University Of Sydney Integrated Water Cycle Management Strategy and Implementation

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Abstract
Over the past 14 years The University of Sydney has reduced its potable water consumption by more than 35%, over which time the student population has nearly doubled. This reduction has been achieved through a range of demand management initiatives and significant leakage reduction programs. The University is now at the point where future potable mains water reductions from these programs are harder to achieve. The University is now looking to other strategies to reduce water consumption so as to "drought proof the campus".

This paper outlines the process and strategy that has been adopted by the University for water sensitive urban design (WSUD) and improved urban water cycle management, outlining the development of a whole of campus strategy with specific implementation projects. The strategy assists the University in identifying a range of appropriate secondary water sources, including stormwater harvesting and sewer mining; minimising water consumption through demand management, landscape selection and recycling; improving the quality of stormwater that leaves the campus and developing policy initiatives for its two main Campuses.

The University, empowered by their integrated water cycle strategy, is ensuring that the redevelopment of the main open space corridor and the addition of two new buildings on the University's main campus incorporates water efficiency and reuse opportunities. This paper discusses the process and outcomes in delivering WSUD through the University, and highlights the integration of WSUD into the urban landscape and built environment, overcoming institutional and socio-economic impediments to WSUD, as well as highlighting case studies with lessons learned.

Keywords
WSUD, Water Sensitive Urban Design, stormwater treatment, reuse

INTRODUCTION
The University of Sydney was established in its present position 3km west of the Sydney CBD in 1855, and over the past 150 years has developed to include more than 100 buildings over its 72 hectare site. As part of the renewal of the campus, the University has developed a major works program "Campus 2010 – Building for the future program" in which the two main open space corridors are to be remodeled with two new buildings added to the campus (University of Sydney, 2006).

To assist the University on a preferred approach, a competition was held in which four teams were selected for the four components of Campus 2010. Ecological Engineering was involved in one of the design teams with a proposal to integrate environmental sustainability through stormwater harvesting and treatment through the public open space renewal.

The University acknowledged that the water cycle management approach developed by Ecological Engineering would realise the environmental objectives of the University as well as addressing a series of external water management drivers. As a result, the University embarked on developing an integrated water cycle management strategy for the whole of the campus. Furthermore, it was decided that the four distinct "Campus 2010" capital works projects would incorporate integrated water cycle management principles into their designs. The University recognised that the components of the scheme were consistent with and actioned the objectives of its environmental strategy, namely (University of Sydney, 2002)

- reduce its consumption of materials and energy and to implement environmentally sound waste management practices.
- landscaping and grounds maintenance practices which minimise water and energy use and promote integrated pest management.

The University's main water related action to date had been a very successful leakage reduction program, which is informed by more than 75 meters. These meters include real-time, monthly and quarterly meters throughout the campus which monitor any anomolus water consumption and any leakge is typically rectified within 48 hours. Since 1988, there has been nearly a doubling of the student population from 16,466 to 32,926 students, with gross floor area increasing from 461,000 to 665,000m^2. However, as a result of the leak reduction and other demand maagement initiatives, water consumption has decreased 35% from 792ML/year to 500ML/year in 2003. Despite these efforts, the University remains Sydney's 23rd largest water user, and future gains in the leakage reduction and demand management program are likely to be less acheivable as the program is operating at an optimal level.

Concurrently, the University is experiencing a range of external drivers to improve its water management, namely;

- Mandatory water restrictions, which restricts open space irrigation, which accounts for approximately 25% of the University water consumption. Importantly, it has been identified that the prolonged nature of the restrictions will have a more significant impact over the long term with minimal water to assist growth and prevent turf diseases.
- The cost of water in Sydney has recently increased to $1.20/kL, up from $1.013. The price will rise to $1.31/kL in 2008-09.
- The University along with all businesses in Sydney that consume more than 50ML/yr are required to prepare a water conservation plan by March 2006.

With its environmental policies largely unrealised, a range of external drivers and a suite of new building programs about to begin, the University acknowledged the need for a holistic and integrated approach to water management.

METHODS

To bridge the gap between is policies, current programs and external drivers, the University engaged Ecological Engineering to develop an Integrated Water Management Strategy (Ecological Engineering 2004) (available at http://www.facilities.usyd.edu.au/projects/docs/water_paper.pdf). The strategy has been developed to build on the past work of the University and identify sustainable water management practices and water savings, address the external water management drivers, while at the same time instigating a series of projects to allow the realisation of its environmental vision. Importantly, the Water Management Strategy has been developed in collaboration with a range of stakeholders to overcome a series of institutional impediments. Further, the strategy allows for the integration of water management initiatives between the buildings elements of the 2010 as well as between the different landholders in the University.

An important first consideration was to benchmark the current water consumption, use and disposal through the University. This water balance is presented in Figure 1, and shows that in an average year nearly 1 gigalitre of rain falls on the campus, and more than half as much again is brought onto the campus as potable mains water. Most of the rainwater runs off as stormwater to Blackwattle and Rozelle Bays carrying litter and other pollutants washed off roads, footpaths and other impervious surfaces through the University, while most of the potable water is used once and discharged to the sewer and thence to the Bondi Ocean Outfall.

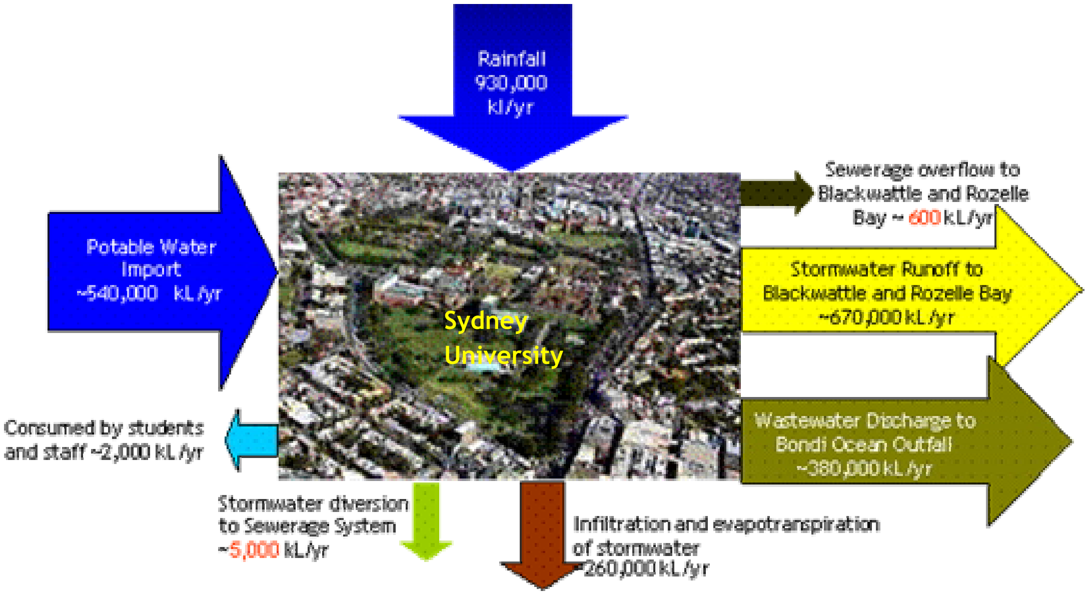

Figure 1 Sydney University Water Balance

The breakdown of water use on campus has been derived from extensive water metering (University of Sydney, 2006a). The results show that the majority of potable mains water used on the campus is consumed by cooling towers and open space irrigation, 30% and 25% respectively. Toilets are the next major user at 16%, with basins, showers and kitchens 8%. A breakdown by buildings and major uses through the University shows that the biggest singular users are the chemistry building (10%), the University Sports facilities (7%), and the Student Union buildings (5%). The chemistry building is the highest water user due to the use of water aspirators, with consumption of 20ML/yr within this building.

The Strategy was developed to optimise the use and appropriate reuse of water through the campus and identifies a range of water cycle options in three stages, which act as a framework for implementation. The stages generally follow the principle of low cost source reduction for Stage 1 options, reuse and recycling for Stage 2 options and innovative and integrated ecosystem principles for Stage 3. The stages also correspond to project inception and development lead times with Stage 1 projects having the least development time and Stage 3 having the longest.

Table 1 - Integrated Water Cycle Options

Stage 1 **1 to 3 years** **Source Reduction**	**Stage 2** **5-10 years** **Reuse**	**Stage 3** **10-20 years** **Innovation**
• Detailed water audit • Leakage Reduction • Aggressive Water Efficiency • Cooling Tower Efficiency • Irrigation Efficiency • Stormwater reuse (immediate options) • Stormwater quality improvement retrofits	• Roofwater reuse • Stormwater Reuse • Greywater reuse • Wastewater reuse	• Source separation of wastewater • Waterless Toilets • Biogas Plant • Vacuum Sewers

The five key recommendations of the strategy were identified as:

- An integrated water management framework - a formalised management structure is the key to the successful management of the water cycle. Water management policies and an integrated water management committee were developed to drive the implementation of specific integrated water programs on campus. This program has been initiated through a memorandum of understanding between the majority of campus landholders and stakeholders.

- Drought proofing the campus - currently the majority of open space irrigation demands are not being met due to water restriction. In the future it is possible that water restrictions will be imposed more frequently and possibly permanently. The University is seeking to proactively move to drought-proof the campus by utilising various alternate supplies available on campus. There are significant cost incentives as currently employed alternatives, such as hand watering are expensive, and the cost of water has just risen by 20%.

- Aggressive Water Efficiency - water efficiency needs to be actively, comprehensively and aggressively pursued. Water efficiency offers the simplest and fastest way to reduce water consumption at least cost. Water efficiency in the near term will be the predominant form of reduction of water usage in existing buildings and thus a major roll-out of water efficiency needs to be adopted. The strategy shows that significant reduction in mains water usage can be made for all forms of water using fixtures across campus including replacing single flush toilets, inefficient urinals, inefficient shower heads taps, and dishwashers.

- Stormwater Quality and the adoption of WSUD - stormwater quality management will gain increasing attention in the medium term. An active local community has already begun to improve creeks downstream of the University. Importantly, the University of Sydney's Camperdown and Darlington Campuses drain to Sydney Harbour, a highly visible receiving water that has an international reputation. Currently the University has limited capture of gross pollutants. Other pollutants including nutrients, organic matter and heavy metals are discharged from the campus and into the Harbour without any treatment.

- Exploiting retrofits and redevelopment – retrofits offer an important opportunity to achieve significant integrated water cycle outcomes. The University now requires the all retrofits and redevelopments including building fixture retrofits, road works, and landscaping works make the most of opportunities for reducing water usage and improving stormwater quality. The University through their "Campus 2010" program is ensuring that these redevelopments systematically include integrated water cycle management elements.

IMPLEMENTATION AND CASE STUDIES

Ecological Engineering was commissioned by the University to investigate the feasibility of WSUD opportunities for the four elements of the "Campus 2010" redevelopment. The investigation included an assessment of all water related elements within the individual designs of the four major projects, and then sought to develop benefits through optimising the water management between the projects and beyond the boundaries of "Campus 2010" projects.

The investigation sought to consolidate information from the four design teams on how stormwater, wastewater and potable water was to be managed on the site. This information, along with there relevant information on building size, catchments and nearby water uses, was used to develop a range of achievable options to enhance urban water cycle management within each 'design package'. A primary focus of this work is to ensure best practice stormwater objectives of 80% reduction in the average annual load of total suspended solids, and 45% reduction in average annual load of total of total nitrogen and total phosphorous (Mouritz et al, 2005). These targets, once achieved, allowed a maximum quantity of stormwater to be made available for storage and reuse.

The analysis of sustainable water management practices within the new building projects allowed an examination of the assumptions applied by each of the design teams. Specifically, each of the buildings were striving for a minimum GreenStar Rating [in principle, as only a commercial rating was available at that time]. This rating system awards buildings four to six stars on a range of environmental criteria, with five stars representing "Australian excellence" and six stars representing "world leader" (ABGR 2005). While the aims of the assessment are admirable, the water components of the rating tool do not offer a real-time assessment or water balance of expected demands. The GreenStar rating tool awards points for roofwater harvesting without consideration of the catchment area that is being harvested. The Greenstar rating tool does not recognise the relationships between stormwater treatment and reuse. Also, the tool does not count benefits beyond the building from stormwater harvesting and reuse, which is the basis of this investigation.

To remedy these shortcomings, stormwater treatment systems and reuse storage volumes were determined using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) (McAlister et al, 2005). MUSIC is a model developed by the Co-operative Research Centre for Catchment Hydrology, and is an industry standard. 20 years of continuous rainfall data recorded at Sydney Observatory Hill was used in the modelling (1973 to 1993) in six-minute timesteps.

For the investigation of the WSUD options for the "Campus 2010" projects, the University was divided into three catchments in the Camperdown Campus (Eastern Avenue, Barff Road, and City Road) and three catchments in the Darlington Campus (Darlington Road, Maze Crescent, and Shepherd St). Water management options that reduce potable mains water demand, provide stormwater treatment and enhance the landscape of the redevelopment, were recommended for each of these catchments.

A combination of *bioretention systems* (vegetated soil filter beds) and *wetlands* (shallow permanent vegetated water bodies) are proposed to treat runoff. These systems have been integrated into the public domain, adding self irrigating green spaces in the otherwise highly impervious area. The recommended water management strategies for Camperdown and Darlington Campus' are shown as case studies below.

Camperdown campus

The WSUD strategy for the Camperdown campus is designed to harvest, treat, store and reuse stormwater from two separate catchments which lie within the "Campus 2010" project boundaries. A preliminary investigation was initially undertaken comparing the feasibility of sewer mining and stormwater harvesting for the Camperdown Campus. Stormwater harvesting was seen as a more cost effective strategy while at the same time providing similar reliability of supply. With no large external sewer carrier available and low numbers of students on campus during the summer months, there is a shortage of water for the high demands in the summer months for irrigation and cooling towers.

Eastern Avenue Catchment. (1.2 hectare catchment including the main University thoroughfare and garden beds, Madsen building, Chemistry Building and Anderson Stuart roofs). Stormwater from the open space thoroughfare will be directed to three raingardens integrated into the landscape, and six "plane tree" bioretention cells adjacent to the Chemistry and Madsen buildings for treatment. Small areas of the catchment that cannot be directed to these treatment areas due to the grade will be directed to three gully filter pits to remove coarse suspended solids (as per Figure 2).

Following treatment, flows are directed to a 75 kL storage tank, and reused for irrigation of the garden beds and street trees along Eastern Avenue and the turf and garden areas south of Carslaw and Madsen Buildings.

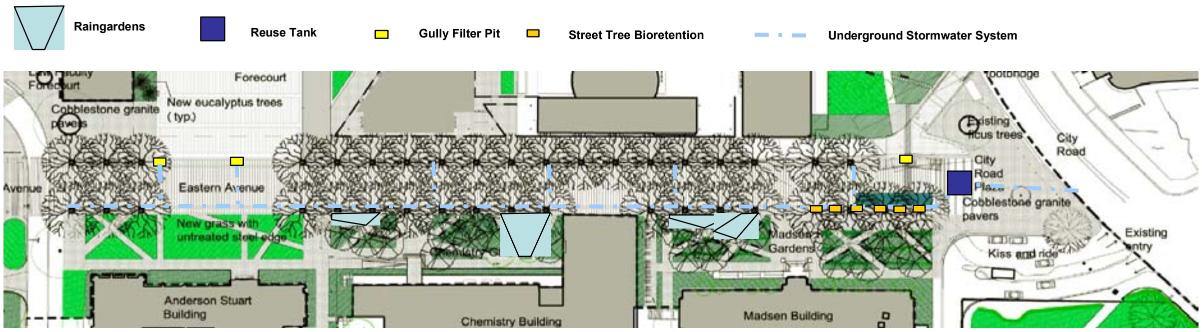

Figure 2 Eastern Avenue Catchment

Barff Road Catchment. A 2.8 hectare catchment predominantly consisting of roof surfaces, including the existing Carslaw, Fisher Library, Fisher Stack, and the new law faculty building and lecture theatres and also includes the law forecourt and Barff Road (Figure 3). The treatment strategy is to isolate the large areas of roofs (Fisher Library, Fisher Stack, Law Faculty and Carslaw) and divert rainwater directly to a reuse tank. The remaining areas of Barff Road and the Law forecourt will be treated in streetscape bioretention systems. Treated runoff and roofwater will be collected in a 200kL storage tank under the law building. Water will be reused for toilet flushing within the Law Building and irrigation of the law forecourt, University Lawn, Tennis Court Lawn, the Chancellor's Garden and the Barff Road North "nature strip".

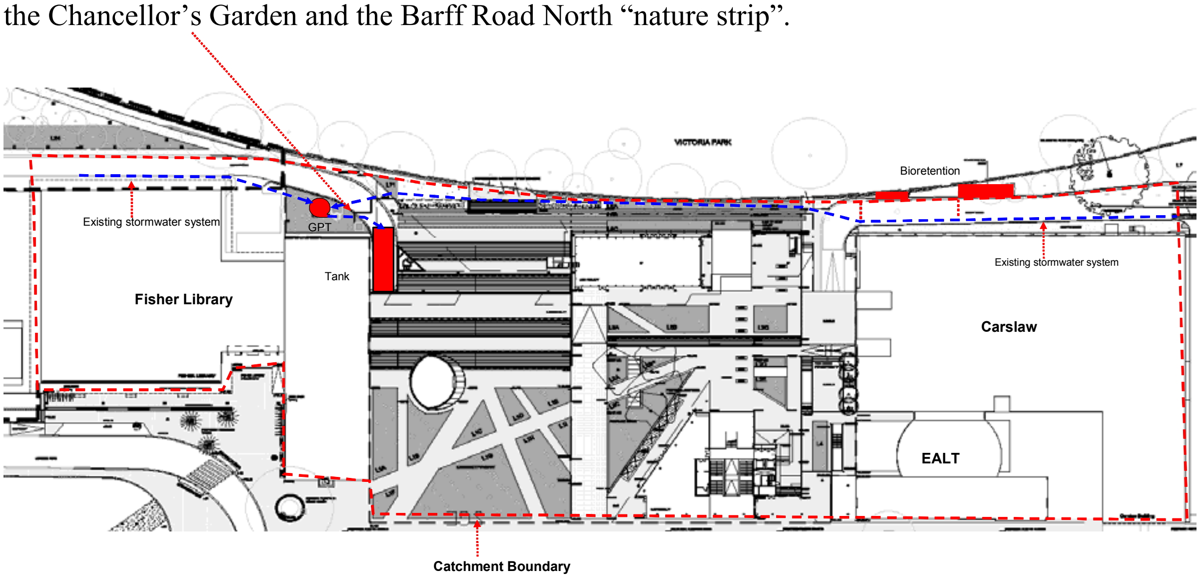

Figure 3 Barff Road Catchment

City Road Catchment. A small 0.2 hectare catchment at the existing entrance to the University from City Road. Stormwater will be treated in bioretention systems as features in the landscape, prior to discharging into the local stormwater system via City Road.

Darlington campus

The WSUD strategy for Darlington Campus is to provide high quality landscaped areas within the public domain that also have a functional role in providing stormwater and wastewater treatment. Stormwater harvesting and treatment from the surrounding catchment as well as treating greywater from the sports facility's showers and washing machines were proposed. While the initial feasibility investigations of the greywater wetland suggested it was feasible it was postponed due to the lack of a suitable reuse application for the treated wastewater within the "Campus 2010" boundaries.

Darlington Road catchment. A 5.4 hectare catchment includes Darlington Road, Merewether, Biochemistry and Microbiology, and The Institute Buildings. Stormwater flows are to be diverted from an existing drain along Darlington Road between Maze Green and City Road into a wetland and bioretention system as the central landscape feature of Maze Green. Flows are treated in the permanent water system and collected for reuse as irrigation of Maze Green and non-potable uses including cooling tower usage and toilet flushing in USYD Central.

Maze Crescent Catchment. A 1.8 hectare catchment including USYD Central and Wentworth buildings. Flow will be diverted from an existing stormwater drain and treated in a bioretention system that forms the eastern perimeter of Maze Green. Treated water will be used to supplement the supplies of the Darlington Road storage tank and will contribute to irrigation of Maze Green, flushing toilets in USYD Central and water to the cooling towers proposed for USYD Central.

Shepherd Street Catchment. A 1.2 hectare catchment including flows from the Sport Centre, tennis courts and local pavement areas**.** A bioretention system is proposed as part of the entrance landscape adjacent to the Shepherd Street entrance bridge. The system will treat runoff to best practice standards and discharge into an existing stormwater system.

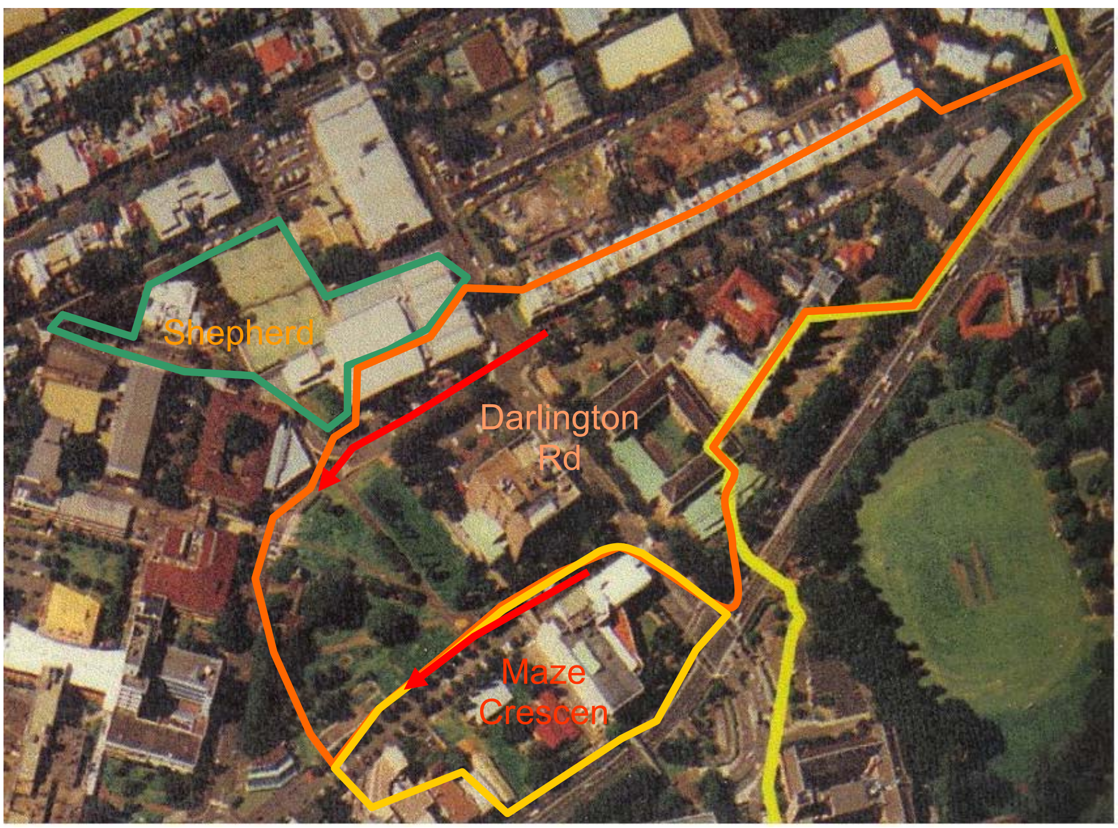

Figure 4 Darlington Campus Catchments

CAMPUS 2010 RESULTS

The implementation of the stormwater treatment and reuse systems in the "Campus 2010" development will allow significant inroads into the University to achieve best practice stormwater treatment for the development area. A total of 12.6 hectares will be treated to best practice standards which is more than 15% of the entire main campus. This is also a significant portion of Blackwattle Bay Catchment flowing into Sydney Harbour (Birch, 2002).

Furthermore the water reuse initiatives will reduce demand on potable mains water by approximately 24 ML/yr and reducing the University's demand for water by 5% and saving approximately $42,000 annually based on water supply and sewer discharge savings.

The "Campus 2010" Water Sensitive Urban Design Initiatives will also supply additional benefits such as helping to drought proof campus. The high reliability stormwater tanks will greatly assist the University in supplying water to landscape areas during compulsory water restrictions. This is particularly important due to the fact that these restrictions are likely to stay in place for the long-term, with questions presently raised over the use of mains water for open space irrigation.

The implementation of WSUD in "Campus 2010" has been an invaluable learning experience. It has enabled the strategies and theories that have been developed during the Integrated Water Cycle Management planning phase to be tested and implemented first hand by the University engineering, landscape, planning, environmental and academic staff.

CONCLUSIONS

The development of the University Water Management Strategy established a framework for current and future water management works and has highlighted the need for better water management through the University. Importantly, by bringing together a range of stakeholders the strategy has overcome a range of institutional impediments to WSUD. Prior to the strategy there was no actualisation of the vision of the Universities environmental policies, and actions by the University were focused on leakage reduction. The development of the Strategy has focused actions and works within an agreed framework, which are now successfully being implemented.

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