varied, thus creating a more diverse and engaging experience for users. Indeed, as Karl Kullmann (2011) explains, a greater overall diversity of spatial types along a Living Stream means that 'a variety of park users are able to find their niche somewhere, frequently forming 'subcultures' along the way' (77). Moreover, incorporating other forms of POS with Living Streams allows 'interesting and unexpected detours and zigzags,' that 'offer choice' (Ellin, in Buckman 2016, 794) as well as varying vantage points which allow users 'views and experiences that give them a sense of the landscapes they are passing through' (Flink, Olka, and Searns 2001, 20; see also Hellmund and Smith 2006). Conversely, an unrelenting and consistently narrow Living Stream profile can result in a heightened 'sense-of-enclosure' and situation which results in a 'claustrophobic feeling within the space' (Hiller in Buckman 2016, 794).

Furthermore, given the role of local, neighbourhood, district parks and Living Streams in maintaining biodiversity, forging direct connections between POS types is potentially important for allowing the movement of wildlife (Weller 2009). While issues of biodiversity could be perceived as having little or no impact on the amenity provided by the Living Stream, data concerning the presence of birdlife in parks increasing their relative attractiveness for human users suggests otherwise (Francis et al. 2012).

The Honeywood Project in Wandi, while a comparatively small in scale, provides an example of where a Living Stream has been integrated with a series of neighbourhood scale parks (Figure 7). As the designers explain:

> We have created open space either side of (the Living Stream) which is really well used and appreciated – the City of Kwinana thinks it was a great outcome and are very supportive of it. It was all about getting (active and passive POS) integration around the living stream. (Interview with landscape architecture firm, 31 October, 2016)

While largely mono-functional, low quality spaces may engender 'necessary' activities (such as dog walking), high quality POS such as provided in the Honeywood project – which is varied in proportion, aesthetics and potential usage – is able to accommodate a range of optional recreational and social activities producing a 'place and situation which invites people to stop, sit, eat, play, and so on' (Francis et al. 2012, 1571). In this instance POS becomes a hybrid system of hydrological, active and passive recreation functions.

Integrate Living Streams with the street network

Beyond integration with POS types the spatial relationships between a Living Stream and the surrounding street network is vitally important for the maximizing of the amenity it provides, visual or recreational, to surrounding residents. First, within reason, it is important to maximize the number of streets running perpendicular to the Living Stream to boost the ability of people to walk to the Living Stream (Kreiger 2004),[13] and view it from their properties (Figure 12). When the networks surrounding Living Streams are designed in this way they operate as 'catching features, meaning that they are relatively easy to encounter' (Kullmann 2011, 78) by people walking or cycling in the street network. These roads, beyond funnelling movement and activity towards the Living Stream, should also incorporate swales which collect water from adjacent rooftops and the streets themselves. In this respect, the visibility of water in swales and channels 'defines the character of the surrounding urban area,' and means residents are able to follow the 'sound, smell, and feel of the water' as it flows towards the Living Stream (Hoyer et al. 2011, 85).

At the same time as the number of roads perpendicular to the Living Stream should be maximized, the number of roads that cross Living Streams should be kept to a relative minimum (Weller 2009). While such crossing points do provide access to the Living Stream (Flink, Olka, and Searns 2001), the effect of a large number of roads crossing the Living Stream is to dissect it into smaller components, create visual barriers and obstruct movement along the Living Stream (Flink, Olka, and Searns 2001) – arguably situations that can be linked to a decrease in the amenity provided. A frequent number of crossings also incur greater cost because the number of bridge/ culvert structures required increases, and as such the project budget that is able to be directed towards other landscape design features is reduced.

While all the selected mini case study projects illustrate both these principles to various degrees, the Piara Waters Living Stream project provides an exemplar in this respect with its perpendicular streets typically at 80 metre spacing and streets crossing the Living Streams generally at 200 metre spacing (Figure 6).

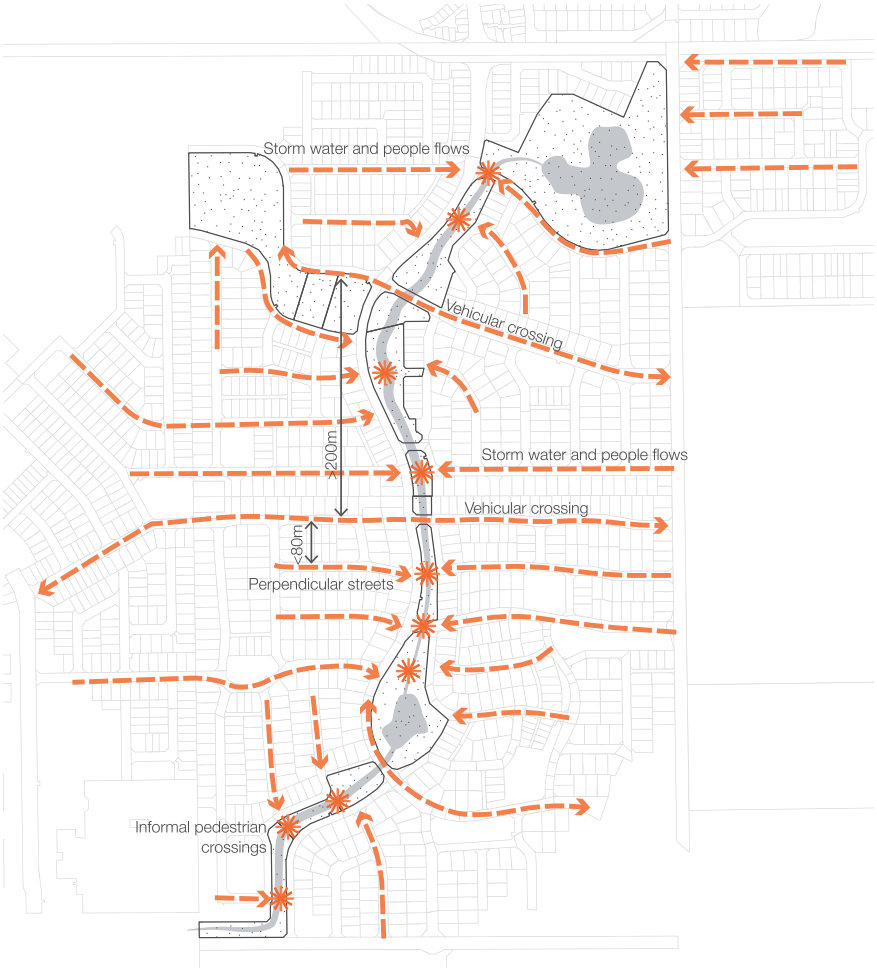

Figure 12. Integrate Living Streams with the street network. Within reason, maximising the number of streets running perpendicular to the Living Stream can boost the ability of people to walk to the Living Stream, and view it from their properties.

Finally, the design of the roads that run alongside the Living Stream is critical to ensuring the Living Stream is able to yield the greatest amount of amenity. By way of one example, heightened bushfire risk in Perth, resulting from a drying climate (Water Innovation Advisory Group 2016), means that the revegetation involved in Living Stream projects poses some risk to surrounding properties (Interview with landscape architecture firm, 31 October, 2016). Allowing for access by emergency vehicles to move along the edges of the Living Stream will help to mitigate this risk. As a result of this emerging situation, some local governments, such as the City of Armadale, are cautious about houses nested into POS without a road in between. This is because any dwelling backing onto POS affects the setback requirements for vegetation and as such can have an impact on the design of the POS (Interview with landscape architecture firm, 31 October, 2016) and potentially the amenity it can provide.

Within the limits of what can be achieved without unduly increasing the risk of housing to bushfires in Living Stream corridors, the streets running adjacent to the Living Stream should be one-way or two-way (of a minimal width) and planted with street trees in such a way that binds them into the Living Stream as one 'single composition'. This perception can also be increased by grading the adjacent streams so that they 'fall' towards the Living Stream and have flush kerbs, all of which helps to unify the adjacent streets and the Living Stream visually and hydrologically (Figure 13). If such measures are not undertaken Living Streams can appear to be spatially separate from the adjacent street, a situation which is less likely to draw people into the Living Stream environment through its disconnection with the surrounding fabric.

Integrate density around Living Streams

As the previous section discussed, Living Streams are perceived to offer a substantial degree of amenity to residents of the adjacent areas, a phenomenon which is reflected in boosted house values (Polyakov et al. 2016). As such, Living Streams potentially could be 'leveraged' and integrated with residential density (Ellin 2010), in part because they offer amenity and as such an incentive for people to live at higher densities than otherwise may be achieved

Figure 13. Binding the Living Streams and adjacent streets into a single composition. Streets running adjacent to the Living Stream should be one-way or two-way (of a minimal width) and planted with street trees in such a way that binds them into the Living Stream as one 'single composition.' This perception can also be increased by grading the adjacent streams so that they 'fall' towards the Living Stream, and have flush kerbs, all of which helps to unify the adjacent streets and the Living Stream visually and hydrologically.

(Bolleter and Ramalho 2014) (Figures 14 and 15). This density could take multiple forms, but a 2–4 storey 'row house' building type could be appropriate as it is typically flexible and can be 'adapted to accommodate communal groups of various sizes with different needs and different societal, cultural or sociological orientations' (Pfeifer and Brauneck 2007, 11). Such a diversity of residents could be crucial for activating the adjacent Living Streams at different times of the day, week and year.

Regardless of the building type deployed, there are a number of synergies that could form between the higher density housing and Living Streams.[14] By way of one example, researchers have found that children living in higher density housing have a greater need for 'publicly accessible greenspaces for play, mental health and social and physical development' (Sipe and Byrne 2010, 5), something that Living Streams could be specifically designed to offer (Figure 16). Moreover, having direct views to a Living Stream from higher density dwellings has many potential health benefits. Indeed, research tells us such views of 'nature' from a home (or indeed workplace or car window) can be restorative, lessen psychological distress (Francis et al. 2012) and have general mental health benefits (McDonald 2015).

From another perspective Living Streams are 'all edge and no middle, and (as such are) heavily defined by their margins' (Kullmann 2011, 74). As a result, denser urban edges adjacent to Living Streams may provide a more appropriate urban 'frame' in comparison to the conventional suburban density typically delivered, as well as increasing the surveillance, safety, and usage[15] and safety of the Living Stream.

Moreover, deploying compact urban form along the edges of Living Streams has significant potential to yield dwellings because the edge length compared to area of such POS is particularly high. For example, in the Wungong project, 21 linear kilometres of Park Avenues are planned to be provided which equates to potentially 42 linear kilometres of denser housing that fronts the avenues (Interview with project director, 9 September, 2016). In this respect the Park Avenues (and Living Streams) could incentivize (Interview with redevelopment authority director, 26 October, 2016) and compensate for significant areas of residential density, as well as provide a compelling branding opportunity for developers in which 'the natural pull of water' acts as a 'driving point for development …' (Buckman 2016, 798). Moreover, by densifying around Living Streams, developers are able to recoup some of the capital that is otherwise lost in having a significant amount of land bound up in Living Streams, such additional costs being regarded as a barrier to the implementation of WSUD in general (Hoyer et al. 2011).

Despite the potential of correlating Living Streams with residential density, only the Wungong masterplan exploited this potential, through integrating urban density with its Living Streams and Park Avenues (Figure 4). That said, the small section of the Wungong project constructed to date shows only a modest increase of density on the Living Stream edges (with suburban lots as small as 300 m^2) and it is not clear to what degree the planned residential densities will be delivered elsewhere in the project.

Provide a natural experience

Pen and Majer (1994) argue that – on a day-to-day basis – 'the average Australian is alienated from the natural world' (198), a situation which could be extrapolated to the greater developed world. In relation to this situation Living Streams potentially have a very important role to play in providing this experience of 'nature' to residents as the mental and physical

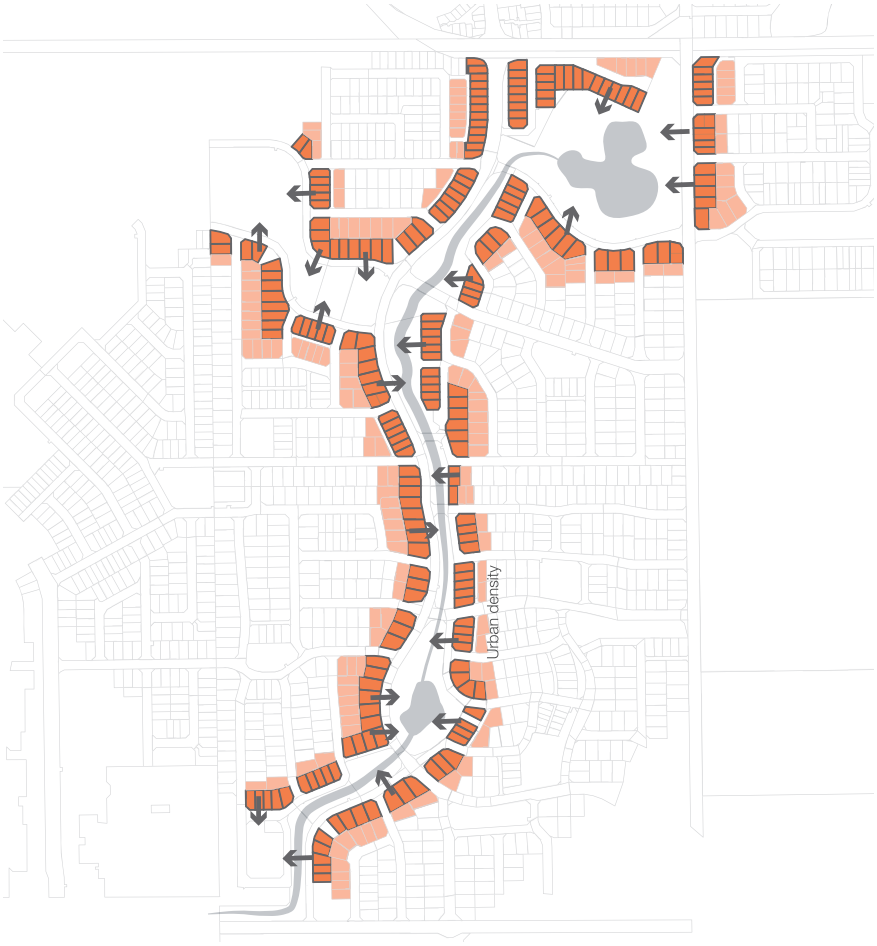

Figure 14. Increase density around Living Streams. Living Streams potentially could be 'leveraged' and integrated with residential density, in part because they offer amenity and as such an incentive for people to live at higher densities than otherwise may be achieved.

health benefits are potentially huge (McDonald 2015). Indeed, in the USA when residents of a major urban area were asked about ways that greenways (which often incorporate a drainage function) influence quality of life, the most important contribution was regarded as 'having natural areas present' (Scott Shafer et al. 2013, 482). While the physical and mental health benefits are yielded by most forms of POS to varying degrees, Living Streams have particular potential in this respect because of their linearity they typically adjoin, and are near to, a large proportion of houses, making them highly accessible. Moreover, because of their typically passive recreational focus, the presence of water and biodiversity means they form an apt substitute for 'nature' in the city.

Due to these factors, Living Streams should be designed, as much as possible, to provide access to nature (Figure 16); however, this term needs to be clarified. The 'nature' which could be emulated in future Living Streams should not be a 'pure' nature, partly because the re-creation of a pure nature is practically and philosophically impossible, and also not necessarily desirable in an urban context. Rather, Living Streams could provide an ecologically rich,

Figure 15. Increase density around Living Streams. Deploying compact urban form along the edges of Living Streams has significant potential to yield dwellings because the edge length compared to area of such POS is particularly high.

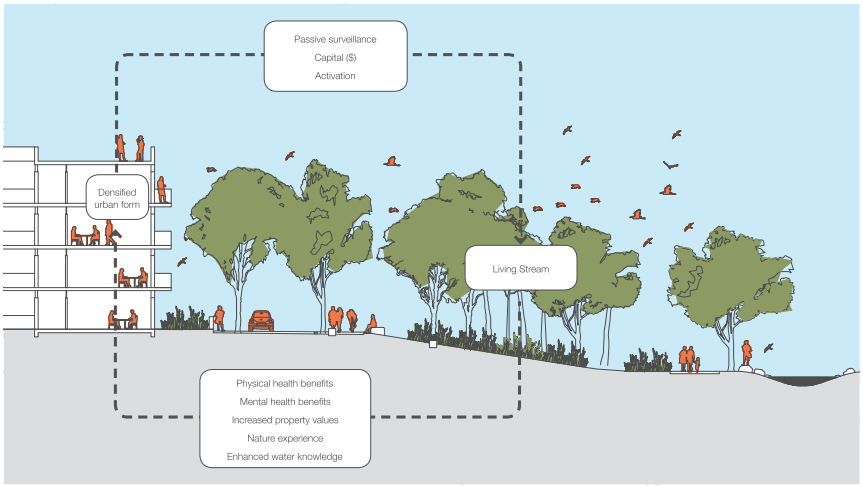

Figure 16. Synergistic density. There a number of potential synergies between densified urban form and Living Streams. Indeed even direct views to a Living Stream from higher density dwellings have many potential health benefits – research tells us such views of 'nature' from a home can be restorative, lessen psychological distress, and have general mental benefits.

diverse (Pen and Majer 1994; Water Corporation 2016), immersive (Kullmann 2011), loose-fit, wild, messy and informal conception of nature (Thompson 2002) which allows for exploration and play, particularly by children (Louv 2007) and provides a window on the ecology of running waters which can be used by local schools (Pen and Majer 1994), particularly if schools are located adjacent to Living Streams.

The potential of Living Stream users to be able to immerse or 'lose' themselves in a 'natural' experience is crucial (Giles-Corti et al. 2005). Karl Kullman describes a linear park that can provide this immersive experience as a 'thicket', as he explains:

> This effect is ostensibly created with overgrown vegetation, but can also be a product of constructed complexity and messiness. From within a thin park constituted as a thicket, depth of field, interior and exterior become obfuscated, making the experience from within both explorative and disorienting. (Kullmann 2011, 80)

Topographic shifts, screening vegetation and tree cover (Kullmann 2011) can all play a part in facilitating a visitors desire to 'lose one's self. Immersion also relies on the path system, for substantial areas, deviating from the road edge and being 'immersed' within the body of the Living Stream POS (Figure 13). Moreover, siting recreation facilities at the edge of Living Streams can help balance degrees of fragility with intensity of use, protecting biodiversity (Hester, Blazej, and Moore 1999).

In addition, Living Streams also could provide a more powerful experience of temporality and change (Interview with water and psychological economics academic, 21 October, 2016) due to changing water flows more than typical parks in Perth, an aspect of Living Streams which helps to illustrate Perth's drying climate and increase awareness in this respect. This is important because research has found a clear correlation between level of knowledge about water and behaviour (Water Innovation Advisory Group 2016). As Hoyer et al. (2011, 37) attest, 'When residents are living alongside the dynamic process of stormwater flow, they are more likely to appreciate and understand the importance of the water cycle in urban areas and can potentially become more aware and sensitive to the limitations of water as a resource'.

Their temporality also implies the potential for a different management approach for Living Streams, as opposed to one where ecological processes are usually arrested in an unchanging, puritanical state (Thompson 2002). Arguably, all of the Living Stream case studies examined in this paper are, to a degree, derivatives of the picturesque/ pastoral movement in which the image is regulated as a largely 'unchanging norm', typified by the large turf expanses which characterize many of Perth's suburban parks and indeed generally the Living Stream mini case study projects. It can be argued that Living Stream projects provide compelling alternatives to such picturesque/ pastoral modes in which a less simplified ecological structure, allowing less natural regeneration or shrub layers (Ignatieva, Stewart, and Meurk 2011), could sustain greater biodiversity. In turn, this increased biodiversity can be linked to greater psychological benefits for Living Stream users (Fuller et al. 2007) and those living adjacent.

Conclusion

This research has addressed both the case for why Perth's Living Streams should generally be considered high amenity POS, and how their role as amenity offering POS could be enhanced through the application of a number of urban design principles. Figure 17 sets out these principles in relation to the mini case study projects and provides a broad measurement of whether the principles find expression in the selected projects. The finding was that there is further potential for such principles to be tested, particularly in relation to increasing residential density around Living Streams and integrating the Living Streams with destinations, and yet there was substantial opinion and evidence assembled in this paper that suggests such principles could increase the amenity provided.

While it is not the explicit focus of this paper, how such principles could be practically applied varies as to the scale of the principle. The integration of Living Streams into a network connecting to regional destinations requires the coordination of District and Local structure plan areas as part of existing planning approval processes (Department of Planning, & Western Australian Planning Commission 2015). The integration of Living Streams with other POS types requires water related regulatory bodies to become more flexible in terms of how the burden of flood management is dispersed outside of existing drainage corridors.

Integration of Living Streams with the surrounding street network requires coordination with local government traffic engineers to develop street typologies which work to maximize the access to and amenity of Living Streams. The development of urban density in correlation with Living Streams requires the backing of developers, who need to be convinced that consumers will trade-off higher density residences for access to Living Stream POS. Finally, the provision of a natural experience requires coordination with local government level maintenance planning, the firefighting services and indeed local schools that would access this 'natural' amenity. Even a brief summation of the stakeholders and regulating bodies that have a role in Living Stream creation indicates the complex economic, regulatory and spatial situation which Living Stream proponents must engage with.

Nonetheless, it is believed that it is important that such principles are tested and developed because as Perth urbanizes further into seasonally waterlogged land that is characteristic of geomorphic wetlands, the Living Stream model for dealing with complex drainage conditions is likely to be employed more and more frequently. It is vital that this urban and landscape model is well understood for the POS amenity of Perth's emerging, and yet to be built, outer suburbs to be maximized.

Ian McHarg (1992) rated floodplains and marshy areas as being the least suited landscapes for urban development, yet given projections for rapid population growth it is unlikely that urban development pressures in these areas will cease. As such, it is imperative that the Living Stream models which attempt to satisfy hydrological, restorative, ecological and cultural functions are scrutinized and improved. This research has been directed towards this end.

Category of analysis	Integrate with destinations	Integrate with other POS types	Integrate with street network	Increase density around Living Streams	Provide a natural experience
Byford					
Piara Waters					
Wandi					
Wungong					

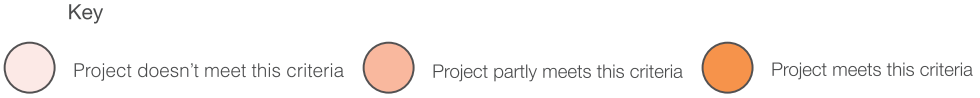

Figure 17. Existing application of the urban design principles in the case study projects. This table sets out the proposed Living Stream urban design principles in relation to the case study projects. The finding was that there is further potential for such principles to be tested, particularly in relation to increasing residential density around Living Streams and integrating the Living Streams with destinations. Please note the 'integration with destination' column was evaluated with respect to accompanying project master planning, all other columns has been evaluated with respect to the sections of Living Streams constructed to date. As such, some of these assessments are likely to change overtime.

Notes

1. Geomorphic wetlands are groundwater dependent wetlands which are typically only seasonally inundated (Department of Biodiversity, C. a. A. 2014).
2. AEP refers to 'Average Exceedance Probability' which is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year (Bureau of Meterology).
3. ARI refers to 'Average Recurrence Interval' is 'the value of the periods between exceedances of a given rainfall total accumulated over a given duration' (Bureau of Meterology).
4. Despite the focus applied to creating linear POS in the form of Park Avenues and Living Streams, the Wungong project also proposed to provide space for active recreation through the shared use of school ovals and regional sports facilities (Wood-Gush 2008).
5. 'Bush forever' is a strategic plan for the conservation of remnant endemic bushland in Perth.
6. This issue is outside of the scope of this necessarily brief paper, but is certainly worthy of further research.
7. Perth's current population of 2 million people is projected to possibly reach 6.6 million by 2061 (Australian Bureau of Statistics 2013). Moreover, 68% of all new residential development tends to be in Greenfield sites (Department of Planning, & Western Australian Planning Commission 2012), many which are within an extensive network of geomorphic wetlands.
8. Amenity in this paper referring to the provision of 'comfort, convenience or pleasure' (Ask.com 2008).
9. These interviews were conducted anonymously in 2016.
10. These mini case study projects will be referred to in this paper by the name of the suburb as some of the Living Streams do not appear to have official names.
11. Given the area is still under construction, such an assessment may change over time.
12. In a greenway planning in the USA 'trail use is correlated positively and significantly with trail segments that have greater land-use diversity …' (Lindsey et al. 2008, 76).
13. This concept is partly borrowed from urban waterfront developments in which 'To avoid the less desirable consequences of a thin line of development, a city must create perpendicular streets and civic corridors that are as desirable as the shoreline drive' (Kreiger 2004, 34).
14. In the Phoenix region in the USA, Nan Ellin has been responsible for a similar proposal concerning canals (referred to as the 'canalscape' initiative) where "vital urban hubs" are being distributed where "canals meet major streets throughout the metropolitan area" (Ellin 2010, 602).
15. In the USA people's use of park amenities and greenway trail systems has been linked to the proximity of their residence to leisure amenities (Scott Shafer et al. 2013), as well as the density of population (Lindsey et al. 2008; Scott Shafer et al. 2013).

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