Stormwater Management

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INCENTIVISING STORMWATER MANAGEMENT IN CITIES AND SUBURBS

EXAMPLES FROM GERMANY AND OPPORTUNITIES FOR AUSTRALIA

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ABSTRACT

We examine an approach to managing the impacts of stormwater from cities and suburbs that accounts for the influence of development. In Australia, the approach to accounting for the impacts of excess stormwater runoff from urban developments is lacking , with a fixed fee applied that doesn't offer an incentive to reduce impacts.

This is despite rapidly increasing urban populations and wide-spread recognition of the negative impacts of excess stormwater runoff, including flooding, degraded waterways, reduced groundwater and increased urban temperatures. A stormwater fee based on connected imperviousness has been applied to developments in Germany since the mid 1990s, and we describe case studies from four regions. Rather than charge a stormwater fee based on fixed pricing, or property value for non-residential, a charge based on stormwater generated can simultaneously provide a financial incentive and increased public awareness of the impacts of imperviousness. In Germany, a fixed price for stormwater management was considered unfair and a 'polluter pays' approach has been highly successful. For example, in the city of Munich, since 1995 over 4.5 Million square metres of imperviousness have been removed, resulting in a runoff reduction of 3000 Million litres per year. A reduction in connected imperviousness was achieved through increasing pervious pavings, implementation of rainwater tanks, and green roofs. Each application varies in the approach to implementation of the fee based on the reduction in imperviousness, and we outline the differences and commonalities, including consistently observed reductions in runoff post-implementation. The introduction of an imperviousness fee for Australian cities could result in economic, environmental and social benefits, leading to a strong business case. Deciding on a feasible and socially-equitable approach to calculation of connected imperviousness is the final step toward implementation.

Key words: Stormwater management, urban water, stormwater fee, imperviousness, social equity

INTRODUCTION

What's the problem with stormwater?

The world's populations are flocking to cities. A forecasted 70% of the world population will be urban by 2050 (United Nations 2007). This has significant implications for the urban landscape and how we manage the impacts. In Australia, more than 90% of the population already live in cities and this is growing at a rate of 1.6% per year, so there is a great imperative to manage the impacts of urbanization. One of the most significant impacts we must deal with is water, particularly the water that runs off the increasingly impervious areas, and through the expanding drainage network directly to our streams. In Melbourne alone, 40,000 new dwellings are being constructed each year, half of which are built on previously grassed paddocks (Vietz et al. 2014).

Stormwater Management

The change from paddocks to a dense urban suburb, and the associated increase in impervious area and stormwater drainage connections, can lead to up to 10 times the volume of stormwater runoff (Burns et al. 2012). In Melbourne during an average year (650mm rainfall), 608 GL of stormwater is generated on roofs and roads (equal to more than 300,000 litres per home per year) (Walsh 2017). The focus of stormwater management is on reducing the generated runoff in the drainage system, with attempts to reduce stormwater at the source an exception rather than the norm.

These increases in stormwater runoff cause significant challenges. Firstly, managing increased frequencies and magnitudes of flooding, particularly when this is coupled with hydrologic change due to climate change (Nelson 2009). Secondly, stormwater runoff creates a significant disturbance to receiving streams, degrading them physically and ecologically (Fletcher et al. 2014, Vietz et al. 2016). Thirdly, with urbanisation replenishment of groundwater aquifers is decreased due to lower infiltration; and finally, increased frequencies of stormwater runoff lead to greater pollution entering streams, estuaries and bays (Nelson et al. 2009).

Issues associated with stormwater runoff are rarely accounted for in the development of cities and suburbs. To better manage stormwater and reduce these impacts, we look toward a new approach to cost the impact of development on stormwater runoff. We investigate case studies from Germany, providing an overview of the German experience with the imperviousness fee including why it was introduced, how it was implemented, and some outcomes. The information was gathered through a literature review and interviews with researchers, water industry and government representatives in Germany. We consider how these may assist stormwater management approaches in Australia, and particularly Melbourne.

Impediments and benefits of change

Traditionally, stormwater management has focused on urban drainage, seeking to remove it from the landscape as quickly as possible (Burns et al. 2014). Increasingly, the value of reducing stormwater runoff is being recognised. Stormwater is currently managed as a 'large scale' problem by the agencies in charge, through construction of large wetlands, large drains, retarding basins, etc. (Burns et al. 2014). The impediment to installing smaller-scale stormwater control devices in streets (e.g. swales, raingardens) or on private houses (e.g. raingardens, rainwater tanks, green roofs) is the cost and maintenance.

The imperative to install such devices is low and often relies on good will of councils, authorities, and landowners. As stated in Victoria's Water Plan, Stormwater management is best improved through a mix of tools, including incentives and education as well as regulation (Victorian Government 2016).

Awareness of the issues associated with stormwater runoff is low, with the public, private industry (including developers), and within government (including planners and policy makers). Improved awareness and education on the negative impacts of imperviousness and conventional drainage systems is required.

We know that improved stormwater management can provide benefits at two scales (Vietz et al. 2014). At the development-scale it can provide benefits including water supply augmentation, improved human comfort and general amenity through cooling provided by irrigation of urban vegetation at the development and surrounding landscape, and reduced nuisance flooding. By attenuating and retaining stormwater we can also provide benefits to downstream waterways including through improved biodiversity of streams and rivers, reduced downstream flooding, reduced erosion and damage to infrastructure, and improved conditions for receiving estuaries and bays (Figure 1). Social benefits from streams in urban catchments are increasingly being sought under intense urbanisation. In particular, many Australian cities and suburbs are looking to the potential for improving water quality such that waterways will be swimmable in the near future.

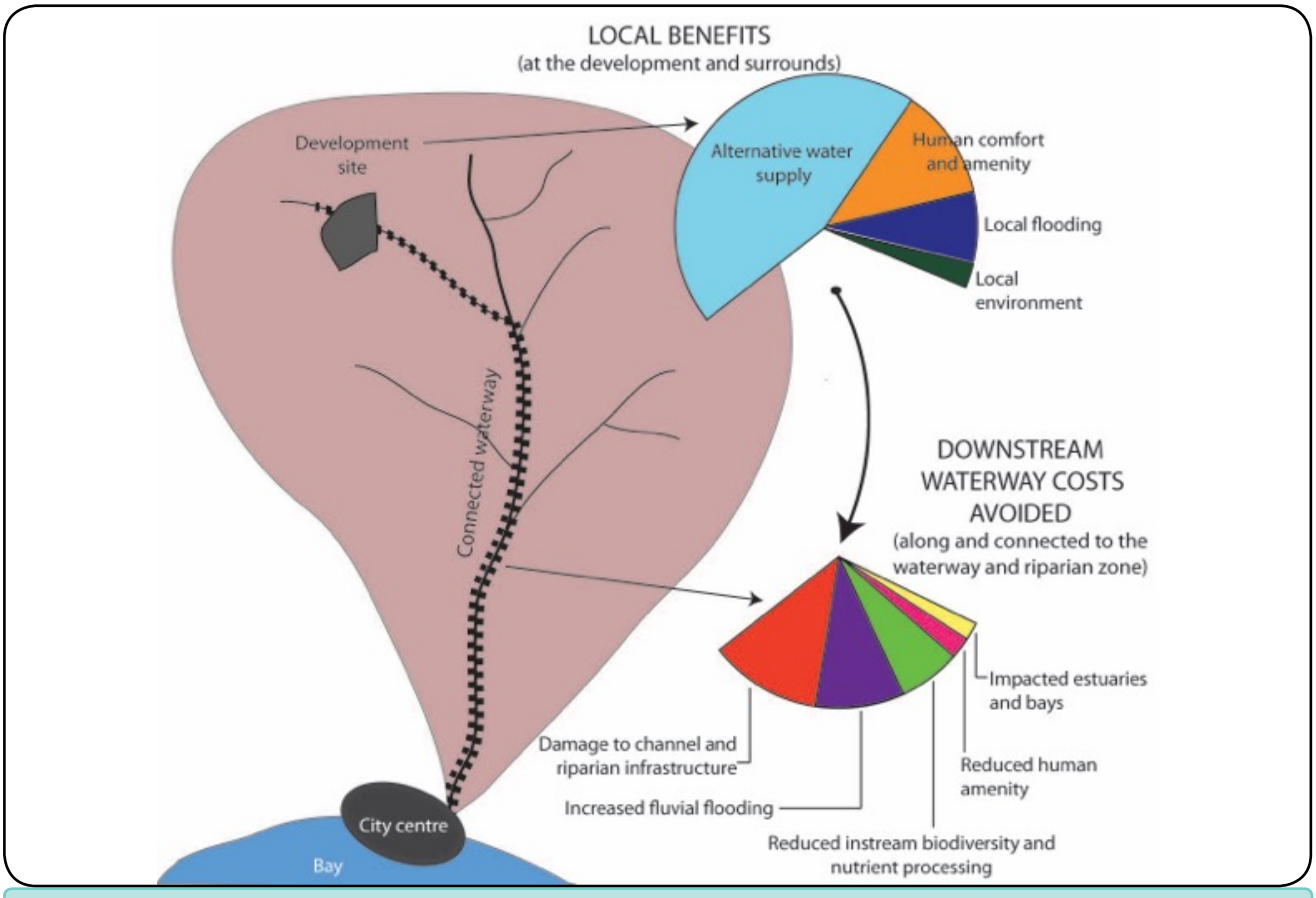

Figure 1. Benefits (or avoided costs) of alternatives to conventional urban drainage design at two scales: locally at the development and to the downstream waterway. The relative size of each segment is a conceptual estimate of their relative magnitude (Vietz et al. 2014).

Incentivising change

The larger an impervious area, such as a roof or driveway, the greater the runoff entering the downstream pipe. With the current fixed stormwater fee, there are few incentives for authorities, developers and landowners to mitigate contributions to the stormwater problem. Those whose properties are producing large impacts on stormwater systems receive no price signal to reduce this impact, and similarly those who make investments to reduce their impact receive no benefit. Incentives for change, and community awareness of the problems of excess stormwater runoff, are sorely lacking.

Compared to a fixed stormwater tax, a more equitable, and arguably more sustainable solution to managing stormwater is through imposing a charge on the size of impervious surfaces connected to the drainage system. An imperviousness fee could mean a fairer 'polluter pays' system. When the incentive leads to retention and amelioration of stormwater runoff there are multiple benefits.

There is precedence for this approach, and evidence is now emerging for its efficacy. In Germany, since the 1990s, cities and towns have been introducing a fee for stormwater, based on the 'polluter pays' philosophy. Households and businesses are charged for their contribution to stormwater runoff commensurate with the net imperviousness of their property.

SOCIAL DRIVERS FOR AN IMPERVIOUSNESS FEE IN GERMANY

In Germany, many cities have combined stormwater and sewage drainage systems, which is why wastewater and stormwater were often accounted for in one combined fee. Stormwater was previously calculated as a percentage of the household's water consumption (as it is the case for wastewater in Melbourne).

This practice was deemed to be inaccurate and unfair, as demonstrated in the example below, and legal cases at a federal and state level brought about a substantive change (Bundesverwaltungsgericht 1985, Bayerisches Verwaltungsgericht 2003, Baden-Wuerttembergisches Verwaltungsgericht 2010). Now, across most German States, an imperviousness fee has been introduced, thus providing fair 'polluter pays' principles of charging. The new fee accurately reflects a property's contribution to the cost of stormwater management, which is reported to be between 20 and 75% of the combined cost of managing stormwater and wastewater (Pecher, 1997).

Since 2000, the European water framework directive is an additional legal cornerstone that supports the introduction of the split fee (European Parliament 2000). Article 9 of the directive demands that local water policy must create incentives to use water resources efficiently, based on user-pays principles.

Example: Why the old way of charging for stormwater in Germany was deemed unfair.

A family of 5 living in an apartment with high water consumption may have a much lower stormwater runoff than a family of 5 living in a large house, yet both dwellings were charged equally for the impact of runoff, because their stormwater fee was calculated based on their water consumption. Following the introduction of the imperviousness fee, the difference in stormwater runoff is now reflected in their water bill (Figure 2). Similarly, the volume of stormwater generated by a large storage warehouse with a large carpark and low water usage was not equitably accounted.

A survey by the German Environment Network BUND, found that the average household saved 14% on their combined wastewater and stormwater bill, and could save up to 28% if they removed (infiltrated or used) all stormwater of their property (Hennebrueder 2006).

In the following we describe the implementation process and initial assessments of four case studies from across Germany: the city of Munich in Bavaria, the city of Hamburg, the city of Dresden in the State of Saxony, and the experience of many smaller townships in the State of Baden-Wuerttemberg. There is currently no standardised method for determining the imperviousness fee, and each drainage authority has developed their own preferred approach. There are, however, some cross comparisons between authorities.

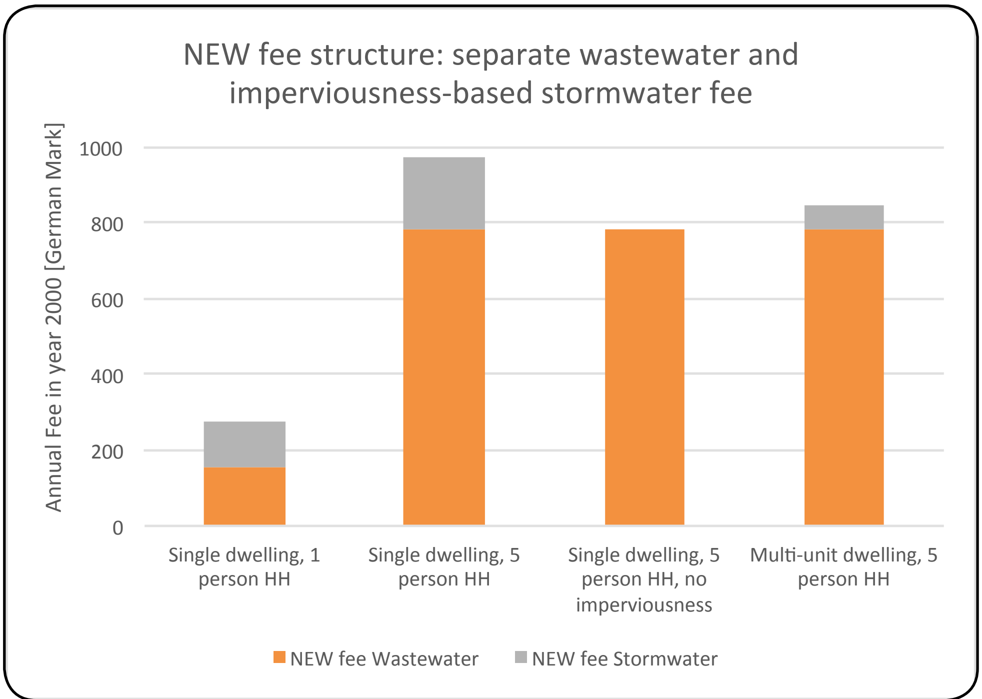

Figure 2. German example of separately calculated wastewater and stormwater fee for the same household (HH) in different dwelling types. The total fee now reflects the property's impact on stormwater.

Unlike in Australia, flood management or environmental benefits were <u>not</u> the drivers for this change to occur. While these benefits are certainly noted in Germany, social equity was the main driver. By charging all landowners a fee that was considered fair they were able to meet the constitution's rule of equality.

Implementation of the stormwater fee

There are 2 different approaches to calculating the imperviousness fee.

1. Based on the assumed imperviousness of a property.

2. Based on the actual imperviousness of a property.

The first approach uses the assumption that properties within a neighbourhood are of a similar character and their imperviousness is alike. This approach, which is used for example in Munich, is less accurate, but also easier to implement.

The second approach requires actual measurement of each property's imperviousness which is more accurate, but requires more customer engagement and assessments upfront. It is used for example in Dresden, Hamburg and Baden-Wuerttemberg.

MUNICH, State of Bavaria (South-East Germany)

In Munich, a city of 1.5 million people, the implementation of the imperviousness fee has commenced already back in 1970 following the ruling of the Bavarian Administrative Court in response to the complaint of a major manufacturer who found it unfair to be charged based on the value of the property (Scheucher 2006).

Stormwater management was further tightened in Munich in 1998, when a rule was introduced that all new buildings and major renovations must install rainwater infiltration systems (Muenchner Stadtentwaesserung 2005).

The city of Munich has set the ambitious goal to reduce imperviousness by 15% over the next 10 years. Munich chose a simplified method for calculating the imperviousness, based on the assumed imperviousness of a property (Muenchner Stadtentwaesserung 2017).

The imperviousness of entire neighbourhoods is classified based on the typical housing stock in that neighbourhood. This is aided by long-standing town-planning regulations that homes in one area must be of one type and similar size. For each neighbourhood, a characteristic "neighbourhood runoff factor" was determined (Figure 3). The imperviousness of a property is determined by multiplying the size of the property with this 'neighbourhood runoff factor'. If a property owner proves that their impervious surface is less than the assumed size, the fee can be reduced.

The city of Hamburg (Northern Germany)

Hamburg is the second largest city in Germany with around 2 million inhabitants, and is experiencing high population growth (around 10,000 additional homes per year) causing an increase in imperviousness of around 0.36 per cent per year. The city has combined wastewater and stormwater sewers in the inner city (1,200km) and separate systems outside the central area (2,300km wastewater and 1,700km for stormwater).

With most water bodies in the city affected by stormwater run-off, and awareness by decision-makers of future impacts on drainage infrastructure due to climate change, a stormwater imperviousness charge was introduced in May of 2012, based on the amount of impervious area of properties and other infrastructure that is connected to the sewer system. The change was also motivated by a drive toward equity, under the polluter pays principle, as well as a desire to provide an incentive to reduce the stormwater impacts of development.

Figure 3. Map of neighbourhood runoff factors in Munich. 0.9 for highly dense 'blue zones' in the inner city; 0.6 for inner city fringe buildings (pink), 0.5 for denser outer suburbs (orange); 0.35 for residential lots with gardens in the outer suburbs (green) (City of Munich 2017).

The separate stormwater charge is calculated to achieve cost-recovery of stormwater management costs, and is currently set at 0.73 €/m2 sealed area per year for each sewer connected property (Bertram et al 2017).

The project was enabled by a broader project which included a comprehensive data collection and mapping project related to stormwater management, providing property-level data on imperviousness (RISA 2017). This data is used to charge landholders for connected imperviousness under three settings (0%, 50% and 100%). Landholders are provided the opportunity to reduce their effective imperviousness by undertaking investments such as rain gardens and rainwater tanks.

Dresden, State of Saxony (East Germany)

Dresden is a city of 550,000 people in the former democratic republic of Germany. Its town centre is a mix of historic buildings and new high-rises. In the suburbs, legacy suburb design from the former democratic republic of Germany can be found: high density high rises and old and unused industrial sites. This is now being reversed through the re-introduction of more parks and trees, and the creation of lower density living options.

Dresden introduced the imperviousness fee based on a property's actual imperviousness in 1998, as one of the first cities in Germany. Questionnaires for home owners were the initial approach, but the disadvantages of the administrative burden, unreturned questionnaires, and potential inaccuracy were deemed too high. Instead, Dresden is now using satellite imagery and automated image analysis. Householders are being informed about how much they would have to pay, with the option of submitting a detailed application to have this assessment adjusted. Most of these questionnaires are also analysed automatically. This self-driven incentive to maximise the accuracy of one's imperviousness is deemed to be very successful for gathering the most accurate data, and can empower the land holder to gain a strong understanding of their impact on stormwater runoff. Spot check site audits are required to validate claims.

Townships in State of Baden-Wuerttemberg (South-West Germany)

Unlike in Australia, where a few large cities dominate, in Germany many small townships are geographically and administratively separated. Townships of under 60,000 inhabitants total 7 million people in the State of Baden-Wuerttemberg alone. The administrative court of the State ruled in 2010 that the fee had to be implemented across the entire State, and regardless of the size of the township. Faced with the need to introduce the imperviousness fee, the "Council of townships" offered to combine efforts and make things easier for them by providing templates and guidelines.

The approach for assessing the imperviousness applied in Baden-Wuerttemberg was markedly different to that in Munich. In most jurisdictions, householders have to report the area and type of the actual impervious surface areas, which is confirmed with aerial imagery.

RESULTS FOR GERMANY:

How has it worked? The introduction of the imperviousness fee has contributed to a significant reduction in impervious surfaces across Germany, and a range of other benefits, which are explored in this section.

In one survey, the reported decrease in imperviousness varied widely, from "No perceived changes" to over 20% reduction (BUND 2001). These differences may be attributed to several factors, including the extent of community engagement, level of the imperviousness fee ('how soon will investments in perviousness pay off?'), and how recent the latest measurement of imperviousness had taken place.

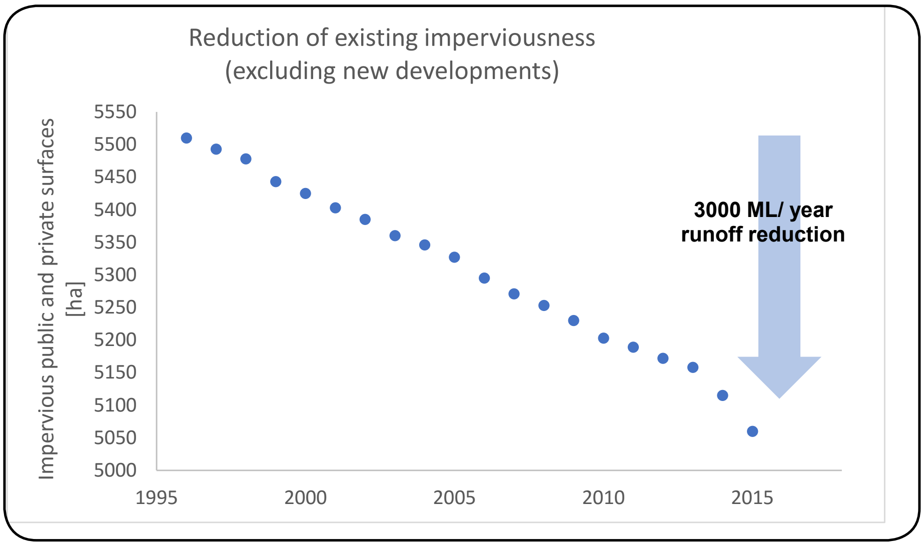

Figure 4. Reduction in existing imperviousness in Munich. Since 1995 over 4.5 Million square meters of imperviousness have been removed, resulting in a 3000 ML/ year runoff reduction.

MUNICH

In Munich 4.5M m2 of impervious surfaces were disconnected from the stormwater system between 1997-2015 (approximately 240,000 m2 per year). Given the typical rainfall in Munich, this means that an estimated 3000 ML of stormwater are now being re-introduced to groundwater, or evaporated to the atmosphere, instead of being transported to the local (combined wastewater and stormwater) treatment plant (Muenchner Stadtentwaesserung 2017) (Figure 4).

This reduction in stormwater volumes is assumed to be similar in other Bavarian cities. They observed declining wastewater treatment volumes that allowed more optimised, targeted treatment processes (of their combined wastewater and stormwater systems). Overloading of the drainage system is reported to occur less frequently (Bavarian Department for the Environment 2017).

Commonly, with urbanisation, groundwater levels decrease. Whereas in Munich, rising groundwater levels have been observed over the last 30 years (Figure 5). There may be multiple reasons for increased groundwater levels including: reductions in imperviousness, climate change, an increase in underground structures (e.g. buildings and tunnels), and improved drainage resulting in less groundwater infiltration to pipes (Muenchner Stadtentwaesserung 2017). Research has started recently to investigate this phenomenon further.

HAMBURG

Unlike some other townships, detailed assessment of the impact of the pricing structure on imperviousness has not yet been undertaken. However, the frequency of combined sewer overflow into waterways in Hamburg has reduced to one per year, which is considered exemplary in Germany. The "infiltration potential maps", produced as part of the wider project that also introduced the fee, are now accessible online, allowing councils and homeowners alike to assess the options for stormwater management on their site (***www.hamburg.de/planungskarten/4130764/versickerungspotentialkarte/***).

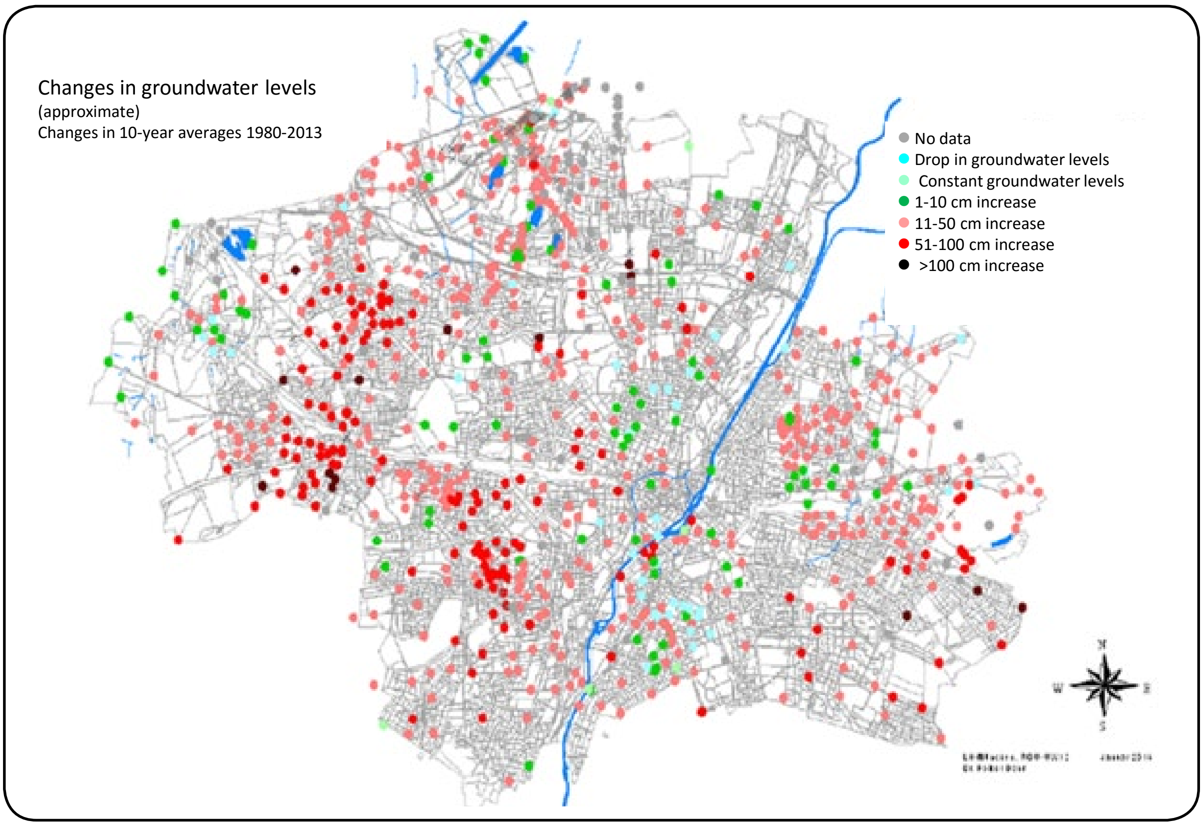

Figure 5. Increasing groundwater levels across Munich 1980 – 2013. (Referat für Gesundheit und Umwelt Muenchen 2014)

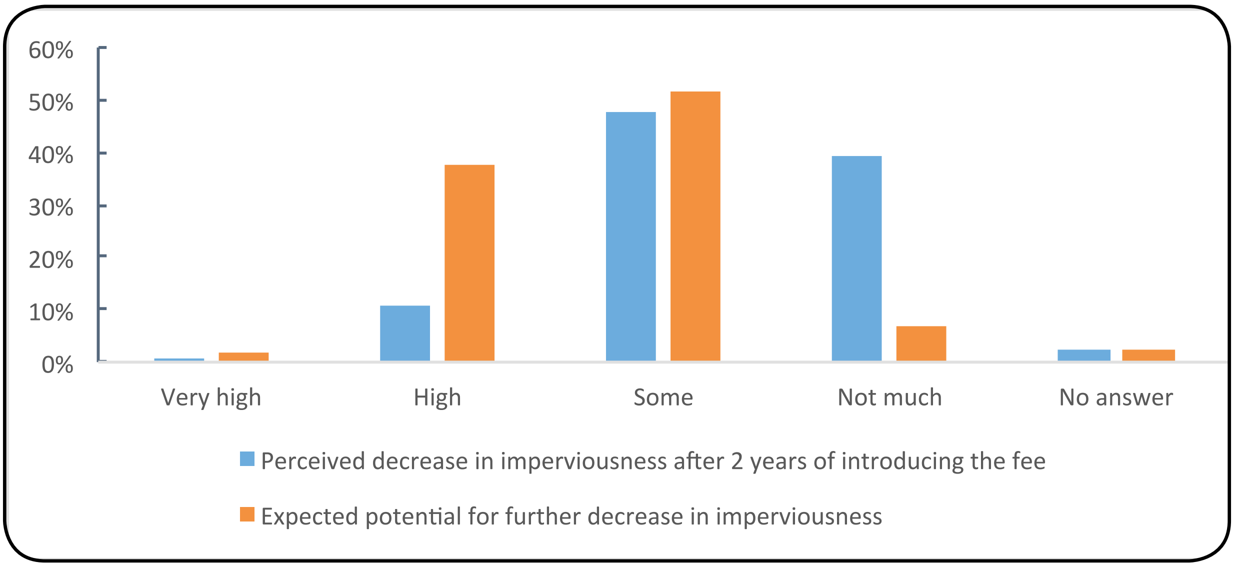

Figure 6. Perceived and expected reduction in imperviousness in Baden-Wuerttemberg townships, 2 years after introduction of the fee.

Townships of Baden-Wuerttemberg

In Baden-Wuerttemberg, within 2 years of the introduction of the fee a qualitative survey found that 48% of townships observed some decreases in imperviousness, with 11% reporting a high decrease (Fehring 2012). The high future potential of the fee leading to further decreases in imperviousness was widely recognised (Figure 6) (Fehring 2012). Initial changes in land holder behaviour can already be observed: particularly businesses changing approaches to paving of parking-lots, and the introduction of green roofs, to achieve savings in imperviousness fee (Figure 7).

"Scharnhauser Park" provides an exemplar of 'green' development, despite being one of the largest new urban development schemes in the State's capital Stuttgart. The area is located on a steep, heavy clay hill close to a tributary feeder to the capital's main river, the Neckar. The urban layout is inspired by an innovative, highly effective rainwater management system, that maintains pre-development runoff to the local waterways (Figure 8, Ramboll 2004).

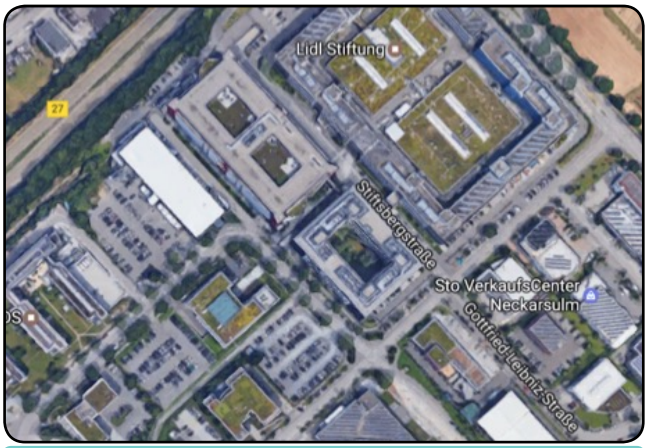

Figure 7. Business district with many green roofs (and solar panels) in Baden-Wuerttemberg (Google maps 2017).

Figure 8. New development near Stuttgart, with no increase in stormwater runoff (Ramboll 2004).

Dresden

In the city of Dresden, imperviousness per person was reduced significantly from 37m2 to 33.5m2 – a 10 per cent reduction (Figure 9). This was achieved despite a population growth of 12% during the same period, and a trend to more detached houses instead of apartments (Stadtentwaesserung Dresden 2017). High-density, multi-storey apartment buildings were replaced with detached homes (Figure 10). At the same time, highly impervious industrial zones were replaced with homes and parks (City of Dresden 2015).

Representatives of Dresden Waterworks stated that they feel that the imperviousness fee has certainly prompted a change in thinking and a sufficient incentive to encourage more stormwater-sensitive approaches for residential and business building owners alike.

In Dresden, there has been a great increase in green roofs on all administrative buildings, schools, industrial buildings, even though the reduction in stormwater discharge fee does generally not offset the cost of the green roof.

The city council is now working on a new regulation to make green roofs compulsory on all non-residential buildings. In addition to stormwater runoff reduction, other benefits of green roofs being equally recognised (thermal insulation, improved air quality, increased longevity of the roof, provision of habitat) (City of Dresden 2014).

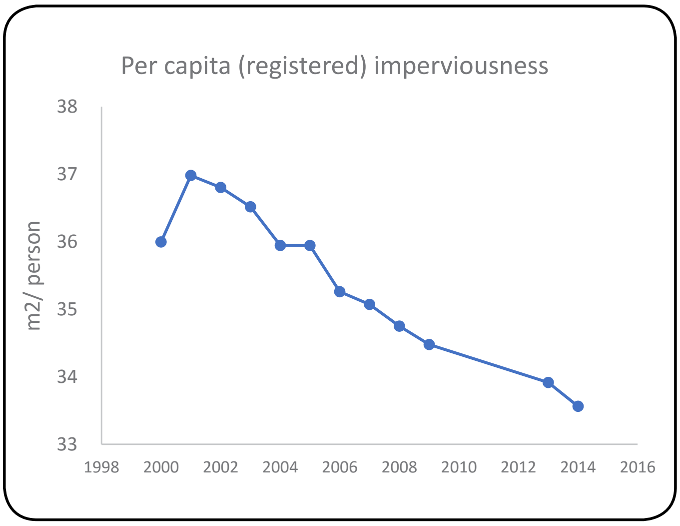

Figure 9. Changes in registered per capita imperviousness for Dresden, Germany

Despite the reduction in imperviousness, no reduction in flood risk is being assumed for flood risk management plans. This is because the decentralised systems are maintained by the property owners, and it can't be guaranteed that they would be maintained to full working order (Stadtentwaesserung Dresden 2017).

Figure 10. Change of building stock in Dresden (black and white images depict the old situation). Top: Concrete high-rises are de-densified and greened. Bottom: industrial zones are turned into residential areas (City of Dresden 2015).

DISCUSSION: LESSONS LEARNT FROM GERMANY

Lessons learnt

An incentive-based approach, alongside with good regulations, has proven to be effective in reducing stormwater runoff from urban development, by encouraging a reduction in effective imperviousness. In some cases, such as in Dresden, significant reductions of 10% can be achieved, despite trends that may have otherwise increased effective imperviousness. This produces significant financial benefit to stormwater managers without creating additional impacts on rate-payers. For charges set at cost-recovery, these changes can be achieved without increasing the total revenue received through the charge. If the administration of the new pricing approach can be implemented at appropriate cost, it appears likely that the benefits of the change can exceed its costs.

To achieve this, legal frameworks are an important starting point. In Germany, as well as in other countries, a change in legislative and administrative frameworks were the first critical element for addressing environmental problems caused by rainfall-runoff from urban surfaces. Across municipal, federal and national regulations, differences need to be overcome, and responsibilities clearly defined. Regulations need to be updated regularly to reflect technology changes and allow for leading edge practice to be implementable (Ellis et al 2007).

Community and stakeholder engagement was critical when incentive-based fees were implemented in the cities of Germany described in the examples. The main messaging was regarding the increased equitability of the revised approach to charging for stormwater runoff. Engagement is most critical when the success of the program relies on community adoption and the honest participation, such as in Dresden where initially an aerial imaging approach was not practical. The reliability of implementation and adoption was most successful when residents could see the benefit of the discount compared to the default imperviousness fee, and this led to the greatest level of effort in data gathering by residents.

The program requires robust facilitation by authorities. In Baden-Wuerttemberg, the "Council for townships" provided guidelines to facilitate the implementation of the imperviousness fee across the State, in line with regulatory requirements. Minimising the duplication of effort in implementation is important when layers of jurisdiction are present. Of the smaller towns, 89% surveyed used the information and guides provided by the "Council of townships", with 54% of them adjusting them to suit local needs (Fehring 2012).

Flow on effects

Across Germany, the introduction of the imperviousness fee had several additional, and often unexpected, benefits. A reduction in (combined) wastewater to be treated was reported in Munich and Dresden, and treatment processes could be optimised. Across Germany, reduced runoff meant that infrastructure updates could be deferred. For example, it was estimated that upcoming repairs of retarding basins would cost 75B Euro over a 10 year period (AU$113B), some of which could be deferred by better stormwater management (Frankfurter Allgemeine Zeitung 2006).

An extensive 3-year field study in the township of Tuendern (2300 inhabitants), compared the cost of upgrading the drainage system conventionally with the cost of lot-scale stormwater infiltration systems. The existing combined drainage system had reached capacity due to densification and increases in imperviousness of 25-36%. The study found that the distributed way of managing stormwater led to a saving of 1.45M Euro, or 35% of the cost of the conventional system (Adams et al 1995).

The increased demand for rainwater tanks is estimated to have created 4000 jobs and saved 75GL of drinking water per year across Germany (Frankfurter Allgemeine Zeitung 2006). Furthermore, the imperviousness data gathered in Dresden and Hamburg is now of an accuracy that allows it to be used for modelling of stormwater runoff, with much improved results.

It is important to note that in addition to fee changes there are a number of other regulations in place that promote stormwater-sensitive design of cities. For example, in Munich, the high adoption rate of green roofs (1.97 m2 per citizen or 2.82 million m2 in total) can be attributed to a regulation (in place since the 1990s) that all flat roofs over 100m2 must be green (DDV 2015). Additional regulations in some jurisdictions demand that all new homes must manage the roof-runoff on site (Baulinks 2011, Wasserhaushaltsgesetz 2009).

What could an imperviousness fee mean for Melbourne?

Currently, a fixed stormwater levy (part of the Waterways and Drainage Charge) is paid per annum per residence in greater Melbourne, irrespective of block size or imperviousness area. For non-residential customers, the levy is based on value of the property, irrespective of how the infrastructure relates to stormwater runoff and the impact on the drainage system or receiving waterways.

In the Australian State of Victoria, the Water Act governs how the Waterways and Drainage Charge can be implemented. It is unclear, in this legislative context, whether the level of imperviousness of a property is an attribute upon which Melbourne Water can base such a charge. Regardless of this fact, the economic case for implementing an imperviousness charge needs to be made before such a charge could be developed, or legislative change undertaken to allow it, should this be required.

Despite the challenges faced in Melbourne and Victoria, the case studies from Germany demonstrate that imperviousness pricing is relatively straightforward to develop and implement and it has significant potential to incentivise behavioural change of households and businesses. This can be achieved without increasing the scale of revenue collected through the charge. In addition, more detailed imperviousness data has the potential to improve flood modelling, predictions of groundwater recharge, and decision-making on investments related to stormwater. In particular a better understanding of imperviousness will improve confidence in the design of stormwater assets, roads (prone to flooding) and bridges.

A consideration of equity supports this case, that those causing the most significant costs to the stormwater network be incentivised to reduce costs, when moving from a fixed to a variable charge.

It is clear that confirming this theory would require more detailed analysis of the costs and benefits of a move to imperviousness pricing in the specific Melbourne context, and further investigation of the social implications, however, the case studies from Germany should provide a useful roadmap and significant optimism.

Figure 11 shows a theoretical example of how a current flat fee for stormwater in Melbourne could be spread to reflect the imperviousness of a home. The total revenue collected for the 20 example homes depicted remains constant; however, the annual stormwater fee paid by each of the example homes varies between $1 and $150. This introduces cost-reflective pricing and creates a financial incentive for the home owner to minimise stormwater impact.

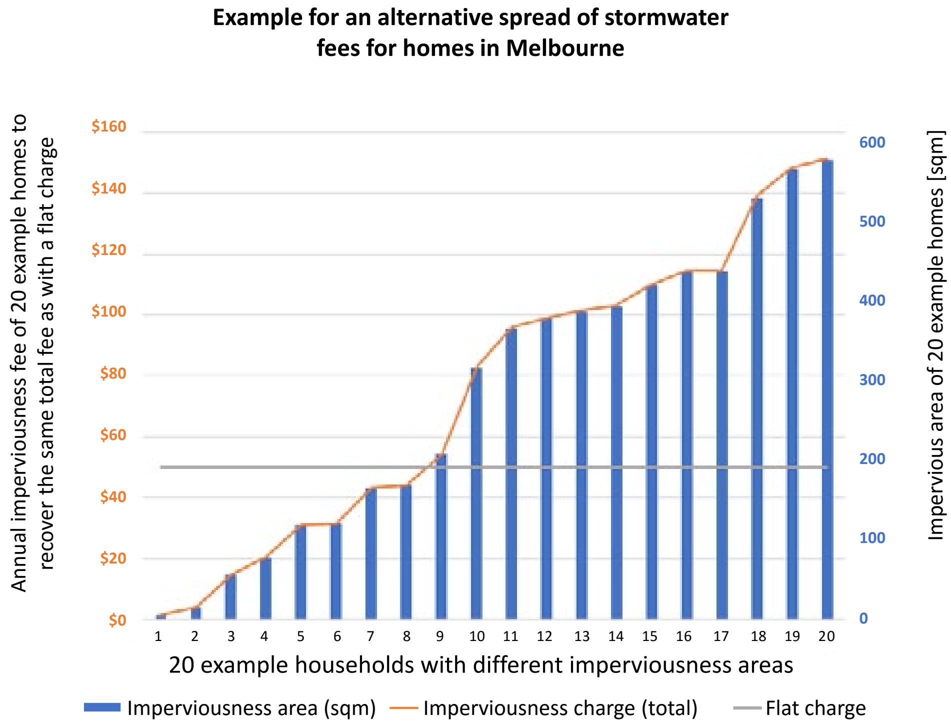

Figure 11. How an imperviousness fee could be spread over 20 households, an example based on Melbourne rates. The total amount of fee collected remains the same as if a flat fee was charged. This example was designed to highlight the potential for creating financial incentives to reducing a property's imperviousness.

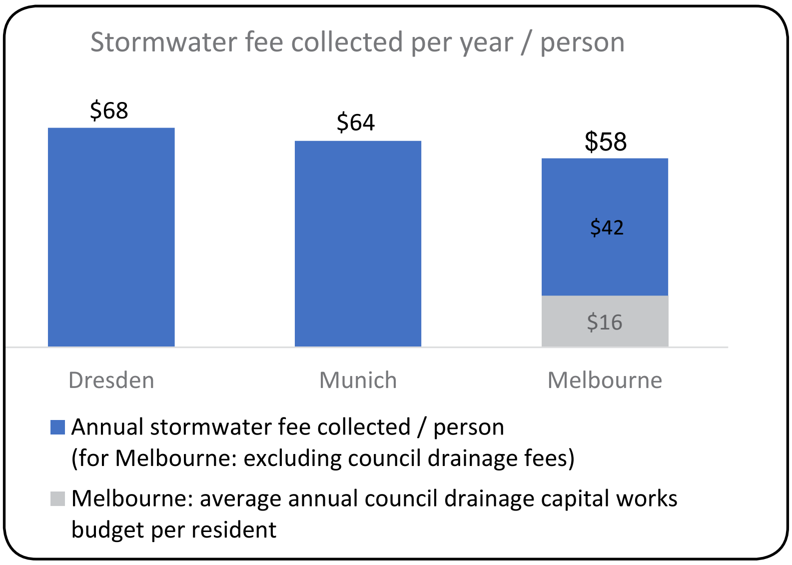

Figure 12. Comparison of annual stormwater fee collected per resident.

How a stormwater levy in proportion to the impact might be placed on Melbourne is yet to be seen, despite interest. The challenge is in resolving how to calculate effective imperviousness within acceptable inaccuracies. A more detailed understanding of how inefficiencies and inaccuracies have been addressed in Germany requires further investigation.

Another important comparison is the income generated from a stormwater levy. High-level estimates of the stormwater fees collected in Dresden, Munich and Melbourne are provided in Figure 12. The per capita stormwater fee currently collected in Melbourne[1] is comparable to the fees collected in the German cities analysed.

An important point of difference between the three cities is shown in Figure 13: Due to the much lower population density in Melbourne (450 people/km2 in Melbourne, vs. 4800 people/km2 in Munich and 2000 people/km2 in Dresden), the length of Melbourne's stormwater drainage dwarfs the drainage of German cities, which means that the funding available per km of drainage is much lower in Melbourne.

The opportunity to invest in some higher-cost stormwater management alternatives, such as large-scale storage and re-use, is dependent in part on the income generated from the stormwater levy. With an imperviousness fee, every household and business in Melbourne would be incentivised to consider their load on the drainage system and how they could contribute to the increasingly difficult task of managing Melbourne's stormwater. By treating stormwater runoff at the source, Melbourne's challenge of an extensive stormwater network may be reduced. In particular, as Melbourne's urban sprawl extends into the headwaters the stormwater runoff is transferred through the entire stormwater network, necessitating upgrades. This includes distal suburbs more than 40km from Melbourne's city centre transferring stormwater through the city centre. Incentivising reductions in connected imperviousness and excess stormwater runoff would be expected to have benefits throughout the drainage and waterway network.

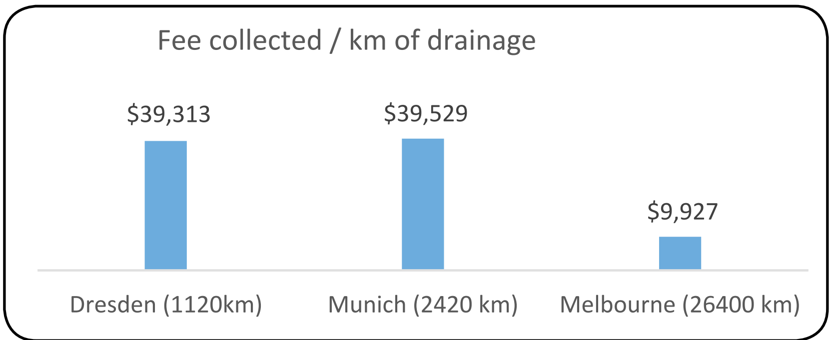

Figure 13. Comparison of annual fees collected per km of drainage in Dresden, Munich and Melbourne. Total length of drainage given is combined stormwater and wastewater for German cities, and both regional drainage (managed by Melbourne Water) and Council drainage for Melbourne. (Dresdner Stadtentwaesserung 2017, Muenchen-Wiki 2015, Melbourne Water 2017)

1. Council drainage capital works budget extracted from council budgets for 18 Melbourne councils for either 2016/17 or 2017/18.

Melbourne Water estimate drawn from Melbourne Water's 2016 pricing submission and ESC Determination, including operating and capital expenditure (return on investment using WACC and depreciation based on asset life). Estimate includes contributions (developer charges and stormwater quality offset). Scope includes residential and commercial customers. The average of 8 consecutive years has been calculated. The calculations assume 2.61 people per Melbourne household.

CONCLUSION:
Opportunity for change

Excess stormwater runoff from our expanding cities and suburbs has significant negative implications for the environment and the economy. The impediment to change is often cited as the increased cost and lack of incentives for alternative. Further investigating the opportunities in Australian cities may be well informed by the experiences in Germany where significant funds are being collected to better address stormwater management, the funds collected are socially more equitable, and the incentives for property owners to minimise the stormwater-runoff from their properties are greater. In Melbourne, an imperviousness fee would be fairer, based on the 'polluter pays' principle, and this will encourage smaller connected imperviousness footprints. With rapid greenfield development, it is a prime time for implementation of an incentive-based fee, particularly with the increased cost of retrofit and amendments. For the government, there are avoided costs associated with the managing the implications of excess stormwater runoff, including stormwater and road infrastructure, and damage to receiving waterways and bays, and well recognised benefits of water retention in the urban landscape, including thermal cooling. With climate change adaptation high on the agenda, the time for considering an appropriate imperviousness fee is upon us. This change has been demonstrated internationally and has the potential to contribute to healthier and more liveable cities and suburbs in Australian cities.

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Dr Lisa Ehrenfried is an experienced integrated water planner, having worked on the topic from various perspectives; in the Victorian State Government, at the Water Services Association of Australia, and at Yarra Valley Water. The recurring question of how to better manage stormwater has prompted her to embark on this independent research, investigating how stormwater is managed in her native Germany, and the lessons we can apply in Australia.

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