Better Urban Water Management:
A Case Study of Perth, WA

A report submitted to the School of Engineering and Energy, Murdoch University in partial fulfillment of the requirements for the Degree of Bachelor of Engineering

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Executive Summary

‘Better Urban Water Management: A Case Study of Perth, WA’ is a collaboration between Murdoch University and ENV Australia. The purpose of this study is to investigate Perth’s achievement of the Better Urban Water Management (BUWM) design objectives (WAPC 2008) and to benchmark Perth in the Urban Water Management Transitions (UWMT) framework (Brown and Wong 2008).

The role of BUWM is to provide guidance in water efficiency and conservation, water quantity and water quality management through the urban planning process. The framework has been active since 2008 as a joint government and industry initiative to integrate WA’s water and land use planning process. The UWMT framework focuses on 6 different city typologies characterised by socio-political drivers and service delivery functions, developed by the Centre for Water Sensitive Cities. The framework encapsulates the historic, current and future water cities of Australia. The two frameworks are an appropriate assessment of current urban water management in Perth as BUWM has played a key role in transforming urban water management in WA in recent years and the UWMT framework provides the next step in creating cities which are resilient to climate change and the associated impacts.

The study has focused on urban residential development in the Perth metropolitan area, with an analysis investigating seven case studies. This included examples of urban development pre-BUWM practice, current business-as-usual practice and best management practice within the two frameworks discussed. The analysis provided an overview of the current status of urban water management in Western Australian urban residential developments. The study concluded that BUWM design objectives are not being met and Perth’s status in the Urban Water Management Transitions (UWMT) framework is a Waterways City, where a business-as-usual approach was applied. The study also concluded a wide range of different typologies are represented in the Perth metropolitan area, ranging from water supply city to water cycle city depending on the case study.

Recommendations are provided to bridge the gap between BUWM and achieving a Water Sensitive City. This included the support of behaviour change programs to nurture normative values of environment and sustainability, to encourage multi functionality of landscaped spaces to support hydro-social interactions, support for fit-for-purpose water systems and a diversification in arrangements and institutional arrangements of managing the water systems.

Acknowledgements

There are many people I would like to thank for their direct involvement with the project and support given throughout my entire studies at Murdoch University.

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Lastly, I would also like to thank my family, friends and partner for their love, understanding and support.

Acronyms

Acronym	**Term**
ABS	Australian Bureau of Statistics
AFC	Australian Fine China
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	Average recurrence interval
BMP	Best Management Practice
BUWM	Better Urban Water Management
CCW	Category Conservation Wetland
COAG	Council of Australian Governments
CoC	City of Cockburn
CMB	Central Management Body
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoE	Department of Environment
DoH	Department of Health
DoW	Department of Water
DWMS	District Water Management Strategy
ED	EnviroDevelopment
ISP	Infill Sewerage Program
IWCM	Integrated Water Cycle Management
LSP	Local Structure Plan
LWMS	Local Water Management Strategy
NWC	National Water Commission
NWI	National Water Initiative
POS	Public Open Space
SRA	Subiaco Redevelopment Authority
SUWM	Sustainable Urban Water Management
UDIA	Urban Development Institute of Australia
UWMP	Urban Water Management Plan
UWMT	Urban Water Management Transitions
WA	Western Australia
WAPC	Western Australian Planning Commission
WELS	Water Efficiency Labelling and Standards
WSC	Water Sensitive City
WSUD	Water Sensitive Urban Design
WWTP	Wastewater Treatment Plant

1 Introduction

Increasingly, climate change is presenting real and tangible impacts. Issues associated with declining water resources from traditional sources, a variable climate and increasing urban populations, urban water planning in Australia is evolving. Water conservation and efficiency are becoming recognised as crucial considerations of the everyday to ensure that our water livelihoods are maintained. In Western Australia, we have long been buffered from the effects of declining rainfall due to large groundwater resources, but this is coming to an end with extended dry periods and continual abstraction.

'Better Urban Water Management: A Case Study of Perth, WA' is a collaboration between Murdoch University and ENV Australia. The purpose of this study is to investigate Perth's achievement of the Better Urban Water Management (BUWM) framework (WAPC 2008) and to benchmark Perth in the Urban Water Management Transitions (UWMT) framework (Brown and Wong 2008).

The aim of this study is to a) determine if the design objectives of Better Urban Water Management are successfully integrated into the urban planning process for the Perth metropolitan area and b) determine the city state typology Perth represents in the Urban Water Management Transitions Framework.

The objectives of this study are to:

- Analyse the progress BUWM has made in urban water management in Perth
- Understand the differences between a business-as-usual approach and best management practice in urban water management
- Investigate the differences between BUWM and the characteristics of a Water Sensitive City.
- Investigate the different typologies represented in Perth
- Provide recommendations to progress Perth to a Water Sensitive City

The study has focused on urban residential development in the Perth metropolitan area, with an analysis investigating examples of urban development pre-BUWM practice, current business-as-usual practice and best management practice within the two frameworks discussed.

The role of BUWM is to provide guidance in water efficiency and conservation, water quantity and water quality through the urban planning process. The guidelines have been active since 2008 as a joint state and local government and industry imitative to integrate WA's water and land use planning process. The UWMT framework focuses on 6 different city typologies characterised by socio-political drivers and service delivery functions developed by the Centre for Water Sensitive Cities. The framework encapsulates the historic, current and future water cities of Australia. The two frameworks share many core concepts of water sustainability, diverse water supplies and water quality. BUWM has played a key role in transforming urban water management in WA and as such UWMT framework provides the next step in creating cities which are resilient to climate change and the associated impacts.

2 Background

2.1 Perth Water History

Australia's development of a centralised water supply occurred early in its European settlement. The capital cities developed rapidly with the Industrial Revolution and created a need for a centralised system to cope with increased water supply demand, sewerage disposal, and increased stormwater from developed urban areas. The historical approach behind urban water planning was to supply the cities with vast amounts of high quality water and removing stormwater and wastewater from the city as quickly as possible. While this approach has provided Perth with a reliable water, sewerage and drainage system for many decades (Chanan et al. 2009), the challenges of climate change are now proving the centralised system to be insufficient. The planning decisions and ideology made in the later 19th century are having a direct impact on our lives today.

Water supply for European settlers began with a highly decentralised system of swamps, lakes and a few fresh water springs in 1829. The common law of England was applied to water supply with the colonisation of Australia, to govern access to, and ownership of, water resources in Australia, and the majority of the population assumed individual rights to water including storage and sale (England 2009). With the settlement of the Perth colony, wells were also used in Perth and Fremantle. The combination of uncontrolled utilisation of water and public health scares resulted in the establishment of a centralised water management system to control, own and manage urban water. This was governed through the state government (England 2009). In response to this shift, many dams were built in the hills and groundwater sources established for water supplies. Victoria dam was constructed in 1891 to provide reliable water supplies for Perth, followed by Mundaring Weir in 1903 to service the Goldfields, with the extension in 1951 allowing the dam to also serve Perth. Artesian bores were sunk with increasing water demand in the early 1900s. The importance of groundwater was not recognised until the 1970s, with groundwater providing up to 50% of Perth's current water supplies. The 1900s and the early 2000s saw the construction of several more dams to service both the metro and rural areas of Western Australian, totalling 110 dams and weirs, with 259 water treatment plants. In recent years Perth has secured its water supply through the addition of desalination plants (Water Corporation 2011).

A centralised wastewater management approach in Perth and Fremantle began in 1910. The institutional shift was attributed to a typhoid breakout, with a large septic tank discharging to the ocean (Water Corporation 2011). The centralised system initially comprised of septic tanks at Claisebrook discharging to the Swan River in 1912. The process has been modified over the last century to include a variety of WWTPs and disposal methods. The main method continues to be ocean disposal of secondary treated effluent (Water Corporation 2011).

The first reported drainage work in WA was in response to winter flooding of the major streets in Fremantle in 1833. The institutional arrangements for these early drainage systems were the responsibility of the municipalities until 1909, when it became under the control of the Metropolitan board of Water Supply and Sewerage. The management of drainage has now shifted to a partnership between the local government and the Water Corporation (and its predecessors) (Water Corporation 2011).

Since the 1980s Australia has experienced an increasing demand for water and rising costs for supply, maintenance and operation. Building new infrastructure is no longer a cost effective solution (England 2009). The key challenge is to ensure that adequate water supplies are available to meet economic and social needs while minimising the impact of the natural environment including the natural hydrological regime. Perth has already undergone a step change in rainfall, with a significant reduction in runoff in water supply catchments (Maheepala and Blackmore 2008).

During the 1990s a shift was occurring with the conceptualisation of Water Sensitive Urban Design (WSUD) as an alternative to large centralised stormwater management systems. This ‘‘paradigm shift’’ started in Western Australia, with the call for a new approach to urban planning and design. The basis for this was that conventional water supply, sewerage and drainage practices which rely on conveyance and centralised treatment and discharge systems cannot be sustained in the long term. This fundamental shift of thinking is now encapsulated in the broader terms of Sustainable Urban Water Management (SUWM), which ‘places an emphasis on demand-side management as well as supply-side management, utilisation of non-traditional water resources and the concept of fit-for-purpose and decentralisation’ (Mitchell 2006: 590). With the turn of the 21st century, several new codes of practices regarding stormwater have been released to aid in the implementation and development of WSUD. These documents include *Clean Stormwater – a Planning Framework* (2004), *WSUD Engineering Procedures: Stormwater* (2005), *WSUD Guidelines* (2005) and *Australian Runoff Quality* (2006).

2.2 Sustainable Urban Water Management

Urban water planning has entered an era of necessary Sustainable Urban Water Management (SUWM) due to population growth and supply security. Traditionally urban water management has been approached with technical solutions to supply management issues (water quality and quantity). This has now shifted due to issues of water scarcity and hence requires sustainable management of supply, demand and disposal issues (Pearson et al. 2010).

The aim of SUWM is to achieve more efficient and effective water use with better outcomes for the environment and built form (Figure 1). Through this approach all water flows are recognised as a potential resource, with a perceived ‘interconnectedness of water supply, groundwater, stormwater, wastewater, flooding, water quality, wetland, watercourses, estuaries and coastal waters with water efficiency, re-use and recycling’ essential processes to SUWM (WAPC 2008:1). These considerations were not considered in the conventional approach.The main principles of SUWM are supported by BUWM and outlined in *State Planning Policy 2.9 Water Resources* (Government of WA 2006). They are:

1. Consideration of all water resources in water planning
2. Integration of water and land use planning
3. The sustainable and equitable use of all water sources, having consideration of the needs of all water users
4. Integration of human water use and natural water processes
5. A whole-of-catchment integration of natural resource use and management.

Figure 1: Managing water resources in an urban development context (WAPC, 2008)

Components of SUWM include managing water supply, wastewater and stormwater systems in a coordinated manner. Through this approach the ability to minimise their impact on the natural environment, maximise contribution to economic vitality and to engender overall community wellbeing and improvement is achievable. It also incorporates water demand management, utilisation of non-traditional water resource, fit-for-purpose and decentralisation. There has also been comment that SUWM is not just an alternative to the traditional centralised approach to water management but is a necessary transition as these methods cannot be sustained in the long term due to pollution management, water scarcity and energy costs amongst other issues (Mitchell 2006). Sustainable water systems can be defined as 'water systems that are managed to satisfy changing demands placed on them (both environment and human) now and into the future, whilst maintaining ecological and environmental integrity of water systems' (Pearson et al. 2010: 364).

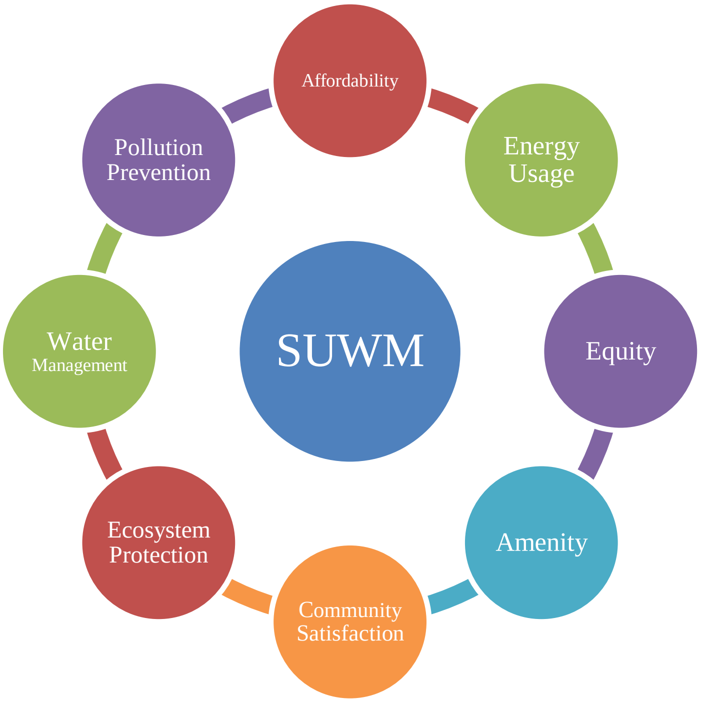


Figure 2: Some of the benefits of adopting SUWM (adopted from Mitchell 2006)

SUWM goes beyond water management as it seeks to enable multi-functionality of urban water services to optimise the outcomes achieved by the system and hence reduce the impact of the urban development on the natural environment (Figure 2) (Mitchell 2006). SUWM is not just about water management but instead integrating sustainability in all levels of developments.

The Better Urban Water Management (BUWM) framework provides guidance to urban developments to achieve SUWM. It is centered on Water Sensitive Urban Design which is reflected through the design objectives. This will be discussed later in the report.

2.2.1 Water Sensitive Urban Design

One of the ways in which SUWM has been reflected in engineering practices is water sensitive urban design (WSUD). WSUD is an integrated approach to stormwater management which focuses on the multi functionality of water, including reuse, aesthetic, habitat protection and recreation (CSIRO 1999). WSUD has many economic, environmental and social benefits which are aligned with the general advantages of SUWM. The objectives of WSUD are (CSIRO 1999):

1. Protect natural systems
2. Integrate stormwater treatment into the landscape
3. Protect water quality
4. Reduce run-off and peak flows
5. Add value while minimising development costs.

WSUD elements are flexible to site conditions, and while there are general guidelines to follow, design can be adapted. WSUD usually involves a combination of several elements, such as a treatment train to effectively manage stormwater from a range of different land uses. Commonly used WSUD elements in Australia include (CSIRO 2005):

- Sediment basins
- Bio-retention swales and basins
- Sand filter
- Swale/buffer systems
- Constructed wetlands
- Ponds
- Infiltration measures
- Aquifer storage and recover.

Several strategies support WSUD objectives in Australia on a national, state and regional level. This includes topics of water quality, sustainable development, sustainability, water quantity and natural resource management (DoW 2011).

To further support stormwater management, *The Stormwater Management Manual for Western Australia* (DoE 2004) provides guidance on the management of stormwater in new developments and redevelopments projects, as well as retrofitting of existing drainage systems. The document describes Best Management Practice’s (BMPs) to reduce pollutant and nutrient inputs to stormwater drainage systems and WSUD principles.

In 2011 *Stormwater Management in a Water Sensitive City* (Wong et al. 2011) was released in response to the shift of urban populations, resilience to climate change, and the emergence of sustainability. The document is envisioned to be an evolving text to articulate how Australian cities can transition to Water Sensitive Cities through three pillars: cities as water supply catchments, cities providing ecosystem services and cities compromising water sensitive communities (The Centre for Water Sensitive Cities 2011). The document in its current form presents an approach rather than specific guidelines or direction to be followed.

2.2.2 Water Modelling

To successfully achieve SUWM it is ‘dependent on a development specific characteristics requiring both quantitative and qualitative information to be fully taken into account’ (Makropoulos et al. 2008: 1448). A number of tools have been developed across the world to assist with achieving SUWM in the following areas (Mitchell 2006):

- Water conservation and efficiency
- WSUD
- Water source availability (rain, grey, storm, and wastewater)
- Application of fit-for-purpose uses
- Stormwater and wastewater source control and pollution prevention
- Stormwater flow and quality management
- Mixture of soft (ecological) and hard (infrastructure) technologies
- Non-structural tools such as education, pricing incentives, regulations and restriction regimes.

As alternative streams are increasingly being considered in the urban water supply cycle Makropoulos et al. (2008) have prototyped a software package that assists in facilitating the selection of combinations of water saving strategies and technologies to support SUWM in new developments. The tool allows the investigation of interactions between major urban water cycle streams as part of the flexible water mass balance model. The assessment includes environmental, economic, social and technical considerations to act as sustainability indicators. The tool successfully assists in identifying and presenting to the user, trade-offs across sustainability indicators (environmental, economic, social and technical) of different urban water scenarios for a development. The importance this has in progressing urban water management is to facilitate discussion and negotiations by providing information and assessment of different urban water scenarios.

Hellstrom et al. (2000) presents a framework for the analysis of urban water and wastewater systems. The framework provides a mechanism which decision makers could utilise to assess the sustainable technologies according to a range of objectives and criteria. The framework is just one way which they could promote the uptake of sustainable technologies through a logical and systematic analysis which incorporates social and cultural aspects, environmental aspects, economy and technical considerations. The scope of sustainable water technologies of BUWM is limited to water demand within the household and POS irrigation, little concern is given to wastewater despite the discussion on WSUD.

Pearson et al. (2010) suggests water models and tools provide adequate understanding and analysis of the managed water systems in urban areas. Traditionally models have dealt with water quality and quantity but an emerging area is the incorporation of public and social issues to address contemporary sustainability issues.

2.3 Water Reform

Australian water reform dates back to the 1980’s, but the 1994 COAG Water Reform Framework that was initiated as part of the National Competition Policy Reforms marks the beginning of modern water reform. The objectives of the water reform in the 1994 framework were to achieve an efficient and sustainable Australian water industry. This included a Commonwealth – State agreement including pricing reform, water allocations and water trading, institutional reform, environmental reform and consultation and public education (Kaspura 2006). Due to the slow progress of the reform the National Water Initiative (NWI) was created in 2003 to provide a water reform framework for Australia. The most relevant element of the NWI is urban water reform, as it contains commitments to develop innovative ways of achieving more efficient water use (Shepherd 2008).

The urban water reform area includes increase in water use efficiency, encourage cost effective reuse and recycling of wastewater, facilitate water trading between and within the urban and rural sectors and encourage innovation in water supply sourcing, treatment, storage and discharge. The NWI also included actions for demand management measures and innovation to create water-sensitive cities. The *Australia Water Reform 2009* report found that state and territory governments have increased investments in water security (diversification), though less attention had been paid to stormwater harvesting (Australian Government, 2011a).

The NWI also contained an agreement to set up the National Water Commission (NWC) to assist with the implementation of the initiative. The Commission was established in June 2004, which Western Australia did not join until later. The Department of Water (DoW) claims that water reform began in WA in 2005 with the creation of the DoW to manage the state's water resources (DoW 2011). *A blueprint for water reform in Western Australia in 2006* provided recommendations for a water reform framework, which the WA government then became a signatory to the NWI.

An additional outcome of this action was the development of the *State Water Plan* (2007) which established a vision for water resource management in WA and to address and integrate a range of water policy reforms at state and national levels. The Plan outlines the Government's commitment management of water resources (Government of WA, 2007).

An assessment of the NWI from 2011 has found that the NWI remain relevant to today's water industry, with some of the benefits already realised, the primary goals of sustainable and efficient water management have still not been achieved (Australian Government 2011b).

The *State Planning Policy 2.9: Water Resources* was gazetted in December 2006. The policy requires land use planning to contribute to the protection and management of water resources. BUWM was developed to provide guidance on achieving current best practice and best planning practices of sustainable water use. The framework integrates both 'land use and water planning through application of water sensitive urban design via the planning and approvals system' (Shepherd 2008: 5).

The BUWM framework in doing so provides guidance on the implementation of *State Planning policy 2.9 Water Resources* (Government of WA 2006), which is a requirement of the *State Water Strategy for Western Australia* (Government of WA 2003).

The Government of Western Australia legally acknowledges the need for SUWM and WSUD to better integrate land and water planning through various policy statements. While water policy and management has progressed significantly in the last decade there are still improvements necessary to move towards SUWM, including (England 2009):

- Pricing reform, including full cost recovery, removal of cross subsidies and provision for asset maintenance and refurbishment
- Clarification and consistency of property rights to water
- Developing a market in tradable water rights
- Institutional and organisational reforms
- Allocating water to the environment as well as for developmental purposes
- Adopting integrated water catchment management.

An examination of Australia's urban water sector (Engineers Australia 2010) found that while Australia has undergone significant changes over the last 15 years, the objectives determined from the water reform agenda in 1994 and intergovernmental agreements in 1994 and 2004 had not been achieved. The two main problems identified within the report with achieving Integrated Water Cycle Management (IWCM) is the necessity of costs and benefits of potable water, waste water and stormwater to be considered simultaneously and that urban water planning is mainly undertaken by existing water utilities resulting in perpetuation of business-as-usual practices and methodologies.

2.4 Better Urban Water Management Framework

Better Urban Water Management (BUWM) framework is the product of the latest water reforms and streamlines the urban water and land development planning process (Figure 3). The BUWM framework has been developed to provide guidance on the implementation of *State Planning Policy 2.9 Water Resources* and to assist in achieving SUWM. The objectives of urban water management are (DoW 2011):

- Manage catchment to maintain or improve water resources
- Manage risks to human life and property
- Ensure the efficient use of water resources
- Ensure that economic, social and cultural values are recognised and maintained.

BUWM aims to achieve the integration of water and land use planning and the objectives of urban water management by (DoW 2011):

- Facilitating better management and use of our urban water resources by ensuring an appropriate level of consideration is given to the total water cycle at each stage of the planning process.
- Assisting regional, district, local, subdivision and development phases of the planning process by identifying the actions and investigations required at each planning stage.
- Applying to proposed greenfield and urban renewal residential, commercial, industrial and rural-residential uses and developments.
- Ensuring consideration of relevant issues at a level of detail appropriate to the planning decision being made and the degree of risk to ecological systems and community assets.
- Identifying the agencies responsible for provision of water resource information.

- Allowing a flexible approach to planning and development assessment.

For each of the scales of land use, guidance is provided to the required documents and content. For the purposes of this study, the focus will be on the local and subdivision scale to ensure there is sufficient water design and planning detail. Local planning produces a Local Water Management Strategy (LWMS) and is directed by ‘higher level’ strategic planning to accompany a local planning scheme amendment report and Local Structure Plan (LSP) outlining how the proposed urban structure will address water use and management. At a subdivision level, an Urban Water Management Plan (UWMP) is required to explain how the final urban form will use and manage water. This document will support the subdivision application to ensure state, regional and local objectives for the management of water are met and plans and policies are implemented (WAPC, 2008).

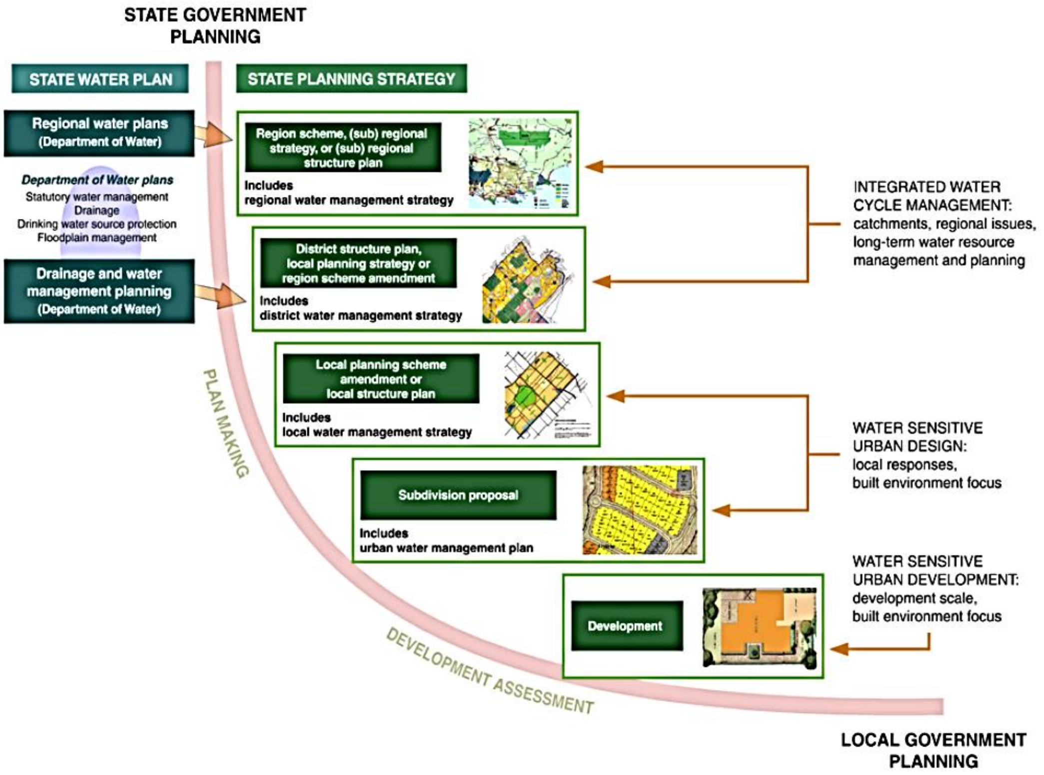


Figure 3: Integrating water planning with the land planning processes (WAPC, 2008)

BUWM guides development through five design objectives for strategic planning of urban water systems. Each of the design objectives are underlined by a design principle which corresponds to certain criteria which must be achieved (Table 1). The design objectives are:

- Water conservation and efficiency
- Water quantity management
- Water quality management
- Stormwater modelling criteria
- Disease vector and nuisance insect management.

DoW has released G*uidelines for preparing plans and for complying with subdivision conditions* (DoW, 2008) to support BUWM, outlining the requirements of UWMP in detail. *Water monitoring guidelines for better urban water management strategies/plans [draft]* (DoW, 2011) has also been recently released in draft form to provide additional guidance on water monitoring and water quality objectives of BUWM.

For the purposes of this study, the focus will be on water conservation and efficiency, water quantity management and water quality management.

Table 1: BUWM design objectives for water sensitive urban design (WAPC, 2008)

Objective	Principle	Criteria
Water Conservation – and efficiency	No potable water should be used outside of homes and buildings with the use of water to be as efficient as possible.	Consumption target for of 100kL/person/yr (State Water Plan target) including not more than 40-60kL/person/yr scheme water
Water quantity management	Post-development annual discharge volume and peak flows will be maintained relative to pre-development conditions, unless otherwise established through determination of Ecological Water Requirements for sensitive environments	Ecological Protection - For the critical one year average recurrence interval (ARI) event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the DoW. Flood Management - Manage the catchment run-off for up to the 1 in 100 year ARI event in the development area to pre-development peak flows, unless otherwise indicated in an approved strategy or as negotiated with the relevant drainage service provider.
Water Quality Management	Maintain surface and groundwater quality at pre-development levels (winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-catchment in which the development is located	Contaminated Sites – To be managed in accordance with the Contaminated Sites Act 2003. All other Land – If the pollutant outputs from the development (measured or modelled concentrations) exceed catchment ambient conditions, the proponent shall achieve water quality improvements in the development area or, alternatively, arrange equivalent water quality improvement offsets inside the catchment. If these conditions have not been determined, the development should meet relevant water quality guidelines stipulated in the National Water Quality Management Strategy (ARMCANZ & ANZECC 2000). Drainage – Ensure that all run-off contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater Management Manual.* In addition, all outflows form subsoils should receive treatment prior to discharge to the stormwater system.
Stormwater modelling criteria	If it is proposed to use a stormwater modelling tool to demonstrate compliance with design objectives, the following design modelling parameters are recommended. As compared to a development that does not actively manage stormwater quality: -At least 80% reduction in the average annual load of total suspended solids; -At least 60% reduction in the average annual load of total phosphorus; -At least 45% reduction in the average annual load of total nitrogen; and -At least 70% reduction in the average annual load of gross pollutants.	
Disease vector and nuisance insect management	To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated in a time period not exceeding 96 hours. Permanent water bodies are discouraged, but where accepted by DoW, must be designed to maximise predation of mosquito larvae by native fauna to the satisfaction of the local government on advice of the Departments of Water and Health.	

2.5 Transitioning to Water Sensitive Cities

The unprecedented levels of urban development have impacted on the natural environment and the resources it provides (Wong and Brown 2008). The pursuit of sustainability is aimed at initiatives for protecting and conserving natural resources and promoting lifestyles that can endure indefinitely as they neither deplete resources nor degrade environmental quality (Wong and Brown 2008). Traditional water systems have now been recognised as unsuitable to meet the future challenges of climate change and population growth and as such new solutions must be found which provide resilience to the future uncertainties in water supplies.

Urban Water Management Transitions framework (UWMT) (Brown et al. 2008) is a conceptual tool to inform the development of urban water transitions policy. The framework supports the progressive movement of SUWM in response to the challenges of environmental degradation, growing urban populations and the impacts of climate change. The framework provides a typology of the driver and attributes of past, present and future hydro-social contracts in Australian cities. The six typologies are:

- Water Supply City
- Sewered City
- Drained City
- Waterways City
- Water Cycle City
- Water Sensitive City

Figure 4 illustrates the six typologies of the different states of transitions of the UWMT framework with their corresponding socio-political drivers and service delivery functions as derived by Brown et al. (2008) in *Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States*.

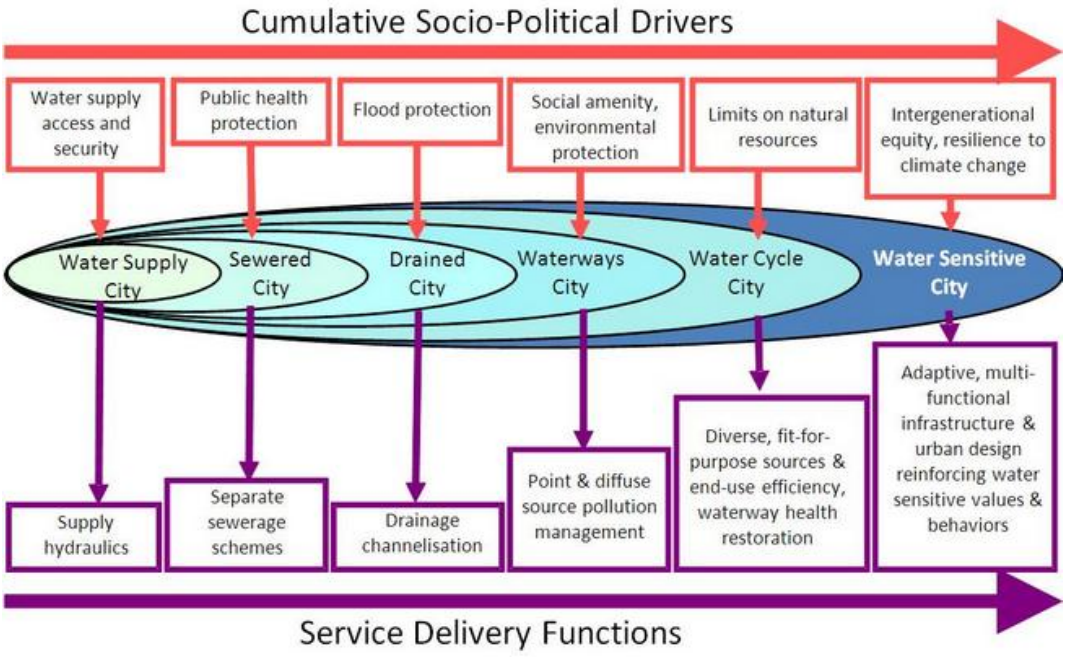


Figure 4: Urban Water Management Transitions Framework (Brown et al. 2008)

The concept of a hydro-social contract is fundamental to the UWMT framework, defined as 'the pervading values and often implicit agreements between communities, governments and business on how water should be managed' (Brown et al. 2008:2). The hydro-social contract is therefore characterised differently within each city typology as it is shaped by the dominant cultural perspective. Achieving a WSC requires major social, institutional and technological changes, which cannot be achieved through conventional approaches (Wong and Brown 2008).

The aim of the framework is to provide a tool to benchmark current city status and then guide future planning policy to take the steps to transition to a Water Sensitive City (WSC). WSCs can be understood in three terms (Ison et al. 2009):

- Cities as supply catchments – a diversity of sources, use and delivery options, resilience and adaptivity of the city, and water managing as part of a holistic and integrated system
- Cities as providing ecosystem services – green infrastructure, space and other visual and physical aspects of a WSC, ambiance and atmosphere of the city, and waterways (including quality)
- Sophisticated and water smart cities – community acceptance and engagement, collaboration, coordination and a range of institutional aspects, and the incorporation of true cost in decision making

Table 2 summarises the differences between a traditional water system approach and a water sensitive approach.

Table 2: Attributes of a Water Sensitive City, compared with current urban water management (CWSC 2011)

Attributes	Traditional Regime	Water Sensitive Regime
System Boundary	Water supply, sewerage and flood control for economic and population growth and public health protection	Multiple purposes for water considered over long-term timeframes including waterway health and other sectoral needs i.e. transport, recreation/amenity, micro-climate, energy etc.
Management Approach	Compartmentalisation and optimisation of single components of the water cycle	Adaptive, integrated, sustainable management of the total water cycle (including land-use)
Expertise	Narrow technical and economic focussed disciplines	Interdisciplinary, multi-stakeholder learning across social, technical, economic, design, ecological spheres etc
Service Delivery	Centralised, linear and predominantly technologically and economically based	Diverse, flexible solutions at multiple scales via a suite of approaches (technical, social, economic, ecological etc)
Role of Public	Water managed by government on behalf of communities	Co-management of water between government, business and communities
Risk	Risk regulated and controlled by government	Risk shared and diversified via private and public instrument

While Perth is not a WSC, the DoW has identified some key steps which the transition requires:

- An adaptive management response that address challenges, such as climate variability and vibrant ‘liveable neighbourhoods’
- Protecting important environment assets
- Providing economically viable options for water use
- Recognising the need for incentives for change in water management

2.6 EnviroDevelopment

EnviroDevelopment is an Australian branding system for land developments to be recognised for their incorporation of sustainable design. It has been developed by the Urban Development Institute of Australia (UDIA). The national framework is based on recognition of high achievement across a wide range of development types and situations. The branding works on a visual logo to reveal the certification to prospective buyers.

The purpose, according to EnviroDevelopment is to enable sustainable lifestyles to be attained through the design process of the development (UDIA 2006). Though importantly, this alone is not enough to ensure a sustainable livelihood. The standards to require EnviroDevelopment certification have been determined by a panel of government, industry and environmental experts, with certification to be achieved across six defined categories of sustainability. The concern of this project is the water element and to a minor degree the ecosystem element (UDIA 2006).

The objective of the water element is for improved water use through water efficiency mechanism and/or source substitution such as rainwater and stormwater harvesting. The target is to achieve a 55% reduction in potable water use across the development instead of meeting basic regulatory standards (UDIA 2006).

The objective of the Ecosystems category is to create healthy, sustainable ecosystems based on natural processes and rich with native biodiversity. Where this category related to this Project is through the consideration of water quality and is supported by the category’s principles (UDIA 2006).

EnviroDevelopment is still taking off in Western Australia, with to date only three projects achieving the Water accreditation. Few examples of EnviroDevelopment in WA are relevant to this project with the following developments achieving either Water and/or Ecosystem categories (EnviroDevelopment 2011):

- Avon Ridge Estate, Brigadoon (Water, Ecosystems)
- The Glades at Byford, Byford (Water, Ecosystem and Community)
- Shorehaven at Alkimos, Alkimos (Water)

Several developments in Queensland, South Australia and Victoria have achieved all 6 of the categories defining EnviroDevelopment.

2.7 International Best Practice Urban Water Management

On an international scale the benefits of SUWM are being recognised with worldwide organisations funding new initiatives and programs to better manage urban water. A key example of this is PREPARED, funded by the European Commission to work with a number of urban utilities worldwide to develop strategies for climate change predicted issues of water supply and sanitation. For example, in Istanbul and Barcelona, the project investigated tools for planning resilient water supply and sanitation systems to incorporate concepts of SUWM. In particular this has led to the investigation of alternative water sources and their associated technologies as the regions suffer from severe water scarcity which is anticipated to worsen with climate change. The study found a number of alternative water sources are available through stormwater harvesting, aquifer recharge and basin storage to increase water storage capacity and water quality (Baban et al. 2011).

Examples are not limited to developing countries adopting new measures for urban water management. New York City of the United States of America has set up several collaborative bodies on adaptation to climate change with a high agenda of urban water issues. The use of multi stakeholders (city agencies, research institutes, private companies) has enabled the city to identify potential adaptation measures, but also a pathway through which the implementation of these measures can be done in a logical and cost effective way (Loftus et al. 2011). Approaches adopted from cities around the globe to adapt urban water systems for climate change includes multi-criteria analysis for prioritising technology choices, making institutional changes to support climate change issues, political support, collaboration with research and stakeholder involvement (Loftus et al. 2011).

3 Methods

This study has a dual function in the analysis of Perth's current urban water management practices. The first is to investigate whether urban developments are achieving the Better Urban Water Management (BUWM) design objectives and secondly where Perth is placed on the Urban Water Management Transitions (UWMT) framework.

3.1 Approach

To provide an overview of the current urban water management practices of Perth, seven Cases studies have been assessed to analyse the effectiveness of BUWM and the current status of Perth's transition to a Water Sensitive City (WSC). The analysis criteria is based on two frameworks: the West Australian government land use and water planning framework: Better Urban Water Management (BUWM) (WAPC 2008) and the Urban Water Management Transitions (UWMT) framework (Brown et al. 2008).

A total of seven Case Studies (Table 3) have been analysed to gain a broad understanding of the differences in planning of urban water management across the Perth metropolitan area. While this does not statistically represent all of residential urban developments in Perth, consideration was given to ensure that each Case Study is not an anomaly in its category. A table reference has been given to each of the Case Studies for easy identification throughout the study (results, appendices).

Table 3: Case Studies analysed in the study with reference

Case Study	Reference	Category
Spearwood, WA	A	1
Housing Estate B[1], WA	B	1
Riverbank, Southern River, WA	C	2
Campbell Estate, Canning vale, WA	D	2
Glades at Byford, Byford, WA	E	3
Australian Fine China, Subiaco, WA	F	3
The Ecovillage at Currumbin, QLD	G	3

[1] Identity of Case Study is disguised to maintain client confidentiality

The Case Studies were selected based on the three following categories:

- Category 1: Water management planning completed before 2008 and hence before the BUWM framework was established

- Category 2: Water management planning completed after the release of the framework BUWM and embody a current business-as-usual approach

- Category 3: Water management is considered best practice or displays examples of water management innovation

The basis for this approach was to enable an analysis of a broad spectrum of examples of Perth urban water management. The break down into the three categories provides insight into the progression BUWM has influenced in Perth and how some urban developments have gone beyond the requirements. The Case Studies are all urban residential developments situated in Perth metropolitan area, with the exception of the Ecovillage at Currumbin which is located in Queensland.

Case Studies A and B constitute Category 1. Case Study A was chosen as a representation of existing development in Perth which was not connected to the centralised sewerage system due to the age of the suburb. The entire suburb is assessed at a high level to gain an overview. The drainage approach of the suburb reflects traditional engineering concepts with stormwater conveyed through a pipe network with minimal treatment. Case Study B was developed in the mid 2000s before BUWM had been released by the DoW. It is 11.5 ha and contains a mixture of residential and mixture business lots. The development's drainage concept is uninspiring with minimal treatment as the larger catchment quality is quite low. The site was chosen as a generic example of urban water management before BUWM was implemented in WA.

Case Studies C and D represent current business-as-usual practices with the implementation of the BUWM framework. A business-as-usual approach means that the legal requirements of water management are implemented into the planning process and may involve a couple of sustainability features, such as the incorporation of Waterwise fixtures. The Riverbank (Case Study C) represents a Case Study which has engaged with BUWM on a comprehensive level. The site is approximately 38 ha and includes a mixture of land uses and several public open space areas. This Case Study incorporates several more sustainability principles than Case Study D which was developed at a similar time.

Category 3 represents best management practice of urban water management. This includes Case Study E, F and G. Case Study E is an example of an accredited EnviroDevelopment development in the areas of water and ecosystems. Case Study F is an innovative site that is being redeveloped with the incorporation of many green technologies with water supply and reuse managed within the site at an individual and community level. Case Study G is a self-sufficient development in the areas of water, wastewater and energy. This Case Study was chosen as an example of best practice to allow a discussion around the Water Sensitive City attributes. Further information regarding the Case Studies can be found in Appendix 1: Phase 1 Analysis Data and Appendix 5: Case Study Profiles.

The assessment will take place through two phases characterised by the two frameworks (BUWM and UWMT). The first phase of assessment is an analysis of the achievement of three of the design objectives of BUWM for each of the Case Studies: 1) water conservation and efficiency, 2) water quantity management and 3) water quality management. The study focused on these three components as they embody the main principles of SUWM. Stormwater modelling has been excluded due to it being required only under certain conditions and due to the lack of modelling tools suitable to WA conditions. Disease vector and nuisance insect management have been excluded from the study as the design objective simply requires that water is not maintained in drainage systems for more than 96 hours. While it has direct health implications it was deemed not fundamental to this study. The aim of this first assessment was to determine which categories were achieving the design objectives of BUWM and if there were any significant differences between each of the categories.

The second phase is an analysis of each of the Case Studies in relation to the typology within the UWMT framework. This second phase will build off the first and will allow insight into the interaction (or lack of) between the BUWM and the UWMT framework. The UWMT framework defines six different typologies which a city transitions through: Water Supply City, Sewered City, Drained City, Waterways City, Water Cycle City, and Water Sensitive City. This analysis will provide a benchmark of each of the categories (1, 2 and 3) and hence will determine where the BUWM framework fits within the UWMT framework.

3.1.1 Methodology

The analysis for this study has been divided into two phases as described in 3.1.

Phase 1

Phase 1 is characterised by a focus on the BUWM design objectives. This first phase will analyse whether the BUWM design objectives are being achieved in the Perth metropolitan area and if there is a difference between each of the Case Study categories. The analysis will be characterised by 3 levels: ‘not achieved’ (red), ‘partially achieved’ (yellow) and ‘achieved’ (green). The grading of ‘not achieved’ translates to the design objective not being met at all or there is no evidence in water planning or management documents of the objective being met. A grading of ‘partially achieved’ means that part of the objective has been demonstrated. Each of the design objectives are comprised of two or more criteria (Table 1), with this grading being awarded if only one of the criteria’s have been achieved. If a Case Study has been graded as ‘achieved’, then all criteria’s of the objective have been demonstrated. A breakdown of each criterion and the requirements necessary to achieve the BUWM design objectives are provided in Table 1. The data has been sourced from various documents including:

- Urban Water Management Plans
- Local Water Management Strategies
- Local Structure Plans
- Integrated Water Management Plans
- Fact sheets
- Outline Development Plans

This project will focus on Local Water Management Strategy (LWMS) and Urban Water Management Plans (UWMP) (where relevant) as they provide the greatest details about drainage, water conservation strategies and water and wastewater servicing. For Case Studies pre-BUWM, alternative documents will be analysed, such as integrated water management plans. The information to support the achievement level of each of the Case Studies can be found in Appendix 1: Phase 1 Analysis Data.

Phase 2

Phase 2 is focussed on the different topologies Brown et al. (2008) presents in the Urban Water Management Transitions (UWMT) framework. This phase is to investigate which typology each of the Case Studies represent. A shading system has been utilised for Phase 2, with full shading indicating the criteria has been achieved, half the box shading representing that the criteria been partially achieved and no colouring meaning that it has not been achieved. A break-down of this for each criterion can be found in Appendix 3: Criteria Assessment for Phase 2 Analysis. While the characteristics are based on the UWMT framework, the criteria have been determined independently for this study. To determine the status of each Case Study within the six different transition states, is based on which transition state represents the majority of the Case Study. The basis of this assessment is founded in Phase 1.

3.2 Results

The results of the Phase 1 and 2 are presented in this section of the report. The main findings of the Phase 1 analysis indicated that the design objectives are only partially met with a business-as-usual approach. Phase 2 analyses indicated that Perth is a Waterways city with a business-as-usual approach but has examples ranging from Water Supply City to Water Cycle City distributed throughout the metropolitan area.

The results from the BUWM and transitioning cities analysis is represented in Table 4, Table 5, Table 6 and Figure 5 and Figure 6.

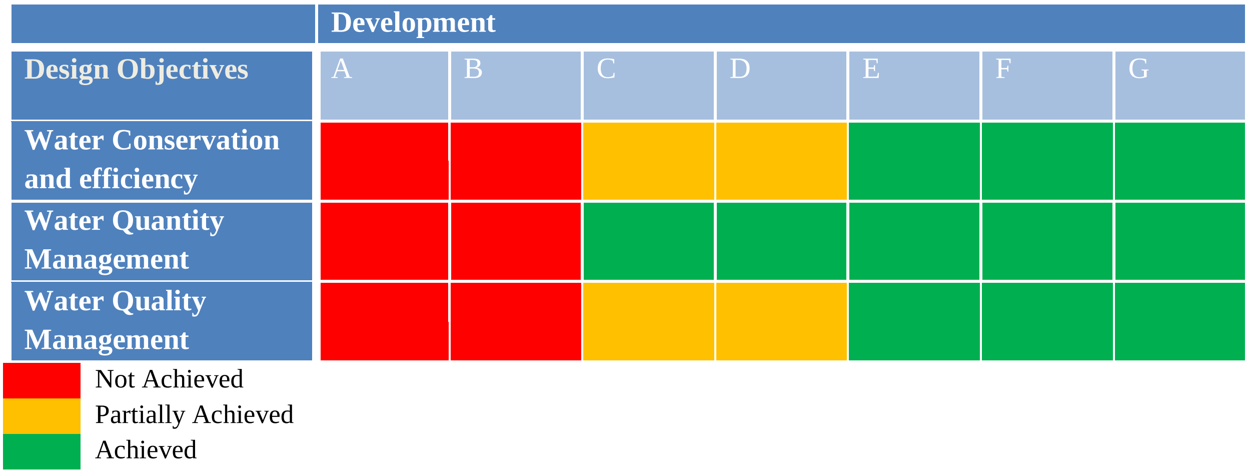
3.2.1 Phase 1: Better Urban Water Management

The first phase of analysis revealed there has been a significant shift in urban water management with the implementation of BUWM. Table 4 provides an overview of the achievements made by the Case Studies of each of the assessed design objectives of BUWM. The biggest improvement to urban water management has seen is water quantity management with developments planned after BUWM fulfilling all criterions. Water conservation and water quality management have had only partial progress with Case Studies C and D (business-as-usual – post BUWM), and Case Studies E, F and G (best management practice) fully achieving all criterions.

The partial achievement result for Case Studies C and D for water conservation and efficiency is because the criteria is divided into two parts: a) consumption target for water of 100kL/person/year and b) not more than 40-60 kL/person/year scheme water. The first component has been achieved by Case Studies C to G, commonly through a mixture of water efficiency measures and landscape packages. The second component essentially requires an alternative water source to supply water for at least external use (Hassal 2010). There is no legislation to enforce this target and is generally seen as an additional cost. Garden bores are popular where the aquifer is suitable for non-potable water abstraction, but with issues of over abstraction and declining water quality this is not always available. Rainwater tanks and greywater reuse have their own barriers to implementation including climatic conditions and social attitude. Therefore, as illustrated through the results, this component of the design objective is not always achieved and particularly with a business-as-usual approach.

A similar Case is exhibited for the water quality management design principle, which requires not only to maintain surface and groundwater quality, but to improve the quality of water leaving the development and to restore ecological systems in the sub-catchment. While Case Studies E, F and G achieved both of these criterions, C and D only partially met the requirements. This is due to the second component of restoring ecological systems in the sub-catchment of the development.

Table 4: Phase 1 results of the Case Studies indicating level of achievement for BUWM design objectives



	Development						
Design Objectives	A	B	C	D	E	F	G
Water Conservation and efficiency	🟥	🟥	🟨	🟨	🟩	🟩	🟩
Water Quantity Management	🟥	🟥	🟩	🟩	🟩	🟩	🟩
Water Quality Management	🟥	🟥	🟨	🟨	🟩	🟩	🟩

🟥	Not Achieved
🟨	Partially Achieved
🟩	Achieved

The analysis of Case Studies when grouped under the three categories (pre BUWM, business-as-usual and best management practice) produced distinct results in overall achievement levels (Table 5).

A business-as-usual approach (Category 2) to urban water management resulted in one of the three design objectives being met. Water quantity management was achieved, and water conservation and efficiency and water quality management was only partially achieved. This is an improved performance to the Case Studies of Category 1, but did not perform as well as Category 3.

Category 1 Case Studies did not achieve any of the BUWM design objectives. This highlights the positive improvement BUWM has made on water planning and management. Category 1 performed the worst out of the group. This is to be expected as BUWM was not incorporated into planning processes at the time of their development.

Category 3 (best practice examples) achieved all assessed design objectives. This result highlights that the BUWM objectives are achievable.

Table 5: Summary of categorical analysis of Better Urban Water Management

Category	BUWM level of achievement
1	Not achieved
2	Partially Achieved
3	Achieved

Appendix 1: Phase 1 Analysis Data outlines the breakdown of the design objectives and criteria's, with the achievements of each of the Case Studies.

3.2.2 Phase 2: Transitioning Cities

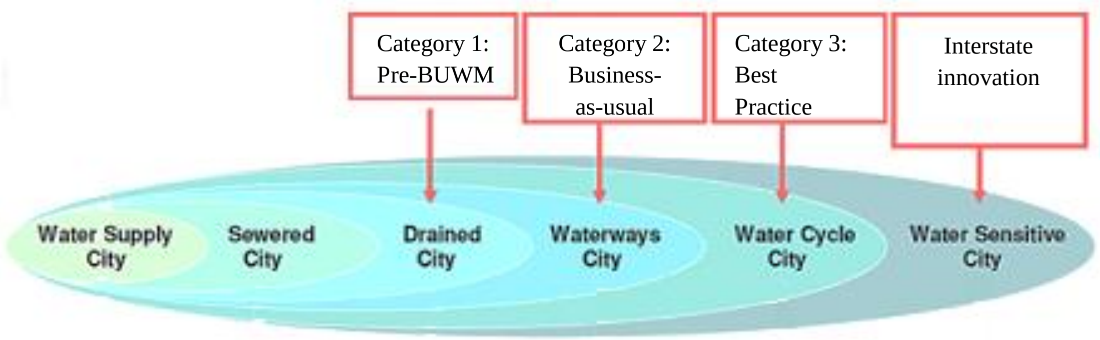
The purpose of the Phase 2 assessment is to analyse the current position of Perth's urban water planning and management in the Urban Water Management Transitions (UWMT) framework (Figure 5). Table 6 outlines the results of the Phase 2 analysis, correlating each Case Study to the typology achieved. The analysis demonstrated that Perth is currently a Waterways City with a business-as-usual approach. Another key outcome of the analysis found that no WA Case Study illustrated the properties of a Water Sensitive City. The highest rating a Case Study achieved was that of a Water Cycle City.

Table 6: Phase 2 results outlining the city typology of each Case Study

Case Study	City Typology
A	Water Supply City
B	Drained City
C	Waterways City
D	Drained City/Waterways City
E	Waterways City
F	Water Cycle City
G	Water Sensitive City

Figure 5 graphically represents the placement of each of the three categories and the associated service delivery functions. As the figure illustrates, each subsequent category progresses along the continuum, though no WA Case Study achieved a Water Sensitive City status.

Figure 5: Graphical Representation of Case Studies results in Urban Water Management Transitions Framework



From a business-as-usual approach (Category 2), Case Study C and D are ranked as a Waterways City. Not all of the Waterways City criteria have been achieved. Most were partially addressed such as diffuse source pollution management, amenity and access to green open space and water integration as an important visual and recreational feature for community. Diffuse source pollution management was the only criterion both Case Studies fully addressed. The only criteria Category 2 partially addressed for a Water Cycle City was water conservation, which is supported through the State Water Plan target of 100kL/person/year. Further decreases are necessary but the issue is making progress.

The Case Studies A and B of Category 1 are characterised at best by a drained city. Due to the history of the Case Study A, the sewerage system is characterised by decentralised septic tanks and leach drains. This results in the classification of a Water Supply City with elements of a Drained City. Spearwood (Case Study A) is not the only area which lacks an adequate sewerage system, with parts of Bunbury, Busselton, Kwinana and Rockingham among several others which are waiting for the Infill Program by Water Corporation to connect developed lots to the central sewerage system. Case Study B, achieves a higher classification of a drained city with planning taking place in 2006. Case Study B, achieves the criteria of a Drained City with features including conveyance of stormwater and a centralised water and sewerage supply. Similar to Case Study A, Case Study B lacks the inclusion of diffuse source pollution, amenity and access to green open space and water integrated as an important recreational and visual feature for communities necessary for a Water Ways City. While there is a significant difference between Case Study A and B, the important difference is the jump Case Study C and D have made with the ranking of a Waterways City with implementation of BUWM. This highlights the role past planning decisions plays in the way we manage water today.

Category 3, Case Studies of best management practice performed best overall. The Glades, representative of the water and ecosystem EnviroDevelopment (ED) criteria, rated as a Waterways City. The Australian Fine China (AFC) site, rated as the highest WA Case Study as a Water Cycle City, and the Ecovillage rated the highest overall as a Water Sensitive City.

The Glades, the EnviroDevelopment (ED) accredited Case Study, achieved a rating of Waterways City, the same as Category 2. While there are improvements from a business-as-usual approach to that of Case Study E, evident through the criteria of the Ecosystem and Water Category (Appendix 4: EnviroDevelopment Category Requirements). Despite the progress evident through the ED water and ecosystem achievements, they were not significant enough to classify the Case Study as a Water Cycle City. The main improvements shown by Case Study E included water integrated as an important visual and recreational feature for communities, water conservation, diverse fit-for-purpose water supplies and sensitive to energy and nutrient cycles. Some of the components of the Water Cycle City were achieved, though greater than half the components were absent resulting in its classification of a Waterways City. Characteristic of WA policy, the main failings of the site included the lack of incorporation of co-management of water cycle between business and government. Similar to most urban developments, Water Corporation is the water and wastewater service provider.

The AFC site (Case Study F) exhibited innovation for water management in several areas, achieving the highest rating for the WA Case Studies of a Water Cycle City. The distinction this Case Study has shown is the incorporation of diverse water sources, and recycling with the risk shared between government, private and resident stakeholders. The approach AFC has adopted is the utilisation of a centralised rainwater storage and reuse for offsetting potable hot water demand in all buildings, in addition to each house installing a 2kL rainwater tank. Additionally, lot scale level grey water collection will take place with reuse on private and public spaces. This has allowed greater fit-for-purpose water applications than standard groundwater for public open space irrigation. Other water saving initiatives that are exhibited in this Case Study and those of Category 2, include 5 star water wise appliances and fixtures and low water demand plants in public open spaces. This water management approach is expected to result in at least a 55% reduction of water use across the site. Commercial buildings will utilise similar water conservation practices. Another way the AFC goes beyond business-as-usual is through the integration of the landscape with water. This is achieved through green roofs; the site has a commitment of at least 10% green roofs across multi-residential and commercial buildings and artwork integrated with the centralised rain water system. While innovation and management approaches are represented in this Case Study, it does not demonstrate a closed water cycle needed to be classified as a Water Sensitive City.

The Ecovillage, ranked as a Water Sensitive City, demonstrates a total water cycle approach is possible in Australia. The site engages a number of water conservation and flexible approaches, with onsite water harvesting, reuse and treatment. All water streams have been incorporated as a possible water source. Rain water is harvested and used for potable water demands, grey water is reused for internal and external non-potable demands, and stormwater swales and ponds provide aesthetic, recreational and ecological services. There is also a strong community atmosphere with active communal areas with workshops for sustainability engagement and education. The Ecovillage is also self-sufficient in energy production and incorporates edible landscaping and street scaping and household farming. Waste recycling on site, traffic saving strategies, wildlife corridors, and diverse housing needs also contribute to the sustainability of the site. The development has received many awards, Australian and international, in recognition of sustainability achievements, including ED accreditation of all six categories.

The next step for urban water management in Perth is for urban development to incorporate fit-for-purpose diverse water supplies, sensitivity to energy cycles, alternative institutional arrangements and additional water conservation targets as are envisioned through BUWM. Phase 2 of the analysis demonstrates that Perth is currently at a Waterways City requiring significant improvement to transition into a Water Sensitive City.

The basis for these categorizations can be found in Appendix 2: Phase 2 Analysis Data and Appendix 3: Criteria Assessment for Phase 2 Analysis.

3.3 Discussion

Essentially there are two parts of achieving a Water Sensitive City; the first through frameworks such as BUWM to provide guidance for new residential developments; and secondly, retrofitting for developments that have been planned before such considerations existed and do not meet the requirements of a Water Sensitive City.

3.3.1 Better Urban Water Management

Urban water management has improved with the implementation of Better Urban Water Management (BUWM) in the areas of water quantity management and to a lesser degree water conservation and water quality management. Before the implementation of BUWM, water quality and quantity management was considered in urban residential planning, but without the criteria and direction BUWM provides. This has resulted in different approaches to managing water with no consistency across the board. Through BUWM, a consideration of water conservation and efficiency, water quality and quantity management has been formalised. The BUWM guidelines have met resistance with a business-as-usual approach failing to meet the design objectives. The design objectives of BUWM are achievable as demonstrated by the Glades and the AFC site.

Water Conservation and efficiency

The approach to water management previously has largely been focused on health concerns, with water conceived largely as an infinite resource. With unpredictable rainfall and Perth's reliance on groundwater, water conservation has in recent times become a crucial component of urban water planning. BUWM specifically addresses the issues through the water conservation and efficiency design objective, stating 'no potable water should be used outside of homes and buildings with the use of water to be as efficient as possible' with a 'consumption target for potable water of 100kL/person/year, with no more than 40-60kL/person/year' (WAPC, 2008). With a business-as-usual approach this is translated to water efficient fixtures and appliances, a portion of houses utilising groundwater for irrigation (if appropriate) and WaterWise landscapes. Through these measures it is possible to meet the state target of 100kL/person/year. To achieve the second stipulation of the objective the additional adoption of alternative water sources, such as rainwater tanks and grey water reuse systems, to service non potable water demand is required. This is not supported by legislation and more often than not this target is not achieved.

There are several current initiatives which passively encourage water conservation such as government grants, behaviour change programs, the WELS rating for appliances and the green star rating supported by the Green Building Council of Australia. Government rebates currently exist for rainwater tanks, solar hot water heating, and showerhead and toilet exchange to upgrade to efficient appliances. In addition to this the Water Corporation with the support of the Federal Government have launched the H2ome Smart Program across the State to promote behaviour change around the home to reduce water consumption. The target of the program is to reduce water consumption by 15%. The program has a dual function, to change and sustain water conservation practices, and habits and to integrate normative values of water sustainability, supply security and environment. As BUWM only applies to new houses and not to existing stock, the program clearly supports the BUWM objectives and provides a direct method to capture residents which are not exposed to educational programs supported by new developments. Water efficiency rating systems have also been introduced for appliances and for buildings.

Active ways to reduce water in WA are less popular than in other states. Greywater and rainwater adoption in WA is significantly lower than the Australia average. The Australian Bureau of Statistics (ABS) reported in 2008 that nearly one quarter of Australian households reported using grey water as their main source of water for the garden. In contrast to this, Western Australia had the lowest proportion of households reporting grey water as their main source of water for the garden at 4.5%. Overall, 42.1% of Perth residents reported greywater as a source of water compared to the Australian average of 54.9%. The same trend applies to rainwater as a source of water, for which 6.9% of Perth residents reported its use compared for the 11.2% Australian average. To complement this, Western Australia has the second highest use of purchased bottle water in Australia (ABS 2008). Public confidence, health and environment concerns, legislation and lack of awareness are some of the barriers recognised to progressing water recycling (Dimitriadis, 2005). While macro policy may support the use of alternative water systems there is a lack in support mechanisms to aid in their realisation. In particular, incompatibility of legislation and policy to support alternative systems that have been appropriate for traditional approaches to water servicing. Coordination across different government agencies has also been a major barrier in the adoption of alternative water systems in Western Australia (Hassall, 2010). Adoption of recycling technology is necessary to reduce our reliance on scheme water for non-potable water sources to conserve water. Many systems are available in Western Australia, though reuse rates in irrigation are restricted by soil type and treatment level to effectively provide a financial alternative system.

The EnviroDevelopment framework supports the move to adopt alternative water sources for non-potable uses. The water principle requires a 40% reduction in potable water use across the development through water efficiency mechanisms or alternative water sources. The Glades achieved this through the installation of 2kL rainwater tanks for each home plumbed to the toilet and laundry, or grey water for internal and external recycling. The AFC site also reduced potable water consumption and increased water use efficiency through individual and community rainwater tanks and grey water reuse. The Ecovillage took this a step further with no scheme water use, through the potable use of rainwater and grey water reuse for non-potable purposes.

Water Quantity

Water quantity is managed sufficiently in urban residential development in relation to ecological protection and flood management with pre-development conditions relatively maintained. However, the current approach tends to focus on a disposal method without practical consideration of the potential stormwater reuse options. Water reuse has value beyond reducing pressure on scheme water resources, as value of water is created for users through the integrating water reuse in resource planning and policy (Miller, 2005). The City of Mandurah supports the first WA subdivision scale stormwater harvesting and reuse project to irrigate new parkland in the Port Mandurah development (City of Mandurah, 2010).

WSUD principles are gaining more popularity in the conveyance and treatment process of stormwater such as vegetated roads swales, living streams, and bio-retention systems. The Glades has creatively included a feature lake in the POS of the development to provide additional stormwater retention storage in major flood events. The Ecovillage has also included multiple dams and ponds for stormwater detention to provide treatment and a nature feature. This is in stark contrast to traditional methods of large piping systems to compensation basins to detain water.

Water Quality

While water quality has been considered throughout water planning, BUWM has directed urban development to include specific guidelines through the *National Water Quality Management Strategy* (ANZECC, 2000). The objective has two requirements, a) to maintain surface and groundwater quality at pre-development level, and, b) to improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-catchment. While efforts of varying degrees, are made to meet pre-development quality levels, little is committed to the improvement of water quality leaving the development area to maintain and restore the ecological system. The Glades effectively fulfils this criterion through the restoration of several site drains into multiple use corridors to provide natural, aesthetic and recreational landscapes. This is supported by EnviroDevelopment with the principles to 'remediate any water quality problems occurring on site or in neighbouring areas'.

WSUD principles provide an effective way to integrate natural processes with stormwater management. Structural controls include conveyance systems such as swales and buffer strips, bio retention systems and living streams; detention systems including wetlands and infiltrations basins and systems. Non – structural controls include maintenance of systems, community education and participation, soil amendment, and construction practices. While many new developments integrate some WSUD principles, many areas have been developed when flood mitigation was the main driver of water quantity management. Retrofitting is an important issue when discussing Perth's water quality management, with the increasing realisation the potential for these systems as important environmental assets (DoE, 2006). As discussed earlier, developments planned before BUWM failed to meet any of the BUWM water quality criteria and with examples of water monitoring revealing that pre-development water quality does not meet ANZECC guidelines corrective action must be undertaken. The purpose of retrofitting is to improve water quality and quantity management.

Stormwater modelling

Stormwater modelling is an important verification process of stormwater quantity and quality management. It is part of BUWM framework but has not been assessed as it is not a mandatory component of the urban water planning process. Stormwater modelling is only required when compliance with design objectives is specified. MUSIC is an Australian modelling tool for urban stormwater hydrology and pollution impacts. While the tool was developed in the eastern states of Australia it has been calibrated for various catchments in developing areas, including the Shire of Busselton and the City of Swan. Due to the limitations of the applications in WA, it is not uncommon for the claim to be made that stormwater modelling cannot be undertaken as currently there is no commercially available tool approved by the DoW to undertake such modelling in WA (Shepherd 2008).

The purpose of the stormwater modelling tools is to not only conceptualise the process of the stormwater management but to be able to quantify the water quality. This allows for an objective assessment of alternative approaches for dealing with stormwater, assessing appropriate treatment to prevent pollution of waterways and make assessment stormwater reuse options (Hatt et al. 2006).

3.3.2 Transitioning to a Water Sensitive City

While Perth has experienced a significant decline in rainfall and reduction in inflows to dams, water security has been ensured through the development of desalination plants to provide approximately 50% of scheme water. While this strategy has helped to meet water demand, the addition of extra water infrastructure will not solve all the water challenges climate change presents to our society. Currently, there are no examples of this aspiration in an actual city form, but there are smaller scale developments that represent the features and concepts of a water sensitive city. The Perth metropolitan area has been assessed against the six typologies presented in UWMT framework: water supply city, sewered city, drained city, waterways city, water cycle city and water sensitive city. Each of the typologies presents a different state that a city transitions though when progressing towards a sustainable system. Each of the city states is marked by a distinct socio – political driver and service delivery functions (Figure 4).

Transitioning to a Water Sensitive City is still in it’s infancy in WA with Perth classified as Waterways City as it generally fulfils the following requirements:

- Point source pollution management
- Diffuse source pollution management
- Amenity and access to green open space
- Reduce pollutant input into waterways

And to a lesser degree Perth demonstrates the partial fulfilment of:

- Water integrated as important visual and recreational features for communities
- Water conservation
- Finding fit-for-purpose diverse water supplies

Current water planning and management strategies may embody these characteristics, but there are still examples through the Perth metropolitan area which exhibit the characteristics of a Water Supply City. Therefore the achievement of a Water Sensitive City is divided between supporting future development and retrofitting past developments to a Water Sensitive City standard. Without progressing sustainable water management, Perth cannot ensure resilience to future uncertainties in urban water supplies.

Best Management Practice

EnviroDevelopment (ED) is a recent residential development accreditation sustainability program. The function of ED is to promote best practice in the industry, but when compared to the Water Sensitive City criteria it falls short with a classification of Waterways City (The Glades). The relevancy to this study is the water and ecosystem category which embodies some of the Water Sensitive City characteristics such as water conservation and protecting waterways. Its main downfall is the lack of direction for alternative institutional arrangements and fit-for-purpose water use. The major strength of ED is the requirement of green spaces as a nature conservation area with the incorporation of natural water courses, ecological corridors linking vegetated and open space areas for native fauna and flora enhancing the social-nature interaction.

This is one of the major deficiencies of BUWM –a lack of integrating water as an important visual and recreational feature through infrastructure and nature scapes.

The Australian Fine China development has successfully provided a WA example of a Water Cycle City. The site's beneficial reuse strategy incorporates a mixture of scheme water, rainwater and grey water to meet the water demands, each with differing arrangements for management. The main factor contributing to this status is the residential development with an alternative arrangement for water supply between residents and the government utilising a centralised rainwater harvesting system. Rainwater is collected from residential and commercial lots across the site through a centralised system. The water is reused and contributes to hot water and irrigation demand. A similar arrangement is incorporated into the site for grey water reuse. Once the associated assets for the rainwater harvesting system are constructed it will not be passed to Water Corporation but instead to a Central Management Body (CMB) which will be responsible for ongoing operation, monitoring and maintenance on behalf of the individual strata's (SRA 2009b). The responsibility of the CMB will include:

- Procuring suitable Manager and Operator/s
- Managing the Environmentally Sustainable Development (ESD) performance of the site and compliance of individual Strata's to all ESD targets
- Applying to the Economic Regulatory Authority for applicable licences and seeking DoH approvals to provide the services and manage the operation, maintenance and monitoring of the systems in accordance with the relevant licence and approval requirements

In addition to a reuse strategy the site incorporates a demand management strategy. This includes high WELS star rated water efficient appliances and water efficient, landscaping practices and an education program to provide individual performance data for residential and commercial occupants. Not only does this exceed the requirements of the *State Water Plan* but also the BUWM design objectives of 'no more than 40-60kL/person/year of scheme water' (WAPC 2008) with an estimated residential scheme water use of 33 kL/person/year. Significant potable water savings are also made in the commercial precinct. Through the water management strategies a 61% reduction in potable water use on typical Perth water usage patterns across the whole development and an estimated residential total water use of 66 kL/person/year (SRA 2009b).

Another area in which the site excels is the integration of water into the landscape. A number of design features have been incorporated into the site's public open space including safety, lighting, sensual interaction and activity. A continuous urban and green link is planned to connect the development to surrounding redeveloped areas. All multi-residential and commercial buildings are to provide a minimum of 10% green roofs to enhance thermal benefits, reduce stormwater generation and enhance the soft landscape aesthetic of the development. Public art is also integrated across the site including the community rainwater collection point (SRA 2009a).

An integrated sustainability strategy has been devised for the entire site to contain rainwater, grey water, geothermal energy, waste management, housing diversity and fostering community (SRA 2009b).

Water Sensitive City

Globally there is not an example of a Water Sensitive City, but there are cities that incorporate distinct and varying attributes of the water sensitive approach (Wong & Brown, 2008). The Ecovillage at Currumbin, Queensland is a small scale example of embodying the characteristics and requirements of a WSC. The Ecovillage sustainably manages the environmental impacts of an urban development with comprehensive consideration given to water, energy, waste, building material, ecosystems and community. Formally, the development is recognised for these achievements through the accreditation of all six EnviroDevelopment categories. The development involves significant partnerships with community universities, industry and various tiers of government (Landmatters 2003).

The Ecovillage is self-sufficient in water supply and sewerage disposal through rainwater, wastewater treatment reuse and groundwater. A truly fit-for-purpose approach has been applied to the site where potable water is supplied by individual household rainwater tanks. A communal sewerage treatment/water reclamation plant supplies non-potable water for toilet flushing, external household use and public open space irrigation. The water cycle is a closed loop system with the site not connected to sewer or scheme mains (Hood et al. 2010).

The average water use at the Ecovillage is 196L/person/day, which is higher than other sustainable housing developments. This is attributed to the site being completely independent of the mains and hence it experiences no restrictions on external water use. The recycled water used for irrigation has a dual function of improving the amenity of the community and preventing the disposal of treated wastewater to waterways. Despite high amenity gardens and public open spaces, the residential water use is well below the WA water use state target and the BUWM guidelines. The water and energy performance of the development is monitored through a centralised network and has validated that the energy and water balances are almost neutral (Hood et al. 2010).

The development is a semi-rural site which has retained 50% of the land as environmental reserve and a further 30% dedicated to open space. The scenery includes ponds, creeks and forests. Productive landscaping on individual lots and public spaces encourage integration with the environment.

From planning to construction there has been a strong commitment to community, with events and activities often focused on environmental issues. Included onsite is a Reduce Reuse and Recycle centre providing a central resource management area that acts as a social centre for the community. To provide for a diverse community of different cultural and socioeconomic backgrounds, differently sized lots and houses with a wider variety of prices than conventional developments are offered. To ensure that the sustainability of the community is ongoing, the development supports an administrative framework to provide social equity and enduring community integrity. Residents also take part in an initial, and ongoing, social planning to foster cohesion and promote a sustainable community. This process is supported through continued education of sustainable living and development practices via the Interpretive Centre (Hood et al. 2010).

Similar to the AFC site, landowners at the Ecovillage have freehold title on their home parcel and a share in the common property of the Ecovillage under a community title subdivision structure. A separate entity was established by the developer to take ownership of some shared assets.

Through this comprehensive approach the Ecovillage provides an example of a development which closes the water cycle, provides diverse and alternative water supplies, with a strong sense of community and sustainable living. Hood et al. (2010) suggested that while it is unlikely decentralised developments, such as the Ecovillage, can be ‘carbon copied’ into mainstream urban development, many of their features are replicable (rainwater tanks, water recycling, solar hot water systems and energy efficient housing construction). It is important to keep in perspective that the technologies implemented at the Ecovillage are not new untested methods, but robust technologies used in combination to achieve beneficial outcomes. Hood et al. (2010) conclude that the Ecovillage could provide a benchmark for urban development in the future, with scaling to suit cluster scale development for greenfield development and infill clusters.

Retrofit

As the analysis illustrated, older developments commonly do not achieve the BUWM requirements, let alone those of a Water Sensitive City. The majority of guidelines and facts sheets supporting WSUD tend to focus on new developments, despite new developments not being the major contributor to overall urban land use in a catchment. Hence, to achieve maximum benefit from WSUD the implementation of WSUD must occur through the implementation of new development and retrofitting WSUD technologies in existing urban areas (Weber et al. 2009). The implementation of WSUD usually occurs via two pathways: part of a dedicated retrofit program or through redevelopment such as AFC.

The *Stormwater Management Manual for Western Australia* (DoE, 2006) presents a number of ways to retrofit urban developments: lot, neighbourhood and catchment scale. At a lot scale, it is possible to maximise opportunities for the capture and use of rainfall through soak wells, rainwater tanks and garden bores; garden practices can be changed to use catchment friendly techniques; replacing impervious paving with pervious paving and installing oil – water separators in commercial car parks and petrol stations. At a neighbourhood scale, retrofitting can take the form of removing kerbs from some sections of roads to allow runoff to flow into parklands and installing infiltration devices within roadways/road reserves. Rehabilitation of open urban drains or removing sub surface pipe to living streams or vegetated swales is an option of retrofitting at a catchment level. The benefits of improving stormwater management include:

- reduced flood risk
- improve public health and safety
- improve water quality
- the restoration and conservation of environmental condition
- create more attractive and liveable neighbourhoods
- enhance the cultural values of the urban water landscape
- improve the use of open space and enhance recreational opportunities
- improve community environmental awareness
- increase cost effectiveness
- demonstrate best management practices (BMPs)

- utilise stormwater as a valuable resource to reduce potable water use.

While the incorporation of WSUD is best at the project planning stage, retrofitting is appropriate in existing development areas were the hydrologic, ecological and water quality requirements have not been adequately addressed. Urban renewal projects are ideal opportunities to incorporate WSUD retrofitting measures in the development.

Despite developments in urban water planning and implementing WSUD, parts of the Perth Metropolitan area are still undergoing capital works to connect to deep sewerage. The Infill Sewerage Program (ISP) started in 1994 and is a State program administrated by Water Corporation. The Program aim is to install central wastewater systems to developed but unsewered residential properties in Perth and country cities and towns. This late move to a centralised waste system seems ironic due to the reconsideration of the sustainability of decentralised versus centralised system. The utilisation of septic tanks and leach drains are recognised as posing a threat to groundwater and ecosystem health in general. The program target areas includes the Swan-Canning River, Blackwood River, Chapman River, Peel-Harvey River amongst others (Water Corporation 2010).

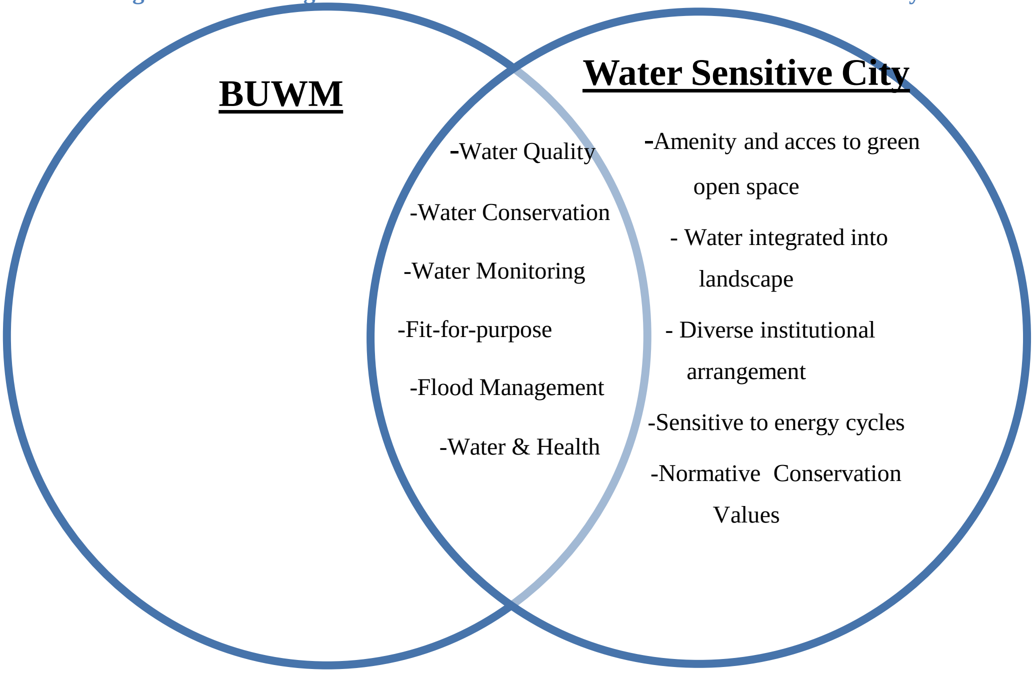
3.3.3 Better Urban Water Management & Water Sensitive Cities

Currently in WA BUWM is the guiding framework for water management for new urban residential developments through the land planning process. As such, BUWM directly influences the hydro-social contract and therefore has the responsibility for shaping the future of WA's water management. In this way BUWM will also be a major contributor to directing our water management to a water sensitive approach. The design objectives of the current framework share some similar concepts with a WSC though, there are some major gaps as Figure 6 illustrates.

The four main areas which need to be addressed in BUWM if it is to guide Perth to a Water Sensitive City are:

- Fit-for-purpose
- Alternative Institutional Arrangements
- Normative Conservation Values
- Landscape integration

Figure 6: Venn diagram of Characteristics of BUWM and Water Sensitive City



Fit-for-Purpose

Fit-for-purpose water use can be understood as the quality of water is appropriate for the intended use (DoH 2011). With many water sources available, scheme water for all water uses is not appropriate for many water demands with a fit-for-purpose approach. The Ecovillage demonstrated that scheme water is not necessary at all, with rainwater for potable water demands and grey water reuse for internal and external non potable demands. With our growing urban population and drying climate with climate change, extra pressure is being placed on our centralised water supply and sewerage systems. To counteract this, a fit-for-purpose approach is necessary to utilise available and accessible alternative water streams.

The water conservation and efficiency design objective of the BUWM framework states that ‘no more than 40 – 60kL/person/year scheme water’ (WAPC 2008), which is only achievable with the combination of alternative water supplies and water use reduction. This part of the criteria, as discussed earlier, is where developments are failing to meet the water conservation and efficiency criteria. These barriers as discussed earlier include a lack in support mechanisms, incompatibility of legislation and policy and coordination across different government agencies (Hassall 2010).

A common attempt at fit-for-purpose is the use of groundwater for irrigation. While this is acceptable, it is not enough. Rainwater and grey water resources are being wasted and placing extra pressure on our sewerage and stormwater infrastructure. This approach does not achieve the 40-60kL/person/year target of scheme water.

Alternative Institutional Arrangements

Centralised water systems have been historically perceived to be the most reliable, economic and easiest to manage. While this viewpoint is no longer universal, with examples such as AFC and the Ecovillage, these are limited. Chanan et al. (2009) suggests the use of diverse, locally appropriate and commonly decentralised infrastructure could provide a balanced means for water resource management.

Perth, like other Australian capital cities, operates under a state owned monopoly model. While Chanan et al. (2009) states that the commercial objective of these water utilities is to make money as non-conventional sustainable water management options pose more of a threat to the business than an opportunity. In recent years, with the adoption of expensive supply options, such as reverse osmosis desalination plants, profits must be decreasing.

The current water management system in Perth and similarly across other Australian urban centres is assessed by many commentators that these nodes are not served well by existing institutional arrangements. Byron *et al.* (2008) concludes that Australia's (including Perth) water supply challenge is not one of scarcity but one of managing water resources given the variance in climatic and geographic factors.

A decentralisation system can be defined 'as the collection treatment and use of rainwater, stormwater, groundwater or wastewater at different spatial scales' (Diaper et al. 2008: 480). Decentralised systems, at the cluster or lot scale, have historically been provided in semi-urban, rural and remote areas, where the provision of centralised systems has not been technically, economically or environmentally feasible. This infers that decentralised systems are the system of choice but the last resort despite many benefits including:

- Reduction in the amount of scheme water imported to the site
- Contaminant loads and volumes to wastewater treatment facilities are reduced
- Stormwater flows and pollutant discharge is reduced
- Potential flooding issues can be avoided
- Improve urban amenity
- Reduce or prevent wastewater overflows
- Reduce costs and energy use

The implementation of decentralised systems is dependent on a number of factors:

- Climate
- Topography and soil types
- Lot size, layout and density
- Water storage and availability

Innovation can often lead to decentralised systems being a viable option, especially if local environmental services, social and other community impacts are taken into consideration.

Possibly the biggest barrier to alternative water supplies is legislation and regulation. Firstly, the current legislation varies from state to state and can vary also from council to council. Progress has been made with water reuse, but the integration of wastewater services has been developing at a slower pace. This can be attributed to a water supply, stormwater and sanitation being traditionally dealt with as separate entities under the different bodies (stormwater can be the responsibility of the council, while water and wastewater is with the water authorities (Diaper et al. 2008). Diaper et al. (2008) suggests there is a strong need for the development of national approaches and guidelines for decentralised and integrated water service systems. Current legislation on decentralised systems legislation currently focuses on mainly the performance and licensing requirements in regard to health and traditional environmental impacts instead of the overall integration. Further to this Hassell (2010) advises that while there is policy to support alternative or distributed water systems there is no adequate support mechanism to aid in their realisation. This discussion then leads to the conclusion that while BUWM supports alternative water supplies there is a lack of actual support to put these systems in place.

Normative Conservation Values

Technology alone is not enough to achieve a Water Sensitive City, and requires the complement of societal conservation values. Pearson et al. (2010: 364) states that 'sustainable water management is not about achieving an end point but rather it is the process of influencing what people believe and what they do' with social learning and engagement is key to the success of integrated urban water management at a strategic and operational scale . Behaviour change is an important part of this process. In the residential sector we are seeing this embraced through education programs from developers and behaviour change programs funded through the government focusing on achieving a reduction in water use.

In recent years, Perth has seen an emergence of behaviour change projects funded through the government. The driver has been to reduce water demand on our water storages, with increasing populations and decreasing rainfall. The aim has been to reduce water consumption through small behaviour changes and water efficient appliances. The future of behaviour change will hopefully also enter the private domain, with land developers offering it as part of the land packages amongst other water saving mechanisms. The State Water Target of 100kL/year and EnviroDevelopment are both drivers in achieving these targets (Mitchell 2006). To target established housing estates, the Water Corporation has launched various behaviour change programs across the state, focusing on providing support for water behaviour change.

The education programs provided to new urban developments by developers vary in quality to support real water conservation instead of being a token effort. Examples of education programs include information package, landscaping packages, installation of water efficient fixtures, installation of grey water and rainwater infrastructure. While this encourages lower water use, it doesn't change the way residents interact with water. The AFC site and the Ecovillage go a step further and offer feedback and support on personal water use and community workshops to engage residents in their behaviour and attitudes.

To further complicate this issue, the link between water conservation values and water conservation behaviour does not always correlate (Dolnicar and Hurlimann 2010). This is why behaviour change programs play a large role in ensuring that values and behaviours are changed to produce positive results in water conservation. The H_2ome Smart Program launched by the Water Corporation and the Federal Government in WA, supports residents in reducing their water use through small technological changes (water efficient shower head, tap aerator) and small behaviour changes (eg. reduce showering by 1 minute, washing with only a full load) to produce big water savings. The goal in this approach is to provide long term water conservation practices and a permanent shift in attitude towards water use.

Community infrastructure and landscaping can also influence conservation values. For example, the Ecovillage at Currumbin incorporates a recycling centre to encourage these practices, food production available to the community irrigated by grey water reuse and ponds supporting the native flora and fauna. Through this approach water conservation values are mainstreamed into the society.

Landscape Integration

Two key features which are not addressed in Better Urban Water Management is the encouragement of ecosystem services and hydro-social interactions, which can be achieved in landscaping. Water supply security is an important feature of a Water Sensitive City, but it is also fundamental that we make use of water in an interactive, useful and aesthetic way. In other words, that we enjoy the water, instead of hiding it out of view in an underground labyrinth of pipes. Public open spaces are an opportunity for people to interact with water in a variety of different forms.

Many WSUD elements can be passively integrated into the landscape to positively impact on the social-environment relationship to provide stormwater management and high amenity areas. For example, the lake at The Glades not only provides an aesthetically pleasing water feature encouraging the habitation of local flora and fauna but doubles as an additional stormwater detention storage are in major floods events. Public art is another way of enhancing interaction with the environment. The AFC site has planned a variety of art forms throughout the development to integrate art, water and heritage to help create a sense of place.

A key characteristic of the Water Sensitive City approach is the provision of ecosystem services. This can be provided by public open spaces incorporating features of flora, fauna, landforms, water bodies, ect. and rehabilitation of the land. Another example from The Glades is the use of multiple use corridors throughout the development to retain and enhance the natural water courses passing through the development. In this way, water, landscape and human interaction are brought together to provide many advantages.

3.4 Recommendations

To progress Perth to a Water Sensitive City, six recommendations are made for the Western Australian water industry. To achieve a Water Sensitive City it will require a combination of technological, social and political changes. The recommendations are a direct result of this study and require further investigation.

1. The revision of Better Urban Water Management framework to incorporate the importance of water, community and landscape interaction. As discussed earlier, landscaped or POS area can play a vital role in facilitating hydro-social interactions. This is important in achieving a Water Sensitive City for two reasons:
    a. A Waterways City is characterised with not only amenity and access to green open space but for water to be integrated into planning functions as important visual and recreational features.
    b. One of the pillars to a Water Sensitive City is to provide ecosystem services. While this includes the built environment, it also means creating useful (aesthetic, recreation, conservation) POS areas.

    While there are examples of successful integration of the natural environment with urban development, it has been determined that this integration is not included in a business-as-usual approach. As Better Urban Water Management is the framework which initiates water consideration into urban development planning, this could provide an appropriate pathway to integrate multipurpose landscape into urban developments.

2. It has been established that Western Australia needs policy and legislation that comprehensively supports:
    a. Alternative and diverse technologies for water supply and wastewater treatment and reuse.
    b. Alternative and diverse institutional arrangements of water supply and wastewater treatment and reuse.

    While there has been some uptake of rainwater tanks and greywater re-use systems there is still the need for further integration of the water cycle and to make full use of water reuse options. To assist with this there also needs to be the opportunity of diverse and alternative governance arrangements for these systems.

3. While Better Urban Water Management provides guidance for future development, to achieve a WSC past development cannot be ignored. With the wide variety of urban water management approaches through past planning decisions need to be structurally retrofitted. In particular, stormwater management needs to be significantly improved in both quality and quantity. This can be achieved by retrofitting developed areas with Water Sensitive Urban Design principles.

4. The continued support and implementation of the behaviour change programs to produce normative values of water conservation, energy conservation and sustainability. Behaviour and attitude is the key to everything, without the support of the community, technological changes can only improve urban water management to a certain degree and political change will not happen as readily.

5. An adequate modelling tool for Sustainable Urban Water Management is required in WA. This will not only address stormwater quality management but successful options analysis of alternative technologies. Cost benefit analysis and the cost of water should also be included

6. Water efficiency and conservation design objective needs to be enforced as the Better Urban Water Management target is currently not being achieved. This will require the support of the building industry and the community to accept alternative water sources. The form which this takes needs to be further defined: mandate regulation, industry code of practice, ect.

It is difficult to provide a timeline as to which these could be achieved by as the two main drivers are climate change and policy making. The severity of the impacts of climate change and when these happen will influence people's perception of climate action and therefore policy implementation. With both drivers unpredictable it is difficult to provide a timeline. If public support and policy implementation are not considered as barriers then the following provides a rough estimate to achieve a Water Sensitive City:

1. A revision of Better Urban Water Management to incorporate landscape interactions would take approximately 2 years to review the document and to negotiate the finer details with relevant governing bodies (Dow and WAPC).Additional time will also be required to educate the urban development industry (approximately 2 years).

2. Policy and legislation change will take a considerable amount of time for laws to be passed through the government and to gain public support. Education, monitoring and enforcement will also be required for these changes to make a difference. This is estimated at 7 years.

3. Retrofitting of stormwater management will be an expensive and extensive process mainly supported by Local Government Authorities (LGAs). It is estimated that this will take 12 years.

4. Behaviour change programs are already taking place, but it is necessary that the programs are rolled out across the entire Perth metropolitan area. As each program takes a year, it could be estimated that this will take 7 years to complete the whole metropolitan depending on the scale of each program.

5. There is currently research already going into developing a suitable stormwater modelling tool for Western Australia. To integrate this and development additional modelling/assessment tools could take between 5 and 10 years.

6. The time it takes for Perth to support the water conservation and efficiency design objective will most likely depend on the support of legislation as there is no current motivator. With the support of legislation to mandate only 40-60 kL/person/year of scheme water and behaviour change programs to support this transition this could be

achieved within the 7 estimated for policy change and the behaviour change programs to be rolled out.

It is necessary for these changes to take place as soon as possible. It needs to be supported by the public, institutions and government, but this takes time. While an aspirational target would be 5 years to ensure resilience against climate change and to secure water supplies sustainably. It would be best that each of the recommendations is implemented simultaneously but realistically this is unlikely to happen. It is therefore estimated that if achieving a Water Sensitive City was a priority of Perth then it could be achieved within 20 years.

4 Reflections

An internship placement was completed at ENV Australia in the Water and Sustainability section between February and August 2011. Karen Lane was the industry supervisor and Martin Anda was the academic supervisor. The focus of the work was urban water management, including behaviour change programs and BUWM documentation. It also included tasks involving alternative energy supplies and contaminated land issues. The majority of the work conducted during the internship was considered chargeable and as such was included in the day to day business of the company.

The knowledge gained from the work experience provided a solid basis for the analysis of urban water management in WA as the internship included writing several BUWM documents (UWMP, DWMS and LWMS).

During the placement I gained valuable skills including:

- Exposure to engineering drawings
- Liaison with clients, engineers and planners
- Costing estimates
- Writing proposals
- Report Writing
- Time management
- Consulting industry

5 Conclusions

Urban water planning for the future is required to mitigate the anticipated impacts of climate change and urban population growth. This study has investigated the ways in which Perth can improve upon its urban water management in relation to water efficiency and conservation, water quality, water quantity management and resilience to climate change.

The study has investigated Perth's achievement of the Better Urban Water Management (BUWM) design objectives and benchmarked Perth in the Urban Water Management Transitions (UWMT) framework from seven Australian case studies of urban residential development. The case studies were divided into three categories of pre-BUWM, business as usual and best management practice to provide insightful delineations between the three.

The aims and objectives of the study were fulfilled, by determining level of integration of the design objectives of Better Urban Water Management into the urban planning process for the Perth metropolitan area and the city state typology Perth represents in the Urban Water Management Transitions Framework.

The result of this was found that with a business-as-usual approach only achieved water quantity management, with partial achievements in the area of water conservation and efficiency and water quality management. In contrast, the analysis of innovative sites proved the achievement of all of the BUWM design objectives. The second phase of analysis also produced distinct results in the typologies each of the categories represent, with analysis proving a wide range of different typologies represented in the Perth metropolitan area from water supply city to water cycle city. A business as usual approach to new urban developments was found to be characterised of a Water Ways city.

A number of recommendations to the water industry have eventuated from the study including a focus of landscaped areas in BUWM to improve hydro-social interactions, the support of legislation for alternative water supply sources and providers, retrofit with WSUD for stormwater management and continued support of behaviour change programs to support normative values of environmental conservation and sustainability.

5.1 Recommendations for Further Work

As this is the first study to benchmark Perth's performance against BUWM and UWMT, the assessment should be firstly replicated. Secondly the recommendations need to be further refined and research to devise a management strategy to progress Perth to a Water Sensitive City. Particular areas which could be investigated are:

- Benchmark other capital cities of Australia
- Compare BUWM to other state water management strategies in the urban residential sector
- Assessment of process and type of retrofitting required in developed areas to be aligned with Water Sensitive Urban Design principles
- Behaviour change programs to nurture environmental and sustainable values
- Investigate the progress and impact EnviroDevelopment has made on urban residential development in WA and Australia.
- Active ways to bring the community together to encourage sustainability values.

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7 Appendices

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Appendix 1: Phase 1 Analysis Data

Developments A - C

Urban Water Management			Development		
Design objectives	Principle	Criteria	A - Spearwood	B – Housing Estate B	C – Riverbank, Southern River
Water conservation and efficiency	No potable water should be used outside of homes and buildings with the use of water to be asefficient as possible.	Consumption target for water of 100kl/person/year, (state water plan target) including not more than 40-60 kl/person/year scheme water.	• no evidence of water conservation • POS is irrigated with groundwater • POS is large lawn areas • city of Cockburn desire to reduce water consumption of residents and corporate entities, but lacking action • potable water servicing through water corporation • wastewater disposal onsite through septic tank and leach drain • potable water is used for in- and ex- house uses • some houses use groundwater bores, but limited due to salinity issues • resident education of water sustainability is available through the city of Cockburn website but there is no active engagement • WSUD principles are limited • integration with the surrounding environment limited	• no evidence of water conservation •no POS • no water consumption target • potable water servicing through water corporation • wastewater is connected to the central sewerage system provided by water corporation • potable water is used for in- and ex- house uses •1/3 of houses use groundwater bores for irrigation issues • WSUD principles are limited • integration with the surrounding environment limited	• mandating the use of Waterwise fittings at construction • Waterwise landscaping include low water use gardens and soil amendments to minimise water and nutrients • minimising water use in POS through the use of low water use landscape, and water efficient irrigation systems are linked to soil moisture characteristics • meets 100kl/person/year state water strategy target • potable water is provided by water corporation • wastewater is connected to the central sewerage system provided by water corporation • potable water is used for some in- and ex- house uses • limited groundwater used due to salinity issues • WSUD principles evident • POS - for local active and passive recreational facilities, the retention of quality vegetation and natural drainage passage and filtration

Urban Water Management			Development		
Design objectives	Principle	Criteria	A - Spearwood	B – Housing Estate B	C – Riverbank, Southern River
Water quantity management	Post-development annual discharge volume and peak flows will be maintained relative to predevelopment conditions, unless otherwise established through determination of ecological water requirements for sensitive environments	Ecological protection Flood management	• stormwater drainage relies on a series of local natural wetlands and eater retention/drainage basins in the area. • final discharge is to a local natural lake • flood control is being investigated by the CoC	• infiltrate similar amount of water to ground as pre development • road drainage managed through the use of a system of drainage culverts and pipes • infiltration of roof water via soak wells • compensation basin will accept stormwater flows	• post development peak flows will be maintained relative to pre-development conditions via infiltration basins • drainage design that limits the peak outflow from the development to predevelopment levels through storage and infiltration on site • providing appropriate separation between 1 in 100 year ARI water levels and floor levels • including appropriate contemporary WSUD BMPs in the road reserve that store and infiltrate the 1 in 1 year event; and • implementing a stormwater system that the model indicates will meet the LWMP targets for nitrogen and phosphorus reduction through the use of swales, living streams and bio-retention systems • allowing the use of controlled groundwater levels only where it can be demonstrated that these will not affect the CCW to the south of the site • include WSUD bmp in road reserve - swales, living streams and bio retention systems

Urban Water Management			Development		
Design objectives	Principle	Criteria	A - Spearwood	B – Housing Estate B	C – Riverbank, Southern River
Water quality management	Maintain surface and groundwater quality at pre-development levels (winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-catchment in which the development is located.	Contaminated sites All other land Drainage	• drainage/retention basin act as primary treatment of stormwater before entering the wetland and lake.	• gross pollutant trap will be used to remove gross pollutants, sediment and nutrients • stormwater quality from this estate is expected to be comparable to the quality of stormwater from the wider catchment and therefore the effect of this development on local aquatic ecosystems will be minimal	• limited use of fertilise in POS • a commitment to further monitoring of groundwater quality on the site to determine whether historical practices have impacted on groundwater quality. • minimise the discharge of pollutants from the shallow groundwater to the intersecting waterway or drain through swale modification • provide education to minimise fertiliser use • install a subsoil treatment cell to treat subsoil drainage

Developments D-G

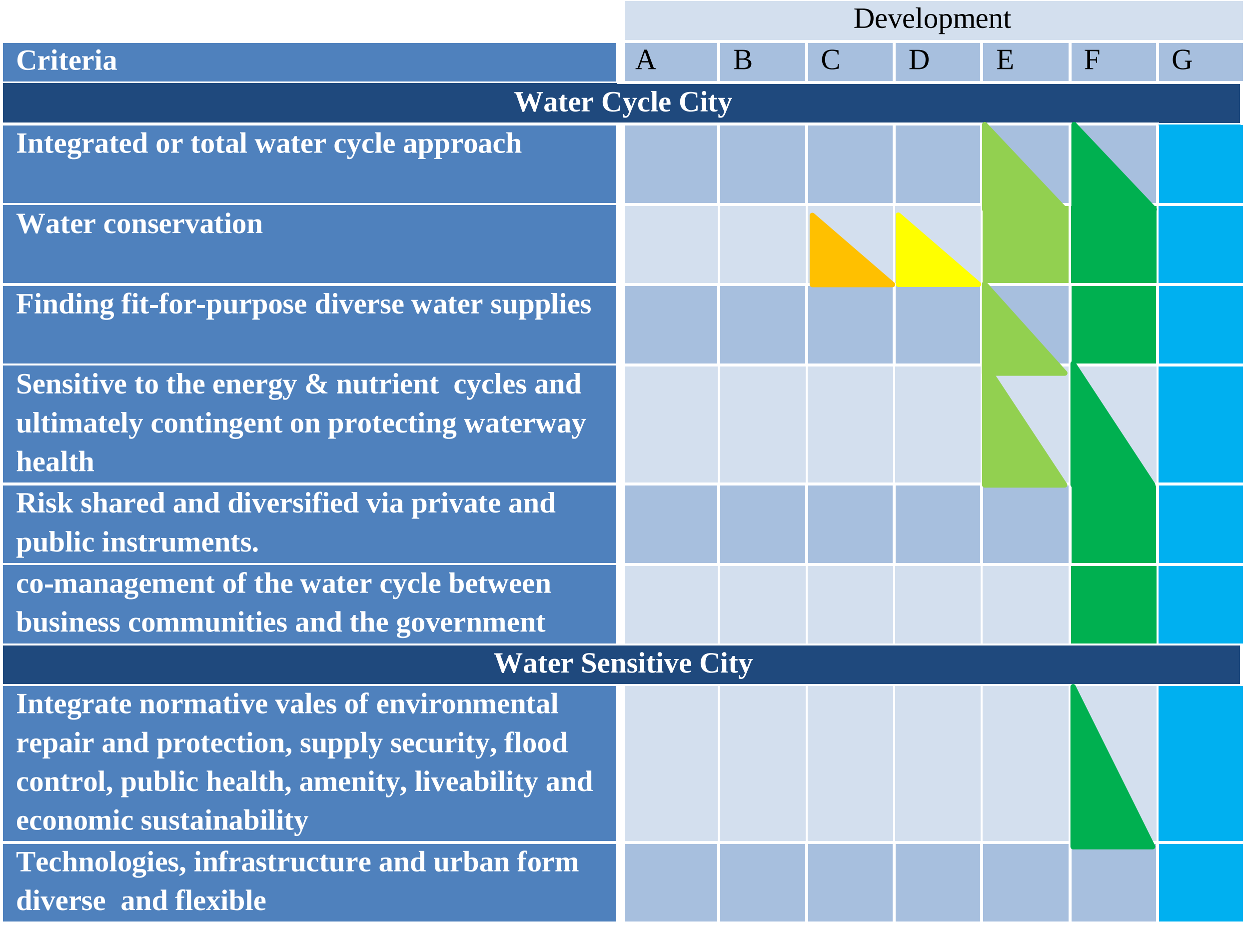
Urban water management			Development			
Design objectives	Principle	Criteria	D – Campbell Estate	E – The Glades	F – AFC	G – The Ecovillage at Currumbin
Water conservation and efficiency	No potable water should be used outside of homes and buildings with the use of water to be aseefficient as possible	Consumption target for water of 100kl/person/year, (state water plan target) including not more than 40-60 kl/person/year scheme water.	• potable water and wastewater disposal is provided by water corporation • potable water is used for some in- & ex- house uses • meets 100kl/person/year state water strategy target • Waterwise landscaping include low water use gardens & soil amendments to minimise water & nutrients • some houses use groundwater bores for irrigation • householder information package (hips) distribution to landowners to provide education on in-house & ex-house Waterwise measures. • minimising water use in POS through the use of low water use landscape, & water efficient irrigation systems are linked to soil moisture characteristics	• potable water and wastewater disposal is provided by water corporation • potable water is used for some in- & ex- house uses • households built consistent with current BCA water efficiency standards & the state government 5 star plus scheme • Waterwise front landscaping package to each home • water savings initiatives: 2kl rainwater tank, grey water, Waterwise rating of AAA appliances • groundwater for POS irrigation • 50% native plants, with water wise irrigation system • use of greywater for irrigation & rainwater for some non-potable internal water uses • bore water used for maintenance of the community lake	• potable water and wastewater disposal is provided by water corporation • potable water is used for some in- & ex- house uses • installation water efficient appliances and fixtures • 55% reduction in scheme water use • centralised rainwater storage & reuse for offsetting potable hot water demand in all buildingS • education & awareness of personal water & energy usage • landscaped areas irrigated with recycled or grey water • low water use species & reducing lawn areas in POS • all multi-residential & commercial buildings are to provide a minimum of 10% 'green roofs	• potable water is provided via individual and community rainwater tanks • sewerage is collected and treated onsite. The water is then recycled for external water uses • not connected to water or sewer mains • water efficient appliances and fixtures • internal water use of 115l/p/day • 48% rainwater, 52% recycled water for individual house • fit-for-purpose – rainwater for potable water, recycled water for non-potable uses, some groundwater used for irrigation • community atmosphere and workshops for engagement and education • 50% of the vegetation/forest remains preserved, 30% of the site is for pos.

Urban water management			Development			
Design objectives	Principle	Criteria	D – Campbell Estate	E – The Glades	F – AFC	G – The Ecovillage at Currumbin
Water quantity management	Post-development annual discharge volume and peak flows will be maintained relative to predevelopment conditions, unless otherwise established through determination of ecological water requirements for sensitive environments	•ecological protection •flood management	• the drainage design focused on the use of in-system management measures & some non-structural source controls. • households will have on-site infiltration through soak wells. • include WSUD bmp in road reserve - swales, bubble up pits, side entry pits, gullies & junction pits • WSUD principles evident	• use of bio-retention treatment systems for detention & treatment of stormwater • major & minor drainage system, consisting of drainage reserves detention or infiltration areas, with use of POS for major storm events • flood protection controls • lake in POS creates increased flexibility in the design of the POS irrigation system by providing storage; additional stormwater detention storage in major flood events	• the drainage network is designed to retain all the storm water from minor storm events & infiltrate on site. Partial on-site storage & infiltration capacity for a 100 year ARI storm event. Storm water that is not retained on site will go to wetland north of the development. • developers are to install internal meters in all buildings to each residential apartment & commercial tenancy to enable monitoring of rainwater reuse, scheme water use & greywater use. •WSUD bmp maximised across the site to achieve maximum stormwater retention & infiltration • drainage into POS	• multiple dams and ponds for stormwater detention • predevelopment flows and quality maintained • roads have been designed to minimise hard kerbs and allow natural drainage and to make best use of the existing vegetation • stormwater swales and ponds provide further treatment and a nature feature for birdlife and villagers to enjoy

Urban water management			Development			
Design objectives	Principle	Criteria	D – Campbell Estate	E – The Glades	F – AFC	G – The Ecovillage at Currumbin
Water quality management	Maintain surface and groundwater quality at pre-development levels (winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-catchment in which the development is located.	•contaminated sites •general land •drainage	• provide education to residents to minimise fertiliser use • vegetation within the POS will local native species & once established, it will not need irrigation or fertiliser application. • POS will provide treatment: absorb nutrients & act as a filter for sediment. • POS - for local active & passive recreational facilities, the retention of quality vegetation & natural drainage passage & filtration	• extensive use of local native species in POS, streetscapes & wetland buffers to reduce nutrient input & conserve water resources • watercourse rehab for those which are degraded on the site through multiple use corridors to provide natural, aesthetic & recreational landscapes • all drainage infrastructure located outside of CCW's & associated buffers • use of multiple use corridors to retain & enhance the natural water courses passing through the development • lake placed in POS: aesthetic function, focus for recreational activity, structural benefits, include • WSUD principles evident: GPT, bio retention system, swales, local infiltration	• planted pocket gardens to provide stormwater infiltration & treatment benefits •use of local native species in POS & streetscapes to reduce nutrient input & conserve water resources	• 80% of natural environment is maintained • all recycled water treated to class a+ level • water quality has been maintained via monitoring • waterways running through the site • WSUD evident

Appendix 2: Phase 2 Analysis Data

	Development						
Criteria	A	B	C	D	E	F	G
Water Supply City							
Safe and secure water supplies	🟫	🟥	🟧	🟨	🟩	🟩	🟦
Centralised provision of water	🟫	🟥	🟧	🟨	🟩	🟩	
Extraction of large quantities of water	🟫	🟥	🟧	🟨	🟩	🟩	
Low cost delivery	🟫	🟥	🟧	🟨	🟩	🟩	🟦
Sewered City							
Reticulated sewerage system to dispose of effluent outside of cities		🟥	🟧	🟨	🟩	🟩	
Water board responsible for water supply and sewerage	🟫	🟥	🟧	🟨	🟩	🟩	
Public health protection		🟥	🟧	🟨	🟩	🟩	🟦
Directing waste flows to an environmentally benign waterway		🟥	🟧	🟨	🟩	🟩	🟦
Drained City (flood protection)							
Conveyance of stormwater to receiving waterway environments	🟫	🟥	🟧	🟨	🟩	🟩	🟦
Numerous waterways piped and located underground	◣	🟥	🟧	🟨	🟩	🟩	
Services delivered by centralised water supply and sewerage authorities	◣	🟥	🟧	🟨	🟩	🟩	
Waterways City							
Point source pollution management	🟫	🟥	🟧	🟨	🟩	🟩	🟦
Diffuse source pollution management		◣	◣	◣	🟩	🟩	🟦
Amenity and access to green open space	◣	◣	◣	◣	🟩	🟩	🟦
Water integrated as important visual & recreational features for communities			◣	◣	🟩	🟩	🟦
Reduce pollutant input into waterways			🟧		🟩	🟩	🟦



	Development						
Criteria	A	B	C	D	E	F	G
Water Cycle City							
Integrated or total water cycle approach					◣	◣	🟦
Water conservation			◣	◣	🟩	🟩	🟦
Finding fit-for-purpose diverse water supplies					◣	🟩	🟦
Sensitive to the energy & nutrient cycles and ultimately contingent on protecting waterway health					◣	◣	🟦
Risk shared and diversified via private and public instruments.						🟩	🟦
co-management of the water cycle between business communities and the government						🟩	🟦
Water Sensitive City							
Integrate normative vales of environmental repair and protection, supply security, flood control, public health, amenity, liveability and economic sustainability						◣	🟦
Technologies, infrastructure and urban form diverse and flexible							🟦

Appendix 3: Criteria Assessment for Phase 2 Analysis

Characteristic	Criteria (Primary)	Criteria (Secondary – if applicable)
Safe and secure water supplies	Water Quality is to a drinking quality standard (class A)	Water demand can be met at all times
Centralised provision of water	Large scale centralised scheme water network system	System is operated, maintained and owned by one asset holder
Extraction of large quantities of water	Water extracted meets demand	
Low cost delivery	Less than $2/kL of water	
Reticulated sewerage system to dispose of effluent outside of cities	Large scale centralised sewerage network	Effluent is treated and disposed outside of the metropolitan area
Water board responsible for water supply and sewerage	Water Corporation of WA manages and bills residents for water and wastewater services	
Public health protection	Water is treated to a drinking quality standard (class A)	Sewerage is transported and disposed of away from urban development
Directing waste flows to an environmentally benign waterway	After treatment wastewater is pumped to the ocean to be assimilated	
Conveyance of stormwater to receiving waterway environments	Water is conveyed by pipe network or WSUD principles to drain, wetland, or other waterway	
Numerous waterways piped and located underground	Centralised network involves large piped systems	Centralised network is underground with components generally unseen
Services delivered by centralised water supply and sewerage authorities	Water and wastewater services are provided by Water Corporation of WA	
Point source pollution management	Point source pollution is managed across the development (if there are any)	
Diffuse source pollution management	Diffuse source pollution treatment across the development (rainfall, runoff)	Includes management of pollution from the wider catchment
Amenity and access to green open space	Public Open Space is available within 500m of each house	Public Open Space is multifunctional (i.e. recreational, aesthetic, environmental)
Water integrated as important visual & recreational features for communities	Water is integrated into the landscape to promote socio-environment interactions	Water is visible in the landscape
Integrated or total water cycle approach	The water cycle is closed (all water is collected, treated and reuse onsite.	
Reduce pollutant input into waterways	A treatment train/process is evident before entering waterway	

Water conservation	**100kL/person/year of scheme water is used**	**40-60% of water used is scheme water**
Finding fit-for-purpose diverse water supplies	No scheme water is used outside, but irrigation still takes place. More than one type of water is used.	Water is treated and reused onsite (grey water, rainwater)
Sensitive to the energy & nutrient cycles and ultimately contingent on protecting waterway health	Before entering water conveyed to waterways undergoes a treatment system	
Risk shared and diversified via private and public instruments.	Water and wastewater servicing is shared between public and private entities	
Co-management of the water cycle between communities and the government	It is the responsibility of not only the State and LGA for water quality, servicing, and treatment but individuals and businesses who share the site	
Integrate normative vales of environmental repair and protection, supply security, flood control, public health, amenity, liveability and economic sustainability	The support and encouragement of normative values through education, training, community events	
Technologies, infrastructure and urban form are diverse and flexible	Each is linked to sustainability principles and social capital, linking society and technology.	

Appendix 4: EnviroDevelopment Category Requirements

EnviroDevelopment supports sustainability through six categories: ecosystem, water, waste, energy, community and materials. The two relevant categories to this study are ecosystem and water. Below is an outline of the principles behind the ecosystem and water category. The criteria required to achieve accreditation of the ecosystem and water category can be found in the source document.

Ecosystem

- Encourage resilient natural ecological communities and protect natural connectivity.
- Encourage maintenance (during and after construction) of native vegetation where existing,
- and rehabilitation of locally native vegetation where not already in existence in a healthy state.
- Encourage protection and rehabilitation of riparian vegetation and wetlands.
- Avoid water pollution and degradation of water quality in waterways and natural systems and
- remediate any water quality problems occurring on-site or in neighbouring areas.
- Minimise disruption to landform and natural ecosystems.
- Encourage development on previously developed or degraded sites, whilst considering affordability.
- Encourage protection (during and after construction) of existing habitats for native animals or
- rehabilitation of such habitats where not already in existence in a healthy state.
- Maintain and enhance viable habitat size to improve connectivity and reduce fragmentation.
- Promote biodiversity and sustainability awareness.
- Ensure the necessary monitoring and maintenance programs exist to assess ongoing ecosystem performance.

Water

- Reduce potable water use. There are two fundamental strategies to achieve this:
- Reduce overall water use by 20% beyond regulatory means – e.g. through water efficiency mechanisms.
- Utilise alternative water sources (e.g. rainwater, stormwater, dual reticulation) to meet irrigation demand for public open space and common areas of the project or use drought tolerant species which require no establishment period.

This has been sourced directly from: Urban Development Institute of Australia (UDIA). 2006. *EnviroDevelopment Technical Standards: National Version 1.0*. Australia: Urban Development Institute of Australia.

Appendix 5: Case Study Profiles

Spearwood

The suburb of Spearwood is located in the City of Cockburn, Western Australia approximately 20km south of Perth on the Swan Coastal Plain. Spearwood is bounded in the north by a line from Cockburn Road through reserve to the Phoenix and Rockingham Roads intersection, and Phoenix Road, in the east by Stock Road, in the south by Barrington Street, Rockingham Road, Troode Street, Hamilton Road, and Beeliar Drive, and in the west by Cockburn Road. The area prior to the Second World War consisted mainly of small rural communities (market gardening and dairy farming). The post war era marked the commencement of housing development in Spearwood and surrounding suburbs, with the area rapidly growing since the 1980s. To support this much of the land has undergone re-zoning to allow for residential developments. It is forecasted that Spearwood and surrounding suburbs of a similar age will be redeveloped to revitalise the area and provide a variety of housing needs (Forecast id. 2011).

Residential development in Spearwood is characterised by a low level of infill and vacant lot development at approximately 5-11 dwellings per annum. It is estimated that the following development remains (Forecast id. 2011):

- Remanent greenfields site – 520 dwellings (2011-31)
- George Weston Foods Limited Site - 149 dwellings (2013-24)
- Residual parcels - 44 dwellings (2010-17)
- Phoenix Central - 4-10 dwellings per annum

The drainage of Spearwood relies on a series of wetlands, referred to as Market Garden Swamp Reserve. There are also includes a number of water retention/drainage basins which receive runoff from the surrounding suburbs. These basins serve as a primary treatment system for stormwater. The flow of the water travels from urban landscape to retention basin/wetland and finally via vegetated swales to Lake Coogee. The City of Cockburn is currently be reviewing drainage infrastructure to determine if it has adequate capacity to cope with potential water level changes to occur as a result of climate change (GHD, 2009).

Within the City of Cockburn, there are also a number of isolated sumps. These sumps are owned and managed by the City of Cockburn. They are steep, fenced structures with poor aesthetics and no formal vegetation. Two of these sumps are located on Bennett Street, three on Cockburn Road (including the one jointly owned with City of Fremantle) and one on vacant land to the south-east of Garston Way. None of the Cockburn sumps have overflows (GHD, 2009).

Apart from the Manning Lake system, the drainage system in the area appears to be more than 50 years old and to have been constructed on an ad-hoc basis as the roads were developed. Because of the age of the infrastructure and the adhoc way in which it was built, the councils advise that basic information such as sump volumes, pipe sizes and invert levels are not available for this site (GHD, 2009).

Spearwood is just one of the areas which remain unsewered in the Perth Metro Area. The Infill Sewerage Program (ISP) is expected to be completed in this precinct late 2011, after investigations undertaken by the Department of Health (DoH) (Water Corporation 2010).

Additional documents relating to the area:

Cossill &Webley Consulting Engineers (CWCE) 2010. *George Weston Foods Land Holding Hamilton Road, Spearwood: Report on development and infrastructure servicing for local structure plan report.* Cossill & Webley Consulting Engineers, Western Australia.

Water Corporation 2008. *Infill sewerage and other water projects underway in Spearwood area*. Water Corporation, Perth.

Housing Estate B

Housing Estate B is located approximately 10km east of Perth. The study area 11.5 ha. The development of the site is a mixture of residential and mixed business lots. The site is located near a wetland and existing urban development. No public open space is located within the development.

The development of the site was subject to the preparation and implementation of an 'Integrated Water management Plan' (IWMP). The focus of the plan is:

- Drainage
- Nutrient management
- Water quality monitoring

The drainage concept of the site includes:

- To maximise infiltration of water and therefore reduce stormwater volumes
- Gross pollutant trap to reduce load of sediments and nutrients into the drainage systems
- Impact of infiltration on water quality will be monitored through groundwater bores
- Stormwater quality from the site is expected to be comparable to the quality of the stormwater from the wider catchment

There is no consideration of water conservation and efficiency measures in the IWMP.

The information surrounding this site was sourced from ENV files which have not been disclosed due to client confidentiality.

Riverbank, Southern River

The Riverbank development is located between Southern River Road, Leslie Street, Matison Street and Holmes Street, in Southern River, City of Gosnells. The site contains a mixture of R25 to R40 residential lots located in areas close to POS, commercial areas and public transport routes.

Public open space has been designated to provide for local active and passive recreational facilities, the retention of quality vegetation, and opportunities for natural drainage passage and filtration.

An area in the north-eastern sector is aimed at protecting the main area of relatively undisturbed remnant bushland within the sub-precinct which is associated with an area of classified as a Multiple Use Wetland. This area also incorporates a natural drainage feature.

In accordance with BUWM, the site:

- Achieves a potable water use of 92kL/person/year
    - Providing households with rainwater tanks for internal water use- toilet flushing and washing machines
    - Mandating the use of WaterWise fittings at construction
    - Providing WaterWise landscaping packages that include low water use gardens and soil amendments to minimise water and nutrient loss; and
    - Minimising water use in Public Open Space through the use of low water use landscaping treatments and water efficient irrigation systems.
- Stormwater Management
    - Implementing a drainage design that limits the peak outflow from the development to pre-development levels through storage and infiltration on site;
    - Providing adequate flood protection by providing appropriate (minimum 300 mm) separation between 1 in 100-year ARI water levels and finished lot levels and ensuring that safe overland flood routes are provided through the development to the Southern River or Main Drain outlets;
    - Including appropriate contemporary Water Sensitive Urban Design (WSUD) Best Management Practices (BMPs) in the road reserve that are able to store and infiltrate the 1 in 1 year ARI event; and
    - Implementing a stormwater system that the model indicates will meet the Southern River Integrated Land and Water Management Plan (DoW, 2009) targets for nitrogen and phosphorus reduction through the use of swales, living streams and bio retention systems.
- Groundwater Management
    - Allowing the use of controlled groundwater levels where it can be demonstrated that it will not impact the Conservation Category Wetland to the south of the site;
    - A commitment to further monitoring of groundwater quality on the site to determine whether historical practices have impacted on groundwater quality.
- Nutrient inputs to groundwater will be minimised by:
    - The use of a high PRI soil amendment in landscaping packages
    - Education to households about reducing fertiliser use

    - The use of native vegetation in major drainage structures to further reduce nutrient inputs to groundwater

Sourced from:

ENV Australia. 2009. *Sub-precinct 3A(1) Southern River: Local Water Management Strategy*. Perth, Western Australia: ENV Australia.

ENV Australia. 2010. *Riverbank, Stages 1 and 2 Southern River: Urban Water Management Plan*. Perth, Western Australia: ENV Australia.

Campbell Estate, Canning Vale

Campbell Estate is located approximately 13km south of Perth, WA. The section of Campbell Estate reviewed totalled 3.67 ha. The development includes low residential and public open space.

A Conservation Category Wetland is located within the Campbell Estate and management of the area must be given special consideration – stormwater quality, quantity, land use.

The details of the Urban Water Management Plan include:

Drainage System

- The district drainage system will accept water from roads, some lots and public open space. In the north of the site, where the potential for infiltration is limited, the drainage system will also accept water from household roofs and paved areas.
- The drainage system will be a series of swales and compensating basins designed to limit the peak flow into the downstream Hughes Street Drain. The swales and compensating basins will be vegetated with local sedge and rush species to trap nutrients and sediments where appropriate.

Water Conservation

- Developers should provide householders with information on Waterwise gardening and water efficient appliances at settlement.
- Irrigation of Public Open Space should be managed to minimise the amount of water required.

Water Quality Management

- Developers will provide householders with information on low fertiliser use gardening at settlement.
- The amount of fertiliser used on Public Open Space should be minimised.

Monitoring and Contingency Planning

- Monitoring of surface water nutrient levels will be undertaken to assess the effectiveness of water quality management. If elevated nutrient levels are encountered, the information provided to householders and management of Public Open Space will be reviewed.
- Swales and compensating basins will be inspected annually for blockages, rubbish and vegetation issues.

Sources:

ENV. 2005. *Campbell Estate, Canning Vale: Urban Water Management Plan*. Perth: ENV Australia.

ENV. 2008. *Lot 13 Campbell Estate, Canning Vale Urban Water Management Plan.* Perth: ENV Australia

The Glades at Byford

The Glades is a residential development located 25km south of the Perth CBD. It is 328ha and is in the south eastern corridor of the Perth Metropolitan Region. It contains 3,500 lots and houses 10,000 people. There has been an emphasis on water sustainability throughout the development with EnviroDevelopment accreditation for the water and ecosystem category. In the area of urban water management, consideration has been given to improve upon the regulatory requirements.

Water Conservation

- Households built consistent with current BCA standards and the state government 5 star scheme
- Sustainability contract with each land owner
- Waterwise front landscaping package to each home
- 2kL rainwater tank for each home plumbed to the toilet and laundry with an overflow to the stormwater drainage system or greywater recycling for internal and external uses.

Landscaping

- Use of Multiple Use Corridors to retain and enhance the natural water courses passing through the study area
- Extensive use of local native species in POS, streetscapes and wetland buffers to reduce nutrient input and conserve vegetation
- Creation of a feature lake in the village centre precinct providing amenity to this community area
- Bore water for POS
- 50% native plants, with WaterWise irrigation system
- The lake has an aesthetic function, focus for recreational activity, structural benefits (including increased flexibility in the design of the POS irrigation system by providing storage and additional stormwater detention.
- The lake is topped up with bore water

Stormwater

- Use of bio-retention treatment systems for detention and treatment of stormwater
- All drainage infrastructure is located outside CCWs and associated buffers
- To prevent flooding swales are built to convey flow away from the brook in rainfall greater than 50 year ARI
- The system is designed with a major and minor system:
    - Major: arrangement of roads, drainage reserves and infiltration areas are located in POS planned to provide safe passage of stormwater runoff from extreme events which exceed the capacity of the minor system
    - Minor: Include treatment train of GPTs and bio-retention system

Sources:

JDA 2009. *The Glades at Byford Local Water Management Strategy*. JDA, Perth

Urbis 2009. *Byford Town Centre Local Structure Plan*. Urbis, Perth.

Australian Fine China, Subiaco

The Australian Fine China (AFC) is located in Subiaco, Perth. It is 400m west of central Subiaco and 4.2 ha. The site housed the old Australian Fine China manufacturing site. The planned use is a mixture of commercial, residential and recreational. The architecture of the buildings with the site will be contemporary while responding to the heritage, creating desirable living space and maximising connection to the public space within the development.

The site has several environmental targets including:

- 55% reduction in scheme water use through a combination of demand management initiatives, reuse and recycling of greywater and rainwater
- 55% reduction in greenhouse gas emissions
- 50% reduction unconventional energy use

Key aspects of the environmental management approach are:

Water Use

- Rainwater diversion infrastructure has been installed on all buildings to capture and divert clean rainwater runoff from roof areas into the existing central rainwater reuse system. A minimum of 75% roof area will be utilised
- All residential lots are installed with infrastructure to use centralised rainwater and also to install 5kl rainwater tanks to be used for indoor purposes only
- Greywater treatment and reuse systems to be installed on residential lots for toilet flushing and irrigation
- All blackwater is sent to the sewer
- Monitoring on all water streams
- Installation of low flow tap fittings, dual flush toilets & garden reticulation
- Water Corporation water wise 5 star home water efficiency rating

Education

Education & awareness of personal water & energy usage patterns via installation of telemetry systems, bills that report against overall targets & communal based sustainability data integrated with interpretive elements

Landscaping

- Low water use species, reducing lawn areas and other high maintenance landscaping
- Open areas to have a mix of soft and hard surfaces
- Landscaped areas irrigated with recycled greywater
- Use of permeable pavements to increase self sufficiency of landscaping
- Planted pocket gardens to improve stormwater infiltration and treatment benefits
- 60% indigenous flora and now weeds to be included
- 10% green roofs for commercial and multi-residential buildings

Drainage

- Retain all stormwater from minor events and infiltrate on site

- Partial on site storage infiltration capacity for 100 year ARI of critical duration
- Design flow paths to direct flow in major events to open space north of the development

Other sustainability aspects to the site include:

- Artwork integrated with rainwater collection
- WaterWise Display Village
- WaterWise development accreditation

Sources:

Subiaco Redevelopment Authority (SRA) .2009a. *Australian Fine China Design Guidelines*. Perth: Subiaco Redevelopment Authority.

Subiaco Redevelopment Authority (SRA). 2009b. *Australian Fine China Precinct Plan*. Perth: Subiaco Redevelopment Authority.

Currumbin Ecovillage, QLD

The Ecovillage at Currumbin is located on the Gold Coast. It is approximately 110ga and provides housing to 144 sustainable homes ranging from 450-6000 sqm. The Ecovillage is self-sufficient in energy use and has complete autonomy in water and wastewater recycling. The site contains a variety of community facilities including a Village centre with co-op community store, café, Interpretive Centre, work/shop spaces, health practitioner rooms, community primary school, plant nursery, recycling centre and recreational facilities including the Village Hall and Village Green. The vision for the community was to 'inspire sustainable living and development practice awareness'.

Apart from collecting, treating and reusing all rainwater and wastewater on site, the Ecovillage boasts several other sustainability initiatives including:

- 80% of the site is open space, with 50% environmental reserve
- Food and material self-sufficiency through edible landscaping and street scaping, household farming and other productive strategies
- Preservation of natural landforms and rehabilitation of the degraded site's environmental integrity
- Extensive wildlife corridors, negligible vegetation loss and extensive native plant regeneration
- Integration of WSUD for water quality
- Cultural heritage honoured and integrated
- Mix of socially orientated innovative ecological, energy efficiency housing catering for diverse needs
- Waste recycling strategies including RRR recycling centre onsite
- Initial and ongoing social planning to foster cohesion and promote sustainable community
- Continuing education of sustainable development
- Sustainable economic performance with the development and ongoing community

The Drainage concept of the site includes:

- Multiple dams and ponds for stormwater detention
- Predevelopment flows and quality maintained
- Roads have been designed to minimise hard kerbs and allow natural drainage and to make best use of the existing vegetation's
- Stormwater swales and ponds provide further treatment and a nature feature for birdlife and villagers to enjoy.

Sources

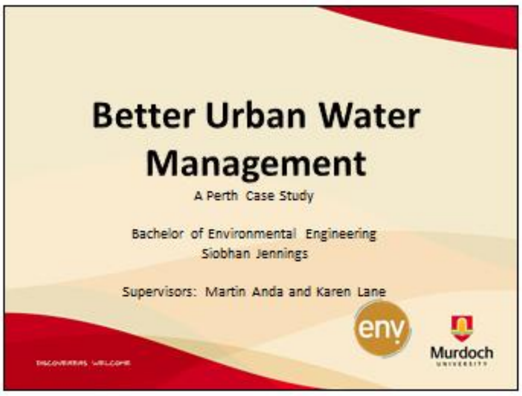
Construction Innovation (CI) 2007. *Sustainable subdivisions – review of technologies for integrated water services.* Constriction Innovation, Brisbane.

Sustainability Victoria 2011. *Ecovillage at Currumbin: A model for commercial viability in an eco-village development*. Sustainability Victoria, Victoria.

Landmatters 2003. *Executive Summary: The Ecovillage at Currumbin*. Landmatters, Queensland.

Hood, B., Gardner, E., Barton, R., Gardiner, R., Beal, C., Hyde, R., Walton, C. 2010. Decentralised development: The Ecovillage at Currumbin, *Water*, Sept (2010), 37-44.

Appendix 6: PowerPoint Presentation

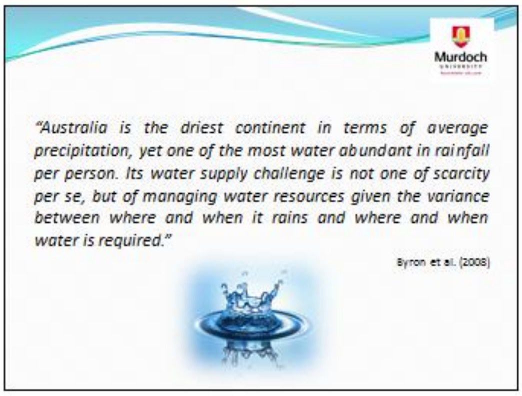


Better Urban Water Management

A Perth Case Study

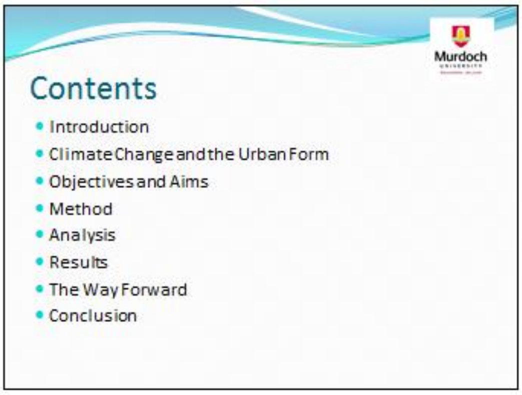
Bachelor of Environmental Engineering
Siobhan Jennings

Supervisors: Martin Anda and Karen Lane



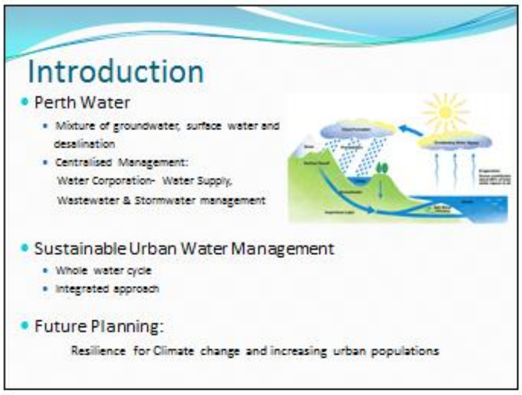
"Australia is the driest continent in terms of average precipitation, yet one of the most water abundant in rainfall per person. Its water supply challenge is not one of scarcity per se, but of managing water resources given the variance between where and when it rains and where and when water is required."

Byron et al. (2008)



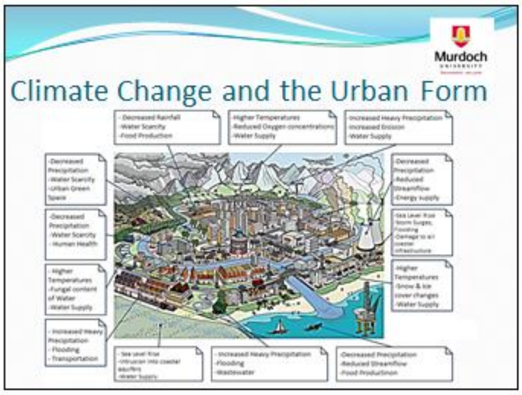
Contents

- Introduction
- Climate Change and the Urban Form
- Objectives and Aims
- Method
- Analysis
- Results
- The Way Forward
- Conclusion



Introduction

- Perth Water
  - Mixture of groundwater, surface water and desalination
  - Centralised Management:
    Water Corporation- Water Supply,
    Wastewater & Stormwater management
- Sustainable Urban Water Management
  - Whole water cycle
  - Integrated approach
- Future Planning:
  Resilience for Climate change and increasing urban populations



Climate Change and the Urban Form

Aims and Objectives

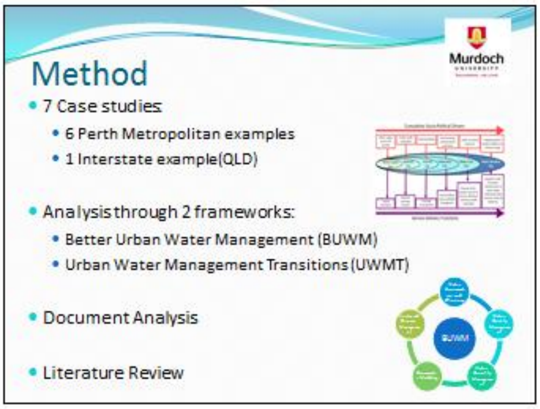
Aims

To determine:

- If the Better Urban Water Management (BUWM) design objectives are being achieved in the Perth metropolitan area
- The city state typology Perth represents in the Urban Water Management Transitions (UWMT) Framework

Objectives

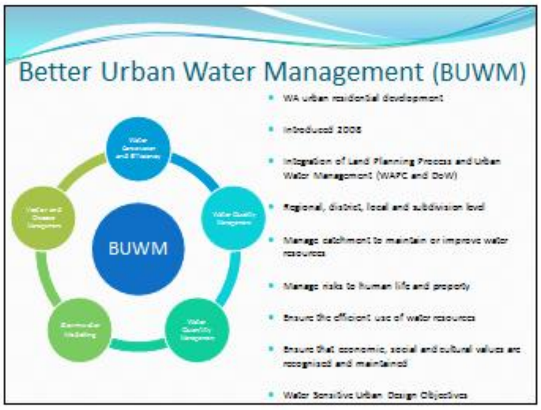
- Analyse the progress BUWM has made in urban water management in Perth
- Understand the differences between a business as usual approach and best management practice in urban water management
- Investigate the differences between BUWM and the characteristics of a Water Sensitive City.
- Investigate the different typologies represented in Perth
- Provide recommendations to progress Perth to a Water Sensitive City



Method

- 7 Case studies
  - 6 Perth Metropolitan examples
  - 1 Interstate example(QLD)
- Analysis through 2 frameworks:
  - Better Urban Water Management (BUWM)
  - Urban Water Management Transitions (UWMT)
- Document Analysis
- Literature Review

Method

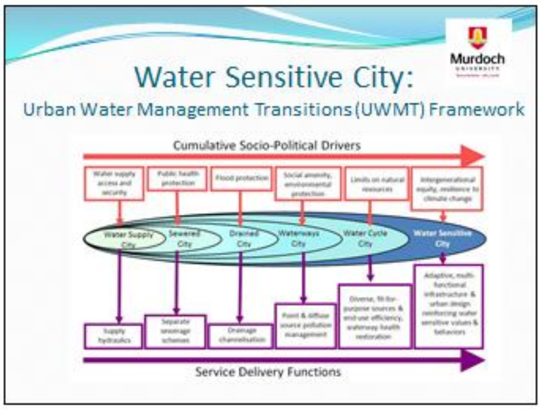


Better Urban Water Management (BUWM)

- WA urban residential development
- Introduced 2008
- Integration of Land Planning Process and Urban Water Management (WAPC and DoW)
- Regional, district, local and subdivision level
- Manage catchment to maintain or improve water resources
- Manage risks to human life and property
- Ensure the efficient use of water resources
- Ensure that economic, social and cultural values are recognised and maintained
- Water Sensitive Urban Design Objectives

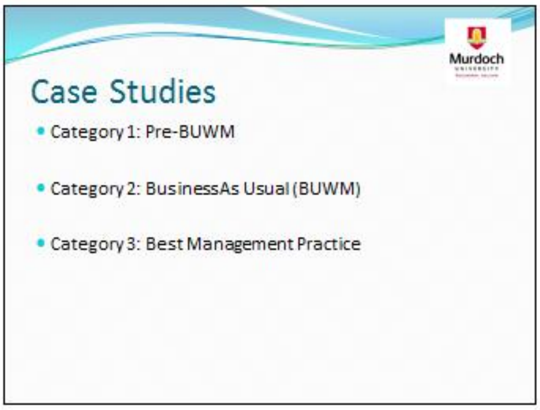
BUWM Design Objectives

Design Objective	Principle	Criteria
Water Conservation	• No potable water outside • Efficient Water Use	• Water consumption target of 100kL/person/year • 40-60kL/person/year scheme water
Water Quantity Management	• Maintain Pre Development hydrological flows	• Ecological Protection • Flood Management
Water Quality Management	• Maintain surface and groundwater quality	• Contaminated Sites • Drainage
Stormwater Modelling	• To meet modelling parameters for: -Total Suspended Solids -Phosphorous and Nitrogen - Gross Pollutants	
Disease Vector & Nuisance Insect Management	• Reduce health risks from mosquitos	



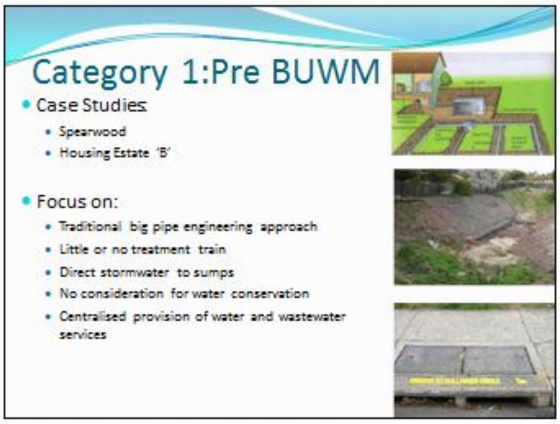
Water Sensitive City:

Urban Water Management Transitions (UWMT) Framework



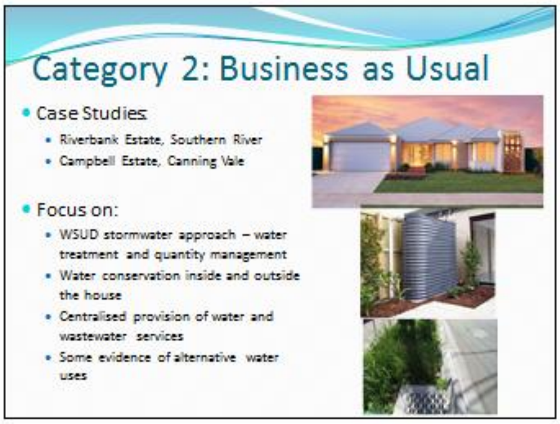
Case Studies

- Category 1: Pre-BUWM
- Category 2: Business As Usual (BUWM)
- Category 3: Best Management Practice



Category 1:Pre BUWM

- Case Studies
  - Spearwood
  - Housing Estate 'B'
- Focus on:
  - Traditional big pipe engineering approach
  - Little or no treatment train
  - Direct stormwater to sumps
  - No consideration for water conservation
  - Centralised provision of water and wastewater services

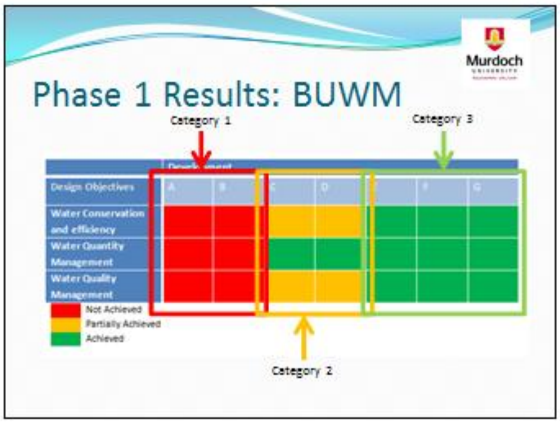


Category 2: Business as Usual

- Case Studies
  - Riverbank Estate, Southern River
  - Campbell Estate, Canning Vale
- Focus on:
  - WSUD stormwater approach – water treatment and quantity management
  - Water conservation inside and outside the house
  - Centralised provision of water and wastewater services
  - Some evidence of alternative water uses

Category 3: Best Management Practice

- Case Studies
  - The Glades at Byford
  - The Australian Fine China Site, Subiaco
  - The Ecovillage at Currumbin, QLD
- Focus on:
  - Water neutral – recycling, considering all streams, closed loop
  - Hydro-social interaction
  - Water in the landscape
  - Ecosystem preservation
  - Sustainability: Energy production, food production, community, national parks,



Phase 1 Results: BUWM

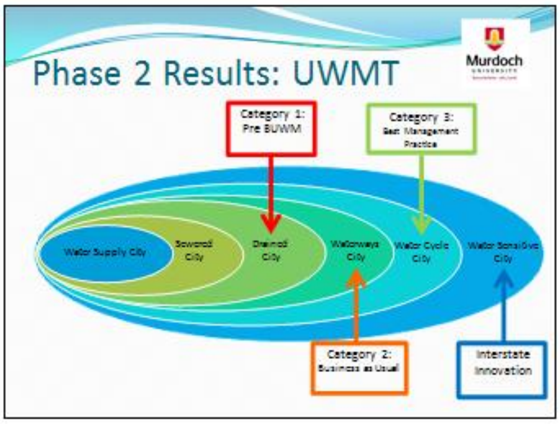
Category 1

Category 3

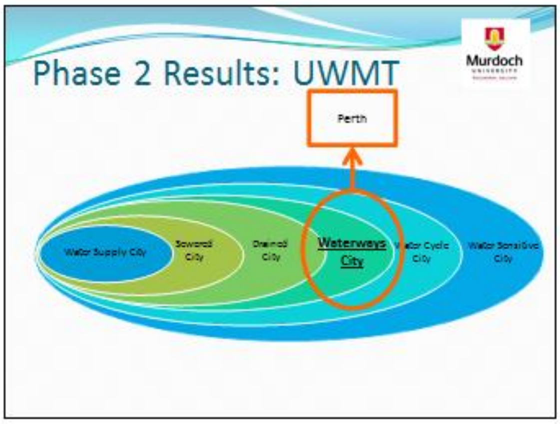
	Development						
Design Objectives	A	B	C	D	[illegible]	F	G
Water Conservation and efficiency	🟥	🟥	🟨	🟨	🟩	🟩	🟩
Water Quantity Management	🟥	🟥	🟩	🟩	🟩	🟩	🟩
Water Quality Management	🟥	🟥	🟨	🟨	🟩	🟩	🟩

🟥 Not Achieved
🟨 Partially Achieved
🟩 Achieved

Category 2



Phase 2 Results: UWMT



Phase 2 Results: UWMT

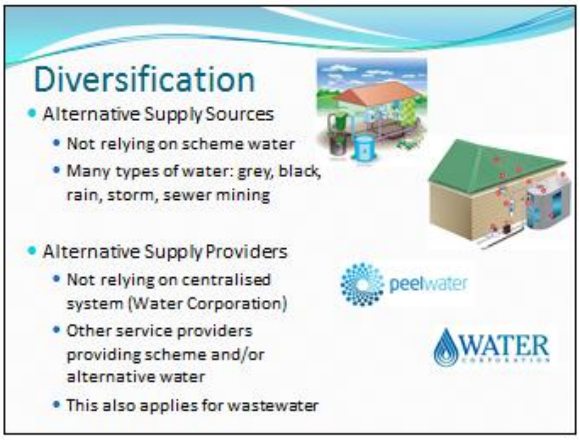
The Way Forward

Fit For Purpose

- Matching water quality with water use
- Preventing unnecessary treatment and transportation of water
- Considering all water streams in the water cycle
- Community Perception
- Lack of support at a legislative level

Landscape Integration

- Hydro-social interactions
- Integrating water into the landscape
- Water should be seen
- Multiple use of landscaped areas: recreation, aesthetic, stormwater management, environmental restoration & preservation
- Water Sensitive Urban Design



Diversification

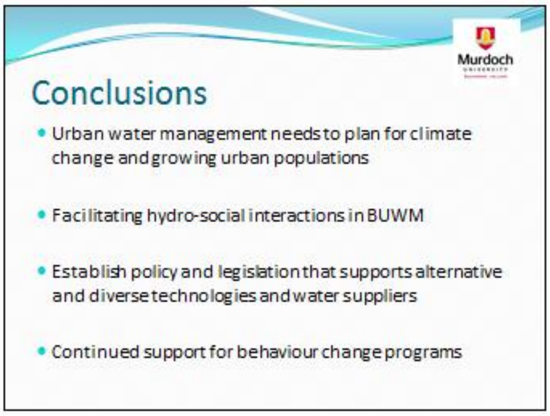
- Alternative Supply Sources
  - Not relying on scheme water
  - Many types of water: grey, black, rain, storm, sewer mining
- Alternative Supply Providers
  - Not relying on centralised system (Water Corporation)
  - Other service providers providing scheme and/or alternative water
  - This also applies for wastewater

Normative Values

- Supporting and encouraging environmental values:
  - Environmental repair & protection
  - Sustainability
- Supporting and encouraging environmental values:
  - Behaviour change programs
  - Community participation & engagement: workshops, communal places

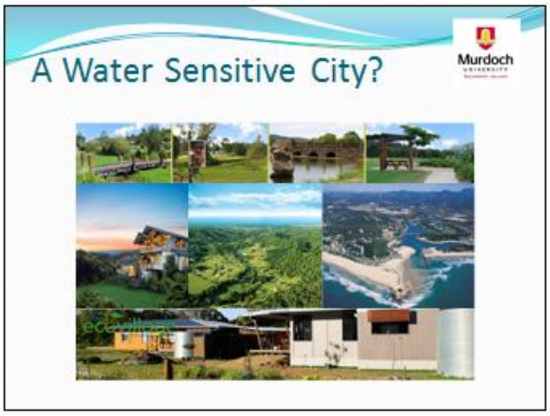
ENV Australia

- Internship placement: Feb – August 2011
- Focus on:
  - Urban Water Management
  - Behaviour Change
- Skills:
  - Report Writing
  - Engineering Drawing
  - Cost Estimates
  - Writing Proposals



Conclusions

- Urban water management needs to plan for climate change and growing urban populations
- Facilitating hydro-social interactions in BUWM
- Establish policy and legislation that supports alternative and diverse technologies and water suppliers
- Continued support for behaviour change programs



A Water Sensitive City?

Appendix 7: ENG450 Engineering Internship Industry and Academic Supervisor endorsement pro forma

This is to be signed by both the industry and academic supervisor and attached to the final report submitted for the internship.

We are satisfied with the progress of this internship project and that the attached report is an accurate reflection of the work undertaken.

Signed:	Signed:
	M. Anda
Industry Supervisor	Academic Supervisor
Karen Lane	Martin Anda