

# **Development and application of the Urban Streamflow Impact Assessment (USIA) to inform stream protection and rehabilitation**

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## **Key Points**

- Urban stormwater runoff and wastewater treatment plant discharge (WWTPs) increases streamflow with negative impacts on the ecological and geomorphic condition of streams
- Urban streamflow characteristics can be linked to social, ecological and geomorphic values using nine hydrologic metrics
- Targeted catchment-scale options can be identified when urban development scenarios are explicitly linked to stream and social values could be lost
- The Urban Streamflow Impact Assessment (USIA) has broad-reaching potential for planning and management of cities and suburbs

## **Abstract**

The urban stream syndrome is a common occurrence worldwide where waterways are degraded physically and ecologically following catchment urbanisation. The primary driver of degradation is recognised as excess stormwater runoff from urban catchments. To add to this wastewater treatment plant discharges can significantly increase streamflow, exacerbating the problem. To address increased flow volume and altered flow patterns, the impacts on stream values under different catchment development approaches needs to be understood. Prior to this study no formal methods were available to achieve this despite the availability of environmental flows methods for other human impacts, e.g. dams. Drawing upon non-urban analogues, the Urban Streamflow Impact Assessment (USIA) was developed to explicitly link the severity of impacts to waterway values (social, ecological and geomorphic) with development scenarios and their streamflow regimes, through the use of hydrologic and hydraulic metrics. The method has been applied to case studies in western Sydney, demonstrating the risk of loss of values associated with ‘business-as-usual’ approaches, highlighting opportunities such as improved stormwater management. The method can be applied across urbanising and urban catchments to inform controls on urban streamflows (what flows to keep out) to inform urban planning, drainage design and stream management and improve liveability of our cities and suburbs.

## **Keywords**

Urbanisation, Stormwater, Development, Aquatic Ecology, Geomorphology, Hydrology, Social amenity

## Introduction

Urban development is placing growing pressure on waterways in Australia and around the world. This in turn reduces social amenity of natural assets for urban populations. Stormwater runoff from streets, roofs and other impervious surfaces in the urban landscape is typically discharged directly to streams, decreasing water quality, as well as increasing streamflow volumes and peaks. Impacts to streams may also be exacerbated by licensed discharges from waste water treatment plants (WWTP).

The 'urban stream syndrome' is used to describe the multiple environmental problems stemming from an increase in the volume of urban streamflow, and an increased frequency of small to medium high-energy surges of stormwater (Booth and Jackson, 1997, Walsh et al., 2005). These changes include increased disturbance of the channel bed and bank, decreased habitat, reduced native macrophytes, reduced organic matter, increased weed invasion and reduced water quality (Vietz et al., 2014, Tippler et al., 2014), as demonstrated in Figure 1. These changes not only negatively impact ecosystems including flora and fauna, but also the social values streams provide to the community (Birtles et al., 2013).

Despite extensive research and increasing recognition worldwide of the importance of, and opportunities for, addressing the source of the problem rather the symptoms (Ball et al. 2016, Bledsoe et al., 2012, Gurnell et al., 2007, Vietz et al., 2016a, Fletcher et al., 2014), there is no formal approach for identifying the impact of streamflow on stream values to inform urban planning and design.

This paper describes the development and application of a new method termed the 'Urban Streamflow Impact Assessment' (USIA) which assesses the role of streamflow in degrading waterways in urban catchments and identifies risks for planning scenarios. USIA has been applied to case studies in the South Creek catchment, Sydney, which is undergoing Australia's most rapid rates of urbanisation with significant potential to impact on waterway physical form and condition (Kermode et al. 2016).

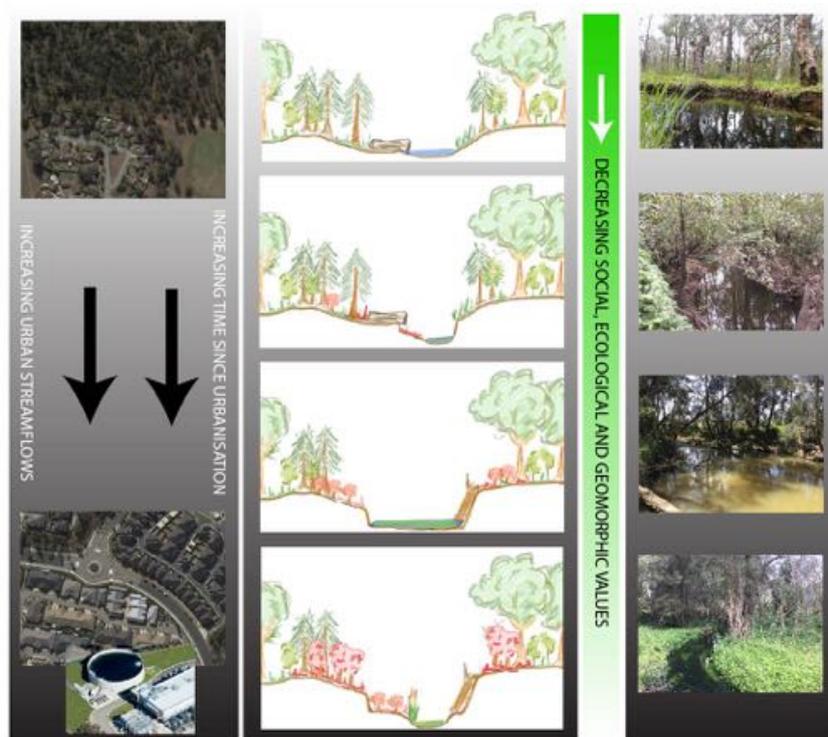


Figure 1. Streamflow and channel changes under urban development including increased channel incision (deepening and widening), decreases in native vegetation (green) and increases in exotic vegetation (red) for increased levels of urbanisation, or time since urbanisation.

### The USIA Method

USIA was developed to assess the impacts of altered streamflows on social, ecological and geomorphic values of creeks in urban catchments, see Figure 2. Values may be specifically defined as for species or ecological communities, social activities or landscape features, which are linked to wider community aspirations and ecosystem services. Stream values are either: a) present and could be lost due to altered urban streamflows; or b) not present but could be returned or added with appropriate streamflow management.

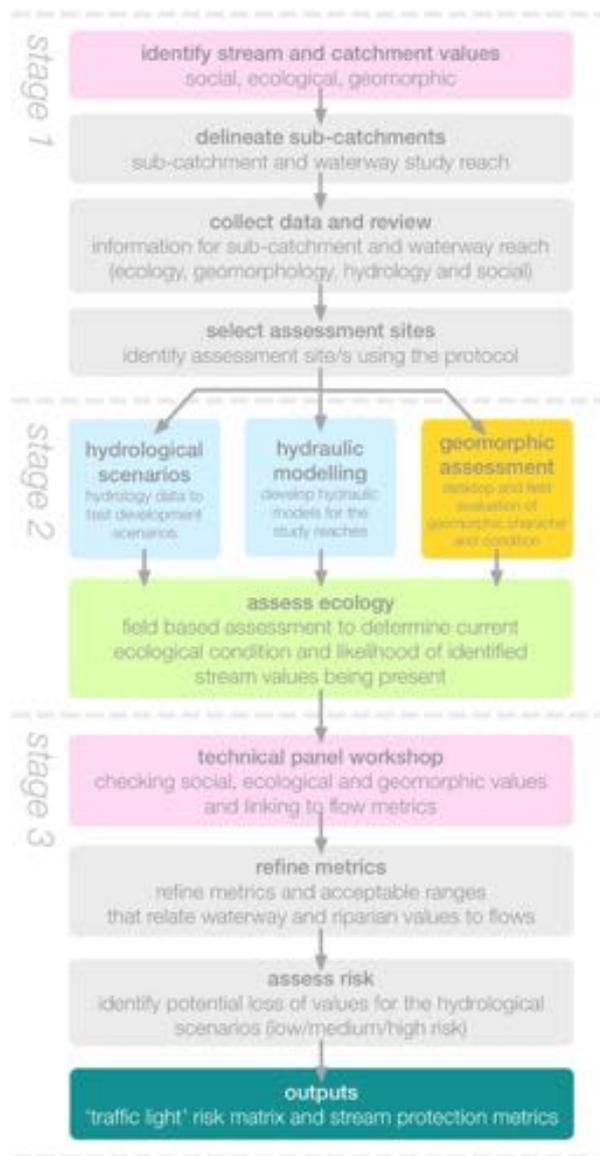


Figure 2. Outline of the Urban Streamflow Impact Assessment (USIA) method.

Each value is linked to a diverse set of metrics which may be ecological, e.g. specific habitat, physical, e.g. presence of large woody debris or focused on amenity, e.g. clear sight to a creek. These are then linked to the streamflow, channel or floodplain attributes that support them. These attributes are traced back to streamflow metrics that can be used to quantify changes in the flow regime and the associated impacts to the physical and ecological condition of the stream and floodplain. The acceptable ranges of deviation of those metrics from baseline conditions and predicted impacts to stream values are refined through a technical

panel workshop. Urban development scenarios can include a range of current and future development types, such as business-as-usual, the application of Water Sensitive Urban Design (WSUD) and the role of WWTPs. Synthetic hydrology is produced for each development scenario using a hydrologic model.

Nine streamflow metrics relevant to urban settings (and that can be linked to social, ecological or geomorphic values) for use in the method at specific sites, include (see Duncan et al., 2014):

1. Annual flow volume
2. Mean duration of zero flow periods
3. Total duration of zero flow periods
4. Baseflow index (ratio of baseflow to total flow volume)
5. Frequency of freshes (flows > 3 times median flow)
6. Total duration of freshes (flows > 3 times median flow)
7. Total duration of flows above channel erosion threshold
8. Frequency of floodplain engagement flows
9. Total duration of floodplain engagement flows

The method uses a range of data, tools and an expert panel, to identify the specific thresholds relevant to the desired creek values. For example, geomorphic assessment based on field-identified bed and bank sediments provides input to two-dimensional hydraulic modelling to assess erosion thresholds which inform the sediment mobilisation metric. The deviation of streamflow from baseline conditions for these metrics, under urban development scenarios, is displayed using a 'traffic light' matrix. This highlights the level of risk and values impacted. The outputs developed by USIA can be applied to assess service options, such as flow regime management of stormwater and WWTP flows or applied to predict positive changes to stream values which may be affected by urban stream restoration projects

USIA requires expert input. A range of technical experts are required including hydrologists, ecologists, geomorphologists and hydraulic modellers to quantify the likely, albeit complex, ecological and geomorphic response to changes in streamflow. The fallibility of expert opinion is acknowledged with transparency of linkages between values and metrics an important component so that refinement can be made during the process as knowledge of physical and ecological response improves. The method was originally developed for the South Creek catchment, Sydney, and the application to one of the case studies, Lowes Creek, is briefly outlined in this paper. Lowes Creek was selected due to planned urban development, incorporating a WWTP.

## **Results for a Sydney Case Study**

The application of USIA to Lowes Creek demonstrated how social, ecological and geomorphic values can be linked to streamflow, and the risks to loss of values under urban development scenarios (Figure 3). The main output of scenario compliance identifies low to high risk of not meeting acceptable deviation from baseline (Table 1). The values within the table are based on hydraulic and hydrologic computations.

USIA demonstrated that under future urban development scenarios, annual flow volumes and the duration above the erosion threshold posed a high risk to ecological values such as microbats (Southern Myotis) and the condition of woodland vegetation (Cumberland Plain woodland) and a range of social values associated with the creek. Loss or degradation of iconic biota and assemblages leads to reduced opportunity for, and quality of, valued human activities dependent on these natural elements. The compounding effect of stormwater runoff and WWTP effluent discharges increased the deviation from baseline of all metrics, posing a high risk of loss to all present ecological values, with subsequent impacts on the social values. High retention WSUD application reduced the extent of loss of values.

Table 1. Scenario compliance assessment of flow metrics for Lowes Creek showing high risk to values (red), medium risk (orange) and low risk (green), with cell values quantified through modelling in the USIA method.

Flow type	Flow metric	Threshold value	Scenarios				
			Baseline	2050 no WSUD	2050 high retention WSUD	2050 no WSUD + WWTP	2050 high retention WSUD + WWTP
Annual flow	Mean annual flow volume		1.015	2.473	1.983	11.039	13.044
Zero flows	Mean duration of zero flow periods	0.001 ML/d	5.8	5.7	7.0	3	3
Zero flows	% of time flow is zero	0.001 ML/d	58%	58%	63%	3%	3%
Baseflow	Baseflow index (ratio baseflow/ total flow)		0.041	0.040	0.033	0.028	0.030
Freshes	Events/year > 3 x baseline median flow	1.94 ML/d	23	31	31	exceeded all the time	exceeded all the time
Freshes	% of time > 3 x median flow	1.94 ML/d	17%	25%	20%	100%	100%
Erosion threshold	% of time > bank/matrix mobilisation threshold	40 ML/d	1.7%	4.8%	1.8%	10.0%	14.0%
Erosion threshold	% of time > bed mobilisation threshold	110 ML/d	1.3%	3.2%	1.4%	3.3%	4.0%
Floodplain engagement flows	Events/year > bankfull discharge	680 ML/d	0.5	0.5	-0.5	0.6	-0.6
Floodplain engagement flows	% of time flow > bankfull discharge	680 ML/d	0.21%	0.21%	-0.15%	0.25%	-0.19%
Ecological values impacted	Southern Myotis, Cumberland Plain Vegetation						
Social value impacted	Connection to place, active recreation, eco-recreation, thermal comfort, aesthetics and enjoyment, passive recreation						Connection to place, active/passive/eco-recreation, thermal comfort, aesthetics and enjoyment, proximity and accessibility

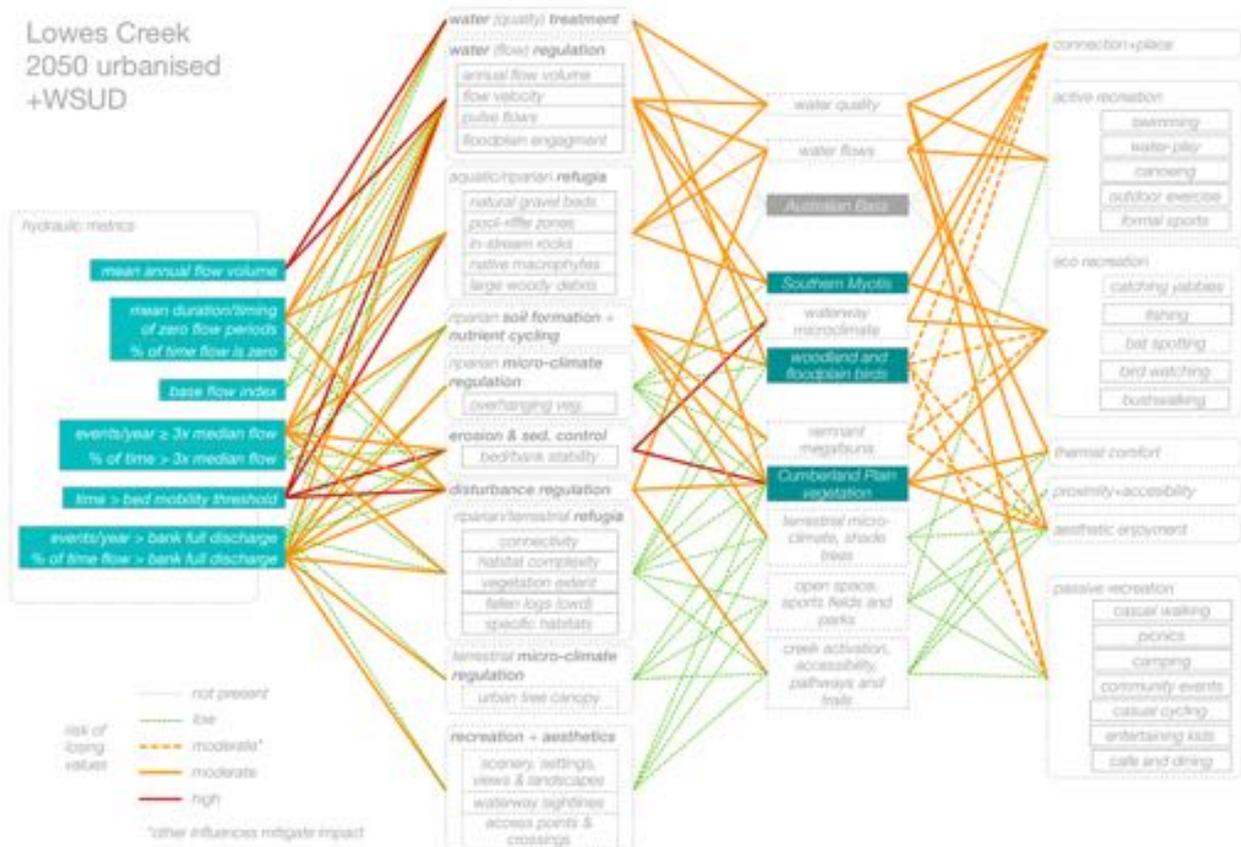


Figure 3. Risks of development to Lowes Creek, Sydney. Schema interpreting links between creek values and flow metrics and risk of full urban development 2050 with maximum WSUD.

To protect values a reduction in the unmitigated annual flow volume of around 50% would be required. Such reductions are likely to require significant stormwater harvesting and reuse, as simplistically illustrated by Figure 4. The key elements are harvesting and use of stormwater and wastewater, through irrigation or alternative water supplies, or transfer out of the catchment. To achieve appropriate reductions the level of stormwater control measure application must be ambitious, but numerous options are available and opportunities are revealing themselves (Vietz and Hawley, 2018). The next phase for Western Sydney will use the outputs from USIA to inform hydrologic modelling of urban stormwater control opportunities (using Source and MUSIC) to identify the practical solutions and feasibility of such as approach.

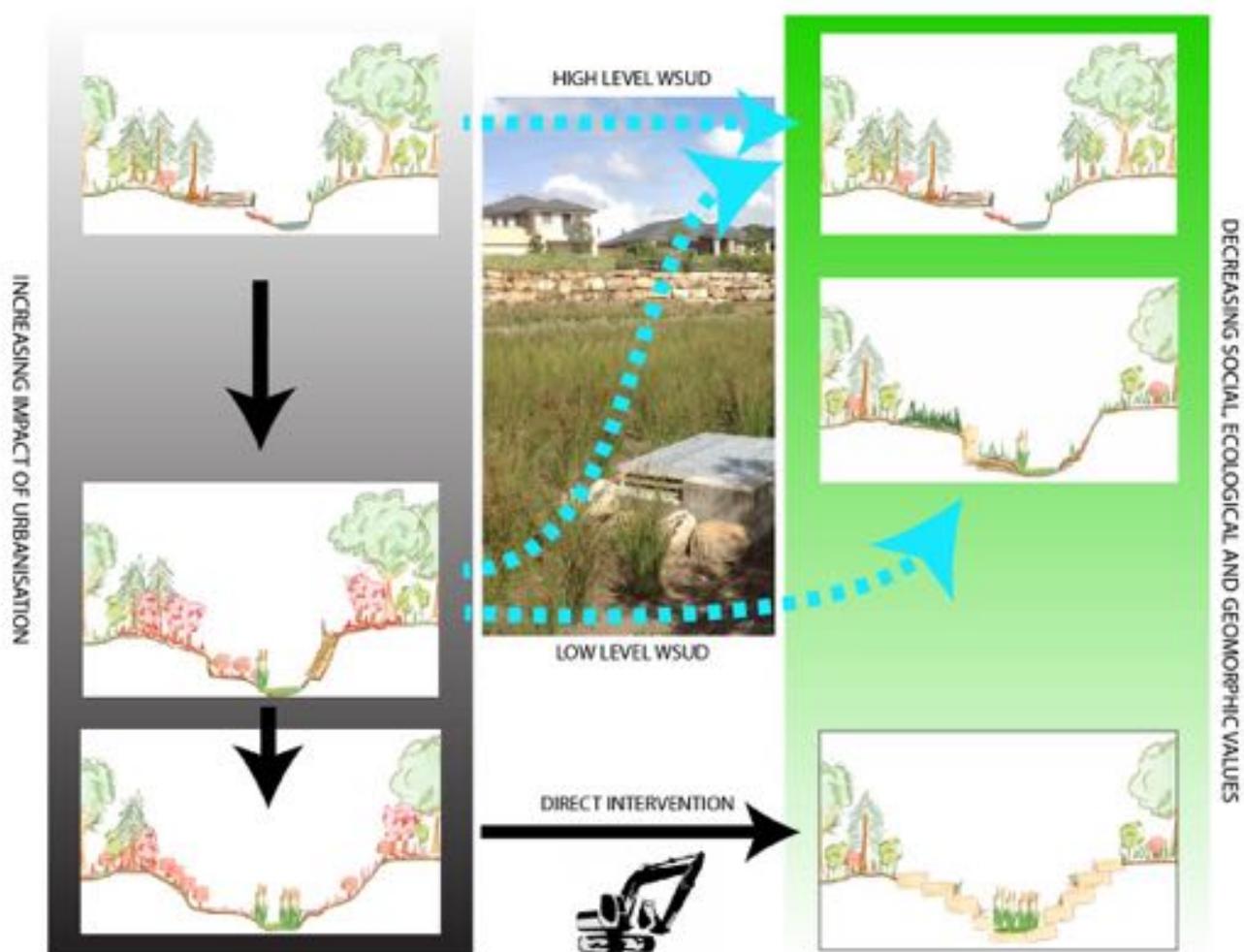


Figure 4. Potential trajectories of adjustment for streams draining urban catchments, with opportunities for returning to a former state, or a novel state, rely on addressing streamflow change through flow controls on stormwater runoff (such as WSUD) and WWTP discharges.

## Conclusions

The USIA method is intended for application wherever urban development threatens the values of receiving non-tidal streams, including streams in greenfield development areas, or peri-urban areas where housing density is increasing through infill development. The method highlights the importance of addressing the

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overall volume of streamflow in urban catchments, as well as disturbance events, and enables informed value judgements to be made relative to development scenarios. Options to address these can have wider benefits including potable water supplies and improved liveability through recreational space provision, watering and cooling. While USIA recognises that urban stream degradation is about more than just streamflow (e.g. Vietz et al., 2016b). By controlling flows, it is expected to strategically protect, rehabilitate or maintain the ecological, geomorphic and social values of existing streams in the urban environment.

As far as we are aware, the USIA developed here is the first practical method available to link urbanisation to streamflow and subsequently quantify the impacts on the key values, including social and ecological. While the method makes explicit links using hydrology, hydraulics and geomorphology, its limitations are the reliance on expert interpretation and the ability to effectively reflect urban development and characteristics such as WSUD development within the hydrologic scenarios.

It is expected that through ongoing application and monitoring the method will be refined. The overarching goal is that the application of USIA adequately informs planning and development within the current NSW policy settings. The application of USIA is being further tested in South Creek, Sydney, followed by potential uptake in the planning and design of cities and suburbs more broadly.

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