Facilitating System Transitions in Urban Water:

Development of the FaST Framework

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ABSTRACT

Climate change, resource limitations, population dynamics, ageing infrastructure and evolving community values are putting pressure on urban water systems. There is growing international acceptance that conventional approaches for managing urban water services, characterised by large-scale, centralised and engineered solutions, are inadequate to deliver the outcomes desired by society. Urban water scholars and practitioners are therefore calling for an urgent shift to more water sensitive approaches. This shift is significant, requiring transformative change in how urban water systems are planned, designed, built, managed and valued. However, there is limited practical or theoretical understanding of how strategic planning and management in urban water sectors can deliberately facilitate this desired transition.

Transition management was developed as a meta-governance approach to provide prescriptive guidance for stimulating innovation and achieving long-term goals through a reflexive, adaptive process. As the first framework of its type, it has made significant contributions to academic debate and policy practices around sustainability transitions; however, there are two critical limitations in its current form. First, transition management has no explicit mechanisms to conceptually link governance processes with diagnostic insights about the transformative capacity of a system in its local context, instead largely relying on the tacit knowledge of actors elicited through process instruments. Second, its approaches are directed at the early stages of a transition and therefore have limited capacity to guide actor strategies that support the mainstreaming of innovations during the later stages.

To address these gaps, this thesis aims to **develop a framework to guide the selection, design and coordination of strategic initiatives for enabling systemic socio-technical change from conventional water servicing to water sensitive alternatives.** This aim was addressed through theoretical and empirical research in the context of Melbourne's water system, which is undergoing significant transformative change.

The first research phase involved development of a suite of tools, based on concepts from transitions, resilience and new institutional scholarship, that are conceptually linked in a procedural design to provide diagnostic insight into a system's transformative capacity. The second and third phases involved qualitative embedded multiple-case studies that drew on perspectives of urban water scholars and practitioners in Melbourne to identify the critical strategic ingredients for supporting transition processes in recent historic and envisaged future urban water system changes. Three empirical cases of innovations that recently emerged were analysed and compared to reveal the scope of actor strategies for supporting trajectories of institutionalisation for innovations with different characteristics. Two illustrative cases, based on outcomes of participatory transition scenario workshops, were analysed to inform the scope, coordinating logic and design base for a strategic program for transitioning to a water sensitive city.

The fourth phase embedded the research findings within a meta-governance framework, named FaST (Facilitating System Transitions). Upon trials, tests and validation, the FaST framework and associated toolkit could form the basis of operational guidance for strategic planners, policy analysts and decision-makers to identify the best opportunities for strategic interventions that will most effectively influence the speed and direction of transformative change in urban water servicing and other infrastructure systems.

GENERAL DECLARATION

MONASH UNIVERSITY

Declaration for thesis based on conjointly published or unpublished work

In accordance with Monash University Doctorate Regulation 17 Doctor of Philosophy and Research Master's regulations the following declarations are made:

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes one original paper published in a peer reviewed journal, one original paper accepted for publication in a peer reviewed journal, three original submitted, unpublished publications and one original unpublished paper accepted for presentation at an international conference. The core theme of the thesis is urban water transitions. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the candidate, working within the School of Geography and Environmental Science under the supervision of Professor Rebekah Brown and Professor Ana Deletic.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of Chapters 2, 3, 5 and 6, my contribution to the work involved the following:

Thesis chapter	Publication title	Publication status	Nature and extent of candidate's contribution
2	Diagnosing transformative change in urban water systems: Theories and frameworks	Published	Formulated research problem, located research within established literature, developed theory, conceptualised and structured paper, wrote paper.
3	A diagnostic procedure for transformative change based on transitions, resilience and institutional thinking	Resubmitted with minor revisions	Formulated research problem, located research within established literature, developed theory, conceptualised and structured paper, wrote paper.
5	The enabling institutional context for achieving integrated water management: Lessons from Melbourne	Submitted	Formulated research problem, located research within established literature, collected and analysed data, conceptualised and structured paper, wrote paper.
5	Tracing transitions through institutional dynamics: An urban water case	Submitted	Formulated research problem, located research within established literature, collected and analysed data, conceptualised and structured paper, wrote paper.
5	A strategic program for transitioning to a Water Sensitive City	In press	Formulated research problem, located research within established literature, developed theory, collected and analysed data, conceptualised and structured paper, wrote paper
6	Extending transition management: A second-generation meta-governance framework	Accepted	Formulated research problem, located research within established literature, developed theory, conceptualised and structured paper, wrote paper.

I have not renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Signed: …B. Ferguson*……………*(* Original signature in hardcopy version)***

Date: …30/5/13……………

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CHAPTER 1. INTRODUCTION

This chapter introduces urban water planning and management and describes the problems associated with conventional urban water servicing in the context of evolving societal needs and external drivers. In response to these problems, the challenge of transitioning to a water sensitive city is posed and existing strategic tools for enabling this transition are reviewed. The research aim emerging from this context is presented, followed by an overview of the research and an outline of each chapter in this thesis.

1.1. Transformative Change in Urban Water Systems

1.1.1. Challenges for urban water servicing

Urban water systems around the world have evolved over multiple centuries in response to society's needs for water resources, public sanitation and flood protection. The infrastructure that services these needs is typically centralised and large-scale, comprising major pipelines and treatment plants that transfer water between catchments (Lundqvist and Turton, 2001; Mouritz, 1996; Newman, 2001; Newman and Kenworthy, 1999). These evolutions are represented in Brown et al.'s (2009) continuum, which synthesises the typical and anticipated developments of cumulative socio-political drivers and the delivery of water services in industrialised cities (Figure 1). The first three city states, to the left of the continuum, reflects conventional urban water servicing, which is based on the compartmentalisation of water supply, sewerage and drainage services, both in terms of the biophysical infrastructure and its supporting institutions (Biggs et al., 2009; Wong and Brown, 2009).

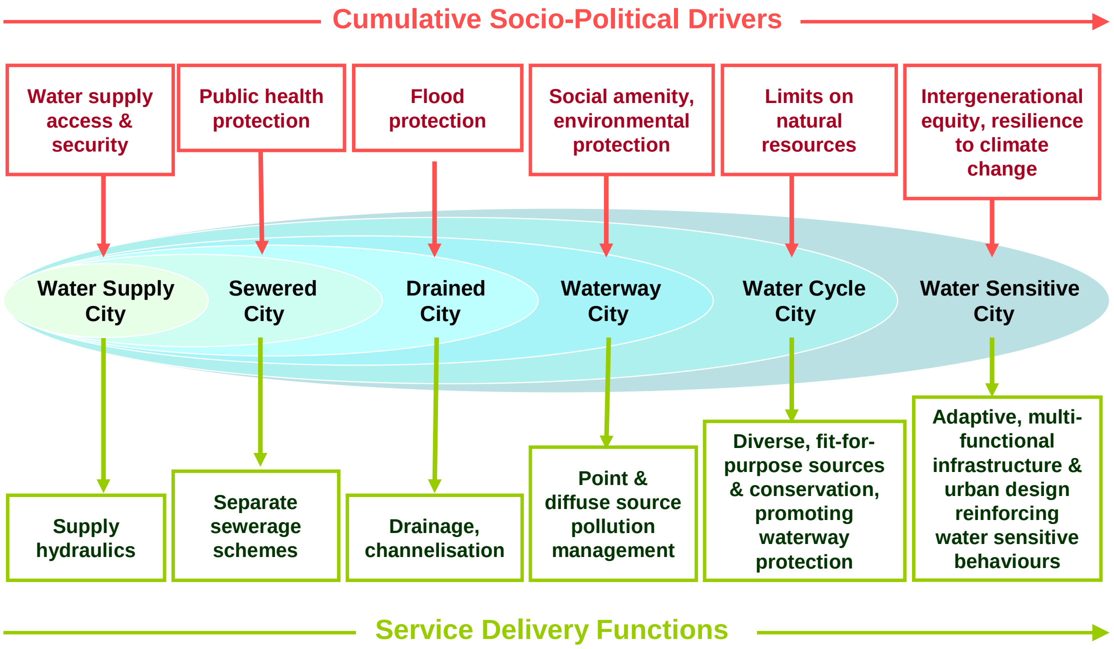

Figure 1. City-state continuum for urban water transition (Brown et al., 2009)

The management paradigm accompanying this conventional water servicing is typically characterised as 'command-and-control' or 'predict-and-control'. It largely aims to reduce uncertainties and control variables through emphasising technical solutions, ignoring radical alternatives and basing decisions on rational cost-benefit assessments made upon consideration of a relatively narrow set of values (Biggs et al., 2009; de Graaf and van der Brugge, 2010; Newman, 2001; Pahl-Wostl, 2007; Pahl-Wostl et al., 2007; Truffer et al., 2010). Key variables such as rainfall patterns, resource availability and community values are typically assumed to be largely linear, stable and predictable (Biggs et al., 2009; Dominguez et al., 2009; Pahl-Wostl, 2007). This approach is typical of the planning and management regimes for industrialised cities' public infrastructure beyond water servicing (de Graaf and van der Brugge, 2010; Dominguez et al., 2009; Newman, 2001; Pahl-Wostl, 2007; Pritchard and Sanderson, 2002; Truffer et al., 2010).

Until recently, urban water servicing from this paradigm served society's needs for water supply security, public health protection and flood protection relatively well (Brown et al., 2009). However, socio-political drivers around social amenity, environmental protection, intergenerational equity and climate resilience are becoming increasingly significant in strategic water decisions, as highlighted by the last three city states to the right of Brown et al.'s continuum in Figure 1. Scholars argue that large-scale centralised infrastructure, managed from a technocratic linear paradigm, are unable to provide adequate levels of service in the context of these new socio-political drivers (Mitchell, 2006; van der Brugge and Rotmans, 2007; Wong and Brown, 2009). For example, Pahl-Wostl et al. comment on "technical end-of-pipe solutions that deal with individual problems in isolation and run the risk of causing unexpected consequences" (2007, p. 2), such as overexploitation and pollution of water resources.

In addition to these new social and environmental drivers, urban water systems are coming under severe pressure due to limitations to natural resources, climate change and variability, rising water demands from population growth, agriculture and industry, as well as increasing levels of urbanisation, environmental degradation and ageing infrastructure (Biggs et al., 2009; Brown, 2008; Brown et al., 2009; Marsalek et al., 2001; Pahl-Wostl et al., 2007; Vlachos and Braga, 2001). Such tensions are having significant impact on water supply security, flooding risks and the health of urban waterways (Pahl-Wostl et al., 2010). Projections show these consequences will continue to worsen in the future, as urban water stresses continue to be exacerbated (Bates et al., 2008; Pahl-Wostl, 2007).

These realities have implications for the type of infrastructure and institutions that constitute urban water systems and challenges arise as they become recognised as social-ecological systems that involve complex dynamic processes of change, significant uncertainty and a limited capacity to control variables. Attempting to steer such systems with control measures, or apply linear solutions to its problems, will be ineffective in securing the delivery of desired outcomes (Brown, 2008; van der Brugge & Rotmans, 2007; Wong & Brown, 2009). In short, complexity, variability and uncertainty will characterise urban water futures and conventional approaches to water planning and management is inadequate to deliver solutions that will cope with this context (Biggs et al., 2009; Mitchell, 2005; Mitchell, 2006; van der Brugge and Rotmans, 2007; Wong and Brown, 2009).

Instead, scholars argue that urban water systems need to transform to a paradigm that embraces uncertainty and provides adaptive capacity through flexibility, diversity and redundancy in its solutions (Aerts et al., 2008; Dominguez et al., 2009; Pahl-Wostl, 2007; van der Brugge and Rotmans, 2007; Vlachos and Braga, 2001). The "water sensitive city" (Figure 1) is a conceptual representation of this alternative paradigm, which is underpinned by practices that prioritise liveability, sustainability and resilience in the strategic planning, management and design of urban water institutions and infrastructure. The water sensitive city focuses on holistic management of the integrated water cycle, aiming to "protect, maintain and enhance the 'multiple' benefits and services of the total urban water cycle that are highly valued by society" (Wong and Brown, 2009, p. 674). It encompasses a broad range of goals for urban water systems that depart from conventional water servicing, including water conservation, fit-for purpose use, flood reduction, pollution minimisation, urban landscape improvement, urban heat island mitigation, co-governance processes, long-term timeframes for planning and an interdisciplinary approach (Brown et al., 2009; Wong and Brown, 2009).

To summarise, in cities around the world, urban water systems are facing the challenge of departing from conventional water servicing based on large-scale centralised infrastructure and technocratic management approaches towards water sensitive alternatives that are adaptive, flexible and diverse.

1.1.2. Enabling transformative change

There is growing scholarly and practical awareness of the need for the infrastructure and institutions of urban water systems to be transformed (Brown, 2008; Pahl-Wostl, 2007). However there is minimal understanding of how water sector actors should strategically plan for and manage transformative change (i.e. fundamental system-wide change in the structure of a system and the way in which it functions) towards a water sensitive future (Brown, 2005, 2008; Vlachos and Braga, 2001). Given the fundamentally different paradigms of conventional water servicing and a water sensitive city, transitioning will require long-term radical changes in the way that water servicing is planned, designed, constructed, operated, managed and valued (Biggs et al., 2009; Mitchell, 2006; Mouritz, 1996; Newman, 2001; Wong and Brown, 2009). This will involve both the development of new technologies and the creation of supportive institutional environments (Brown, 2008).

The imperative of transformative change is not unique to urban water; indeed infrastructure systems all over the world such as water, energy and transportation are facing similar sustainability challenges (Frantzeskaki and Loorbach, 2011). As such, strategic thinkers in practice and academia have begun to grapple with the challenges of long-term planning of urban infrastructure systems. Dominguez et al. contend that traditionally, "strategic planning has received rather little attention in the infrastructure sectors …. there was no vital need for sophisticated strategy making …. [as] socio-economic context conditions remained within certain bounds" (2009, p. 32). As the need to address issues of sustainability and resilience has become increasingly apparent, a range of strategic approaches has been developed to support decision-making and assessments for complex infrastructure systems in uncertain contexts. Table 1 outlines some of the approaches commonly used in practice today, including participatory methods, analytic frameworks and computer simulations.

While the approaches outlined in Table 1 were generally developed from a systemic paradigm, and some provide specific means for considering multiple objectives and future uncertainties, they do not address the question of how *transformative change* can be planned for or managed. They tend to be implemented and evaluated within a linear operational context and operate on the assumption that strategic initiatives can be selected and designed through analysis of simple 'cause and effect' mechanisms (Foxon et al., 2009). As Gunderson et al. (2002) argues, institutions are set up to spend most of their time and resources implementing policies and monitoring key indicators but have little consideration for the need to plan for change. These limitations are further exacerbated by the fact that most strategic approaches for infrastructural systems have a short planning cycle (de Graaf and van der Brugge, 2010; Gunderson et al., 2002). Instead, strategic planning and management for sustainable and resilient urban infrastructure requires a systems perspective that has an explicit focus on how strategic initiatives can facilitate long-term planning for nonlinear transformative change (de Graaf and van der Brugge, 2010; Foxon et al., 2009; Frantzeskaki and Loorbach, 2010).

Table 1. Common approaches for strategic planning and management in urban infrastructure

Approach	**Purpose**	**Examples**
Scenario planning	Address the inherent uncertainty about the future by designing strategic plans that will be effective under a range of possible scenarios.	Dominguez et al., 2009 Hatzilacou et al., 2007 Kallis et al., 2006 Lienert et al., 2006 Mahmoud, 2008
Visioning	Guide strategic planning toward a particular shared normative goal.	Hatzilacou et al., 2007 Kallis et al., 2006 Lienert et al., 2006
Stakeholder participation	Integrate a range of values and perspectives into strategic plans and minimise the potential for conflict during implementation of those plans.	Hatzilacou et al., 2007 Kallis et al., 2006
Multi-criteria analysis	Make the diverse range of values of a system explicit so they can be weighed up against each other and trade offs can be taken into account in the design of strategic plans.	Kallis et al., 2006
Decision support systems	Make the potential consequences of decisions explicit so that strategic plans can account for them.	Makropoulos et al., 2008b
Computational modelling	Provide insight into the possible outcomes of interactions between complex factors that cannot be analysed with other techniques.	Hatzilacou et al., 2007 Kallis et al., 2006
Capability assessments	Identify capabilities that should be built up in order to implement strategic actions, often to complement 'SWOT' (Strengths, Weaknesses, Opportunities, Threats) analyses.	Dominguez et al., 2009

Enabling transformative change (compared to incremental linear change) in urban infrastructure systems involves fundamental engagement with the question of how to overcome path-dependencies associated with the locked-in conventional system and support the emergence, up-scaling and stabilisation of innovative technologies and practices (Brown et al., in press; de Graaf and van der Brugge, 2010; Frantzeskaki and Loorbach, 2010; Pahl-Wostl, 2007). These questions have attracted significant scholarly attention and new research fields have emerged to specifically address the topics of transitions in socio-technical systems (e.g. Grin et al., 2010) and resilience of social-ecological systems (e.g. Gunderson and Holling, 2002; Chapin III et al., 2009). Scholars in these fields examine the phenomenon of transformative change in a wide range of different contexts to develop generalised theory about why and how it occurs.

As Geels (2004) argues, understanding of the dynamics of transformative change can help policy makers wanting to deliberately steer a transition and facilitate these changes. However, scholarship on this topic is still young. Chapin III et al. (2010, p. 247) contend that the link between transformative change and strategic action is underdeveloped, arguing that, "there is currently neither sufficient theory nor empirical evidence to identify … [the] relative importance [of strategic approaches] in the complex dynamics that play out in specific situations". Huitema et al. (2009) also argue that further empirical and theoretical research is needed to determine how transitions can be adaptively co-managed towards desired system transformation. Elzen and Wieczorek (2005) further comment on the challenge of applying insights in dynamic transition processes to the development of strategies and policies to facilitate transitions.

Literature from transitions and resilience scholarship identify a range of strategic initiatives that has been empirically observed to influence transformative change. For example, implementing participatory visioning processes (e.g. Loorbach & Rotmans, 2010; Voβ et al., 2009), technological and governance experimentation (e.g. Farrelly & Brown, 2011; Huitema et al., 2009); stimulating and incubating innovation (e.g. Westley et al, 2011); fostering social learning (e.g. Bos et al, in press; Pahl-Wostl et al. 2007); creating shadow networks that operate outside of the mainstream (e.g. Olsson et al., 2006); supporting leadership and enabling champions (e.g. Huitema & Meijerink, 2010; Olsson et al., 2006); and coordinating bridging organizations (e.g. Berkes, 2009; Folke et al., 2005). These insights emphasise that strategic planning and management for transformative change is not straightforward. A vast range of strategic objectives and planning processes need to be incorporated and coordinated amongst many different actors, and many of the approaches listed in Table 1 are used to support their implementation. However, there is limited operational guidance on the logic of how and when different initiatives should be utilised and coordinated to most effectively influence the speed and direction of transformative change.

In the absence of prescriptive guidance of this nature, transition management was recently developed as a meta-governance approach (Loorbach, 2007; Loorbach, 2010; Voβ et al., 2009). (The term meta-governance is used here to represent that the approach reflects a set of principles or norms that shape and steer the embedded governing processes.) Transition management is a pioneering framework, designed with a focus on long-term sustainability goals by stimulating new innovations through a reflexive adaptive process (Loorbach, 2010). Transition management has attracted intense interest within transitions scholarship and has made a significant contribution to academic debate on the governance of long-term change for more sustainable outcomes. It has also influenced policy practices in Europe and more broadly, with a number of transition experiments and innovation programs established as a result of transition management processes (e.g. Loorbach & Rotmans, 2010; Nevens et al., 2013). Empirical testing of transition management in different policy arenas is ongoing (Loorbach & Rotmans, 2010; Nevens et al., 2013) and while there has been some contention around its empirical validity, effectiveness and engagement with power, politics and agency (Grin et al., 2011; Grin, 2012; Loorbach and Rotmans, 2010; Rotmans and Kemp, 2008; Shove and Walker, 2007; Voβ et al., 2009), the framework makes substantial inroad towards addressing the question of how to deliberately facilitate transformative change in urban infrastructure (and other societal) systems.

Nonetheless, there are two critical limitations in the current form of the transition management framework. First, transition management does not have explicit mechanisms to conceptually link governance processes with analytic insights about transition dynamics. Instead, it largely relies on the tacit knowledge of actors elicited through process instruments, to identify and prioritise strategies for enabling a transition (Loorbach, 2010; Nevens et al., 2013). While tacit knowledge is valuable, theoretical knowledge about transition dynamics and diagnostic insights about a system's transformative capacity would form a much stronger base for selecting and designing actor strategies that best fit local contextual conditions. Second, transition management approaches are directed at the early stages of a transition, when innovations are only just beginning to emerge (Loorbach, 2010; Loorbach and Rotmans, 2010). It therefore has limited capacity to guide the selection and design of actor strategies that support the mainstreaming of innovations during the later stages of a transition (Grin, 2012).

In conclusion, while transition management provides a critical foundation, there lacks a meta-governance framework that can provide operational guidance on the selection, design and coordination of actor strategies that will most effectively influence the speed and direction of transformative change in urban water servicing and other infrastructure systems. Informed by diagnostic insights about the transformative capacity of a system in its local context, such a framework would enable strategic planners, policy analysts and decision-makers to identify the best opportunities for strategic interventions to facilitate transitions towards more sustainable futures.

1.2. This Thesis

1.2.1. Research aim and objectives

Against the background described in Chapter 1.1, this PhD research aimed to ***develop a framework to guide the selection, design and coordination of strategic initiatives for enabling systemic socio-technical change from conventional water servicing to water sensitive alternatives***.

To achieve this aim, three research objectives were established and addressed through exploration of a case study of the urban water system in Melbourne, which exemplifies the challenges described in Chapter 1.1.1 and is in the midst of a significant period of transformative change:

1. Derive a conceptual framework for diagnosing the transformative capacity of urban water systems in relation to a desired future vision.
2. Reveal the critical strategic ingredients for supporting innovation and transition processes in urban water servicing through valid and reliable case studies of recent historical and envisaged future transformative change in Melbourne's water system.
3. Design a meta-governance framework for guiding strategic initiatives that best fit a system's current conditions to facilitate system-wide transitions in urban water servicing.

1.2.2. Research overview

Addressing the research objectives required the development of in-depth understanding about the influence and role of different types of actor strategies on processes of innovation and transformative change. A qualitative embedded multiple-case study (Yin, 2009) was therefore employed and Melbourne's water system was selected as the unique case context for study, from which broader implications for theory were drawn. The case studies involved a retrospective and prospective analysis of the technical, environmental, social, policy and institutional developments of recent historical and envisaged future water servicing in Melbourne.

The research involved four distinct phases. The first phase focused on theory, drawing on scholarship on socio-technical transitions, social-ecological systems and new institutionalism. A scope for a diagnostic procedure for transformative change was first derived from the literature. Concepts that explain the dynamics of transitions and potential influence of actor strategies were then integrated in a series of diagnostic steps that guide analysis of the transformative capacity of a system in relation to a desired future state.

The second phase involved the development of three embedded empirical cases of contemporary change in Melbourne's water system, representing a slow, moderate and fast pace of institutionalisation of water service innovations. Primary interview data and secondary documentation were collected and analysed to first develop a detailed chronological narrative of the Melbourne case context. Individual narratives of the three embedded cases were then developed and each case was analysed to reveal the scope of actor strategies that supported its institutional trajectory of the innovation. Comparative analysis of the trajectories was then undertaken to derive theoretical insights on the aim and type of actor strategies that were most effective for institutionalising innovations of different characteristics.

The third research phase involved the development of two illustrative cases of envisaged future changes in Melbourne's water system. Participatory transition scenario workshops were used to generate data, which captured the tacit knowledge of water practitioners in Melbourne. The transition scenarios for each case were analysed to identify the scope, coordinating logic and design base for a strategic program for transitioning to a water sensitive city.

The fourth research phase drew on the insights and outputs from the previous three phases, refining the diagnostic procedure and conceptually linking the various tools developed in the research. These were then embedded within a meta-governance framework for guiding strategic initatives to facilitate urban water transitions.

In addressing the research objectives, this thesis makes contributions to both academic scholarship and to water management practice. From a scholarly perspective, it:

(1) Creates a detailed empirical case study of transitions in urban water as a base to inform theorising on transformative change as part of water resources, transitions and resilience scholarship.

(2) Creates a suite of tools within transitions, resilience and strategy scholarship (a) providing diagnostic insight into the transformative capacity of a system and (b) operational guidance for how to steer transformative change in urban infrastructure systems

(3) Extends transitions and resilience scholarship with the proposition of hypotheses on the links between the dynamics of transformative change and the scope of actor strategies for effective strategic intervention

(4) Extends transition management scholarship with the development of an architecture of a second generation meta-governance framework for guiding the selection, design and coordination of strategic initiatives to enable transformative change in complex urban infrastructure systems

From a practical perspective, the diagnostic tools and meta-governance framework create a platform for providing operational guidance for supporting strategic planning and management in urban water systems.

1.2.3. Thesis outline

This PhD research is presented as a series of six scholarly publications embedded within thesis chapters, forming a *thesis by publication*. Table 2 summarises the thesis content, indicating how each research objective and associated sub-objectives are addressed through these publications. Each chapter introduces the publication's content and highlights its contribution to the overall thesis narrative. An additional chapter provides further detail on the research methods. The publications are self-contained so, while repetition has been minimised, there is some overlap in descriptions of the research rationale and methodologies. The thesis has been prepared in accordance with Monash University School of Geography and Environmental Science guidelines for theses by publication.

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Table 2. Addressing the thesis objectives

Thesis Chapter / ***Publication*** / *Journal* / **Thesis Objective**	**2: Literature Review** ***Publication 1:*** Diagnosing transformative change in urban water systems: Theories and frameworks — *Global Environmental Change*	**3: Theory Dvpt** ***Publication 2:*** A diagnostic procedure for transformative change based on transitions, resilience and institutional thinking — *Ecology & Society*	**5: Results** ***Publication 3:*** The enabling institutional context for achieving integrated water management: Lessons from Melbourne — *Water Research*	**5:Results** ***Publication 4:*** Tracing transitions through institutional dynamics: Cases in urban water — *Enviro. Innovation & Societal Transitions*	**5: Results** ***Publication 5:*** A strategic program for transitioning to a Water Sensitive City — *Landscape & Urban Planning*	**6: FaST Framework** ***Publication 6:*** Extending transition management: A second generation meta-governance framework — *4th Int.Conference on Sust.Transitions 2013*
1. Derive a conceptual framework for diagnosing the transformative capacity of urban water systems in relation to a desired future vision.	1.1. Develop a scope for diagnostic procedure 1.2. Review existing frameworks from transitions & resilience theory to reveal how they could contribute to a diagnostic procedure	1.3. Synthesise conceptual understandings of transition dynamics from literature 1.4. Design a preliminary diagnostic procedure and demonstrate its application on a case study of Melbourne				1.5 Conceptually link analytic and diagnostic tools developed in a procedural design for informing the selection and design of actor strategies that best fit the system
2. Reveal the critical strategic ingredients for supporting innovation and transition processes in urban water servicing through valid and reliable case studies of recent historical and envisaged future transformative change in Melbourne's water system.			2.1. Present case studies of transformative changes in Melbourne's water system 2.2. Identify the institutional context that enabled transformative changes in the Melbourne cases	2.3. Identify institutional trajectories of innovations in the contemporary Melbourne case 2.4. Derive theoretical insights from the Melbourne case on the scope of actor strategies for supporting institutional trajectories	2.5. Present an illustrative case study of transition scenarios for water in Melbourne 2.6. Derive lessons from the future Melbourne case related to strategic planning and management for urban water transitions	
3. Design a meta-governance framework for guiding strategic initiatives that best fit a system's current conditions to facilitate system-wide transitions in urban water servicing.				3.1. Design an analytic method for characterising a water system and its institutional trajectories	3.2. Design a strategic program that coordinates actor strategies for facilitating urban water transitions	3.3. Design a framework that embeds the diagnostic tools with governance processes for guiding strategic initatives to facilitate urban water transitions

The thesis comprises seven chapters. This introductory chapter provides background and context for the urban water and transformative change questions considered in the thesis, as well as an overview of how the research aim and objectives are addressed.

A review of literature on socio-technical transitions and transformative change in social-ecological systems is presented in Chapter 2. The purpose of the literature review was to identify theoretical knowledge gaps and potential foundations for the development of a diagnostic framework focused on enabling transformative change in an urban water system, as well scope the details of the composition of such a framework. The findings from the literature review are presented in Publication 1.

Chapter 3 integrates theoretical concepts from transitions, resilience and institutional studies to develop a preliminary diagnostic procedure for revealing insights into the strategic initiatives that best fit a system's current conditions in order to influence the direction and pace of change in an urban water system. Publication 2 presents this diagnostic procedure and demonstrates its application on a case study of recent transformative change in Melbourne's stormwater management system.

The research methods are presented in Chapter 4, starting with an explanation of the rationale for the case study approach and selection of Melbourne's water system as a unique context for two multiple-case studies. The research design is then presented and the methodological techniques used to address each objective are described. Approaches for maintaining research reliability and validity are also explained.

Chapter 5 provides the results of the two multiple-case studies. Publication 3 presents the overall Melbourne case study context, comprising results from both the empirical case study and the illustrative future case study. It reflects on the enabling institutional context supporting the transformative change experienced and anticipated in Melbourne's water system between 1997 and the future water sensitive city in 2060. Publication 5 analyses three embedded cases within the context of Melbourne's water system in the 1997 to 2012 case study period, focusing on trajectories for the institutionalisation of desalination, wastewater recycling and stormwater harvesting as innovative practices. Theoretical insights about the scope of actor strategies that were influential in facilitating the transitional changes are drawn from these results. Publication 5 presents the embedded illustrative case studies of Melbourne's future transition to a water sensitive city, in the form of transition scenarios. The scenarios are synthesised and analysed to develop a design base of a strategic program for transitioning to a water sensitive city.

Chapter 6 triangulates across the results from the research to develop a meta-governance framework and toolkit for transformative change, extending scholarship on transition management. Publication 6 presents the framework, which draws on theoretical insights from literature, empirical and methodological insights from the multiple-case study analyses and practical insights from the experience of implementing the transition scenario process. The framework, named "FaST" (FAcilitating System Transitions), aims to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model that can provide operational guidance for selecting, designing and coordinating strategic initiatives that best fit the conditions of a system in order to facilitate transformative change.

The thesis conclusion in Chapter 7 describes the scholarly and practical implications of the research. Limitations of the research are also described and future research agenda is proposed.

CHAPTER 2. LITERATURE REVIEW

This chapter presents a review of literature on socio-technical transitions and transformative change in social-ecological systems, as well as new institutionalism. The purpose of the literature review was to review potential foundations for the development of a diagnostic framework focused on enabling transformative change in an urban water system, as well scope the details of the composition of such a framework. The findings from the literature review are presented in Publication 1. Knowledge gaps are also identified, leading to the development of an overarching research question for the thesis.

SPECIFIC DECLARATION FOR PUBLICATION 1

Monash University

Declaration for Thesis Chapter 2.2

Declaration by candidate

In the case of Chapter 2.2, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulated research problem, located research within established literature, developed theory, conceptualised and structured paper, wrote paper.	90%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah Brown	Supported the research conceptualisation, reviewed and edited the paper	N/A
Ana Deletic	Supported the research conceptualisation, reviewed and edited the paper	N/A

		Date
Candidate's Signature	B. Ferguson*	30/5/13

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	**Geography & Environmental Science, Monash University, Clayton Campus**

		Date
Signature 1	R. Brown*	30/5/13
Signature 2	A. Deletic*	27/5/13

* Original signature in hardcopy version

2.1. Transformative Change in Urban Water

The development of a framework for mapping and diagnosis of dynamic transition pathways in urban water servicing needs to be framed by literature that focuses on theoretical understanding of transformative change in complex systems.

2.1.1. Complex adaptive systems

Diagnosing societal transitions in an integrated system such as urban water requires theoretical approach that take a systems perspective, embracing uncertainty and capable of revealing the complex dynamic processes of change. System theory is an interdisciplinary field of study that holistically examines the nature of complex systems in society, nature, science and technology (Rotmans and Loorbach 2009). Von Bertalanffy’s (1968) seminal work on general systems theory provided a framework through which systems could be understood and analysed and in the decades since, the theoretical ideas have evolved such that a range of systems approaches have been developed across the broad spectrum of scholarly disciplines with diverse lineages (Ison, 2010).

Complexity theory stems from general systems theory; complex systems are considered a special type of system (de Haan, 2010). Complexity theory focuses on the nonlinear development of systems and the aim of complex systems theory, as described by Rotmans and Loorbach, is to “understand the behaviour of complex systems that run through cycles of relatively long periods of equilibrium, order and stability, interspersed with relatively short periods of instability and chaos” (2009, p. 186). Complex systems are typically open systems that comprise a range of elements, their elements interact with each other, they contain feedback loops, they are path dependent and they have emergent properties and multiple attractors (van der Brugge and Rotmans, 2007; Ison, 2010; Rotmans and Loorbach, 2009).

Complex adaptive systems are special cases of complex systems: they have capacity to adapt and learn from the past, through their unique features of coevolution, emergence and self-organisation (Rotmans and Loorbach, 2009). Coevolution refers to the interactions between subsystems that influence the dynamics in the system, resulting in irreversible patterns of change (de Haan, 2010; Rotmans and Loorbach, 2009). Emergence is the phenomenon in which whole systems have properties that their individual objects in isolation do not have, and that it is the interactions between these individual objects that cause the whole system properties to come about (de Haan, 2006, 2010; Ison, 2010). Self-organisation occurs when a system internally organises itself to become more structured and increase in complexity, without being controlled by an external source (de Haan, 2010; Rotmans and Loorbach, 2009). Complex adaptive systems spend most of their time in dynamic equilibrium but they can be forced to shift to a relatively short phase of instability and chaos when external sources exert pressure of some kind (Rotmans and Loorbach, 2009).

2.1.2. Urban water as a socio-technical and social-ecological system

While the conceptualisation of complex adaptive systems can apply in many different realms, socio-technical and social-ecological systems are special types that have social and biophysical properties. Urban water systems function as a complex adaptive system, comprising water resources, ecosystems, technology and infrastructure, institutions and actors. The system is place-bound, whereby the societal system is integrated with its ecosystem. It is therefore understood as both a socio-technical and social-ecological system. The system is open, embedded in a broader environment that interacts with the system via feedbacks.

In conceptualising urban water systems as socio-technical and social-ecological, technology and infrastructure seem to provide the majority of interfaces between the social and the ecological elements of the system. This role of technology and infrastructure highlights a fundamental aspect of defining the system's characteristics, specifically the nature of its function. The distinction between different types of function is found only implicitly in the literature. For example, in ecosystems such as wetlands or lakes, 'function' is interpreted as a system's ecological functions that emerge naturally out of interactions between chemical, biological and physical mechanisms. Human influence in social-ecological systems of this type is limited to maintaining or disturbing this 'ecological function' through human actions. In contrast, urban areas are engineered landscapes, in which humans decide (implicitly and explicitly) how the landscape will function, effectively determining an 'engineering function'. Specifically, the engineering function of a system emerges out of decisions that are made with regard to a system's institutional structures and associated actor practices. While these decisions may or may not be made with explicit targets for desired functions, they are underpinned by value judgements around which functions are prioritised. Urban water systems are engineered landscapes, with multi-faceted engineering functions (Biggs et al., 2009; van der Brugge, 2009) shaped by normative priorities and decisions. For example, over the last 50 years, the protection of private property from flood waters has been prioritised at the expense of healthy ecosystems and aesthetic waterways for social amenity, resulting in the channelisation of waterways for efficient conveyance of stormwater away from urban areas.

The normative decisions in an engineered water system have implications for how the dynamics of change will unfold, in particular due to the diverse perspectives of actors in the system and their often competing interests. Such characteristics exemplify some of the challenges in managing a complex adaptive system. Until recently, water infrastructure systems (and other city-wide systems of infrastructure) were considered "engineering challenges and administrative issues" (Hodson and Marvin, 2010, p. 477). However as van der Brugge (2009) notes, urban water management practices are complex, constrained by physical characteristics, regulations, contracts and politics; in other words they present 'persistent' (Dirven et al., 2002, in van der Brugge and Rotmans, 2007) or 'wicked' (Rittel and Weber, 1973) problems. In these cases, the system's functioning no longer satisfies its drivers and the failure cannot be corrected by current policies or simple market interventions (Rotmans and Loorbach, 2009); the problem can only be addressed through systemic transformative change. Wicked problems are common in complex societal systems. Westley et al. (2002, p.116) describe how cultural filters and institutional frameworks have repeatedly "inhibited otherwise highly successful societies and people of great creativity and intelligence from accurately perceiving the problems that beset them and acting to remedy them in a timely fashion".

To address these challenges, understanding of how a system functions and its transformative dynamics is needed in order to gain insight into the possibilities for influencing the direction and pace of its transition to a more desirable direction (Rotmans and Loorbach, 2009). Effective management of complex adaptive socio-technical and social-ecological systems, particularly for achieving sustainability goals through system transformation, requires recognition of their unique features of coevolution, emergence and self-organisation and an embracing of the uncertainty and unpredictability that is inherent to complex adaptive systems. Two main bodies of research use complex adaptive systems as the underpinning framework for analysing the dynamics of transformative change in integrated systems with a focus on sustainability: transition theory, focused on socio-technical systems, and resilience theory, focused on social-ecological systems.

2.1.3. Strategic planning and management of urban infrastructure

The complex nature of socio-technical and social-ecological systems makes strategic planning and management for steering systems in particular desired directions a challenging task. This is highlighted in literature addressing key issues that require attention in long-term planning and strategic management of urban infrastructure. For example, large urban infrastructure systems are typically locked into existing practices through institutional inertia and persistent socio-technical regimes (Berkhout, 2002; Dominguez et al., 2009; Smith et al., 2005; Störmer et al., 2009). Long-term planning and short-term decision-making for urban infrastructure systems tend to be influenced by normative goals and policy agendas of actors with diverse interests, responsibilities and perspectives (Albrechts et al., 2003; Albrechts, 2004; Störmer et al., 2009; Voβ et al., 2009). Urban infrastructure systems are inherently complex, comprising multiple objectives and interlinked technological, ecological, spatial, social, institutional, economic and political dimensions (Dominguez et al., 2009; Monstadt, 2009). And finally, planning and decision-making for long-term transformative change brings a high degree of uncertainty in the context conditions faced by urban infrastructure systems (Albrechts, 2004; Dominguez et al., 2011; Störmer et al., 2009; Voβ et al., 2009).

Review of scholarship on strategic planning and management for corporate and public organizations provides some insight into how these challenges could be addressed (Albrechts, 2004; Bryson, 1988). (Although it is important to acknowledge that differences in the approaches taken for single organizations versus urban infrastructure, which tends to be more democratic, transparent, complex and slow due to the broader range of actors involved (Dimitriou, 2007).) The role and effectiveness of strategic planning in how companies manage their futures in complex and uncertain business environments has been examined closely, fueling a long-running debate between ‘design’ and ‘process’ schools of thought. The design school argues that strategic planning is valuable for designing a strategic plan while the process school argues that the learning that takes place during strategic processes is the important feature (e.g. Grant, 2003; McKiernan, 1997). While this debate is ongoing, recent literature argues that both ‘rational design’ and ‘emergent process’ play important roles in strategy formulation and management (Albrechts, 2004; Whittington et al., 2006). These findings emphasise that any framework designed to inform strategic planning and management of transformative change in urban infrastructure needs to involve both strategy content and strategy processes.

2.1.4. Actors and institutions

This research takes an explicitly structural and functional perspective, exploring the phenomena of dynamic transformative change at a higher analytic level than that of individual or organisational actors. Notwithstanding this, actors are clearly fundamental for enabling systemic socio-technical change in a system such as urban water servicing. The research considers this agency by examining how it affects the system function. In other words, the outcomes and impacts of strategic initiatives are investigated, rather than actor psychology, power relationships or the political dimensions of transformative change. In contrast to actor-oriented research, the outcomes of this thesis are focused on deriving implications for the functional use of strategic action and policy decisions to drive a system towards a desired trajectory.

To link the structural and functional concepts of transformative dynamics with an understanding of how actors can influence a system, this research draws on the research field of new institutionalism. Gidden's structuration theory (1984) is at the foundation of this scholarship, perceiving human action as both being constrained by social structures and reproducing social structures. These social structures are considered to be 'rules' that structure how individuals and organisations behave (e.g. Ostrom, 2005), and in turn, it is individuals and organisations that uphold and shape these rules.

Scott (2008) defines social structures as institutions and identifies three analytical elements that comprise institutions and therefore shape the practices of actors. Regulative institutional elements are typically formal social structures that are monitored and evaluated, such as rules, laws and sanctions (informal systems of rules may also be regulative). Normative elements define the goals of a system through specifying the values, norms and standards that are expected to be upheld within the institution. Cultural-cognitive elements encompass the common beliefs, logics and meaning that are shared within an institution, resulting in actor behaviours and routines that often seem instinctive or taken for granted. These three institutional pillars encompass the symbols, practices and material resources in a system.

Building on this framing, processes of institutional change are fundamental for this research. Strategic initiatives to enable transformative change must act on each of Scott's (2008) three institutional pillars in order to radically reshape the structures and practices of an urban water system. The concept of institutional work (Lawrence and Suddaby, 2006) considers the purposive action of individuals and organisations aimed at creating, maintaining and disrupting institutions. Linking the dynamics of transformative change with the concept of institutional work mechanisms provides insight into how strategic initiatives can influence the direction and pace of change in a system.

2.1.5. Theoretical positioning of the thesis

Figure 2 synthesises the above brief introduction to the main theoretical bodies that inform this research, showing where the thesis topic and conceptual framing is positioned within literature.

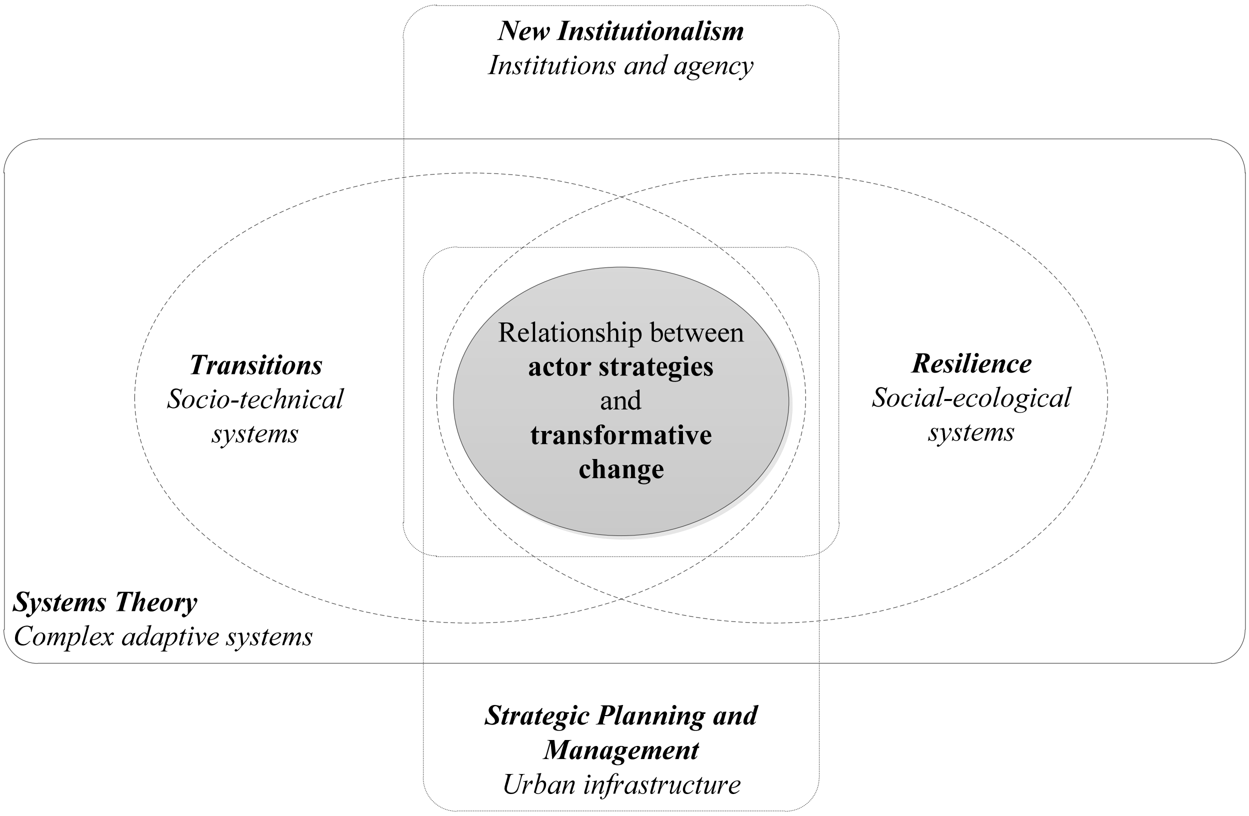

Figure 2. Location of research within theory

2.2. Publication 1: Diagnosing transformative change in urban water systems: Theories and frameworks

2.2.1. Introduction

Chapter 2.1 located this research within established theoretical bodies of work, concluding that a framework for diagnosing the transformative capacity of an urban water system would need to be underpinned by a complex adaptive systems approach that can analyse social and biophysical variables in detail. Transitions theory and resilience theory were identified as potentially fruitful research fields to support such a framework's development. Publication 1 continues the literature review by exploring existing frameworks within these areas of scholarship.

First, the article draws on literature to define what is meant by a *diagnostic approach for urban water systems* and uses these insights to develop an operational scope for a diagnostic procedure that is capable of guiding an analyst to select and design strategic initiatives that best fit the current conditions of an urban water system to enable desired system changes.

Second, the article identifies existing analytic frameworks from transitions and resilience literature for detailed review. Amongst other criteria, the frameworks were selected based on their potential for use in a diagnostic capacity. The frameworks are then each applied to a reference empirical case of successful transformative change in the management of stormwater in Melbourne, in order to identify how each could contribute to a diagnostic procedure that has the operational scope developed earlier in the article.

The outcomes of Publication 1 contribute to the third research objective of this thesis, namely to "develop a diagnostic procedure for guiding the selection and design of strategic initiatives that best fit a system's current conditions for enabling systemic transformation" (see Table 2).

2.2.2. Manuscript

Diagnosing Transformative Change in Urban Water Systems: Theories and Frameworks

B.C. Ferguson, R.R. Brown, A. Deletic

Published in Global Environmental Change, 23(1), 264-280.

Abstract: As urban water systems become increasingly stressed from climate change impacts, population growth and resource limitations, there is growing acceptance by scholars and practitioners of the need to transform practices towards more sustainable urban water management. However, insights into how strategic planning should be made operational to enable this transformation are limited; there is a need for a reliable diagnostic procedure that could assist planners, policy analysts and decision-makers in selecting and designing strategic action initiatives that best fit an urban water system's current conditions to enable desired system changes. This paper is the first step in the development of such a diagnostic approach by proposing a scope for an operational procedure that maps a system's current conditions and identifies its potential transformative capacity. It then reviews five existing analytic frameworks, which are influenced by transitions theory and resilience theory, and applies them each to a common empirical case study of successful transformative change in the stormwater management system of Melbourne. In this way, the paper explores how existing frameworks could potentially contribute to a diagnostic procedure for selecting and designing strategic action initiatives from the perspective of dynamic transformative change. The paper found that such a procedure should guide an analyst through steps that develop descriptive, explanatory and predictive insights to inform which strategic action initiatives best fit the current system conditions. The types of insights offered by different analytic frameworks vary, so a diagnostic procedure should be designed with a particular aim, problem or question in mind and the underpinning framework(s) selected accordingly.

Keywords: diagnosis; strategic planning; sustainability; transformative change; transition; urban water

1. Introduction

Urban water systems are under increasing pressure due to climate change, population growth, ongoing urbanisation, environmental pollution, resource limitations and ageing infrastructure. These stresses threaten water supply security, heighten flooding risk and lead to deterioration of urban waterway health in cities around the world (Pahl-Wostl et al., 2010). The ensuing water management challenges will be exacerbated, particularly as global impacts of climate change become more severe (Bates et al., 2008), and there is now a growing awareness and acceptance of the need for urban water servicing to transition to more sustainable approaches so that the acknowledged complexity of interconnected social, technical and ecological challenges can be addressed (e.g. de Graaf and van de Brugge, 2010; Pahl-Wostl, 2009; Truffer et al., 2010).

To tackle the sustainability challenges facing cities, Grove (2009, p. 293) emphasises that development of solutions will require "approaches that perceive cities as complex, dynamic, and adaptive systems that depend upon interrelated ecosystem services at local, regional, and global scales". Strategic planning in urban water sectors does not typically embrace this approach for developing solutions (Dominguez et al., 2009; Truffer et al., 2010). Therefore, system transformation (i.e. fundamental system-wide change in the structure of a system and the way it functions) is required for water servicing in cities to become more sustainable. Transformation in an urban water system would involve radical changes to the way in which water servicing is planned, designed, constructed, operated, managed, governed and valued, in order to achieve more sustainable outcomes. However, transformation of social and biophysical structures and processes is impeded by a range of barriers, including institutional inertia and fragmentation, lock-in due to technological path-dependencies, and inadequate organizational, professional and community capacity to engage in new management practices (Brown, 2008; Farrelly and Brown, 2011; Pahl-Wostl, 2009).

Urban water scholars are currently considering the question of which governance arrangements are suitable for overcoming these barriers to shift towards sustainable urban water management; for example, a network, hierarchical, market or hybrid governance approach (see, for example, van de Meene et al., 2011). However, there remains limited research on how strategic planning should be made operational in order to enable a transformation towards more water sensitive practices (Farrelly and Brown, 2011).

Academic discourse is starting to explore the concept of planning for sustainability in a range of multi-sectoral or administratively integrated systems (for example, energy supply, transportation, natural resources). Recent literature argues for the need to avoid panaceas or blueprints (e.g. Cox, 2011; Ostrom, 2007, 2009; Pahl-Wostl, 2009; Pahl-Wostl et al., 2010), which have been widely critiqued as being too simplistic to cope with the complex, uncertain, nonlinear and changing contexts within which integrated systems are managed. The use of simplistic approaches carries the significant risk that adaptation strategies result in maladaptations, as highlighted by Barnett and O'Neill (2010) for the urban water sector in Melbourne, in which decisions made with good intentions failed to achieve their objectives and increased the vulnerability of the system.

Instead, scholars argue that diagnostic approaches need to be developed, which typically aim to determine the nature, cause or source of some problem, undesirable outcome or system state by taking complexity into account in a systemic fashion (Cox 2011; Ostrom and Cox, 2010; Pahl-Wostl, 2009). Despite these recent calls, to date there has been an absence of published scholarly articles that present a dedicated diagnostic procedure that can be applied in practice with the explicit purpose of determining the potential transformative capacity in urban water systems (or other integrated systems) to assist with the selection and design of strategies (Chapin III et al., 2010; Dolata, 2009; Smit and Wandel, 2006).

Chapin III et al. (2010, p. 247) argue that the scholarly literature currently provides "neither sufficient theory nor empirical evidence to identify [the] relative importance [of different strategic approaches] in the complex dynamics that play out in specific situations". Such insights would be critical for diagnostic procedures that aim to identify which strategic actions are likely to lead to a desired future. For example, a city in drought may lead policy analysts to consider increasing the volumetric water supplies through the introduction of seawater desalination plants and adopting regulative tools such as household water restrictions – both strategic actions. However, without sufficient diagnosis of the transformative capacity of the current system, there may be a poor fit between these strategic initiatives. For example, such initiatives could result in unanticipated and undesirable consequences, such as higher water consumption by communities, increased greenhouse emissions from desalination plants, or loss of critical social infrastructures such as parks, street trees and sports ovals due to water restrictions (Werbeloff and Brown, 2011). This current practical reality is exacerbated by the distinct lack of a reliable diagnostic procedure in the analyst's toolbox. Theoretical and empirical insights are thus required to understand the links between strategic action and the complex dynamics of transformative change in order to develop theoretically grounded frameworks for supporting planning and decision-making in systems where sustainability transformations are desired.

This paper is the first step in the development of a diagnostic procedure that could assist planners, policy analysts and decision-makers in understanding an urban water system's current conditions in order to select and design strategic action initiatives that are likely to enable transformative change. It has two clear objectives. First, it proposes a scope for an operational diagnostic procedure. Second, it reviews existing frameworks that are influenced by transitions theory and resilience theory and applies them each to a common empirical case study of successful transformative change in the stormwater management system of Melbourne. The case study application reveals insights into how each framework could contribute to a diagnostic procedure for selecting and designing strategic action initiatives from the perspective of dynamic transformative change.

The research approach for the first objective involved: (a) reviewing literature on transition studies, resilience thinking, integrated systems and diagnostic approaches in order to define what is meant by a diagnostic procedure for transformative change in urban water systems; and (b) synthesizing findings from the literature review to propose an operational scope for the design of such a diagnostic procedure. The approach for the second objective involved: (a) selecting frameworks identified in the literature review based on criteria derived from the first aim; (b) applying the selected frameworks to a common case study of successful transformative change in an urban water system; and (c) using the findings from the frameworks' application to identify how each could potentially underpin the development of a diagnostic procedure with the operational scope proposed from the first aim.

2. Diagnostic Approaches for Urban Water System Transformation

2.1 Defining an Urban Water System

The first step is to define what is actually meant by urban water system. From a systems thinking perspective, the urban water system consists of many different structures; these may be social (e.g. rules, knowledge, values), ecological (e.g. rivers, wetlands, green infrastructure) or technological (e.g. pipes, pumps, dams). Urban water systems can therefore be understood as social-ecological systems, in which technology provides a critical interface between the social and ecological structures (unlike many natural or common-pool resource systems). In urban social-ecological systems such as water servicing, actors fundamentally shape the functionality of the system by

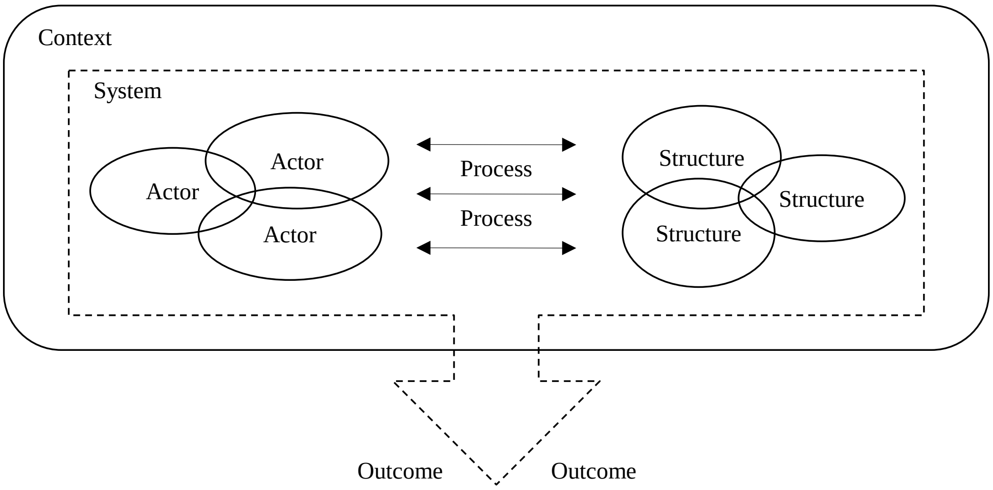

Figure 1. Types of variables in an urban water system.

their implicit and explicit choices about infrastructure and technology (e.g. design standards, licensing agreements, funding priorities).

The urban water system can be considered to comprise five different types of variables (Figure 1). Structures may be either social or biophysical (ecological or technological, for example, institutions, rivers and pipe networks. Processes, which may be social or biophysical, produce and reproduce the system structures. Actors (individuals or organizations) influence system structures by shaping processes through their practices, and in turn, their practices are shaped by the structures. The system's context creates conditions which influence its functioning but are derived outside its boundaries (for example, political, economic, social or environmental domains). Finally, the system's functional outcomes are dependent on the interplay between the other four variables.

Urban water servicing is therefore defined here as a social-ecological system that comprises social and biophysical structures, which actors can shape through different processes under local contextual conditions to achieve outcomes in the system functioning. Understanding how transformative change in such a system can be enabled therefore requires a capacity to analyse each of these variables in detail. Diagnostic approaches are proposed as a useful way forward (Cox, 2011; Ostrom and Cox, 2010; Pahl-Wostl et al., 2010).

2.2 Defining a Diagnostic Approach

Young (2002, 2008) explores the concept of diagnostics, describing the approach as one in which the individual elements of a problem (that are significant for problem-solving) are analysed and then systematically recombined to develop recommendations that will be effective for the particular set of conditions in the case under consideration. A diagnostic approach to gain insights about strategic action for enabling transformative change in an urban water system would therefore involve analysis of the overall system dynamics and of how specific variables (actors, structures, processes, context and outcomes) contribute to these dynamics. The approach should identify how these variables could most effectively be influenced such that recommendations for strategic action can be made. Detailed methods for this type of analysis are yet to be developed for social-ecological systems (Ostrom and Cox 2010), but Cox (2011) offers an exploration of what it means to undertake a diagnosis for achieving some level of generalizability and predictability in order to "make useful prescriptions on how to interact with such complex systems" (p. 347).

For Cox (2011), diagnosing an outcome means asking a series of questions about a particular system. These questions are nested, where the answers from previous questions inform the design of the next questions. These diagnostic questions aim "(1) to identify the causes of a particular outcome in a case; (2) to compare this case to others as a means of deriving generalizations or theories about a set of cases; (3) to use this knowledge to formulate hypothesis or prescriptive predictions" (p. 349). Cox argues that different types of reasoning are needed to analyse the sets of questions corresponding to these different aims. Results-based reasoning uses existing theory to explain the results observed in a particular case (aim 1). Case-based reasoning establishes theory by comparing different cases (aim 2). Rule-based reasoning formulates theory-based rules or hypotheses in order to prescribe change for specific cases (aim 3). Cox highlights the challenge of structuring successive diagnostic questions so they provide the required level of specificity without overwhelming analysts with unnecessary detail and proposes that a multi-level arrangement is a useful approach.

Building on Cox's (2011) concept of progressive questioning and bases of reasoning, Table 1 proposes a nested multi-level sequence of questions about the transformative change dynamics in an urban water system that lead to prediction about what suite of strategic actions would be most likely to enable desired system changes. These questions reveal two critical dimensions of analysis in diagnostic procedures. The first dimension is scale. Analysis needs to be undertaken at scales of both the system as a whole and of individual variables (actors, structures, processes, context and outcomes) in order to address the nested layers of analytic specificity. Ostrom and Cox (2010) refer to this as the decomposability of the system. The second dimension is the dynamism of the analysis: both static snapshots of the system and the dynamic links between system states provide understanding of the system and how its variables could be influenced. The proposed diagnostic questions are plotted against these two dimensions in Figure 2.

Figure 2 highlights that a diagnostic procedure would need to involve multiple analytic perspectives (i.e. covering all four quadrants) in order to guide the selection and design of strategic action initiatives that best fit the current system conditions, and therefore are likely to enable the desired system changes. Choice of analytic lens should align with the specific diagnostic questions being considered for a particular phase of the diagnostic procedure.

.3 Developing an Operational Scope for a Diagnostic Procedure

The results from the previous sections are synthesized here to outline features of a diagnostic procedure for guiding the selection and design of strategic action initiatives that best fit the current conditions of an urban water system to enable transformative change towards a desired future system. The proposed operational scope for such a procedure is outlined below:

- The procedure should guide the analyst to address a nested sequence of diagnostic questions that become increasingly specific as more detailed understanding of the system or problem is gained.

Table 1. Proposed Diagnostic Questions (DQ) for transformative change in urban water systems.

	Aim of Diagnostic Questions (DQ)		
Diagnostic purpose	(1) *Results-based reasoning* to identify the causes of a particular outcome in a case	(2) *Case-based reasoning* to compare this case to others as a means of deriving generalizations or theories about a set of cases	(3) *Rule-based reasoning* to use this knowledge to formulate hypothesis or prescriptive predictions
Retrospective analysis of system problem or system changes	***DQ 1: Take snapshots in time.*** What are the system variables? ***DQ 2: Trace changes over time.*** What changes have occurred in the system variables over time?		
	DQ 3: Identify causal variables. What specific variables are significant for the system problem under consideration? ***DQ 4: Identify causal relationships.*** What are the relationships between these specific variables? ***DQ 5: Trace impacts of causal variables and relationships.*** Why have specific variables and relationships led to the system changes?		
Identification of which strategic actions best fit the current system conditions			***DQ 6: Predict impacts of causal variables and relationships.*** How could specific variables and relationships change the system outcomes?
			DQ 7: Predict suite of strategic action initiatives. What strategic action mechanisms are more likely to enable desired change?

Note: Variables may be actors, structures, processes, context or outcomes.

- The procedure should offer analytic lenses that can address questions related to two critical dimensions: scale (allowing analysis of how individual variables relate to the broader system) and dynamism (allowing analysis of both static snapshots in time and the dynamic links between these system states).
- The procedure should be capable of analysing the five categories of nested variables listed in Figure 1 and their relationships.
- The procedure should incorporate a methodological framework that provides operational guidance for applying the diagnostic procedure in a consistent manner across multiple case studies in order to derive generalized understandings about the set of cases.
- The procedure should be underpinned by conceptual frameworks from multiple levels of theory in order to provide both description and explanation of a system problem or system changes, such that the key features of an observed phenomenon can be theoretically explained in a retrospective analysis.
- The procedure should be capable of applying empirically tested theoretical explanations to formulate hypotheses and provide prediction about the impacts of strategic action on the system's dynamics.
- Ultimately, the procedure should reliably position the analyst to select and design strategic action initiatives that best fit the current system conditions in order to enable the desired system changes.

3. Analytic Frameworks for Sustainability and Transformative Change

3.1 Identifying Existing Frameworks

In the absence of an established procedure for diagnosing the transformative capacity of urban water systems, this section aims to review and apply existing frameworks to reveal how each could potentially underpin the development of such a diagnostic procedure.

A review of literature focused on the themes of sustainability and transformative change in integrated systems identified two main areas of scholarship that aim to understand the dynamics of change in complex systems so that governance and management actions are better designed to enhance the sustainability of the system: transitions in socio-technical systems and resilience of social-ecological systems. The resilience literature focuses on how a system can maintain its function and structure in the face of perturbations in order to be more sustainable. The transitions literature focuses on patterns and processes of change towards a sustainability goal (the focus in this paper is on patterns of societal change rather than the uptake and diffusion of specific technologies).

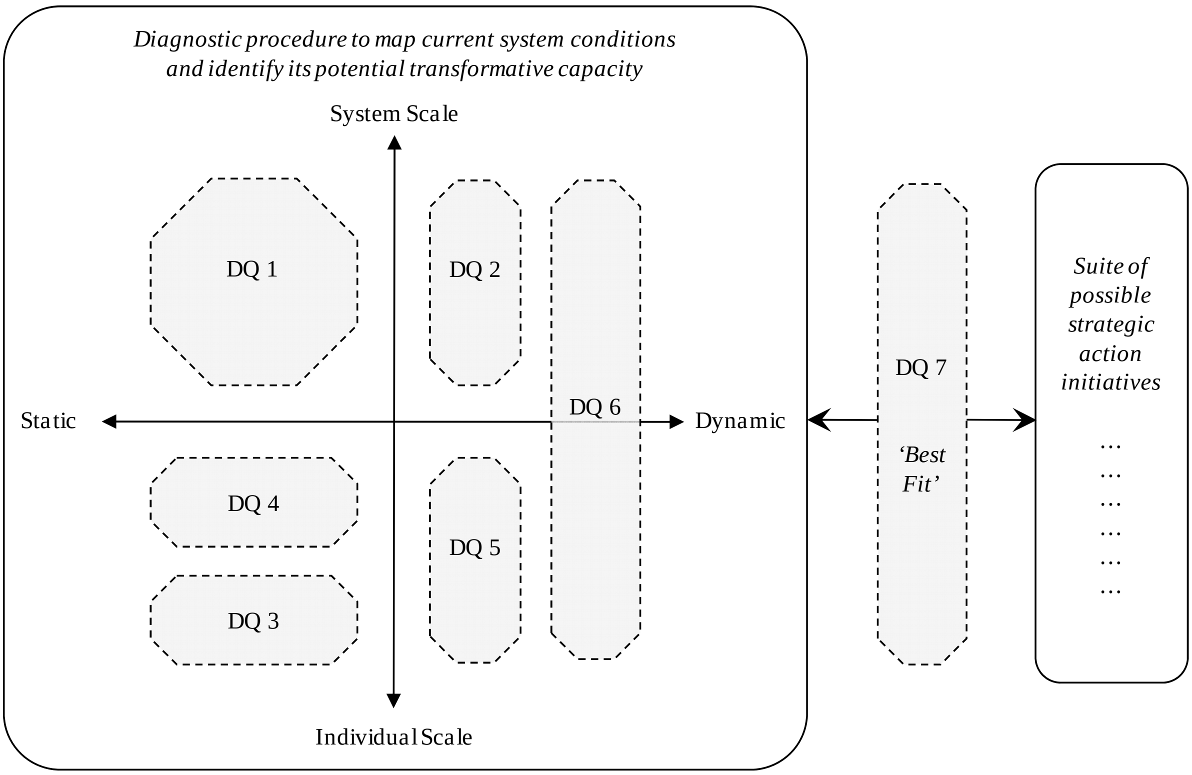

Figure 2. Dimensions of proposed Diagnostic Questions (refer Table 1).

Five analytic frameworks identified in the literature on transitions and resilience were selected for review. Collectively they provide capacity for description, explanation and prediction, such that the different analytic perspectives required for diagnosing the current system conditions and predicting the impacts of changes to specific variables are covered (Diagnostic Questions 1 to 6, proposed in Table 1 and Figure 2). Frameworks for addressing the selection and design of suites of strategic actions to fit the diagnosed conditions (Diagnostic Question 7) are beyond the scope of this paper. Framework selection was further based on the following criteria. The framework: (i) is influenced by the theoretical roots of socio-technical system transitions or social-ecological system resilience; (ii) has been published in peer reviewed literature; (iii) has been applied empirically; (iv) is capable of addressing at least two of the first six diagnostic questions proposed, although it may not have been specifically designed for a diagnostic application; and (v) is capable of investigating at least two of the identified system variable types (Figure 1).

The shortlisted frameworks include: (1) the Social-Ecological System (SES) Sustainability Framework; (2) the Ecosystem Stewardship Framework; (3) the Panarchy Framework; (4) the Multi-Pattern Transitions Framework; and (5) the Management and Transitions Framework. As these frameworks each come from transitions and/or resilience scholarship, they inevitably share theoretical roots, language and conceptual framing. All frameworks are underpinned by a complex adaptive systems perspective and some share particular technical concepts; the major overlaps are highlighted here. Both the Management and Transitions Framework (5) and the SES Sustainability Framework (1) draw on the concept of 'action situations', developed in the Institutional Analysis and Development framework (Ostrom, 2005). The concept of the 'adaptive cycle' (Holling and Gunderson, 2002) is part of both the Ecosystem Stewardship Framework (2) and the Panarchy Framework (3). Both the Multi-Pattern Transitions Framework (4) and the Management and Transitions Framework (5) draw on understandings of multi-level interactions to give insight into the dynamics of transformative change.

Table 2 outlines the attributes of each framework, key references and example empirical applications and Section 3.2 includes a brief overview of each (for further details on each framework, the reader can refer to the literature cited in Table 2). Plotting the frameworks against the dimensions of scale and dynamism shows where each provides analytic focus and indicates which diagnostic questions each framework is capable of addressing (Figure 3).

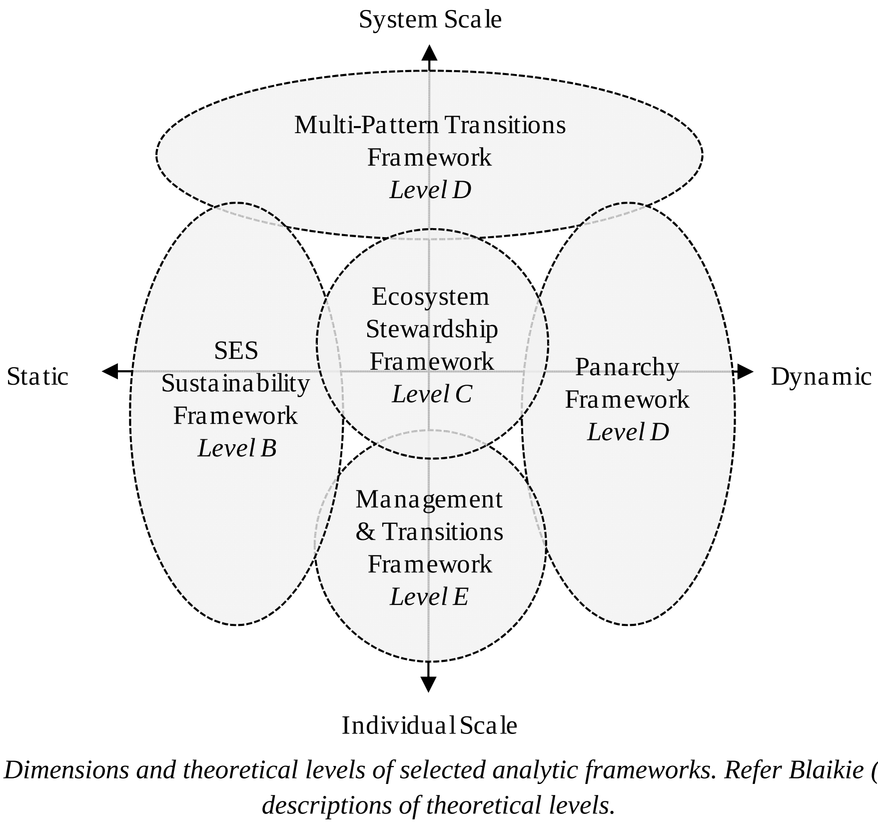

Figure 3. Dimensions and theoretical levels of selected analytic frameworks. Refer Blaikie (2010) for descriptions of theoretical levels.

Table 2. Attributes of selected analytic frameworks.

Attribute	SES Sustainability Framework	Ecosystem Stewardship Framework	Panarchy Framework	Multi-Pattern Transitions Framework	Management & Transitions Framework
Key references	Cox, 2011; McGinnis, 2010 Ostrom, 2007; 2009 Ostrom & Cox, 2010	Chapin III et al., 2009a; 2010	Berkes et al., 2003 Folke, 2006 Gunderson & Holling, 2002	de Haan, 2010 de Haan & Rotmans, 2010	Pahl-Wostl, 2009 Pahl-Wostl et al., 2010
Theoretical roots	Resilience; social-ecological systems; institutional analysis & development	Resilience; ecology; social-ecological systems; natural resource management	Resilience; ecology; social-ecological systems, complexity	Transitions; complexity; technology diffusion; innovation	Transitions; social-ecological systems; social learning; institutional analysis & development
Key concepts	Nested tier of variables; networked action situations	Vulnerability; adaptability; resilience; transformability	Adaptive cycle; panarchy; rigidity trap; poverty trap	Transition condition; transition pattern	Action situation; policy cycle; social learning
Level of theory (Blaikie, 2010)	B – Taxonomical system to organise data	C – Conceptual framework to systematise relationships between concepts	D – Theoretical system to explain conceptual relationships	D – Theoretical system to explain conceptual relationships	E – Operational scheme to test theoretical systems with empirical data
Purpose	Organise variables typologically to aid meta-analysis of case studies	Identify suites of strategies to support ecosystem stewardship	Analyse disturbances and adaptive capacity in dynamic systems	Analyse dynamics of societal transitions	Guide management of water systems by comparative analyses of case studies
Diagnostic Questions (Table 1, Figure 3)	DQ 1, DQ 3, DQ 4	DQ 1, DQ 2, DQ 3, DQ 4, DQ 5, DQ 6	DQ 2, DQ 5, DQ 6	DQ 1, DQ 2, DQ 6	DQ 3, DQ 4, DQ 5, DQ 6
Example empirical applications	Intentional communities in Indiana (Fleischman et al., 2010); Voluntary action in tourism for common-pool resource management (Blanco, 2011)	Impact and response of Hurricane Katrina (Chapin III et al., 2010); Individual key concepts are empirically applied in Chapin III et al. (2009).	Boreal forests in Sweden (Moen & Keskitalo, 2010); Management of the Galapagos Islands (González et al., 2008)	Dutch health care system (Van Raak & de Haan, 2012); Overcoming barriers in the transition from piped to alternative drainage systems (Ashley et al., 2011)	Flood protection in the Tisza basin (Knieper et al., 2010); Groundwater in the Upper Guadiana Basin (Knüppe & Pahl-Wostl, 2011)

Table 2 highlights that the frameworks are not all designed to provide the same level of theoretical insights. Blaikie (2010) describes five levels of theory that “move from ‘mere’ description, through patterns of relationships, to explanatory schemes, and then to empirical testing of the theoretical ideas” (p. 130). These five levels are: (A) ad hoc classificatory systems to summarize data; (B) categorical or taxonomical systems to organize data; (C) conceptual frameworks to systematize relationships between concepts; (D) theoretical systems to explain conceptual relationships for categories of data; and (E) operational schemes to test theoretical systems with empirical data (Denzin in Blaikie, 2010). Identifying which level of theory each analytic framework is designed to occupy is a critical first step in understanding how it could be used in a diagnostic procedure, as it determines what type of theoretical insights the framework can offer. For example, the SES Sustainability Framework provides a categorical system for organizing data (Level B), which means it can offer descriptive insights. In contrast, the Ecosystem Stewardship Framework offers explanatory insights, as it provides a system for showing how individual concepts are related (Level C). Similarly, the Panarchy Framework and the Multi-Pattern Transitions Framework provide theoretical explanations for the conceptual relationships in different parts of a system (Level D). The Management and Transitions Framework could potentially offer predictive insights, as it provides operational steps for empirically testing theoretical explanations (Level E).

3.2 Applying the Existing Frameworks

As already discussed, Figure 3 highlights the differences between the analytic focus and theoretical level of the five frameworks, as well as a hypothesis of which of the proposed diagnostic questions each is capable of addressing, according to their quadrant location. These insights provide an initial indication of how each framework could most effectively be used in diagnostic procedure (the second objective of the paper). This section builds on these literature-informed insights by applying each framework to a reference empirical case of recent transformational change in an urban water system.

The empirical case, herein referred to as the “reference case study”, was a grounded historical analysis of how urban stormwater management in Melbourne was transformed from traditional hydraulic conveyance to an approach that focuses on keeping water in the landscape and providing water quality treatment to improve waterway health. This represented a radical change in philosophy and practice over the period 1960 to 2006 (for full details of the case study see Brown and Clarke, 2007). The reference case study is significant as an international example of how a leading city from a waterways management perspective (Jefferies and Duffy, 2011; Roy et al., 2008) was able to transform mainstream policy and on-ground practice to incorporate management measures that address the quality of stormwater runoff. It is important to highlight that the practice of urban stormwater quality management is still in an embryonic state for the majority of cities in the industrialised world, yet stormwater pollution is widely acknowledged as a critical environmental degradation problem (e.g. Burton and Pitt, 2002). Therefore, this unique case of successful change in practice was considered ideal for the purpose of being a common reference case study for considering each of the frameworks.

The reference case study offers critical understanding of transformative processes that occurred in an urban water system. While the frameworks have each been applied empirically to a range of different cases (refer Table 2), the value of applying them to this particular reference case is that it provides a common base from which to contrast the different types of diagnostic insights each framework reveals and therefore their potential to describe, explain and predict transformative success in an urban water system as part of an overall diagnostic procedure. The basic case study details are provided here for background and context but the empirical case itself is not the focus of this research.

The context for the reference case study is the management of diffuse sources of pollution from the stormwater drainage system in Melbourne. Melbourne is an Australian city of 3.6 million people that spans an area of around 1500 km2. The stormwater drainage system in Melbourne is separated from the sewerage system, with minor stormwater runoff directed to local waterways via a network of pipes and drainage channels, before being discharged to Port Phillip Bay. Runoff from major storm events flows overland along roads, easements and designated floodways towards the receiving creeks and rivers. Only 25% of Melbourne’s waterways are considered to be healthy (Melbourne Water and Environment Protection Authority Victoria, 2009), while the rest are rated as having moderate, poor or very poor water quality. Point sources of pollution, such as industrial effluent, were largely addressed with the widespread availability of sewerage networks from the 1960s. However the diffuse nature of stormwater has made it more difficult to manage, despite broad recognition that it is a key source of pollution for urban waterways.

The key developments during the period investigated in the reference case study are summarized as follows: (a) from 1960, growing community awareness and concern about the poor health of

Melbourne's waterways led to a scientific focus on understanding the causes of urban waterway degradation and developing methods for reducing stormwater pollution; (b) new innovative technologies for improving the quality of stormwater before it enters urban waterways were developed during the 1990s; and (c) towards the end of the case study period in 2006, practices that prioritised urban stormwater quality management were institutionalized, fundamentally changing the direction of mainstream stormwater management policy (Brown and Clarke, 2007).

This paper reinterprets the reference case study through the application of the five frameworks presented in Table 2. The historic account presented in Brown and Clarke's (2007) case report was handled as secondary data in the form of a narrative (see, for example, Creswell, 2007) that contains information about the causal relationships in the chronological sequence (Yin, 2009). The narrative content was then qualitatively analysed through each separate theoretical lens offered by the different frameworks. These results were then used to assess the capacity of each framework to address the different elements of the proposed scope for a diagnostic procedure for transformative change in urban water systems – (a) diagnostic questions, (b) variables and relationships, (c) methodological guidance and (d) theoretical insights.

3.2.1 Social-Ecological System (SES) Sustainability Framework

As outlined in Table 2, the SES Sustainability framework has been developed specifically in response to scholarly calls for diagnostic approaches to analyse complex resource systems (McGinnis, 2010; Ostrom, 2007, 2009; Ostrom and Cox, 2010). The framework builds on the foundation of Ostrom's Institutional Analysis and Development (IAD) framework (2005), by integrating concepts from studies of ecological systems, socio-economic systems, and linked social-ecological systems. The framework aims to organise key variables that are considered relevant for the governance of social-ecological systems (particularly common-pool resources) into multiple levels, to aid analysts in identifying factors that may affect how likely particular policies are to enhance sustainability in different types of resource systems. It explores the nested entities of a social-ecological system's resource systems, resource units, the actors involved and the governance systems, which are embedded in a broader societal, political, economic and environmental context. These entities interact with each other in a series of networked focal action situations, producing patterns of interactions and outcomes that change over time and in space (Ostrom and Cox, 2010).

Application of the SES Sustainability Framework to the reference case study reveals there were multiple first-tier entities of Melbourne's stormwater system (Figure 4a). The attributes (second tier) of each of these entities are not presented in this paper due to space limitations; however the SES Sustainability Framework provides a means of categorising nested tiers of attributes and sub-attributes that describe each of these entities in greater detail. This classification system is intended to allow researchers to conduct meta-analyses of similar cases to identify patterns in how different attributes contribute to a system's sustainability.

Application of the framework further reveals there were six distinct Focal Action Situations that represent key processes in the reference case study: society and politics (present at 1960); rule-making, provision, implementation and end use (emerging during the mid 1990s); and monitoring and sanctioning (emerging in 2006) (Figure 4b). These action situations create a network, with outcomes of one action situation providing inputs to an adjacent action situation (McGinnis, 2010). There was significant overlap in the actors that were involved in the rule-making, provision and implementation action situations, indicating their potential for self-organisation. In particular, the waterway manager and the municipalities were shown to be key actors in almost all the action situations, highlighting the need for positive interactions between these key actors and their relative importance for successful functioning of the system. Further analysis could show how different attributes of the entities influenced the interactions in each type of action situation at different snapshots in time.

3.2.2 Ecosystem Stewardship Framework

The Ecosystem Stewardship Framework draws on research in ecology, biodiversity conservation and natural resource management, as well as human wellbeing and socio-economic sustainability (Table 2). It integrates these approaches in an overarching framework to foster social-ecological sustainability by guiding the identification of strategies to reduce system vulnerability to known stresses, to proactively prepare for and shape system change, and to avoid or escape unsustainable trajectories by enabling system transformations. The Ecosystem Stewardship Framework consists of a suite of four conceptual approaches for enhancing sustainability: vulnerability, adaptive capacity, resilience and transformability of a system (Chapin III et al., 2009, 2010). Figure 5 presents the overarching framework, which explains how different system drivers, responses and outcomes are conceptualised.

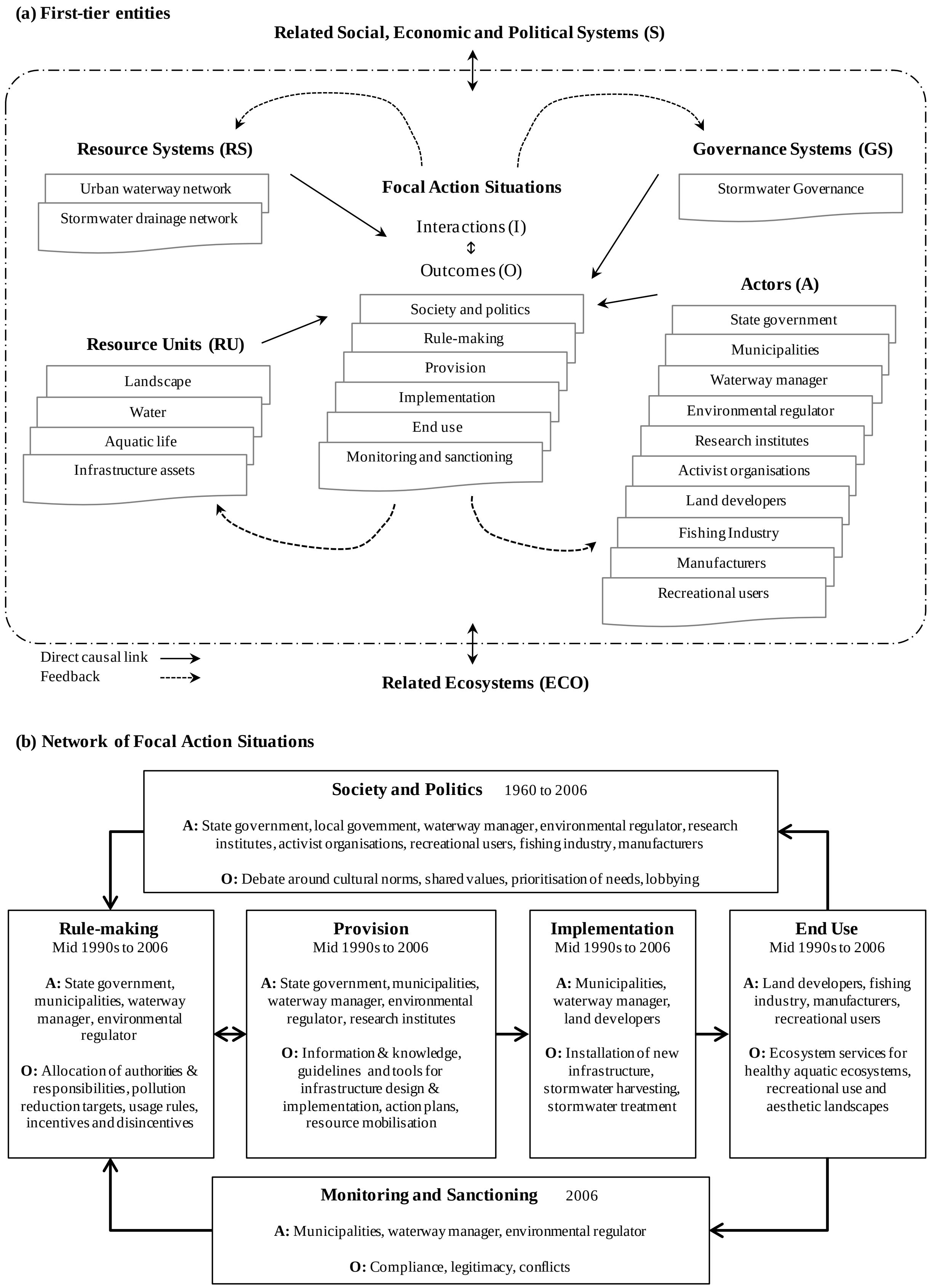

Figure 4. Application of SES Sustainability Framework to Melbourne's stormwater quality management system: (a) Multiple first-tier entities; (b) Network of focal action situations for different periods of time during the reference case study (A = Actor, O = Outcome).

Application of the Ecosystem Stewardship Framework to the reference case study reveals four distinct phases in the system's evolution towards stormwater quality management: ignorance of the negative impacts of traditional channelized drainage infrastructure on urban waterway health (Phase 1); growing awareness of these negative impacts (Phase 2); development of innovative alternatives to traditional drainage infrastructure (Phase 3); and transformation of stormwater management by the mainstreaming of decentralised stormwater quality technologies (Phase 4) (Table 3).

The external stress in the system was that urbanisation of the landscape resulted in large volumes of highly polluted stormwater being generated during rainfall events (Phases 1 to 4). The impact of this stormwater for Phases 1 to 3 was that high levels of pollution entered urban waterways and resulted in an unintended transformation, namely that the waterways became highly degraded. From Phase 2, however, awareness of the impacts of polluted stormwater on urban water health grew and the role of channelized drainage infrastructure in exacerbating these impacts was realised. From Phase 3, a key change in the social learning dimension occurred, as new decentralised stormwater quality management alternative technologies were innovated. This led to a build up of human and social capital in terms of knowledge, skills and networks centred on decentralized stormwater treatment technologies. As capital continued to increase, more stormwater treatment technologies were installed to treat the stormwater before it entered the waterways, the system's sensitivity was reduced. These positive dynamics continued such that the stormwater quality management approaches started to break into the mainstream during Phase 4, allowing the system to continue along the path of the actively navigated transformation.

3.2.3 Panarchy Framework

As Table 2 outlines, Panarchy is a conceptual framework within resilience theory that has been developed to enable understanding and analysis of the dynamics of social-ecological systems and their implications for governance (Berkes et al., 2003; Folke, 2006; Gunderson and Holling, 2002). The key conceptual element of the framework is the adaptive cycle; it represents a fundamental unit of dynamic change and is used to distinguish periods of incremental growth and dynamic stability alternating with periods of change and variety within a complex system that responds to disturbances over time (Figure 6c). A panarchy represents a system hierarchy as a nested set of adaptive cycles and is conceptually used to understand how cross-scale processes shape ecological and social dynamics in a healthy social-ecological system that can invent and experiment. Each hierarchical level operates at its own pace, protected from above by slower, larger conservative levels but invigorated from below by faster, smaller cycles of innovation. Gaining insight into the adaptive cycles and their scales of a social-ecological system provides the ability to identify when the system is capable of accepting positive change and when it is vulnerable to disturbance (Holling et al., 2002).

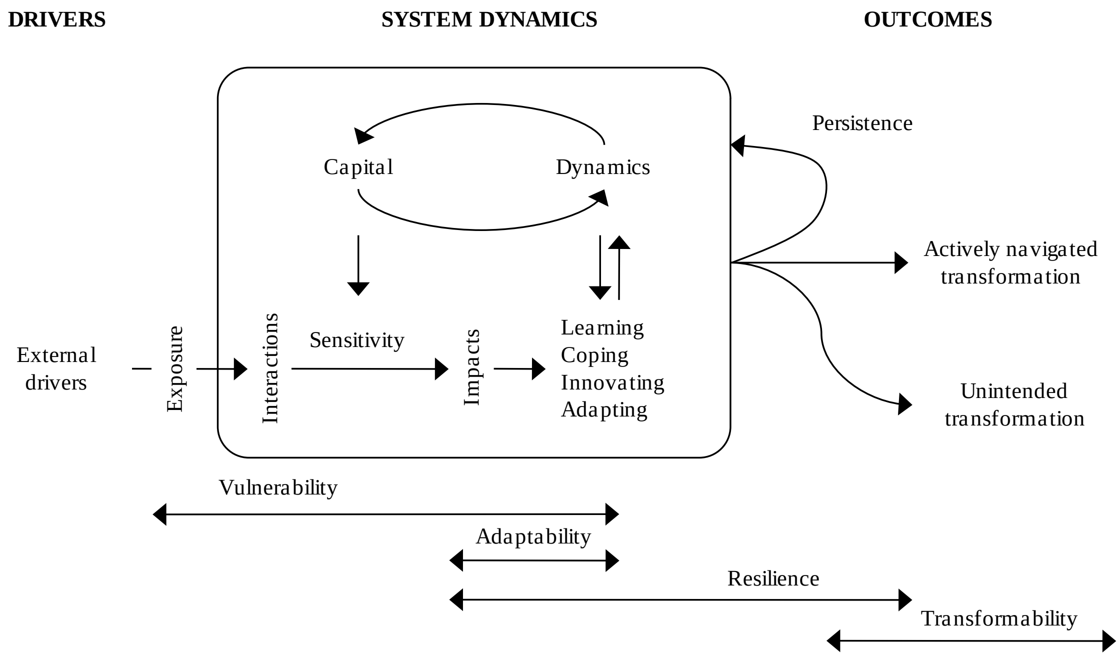

Figure 5. Ecosystem Stewardship Framework: Identifying vulnerability, adaptability, resilience and transformability strategies to foster sustainability (Chapin III et al., 2009, 2010).

Table 3. Application of Ecosystem Stewardship Framework to Melbourne's stormwater (SW) quality management system: System dynamics for different phases.

	Phase 1: 1960-1979 **Ignorance of negative impacts**	**Phase 2: 1980-1995** **Awareness of negative impacts**	**Phase 3: 1996-2005** **Development of innovative alternatives**	**Phase 4: 2006-** **Transformation of mainstream approach**
Vulnerability				
External drivers	Increasing urbanization, rainfall events	Increasing urbanization, rainfall events	Increasing urbanization, rainfall events	Increasing urbanization, rainfall events
Interactions	Large volumes of polluted SW generated	Large volumes of polluted SW generated	Large volumes of polluted SW generated	Large volumes of polluted SW generated
Impacts	Increasing volumes of water and pollution enter waterways	Large volumes of water and pollution enter waterways	Large volumes of water and pollution enter waterways	Decreasing volumes of water and pollution enter waterways
Social learning				
Learning	-	Understand impacts of SW	Develop options for SW treatment	Improve performance of decentralized SW treatment technologies
Coping	-	Regenerate local waterways	Regenerate local waterways	Regenerate local waterways
Innovating	-	-	Develop decentralized SW treatment technologies	Develop decentralized SW treatment technologies
Adapting	-	-	-	Implement mainstream policy changes
Capital				
Natural	Waterways	Waterways	Waterways	Waterways, green infrastructure
Built	Central drainage infrastructure	Central drainage infrastructure	Central drainage infrastructure Demonstration SW treatment infrastructure	Central drainage infrastructure Decentralized SW treatment infrastructure
Human	Centralized management skills	Centralized management skills	Centralised management skills	Centralised management skills
Social	Professional networks	Professional networks	Professional networks, innovation networks	Science-policy networks
Dynamics				
Natural	Pollutant flows	Pollutant flows	Pollutant flows	Pollutant flows
Built	Land development, infrastructure building	Land development, infrastructure building	Land development, infrastructure building	Land development, infrastructure building
Human & Social	-	-	Science-policy network building	Science-policy network building
Outcomes				
Persistence	SW pollution impacts on waterways not yet acknowledged so persistence of existing approaches	-	-	-
Actively navigated transformation	-	-	Initial steps taken to prepare for system change towards decentralized SW technologies	Activities for mainstream adoption of decentralized SW treatment technology alternatives
Unintended transformation	Continue building centralized infrastructure, which causes ongoing degradation of urban waterways	Continue building centralized infrastructure, which causes ongoing degradation of urban waterways	Continue building centralized infrastructure, which causes ongoing degradation of urban waterways	-

(a) Sequence of Developments

	Mainstream Policy	**≈ Year**
M1	Widespread implementation of channelized drainage infrastructure	1960
M2	Stormwater policy in a Rigidity Trap, as path-dependent approaches continue	1989
M3	Existing policy fails to meet community expectations about waterway health	1990
M4	Mainstream policy failure creates a window of opportunity for innovative approaches from the lower scale to influence the mainstream	1995
M5	Policy alternatives developed for managing stormwater quality as part of the mainstream	2000
M6	Adoption of new policy alternatives by mainstream	2002
M7	Alternatives are of a different paradigm; a transition in the mainstream approach occurs	2003
M8	Policy plans for the new mainstream approach are still under development	2006
	Innovative Approaches	
I1	New research and partnerships to develop stormwater quality treatment technology	1990
I2	Development of new technologies, networks, design tools and guidelines	2000

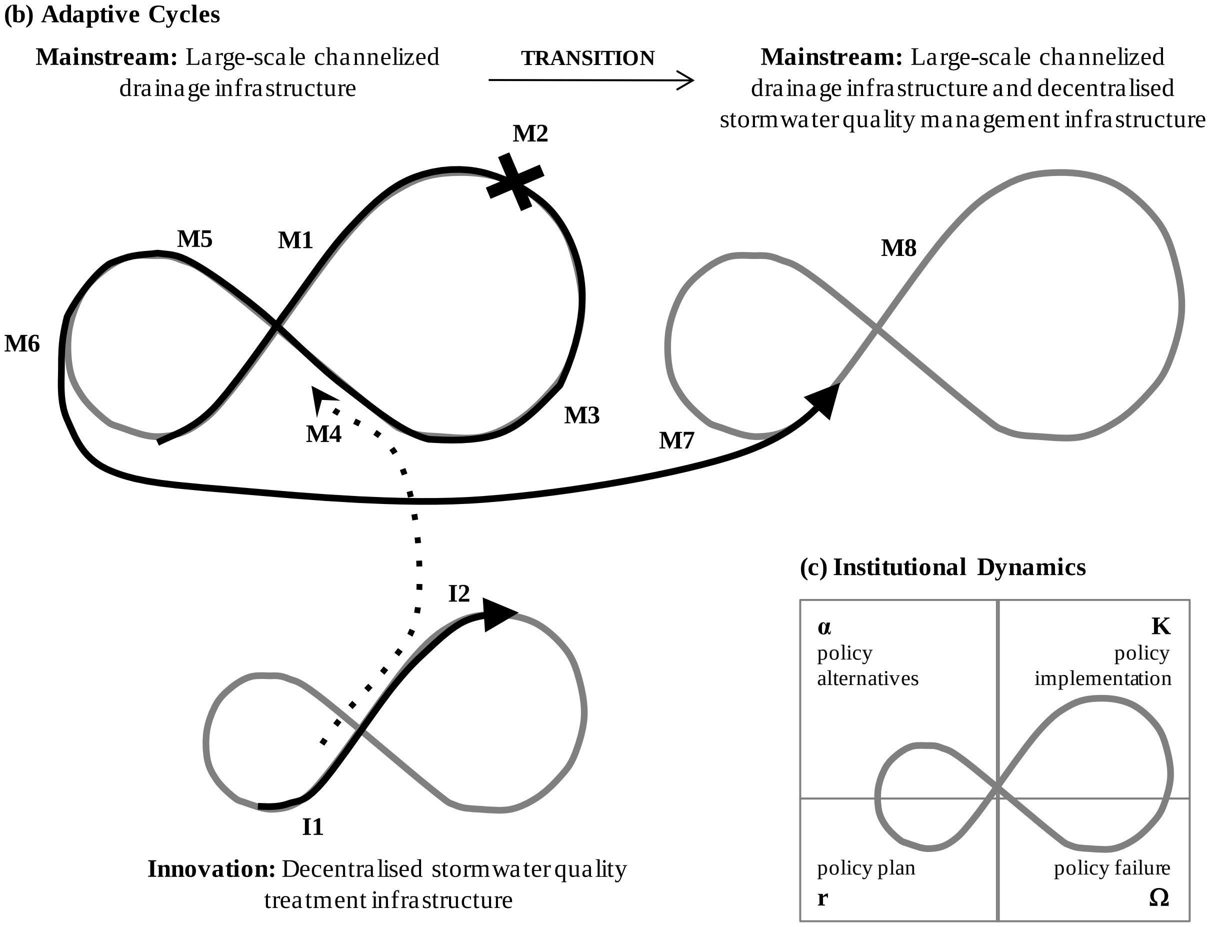

Figure 6. Application of Panarchy Framework to Melbourne's stormwater quality management system: (a) Description of the sequence of key developments in the case; (b) Adaptive cycles for mainstream policy and innovative approaches; (c) Four-phase adaptive cycle heuristic for institutional dynamics (adapted from Holling and Gunderson, 2002; Janssen, 2002).

Application of the Panarchy Framework to the reference case study reveals two hierarchical scales for stormwater management; the higher scale represents mainstream policy and the lower scale represents innovative approaches (Figure 6a, b). The adaptive cycle at the mainstream scale reflects a long slow period of policy development around large-scale channelized drainage infrastructure that ignored stormwater quality issues (M1). Despite growing community awareness and expectations around environmental issues, mainstream policy was stuck in a "rigidity trap" (M2), which meant there was no adaptation to the stormwater management approach. Eventually community pressure forced mainstream stormwater managers to acknowledge that policies based solely on stormwater quantity were failing (M3) and the neglect of stormwater quality issues was no longer acceptable for society. During the same period of time, the adaptive cycle at the innovation scale reflects a period of developing new research, partnerships and technologies around stormwater quality management (I1, I2). The policy failure at the mainstream scale (M3) offered a window of opportunity for these innovative developments to offer a range of infrastructure options to support the development of mainstream policy alternatives (M4, M5). These alternative policy options were underpinned by a new paradigm, based on small-scale decentralized stormwater quality management infrastructure. The mainstream adoption of this alternative approach (M6) is reflected by a new and different adaptive cycle at the mainstream level (M7); in other words, transformative change took place. The transformation, however, is only partially complete as policy plans are still in development and there is much growth needed before the new approaches are implemented and stabilised as mainstream (M8).

The key insights about the reference case study revealed by the Panarchy Framework include the impact of a changing context (community pressure) on mainstream policy and of innovative alternative structures on mainstream structures at particular points in time, which in turn influenced the changing outcomes of the system.

3.2.4 Multi-Pattern Transitions Framework

The Multi-Pattern Transitions Framework is a recent development within transition theory, which aims to understand both the dynamics of transformative change in societal systems and ways in which such transformations can be governed (Table 2). Transition theory draws on complexity theory, integrated assessment, technology diffusion, innovation and governance (Geels, 2004; Rotmans and Loorbach, 2009; Rotmans et al., 2001). In this approach, transitions are conceptualised as a shift from a relatively stable system, through a period of rapid change to a new, hopefully more sustainable, period of relative stability (Rotmans and Loorbach, 2009). The framework builds upon established transitions concepts of the multi-level perspective (distinguishing between changes that occur at and between the landscape, regime and niches of a system) (e.g. Geels, 2004) and multi-phase change (describing a typical transition pathway through phases of pre-development, take-off, acceleration and stabilisation) (e.g. Rotmans et al., 2001).

The Multi-Pattern Transitions Framework conceptualizes a set of subsystems, or constellations, each of which functions to meet certain societal needs. Each constellation comprises social and biophysical structures, including formal and informal institutions, ecosystems, infrastructure and technologies. The influence of a constellation on the overall system functioning is reflected by its “power”, or size, determining whether it is a regime, niche-regime or niche. Actors are not explicitly described in any one constellation because they can have agency in multiple constellations. Constellations interact with each other and the landscape that embeds the system. Transitions are structural shifts in how the system functions to meet needs, which in this framing means a different power balance between constellations. To explain these dynamic interactions, the framework identifies conditions for transitional change (tension, pressure and stress), which drive different transition patterns (top-down or ‘reconstellation’; bottom-up or ‘empowerment’; and internal or ‘adaptation’). Over time these patterns can concatenate into pathways that lead to a transition. The transition pathway experienced depends on the power dynamics between the existing regime, upcoming niches and landscape tensions (de Haan, 2010; de Haan and Rotmans, 2011).

Application of the Multi-Pattern Transitions Framework to the reference case study reveals the dynamics of the system-wide changes in the period of analysis (Figure 7). From 1960 to 1989, growing community engagement with the urban landscape and awareness of environmental issues (modern environmentalism) placed the channelized drainage regime in a condition of tension and led to a significant increase in the degree to which society’s need for ecosystem protection was expressed. Between 1990 and 1999, the unmet societal need for ecosystem protection led to the emergence of a decentralized stormwater treatment niche. As new technologies for improving stormwater quality were developed and implemented, the niche offered an increasingly viable alternative to channelized drainage systems, leading to its empowerment to become a niche-regime in the period 2000 to 2006. The empowered decentralized stormwater treatment niche-regime placed the regime in a condition of pressure (as well as ongoing tension from the landscape), leading to a transition pattern of disempowerment. The conditions at 2006 indicate that future developments could see further disempowerment of the regime such that it either absorbs the niche-regime by adapting the way in which it functions, or is replaced by the niche-regime in a complete system transition.

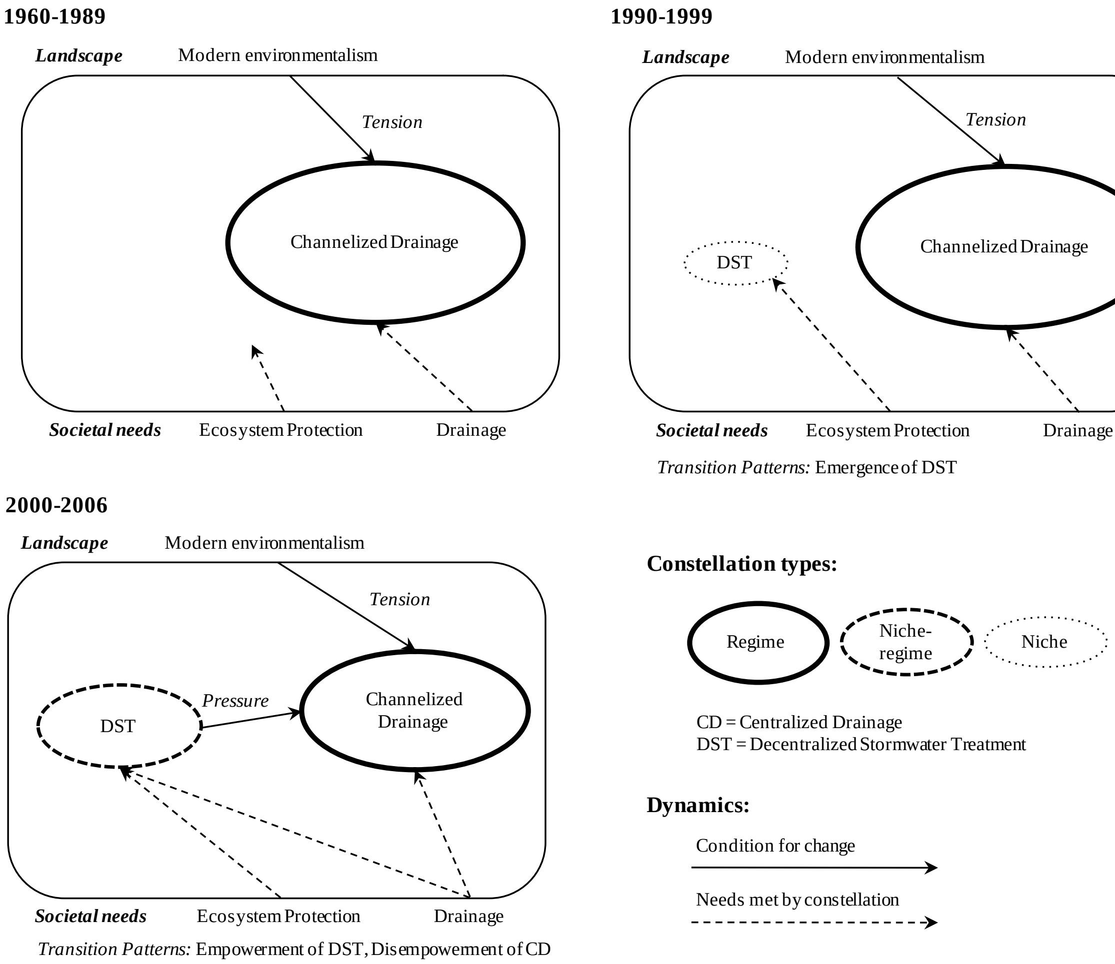

Figure 7. Application of Multi-Pattern Transitions Framework to Melbourne's stormwater quality management system: Conditions and patterns for the transition to stormwater quality management.

3.2.5 Management and Transitions Framework

As outlined in Table 2, the Management and Transitions Framework was developed as a conceptual and methodological framework to support analysis of governance regimes in water systems, in particular by providing a structured approach to enable meta-analyses of multiple cases so that generalized understanding of how transitions in complex water systems can be gained (Knieper et al., 2010; Pahl-Wostl et al., 2010). The framework draws on Ostrom's Institutional and Analysis Development framework (2005) and seeks to translate it for specific application to provide guidance for implementing transition processes in water systems by drawing on literature from adaptive management and social learning (Pahl-Wostl, 2009; Pahl-Wostl et al., 2010). Single, double and triple loop social learning (Hargrove, 2002) is one of the conceptual bases of the framework, developed from the premise that transitional change will only occur with social learning that proceeds through all three loops (Pahl-Wostl, 2009; Pahl-Wostl et al., 2010). The framework enables analysis of how different types of action situations influence formal processes (as part of the policy cycle) and informal processes (as part of the social learning cycle), to achieve institutional, knowledge or operational outcomes for the system.

Application of the framework to the reference case study reveals a complex web of thirty individual but connected action situations that represent the major processes in the development and implementation of stormwater quality management policies and measures between 1960 and 2006. Table 4 lists each action situation and its key attributes while Figure 8 plots how the outcomes of one action situation lead directly to another, therefore they should be read in conjunction with each other. The results presented in this paper are simplified due to space limitations (further analysis reveals insights about the type of action situations – constitutional, collective-choice or operational – and the type of outcomes – institutions, knowledge or operational).

Table 4. Application of Management and Transitions Framework to Melbourne's stormwater quality management system: Individual action situations in the development and implementation of stormwater quality management policies and measures. (This should be read in conjunction with Figure 8.)

Start Year	Action Situation	#	Type	Spatial Level	Lead Actor
1960	Promotion of public and media campaigns	1	Informal	Local	Local
1970	Regulation of pollution emissions	2	Formal	State	State
1973	Study of environmental conditions in receiving waterway	3	Formal	State	National
'75-88	Development of environment protection policy	4	Formal	State	State
1992	Activities of Cooperative Research Centres	5	Formal	National	National
1995	Development of discourse on stormwater quality management	6	Informal	National	National
1996	New study of environmental conditions in receiving waterway	7	Formal	State	National
1996	Amendment of state policy to reflect pollution reduction targets	8	Formal	State	State
1996	Adoption of pollution reduction targets	9	Formal	State	State
1996	Introduction of land developer charges for stormwater quality	10	Formal	Local	State
1996	Activities of state-led stormwater committee	11	Informal	State	State
1997	Implementation of demonstration projects	12	Informal	Local	National
1997	Training of practitioners	13	Informal	State	National
1999	Development of stormwater pollutant reduction targets	14	Formal	State	State
1999	Development of best practice guidelines	15	Informal	State	State
1999	Upgrade of treatment plant, construction of wetlands	16	Formal	Local	State
2000	Activities of state-led stormwater action program	17	Formal	State	State
2000	Development of stormwater management plans	18	Formal	Local	State
2000	Activities of capacity building organisation	19	Informal	Local	State
2000	Adoption of pollution reduction target from wetlands	20	Formal	State	State
2000	Construction of wetlands to achieve pollution reduction target	21	Formal	Local	State
2000	Activities of stormwater quality focused conferences	22	Informal	National	National
2001	Development of software tools	23	Informal	National	National
2003	Establishment of formal stormwater agreements	24	Formal	State	State
2004	Development of stormwater planning framework	25	Informal	State	Loc., St.
2005	Introduction of stormwater quality offset strategy	26	Formal	State	State
2005	Development of stormwater treatment design guidelines	27	Formal	Local	Local
2005	Development of stormwater engineering procedures manual	28	Formal	State	State
2006	Amendment of state planning provisions	29	Formal	State	State
2006	Development of national stormwater quality guidelines	30	Formal	National	National

Figure 8 reveals that informal learning processes (double and triple loop learning) were critical factors for driving changes in the way in which stormwater was managed. Informal action situations covered all phases in the learning cycle and formal action situations typically emerged from outcomes of previous informal action situations. There was a concentration of formal action situations in the state domain and the majority of action situations were led by state actors, with a clear lack of locally led or based processes. Most of the formal action situations were focused on developing policy, operational goals and measures, with much less emphasis on both strategic goal setting and monitoring as the two extremes of the policy cycle. These gaps potentially indicate where future efforts should be focused to stabilise the implementation of stormwater quality management in the mainstream.

3.3 Developing a Diagnostic Procedure with Existing Frameworks

The application of each analytic framework to a common case study enables exploration of their potential to underpin the development of a diagnostic procedure for guiding strategic action initiatives to enable transformative change in an urban water system. Tables 5, 6 and 7 draw on the findings from the reference case study applications to demonstrate how each framework relates to the operational scope for a diagnostic procedure proposed in Section 2. The aim of these tables is not to directly compare the five selected analytic frameworks; their different purposes and theoretical levels means direct comparison is neither possible nor desirable. The tables aim to summarize insights about how each framework could individually contribute to a diagnostic procedure.

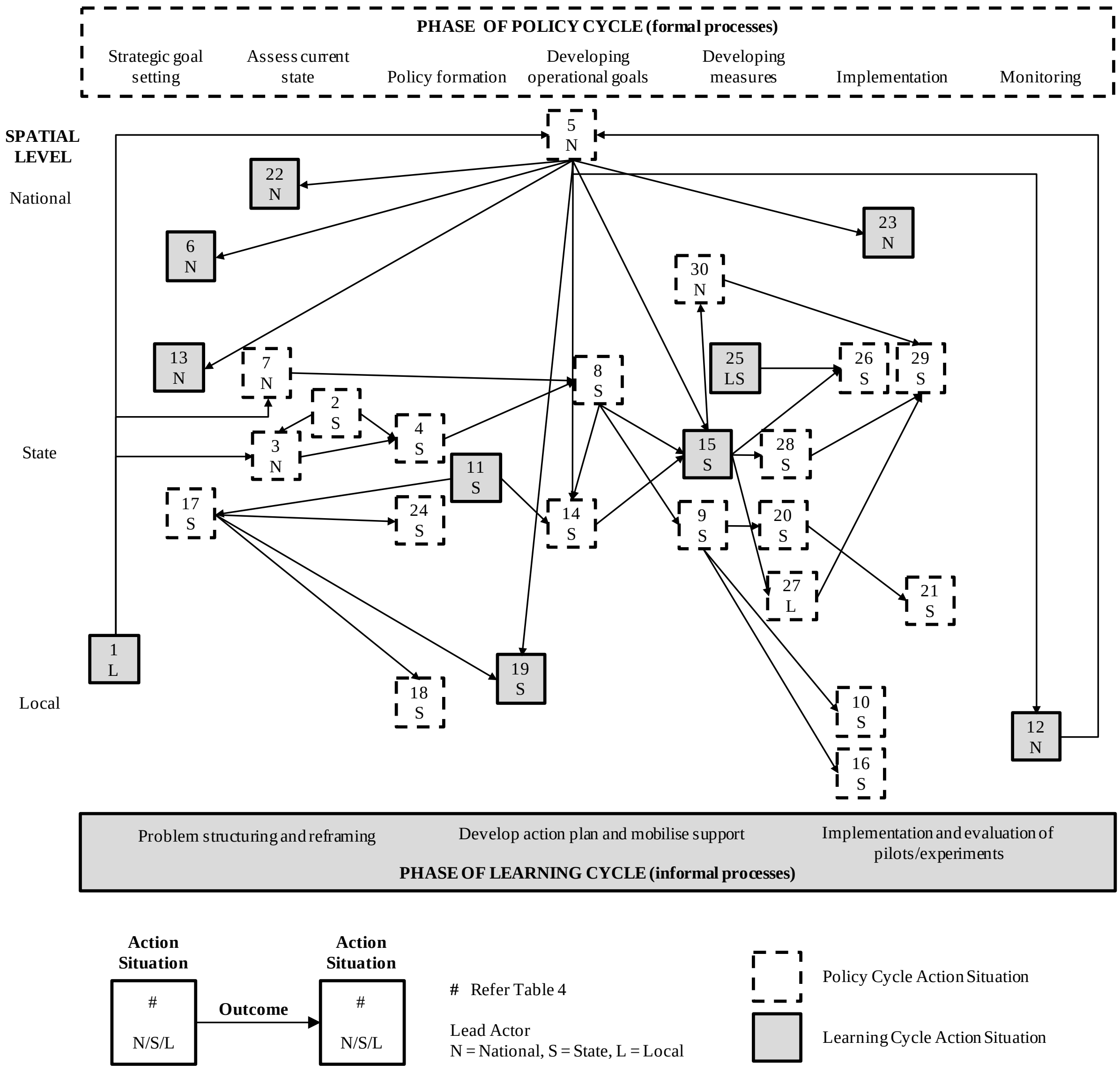

Figure 8. Application of Management and Transitions Framework to Melbourne's stormwater quality management system: Connections between individual action situations (see Table 4 for action situation list). Outcomes of one action situation that lead directly to another action situation are indicated by arrows. Horizontal location of each action situation corresponds to either the policy cycle (on the top axis for formal processes) or the learning cycle (on the bottom axis for informal processes). Vertical location of each action situation corresponds to its spatial level (national, state or local).

4. Discussion and Conclusions

This paper has shown that a diagnostic procedure requires multiple analytic lenses to reveal descriptive, explanatory and predictive insights. Different frameworks are therefore likely to be useful for different purposes. The application of the frameworks to the reference case study has revealed details about how each considers the system variables and relationships (Table 6), which in turn, influences how the framework addresses the proposed diagnostic questions (Table 5). For example, only the SES Sustainability and Management and Transitions Frameworks have an explicit focus on actors in the system. Each of the frameworks have a different way of defining the structures in the system. The definition of processes in the SES Sustainability, Ecosystem Stewardship and Management and Transitions Frameworks reflect real world interactions, while the processes in the Multi-Pattern Transitions Framework are conceptual. The Ecosystem Stewardship, Panarchy and Multi-Pattern Transitions Frameworks identify individual contextual drivers that impact directly on the system, while the SES Sustainability Framework describes contextual conditions more generally. The way that outcomes are defined varies amongst each of the frameworks.

Table 5. Capacity of selected frameworks to address the operational scope for a diagnostic procedure: (a) Proposed Diagnostic Questions.

Scope	SES Sustainability Framework	Ecosystem Stewardship Framework	Panarchy Framework	Multi-Pattern Transitions Framework	Management & Transitions Framework
(a) Diagnostic Question (DQ) (refer Table 1)					
DQ1: Take snapshots in time	Identifies multi-level system variables for snapshots in time	Identifies system elements for distinct phases of development		Identifies overall system structure (constellations, landscape influences, societal needs) for snapshots in time	
DQ2: Trace changes over time		Traces major changes in system elements over different phases	Traces changes in context and structure of nested hierarchical elements over time	Traces changes in overall system structure (constellations, landscape influences, societal needs) between different snapshots in time	
DQ3: Identify causal variables	Identifies the sets of variables that are significant in focal action situations of the system	Identifies the specific system elements that are significant for the problem under consideration			Identifies the action situations that are significant for the system's development
DQ4: Identify causal relationships	Identifies relationships between significant variables within focal action situations	Identifies relationships between elements that contribute to system changes			Identifies the types of outcomes that link different action situations
DQ5: Trace impacts of causal variables and relationships		Traces why significant elements and their relationships led to system change	Traces why changes in structure and context led to changes in adaptive cycle location of nested hierarchical elements		Traces why the sequence of different action situations led to structural change in the system
DQ6: Predict impacts of causal variables and relationships		Predicts how strategic interventions in significant system elements could influence system outcomes	Predicts how changes in adaptive cycle location are likely to occur, given current adaptive cycle location	Predicts how the system structure is likely to change, given the transition conditions and patterns currently present	Predicts how changes in the governance regime are likely to occur, given the current structural conditions and sequence of actions situations

Table 6. Capacity of selected frameworks to address the operational scope for a diagnostic procedure: (b) Variables and relationships; (c) Methodological guidance.

Scope	SES Sustainability Framework	Ecosystem Stewardship Framework	Panarchy Framework	Multi-Pattern Transitions Framework	Management & Transitions Framework
(b) Variables and Relationships					
Actors	Organizations				National, state or local lead actor
Structures	Resource systems; resource units; governance systems	Natural, built, human and social capital	Structures of different hierarchical scales	Structure of overall system (different constellations)	Ecological systems, societal systems, institutions, technical infrastructure
Processes	Interactions within focal action situations	Natural, built, human and social dynamics; social learning		Transition conditions (tension, pressure, stress)	Formal and informal action situations that are part of a policy or social learning cycle
Contexts	Related social, economic, political systems; related ecosystems	External drivers and their interactions that lead to system vulnerability	Impact of contextual factors on adaptive cycle location	Landscape influences on individual constellations	
Outcomes	Outcomes of focal action situations	Persistence, actively navigated transformation, unintended transformation	Locations within adaptive cycle	Degree to which societal needs are met; transition patterns (reconstellation, empowerment, adaptation)	Institutions, knowledge or operational outcomes
(c) Methodological Guidance (to ensure consistent empirical application for gaining generalized insights)					
	Database to support consistent collection, accumulation and organisation of empirical data from multiple case studies				Language and database for collecting standardized data to enable comparative analyses across multiple case studies

Table 7. Capacity of selected frameworks to address the operational scope for a diagnostic procedure: (d) Theoretical insights.

Scope	SES Sustainability Framework	Ecosystem Stewardship Framework	Panarchy Framework	Multi-Pattern Transitions Framework	Management & Transitions Framework
(d) Theoretical Insights (for definition of theoretical levels refer to Blaikie, 2010)					
Description (Level A & B)	Classifies nested tiers of variables that are significant for the problem under consideration				
Explanation (Level C & D)		Conceptually frames how significant elements of the system's overall dynamics are connected.	Theoretically explains how system dynamics at individual scales and interactions between scales led to system changes.	Theoretically explains how changes in system functioning are influenced by context, expression of societal needs and interactions between constellations of different power.	
Prediction (Level E)					Characterizes general patterns in empirical cases to explain the success or failure of governance regimes and predict how water management processes are likely to lead to governance regime changes under particular structural conditions

Ultimately, a diagnostic procedure for transformative change in urban water systems should position the analyst to select and design strategic action initiatives that best fit the current conditions to enable desired system changes. A synthesis of the above and other results from the review and application of the five frameworks (as elaborated on in Tables 5, 6, and 7) provide insight into the potential basis for each to inform strategic action.

The SES Sustainability Framework provides a systematic and comprehensive method for organizing nested tiers of variables from all five categories relevant for urban water systems (Figure 1). It could be used to inform which sets of variables are significant for determining sustainability outcomes, but it is not designed to focus on transformative change specifically.

The Ecosystem Stewardship Framework conceptualization of a system and its interconnected elements aids the identification of which suites of strategies would be likely to support desired sustainability outcomes, whether those outcomes are related to transformative change or persistence of a system's current dynamics. However, it is not designed to predict the impacts of specific strategic actions and further analytic frameworks would be required to reveal insights at this level of detail.

The Panarchy Framework offers theoretical explanation of a system's dynamics within and between different scales of adaptive cycles. These explanations could potentially provide insight into the likely effectiveness of different types of strategies, given the current adaptive cycle location and, hence, the likely future system dynamics. However, further conceptual tools would be required to provide insight into how specific variables relate to the adaptive cycle location and dynamics in order to inform the selection and design of particular strategic action initiatives.

The Multi-Pattern Transitions Framework theoretically explains how different system conditions give rise to particular dynamics that may lead to transformative change in the system composition. These explanations offer the potential to indicate the likelihood of different types of strategies effectively inducing conditions for transformative change that would produce the patterns that are likely to result in desired changes to the system composition and its functioning. Further conceptual tools would be required to provide insight into how specific variables relate to the system conditions in order to inform the selection and design of particular strategic action initiatives.

Finally, the Management and Transitions Framework offers detailed insights into how the different water management processes and structural conditions of a governance regime lead to the success or failure of a system's transformation. Such explanations could potentially be used to predict how strategic action initiatives could enable action situations with attributes (outcome type, institutional type, process type, spatial level, lead actor) that are likely to lead to desired changes in the governance regime.

The discussion above highlights that the analytic frameworks provide different types of diagnostic insights, depending on their theoretical level and topic of focus. An analyst must therefore be clear about the aim and purpose of any diagnostic procedure, and hence, what types of variables are significant and what sequence of diagnostic questions needs to be addressed for the particular system or problem under consideration. These choices will determine which analytic framework(s) will support the specific diagnostic procedure being undertaken. Further, different frameworks could potentially be merged into hybrid frames of analysis in order to meet the range of objectives set out by the proposed operational scope for a diagnostic procedure, given the different analytic lenses and types of reasoning outlined by Cox (2011). In general, however, the sequence of diagnostic questions and use of corresponding frameworks should guide the analyst through a procedure that provides first description, then explanation and finally prediction.

Nonetheless, a diagnostic procedure based on one, or more, of the reviewed frameworks could not yet be applied in practice. Significant testing, empirical validation and, in some cases, methodological development of each framework is necessary before it is used for operational purposes.

This paper has focused on frameworks that address diagnostic questions related to transformative change in urban water systems. Each could be used as part of a diagnostic procedure to map a system's current conditions and identify its potential transformative capacity, in order to predict how changes in particular variables might impact on change trajectories of the overall system (proposed Diagnostic Questions 1-6 in Table 1). The next research step is to link these insights with detailed understandings about how different types of strategic action initiatives could intervene in the system to influence patterns of change towards desired future directions (Diagnostic Question 7 in Table 1). This research would bring theoretical and empirical understandings of the best matches between different suites of strategic action initiatives with the diagnosed conditions and potential transformative capacity of a system.

Scholarship on sustainability and transformative change in social-ecological systems is only just beginning to develop approaches for diagnosing current conditions and providing insights into how systems can be better managed. While this paper is focused on using diagnostic procedures to support transformative change in urban water systems, we hope the explorations here contribute to advancing these emergent discussions around diagnostic approaches more broadly. In particular, we hope it offers a base from which to support the development of diagnostic approaches for guiding strategic action for transformative change in a range of other integrated, large-scale, technical systems, such as energy, transport, housing and communications infrastructure.

Key directions for a future research agenda to develop such diagnostic approaches include: (a) empirical validation and methodological development of underpinning analytic frameworks; (b) design of overall diagnostic procedures to ensure the underpinning frameworks collectively provide sufficient descriptive, explanatory and predictive insights for the particular system or problem under consideration; (c) theoretical development and empirical validation of conceptual frameworks that link different types of strategic action initiatives with the complex dynamics of system change that unfold in specific situations.

As well as providing academic insights, underpinning diagnostic approaches with outcomes of this research agenda would have significant practical benefit. For cases of urban water, a diagnostic procedure would enable the selection and design of policy interventions that can leverage key variables through strategic action initiatives to overcome barriers and prepare the system for opportunities to transform practice towards more sustainable water management. More broadly, such a diagnostic procedure could be applicable to any multi-sectoral or integrated system for which the design of policy and strategic action initiatives for enabling transformative change towards a more sustainable future system state is desired.

Acknowledgements

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CHAPTER 3. THEORY DEVELOPMENT

This chapter integrates theoretical concepts from transitions, resilience and institutional studies to develop a preliminary diagnostic procedure. The procedure aims to reveal insights into the strategic initiatives that best fit a system's current conditions so that actor strategies can most effectively influence the direction and pace of change in an urban water system. Publication 2 presents this diagnostic procedure and demonstrates its application on a case study of recent transformative change in Melbourne's stormwater management system.

SPECIFIC DECLARATION FOR PUBLICATION 2

Monash University

Declaration for Thesis Chapter 3.1

Declaration by candidate

In the case of Chapter 3.1, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Formulated research problem, located research within established literature, developed theory, conceptualised and structured paper, wrote paper.	90%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	**Nature of contribution**	**Extent of contribution (%) for student co-authors only**
Rebekah Brown	Supported the research conceptualisation, reviewed and edited the paper	N/A
Ana Deletic	Supported the research conceptualisation, reviewed and edited the paper	N/A

		Date
Candidate's Signature	B. Ferguson*	30/5/13

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	**Geography & Environmental Science, Monash University, Clayton Campus**

		Date
Signature 1	R. Brown*	30/5/13
Signature 2	A. Deletic*	27/5/13

* Original signature in hardcopy version

3.1. Publication 2: A diagnostic procedure for transformative change based on transitions, resilience and institutional thinking

3.1.1. Introduction

Chapter 2 developed an operational scope for a diagnostic procedure that could reveal insights into which strategic initiatives are most likely to influence the direction and pace of change in an urban water system towards a desired trajectory. It identified a number of existing analytic frameworks within transitions and resilience scholarship that could underpin the development such a diagnostic procedure. Publication 2 integrates specific concepts within two of these existing frameworks (the Multi-Pattern Transitions Framework and the Panarchy Framework) and extends them by incorporating concepts from new institutionalism to form the conceptual building blocks of a diagnostic procedure that meets the proposed scope.

The article then proposes a step-by-step procedure that draws on these integrated theoretical concepts for mapping a current and envisioned future system, determining what changes are required and identifying how strategic initiatives could most effectively enable the desired system transition. Application of this procedure is demonstrated on a case study of recent transformative change in the stormwater management system of Melbourne (the same reference case study used in Publication 1).

The outcomes of Publication 2 contribute to the third research objective of this thesis, presenting the preliminary development of a diagnostic procedure (see Table 2).

3.1.2. Manuscript

A Diagnostic Procedure for Transformative Change based on Transitions, Resilience and Institutional Thinking

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Abstract: Urban water governance regimes around the world have traditionally planned large-scale, centralized infrastructure systems that aim to control variables and reduce uncertainties. There is growing sectoral awareness that a transition towards sustainable alternatives is necessary if systems are to meet society's future water needs in the context of drivers such as climate change and variability, demographic changes, environmental degradation and resource scarcity. However, there is minimal understanding of how the urban water sector should operationalize its strategic planning for such change in order to facilitate the transition to a sustainable water future. This paper integrates concepts from transitions, resilience and institutional theory to develop a diagnostic procedure for revealing insights into which types of strategic action are most likely to influence the direction and pace of change in the overall system towards a desired trajectory. The procedure uses the multi-pattern approach, from transition theory, to identify the system conditions and type of changes necessary for enabling system transformation. It incorporates the adaptive cycle, from resilience theory, to identify the current phase of change for different parts of the system. Finally, it draws on the concepts of institutional pillars and institutional work to identify mechanisms that are likely to be most effective in influencing the transformative dynamics of the system towards a desired trajectory. The paper demonstrates application of the proposed diagnostic procedure on a case study of recent transformative change in the urban water system of Melbourne, Australia. We propose that an operational diagnostic procedure provides a useful platform from which planners, policy analysts and decision-makers could follow a process of deduction that identifies which types of strategic action best fit the current system conditions.

Keywords: institutions; resilience; strategic planning; sustainability; transformative change; transition; urban water

1. Introduction

Governance regimes in urban water sectors around the world have traditionally planned large-scale, centralized infrastructure that aim to control variables (e.g. supply, demand) and reduce uncertainties. However, climate change and variability, demographic changes, environmental degradation and resource scarcity mean that future social-ecological drivers will not be addressed by this conventional approach. The increasing awareness of this uncertain future context and the need to transition towards sustainable alternatives in a range of infrastructure sectors (e.g. energy supply, transport) is reflected by the growth of research focused on the challenge of escaping locked-in path-dependencies of large-scale socio-technical systems (e.g. Berkhout 2002, Farrelly and Brown 2011, Frantzeskaki and Loorbach 2010, Truffer et al. 2010). However, there is minimal scholarly or practical understanding of how sectors should make planning and policy-making operational to enable a transition to a sustainable and resilient future (e.g. Chapin III et al. 2010, Dolata 2009, Smit and Wandel 2006).

A transition, or transformative change, refers to the fundamental system-wide change in the structure and functioning of a system. For urban water systems, transformative change means a radical shift in how water servicing is planned, designed, constructed, operated, managed, governed and valued. Insights into patterns of dynamic transformative change would be invaluable for identifying which types of strategic action best fit the current conditions of an urban water system so that governance actors are better equipped to address current and future water management challenges. However, scholars have argued that the links between policy, strategy and action and the complex dynamics of transformative change are underdeveloped, from both a theoretical and empirical research perspective (e.g. Chapin III et al. 2010, Elzen and Wieczorek 2005, Geels 2004). This highlights gaps in the scholarship of strategic planning in relation to systemic change, which are reflected by how planning is undertaken in practice. Dominguez et al. (2009) note there is growing awareness of the need for improved planning of infrastructure systems and that a range of approaches are being developed, including participatory methods, analytic frameworks and computer simulations. However, strategic planning tools are typically developed, implemented or evaluated from a paradigm of incremental linear change, based on the assumption that strategic actions can be designed through analysis of simple 'cause-and-effect' mechanisms (Truffer et al. 2010). Instead, infrastructural systems should be understood through a systems perspective that embraces uncertainty and complexity over the long-term and facilitates planning for nonlinear change (de Graaf and van der Brugge 2010, Foxon et al. 2009, Truffer et al. 2010).

Tools to inform strategic planning in a complex infrastructural system, such as urban water, should address important questions related to nonlinear systemic change over long timeframes (in the order of decades). For example, how should current planning be designed to address future system needs? When is the potential for transformative change likely to occur? What is the system's current phase of change? How should the system prepare for transformative change? What types of strategic initiatives are likely to be most effective for the current conditions? How are feedback loops in the system likely to impact on the efficacy of planned strategic action? What interventions are likely to be effective in the long-term, given the uncertain and nonlinear future contexts? These types of questions highlight limitations of existing approaches for selecting and designing strategic initiatives, and while some planning approaches could be applied within a systems paradigm, there is an absence of conceptual tools for use in critically informing strategic planning from the perspective of dynamic transformative change (Chapin III et al. 2010, Van de Meene et al. 2011, Walker et al. 2006). This absence may be because planning initiatives tend to be undertaken within a timeframe that reflects short-term electoral cycles, whereas strategic action for transformative change would be likely based on a much longer term view, perhaps in the order of 20-50 years, which presents a range of pragmatic challenges.

Recent literature argues the need to avoid panaceas in planning and managing integrated systems, instead proposing that diagnostic approaches are a better alternative (e.g. Cox 2011, Ostrom 2007, 2009, Pahl-Wostl 2009). We therefore propose that the above questions for strategic planning could be addressed effectively if initiatives were guided by the use of a diagnostic procedure that can determine the potential transformative capacity of a system and therefore identify which types of strategic action best fit the current system. Such a procedure would enable strategic planners and decision-makers to identify opportunities for strategic initiatives that are likely to fundamentally change practices and enable the transition to sustainability. As such, this paper aims to develop a diagnostic procedure for revealing insights into which types of strategic action are most likely to influence the direction and pace of change in an urban water system towards a desired trajectory.

Ferguson et al. (2013) outline a scope for the design of an operational diagnostic procedure that maps a system's current conditions and identifies its potential transformative capacity. They suggest such a procedure should include the following characteristics: (1) addresses a sequence of nested diagnostic questions that provide retrospective analysis of a system problem or system changes; (2) offers analytic lenses that relate to the broad system scale, individual variables, static snapshots in time and dynamic links between system states; (3) is capable of analysing system variables that are actors (individuals or organizations), structures (social, ecological or technological), processes (social or biophysical), contexts (political, economic, social or environmental) and outcomes; (4) incorporates a methodological framework that provides operational guidance; (5) is underpinned by conceptual frameworks that provide description and explanation of a system problem or changes; (6) is capable of predicting the impacts of strategic action on a system's dynamics; and (7) is capable of informing the selection of strategic initiatives that best fit the current system conditions.

This paper proposes an operational diagnostic procedure for urban water systems that follows this scope and could underpin a strategic planning tool. The proposed diagnostic procedure integrates concepts from the fields of transition studies, resilience of social-ecological systems and new institutionalism, and its application is demonstrated on a case study of recent transformative change in the urban water system of Melbourne, Australia.

This paper makes the normative assumption that a transition to sustainable water management is necessary if the broad range of societal needs from an urban water system is to be satisfied within the context of future social-ecological drivers. While not the focus of this paper, we acknowledge that the prospect of actively navigating a transition has been contentious in the literature. Commentators have expressed concern about a lack of focus on the political nature of managing a transition, whether it is desirable to manage a transition and whether it is even possible to manage a transition (e.g. Elzen and Wieczorek 2005, Genus and Coles 2008, Shove and Walker 2007, Smith and Stirling 2010, Smith et al. 2005). To address these concerns in relation to the use of the operational diagnostic procedure proposed in this paper, we emphasise from a pragmatic stance that strategic planning for urban infrastructure is continually undertaken, regardless of the paradigm from which the planning is conducted. We therefore contend that the development and use of a diagnostic procedure for transformative change brings significant improvement over existing planning tools, which are widely accepted as having limited ability to deal with the challenges of complex, interconnected and uncertain future contexts (Dominguez et al. 2009, Farrelly and Brown 2011, Foxon et al. 2009, Truffer et al. 2010). However, we note that all decision support tools should be applied with caution, ensuring the participation of a broad range of stakeholders and consideration of the perspectives of all relevant actors, in combination with a reliable assessment of the boundaries and limitations of the biophysical conditions of the system.

2. Development of Diagnostic Procedure

2.1 Theoretical Background

Two main areas of scholarship that could underpin the development of a diagnostic procedure for analysing the dynamics of transformative change were identified: transition theory and resilience theory. These fields each aim to explore the transformative dynamics in integrated complex systems so that governance interventions are designed to achieve desirable system states in the future. While each theory's heritage lies in diverse research fields and their perspectives sometimes appear to conflict, there are many parallels in how they understand the nature of complex adaptive systems and conceptualize system transformations. Until recently, the two theories (and hence scholarly activity) have remained separate; however, researchers are now considering ways in which each can provide insight and strengthen overall understanding of transformative change and implications for governance (e.g. Foxon et al. 2009, Smith and Stirling 2010, van der Brugge and van Raak 2007). Table 1 synthesizes key insights for how each theory explains different dimensions of transformative change in an integrated system.

The synthesized understandings about transformative change, described in Table 1, highlight the parallel concepts shared by transition theory and resilience theory. This common base means there is potential to integrate concepts from both transitions and resilience thinking to develop a diagnostic procedure for analysing transformative dynamics.

A diagnostic procedure for guiding strategic action requires conceptual links with how actors can influence a system. While transitions and resilience literature acknowledges the fundamental role of actors in shaping a system, they lack operational tools for analyzing how transformative change can be enabled through actor strategies (Brown et al. in press, Farla et al. 2012). Ferguson et al. (2013) identify that the functionality of urban water systems is predominately influenced by actors' implicit and explicit decisions about material elements, such as technology and infrastructure. In this sense, change in the biophysical dimensions of a socio-technical system is achieved through change in the social dimensions. The proposed diagnostic procedure therefore takes the concept of institutional change as the entry point for how transitions can be deliberately induced and navigated by actors (whilst acknowledging there would be a lag time in observations of corresponding changes in technology or infrastructure).

New institutionalism is a research field that aims to offer insight into the nature of institutions and processes of institutional change, particularly by analysing the interplay between institutions and agency (Lawrence et al. 2009). Two concepts within institutional theory are used in the diagnostic procedure to provide insight into how actors can influence the direction of transformative change in a system. The concept of institutional pillars, proposed by Scott (2008), identifies three analytical elements that comprise institutions and therefore shape the practices of actors. Regulative institutional elements are the, typically formal, social structures that are monitored and evaluated, such as rules, laws and sanctions (informal systems of rules may also be regulative). Normative elements define the goals of a system through specifying the values, norms and standards that are expected to be upheld within the institution. Cultural-cognitive elements encompass the common beliefs, logics and meaning that are shared within an institution, resulting in actor behaviours and routines that often seem instinctive or taken for granted. These three institutional pillars form the underpinning social structures of a socio-technical system.

The concept of institutional work is a recent development in institutional theory, aiming to re-emphasize the agency of actors in shaping institutions. At its foundation is Gidden's structuration theory (1984), which perceives human action as both being constrained by social structures and reproducing social structures. The institutional work concept applies this 'duality of structure' to institutions, conceptualizing that "institutions shape people's practices, but it is also people's practices that constitute (and reproduce) institutions" (Battilana and D'Aunno 2009, p43). The idea that actors can shape institutions is at the core of institutional work, which Lawrence and Suddaby (2006) define as the purposive action of individuals and organisations aimed at creating, maintaining and disrupting institutions. Therefore, it focuses analyses on the efforts of individual and collective actors to influence institutions, rather than on the outcomes or results (Lawrence et al. 2011). The concept builds on research within institutional theory that examines processes of institutionalization and deinstitutionalization, as well as practice theory, which delves inside processes of change to examine the intelligent, situated activities undertaken by actors (Lawrence and Suddaby 2006).

Table 1. Key dimensions of transformative change.

DIMENSION	TRANSITION LITERATURE	RESILIENCE LITERATURE	SYNTHESISED UNDERSTANDING
	(e.g. Berkhout et al., 2004; de Haan and Rotmans, 2011; Geels, 2002; Geels and Schot, 2007; Rotmans et al., 2001; Rotmans and Loorbach, 2009; Smith et al., 2005; Smith et al., 2010)	(e.g. Berkes et al., 1998; Berkes et al., 2003; Chapin III et al., 2009, 2010; Folke, 2006; Gunderson and Holling, 2002; Holling, 1973; Olsson et al., 2006; Walker et al., 2006)	about transformative change in complex infrastructure systems
Theoretical roots	Integrated assessment, technology diffusion, evolutionary economics, innovation, governance.	Ecology, social-ecological systems, governance.	
Goal	Radically change system structures so its function becomes sustainable and desirable in future contexts. Sustainability goals are explicitly normative.	Maintain system function so it is ecologically resilient to disturbance in the form of acute shocks and chronic stress.	Transform system structures toward vision of sustainability and resilience in context of uncertain future. Goal is a resilient system, not a resilient regime.
Functional scale	*Multi-level perspective* distinguishes between three scales of structures and processes: broad landscape, dominant regimes and innovative niches. Elements of each can change over time, e.g. niches can grow to niche-regimes, which can eventually replace regimes. Micro-dynamic patterns of change drive overall system dynamics, i.e. niche-regime-landscape interactions.	*Panarchy* represents a nested hierarchy in which higher levels have larger structures and slower processes, while lower levels have smaller structures and faster processes. Elements of scale can change over time, e.g. new levels can be added in a panarchy. Micro-dynamics of change drive the overall system dynamics, e.g. 'revolt' and 'remember' functions.	Change occurs at multiple functional scales and the dynamic interactions between and within scales are fundamental drivers of a system transformation.
Spatial scale	The relevance of the spatial context depends on the system under consideration.	The spatial context needs explicit consideration. Spatial scales can be nested.	Spatial dimensions provide unique characteristics, potentially influencing how transformative change occurs.
Temporal scale	Change is nonlinear and characterized by punctuated equilibriums, represented by the 4 phases in the S-curve (pre-development, take-off, acceleration, stabilisation). The different phases of the S-curve each have their own temporal scale.	Change is nonlinear and characterized by punctuated equilibriums, represented by the 4 phases of the *adaptive cycle* (exploitation, conservation, release, reorganization). Temporal scales can be nested, with different levels going through different phases at each point in time.	Transformative change is characterized by punctuated equilibriums, in which phases alternate between long periods of steady incremental change and short periods of rapid transitional change. Different functional scales and phases of change have different temporal scales.
Speed	Landscape structures and processes change slowly while niche structures and processes change quickly. Transitions occur over long timeframes, in the order of 25-50 years.	Different scales change at different speeds: higher scales change slowly, lower scales change quickly.	Higher functional scales change slowly while lower functional scales change quickly.
Timing	Windows of opportunity are critical for enabling transformative change.	Windows of opportunity are critical for enabling transformative change. System response to an issue will be different at different times.	Timing is critical. The timing of strategic action, in relation to windows of opportunity, will influence its effects on the overall system.
Actors	Actors are fundamental but have had minimal consideration in transition literature on change dynamics.	Actors are fundamental but have had minimal consideration in resilience literature on change dynamics.	Actors are fundamental but theory currently lacks tools for analyzing their role and implications for governance.

2.2 Conceptual Building Blocks

This section describes how particular concepts from transitions, resilience and new institutionalism are used in the proposed diagnostic procedure.

The multi-pattern approach (MPA) for analysing transitions (de Haan 2010, de Haan and Rotmans 2011) conceptualises that a societal (or socio-technical) system exists in order to meet a range of societal needs. For example, an urban water system provides a range of services to meet the need for water supply, sanitation, flood protection and more. The way the system provides these services can shift over time in response to changing societal needs, contextual drivers and internal stresses.

The MPA perceives that transformative change in a system can unfold in many different ways over time, depending on the dynamic mechanisms that occur. It builds upon established transition concepts of the multi-level perspective and multi-phase change to theoretically deduce the full range of possible transition pathways. This theoretical approach means that it can be applied to identify universal transition pathways for use in 'futures' research, a key gap that Genus and Coles (2008) argue exists in other transition approaches focused on pattern identification in historic empirical cases for analysing transition pathways (e.g. Berkhout et al. 2004, Geels and Schot 2007, Smith et al. 2005).

The MPA extends the multi-level perspective's landscape, regime and niche concepts using a complexity approach to analyse the mechanisms that drive interactions between them (de Haan and Rotmans 2011). The MPA conceptualizes the system as a set of subsystems, known as constellations. Each constellation is comprised of structures, including institutions and biophysical structures such as ecosystems, infrastructures and technologies. Actors are not part of constellations; they reside on a different conceptual layer and relate to the constellation structures via emergent processes. Individual actors can therefore have agency in multiple constellations, removing the need to distinguish between 'regime actors' and 'niche actors' (Figure 1).

Constellations are defined by the function they provide in meeting different societal needs. The constellation(s) with the greatest share of functioning are the most powerful, forming a regime. The combined functioning of the regime constellation(s) dominates the overall system functioning. Constellations interact with each other and the landscape in which the system is embedded. System transformation occurs when the power balance between constellations fundamentally shifts, radically changing the underlying system structure and the way in which it functions to meet society's needs.

To explain the interactions between constellations, the MPA identifies top-down, bottom-up and internally induced drivers of, or conditions for, transformative change (tension, pressure and stress, Figure 1). These conditions drive different transition patterns ('intervention' or top-down, 'empowerment' or bottom-up, and 'adaptation' or internal), which, over time, can concatenate into pathways that lead to a transition. This creates a theoretically derived typology of all possible transition pathways, dominated by one or more of the transition patterns. The transition pathway experienced within a system at a given time will depend on the power dynamics between the existing regime, upcoming niches and landscape tensions.

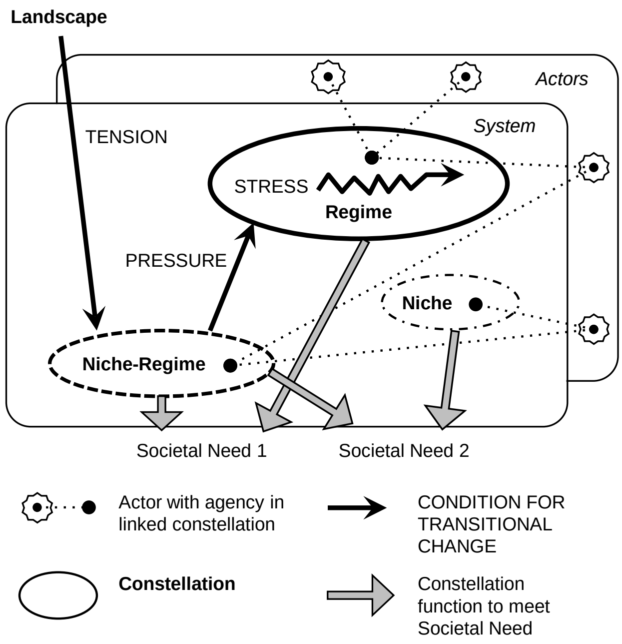


Figure 1. Conceptualization of the Multi-Pattern Approach.

The MPA shows promise in decoupling the societal mechanisms (the patterns) from what drives them (the conditions) and how they manifest in systems (the pathways). However, investigation of the potential effectiveness of particular strategic initiatives on future transitions requires insight into the likely timing and strength of conditions for change so that the impact of system interventions can be anticipated. The timing and strength of transition conditions will be significantly influenced by the dynamics of structures internal to constellations, an aspect acknowledged and speculated on in the transitions literature (e.g. de Haan 2010, Geels 2002, 2004, Geels and Schot 2007) but not dealt with from an analytical perspective (Genus and Coles 2008).

The underpinning concept of the Panarchy framework in resilience theory, the adaptive cycle, is the next building block of the proposed diagnostic procedure. It is introduced to the procedure to provide conceptual insight into these internal constellation dynamics. The adaptive cycle represents a fundamental unit of dynamic change. It makes a distinction between alternating phases of change in a complex system that responds to disturbances over time, cycling through periods of growth and dynamic stability and periods of change and variety (Holling and Gunderson 2002).

Three properties shape the responses of social-ecological systems to crisis and influence the future state of the system; these form the three dimensions of the adaptive cycle (Figure 2a). The inherent potential of a system for enabling change will determine what options are possible in the future (also referred to as the 'wealth' or 'capital' of a system). The level of connectedness between variables will influence how flexible or rigid the system is. The resilience, or adaptive capacity, of a system will determine its vulnerability to disturbance, whether the disturbance is in the form of chronic stress or acute shocks (Smith and Stirling 2010).

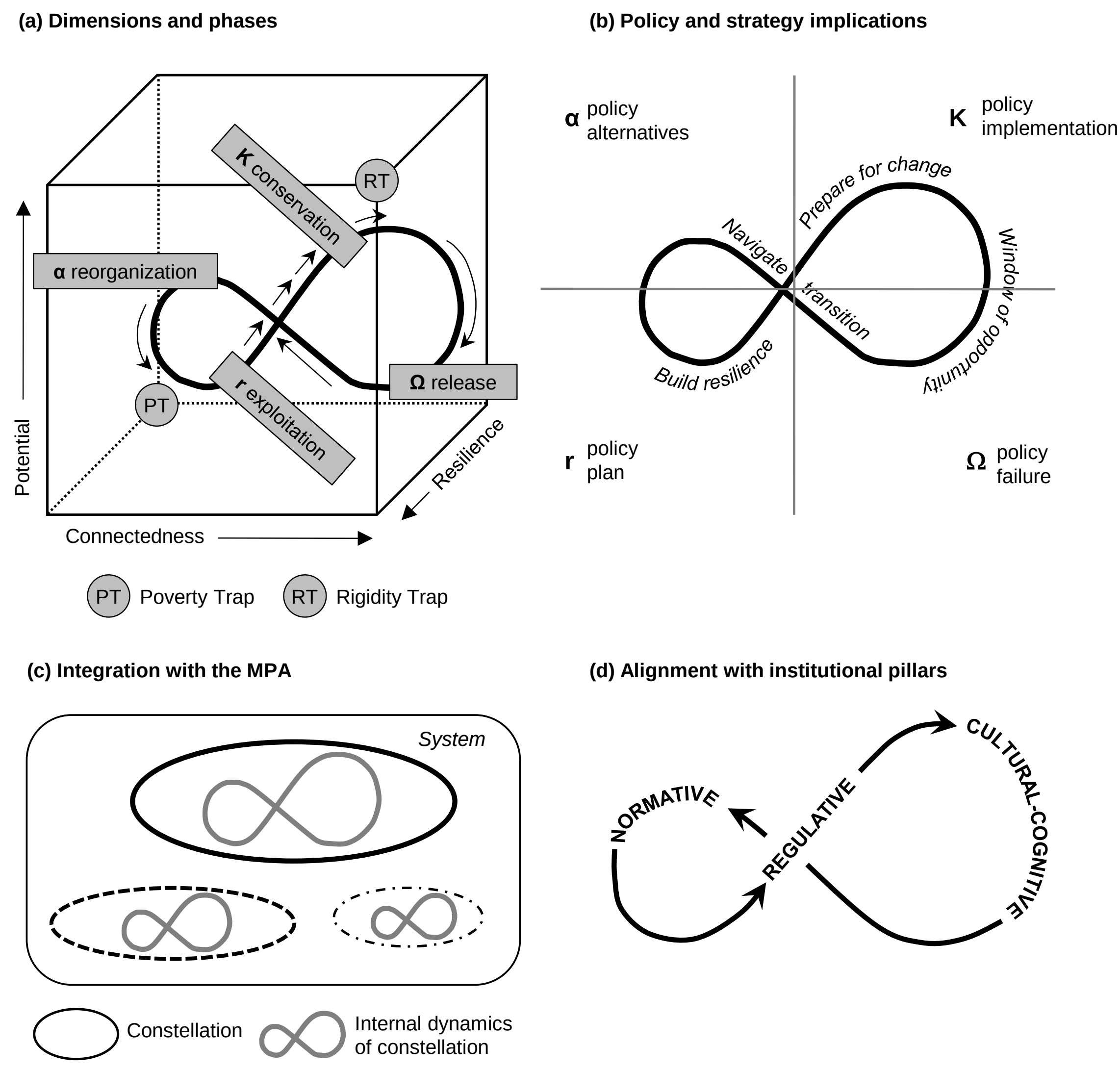


Figure 2. The adaptive cycle: (a) Dimensions and phases (adapted from Holling and Gunderson, 2002); (b) Implications for policy and strategy (adapted from Gunderson et al., 2002 and Olsson et al., 2006); (c) Integration with the Multi-Pattern Approach (de Haan and Rotmans, 2011; refer Figure 2); (d) Alignment with institutional pillars (Scott, 2008) to indicate the pillar of focus for strategic action.

There are four distinct phases of an adaptive cycle (Figure 2a); the trajectory alternates between long slow periods of exploitation and conservation of resources (from r to K in the 'front loop'), interspersed with short periods that maximise opportunities for innovation (from Ω to α in the 'back loop'). Subsequent cycles either continue along the same trajectory, with similar structures and processes, or the system enters a new cycle if innovations developed in the back loop stimulate sufficiently divergent structures and processes. If a new cycle is entered, transformative change is considered to have occurred in the system (Holling and Gunderson 2002).

Gaining insight into the nested adaptive cycles of a social-ecological system provides an ability to identify when the system is capable of welcoming change and when it is vulnerable (Holling and Gunderson 2002). Pritchard and Sanderson (2002) argue that understanding the location of a social-ecological system within its episodic phases of the adaptive cycle is important for system management, as actions that are effective at one phase of the cycle may not be suitable at another. Scholars are starting to explore how governance regimes can use the concept of adaptive capacity to deal with uncertainty and change. For example, Olsson et al. (2006) identify three phases of social-ecological system transformation that would have distinct strategies linked to them: (i) preparing for change through developing new knowledge, leadership capacity and shadow networks; (ii) navigating the transition through anticipating a window of opportunity, nurturing innovation and maintaining flexible institutions; and (iii) developing resilience of the new direction through fostering networks and building support. The system's location within its adaptive cycle will influence which of these strategies will be most effective at the given point in time (Figure 2b).

Holling and Gunderson (2002) note that not all systems follow the same type of adaptive cycle. Indeed, some cycles are considered maladaptive and can cause a system's decline and eventual collapse. Poverty traps (Figure 2a) are such an example: the erosion of potential and diversity in a system, through internal stress or an external disturbance, can cause a system's collapse, resulting in an impoverished state with low connectedness, low potential and low resilience. Maladaptive systems can also be sustainable, in cases where a system has developed high potential, high connectedness and high resilience; this is known as a rigidity trap. A rigidity trap (Figure 2a) represents a wealthy, tightly regulated and resilient subsystem; however, this type of resilience is limited to the subsystem scale and emphasizes efficiency, control, constancy and predictability (engineering resilience). When disturbance eventually occurs, there is little capacity to adapt and the subsystem risks collapse with no renewal, potentially causing the overall system's decline.

In contrast, ecological resilience refers to persistence, adaptability, variability and unpredictability as the measure of a healthy system's capacity to absorb disturbance and still maintain integrity of function and structure (Holling and Gunderson 2002). Further, functional integrity and structural integrity are not synonymous and a system may actually require transformation of its structure in order to maintain resilience of its function (Smith and Stirling 2010). In other words, the shift of one scale into a new dynamic equilibrium is not necessarily bad for the system and may, in fact, be positive. For urban water systems, regime structures that have evolved to facilitate centralized engineering solutions may need to transform in order for a city to maintain all its water-related functions (ranging from water supply to ecosystem services to urban amenity) as the traditional approach is challenged by contextual changes. In this sense, the goal of transformative change is to maintain ecological resilience of the overall system, rather than engineering resilience at the regime scale. The regime's adaptive capacity will therefore significantly influence which transition pathways are likely.

To integrate these resilience ideas into the proposed diagnostic procedure, constellations are considered to be conceptually positioned along an adaptive cycle, which represents their internal dynamics (Figure 2c). The regime (comprised of one or more constellations) follows a single adaptive cycle and niche constellations each follow their own adaptive cycle. The progress of an adaptive cycle through periods of exploitation, conservation, release and reorganization (or its lock-in to a poverty or rigidity trap) will depend on the development of internal constellation structures, external drivers and dynamics between constellations at different scales.

The Panarchy logic holds that these cross-scale dynamics between nested adaptive cycles (interpreted here as between a regime and niches) can lead to transformative change (Holling and Gunderson 2002). Geels and Schot (2007) argue that the type of transition path that unfolds due to regime-niche interactions will depend on the state of development of a niche at the time when the regime comes under pressure. In this line of thinking, we propose that the presence of conditions for transformative change will largely depend on the relative positions of regime and niche constellations along their adaptive cycle at a given point in time.

The integration of the transition theory's MPA and resilience theory's adaptive cycle provides a systemic framework for analysing the dynamics of transformative change in an integrated system. However the conceptual link with how human action can influence these dynamics is still missing. This leads to the introduction of concepts from institutional theory as the third building block of the proposed diagnostic procedure. As explained earlier, the procedure adopts institutional change as the entry point for actors to enable system change, since the biophysical functioning of urban socio-technical systems is fundamentally driven by human choices (Ferguson et al. 2013). Analysis of a system's institutions and processes of institutional change is therefore essential for understanding how actors can influence the system's dynamics.

Scott (2008) argues that institutions comprise all three institutional pillars (regulative, normative and cultural-cognitive). Institutions may be supported by one key pillar at a particular time and as circumstances change, a different pillar may become dominant. However in general, these rules, norms and meanings need to work in combination to maintain resilient social structures. When the regulative, normative and cultural-cognitive elements are not well-aligned, there is likely to be confusion and conflict within an institution, creating conditions that are conducive to institutional change. This situation provides opportunity for actors to enable transformative change by mobilising resources to exploit these differences. However shifts in each of the pillars would need to be mutually reinforcing for a new set of institutions to eventually be stabilized. Therefore purposeful strategic action for enabling a system transformation would need to target each of these three institutional elements in mutually reinforcing ways.

According to Scott (2008), cultural-cognitive institutions are the most deeply embedded in society and therefore most difficult to change, while regulative institutions are the shallowest and therefore easiest to change. In this sense, Roland (2004) classifies institutions as either 'slow-moving' or 'fast-moving'. De la Torre-Castro and Lindström (2010) provide empirical evidence in a case study of fisheries management to demonstrate the slow-moving nature of cultural-cognitive and normative institutions, compared with fast-moving regulative institutions. From this study, they conclude that "unless [regulative institutions such as property rights] rests on both the normative and the cultural-cognitive pillars, they are prone to fail" (De la Torre-Castro and Lindström 2010, p.82). From insights such as these, it appears that, while shifts in the three institutional pillars should be mutually reinforcing, at the system-wide scale there is a dominant and sequential pattern in how transformative institutional change occurs. As such, we hypothesize that a deep cultural-cognitive shift is most likely to initially drive a transition, followed by corresponding normative and regulative shifts. In turn, the development of regulative structures is likely to be the principle focus towards the end of the transition, as formal rules, laws and sanctions incrementally work to stabilise the new transformed system.

Mapping this sequence of institutional change (cultural-cognitive, then normative, then regulative) onto the adaptive cycle provides a conceptual base for guiding which institutional pillars should be the focus of strategic initiatives during different phases of change for individual constellations (Figure 2d). For example, cultural-cognitive mechanisms are expected to be most effective during the Ω (release) and α (reorganization) phases of the adaptive cycle, when the previous system conditions have destabilised, uncertainty dominates and changed meanings can lead to system renewal. Normative mechanisms are expected to be most effective during the α (reorganization) and r (exploitation) phases of the adaptive cycle, when the period of experimentation results in multiple innovations that compete for resources, only some of which will survive and be exploited. Regulative mechanisms are expected to be most effective during the r and K phases, when 'winners' accumulate resources and become increasingly connected. While these hypotheses hold logical validity, they require substantiation. Nonetheless, they lead to the conclusion that the choice of strategic initiatives should account for the sequential logic of how institutional pillars shift to reinforce each other. Note that this conceptual framing is not intended to provide predictive capacity in a temporal sense, but rather to indicate the likely sequencing of change.

The final concept introduced to the proposed diagnostic procedure, institutional work, links different types of action by individuals and organisations with the institutional pillars targeted for strategic intervention. Lawrence and Suddaby (2006) reviewed empirical-based research on institutions to draw insights into the distinct sets of practices that actors employed to create, maintain and disrupt institutions. Table 2 lists these sets of empirically observed mechanisms and categorizes them according to whether they most closely act on the regulative, normative or cultural-cognitive institutional pillar. Explanation of each form of institutional work is provided, with brief examples of activities actors may undertake in doing the institutional work. While Lawrence and Suddaby (2006) acknowledge their typology of mechanisms could be expanded, it is useful as a means to identify distinct categories of institutional work that can be seen to act on each of the institutional pillars.

Table 2. Explanations of mechanisms of institutional work for each institutional pillar (see Lawrence and Suddaby, 2006, for more details)

PILLAR	CREATING INSTITUTIONS		MAINTAINING INSTITUTIONS		DISRUPTING INSTITUTIONS	
Regulative	Defining	Defining rules and boundaries through activities that, for example, allocate responsibilities, create membership rules, formalize standards and compliance criteria, introduce accreditation and certification schemes.	Enabling work	Creating rules through activities such as amending regulations and setting targets, to enable authorizing agents to carry out routines, divert resources and create certainty for institutional survival.	Disconnecting sanctions / rewards	Disconnecting rewards and sanctions from institutionalized practices, technologies or rules, for example, through court rulings, challenges to the prevailing regulatory structure, and redefinition of technical standards and assumptions on which an institution is based.
	Vesting	Dividing vested rights and interests by government authorities through processes such as regulative bargaining to create new actors and change market rules and relations.	Policing	Using sanctions and rewards to enforce, audit and monitor compliance of institutionalized practices.		
	Advocacy	Influencing the allocation of resources and socio-political support through activities such as lobbying, advertising, promoting agendas and litigation.	Deterring	Using economic or authoritative measures to provide the threat of coercion and instill conscious obedience of actors.		
Normative	Constructing identities	Collective action to create shared understandings of the relationship between actors and their field of work, particularly in the emergence of new or transformation of existing professions.	Valourizing and demonizing	Promoting particularly positive or negative examples that illustrate the moral foundations of the institution, for example, public recognition of 'good' and 'bad' practices.	Disassociating moral foundations	Gradually undermining the moral foundations of institutions through indirect sets of practices.
	Changing normative associations	Extending or adapting existing practices to promote new moral and cultural associations through activities that create strategic realignments and develop new policy directions.				
	Constructing normative networks	Creating loose peer networks that normatively sanction certain practices and exist in parallel to established institutional structures, through activities that bring people together, for example, workshops, conferences, demonstration projects or case studies.	Mythologizing	Creating and sustaining myths around the history of the institution through story-telling in a public arena.		
Cultural-Cognitive	Mimicry	Leveraging existing taken-for-granted practices, technologies and rules to associate new with old to ease adoption, for example, designing elements and selecting symbols to mimic and emphasize similarities with the old.	Embedding and routinizing	Embedding daily routines and repetitive practices with institutional values and morals through activities such as training, education, recruitment, certification and ceremony.	Undermining assumptions and beliefs	Decreasing the costs associated with a new practice, technology or rule through innovation that breaks existing institutional assumptions and templates, or gradual undermining through contrary practice.
	Theorizing	Naming and developing a language around new concepts and practices to cognitively map them within the field, and articulating narratives of cause-and-effect relationships among institutional elements.				
	Educating	Developing new skills and knowledge in actors to support novel practices through activities such as training programs, establishment of working groups, demonstration projects, case studies, creation of guidelines, frameworks and templates.				

Mechanisms of institutional work are how actors can influence the institutional dynamics of a societal system. In the case of an urban water system, changes to its biophysical structures (e.g. rivers, pipelines) will be facilitated by actors initiating changes to its social structures (e.g. policies, design standards) through the employment of different forms of institutional work. Therefore, analysts can identify strategic action types based on an assessment of what institutions need to be created, maintained and/or disrupted and how to most effectively influence the institutions at a particular point in time, whether via the regulative, normative or cultural-cognitive elements, given the adaptive cycle position (Figure 3).

2.3 Proposed Diagnostic Procedure

Integration of the MPA, adaptive cycle, institutional pillars and institutional work mechanisms provides the conceptual basis for identifying which types of strategic action would be most effective for enabling change, in a complex system characterised by uncertainty and nonlinear change. For example, at a given point in time strategic planners need to understand the current state of the system, the phase of change for individual constellations and the type of upcoming changes that are expected, so that interventions can focus on which mechanisms are likely to be most effective in the short and long-term. The proposed diagnostic procedure follows the five steps described below (see also Figures 4 and 5).

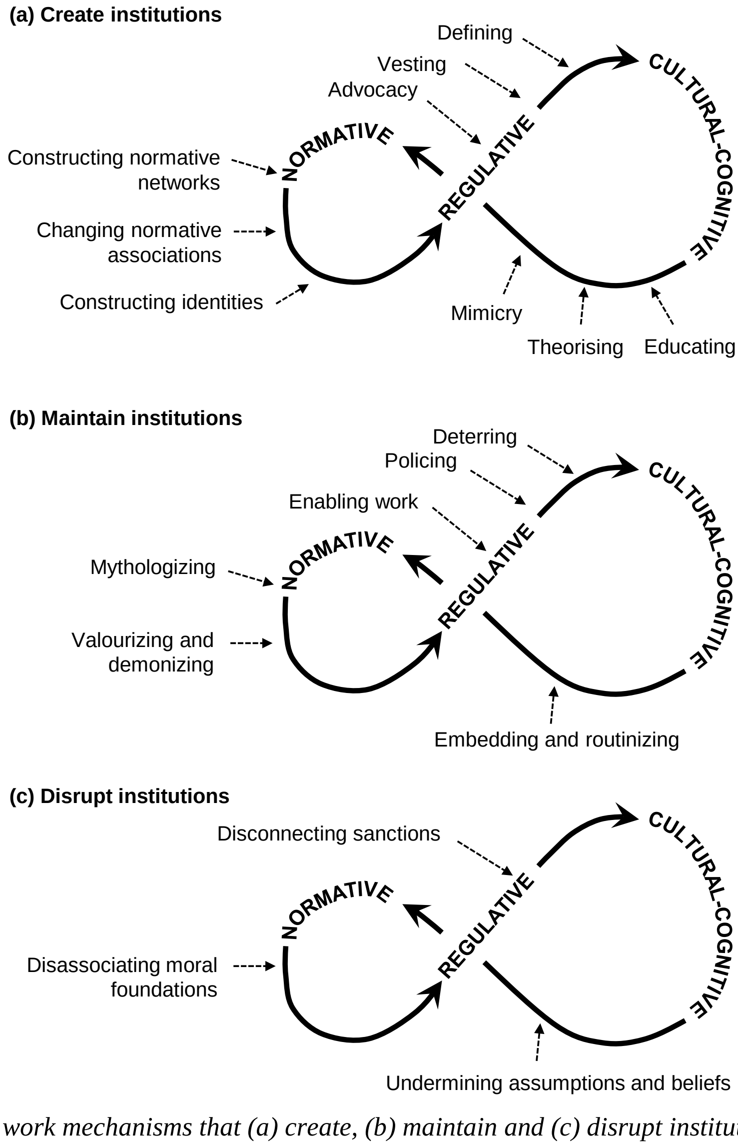


Figure 3. Institutional work mechanisms that (a) create, (b) maintain and (c) disrupt institutions (Lawrence and Suddaby, 2006). These are conceptually positioned at different phases of the adaptive cycle to align with the institutional pillar (Scott, 2008) that this paper hypothesizes would represent the most effective mechanisms for the system conditions at that particular adaptive cycle position. (Note that the sequential order of individual mechanisms within the adaptive cycle phase for each pillar is not important, only the overall category of mechanisms that are indicated by the institutional pillar.)

Step 1. Define current system composition and envision desired future system composition (Figure 4). Identify the constellations that currently comprise the system and empirically map how each meets different components of society's needs. Follow envisioning processes to map the desired future system and define its composition. There is extensive scholarship on processes for futures studies, for example, visioning, backcasting, roadmapping, scenario planning (e.g. Borjeson et al. 2006; Dreborg 2006; Robinson 2011, Swart et al. 2004; Ziegler 1991). Details of these processes are beyond the scope of this paper but we highlight that a suitable and rigorous methodology should be selected and that broad participatory approaches are typically preferred.

Step 2. Determine the possible transition conditions for driving desired transition patterns (Figure 4). Determine which transition patterns (reconstellation, empowerment or adaptation) would be likely to result in the system composition changes required for the desired transformation. Then determine the conditions for transformative change (tension, pressure or stress) that would be likely to drive these patterns.

Step 3. Determine the institutional changes that could induce the conditions for change (Figure 4). Determine which type of institutional change processes (create, maintain or disrupt) for each constellation could induce the conditions for the desired transformative change identified in Step 2. Note that the 'tension' condition would not be induced through institutional change, as by definition, tension occurs when a landscape force acts on the system. The aim is therefore to create, maintain or disrupt institutions within constellations so that when a landscape influence does result in the tension condition being present, the constellations exert complementary stress or pressure conditions to drive a transition pattern.

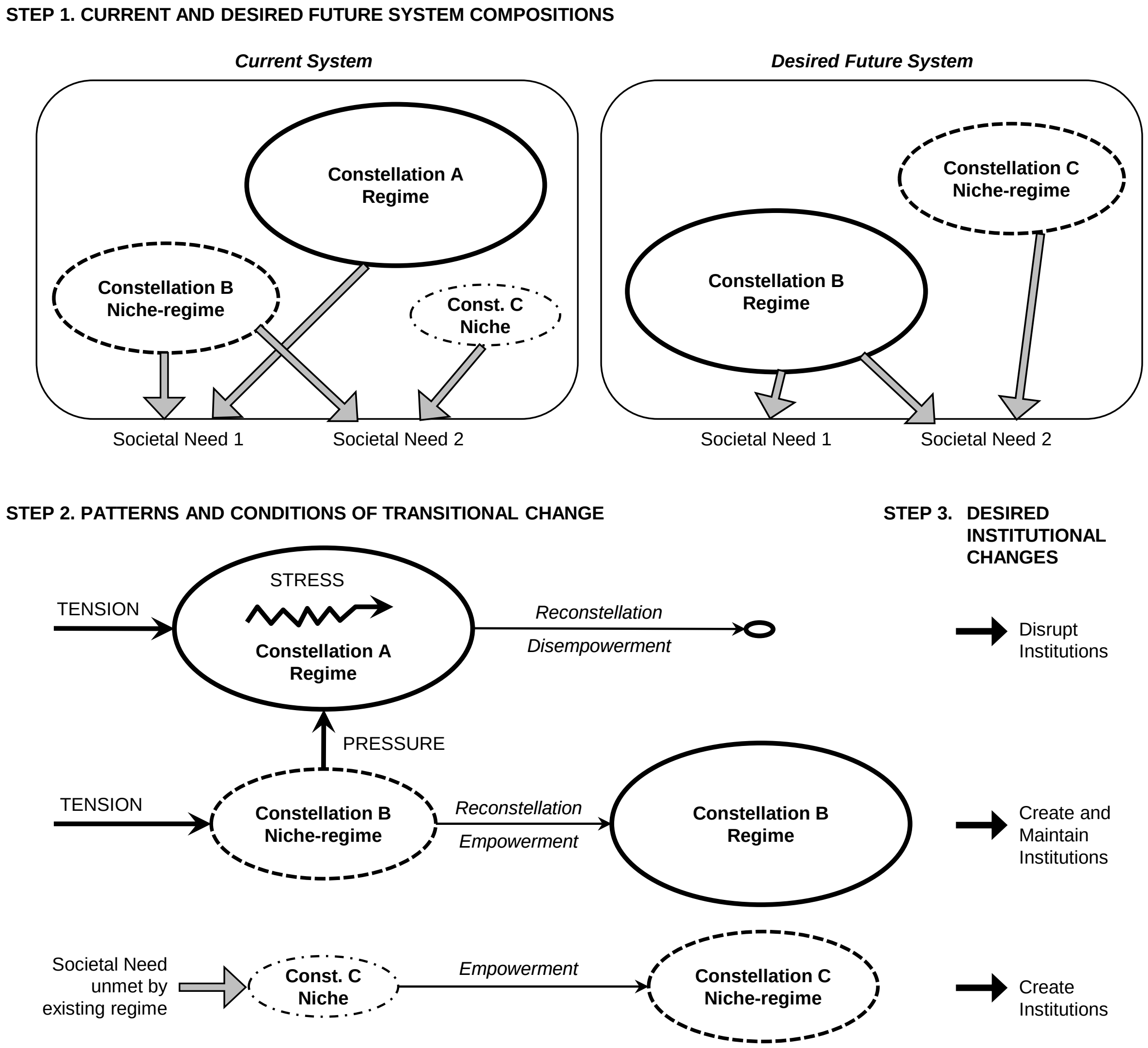


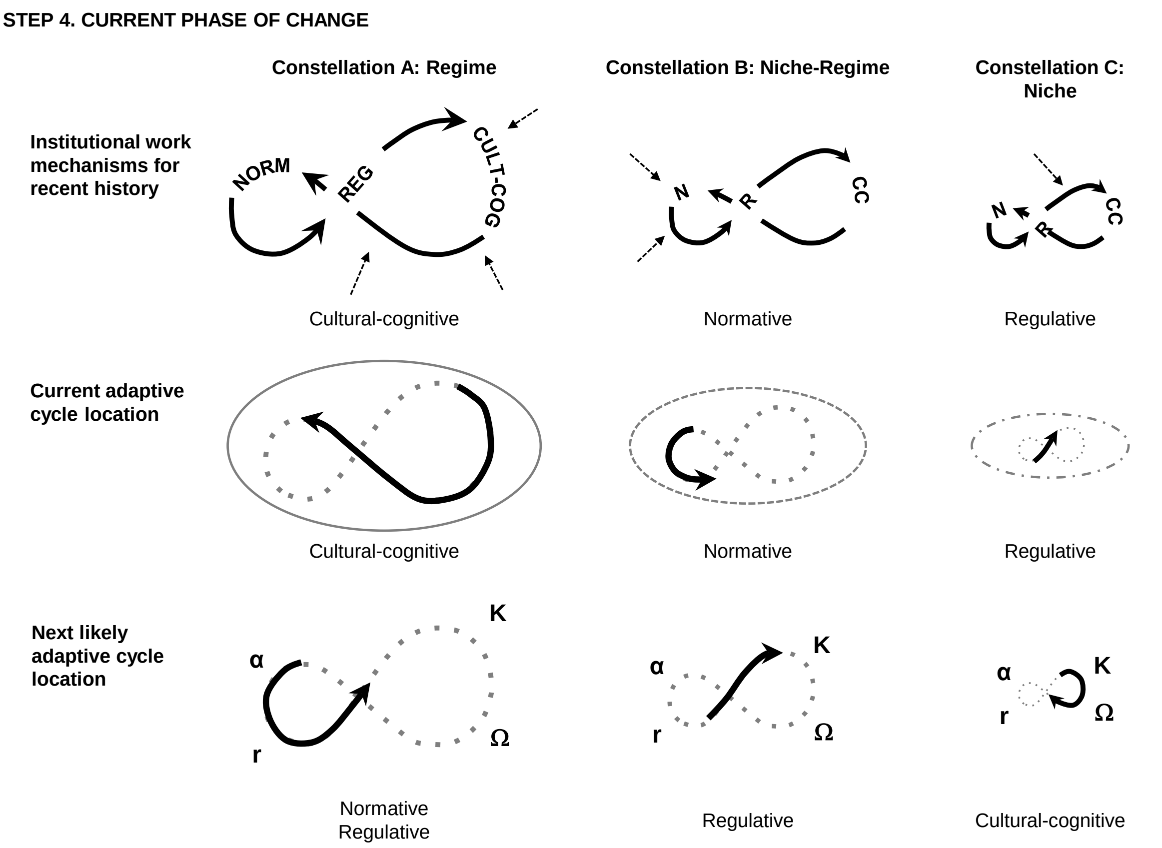
Figure 4. Steps 1, 2 and 3 of the proposed diagnostic procedure.

Step 4. Determine the phase of change for each constellation (Figure 5).

Determine each constellation's current phase of change (adaptive cycle) by mapping its recent history of change using empirical data. The effectiveness of different mechanisms of institutional work provides an indicator of where in the adaptive cycle the constellation is currently positioned. For example, if the focus of recent strategic initiatives had been on regulative dimensions, the constellation is likely to be in the r to K phase. If the focus had recently been on network building and experimentation, the constellation is likely to be in the α to r phase. Tracing the history of change back to one previous adaptive cycle location should be sufficient to identify the current location. Once the current phase of change has been mapped, identify the phase of change that is likely to occur next by examining the adaptive cycle position. This then implies which institutional pillar (cultural-cognitive, normative, regulative) should be focused on through strategic initiatives in order for institutional work mechanisms to be most effective.

Step 5. Identify institutional work mechanisms that best fit the current system conditions (Figure 5).

Use the outcomes of Steps 3 and 4 to identify the category of institutional work mechanisms that should be employed through strategic initiatives to most effectively enable a transition. Select mechanisms according to whether the aim is to create, maintain or disrupt institutions and whether the phase of change is in the cultural-cognitive, normative or regulative part of the adaptive cycle. Short-term strategic initiatives and long-term planning activities can then be identified for implementing these mechanisms.



STEP 5. FUTURE INSTITUTIONAL WORK MECHANISMS

Select and design strategic action initiatives (refer Table 2)	**Institutional Work Mechanisms** (Step 3)		
Institutional Pillar (Step 4)	Create Institutions	Maintain Institutions	Disrupt Institutions
Regulative	Constellation B	Constellation B	Constellation A
Normative			Constellation A
Cultural-Cognitive	Constellation C		

Figure 5. Steps 4 and 5 of the proposed diagnostic procedure.

Drawing on the strategies identified by Olsson et al. (2006), actors can prepare for system transformation by anticipating when windows of opportunities are likely to occur and undertaking institutional work activities that ensure the niche constellations are in the r or K phase of the adaptive cycle (e.g. through activities that build up knowledge, leadership capacity and shadow networks). In these phases, niches are best prepared to influence the regime when a strong landscape influence opens a window of opportunity. Similarly, actors can undertake institutional work that encourages regimes to be in the Ω or α phase of the adaptive cycle (e.g. through activities that challenge existing assumptions and knowledge) to maximize their capacity to adapt, as well as to escape rigidity and poverty traps. Once a window of opportunity has opened, there is the potential for navigating a transition and fostering resilience of the new system by undertaking institutional work that encourages new innovations and breaks down any barriers that would prevent stabilization of the new system composition.

3. Example Application of the Diagnostic Procedure

Figures 6 and 7 provide a simplified application of the diagnostic procedure to a case study from Melbourne, Australia. The case study was a grounded historical analysis of the transformation in urban stormwater management between 1960 and 2006 (refer to Brown et al. in press, for full details). The study provides an example of how actors in an international leading city from a waterways management perspective (Jefferies and Duffy 2011, Roy et al. 2008) were able to transform the mainstream approach of piped drainage to incorporate Water Sensitive Urban Design (WSUD) practices.

For the case study period, the system functioning was dominated by a piped drainage regime that aimed to rapidly convey large volumes of stormwater to receiving water bodies. Downstream waterways were highly polluted since stormwater quality was not a consideration of this piped drainage regime. However, from the 1960s, there was growing community awareness and concern about the poor health of Melbourne’s waterways. These concerns continued throughout the case study period and are conceptualized as landscape influences of environmentalism and waterway pollution. In response to these tensions and the unmet societal need for ecosystem protection, a WSUD niche emerged during the 1990s. The innovative approaches in the WSUD constellation aimed to improve the quality of stormwater before it enters the receiving waterways, thereby reducing the level of pollution in downstream waters. With the support of research and development, demonstration projects and growing practitioner networks, the WSUD niche gradually increased its power over the years. By 2006, the WSUD niche had stabilized into a niche-regime that was sufficiently powerful to compete with the established piped drainage regime in providing system function to meet society’s need for ecosystem protection and drainage.

Figures 6 and 7 apply the proposed diagnostic procedure to demonstrate how it can be used to explain and anticipate the transformative dynamics in Melbourne’s stormwater management, and therefore lead to insights for identifying which types of future strategic initiatives would best fit the system conditions in 2006.

Step 1 used empirical data to map the 2006 system, identifying that both the piped drainage regime and the WSUD niche-regime met the societal need for drainage. However, only the WSUD niche-regime met the need for ecosystem protection. The envisioned future system (approximately ten years later, in 2016) comprises a regime that incorporates both piped drainage and WSUD structures, such that ecosystem protection and drainage needs are well met by structures that address both stormwater quantity and quality.

Step 2 determined that in order for this combined regime to be achieved, the current piped drainage regime would need to adapt to incorporate the WSUD structures. Transition patterns of reconstellation and/or adaptation could lead to this change. At the same time, the WSUD niche-regime would need to continue to grow in power so that it increases its influence on the regime and offers a viable means for the regime to meet the need for ecosystem protection (the empowerment transition pattern). The transition conditions on the piped drainage regime that could lead to reconstellation and/or adaptation is a combination of external tension, internal stress due to an inability to meet societal needs, and pressure from the competing WSUD niche-regime. In 2006, tension was already present in the form of environmentalism and waterway pollution.

Step 3 identified that pressure on the regime could be induced if the WSUD niche-regime maintains its existing institutions and creates new institutions. Further, stress in the regime could be induced if, through mechanisms that disrupted institutions, the piped drainage regime recognized its inability to meet the societal need for ecosystem protection.

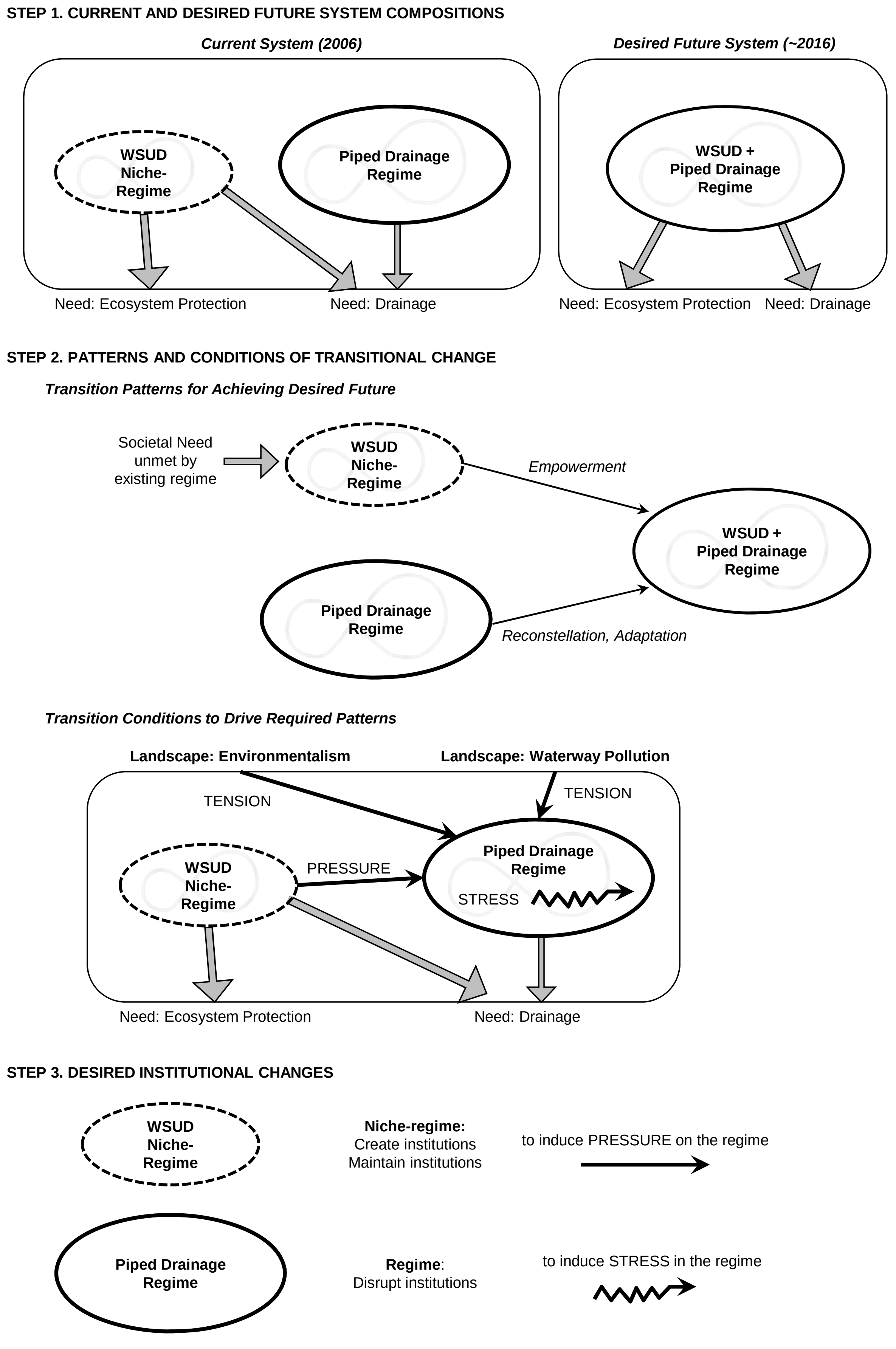
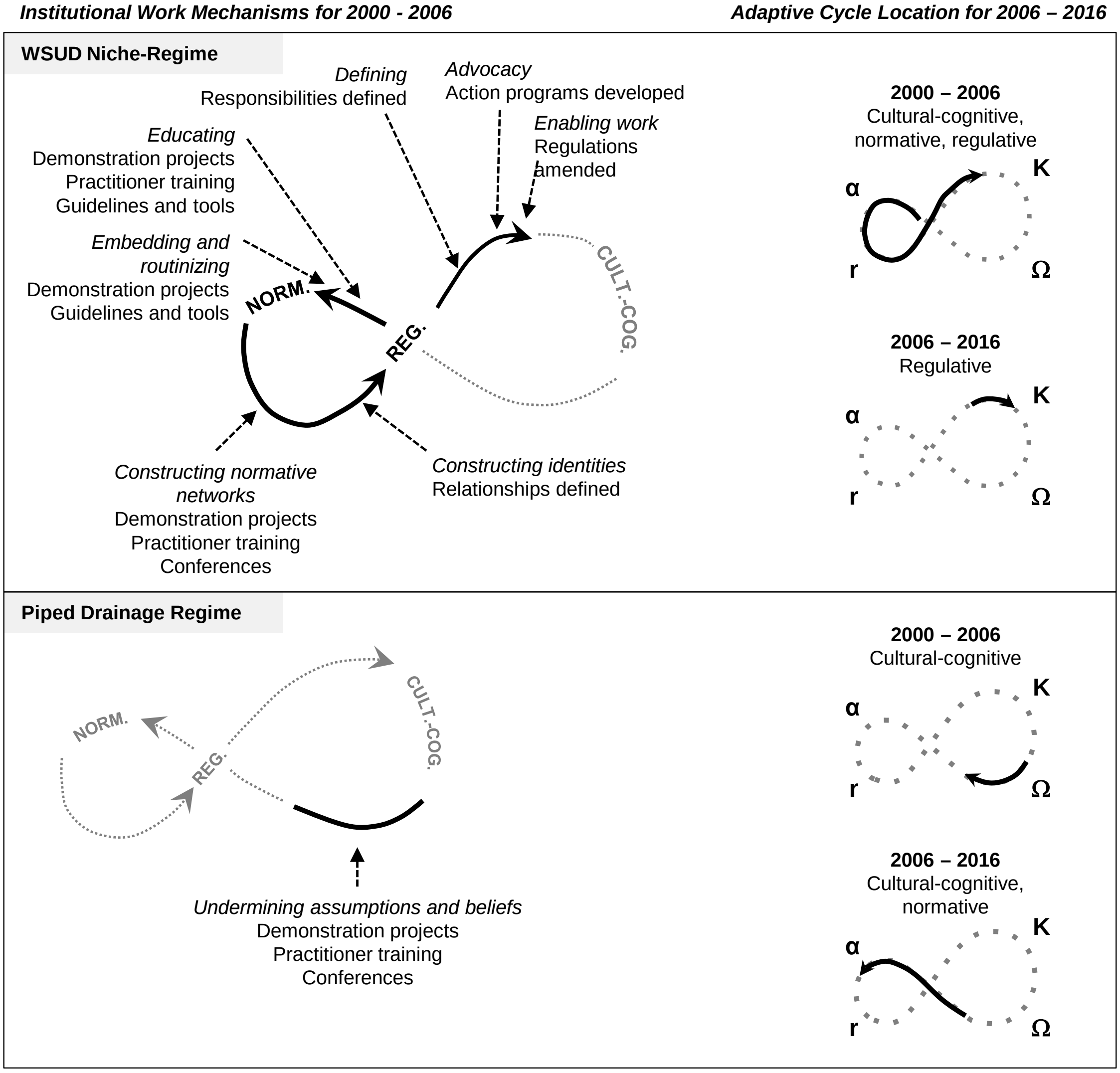


Figure 6. Application of Steps 1, 2 and 3 of the proposed diagnostic procedure to the Melbourne case study for 2006: Piped Drainage Regime and WSUD Niche-Regime.

STEP 4. CURRENT PHASE OF CHANGE



STEP 5. FUTURE INSTITUTIONAL WORK MECHANISMS

Select and Design Strategic Action Initiatives	Institutional Work Mechanisms		
Institutional Pillar	Create Institutions	Maintain Institutions	Disrupt Institutions
Regulative	**WSUD Niche-Regime**		
Normative			**Piped Drainage Regime**
Cultural-Cognitive			

Figure 7. Application of Steps 4 and 5 of the proposed diagnostic procedure to the Melbourne case study for 2006: Piped Drainage Regime and WSUD Niche-Regime.

Step 4 mapped the system changes that occurred between 2000 and 2006 to identify the adaptive cycle positions of both constellations. The institutional work mechanisms between 2000 and 2006 that led to niche growth, such that it became a WSUD niche-regime, included demonstration projects, sharing of knowledge through practitioner training and conferences, formalization of relationships, implementation of action plans, development of guidelines and other tools, and amendment of regulations. These mechanisms were cultural-cognitive, normative and regulative in nature. This information alone is insufficient to determine the precise adaptive cycle position, given the mechanisms were aligned with all three institutional pillars. However, analysis of empirical data from 1960 to 2000 traced the institutional work mechanisms back to previous adaptive cycle positions and determined the 2006 location shown in Figure 7 (space limitations of this paper means the analysis between 1960 and 2000 is not presented here). Given its phase of change in 2006, the WSUD niche-regime is likely to remain in the K phase of the adaptive cycle, where regulative institutional work is expected to be most effective for the next phase. From 2006 onwards, the regime is likely to move through the 'back loop' of the adaptive cycle between the Ω and α phases, where cultural-cognitive and normative institutional work mechanisms are likely to be most effective.

Step 5 drew on the outcomes of Steps 3 and 4 to identify which type of institutional work mechanisms are expected to best fit the 2006 conditions, in order to achieve a future system in which a regime combines both piped drainage and WSUD structures. Use of the diagnostic procedure indicates that institutional work mechanisms for the 2006 WSUD niche-regime should aim to create and maintain institutions and that are regulative in nature. Mechanisms for the 2006 piped drainage regime should aim to disrupt institutions and be cultural-cognitive or normative in nature. Actors should therefore consider how the relevant institutional work mechanisms (Table 2) are best employed through the selection of particular strategic initiatives.

4. Discussion and Conclusion

Concepts in transition theory and resilience theory offer a promising basis for analysing the dynamic patterns of transformative change. While there are some differences in the background and approach of these two fields, they have fundamentally similar understandings of dynamic transformative change. The MPA, from transition theory, identifies the system conditions and changes that are considered necessary for enabling a system transformation. The adaptive cycle, from resilience theory, identifies the current phase of change for different parts of the system. Institutional theory provides valuable understanding of the links between human action and its impact on transformative change. Used in conjunction with insights into the transformative dynamics of a system, the concepts of institutional pillars and institutional work identify which type of mechanisms are likely to be most effectively employed through strategic initiatives to enable a transition towards a desired future. This paper has integrated concepts from these three theoretical fields to propose a diagnostic procedure for revealing insights into which types of strategic action are most likely to influence the direction and pace of change in an overall system towards a desired trajectory. To provide some reflection on the potential for this procedure to support strategic planning for transformative change in urban water systems, here we consider the scope for an operational diagnostic procedure proposed by Ferguson et al. (2013).

The procedure should address a set of nested diagnostic questions (DQs) that provide retrospective analysis of a system problem or changes. It should offer analytic lenses that relate to the broad system scale, individual variables, static snapshots in time and dynamic links between system states. Ferguson et al. (2013) propose a general set of diagnostic questions for transformative change in urban water systems. Given the system-wide focus of the procedural steps presented in this paper, they address the questions relevant for the whole system, considering both static snapshots and their dynamic links (Table 3). The diagnostic questions related to individual variables and relationships (DQ 3, 4 and 5) are not addressed by the proposed procedure. Additional steps, underpinned by different analytic frameworks, would need to be incorporated if the procedure was to consider individual variables.

The procedure should be capable of analyzing system variables that are actors, structures, processes, contexts and outcomes. The system-wide focus of the proposed diagnostic procedure gives it a functionalistic perspective. Actors and structures are considered only in terms of their function in the system. Contextual factors are conceptualized as landscape influences on the system functioning. Outcomes are expressed as the degree to which societal needs are met by the system functioning. Processes are considered in terms of the institutional work mechanisms that function to create, maintain or disrupt institutions. If a different perspective (e.g. actor networks, power relationships) is required for a particular application, additional steps that are underpinned by different analytic frameworks, would need to be incorporated into the procedure.

Table 3. Diagnostic questions addressed by the proposed diagnostic procedure (Ferguson et al., 2013).

Step in Proposed Diagnostic Procedure	Diagnostic Question Addressed
1. Define current system composition and envision desired future composition	DQ 1. Take system snapshots in time
2. Determine the possible transition conditions for driving desired transition patterns	DQ 6. Predict impacts of system changes
3. Determine the institutional changes that could induce the conditions for change	DQ 6. Predict impacts of system changes
4. Determine the phase of change for each constellation	DQ 2. Trace system changes over time
5. Identify institutional work mechanisms that best fit the current system conditions	DQ 7. Predict suite of strategic action initiatives
The following diagnostic questions are not addressed by the proposed diagnostic procedure: DQ 3. Identify causal variables; DQ 4. Identify causal relationships; DQ 5. Trace impacts of causal variables and relationships	

The procedure should incorporate a methodological framework that provides operational guidance. The diagnostic procedure provides clear methodological steps for consistent empirical application to gain generalized insights.

The procedure should be underpinned by conceptual frameworks that provide description and explanation of a system problem or changes. The diagnostic procedure is underpinned by concepts (MPA and adaptive cycle) that are capable of both describing and explaining a system's transformative dynamics observed in empirical data.

The procedure should be capable of providing prediction about the impacts of strategic action on a system's dynamics. It should be capable of informing the selection of strategic initiatives that best fit the current system conditions. The hypothesis in this paper regarding the sequential nature of effective institutional work mechanisms, in relation to the adaptive cycle and institutional pillars, needs further substantiation. The hypothesized correlation between the presence of conditions for transformative change and the relative positions of constellations along their adaptive cycles also needs substantiation. In particular, case studies of successful and unsuccessful transformative change that demonstrate the effectiveness of different types of strategic initiatives should be investigated and analysed through the diagnostic procedure to validate its ability to describe, explain and predict the different types of change observed in the cases. With this further substantiation, the diagnostic procedure would be capable of predicting how different mechanisms could impact on the system, thereby enabling an analyst to follow a process of deduction to identify which types of strategic action best fit the current system conditions.

We hope this exploration of how concepts from different theories can be integrated into a diagnostic procedure makes a contribution to the current scholarly activity focused on diagnostic approaches for addressing the science and policy questions around how transitions can be navigated to support the shift towards sustainability in urban water servicing and other infrastructure sectors. It is proposed that, with further empirical testing and subsequent refinements of the diagnostic procedure presented here, the integration of the transitions, resilience and institutional concepts proposed in this paper would be a useful platform from which to develop an operational tool that planners, policy analysts and decision-makers could use to diagnose critical mechanisms of transformative change and therefore identify which types of strategic action are likely to provide the best fit, given the current system conditions.

Use of diagnostic approaches to support the planning of infrastructure systems would address some of the critical flaws in planning agendas that focus on controlling variables and reducing uncertainties for linear change processes. Instead it would enable scholars and practitioners to examine proposed policy and action within the context of the broader system, embracing the reality of its complexity, interconnectedness and contextual uncertainty that frames society's needs from its infrastructure. This perspective would be particularly valuable for cases in which transformative change of the system is considered necessary to achieve sustainable outcomes. It would provide insight into the likely timing of windows of opportunity so that strategic initiatives could be selected to achieve maximum effectiveness at different phases of a transformation and to prepare the system for likely upcoming changes. Finally, it would provide actors with a systemic understanding of how adaptive change can be welcomed rather than resisted, encouraging the proactive development of strategic plans to increase adaptive capacity and facilitate the transition towards a resilient and sustainable system.

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CHAPTER 4. RESEARCH METHODS

This chapter presents the research methods, starting with an explanation of the rationale for the case study approach, the selection of Melbourne's water system as a unique context and five embedded cases for study. The overall research design is then presented and the methodological techniques used to address each research objective are described. Specific approaches for data collection, data analysis and maintaining research reliability and validity are also explained.

4.1. Research Philosophy

This research is framed by the real world problem that the traditional engineering approach for managing urban water systems is inadequate for coping with current and future contexts and changing societal needs. The vision of a water sensitive city is introduced as an alternative approach, undperinned by an adaptive paradigm. The research is therefore explicitly normative, aiming to develop a framework for guiding strategic initiatives to enable the transition to a water sensitive city.

Given the real world context of the research problem, the approach for addressing this aim needs to engage with both theory and practice, an interaction typically embraced by pragmatist philosophy (Creswell, 2009). Pragmatic research focuses on a particular social issue and utilises whichever research methodologies are considered most useful for revealing insights on solutions that could best address the associated problems (Patton, 1990). Pragmatic approaches are also useful when both academic and practitioner knowledge are considered valuable for developing answers to practical questions (Denscombe, 2008).

In adopting a pragmatist philosophy, the research was undertaken from a perspective in which core realities about urban water system problems are acknowledged (particularly with respect to its biophysical elements), but with the understanding that these problems occur within social, historical and political contexts that involve socially constructed realities (Creswell, 2009). This pragmatic approach utilises qualitative social research methods to develop insights into the role and influence of actor strategies during innovation and transition processes within the urban water system realities in order to gain the best possible understanding of how it can be positively influenced by system actors.

4.2. Research Design

Blaikie (2010) emphasises the importance of making research decisions explicit to ensure the different elements of a research design are consistent with each other and ontological assumptions that are made. This section describes the case study research design for this thesis.

4.2.1. Qualitative case studies

To support the development of a framework for guiding strategic initiatives in urban water servicing, a qualitative case study approach (Yin, 2009) was adopted. For Yin, a case study is valuable as a research approach when in-depth investigation of a contemporary phenomenon within its real-life context is required. Moreover, unlike many other research designs, the case study can cope with situations in which there are many more variables of interest than data points and where there are unclear boundaries between the phenomenon and context being studied (Yin, 2009). The phenomenon of transformative change in urban water systems is complex, with many factors influencing why and how transitions occur. Case study methods produce results that can provide both description and explanation of these system changes, which can then potentially be used to develop theoretical generalisations with implications for strategic planning and management of water servicing.

The research involved a single context of Melbourne, with two separate embedded multiple-case studies (Yin, 2009). The first embedded multiple-case study was a longitudinal investigation operating in explanatory mode; the institutional trajectory of new innovations in Melbourne's contemporary water system was the unit of analyses. The second embedded multiple-case study was an investigation of the vision for Melbourne as a future water sensitive city and strategies that would achieve this vision from current system conditions. The units of analysis were the envisioned future water system and the actor strategies identified; these case studies operated in descriptive mode (Yin, 2009). The two embedded multiple-case studies were conducted as distinct investigations; however, the cases collectively provided insight into the institutional context and selection, design and coordination of actor strategies for facilitating Melbourne's transition from a traditional water system rooted in the engineering paradigm to its stabilisation as a future water sensitive city. The results from the two multiple-case studies were drawn upon to support the development of the framework for guiding strategic initiatives.

4.2.2. Research phases

The research involved four distinct phases, which collectively addressed the objectives of this thesis. The first phase involved theory development to design the preliminary diagnostic procedure presented in Chapter 3. The second phase involved the development of an embedded multiple-case study of three cases of contemporary change in Melbourne's water system. The third phase involved the development of an embedded multiple-case study of two illustrative cases of envisaged future changes in Melbourne's water system. The fourth research phase synthesised the outcomes from the previous phases to refine the diagnostic procedure and embed it in a meta-governance framework for transformative change. Figure 3 presents these phases in an overall research design.

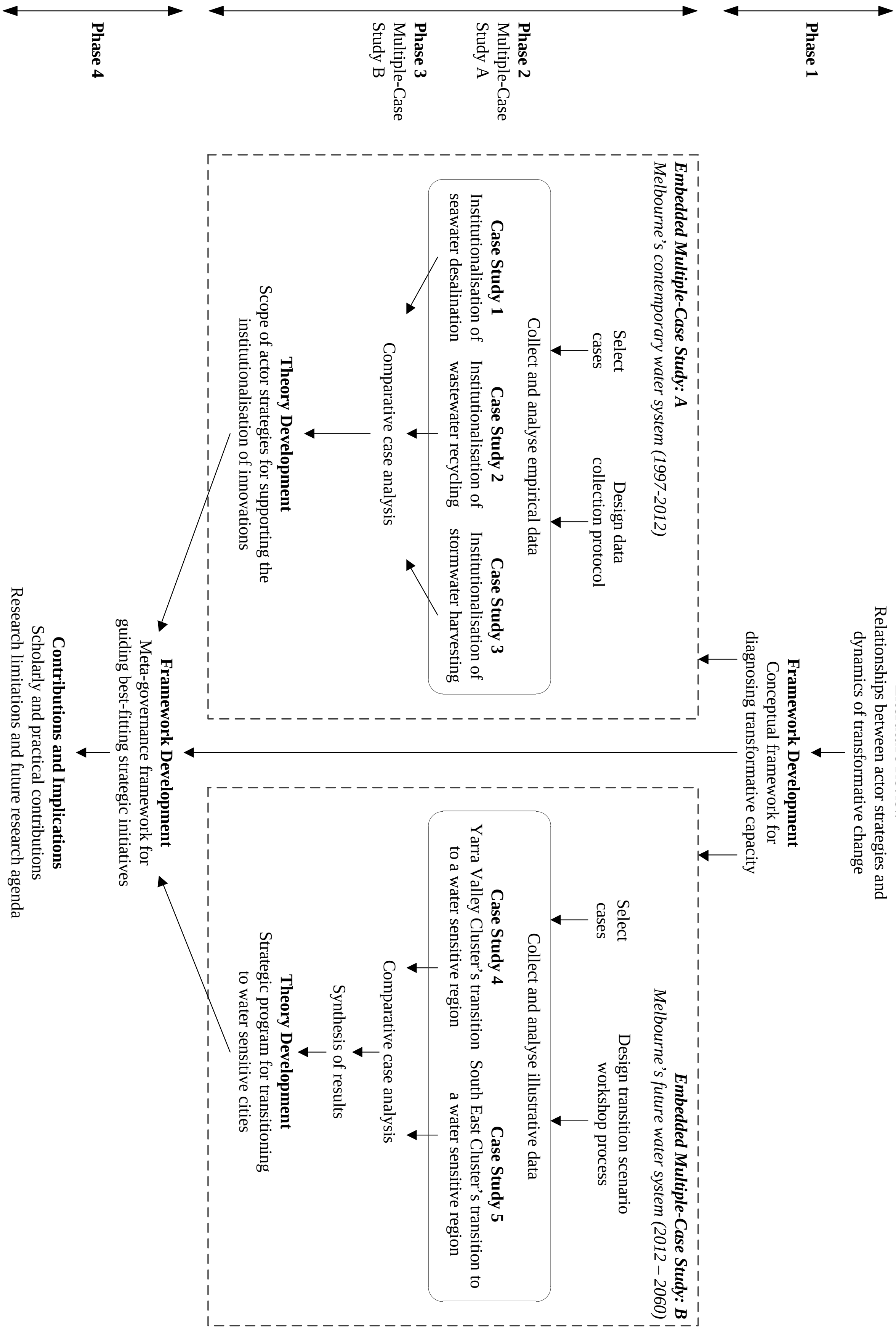


Figure 3. Research design

The research drew on multiple sources of evidence to develop converging lines of inquiry from both primary and secondary data, such that the different sources of evidence could be triangulated to corroborate the findings (Yin, 2009). These sources included interview transcripts and transition scenarios as primary data, as well as secondary documentation, detailed in Chapters 4.4, 4.5 and 4.6. These research methods are summarised in Table 3 and described below. The specific research questions linked with each of the objectives are also presented.

Table 3. Summary of research methods

Research Phase	**Method**	**Data sources**
1. Theory development	Literature review	Scientific literature
2. Contemporary changes in Melbourne	Embedded multiple-case study A	Interviews, secondary documentation
3. Envisaged future changes in Melbourne	Embedded multiple-case study B	Transition scenario workshops
4. Development of meta-governance framework	Theory development	Outcomes of research phases 1, 2 and 3

4.2.3. Case Selection

Melbourne's water system has been traditionally dominated by separate water supply, sewerage and drainage pipe networks, centralised surface water reservoirs, centralised wastewater treatment plants and channelised drains. This infrastructure is characterised by an 'engineering' management approach which emphasises large-scale technical solutions. However, since the 1990s innovative decentralised technologies for stormwater treatment, stormwater harvesting and wastewater recycling have been adopted and their associated practices are becoming institutionalised as part of mainstream water management (e.g. Barker et al., 2011; Mitchell, 2006). This represents a radical departure from the traditional water system and reflects a period of transformative change.

The last decade has also seen Melbourne's water sector significantly change its discourse toward a more water sensitive direction and it is now internationally recognised as a world leader in sustainable urban water management (Jefferies and Duffy, 2011; Roy et al., 2008). Following a thirteen year period of drought and then two years of extreme rainfall and flood events, a new water management philosophy underpinned by notions of liveability, sustainability and resilience has become formal government policy (Victorian Government, undated). The concept of the water sensitive city has taken root as a desired, albeit undefined, symbol of an urban water system that is sustainable, resilient and supports a city's liveability. These developments are reflected by the recent awarding of a Cooperative Research Centre for Water Sensitive Cities, which involves 74 research, industry and government partners, as well as the establishment of an 'Office for Living Victoria' by the Victorian Government, whose agenda is to drive generational reform for "creating a smart resilient water system for a liveable, sustainable and productive Melbourne" (Victorian Government, undated).

These experiences made Melbourne's water system an ideal unique single case context, worthy of investigation to gain understanding about transformative change in urban water systems and develop insights for extending theory on transitions (Yin, 2009). Analysis of the institutionalisation of specific innovative water solutions was expected to provide critical insight into the scope of actor strategies for influencing innovations of varying characteristics, while the tacit knowledge of actors who have lived through Melbourne's recent experience of significant water sector changes was expected to provide rich data about how to support innovation and reform mainstream approaches through strategic initiatives.

The cases selected for the two embedded multiple-case studies are outlined in Table 4

Table 4. Selected embedded cases

Case type	Case		Replication logic
Embedded multiple-case study A: Contemporary	1	Institutionalisation of seawater desalination in Melbourne (1997 − 2012)	Theoretical (producing contrasting results that are anticipatable from theory)
	2	Institutionalisation of wastewater recycling in Melbourne (1997 − 2012)	
	3	Institutionalisation of stormwater harvesting in Melbourne (1997 − 2012)	
Embedded multiple-case study B: Future	4	Yarra Valley Cluster's transition to a water sensitive region (2012 − 2060)	Literal (producing similar results)
	5	South East Cluster's transition to a water sensitive region (2012 − 2060)	

Cases 1, 2 and 3 were selected to represent new water sector innovations that had three distinct speeds of institutionalisation from the period when drought began, in January 1997, to June 2012 and provided theoretical replication (contrasting results that theory can explain) (Yin, 2009). The innovation in Case 1 (desalination) was rapidly institutionalised, reinforcing the conventional engineering paradigm. The Case 2 innovation (wastewater recycling) had moderate pace of institutionalisation, incorporating features from both the conventional paradigm and the new water sensitive paradigm. The innovation in Case 3 (stormwater harvesting) had a slow pace of institutionalisation, representing a significant shift in how water servicing is delivered and disrupting the conventional engineering paradigm. Analysis and comparison of these embedded cases was therefore expected to reveal different trajectories of instituitonalisation and provide a rigorous basis for generalisations.

Cases 4 and 5 were considered to be 'illustrative' rather than empirical because the data was based on informed perspectives about future change (since it is not possible to empirically observe phenomena about future conditions; for examples of futures research see Kok et al, 2011; Sarpong and Maclean, 2011; Sheppard et al., 2011). The cases were carefully generated to provide understanding of the dynamics of the system's transition towards, and stabilisation of, the new water sensitive paradigm for two particular regions of Melbourne. The large geographic size of Melbourne (7,700 km^2) means there is a wide range of geographic, socio-economic and administrative contexts for water servicing. In order to reveal detailed insights on the actor strategies that would be effective at both local and city-wide scales, the research was conducted within particular clustered regions to provide contextual focus. Case 4 focused on the "Yarra Valley Cluster", covering the municipalities of the City of Boroondara, the City of Manningham and Maroondah City Council (three of the 32 municipalities across Melbourne). Case 5 focused on the "South East Cluster, covering the City of Casey, the City of Greater Dandenong, Frankston City Council and the City of Kingston (see Figure 4) (four of the 32 municipalities across Melbourne). The two cases comprised a diversity of institutional perspectives, organisational profiles, geographic characteristics, urban development trends and sustainable water management performances. However, the results of the case studies were very similar, providing literal replication (multiple sets of results that are alike) (Yin, 2009) for the generalisations drawn with regard to their implication for strategic management of urban water servicing.

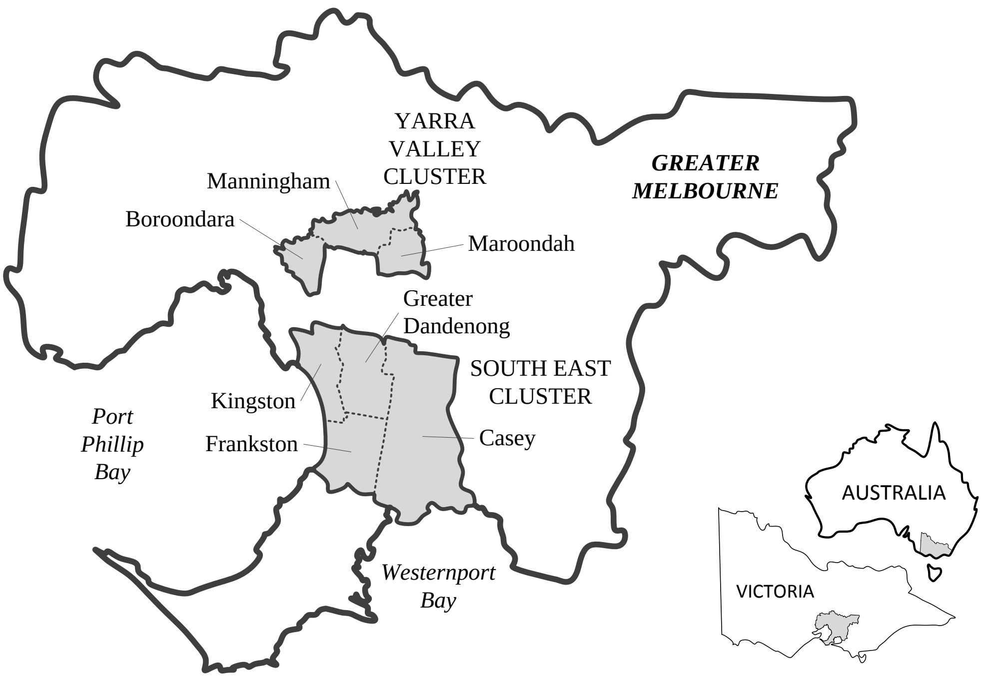


Figure 4. Geographic regions of Cases 4 and 5

4.2.4. Objective 1: Conceptual framework for diagnosing transformative capacity

The first research objective was to **derive a conceptual framework for diagnosing the transformative capacity of urban water systems in relation to a desired future vision.** Key research questions included: What should be the structure and composition of a diagnostic procedure? What variables and relationships need to be considered in the diagnosis of a system's transformative capacity? What existing theories and frameworks could contribute to system diagnosis? What conceptual elements are required to link understandings of a system's dynamics with strategic initiatives for facilitating transitions? These research questions led to a series of five sub-objectives:

1.1. Develop a scope for a diagnostic procedure for transformative change
1.2. Review existing frameworks from transitions & resilience theory to reveal how they could contribute to a diagnostic procedure
1.3. Synthesise conceptual understandings of transition dynamics from literature
1.4. Design a preliminary diagnostic procedure and demonstrate its application on a case study of Melbourne
1.5. Conceptually link analytic and diagnostic tools developed in a procedural design for informing the selection and design of actor strategies that best fit the system

The research to address these objectives first involved reviewing literature on diagnostic approaches, integrated assessment, transitions theory and resilience theory to develop an operational scope for a diagnostic procedure that is capable of guiding an analyst to select and design strategic initiatives that best fit the current conditions of an urban water system to enable desired system changes. Literature on transitions theory and resilience theory was then reviewed to identify existing analytic frameworks that meet criteria related to diagnostic capacity, analytic focus and empirical applicability. These existing frameworks were then applied to a reference empirical case of successful transformative change in the management of stormwater in Melbourne, in order to identify how each could contribute to a diagnostic procedure that has the operational scope developed (see Publication 1).

The next methodological steps was to reviewing particular concepts in transitions theory and resilience theory to identify how each scholarship explains different dimensions of transformative change. The shared understandings were then synthesised to develop a conceptual base for the design of a diagnostic procedure. Specific concepts within the multi-pattern approach (de Haan, 2010; de Haan and Rotmans, 2011), the Panarchy framework (e.g. Gunderson and Holling, 2002) and new institutionalism (Scott, 2008; Lawrence and Suddaby, 2006) were then integrated to form the conceptual building blocks of a diagnostic procedure that meets the scope proposed earlier. The conceptual building blocks were then organised in a step-by-step procedure (see Publications 2 and 6.)

4.2.5. Objective 2: Strategic ingredients for transformative change from case studies

The second research objective was to **reveal the critical strategic ingredients for supporting innovation and transition processes in urban water servicing through valid and reliable case studies of recent historical and envisaged future transformative change in Melbourne's water system.** Key research questions included: What infrastructural and institutional changes have occurred in Melbourne's water system historically and since 1997? What patterns of actor strategies led to the institutionalisation of innovative technologies and their associated practices in Melbourne's water system? What are the envisioned urban water servicing arrangements required to address anticipated future societal needs of Melbourne's water system? What infrastructural and institutional changes would be required to achieve the envisioned future for urban water servicing in Melbourne? What actor strategies would be effective in achieving these infrastructural and institutional changes? These research questions led to a series of six sub-objectives:

- 2.1. Present case studies of transformative changes in Melbourne's water system
- 2.2. Identify the institutional context that enabled transformative changes in the Melbourne cases
- 2.3. Identify institutional trajectories of innovations in the contemporary Melbourne case
- 2.4. Derive theoretical insights from the Melbourne case on the scope of actor strategies for supporting institutional trajectories
- 2.5. Present an illustrative case study of transition scenarios for water in Melbourne
- 2.6. Derive lessons from the future Melbourne case related to strategic planning and management for urban water transitions

The research to address these objectives involved the development and analysis of two embedded multiple-case studies in the single context of Melbourne's water system. For the empirical multiple-case study A, primary interview data and secondary documentation were collected and and analysed to develop a chronological account of the recent historic water servicing developments in Melbourne (see Publication 3). Individual narratives for Cases 1, 2 and 3 were then developed, representing innovations of different characteristics that had slow, moderate and fast paces of institutionalisation. Analytic frameworks from transitions theory and new institutionalism were used to analyse these case narratives and develop trajectories that mapped the role and influence of different types of actor strategies on the institutional development of the innovation. Comparative analysis of these trajectories was then undertaken to identify theoretical generalisations on the scope of actor strategies for institutionalising innovations (see Publication 4).

The illustrative multiple-case study B involved an action research approach based on the transition management methodology (Loorbach, 2007) to develop normative transition scenarios for Cases 4 and 5. This methodology was designed to capture the tacit knowledge of water practitioners in Melbourne on how to support innovation and reform mainstream approaches through strategic initatives. The transition scenarios from the two cases were synthesised into a single Melbourne-wide transition scenario, since the features for each case were very similar. The content of the synthesised scenario was inductively analysed, guided by key questions found in literature related to the long-term planning for urban infrastructure, to identify lessons for strategic planning and management of urban water transitions (see Publication 4).

4.2.6. Objective 3: Meta-governance framework for guiding best-fitting strategies

The third research objective was to **design a meta-governance framework for guiding strategic initiatives that best fit a system's current conditions to facilitate system-wide transitions in urban water servicing.** Key research questions include: How can a system's current conditions be characterised in a way that provides insights for the selection and design of actor strategies? How can the 'best-fitting' actor strategies be determined? How should best-fitting actor strategies be coordinated to most effectively influence transformative change? What governance processes need to accompany diagnostic processes to effectively guide strategic initiatives? How should the required range of governance, diagnostic and other processes be coordinated to most effectively influence transformative change? These research questions led to a series of three sub-objectives:

3.1. Design an analytic method for characterising a water system and its institutional trajectories
3.2. Design a strategic program that coordinates actor strategies for facilitating urban water transitions
3.3. Design a framework that embeds the diagnostic tools with governance processes for guiding strategic initatives to facilitate urban water transitions

The research to address these objectives triangulates across the results from objectives 1 and 2. First, the frameworks used to analyse the institutional trajectories of Cases 1, 2 and 3 were procedurally linked in an analytic method for characterising the elements of a system, including their institutional composition and alignment with mainstream components (see Publication 3). Second, the lessons from the transition scenario synthesised from Cases 4 and 5 were combined with theoretical insights from strategy literature to inform the scope, coordinating logic and design base of a strategic program for enabling transformative change from conventional water servicing to a water sensitive approach (see Publication 4.) Finally, the diagnostic procedure developed (see Publications 1 and 2), the analytic method for system characterisation and strategic program for transitioning were embedded within a meta-governance framework for transformative change. Design of the framework and accompanying toolkit also integrated insights from transitions and resilience literature related to transformative governance processes, as well as methodological insights gained in the facilitation of the transition scenario workshop processes during the research.

4.3. Multiple-Case Study A: Contemporary

The first embedded multiple-case study (Cases 1, 2 and 3) was undertaken in the second research phase and involved the collection and analysis of primary and secondary data. This section presents full details of the methods used in this research phase; a summary is also provided in Publications 3 and 4 so there is some repetition.

4.3.1. Primary data collection

Primary data was collected through interviews with actors who had been directly involved in the changes of Melbourne's water system between 1997 and 2012. Interviewees were identified through a search of industry literature and a snowball sampling process of peer recommendation. Interviewees represented a range of perspectives and stakeholder groups (including state government, water utilities, local municipalities, academia, private sector and community), and who have had extensive experience in Melbourne's water sector. They were typically currently or previously in middle to senior level positions in capacities ranging from executive decision-maker, technological expert and project manager. For each case the interviewees collectively represented a detailed understanding of the strategic planning processes, decision-making context and management issues of the innovation being studied. Table 5 provides a summary of the interview details, including organisations represented, organisational positions of interviewees and interview type.

Interviewees were approached directly, where their contact details were publicly available, otherwise permission to contact potential participants was sought from senior organisational representatives. Interviewees were guaranteed anonymity and confidentiality to maximise their comfort and confidence in speaking freely with the researcher. All procedures associated with the interviews (including approaching potential interviewees, conducting the interviews and maintaining confidentiality of interviewees) complied with the requirements of the Human Ethics Certificate of Approval (number CF10/3357 - 2010001774), granted by the Monash University Human Research Ethics Committee.

The objective of the interviews was to identify implicit experiential insights covering key events, external drivers and actor strategies during the case study period (January 1997 to December 2012), with emphasis on the changing structures and processes that occurred. Two types of interviews were conducted. Twenty *oral histories* (Blaikie, 2010; Fontana and Frey, 2008) were collected from individual actors who had employed strategies that instrumentally supported the institutionalisation of at least one of the innovations investigated in Cases 1, 2 or 3. Oral history interviews were free-flowing narrative personal accounts of the developments of Melbourne's water systems. Four *group interviews* (Blaikie, 2010; Fontana and Frey, 2008) were also conducted, with two or three individuals participating in each. Group interviews were in-depth and free-flowing, allowing participants to provide detailed narratives of their personal recollections, as well as discuss with each other their perceptions of the drivers of key system changes that occurred during the case study period. In both oral history and group interviews, the researcher asked open-ended questions designed to stimulate the personal accounts of the interviewees and took opportunity to probe for further depth and understanding of the topic being discussed when necessary.

Table 5. Interview details

Actor type	Organisation	Number of interviewees		Position type
		Oral history	Group interview	
State Government	Department of Sustainability and Environment	2		Management
	Department of Health		3 (1 interview)	Project
	Department of Planning and Community Development		2 (1 interview)	Project
	Growth Areas Authority	1	2 (1 interview)	Executive, management, project
	Parliament	1		Member of Parliament
Water utility	Melbourne Water	5		Executive, management, project
	Yarra Valley Water	2	2 (1 interview)	Executive, management, project
	South East Water	2		Management, project
	City West Water	1		Management
Local municipality	City of Manningham	1		Executive
Academia	Monash University	1		Executive
	Melbourne University	1		Executive
Consultant	Coomes Consulting	1		Project
	GHD	1		Project

An initial round of interviews was conducted in person between July and November 2011. Interviews were typically 45 to 90 minutes in length and were conducted in the private rooms of the participants' workplace. The interviews were audio-recorded by a digital recorder (with written consent from each interviewee) and the recording of each interview was fully transcribed by an independent transcription contractor. Detailed notes were also taken by the researcher during the interview and summary notes were documented shortly after the interview to capture initial reflections of the researcher. Short follow-up interviews were conducted by telephone with key informants in November 2012 to supplement the case study with additional data about changes that occurred in Melbourne's water system between the 2011 series of interviews and the end of the case study period.

4.3.2. Secondary data collection

Secondary data included academic literature, historic and current policy and regulatory documents, organisational publications and records, media materials and other documentation covering Melbourne's urban water sector. This documentation was collected through desktop searches of the internet, exploring the archives of public libraries and sourcing particular documents from the private libraries of individuals or organisations. Secondary documentation was compiled and catalogued for reliable access during the research.

Secondary oral history data in the form of interview transcripts was also collected from a previous research project about Melbourne's water system undertaken at Monash University.

4.3.3. Data analysis

Analysis for the first multiple-case study occurred in three stages. First, the case narratives were developed; second, a transitions analysis of each individual case was undertaken; and third, a comparative analysis of the three cases was conducted.

To develop the case narratives, the content of interview transcripts and secondary documentation was first analysed to construct a chronological account of developments in Melbourne's water system, with a broad view of long-term historic changes and a more detailed view on changes between 1997 and 2012. This data analysis was undertaken during and after the data collection process, iteratively developing the narrative with each new piece of evidence. Data was triangulated to corroborate the findings and any contradictions were further investigated to ensure accurate interpretations were made. Individual narratives of the three embedded cases were then extracted, along with specific details of the system context and mainstream water servicing infrastructure and institutions. These case narratives were then used as base for mapping and analysing the influence of different actor strategies on the trajctories for the institutionalisation of desalination, wastewater recycling and stormwater harvesting, using Scott's framework of cultural-cognitive, normative and regulative institutional pillars. Finally, a cross-case comparison of the three innovation trajectories was undertaken to develop theoretical insights about the scope of actor strategies that were effective for supporting the growth of innovations with different characteristics. Further details on the data analysis for multiple-case study A are found in Publication 4.

4.3.4. Validity and reliability

Yin (2009) outlines common concerns about the potential lack of rigour in case study research, which is usually the result of the researcher not using systematic procedures or allowing biased perspectives to influence the findings (see also Blaikie, 2010, for an overview of criticisms about case study research). To address some of these potential limitations, a number of verification processes were adopted to ensure the validity of the data collection and analysis. For qualitative data this validation involves determining that the research findings are accurate from the perspective of the researcher, participant and reader (Creswell, 2009).

Yin (2009) refers to construct validity as ensuring that correct operational measures have been identified for the concepts being studied. As described in the previous sections, each of the methods in this research drew on multiple sources of evidence to develop converging lines of inquiry. Construct validity of the narratives for Cases 1, 2 and 3 was ensured by triangulating different data sources to build converging narratives from different interviewee perspectives and the secondary documentation (Yin, 2009). In addition, chains of evidence were maintained so that conclusions of the study could be traced back to the initial questions (and vice versa), with clear cross-referencing to the data collection procedures and evidence obtained. External verification of the construct validity of the narratives for Cases 1, 2 and 3 was achieved in two stages. First, tabulated actor strategies for each embedded case were presented to three water sector leaders in a validation workshop. These actors had participated in oral history interviews and, collectively, were instrumentally involved in the institutionalisation of all three innovations studied. They thoroughly reviewed the identified strategies and critiqued whether any were missing and that the significance of each strategy was accurately emphasised. Second, the synthesised case narratives were sent to the same actors for further review and critique.

Internal validity involves seeking to establish valid and authentic causal relationships, in which certain conditions are believed to lead to other conditions and the relationships have not been misinterpreted (Yin, 2009). Rigorous analysis of the data is key to ensuring internal validity. The research therefore utilised a range of analytic techniques, including pattern matching and explanation building. Analysis focused on the most important aspects of the studies and interpretations addressed all the available evidence. Rival explanations were tested to further ensure internal validity of the findings. External verification of the internal validity of the transition dynamics for Cases 1, 2 and 3 was achieved in two stages. First, the institutional trajectory for each innovation was presented to three water sector leaders in a validation workshop. These actors had participated in oral history interviews and, collectively, were instrumentally involved in the institutionalisation of all three innovations studied. Second, the synthesised transition pathways were sent to the same actors for further review and critique. They thoroughly reviewed the transition pathways and critiqued the role of the landscape pressures and timing of each constellation's growth.

Ensuring the external validity of a case study is a matter of "defining the domain to which a study's findings can be generalised" (Yin, 2009, p. 40). A key concern about the case study method is associated with their ability to provide a sufficient basis for generalisation. In response, Yin (2009) points out that case studies do not represent a population 'sample' or aim to provide statistical generalisation; instead, good case studies provide a basis for analytic generalisation, with the goal being to expand and generalise theories. To ensure external validity, the cross-case analysis of Cases 1, 2 and 3 used replication logic to draw general insights. Cases were selected to provide different analytic logics (slow, moderate and fast speeds of institutionalisation) that would allow for theoretical replication (demonstrating conflicting results for anticipatable reasons) about the causes of the different speeds in order to develop generalisations.

An important principle of high quality research is to demonstrate that if the study was repeated it would produce the same results; in other words, that it is reliable (Yin, 2009; Neuman, 2000). To this end, case study protocols were initially designed to ensure that all the potential issues were considered prior to the data collection phase of the research. In addition, a database was established as a means to organise and document all the data collected during the research.

4.4. Multiple-Case Study B: Future

The second embedded multiple-case study (Cases 4 and 5) involved action research to develop transition scenarios as part of the third research phase. This section presents details of the methods used in this research phase; a summary is also provided in Publications 3 and 5 so there is some repetition.

4.4.1. Primary data collection

Process Design

Two key aims for the transition scenario workshops emerged out of the need to capture the tacit knowledge of water practitioners in Melbourne in a way that would provide reliable and valid data for informing the design of a strategic program for transitioning to water sensitive city. First, that the process needed to be participatory to encourage a diverse range of perspectives and rigorous discussion. Second, that the content of the transition scenarios provided detailed description of the region as a future water sensitive city and the actor strategies that would be expected to drive the transition towards this vision. An additional aim focused on maximising the practical impact of the project was also identified, to ensure that participation in the workshops would be valuable for individuals and their organisations. Part of this impact was expected to be through the publication of industry-focused deliverables, however the social learning (e.g. Steyaert and Jiggins, 2007; Ison et al., 2007) of workshop participants was also expected to be an important outcome of the project.

Transition scenarios are considered to be normative and explorative in nature and require multiple methodological steps that take an explicit long-term perspective and merge creative envisioning techniques with rational backcasting techniques to generate strategies for achieving a specific vision. The 'TRANSCE' methodology developed by Sondeijker (2009) is such an example and versions of it are used in transition management processes for a range of contexts such as waste management, health care, energy and transport. These processes typically produce: (1) a definition of the problem, for example in the form of underlying challenges; (2) a long-term future vision, which may consist of a number of themes described in narratives and defined by guiding principles and strategic objectives that make the vision operational in a specific local context; (3) strategic transition pathways, formulated in thematic sets and subsets of strategies and actions (e.g. Loorbach and Rotmans, 2010; Voβ et al., 2009). Transition management embeds the methodology and outputs in a broader governance approach designed to stimulate sustainability innovations to influence mainstream practice (Frantzeskaki et al., 2012; Loorbach, 2010).

The methodology used to generate transition scenarios for this research was therefore based on the standard transition management process design but incorporated a number of adaptations to suit the needs of this research. The adapted methodology was then tested in a pilot workshop, in which members of the research team and invited industry representatives rapidly stepped through the planned process and consolidated ideas about each step would best be adapted for the Melbourne context. The pilot workshop actively looked for parts of the proposed methodology that might not be suitable to ensure the process would be smooth and effectively achieve the project aims.

The major adaptation was to ensure the process suited the particular context of Melbourne's water system. In particular, Melbourne's mainstream water sector was already engaging in dialogue about how its future water system should be designed and managed in response to extreme climatic conditions recently experienced (e.g. Living Victoria Ministerial Advisory Council, 2012; Binney et al, 2010). The project was therefore designed to build on this existing momentum around the vision of a water sensitive city. It was considered important to involve all the key organisational actors in the process, including local municipalities, state government departments, environmental and health regulators, water utilities and community members. Industry associations, land developers and consultants were also invited to be part of the process. This compares to typical transition management processes in which community frontrunners comprise the core of the participant body.

A second adaptation was in the selection of the contexts for each workshop series. Cases 4 and 5 each focused on a geographic region covering a cluster of adjacent local municipalities (see Figure 4). Typical transition management processes focus on only one municipality and context, so this adapted approach was expected to reveal more diversity in the types of transition pathways produced, given the different starting points of municipality in terms of their sustainable water management performance.

The third adaptation to the typical transition management process was to introduce the idea of resilience through two additional methodological steps that considered how the transition scenarios developed would respond to future external contexts and extreme or surprising events. This adaptation is further explained in Steps 6 and 8 below.

Workshop Details

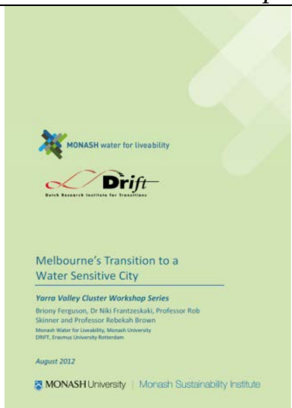
A range of organisations is involved in water management in Melbourne; a full list of organisational actors and their responsibilities is provided in Chapter 5.1.3. For the outputs of the workshops to be used as valid and reliable data, and given the project aimed to influence mainstream policy and practice, it was considered important to have representatives from key local and central organisations in order to build legitimacy of the process and ensure the transition scenarios captured the different types of tacit knowledge held within different actor organisations. Significant strategic grounding of the project was therefore required in the six months prior to the first workshops. This background work was intended to prepare the ground for the project and to highlight its potential value so that actors in mainstream policy and practice would welcome and embrace the outputs. The project team considered it to be particularly important to communicate how this project would build on previous envisioning and strategic planning activities, as well as how the project outputs could influence practice. It was also considered important to communicate clearly about what the project outputs would be, with an emphasis on their tangibility and practicality for practitioner use. As well as informal discussions with representatives from key organisational actors, an information session was hosted by the project team to communicate these project details and invite questions in a formal setting.

Executive leaders from key organisations were initially introduced to the project and their commitment was sought; this helped to overcome anticipated scepticism and hesitance about involvement in another participatory process when there had already been recent visioning activities. Once commitment was obtained, the criteria for individual participants were communicated to each key organisation, who then nominated their own representatives: (a) good strategic understanding of the system; (b) strong influence within their organisation or community; (c) commitment to sustainability; (d) open to creative and visionary thinking; and (e) willing to contribute to rigorous discussions. In seeking the commitment of participants, it was made clear that they would be involved as individuals, not as formal representatives of their organisation. Participants would be expected to bring the understandings and experience of their organisation but would not be asked to represent their organisation's official perspectives. Finally, it was made clear that endorsement of the outputs would be at the participating organisation's discretion. Individual participants would not be expected to endorse the project outputs on behalf of their organisation, as the research team did not want people to feel constrained in the workshop discussions.

The workshops were conducted in two separate series in order to collect data from two different geographic, socio-economic and administrative contexts (Figure 4). The Yarra Valley Cluster series involved four workshops between March and June 2012, while the South East Cluster series involved five workshops between February and June 2012. Each workshop ran for approximately four hours. The original intention was for five workshops for both cases; however, delays in receiving commitment from participant organisations for the Yarra Valley Cluster meant there was only time for four workshops and modifications were made to the methodology accordingly. The same set of participants was invited to each workshop in their individual series, while members of the project team were involved in both series. Table 6 summarises the workshop details. All procedures associated with the workshops (including approaching potential participants, conducting the workshops and maintaining confidentiality of workshop participants) complied with the requirements of the Human Ethics Certificate of Approval (number CF10/3357 - 2010001774), granted by the Monash University Human Research Ethics Committee.

The participatory process was designed to bring together different stakeholders together in an open forum to co-create strategies in a bottom-up process. Therefore specific criteria for participating in the process were established at the beginning of the workshop series to ensure positive group dynamics were fostered. These 'participation ground rules' included that all ideas have space to be voiced and heard; personal views and opinions are sought, rather than officially endorsed organisational perspectives; there is no right or wrong; disagreement is normal and accepted; shifting views is normal and expected; and people's identity would be protected in external discussions about the process. Gaining commitment from all participants to these criteria was deemed important to ensure everyone felt comfortable and part of a safe forum to have the creative and rigorous discussion that was fundamental to the process.

Table 6. Workshop details



Participating Organisations (number of participants in brackets)		
Water utilities	Yarra Valley Water (2) Melbourne Water (2)	South East Water (2) Melbourne Water (2)
State Government departments	Department of Sustainability and Environment (1) Department of Health (1) Department Planning and Community Development (1)	Department of Sustainability and Environment (1) Department of Health (1) Department Planning and Community Development (1) Growth Areas Authority (1)
Municipalities	City of Boroondara (2) City of Manningham (2) City of Maroondah (2)	City of Casey (2) Frankston City Council (1) City of Greater Dandenong (2) Kingston City Council (2)
Consultants	Alluvium (1) GHD (1)	CPG (1) AECOM (1)
Community groups	Yarra Riverkeeper's Association (1)	-
Academia	Monash Water for Liveability (4)	Monash Water for Liveability (4)
Workshops (number of attendees in brackets)		
Workshop 1	21 March 2012 (18)	14 February 2012 (20)
Workshop 2	23 April 2012 (15)	13 March 2012 (15)
Workshop 3	25 May 2012 (16)	17 April 2012 (17)
Workshop 4	19 June 2012 (13)	7 May 2012 (12)
Workshop 5	-	1 June 2012 (15)
Methodological Steps *(see Figure 6* for details on each step)		
1. System analysis	Pre-workshop	Pre-workshop
2. Uncover the imperative for change	Workshop 1	Workshop 1
3. Formulate guiding principles	Workshop 1	Workshop 1
4. Define the vision	Workshop 2	Workshops 2 and 3
5. Describe the vision	Workshop 2	Workshops 2 and 3
6. Build vision resilience	Workshop 3	-
7. Generate strategic pathways	Workshops 3 and 4	Workshop 4
8. Build system resilience	Workshop 4	-
9. Prioritise paths	Workshop 5	-

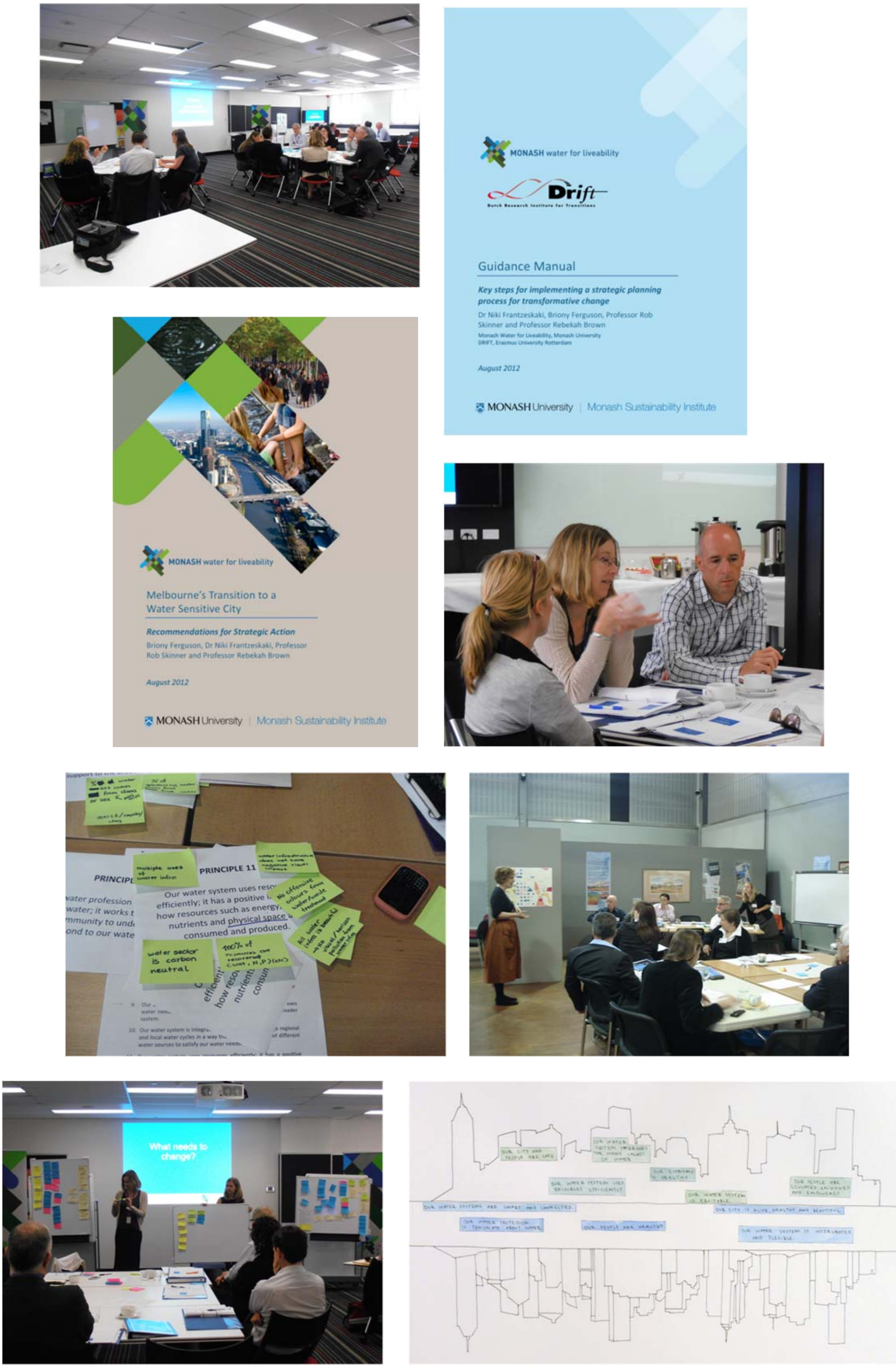


Figure 5. Images from the workshop series

Role of the Researchers

Ison et al. (2007) argue that when developing action-oriented social research, the relationship between the research and action is complex, given the process of social learning by participants and the different types of knowledge each person brings to a situation. It is therefore important to understand and clarify the role of the researcher in the action research in order to be explicit about the impact of a researcher on the outcomes (Rodela et al., 2012; Ison et al., 2007; Steyaert and Jiggins, 2007).

A team of four researchers was established to design and implement the project, adopting multiple roles during the project. Ms Briony Ferguson (this author) was the project manager, facilitator and analyst. Dr Niki Frantzeskaki, a visiting scholar from the Dutch Research Institute For Transitions, was a facilitator and analyst. Professor Rob Skinner (recently retired from the position of Managing Director Melbourne Water and a former CEO of the City of Kingston, one of the municipalities participating in the project) was a project ambassador. Professor Skinner brought his knowledge, experience and networks to lead the project's engagement with industry stakeholders and also facilitated small group discussions when required. Professor Rebekah Brown was a project director, providing overall leadership for the project and facilitating small group discussions when required. The research team collectively designed the methodological steps for the workshops, led by Dr Frantzeskaki who had previous experience in implementing transition management processes.

The facilitation role of the project team involved utilising skills, tools and data to help the learning of stakeholders who have been brought together in a new relationship, following the description by Steyaert and Jiggins (2007). During facilitation, the researchers did not contribute any content to the group discussions, instead prompting the participants with questions and guidance to lead them to produce outputs that were consistent with the process objectives. Ms Ferguson and Dr Frantzeskaki occasionally provided analytic input into the workshops to stimulate discussions; the distinction between group outputs and analytic inputs was made clear to participants at each stage of the process. Between workshop sessions, Ms Ferguson and Dr Frantzeskaki adopted the role of analysts, in which they consolidated and analysed notes from the workshop discussions before synthesising them into outputs in the format required for the workshop methodology.

An artist, Ms Therese Keogh, was also involved as part of the project team, providing visual interpretation of both the process steps and the participants' vision of the South East Cluster workshops (Case 5). Ms Keogh attended each of the South East Cluster workshops and gave a short presentation on her artwork at the beginning of each session.

Methodological Steps

An overview of the methodological steps is shown in Figure 6 and each step is described in more detail below. Full details of the methodology are presented in Appendix C, which contains the Guidance Manual developed as an industry output from the transition scenarios project (Frantzeskaki et al., 2012b). The methodological steps were modified for the Yarra Valley Cluster, since it had one less workshop. Further, the time spent on each methodological step varied between cluster groups, depending on how quickly the participants were able to progress. For example, the Yarra Valley Cluster required two workshops for defining and describing the vision (Steps 4 and 5), while the South East Cluster only required one. The research team were flexible and adaptive in their planning and facilitation to ensure the needs of the individual workshops were met while achieving the overall goals of the process.

The process was designed to stimulate a ‘pressure-cooker’ environment, with a fast pace and intense focus that would provide conditions for creative and rigorous thinking. A mix of small-group (5-8 participants) and whole-group discussions (15-20 participants) were utilised in the facilitation of the workshops. Small-group discussions facilitated by one of the project team were most effective for generating ideas and exploring them in-depth. Whole-group discussions were most effective for developing shared views and consolidating outputs after initial small group discussions. Between workshops, the project team synthesised and analysed the previous workshops outputs so that they could be presented to participants in the next session in the format required for subsequent methodological steps.

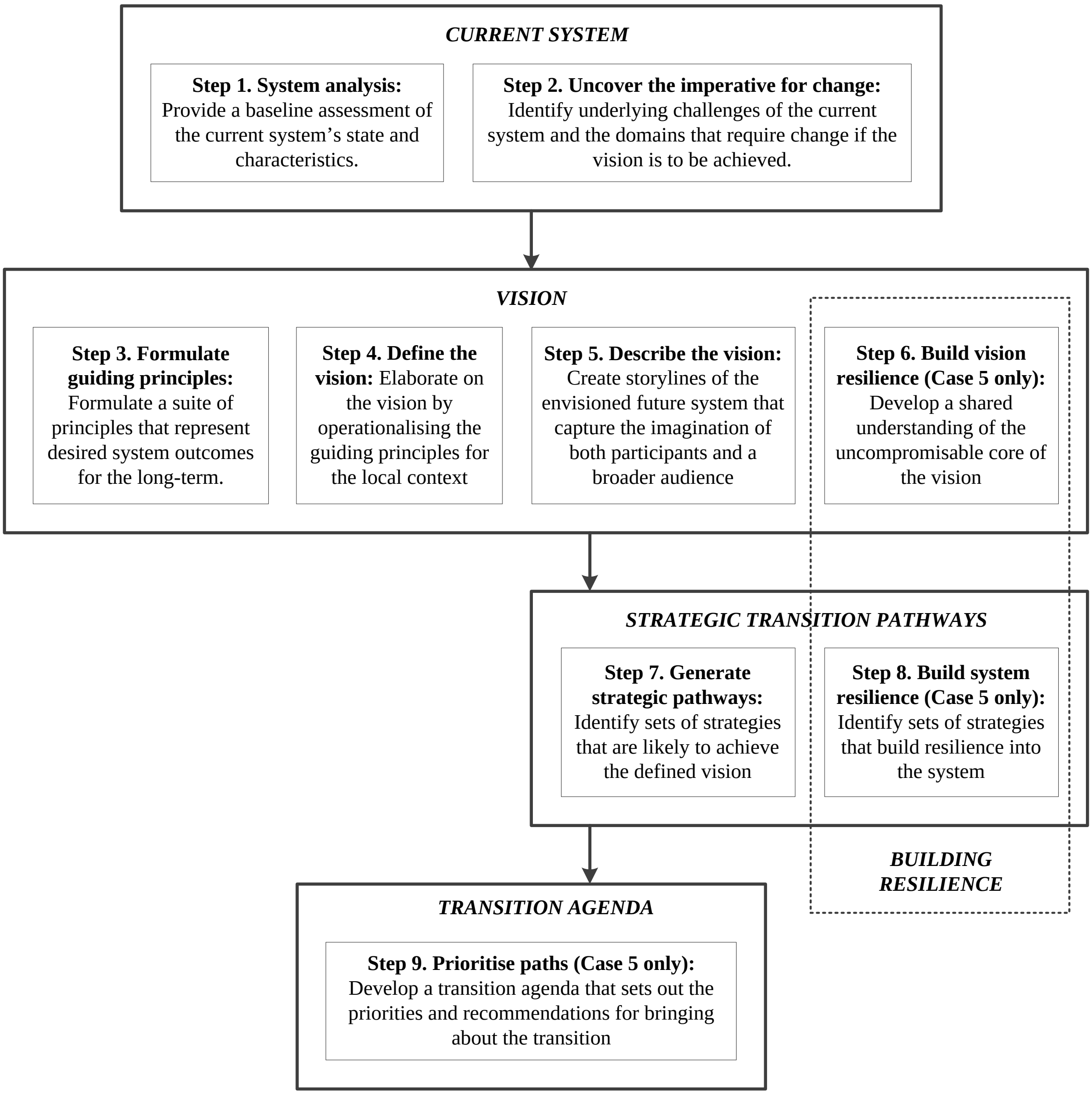


Figure 6. Overview of methodology for transition scenario workshops

An in-depth understanding of the current system conditions and how its components contribute to the problems experienced was the first phase, in order to develop a baseline from which to contrast the future vision. Steps 1 and 2 were focused on developing this understanding.

Step 1 (system analysis) involved collecting primary and secondary data about the socio-economic features of the cluster areas for each case. Sources of secondary data included reports, policy and organisational documents, Australian Bureau of Statistics and scientific literature. Primary data was collected through focus groups held at each of the seven participating local municipalities. Each focus group involved between 5 and 12 municipality officers from different disciplines (e.g. engineering, planning, environment, landscape, urban design, parks and recreation) and, through semi-structured questions, explored questions about the regional characteristics, historic, current and expected future trends and water management challenges in the system. This data was analysed and synthesised into a report that comprised a description of the historical evolution, system operation, system components and identified problems (in the form of pressures and perceptions of current challenges). See Findeison and Quade (1985), Sage and Armstrong (2000) and Walker (2000) for more details on system analyses.

Step 2 (uncover the imperative for change) involved facilitated small and whole group discussions during the workshops, following a presentation from the outputs of the system analysis (Step 1). Participants were asked to identify the underlying challenges that explained why the current problems revealed in the system analysis persist, with a focus on the governance system's institutions and practices. Participants were also asked to identify domains that need to be modified or removed from the system in order to address the underlying challenges and open the way for achieving a set of guiding principles for a future water sensitive city. Detailed notes were taken by the facilitators during the discussions, which were later synthesised into a list of a underlying challenges and a list of domains of change. See Loorbach and Rotmans (2010) for more details on uncovering challenges.

The second phase of the process developed the vision of a water sensitive city. Envisioning involves imagining the conditions of a desirable future; it creates understanding and framing of the desirable directions or images associated with sustainability, while maintaining a sense of place (Sheppard et al., 2011; Sarpong and Maclean, 2011).

Step 3 (formulate guiding principles) involved facilitated small and whole group discussions during the workshops. Participants were asked to identify a set of guiding principles that will guide how planning, investment, design, management, regulation, monitoring and evaluation occur in a water sensitive city. The principles were developed using the outputs from a previous visioning exercise for Melbourne (Living Victoria Ministerial Advisory Council, 2012) as a base from which to modify and expand in identifying the Clusters' desired sets. Facilitators encouraged participants to consider broad long-term aspirations, rather than quick fixes of current system problems, and the discussions were steered away from identifying solutions or strategies. Detailed notes were taken by the facilitators during the discussions, which were later synthesised into a list of guiding principles. See Lehmann (2010) and Newman and Jennings (2008) for more details on guiding principles.

Step 4 (define the vision) involved facilitated small and whole group discussions during the workshops. Once the set of guiding principles were agreed upon, participants were asked to specify what the principles mean and how their achievement would be experienced in a future water sensitive city. These were formulated into a set of strategic objectives that operationalise the guiding principles for the local Melbourne context, defining the vision of Melbourne a future water sensitive city. Detailed notes were taken by the facilitators during the discussions, which were later synthesised into a set of strategic objectives for each guiding principle. See Keeney (1996a, 1996b) for more details on strategic objectives.

Step 5 (describe the vision) involved collating the notes from the workshop discussions in Steps 3 and 4 to compile the phrases, words, descriptions and interpretations used by participants to express their vision. The researchers drew on these to develop descriptive narratives for each major theme which emerged for the vision to bring the desired water sensitive future to ‘life’ through language. See van Notten et al. (2005), Sondeijker et al. (2006) and Wiek et al. (2006) for more detail on vision descriptions.

Step 6 (build vision resilience) involved the development of context scenarios and facilitated small and whole group discussions during the workshops for Case 5 (South East Cluster) only. Context scenarios were developed by combining families of external trends that would influence the functioning of Melbourne’s water system (population growth, climate change, economic conditions, technology development, energy policy and urban development patterns). These external trends were initially identified by the research team and then validated and refined by a panel of experts. Full details of the context scenario methodology are found in Appendix D. Participants in the transition scenario workshops were then asked to consider and discuss whether their ambitions for achieving each of the strategic objectives developed in Step 4 would be adapted (raised, lowered or maintained) under different context scenarios. Facilitators encouraged participants to reveal their thinking behind their adaptation choices, encouraging reflection on the level of commitment and deep societal values captured in the vision. Adaptations were systematically documented in a template that mapped each strategic objective against different context scenarios. See Walker and Salt (2006) for more details on resilience approaches.

The third phase of the process focused on strategy development through backcasting. Backcasting is an approach that facilitates strategy generation by taking a future vision as a desirable end and examining how that future vision could be achieved (Phdungsilp, 2011; Quist et al., 2011).

Step 7 (generate strategic pathways) involved facilitate small and whole group discussions during the workshops. Participants were asked to identify short, medium and long term strategies that could (a) achieve each guiding principle and its strategic objectives, and (b) bring about transformative change by overcoming the challenges of the current system. The participants defined short-term to mean 2020, medium-term to mean 2040 and long-term to mean 2060. Facilitators steered the discussion away from finding a direct match between guiding principles and strategies, instead exploring how strategies could enable transformative change in a synergistic way. Detailed notes were taken by the facilitators during the discussions, which the researchers later formulated into thematic bundles of strategies, referred to as strategic transition pathways. Each strategic transition pathway was operationalised with specific actions and mechanisms that emerged from the workshop discussions. See Quist (2007), Phdungsilp (2011) and Robinson et al. (2011) for more details on backcasting.

Step 8 (build system resilience) involved the development of wildcards and facilitated small and whole group discussions during the workshops for Case 5 (South East Cluster) only. Wildcards were developed by describing a range of extreme and/or surprising events that would impact on the functioning of Melbourne's water system (e.g. climate refugees, bushfires in water catchments, mystery technology). These wildcards were initially identified by the research team according to the STEEP framework and then validated and refined by a panel of experts. Full details of the wildcards methodology are found in Appendix E. Participants in the transition scenario workshops were then asked to consider and discuss what additional or complementary strategies would be required to build resilient economies, communities, infrastructure and ecosystems to anticipate, mitigate or cope with the wildcard event over the course of the transition. Detailed notes were taken by the facilitators during the discussions, which the researchers later incorporated with the transition pathways developed in Step 7. See Wardekker et al. (2010) and Saritas and Smith (2011) for more details on resilience approaches and wildcards.

The fourth phase of the process focused on developing a transition agenda that sets priorities and recommendations for bringing about the transition to a water sensitive city.

Step 9 (prioritise paths) involved facilitated small and whole group discussions during the workshops for Case 5 (South East Cluster) only. Participants were asked to identify which strategic transition paths were critical in the short, medium and long terms for Melbourne's transition to a water sensitive city. They were then asked to recommend five next steps for taking action and to identify the "low-hanging" and "hard-to-reach" strategies for achieving the critical short-term milestones. Detailed notes were taken by the facilitators during the discussions, which the researchers later synthesised to reflect the core strategic features of an overall transitions, as well as recommendations about the critical strategies for immediate action.

Data Outputs

Reporting on each methodological step was provided to participants progressively, so they had sufficient time and opportunity to read, digest and reflect on outcomes of the previous workshop before entering into the next session's discussion. Each workshop provided time for participants to voice their feedback and propose refinements of outputs from the previous session. This refinement process was iterative throughout each workshop in the series, such that by the final session, participants said they felt ownership of all the different elements of the transition scenarios produced. The collective outputs from the methodological steps were documented in separate reports for each Cluster (Cases 4 and 5, see Appendix F for a summary. Full details are found in Ferguson et al., 2012c, 2012d,). A recommendations report was also prepared, presenting the research team's synthesis and interpretation of the outcomes from both workshop series and translates them to provide recommendations for action in Melbourne (see Ferguson et al., 2012b).

A transition scenario was developed for each of Cases 4 and 5, consisting of multiple elements:

1) A list of underlying challenges and associated domains of change
2) A vision of Melbourne as a water sensitive city, including guiding principles, strategic objectives, narratives and visual representations
3) Strategic transition pathways, including thematic groupings, specific actions and mechanisms and prioritised paths for achieving the vision from current conditions

4.4.2. Data analysis

Data analysis occurred progressively during the data collection as part of the transition scenario workshop series, in order to synthesise the workshop outputs into formats required for the process methodology. These analytic steps (described as part of the methodology in Chapter 4.5.1.3. resulted in the development of a set of transition scenarios for each case. The scenarios developed for each cluster were very similar. The research team could therefore synthesize the data into a single Melbourne-wide transition scenario. Variations in detail between the two scenarios were incorporated so that features of both cluster contexts were represented in the final synthesized scenario.

Analysis then occurred in two stages. First, the content of the synthesized transition scenario was inductively analyzed (Blaikie, 2010) by Ms Ferguson and Dr Frantzeskaki, coding to four key questions emerging from literature on long-term planning of urban infrastructure: (1) How can socio-technical path dependencies be overcome through strategic planning and management? (2) How can strategic planning and management guide the direction of transformative change in a ‘desirable’ direction? (3) How can strategic planning and management accommodate system complexity? (4) How can strategic planning and management cope with uncertainty?

The second analytic stage involved organizing the coded data from the first stage within the categories of a coordinating logic developed drawing on strategy literature. This was initially conducted by Ms Ferguson, drawing on contextual understanding (developed in this research) about existing and desired institutional capacities for Melbourne’s water system in relation to the vision and strategic pathways, and implications for the roles, responsibilities and power relationships of water sector actors in delivering a strategic program for transformative change.

4.4.3. Validity and reliability

Chapter 4.3.4 describes the definitions of construct validity, internal validity, external validity and reliability.

Construct validity of the transition scenarios for Cases 4 and 5 was achieved through implementation of a well-designed process that was based on theoretically informed methodological steps adapted for the specific context of Melbourne. Participants for the process were selected according to criteria that ensured a broad range of organisational perspectives would be represented and that a sufficient depth of tacit knowledge and experience would be available in the group. Sondeijker (2009) contends that the content of transition scenarios should include a long time horizon (more than 30 years), a systems perspective, be utopian and realistic in character, and be consistent and coherent. The transition scenarios developed met these criteria. External verification of the construction validity of the transitions scenarios was achieved through iterative individual and collective reviews of reports by workshop participants. Workshop participants were also given the opportunity to review and critique the final transition scenarios for each case.

Internal validity of the analysis of the content of transition scenarios developed in Cases 4 and 5, including the lessons and strategic program design, was ensured through the analytic processes. The scenarios were independently and collectively peer-reviewed by the transition scenarios project team members in an iterative manner, including a reflection on both the coherence and quality of the coding. Interim findings from the transition scenarios were presented to fellow academics and leading water industry practitioners for critique and reflection (Figure 7) and this feedback on the analysis was used to refine the coding and synthesis of the final outcomes.

Figure 7. Images from the transition scenarios validation session

External validity of Cases 4 and 5 was ensured by drawing on literal replication logic in the comparison between the different transition scenarios developed for each case.

Reliability of Cases 4 and 5 was ensured through carefully designing the action research process, including running a pilot workshop to anticipate potential issues. The methodological steps that were designed were thoroughly documented, as were modifications that were made during and after the workshops. The researchers continually reflected on the process, documenting their perspectives on both the process and the outcomes.

CHAPTER 5. RESULTS

This chapter introduces the Melbourne water system and provides the results of the embedded multiple-case studies in two sections. Publication 3 presents the empirical multiple-case study (A) of Melbourne's water system between 1997 and 2012, focusing on the pathways for the institutionalisation of desalination, wastewater recycling and stormwater harvesting as innovative practices. Theoretical insights about the dynamics of transitional change are drawn from these results. Publication 4 presents the illustrative multiple-case study (B) of Melbourne's future transition to a water sensitive city, in the form of transition scenarios. The scenarios are analysed to develop a scope, coordinating logic and design base of a strategic management program for enabling transitional change in urban water systems.

SPECIFIC DECLARATION FOR PUBLICATION 3

Monash University

Declaration for Thesis Chapter 5.2

Declaration by candidate
In the case of Chapter 5.2, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Formulated research problem, located research within established literature, collected and analysed data, conceptualised and structured paper, wrote paper.	90%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	**Nature of contribution**	**Extent of contribution (%) for student co-authors only**
Rebekah Brown	Supported the research conceptualisation, reviewed and edited the paper	N/A
Niki Frantzeskaki	Supported the research conceptualisation, reviewed and edited the paper	N/A
Fjalar de Haan	Supported the research conceptualisation, reviewed and edited the paper	N/A
Ana Deletic	Supported the research conceptualisation, reviewed and edited the paper	N/A

Candidate's Signature		**Date**
	B. Ferguson*	30/5/13

Declaration by co-authors
The undersigned hereby certify that:
(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; &
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	**Geography & Environmental Science, Monash University, Clayton Campus**

		Date
Signature 1	R. Brown*	30/5/13
Signature 2	N. Frantzeskaki*	21/5/13
Signature 3	F. de Haan*	30/5/13
Signature 4	A. Deletic*	27/5/13

* Original signature in hardcopy version

SPECIFIC DECLARATION FOR PUBLICATION 4

Monash University

Declaration for Thesis Chapter 5.3

Declaration by candidate

In the case of Chapter 5.3, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulated research problem, located research within established literature, collected and analysed data, conceptualised and structured paper, wrote paper.	90%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah Brown	Supported the research conceptualisation, reviewed and edited the paper	N/A
Fjalar de Haan	Supported the research conceptualisation, reviewed and edited the paper	N/A
Ana Deletic	Supported the research conceptualisation, reviewed and edited the paper	N/A

Candidate's Signature		Date
	B. Ferguson*	30/5/13

Declaration by co-authors
The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
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(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	
	Geography & Environmental Science, Monash University, Clayton Campus

		Date
Signature 1	R. Brown*	30/5/13
Signature 2	F. de Haan*	30/5/13
Signature 3	A. Deletic*	27/5/13

* Original signature in hardcopy version

SPECIFIC DECLARATION FOR PUBLICATION 5

Monash University

Declaration for Thesis Chapter 5.4

Declaration by candidate

In the case of Chapter 5.4, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulated research problem, located research within established literature, collected and analysed data, conceptualised and structured paper, wrote paper.	80%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Niki Frantzeskaki	Supported the data collection, data analysis and writing of the paper.	N/A
Rebekah Brown	Supported the research conceptualisation, reviewed and edited the paper	N/A

Candidate's Signature	B. Ferguson*	**Date** 30/5/13

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	**Geography & Environmental Science, Monash University, Clayton Campus**

		Date
Signature 1	N. Frantzeskaki*	21/5/13
Signature 2	R. Brown*	30/5/13

* Original signature in hardcopy version

5.1. Melbourne Context

5.1.1. Regional features

Melbourne is the capital of Victoria and the second largest city in Australia, home to 4.1 million people. It covers a land area of 7,700 km^2 , spanning around a large natural bay known as Port Phillip Bay. The city centre is located on the estuary of the Yarra River, which flows into Port Phillip Bay at its northern most point. The coastline of Port Phillip Bay and the banks of the Yarra River provides a strong sense of identity for people in these local areas. Westernport Bay is another major natural feature, although it is not as well embraced and valued by the community. Most of Melbourne has an extensive network of parks, reserves, bicycle trails and walking tracks. Sports facilities such as ovals, stadiums and aquatic centres are common in most municipal areas. There are a number of wetlands listed as internationally important under the Ramsar Convention, such as the Edithvale-Seaford Wetlands and the sewage treatment lagoons of the Western Treatment Plant in Werribee. An extensive network of rivers and creeks run through Melbourne. Their health is variable and many waterways are highly degraded. Significant areas of the city have native vegetation and bushland, although many of these are potentially under threat as large areas of land are developed.

Melbourne's population is culturally diverse, with many waves of immigration since European settlers first arrived. After indigenous tribes spent tens of thousands of years living in the area now known as Melbourne, British colonists invaded in 1835 and established Melbourne as an administrative centre of colonial Australia. Since then, people from all over the world, including China, Greece, Italy, Vietnam, Somalia, Sudan and Afghanistan, have come to Melbourne, making it renowned as a city with a blend of many different ethnicities. This immigration, as well natural birth rates, has meant the population of Melbourne has steadily increased, and this growth is projected to continue. Recent projections indicate that the population of Melbourne will increase up to 8 million by 2056 (Australian Bureau of Statistics, 2008). Absorption of this growth is planned through urban expansion and densification through urban renewal. Farming land to the south-east, north and west of Melbourne has been rezoned as growth growth corridors to make way for new residential and industrial estates. More medium and high-density residential developments are planned, particularly along main transport routes. Growth will be particularly focused around key economic centres, known as Central Activity Areas, which serve as hubs for employment, community services and transport.

5.1.2. Water history

This section provides a brief description of key phases in the historic evolution of Melbourne's water system. Reference is made to the city-state continuum for urban water transitions by Brown et al. (2009, see Figure 1).

1835 – 1850 European Settlement

Europeans settlers first arrived in Melbourne in 1835 and needed a secure supply of water. They fetched water from the local Yarra River and dumped waste in the streets, however, since the population was low there were limited impacts (Otto, 2005; Keating, 1992).

1850 – 1880 Gold Rush

The Gold Rush of the 1850s led to a rapid population growth, rapid expansion of industry and rapid growth in wealth for Melbourne (Powell, 1989). The community vocalised strong demands for better quality and quantity of water supplies, particularly as the growth in population and industry meant the water supply from the Yarra River was highly contaminated (Keating, 1992). The large wealth that was accumulating meant there was money available to provide a centralised resource through the construction of Yan Yean Reservoir to the north of Melbourne and a connected supply network. Melbourne emerged as a "water supply city".

1880 – 1950 Smellbourne

The population of Melbourne continued to grow and by the 1880s, public health had become a significant problem with regular outbreaks of typhoid and cholera (Powell, 1989). There was no infrastructure for disposal of sewage or solid wastes so people dumped their waste in the street channels and a very unreliable nightsoil system was in place. Public demand for a solution was very strong and Melbourne was considered an international embarrassment, given the derogatory pseudonym of "Smellbourne". In response to these pressures, a centralised sewerage network was progressively built from the 1890s and the Western Treatment Plant in Werribee was operational from 1897 (Dingle and Rasmussen, 1991). The water supply network and sewage network continued to expand during the first half of 1900s. Melbourne had become a "sewered city".

1950 – 1980 Urban Expansion

After World War II Melbourne experienced significant levels of immigration, as well as internal population growth due to the baby boom. People had grown used to living on large suburban blocks of land so as the population increased, urban growth spread outwards so that everyone could maintain the backyard lifestyle (Neutze, 1978; Powell, 1989). This led to a significant period of urban expansion and as vast areas of land were covered with impervious materials, drainage of stormwater became a big issue (Dingle and Rasmussen, 1991). Eventually regulations were introduced to ensure adequate road drainage infrastructure was built to service any new land that was developed. Drainage infrastructure was constructed separately from the sewerage system, with minor stormwater runoff directed to local waterways via a network of pipes and drainage channels, before being discharged to Port Phillip Bay. Runoff from major storm events was directed to flow overland along roads, easements and designated floodways towards the receiving creeks and rivers. Melbourne was now a "drained city".

1980 – 2000 Healthy Waterways

Community attitudes started to shift during the late 1960s and 1970s, with the rise of modern environmentalism. This meant people began to care more about ecological health and urban amenity and this new set of societal needs started to be reflected in the way infrastructure was designed during the 1980s and 1990s. Point sources of pollution, such as industrial effluent, were largely addressed with the widespread availability of sewerage networks and regulation of waste discharges upon the establishment of the Environment Protection Authority of Victoria in 1970. However, the diffuse nature of stormwater was more difficult to manage, despite broad recognition that it is a key source of pollution for urban waterways. Research into stormwater quality management infrastructure began, developing technologies (e.g. vegetated swales, biofilters, wetlands) that could replace concrete-lined drains. This new innovative approach started to take off in the 2000s, as regulations and institutions evolved to start to make it mainstream for stormwater quality, as well as quantity, to be considered. This process is not complete but it has a lot of momentum and the industry in general appreciates that this is the direction stormwater management is headed (Brown and Clarke, 2007). Melbourne was starting to become a “waterways city”.

2000 − 2012 Drought and Floods

The last decade has seen Melbourne’s urban water system face climatic extremes, with severe drought extending from 1997 to 2010, followed by two years or record levels of rainfall. This has put the system under severe pressure. For example, over the last 12 years, for example, average inflows to Melbourne’s major reservoirs has been around 35% lower than the long term average (Melbourne Water, 2009) and only 25% of Melbourne’s rivers and creeks are currently considered in good or excellent condition (Melbourne Water and Environment Protection Authority Victoria, 2009). More recently, flash flooding has become a significant community concern and municipalities are being challenged to provide infrastructure that provides adequate drainage in high intensity rainfalls. Melbourne’s response to the water shortages was to firstly introduce a widespread water saving campaign, designed to change consumer behaviour and increase the efficiency of water use by business and industry. This resulted in a bulk per person water use reduction by 39% in 2008/09, compared to the 1990s average (Department of Sustainability and Environment, 2009). The Victorian Government complemented these water savings measures by commissioning a number of major infrastructure projects, including Australia’s largest desalination plant and the Sugarloaf pipeline, designed to convey water to Melbourne from the Goulburn River system in rural Victoria (Department of Sustainability and Environment, 2009). New innovations such as wastewater recycling and stormwater harvesting also emerged during this period. More recently, water dialogue shifted to the topic of urban liveability, in particular the role of water in the landscape and its potential to provide amenity, recreational and ecological services (Living Victoria Ministerial Advisory Council, 2012).

2013 − 2060 Anticipated Future

While there are inherent uncertainties in climate change predictions, Melbourne is likely to experience trends of increased average and summer temperatures, reduced rainfall and more extreme events, including more hot days, more dry days and increased rainfall intensity during storm events (Howe et al., 2005). With the expected population growth, potential consequences of these predictions are that by 2050 there will be a 50% increase in urban water demand, lower inflows to water storage reservoirs due to streamflow reduction of up to 35%, increasingly stressed aquatic ecosystems and a higher flood risk due to rainfall intensity (Department of Sustainability and Environment, 2006; Howe et al., 2005). Moreover, these outcomes are expected to be set against a backdrop of changing community values, in which environmental protection and conservation of resources for future generations are key drivers in decision-making (Brown et al., 2009; Vlachos and Braga, 2001).

5.1.3. Organisational actors

A range of organisations is responsible for water planning and management in Melbourne. State Government departments are responsible for water policy, human health and land use planning. A central water utility is responsible for the wholesale supply of water and removal of wastewater, major drainage systems for large catchment areas and the health of rivers and creeks. Water retail companies provide the interface with customers for water and sewage services. Municipalities are responsible for the minor drainage system, local amenity and community wellbeing. Community groups are active in lobbying and engaging with water issues. Table 7 provides a list of all the actors involved to varying degrees in Melbourne's water system, which highlights their key roles, responsibilities and strategic documents and Figure 8 demonstrates the institutional connections between key organisations.

Table 7. List of actors in Melbourne's water system

Organisation	**Legislation / Policies / Responsibilities**	**Strategies / Action Plans / Guidelines**
Clearwater	Provides capacity building services for urban and water practitioners through technical training, tours, events, advice and online information	
Port Phillip & Westernport Catchment Management Authority	Oversees the implementation of the Regional Catchment Strategy via the Catchment and Land Protection Act *(1994)*	Regional Catchment Strategy (*2004, currently being updated*)
Community Groups	Community managed groups with diverse missions and responsibilities	Opportunity to contribute to strategies and action plans by other organisations (e.g. MW, RWCs, LG)
Co-operative Research Centre for Water Sensitive Cities	Leads research in collaboration with research, industry and government partners *(established 2012)*	CRC Research Proposal *(2011)*
Developers	Diverse companies which invest in urban renewal and greenfield development of residential and industrial sites	
Department of Health	Regulates drinking water quality via the Safe Drinking Water Act *(2003)* and Safe Drinking Water Regulations *(2005)* Endorses Class A recycled water schemes from a public health protection perspective Administers the Health (Flouridation) Act *(1973)* Provides guidance and advice to Government, the water sector and the public on alternative water supplies (sewage, greywater, stormwater and rainwater) and private drinking waater supplies	Victorian framework for water treatment operator competencies: Best practice guidelines (with VicWater) *(2010)*
Department of Human Services	Supports people and communities in need, through planning, funding and delivering community and housing services	
Department of Planning & Community Development	Administers the Victorian Planning Provisions via the Planning and Environment Act *(1987)* Prepares and administers the State Planning Policy Framework	Metropolitan Planning Strategy *(current work)* Melbourne 2030 *(2002)*

Organisation	Legislation / Policies / Responsibilities	Strategies / Action Plans / Guidelines
Office of Water, Department of Sustainability & Environment	Provides policy advice and supports the Minister for Water Our Water, Our Future: Next stage of Government's water plan *(2007) and* Our Water, Our Future: Securing our future together *(2004).* Note that these policy frameworks are superseded, given the Government Living Melbourne, Living Victoria Policy. Changes the Water Industry Regulatory Order *(future work)* Extends MW's stormwater licensing arrangements (with LG, MW and RWCs) *(future work)* Improves regulatory arrangements for alternative water sources *(future work)*	Victorian Coastal Strategy *(2008)* Central Region Sustainable Water Strategy *(2006)* Yarra River Action Plan *(2006)* Port Phillip Bay Environmental Management Plan *(2002)* Victorian River Health Strategy *(2002)* Victorian Biodiversity Strategy *(1997)* Sewer mining guidelines *(future work)*
Department of Treasury & Finance	Provides policy advice to the Government on economic, financial and resource management in compliance with the Financial Management Act *(1994)*	
Environment Protection Authority, Victoria	State Environmental Protection Policy (SEPP): Waters of Victoria *(1998)* State Environmental Protection Policy (SEPP): Groundwaters of Victoria *(1997)* Protects water environments from pollution via the Environment Protection Act *(1970)*	Better Bays and Waterways Plan (with MW) *(2007)* Guidelines for Environmental Management: Use of Reclaimed Water *(2003)* Guidelines for Environmental Management: Dual Pipe Water Recycling Schemes - Health and Environmental Risk Management *(2005)*
Essential Services Commission	Regulates water pricing and monitors service standards and market conduct of MW and RET under the Water Industry Act *(1994)* and the Water Industry Regulatory Order *(2003)* Established under the Essential Services Commission Act *(2001)*	
Growth Areas Authority	Facilitates coordination of infrastructure planning and development in growth areas via the Planning and Environment (Growth Areas Authority) Act *(2006)*	Precinct Structure Plans
Individuals, households and businesses	End users of water services Pay rates, fees and other charges for water services Contribute to water servicing via local on-site infrastructure (subject to relevant legislation and regulations)	Opportunity to contribute to strategies and action plans by organisations (e.g. MW, RWCs, LG)

Organisation	Legislation / Policies / Responsibilities	Strategies / Action Plans / Guidelines
Local Governments	Established and operated via the Local Government Act *(1989)* Prepares Municipal Strategic Statements, via the Planning and Environment Act *(1987)* Prepares and administers local Planning Schemes Councils are directly responsible to their constituents, including ratepayers	A range of local strategies and plans, e.g.: Integrated Water Management Strategy Sustainability Strategy Open Space Strategy Activity Centres Strategy Tourism Strategy Stormwater Management Plan Green Wedge Management Plan Health and Wellbeing Plan Climate Change Action Plan
Minister for Water	Reports to Parliament on the performance of water businesses via the Water Act *(1989)*	
Melbourne Water	Meets the Statement Of Obligations set out in the Water Industry Act *(1994)* and its subsequent amendments Directly responsible to their customers via the Waterways and Drainage Charge (billed via the RWCs)	Metropolitan Integrated Water Cycle Strategy (with OLV and RWC) Draft Healthy Waterways Strategy *(2013-2018)* Draft Stormwater Strategy *(2013-2018)* Waterways Operating Charter *(2009)* Water Plan *(2009)* Waterways Water Quality Strategy *(2008)* Waterways Water Plan *(2008)* Better Bays and Waterways Plan (with EPA) *(2007)* Port Phillip & Westernport Region Flood Management and Drainage Strategy *(2007)* Water Supply-Demand Strategy *(2006)* (to be replaced by Metropolitan Integrated Water Cycle Strategy) Water Recycling Action Plan *(2002)*
Monash Water for Liveability	Leads socio-technical research on urban water (formerly the Centre for Water Sensitive Cities)	
Non-Government Organisations	Formal organisations with diverse missions and responsibilities	Opportunity to contribute to strategies and action plans by other organisations (e.g. MW, RWCs)
National Water Commission	Administers the National Water Initiative under the National Water Commission Act *(2004)* Advises the Council of Australian Governments on national water issues	National Water Initiative *(2004)*
Office of Living Victoria	Administers the Leading the Way – Living Victoria Fund Prepares Regulatory Impact Statement for building controls Focuses research effort and create an industry knowledge hub (with SWF and CRC)	OLV Business Strategy Metropolitan Integrated Water Cycle Strategy and Plans (with MW and RWC) Victoria Planning Provisions amendments for stormwater management (with DPCD) Investment guidelines and decision-making tools for broad societal values

Organisation	Legislation / Policies / Responsibilities	Strategies / Action Plans / Guidelines
Peak Industry Bodies (VicWater, AWA, WSAA and others)	Provides industry representation, knowledge sharing and leadership on water issues	
Politicians	Represents electorates in Parliament	
Parks Victoria	Manages designated land, waterways and infrastructure under the Parks Victoria Act *(1998)*	
Places Victoria (Urban Renewal Authority Victoria)	Established in 2011 under amendments to the Urban Renewal Authority Victoria Act *(2003).* Facilitates large-scale urban renewal for residential and mixed use purposes	
Retail Water Companies: South East Water, Yarra Valley Water, City West Water	Meets the Statement Of Obligations set out in the Water Industry Act *(1994)* and its subsequent amendments Directly responsible to their customers via the water supply, sewage and trade waste charges	Metropolitan Integrated Water Cycle Strategy (with OLV and RWC) *(future work)* Water Plan *(2009)* Water Supply-Demand Strategy *(2006)* (to be replaced by Metropolitan Integrated Water Cycle Strategy)
Other Research Institutes, Universities or TAFEs	Undertakes research Provides education and training	
Smart Water Fund	Invests in water industry led research and innovation in urban water management	
VicRoads	Plans, develops and manages Victoria's road network under the Transport Integration Act *(2010)* Administers the Road Management Act *(2004)*	
Third Party Technology Providers	Diverse companies which invest in the development, provision and management of water technologies	

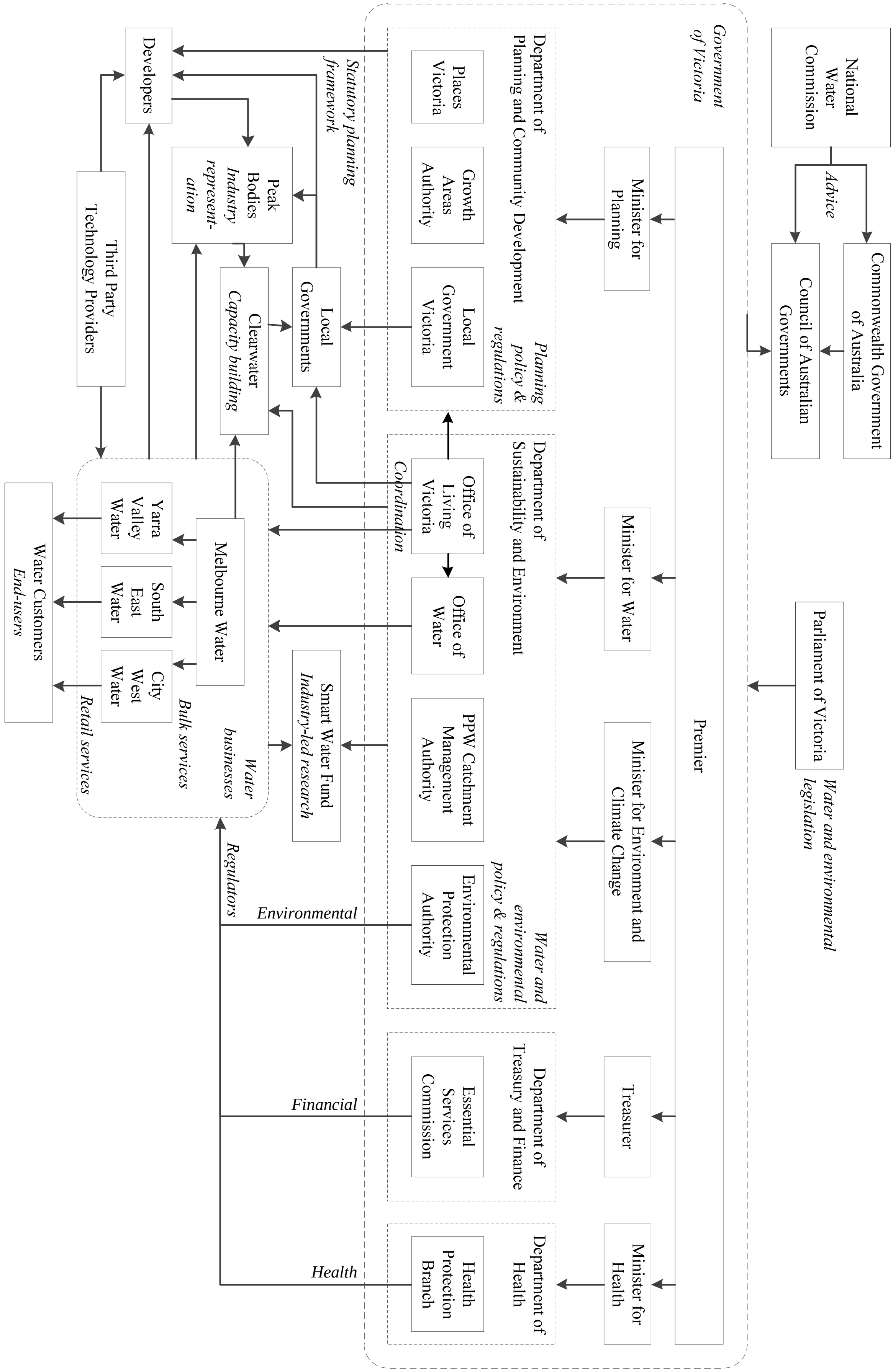

Figure 8. Key organisations in Melbourne's water system

5.2. Publication 3: The enabling institutional context for achieving integrated water management: Lessons from Melbourne

5.2.1. Introduction

Chapter 4 detailed the research methods used to conduct the empirical and illustrative case study of Melbourne. Framed by the case context described in Chapter 5.1, Publication 3 presents the overall results of this investigation, drawing on the primary and secondary data about Melbourne's historic (pre-1997), contemporary (1997-2012) and envisioned future (2060) water system. The article focuses on Melbourne's shift towards a hybrid of centralised and decentralised infrastructure over this period to draw lessons about the institutional context for enabling this shift.

The article first presents a chronologic narrative of the developments in Melbourne's water system during the case study. It then compares the functional characteristics of the system at three key stages of its development to reveal distinct differences in the infrastructure and institutions that deliver the city's water services. Scott's (2008) institutional framework is then applied to the narrative to reveal critical insights about the core contextual features that emerged during the shift to integrated water management for each of the cultural-cognitive, normative and regulative dimensions of the system. Levers that may support the creation of such an enabling institutional context are then presented.

The outcomes of Publication 3 contribute to the first and second research objectives of this thesis (see Table 2). The case study of Melbourne, integrating both the empirical and illustrative research from multiple-case studies A and B, presents a detailed chronological account of system change towards a desired liveable, sustainable and resilient future. This account then forms the basis for further analysis to: identify the enabling institutional context (in Publication 3); identify the scope of actor strategies that were effective for supporting the institutionalisation of particular innovations in the case (Publication 4); and identify the functional characteristics of the envisioned future water sensitive city (Publication 5).

5.2.2. Manuscript

The Enabling Institutional Context for Achieving Integrated Water Management: Lessons from Melbourne

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Abstract: There is widespread international acceptance that climate change, demographic shifts and resource limitations impact on the performance of water servicing in cities. In response to these challenges, many scholars propose that a fundamental move away from traditional centralised infrastructure towards more integrated water management is required. However, there is limited practical or scholarly understanding of how to enable this change in practice and few modern cities have done so successfully. This paper addresses this gap by analysing empirical evidence of Melbourne's recent experience in shifting towards a hybrid of centralised and decentralised infrastructure to draw lessons about the institutional context that enabled this shift. The research was based on a qualitative single-case study, involving interviews and envisioning workshops with urban water practitioners who have been directly involved in Melbourne's water system changes. It was found that significant changes occurred in the cultural-cognitive, normative and regulative dimensions of Melbourne's water system. These included a shift in cultural beliefs for the water profession, new knowledge through evidence and learning, additional water servicing goals and priorities, political leadership, community pressure, better coordinated governance arrangements and strong market mechanisms. The paper synthesises lessons from the case study that, with further development, could form the basis of prescriptive guidance for enabling the shift to new modes of water servicing to support more liveable, prosperous, sustainable and resilient outcomes for future cities.

Key words
decentralised infrastructure; institutions; integrated urban water management; liveability; social transitions; social research; vision

1. Introduction

Water systems in cities globally are facing environmental and societal pressures such as water scarcity, degraded waterways, flooding, changing demographics and aging infrastructure. Water resources scholarship acknowledges that centralised water infrastructure, typically comprising large-scale pipelines, treatment plants and drainage systems, exacerbates impacts of these pressures and erodes the resilience of cities (Mitchell, 2006; Pahl-Wostl, 2007; Wong and Brown, 2009). Moreover, this traditional water infrastructure is usually accompanied by a technocratic management approach, based on assumptions that key variables (such as rainfall and water demand) can be predicted or controlled. This approach is now widely considered inadequate to respond to uncertainties and extremes expected with climate change and other contextual conditions (Dominguez et al., 2011; Gersonius et al., 2012; Milly et al., 2008; Pahl-Wostl, 2007; Truffer et al., 2010).

In this context, scholars argue that cities need to move away from traditional water servicing towards hybrid solutions that integrate centralised and decentralised technologies to deliver fit-for-purpose solutions (Chocat et al., 2007; Mitchell, 2006; Newman, 2001). These alternatives are based on fundamentally new principles for designing infrastructure, incorporating flexible, modular and multi-scale characteristics, making them highly adaptable in changing conditions (Ashley, 2005; Barbosa et al., 2010; Brandes and Kriwoken, 2006; Brown et al., 2009; Chocat et al., 2007; Dawson, 2007; Truffer et al., 2010).

While scholarship and policy rhetoric calls for this integrated water management approach, and individual technology options have been developed, modern cities have little experience incorporating new infrastructure models associated with decentralised solutions into water management practice (Gleik, 2003; Harding, 2006; Mitchell, 2006). Reported exceptions include some cities in Australia that have adopted innovative wastewater recycling, stormwater quality treatment and stormwater harvesting initiatives in response to environmental concerns and the country's recent Millennium Drought (Barker et al., 2011; Brown et al., 2013; Mitchell, 2006). The global lack of critically reported practical experience with decentralised infrastructure means there is limited understanding of how urban water servicing can be deliberately managed to support the system-wide changes required (Ferguson et al., 2013; Jefferies and Duffy, 2011; Monstadt, 2009).

Literature on water resources provides some insight. Scholars have identified important factors for urban water management, including social, political, legal, economic and environmental influences (Barbosa et al., 2012; Chocat et al., 2007, de Graaf and van der Brugge, 2010; Dolnicar et al., 2011). Hurlimann and Dolnicar (2010, 2012) highlighted the strong influence of public opinion on the success, or otherwise, of novel water servicing solutions. Brown and Farrelly (2009) reviewed barriers to delivering sustainable urban water management, revealing they are largely socio-institutional (rather than technical), including lack of practitioner capacity, ineffective institutional arrangements and insufficient community involvement and lack of political will. In light of these and other studies, scholars argue that critical evaluation of socio-institutional dimensions is essential for gaining deeper understanding about urban water system change (Blomquist et al., 2004; Brandes and Kriwoken, 2006; Brown et al., 2009, 2011; de Graaf and van der Brugge, 2010; Pahl-Wostl, 2007).

In summary, the shift to new integrated forms of urban water management will not occur without a supportive institutional context. Establishing such enabling conditions requires active attention but there is limited practical guidance in the water resources literature for deliberately supporting policy development, strategic planning and decision-making to this end (Brown and Farrelly, 2009; Ferguson et al., accepted; Monstadt, 2009; Rijke et al., 2013).

This paper contributes to this gap by increasing scholarly understanding with empirical insights from a case study of water system change. Melbourne's recent shift towards integrated water management is analysed to identify the enabling institutional context features and draw key lessons. The research was based on a qualitative case study, involving interviews and workshops with urban water practitioners who were directly involved in Melbourne's water system changes. Insights from the case are presented and with further development, could form the basis of prescriptive guidance for enabling shifts to new water servicing modes to support more liveable, prosperous, sustainable and resilient future cities.

2. Methods

The research took a qualitative single-case study approach (Yin, 2009), involving collection and analysis of primary and secondary data to draw insights for water resources scholarship and practice (Figure 1).

2.1. Case Selection

Since 1997, water management in Melbourne (4.1 million people) experienced significant changes during and beyond an extended drought. The system moved from purely traditional centralised infrastructure to incorporate decentralised technologies as part of an emerging commitment to integrated water cycle management and liveability outcomes (Ferguson et al., accepted). While success in Melbourne was, in part, necessitated by water resource impacts of drought, it was major shifts in the institutional dimensions that enabled these new modes of water service delivery. Analysis of the changes in Melbourne's water system would therefore be expected to reveal critical insights about the enabling institutional context to identify lessons on how new servicing modes can be supported in practice. Water servicing in Melbourne was therefore selected as a unique case for empirical study (Figure 2).

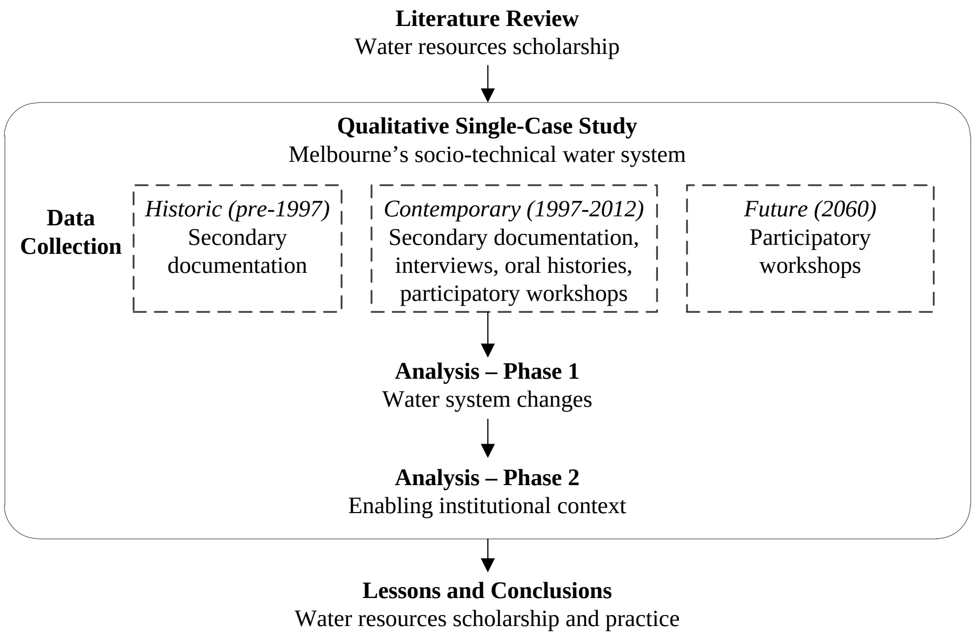


Figure 1. Research design

2.2. Data Collection, Analysis and Validation

Three stages of development in Melbourne's water system were mapped in the research (Figure 1): pre-1997, 1997 to 2012, and an envisioned future system of 2060. Secondary data sources included historic records, published texts, policy materials, organisation reports, media reports and scientific literature. Primary data for the contemporary case period was collected through interviews (oral histories and group interviews, as per Fontana and Frey, 2008) outlined in Table 1. Primary data for the future case period was collected through an action research process using a methodology from participatory transition workshops (Loorbach & Rotmans, 2010; Voβ et al., 2009). The workshops also provided data that reflected the mindset of water practitioners in the 2012 system with regard to drivers, barriers and possible strategies for achieving the envisioned water future. Two series of workshops were conducted to provide contextual focus for specific clusters of municipalities (Table 1); results from the two series were similar and could be synthesised into one vision by the research team. All research participants had direct experience of changes in Melbourne's water system and occupied middle or senior positions (technical and management).

Phase 1 of analysis (Figure 1) developed a chronological narrative of the development of Melbourne's water system from European settlement to 2012, and the envisioned future in 2060. This involved triangulation of different data sources to construct converging narratives. The narrative refers only to highly significant documents for the case study; it is beyond the paper's scope to identify all scientific and policy documents which influenced Melbourne's water system evolutions. These results were used to define distinct system characteristics for the historic (1997), contemporary (2012) and envisioned future (2060) water systems of Melbourne to highlight the functional changes in water servicing delivery.

Phase 2 (Figure 1) applied an inductive mode of analysis (Blaikie, 2010), grounded in the Phase 1 results. The case narratives were systematically analysed from a new institutionalism perspective, using Scott's (2008) framework of three institutional pillars that underpin society: cultural-cognitive, normative and regulative structures. The inductive analysis involved identifying sub-categories within these pillars to explain the key institutional factors that supported the identified functional changes in the Melbourne case.

External validity (Yin, 2009) of the 1997-2012 analysis was ensured through a validation focus group with three key informants and their subsequent review and critique of the narrative. The 2060 vision was validated at two workshops involving more than 150 water practitioners from Melbourne and across Australia; its recommendations were endorsed by the head of the Office of Living Victoria (the Government body responsible for driving change in Melbourne's water system).

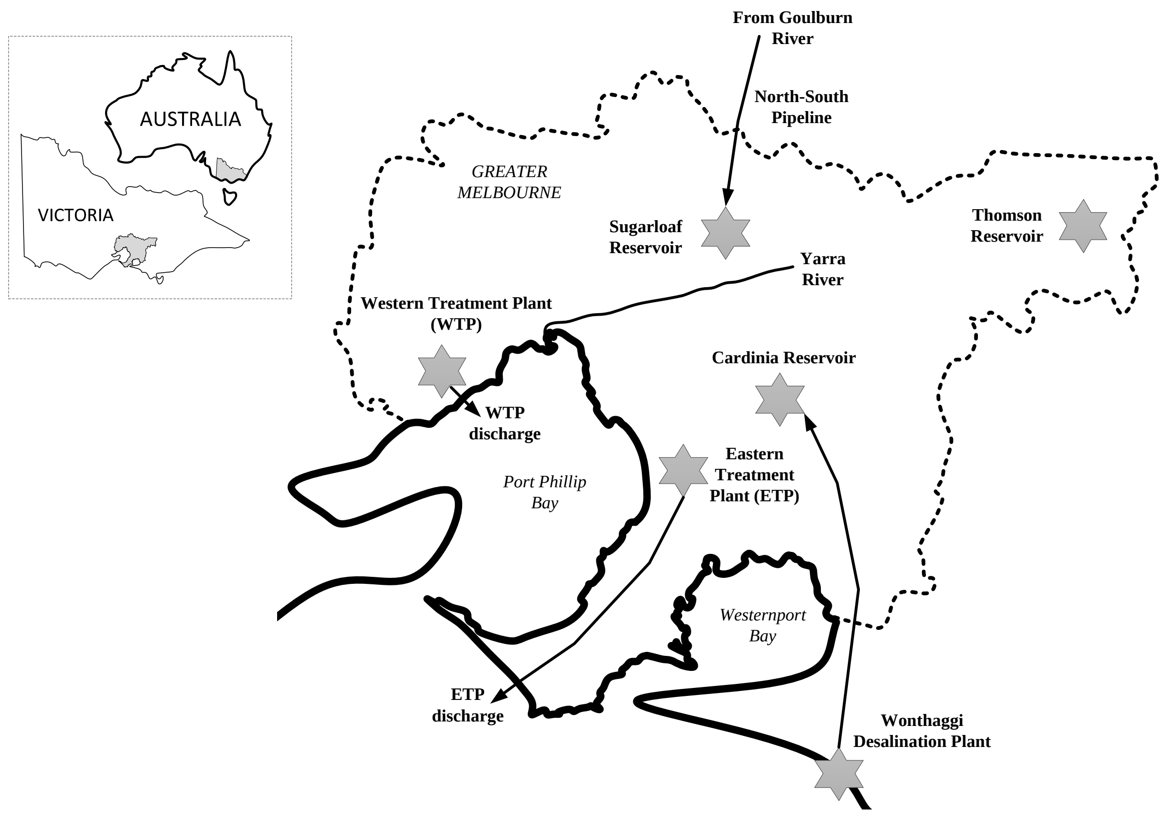


Figure 2. Case study location

Table 1. Primary data collection

CONTEMPORARY				
Type	**Interviews**[a]	**Objectives**	**Participants**[b]	**Roles**
Oral histories	20 people (Jul-Nov 2011)	Elicit detailed personal accounts of the social context that enabled system changes between 1997-2012 though in-depth free-flowing interviews	Water utilities (12) State government (12) Municipalities (1) Academia (2) Private sector (2)	Executives, managers
Group interviews	9 people over 4 interviews (Jul-Nov 2011)			Managers, project officers
FUTURE				
Series	**Workshops**	**Objectives**	**Participants**[c]	**Roles**
South East Cluster ($760\ km^2$, 700,000 people)	5 half-day visioning workshops (Feb-Jun 2012)	Develop a long-term future vision of Melbourne's water system: • Guiding principles to inform planning, design and management decisions • Strategic objectives to provide more specific definition for each guiding principle Develop shared understanding of drivers, barriers and strategies for achieving the future vision from the contemporary system of 2012	Water utilities (4) State government (4) Municipalities (7) Academia (4) Private sector (2)	Managers, project officers
Yarra Valley Cluster ($234\ km^2$, 400,000 people)	4 half-day visioning workshops (Mar-Jun 2012)		Water utilities (4) State government (3) Municipalities (6) Academia (4) Private sector (2) Community (1)	

a) Short follow-up interviews were conducted by phone with key informants in November 2012 to supplement case study with additional data about changes since the original interviews.
b) Participants identified through snowball sampling (referrals from key water sector actors)
c) Participants from diverse disciplinary backgrounds, nominated by their organisation

3. Results: Water System Changes

This section presents a narrative of the socio-technical changes for the historic, contemporary and future water systems in Melbourne. Figures 3 and 4 present selected quantitative data on social and infrastructural changes in Melbourne that accompanied the institutional dynamics described in the narrative.

3.1. Historic (pre-1997)

European settlement led to the construction of Melbourne's first water systems, starting with water supply in 1857 and expanding to separate sewerage and drainage networks over the following decades. These systems featured centralised infrastructure, including large-scale storages, treatment plants, pipelines and channels that served society's needs for water security, public sanitation and flood protection. As population grew, the city expanded; additional reservoirs, wastewater treatment plants and pipe networks were gradually built, extending the existing infrastructure to cope with the increasing demand and periodic water shortages (Figure 3a,b,c). Prior to Melbourne's Millennium Drought (1997-2009), the last major water supply augmentation was the construction of Thomson Reservoir in response to the major drought of 1982-83. Completed in 1984, it was Melbourne's largest water storage and heralded as making the city 'drought-proof' (Figure 3b). Augmentation of the wastewater system was gradual throughout this period (and into the 2000s), extending to parts of Melbourne still reliant on onsite septic tanks for wastewater treatment and disposal (Figure 3c).

The late 1980s-90s saw a shift in the planning and management of Melbourne's water system and the Victorian Government's role grew in prominence. Economic rationalism had become dominant in public policy; capital investments in the water system were no longer only driven by technical rationale on the advice of engineers, but also needed to provide positive financial returns for taxpayers. Efficiency of public organisations became a priority and, in 1994, the major water utility was divided into four corporate entities (Melbourne Water as a wholesale water company and three water retail companies, each solely owned by Government).

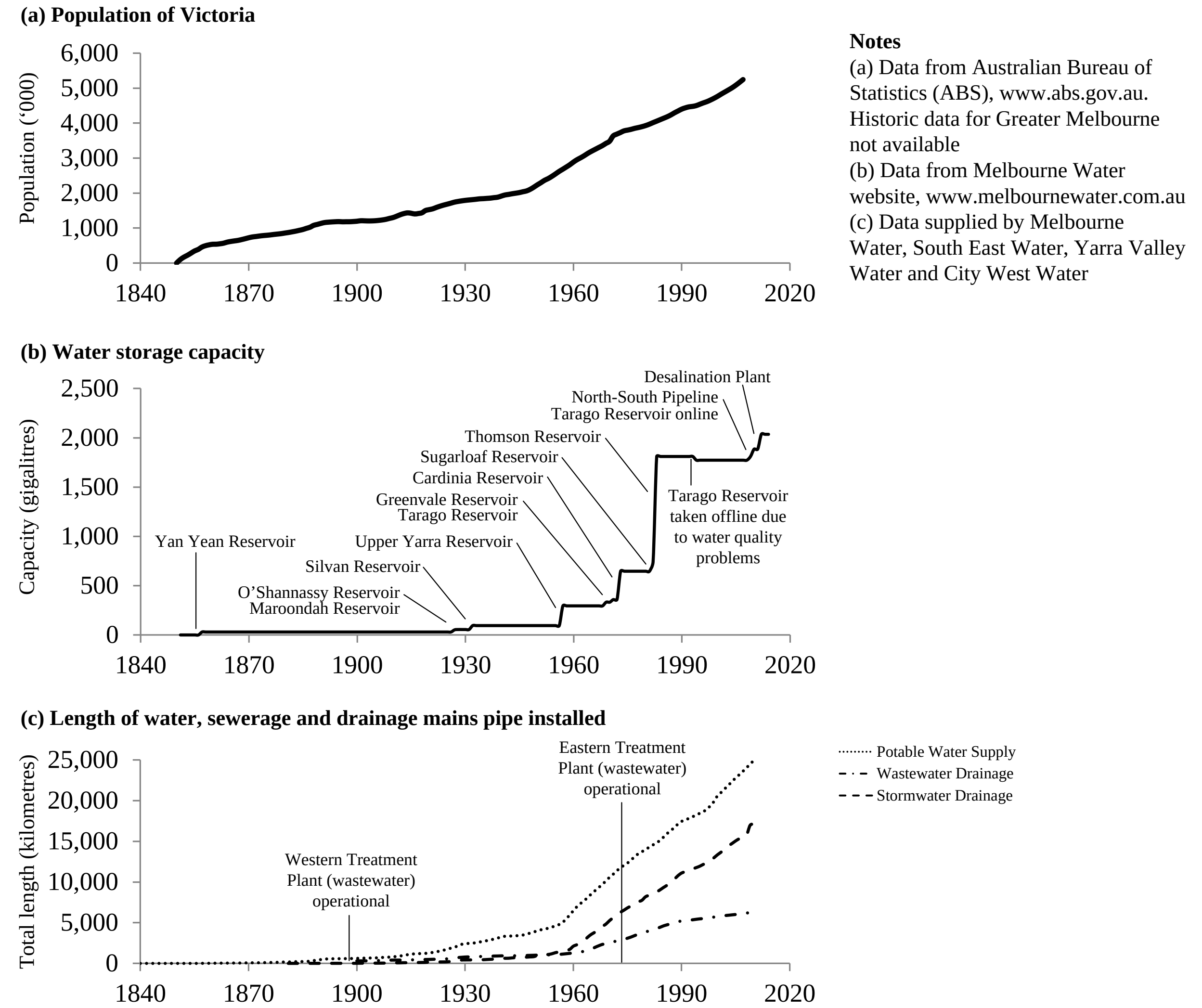


Figure 3. Historic water system changes for Melbourne

A second major shift emerged as the environmental movement gained momentum globally through the 1970-80s, influencing community perceptions and values around water in the urban landscape. Rivers and creeks were no longer considered simply drains for wastewater and stormwater, but social and environmental assets with importance for ecological health and urban amenity. The Environmental Protection Authority of Victoria (EPA) was established in 1970 and regulated discharges from point sources to improve urban waterway health. However, by the 1990s it was found these initiatives did not fully address downstream water quality problems. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) undertook an environmental study of Port Phillip Bay, following serious concerns about its health. The study recommended reductions in nitrogen loads entering the bay by 500 tonnes/year from the Western Treatment Plant (WTP) and 500 tonnes/year from stormwater discharges (Harris et al., 1996).

3.2. Contemporary (1997-2012)

The Millennium Drought started in 1997 (Figure 4a), although since short durations of low rainfall were not unusual in Australia's naturally variable climate, drought conditions were not immediately recognised by water resource planners and this period was dominated by environmental concerns. The EPA placed significant pressure to reduce pollution discharges from the major wastewater treatment plants (WTP and Eastern Treatment Plant, ETP) and by 2001, Melbourne Water had starting planning upgrades for both plants to achieve higher treatment levels. In 2001, the Victorian Government introduced a target for 20% of Melbourne's wastewater to be recycled by 2010 (only 1% was recycled at the time) in order to reduce wastewater (and therefore pollution) discharged to downstream waterways.

The need to reduce stormwater pollution led to research and development activities on stormwater quality treatment technologies (for a detailed account see Brown et al. (2013)). Technologies such as gross pollutant traps, constructed wetlands and biofilters were developed and trialled during the 1990s (Figure 4d). New networks across scientific institutions, policy-makers, land developers, municipalities and water practitioners were established and through these partnerships, pilot projects (designed as proof-of-concept demonstrations) were implemented from the late 1990s. Best practice stormwater management guidelines were published in 1999 and a software tool, MUSIC, was released in 2001 to support decision-making about stormwater treatment solutions. These activities also increased understanding about the impacts of high runoff volumes, highlighting the need to retain stormwater (rather than rapidly convey it), as part of urban stormwater management for improving waterway health.

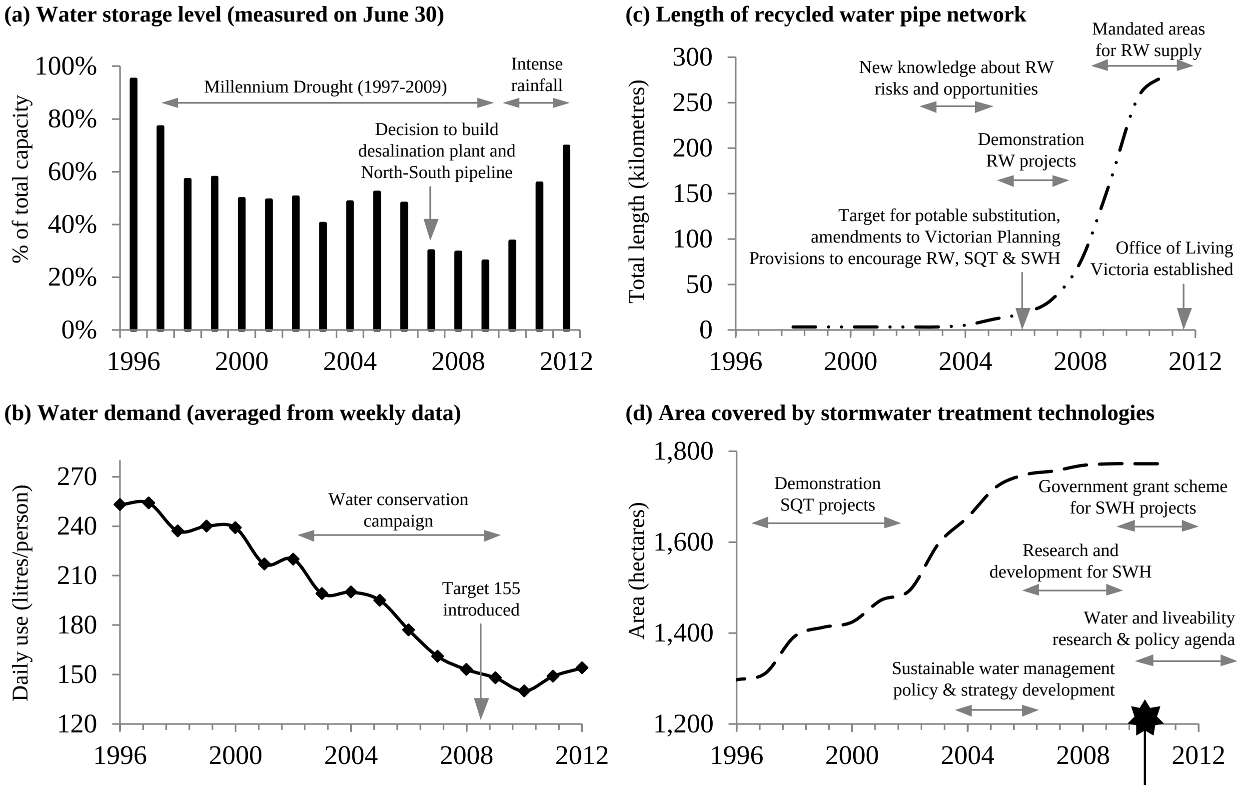
By 2002, low rainfall conditions had persisted for six years. The Victorian Government now recognised that with projected growth in Melbourne's population and the potential (but uncertain) impacts of climate change on water resources, water security needed attention. An expert panel (WRSCMA, 2002) recommended a widespread campaign to encourage water conservation and efficiency (Figure 4b), and concluded no major augmentations were required. Water restrictions were introduced for the first time in 20 years and from 2002, water pricing strategies were adopted as incentive for reducing water consumption. Rebates for water efficient showerheads and water efficiency labelling and standards for household appliances (e.g. washing machines) were implemented. In 2004, rising block tariffs for water supply and permanent water saving rules were introduced. By then, the Government, Melbourne Water and the retail water companies were collectively encouraging households, businesses and industries to reduce their water consumption (despite the collection of lower revenues as a result) through the provision of educational materials, financial incentives and support for companies to develop water management plans. Melbourne’s major newspaper published water storage levels on the front page, allowing the community to track daily changes. The community’s understanding about the threats of drought was high and people were willing to contribute to solutions; average daily per capita consumption dropped by 22% between 2002 and 2006 (Figure 4b).

During this time, the Victorian Government continued to emphasise environmental issues and developed new state-wide policy centred on sustainable water management. Key policy and strategy documents were developed through sector-wide consultation (DSE, 2004 & 2006) and placed strong focus on protecting natural water environments (Figure 4d). Melbourne’s water retail companies started to incorporate sustainability principles as strategic business priorities. While innovation around wastewater and stormwater management had (so far) been driven by the protection of waterway health, in the context of drought the supply of alternative water sources were now identified as important means for achieving sustainability goals. The Victorian policy and Melbourne strategy (DSE, 2004 & 2006) explored how alternatives such as recycled wastewater and harvested stormwater could boost water supplies and canvassed larger scale options such as desalination, concluding that large-scale augmentation would not be required until 2015.

Supply of recycled wastewater began once the WTP was upgraded in 2004 to treat wastewater to “Class A” quality, fit for application to food crops and for non-potable uses in urban areas. From early 2005, the Werribee Irrigation District scheme was established to supply this Class A recycled water to vegetable growers who had been suffering from water shortages since 2003 when drought conditions began to worsen. Supply of Class A water to residential customers via a separate pipe (referred to as “dual pipe” schemes) was also introduced, with fairly rapid uptake (Figure 4c). Melbourne’s continued urban expansion required new water and sewerage services to the city’s fringe. Some consultants involved in these greenfield projects saw the potential for dual pipe schemes to recycle wastewater locally (rather than connecting to main sewers of the water retail companies), thereby enabling out-of-sequence land development and offering significant economic benefits for developers.

From 2003 to 2005, the water retail companies received proposals to develop dual pipe schemes; however, they were initially resistant due to a lack of knowledge, tools and organisational structure required for delivering recycled water systems (Figure 4c). Steering committees and working groups were established to address these challenges, involving water retail companies, Melbourne Water, health and environmental regulators, industry peak body representatives and other experts. Their aim was to learn from experience elsewhere and develop new knowledge that could inform the development of design standards and risk management guidelines for Victoria (which were published from 2004 to 2006).

The drought continued to worsen and became acute from 2006. The 12 month period from June 2006 saw unprecedented low rainfall; Melbourne’s overall water storage volume dropped from 49% to 29% (Figure 4a). Modelling showed that if severely dry conditions continued, Melbourne would need an additional 240 gigalitres (an increase of about 50% of annual demand) within a few years. This potential water security threat



(e) Stormwater harvesting projects operational in 2010
17 projects <10 ML/yr
17 projects 10-100 ML/yr
3 projects >100 ML/yr

Notes
(a,b) Data from Melbourne Water website, www.melbournewater.com.au
(c) Recycled water (RW) data supplied by Melbourne Water, South East Water, Yarra Valley Water and City West Water
(d) Stormwater* quality treatment (SQT) data supplied by Melbourne Water. Stormwater quality treatment technologies include wetlands, sedimentation ponds, retarding basins and biofiltration systems
(e) Stormwater* harvesting (SWH) data from Melbourne Water website. Does not include domestic rainwater tanks. Data not available for other years
** Does not include stormwater systems managed by organisations other than Melbourne Water due to lack of data*

Figure 4. Contemporary water system changes for Melbourne

was unanticipated in recent water resource strategy development, so a sense of crisis ensued. Urgent political attention focused on identifying what form of augmentation could supply the required amount of water in the time available and with adequate public receptivity. Leaders from Melbourne Water and the Victorian Government considered the options, with input from technical consultants. Large-scale wastewater recycling was assessed as unfeasible due to the time constraints and uncertainty around community perceptions. A proposed project to extract stormwater from Melbourne's Yarra River, rainwater tanks and other decentralised stormwater infrastructure were not considered able to generate sufficient water volumes. A seawater desalination plant was assessed to be the only publicly acceptable option in the time available.

Preliminary investigations and a feasibility study for desalination were conducted in late 2006 and early 2007. In June 2007, the Victorian Government decided a 150 gigalitre plant would be built as a fast-tracked project at Wonthaggi to treat seawater and transfer potable water 85 km to Cardinia Reservoir (an existing water storage), with expected completion in 2012 (Figure 4a). The required urgency for decision-making meant there was minimum community consultation or broad sectoral engagement about the rationale, size or location for the desalination project.

During this same period, a group of irrigators and community leaders in north-east Victoria were advocating a scheme to upgrade irrigation infrastructure in the region to improve its efficiency. In return for taxpayer funding of the upgrade works, one third of the water saved (75 gigalitres) would be transferred from the Goulburn River to Melbourne for urban use (the remaining two thirds would be split evenly between the environment and farmers). The project was controversial, speaking to a long-running debate on whether Melbourne had rights to water from rural catchments. Despite opposition from many in the farming community, in June 2007 the Victorian

Government announced the irrigation upgrades and North-South pipeline would be constructed (by early 2010), providing water security to Melbourne until the desalination project was operational in 2012 (Figure 4a).

The desalination project and the North-South pipeline were the subject of public protests, heated debate and media commentary in the following years. The community expressed anger and frustration that substantial taxpayer investment was required because of a perceived unpreparedness by Government. Commentators argued the projects were unnecessary and alternatives such as recycled wastewater and household rainwater tanks should be favoured. Justification for the projects was not seen to be well explained by Government and proponents felt the media was providing biased coverage of the issues. Nonetheless, the desalination plant and North-South pipeline progressed through the planning, design and approvals phase and construction of the North-South pipeline was completed in early 2010 (Figure 3b).

The perceived water security threat during this critical period of drought (2006-2009) had drawn the attention of Government and the water sector away from environmental, sustainability and water quality concerns. Nonetheless, there was substantial progress in the development of wastewater recycling and stormwater harvesting as alternative services, now with the motivation of boosting water supplies in addition to preventing waterway health impacts. In 2006, the Government introduced an annual target to substitute 10 gigalitres of potable water with alternative sources and it amended the Victorian Planning Provisions to require new developments to integrate alternative water resources (Figure 4c). The first dual pipe scheme for reticulating recycled wastewater to residential customers became operational in late 2006 and the next few years saw the water retail companies restructure their organisations to define specific responsibilities for its planning and delivery. The water businesses provided educational material through school curriculums, households and media campaigns to raise community awareness of the potential for recycled water to provide additional water security in drought conditions. By 2008, the Victorian Government's 20% recycling target was achieved and supply of recycled water to 165,000 customers across outer Melbourne was mandated (Figure 4c).

Despite the Victorian Government's receptivity to stormwater harvesting as an alternative approach, it took some time to gain momentum within the water sector. An early project came up against regulatory barriers associated with potential human exposure to the water (e.g. the Royal Park constructed wetland in 2006). Scientific advancements in biofiltration technologies (2005-2009) needed to provide proof-of-concept that green infrastructure could achieve sufficient treatment levels before alternative technologies could be used to harvest, treat and reuse stormwater (Figure 4d). Through the networks and knowledge formed by activities focused on stormwater quality treatment, pilot projects that could trial stormwater harvesting technologies were planned and, in 2009, the Federal Government established a large grant scheme that provided the financial support required to realise these projects (Figure 4d).

These developments brought sector focus to how alternative water sources can most effectively be utilised in an integrated water cycle management approach. A key question is the relative value of different water sources or servicing solutions in local contexts, which cannot be addressed without integrated assessment frameworks that provide independent evaluations of which option is best for a particular project. The early harvested stormwater and recycled wastewater initiatives also highlighted the need for coordinated strategic planning (of both water resources and land use) at central, regional and local scales so opportunities for the best value projects can be identified and subsequently implemented.

As the drought continued, Government increased the severity of water restrictions and, in November 2008, introduced a voluntary daily target of 155 litres/person to provide a benchmark for household consumption (now 40% lower than in 2002, Figure 4b). These measures limited how often parks, grass and street trees could be watered and Melbourne became distinctly 'brown', as private gardens and public vegetation went thirsty. Trees that were over 100 years old and provided distinct shade, greenery and character to the city came under serious threat. Urban ecosystems were degraded through lack of water and important social infrastructures, such as community sportsgrounds and recreational lakes, were too hard or dry to be utilised. These experiences highlighted the vital role of water in an amenable and healthy urban landscape and led to a new focus on water supporting a city's liveability through the provision of ecological services, urban amenity and microclimate control (Figure 4d). This liveability agenda was explored through collaborative and large-scale industry, government and research programs from 2010 (e.g. "Cities as Water Supply Catchments" (Wong et al., 2011) and the Cooperative Research Centre for Water Sensitive Cities (undated)).

After fourteen years, drought eventually broke in late 2009 and two years of intense rainfall followed (Figure 4a). Melbourne Water and municipalities across the city were inundated with public complaints about the impacts of regular flood events. Meanwhile, the desalination project was underway, despite the public resentment and new water sector focus on integrated water management and liveability. A 30 year public-private partnership was established after a competitive process to select a private consortium and construction began in October 2009. The project was significantly delayed by industrial action and wet weather, but commissioning was completed in December 2012).

By the November 2010 election, both the Government and opposition had developed new policy platforms focused on integrated water management. The Government lost the election and the new Government sought to distance itself from the previous large-scale water infrastructure with its "Living Melbourne, Living Victoria" policy. It appointed an independent Ministerial Advisory Council to advise on integrating alternative water sources as Melbourne's next major supply augmentation and improving the liveability of Victoria's urban areas. A new Government body, the Office of Living Victoria, was established in May 2012 to drive generational reform for delivering a "smart and resilient water system for a liveable, sustainable and productive Victoria" (Figure 4c). Its agenda includes coordinating urban and water planning at city and regional scales, developing industry capacity to deliver an integrated water cycle approach and reforming regulatory frameworks to clarify roles, responsibilities and expectations associated with alternative water sources (Victorian Government, undated).

3.3. Future (2060)

By 2012, the water sector and Victorian Government understood that traditional water approaches would not be adequate for future servicing. Climate uncertainties and extremes needed better accommodation in the system's planning and design. Liveability values, such as ecological health, amenity, thermal comfort, beauty and equity were now recognised as important functional outcomes, without diminishing the critical value of traditional services of clean water, sanitation and flood protection.

Table 2. Vision of Melbourne's 2060 water system

Vision Themes	Guiding Principles	Example Strategic Objectives
Social and Ecological Health	1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.	• People live and work within walking distance of green space
	2. Our city is alive, healthy and green; its environmental wellbeing is valued, protected and enhanced. We live in harmony with our natural environment.	• All urban waterways are in "good" to "excellent" condition
	3. Our city, people and ecosystems are safe and resilient; we are prepared for surprises and extremes.	• No fatalities or loss of critical infrastructure from flood events
Connected Communities	4. Our identity embraces water; we celebrate our water sensitive city and take pride in the path it paves for a sustainable future.	• People are proud of Melbourne's iconic waterway environment
	5. We are educated, engaged and aware; we understand and take responsibility for our water. Our water sector collaborates and co-creates understanding and solutions with community and associated sectors. We understand and act upon community water needs.	• All households and businesses are water literate
Shared Prosperity	6. We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system.	• Every water infrastructure decision delivers the highest societal and ecological benefit
	7. Our water system is equitable; water is available for us all to meet our basic needs.	• Everyone has access to water for basic needs
Water System Design	8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum societal value.	• All benefits and impacts of water are identified, quantified and communicated
	9. Our water system is smart, integrated, connected, flexible and adaptive.	• All possible water sources contribute to fit-for-purpose supply
	10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water, nutrients and physical space are consumed and produced.	• Maximised energy and nutrient recovery from the water system

The 2060 vision for Melbourne's water system provides a fuller expression of these broad concepts and reflects the tacit knowledge water practitioners developed through engaging with these new challenges and directions. The vision comprised ten principles in four themes. Each principle was further defined by strategic objectives that represent specific goals that would indicate the principle's achievement. Table 2 presents the principles and example strategic objectives (see Ferguson et al., accepted, for further details).

3.4. Changing Characteristics

Comparison of the historic, contemporary and envisioned future water systems of Melbourne reveals distinct differences in the infrastructure and institutions that function to deliver water services.

The 1997 system was dominated by large-scale centralised infrastructure, with early activities around stormwater quality treatment (Figure 5). The supporting institutions were deeply embedded, having evolved since the 1850s. Water professionals operated from an assumption that environmental variation could be predicted or controlled through technical solutions based on historic data. Knowledge was highly developed and codified in manuals, guidelines and models. Engineers were responsible for water and the community was primarily engaged through taxes and charges in return for services. Performance standards, regulative instruments and governance arrangements were well-established, configured around separate management of water supply, wastewater and stormwater.

By 2012, Melbourne's water system was a hybrid of centralised and decentralised infrastructure and institutions that delivered additional functionality (Figure 6). The desalination plant and rural transfer pipeline reinforced conventional characteristics, supplying new water to existing reservoirs. In contrast, stormwater quality treatment, stormwater harvesting and wastewater recycling introduced decentralised technologies at local and regional scales. These supplied non-potable water to end-users through a second reticulation network. New communities of practice were established, as water responsibilities extended beyond engineers to urban planners, ecologists and landscape architects. The public became more active, adopting conservation measures and implementing household water infrastructure. The administrative arrangements were better coordinated, as organisations developed new approaches for jointly managing the more complex hybrid system.

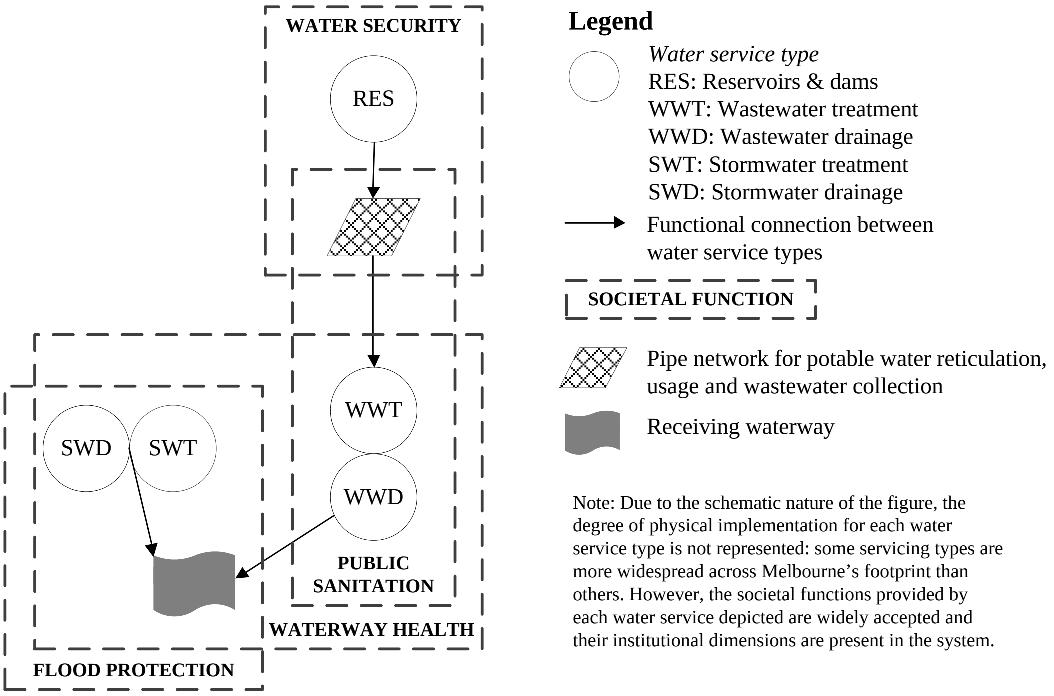


Figure 5. Functional characteristics of Melbourne's 1997 water system

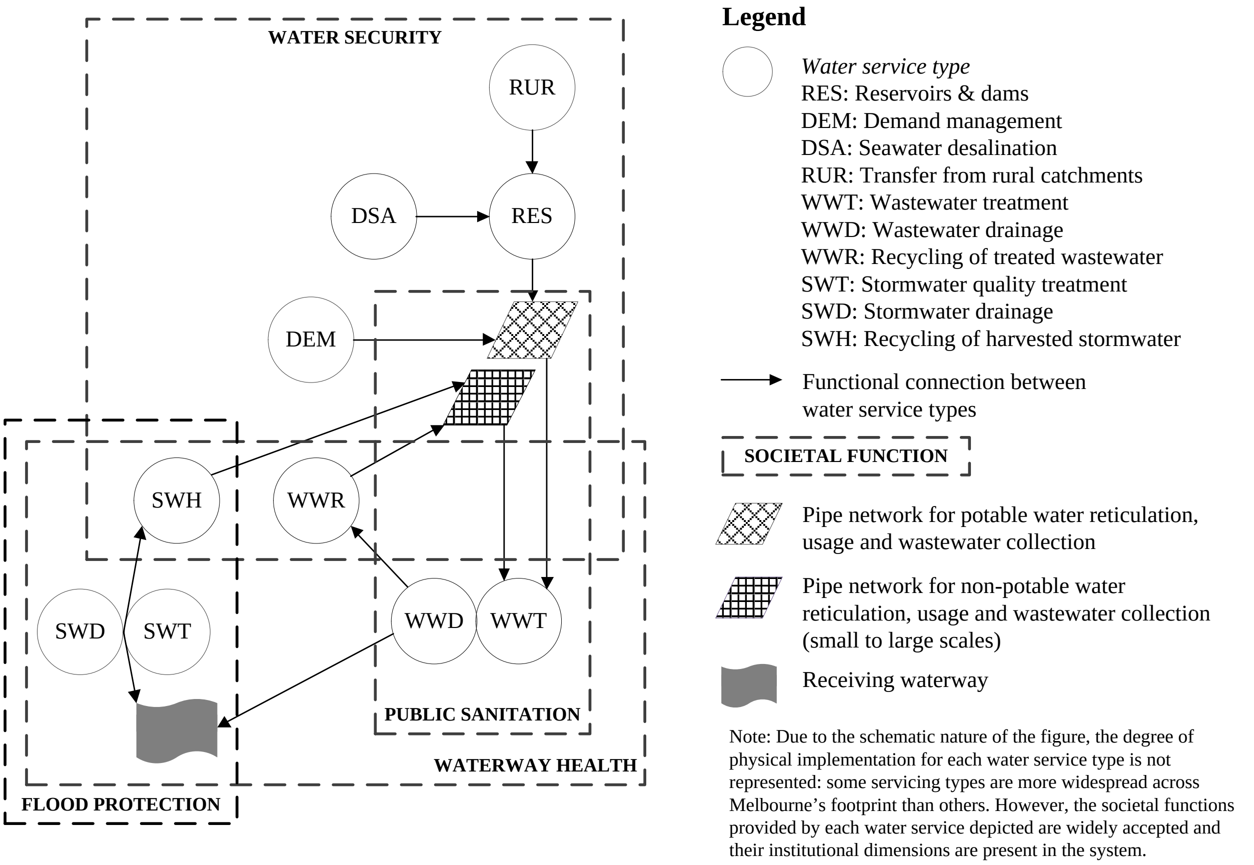


Figure 6. Functional characteristics of Melbourne's 2012 water system

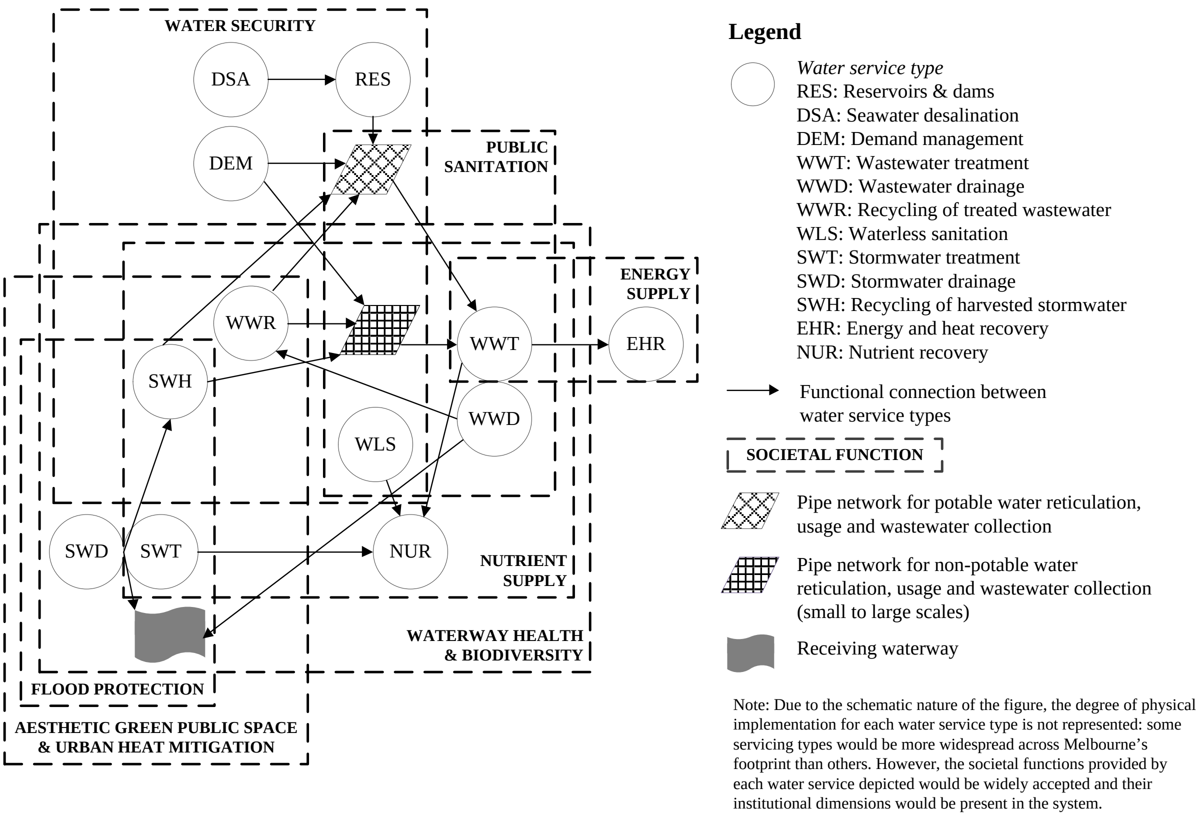


Figure 7. Functional characteristics of Melbourne's envisioned 2060 water system

The envisioned future water system for Melbourne describes the broad societal outcomes water servicing would support. The vision does not prescribe the necessary type and arrangement of infrastructure; however, system functionality can be inferred (Figure 7). It would comprise centralised and decentralised technologies integrated at multiple scales to provide flexibility and adaptability. Supply networks would deliver water quality that is fit-for-purpose. There would be no waste streams, so water, nutrients and energy would be managed in closed cycles where all flows are valued as resources. Green infrastructure and waterscapes would provide functional and amenity services. The importance of different technologies would vary with climatic contexts so the system would incorporate redundancies (e.g. desalination would be valued more in drought). The specific infrastructure implemented across Melbourne would be non-uniform, since local context determines what type and scale is most suited. The water profession would need knowledge and tools for evaluating differentiated water needs and opportunities. Governance would involve actors operating at multiple scales, in multiple disciplines and from other urban sectors.

4. Results and Discussion: Enabling Institutional Context

Significant change in water servicing cannot be driven solely by technological advancement; the institutional context needs to support any directional shifts (Blomquist et al., 2004; Brandes and Kriwoken, 2006; Brown et al., 2009, 2011; Pahl-Wostl, 2007). This section analyses the societal dimensions that enabled the functional changes in Melbourne's water system using Scott's institutional framework (2008) (Figure 8).

4.1. Cultural-Cognitive

The cultural-cognitive underpinnings of the water sector underwent significant changes, specifically the cultural *beliefs* about capacities to predict and control the system, and the sectoral *knowledge* developed through research, demonstration and practitioner learning.

Beliefs: The experience of chronic and acute drought drove a major cognitive shift for the water profession and decision-makers, away from a belief that key variables in the water system (such as demand and supply) were predictable and controllable. Water resource planning was based on narrow and linear assumptions about future conditions, and while climate change was foreshadowed in the early 2000s, its degree and nature of influence was uncertain. The drought crisis presented a major cognitive challenge. Historic patterns of rainfall could no longer be relied upon, predictions about water resource availability were difficult and the impacts of climate change could be far more severe than previously anticipated. The possible consequences of climatic extremes needed attention; contingency planning, water source diversity and adaptive management would now underpin the future of water resources in Melbourne. The suddenness of this cognitive shift, triggered by a failure to anticipate the severity of cumulative impacts of climate change and natural rainfall variability, forced the water sector into urgent action on desalination.

Knowledge: There was significant knowledge developed by water researchers and practitioners in Melbourne. Scientific advancement of stormwater quality treatment technologies was critical for understanding and proving the level of water treatment that could be achieved through green infrastructure and therefore its potential as a supply source. Specialist knowledge about desalination technology was imported and disseminated during the plant's design and construction. Innovative technologies for stormwater harvesting and wastewater recycling were trialled in demonstration projects, which provided the sector with the confidence to further invest in their development and implementation. Trials of new fit-for-purpose modes of supply, as well as evidence from innovations in other places, identified health, environmental and operational risks that needed management. Sector-wide learning was required to build the technical knowledge and practical experience for underpinning guidelines, regulations and organisational structures that would instil trust in the actors responsible for delivering water services safely and efficiently.

4.2. Normative

The norms and values represented in the water system shifted substantially, reflected by additional water servicing *goals* becoming prioritised, political *leadership* and bottom-up pressure from the *community*.

Goals: A normative shift occurred, influencing the water servicing goals and priorities for the water profession and decision-makers. The growing emphasis on waterway health drove development of stormwater quality treatment and wastewater recycling services, as well as a new policy focus on sustainable water management. Water sector dialogue about the potential for green technologies and stormwater retention in the urban landscape to support Melbourne's liveability emerged in response to drought impacts. These shifts reflected increasing recognition of water services beyond the traditional water supply, sanitation and flood protection, and infrastructure that delivers multiple benefits was increasingly valued. Nonetheless,

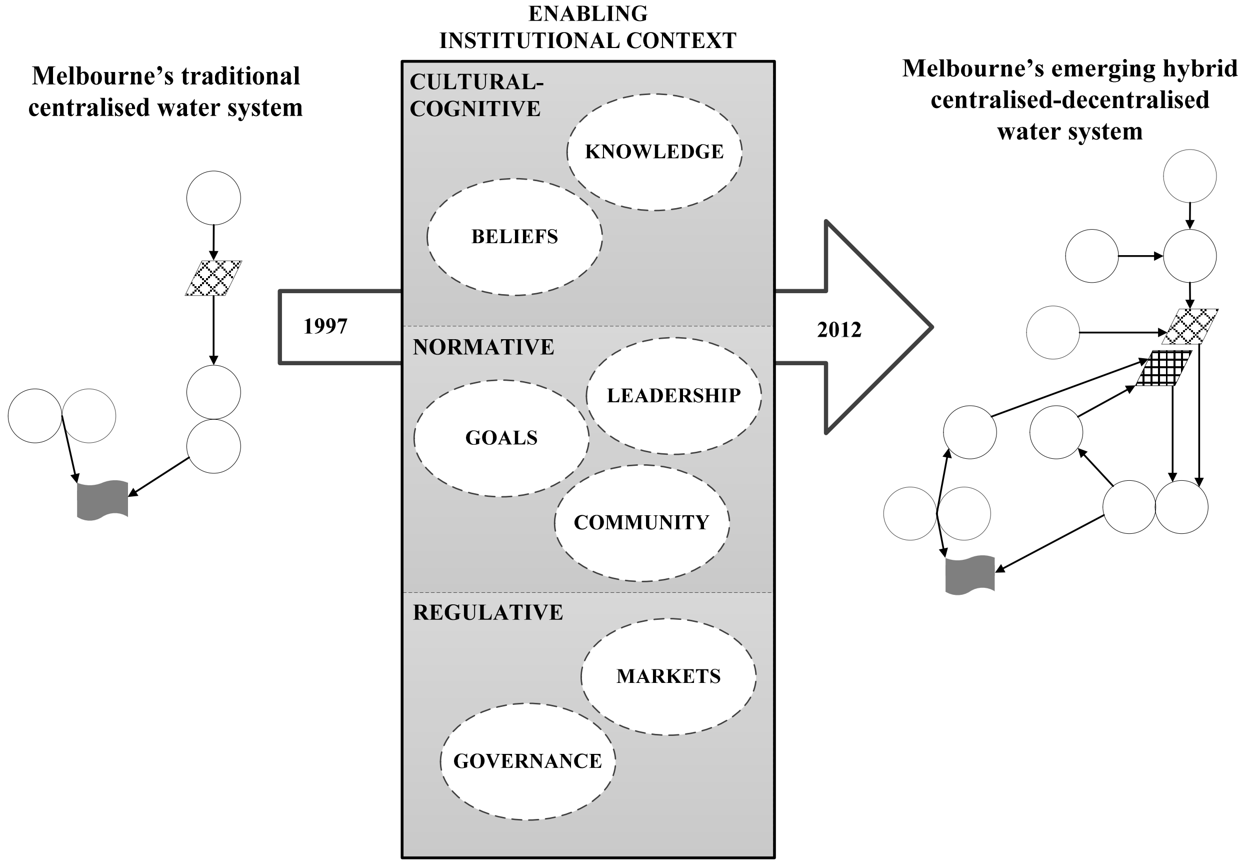


Figure 8. Institutional context for enabling water system change in Melbourne

traditional water services remain the highest priority, as demonstrated during the acute drought from 2006. In this period, the predominant focus was on water security, despite earlier emphasis on waterway health. While desalination provides only the single benefit of water supply and has higher costs than alternatives (e.g. financial, energy, environmental), it was considered the best option when water availability was threatened. However, investment in the desalination plant meant there is now sufficient water security to make resources available for identifying and addressing implementation challenges associated with novel supply alternatives (such as stormwater harvesting), so that large-scale infrastructure is not required for future augmentations.

Leadership: Changes in the political dimensions had a significant influence on Melbourne's water system. The Victorian Government provided strong leadership on sustainable water management and was commended for extensive stakeholder engagement and the innovative approach of its 2004 water policy (DSE, 2004). However, this same Government was later criticised as unprepared for the perceived water crisis and for making what was seen by some people as a rushed and unwarranted decision to build the desalination plant and North-South pipeline. In the context of urgency, there was no time for broad consultation so only trusted advisors informed the decision-making and actors that were not already politically connected had no opportunity to influence discussions. The new policy focus on alternative and integrated water sources by both the Government and opposition prior to the November 2010 election reflected their response to the major cognitive and normative shifts regarding future climatic extremes and liveability values.

Community: Within the community there was a strong build-up of social capital about water, initially driven by the Government-led demand management campaign. As awareness of drought and the need to save water increased, people implemented innovative household water recycling schemes, increased their use of domestic rainwater tanks and expressed pride at their conservation efforts. The introduction of Target 155 in 2008 provided a benchmark for monitoring households' water use and average daily water consumption was still at approximately 155 litres/person in 2012, even though water restrictions had been lifted three years earlier. This personal commitment to water saving meant the public felt highly invested in water servicing, which translated into pressure to ensure the system was managed to their satisfaction. Water issues were regularly discussed in the media and the community was vocal when it did not agree with water decisions (such as the desalination plant and North-South pipeline).

Alternatives such as recycled wastewater and harvested stormwater made intuitive sense to many parts of the public, although receptivity is yet to be widely tested.

4.3. Regulative

The regulative foundations of the water system changed, as *governance* and administration arrangements became more coordinated and *market* mechanisms shaped the economic drivers and directions within the sector.

Governance: Better coordination in governance was required to support the changing functional characteristics of Melbourne's water system. While the traditional system was managed through administrative silos related to water supply, wastewater and stormwater, new decentralised infrastructure projects need approaches that are more systemic and organisationally aligned. These regulative changes were seen through the collective messaging about water conservation and wastewater recycling delivered from the Government and water businesses and the extensive stakeholder engagement in the development of Melbourne's sustainable water strategy in 2006 (DSE, 2006). The recent emphasis on liveability, sustainability and resilience involves extensive sector-wide discussion and collaboration on how integrated water management and water sensitive planning and design can be achieved in practice. While there are still many implementation issues to be identified and addressed, a shared future direction is emerging and being endorsed through formal commitments, most recently demonstrated by the Government's establishment of the Office of Living Victoria.

Markets: Economic factors significantly influenced the changes in Melbourne's water system. Investment and delivery models for core water infrastructure, designed to outsource responsibility and risk to the private sector, grew in prominence (e.g. public-private partnership models were adopted for major projects). The expected economic benefit for private developers by implementing dual pipe reticulation of recycled wastewater on Melbourne's fringe was the key motivation for its delivery. Financial mechanisms supported a range of new initiatives, such as incentives for households, businesses and industry to implement water efficiency measures. Government subsidies enabled innovative stormwater harvesting projects to be implemented when viability had not yet been demonstrated through business cases. The sector now recognises that a major challenge for furthering integrated water management is the lack of evaluation frameworks that account for all the costs and benefits of different servicing alternatives, including less tangible values associated with liveability. Without such tools, robust integrated business cases for alternative approaches cannot be developed for revealing which water source and servicing solution offers the best overall value for a particular local context.

4.4. Lessons from the Melbourne Case

Critical insights from the Melbourne case are synthesised in Table 3 to highlight core contextual features that emerged for each institutional dimension. Levers that helped to create the enabling institutional context are presented, along with other possible levers identified by research participants through the interviews and workshops.

Table 3 reinforces that development of new technologies and models on their own will be insufficient to enable fundamental change in urban water systems. The institutional context of water infrastructure is critical and significant attention must be paid to establishing enabling conditions if new modes of water servicing are to be supported.

Melbourne's water system represents a unique case, in which the water sector has demonstrated its capacity to innovate, learn and adapt as conditions change. There continues to be barriers that challenge further shifts towards the city's envisioned water future. However, the existing momentum within each identified institutional dimension potentially offers a supportive social context, provided water sector actors can successfully navigate these and future barriers. As such, the challenge for water scholars and practitioners is to consider how change towards integrated modes of service delivery can be *deliberately* facilitated to support liveable, prosperous, sustainable and resilient water servicing outcomes for cities.

5. Conclusion

This paper has presented empirical evidence of the institutional context that was critical for enabling significant change towards integrated water management in Melbourne. The drought crisis was an important driver in Melbourne's success to date but the obvious question arises: how can other cities establish enabling social conditions for more integrated approaches to water servicing in their own institutional contexts, without needing to experience similar crises?

Table 3. Enabling system change towards integrated water management.

Institutional Dimension		Enabling Context	Possible Levers
Cultural-Cognitive	Beliefs	*New cultural beliefs* that the environment needs to be protected and acceptance that environmental variation cannot be predicted and controlled.	Direct experience of climatic extremes or environmental disturbance, scenario planning processes to anticipate possible future contexts and surprises.
	Knowledge	*Knowledge and evidence* that builds trust and confidence in new and innovative water solutions.	Research and trials to develop evidence base, demonstrations to build practical experience, mechanisms to share lessons widely.
Normative	Goals	*Additional water servicing goals* that reflect and prioritise the sustainability, liveability and resilience benefits provided.	Deprivation of benefits to highlight their value, visioning processes to develop shared future goals.
	Leadership	*Political leadership* that sets new directions, fosters sector-wide commitment and mobilises resources.	Active political lobbying and engagement by knowledgeable advocates for change, processes to gain commitment to a strong long-term vision, linking desired policy directions with popular solutions.
	Community	*Community pressure* that holds the water profession and decision-makers to account.	Community education and commitment to water servicing solutions, visioning processes that involve community, co-governance processes and structures.
Regulative	Governance	*Governance arrangements* that support sector-wide coordination and collaboration.	Partnerships and alliances to plan and deliver cross-boundary projects, planning processes to develop shared problem definitions and strategic programs of action.
	Markets	*Receptive markets* that provide economic mechanisms that support the adoption of preferred servicing alternatives.	Government incentives to support desired outcomes, transparent costs and benefits to enable business case success, market certainty to encourage investment.

The lessons from the Melbourne case offer valuable insight for other places seeking to make similar shifts in water servicing. With further development, testing and validation of the findings in this paper through other cases, prescriptive guidance about how to establish an enabling institutional context could be developed to support policy development, strategic planning and decision-making for shifting to new integrated forms of urban water management.

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5.3. Publication 4: Tracing transitions through institutional dynamics: Cases in urban water

5.3.1. Introduction

Publication 3 provided the overall narrative of development in Melbourne's water system, with a detailed chronological account of how and why different changes occurred between 1997 and 2012. Publication 4 zooms in on this contemporary period, focusing on the institutional trajectories of three water supply innovations that emerged: desalination, wastewater recycling and stormwater harvesting.

The article presents a brief narrative of the landscape pressures, existing regimes and the actor strategies that led to the development of cultural-cognitive, normative and regulative institutions for each of the three new technological innovations. It then undertakes a comparative analysis of these trajectories to develop theoretical insights about the aim and type of actor strategies that are likely to most effective for innovations of different levels of power (pre-niche, niche, niche-regime) and institutional alignment with existing regimes (reinforcing, mixed or disrupting relationship).

The outcomes of Publication 4 contribute to the second and third research objectives of this thesis (see Table 2). Analysis of the three cases to describe and explain the institutional trajectories for each innovation supports the explanation of structures, mechanisms and dynamics for successful urban water transitions as part of the second objective. The theoretical insights derived further address the second objective by offering hypotheses about the scope of actor strategies that are most likely to be effective in supporting the growth of an innovation as part of transition processes. The analytic method developed for analysing the three trajectories contributes to the third objective by extending the methodology for Step 4 of the proposed diagnostic procedure ("Determine the phase of change for each constellation"). The additional insights provided by the analytic method in Publication 4 address the Diagnostic Questions 3, 4 and 5, which is not done by the preliminary diagnostic procedure in Publication 2.

5.3.2. Manuscript

Tracing Transitions through Institutional Dynamics: Cases in Urban Water

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Abstract: Complex infrastructure systems such as water, energy and transportation are facing immense sustainability challenges. Despite a growing awareness amongst scholars, policy-makers and practitioners that fundamental changes in the structure and function of urban infrastructure systems are required, sectors are locked into their current practices due to barriers related to path-dependencies. The study of transitions aims to understand the dynamics of transitional change in socio-technical systems so that strategic interventions can more effectively influence pathways towards sustainability. Transition scholarship provides a range of concepts for describing and explaining the mechanisms that drive a system's dynamics along different trajectories. However, there is a need for more critical insight into how actor strategies shape the environment and functioning of innovations in these systems. To this end, the paper focuses on the dynamics of micro-level processes of an innovation's institutionalisation. It aims to identify relationships between the innovation's level of power (pre-niche, niche or niche-regime), its institutional alignment with existing regimes (reinforcing, mixed or disrupting) and the actor strategy aims and types that were most effective in supporting innovation growth. It analyses three empirical cases of innovation in the urban water system of Melbourne, Australia, which represent innovations that have emerged since 1997: desalination, wastewater recycling and stormwater harvesting. The paper traces the three trajectories of institutionalisation and compares them to derive theoretical insights about the scope of actor strategies are effective in institutionalising different types of innovations.

Key words
innovation; institutions; actor strategies; sustainability; transitions; urban water

1. Introduction

Complex infrastructure systems such as water, energy and transportation are facing immense sustainability challenges globally. Impacts of climate change, population growth, ecosystem degradation and resource limitations are having significant consequences for how well these systems function to deliver services that adequately meet societies' needs (e.g. Bates et al., 2008; Frantzeskaki and Loorbach, 2010; Westley et al., 2011). Despite a growing scholarly and practical awareness that fundamental changes in the structure and function of urban infrastructure systems are required (see e.g. Chapin III et al., 2010; de Graaf and van der Brugge, 2010; Pahl-Wostl, 2009; Truffer et al., 2010), sectors are locked into their current practices due to barriers such as path-dependencies, institutional inertia and inadequate actor capacity to engage in new practices (Berkhout, 2002; Farrelly and Brown, 2011; Frantzeskaki and Loorbach, 2010; Pahl-Wostl, 2009; Westley et al., 2011). To overcome these challenges, scholars argue it is critical to support the emergence, up-scaling and stabilisation of innovative technologies and practices that increase the sustainability of urban infrastructure systems (Frantzeskaki and Loorbach, 2010; Pahl-Wostl, 2009; Truffer et al., 2010).

Studies of sustainability transitions have emerged in the last fifteen years to address questions related to overcoming path-dependencies through innovation. Transitions research aims to understand the dynamics of transitional change in socio-technical systems so that strategic interventions can more effectively influence transition patterns and pathways (referred to in this paper as trajectories), towards sustainability. Through empirical investigation and conceptual development, this paper explores how actor strategies can most effectively support the growth of innovations as part of transition processes.

1.1. Key Transition Concepts

A number of approaches within transitions scholarship provide insight into how transition trajectories unfold. The multi-phase S-curve heuristically represents a system-wide transition as four stages (pre-development, take-off, acceleration and stabilisation) across long periods of incremental change interspersed with a short period of rapid change (Rotmans et al., 2001; van der Brugge and Rotmans, 2007). Strategic niche management focuses on the facilitation of innovation trajectories through nurturing technological niches in protected spaces, then further developing them into market niches and leading eventually to a regime shift (Kemp et al., 1998; Schot and Geels, 2008). The multi-pattern approach examines sequences of change patterns amongst elements of a complex adaptive system that form trajectories for societal transitions (de Haan and Rotmans, 2011; de Haan, 2010).

Concepts have been developed within these approaches to describe and explain the mechanisms that drive a system's dynamics along different trajectories. The multi-level perspective (e.g. Geels, 2002; Geels, 2004; Geels, 2011; Smith et al., 2010; Rip and Kemp, 1998) distinguishes between dominant elements of the system (regimes), novel alternatives (niches) and the contextual conditions in which they are embedded (landscape).

Geels and Schot (2007) conceptualise that niches and regimes are similar kinds of structures but with different sizes and stabilities. In this vein, the multi-pattern approach (de Haan and Rotmans, 2011; de Haan, 2010) frames regimes and niches from a complexity perspective to conceptualise a societal system as comprised of multiple subsystems (known as constellations), with varying degrees of influence, that co-exist and interact (Figure 1a). Each constellation comprises social and biophysical structures, which function to meet societal needs with varying degrees of influence on the overall system. Individual constellations are distinguishable by the service(s) they deliver and the way in which the service is delivered.

The multi-pattern approach defines a constellation's degree of influence on the system as its power. While power is a continuous measure, it identifies ideal types of constellations according to their overall share of system power. Regimes are the most powerful, dominating and determining how a system functions. Niche-regimes have moderate power, exerting significant influence on system function and regimes. Niches have low power; they are innovations that have some system function but no impact on regimes. Pre-niches are introduced in this paper as constellations that exist but provide no system function and, therefore, have no power. Figure 1b represents the growth of a constellation over time; its increasing power corresponds to phases of the multi-phase S-curve (Rotmans et al., 2001; van der Brugge and Rotmans, 2007). While the multi-phase concept typically characterises a transition at the system scale, its use in Figure 1 reflects Rogers' (2003) representation of innovation diffusion, which in this paper is conceived as the increasing power of an individual constellation.

Geels and Schot (2007) contend that the growth dynamics of a transition trajectory are influenced by two key factors: the nature and timing of interactions between the landscape, regimes and niches. First, they argue that niches will have either a competitive (disrupting) or symbiotic (reinforcing) influence on regimes, depending on whether their nature is to replace a regime or be a competence-enhancing add-on. Second, timing is considered important since the relative levels of power between two constellations, at the point in time when a landscape pressure is applied, will influence how they interact. Synthesising these arguments, the type of mechanisms that will most effectively support the growth trajectory of a constellation will vary with time, influenced by the constellation's power level (pre-niche, niche, niche-regime and regime) and the nature of its relationship with the existing regime (reinforcing, mixed or disruptive).

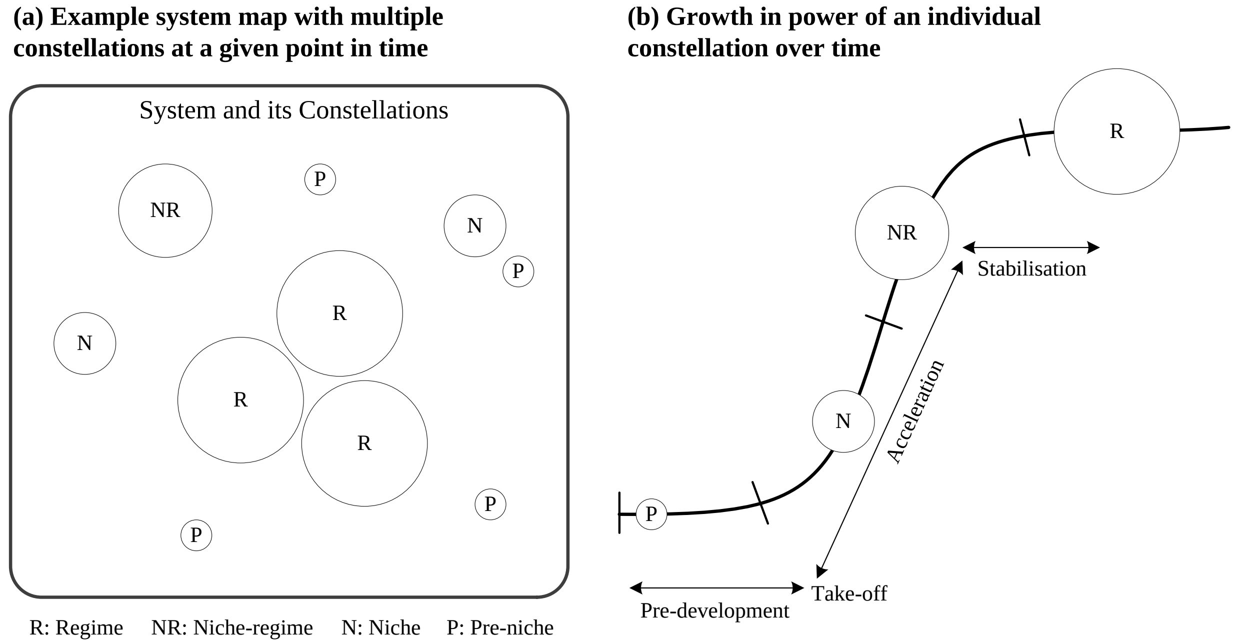

Figure 1. Conceptualisation of a societal system and its constellations.

Transitions literature highlights the important role of agency in sustainability transition processes, emphasising a need to understand how actors can purposefully steer innovation trajectories in a desired direction by triggering different mechanisms through their actions. To this end, scholars have recently called for more critical insight into how agency shapes the environment and functioning of innovations in socio-technical systems (Farla et al., 2012; Grin et al., 2011; Markard et al., 2012) and recent studies are starting to explore the topic (see Brown et al., in press, and Söderhelm, 2013, for some first examples in urban water). Tracing the institutional dynamics across multiple cases of real transitions in practice would improve our understanding of what types of actor strategies are effective during different phases of a transition, under what types of system conditions and in response to what types of landscape drivers and competing influences. Such insights could inform the selection of strategic initiatives for steering transitions in urban infrastructure and other societal systems.

An institutional perspective has been promoted as a useful means for engaging with questions around agency in sustainability transitions and several authors have applied particular concepts from new institutionalism scholarship to transition questions (e.g. Brown et al., in press; Geels, 2004; Geels and Schot, 2007; Truffer et al., 2009). New institutionalism literature explores the nature of institutions and processes of institutional change. In this field, Scott (2008) synthesises a vast array of literature to define institutions as comprised of three pillars: cultural-cognitive, normative and regulative structures or rules that provide stability and meaning in society. From the perspective of Giddens' structuration theory (1984), actors are both constrained by these institutions and capable of shaping them. The concept of institutional work brings focus to the role of agency in creating, maintaining and disrupting institutions (Lawrence and Suddaby, 2006) and offers a framework for examining the deliberate action by individual and organisational actors in processes of institutional change.

Institutional analysis therefore seems a promising approach for revealing how actors can influence trajectories of system innovation. However, there is an absence of published literature that reports on the ongoing interplay between actor strategies and institutional change (i.e. micro-level processes) throughout the trajectories of a transition from pre-development to stabilisation. This micro-dynamics perspective is important for informing the selection and design of actor strategies with insights about the relative power levels and type of relationship between an innovation and the existing regime. A key research question therefore emerges: What scope of actor strategies is most likely to support the institutionalisation of innovation during transition processes?

1.2. This Paper

To address the above research question, this paper aims to: (a) analyse the institutional dynamics of three empirical cases of innovation in the single context of a contemporary urban water system, and (b) derive theoretical insights about the aim and type of actor strategies that are effective in institutionalising different types of innovations.

The empirical cases selected represent three novel and qualitatively different technological innovations that emerged in Melbourne's water system since 1997: desalination, wastewater recycling and stormwater harvesting. These innovations had fast, moderate and slow speeds of institutionalisation respectively, despite sharing the same socio-political context and landscape pressures. Analysis of the three innovations as embedded cases would therefore be expected to reveal different transition dynamics for different types of innovation, providing a rigorous basis for cross-case comparison and generalisations. The paper first traces the trajectories of institutionalisation in response to landscape influences and actor strategies for each case. Comparative analysis of these trajectories then forms a basis for extending theory on the scope of actor strategies that are effective in the emergence, up-scaling and stabilisation of different types of innovations in a sustainability transition.

2. Research Approach

To explore the institutional dynamics for different innovation trajectories, a single longitudinal qualitative case study with multiple embedded units of analysis was undertaken (Yin, 2009). The research steps are explicated and justified below.

2.1. Case selection

Melbourne is the capital of the Australian state of Victoria and home to 4.1 million people. It is located on Port Phillip Bay and covers approximately 7,700km2. The city has recently experienced climatic extremes: drought began in 1997 and lasted for thirteen years, followed by two years of intense rainfall events and severe flooding. During this period, it became internationally acknowledged as a world leader in sustainable urban water management (Jefferies and Duffy, 2011; Roy et al., 2008) and significant changes in technology and practice occurred. While there is debate about how sustainable some of these innovations are (e.g. Barnett and O'Neill, 2010), the system is considered to be undergoing transitional change (Ferguson et al., in press) and would offer a rich empirical case context for study. The case study period extends from the beginning of the drought in January 1997 to July 2012.

2.2. Data Collection, Analysis and Validation

2.2.1. Phase 1: Case narratives

Phase 1 involved the collection, compilation and analysis of primary and secondary qualitative data to develop chronological narratives for the system context (landscape), dominant system (regime) and the three embedded cases (innovations). Oral histories (n = 20 interviewees) were collected from individual actors who had employed strategies that instrumentally supported the institutionalisation of at least one of the innovations investigated. Four group interviews (n = 9 interviewees) were conducted, with two or three individuals participating in each. Interviewees were identified through snowball sampling, which involved finding potential participants through referrals from key actors in major organisations of Melbourne's water system. All interviewees were directly involved in the changes of Melbourne's water system through the case study period and represented state Government departments, water utilities, local municipalities, academia and the private sector. Interviewees held middle to senior-level positions in their organisations during the case study period, in both technical and managerial domains. Oral history and group interviews were in-depth and free-flowing, allowing participants to provide detailed narratives of their personal recollections of key system changes in recent decades. Secondary data included policy materials and reports from stakeholder organisations (including government agencies, water utilities, peak industry bodies), media articles (e.g. newspapers) and relevant scientific literature.

Interview transcripts and secondary documentation were analysed with the aim of constructing succinct and engaging chronological narratives of the landscape drivers, current regime and three selected innovations of Melbourne's water system. The themes, perceptions and explanations in the qualitative data were contrasted and compared by the research team to develop converging accounts of the actor strategies and institutional dynamics for each case. The results from this analytic phase are presented as stylised narratives rather than as raw data (e.g. interviewee quotes). Policy documents that were instrumental in shifting the direction of water management in Melbourne are referred to in the narratives but it is beyond the paper's scope to identify all scientific and policy documents which relate to the institutionalisation of the three innovations studied.

Ensuring the validity of qualitative data involves determining that research findings are accurate from the perspective of the researcher, participant and reader (Creswell, 2009). Validity of the case narratives was achieved by triangulating different data sources to build converging narratives from different interviewee perspectives and secondary documentation (Yin, 2009). Disparities and contradictions in the evidence were further investigated and clarified in short follow up interviews with key informants. External validation of the case narratives was achieved in two stages. First, tabulated actor strategies for each embedded innovation case were presented to three water sector leaders in a validation workshop. These actors had participated in oral history interviews and, collectively, were instrumentally involved in the institutionalisation of all three innovations studied. They thoroughly reviewed the identified strategies and critiqued whether any were missing and that the significance of each strategy was accurately emphasised. The synthesised case narratives were then sent to the same actors for further review and critique.

2.2.2. Phase 2: Trajectories of Institutionalisation

The case narratives provided a detailed base for mapping and analysing the influence of different actor strategies on the institutional dynamics for desalination, wastewater recycling and stormwater harvesting.

Key landscape pressures that significantly influenced the developments in Melbourne's water system were identified and described according to their type of impact using Suarez and Oliva (2005) typology of environmental change (as adopted used by Geels and Schot (2007)). Disruptive influences develop gradually and are intense in one dimension, while shock influences are rapid and highly intense within a narrow scope.

The major components of Melbourne's water system were each considered constellations. Regime constellations were identified as the dominant infrastructures and institutions that determined the system functioning for many decades. The three innovations of desalination, wastewater recycling and stormwater harvesting were each considered an individual constellation (as either pre-niche, niche or niche-regimes).

The infrastructures and institutions of each constellation were then characterised. In particular, the institutions of the three innovations were described according to Scott's (2008) typology of cultural-cognitive, normative and regulative institutional pillars. Within each pillar, categories of structures were

Table 1. Types of institutions for Melbourne's water system

Institutions		**Examples**
Cultural-Cognitive	Cultural knowledge	Awareness, beliefs, meanings, language, narratives, symbols
	Technical knowledge	Scientific knowledge, theories, empirical data, technology development, technology testing, technical designs
	Experiential knowledge	Tacit knowledge, practical experience, skills in operating & maintaining technologies
	Implementation tools	Procedures, templates, guidelines, routines, manuals, models, frameworks
Normative	Public expectations	Values, concerns, perceptions, visions
	Communities of practice	Formal networks, informal networks, loose affiliations, coalitions, alliances, project teams, organisational departments, partnerships
	Roles and responsibilities	Allocation of stakeholder responsibilities, advisory network for decision-makers, formal obligations, informal obligations
	Goals and commitments	Formal policy, strategic documents, strategic programs, official announcements, media statements, organisational commitments
	Standards	Accreditation, benchmarking, product labelling, best practice guidelines, design standards, case studies, codes of practice, industry awards
Regulative	Governance arrangements	Service delivery & revenue collection by Government agencies, private companies, communities, households
	Resource mobilisation	Taxpayer funding, public grants, public-private partnerships, private investment, household investment
	Regulatory mechanisms	Laws, bans, limits, targets, restrictions, performance indicators, contractual clauses, audits, sanctions, licences

inductively developed from literature on new institutionalism (Scott, 2008; Lawrence and Suddaby, 2006; Lawrence et al., 2011) and the case study data to represent the broad range of institutions that comprehensively describe Melbourne's water system (Table 1). In order to determine the nature of the relationship of the innovation with existing regimes, three types of institutions within non-regime constellations were defined: (a) institutions that are already existing in current regimes; (b) new institutions that are non-competitive and can co-exist with regime institutions; and (c) new institutions that are competitive and require existing regime institutions to adapt if they are to further develop. An aggregate assessment of the constitutive institutions for each constellation therefore led to its categorisation as having a reinforcing, mixed or disrupting relationship with existing regimes.

The trajectories leading to the institutionalisation of each innovation were then analysed, focusing on the actor strategies employed to develop cultural-cognitive, normative and regulative institutions, in the vein of Lawrence and Suddaby's (2006) concept of institutional work. The level of power during different phases was assessed according to the innovation's degree of functioning and the regimes' responses: regimes determine how the system functions; niche-regimes influence the regimes and system functioning but are not dominant; niches have some system function but regimes are not engaged with their activities; and pre-niches involve some activity but provide no system function. In developing the trajectories, interview transcripts and secondary documentation were used to identify specific actor strategies within the analytic boundaries set by the case narratives. The trajectory of institutionalisation for each constellation was then plotted, representing its growing power in response to the landscape pressures and actor strategies.

Validation of the institutional dynamics was achieved in two stages. First, the trajectory for each innovation was presented to three water sector leaders in a validation workshop, which validated the role of the landscape pressures and timing of each constellation's growth. The synthesised trajectories were then reviewed by the same actors for further validation.

2.2.3. Phase 3: Cross-Case Comparison

Phase 3 involved a comparative analysis of the three trajectories to develop theoretical insights about the scope of actor strategies that were effective for supporting the growth of innovations with different characteristics. This was an iterative process of explanation building, drawing on pattern matching techniques (Yin, 2009) to draw conceptual generalisations on the dynamic links between the power level of an innovation, the nature of its relationship with existing regimes and the aim and type of actor strategies that led to its institutionalisation.

3. Results

The narratives for the landscape, regime and three innovations in Melbourne's water system during the case study period are presented here. The trajectories of institutionalisation for the three innovations are also presented.

3.1. Landscape

3.1.1. Narrative

New environmental values emerged in Australian society from the 1960s onwards. Environmentalism gained momentum as a social movement and people became more aware of the impact of human activities on ecological systems and the earth's limited capacity to support ongoing growth. For the water system in Melbourne, these new values manifested in communities caring more about waterway health and urban amenity. Point sources of pollution from wastewater treatment plants and industrial factories were regulated from the early 1970s through discharge licensing. A focus on diffuse pollution in stormwater emerged in the 1990s and innovative 'green' technologies to treat, retain and convey stormwater were developed as an alternative to concrete-lined drains. Environmentalism continued as a landscape driver throughout the case study period, placing ongoing pressure on Melbourne's water system to minimise waterway pollution and manage water resources sustainably.

The 1980s and 1990s saw a new emphasis on neoliberal economic policies in Australia, stimulating market deregulation, privatisation of government agencies and trade liberalisation. As part of this landscape shift, public policy goals prioritised financial return on publicly owned assets, which changed the role of Government in strategic planning of Melbourne's water system. Where previously Governments rarely questioned engineering advice from the water utility about required investments, the push for maximised dividends meant the return on capital investment also needed consideration in major water planning decisions, leading to Government taking a central planning role. This period saw a focus on efficiency of public organisations and, in 1994, Melbourne's major water utility was split into four Government-owned corporate entities (Melbourne Water, as a wholesale water company, and three water retail companies). Neoliberalism continued as a driver throughout the case study period, with ongoing emphasis on economic rationalism and efficiency in all water investments.

Drought was the third landscape driver during the case study period, persisting for thirteen years (1997 to 2010) and labelled the 'Millennium Drought'. Water resource planners assumed the first few years of the Millennium Drought was part of Australia's natural long-term climate variability. However, by late 2002 the Victorian Government recognised that after six dry years and projections of population growth, the issue of water security needed action. Upon expert advice (WRSCMA, 2002), its response was to reduce demand through a widespread water saving campaign, designed to change consumer behaviour and increase the efficiency of water use by business and industry.

Reduced water availability due to climate change was foreshadowed during this period but its degree of impact was uncertain (DSE, 2004 & 2006; Howe et al., 2005). The Government began investigating options for boosting supply in the short, medium and long-term (including desalination and alternatives such as recycled water), through broad consultation across the sector to develop its Victorian water policy and accompanying Melbourne strategy (DSE, 2004 & 2006). These reports concluded that immediate large-scale augmentation was not required but would be appropriate in the medium term (2015-2020). Drought continued, becoming acute in 2006; reservoir levels dropped from 49% to 29% from June 2006 to June 2007. Melbourne Water modelling showed that if 2006 rainfall levels were repeated in coming years, Melbourne was at serious risk of running out of water. Severe drought conditions continued until late 2009, with record-breaking periods of low rainfall and reservoir inflows. Climate scientists were starting to report that these conditions were significantly outside historic statistical variability and were, in fact, due to a climatic shift (Tan and Rhodes, 2008).

Table 2. Landscape influences on Melbourne's water system

Influence duration	Description of landscape influences	Influence type*
Jan 1997 – Dec 2012	Environmentalism led to a shift in community values, as people cared more about ecological health and urban amenity	Disruptive
Jan 1997 – Dec 2012	Neoliberalism led to a shift in public policy goals, prioritising financial return on publicly owned assets	Disruptive
Jan 1997 – Dec 2001	Drought began but there were no active responses to its impacts in the water system	-
Jan 2002 – Jun 2006	Drought continued and prompted responses in the water system; drought was considered a consequence of natural variability	Disruptive
Jul 2006 – Dec 2009	Drought became severe and urgent responses were required; drought was considered a consequence of climate change	Shock
Jan 2010 – Dec 2012	Drought subsided	-

* Based on Suarez and Oliva (2005), in Geels and Schot (2007)

3.1.2. Trajectory

Three major landscape influences occurred during the case study period: environmentalism and neoliberalism as constant influences, and drought as a variable influence. Table 2 describes the impact of these drivers on the water system and characterises them according to their type of influence.

3.2. Regime

3.2.1. Narrative

Europeans arrived in Melbourne in 1835 and established a centralised water supply system based on reservoirs and dams in the late 1850s. The water supply network was expanded throughout the following century, with new dams periodically built in response to water shortages. The most recent addition was the construction of Melbourne's largest storage, Thomson Reservoir, and upon its completion in 1984, the new dam was thought to have 'drought-proofed' the city.

A sewage system was built in the early 1890s, involving the collection, treatment and disposal of wastewater through large networks of pipes and pumps. While parts of Melbourne still relied on onsite treatment with septic tanks during the twentieth century, the wastewater system gradually expanded, with a new major wastewater treatment plant built in the 1970s to cope with increasing demand.

Significant urban expansion occurred in Melbourne after World War II and vast areas of land became impervious. Flooding became a serious issue so a large-scale stormwater drainage network, based on channelized waterways and large pipes separate from the sewer system, was constructed from the 1950s, expanding as new land was made available for development in the following decades.

3.2.2. Trajectory

There are three powerful constellations of Melbourne's water system. The reservoirs and dams constellation serves the need for water supply by providing potable water from regional catchments through a large-scale centralised network of dams, treatment plants, pipelines and pumping stations. The wastewater treatment and disposal constellation serves the need for public sanitation and waterway health by disposing of sewage and industrial trade waste and reducing pollutant flows to receiving waterways through a large-scale centralised network of pipelines, pumping stations and treatment plants. The stormwater drainage constellation serves the need for flood protection by draining stormwater from impervious surfaces through a large-scale centralised network of inlet pits, pipelines and channelized waterways.

These constellations remained dominant during the case study period and are deeply institutionalised since they have been evolving since Melbourne's first water supply system was built; they collectively form Melbourne's water regime. The institutions that support their functioning are similar for all three constellations, as described below.

Cultural-cognitive institutions of the regime include technical and experiential knowledge of hydraulics, hydrology, dams and treatment processes, along with manuals, procedures, models and guidelines that codify this knowledge. Cultural beliefs are underpinned by the notion that variables in the water system can largely be controlled with engineering approaches.

The regime's normative institutions include technocratic communities of practice, comprising networks of water, wastewater and drainage engineers. Engineers are responsible for water services and are the main source of advice for water servicing decisions. Asset maintenance involves structural, mechanical and electrical infrastructure. The role of households and businesses is to pay taxes, service charges and usage charges in exchange for water services. Performance standards for hydraulic design, treatment process design and dam safety design are well-established.

Regulative institutions of the regime are based on policy-making by Government departments and centralised management of water infrastructure by Government-owned companies and local municipalities. Water retail companies and municipalities collect revenues for water servicing from end users. Legislation and regulations define obligations for financial management, water governance, safe drinking water, environmental discharges, pricing and service delivery and organisations formally annually report on their system performance.

3.3. Innovation: Desalination

3.3.1. Narrative

The water sector was aware of desalinated seawater as a potential resource for several decades before the case study period; however, the assumed high level of water supply security in the existing system based on reservoirs and dams meant it was not regarded as necessary. Between 2002 and 2006, water resource strategies identified desalination as a long-term water supply option but since there was no anticipated need for major short-term augmentations, it was not pursued in detail (WRSCMA, 2002; DSE, 2004 & 2006). However, as drought continued, the prospect of desalination took stronger hold and preliminary investigations were undertaken in late 2006.

By early 2007, the need for urgent water supply augmentation was apparent and Victorian Government and water sector leaders explored possibilities for supplying a sufficient volume of water in a short timeframe. The Government commissioned a feasibility study for seawater desalination, which informed discussions among political and water sector leaders about specific details of a possible desalination project (e.g. location, capacity, financing arrangements). In a context of urgency, these discussions were not held with the water sector or community more broadly.

In June 2007, the Victorian Government announced that a desalination plant that could supply roughly one third of Melbourne's annual water demand would be delivered (DSE, 2007). Later it was decided this would be as a Public-Private Partnership (PPP) under a 30-year contract. The desalination projects was, and continues to be, mired by controversy, reflected by community protests and strong media debate questioning the need for large infrastructure developments, their cost to taxpayers and the wisdom in selecting the desalination project over other alternatives, such as household raintanks and recycled wastewater. The need for urgent decision-making meant the message that desalination was a justified and necessary investment was not well prosecuted by the Victorian Government, with a lack of public explanation or community engagement. Supporters of the desalination plant perceived that the media did not offer objective coverage, which further hampered the Government's message. Within the water sector, some actors were disenchanted with the decision to build a desalination plant, as it had not been seriously canvassed or subjected to debate in the recent strategic and broadly consultative work (WRSCMA, 2002; DSE, 2004 & 2006).

Despite the controversy, the desalination project continued and, from July 2007 to July 2009, the Victorian Government developed technical designs, environmental studies and planning approvals, and managed a competitive process for private consortiums to bid to finance, design, construct, operate and maintain the desalination plant for 30 years. The successful private consortium began construction in October 2009 and, after suffering significant delays due to adverse weather conditions and industrial action, the project was almost complete at the end of the case study period and the water sector had generally accepted the role of desalination as part of water supply resilience.

3.3.2. Trajectory

The infrastructure and institutions of the desalination constellation is highly similar to the regime, since its basic functioning consists of the capacity to transfer large volumes of potable water through a centralised pipeline to an existing hydraulic supply network. As such, the majority of institutions for desalination already existed and simply needed to be imported from the regime constellations, as indicated in Table 3 by those marked with 'E'. New institutions were mostly non-competitive ('N' in Table 3), except for cultural beliefs and public expectations, which were considered competitive ('C' in Table 3) with existing regime institutions. The spread of institutional relationships in Table 3 leads to the assessment that, overall, the desalination constellation reinforces the existing regime

The individual actor strategies that led to the development of these institutions for desalination are detailed in Table A.1 of the supplementary data. Table 4 synthesises which of the cultural-cognitive, normative and regulative institutions these actor strategies worked on during different phases of the constellation's institutionalisation as it grew from being non-existent to a pre-niche, niche and niche-regime. The shading in Table 4 reflects whether the institutions developed for desalination were existing, non-competitive and competitive with the existing regime (as per Table 3). The diagonal shading indicates which of the institutions were fully developed by the end of the case study period in July 2012.

Table 4 shows that for desalination to be institutionalised, it took time for the landscape pressure of drought to drive a system response, with very little institutional work undertaken until January 2007. Once the influence of drought intensified into a specific shock, the niche phase was rapid, largely relying on cultural-cognitive work to import knowledge for addressing a single issue (water supply). The niche-regime phase involved normative and regulative work to add institutions such as new design standards, resources and governance arrangements to the old regime based on reservoirs and dams. By July 2012, only cultural beliefs and public expectations were not fully institutionalised, reflected by ongoing resentment about the desalination project, which indicates the constellation is on the verge of becoming a regime. Overall, the trajectory for desalination was rapid, as the innovation was easily adopted under sufficient landscape pressure due to its reinforcing relationship with the existing regime.

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Table 3. Desalination institutions and relationship with existing regime

	Institution	Characteristics	*
Cult.-cognitive	Cultural knowledge	Belief that water security can only be achieved with a rain-independent source	C
	Technical knowledge	Knowledge of hydraulics & treatment processes	E
		Knowledge of desalination systems	N
	Experiential knowledge	Experience with hydraulic engineering	E
		Experience with desalination plants	N
	Implementation tools	Models & guidelines for hydraulic design	E
		Manuals & procedures for water treatment plants	E
Normative	Public expectations	Citizens have a right to fresh drinking water but the cost of servicing will be significant	C
	Communities of practice	Water supply engineers	E
	Roles & responsibilities	Engineers responsible for water service planning	E
		Asset managers responsible for 'hard' infrastructure	E
		End users responsible for paying service charges	E
	Goals & commitments	Desalinated water in a water resource portfolio	N
	Standards	Standards for hydraulic water pressure	E
		Standards for drinking water quality	E
Regulative	Governance arrangements	Dams, storage reservoirs & transfer mains centrally managed by Melbourne Water	E
		Water reticulation network centrally managed by water retail companies	E
		Desalination plant financed & managed by private consortium under contract	N
	Resource mobilisation	Revenue collected by water retail companies from end users for water supply services	E
		Government payment for service charges & purchase of water from private consortium	N
	Regulatory mechanisms	Finance, governance, safety, price & performance obligations defined by legislation	E
		Performance of water companies monitored with annual reporting	E
		Performance requirements & costs defined by contract with private consortium	N

***** Relationship with existing regime(s): *Existing* institution: **E** New *non-competitive* institution: **N** New *competitive* institution: **C**

3.3. Innovation; Wastewater Recycling

3.3.1. Narrative

Wastewater recycling for agricultural irrigation started in inland Victoria and was initially driven by the need to reduce pollution from treatment plant discharges entering waterways. However, in Melbourne, less than 1% of the treated wastewater collected at the two major treatment plants (Western Treatment Plant, WTP, and Eastern Treatment Plant, ETP) was recycled at the start of the case study period. In November 2001 the Victorian Government set a target to recycle 20% of Melbourne's wastewater by 2010 to reduce environmental pollution. This target (achieved in 2008) drove significant investment in wastewater recycling and provided justification for expenditure on recycled water schemes that would not have otherwise been financially viable.

Environmental studies that highlighted the impact of nitrogen on waterways (Harris et al., 1996) led to planning for major upgrades of WTP and ETP for the primary purpose of achieving discharge licence requirements set by the environmental regulator; production of recycled wastewater was a secondary benefit. Melbourne Water subsequently upgraded WTP in 2004 to reduce nitrogen loads entering Port Phillip Bay, now treating wastewater to "Class A" quality that is suitable for non-potable urban uses and irrigation of food crops. The Werribee Irrigation District scheme was established in January 2005 to supply Class A recycled water to vegetable growers in the region, who had experienced water supply shortages from 2003 under the drought conditions. Similarly, plans to upgrade ETP to reduce pollutant loads and produce Class A recycled water were made from 2001, although the project did not proceed until late 2006. Meanwhile, Melbourne Water and a private company jointly developed the Eastern Irrigation Scheme (April 2005), including a Class A plant that recycles 3.5% of ETP treated wastewater, to respond to demand for secure supply of non-potable water during the drought and to make further progress in achieving the Government's 20% recycling target.

Schemes that deliver Class A recycled water to customers via a separate pipe (known as 'dual pipe' systems), emerged in Melbourne in the early 2000s. They were initially driven by individual consultants and land developers who saw economic advantage in dual pipe schemes enabling the early development of greenfields that were not yet due to be serviced with conventional sewerage infrastructure. Initial proposals for dual pipe schemes (2003-2005), presented significant challenges to water retail companies, which were not organisationally equipped to supply recycled water. However, water companies were incorporating environmental and sustainability principles as strategic business priorities and recognised the role of recycled water in achieving their sustainability goals. An intense period of learning and cooperation ensued, including study tours and international reviews.

Table 4. Influence of actor strategies on institutions of desalination constellation

Time period[#]	Institutions worked on by actor strategies: Cultural-Cognitive: Cultural knowledge	Cultural-Cognitive: Technical knowledge	Cultural-Cognitive: Experiential knowledge	Cultural-Cognitive: Implementation tools	Normative: Public expectations	Normative: Communities of practice	Normative: Roles and responsibilities	Normative: Goals and commitments	Normative: Standards	Regulative: Governance arrangements	Regulative: Resources mobilisation	Regulative: Regulatory mechanisms	Outcomes of actor strategies and institutional changes	Constellation power
(a) Jan 97													-	-
(b) Jul 02	C	N											High level reviews of long-term water resource needs & potential climate impacts; preliminary scoping of long-term desalination opportunities	Pre-niche
(c) Jan 07	C	N E						N					Realisation of a critical need for supply augmentation; technical investigations about desalination; debate amongst political & water sector leaders about augmentation options	Niche
(d) Jul 07		N E		E	C	E		N	E	N	N	N	Decision to proceed with fast-tracked desalination project; development of technical designs & environmental studies; planning approvals; contract award to private consortium; strong community protests	Niche-regime
(e) Oct 09			N E			E	E			E	E	E	Construction & commissioning of desalination project; project completion; strong community protests	Niche-regime

Time periods referred to in Figure 2 — Actor work on *existing* institution(s): E — Actor work on new *non-competitive* institution(s): N — Actor work on new *competitive* institution(s): C — Institutions that were fully developed by July 2012: (hatched)

Multi-stakeholder steering committees and working groups were established to develop new knowledge, which informed risk management guidelines and design standards published by industry peak bodies and health and environmental regulators (2004-2006).

In October 2006, recycled water was delivered to its first residential customers via a third pipe as part of the Eastern Irrigation Scheme. Potential greenfield sites for future dual pipe schemes were identified and by 2008 each water retail company had mandated the supply of recycled water for growth areas across Melbourne, totalling approximately 165,000 customers. These schemes are now being rolled out as land development occurs and more Class A recycled water becomes available through treatment plant upgrades. From 2006, the water retail companies undertook education campaigns through media and school curriculums to raise the community's awareness about the role of recycled water in Melbourne's drought response. Customer surveys conducted by the water retail companies show the public is highly supportive of recycled water and have generally positive feedback, although there are concerns about occasional colour and odour. Pricing of recycled water has emerged as an issue, since the cost of its delivery is equivalent to potable water but the product is perceived as lower quality.

Industrial and commercial water customers also adopted wastewater recycling. A Victorian Government program was established in 2004 to encourage top industry water users to reduce consumption, giving many businesses incentive to invest in onsite recycling. Environmental rating schemes also led to innovative wastewater recycling projects in commercial buildings. Other initiatives included a Government target of substituting 10 gigalitres per year potable water with alternative sources and amendment of the state planning framework to require integration of alternative water resources in new developments (both in October 2006). The Australian Water Recycling Centre of Excellence was established in early 2010 to develop industry and research partnerships for progressing water recycling. The National Recycled Water Regulators Forum was also established in 2010 to support national consistency in regulation.

3.3.2. Trajectory

The institutions of the wastewater recycling constellation have some similarities with the regime but also core differences (Table 5). Its regulative institutions are either existing (e.g. revenue collection) or non-competitive (e.g. governance arrangements for of recycled water network), and while there are some new competitive cultural-cognitive and normative institutions (associated with supplying water that is unsuitable for drinking), they also comprise many existing and non-competitive ones. This combination of symbiotic and competitive institutions for wastewater recycling (Table 5) suggests that overall the wastewater recycling constellation has a mixed relationship with the existing regime.

Table 5. Wastewater recycling institutions and relationship with existing regime

	Institution	Characteristics	*
Cult.-cognitive	Cultural knowledge	Belief that wastewater should be treated & reused as a fit-for-purpose supply	C
	Technical knowledge	Knowledge of hydraulics & treatment processes	E
		Knowledge of risk management for use of wastewater recycling & dual pipe systems	C
	Experiential knowledge	Experience with hydraulic engineering	E
		Experience with recycled water systems	C
	Implementation tools	Models & guidelines for hydraulic design	E
		Manuals, procedures & guidelines for recycled water treatment systems	N
Normative	Public expectations	Drinking quality water should not be used for purposes that could use lower quality	C
	Communities of practice	Water supply & wastewater engineers	E
	Roles & responsibilities	Engineers responsible for water service planning	E
		Asset managers responsible for 'hard' infrastructure	E
		End users responsible for paying service charges	E
	Goals & commitments	Recycled water in a water resource portfolio	N
	Standards	Standards for hydraulic water pressure	E
		Standards for recycled water quality & use	C
Regulative	Governance arrangements	Major wastewater treatment plants centrally managed by Melbourne Water	E
		Dual pipe reticulation networks centrally managed by water retail companies	N
		Recycled water plants financed & managed by private companies under contracts	N
	Resource mobilisation	Revenue collected by water retail companies from end users for water supply services	E
		Water retail companies payment to private companies for supply of recycled water	N
	Regulatory mechanisms	Finance, governance, safety, price & performance obligations defined by legislation	E
		Performance of water companies monitored with annual reporting	E
		Performance requirements & costs defined by contracts with private companies	N

***** Relationship with existing regime: *Existing* institution: **E** New *non-competitive* institution: **N** New *competitive* institution: **C**

Table 6. Influence of actor strategies on institutions of wastewater recycling constellation

Time period[#]	Institutions worked on by actor strategies: Cultural-Cognitive: Cultural knowledge	Cultural-Cognitive: Technical knowledge	Cultural-Cognitive: Experiential knowledge	Cultural-Cognitive: Implementation tools	Normative: Public expectations	Normative: Communities of practice	Normative: Roles and responsibilities	Normative: Goals and commitments	Normative: Standards	Regulative: Governance arrangements	Regulative: Resources mobilisation	Regulative: Regulatory mechanisms	Outcomes of actor strategies and institutional changes	Constellation power
(f) Jan 97												C	Target set for reducing pollution load from treated wastewater	-
(g) Jan 01	C				C			N				C	Emergence of the need to consider recycled wastewater to achieve pollution reduction targets; preliminary scoping of recycled wastewater opportunities	Pre-niche
(h) Jan 03	C	C E	C	C		E	N	N	C N	N	N		Knowledge building & sharing about recycled wastewater use & dual pipe schemes; planning of trial projects for recycled wastewater; development of guidelines & standards for recycled wastewater systems	Niche
(i) Jan 06	C	C E	C E	C E	C	E	E	N	E	N E	N E	C E	Implementation of trial recycled wastewater projects; planning of up-scaled future dual pipe schemes	Niche-regime
(j) Jan 09	C	C N	C N	C N	C	E		N			N E	N	Progressive implementation of up-scaled future projects; broadening industry dialogue about the integrated role of recycled wastewater, its potential as a potable water supply & its economics	Niche-regime
		hatched				hatched	hatched			hatched				

Time periods referred to in Figure 2 — Actor work on *existing* institution(s): **E** — Actor work on new *non-competitive* institution(s): **N** — Actor work on new *competitive* institution(s): **C** — Institutions that were fully developed by July 2012: hatched

The individual actor strategies that led to the development of these institutions for wastewater recycling are detailed in Table A.2 of the supplementary data. Table 6 synthesises which institutions were worked on by actor strategies during different phases of the constellation's institutionalisation as it grew from being non-existent to a pre-niche, niche and niche-regime.

Table 6 shows that the institutionalisation of wastewater recycling began under the landscape pressure of environmentalism in a relatively short pre-development phase. While initially driven by regulative targets, strategies in the niche phase focused on building new cognitive and normative institutions such as knowledge to inform delivery tools and standards. Ongoing strategic effort was applied to reshape cultural beliefs and public expectations around the use of recycled wastewater and once a certain level of institutionalisation had occurred, goals and commitment were progressively made by different organisations. Many regulative institutions already existed in current regimes. The niche-regime phase featured gradual change in technology and its associated practices as the regime reconfigured. By July 2012, only some institutions were fully developed, indicating that it will be some time before wastewater recycling is considered a regime constellation. Overall, the trajectory for wastewater recycling was a relatively moderate pace, with both reinforcing and disruptive forces influencing its uptake within the existing regime.

3.4. Innovation: Stormwater Harvesting

3.4.1. Narrative

Stormwater harvesting emerged from innovations in stormwater quality treatment, which was focused on the development and diffusion of new technologies (e.g. gross pollutant traps, constructed wetlands, grassed swales, biofilters) for treating stormwater to meet nitrogen load reduction targets recommended by an environmental study of Port Phillip Bay (Harris et al., 2006). The associated community of practice, comprising scientists, engineers, ecologists, urban designers and landscape architects, identified the potential for this same infrastructure to be utilised for stormwater harvesting to limit the detrimental impacts on receiving waterways of the high runoff volume generated from rainfall in urban areas (late 1990s). The drought further highlighted its potential as a water resource and, from 2010, the potential for stormwater harvesting to increase urban amenity through green infrastructure and water retention was also becoming recognised.

The Victorian Government's receptivity to stormwater harvesting was reflected by two initiatives: (1) a target to substitute 10 gigalitre per year of water from reservoirs with alternative sources, and (2) amendments of the state planning framework to require integration of alternative water resources in new developments in October 2006. However, industry action did not take off until two major research programs (the Facility for Advancing Biofiltration and the National Urban Water Governance Program) were established in 2005, focusing on biofiltration technologies and socio-technical governance for stormwater quality treatment and harvesting. Scientific developments in these programs proved the concept that stormwater could be treated with green infrastructure to a sufficient level to enable its use as a water resource. In early 2010, these existing activities supported the formation of an interdisciplinary research program, "Cities as Water Supply Catchments", which focused on supporting urban liveability through harnessing the potential of stormwater as a water resource and ecosystem service provider (Wong et al., 2011). Stormwater practitioners also saw these research programs as a hub for innovation, learning and networking.

Drawing on the knowledge and networks supported through these research activities, the retail water companies began investigating the possibility of incorporating stormwater as a resource into future plans as a means to achieve better community outcomes. Formal measures to support these initiatives were introduced in late 2009, through the establishment of a large Federal Government grant scheme to subsidise stormwater harvesting projects. This funding enabled the water retail companies to implement their planned trial projects (from 2010 onwards). In July 2009, national risk management guidelines for stormwater harvesting and reuse were published, providing further guidance and support for project implementation. A collaborative program involving government, water business, municipality and community actors was established in 2011 to explore how urban water, particularly stormwater, can be managed to support public green space and provide health and wellbeing benefits in the driest and hottest region of Melbourne.

Since 2010, water sector dialogue has centred on the role of harvested stormwater compared with other alternative sources (Living Victoria MAC, 2012). Other issues include the potential for potable use of harvested stormwater and development of a regulatory framework for managing health risks. There are also informal discussions about regulating minimum performance levels for municipalities of stormwater management to improve the health of downstream waterways. To progress these and other discussions related to liveability, urban water and planning, in May 2012 the Government established an Office of Living Victoria, whose agenda is to drive generational reform in how Melbourne's water is managed.

3.4.2. Trajectory

Stormwater harvesting has mostly new institutions that are competitive with the existing regime, particularly in the cultural-cognitive and normative categories (e.g. technical knowledge about stormwater quality, disciplinary focus of individuals involved) (Table 7). Its regulative institutions share some overlap with those already existing (e.g. governance of stormwater drainage services, performance monitoring of key agencies) but there are also competitive regulative institutions. Overall, the stormwater harvesting constellation described in Table 7 is assessed as having a disruptive relationship with the existing regimes.

The individual actor strategies that led to the development of these institutions for stormwater harvesting are detailed in Table A.3 of the supplementary data. Table 8 synthesises which institutions were worked on by actor strategies during different phases of the constellation's institutionalisation as it grew from being non-existent to a pre-niche and niche.

Table 8 shows that stormwater harvesting had a long period of pre-development directly associated with stormwater quality treatment. The stormwater drainage regime could not respond to the landscape pressure of environmentalism, so new technologies were developed to reduce stormwater pollution. The potential for this same technology to be utilised for stormwater harvesting was identified in the pre-development phase but the constellation remained a niche throughout the case study as it was not sufficiently developed to take advantage of the window of opportunity presented by the drought. Strategies to institutionalise stormwater harvesting during the niche phase focused on developing new cultural-cognitive institutions, with normative work around new roles, responsibilities, goals and commitments starting to occur more recently. By July 2012, the only institutionalised structure was public expectations, which emerged as the community looked for preferred alternatives to the unwelcome desalination plant. Overall, the trajectory for stormwater harvesting was slow, inhibited by disruptive forces from the existing regime.

Table 7. Stormwater harvesting institutions and relationship with existing regime

	Institution	Characteristics	*
Cult.-cognitive	Cultural knowledge	Belief that stormwater should be harvested & reused as a fit-for-purpose supply	C
	Technical knowledge	Knowledge of stormwater pollution & treatment	C
		Knowledge of risk management for stormwater harvesting & dual pipe systems	C
	Experiential knowledge	Experience with stormwater treatment systems	C
		Experience with stormwater harvesting systems	C
	Implementation tools	Models & guidelines for hydraulic, hydrologic design	E
		Models, procedures & guidelines for stormwater treatment systems	N
Normative	Public expectations	Drinking quality water should not be used for purposes that could use lower quality	C
	Communities of practice	Stormwater engineers, ecologists, landscape architects & urban designers	C
	Roles & responsibilities	Engineers, landscape architects & urban designers responsible for water service planning	C
		Asset managers & end users responsible for co-managing 'green' infrastructure	C
		End users responsible for paying service charges	E
	Goals & commitments	Harvested stormwater in a water resource portfolio	N
	Standards	Standards for hydraulic water pressure	E
		Standards for stormwater treatment & use	C
Regulative	Governance arrangements	Major stormwater drainage infrastructure centrally managed by Melbourne Water	E
		Dual pipe reticulation networks centrally managed by water retail companies	N
		Financed & managed by water businesses, municipalities, companies & households	C
	Resource mobilisation	Revenue collected by Melbourne Water & municipalities for drainage services	E
		Revenue collected by stormwater supplier from end users for water supply services	C
	Regulatory mechanisms	Finance, governance, safety, price & performance obligations defined by legislation	E
		Performance of water companies & municipalities monitored with annual reporting	E
		Performance requirements & costs defined by contracts with private companies	N

* Relationship with existing regime: *Existing* institution: E New *non-competitive* institution: N New *competitive* institution: C

Table 8. Influence of actor strategies on institutions of stormwater harvesting constellation

Time period[#]	Institutions worked on by actor strategies: Cultural-Cognitive: Cultural knowledge	Technical knowledge	Experiential knowledge	Implementation tools	Normative: Public expectations	Communities of practice	Roles and responsibilities	Goals and commitments	Standards	Regulative: Governance arrangements	Resources mobilisation	Regulatory mechanisms	Outcomes of actor strategies and institutional changes	Constellation power
(k) Jan 97	C					C						C	Target set for reducing pollution load from stormwater runoff. Emergence of the potential to harvest stormwater to reduce stormwater flow impacts on downstream waterways	Pre-niche
(l) Jul 02	C					C		N			N	C	Emergence of the potential to harvest stormwater that has been treated for pollution reduction as an alternative resource	Pre-niche
(m) Jan 07	C	C				C					N		Research & development of stormwater treatment & harvesting technologies; industry knowledge building & sharing	Niche
(n) Jan 09	C	C	C	C		C E		N			N	C	Grant funding provision; planning & implementing trial projects; broadening industry dialogue about the integrated role of harvested stormwater, its economics & its potential liveability benefits & as a potable supply	Niche

Time periods referred to in Figure 2 | Actor work on *existing* institution(s): E | Actor work on new *non-competitive* institution(s): N | Actor work on new *competitive* institution(s): C | Institutions that were fully developed by July 2012: (hatched)

4. Discussion

4.1. Cross-Case Comparison

Table 9 compares the existing regime relationships of each innovation. It highlights that, in general, desalination is reinforcing (with mostly existing institutions), wastewater recycling is mixed (with a combination of existing, new competitive and new non-competitive institutions) and stormwater harvesting is disruptive (with mostly new competitive institutions).

The corresponding trajectories for the institutionalisation of the three innovations, in response to landscape pressures and actor strategies, are plotted in Figure 2. The trajectories depict the key phases for each constellation's development, indicated by (a)…(n), and highlights the duration spent at each power level (pre-niche, niche, niche-regime, regime). The landscape pressures that were present during the case study period are also depicted in Figure 2. However, the impact of these pressures on each constellation was variable, so Figure 2 indicates which of the landscape influences acted on each constellation for key phases.

The regime relationships in Table 9, trajectories in Figure 2 and the institutional dynamics synthesised in Tables 4, 6 and 8, provide a base for the comparative analysis of the growth in power for the three innovative constellations in Melbourne's water system. For each power level, Table 10 identifies the: (1) speed of growth (the relative number of years the constellation spent at each power level); (2) limiting conditions (institutional impediments that could limit the constellation's increase in power); and (3) strategies employed to support the growth (the type of strategic work employed by actors to overcome the limiting conditions).

4.2. Insights for Theory

The cross-case comparison provides insights for extending theory on transitions, specifically regarding the scope of actor strategies that most effectively works to institutionalise innovations during transition processes. This section identifies the aim and type of strategies successfully employed during the pre-niche, niche and niche-regime phases of the case innovations as a basis for further theory development.

Table 9. Comparison of innovations with existing regimes in Melbourne's water system

	Institution	**Desalination**	**Wastewater Recycling**	**Stormwater Harvesting**
	Overall relationship with regime:	Reinforcing	Mixed	Disrupting
Cult.-cognitive	Cultural knowledge	C	C	C
	Technical knowledge	E	E	C
		N	C	C
	Experiential knowledge	E	E	C
		N	C	C
	Implementation tools	E	E	E
		E	N	N
Normative	Public expectations	C	C	C
	Communities of practice	E	E	C
	Roles & responsibilities	E	E	C
		E	E	C
		E	E	E
	Goals & commitments	N	N	N
	Standards	E	E	E
		E	C	C
Regulative	Governance arrangements	E	E	E
		E	N	N
		N	N	C
	Resource mobilisation	E	E	E
		N	N	C
	Regulatory mechanisms	E	E	E
		E	E	E
		N	N	N

Existing institution: E; New *non-competitive* institution: N; New *competitive* institution: C

The constellations each emerged as a pre-niche due to disruptive landscape pressure. However, the presence of landscape pressure alone was not sufficient for continued constellation growth: actors needed awareness of the significant impacts of the landscape pressure on the system functioning and the potential for the constellation to mitigate these impacts. While the speeds of constellations through the pre-niche phase varied significantly, the strategies employed all initially focused on cognitive work to understand the potential benefits of the innovation in relation to the water system's functioning that was being adversely impacted on by the landscape pressure.

The speed of the niche phase of a constellation appears related to how closely its institutions align with equivalents in existing regimes. For example, the desalination institutions are symbiotic with the regime and lack of knowledge and commitment were the only limiting conditions. Cognitive work focused on importing external knowledge rather than developing new knowledge, which led to a fast niche phase. A very small amount of normative work for desalination was focused on the key decision-makers. The regulative institutions for wastewater recycling are well-aligned with existing regimes. However, cognitive and normative work was required to address a lack of knowledge, tools and standards in the constellation for its continued growth, which led to a moderate niche phase. The institutions of stormwater harvesting are largely competitive with existing regimes. Cognitive strategies were employed to develop new knowledge and tools during a slow niche phase. Normative and regulative work was also required to develop new communities of practice and delivery standards, build commitment and mobilise resources, since very few existing institutions could be imported from the regimes.

The speed of the niche-regime phase appears related to the transactional complexity of a constellation in terms of the interaction of diverse institutions, infrastructures and actors to meet societal objectives. Desalination is a large-scale, mono-functional infrastructure, characterised by centralised ownership and management. Once it became a niche-regime upon securing top-down commitment, resources could be mobilised and there were few limitations to the constellation's continued growth to a regime. The lack of public acceptance could be ignored by actors in the context of the urgent need to augment water supplies, since desalination implementation did not rely on the community's engagement. The speed of the phase was only limited by the moderate pace at which the large-scale infrastructure could be built.

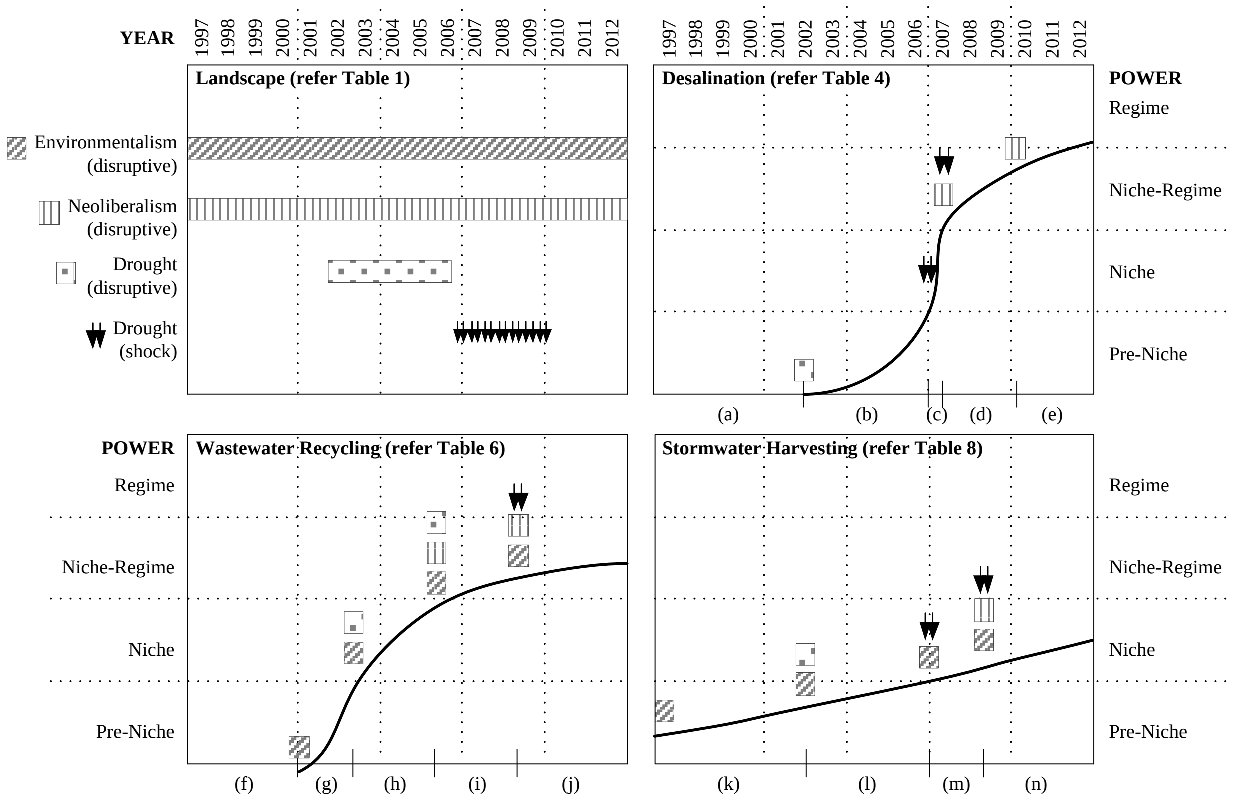

Figure 2. Institutional trajectories of innovative constellations in Melbourne's water system. Refer to Tables 4, 6 and 8 for details of the key phases indicated by (a)…(n)

Table 10. Comparative analysis of the trajectories of innovative constellations of Melbourne's water system

		Desalination	**Wastewater Recycling**	**Stormwater Harvesting**
Relationship with regime		Reinforcing	Mixed	Disrupting
Pre-niche	Speed	Moderate (4.5 years)	Fast (2 years)	Slow (26 years)
	Limiting conditions	Lack of landscape pressure impacts	Lack of landscape pressure impacts	Lack of landscape pressure impacts
	Strategies employed	Cognitive work to understand impacts of landscape pressure and potential benefits of the innovation	Cognitive work to identify potential benefits of the innovation	Cognitive work to identify potential benefits of the innovation. Normative work to develop communities of practice
Niche	Speed	Fast (0.5 years)	Fast (3 years)	Slow (6+ years)
	Limiting conditions	Lack of local knowledge & commitment	Lack of local knowledge, tools & standards	Lack of knowledge, tools, standards, commitment & resources
	Strategies employed	Cognitive work to import external knowledge.	Cognitive work to import external knowledge & develop new delivery tools. Normative work to import communities of practice, develop new delivery standards & build public expectations	Cognitive work to develop new knowledge and tools. Normative work to build communities of practice and commitment and develop new delivery standards. Regulative work to mobilise resources
Niche-regime	Speed	Moderate (5.5 years)	Slow (7+ years)	-
	Limiting conditions	Lack of public acceptance	Lack of local knowledge, commitment, resources & regulations	-
	Strategies employed	Lack of public acceptance ignored. Cognitive work to develop technical designs. Normative work to build public acceptance and import existing water supply roles, responsibilities and standards. Regulative work to mobilise resources	Cognitive work to learn from experience. Normative work to build commitment and import existing water supply roles and responsibilities. Regulative work to mobilise resources and establish governance arrangements	-

In contrast, wastewater recycling is partially decentralised, requiring an integration of delivery scales (small, medium and large-scale technologies). It depends on the involvement of a broader range of actors and a more sophisticated regulatory framework to ensure public health is protected in a fit-for-purpose approach to water supply. Additionally, more complex assessment frameworks are needed for the multiple benefits of recycled wastewater (protecting waterway health and supplying water) to be economically valued so that resources can be mobilised for mainstreaming its implementation. These transactional complexities, which are likely to be even more apparent for a future phase of the stormwater harvesting constellation, led to a slow niche-regime phase. Ongoing landscape pressure was required to provide continued motivation for actors to employ strategies to slowly develop the complex institutions required for the constellation's growth in power.

These theoretical insights are synthesised in Figure 3, highlighting the conditions that limit the innovation's continued growth and the strategy aims and types that are likely to be most effective in overcoming these limitations and supporting further innovation growth. Cultural-cognitive strategies are likely to be most effective for all types of innovations during the pre-niche phase and it is unlikely that normative or regulative institutions will be developed if there is not an existing base of cultural-cognitive institutions. The strategies required to support growth beyond the pre-niche stage (i.e. niche or niche-regime) depends on the relationship of the innovation with existing regimes. Innovations that reinforce existing regimes require a narrow scope of actor strategies, building up normative and then regulative institutions. In contrast, innovations that compete with existing regimes require a broader scope of actor strategies once initial cultural-cognitive institutions have been developed, covering the full spectrum of cultural-cognitive, normative and regulative work at all power levels.

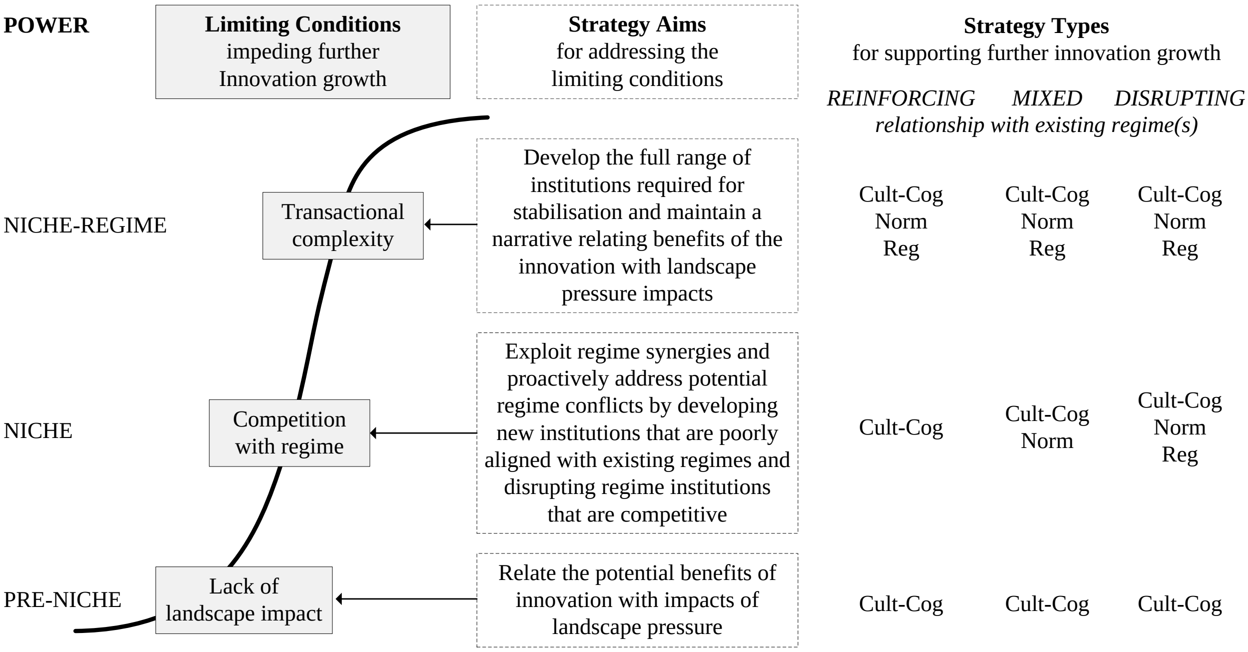

Figure 3. Scope of actor strategies for institutional trajectories of successful innovation growth. Strategy types are abbreviations of 'cultural-cognitive', 'normative' and 'regulative'.

5. Conclusions

This paper represents one of the first empirical explorations of how actor strategies influence the micro-dynamics of institutionalisation of innovations in a contemporary transition process. Through analysis of three cases of innovation in the context of transitional change in Melbourne's water system, the scope of actor strategies that worked to develop cultural-cognitive, normative and regulative institutions was traced. Each innovation had a different relationship with existing regimes (reinforcing, mixed or disruptive), which influenced their speeds of institutionalisation and the type of actor strategies that supported their growth. As such, it has shown that the most effective type of actor strategy will highly depend on an innovation's level of power and its institutional alignment with existing regimes, and therefore will change over time. Diagnostic approaches for strategy development are therefore critical for ensuring the current system conditions are understood in relation to the power levels and existing regime relationships of upcoming innovations.

Comparative analysis of the institutional dynamics for the three different innovation cases revealed patterns that provided theoretical insights into actor strategies as they relate to the emergence, uptake and stabilisation of innovations. These insights form a basis for extending theory on system innovation and agency in a sustainability transition. Further, they offer important implications for actors wanting to deliberately steer a transition in a desired direction by informing the selection and design of strategic initiatives to support the institutionalisation of an innovation. If potential limitations to the future growth of a constellation can be anticipated, then it is conceivable that strategies can be proactively employed to develop the necessary institutions ahead of time so that the constellation is prepared to take advantage of windows of opportunity when they are opened through significant landscape pressure. However, the theorised scope of actor strategies presented in this paper needs extensive testing and refinement with further empirical studies that cover a wide range of trajectories in different infrastructure systems.

The analytic method in this paper can potentially be used as a diagnostic tool for revealing important nuances in the actor strategies and institutional dynamics that influence transition processes. It could also provide the basis of a tool for guiding actors to steer a trajectory in a desired direction. For a sustainability transition to be successful, institutions within all three of the cultural-cognitive, normative and regulative categories need to be developed. By analysing the institutions in existing regimes and new innovations to identify synergies and potential conflicts, strategies to institutionalise new competitive and non-competitive institutions in an upcoming innovative constellation can be purposefully selected to maximise their effectiveness.

To further develop the theoretical concepts explored in this paper, future research is needed to focus on understanding how the institutionalisation of individual innovations relates to an overall societal transition. This would involve exploration of the interactions between constellations and how they compete with or empower each other as part of a system's overall dynamics and should address the actor strategies employed to maintain or disrupt existing institutions to support transition processes. Further insight would be gained by investigating how actor networks, power relationships, political agendas and levels of responsibilities influence the type of actor strategies (cultural-cognitive, normative or regulative) that are most effective in supporting innovation growth.

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Supplementary Data

Tables A.1, A.2 and A.3 set out the specific actor strategies that were employed to develop different institutions for desalination, wastewater recycling and stormwater harvesting in Melbourne's water system during the case study. These form the base of Tables 4, 6, and 8 in the main article.

'I' refers to the institutions type listed in Table 1 of the main article:

Cultural knowledge
Technical knowledge
Experiential knowledge
Implementation tools
Public expectations
Communities of practice
Roles & responsibilities
Goals & commitment
Standards
Governance arrangements
Resource mobilisation
Regulatory mechanisms

'E/N/C' refers to the relationship of institutions created with existing regimes:

E: Importation of EXISTING institutions
N: Development of new institutions that have a NON-COMPETITIVE relationship
C: Development of new institutions that have a COMPETITIVE relationship

Table A.1 Actor strategies to institutionalise the desalination constellation

I	E/N/C	Actor strategies to institutionalise DESALINATION (DSA)	Period
1	C	Strategic reports identified desalination as a long-term option for water supply but concluded no large-scale augmentations would be required in the short or medium term and desalination not pursued in any detail	Oct 2002-Nov 2006
	C	Government undertook preliminary investigations into the feasibility, costs and benefits of desalination	Late 2005
	C	Scientific research identified that the low rainfall in 2006 was statistically significant as a climate shift and not within historic variability	Late 2006-early 2007
	C	Sector-wide dialogue about potential climate change impacts on water resources & implications for reliance on rain-dependent sources	mid 2006-mid 2007
	C	Government & water sector leaders initiated internal dialogue about the need for urgent augmentation of water supplies	Jan-Jun 2007
2	N	Government undertook preliminary investigations into the feasibility, costs and benefits of desalination	Late 2005
	E, N	Government undertook feasibility study for a desalination plant as urgent augmentation option	Early 2007
	E, N	Development of technical designs, environmental studies & planning approval applications for proposed desalination project by Government consultants	Jul 2007-Jun 2008
	E, N	Government managed competitive process for private consortiums to bid to finance, design, construct, operate and maintain the desalination plant for 30 years	Jun 2008-Jul 2009
3	E, N	Private consortium undertook construction and commissioning of desalination project	Oct 2009-Dec 2012
4	E	Development of technical designs, environmental studies & planning approval applications for proposed desalination project by Government consultants	Jul 2007-Jun 2008
5	C	Government publicity to raise awareness of the need for desalination as a water supply augmentation necessity	2007-2008
6	E	Government managed competitive process for private consortiums to bid to finance, design, construct, operate and maintain the desalination plant for 30 years	Jun 2008-Jul 2009
	E	Private consortium undertook construction and commissioning of desalination project	Oct 2009-Dec 2012
7	E	Private consortium announced desalination project was fully operational and would be ready for final completion early 2013	Dec 2012
8	N	Government announced a feasibility study for desalination during election campaign; opposition announced they would build a 50GL desalination plant	Nov 2006
	N	Debate amongst political leaders, with input from water sector leaders, about the specifics of proposed augmentation projects	May 2007-Jun 2007
	N	Government announced that desalination plant would be constructed to augment water supplies	Jun 2007
9	E	Development of technical designs, environmental studies & planning approval applications for proposed desalination project by Government consultants	Jul 2007-Jun 2008
10	N	Government managed competitive process for private consortiums to bid to finance, design, construct, operate and maintain the desalination plant for 30 years	Jun 2008-Jul 2009
	N	Government awarded contract to private consortium to establish a 30-year public-private partnership for the desalination project	Jul 2009
	E	Private consortium announced desalination project was fully operational and would be ready for final completion early 2013	Dec 2012
11	N	Government awarded contract to private consortium to establish a 30-year public-private partnership for the desalination project	Jul 2009
	E	Private consortium announced desalination project was fully operational and would be ready for final completion early 2013	Dec 2012
12	N	Government awarded contract to private consortium to establish a 30-year public-private partnership for the desalination project	Jul 2009
	E	Private consortium announced desalination project was fully operational and would be ready for final completion early 2013	Dec 2012

Table A.2 Actor strategies to institutionalise the wastewater recycling constellation.

I	E/N/C	Actor strategies to institutionalise WASTEWATER RECYCLING (WWR)	Period
1	C	Advocacy by consultant to develop recycled water dual pipe system in new development because of economic advantages of supplying recycled water	2001
	C	Investigation of sustainability water cycle principles by Melbourne Water, including recycling to reduce discharge impacts & make better use of wastewater resources	2001
	C	Dialogue amongst independent expert panel, convened by water retail company, about sustainable servicing solutions for new development, including recycled water	2002
	C	Advocacy to water retail corporations by land developers wanting to incorporate dual pipe systems into new developments	2003-2005
	C	Position statements released by various organisations about potable use of recycled water	2006-2007
	C	Robust dialogue in water sector about recycling to potable water standard, the value of recycled water in comparison to other sources and the associated economics	2010-2012
	C	Living Victoria Ministerial Advisory Council appointed to provide independent advice to Government on reforms needed in urban water to deliver liveability outcomes; road map & implementation plan developed with broad stakeholder input	Jan 2011-Feb 2012
2	C	Educational tours by water retail companies and their key stakeholders to existing dual pipe schemes in operation elsewhere in Australia	2003-2005
	C	Multi-stakeholder steering committee and working groups established to develop knowledge to inform new risk management rules about dual pipe schemes	Sep 2003-Sep 2005
	E, C	Planning for trial wastewater recycling dual pipe projects by land developers and water retail companies	2005
	E, C	Feasibility study for large-scale recycling project in eastern region undertaken	Sep 2004
	E, C	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
	N, C	Water retail company worked with stakeholders to develop integrated water management strategy for Melbourne's south-east, which in part considered wastewater recycling	2009-2011
	N, C	Australian Water Recycling Centre of Excellence established with significant federal funding to enhance the management & use of water recycling through industry & research partnerships	Mar 2010
3	C	Industry water users program established to support demand reduction through measures such as investment in onsite recycled water schemes	2004-2009
	C	Establishment of Werribee Irrigation District scheme (recycled water for vegetable growers), with some concerns about public perception and high salinity	Jan 2005
	E, C	Operation of trial dual pipe systems in new developments to deliver recycled water	2006-2008
	N, C	Australian Water Recycling Centre of Excellence established with significant federal funding to enhance the management & use of water recycling through industry & research partnerships	Mar 2010
4	C	Multi-stakeholder steering committee and working groups established to develop and publish guidelines for health and environmental risk management of dual pipe systems	Sep 2003-Sep 2005
	C	National recycling and validation guidelines for risk management developed and published (multiple phases focused on different sources and uses of water)	2006-2012
	E, C	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
	N	National Recycled Water Regulators' forum established to ensure national consistency in the implementation of national recycling guidelines	2010-2012
5	C	Community consultation about the potential of recycled wastewater as a resource	2001
	C	Melbourne Water & water retail companies implemented education programs in target communities & schools to build receptivity & knowledge of recycled water	2006-2012
	C	Public dialogue and media campaigns about recycled wastewater projects during drought	2006-2009
6	E	Educational tours by water retail companies and their key stakeholders to existing dual pipe schemes in operation elsewhere in Australia	2003-2005
	E	Multi-stakeholder steering committee and working groups established to develop knowledge to inform new risk management rules about dual pipe schemes	Sep 2003-Sep 2005
	E	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
	E	Water retail company worked with stakeholders to develop integrated water management strategy for Melbourne's south-east, which in part considered wastewater recycling	2009-2011
	E	Australian Water Recycling Centre of Excellence established with significant federal funding to enhance the management & use of water recycling through industry & research partnerships	Mar 2010
	E	National Recycled Water Regulators' forum established to ensure national consistency in the implementation of national recycling guidelines	2010-2012

I	E/N/C	Actor strategies to institutionalise WASTEWATER RECYCLING (WWR)	Period
	E	Living Victoria Ministerial Advisory Council appointed to provide independent advice to Government on reforms needed in urban water to deliver liveability outcomes; road map & implementation plan developed with broad stakeholder input	Jan 2011-Feb 2012
7	N	Private company established to finance and manage recycled water treatment plants for supplying recycled water in south-east Melbourne	2005
	E	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
8	N	Melbourne Water submitted works approval application to upgrade Eastern Treatment Plant	2001
	N	Water businesses incorporating environmental and sustainability principles as strategic priorities for their business, stimulating cultural change	2003-2006
	N	Victorian Government & Melbourne Water announced Eastern Treatment Plant upgrade	Oct 2006
	N	Water retail company worked with stakeholders to develop integrated water management strategy for Melbourne's south-east, which in part considered wastewater recycling	2009-2011
	N	Living Victoria Ministerial Advisory Council appointed to provide independent advice to Government on reforms needed in urban water to deliver liveability outcomes; road map & implementation plan developed with broad stakeholder input	Jan 2011-Feb 2012
	N	Office of Living Victoria established to drive 'generational reform' in how urban water is managed, including recycled wastewater	May 2012
9	C	Environment Protection Authority developed standards for the use of reclaimed water	Nov 2003
	N	Green Building Council of Australia launched Green Star environmental rating system to provide incentives for commercial buildings to include recycled water schemes	2003
	N	Water Services Association of Australia developed a supplement to the Water Supply Code to set standards for the design and construction of dual pipe systems for new developments	Jul 2004
	E	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
10	N	Private company established to finance and manage recycled water treatment plants for supplying recycled water in south-east Melbourne	Apr 2005
	E, N	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
11	N	Industry water users program established to support demand reduction through measures such as investment in onsite recycled water schemes	2004-2009
	N	Private company established to finance and manage recycled water treatment plants for supplying recycled water in south-east Melbourne	Apr 2005
	E	Victorian Government & Melbourne Water announced Eastern Treatment Plant upgrade	Oct 2006
	E	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
	E	Upgrades to wastewater treatment plants undertaken (including Eastern Treatment Plant) to provide additional sources of recycled water	2010-2012
	N	Water retail companies worked with land developers and municipalities to implement dual pipe infrastructure in mandated areas	2010-2012
	N	Water retail companies identified, planned and implemented recycled water & dual pipe systems for urban renewal projects (Doncaster, Docklands)	2010-2012
	N	Water retail companies investigated economics and pricing options for recycled wastewater in response to customer concerns about value for money	2011-2012
12	C	Government set target for reducing nitrogen from Western Treatment Plant discharges	1996
	C	Government introduced target of recycling 20% of Melbourne's wastewater by 2010	Nov 2001
	C	Government introduced a target of 10 GL/yr from alternative sources by 2030	Oct 2006
	C	Government amended Victorian Planning Provisions to require the integration of alternative water resources in new developments where potable quality not required	Oct 2006
	E	Water retail companies delivered recycled water from implemented trial dual pipe systems in new developments	2006-2008
	C	Water retail companies worked with key stakeholders to identify suitable growth areas for mandating the supply of recycled water with dual pipe systems	2007-2008
	N	Investigations into how to fill regulatory gaps about recycling schemes	2010-2012

Table A.3 Actor strategies to institutionalise the stormwater harvesting constellation

I	E/N/C	Actor strategies to institutionalise STORMWATER HARVESTING	Period
1	C	Research, technology development, trial projects & conferences on stormwater treatment reveals the need to retain stormwater to further improve receiving waterway health	1997-2012
	C	Research, technology development, trial projects & conferences on stormwater reveals the potential for harvested stormwater to be used as a resource as part of a diverse supply	2003-2012
	C	Strategic reports identified harvested stormwater as a potential option for water supply but not pursued in any detail	Oct 2002-Nov 2006
	C	Robust dialogue in water sector about the role of stormwater in supporting liveability through harvesting and quality treatment, reusing stormwater for potable uses, the value of harvested stormwater in comparison to other sources and the associated economics	2010-2012
	C	Living Victoria Ministerial Advisory Council appointed to provide independent advice to Government on reforms needed in urban water to deliver liveability outcomes; road map & implementation plan developed with broad stakeholder input	Jan 2011-Feb 2012
2	C	Interdisciplinary research programs with strong industry partnerships established to develop socio-technical knowledge on stormwater treatment, harvesting & governance	2007-2012
	C	Feasibility study for a large-scale stormwater harvesting project undertaken	Jun 2007
	C	Water retail companies planned & implemented stormwater harvesting pilot projects, with significant support from Federal Government grant funding	2009-2012
	C	Water retail company worked with stakeholders to develop integrated water management strategy for Melbourne's south-east, which in part considered stormwater harvesting	2009-2011
	C	Informal dialogue between health regulator & water sector about how to address potential health risks of stormwater harvesting in the absence of a regulatory framework for stormwater	2010-2012
	C	Development of multi-stakeholder collaborative project to investigate potential of stormwater harvesting in providing health and wellbeing benefits, & to develop planning tools to support feasibility assessments and decision-making about green infrastructure	2011-2012
3	C	Water retail corporations planned & implemented stormwater harvesting pilot projects, with significant support from Federal Government grant funding	2009-2012
	C	Introduction of pilot project to incorporate training criteria in construction contracts to build industry capacity for delivery of stormwater treatment & harvesting projects	2011-2012
4	C	National recycling guidelines for risk management developed and published (focused on stormwater harvesting and reuse)	Jul 2009
	C	Interdisciplinary research programs with strong industry partnerships established to develop socio-technical delivery tools for stormwater treatment, harvesting & governance	2010-2012
	C	Development of multi-stakeholder collaborative project to investigate potential of stormwater harvesting in providing health and wellbeing benefits, & to develop planning tools to support feasibility assessments and decision-making about green infrastructure	2011-2012
5	-	-	-
6	C	Trial projects, conferences and capacity building programs on stormwater treatment to build community of practice that expanded its focus to stormwater harvesting	1997-2012
	C	International working group on Water Sensitive Urban Design established under International Water Association & Association of Hydraulic Research	2005
	C	Interdisciplinary research programs with strong industry partnerships established to support communities of practice for stormwater treatment, harvesting & governance	2005-2012
	E, C	Water retail company worked with stakeholders to develop integrated water management strategy for Melbourne's south-east, which in part considered stormwater harvesting	2009-2011
	E, C	Living Victoria Ministerial Advisory Council appointed to provide independent advice to Government on reforms needed in urban water to deliver liveability outcomes; road map & implementation plan developed with broad stakeholder input	Jan 2011-Feb 2012
	E, C	Development of multi-stakeholder collaborative project to investigate potential of stormwater harvesting in providing health and wellbeing benefits, & to develop planning tools to support feasibility assessments and decision-making about green infrastructure	2011-2012
7	-	-	-
8	N	Water businesses incorporating environmental and sustainability principles as strategic priorities for their business, stimulating cultural change	2003-2006
	N	Water retail company worked with stakeholders to develop integrated water management strategy for Melbourne's south-east, which in part considered stormwater harvesting	2009-2011
	N	Living Victoria Ministerial Advisory Council appointed to provide independent advice to Government on reforms needed in urban water to deliver liveability outcomes; road map & implementation plan developed with broad stakeholder input	Jan 2011-Feb 2012
	N	Office of Living Victoria established to drive 'generational reform' in how urban water is	May 2012

I	E/N/C	Actor strategies to institutionalise STORMWATER HARVESTING	Period
		managed, including recycled wastewater	
9	-	-	-
10	-	-	-
11	N	Victorian Government established small-scale grant scheme to fund localised stormwater harvesting demonstration projects	2004-2012
	N	Federal Government established large-scale grant scheme to fund urban stormwater harvesting and reuse projects that reduce the demand on potable supplies	May 2009-Dec 2012
12	C	Government set targets for reducing nitrogen from stormwater discharges	1996
	C	Government introduced a target of 10 GL/yr from alternative sources by 2030	Oct 2006
	C	Government amended Victorian Planning Provisions to require the integration of alternative water resources in new developments where potable quality not required	Oct 2006
	C	Informal dialogue between environmental regulator & water sector about introducing regulation of stormwater volume discharges	2011-2012

5.4. Publication 5: A strategic program for transitioning to a Water Sensitive City

5.4.1. Introduction

Publications 3 and 4 presented the results of the empirical case study for Melbourne's water system between 1997 and 2012. Publication 5 now takes a prospective lens to present the results of the illustrative case studies of Melbourne's future transition to a water sensitive city. This investigation drew on strategy literature and primary data in the form of transition scenarios to develop a strategic program for transitioning to a water sensitive city.

The article draws on literature in strategic planning and strategic management to develop a scope and coordinating logic of a strategic program for enabling transformative change in urban infrastructure systems. It then presents a transition scenario that synthesises the results from participatory workshop series for the two embedded future cases of different Melbourne regions. The scenario comprises a set of underlying challenges, a 50-year vision for Melbourne as a water sensitive city and sets of strategic transition pathways for achieving the vision. The scenario is then analysed to inform the customisation of the strategic program scope and logic for the particular purpose of enabling the transition to a water sensitive city.

The outcomes of Publication 5 contribute to the second and third research objectives of this thesis (see Table 2). It addresses the second objective by developing illustrative future case studies of transformative change in Melbourne's water system in the form of transition scenarios and deriving lessons from the scenarios related to strategic planning and management. The third objective is addressed by catagorising these lessons in a strategic program which coordinates actor strategies for most effectively facilitating transformative change in urban water transitions.

The key findings from Publication 5 are outlined in the following section, followed by the article manuscript. Full results from the transition scenario workshops are found in the associated industry reports (Ferguson et al. 2012b, 2012c, 2012d).

5.4.2. Manuscript

A Strategic Program for Transitioning to a Water Sensitive City

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Abstract: In the context of climate change, resource limitations and other drivers, there is growing international acceptance that conventional technocratic approaches to planning urban water systems are inadequate to deliver the services society requires. Instead, scholars and practitioners are calling for a shift to an adaptive approach that increases a system's sustainability and resilience. This shift is significant, requiring transitions in the way urban water systems are planned, designed and managed. However, there is limited understanding of how strategic initiatives can be deliberately managed and coordinated to reform mainstream policy and practice. This paper aims to develop a strategic program for this purpose. It draws on strategy literature to develop a scope and logic for a general program that can address challenges for long-term urban infrastructure management related to path-dependencies, the direction of transformative change, system complexity and future uncertainty. The content of a normative transition scenario, developed in participatory workshops by water practitioners in Melbourne, is then presented, focusing on the transition to a "water sensitive city". The scenario comprises a problem definition, vision and strategies, which provide lessons for contextualizing the strategic program for the specific purpose of enabling transformative change in urban water systems. These lessons are synthesized in strategy goals and planning processes that form the design base of a strategic program. With tailoring for local contexts, the strategic program can provide operational guidance for planners, designers and decision-makers in strategically planning and managing initiatives to facilitate sustainability transitions in urban water systems.

Key words
strategic management; transition; transition scenario; urban water; vision; water sensitive city

1. Introduction

Urban water systems exist to meet a broad range of societal needs. The most obvious and long-standing are for water resources, sanitation and flood protection, which are typically served by centralized water supply, sewerage and drainage infrastructure. Strategic management of these infrastructure types is traditionally characterized by an engineering 'command-and-control' approach, which aims to reduce uncertainties through emphasizing technical solutions, ignores radical alternatives and bases decisions on rational cost-benefit assessments that consider a narrow set of values (e.g. Dominguez, Truffer & Gujer, 2011; Pahl-Wostl, 2007; Truffer, Störmer, Maurer & Ruerf, 2010). Strategic planning from this perspective adopts a paradigm of linear change, in which key variables such as rainfall patterns, resource availability and community values are assumed to be predictable (Brown, 2008; Dominguez, Worch, Marker, Truffer & Gujer, 2009; Pahl-Wostl, 2007).

Until recently, this engineering approach served the urban water needs of society relatively well. However, tensions are now experienced in cities globally, as socio-political drivers and broader contextual factors, such as climate change, resource limitations and the prioritization of urban amenity and ecological health, challenge the ability for traditional systems to deliver adequate levels of water service. These challenges arise as urban water systems are becoming recognized as social-ecological systems that encompass complex dynamic processes of change, high levels of uncertainty and a limited ability to control variables. Attempting to steer a complex system with control measures, as well as apply linear solutions to its problems, will be ineffective in securing the delivery of desired outcomes (Brown, 2008).

To summarize, complexity, variability and uncertainty will characterize urban water futures and conventional water planning is inadequate to deliver solutions that will cope with this context (van der Brugge & Rotmans, 2007; Wong & Brown, 2009). There is now growing international acceptance that strategic planning of urban systems needs to increase the resilience of infrastructure, ecosystems, community and the economy by adopting an adaptive paradigm that embraces uncertainty and complexity and provides adaptive capacity through flexibility, diversity and redundancy in its solutions (Ahern, 2011; Brown, 2012; Dominguez et al., 2009; Lessard, 1998, Wollenberg, Edmunds & Buck, 2000).

The "water sensitive city" is a conceptual representation of this alternative paradigm for urban water systems, building on sustainable urban water planning and management practices and prioritizing liveability, sustainability and resilience in the design of its institutions and infrastructure. Wong and Brown (2009) describe three pillars of a water sensitive city:

cities as water supply catchments, cities providing ecosystem services and cities comprising water sensitive communities. Compared with conventional approaches, its innovative aspirations include: (a) harmony between water planning and urban planning; (b) adaptive and multi-functional infrastructure; and (c) productive and ongoing collaborations between science, policy, practice and community (Brown, Keath & Wong, 2009, Wong & Brown 2009). There is not yet an example of a water sensitive city in the world, nor is there an accepted set of attributes and indicators for defining one. However, the concept is starting to be adopted broadly, with growing international interest by communities, governments, planning sectors, water sectors and academia (e.g. Brown, 2012; COAG, 2004; Cooperative Research Centre for Water Sensitive Cities, n.d.; Howe & Mitchell, 2012; ICLEI, 2012; Ison, Collins, Bos & Iaquinto, 2009; Jefferies & Duffy, 2011; Victorian Government, n.d.).

The shift from an engineering approach to a water sensitive approach is significant, requiring transformative change in how urban water systems are planned, designed, built and managed. However, there is limited academic and practical understanding of how strategic planning and management can be purposefully undertaken to facilitate the long-term transition required (Dominguez et al., 2011; Ferguson, Brown & Deletic, 2013; Monstadt, 2009).

To address this critical gap, this paper aims to develop a strategic program for coordinating action to enable a conventional water system's transition to a water sensitive city. First, the paper draws on conceptual insights from literature on strategic planning, strategic management, transition management and adaptive management to develop a scope and logic for such a program. Second, the paper presents a normative transition scenario (comprising a problem definition, vision and strategies) developed for Melbourne's water system. The scenario was produced with the tacit and co-developed knowledge of water practitioners elicited during workshops based on the transition arena methodology used in transition management (Loorbach & Rotmans, 2010; Frantzeskaki, Loorbach & Meadowcroft, 2012; Nevens, Frantzeskaki, Gorissen & Loorbach, 2013). Third, the content of the transition scenario is analyzed to identify lessons for informing the design base of a strategic program that has the specific purpose of enabling transformative change in urban water systems.

2. Developing a Program Scope and Logic

Scholarship addressing urban infrastructure management identifies system characteristics that present key challenges requiring attention in long-term planning. These challenges pose four questions that frame the scope of a strategic program for enabling transformative change. (1) Large urban infrastructure systems are typically locked into existing practices through institutional inertia and persistent socio-technical regimes (Berkhout, 2002; Dominguez et al., 2009; Smith, Stirling & Berkhout, 2005; Störmer et al., 2009): How can socio-technical path dependencies be overcome through strategic planning and management? (2) Long-term planning and short-term decision-making for urban infrastructure systems are influenced by normative goals and policy agendas of actors with diverse interests, responsibilities and perspectives (Albrechts, Healey & Kunzmann, 2003; Albrechts, 2004; Störmer et al., 2009; Voβ, Smith & Grin, 2009): How can strategic planning and management guide the direction of transformative change in a 'desirable' direction? (3) Urban infrastructure systems are inherently complex, comprising multiple objectives and interlinked technological, ecological, spatial, social, institutional, economic and political dimensions (Dominguez et al., 2009; Monstadt, 2009): How can strategic planning and management accommodate system complexity? (4) Planning and decision-making for long-term transformative change brings a high degree of uncertainty in the context conditions faced by urban infrastructure systems (Albrechts, 2004; Dominguez et al., 2011; Störmer et al., 2009; Voβ et al., 2009): How can strategic planning and management cope with uncertainty?

Literature on transition management and adaptive management offer insight into the types of strategic initiatives that can respond to this scope. For example, visioning (e.g. Loorbach & Rotmans, 2010; Voβ et al., 2009), experimentation (e.g. Farrelly & Brown, 2011; Huitema, Mostert, Egas, Moellenkamp, Pahl-Wostl & Yalcin, 2009); innovation (e.g. Westley, Olsson, Folke, Homer-Dixon, Vredenburg, Loorbach, Thompson, Nilsson, Lambin, Sendzimir, Banerjee, Galaz & van der Leeuw, 2011); social learning (e.g. Bos, Brown & Farrelly, 2013; Pahl-Wostl, Sendzimir, Jeffrey, Aerts, Berkamp & Cross, 2007); shadow networks (e.g. Olsson, Gunderson, Carpenter, Ryan, Lebel, Folke & Holling, 2006); leadership (e.g. Huitema & Meijerink, 2010; Olsson et al., 2006); and bridging organizations (e.g. Berkes, 2009; Folke, Hahn, Olsson & Norberg, 2005).

Accordingly, a vast range of strategy goals and planning processes needs to be incorporated into a strategic program for enabling transformative change. Transition management is a meta-governance approach for coordinating these types of initiatives. It uses a range of instruments and methods to bring frontrunners together to compete with dominant actors and practices during the early phase of a transition, when the aim is to stimulate new innovations. However, there is a lack of theory or empirical evidence for developing operational programs to influence later phases of a transition by engaging with regime actors and their practices within mainstream strategic management of urban infrastructure systems (Loorbach & Rotmans, 2010).

Literature on strategic planning and management is therefore drawn upon to develop the logic of a strategic program that can (a) meet the scope of four questions developed above and, (b) accommodate the diversity of organizational actors that have different degrees of power, influence and responsibility in the mainstream management of an urban infrastructure system. This logic would need to make the interactions and dependencies of strategic initiatives explicit so that coordinated and aligned action across multiple organizations deliver on shared objectives.

Scholarship on strategic planning for corporate and public organizations offers valuable insights (Albrechts, 2004; Bryson, 1988), notwithstanding key differences in planning for single organizations versus urban infrastructure, which tends to be more democratic, transparent, complex and slow due to the broader range of actors involved (Dimitriou, 2007). The literature reveals a long history of examining the role and effectiveness of strategic planning in how firms manage their futures in complex and uncertain business environments. Mintzberg (1994) contends that formalized strategic planning is analytic and programmatic in nature and needs to be complemented by informal processes that stimulate intuitive and creative thinking for generating strategies. This critique reflects a long-running debate between 'design' and 'process' schools of thought, which argues whether strategic planning is valuable for designing a strategic plan or for the learning that takes place during strategic processes (e.g. Grant, 2003; McKiernan, 1997). Grant (2003) critically informed this debate through an empirical case study of strategic planning in major oil companies facing rapidly changing contexts and observed three different roles for strategic planning: (1) as a context for strategic decision-making; (2) as a mechanism for coordination; and (3) as a mechanism for control (see also Giraudeau, 2008; Nordqvist & Melin, 2008). Grant concluded that both 'rational design' and 'emergent process' play important roles in strategy formulation, a finding reiterated in more recent literature (Albrechts, 2004; Whittington, Molloy, Mayer & Smith, 2006).

A strategic program therefore needs to address both the process of strategy development and the content of strategic plans developed. The three roles for strategic planning identified by Grant (2003) inform the development of a logic for process and content-based initiatives that are coordinated in a strategic program (Figure 1). The following paragraphs describe this logic and its constitutive dimensions.

Strategic planning as a context for decision-making involves consideration of the external environment that a system may encounter (e.g. through forecasting and scenario analysis) and the internal strategic direction the system aims to head (e.g. through outlining a vision, goals and objectives in a strategic plan) (e.g. Schoemaker, 1992). Hence, there must be sector-wide understanding of the system context and strategic direction.

Strategic planning as a mechanism for communication and coordination across organizations focuses on two dimensions: first, understanding what system capacity (e.g. knowledge, tools and resources) currently exists and what needs to be increased in anticipation of future challenges and opportunities; and second, identifying and evaluating strategic options for implementation by considering the system capacity, system context and strategic direction (e.g. Bryson, 1988).

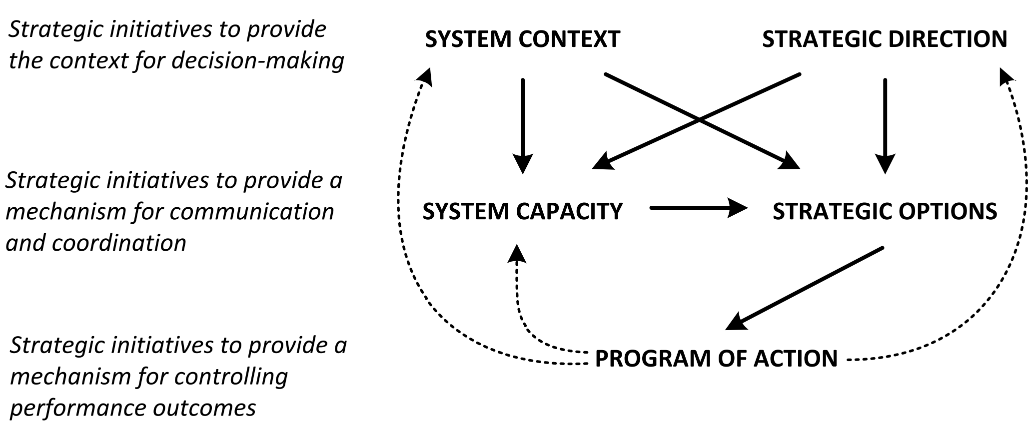

Figure 1. Coordinating logic of a strategic program

Strategic planning as a mechanism to control the performance of individual organizations or projects provides an operational focus through programs of action, with specific actions, budgets, responsibilities and timelines assigned (e.g. Giradeau, 2008). Once programs of action have been implemented, monitoring and evaluation must occur, feeding back to the higher levels so that the strategic program is flexible and adaptive to cope with new system conditions (e.g. Lessard, 1998).

3. Research Design

The scope and logic presented in Section 2 is generic and does not consider requirements for specifically enabling transformative change in urban water systems. The rest of the paper focuses on developing a design base of a strategic program for this particular purpose, drawing on insights from recent transformative change in Melbourne's water system. Actors in the city's water sector have developed tacit knowledge about how to support innovation and reform mainstream approaches through strategic initiatives. Their insights, collected in the form of a transition scenario, offer unique data to inform the design of a strategic program for steering an urban water system's transition from a conventional engineering approach to an adaptive water sensitive approach.

These insights were developed in two phases (see Figure 2). First, a normative transition scenario was generated through a transdisciplinary research process, based on the typical methodology of transition arenas (Loorbach & Rotmans, 2010; Nevens et al., 2013; Voβ et al., 2009). The transition scenario was then used as data in the second phase to inform the development of a strategic program for enabling transformative change in an urban water system.

3.1 Melbourne's Water System Context

Melbourne, the capital of Victoria, Australia, covers approximately 7,700 km2 and has 4.1 million people. This population is projected to increase up to 8 million by 2050, accommodated by both urban expansion and densification. Natural water systems feature in the city, including Port Phillip Bay and the Yarra River.

Melbourne's water system was traditionally dominated by separate water supply, sewerage and stormwater pipe networks, centralized surface water reservoirs, centralized wastewater treatment plants and channelized drains.

A focus on stormwater quality management through control of diffuse sources of pollution emerged during the 1990s, in response to changing community attitudes towards urban amenity and ecological health (Brown, Farrelly & Loorbach, in press). The last decade of water management in Melbourne has been dominated by extremes. Severe drought struck in 1997 and persisted for thirteen years, prompting water saving campaigns and the construction of a large desalination plant. The drought broke in 2010 and Melbourne has since experienced intense rainfall and severe flooding. During this period, innovative technologies for wastewater recycling and stormwater treatment and harvesting have been adopted and their associated management practices are gradually becoming institutionalized (e.g. Barker, Faggian & Hamilton, 2011; Mitchell, 2006).

These changes represent a radical departure from the traditional centralized infrastructure system. Most recently, a new adaptive water management philosophy has become formal government policy and an 'Office of Living Victoria' has been established, with an agenda to drive generational reform in how water in Melbourne is managed (Victorian Government, n.d.). The concept of the water sensitive city has taken root in both policy and practice as a desired, albeit undefined, representation of an urban water system that is sustainable, resilient and supports a city's liveability.

3.2 Transition Scenario Generation (Phase 1)

This section describes the Phase 1 steps (outlined in Figure 2); insights about facilitation of the participatory process are beyond the paper's scope and are documented elsewhere (Frantzeskaki, Ferguson, Skinner & Brown, 2012; Loorbach & Rotmans, 2010).

3.2.1 Process design

The research aimed to capture the tacit knowledge of water practitioners in Melbourne as reliable and valid data to inform the design of a strategic program for enabling transformative change towards a water sensitive approach. The process therefore needed to encourage a diversity of perspectives and rigorous discussion and the outputs needed to enrich understanding about how a future water sensitive city could be achieved.

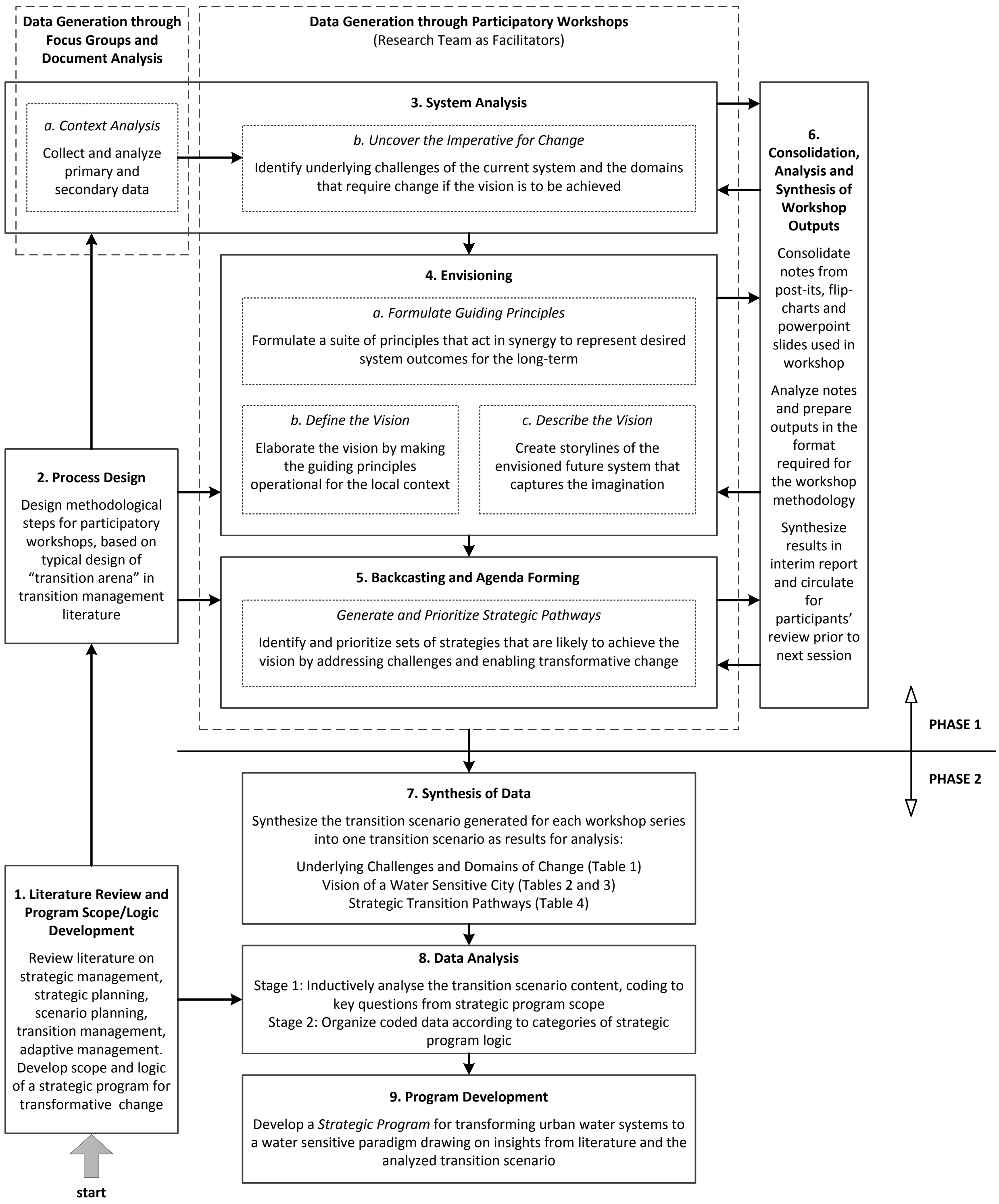

Figure 2. Research design

Scenarios are an increasingly popular approach for planning in water, landscape and urban environments (e.g. Kok, van Vliet, Bärlund, Dubel & Sendzimir, 2011; Makropoulos, Memon, Shirley-Smith & Butler, 2008; Pearson, Park, Harman & Heyenga, 2010; Vervoort, Kok, Beers, van Lammeren & Janssen, 2012; Wollenberg et al., 2000), although there is significant diversity in their purpose and approach. Van Notten, Rotmans, van Asselt and Rothman (2003) present a scenario typology based on the project goal, process design and scenario content. In this classification, transition scenarios are explicitly normative and take a long-term future vantage point, created through a participatory process that merges creative envisioning techniques with rational backcasting techniques to explore strategies for arriving at a desired future (Sondeijker, Geurts, Rotmans & Tukker, 2006).

The methodological steps taken to develop transition scenarios for Melbourne's water system were based on the typical process design for transition arenas, described in transition management literature and applied to a range of contexts such as waste management, health care, energy and transport (Loorbach & Rotmans, 2010; Nevens et al., 2013; Voβ et al., 2009). A series of transition arenas produce a transition scenario, comprising: (1) problem definition; (2) a long-term future vision; and (3) strategic transition pathways.

A major adaptation was made to the transition arena methodology to suit the context of Melbourne's water system, namely the process for selecting workshop participants. A transition management team typically screens and selects 'frontrunners' to participate in the transition arenas, without requiring formal representation from particular organizations. For Melbourne, sector-wide dialogue about water sensitive cities was underway prior to the project (Victorian Government, n.d.), so the workshops needed to build on this existing momentum. Each organization involved in water planning, design and management has its own perspectives, experiences and cultures, which are reflected by different types of tacit knowledge. This knowledge needed to be integrated into the scenario so it would form valid and reliable data for informing a strategic program. Key organizations included: (a) Victorian Government departments (responsible for water policy, human health and land use planning); (b) a wholesale water company (responsible for the bulk supply of water and removal of wastewater, major drainage systems and the health of waterways; (c) water retail companies (responsible for the interface with customers for water and sewage services); (d) municipalities (responsible for minor drainage systems, local amenity and community wellbeing); (e) consultants (responsible for technical water system designs); and (f) community groups (active in lobbying and engaging with water issues). Commitment was obtained from executive leaders of these organizations, who then nominated representatives in response to the research team's request that participants aspire to sustainability principles and have strategic understanding of Melbourne's water system. Participants typically had 5 to 20 years' water sector experience, with diverse organizational roles and disciplinary backgrounds (e.g. engineering, ecology, landscape architecture, community engagement).

Given Melbourne's large size, the research was focused at a scale of clustered municipalities to provide contextual focus. Two clusters were selected in order to develop a transition scenario for two different geographic, socio-economic and administrative sub-contexts within Melbourne. The Yarra Valley Cluster (YVC) comprised three municipalities over 234 km^2 (400,000 people) and the South East Cluster (SEC) comprised four municipalities over 760 km^2 (700,000 people) (Figure 3). The research team anticipated the different local contexts would result in differences between the two scenarios, although this did not eventuate (see Section 3.3). Between February and June 2012, four half-day workshops were conducted for the YVC and five half-day workshops for the SEC. The same set of participants was invited to each workshop in the series, although some could not attend all sessions; each session had between 13 and 21 practitioners in attendance. Workshop discussions were conducted in small groups of 5 to 7 people to generate ideas and as a whole group to synthesize and consolidate workshop outputs.

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Figure 3. Cluster areas for data collection

3.2.2 System analysis

The research team undertook a context analysis in Step (a) prior to the first workshop (Figure 1). This involved collection and analysis of primary and secondary data to synthesize the social, economic and ecological characteristics and historical, recent and expected future trends of the cluster area. Water governance problems (framed as 'perceived challenges') were also identified. Primary data was collected through focus groups at each municipality (5-12 participants in each). Secondary data included organizational and policy documents, statistics and scientific literature on urban water governance in Melbourne. The context analysis was presented in the first workshop to stimulate discussions in Step (b).

An in-depth understanding of the current system conditions, and its elements that contribute to the problems experienced constituted a baseline from which to contrast the future vision (Loorbach & Rotmans, 2010). Step (b) involved facilitated discussions to identify underlying challenges that explained why current problems revealed in the context analysis persist, as well as the system domains that need to be modified for these challenges to be overcome if a water sensitive city vision is to be achieved.

3.2.3 Envisioning

The envisioning steps involved imagining the conditions of a future water sensitive city to create understanding and framing of the desirable directions or images, while maintaining a sense of place in the local context (Sheppard, Shaw, Flanders, Burch, Wiek, Carmichael, Robinson & Cohen, 2011; Sarpong & Maclean, 2011). In Step (a), participants formulated guiding principles that guide how planning, investment, design, governance and evaluation would occur in a water sensitive city. Outcomes from previous visioning exercises in Melbourne (Victorian Government, n.d.) were provided to participants as a base from which to modify and expand upon in formulating their set of guiding principles. The guiding principles were organized in themes that emerged from the discussions. Once the guiding principles were agreed upon, in Step (b) participants specified what the principles mean and how their achievement would be experienced in a future water sensitive city; this provided further vision definition in the form of strategic objectives. Finally, phrases, words, descriptions and interpretations used by participants to express their vision were compiled in Step (c) to develop descriptive narratives of the vision.

3.2.4 Backcasting and agenda forming

Backcasting is an approach that facilitates strategy generation by taking a future vision as a desirable end and examining how that future vision could be achieved (Phdungsilp, 2011; Quist, Thissen & Vergragt, 2011). Participants identified short, medium and long-term strategies that could achieve each guiding principle and enable a transition by overcoming the current challenges. They then proposed immediate next steps for strategies they considered a short-term priority.

3.2.5 Consolidation, analysis and synthesis of workshop outputs

Workshop discussions were captured by facilitators and participants through note-taking on post-its, flipcharts and powerpoint slides. An artist was also engaged to observe the SEC workshops and develop illustrations of the future vision. After each workshop, the research team consolidated the notes and undertook analysis according to the relevant process objective. The analyzed outputs were prepared in the format required for the methodology (e.g. a set of guiding principles) and synthesized in an interim report. Each interim report was provided to participants at least one week in advance of the next workshop, so they had sufficient opportunity to read, digest and reflect on the outcomes before entering the next session's discussions. Each workshop provided time for participants to confirm the interim report's accuracy and make any necessary refinements. The next discussion phase did not progress until all participants were satisfied the report accurately reflected their ideas and opinions. Workshop discussions were robust and while individual participants demonstrated particular emphasis on their main topics of interest, this gave breadth to the range of ideas explored and all participants were in agreement about the final transition scenario produced for each cluster.

3.2.6 Roles of the research team

In action research, researchers' roles must be explicated to identify their impact on project outcomes (Rodela, Cundill & Wals, 2012; Ison et al., 2007). The research team adopted dual roles of facilitators and analysts. During facilitation, the research team did not contribute content to group discussions; instead they guided participants through the process steps and prompted them with questions to encourage elaboration on key points so that meanings were fully understood and captured in workshop notes. Between workshop sessions, the researchers were analysts, consolidating and analyzing workshop notes before synthesizing outputs in the format required for the workshop methodology.

3.3 Program Development (Phase 2)

The scenarios developed for each cluster were very similar. The research team could therefore synthesize the data into a single Melbourne-wide transition scenario. Variations in detail between the two scenarios were incorporated so that features of both cluster contexts were represented in the final synthesized scenario.

Analysis occurred in two stages. First, the content of the synthesized transition scenario was inductively analyzed (Blaikie, 2010) by the first and second author, coding to the four key questions that frame the strategic program scope developed in Section 2. The second analytic stage involved organizing the coded data from the first stage within the categories of the coordinating logic developed in Section 2 (Figure 1). This was initially conducted by the first author, drawing on contextual understanding (developed through project scoping and the focus groups described in Section 3.2.2) about existing and desired institutional capacities for Melbourne's water system in relation to the vision and strategic pathways, and implications for the roles, responsibilities and power relationships of water sector actors in delivering a strategic program for transformative change. Throughout the two analytic stages, all authors reflected both independently and together on the coherence and quality of the coding and iteratively peer-reviewed the emerging strategic program design base. Interim findings were presented to fellow academics and leading water practitioners for critique and reflection. Their feedback was used to refine the coding and synthesis of the final outcomes.

4. Results

This section presents the elements of the synthesized transition scenario in tabulated form, with short descriptions to guide the reader through the tables. Details of the transition scenario produced by each individual cluster are available elsewhere (Ferguson, Frantzeskaki, Skinner & Brown, 2012a,b).

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Table 1. Underlying challenges and domains of change

Underlying Challenge	Domain of Change
Absence of long-term commitment by political parties. Long-term commitment to water sensitivity is compromised by different priorities, conflicting agendas and short-term political cycles.	Political commitment to achieve water sensitive outcomes
No compelling vision to drive change. The vision does not connect with society's values and beliefs in way that communicates the benefits of a water sensitive city and compels people to act conscientiously.	Communication of the need, vision and desires Valuation of water
Boundaries and relationships are not defined in a useful way. Existing arrangements for sharing authority, responsibility, knowledge and resources do not suffice for the new roles that are emerging around water sensitive planning, design and management.	Definition of water boundaries Planning of water servicing
Legacy of the past inhibits new approaches. The existing management culture results in a reluctance to revisit assumptions, to raise issues, to manage different types of risks and to adapt to new ways of doing things. While acknowledging the need to change its approach, the water sector faces hurdles due to decades of investment in traditional infrastructure and its associated knowledge, skills and formal rules.	Water sector collaboration, internally and externally Perception and incentives for collective benefits Legislated performance standards of water infrastructure
Integration creates new opportunities and complexities. Integration means that multiple water sources, geographic scales, infrastructure types, ecological assets, as well as a diversity of stakeholders and their interests, need to be considered. These interconnected elements create complexity, but also new opportunities.	Knowledge and tools of the water and planning sectors Community knowledge and attitude towards water Risk perception and management
Insufficient cultural, technical and social capacity. New knowledge, new tools and new ways of engaging and collaborating are required to address emerging water challenges. There is currently insufficient capacity to bridge these gaps.	
Current economic paradigm has limits. Current economic thinking values growth, individualism and private interests. There are no drivers or incentives for the water sector to operate differently. Frameworks for valuing long-term intangible benefits do not exist.	Definition of success

4.1 Problem Definition

The participants recognized that while recent mainstream uptake of a range of new technologies and management practices in Melbourne indicates an acceleration of the transition to a water sensitive city, this transition is far from complete. Table 1 provides a critical view of the root causes of problems that currently hinder the transition, in the form of underlying challenges and their associated domains of change. The underlying challenges are deeply embedded, systemic and complex; they will be confronting to address and in fact, will require the culture of Melbourne's water sector to be transformed at individual, organizational and institutional scales.

Table 2. Visions of Melbourne as a water sensitive city: Social and ecological health, connected communities

A Vision of Social and Ecological Health 	Water is essential for all life forms. We respect the water needs of all species. Our waterways and other ecosystems are in a healthy condition and support our public health and wellbeing. We appreciate our environment and connect with nature through a range of experiences. Green landscapes and vegetated corridors support native biodiversity. Water supports the greening of our city's infrastructure and fosters good quality, connected greenscapes. We all live and work within walking distance of waterways or green public open space. It is our place to meet, play and relax. Water and vegetation provide a cooling effect in heatwaves and reduce the urban heat island effect. Our people are healthy and active. We enjoy green and blue corridors for passive and active recreation, such as reading, walking, cycling, swimming and other community activities. Our green city has space for us to grow our own fruit and vegetables. The water we drink and use is safe and of excellent quality. We are prepared for droughts, floods and heatwaves and our people, ecosystems and property are safeguarded against surprises.

Guiding Principles	Example Strategic Objectives
1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.	Everyone has access to good quality waterways and their banks Everyone lives and works within walking distance of a neighbourhood parks that has good quality canopy cover Everyone identifies and feels connected with their local neighbourhood
2. Our city is alive, healthy and green; its environmental wellbeing is valued, protected and enhanced. We live in harmony with our natural environment.	More habitats are protected and enhanced to prioritize biodiversity and abundance All urban development is designed to maintain natural flow regimes (e.g. runoff from impervious surfaces) Maximum vegetation coverage of active transport corridors
3. Our city, people and ecosystems are safe and resilient; we are prepared for surprises and extremes.	Minimized mortality and morbidity from heat waves Efficient system response when conditions change All decisions are made in consideration of their impact on the water cycle

A Vision of Connected Communities 	We feel a connection with nature and to our neighbourhoods. Water links us with the landscape and fosters a sense of identity and community. We celebrate water; people play with water and our urban waterways are used for recreation. We are water literate; we see how water flows and understand the different phases of its cycle. We are all committed to a shared water vision and have a clear understanding of its benefits. We are passionate about water and engage in vibrant community conversations about water. A spirit of cooperation underlies how plans and designs are realized and we share a clear understanding of our different roles and responsibilities. Community is empowered to contribute and co-create real options with the water sector. Our water profession is community literate; it is are able and eager to engage with communities and value their input. Professionals involved in planning and management of the water cycle appreciate different perspectives and are open to new approaches.

Guiding Principles	Example Strategic Objectives
4. Our identity embraces water; we celebrate our water sensitive city and take pride in the path it paves for a sustainable future.	Everyone is proud of the Yarra's iconic status as a healthy river where people can swim and fish Increased visibility of water in urban space Everyone who adopts water sensitive practices are appreciated and celebrated
5. We are educated, engaged and aware; we understand and take responsibility for our water. Our water sector collaborates and co-creates understanding and solutions with community and associated sectors. We understand and act upon community water needs.	Increased awareness and knowledge of people about water issues, decisions and systems All organisations have mechanisms to meaningfully involve communities in vision building and decision-making All water-related institutions are transparent, adaptive and collaborative High diversity of backgrounds of professionals involved in decision-making about water

4.2 Future Vision

Tables 2 and 3 present descriptive narratives, artistic impressions, guiding principles and specific local definitions in the form of strategic objectives for the 50-year vision of Melbourne as a water sensitive city. Four themes emerged from the vision: Social and Ecological Health, Connected Communities, Shared Prosperity and Water System Design. Each theme stresses a dimension of the water sensitive paradigm that distinguishes it from the conventional engineering paradigm, such as striving for ecological health rather than only environmental protection, shared prosperity rather than economic growth, and empowered communities rather than passive end users or service recipients. The vision emphasizes the vital role of water in the urban landscape as an underpinning enabler for liveability, health, amenity and resilience, while recognizing the value of traditional infrastructure in maintaining reliable water servicing for public health and safety.

Table 3. Visions of Melbourne as a water sensitive city: Shared prosperity, water system design

A Vision of Shared Prosperity 	We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system. Water supports the development of business opportunities without unduly contributing to economic risks. Investment decisions about water are made with a long-term perspective, creating a resilient economy. Our decisions are driven by the societal benefits they produce. Water prices represent the true value of water. Water services are available, accessible and affordable for us all to meet our basic water needs. Our measure of success is based on equity amongst different communities, generations and species.
Guiding Principles	**Example Strategic Objectives**
6. We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system.	Every infrastructure decision delivers the highest societal and ecological benefit Every water infrastructure decision is based on a lifecycle assessment that includes future options, externalities and local conditions Maximized opportunities for multiple uses of assets throughout their construction, management and renewal
7. Our water system is equitable; water is available for us all to meet our basic needs.	Everyone has access to water for basic needs, irrespective of socioeconomic status Everyone has amenity opportunities Healthy ecosystems are maintained in all climatic conditions Ensure equity in the costs of water servicing across the city
A Vision of Water System Design 	Our water system embraces the many values of water. We transparently identify and measure the benefits and impacts of all the services provided by water. We equitably share these benefits and impacts. We holistically evaluate, plan and design our water systems. We know how much water has been used in the whole life cycle of our products and activities. We consider our impacts on water systems, including those that extend beyond our city's boundaries. The design of our cities and water systems aligns with the characteristics of the local landscape. Our water systems are designed to utilize every possible water source. We have a smart water grid that matches sources of water to their demands, enhancing our resilience. We optimize our self-sufficiency at different spatial scales. Our water system uses energy efficiently and maximizes the use of renewable energy sources. Our water system enables interconnections between nutrient, mineral, energy, carbon and water cycles and utilize their productive potential. Our water infrastructure is designed to add to the amenity of our area.
Guiding Principles	**Example Strategic Objectives**
8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum societal value.	All benefits and impacts of water are identified, quantified and communicated (in monetary or non-monetary terms) Infrastructure costs are shared across organisations to reflect the distribution of benefits All urban design decisions consider the total cost of water servicing
9. Our water system is smart, integrated, connected, flexible and adaptive.	All water demands are met by fit-for-purpose sources of water Optimized self-sufficiency at all scales Increased use of recycled wastewater and harvested stormwater No toilet uses potable water Minimized impact of the urban environment's water needs on regions outside its boundaries
10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water, nutrients and physical space are consumed and produced.	All energy and nutrients from water are recovered and used for productive purposes Positive impact of water system on the environment Water system relies entirely on renewable energy sources All urban developments are net neutral in water, energy and nutrients

4.3 Strategic Transition Pathways

Table 4 provides the list of short (2020), medium (2040) and long-term (2060) strategies for the transition scenario (participants defined the time horizons during the workshops). The strategies are thematically bundled into different transition pathways and their subset paths, addressing infrastructure, landscape, technology, experimentation, community, economy, institutions and governance arrangements.

5. Analysis and Discussion

The content of the transition scenario for Melbourne's water system is now inductively analyzed to inform the development of a strategic program that builds on the scope and logic in Section 2.

Table 4. Pathways for Melbourne's transition to a water sensitive city

Strategic Transition Pathway	Example Strategic Actions
Pathway A – Embed the Water Sensitive City Vision	
Path A1 – Develop the vision	Develop metrics for the vision; embed vision in broader sustainability agenda
Path A2 – Communicate vision	Communicate specific benefits of vision
Path A3 – Build broad ownership	Develop shared vision amongst all stakeholders
Path A4 – Commit to the vision	Regularly review and adapt vision
Pathway B – Foster Community Connections with Water	
Path B1 – Build public understanding	Use social media; facilitate community conversations; embed holistic water education into schools; develop tools for people to self-monitor their water
Path B2 – Empower communities	Engage with communities to co-create water solutions; value community input, foster community water ambassadors; reward good water practices
Path B3 – Celebrate water	Establish an annual water festival; design play spaces for discovery and learning about water by children; commission public artworks based on water
Pathway C – Support Water Collaborations	
Path C1 – Align objectives of water-related organizations	Expand scope of water organisations to empower them to address future water needs; improve communication
Path C2 – Communicate a common message	Develop a clear shared language; develop a communication campaign across water sector organisations; use multi-disciplinary and multi-agency teams
Path C3 – Actively support collaborative approaches	Establish broad networks; develop a range of skills, knowledge and leadership capacities in specialists and generalists; improve collaborations between organisations and disciplines; establish a collaborative governance experiment
Pathway D – Support Water Innovations	
Path D1 – Develop a learning strategy	Identify learning gaps; establish independent reference group to develop and steward a demonstration strategy
Path D2 – Demonstrate new approaches	Link funding opportunities with learning gaps; initiate a diversity of demonstrations; support innovation with mechanisms for managing risks
Path D3 – Learn from experiences	Integrate evaluation and learning as part of demonstrations and all projects
Path D4 – Scale up demonstrations	Set benchmarks to communicate best practice to industry; develop tools to support mainstreaming of new approaches
Path D5 – Lead innovations	Commercialize and export knowledge and skills
Pathway E – Integrate All Values of Water	
Path E1 – Identify and measure all water values	Identify and define all values of water; develop measures for benefits and impacts of water
Path E2 – Develop evaluation frameworks	Develop holistic evaluation frameworks and decision making tools to support prioritisation processes
Path E3 – Develop incentives based on broad water values	Make costs of different types of water transparent and charge accordingly; use price mechanisms as incentives; establish charges for liveability benefits; introduce accreditation and benchmarking tools
Path E4 – Broaden water markets	Develop business cases; establish mechanisms for co-investment
Path E5 – Ensure equity in the distribution of water values	Define 'equitable' and 'basic water needs'; identify vulnerable communities; develop support schemes

Table 4 (cont.). Pathways for Melbourne's transition to a water sensitive city

Strategic Transition Pathway	Example Strategic Actions
Pathway F – Harmonize Water and Planning	
Path F1 – Embed broad water values in planning paradigm	Ensure water is a priority in all phases of urban planning; integrate water sensitive objectives into planning
Path F2 – Identify and seize cross-boundary opportunities	Deliver on opportunities for multi-functional infrastructure; remove delivery impediments
Path F3 – Develop data, knowledge and tools for planning	Generate and collect raw data; compile and share data; develop legislative and policy tools
Path F4 – Empower local administration	Build capacity through training; coordinate planning activities; utilize strategic planning opportunities; establish interdisciplinary forums
Pathway G – Develop a Portfolio of Water Resources	
Path G1 – Develop data, knowledge and tools for technologies	Ensure transparency in data sharing; develop better understanding of decentralized technology dynamics; invest in research and development for new tools and flexible technologies
Path G2 – Develop guidelines, standards and regulations for fit-for-purpose supply	Maintain drinking water quality guidelines; develop guidelines for alternative fit-for-purpose water sources; develop additional building controls for fit-for-purpose water sources
Path G3 – Actively support retrofit opportunities	Ensure drinking water quality standards are maintained; regulate alternative water systems
Pathway H – Support Healthy Urban Ecosystems	
Path H1 – Manage green space and green infrastructure	Enhance quantity, quality, accessibility and connectivity of urban green space
Path H2 – Enhance biodiversity and urban catchments	Protect biodiversity; promote biodiversity corridors; restore urban catchments; revegetate riparian zones
Path H3 – Protect environmental flows	Use alternative water sources to maintain flows; reduce the area of impervious surfaces; expand scope of water organisations to require consideration of impacts of decisions on water cycle
Pathway I – Prepare for Uncertainty	
Path I1 – Anticipate extremes and surprises	Use scenarios for long-term planning; prepare a portfolio of emergency plans; develop diverse water resources; adopt early warning systems
Path I2 – Prepare and mitigate for extremes and surprises	Develop assessment tools for mitigation; remove houses from floodplains; design for higher levels of protection; design flexible adaptable infrastructure,
Path I3 – Educate and communicate about extremes and surprises	Communicate about variability and its implications for urban ecosystems; ensure transparency with community to maintain trust; enable effective communication interfaces; improve knowledge capacity
Path I4 – Respond and adapt to extremes and surprises	Develop a response portfolio of extremes and surprises; develop adaptation schemes for future climate norms
Path I5 – Support vulnerable communities	Identify vulnerabilities faced; determine locations of vulnerable communities; consider cross-subsidies

5.1 Analysis of the Transition Scenario

The first stage of analysis identified lessons from the transition scenario that respond to each question of the strategic program scope, in order to provide specific insights for the design of a strategic program for urban water system transitions. Many of the lessons described validate commentary and hypotheses about important strategic initiatives for enabling transitions found in literature on adaptive management and transition management (highlighted in Section 2); however, exploration of this validation is beyond the paper's scope.

5.1.1 Overcoming socio-technical path dependencies

Many underlying challenges of the transition scenario relate to legacies of the past, such as boundary definitions, existing capacity and cultural approaches. A strategic program should therefore consider short-term strategies that will directly or indirectly support removal of historic barriers and mobilize resources for innovation. For example, redefinition of institutional boundaries for sharing authority, responsibility, knowledge and resources would be enabled by strategies that support active and broad collaborations between actors, as well as cultural change programs within organizations to make the profession more open to innovation and increase its community literacy. However, short-term strategies should not be limited to reactive responses that focus only on current system problems. A strategic program should proactively consider what system capacities will be needed to effectively address path-dependencies by anticipating forthcoming problems and opportunities through processes for experimentation and social learning.

5.1.2 Guiding the direction of transformative change in a desirable direction

An underlying challenge in Melbourne's water system is the lack of a compelling vision to drive change; a pathway focused on further developing the water sensitive city vision was developed in response. A strategic program should thus develop and communicate a shared urban water vision that acts as an instrument to orient, coordinate and inspire action and secure long-term commitment for enabling the transition towards a water sensitive city. In revealing that envisioning processes are essential to guide a transition's direction, the scenario highlighted that for the vision to be effective, it needs the following characteristics: (a) emerged from self-identified needs of the community; (b) articulated in ways that have genuine meaning and connection for different actors in their everyday activities; (c) associated with clear and defined metrics; (d) broadly owned by a range of stakeholders, including the water profession, community, government and the private sector; (e) embedded in a broader sustainability agenda; and (f) regularly reviewed and updated to reflect changing societal values, new knowledge and system conditions. Finally, a strategic program should facilitate social learning processes to connect outcomes from short-term initiatives with the long-term vision.

5.1.3 Accommodating system complexity

The transition scenario revealed complexity in how the system is structured, how it functions, the challenges underpinning its recent problems, as well as in the multitude of goals that form the future vision.

The vision presents the desired functional outcomes of the future system. The societal needs identified in the water sensitive city vision range from water supply, sanitation and drainage, met by traditional water servicing, through to ecological health, amenity, equity and identity. This highlights that a strategic program requires a broad systemic perspective, focusing on how water systems can be planned, designed and managed to respond to a wide variety of societal needs. In this sense, the transition scenario is holistic, encompassing domains far beyond traditional water infrastructure. For example, it reveals complex interconnections between human health, parks and gardens, green infrastructure, biodiversity, land use, mobility corridors and economic activity. The functioning of these domains relates directly or indirectly to urban water planning and emphasizes the need for cross-sectoral strategic management so that water infrastructure is not planned in isolation from other urban activities. The transition pathways strongly focus on collaboration and harmonization of urban planning with water. A strategic program therefore needs to mobilize resources for activities that support active collaboration between multiple actors, recognizing and accepting that associated transaction costs are necessary for achieving the desired outcomes. Further, it needs to consider and define both geographic and institutional boundaries in a way that accommodates the system complexity and encourages effective cross-boundary relationships.

The transition scenario also highlights that the expression of societal values will change over time, as contextual drivers (such as resource limitations, environmental impacts and socio-economic conditions) influence the system. Since these factors cannot be controlled, underlying assumptions about the system complexity will not always hold, so a strategic program should not prescribe the structure and relationships for integrating different stakeholder interests, water sources, geographic scales, infrastructure types and ecological assets. Instead, it should incorporate flexibility so that, when necessary, the system can adapt to new conditions. Further, a strategic program should mobilize resources for developing innovative knowledge and tools that allow water practitioners to anticipate and respond to system changes.

The vision highlights potential synergies and tradeoffs between specific strategic objectives. For example, the strategic objectives that 'everyone has access to good quality waterways and their banks' and 'more habitats are protected and enhanced to prioritize biodiversity and abundance' may conflict during decision-making about a particular local creek. A strategic program should therefore consider how these tradeoffs and synergies could be balanced to achieve desirable outcomes and avoid the risk of deepening problems by artificially simplifying the system. The transition scenarios highlight that evaluation and decision-making frameworks need to account for the complexities of urban water systems. All benefits and impacts of water should be considered, yet they cannot all be measured in traditional monetary terms. A strategic program should therefore utilize decision-support tools that account for all values of water to enable prioritization of outcomes that result in the highest overall societal benefit.

5.1.4 Coping with uncertainty

The language in the transition scenario reveals a distinct shift away from the traditional engineering approach that aims to 'control', 'secure' and 'drought-proof' Melbourne's water system, towards a water sensitive approach that aims to make the city 'prepared', 'adaptive' and 'flexible'. A strategic program should not assume there is capacity to control uncertainty and instead aim to build system resilience. Resilience thinking should underpin all strategic activities if the broad range of societal water needs is to be met in any future context. The vision explicitly describes different ways that resilience would manifest in Melbourne's water system. The transition pathways incorporate strategies specifically aimed at building resilience and further embedding this resilience thinking in all future practice.

The transition scenario recognizes that a resilient water system does not mean it is protected from all risks. Future uncertainty is inevitably associated with possibilities for failure, loss and damage. Instead, a strategic program should build resilience through initiatives that prepare the system for future extremes and surprises, mitigate their impacts, recover in the aftermaths and support the system's adaptation to new conditions. Identified strategies include using explorative scenario techniques for long-term planning, improving knowledge capacity, developing suitable tools, designing flexible and adaptable infrastructure that is not locked into current generations of technology, designing for higher levels of protection, adopting early warning systems, preparing portfolios of emergency response plans, ensuring transparency with community and enabling effective communication interfaces. Strategies identified to build resilient water supply systems specifically include developing a diverse portfolio of water sources and implementing smart, integrated and connected water grids that allow self-sufficiency and fit-for-purpose water to meet demands.

The interconnections between a healthy ecosystem, society and economy were revealed. A resilient system does not consist of silos that are individually healthy. Instead, future resilience will be achieved through strategic initiatives that support communities, businesses and the environment to foster synergistic and productive connections with each other, rather than those pursuing isolated goals. Actors with a diversity of backgrounds, disciplines and interests should be involved in strategic processes so that broad and integrated understandings underpin all water-related decisions. Further, investment decisions should be made with a long-term perspective that accounts for externalities, proactively anticipates changes in local conditions and considers possible future developments.

The vision highlights that a strategic program should consider how equity amongst different communities, generations and species would be maintained; strategies for supporting vulnerable communities (human and non-human) are critical for building system resilience. Fostering a shared appreciation of all values of water will support equitable outcomes and overall, resilience will be reinforced by strong connections between water practitioners, communities, businesses and governments, as well as transparent, adaptive and collaborative institutions.

5.2 Strategic Program Development

The lessons from the transition scenario provide insight into specific features required for strategic goals and processes to enable transformative change in an urban water system. Table 5 synthesizes and categorizes these lessons according to the coordinating logic developed in Section 2. This serves as a design base of a strategic program for urban water transitions; it requires tailoring for application to particular local contexts but identifies the range of strategy goals and processes that should be considered.

An actor's role in executing the strategic program will depend on its sector responsibilities. At the context-setting level of the coordinating logic (Figure 1), ongoing work led by central organizations (such as state government departments and water utilities) and involving the whole water sector is required to set the long-term strategic direction of the system, within current and possible future contexts.

At the communication and coordination level (Figure 1), ongoing work across collective organizations is required to develop shared understandings as a base for assessing capacities and evaluating medium-term strategies. This shared understanding then sets a base for decentralized strategic decision-making, a necessary aspect for managing the integrated scales of infrastructure that form the envisioned a water sensitive city.

At the performance control level (Figure 1), ongoing work within individual organizations, coalitions or project alliances is required to establish short-term delivery frameworks for implementing selected strategies. Importantly, for an organization's program of action to be genuinely embedded within the broader strategic program, the organization would need to have been deeply involved in planning processes for each of the higher levels in order to legitimize the program's strategic direction and to secure the organization's internal commitment to the selected strategic options. Further, an individual organization's program of action should offer the freedom for innovation and experimentation, within a context of aligned strategic direction for the whole sector. This ensures that the system can self-organize and that when a quick decision is required from an individual actor, it is made within the context of solid, visionary, sector-wide medium and long-term strategic commitments.

Table 5. Design base of a strategic program for enabling the transition a water sensitive city

	Dimension	Strategy Goals	Strategy Processes	Actors
Decision-making Context Long-term*	**Strategic Direction** Vision Priorities Objectives	• Commit to & communicate a shared long-term vision of a water sensitive city, defined with clear strategic objectives and metrics that all actors identify with (including water profession, urban planners, government, regulators, community, technology providers). • Embed the water sensitive city vision in a broad sustainability agenda & find links with other urban sectors such as land use planning, transport & housing.	• Processes involving diverse actors to develop a vision, foster broad vision ownership & regularly review & update it.	Whole sector, led by central government agencies
	System Context Scenarios Challenges Opportunities	• Consider possible future trends (internal & external) that could impact on water system performance, consider how to achieve system resilience for different context scenarios. • Understand causes of problems in water system, including hidden or persistent issues. • Anticipate what windows of opportunity may open in the future due to climate, economy, technology developments, changing societal values or other context trends, consider how the system would need to be positioned in order take advantage of them.	• Processes involving diverse actors to explore context scenarios, dissect current problems & consider potential windows of opportunities.	Whole sector, led by central government agencies
Communication & Coordination Medium-term*	**System Capacity** Resources Knowledge Tools	• Promote positive cultural change in water organizations to prioritize transparency, adaptability & collaboration. • Identify capacities required for overcoming socio-technical path dependencies, anticipating forthcoming problems, preparing for future opportunities.	• Processes to encourage the sharing of knowledge, tools & other capacities.	Across organizations with overlapping responsibilities
	Strategic Options Options Evaluations	• Connect medium & short-term initiatives with the long-term vision in an ongoing learning loop, in which lessons from established water projects inform the identification & evaluation of new strategic options. • Adopt a broad systemic perspective to consider how trade-offs & synergies for different water solutions can be balanced to achieve the most water sensitive outcomes. • Frame strategies in relation to water sensitive outcomes connected with the vision to maintain flexibility and innovation potential, rather than by prescribing how different actor interests & solutions should be integrated. • Give specific consideration to how the system can prepare for future uncertainties, through mitigation, recovery and adaptation strategies, with a particular focus on communities that will be most vulnerable to water stress. • Utilize decision-support tools that account for all values of water servicing, including intangible & non-monetary benefits such as urban liveability.	• Processes to coordinate planning across different actors to identify & evaluate strategic options.	Across organizations with overlapping responsibilities
Performance Control Short-term*	**Program of Action** Actions Resources Responsibilities Timing	• Establish institutional boundaries that accommodate the spatial, ecological, technological & societal complexities of the water system & support strategies that bridge boundaries to facilitate collaborative solutions. • Prioritize actions that address identified deficiencies in system capacity & directly address socio-technical path dependencies. • Mobilize resources for innovation & experimentation that responds to the learning needs & capacity deficiencies. • Consider the impact of all actions on the resilience of the water system. • Monitor action & evaluate performance with indicators that directly connect with the long-term strategic direction set by the sector-wide vision of a water sensitive city.	• Processes to support active collaboration between actors to develop & implement programs of action & learn from their outcomes.	Within organizations, alliances & project teams responsible for delivering particular outcomes

* Planning horizon timeframes: In the range of 50 years for long-term, 10 years for medium-term & 2 years for short-term.

Significant cultural change at the individual, organizational and institutional scales of urban water systems will be essential for delivering a sector-wide strategic program for transitioning to a water sensitive city. Strong connections will underpin the program's success: personal identification with water must be nurtured, the water sector and community must co-create solutions and collaborations within the water sector and with other urban sectors must be supported. Successful delivery of the program will also require the water sector to adopt a resilience mindset. In every strategic initiative, there must be focus on incorporating contingencies, flexibility and adaptability in order to foster the resilience of economies, communities, infrastructure and ecosystems.

6. Implications

Theoretical and empirical work within transitions management and adaptive management scholarship offers valuable insight into how different types of strategic initiatives can respond to the challenges of urban infrastructure systems locked in an unsustainable trajectory. However, to date they have not provided operational guidance on how these initiatives should be coordinated and implemented within a broader framework that engages with regime actors and complements mainstream governance structures. This paper contributes to scholarship on landscape planning, design and management by addressing this gap through the development of a strategic program for enabling the transition of urban water servicing from a conventional system to a water sensitive city.

The paper initially developed a general scope and logic of a strategic program for urban infrastructure systems, by drawing on conceptual insights from literature on strategic planning, strategic management, transition management and adaptive management. It then analyzed the content of a normative transition scenario developed for Melbourne's water system to identify lessons for informing the design base of a strategic program that has the specific purpose of enabling transformative change in urban water systems.

The strategic program involves both goals and processes at three conceptual levels: setting a decision-making context, communicating and coordinating action, and controlling performance outcomes. Actors will have different types of roles at each of these levels, depending on their sector responsibilities, and strategies across the sector will need to be highly coordinated and harmonized for the program to be successfully implemented. The program would be underpinned by strategies that enable envisioning, learning and executing, while cultural transformation will also be required to provide a supportive institutional context within urban water systems for its effective delivery.

While the strategic program proposed in this paper needs testing, as a tool it offers significant potential in providing practical guidance for urban water planners, designers and decision-makers who are faced with the immense challenge of developing policies, plans and processes that can effect transformative change in water systems to achieve more water sensitive outcomes. Finally, with further development and contextualization, the proposed strategic program also has potential as an operational tool for facilitating sustainable solutions in urban landscapes beyond water servicing.

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CHAPTER 6. THE FAST FRAMEWORK

This chapter brings together outcomes from the previous chapters, synthesising them into a meta-governance framework for guiding strategic initiatives to enable transformative change in complex urban infrastructure systems. This framework is named "FaST: Facilitating System Transitions". The multi-phase architecture of FaST is introduced and an explanation of how FaST should and could be used is provided. Finally, the content and process-based tools that are required to achieve the goals of each FaST phase are presented, showing how they constitute the toolkit for the FaST framework.

SPECIFIC DECLARATION FOR PUBLICATION 6

Monash University

Declaration for Thesis Chapter 6.1

Declaration by candidate

In the case of Chapter 6.1, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulated research problem, located research within established literature, collected and analysed data, conceptualised and structured paper, wrote paper.	90%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah Brown	Supported the research conceptualisation, reviewed and edited the paper	N/A

Candidate's Signature	B. Ferguson*	**Date** 30/5/13

Declaration by co-authors

The undersigned hereby certify that:

(7) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(8) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(9) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(10) there are no other authors of the publication according to these criteria;
(11) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(12) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	**Geography & Environmental Science, Monash University, Clayton Campus**

		Date
Signature 1	R. Brown*	30/5/13

* Original signature in hardcopy version

6.1. Publication 6: Extending Transition Management: A second-generation meta-governance framework

6.1.1. Introduction

The thesis so far has presented a range of studies that provided conceptual, methodological and empirical insights related to the deliberate facilitation of transformative change in urban water systems. Publication 6 triangulates across the results from Publications 1, 2, 3, 4 and 5 to inform the design of a scope and architecture of a meta-governance framework, as a scholarly basis for guiding strategic initiatives to enable transformative change in complex urban infrastructure systems.

The article outlines the foundations of the existing *transition management* meta-governance framework (Loorbach, 2010; Rotmans and Loorbach, 2010; Voβ et al., 2009) and highlights two areas for extending transition management in order to optimise its capacity for critically informing the selection and design of strategic initiatives to most effectively influence each stage of a transition. It then proposes an architecture of a second generation meta-governance framework as a starting point for addressing these gaps by incorporating explicit mechanisms that conceptually link governance processes with analytic insights about transition dynamics during different stages of a transition. The article then introduces the concept of the framework toolkit, which consists of different content and process tools that should be utilised by actors for delivering the range of goals associated with different parts of the overall architecture. Use of the framework in practice is then reflected on.

The outcomes of Publication 6 contribute to the third research objective of this thesis, embedding the diagnostic procedure in a broader meta-governance framework for guiding the selection and design of strategic initatives that best fit a system’s current conditions (see Table 2).

6.1.2. Manuscript

Extending Transition Management: A second-generation meta-governance framework

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Accepted for presentation at the 4th International Conference on Sustainability Transitions, 19-21 June 2013, Zurich, Switzerland

Abstract: It is widely recognised that sustainability challenges in climate, energy, transport and water contexts mean radical changes in the design and management of socio-technical systems are urgently required. Transition management was developed as a meta-governance framework to address these challenges, focused on governing towards long-term sustainability goals by stimulating new innovations through a reflexive adaptive process. However, it has two limitations in its current form. First, it does not have explicit mechanisms to conceptually link governance processes with analytic insights about transition dynamics. Second, the instruments and methods used in transition management are directed at the pre-development stage of a transition and is therefore limited in its application at the take-off, acceleration and stabilisation stages. This paper aims to extend transition management to address these critical gaps by proposing an architecture of a second generation meta-governance framework for transformative change. The framework is designed to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model for application in specific transition contexts during all stages of a transition. The framework architecture is based on an iterative six-phase cycle that comprises specific process and content goals, with content and learning flows between phases. Different content and process tools are required to deliver the goals for each phase, constituting a toolkit that accompanies the meta-governance framework; existing transition tools fit one or more phases. The proposed framework provides an overarching logic for coordinating research focus and outcomes in the development of the next generation of transition management initiatives.

Key words
diagnostic procedure; governance; meta-governance framework; sustainability transitions; transition management

1. Introduction

Sustainability challenges are well explored in literature from diverse research fields and in many contexts, such as climate, energy, transport and water. The common message is that scholars and practitioners recognise radical changes in the design and management of socio-technical systems are urgently required (Grin et al., 2010; Chapin III et al., 2009). Despite robust debate within the literature on whether active navigation of a transition is desirable or possible (see, for example, Genus and Coles, 2008; Shove and Walker, 2007; Smith and Stirling, 2010), there is a growing community of academics, planners, policy analysts and decision-makers interested in making explicit interventions targeted at enabling sustainability transitions. While desired technological and/or procedural practices have been identified and tested for many socio-technical systems, there is limited understanding of how to intervene effectively in particular implementation contexts to enable the broader societal transitions for supporting new innovative solutions (Chapin III et al., 2009, Grin et al., 2010; Westley et al., 2011).

Transition management was recently developed as a meta-governance approach in the absence of prescriptive guidance for enabling transformative change (Loorbach, 2007; Loorbach, 2010; Voβ et al., 2009). This is a novel framework, focused on achieving long-term sustainability goals by stimulating new innovations through a reflexive adaptive process (Loorbach, 2010). As the first proposed framework of its type, it has attracted strong interest within transitions and governance scholarship. While there is contention around its empirical validity, effectiveness and engagement with power, politics and agency (Grin et al., 2011; Grin, 2012; (Loorbach and Rotmans, 2010; Rotmans and Kemp, 2008; Shove and Walker, 2007; Voβ et al., 2009), transition management has made a significant contribution to academic debate on governing long-term change for more sustainable outcomes. Policy practices in Europe and beyond have also been influenced, with a wide range of transition experiments and innovation programs established through the facilitation of transition management processes. Empirical testing of transition management in different policy arenas is ongoing (Loorbach & Rotmans, 2010; Nevens et al., 2013); however, there are two critical limitations in its current form.

First, transition management does not have explicit mechanisms to conceptually link governance processes with analytic insights about transition dynamics. Research within the field of sustainability transitions has sought to explain the patterns and trajectories of transformative change with increasingly sophisticated concepts and models (e.g. Rip and Kemp, 1998; Rotmans et al., 2001; Geels and Schot, 2007; de Haan and Rotmans, 2011). As such, there is significant potential for diagnostic insights about a socio-technical system's dynamics and transformative capacity (based on transition concepts) to inform the selection and design of strategic initiatives. Instead, transition management largely relies on the tacit knowledge of actors elicited through process instruments, to identify and prioritise strategies for enabling a transition (Loorbach, 2010; Nevens et al., in press). While tacit knowledge is valuable, theoretical knowledge about transition dynamics, developed through diagnosis of a wide range of cases, would significantly improve the basis for strategy selection and design in local system contexts.

Second, the instruments and methods used in transition management are directed at the pre-development stage of a transition (Loorbach, 2010; Loorbach and Rotmans, 2010). It is therefore limited in its application beyond the initial stimulation of niches and does not have the capacity to guide engagement with regime actors for mainstreaming innovations (Grin, 2012). Most transitions, particularly in urban infrastructure systems, are unlikely to involve complete substitution of a new technology. In urban water, for example, the regime of centralised water supply infrastructure provides a highly valuable role for society in equitably delivering safe, clean and secure supplies of drinking water across a city. System transformation needs to occur, but the regime must be engaged in that transition, particularly in its later stages. While stimulation and incubation of innovations are important and may be best undertaken outside of the regime, the take-off, acceleration and eventual institutionalisation of those niches with mainstream will require different governance processes and engagement with a much broader range of actors.

Empirical observation of transition management processes, as well as the related fields of strategic niche management and adaptive management, highlights strategic features that have been critical for enabling successful transitions. For example, sharing a common vision (e.g. Loorbach and Rotmans, 2010; Voβ et al., 2009), technical and governance experimentation (e.g. Farrelly and Brown, 2011; Huitema et al., 2009); incubation of innovation (e.g. Westley et al., 2011); stimulation of social learning (e.g. Bos et al., 2013; Pahl-Wostl et al., 2007); shadow networks (e.g. Olsson et al., 2006); nurturing of leadership (e.g. Huitema and Meijerink, 2010; Olsson et al., 2006); and creation of bridging organisations (e.g. Berkes, 2009; Folke et al., 2005). However, there is limited scholarly guidance on how and when these different initiatives should be utilised to most effectively influence the speed and direction of a transition. Development of a logic for coordinating different types of strategic interventions throughout a transition is a critical next step in the scholarly and practical extension of transitions governance concepts.

In summary, the transition management framework needs extension if it is to be capable of critically informing the selection and design of strategic initiatives to most effectively influence each stage of a transition. Key research questions for developing transition management in this direction include: How can diagnostic insights about transition dynamics inform governance interventions for transformative change? How should a governance framework be designed so it is applicable for all stages of a transition? What strategic initiatives are most effective for different transition stages? How can existing transition tools be best utilised to support strategic initiatives?

This paper aims to provide a starting point for systematically and critically engaging with these research questions by proposing an architecture of a meta-governance framework as a scholarly basis for developing practical strategic guidance. The framework aims to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model for application in specific transition contexts and provides operational guidance for actors wanting to steer system-wide transitions. The proposed framework provides direction for transitions scholars to develop the second generation of transition management with an overarching logic for coordinating research focus and outcomes.

2. Developing the Framework

The approach for developing a second-generation transition management framework, that addresses the critical gaps identified above, involved meta-analysis of scientific literature and an empirical case study of a successful practice transition in the urban water system of Melbourne, Australia. This research was undertaken through a doctoral program and the current paper represents the overall contribution from that work.

Details of the methods for individual components of the research are documented in separate publications. Ferguson et al. (2013) reviews existing frameworks in scientific literature on transformative change to assess their potential for contributing to diagnostic assessments; Ferguson et al. (submitted a) proposes a diagnostic procedure based on theoretical concepts from transitions, resilience and institutional scholarship; Ferguson et al. (in press) proposes a strategic program for transformative change in urban water systems drawing on lessons gained through a transition scenario development process implemented in Melbourne.

Results across these individual studies were triangulated to inform the design of a scope, architecture and toolkit for the proposed meta-governance framework. The following section presents these findings.

3. Presenting the Framework

The proposed second generation meta-governance framework for transition management is explicitly normative in its application, underpinned by the long-term goal of achieving a desired future system. The framework aims to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model that can provide operational guidance to actors wanting to facilitate transformative change in a system.

3.1. Framework Scope

Meta-analysis of literature on transitions and governance guided scoping of the proposed meta-governance framework. While space limitations mean full explication of individual results from this research cannot be detailed here, key outcomes are presented to demonstrate how they informed the design of the meta-governance framework.

Literature on the dynamics and governance of transformative change identifies key principles underpinning the design of a governance framework for guiding transformative change (e.g. Chapin III et al., 2009; Grin et al., 2010). The tenets of transition management proposed by Loorbach (2010) integrate many of these principles:

- Content and process go hand-in-hand
- Short-term goals are based on long-term thinking
- Objectives are flexible and adaptable, rather than formulated with a blueprint approach
- The timing of interventions has explicit consideration
- Periods of chaos and disruption bring opportunities for effective interventions
- Innovation is fostered in spaces protected from competition with existing regimes
- Internal and external factors influence system change
- Social learning is critical for facilitating transformative change
- Policy development and social learning are facilitated in participatory settings.

These tenets, as the foundation of transition management, form the overall scope of the proposed meta-governance framework. However, there are also specific requirements for individual components of the framework if it is to have diagnostic capacity for informing the selection and design strategic initiatives to enable transitions.

Ferguson et al. (2013) provides a detailed examination of the concept of diagnostic approaches for informing the selection and design of strategic initiatives. In reviewing literature on socio-technical and social-ecological systems in relation to system diagnosis, they propose a scope for a diagnostic procedure that:

- Guides questions about the system that become more specific as new information is discovered
- Is capable of analysis at scales of both the whole system and its individual variables
- Is capable of analysis of both static and dynamic system dimensions
- Is capable of analysis of a system's external context, actors, structures, processes and outcomes
- Incorporates a methodological framework for consistent application across different cases
- Is underpinned by analytic concepts that can describe and explain system changes
- Is capable of leading to predictions about how strategic initiatives will influence the system dynamics
- Identifies what strategic initiatives best fit the current system conditions for enabling desired changes.

Ferguson et al. (submitted a) conceptually develops a diagnostic procedure that meets the above scope for mapping the dynamics of a current socio-technical system and revealing insight into the types of strategic initiatives that are most likely to steer a transition in a desired direction. The procedure draws on transitions, resilience and institutional literature, and while it requires further development and validation, it sets out clear steps for diagnosing a system's transformative capacity:

1. Define the current system components and envision a desired future system
2. Determine what phase of change each relevant part of system is currently in
3. Determine what system conditions and transition patterns would be likely to result in the system changes required for achieving the future vision
4. Determine what institutional changes would be likely to induce the necessary conditions for enabling a transition
5. Identify the range of mechanisms for acting on institutions in the system to create the required changes for enabling a transition

The proposed meta-governance framework therefore would need to have capacity for guiding an analyst through these five steps in order to reveal how strategic interventions could trigger the required mechanisms for enabling system change.

The framework also needs to be capable of coordinating these interventions in a logical and practical manner for implementation by system actors. To address this question, Ferguson et al. (in press) propose a scope, logic and design base of a strategic program for coordinating and aligning action towards achieving a desired long-term future in urban water sectors.

Ferguson et al.'s (in press) strategic program was developed by drawing on conceptual insights from strategy and transitions literature, as well as from lessons in the content of a normative transition scenario produced by Melbourne's water practitioners during participatory workshops based on transition arena methodologies (Nevens et al., in press). The strategic program was specifically focused on the transition of a conventional urban water system based on technocratic engineering principles to an adaptive water sensitive system; however, with contextualisation, it would be applicable to other socio-technical systems. The strategic program comprised a series of content and process goals for the following dimensions:

- Set the decision-making context for the long-term:
    - Develop a shared sector-wide strategic direction through articulating visions, priorities and objectives that guide all strategic initiatives.
    - Develop a shared understanding of the system context by exploring possible future scenarios, challenges and opportunities that would shape the system's performance.
- Establish mechanisms for communication and control in the medium-term:
    - Develop a shared understanding of the system capacity by assessing the current and required resources, knowledge and tools across different

organisations that could respond to the strategic direction and system context.
    - Develop a series of strategic options across organisations to identify and evaluate the most effective options for delivering the long-term vision with the current system capacity
- Establish mechanisms for performance control in the short-term:
    - Develop programs of action related to selected strategic options for individual organisations or project teams to allocate resources and responsibilities for implementing actions in specific timeframes.

The various features outlined above provided the scope for guiding the design of an architecture and toolkit of the second generation meta-governance framework for transition management. The scope was synthesised into four key objectives that need to be supported by elements of the framework:

a) Diagnostic insights about the system's transformative capacity
b) Selection and design of strategic initiatives that best fit the current system
c) Learning and innovation through the execution of strategic initiatives
d) Reflexivity, flexibility and adaptability in the overall system governance

The following section presents the architecture of the framework in relation to these four objectives.

3.2. Framework Architecture

The framework architecture is based on an iterative cycle of six phases (Figure 1). Each phase has specific process and content goals; the process goal is either dependent on the content goal, or vice versa. The cycle demonstrates the sequential content and learning flows between phases, highlighting the type of understanding required during each phase for effective strategic interventions. 'Content flows' are actual products that have been developed, such as system data, visions, strategic plans and assessment outputs. 'Learning flows' are the insights gained by actors through process participation (in other words, the social learning). There is no prescribed timing for the implementation of each phase and multiple phases are likely to occur simultaneously. For example, there will always be activities occurring for Phase 5 (Strategy Implementation) and Phase 6 (System Monitoring), while Phase 2 (Desired Future System Mapping) may only occur every few years.

In strategic planning literature, Mintzberg (1994) argues that strategic success requires both creative and intuitive thinking as well as the analytic and programmatic thinking that tends to lead to the development of strategic plans (see also Heracleous, 1998). A meta-governance framework for guiding strategic initiatives therefore needs to coordinate these different modes of thinking in a way that will be most effective. Building on Loorbach's (2010) categorisation of four types of governance activities (strategic, tactical, operational and reflexive), the proposed framework defines six modes of thinking that are required to achieve the process and content goals in the different phases of its cycle. Strategic thinking refers to setting direction, synthesising ideas and identifying opportunities within a broad context. Tactical thinking refers to calculated and deliberate consideration of how to achieve goals within a specific context. Operational thinking refers to determination of how individual actions can be implemented within a specific context. Reflexive thinking refers to inward reflection on successes and failures in order to learn from experience and inform future decisions. Two additional modes of thinking are defined for the framework. Creative thinking refers to imaginative, divergent and original expression of thoughts and ideas. Analytic thinking refers to coherent and logical examination to gain detailed understanding.

Phase 1 of the framework aims to map the individual elements of an existing system and diagnose its current phase of change, through processes that allow actors to develop a shared understanding of the system, its recent history and the underlying causes of its persistent problems. These steps require analytic thinking.

Phase 2 aims to map a desired future system in terms of its envisioned composition and pathways for reaching it. This firstly involves processes with system actors to develop a shared vision of the future system (through creative thinking) and brainstorm strategies that could achieve the vision (through strategic thinking). It then involves processes where actors consider how resilience of the vision and pathways could be enhanced to cope with different future contexts and surprises (creative and strategic thinking).

Phase 3 aims to diagnose the transformative capacity of the existing system by contrasting its current conditions with the desired future. Analysis of the outputs from Phases 1 and 2 lead to insights about what parts of the system are receptive to change and the type of strategic initiatives likely to be most effective in steering desired change. System actors need to validate the outputs from this analytic mode of thinking in order for them to be relied upon as a base for developing a strategic program during the next phase.

Phase 4 aims to integrate the outputs from Phases 2 and 3 to design a strategic program for enabling transformative change in the system. This requires coordinated strategic planning processes across the whole system, where all relevant actors are engaged in strategic and tactical thinking. The output of this phase is a strategic program which aligns strategic planning and management initiatives for the whole system, including activities to implement the other phases. For example, the strategic program would need to address the future initiation of processes for Phase 1 (existing system mapping) and Phase 2 (desired future system mapping). In this sense, while design of the strategic program is embedded within the framework, the activities of each phase are delivered by embedding them within the strategic program to allocate responsibility for their actual implementation.

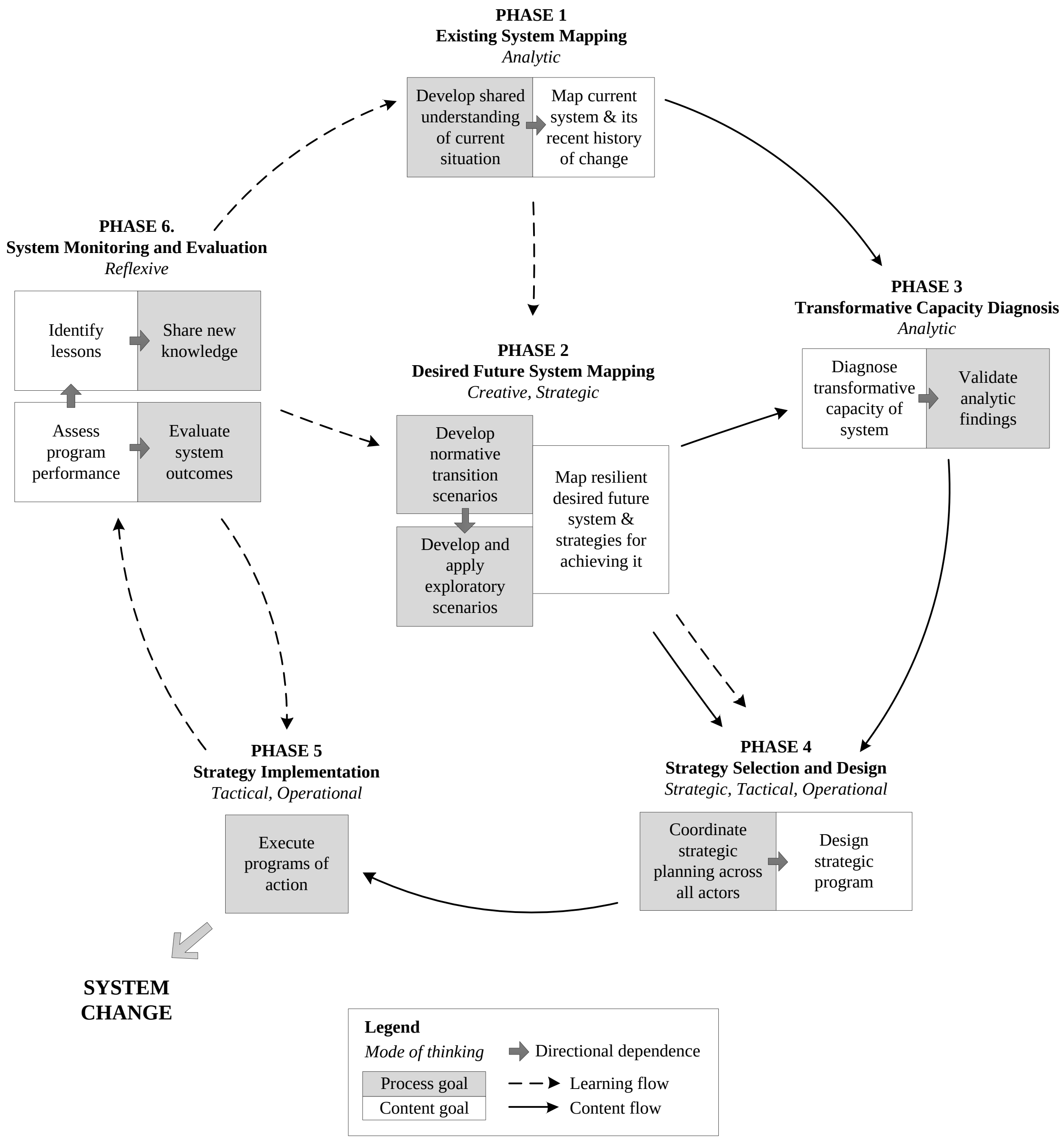

Figure 1. Architecture of proposed second generation meta-governance framework

Phase 5 aims to execute the programs of action defined in the strategic program from Phase 4 and as such, there are no content goals. Actual change in the system is achieved in this phase, through the implementation of actions in the specific system context (although the social learning of actors through all phases also contributes to system change). This phase requires tactical and operational modes of thinking.

Phase 6 aims to evaluate the performance of strategies that are executed in Phase 5, through making objective assessments of different elements of the programs of action. This assessment then allows overall evaluation of the system to be conducted with relevant actors, as well as specific lessons to be identified. Processes for sharing these lessons are also part of this phase. Reflexive thinking is at the heart of Phase 6.

The four key objectives for the meta-governance framework synthesised in Section 3.1 are addressed through combinations of phases (Figure 2). Content and process steps for Phases 1, 2 and 3 lead to diagnostic insights about the current system in relation to its capacity for transitioning towards the desired future vision. Steps for Phases 2, 3 and 4 involve the identification of strategic initiatives that are most likely to enable transformative change towards the desired future, given the current system's conditions. Steps for Phases 5 and 6 are focused on implementing action to support learning and innovation in the execution of the strategic initiatives. Steps for Phases 6, 1 and 2 adopt a paradigm of reflexivity, flexibility and adaptability to inform future system directions with the insights from past experiences.

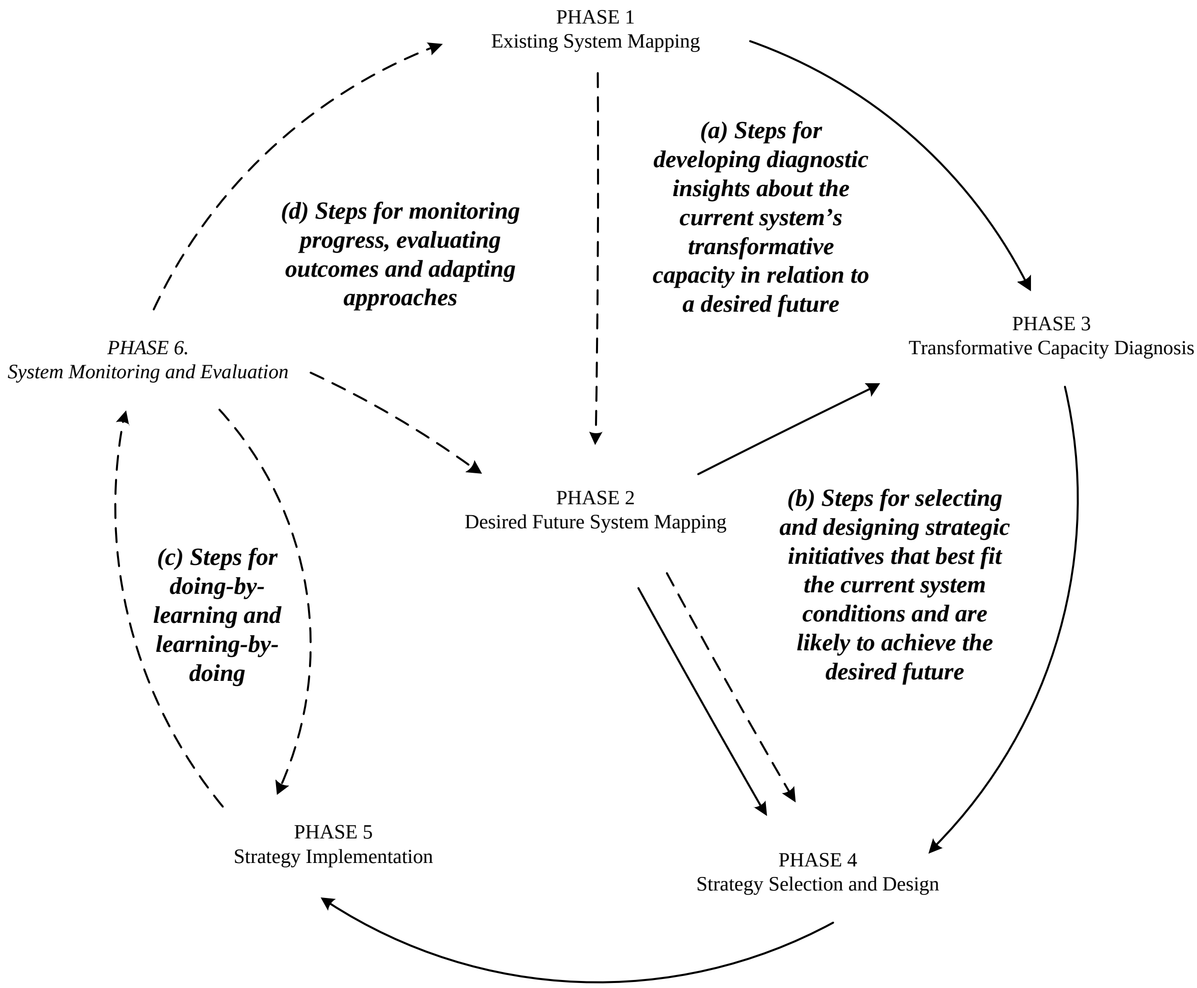

Figure 2. Key objectives for the meta-governance framework: (a) Diagnostic insights about the system's transformative capacity; (b) Selection and design of strategic initiatives that best fit the current system; (c) Learning and innovation through the execution of strategic initiatives; (d) Reflexivity, flexibility and adaptability in the overall system governance.

3.3. Framework Toolkit

Each phase of the proposed framework requires different content and process tools for delivering its goals (the term 'tool' is used here in the broadest sense). Content tools support the systematic, logical and detailed examination of a phenomenon (for example, empirical methods, conceptual relationships, theoretical propositions, assessment frameworks, metrics and models). Process tools engage with actors, implement initiatives and facilitate learning (for example, networks, forums, participatory methods, communication devices and policy instruments). Many existing tools from transitions studies fit one or more phases of the framework (Table 1).

The existing tools are at varying stages of development. Some tools are fully operational but require empirical testing and validation. Others are at a conceptual stage and require further methodological development to guide its application. Yet others have theoretical hypotheses embedded within that require empirical testing and validation for the tool to be relied upon. It is beyond the scope of this paper to comment on the current status and necessary future development for the various tools. However, a systematic review of all possible tools associated with transformative change (from transitions literature and beyond) is an important next step in the development of this second generation meta-governance framework. This would also serve to identify critical gaps, highlighting where research should focus to extend existing or develop new tools to support transitions.

The use of particular content and process tools in the proposed meta-governance framework will vary with the stage of a transition. For example, the transition arena process tools are largely designed for shadow track activities which would be most effective in the pre-development stage of a transition. Exploratory scenario tools are likely to be suitable for later stages where the regime needs to consider how it will continue to function in all possible future contexts. As such, the toolkit sits alongside the overall framework architecture and particular tools should be selected to best suit the specific governance needs at different transition stages. Again, further research is required to provide guidance on which tools are most effective at different stages of a transition.

Table 1. Existing transition management tools located in the meta-governance framework.

Phase	Content Tools	Process Tools
1. Existing system mapping	• Multi-level perspective for mapping interactions between landscape, regime and niche scales (Geels, 2002; Geels, 2004; Rip and Kemp, 1998; Smith et al., 2010) • Multi-phase S-curve for mapping different stages of transition processes over time (Rotmans et al., 2001; van der Brugge and Rotmans, 2007) • Multi-pattern approach for mapping patterns of system change over time (de Haan and Rotmans, 2011)	• Transition arena methods for participatory definition of existing system problems (Loorbach, 2010; Nevens et al., 2013; Voβ et al., 2009)
2. Desired future system mapping	• Transition scenarios, including vision and strategies (Sondeijker et al., 2006; Wiek et al., 2006)	• Transition arenas methods for participatory development of long-term future visions (Loorbach, 2010; Nevens et al., 2013; Voβ et al., 2009) • Transition arena methods for participatory backcasting of strategic transition pathways (Phdungsilp, 2011; Quist et al., 2011; Robinson et al., 2011) • Methods for participatory development of explorative context scenarios and wildcards (Saritas and Smith, 2011; van Notten et al., 2005; Walker and Salt, 2006; Wardekker et al., 2010)
3. Transformative capacity diagnosis	• Theory on the dynamics of transitions, validated with empirical research (Geels and Schot, 2007; Ferguson et al., submitted b) • Operational diagnostic procedure for transformative change (Ferguson et al., 2013; Ferguson et al., submitted a)	
4. Strategy selection and design	• Strategic program for transformative change (Ferguson et al., in press). • Design framework for creating social learning situations (Bos et al., 2013). • Framework for understanding power and legitimisation in transition processes (Grin, 2012)	• Methods used in transition arenas for participatory development of transition agendas (Loorbach, 2010; Nevens et al., 2013; Voβ et al., 2009) • Transition arena processes for fostering shadow actor networks (Loorbach, 2010; Olsson et al., 2006; Voβ et al., 2009)
5. Strategy implementation	• Competence kit (learning module) for practitioners involved in transition experiments (Raven et al., 2010) • Framework of success factors in governance experimentation (Bos and Brown, 2012)	• Transition experiments for stimulating innovation (Farrelly and Brown, 2011; van den Bosch, 2010) • Strategic niche management processes for incubating and up-scaling innovation (Raven and Gregersen, 2007; Schot and Geels, 2008)
6. System monitoring and evaluation	• Organisational capacity assessment framework (Bos and Brown, submitted)	• Processes for knowledge generation and sharing (Berkes, 2009)

Note: This list is not exhaustive but serves to highlight common tools referred to in transitions literature. Only selected references are indicated.

4. Using the Framework

While there will be no one privileged position for an actor to steer a system's trajectory, the meta-governance framework provides a logic and architecture for coordinating the activities of multiple actors who seek to intervene in a system to enable a transition. These actors could be scientists, strategic planners, policy analysts and decision-makers with formal roles and responsibilities in a system, or they could be operating outside the existing regime as part of an informal network. In fact, the actors who are involved in governance initiatives of a system will largely depend on the stage of a transition. For example, during the pre-development stage it is likely that the governance activities identified in the framework will be conducted informally as part of a shadow network, while the stabilisation stage may require the fundamental involvement of mainstream governance actors in strategic planning and implementation activities.

The decision of when and how the regime should be involved needs careful consideration. While individual regime actors may be innovative and make a valuable contribution to shadow track activities, the regime as a whole could potentially stifle creativity, experimentation and innovation if it is engaged too early in a transition, since resistance to change is a core part of a regime's characteristics. On the other hand, regime involvement will eventually be critical for a transition to be achieved, particularly in systems where the aim is not regime replacement but adaptation (urban water servicing is a prime example of such a system). From research undertaken in the development of this paper, it would anecdotally seem that the most effective time to engage with the regime is when the transition is sufficiently progressed to already have substantial momentum, evidence and commitment, so that the existing regime can be convinced of the value in adapting its approach. However, further research is required to develop guidance about when and how a regime is best brought into transition governance processes.

The proposed second generation transition management framework is generic and can be utilised at different operational scales and contexts. For example, while it is well suited to an urban water sector that comprises integrated scales of infrastructure and a diversity of actors, it could equally be applied to a particular technological industry, a social-ecological system or an individual organisation that needs to undergo transformative change. This flexibility comes with its meta-governance nature, since the aim of the framework is not to replace existing governance processes. Instead it is designed to complement them, linking diagnostic insights about a system's transformative capacity with governance processes to enhance the effectiveness of strategic initiatives for enabling a transition.

5. Conclusions

This paper proposed a second-generation meta-governance framework, building on the established foundations of transition management. The logic of the framework architecture and toolkit sets the direction for transitions researchers to coordinate the focus and outcomes of future activities. With this coordination, the next wave of transition management scholarship can work towards developing the capacity to critically inform the selection and design of strategic initiatives with diagnostic insights into how change can most effectively be influenced during all stages of a transition.

The paper has highlighted a number of areas where significant research is required to develop this capacity within transition studies. First, existing tools within literature on transitions and transformative change should be systematically reviewed to take stock of established capacities and reveal critical knowledge gaps that require attention. Examination of which process and content tools are most effective for different stages of a transition should also be undertaken so that transition management concepts can be extended beyond the pre-development stage. Insight into the type of actors (from niches and regimes) and their roles, relationships and responsibilities during different stages of a transition is needed so that guidance for governance processes can be developed. Substantial empirical evidence about the patterns and trajectories of transformative change is needed so that reliable theory on transition dynamics can be developed to support diagnostic assessments of a system's transformative capacity. Finally, the influence of actor strategies on these transition dynamics needs empirical examination and theorising so that best-fitting strategic initiatives can be selected and designed.

There is clearly a full research agenda for the development of the next generation of transition management concepts. While debate about the potential, politics and practicality of deliberately steering transformative change is important and set to continue, the question of how actors can influence system change effectively is critical if society is to address growing challenges around the sustainability and resilience of socio-technical systems. As such, we look forward to new and valuable insights to inform these issues from transitions research in the coming years.

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6.2. The FaST Framework

The framework presented in Publication 6 is named "FaST: Facilitating System Transitions". As described above, the FaST framework in its entirety provides guidance for actors wanting to steer the direction and pace of transformative change in a system. In addition, the individual elements of FaST offer other utilities. For example, the content tools of Phases 1 to 3 can be used independently of FaST, as a structured base for guiding retrospective empirical studies with a diagnostic purpose. Critical comparison of multiple case studies would then enable theory building and hypothesis testing, further informing the development of new and existing tools that constitute the FaST toolkit.

It is expected that as further research on transformative change is conducted, established tools that are refined and new tools that are developed would form part of the toolkit. Positioning these content and process tools within the FaST framework architecture explicates their dependencies and interconnections with other strategic and governance initiatives so they can be most effectively utilised to steer system change in a desired direction. To highlight this, the following section details how contributions from this thesis conceptually link together as part of the FaST toolkit.

6.3. Contributions to the FaST Toolkit from this Thesis

The FaST toolkit is far from complete, although many preliminary and established tools from the literature on transitions and resilience fit one or more phases of the framework (see Table 1 of the manuscript in Section 6.1). Some content tools were newly developed during this PhD research, focusing on linking detailed insights about transition dynamics with the selection of strategic initiatives so that implemented actions best fit the current local context of the system, as described in Chapter 6.3.1. Some existing process tools were also applied during this research, as detailed further in Chapter 6.3.2.

6.3.1. Content tools

The content tools deliver specific content outcomes for each phase of the FaST cycle. As such, many of the tools are conceptually linked in a procedural design to enable the required flow of content through the phases. For example, one content tool in Phase 1 is a method to produce a map of the existing system describing its overall composition and the structure of individual subsystems. This map is used by a different content tool in Phase 2 as data for addressing diagnostic questions. The sequence for applying the content tools is therefore important and dependencies between different tools needs to be made clear in order to understand how their outputs will inform either analyses or processes of subsequent phases.

The tools for Phases 1, 2 and 3 map the structures and dynamics of the system in order to diagnose its transformative capacity. Collectively, they address the range of diagnostic questions proposed in the operational scope of a diagnostic procedure of Publication 1. The tools for Phase 4 use these insights to inform the design of the strategic program for enabling transformative change. Table 8 provides an overview of these new content tools and Figure 9 highlights the procedural sequence that should be followed in their application. Each tool is then briefly described, along with an explanation of how it should be used to deliver the content goals required for the FaST framework. The relevant thesis chapter (listed in Table 8) can be referred to for further details of each tool.

Table 8. New content tools developed in this thesis

Phase		Content Tool	Objective	Contribution	Thesis Reference	DQ*	Status	Future Work
1. Existing system mapping	(a)	Method for system mapping and characterisation of empirical cases	Develop a system map of current constellations	New method developed	Publication 4 (5.3.2) Publication 2 (2.2.2)	1, 3, 4	Operational	Empirical testing
	(b)	Method for tracing impact of actor strategies on institutional trajectories in empirical cases	Analyse recent dynamics of individual constellations	New method developed	Publication 4 (5.3.2)	2, 5	Operational	Empirical testing
	(c)	Conceptual relationship for mapping institutional work types against the adaptive cycle	Determine the phase of change for each constellation	New relationship and hypotheses developed	Publication 2 (2.2.2)	2	Conceptual Theoretical	Methodological development Empirical testing and validation
2. Desired future system mapping	(a)	Method for system mapping and characterisation of illustrative cases	Develop a system map of desired future constellations and list of possible transition strategies	New method developed	Publication 4 (5.3.2)	1	Operational	Empirical testing
3. Trans-formative capacity diagnosis	(a)	Conceptual framework for analysing transition conditions and patterns	Determine the conditions and patterns required to drive desired changes	Established framework extended	Publication 2 (2.2.2)	6	Conceptual	Methodological development
	(b)	Conceptual framework for determining which institutions need to be created, maintained or disrupted	Determine the institutional work required in each constellation to achieve desired changes	Established framework developed	Publication 2 (2.2.2)	6	Conceptual	Methodological development
	(c)	Conceptual relationship for identifying which institutional work mechanisms best fit the current system	Identify the best-fitting mechanisms for enabling desired change	New relationship developed	Publication 2 (2.2.2)	7	Conceptual	Methodological development
	(d)	Theory about about effective strategies for different transition phases and institutional alignment with existing regimes	Identify the priority mechanisms for overcoming limitations to desired constellation growth	New hypotheses developed	Publication 4 (5.3.2)	7	Theoretical	Empirical testing and validation
4. Strategy selection	(a)	Conceptual relationship for mapping actor strategies against best fitting institutional work mechanisms	Develop a suite of actor strategies for enabling desired changes	New relationship developed	Publication 5(5.4.2)		Conceptual	Methodological development
	(b)	Scope, logic and design base of strategic program for transformative change	Design a strategic program for enabling desired changes	New framework developed	Publication 5 (5.4.2)		Conceptual	Methodological development

*** DQ: Diagnostic Questions addressed (Publication 1):** (1) What are the system variables? (2) What changes have occurred in the system variables over time? (3) What specific variables are significant for the system problem under consideration? (4) What are the relationships between these specific variables? (6) How could specific variables and relationships change the system outcomes? (7) What mechanisms are likely to enable desired change?

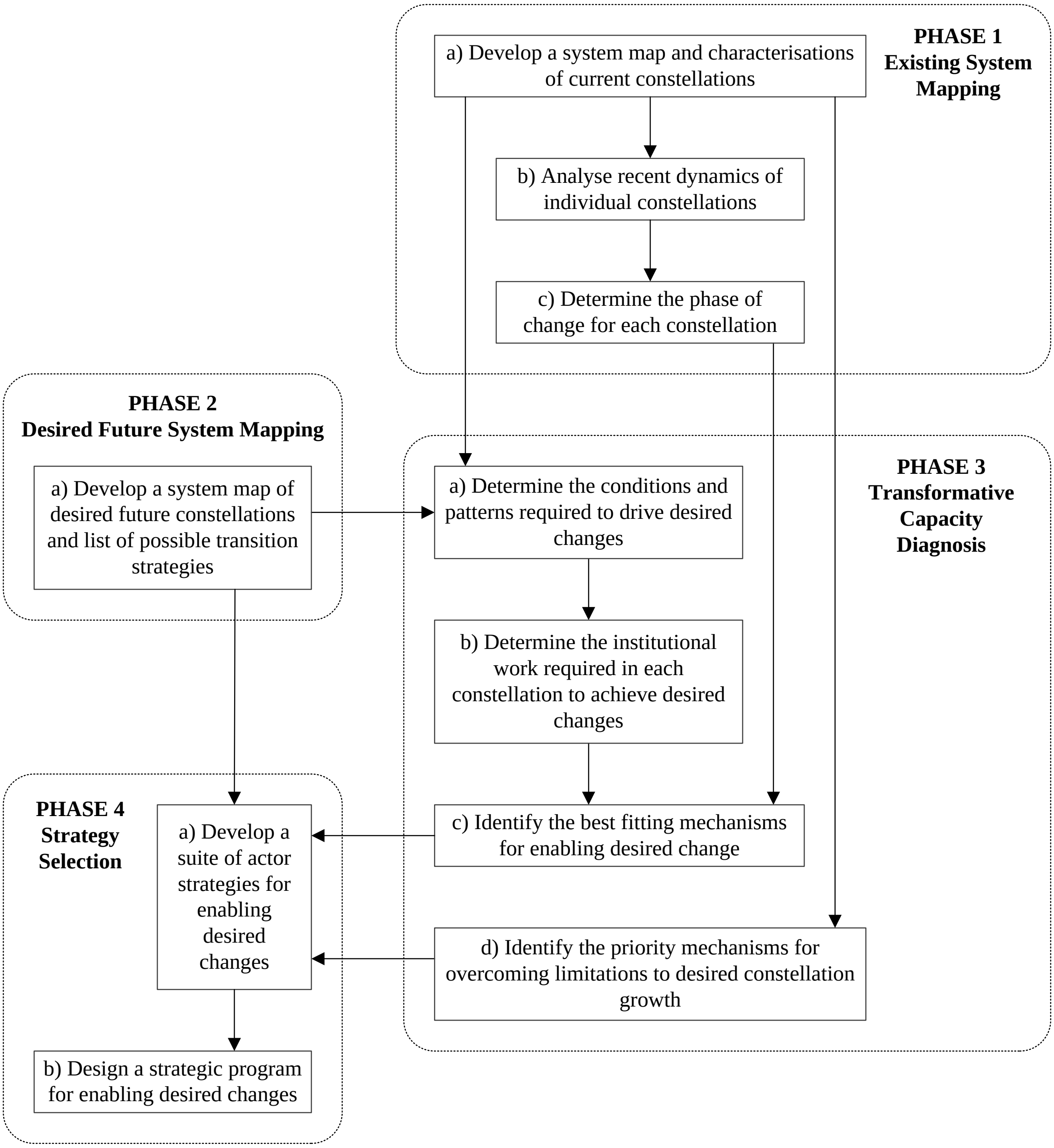

Figure 9. Procedural steps for the application of new content tools developed in this thesis

Phase 1 (Existing system mapping)

(a) Develop a system map and characterisations of current constellations

The analytic method for studying empirical cases of transitional change (detailed in Publication 4) is used to translate the shared understanding of a system developed in Phase 1(i) to a system map that identifies the full set of constellations in a system. The method is also used to characterise the constellations according to their level of power and institutional alignment with existing regimes. Constellations will either be regimes, niche-regimes, niches or pre-niches, depending on their degree of influence in the system. Each constellation will comprise a range of cultural-cognitive, normative and regulative institutional structures, which will determine whether it has a reinforcing, neutral or disrupting relationship with existing regimes. This method, as presented in Publication 4, is fully operational but requires further empirical testing.

(b) Analyse recent dynamics of individual constellations

The analytic method for studying empirical cases of transitional change (detailed in Publication 4) is used to map the impact of landscape pressures and actor strategies on the institutionalisation pathways of individual constellations identified in the existing system map (developed in 1(a)). Landscape pressures will either have a disruptive or specific shock influence on the system. Actor strategies will have impact on a constellation's cultural-cognitive, normative and/or regulative institutional structures. This method, as presented in Publication 4, is fully operational but requires further empirical testing.

(c) Determine the phase of change for each system constellation

The hypothesised associations between institutional work mechanisms and phases of an adaptive cycle (detailed in Publication 2) are used to determine each constellation's current phase of change according to which types of institutional structures were the focus of recent actor strategies identified in 1(b). Cultural-cognitive mechanisms are hypothesised to be most effective in the release and reorganisation phases of an adaptive cycle, normative mechanisms in the reorganisation and exploitation phases and regulative mechanisms during the exploitation and conservation phases. These conceptual relationships are hypotheses which require empirical testing and validation. The tool also requires further methodological development to provide guidance for how the actor strategies should be be used as indicators for the adaptive cycle position.

Phase 2 (Desired future system mapping)

(a) Develop a system map of desired future constellations and list of possible transition strategies

This step translates the transition scenario developed in Phase 2(i) into content that can be used in other Phases. First, the transition scenario is directly translated into a list of potential strategies that could be incorporated into a strategic program as part of Phase 4. Second, the analytic method for studying empirical cases of transitional change (detailed in Publication 4) is used to identify the full set of constellations in the system that would represent the desired future vision. Constellations are characterised according to their level of power and institutional structure types. Constellations will either be regimes, niche-regimes, niches or pre-niches, depending on their level of influence in the system. Each constellation will comprise a range of cultural-cognitive, normative and regulative institutional structures, which will already be existing in current regimes, new and non-competitive with regime structures or new and competitive with regime structures. This tool is conceptual, taking the same system mapping approach as 1(a), and requires methodological development to guide the translation of the vision to a system map.

Phase 3 (Transformative capacity diagnosis)

(a) Determine the conditions and patterns required to drive desired changes

This objective involves contrasting the system map of the existing system map (developed in 1(a)) and desired future system map (developed in 2(a)) to determine what changes are required to move from one to the other. The multi-pattern approach (detailed in Publication 2) is used to determine which transition patterns (reconstellation, empowerment or adaptation) are likely to result in the constellation changes required for the desired transition and the conditions (tension, pressure or stress) that would be likely to drive these patterns. This tool requires methodological development to guide the application of these concepts for empirical cases.

(b) Determine the institutional work required in each constellation to achieve desired changes

This step integrates existing conceptual frameworks (the multi-pattern approach and institutional work, as detailed in Publication 2) and applies them to determine which institutional structures in the existing system need to be created, maintained or disrupted for each constellation in order to induce the conditions for desired change identified in 3(a). Further methodological development is required to guide this tool's application for empirical cases.

(c) Identify the best fitting mechanisms for enabling desired changes

The phase of change for each constellation, identified in 1(c), is used by the tool in this step (detailed in Publication 2) to determine whether cultural-cognitive, normative or regulative mechanisms would most effectively work to create, maintain or disrupt institutional structures within a constellation to enable the desired changes. As for the other content tools in this phase, further methodological development is required to guide its application for empirical cases.

(d) Identify the priority mechanisms for overcoming limitations to desired constellation growth

This step draws on the theoretical insights about constellation growth (developed in Publication 4) to identify the scope of actor strategies that are likely to be most effective in enabling desirable growth of constellations, given their level of power and institutional alignment with existing regimes, as identified in 1(a). The following hypotheses are made about the *aim* of actor strategies during different phases of a constellation's growth: institutional work for *pre-niche* constellations should aim to relate the potential benefits of the constellation to the adverse impacts on the system functioning due to the landscape pressure; institutional work for *niche* constellations should aim to exploit regime synergies, institutionalise new constellation structures and deinstitutionalise competitive regime structures; and institutional work for niche-regime constellations should aim to develop the full range of required institutional structures and maintain an ongoing narrative to relate the benefits of the constellation with adverse landscape pressure impacts on the system functioning. The following hypotheses are made about the *type* of actor strategies for constellations with different relationships with regimes; cultural-cognitive work will be the initial driver for institutional change in all types of constellations during the pre-niche phase; constellations that have a *disrupting relationship* with existing regimes will require cultural-cognitive, normative and regulative work during all phases of its growth; constellations that have a *reinforcing* relationship will be likely to require a narrower scope of institutional work, with cultural-cognitive and normative work during the niche-phase, and then additionally regulative work during the niche-regime phase. These insights inform the identification of which mechanisms are a priority for implementation and therefore the selection of actor strategies that would trigger them accordingly. The hypotheses at the foundation of this tool need empirical testing and validation.

Phase 4 (Strategy selection)

(a) Develop a suite of actor strategies for enabling desired changes

This objective involves mapping the list of strategies for achieving the desired future developed in 2(a) against the best fitting and priority institutional work mechanisms identified in 3(c) and 3(d). The result of this analysis is a suite of actor strategies that are expected to most effectively enable the desired system changes. The relationship between transformative capacity and actor strategies for enabling change is conceptual and requires further methodological development for it to be used as a tool in empirical cases.

(b) Design a strategic program for enabling desired changes

This step organises the suite of actor strategies developed in 4(a) into a structure that fits the scope, logic and design base of a strategic program for transformative change (detailed in Publication 5). Specific strategies are allocated to individual or groups of actors according to their roles and responsibilities, but the strategic program provides effective coordination of the collective sets of initiatives to most effectively enable system-wide change. Programs of action are designed, specifying actions, resources, responsibilities and timing for delivering the recommended strategies.

6.3.2. Process tools

The process tools of FaST are specifically designed to achieve a process goal for a particular phase. The methods used in transition arenas (e.g. Loorbach and Rotmans, 2010), is one such example. A transition arena brings a small network of frontrunners together to engage with each other while exploring different system questions. In Phase 1 of FaST, the transition arena provides a forum for defining the system's current problems through specific methodological steps. In Phase 2 of FaST, the transition arena provides a forum for actors to collectively envision a desired future, through a different set of methodological steps. Application of a process tool results in the social learning of actors engaged in the process and/or the achievement of a content goal.

This PhD research applied several established and preliminary process tools as part of the multiple-case study B, as highlighted inTable 9. The use of these tools focused on developing transition scenarios for two different municipality clusters of Melbourne. The methodological steps are found in Appendix C and Frantzeskaki et al. (2012b) and the outcomes of their application are found in Appendix F and Ferguson et al. (2012c, 2012d). Appendix D describes the development and results from the context scenarios tools and Appendix E describes the wildcard tools. While testing and validation of these tools was not a core aim of this thesis, insights from their application were gained regarding the status of the tool and required future work.

Table 9. Established and preliminary process tools applied in this thesis.

Phase		Process Tool	Objective	References	Contribution	Thesis Reference	Status	Future Work
1. Existing system mapping	(i)	Method for participatory definition of existing system problems	Develop a shared understanding of current system conditions and problems	Loorbach, 2010; Nevens et al., 2012	Established methods applied	Publication 5(5.4.2)	Operational	Empirical testing and validation
2. Desired future system mapping	(i)	Method for participatory development of normative transition scenarios	Develop a shared long-term vision of a desired future and strategies for achieving it	Phdungsilp, 2011; Quist et al., 2011; Sarpong and Maclean, 2011; Sheppard et al., 2011; Sondeijker et al., 2006	Established methods applied	Publication 5(5.4.2)	Operational	Empirical testing and validation
	(ii)	Method for participatory development of context scenarios and wildcards	Develop descriptions for a broad range of future contexts and scenarios that could influence the system functioning	Saritas and Smith, 2011; Walker and Salt, 2006; Wardekker et al., 2010	Established methods applied	Publication 5(5.4.2)	Operational	Empirical testing and validation
	(iii)	Method for participatory exploration of transition scenario resilience	Develop a shared understanding of how the resilience and robustness of the vision and strategies could be enhanced	Kok et al, 2011	Preliminary methods applied	Publication 5(5.4.2)	Conceptual	Conceptual and methodological development

Phase 1(Existing system mapping)

(i) Develop shared understanding of the current causes of system problems

The tool for this process step comprises methodological steps for participatory analysis of an existing system to come to a shared definition of its problems and underlying causes. These steps are based on methods used in transition arenas (Loorbach, 2010; Nevens et al., 2012), as detailed in Chapter 4.5 and Publication 4. This tool is well established; however, it requires empirical testing and validation, particularly with regard to its use in a range of socio-political contexts, as well as its effectiveness in informing strategic initiatives for enabling transitional change.

Phase 2 (Desired future system mapping)

(i) Develop a shared vision and strategies for achieving it

The tool for addressing this objective is a method for participatory development of normative transition scenarios. It involves steps for envisioning a desired future to identify images and objectives that represent long-term goals, as well as steps for backcasting to identify short, medium and long-term strategies that will overcome current challenges and enable the transition to the desired future vision (e.g. Phdungsilp, 2011; Quist et al., 2011; Sarpong and Maclean, 2011; Sheppard et al., 2011; Sondeijker et al., 2006). These steps are based on methods used in transition arenas (Loorbach, 2010), as detailed in Chapter 4.5 and Publication 4. This tool is fully operational and has been applied in a number of cases for different systems (Loorbach and Rotmans, 2010). However, it requires empirical testing and validation, particularly with regard to its use in a range of socio-political contexts, as well as its effectiveness in achieving transitional change in a system.

(ii) Develop scenarios of the future contexts and surprises that could affect the system

This objective is addressed through a method for participatory development of context scenarios and wildcards, collectively referred to as exploratory scenarios. It involves steps for considering the external trends, shocks and extremes that could potentially affect the implementation of strategies and successful achievement of the vision (e.g. Saritas and Smith, 2011; Walker and Salt, 2006; Wardekker et al., 2010). Factors that are considered significant are synthesised into a set of context scenarios and wildcards (see Appendix D and E). These steps are based on methods used in scenario planning, as detailed in Chapter 4.5. The development of exploratory scenarios is a fully operational tool and has been applied in many different contexts, although the development of wildcards is less established. The effectiveness of exploratory scenario planning in improving long-term planning needs to be further tested.

(iii) Consider the vision and strategies in the context of exploratory scenarios

This objective is addressed by integrating the normative transition scenario developed in 2(i) with the exploratory scenarios developed in 2(ii) in a participatory process. The method involves considering how the vision and strategies would need to be adapted to better cope with the range of future contexts and surprises presented in the scenarios. Combining exploratory and normative or backcasting methodologies is preliminary in its use, with a few examples in the literature canvassing its possibilities for use in scenario planning (e.g. Kok et al, 2011). However, there are limited examples of how it is operationally conducted in practice. Its application in this research revealed that such a tool is feasible and offers significant potential but that more conceptual and methodological work is required for it to be best utilised for enhancing the resilience of a transition scenario.

CHAPTER 7. IMPLICATIONS AND OUTLOOK

This chapter describes the scholarly and practical implications of the research presented in this thesis. Limitations of the research are outlined and a future research agenda is scoped.

7.1. Scholarly Implications

There are four key scholarly contributions of this thesis:

1) In-depth case studies of transitions in urban water as a base to inform theorising on transformative change as part of water resources, transitions and resilience scholarship.
2) Developed a suite of tools within transitions, resilience and strategy scholarship: (a) a diagnostic procedure for revealing insight into the transformative capacity of a system; (b) an analytic method for characterising a system and its institutions; and (c) a strategic program for guiding transformative change initiatives in urban infrastructure systems.
3) Extended transitions and resilience scholarship with hypotheses on the links between the dynamics of transformative change and the scope of actor strategies for effective strategic intervention.
4) Extended transition management scholarship with an architecture of a second generation meta-governance framework for guiding the selection, design and coordination of strategic initiatives to enable transformative change in complex urban infrastructure systems.

The implications of each of these contributions are detailed below.

7.1.1. Empirical case studies of transitions in urban water

There is wide recognition that there is a lack of empirical evidence about the dynamics of transformative change (Chapin III et al., 2010; Farla et al, 2012; Loorbach, 2010; Westley et al, 2011). Tentative explanations about the patterns of interactions between different variables at the macro, meso and micro levels of a system are offered in the literature (e.g. Geels, 2002; Smith et al., 2005), however there is a need to build a rich empirical evidence base so that generalisations about trajectories of change can be made. Empirical cases provide the data with which to test, refine and validate theory about the dynamics of transformative change, which can then more effectively support efforts to purposefully intervene in a system to steer the direction and pace of a transition. The two multiple-case studies developed in this thesis contribute to building this empirical base.

Multiple-case study A is a detailed case study of Melbourne’s contemporary water system from 1997-2012, presented in Publications 3 and 4. Melbourne is internationally recognised as a leading city in terms of innovation in sustainable water management (Jefferies and Duffy, 2011; Roy et al, 2008) and during the last 16 years, a range of system-wide transformative changes have occurred. Detailed investigation of how and why these changes occurred provides insight into the dynamics of transformative change in an urban water system and the scope of actor strategies required for enabling such change.

Multiple-case study B is an illustrative case study of anticipated transitions in Melbourne’s future water system between 2012 and 2060, presented in Publications 3 and 5. Presented as a transition scenario for two municipality clusters, the case study data was generated through participatory workshops with practitioners from Melbourne’s water sector. These water practitioners have developed tacit knowledge about how to support innovation and reform mainstream approaches through strategic initiatives and therefore offer unique case study data for informing thinking about strategical planning and management of urban water transitions.

The data from both multiple-cases case studies could be further analysed to give different insights in future work that asks new research questions. For example, the case studies validate many of the concepts and hypotheses found in literature on adaptive management and transition management about important strategic initiatives for enabling transitions, which could be explored in future research. The data could also be used in comparisons with other case studies of urban infrastructure transitions in order to develop new insights about the role and influence of actor strategies in facilitating transformative change. Finally, the data could be used to extend scholarship on the multi-pattern transitions approach (de Haan and Rotmans, 2011), by analysing how the micro-processes that institutionalised individual innovations related to dynamic changes across the overall water system in Melbourne.

7.1.2. Suite of tools for diagnosing transformative capacity and operational guidance

Sustainability scholars warn against blueprints or panaceas for addressing a system problem, instead urging for diagnostic approaches be adopted, which aim to determine the nature, cause or source of a problem by systemically taking complexity into account (Cox, 2011; Ostrom and Cox, 2010; Pahl-Wostl, 2009; Pahl-Wostl et al., 2010). Calls for the use of diagnostic approaches has only recently emerged in the literature and these early articles are exploratory in nature, still defining what is even meant by diagnosis of environmental problems (e.g. Cox, 2011). Hence, there is a lack of knowledge about how diagnostic approaches can be used to provide insights into how integrated systems can be better managed in their local contexts. Further, transitions scholars have consistently called for new analytic methods for understanding transition dynamics and there are limited examples of *operational* tools to support scientific and policy conceptions of actor strategies (e.g. Markard et al., 2012; Elzen and Wieczorek, 2005; Genus and Coles, 2008; Holtz, 2012; Smith et al., 2008).

While existing frameworks within the literature on socio-technical systems and social-ecological systems can potentially provide diagnostic insights (e.g. Social-Ecological Systems Sustainability Framework, Ecosystem Stewardship Framework, Panarchy Framework, Multi-Pattern Transitions Framework and the Management and Transitions Framework), they are not capable of being (or designed to be) applied in practice for the explicit purpose of diagnosing the transformative capacity of social-ecological systems. This thesis took on this challenge to develop a suite of analytic tools that can potentially contribute to diagnostic approaches.

The first tool, a diagnostic procedure for revealing insight into the transformative capacity of a system, was developed in Publication 2 and guided by the operational scope proposed in Publication 1. It integrates concepts from transitions theory (the multi-pattern approach), resilience theory (the adaptive cycle) and new institutionalism (institutional pillars and institutional work) in a sequence of analytic steps that identifies the type of strategic initatives that are likely to be most effective in enabling change. The second tool, an analytic method for characterising a system and its institutions, was developed in Publication 4. It uses transition concepts and institutional pillars in a framework for identifying the constellations that comprise a system, their institutional composition, degree of influence and relationship with existing regimes. The third tool, a strategic program for transitioning to water sensitive cities, was developed in Publication 5. It operationalises transitions and resilience concepts to provide practical guidance for how sustainability challenges can be addressed through adaptive and transformative planning and management approaches.

Collectively, these tools address the range of diagnostic questions considered important for informing the selection, design and coordination of strategic initiatives for facilitating transformative change. While empirical testing and methodological development of the tools are required, they offer scholarly and practical steps forward in the operational use of diagnostic approaches, particularly for using insights about a system's recent history to inform the selection, design and coordination of strategic initiatives that best fit the current system conditions.

7.1.3. Hypothesised links between transition dynamics and actor strategies

It is widely recognised in transitions and resilience scholarship that the links between transformative change and strategic action are underdeveloped and further empirical and theoretical research is needed to determine how system change can be most effectively steered in a desired direction and pace (e.g. Chapin III et al., 2010; Elzen and Wieczorek, 2005; Huitema et al., 2009; Loorbach, 2010). While the literature identifies that mechanisms to support innovation and social learning are critical for enabling transformative change, there is little insight into how and when different types of strategic initiatives are likely to have the most significant influence on a system going through different phases of change. This question was addressed during this PhD research through the formulation of two sets of hypotheses in the conceptual development of tools and analysis of the empirical cases.

The first set of hypotheses considers the relationship between cultural-cognitive, normative and regulative institutional pillars and positions of the adaptive cycle. It contends that strategic mechanisms that act on the cultural-cognitive pillar will be most effective during the Ω (release) and α (reorganisation) phases of the adaptive cycle. Mechanisms that act on the normative pillar will be most effective during the α (reorganisation) and r (exploitation) phases. Mechanisms that act on the regulative pillar will be most effective during the r (exploitation) and K (conservation) phases. While these hypotheses require empirical testing and validation, they offer significant implications for selecting strategic initiatives to enable future change. By mapping the recent history of a system according to the adaptive cycle positions of strategic initiatives, insight into what future mechanisms are likely to be most effective can be gained.

The second set of hypotheses relates actor strategies to different parts of the system, namely their power levels and institutional alignment with existing regimes. It proposes that strategies to enable the continued growth of a pre-niche should aim to highlight the potential benefits of the pre-niche to the adverse system impacts caused by a landscape pressure. Strategies to enable the continued growth of a niche should aim to exploit regime synergies, develop new institutions and destabilise competitive institutions in the regime. Strategies to enable the continued growth of a niche-regime should aim to reduce transactional complexity by developing the full range of required institutions and to maintain an ongoing narrative to relate the benefits of the niche-regime with adverse landscape pressure impacts on the system. It further proposes that cultural-cognitive institutional work would be most effective for pre-niches, regardless of their instiutional alignment with existing regimes.However, for niches and niche-regimes, the type of institutional work required will depend on the nature of their relationship with the regime. Disrupting relationships require cultural-cognitive, normative and regulative work during niche and niche-regime stages, while reinforing relationships are likely to only need regulative work during the niche-regime stages. These hypotheses also require empirical testing and validation. However, they potentially provide significant insight into the scope of strategies that should be utilised at different stages of a transition for different types of innovation. By mapping the recent institutional dynamics of individual constellations, the types of strategies that should be prioritised in future programs of action can be revealed.

These two sets of hypotheses establish a new theoretical base from which to explore the role of actor strategies in enabling transitional change. There is very limited evidence in the literature on how specific mechanisms have affected the dynamics of a transition. As such, regardless of whether or not the hypotheses are found to be valid, they provide a purposeful scholarly contribution by providing a base from which to theoretically and empirically explore of the impact of strategic interventions on the unfolding of dynamic processes of transformative change.

7.1.4. Architecture of a second generation meta-governance framework for transformative change

This thesis has developed the architecture of a second generation meta-governance framework for guiding the selection, design and coordination of strategic initiatives to enable transformative change in urban infrastructure systems. This framework, known as "FaST" (FAcilitating System Transitions) aims to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model that provides operational guidance for actors wanting to steer the direction and pace of a system-wide transition. The FaST framework extends scholarship on transition management (Loorbach, 2007; Loorbach, 2010; Voβ et al., 2009) by addressing two critical limitations of the transition management framework in its current form.

First, transition management does not have explicit mechanisms to conceptually link governance processes with analytic insights about transition dynamics, instead largely relying on the tacit knowledge of actors elicited through process instruments, to identify and prioritise strategies for enabling a transition (Loorbach, 2010; Nevens et al., in press). Phase 3 of the FaST framework (transformative capacity diagnosis) provides this critical analytic step by informing the selection of strategic initiatives with detailed insight into what types of interventions are likely to best fit a given set of local conditions. While a strong empirical evidence base is required for the theoretical insights to be relied upon, this innovation of the FaST framework offers significant potential in improving the effectiveness of strategic initiatives selected to facilitate transformative change.

Second, the instruments and methods used in transition management are directed at the pre-development stage of a transition (Loorbach, 2010; Loorbach and Rotmans, 2010), which means it is limited in its application beyond the initial stimulation of niches and does not have the capacity to guide engagement with regime actors for mainstreaming innovations (Grin, 2012). The FaST framework's architecture allows flexibility in its use and its six phases are relevant for all stages of a transition. However, the FaST tools that are selected for implementation will vary with each stage, as will the actors involved in using those tools. Further, the development of a strategic program in Phase 4 particularly supports the interface with mainstream governance processes, by providing a mechanism for coordinating strategic initiatives while accommodating the complexity of organisational actors involved in the system.

Other governance approaches in sustainability scholarship, beyond transition management, explore how the sustainability or resilience of a system can be enhanced. Strategic niche management, in transitions literature, focuses on the incubation of innovations by providing a protected space for socio-technical niches to develop before competing in the mainstream market. Adaptive management is described in socio-ecological systems literature as a means for enhance the resilience of a system through principles of reflexivity and adaptive capacity, long-term perspectives and systems thinking. These approaches, as well as transition management, highlight factors that have been empirically observed as being critical features of transformative change: sharing a common vision (e.g. Loorbach and Rotmans, 2010; Voβ et al., 2009), technical and governance experimentation (e.g. Farrelly and Brown, 2011; Huitema et al., 2009); incubation of innovation (e.g. Westley et al., 2011); stimulation of social learning (e.g. Bos et al., in press; Pahl-Wostl et al., 2007); shadow networks (e.g. Olsson et al., 2006); nurturing of leadership (e.g. Huitema and Meijerink, 2010; Olsson et al., 2006); and creation of bridging organisations (e.g. Berkes, 2009; Folke et al., 2005). However, there is limited scholarly guidance on how and when these different initiatives should be utilised to most effectively influence the speed and direction of a transition. The FaST framework provides the capacity to logically position these success factors in an overall architecture so that their dependencies and interconnections can be explicated. FaST highlights the content goal, process goal and modes of thinking required for each of its sequential phases and in doing so, connects different types of strategic initiatives according to where they would be most effectively utilised. For example, social learning is promoted as an essential ingredient of transformative change. Tracing the 'learning flows' of the FaST framework allows the role and type of learning required to be more clearly specified, and as a result, the tools for enabling that learning can be better designed.

In summary, the architecture of FaST is a significant scholarly contribution because it extends transition management as a second generation meta-governance framework by: (a) incorporating diagnostic insights to improve the effectiveness of strategic initiatives selected to facilitate transformative change; (b) providing a flexible meta-governance approach that can be applied for all stages of a transition, including engagement with the regime; (c) providing a coordinating logic for positioning different strategic initiatives within an overall framework to maximise their influence on the speed and direction of a system's transition; and (d) providing direction for transitions scholars to further develop the second generation of transition management with an overarching logic for coordinating research focus and outcomes.

7.2. Practical Implications

This research is framed by the real world problem that the traditional engineering approach for managing urban water systems is inadequate for coping with current and future contexts and changing societal needs. These sustainability challenges are not just relevant for urban water but for many different integrated systems such as energy, waste and transport infrastructure. Practitioners in these sectors are increasingly aware of the need to shift the ways in which strategic planning and management is undertaken but the pressing question of *how* to support joined-up action across multiple stakeholders to enable transformative change and achieve aligned objectives is yet to be answered in way that provides practical guidance. The aim of the research was therefore to not only contribute scholarly insights into the dynamics of transformative change but also to provide practical insight into how transformative change can be facilitated in real urban infrastructure systems.

From an overall perspective, the FaST framework is a prescriptive model, designed to provide operational guidance to actors wanting to facilitate transformative change in a system. While it was developed through the exploration of urban water systems and its applicability to urban water systems is therefore obvious, it could equally be used by actors in other complex adaptive systems such as urban infrastructure sectors. The application of the FaST framework and toolkit still needs to be tested; however, its modular and flexible nature makes it suitable for tailoring to particular local contexts, including the individual content and process and the actors that are involved in implementing different strategic initiatives. The FaST framework provides guidance on when and how a range of content and process tools (such as empirical methods, assessment frameworks, metrics, models, actor networks, forums, participatory methods, communication devices and policy instruments) would be most effectively utilised to facilitate transitions. It further offers guidance for how strategic initiatives can be coordinated and implemented within a strategic program that engages with regime actors and complements mainstream governance structures.

The diagnostic procedure developed in the thesis (described in Publication 2) provides a platform for underpinning an operational tool for supporting strategic management and decision-making in urban water systems. Use of diagnostic approaches to support the planning of urban infrastructure systems would address some of the critical flaws in planning agendas that focus on controlling variables and reducing uncertainties for linear change processes. Instead it would enable practitioners to examine proposed policy and action within the context of the broader system, embracing the reality of its complexity, interconnectedness and contextual uncertainty that frames society's needs from its infrastructure. It would provide insight into the likely timing of windows of opportunity so that strategic initiatives could be selected to achieve maximum effectiveness at different phases of a transformation and to prepare the system for likely upcoming changes. Finally, it would provide actors with a systemic understanding of how adaptive change can be welcomed rather than resisted, encouraging the proactive development of strategic plans to increase adaptive capacity and facilitate the transition towards a resilient and sustainable system.

The analytic method developed in Publication 4 provides an individual tool for steering a trajectory in a desired direction. For a transition to be successful, institutions within all three of cultural-cognitive, normative and regulative categories need to be developed. Actors wanting to facilitate a transition can use this tool to map and analyse the institutions in existing regimes and other subsystems to identify synergies and potential conflicts. Actors can then purposefully select strategies to institutionalise new structures in an upcoming innovation, as well as strategies that can deinstitutionalise structures within existing subsystems that are likely to compete with new desirable institutions. Informing the selection of strategies in this way would help to maximise their effectiveness in enabling desired transformative change in a system.

To summarise, the practical implications of this PhD research is in the development of an overall meta-governance framework and collection of tools that provide practical guidance to actors who want and need to develop, implement and evaluate policies, strategic plans, processes and actions that can effect desired transformative change in a system.

7.3. Research Limitations

The research has several limitations, although many of these can be addressed through future investigations.

The new content tools presented in this thesis are not fully developed. Some are fully operational (i.e. 1(a) and (b)) as an analytic method, however they require further empirical testing. Others are presented as preliminary conceptual relationships (i.e. 1(c), 2(a) 3(a), 3(b), 3(c), 4(a), 4(b)) but require further methodological development if they are to be applied consistently as a tool. Other tools (i.e. 1(c), 3(d)) are based on theoretical hypotheses that require empirical testing and validation before they can be used to inform the selection of strategic initiatives in practice.

The overall FaST framework is yet to be applied in practice and empirically tested. Without this testing, the real value and potential for the application of the FaST framework to a broad range of systems cannot be assessed. In particular, the tools that form the diagnostic procedure within Phases 1-4 of FaST have not been tested on a whole empirical case. While individual tools have been applied to parts of the case, the research would benefit from a whole application to any water system to demonstrate its effectiveness for informing the design of a strategic program to enable its transition to a water sensitive city.

The research has not considered the full range of tools that are available or would be required for the FaST framework to be considered complete. The status and required future work for specific tools developed or applied in this thesis are commented on; however the further development of FaST would benefit from a review of all the tools that are available in literature on transitions and adaptive management (or other scholarly fields of work), as well as a consideration of the full suite of process and analytic tools that would be necessary for the goals in each phase of FaST to be achieved.

The research has not investigated how the power relationships and dynamics between actors influence the effectiveness of actor strategies on facilitating system transitions. Instead it has taken a functional perspective that only considers actors in terms of their functional role in selecting, implementing and evaluating strategic initiatives.

7.4. Future Research Agenda

As implied above, there are a range of theoretical, methodoligcal and empirical gaps that need to be filled for the FaST framework and accompanying toolkit to be considered operational. Reflecting on such limitations poses a future research agenda for extending and challenging the scholarly and practical contributions of this thesis.

7.4.1. Next theoretical steps

Theoretical work is required to develop detailed insights into the characteristics of a system during different phases of a transition. This includes conceptualising key variables and relationships that feature during these different phases, as well as developing sets of indicators that can function as an analytic tool for positioning a system along a transition trajectory. This positioning could then provide a basis for making assessments about which types of strategic initiatives will be most effective at a given point in time. The links between different phases of a transition and the effectiveness of different types of analytic and process tools also needs further theorisation. Similarly, theoretical work is needed to understand the types of roles different actors should play to most effectively support each phase of a transition.

Theoretical research to support the development of individual content tools is required. For example, this thesis focused mainly on dynamics for institutionalising new innovations. New theoretical insight about institutional disruption and maintenance is critical for further enhancing knowledge about how transitional change can be enabled. This would involve the development of new conceptual frameworks that enrich understanding about how actor strategies and landscape pressures can work to deinstitutionalise existing regime structures.

Further theoretical research is also required to understand how the institutionalisation of individual subsystems relates to an overall societal transition. This would involve exploration of the interactions between subsystems and how they compete with or empower each other as part of a system's overall dynamics. Such conceptual insights would further inform the selection of strategic initiatives for facilitating system transitions.

Enriched theoretical insight into the impact of different types of socio-political drivers on a system's transition dynamics would also be valuable. For example, what are different conceptualisations of landscape pressures and how do they affect different types of system change? What impact does the evolution of societal needs have on the dynamics of a system? These types of nuanced insights may have critical influence on when and how different types of strategic initiatives are most effective so the development of suitable conceptual tools is necessary for critically analysing their impacts.

Finally, the FaST framework and toolkit needs to be assessed in the context of a broad literature review to confirm its six phases and associated content and process goals are sufficient for enabling transformative change in a system. Such a review should also assess whether the content and insight flows identified are suitable and valid. It would also lead to the identification of missing tools, as well as opportunities to incorporate and develop additional tools that support the operationalisation of the FaST framework for facilitating system transitions in practice.

7.4.2. Next methodological steps

There are key methodological questions that need to be addressed for both the individual tools developed in this thesis, and the FaST framework as a whole.

Methodologies for integrating different content and process tools should also be explored. For example, there is significant potential for the framework and toolkit to form a platform for developing computer-aided decision support tools. An example of such software currently under development is "DAnCE4Water" (Dynamic Adaptation for Enabling City Evolution for Water), which produces virtual scenarios of developments in societal systems, urban form and water infrastructure and allows exploration of how they evolve in response to various external and internal factors (e.g. Rauch et al., 2012). Tools such as this, designed to explore future scenarios by providing computer simulations that support rigorous policy experimentation, offer significant potential as part of the FaST toolkit. The use of these types of exploratory tools within participatory processes aimed at strategic thinking and planning requires substantial methodological research.

Methodological development required for individual tools includes research into how exploratory context scenarios and wildcards can be most effectively utilised. For example, how should the use of context scenarios and wildcards be operationalised within a participatory process to enhance the resilience of a future vision and its strategic pathways? How can exploratory scenarios be used to anticipate potential windows of opportunity that may be taken advantage of by through different types of strategic initiatives?

Other methodological developments required relate to the new content tools developed as part of the diagnostic procedure in this thesis. Many of these tools are not yet operational, since to date they are only based on a conceptual relationship. Further development is required to demonstrate the methodological steps an analyst must take in applying each of these the tools. This guidance would promote consistency in the tool's application, so that critical comparisons of different cases analysed with the tools can be made.

A methodological approach for the use of FaST needs to be developed. A system transition requires the coordination and alignment of many different actors, each of whom will have their own perspectives and interpretations. The political nature of navigating transitions is regularly highlighted in the literature (e.g. Stormer et al., 2009; Shove and Walker et al., 2010; Smith et al., 2005; Voss et al., 2009) so the development and use of the FaST framework needs to be mindful of how different agendas, interests and responsibilities can be accommodated in a transparent and effective way.

Future methodological research should also reflect on how the transition arena process steps were adapted for the Melbourne context. Transitions literature comments on the need to implement transition management processes in many broad contexts in order to test and validate its methodology (e.g. Loorbach and Rotmans, 2010). The Melbourne case study application therefore provides rich data for such a reflection.

7.4.3. Next empirical steps

Empirical testing of the two major sets of hypotheses (outlined in Chapter 7.1.3) is required, through detailed case study investigations in a broad range of contexts. Empirical validation of the links between the effectiveness of institutional work mechanisms and a system's adaptive cycle positions would support the theoretical base for informing the selection of future strategic initiatives. Further, empirical validation of the scope of actor strategies that are hypothesised to be most effective for enabling the continued growth of pre-niche, niche and niche-regime constellations is required if the hypotheses are to inform strategic priorities.

The FaST framework and toolkit needs to be applied and tested in empirical contexts to assess its value, potential and limitations. This includes both the overall framework and its individual tools, and it should be tested in urban water and other types of systems. Of particular empirical interest is how the different stages of a transition influence the effectiveness of tools that are implemented and actors that are involved for each of the six FaST phases.

Finally, many more detailed empirical cases of transitional change need to be developed to provide a rich evidence base for the many theoretical developments still required for strategic interventions to be most effective in facilitating system-wide transitions.

7.4.4. A full research agenda

In summary, the development of a meta-governance framework and individual tools in this thesis makes a substantial scholarly and practical contribution. However, research that can support transformative change in systems such as urban water servicing is young and there are many avenues of research that require further exploration. The FaST framework is offered as an architecture for coordinating the outcomes of such research in a form that provides operational guidance for practitioners and researchers. It is hoped that this framework and its toolkit can be used to maximise the effectiveness of joined-up strategic initiatives for facilitating real world change to a resilient and sustainable future.

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APPENDICES

APPENDIX A. RESEARCH ETHICS FORMS

Explanatory forms for research interviews and participatory workshops

Consent forms for research interviews and participatory workshops

MONASH University

School of Geography and Environmental Science, Faculty of Arts

EXPLANATORY STATEMENT for Persons Participating in Research Interview

Title: Enabling the transition to a Water Sensitive City: Melbourne case-study

This information sheet is for you to keep.

My name is Briony Ferguson and I am a PhD candidate, supervised by Professor Rebekah Brown in the School of Geography and Environmental Science, conducting research for the Centre for Water Sensitive Cities at Monash University. The aim of this research is to develop a framework to guide strategic action for enabling systemic socio-technical change from conventional water servicing to water sensitive alternatives, based on the case of Melbourne. The research will investigate the historical, contemporary and possible future developments in Melbourne's water system in order to gain an improved understanding of the patterns and mechanisms that have been significant for systemic transformational change. These insights will be used to develop a conceptual model that allows planners, policy-makers and decision-makers a means with which to examine the potential long-term effectiveness of proposed policy and action within the context of the broader urban water system.

I am requesting your participation in this research in order to develop an understanding of how the developments in Melbourne's water system have unfolded from a socio-institutional perspective. You were contacted via a publicly-listed telephone number or email and asked by one of our research team to participate in this interview as someone who could provide insight into the urban water industry. We expect to interview approximately 30-40 persons from the Melbourne water sector. I will be collecting and analysing the data, under the guidance of Associate Professor Rebekah Brown. We are both located at the School of Geography and Environmental Science at Monash University.

The duration of the interview is expected to be between 45-90 minutes. I would like to interview you at a time and place convenient to you between 18 July and 31 August 2011. The interview is voluntary and anonymous and you have the right not to answer any questions for any reason. You can choose to withdraw from the research at any time by contacting the researchers (listed below). Your permission will be sought to audio-record your interview for subsequent written transcription. You will not be identified by name or organisation in the research. Quotations from the interview will only be used where you have given prior permission to use them in our reporting to industry. The data will also be reported in a PhD thesis, journal articles, conference presentation or used in future research projects.

The data you provide will only be available to our research team within the school; your name and identity will not be revealed in any other way. Storage of the data will adhere to University regulations and kept on University premises in a locked filing cabinet for 5 years.

Thank you for your time. Your input into this research is very much appreciated.

If you would like more information about any aspect of this study, please contact the researchers:	If you have a complaint concerning the manner in which this research CF10/3357 - 2010001774 is being conducted, please contact:
Ms Briony Ferguson (PhD Candidate) School of Geography and Environmental Science Building 11, Clayton Campus Monash University VIC 3800 [redacted] Professor Rebekah Brown (Chief Investigator) School of Geography and Environmental Science Building 11, Clayton Campus, Monash University VIC 3800 Tel.: 03 9905 9992 [redacted]	Executive Officer Monash University Human Research Ethics Committee (MUHREC) Building 3e Room 111 Research Office Monash University VIC 3800 [redacted]

MONASH University

School of Geography and Environmental Science, Faculty of Arts

EXPLANATORY STATEMENT for Persons Participating in Workshop Series

Title: Enabling the transition to a Water Sensitive City: Melbourne case-study

This information sheet is for you to keep.

My name is Briony Ferguson and I am a PhD candidate, supervised by Professor Rebekah Brown in the School of Geography and Environmental Science, conducting research for the Centre for Water Sensitive Cities at Monash University. The aim of this research is to develop a framework to guide strategic action for enabling systemic socio-technical change from conventional water servicing to water sensitive alternatives, based on the case of Melbourne. The research will investigate the historical, contemporary and possible future developments in Melbourne's water system in order to gain an improved understanding of the patterns and mechanisms that have been significant for systemic transformational change. These insights will be used to develop a conceptual model that allows planners, policy-makers and decision-makers a means with which to examine the potential long-term effectiveness of proposed policy and action within the context of the broader urban water system.

I am requesting your participation in this research in order to develop an understanding of how the developments in Melbourne's water system have unfolded from a socio-institutional perspective. You were contacted via a publicly-listed telephone number or email and asked by one of our research team to participate in a series of workshops as someone who could provide insight into the urban water industry. Approximately 20 people from the Melbourne water sector will participate in the workshop series. I will be collecting and analysing the data, guided by Associate Professor Rebekah Brown. We are both located at the School of Geography and Environmental Science at Monash University.

The series is expected to consist of 4 to 6 one-day workshops, conducted over a period of approximately 7 months. A tentative workshop schedule will be sent to you at least 1 month in advance of the first workshop. Participation is voluntary and you can choose to withdraw from the research at any time by contacting the researchers (listed below). Your permission will be sought to photograph, video- and/or audio-record the workshops for subsequent analysis. You will not be identified by name or organisation in the research. Images, video and quotations of you from the workshop will only be used where you have given prior permission to use them in our reporting to industry. The data will also be reported in a PhD thesis, journal articles, conference presentation or used in future research projects.

The data you provide will only be available to our research team within the school; your name and identity will not be revealed in any other way. Storage of the data will adhere to University regulations and kept on University premises in a locked filing cabinet for 5 years.

Thank you for your time. Your input into this research is very much appreciated.

If you would like more information about any aspect of this study, please contact the researchers:	If you have a complaint concerning the manner in which this research CF10/3357 - 2010001774 is being conducted, please contact:
Ms Briony Ferguson (PhD Candidate) School of Geography and Environmental Science Building 11, Clayton Campus Monash University VIC 3800 [redacted] Professor Rebekah Brown (Chief Investigator) School of Geography and Environmental Science Building 11, Clayton Campus, Monash University VIC 3800 [redacted]	Executive Officer Monash University Human Research Ethics Committee (MUHREC) Building 3e Room 111 Research Office Monash University VIC 3800 [redacted]

MONASH University

School of Geography and Environmental Science, Faculty of Arts

CONSENT FORM for Persons Participating in Research Interview

Title: Enabling the transition to a Water Sensitive City: Melbourne case-study

Researchers: Ms Briony Ferguson, Professor Rebekah Brown

Consent Form for ____________________ of ___________________________

(participant name) *(organisation)*

I agree to take part in the Monash University research project specified above. I have had the project explained to me, and I have read the Explanatory Statement, which I keep for my records. I understand that agreeing to take part means that:

List all procedures relevant to your data collection – delete those not applicable

I agree to be interviewed by the researcher	☐ **Yes** ☐ **No**
I agree to allow the interview to be audio-taped	☐ **Yes** ☐ **No**
I give permission for anonymous quotes from my transcript to be reported in publications of the research findings	☐ **Yes** ☐ **No**
I agree to make myself available for a further interview if required	☐ **Yes** ☐ **No**

I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way.

I understand that any data that the researcher extracts from the interview for use in reports or published findings will not, under any circumstances, contain names or identifying characteristics.

I understand that any information I provide is anonymous, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party.

I understand that data from the interview will be kept in a secure storage and accessible to the research team. I also understand that the data will be destroyed after a 5 year period unless I consent to it being used in future research.

Participant's name:

Signature: **Date:**

NOTE: This consent form will remain with the Monash University researcher for their records

MONASH University

School of Geography and Environmental Science, Faculty of Arts

CONSENT FORM for Persons Participating in Workshop Series

Title: Enabling the transition to a Water Sensitive City: Melbourne case-study

Researchers: Ms Briony Ferguson, Professor Rebekah Brown

Consent Form for ____________________ of ___________________________

(participant name) *(organisation)*

I agree to take part in the Monash University research project specified above. I have had the project explained to me, and I have read the Explanatory Statement, which I keep for my records. I understand that agreeing to take part means that:

List all procedures relevant to your data collection – delete those not applicable

I agree to participate in the workshop series led by the researcher ☐ **Yes** ☐ **No**

I agree to allow the workshop series to be audio- and/or video-taped ☐ **Yes** ☐ **No**

I give permission for anonymous quotes from the transcript of my contributions to the workshop series to be reported in publications of the research findings ☐ **Yes** ☐ **No**

I agree to make myself available for a further interview if required ☐ **Yes** ☐ **No**

I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way.

I understand that any data that the researcher extracts from the workshops for use in reports or published findings will not, under any circumstances, contain names or identifying characteristics.

I understand that any information I provide is anonymous, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party.

I understand that data from the interview will be kept in a secure storage and accessible to the research team. I also understand that the data will be destroyed after a 5 year period unless I consent to it being used in future research.

Participant's name:

Signature: **Date:**

NOTE: **This consent form will remain with the Monash University researcher for their records**

APPENDIX B. ADDITIONAL CONFERENCE PAPERS

Ferguson, B.C., de Haan, F.J., Brown, R.R., Deletic, A. (2012) 'Testing a Strategic Action Framework: Melbourne's Transition to WSUD'. Proceedings for the 7th International Conference on Water Sensitive Urban Design, 21-23 February, Melbourne, Australia.

Ferguson, B.C., Brown, R.R., Deletic, A. (2011) Towards a socio-technical framework for mapping and diagnosing transformational dynamics in urban water systems. Proceedings for the 12th International Conference on Urban Drainage, 11-16 September, Porto Alegre, Brazil.

12th International Conference on Urban Drainage, Porto Alegre/Brazil, 11-16 September 2011

Towards a socio-technical framework for mapping and diagnosing transformational dynamics in urban water systems

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ABSTRACT

As the stress on urban water systems from climate change impacts, population growth and resource limitations continues to grow, the need to transition to sustainable urban water management is being increasingly acknowledged. However, understanding of how strategic planning should be made operational to enable this transition is limited, as the links between strategic action and the processes of transitional change are poorly understood. This paper reports on a social research investigation that aims to develop a diagnostic tool that can be used to inform the design of strategic action in urban water systems from the perspective of dynamic transformative change. A meta-analysis of literature that proposes frameworks for understanding the sustainability of complex socio-technical systems was undertaken in relation to an empirical case of recent transformational change in the stormwater management system of Melbourne, Australia. Each framework revealed useful insights but none were sufficient to fully map, explain and predict the transformational change in the case study. Comparison of the frameworks identified their distinct aims and key strengths and each was located within a schema that highlights how they could most usefully be used within an overall diagnostic process.

KEYWORDS

Urban water; transition; transformative change; strategic planning; diagnostic framework; sustainability

INTRODUCTION

Urban water systems are coming under increasing pressure due to climate change, population growth, ongoing urbanisation, environmental pollution, resource limitations and ageing infrastructure. These stresses have caused threats to water supply security, heightened flooding risk and the deterioration of urban waterway health in cities around the world (Pahl-Wostl *et al.*, 2010). The ensuing water management challenges will be exacerbated into the future, particularly as global impacts of climate change become more severe (Bates *et al.*, 2008), and there is now a growing awareness and acceptance of the need for urban water servicing to transition to sustainable approaches (Pahl-Wostl, 2009; Pahl-Wostl *et al.*, 2010).

For this transition in urban water systems to occur there will need to radical changes to its social and biophysical structures and processes. However, transformative change is impeded by a range of socio-institutional barriers, including institutional inertia and fragmentation, lock-in due to path-dependencies, and inadequate institutional, professional and community capacity to engage in new management practices (Brown, 2008; Pahl-Wostl, 2009).

There is limited research on how strategic planning should be made operational in order to overcome such socio-institutional barriers and enable a transition (Brown, 2008), although academic discourse is now starting to explore the topic. Recent literature argues the need to avoid panaceas or blueprints, which have been widely critiqued as being too simplistic to cope with complex, uncertain, nonlinear and changing contexts within which interdisciplinary systems are managed. Instead scholars (eg. Ostrom, 2009; Pahl-Wostl *et al.*, 2010) argue that diagnostic approaches need to be developed, which typically aim to determine the nature, cause or source of some problem, undesirable outcome or system state by considering complexity in a systemic fashion (Ostrom and Cox, 2010; Pahl-Wostl, 2009).

Despite these recent calls for new approaches, diagnostic tools have not yet been applied to gain operational insights for urban water servicing. Such insights would be particularly valuable for situations where radical changes to the way in which water servicing is designed, operated, managed, governed or valued are required to achieve more sustainable, or water sensitive, outcomes. Fundamental system-wide change in the structure of a system and the way in which it functions, as described above for water servicing, is more generally referred to as transformative or transitional change.

There is currently limited understanding of the links between strategic action and complex dynamics of transformative change (Chapin III *et al.*, 2010), so more research is required in order for tools to be developed to support strategic planning from this perspective. This paper reports on the first phase of a qualitative social research investigation that aims to develop a diagnostic tool that planners, policy analysts and decision-makers can use to inform the design of strategic action in urban water systems from the perspective of dynamic transformative change.

APPROACH

The methodological approach for this research involved theory testing and comparison as part of a meta-analysis of literature that examines the sustainability of complex interdisciplinary systems. Four analytic frameworks were applied to a common empirical case study in order to compare their features and test their potential value as platforms from which to build a diagnostic tool for transformative change in urban water servicing.

The frameworks were selected for review and application to the empirical case based on their interdisciplinary and systemic nature, their focus on sustainability and their applicability to the context of urban water servicing. The key attributes of each framework are outlined in Table 1.

The frameworks in Table 1 were each applied to an established empirical case of recent transformational change. The case study was a grounded historical analysis of how urban stormwater management in Melbourne has changed from mid 1960s to 2006 (for full details of the case study see Brown and Clarke, 2007). The empirical data in this case provided a reference case study with which to compare and benchmark the different analytic frameworks.

The context for the reference case study is the management of diffuse sources of pollution in the stormwater drainage system in Melbourne, Australia. During the period of study, growing awareness and community concern about the poor health of Melbourne’s waterways led to a scientific focus on understanding the causes of urban waterway degradation and developing ways in which stormwater pollution could be reduced. New innovative technologies for improving the quality of stormwater before it enters urban waterways were developed and, over time, practices that prioritised urban stormwater quality management (USQM) were institutionalised, fundamentally changing the direction of mainstream stormwater management policy (Brown and Clarke, 2007). The reference case study provides an analysis of how and why these transformative processes occurred. It is significant as an international exemplar of a city in which stormwater quality management practices have been mainstreamed.

Table 1. Attributes of the analytic frameworks.

Attribute	**Panarchy Framework**	**SES Sustainability Framework**	**Management and Transitions Framework**	**Multi-Pattern Transitions Framework**
Purpose	Analyse adaptive capacity and resilience in social-ecological systems.	Analyse sustainability in social-ecological systems.	Analyse water governance processes.	Analyse societal transitions.
Analytic Goal	Describe and explain dynamics of system-wide change and their implications for governance.	Describe, explain and organise the key variables that are significant for system sustainability.	Organise the structures and processes in a transitional system and their implications for governance.	Describe and explain the conditions, patterns and pathways of system-wide change.
Theoretical roots	Ecology; social-ecological systems; resilience.	Institutional Analysis and Development; ecology; socio-economic systems; social-ecological systems; resilience.	Institutional Analysis and Development; social-ecological systems; multi-loop social learning; adaptive management; transitions.	Complexity theory; integrated assessment; technology diffusion; innovation; societal transitions.
Theoretical concepts	Adaptive cycle; panarchy; rigidity trap; poverty trap.	Nested tiers of variables; networked action situations.	Action arenas and action situations; single, double and triple-loop learning.	Conditions – tension, stress, pressure; patterns – empowerment, reconstellation, adaptation.
Key references	Berkes *et al.*, 2003; Folke, 2006; Gunderson and Holling, 2002.	McGinnis, 2010; Ostrom, 2009; Ostrom and Cox, 2010.	Knieper *et al.*, 2010; Pahl-Wostl, 2009; Pahl-Wostl *et al.*, 2010.	de Haan, 2010; de Haan and Rotmans, 2011; Rotmans and Loorbach, 2009.

This paper reinterprets the reference case study through the application of the four frameworks to compare and contrast their features in relation to the development of a tool for mapping and diagnosing transformative change. Key understandings about the reference case study that were revealed through each framework were explored and any clear analytic gaps were identified.

While the frameworks have distinct backgrounds and purposes, the results provided insights on the ability of the existing concepts in these analytic frameworks to explain the variables, mechanisms and dynamics in the empirical case study. These insights were then used to outline the necessary features of a diagnostic tool that can map, explain and predict transformational change in urban water servicing.

APPLICATION OF FRAMEWORKS

The four frameworks were applied to the reference case study. Key understandings about the case study that were revealed through each analysis are described in the following sections.

Panarchy Framework

The framework revealed a long period of policy development around large-scale centralised drainage infrastructure. This regime was stuck in a "rigidity trap" for around 20 years, which limited the system's ability to adapt to new conditions. Growing community awareness and expectations around environmental issues led to significant contextual changes, forcing the regime to break from its rigidity trap as its traditional stormwater management policy began to fail; it was no longer adequate to the meet society's need for healthy waterways and bays.

This failure offered a window of opportunity for the innovative developments to transform mainstream policy. While the regime was in its rigidity trap, the lower scale innovation around decentralised USQM infrastructure had been developing new technologies. When the policy failure intensified, the innovation could provide the regime with a range of infrastructure options to support the policy alternatives.

The policy options stimulated by the USQM innovation were underpinned by a new paradigm, based on small-scale decentralised flexible infrastructure. As the regime began to adopt these policy alternatives, it entered a new and different adaptive cycle, exiting from the old centralised drainage cycle; in other words a transition took place. The transition, however, is only partially complete as policy plans in the new adaptive cycle are still in development and there is much growth needed before the new policy regime is implemented and stabilised.

SES Sustainability Framework

The framework identified six distinct action situations that were important for creating change to the way in which stormwater is managed were identified: society and politics; rule-making; provision; implementation; use; monitoring and sanctioning. These action situations form a network, with outcomes of one action situation providing inputs to an adjacent action situation (McGinnis, 2010), emphasising the need for entities to be interacting in each of the different adjacent functional action situations in order for the system to function properly.

There was significant overlap in the types of actors that were involved in the rule-making, provision and implementation action situations, indicating the strong potential for self-organisation amongst the actors and potentially explains the success of the transition towards more sustainable stormwater management. In particular, the state-owned water utility and the municipalities were shown to be key actors in almost all the action situations, highlighting the need for positive interactions between these key actors and their relative importance for successful functioning of the system.

Management and Transitions Framework

Informal processes (double- and triple-loop learning) played a key role in transforming the way in which stormwater was managed. Informal action situations covered all the phases in a learning cycle and all three institutional rule levels (constitutional, collective-choice, operational), potentially explaining the success of the innovation's growth to date. Formal action situations typically stemmed from previous informal action situations, further highlighting their importance in the overall transition.

There was a lack of locally driven action situations; most local situations were driven by state actors. This explains the case study's conclusions that there needs to be a strong emphasis on increasing the capacity of local councils in the area of stormwater quality management. Finally, the analysis highlighted that most of the action situations have been focused on developing policy, operational goals and measures, with much less emphasis on formal strategic goal setting as part of the policy cycle, as well as the other end of the cycle, implementation and monitoring. Perhaps these gaps indicate where future efforts should be focused to finalise the transition and make stormwater quality management mainstream.

Multi-Pattern Transitions Framework

Over a period of 20-30 years, growing community engagement with the urban landscape and awareness of environmental issues led to a significant change in how society values the health of urban creeks, rivers and bays. This new prioritisation of urban waterway health was a key top-down driver for change to the way in which stormwater is managed and led to the empowerment of a niche centred on the development of decentralised technologies for improving stormwater quality before it enters receiving waterways.

As society's need for healthy waterways grew, the empowered stormwater quality technology niche offered an increasingly viable alternative to the established regime, which was focused on the efficient conveyance of stormwater through large-scale centralised drainage infrastructure. The power dynamics between the regime and the niche were critical factors in determining how the system transformed in terms of the functioning of its stormwater management.

RESULTS AND DISCUSSION

Analysis of the four interdisciplinary sustainability-focused frameworks showed that each revealed useful understanding about the reference case study but, in isolation, none were sufficient to fully map, explain and predict the transformational change that has occurred in Melbourne's stormwater quality management system. The strengths and weaknesses of each framework in relation to explaining the data in the reference case study are summarised in Table 2.

Comparing and contrasting the four frameworks highlights that each has distinct aims and strengths, all of which are useful for understanding different aspects of the sustainability of interdisciplinary systems. However none of the frameworks are explicit about what specific diagnostic questions each intends to address and therefore how they should be used within an overall diagnostic process.

Table 2. Analytic strengths and weaknesses of each framework in relation to explaining the data in the reference case study.

	Strengths	Weaknesses
Panarchy Framework	Reveals the relative adaptive capacity of different scales and how this influences system change. Highlights critical interactions between scales that shape system change.	Limited in providing insight for designing policy action. Relatively abstract framework, which can be difficult to operationalise for application to empirical cases.
SES Sustainability Framework	Organises nested levels of variables so those that are critical can be identified. Determines functional adjacent action situations and key actors involved. Provides a framework for organising the collection of data (to enable meta-analyses of different case studies).	Narrowly defines a social-ecological system to common-pool natural resources. Provides a static analysis only. Assumes that transformational change in a system is negative, focusing instead on avoiding disturbance to maintain resilience.
Management and Transitions Framework	Highlights key sequences of processes and links between formal policy processes and informal social learning processes. Determines the role of actors in different action situations.	Provides limited insight into the impact of context. Does not reveal power dynamics between established formal processes and innovative informal processes.
Multi-Pattern Transitions Framework	Provides analysis of narratives of system-wide change. Reveals contextual and internal influences on system changes. Explores power dynamics between an institutionalised regime and new niche-innovations. Considers societal needs and how they may be met in the future.	Does not reveal insight into the internal dynamics of subsystems. Limited ability to reveal the smaller-scale processes and lower level variables that drive the patterns of system-wide change. No reference to actors and their role in influencing system change.

Comparison of the frameworks reveals two critical dimensions for mapping and diagnosis. The first is the scale of analysis. Analysis needs to be undertaken at both the system-wide scale and the scale of the individual system elements. The second is the dynamism of the analysis. Both static and dynamic perspectives are required in order to gain full understanding of the system. Figure 1 plots the frameworks considered in this research against these two dimensions, demonstrating where each currently provides focus (it is acknowledged that the frameworks are generally in early phases of development so their location may change with further research).

Figure 1 emphasises a key conclusion of this paper; there are different elements to diagnosis that require different analytic lenses to reveal useful information. So for an analyst with a particular problem that could be usefully addressed through a diagnostic approach, the framework that is selected for use depends on what specific diagnostic questions are being considered. For example, if understanding of the static individual variables that a system comprises were required for one point in time, then the SES Sustainability Framework would be the most suitable. If understanding of the system-wide dynamic changes were required, then the Multi-Pattern Transitions Framework would be the most suitable.

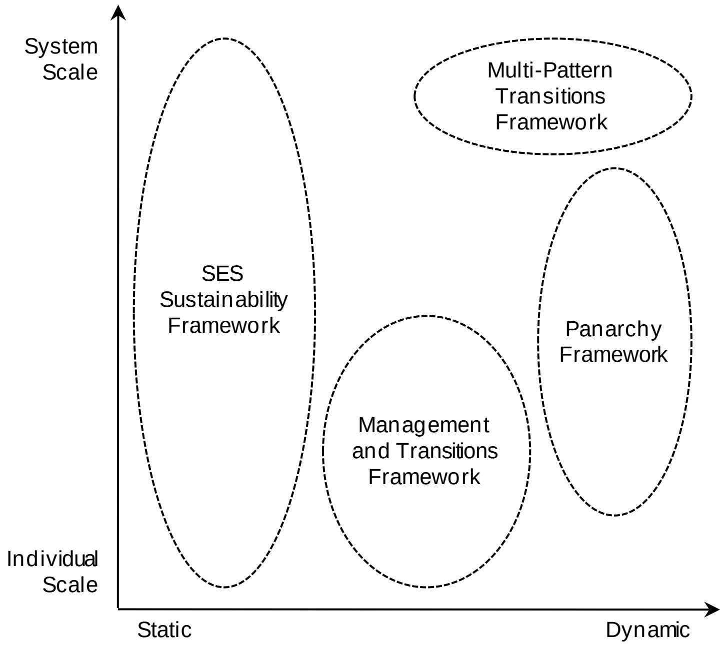

Figure 1. Key dimensions of diagnostic frameworks

If the diagnosis aims to fully map, explain and predict changes in the system, then multiple frameworks may need to be used. Application of multiple frameworks to provide a comprehensive diagnosis for transformative change in a system should provide understanding of the key institutional and biophysical dimensions of a system; the variables that describe the system’s biophysical and social features; the processes or mechanisms that shape significant change within the system; the macro-level, meso-level and micro-level dynamics that explain how the system changes; and the dynamics of both incremental and transformative change in the system.

CONCLUSIONS

The analysis in this paper has shown that existing analytic sustainability frameworks revealed useful understanding but, in isolation, none were sufficient to fully map, explain and predict the transformational change that has occurred in Melbourne’s stormwater management system since the 1960s.

Comparison of the different frameworks revealed that there are different elements to diagnosis that require different analytic lenses to reveal useful information. Understanding what specific diagnostic questions need to be considered is an important step to selecting the most suitable framework(s) for analysing a particular problem.

A combination of the frameworks reviewed in this research would provide a strong basis from which to build a diagnostic tool that can provide operational insights into strategic planning for transformative change in an urban systems such as Melbourne’s water servicing.

ACKNOWLEDGEMENTS

This research will contribute to the development of an explorative computational planning tool, DAnCE4Water (Dynamic Adaptation for eNabling City Evolution for Water). The DAnCE4Water project is funded by the EU Framework Programme 7 PREPARED: Enabling Change and the Australian Government's Department of Industry Innovation, Science and Research.

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7th International Conference on Water Sensitive Urban Design, Melbourne, 21-23 February 2012

Testing a Strategic Action Framework: Melbourne's Transition to WSUD

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ABSTRACT

This paper provides the first empirical testing of a conceptual framework proposed as a basis for informing the design of strategic action for enabling a transition in urban water systems towards water sensitive practices. This Strategic Action Framework integrates transitions, resilience and institutional theories to provide insight into how actors can influence system dynamics to facilitate transitional change. The paper applies the framework to the case of stormwater management in Melbourne from 2000, in which mainstream practice has transitioned from traditional piped drainage for flood prevention to Water Sensitive Urban Design for improving stormwater quality before it enters downstream waterways. The research involved analysis of an existing historical case to identify how strategic action influenced the patterns and processes of change. The framework showed that the effectiveness of different types of strategic action depended on the varying dynamics during each phase of the transition. The paper further presents how the dynamics revealed in this case study will be modelled using a computer-aided strategic planning tool, DAnCE4Water. The societal module of DAnCE4Water is based on the Strategic Action Framework and is operationalised in modelling form to explore scenarios of city-wide urban water system change.

KEYWORDS

Institution; Resilience; Strategic Planning; Sustainability; Transition; Urban water

INTRODUCTION

The traditional approach to managing urban water systems is based on planning large-scale and centralised infrastructure that aims to reduce uncertainties and control variables such as water supply and demand. However as pressures from climate change, population growth, urbanisation, pollution, resource scarcity and ageing infrastructure increase, a new sustainable approach to managing urban water is required. Awareness of the changing context and the need for a transition towards water sensitive alternatives is increasing; however there is little understanding of how the urban water sector should make its strategic planning operational to facilitate a city's transition to a water sensitive future (Elzen and Wieczorek, 2005; Chapin III et al., 2010; Truffer et al., 2010).

Ferguson et al. (submitted) draw on established concepts from transitions theory (e.g. Geels, 2002; de Haan and Rotmans, 2011), resilience theory (e.g. Gunderson and Holling, 2002; Folke, 2006) and institutional theory (e.g. Lawrence and Suddaby, 2006; Scott, 2008) to develop a conceptual framework that aims to provide insight into the links between transitional dynamics and strategic action. This *Strategic Action Framework* is intended as the basis of an operational tool that can be used in a diagnostic manner to inform the design of policy and action in urban water systems from the perspective of dynamic transitional change. This paper provides the Framework's first empirical testing and demonstrates how it is applied in narrative form or with the aid of computer modelling.

DESCRIPTION OF THE STRATEGIC ACTION FRAMEWORK

System composition

The *multi-pattern approach* (MPA), from transitions theory, analyses different pathways of how transitions unfold (de Haan and Rotmans, 2011). It conceptualises a set of subsystems, or constellations, each of which functions to meet certain societal needs, for example a Piped Drainage Regime (Figure 1). Each constellation comprises social and biophysical structures, including formal and informal institutions, ecosystems, infrastructure and technologies. The influence of a constellation on the overall system functioning is its power. Actors are not explicitly described in any one constellation because they can have agency in multiple constellations, which allows the complementary integration with a framework of institutional theory and human action.

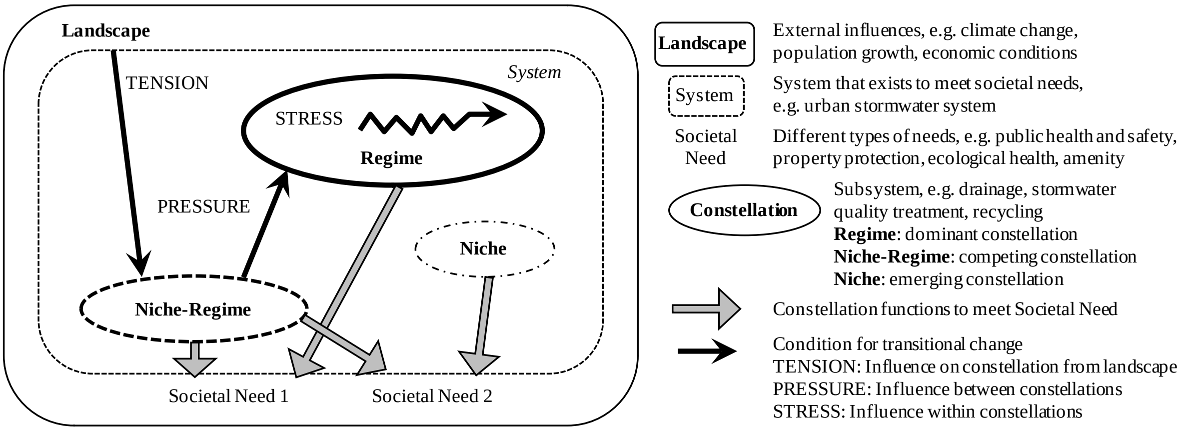

Figure 1. Conceptualization of the MPA (adapted from de Haan and Rotmans, 2011).

Transition dynamics

Constellations interact with each other and the landscape that embeds the system. Transitions are structural shifts in how the system functions to meet needs, which in this framing means a different power balance between constellations. To explain these dynamic interactions, the MPA identifies *conditions* for transitional change (tension, pressure and stress) (Figure 1). These conditions drive different transition *patterns* (top-down or 'reconstellation'; bottom-up or 'empowerment'; and internal or 'adaptation'). Over time these patterns can concatenate into *pathways* that lead to a transition. The transition pathway experienced depends on the power dynamics between the existing regime, upcoming niches and landscape tensions (de Haan and Rotmans, 2011).

It is hypothesised that conditions for transitional change will also depend on the *internal* dynamics of constellations. The MPA, however, only considers dynamics *between* constellations. Internal dynamics are therefore characterized by the *adaptive cycle* (Gunderson and Holling, 2002), from resilience theory. The adaptive cycle represents a fundamental unit of dynamic change and distinguishes periods of growth and dynamic stability from periods of change and variety (Gunderson and Holling, 2002) (Figure 2a). Resilience theory claims that a healthy system should follow the adaptive cycle trajectory. If innovations developed in the back loop stimulate sufficiently divergent structures and processes, a new cycle is entered and a transition has occurred. Unhealthy systems may not follow an adaptive cycle; maladaptive cycles can cause a system's decline and eventual collapse. A system's adaptive cycle indicates when it is capable of welcoming change and when it is vulnerable (Gunderson and Holling, 2002). A system's adaptive cycle location will influence which strategy will be most effective (e.g. Olsson et al., 2006). The Strategic Action Framework conceptually locates each constellation along an adaptive cycle (Figure 2b). Each constellation cycles through periods of exploitation, conservation, release and reorganisation at its own pace, or they may be stuck in a poverty or rigidity trap. Relative locations of multiple constellations along their adaptive cycle will influence the overall system dynamics.

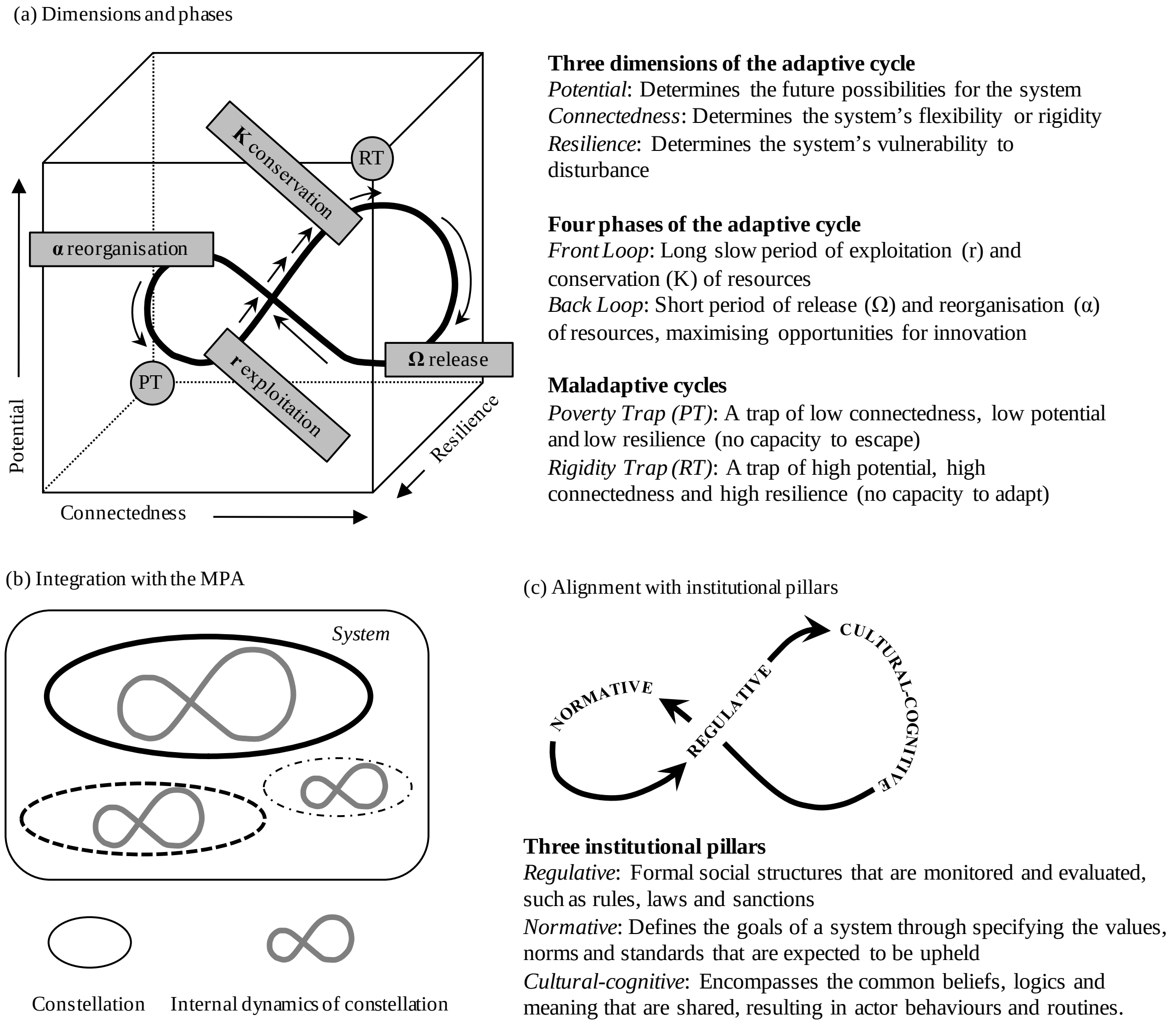

Figure 2. The adaptive cycle: (a) Dimensions and phases (adapted from Gunderson and Holling, 2002); (b) Integration with MPA (adapted from de Haan and Rotmans, 2011); (c) Alignment of phases with institutional pillars (adapted from Scott, 2008).

Human action

The link between transition dynamics and how human action can influence these dynamics is drawn from concepts in institutional theory. Changes in biophysical outcomes are achieved through reshaping the system's social structures (institutions) and processes. Scott (2008) argues that all institutions comprise three institutional pillars: regulative, normative and cultural-cognitive (Figure 2c). The three institutional pillars need to work in combination to maintain resilient social structures. When they are not well aligned, there is likely to be confusion and conflict within an institution, creating conditions that are conducive to institutional change. The Strategic Action Framework hypothesises that changes in each pillar are sequential and indicates which institutional pillars should be the focus of strategic action for different adaptive cycle locations (Figure 2c).

The Strategic Action Framework finally draws on Lawrence and Suddaby's (2006) concept of institutional work to provide insight into specific mechanisms that actors can employ according to whether the envisioned transition requires an institution to be created, maintained or disrupted, and whether the regulative, normative or cultural-cognitive elements of the target institutions would most effectively be influenced (Table 1).

Table 1. Institutional work mechanisms (adapted from Lawrence and Suddaby, 2006).

	Creating Institutions	Maintaining Institutions	Disrupting Institutions
Regulative	*Defining* rules and boundaries *Vesting* rights and interests *Advocacy* for resource allocation and political support	*Enabling work* by creating rules *Policing* using sanctions / rewards *Deterring* using economic or authoritative measures	*Disconnecting sanctions and rewards* from institutionalised practices
Normative	*Constructing identities* through collective action *Changing normative associations* of existing practices *Constructing normative networks* of peers	*Valourizing and demonizing* by promoting good and bad examples *Mythologizing* to maintain the historical roots	*Disassociating moral foundations* of existing institutions
Cultural-Cognitive	*Mimicry* of existing practices *Theorizing* of new practices *Educating* actors	*Embedding and routinizing* of practices	*Undermining assumptions and beliefs* associated with existing practices

APPLICATION OF FRAMEWORK TO THE MELBOURNE CASE

The conceptual framework described was applied to a case study from Melbourne, Australia, to test the assumptions and hypotheses made in its development. The case study was a grounded historical analysis of urban stormwater management between 1960 and 2006 (Brown and Clarke, 2007, has full details). The study provides an example of how actors in an international leading city from a waterways management perspective (Jefferies and Duffy, 2011) are transforming the mainstream approach of piped drainage to incorporate Water Sensitive Urban Design (WSUD) practices, improving the quality of stormwater before it enters the receiving waterways and thereby reducing the level of pollution in downstream waters. Given space restraints, the results presented in this paper are for the case developments between 2000 and 2006 only.

Narrative application of the Strategic Action Framework

The application of the Strategic Action Framework to the Melbourne case in the years 2000 to 2006 are presented in Table 2 and Figure 3. These results demonstrate the potential of the MPA and the adaptive cycle concepts for explaining transition dynamics, as well as how the links with institutional theory provide analytic insight into the strategic action undertaken by actors to enable these dynamic changes.

The Strategic Action Framework can also be used for predictive purposes to inform the design of strategic action. From Figure 3 we see that in 2006, the WSUD Niche-Regime was in the *K* phase of the adaptive cycle, where the focus of institutional work was the regulative pillar. The Piped Drainage Regime was in the Ω phase, where the old cultural-cognitive institutions had been disrupted by various mechanisms. These relative adaptive cycle locations indicate the regime has adaptive capacity and that the niche-regime is strong enough to be influential. Therefore, with suitable institutional work mechanisms, the years following 2006 could see the regime absorb the niche-regime, completing the transition to form a new regime based on piped drainage *and* WSUD. Strategic action to enable this would initially need to focus on creating and maintaining the cultural-cognitive and normative institutions of the new regime to encourage support and acceptance from mainstream actors who had not yet embraced the innovative WSUD niche-regime practices. After this phase, regulative activities would then need to be employed to force resistant actors to comply with the new standards and practices for stormwater management.

Table 2. Key developments in the Melbourne case between 2000 and 2006.

Element	Key developments between 2000 and 2006: *Niche Stabilisation*
Constellations	*Piped Drainage constellation* weakened as a Regime *WSUD constellation* strengthened from a Niche to Niche-Regime.
Landscape	Community concern about pollution and poor health of Melbourne's waterways
Societal Needs	*Flood protection* met partially by Piped Drainage Regime and partially by WSUD Niche-Regime. *Ecosystem protection* met by WSUD Niche-Regime.
Conditions	*Tension* from landscape. *Stress* from Piped Drainage Regime's inability to meet ecosystem protection need. *Pressure* from empowered WSUD Niche-Regime.
Patterns	*Reconstellation* and *empowerment*, causing growth and stabilisation of WSUD constellation as a Niche-Regime to better meet the ecosystem protection need and compete with the Piped Drainage Regime to meet the flood protection need.
Inst. changes	*Create* and *maintain* niche-regime institutions. *Disrupt* regime institutions.
Institutional work	*Cultural-cognitive*: Share knowledge and experience about WSUD technologies through demonstration projects, practitioner training, conferences and design guidelines and tools. *Normative*: Formalise relationships and stabilise networks through committees, demonstration projects and training. *Regulative*: Define responsibilities, implement action plans and amend regulations.

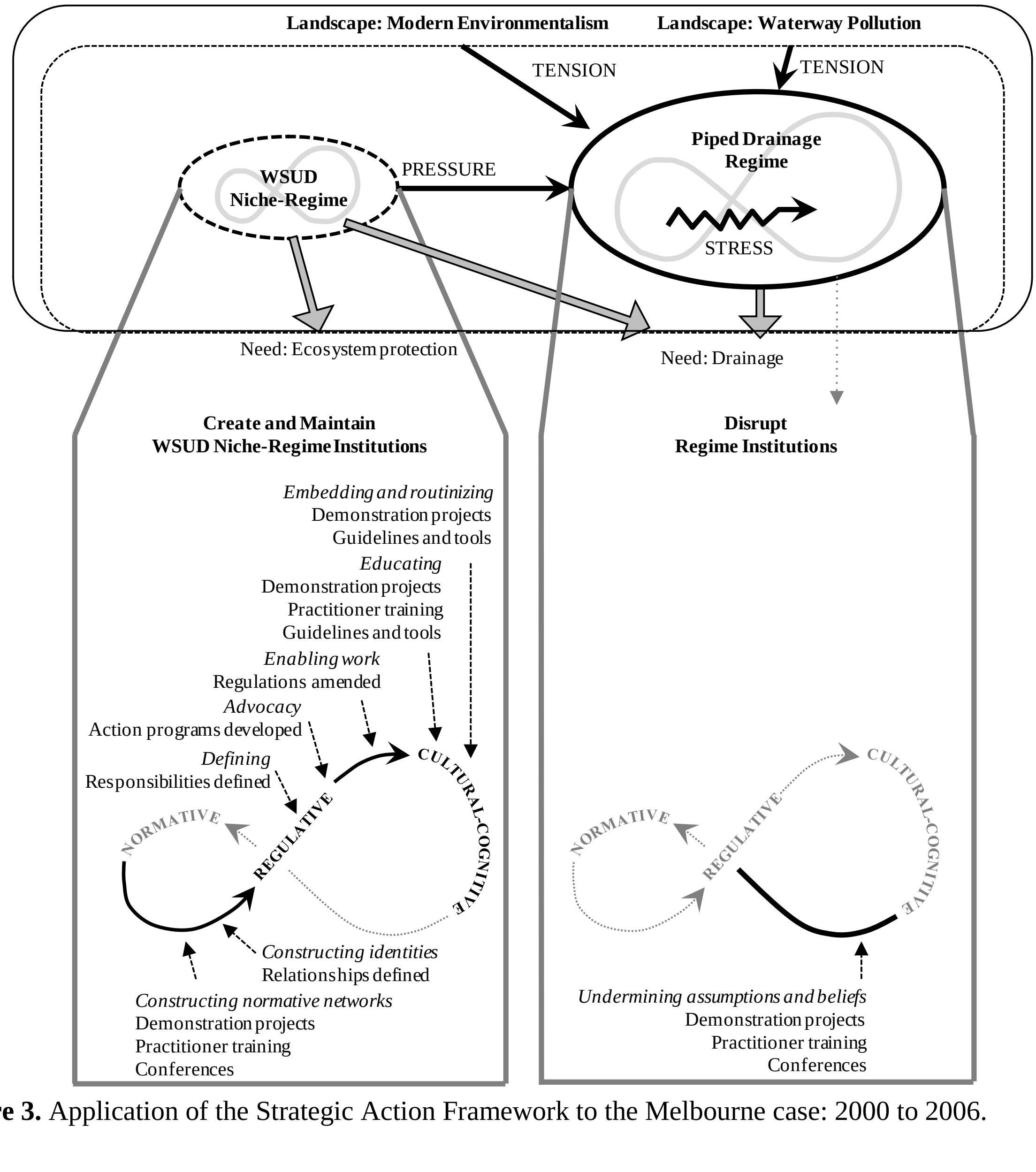

Figure 3. Application of the Strategic Action Framework to the Melbourne case: 2000 to 2006.

This narrative application of the Strategic Action Framework demonstrates how it can be applied empirically to analyse the effectiveness of different types of institutional work at different phases of change. It also shows that by mapping recent historical changes against the adaptive cycle using institutional work mechanisms as indicators, we gain insight into the types of short and long-term activities that should be the focus for enabling transitional change through strategic action.

Modelling application of the Strategic Action Framework

The Strategic Action Framework was developed with the intent that it be used as the basis of an operational tool that strategic planners can apply to inform their decision-making. An operational tool may be narrative, as demonstrated in the previous section, but application as a computer model also provides a valuable means for rigorous thought-experimentation. DAnCE4Water is an example of such a computer-aided strategic planning tool; it allows users to explore scenarios of urban water system change at a city-wide scale by examining the impacts of socio-institutional trends and changes in the urban form on how water infrastructure develops. The development of the societal module of DAnCE4Water is based on the Strategic Action Framework, in particular the MPA concept. Modelling socio-institutional developments requires assumptions and simplifications to be made so that qualitative data can be dealt with in a semi-quantitative manner. This section demonstrates how the Strategic Action Framework has been tailored for application as a computer model. This model algorithms draw extensively on de Haan (2010), with further extension based on the conceptual underpinnings of the Strategic Action Framework. Calibration of the model is informed by empirical application of the Strategic Action Framework to the Melbourne case.

Quantitative system description. Constellations are composed of quantifiable facets (f_k). Facets are the dependent variables of the model and the extent to which individual facets are present within a constellation (described by a continuous scale) varies with time. Facets are defined by an infrastructure (biophysical structure) and an institution (social structure). Infrastructures may be either technological (e.g. pipes) or ecological (e.g. rivers). Institutions may be cognitive (e.g. research program), normative (e.g. public campaigns) or regulative (e.g. mandated targets). Examples of facets that are relevant for the Melbourne case from 2000 to 2006 are listed in Table 3.

Table 3. Example facets for the Melbourne case.

Facets for Constellation, C_x $f_{kCx}(t)$	Infrastructure		Institution		Scale
f_{1Cx}	Pipes & drainage channels	T	Limits to pollution discharge	R	[0,2]
f_{2Cx}	Pipes & drainage channels	T	Engineering design templates	C	[0,2]
f_{3Cx}	Rivers & creeks	E	Valued as a recreational asset	N	[0,2]
f_{4Cx}	Rivers & creeks	E	Valued as an environmental asset	N	[0,2]
f_{5Cx}	Constructed wetlands	T/E	Research on wetland function	C	[0,2]
f_{6Cx}	Constructed wetlands	T/E	Targets for nutrient reduction	R	[0,2]

T=Technology E=Ecology C=Cultural-Cognitive N=Normative R=Regulative

Landscape influences and societal needs are model inputs, provided as scenarios that are functions of time (t). Landscape influences (L_i) are described by an integer scale, representing the extent to which they are each present. Similarly, societal needs (N_j) are described by an integer scale, representing the extent to which the need is present. Table 4 shows the landscape influences and societal needs that are relevant for the Melbourne case in the years 2000 to 2006.

Table 4. Landscape influences and societal needs for the Melbourne case.

Landscape influences, L_i *(t)*		Scale	Societal needs, N_j *(t)*		Scale
L_1	Waterway pollution	{0, 1, 2}	N_1	Drainage	{0, 1, 2, 3, 4}
L_2	Modern environmentalism	{0, 1, 2}	N_2	Ecosystem protection	{0, 1, 2, 3, 4}

Each facet meets a particular societal need and responds to different landscape influences. Not all influences and needs are relevant for every facet; a matrix that couples L_i with f_k and a matrix that couples N_j with f_k are therefore required to fully define the system (beyond the scope of this paper).

Calculation of system dynamics. The algorithms that drive the model dynamics are beyond this paper's scope; however the operational concepts that underpin them are presented in Table 5.

Table 5. Conditions that drive transitional dynamics.

Condition	Driver	Source	Dynamic Function, F
Tension *T*	On constellation	Landscape influence, L_i, impedes constellation, C_1, in meeting societal needs	$T_{C1} = F(f_{kC1}(t), L_i(t))$
Stress *S*	Within constellation	Constellation, C_1, inadequately or excessively meets certain needs, N_j	$S_{C1} = F(f_{kC1}(t), N_j(t))$
Pressure *P*	Between constellations	An alternative constellation, C_2, competes with C_1 to meet certain needs	$P_{C1} = F(f_{kC1}(t), f_{kC2}(t))$

Facets of a constellation grow or shrink (increase or decrease their value) over time in order for the system to better meet societal needs, given the presence of a particular set of conditions (Table 5). The response of the system to the conditions for change is determined by the three possible transition patterns: *reconstellation*, *adaptation* and *empowerment*. Each pattern applies a distinct mechanism for reshaping the facets. For example, the facets of a constellation under tension will grow or shrink according to the reconstellation algorithms; the facets of a constellation under pressure will grow or shrink according to the empowerment algorithms. All facets will not change concurrently. Sequencing of facet growth will be determined by the institutional elements. Using the hypotheses described earlier, regulative facets for a particular infrastructure will not grow unless normative counterparts are present. In the same vein, normative facets for a particular infrastructure will not grow unless cultural-cognitive counterparts are present.

A constellation with high-valued facets that meet many societal needs will have more power than a constellation with low-valued facets that meet few societal needs; it will therefore be more dominant in the system function. Changes in the facets of different constellations therefore correspond to a shift in power within the system and can indicate a transition has occurred.

Application for model users. Modelling the dynamics of the system in this manner allows users to explore how different scenarios of societal needs, landscape influences and policy experiments will affect the system composition over time and to understand how different mechanisms could lead to possible transition pathways. For the Melbourne case, this approach is used to simulate scenarios of other development trajectories that may have occurred for the given set of initial inputs. It is also used to interact with the model in 'game mode' by intervening at periods of time to change the input scenario after receiving feedback, thereby exploring how different interventions could have changed the outcomes for Melbourne's stormwater management system.

CONCLUSIONS

The Strategic Action Framework presented in this paper is at a preliminary stage of development. Application to the Melbourne case has provided an early empirical testing of the hypotheses regarding the sequential nature of effective institutional work mechanisms and the hypothesised correlation between the presence of conditions for transitional change and the relative positions of constellations along their adaptive cycles. While further empirical testing on cases of both successful and unsuccessful transitional change is required, results from this study indicate the framework is a promising means for explaining and predicting different types of change in a system.

With further development as both a narrative tool and within the context of a computer-aided modelling tool, the Strategic Action Framework would be valuable for strategic planners, policy analysts and decision-makers to use to diagnose critical mechanisms of transitional change processes in an urban water system and to use these insights to design strategic action accordingly.

ACKNOWLEDGEMENT

This research will contribute to the development of an explorative computational planning tool, DAnCE4Water (Dynamic Adaptation for eNabling City Evolution for Water). The DAnCE4Water project is funded by the EU Framework Programme 7 PREPARED: Enabling Change and the Australian Government's Department of Industry Innovation, Science and Research.

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APPENDIX C. GUIDANCE MANUAL FOR DEVELOPING TRANSITION SCENARIOS

Frantzeskaki, N., Ferguson, B.C., Skinner, R., Brown, R.R. (2012b) Guidance manual: Key steps for implementing a strategic planning process for transformative change. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, ISBN 978-1-921912-14-6.

MONASH water for liveability

Drift
Dutch Research Institute for Transitions

Guidance Manual

Key steps for implementing a strategic planning process for transformative change

Niki Frantzeskaki, Briony Ferguson, Rob Skinner and Rebekah Brown

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August 2012

MONASH University | Monash Sustainability Institute

GUIDANCE MANUAL
Key steps for implementing a strategic planning process for transformative change

ISBN 978-1-921912-14-6

This Guidance Manual documents the strategic planning methodology used in two series of workshops as part of the *Melbourne's Transition to a Water Sensitive City* project, led by Monash Water for Liveability. This project involved participants from a range of organisations who have a role in the planning, design, management and use of Melbourne's water system.

The report should be referenced as the following:
Frantzeskaki, N., Ferguson, B.C., Skinner, R. and Brown, R.R. (2012) Guidance Manual: Key steps for implementing a strategic planning process for transformative change. Dutch Research Institute For Transitions, Erasmus University Rotterdam, The Netherlands. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-14-6.

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Table of Contents

Glossary

Liveability (supported by water)	Satisfaction of all urban water needs
Sustainability (supported by water)	Carrying capacity for ongoing satisfaction of all urban water needs in the face of resource limitations
Resilience (supported by water)	Coping capacity for ongoing satisfaction of all urban water needs in the face of uncertain conditions
Sustainability Transition	Fundamental shift in the cultures, structure and practices of a system in a more sustainable direction
Project Team	Core group of people that initiate, drive and manage the project
Facilitator	Project team member who facilitates the workshop sessions
Analyst	Project team member who synthesises and analyses the workshop outputs
Participant	Individual who participates in the workshop series
Stakeholder	Organisation or group that has an interest in the project topic
Key Stakeholder	Organisation or group that is important to have represented during the workshop series
Underlying Challenge	Descriptive statement of a root cause of problems experienced in the current system
Domain of Change	Dimension of the system that would need to undergo change if the desired future is to be achieved
Vision	An imagined, long-term desired future
Vision Image / Vision Theme	Parts of the vision that have common or related elements
Guiding Principle	Descriptive statement of a desired outcome for the long-term future
Vision Definition	Specific aspiration that makes a guiding principle operational for the local context (e.g. strategic objective, target)
Vision Narrative	Rich description of the desired future that synthesises different parts into an imaginative storyline
Vision Illustration	Artistic interpretation of the desired future
External Driver	Influences from outside the system that would have a high probability of occurring and a high impact on the system
Trend	Expression of a driver in a particular direction (e.g. low, high)
Context Scenario	Families of trends for the external drivers that represent a possible future context
Extreme / Surprise	Event or situation that has a low probability of occurring and a high impact on the system
Wildcard	Description of a specific extreme or surprise (e.g. a social, technological, ecological, economic or political disturbance) in a particular local context
Strategic Transition Pathway	Bundled set of short, medium and long-term strategies that move the current system towards the future vision
Strategic Transition Path	Subset of a strategic transition pathway with focus on a particular type of outcome within the full set
Critical Path	Strategic transition path that is considered a short, medium or long-term priority for bringing about the transition
Resilient Transition Path	Strategic transition path that incorporates strategies for building resilience into the system
Transition Agenda	Sets out the priority transition pathways (critical paths) and recommendations for making pathways operational with actions and timelines for immediate next steps

Introduction

This Guidance Manual

This Guidance Manual documents a methodology for use by practitioners and researchers to facilitate a **strategic planning process focused on transformative change towards a long-term vision of a sustainable future**.

While the methodology is a generic approach, the steps presented here were developed for the *Melbourne's Transition to a Water Sensitive City* project, led by Monash Water for Liveability. The methodological steps have therefore been **tailored for the urban water context of Australia.**

Application of the methodology in other contexts would follow the overall structure, but details of the steps would need to be adapted accordingly. For example, the methodology could be implemented across an infrastructure sector that involves a range of stakeholder groups to inform the development of long-term sector-wide strategy. It could be implemented within an organisation as a planning process to develop a specific strategic plan. It could be implemented as a means to engage with community members about a neighbourhood vision and actions.

The purpose of a particular project will inform the way in which this Guidance Manual is used and the adaptations that will be required. In general, however, participants in the workshop series should have a clear understanding of the basis of their involvement and where the project outcomes are expected to lead.

Key assumptions that underpin the methodology described in this Guidance Manual include:

- The methodology is being applied in a context which aims to enable a sustainability transition through a long-term visionary strategic planning process.
- Estimates of resources required for each step are based on a core project team consisting of a project leader, two analysts who also facilitated workshop discussions, and an additional facilitator when required for small group discussions.

The steps described in this Guidance Manual have been refined after learning from the experience of implementing them in the *Melbourne's Transition to a Water Sensitive City project*. The steps may therefore not reflect exactly how they were followed during the two workshop series. Details of this project are found in Appendix A.

Process Overview

The methodology described is a strategic planning process focused on **long-term, visionary transformative change**. Transformative change, or a transition, occurs over decades and involves radical shifts in how a socio-technical system functions. For water, a transition refers to fundamental changes to how water servicing is planned, designed, constructed, operated, managed, governed and valued. The methodology draws on the latest international thinking in two scientific fields:

Transitions Approach[1]
The field of transitions research aims to understand patterns and processes of transformative change towards sustainability goals. Its main focus is on socio-technical systems (such as transport, water and energy) and asks the question, how can we enable transformative capacity in the institutions, communities, technology and infrastructure of our system? Transitions thinking identifies that **sustainable outcomes will only be achieved if there are complementary transformations in the structures, cultures and practices of a system**. Transition Management is an alternative governance approach, originally developed at the Dutch Research Institution For Transitions. It is designed to initiate and enable transformative change by creating space for innovations, empowering champions, fostering collaborations and stimulating ongoing experimentation, evaluation and learning.

Resilience Approach[2]
The field of resilience research aims to understand and account for uncertainties in ecosystem dynamics, so that a system can continue to function in the face of disturbances. Its main focus is on social-ecological systems (such as natural resources, waterways and grasslands) and asks the question, how can we build resilient institutions, communities, ecosystems and economies in our system? Resilience thinking identifies that **resilient outcomes will only be achieved if there is adaptive capacity and continuous learning in a system**.

The process described in this Guidance Manual builds on the Transition Management approach as an overarching framework to consider how transitional change towards a sustainable future can be enabled. It was then expanded to incorporate additional steps focused on building system resilience, with the understanding the resilience thinking needs to underpin a sustainable future.

This Guidance Manual translates these theoretical approaches into a practical and implementable methodology for real situations. The particular innovations of the design include: (1) It has an explicit focus on long-term planning; (2) It merges a creative visioning process – 'what' – with a rational and operational strategy generation process – 'how'; (3) It brings science, policy and community stakeholders together in a safe, open forum; (4) It co-creates strategies in a bottom-up process, providing opportunity for new perspectives and directions; and (5) It incorporates the resilience of future desires for the system into a long-term sustainability transitions agenda.

[1] Frantzeskaki, N., Loorbach, D., and Meadowcroft, J. (2012) Governing transitions to sustainability: Transition management as a governance approach towards pursuing sustainability. International Journal of Sustainable Development 15 (1,2), 19-36.
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Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T. and Rockstrom, J. (2010) Resilience thinking: Integrating resilience, adaptability and transformability. Ecology and Society 15 (4), article 20.

While it is difficult to provide Position Descriptions that would suit the needs of every project, the authors have drawn on their own reflections, and feedback from participants in the *Melbourne's Transition to a Water Sensitive City* project, to provide some clear recommendations on the critical role of the Facilitators and Analysts in the project.

Role of the Facilitators

- Facilitators should have a clear knowledge of the context, sector and topic being investigated in the process.
- Facilitators should have a detailed understanding of the overall process and each methodological step described. In particular they should have a clear understanding of the objectives of every step and adapt the process or facilitation style to achieve the objectives accordingly (objectives are defined during the scoping phase of the project and can be both content and learning oriented).
- Facilitators should have a dedicated focus on creating and ensuring a safe space for participants throughout the entire project.
- The style of facilitation required varies throughout the process. For some sessions, particular outcomes should be elicited through direct facilitation. For other sessions, exploratory discussion should be encouraged through broad and open questioning.
- Facilitators should provide opportunity at the beginning of each workshop for participants to voice their feedback and refine outputs from the previous session. Depending on the group, this may require a substantial amount of time.
- Facilitators should regularly assure participants that their outputs should be iterative, and as their ideas and perspectives evolve, so too will the outputs they produce.
- Facilitators should be flexible and adaptive to provide opportunity for creativity and surprises, as well as to ensure the needs of the individual workshop are met. It is desirable for the facilitators to bring energy to the discussions, while respecting the pace of learning and reflection by the participants.

Role of the Analysts

- It is recommended that analysts also have a facilitator role during the workshops to ensure their full understanding of the discussions. Analysts should bring the view and insights of the participants of the workshops into the reporting and analysis of the workshop outputs, rather than their individual opinion or judgments.
- Analysts should have a clear knowledge of the context, sector and topic being investigated in the process.
- Analysts should synthesise the outcomes of each workshop in a way that provides a true reflection of the participant discussions. At the same time, they should add clarity and depth to the outputs so that participants start from an enriched point of discussion at the next workshop.
- Analysts are responsible for selecting methods to process workshop outputs that best fit the objectives of every methodological step.
- Analysts (and facilitators) should consider the workshop audience for each stage of the project. Analytic insights need to be presented in a way that is sufficiently provocative to stimulate rigorous and creative discussion. However, they also need to be appropriately framed so that participants will not feel offended or discouraged.
- Expert panels can be used in different stages of the project to complement the analytic capacities of the project team.

In the Melbourne project, the facilitators and analysts were all from research institutes (Monash Water for Liveability and the Dutch Research Institute For Transitions) but this is not essential.

Overall Tips

Throughout this Guidance Manual, tips are provided to offer insight into how each methodological step would most effectively be implemented. Listed below are suggestions for the process as a whole:

- Consider the timing of workshop sessions when initially designing the project. One workshop per month works well, as it is regular enough to keep momentum but not too often to be intrusive with people's regular work commitments.

- Small group discussions (5-8 participants) are most effective for generating ideas and exploring them in-depth. Whole group discussions (20-25 participants) are most effective for developing shared views and consolidating outputs after initial small group discussions.

- Consider the duration of workshop sessions when initially designing the project. Participants seem to tire after around 3.5 hours.

- Allow for the opportunity to negotiate additional workshop sessions with the participants as the process unfolds, if considered necessary.

- At the beginning of the workshop series, propose a set of ground rules for working together and seek agreement and commitment to these rules from all participants.

- Provide reporting between workshop sessions progressively, so that participants have sufficient time and opportunity to read, digest and reflect on the outcomes of the previous workshop before entering into the next session's discussions.

- Prepare presentations and supporting material for each workshop to outline the session's agenda and activities in step-by-step explanations.

- Ensure each facilitated step is sufficiently introduced, including examples of the types of outcomes that are expected, so that small group discussions follow the desired direction. When needed, prepare materials (e.g. posters, templates) to support structured discussions.

- Consider involving an artist in the workshops to provide a visual interpretation of both the process steps and the participants' visions.

- Consider involving someone to take on a critical observation role during the workshops and provide feedback to the facilitators, analysts and participants.

Methodological Steps

This section provides a step-by-step presentation of the methodology to develop a transition agenda for enabling the transition to water sensitive regions through strategic action. The methodology has five distinct phases, although the process is designed to be iterative, with outcomes of previous workshops being revisited as necessary.

The first phase is for **preparation**, and involves establishing a project team, understanding the project context, designing the conceptual details of the project, planning the project logistics and tailoring the methodological steps for the particular project application. This phase also involves engaging with key stakeholders and gaining their commitment to participant in the project.

The second phase is to understand the **current system**. It involves some analytic work, prior to the start of the workshops, focused on compiling a synthesis of the system's evolution, operation, components and current challenges. The first workshop is also part of this second phase, designed to uncover the imperative for change by exploring what is underlying the current challenges and what domains need to change if sustainable outcomes are to be achieved.

The third phase is to develop a **vision** for the future system. It involves approximately four workshops, designed to formulate guiding principles, describe the vision through narratives or other means, define the vision with a specific articulation and then to consider what parts of the vision are resilient in different future contexts.

The fourth phase is to generate **strategic transition pathways** and utilises backcasting techniques (developing strategies by thinking about the future vision as the starting point, rather than today's challenges). It involves approximately three workshops to brainstorm strategies and actions and formulate them into qualitatively different pathways, as well as considering what additional strategies may be required to build resilience into the system to cope with future extremes and surprises.

The fifth phase is to form a **transition agenda**, which involves a workshop focused on which strategic paths are considered priorities and starts to consider how the paths may be operationalised in the system context.

The project team may also like to consider a finalisation workshop, designed for presenting and seeking validation of the consolidated project outputs, as well undertaking evaluation and feedback.

This process is designed to stimulate a 'pressure-cooker' environment, as previous experience has found that its fast pace and intense focus provides the right conditions for the creative and rigorous thinking desired from participants.

Table 1 suggests a recommended format for each of the methodological steps while Figure 1 provides an outline of the overall methodology. Methodological steps have different types of focus (e.g. planning, facilitation, analysis), as indicated throughout the Guidance Manual.

Table 1. Recommended Format for each Methodological Step.

Month	Phase	Step	Suggested Format
1-6	Preparation	A.1 Plan the project	Planning sessions
		A.2 Scope the project	Planning sessions
		A.3 Engage key stakeholders	Personal contact, information session
7-8	Current System	B.1 Analyse the system	Desktop, interviews, focus groups
9		B.2 Uncover the imperative for change	1 x 3.5 hour workshop and analysis
10	Vision	C.1 Formulate guiding principles	1 x 3.5 hour workshop and analysis
11-12		C.2 Define the vision	2 x 3.5 hour workshops and analysis
11-12		C.3 Describe the vision	
13		C.4 Build vision resilience	1 x 3.5 hour workshop and analysis
14-15	Strategic Transition Pathways	D.1 Generate strategic pathways	2 x 3.5 hour workshops and analysis
16		D.2 Build system resilience	1 x 3.5 hour workshop and analysis
17	Transition Agenda	E.1 Prioritise paths	1 x 3.5 hour workshop and analysis
18	Finalisation	Consolidated outputs, validation, feedback	1 x 3.5 hour workshop and analysis

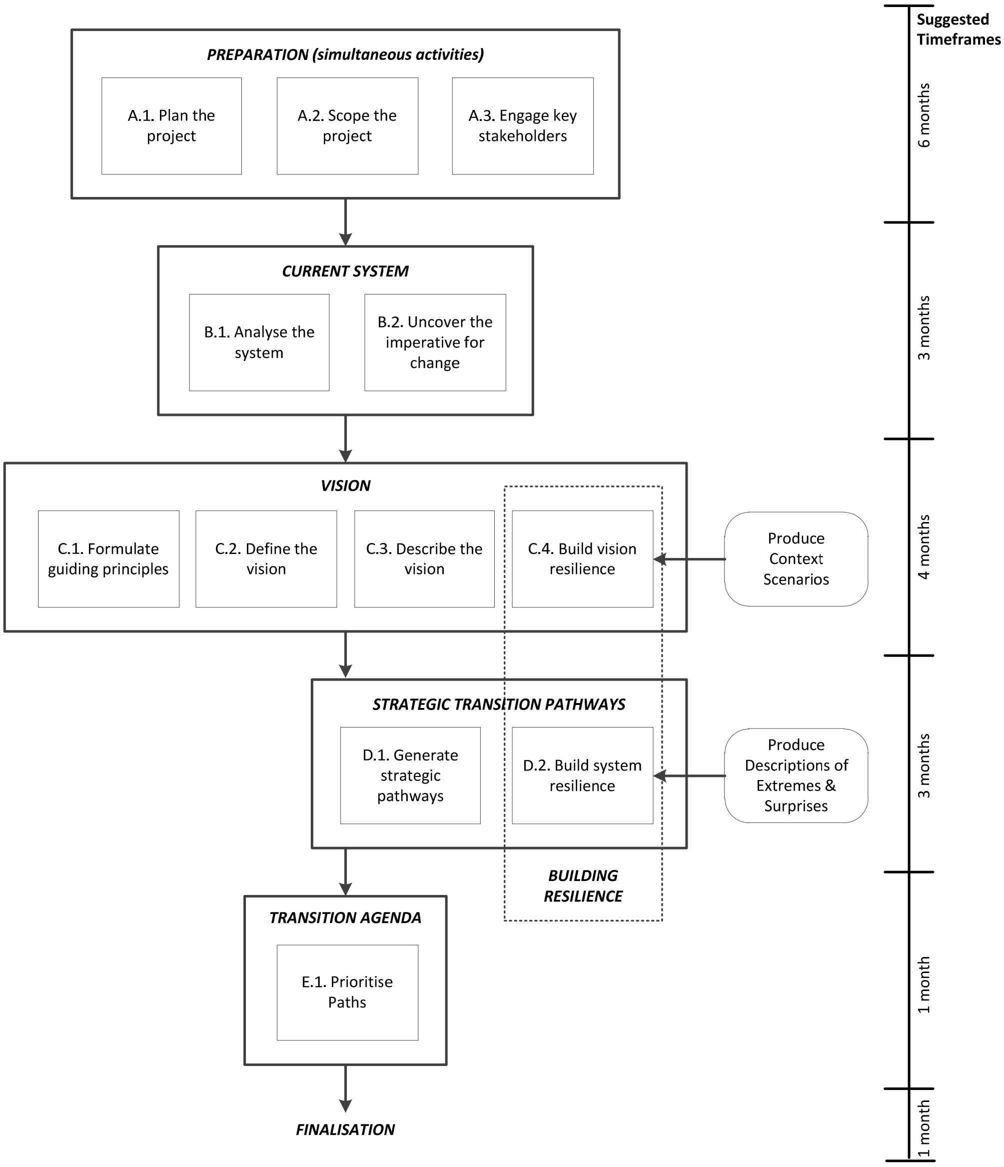


Figure 1. Overview of Methodology.

PHASE A. PREPARATION

STEP A.1 – PLAN THE PROJECT

Objectives: Plan the logistical details of the project and form a project team.

Resources:

- Estimated 6 months for planning
- Project team would typically involve around four to eight people

Methodology:

PROJECT TEAM

1. Form a project team with the following range of capacities (note there is likely to be overlap as individuals may fill more than one role):
   a. Project ambassador(s) who will bring their knowledge, experience and networks to provide leadership in the local context
   b. Project manager(s) who will be responsible for the logistics, coordination and communication
   c. Project facilitator(s) who will plan the methodology and facilitate the workshop sessions
   d. Project analyst(s) who will analyse and synthesise the workshop outputs (it is recommended that analysts also have the role of facilitators)

PROJECT TEAM

2. Plan the project logistics, including the following:
   a. Timeframe
   b. Budget
   c. Deliverables
   d. People
   e. Workshop venues

Tips:

- In the planning phase you may like to consider whether engaging an artist to attend the workshops would add value to the project by creating visualisations to support the project outputs.

Outputs: Detailed project plan, which will evolve throughout the project

Next step: Scope the project

PHASE A. PREPARATION

STEP A.2 – SCOPE THE PROJECT

Objectives: Scope the methodological and conceptual details of the project

Resources:

- Estimated 3-6 months for project scoping

Methodology:

PROJECT TEAM

1. Map and understand the context
   a. Map current institutional setting (politics, organisations, capacities, connections between organisations, policies and strategic plans)
   b. Identify previous or current activities that may relate to the project

PROJ. TEAM

2. Identify how the project will add value to the current context

PROJ. TEAM

3. Define the aim, objectives and required outputs for the project, taking into account the likely expectations of different sets of stakeholders that will be involved

PROJECT TEAM

4. Based on project aim and scope, define criteria for identifying key stakeholder groups
   a. Define criteria for stakeholder groups to be involved Identify stakeholder groups that are critical for the project
   b. Identify stakeholder groups that can potentially be involved

PROJECT TEAM

5. Tailor the methodology by considering how each process step would be best adapted and applied in the project context. Consider the following:
   a. Methodological steps
   b. Facilitation techniques
   c. Analytic approaches
   d. Language and framing
   e. Communication and reporting requirements
   f. Monitoring and evaluation needs

Tips:

- Hosting a pilot workshop, where the project team and other invited contributors go through the planned methodology, helps to consolidate ideas about how each step would best be adapted for the project context.
- Project team should actively look for parts of the methodology which may not suit the project context (ie. play the devil's advocate) to ensure the project is well designed for the particular application.

Outputs: Detailed project plan with identified scope and an evolving methodology.

Next step: System Analysis

PHASE A. PREPARATION

STEP A.3 – ENGAGE KEY STAKEHOLDERS

Objectives: Prepare the sector for the project, gain commitment from key stakeholders and select participants

Resources:

- Estimated 6 months for stakeholder engagement
- Information session would typically be a 1-2 hour event

Methodology:

PROJECT TEAM

1. Seek commitment from the leadership of key stakeholders (e.g. CEOs, General Managers) for their organisation to participate in the project. Understand what stakeholders hope to gain from participation in the project and consider how these expectations could be met. Ensure stakeholders understand the grounds on which their representatives will be asked to participate (Box 1)

PROJECT TEAM

2. Host an information session to provide key stakeholders with project details and gain their trust and commitment to the process. The agenda should cover:
   a. Background and context
   b. Aim, objectives, expected outputs
   c. Process design (methodology)
   d. Desired characteristics of workshop participants
   e. Required time commitment

PROJECT TEAM

3. Work with key stakeholders to identify who will participate in the workshops. The overall set of participants should represent a broad mix of stakeholders, backgrounds and disciplines. Individually, the desired personal characteristics for participants include:
   a. Good strategic understanding of the system
   b. Strong influence within their organisation or community
   c. Commitment to sustainability
   d. Open to creative and visionary thinking
   e. Willing to contribute to rigorous discussion

Tips:

- Engagement with key stakeholders can work best if they start with informal discussions, followed up with formal written details.
- It is critical in this stage to be professional and organised so that prospective participants and their organisations have confidence in committing to the project.
- Provide handouts at the information session and other stakeholder engagement activities so that people have the project details readily available.

Outputs: Set of participants committed to the full series of workshops

Key references:

Bryson, J.M., (2004), What to do when stakeholders matter, Public Management Review, Vol. 6 Issue 1, pp. 21–53.

Hermans, L.M., and Thissen, W.A.H., (2009), Actor analysis methods and their use for public policy analysts, European Journal of Operational Research, Vol.196, pp.808-818.

Patton, C.V., and Sawicki, D.S., (1986). Basic Methods of Policy Analysis and Planning, Prentice-Hall

Next step: System Analysis

Box 1. Example grounds of participation.

During the stakeholder engagement activities, targeted stakeholders were informed about the participation grounds to the process.

a. Participants will be involved as individuals, not as formal representatives of their organisation
b. Participants will be expected to bring the understandings and experience of their organisation but will not be asked to represent their organisation's official perspectives
c. Participants will not be expected to endorse workshop outputs on behalf of their organisation

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University, Rotterdam. Monash Water for Liveability, Monash University, Melbourne.
Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: Yarra Valley Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University, Rotterdam. Monash Water for Liveability, Monash University, Melbourne.

PHASE B. CURRENT SYSTEM
STEP B.1 – SYSTEM ANALYSIS

Objectives: Provide a baseline assessment of the current system's state and characteristics.

Resources:
- Estimated 2 months for conducting a system analysis (collection and synthesis of data)

Methodology:

ANALYST
1. Define the socio-economic system for analysis and its boundaries
2. Collect data through interviews, focus groups, desktop research etc.
   a. Decide on key information that is required

ANALYST
3. Analyse the historical evolution of the system
   a. Key events and significant developments
   b. Descriptions of key historical periods
   c. Maps and images
   d. Timelines of important system indicators {Choose system indicators that are important for the system or problem under consideration}

ANALYST
4. Analyse the system operation in a holistic manner to create a comprehensive base for discussion
   a. Choose analytical tools (Box 2)
   b. Identify components of the system
   c. Map relationships between the components

AN.ALYST
5. Formulate an integrated understanding of the problem(s) based on the system operation
6. Identify system components and relationships that contribute to its problem(s)

FAC.
7. Synthesise and present the system analysis results as a base for participatory framing of the problem(s) during the workshops (Box 3)

Tips:
- System analysis outputs are presented in the first workshop to kick-start discussions and stimulate holistic thinking about the system and its problem(s).
- There is a variety of choices to be made in this step, for example, what is defined as the system, what aspects of the system will be focused on, what analytic tools will be used. For each choice, the project team needs to consider the project objective and aims, the intended focus of discussions, the information already available, and the design of the first workshop.
- Presentation of the system analysis needs to consider the audience and how they may interpret the system analysis results.

Outputs: A synthesis of the historical evolution, system operation, system components and identified problems in the form of pressures and perceptions of current challenges.

Key references:

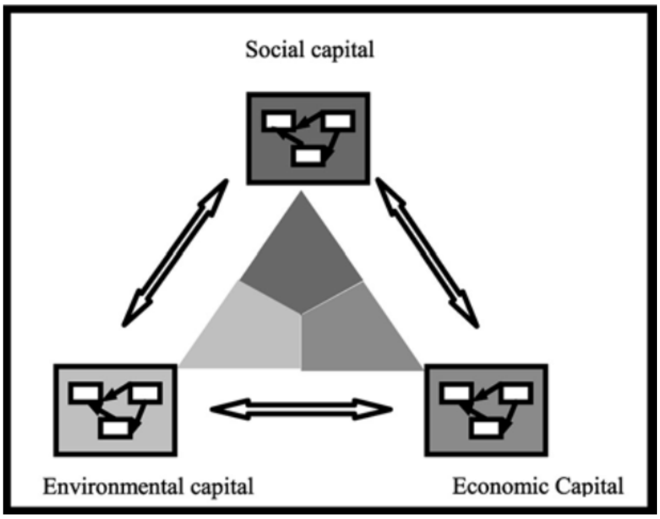
Findeisen, W. and E.S. Quade (1985), The Methodology of Systems Analysis, Chapter 4 in H.J. Miser and E.S. Quade (eds.), Handbook of Systems Analysis: Overview of Uses, Procedures, Applications, and Practice. New York: Elsevier Science Publishing Co., Inc.

Sage, A.P. and J.E.Armstrong Jr. (2000). Introduction to Systems Engineering. New York: John Wiley & Sons.

Walker, W.E. (2000). Policy Analysis: A Systematic Approach to Supporting Policymaking in the Public Sector, Journal of Multicriteria Decision Analysis, 9:11-27.

Next step: Formulate Guiding Principles

Box 2. Example analytical tool for system analysis.



The SCENE model: Representation of the system as interconnection between three domains: ecology, economy and society. Each domain has its own dynamics and trends and is strongly interrelated to the other domains. Sustainability of the system is hypothesised as a balance between the three domains. The SCENCE model has been developed as a core analytic model for Integrated Sustainability Assessment.

Grosskurth, J., and J. Rotmans. 2005. The SCENE Model: Getting a grip on sustainable development in policy making. Environment, Development and Sustainability 7:135-151.

Other analytical tools include:
- **System's Diagram**

Lei, T.E. van der, B. Enserink, W. A. H. Thissen, and G. Bekebrede (2010). How to use a Systems Diagram to Analyse and Structure Complex Problems for Policy Issue Papers, *Journal of the Operational Research Society* 62**:**1391-1402.

- Causal Relation Diagrams

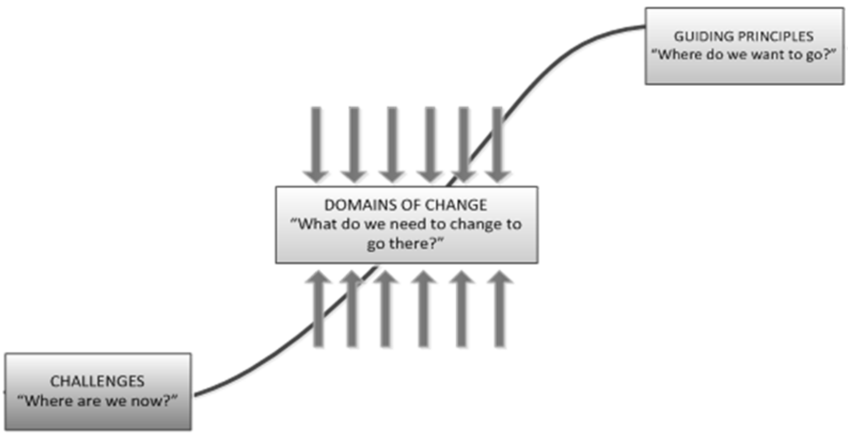
Sterman, J.D., (2000). Business Dynamics, Systems Thinking, and Modeling for a Complex World, McGraw Hill. pp. 137-156.

- **Transition Management Cycle**

Loorbach, D., (2010), Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework, Governance: An International Journal of Policy, Administration, and Institutions, 23(1), 161–183.

Box 3. Transition Snapshot to assist discussions during first workshop.

The "challenges" of today's conditions are contrasted with "guiding principles" of where we want to go. This frames the agenda of the workshop series: How do we overcome today's problems and create transformative change to achieve our desired future?



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

And Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: Yarra Valley Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-16-0.

PHASE B. CURRENT SYSTEM
STEP B.2 – UNCOVER THE IMPERATIVE FOR CHANGE

Objectives: Identify underlying challenges of the current system and the domains that require change if the vision is to be achieved

Resources:
- 2-4 hours of small group work with direct facilitation
- 1-2 days for analysis of workshop notes and consolidation into a set of underlying challenges and domains of change

Methodology:

FACILITATOR
1. Identify the breadth of challenges that underlie the causes of system problems
   a. Differentiate between symptoms and causes
   Facilitation question examples:
   Why do these problems persist?

FACILITATOR
2. Develop a shared understanding of what constitutes the problem
   Facilitation question examples:
   What underlies the problem?
   What are the different characteristics of the problem?

GO TO STEP C.1 (FORMULATE GUIDING PRINCIPLES)

FACILITATOR
3. Contrast guiding principles with underlying challenges to identify what embeds the current way of operating and thinking (Box 4)
   Facilitation question examples:
   What areas require change?

ANALYST
4. Report back to the participants the lists of underlying challenges and domains of change. Provide opportunity for refinements (Box 5)

Tips:
- Focus on domains or areas in the system that constrain existing operations and previous attempts to change.
- Facilitators and analysts need to achieve a balance between communicating the extent of the system challenges and a digestible presentation of them.

Outputs: A list of underlying challenges and a list of domains of change

Key references:
Loorbach, D., and Rotmans, J., (2010), The practice of transition management: Examples and lessons from four distinct cases, Futures, Vol.42, pp.237-246

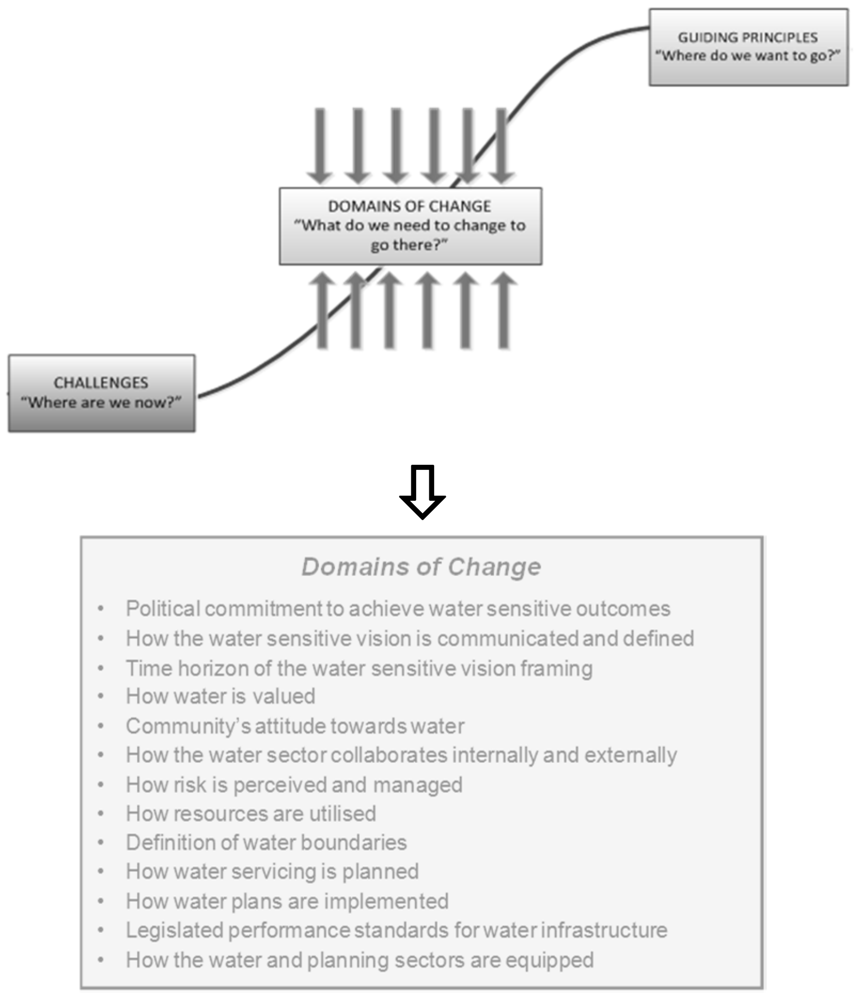
Output from this step flows into Phase D. Inside the pathways box

Box 4. An example of underlying challenges

No bipartisanship for long term commitment
No compelling vision to drive change
Existing management culture inhibits innovation
Boundaries and relationships are undefined
Legacy of the past sets hurdles
Integration creates new complexities

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

Box 5. An example of domains of change



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE C. VISION

STEP C.1 – FORMULATE GUIDING PRINCIPLES

Objectives: Formulate a suite of principles that represent desired system outcomes for the long-term.

Resources:

- 2-10 hours of small group work with direct facilitation
  depends on group's experience in prior envisioning activities and knowledge of similar work
- 2-3 days for analysis of workshop notes and consolidation into a set of principles

Methodology:

FACILITATOR
1. Stimulate thinking about long-term aspirations rather than quick fixes of current system's problem(s)
   Facilitation question examples:
   Where do we want to go from here?
   What is the ideal region?
   What are your dream principles?
   What do you think it is essential for future sustainability of the region/city?

GO TO STEP B.2 (UNCOVER IMPERATIVE FOR CHANGE)

ANALYST
2. Identify principles that reflect the system's broad operations
   a. Formulate principles as descriptive statements of the desired future system
   b. Cluster principles in themes that capture similar functions or aspirations (Box 6)

FAC.
3. Develop shared understanding that principles work in synergy with each other

FAC.
4. Report back to the participants the list of guiding principles and provide opportunity for refinements

Tips:

- Acknowledge past and contemporary visioning work that relates to the project.
- Provide the choice to the participants to either build on existing work or start with a new perspective to build principles.
- Facilitators need to be careful to harvest aspirations and desires from the group work and steer the discussion away from solutions or descriptions that have origins elsewhere.

Outputs: A list of guiding principles

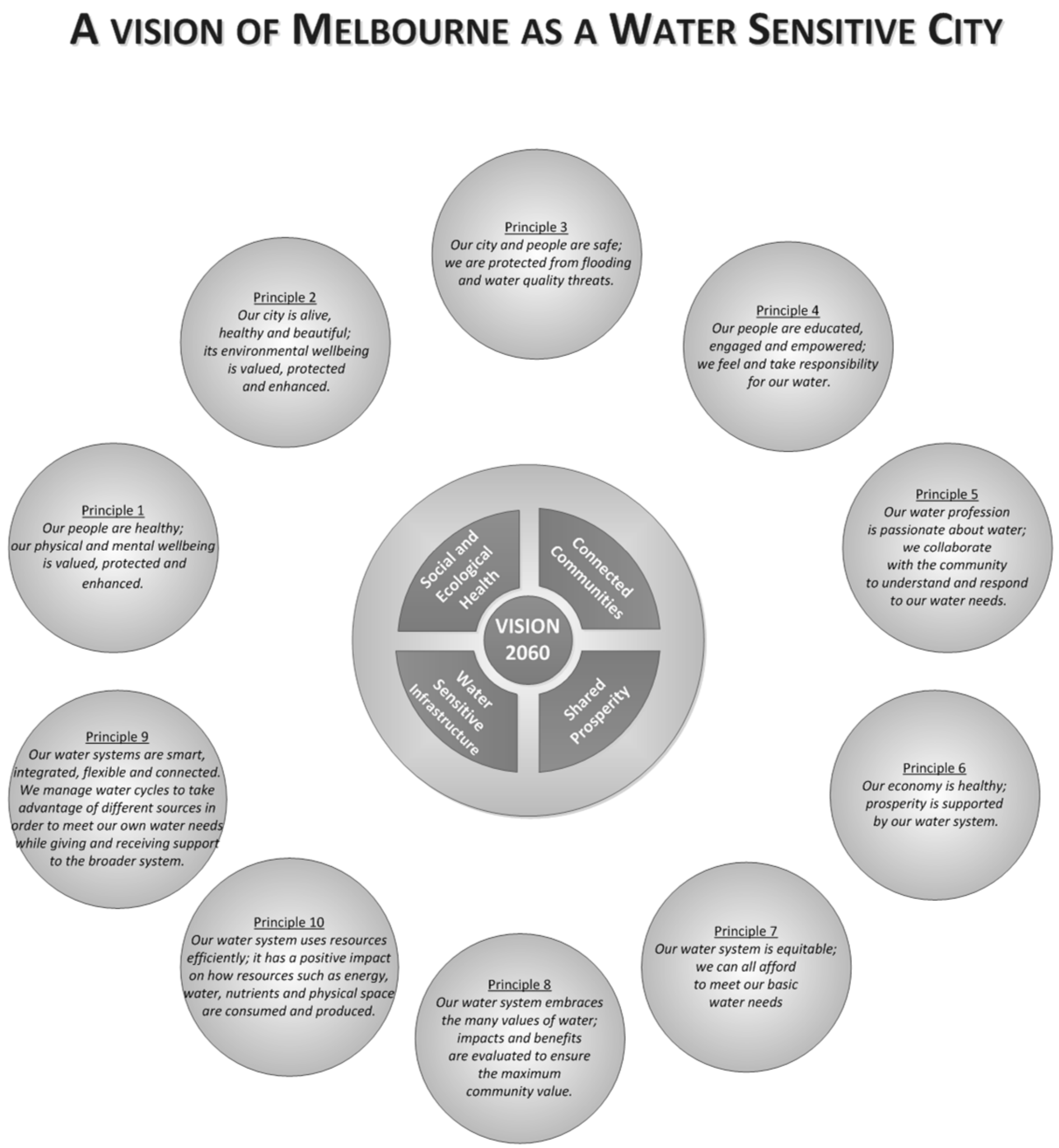
Key references:

Lehmann, S., (2010), The principles of green urbanism, Transforming the city for sustainability, Earthscan: London.

Newman, P., and Jennings, I., (2008), Cities as sustainable ecosystems: Principles and Practices, Island Press: London

Output from this step flows into Phase C. Vision

Box 6. An example presentation of guiding principles.



The principles here built on previous work:

- Ministerial Advisory Council for the Living Melbourne, Living Victoria Plan for Water (2011). Living Melbourne, Living Victoria Roadmap, Department of Sustainability and Development, Victorian Government, Australia p9.
- Binney, P., Donald, A., Elmer, V., Ewert, J., Phillis, O., Skinner, R. and Young, R. (2010), IWA Cities of the Future Program: Spatial Planning and Institutional Reform Conclusions from the World Water Congress. International Water Association, p9.

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE C. VISION

STEP C.2 – DEFINE THE VISION

Objectives: Elaborate the vision by operationalising the guiding principles for the local context

Resources:
- 2-4 hours of small group work with direct facilitation to generate strategic objectives
- 2-4 hours of whole group work with exploratory facilitation to review and refine the strategic objectives
- 4-5 days for analysis of workshop notes and consolidation into a vision description

Methodology:

ANALYST
1. Decide on the most suitable format of the operationalised definition of the vision (e.g. targets, strategic objectives, objectives hierarchies)
   a. For this choice, project team and analysts need to consider the project objective and aims, the intended focus of discussions and intended use of the project outputs (Box 7). For example, targets are used to set a quantitative value that leaves no ambiguity, while strategic objectives do not typically create such rigid definition

FACILITATOR
2. Generate a set of vision definitions for each guiding principle (Box 8)
   Facilitation question examples:
   What does this principle mean for the system?
   How do you define the image?
   How would you know if the image has been achieved?

FACILITATOR
3. There may be trade-offs and synergies between specific definitions when it comes to working towards achieving the principles. Facilitated discussion about these trade-offs and synergies may be valuable if the project aim is to create operational outcomes.

FAC.
4. Report back to the participants the set of vision definitions and provide opportunity for refinements

Tips:
- The vision definition should give specific meaning to the abstract ideas depicted in the vision for the particular project context (system, location, time).

Outputs: A set of definitions for each guiding principle

Key references:

Keeney R.L., (1996a). Value-Focused Thinking: Identifying Decision Opportunities and Creating Alternatives, European Journal of Operational Research, Vol. 92, pp. 537-549.

Keeney, R.L., (1996b). Value-Focused Thinking: A Path to Creative Decisionmaking, Chapter 3, Harvard University Press.

Box 7. Characteristics of strategic objectives as an example vision definition.

Strategic objectives define the vision aspirations by showing which characteristics of the vision are ultimately important (Keeney 1996a). Strategic Objectives need to be:

a. Measurable
b. Contextualised
(have specific meaning at a specific context)
c. Comprehensive
d. Relevant

A step in defining strategic objectives is to define the direction of the objective to reflect the ambition of the vision.

Source: Keeney R.L., (1996a). "Value-Focused Thinking: Identifying Decision Opportunities and Creating Alternatives", *European Journal of Operational Research*, Vol. 92, pp. 537-549.

Box 8. Example of strategic objectives defining a guiding principle

Our city and people are safe; we are prepared for flooding and water quality threats.

Strategic Objective

3A Full compliance with drinking water quality standards for potable water

3B Full compliance with fit-for-purpose quality standards for non-potable water

3C No human fatalities from flood events

3D No critical infrastructure built in flood prone areas (e.g. treatment plants, pump stations, storages, energy supply, telecommunications, hospitals, aged care facilities, emergency services)

3E Low frequency of exposure of critical infrastructure to flood risk (e.g. 1:200 years)

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE C. VISION

STEP C.3 – DESCRIBE THE VISION

Objectives: Create storylines of the envisioned future system that capture the imagination of both participants and a broader audience

Resources:
- 2 hours of small group work with direct facilitation
- 1-2 days for analysis of workshop notes and consolidation into a vision description

Methodology:

FACIL.
1. Keep notes of phrases, words, descriptions and interpretations of desired future(s) during all envisioning discussions

ANALYST
2. Compile the expressed descriptions that reflect the experience of living in the desired future (Box 9 and 10)
   a. Descriptions should be comprehensive (e.g. landscape features, lifestyle, practices, ways of operating) and include how different system components interact

FAC.
3. Report back to the participants the vision description and provide opportunity for refinements

Tips:
- Facilitators should steer discussion away from criticism about expressed desires and out-of-the-ordinary ideas during the envisioning discussions, instead bringing focus to the shared aspirations of the participants.

Outputs: A rich description of the vision that synthesises different parts of the desired future. The vision could be presented as an overarching vision or in separate themes. The format of the description could be narratives, photos, illustrations, newspaper headlines or front pages.

Key references:

Van Notten, P.W.F., Sleegers, A.,M., van Asselt, M.B.A., (2005), The future shocks: On discontinuity and scenario development, Technological Forecasting and Social Change, 72, 175-194.

Sondeijker, S., Geurts, J., Rotmans, J., and Tukker, A., (2006), Imagining sustainability: the added value of transition scenarios in transition management, Foresight, Vol.8, No.5, pp.15-30.

Wiek, A., Binder, C., Scholz, R.W., (2006), Functions of scenarios in transition processes, Futures, Vol.38, pp.740-766.

Box 9. Example of vision description: narrative

Water Sensitive Infrastructure

Our knowledge about the water cycle is based on information that is reliable, accurate, up-to-date and user-friendly. We have smart tools for using this information to support water planning and management. We plan for contingencies and are prepared for surprises. Our water cycles are planned such that we take advantage of different water sources that are safe and support self-sufficiency at local, neighbourhood and regional scales. In parallel, there is capacity in our city's central system to supply water to meet the basic needs of our households, businesses and communities. We seize the productive potential of different resource streams, in terms of nutrients, minerals and energy. Our water infrastructure is energy efficient and does not have a net negative impact on our atmosphere or biosphere. Our water sensitive infrastructure is designed to provide benefits in addition to its core functions. It adds to the beauty and value of our area.

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

Box 10. Example of vision description: Illustration

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE C. VISION

STEP C.4 – BUILD VISION RESILIENCE

Objectives: Develop a shared understanding of which parts of the vision cannot be compromised on

Resources:

- 2-3 hours of small group work with direct facilitation
- 2 hours of whole group work with exploratory facilitation
- 1-2 days for analysis of workshop notes and reflection of the vision core

Methodology:

ANALYST

1. Produce different future context scenarios to represent a range of possible combinations of trends that could affect the system, for example:
   a. Use existing scenarios, e.g. this project, IPCC, national scenarios, or
   b. Tailor existing scenarios for the specific project, or
   c. Develop context scenarios for the specific project (Box 11)

FACILITATOR

2. Examine how each definition of the vision (e.g. strategic objectives) would be adapted (raised, lowered or maintained ambitions) under different future context scenarios (Box 12)
   a. Systematically document the adaptations (e.g. template)
   b. Steer discussions to reveal participants' thinking behind their adaptation choices

   Facilitation question examples:

   How will this target change under the scenario?
   In this future context, do we raise, lower or maintain our ambitions to achieve the strategic objective?
   Or more broadly, what can we compromise on?
   When can we raise our ambitions?

ANALYST

3. Analyse discussions and notes
   a. Identify the core of the vision (parts of the vision that are uncompromisable in terms of commitment to achieving them)
   b. Hypothesise explanations of adaptations in different future contexts

FACILITATOR

4. Report back to the participants the core of the vision and hypotheses
   a. Stimulate discussions about deep values and future needs
   b. Explore group ideas about why level of commitment to achieve different parts of the vision changes in different future contexts

Tips:

- This methodological step is only possible when vision definitions are clearly formulated and shared by the group.
- Development of context scenarios will require substantial analytic input prior to this methodological step. There are multiple options for this step and may require the involvement of a panel of experts. See Box 11.
- Facilitators should steer the discussion away from identifying strategies to respond to different future contexts, as strategy development comes later.
- Participants may not wish to adapt the vision in different future contexts, if they consider the aspirations should be maintained regardless of the context conditions. In this case, place focus on how level of commitment (e.g. in terms of available resources) would be adapted.
- Depending on the purpose of the project, careful facilitation may be required to encourage thinking and discussion around deep societal values and level of commitment to the vision.

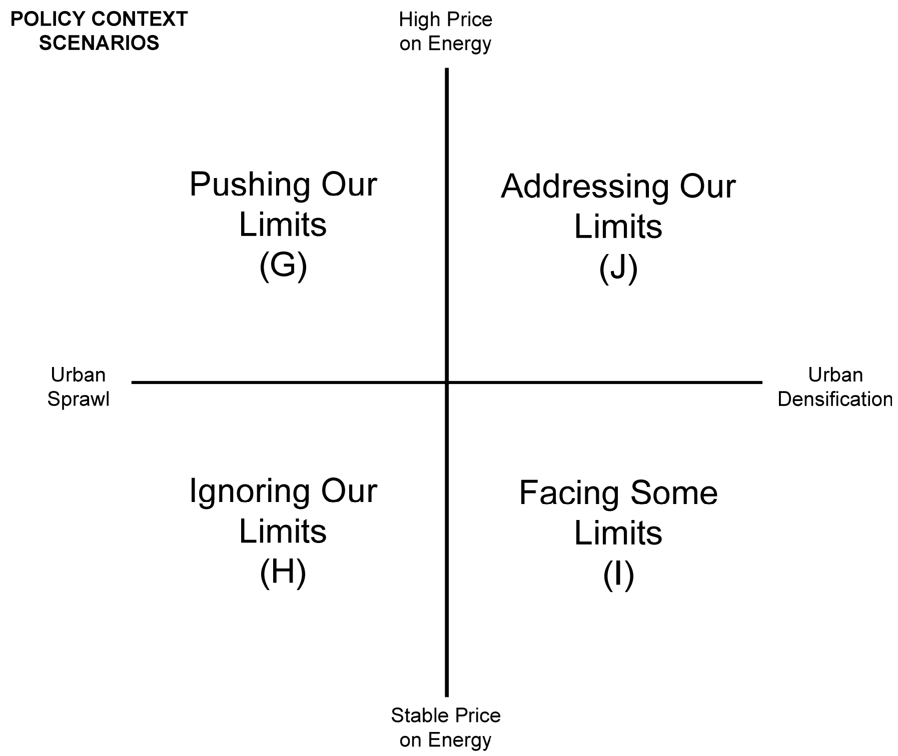
Outputs: Synthesis of the vision core and explanations of adaptations in different future contexts.

Key references:

Walker, B., and Salt, D., (2006), Resilience thinking, Sustaining ecosystems and people in a changing world, Island Press.

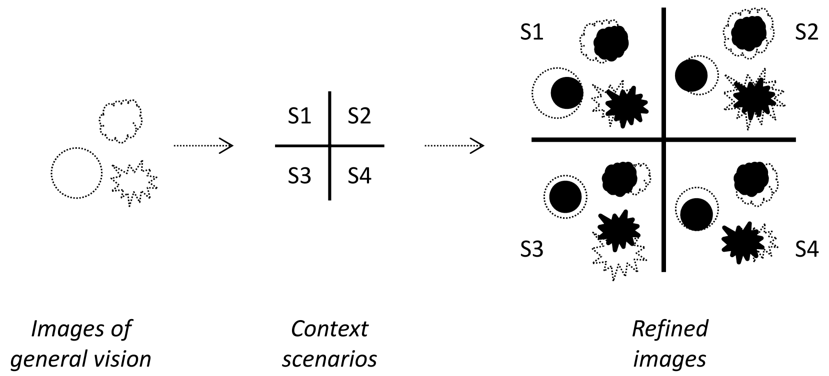
Box 11. Development of context scenarios.

The *Melbourne's Transition to a Water Sensitive City* project used a panel of experts to develop context scenarios for use in the workshops. The expert panel identified a list of external drivers and trends that had a high probability of occurring and a high impact on the water system if it did occur. The project analysts then formulated these trends into families of context scenarios, an example of which is shown below. See Appendix C.2 of Ferguson et al, (2012) for more information.



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

Box 12. Example presentation of conceptual images of the vision core to steer discussions.



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE D. STRATEGIC TRANSITION PATHWAYS

STEP D.1 – GENERATE STRATEGIC PATHWAYS

Objectives: Identify sets of strategies that are likely to achieve the defined vision

Resources:

- 5-10 hours of small-group work with direct facilitation over 2-3 workshops
- 5-8 days for analysis of workshop notes and consolidation into sets of strategic pathways

Methodology:

FACILITATOR

1. Develop strategies to reach the future vision
   a. Backcast from each guiding principle and associated set of specific definitions to identify a broad range of actions
   Facilitation question examples:
   How can we achieve this principle?
   How can we achieve this strategic objective?

FACILITATOR

2. Develop strategies to bring about transformative change from today's conditions
   a. Backcast from each domain of change and underlying challenge to identify a broad range of actions
   Facilitation question examples:
   What strategies could enable these changes?
   What strategies could enable changes for Y domain in the context of X pathway?

FACILITATOR

3. Set time definitions for strategies
   a. Define short, medium and long-term horizons
   b. Assign time-horizon to every strategy developed
   Facilitation question examples:
   What needs to be done now?
   What needs to be done in the near future?
   What needs to be done in the far future?
   Or, more specifically:
   When should each strategy be implemented?

ANALYST

4. Formulate strategic transition pathways (Box 13)
   a. Bundle strategies into transition pathways. Given the developed strategies, analysts decide whether to form bundles based on the outcome of the pathway (e.g. green the city) or on the thematic focus of the pathway (e.g. institutional, economic)
   b. Identify subsets within pathways (strategic transition paths) that would lead to different outcomes (Box 13)

ANALYST

5. Operationalise each strategic transition path (Box 14)
   a. Categorise strategies within paths along time horizons to show the anticipated progressive impacts of each successive strategy
   b. Aggregate strategies within paths to consistently show how they are operationalised into actions and mechanisms

FAC.

6. Report back to the participants the set of strategic transition pathways and provide opportunity for refinements

Tips:

- Generation of strategies may require different sessions rather than one lengthy session. This allows time for analytic input and for participants to reflect on the outputs.
- Facilitators should avoid steering the backcasting discussion towards finding a direct match between guiding principles and formulated pathways. The pathways should be formulated in a way that shows how they would enable the overall transition in a synergistic way.
- Careful facilitation may be required to encourage participants to move beyond short-term thinking and consider strategies for the long-term.
- Formulation of the strategic pathways needs to consider the audience and intended use of the project outputs.

Outputs: A suite of strategic transition pathways that, in synergy, would achieve the vision and bring about

PHASE D. STRATEGIC TRANSITION PATHWAYS

STEP D.1 – GENERATE STRATEGIC PATHWAYS

an overall transition.

Key references:

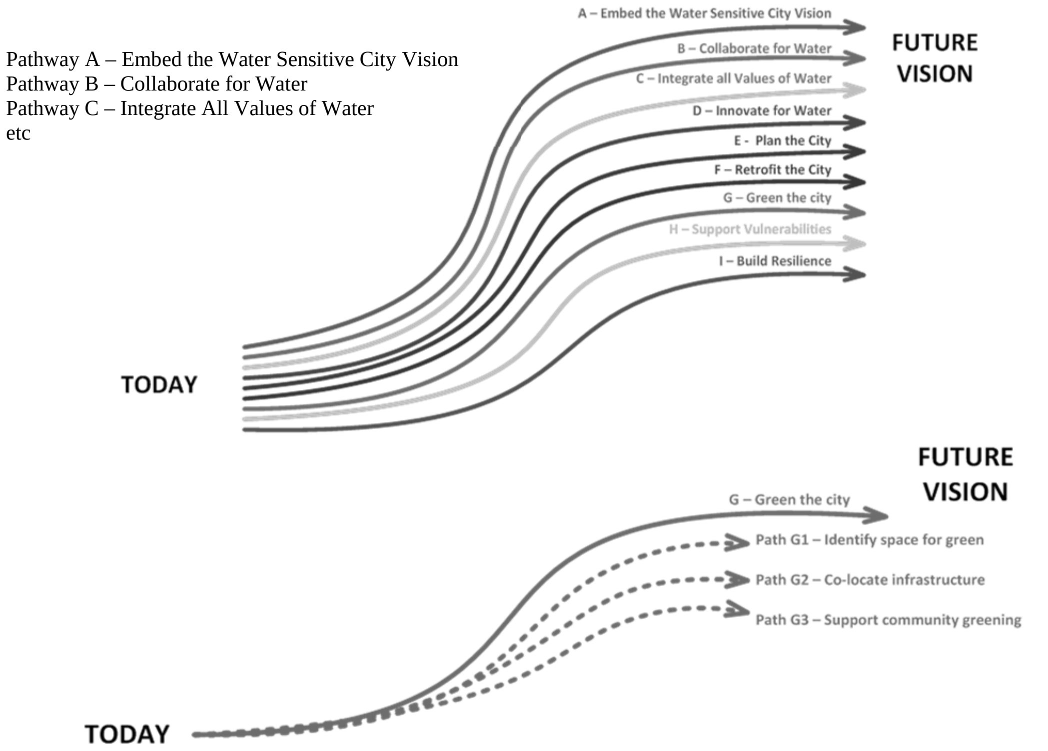
Quist, J., (2007), Backcasting for a sustainable future, the impact after 10 years, PhD Thesis, Eburon: The Netherlands

Phdungsilp, A., (2011), Future studies' backcasting method used for strategic sustainable city planning, Futures, 43, 707-714.

Robinson, J., Burch, S.,Talwar, S., O'Shea, M., Walsh, M., (2011), Envisioning sustainability: Recent progress in the use of participatory backcasting approaches for sustainability research, Technological Forecasting and Social Change, 78, 756-768.

Next step: Build system resilience

Box 13. Visualisation of transition pathways and paths.



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

Box 14. Example of an operationalised strategic transition path

Pathway B – COLLABORATE FOR WATER	Short-term Strategies	Medium-term Strategies	Long-term Strategies
B1: Collaborate among disciplines	Establish broad multi-disciplinary education o Develop multi-disciplinary broad university curriculum	Encourage water professionals to consider non-engineering solutions	Co-design water infrastructure as landscape art

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE D. STRATEGIC TRANSITION PATHWAYS

STEP D.2 – BUILD SYSTEM RESILIENCE

Objectives: Identify sets of strategies that build resilience into the system

Resources:

- 1-2 hours of small-group work with direct facilitation
- 1 day for analysis of workshop notes and incorporation into the set of strategic transition pathways

Methodology:

ANALYST

1. Produce descriptions of different extremes and surprises to represent a range of disturbances the system could face, for example (Box 15):
   a. Use existing scenario work about extreme unlikely scenarios e.g. this project, national scenarios, or
   b. Tailor existing extreme scenarios for specific project, or
   c. Develop wildcards for the specific project
   d. Descriptions should include a depiction of the extreme or surprise and its impact on system during aftermath

FACILITATOR

2. Use the descriptions of each extreme or surprise to develop (Box 16):
   a. Mitigation strategies that build resilience through preparation
   b. Adaptation strategies that build resilience through response
   c. Recovery strategies that build resilience through coping

   Facilitation question examples:

   What additional strategies will be required to prepare for this surprise?

   Or more broadly, how can we prepare our economy, communities, infrastructures and ecosystems to cope with extreme futures such as this surprise?

ANALYST

3. Analyse discussions and notes
   a. Incorporate strategies that build overall system resilience into the developed set of strategic transition pathways
   b. Distinguish a separate set of strategies that only respond to specific extremes or surprises (these could be considered as emergency strategies)

FA.

4. Report back to the participants the broadened set of strategic transition pathways that would build system resilience

Tips:

- This methodological step builds on outputs of the previous strategy generation step so that participants can identify complementary strategies that build system resilience.
- Development of a set of extremes and surprises will require substantial analytic input prior to this methodological step.
- Facilitators should steer the discussion away from assessing the likelihood of the extremes and surprises.
- Careful facilitation is required to encourage thinking and discussion about the system's preparedness and capacity to deal with extremes and surprises, while avoiding defensive thinking.
- Facilitators should steer the discussion to consider broad system resilience, including economy, community, infrastructure and ecosystems.

Outputs: A broadened set of strategic transition pathways that would build system resilience over the course of a transition

Key references:

Wardekker, J.A., de Jong, A., Knoop, J.M., and van der Sluijs, J.P., (2010), Operationalising a resilience approach to adapting an urban delta to uncertain climate changes, Technological Forecasting and Social Change, Vol. 77, pp.987-998.

Saritas, O., and Smith, J.E., (2011), The big picture – trends, drivers, wild cards, discontinuities and weak signals, Futures, 43, 292-312.

Next step: Prioritise Paths

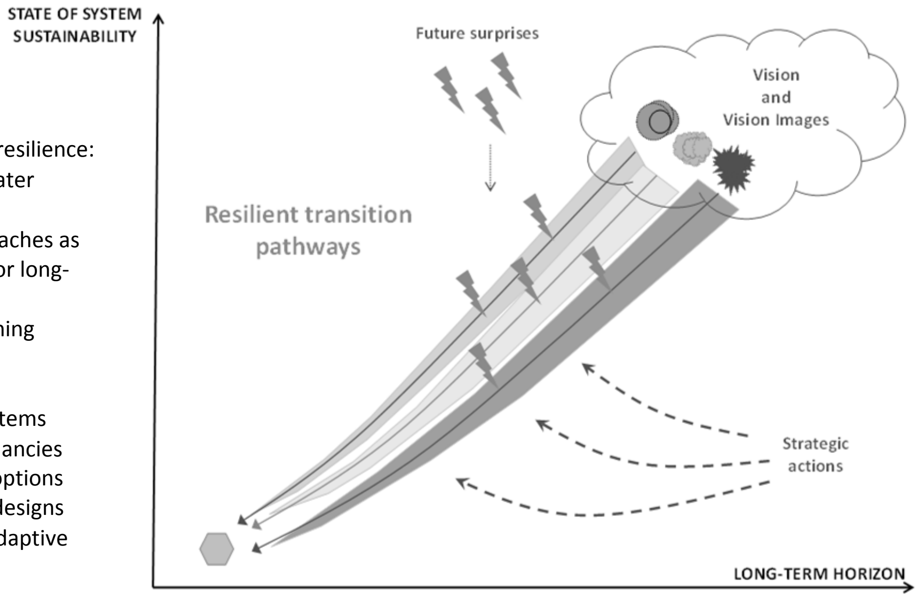
Box 15. Example presentation of a surprise based on wildcards method.

Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

Box 16. Example presentation of system's resilience over the course of the transition to stimulate group discussions

Example strategies for resilience:

- Establish trust in water authorities
- Use scenario approaches as standard practice for long-term planning
- Establish early warning systems
- Develop effective communication systems
- Incorporate redundancies and decentralised options into water system designs
- Build flexible and adaptive infrastructure



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

PHASE E. TRANSITION AGENDA
STEP E.1 – PRIORITISE PATHS

Objectives: Develop a transition agenda that sets out the priorities and recommendations for bringing about the transition

Resources:
- 4-8 hours of small-group work with direct facilitation
- 2-3 days for the assessment of the strengths of each strategic path
- 5-8 days for the analysis of workshop notes and synthesis into a transition agenda

Methodology:

ANALYST

1. Assess strengths of each strategic transition path. For example:
   a. Which paths could address the underlying challenges?
   b. Which paths align with existing policy documents and strategic plans?
   c. Which paths are likely to be robust (i.e. have resources available and mobilised) in different future contexts?

FAC.

2. Highlight the strengths of each path to the group to support their thinking about which paths may be considered priorities

FACILIATOR

3. Identify which strategic transition paths are the priorities for bringing about the transition (Box 17)
   a. Identify which paths are critical for short, medium and long-term change
   b. Steer discussions to reveal participants' thinking behind their choices
      Facilitation question examples:
      What is the critical sequence of paths?

ANALYST

4. Analyse discussions and notes
   a. Synthesise the outputs into a representation of the interconnected critical paths
   b. Draw out the core strategic features into an overall transition pathway for achieving the future vision (Box 18)
   c. Report back to the participants the critical paths and the overall transition pathway

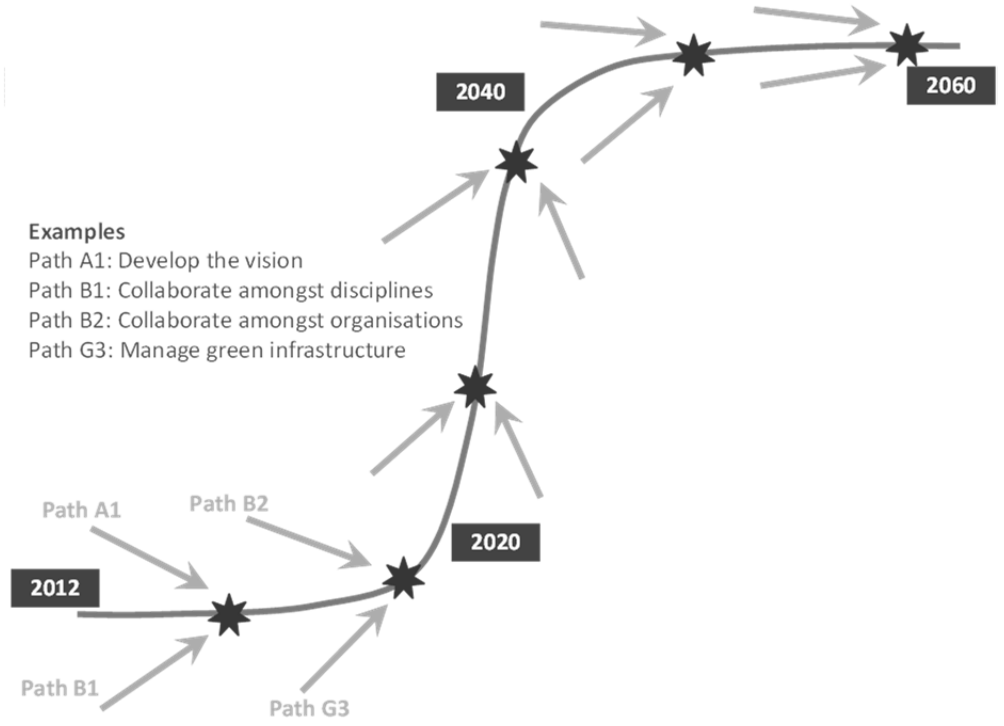
FACILITATOR

5. Make the short-term critical paths operational
   a. Identify which strategies from each critical path would be easy to achieve in the short-term
   b. Identify which strategies for each critical path would be hard to achieve in the short-term
      Facilitation question examples:
      What are the "low hanging" short-term strategies?
      What are the "hard to reach" short-term strategies?
   c. Identify immediate next steps to assist the delivery of the critical paths. Facilitation question examples:
      What are the most critical next steps?
      What are the overarching next steps for the short-term strategies?

Tips:
- Assessment of strengths of each strategic transition path will require substantial analytic input prior to this methodological step
- This methodological step builds on outputs of the previous strategy generation steps
- Facilitators should be careful to present the highlighted strengths of each path as an analytic output that forms a tool to assist prioritisation, rather than a prescription for which paths should be priorities
- Facilitators should steer the discussion away from allocating roles and responsibilities to individuals or stakeholders represented in the group if the intended purpose is not to develop specific action plans that representatives are committed to delivering
- Facilitators should communicate clearly about the extent to which operationalisation of the short-term critical paths can be realised in consistency with the project's aim and scope

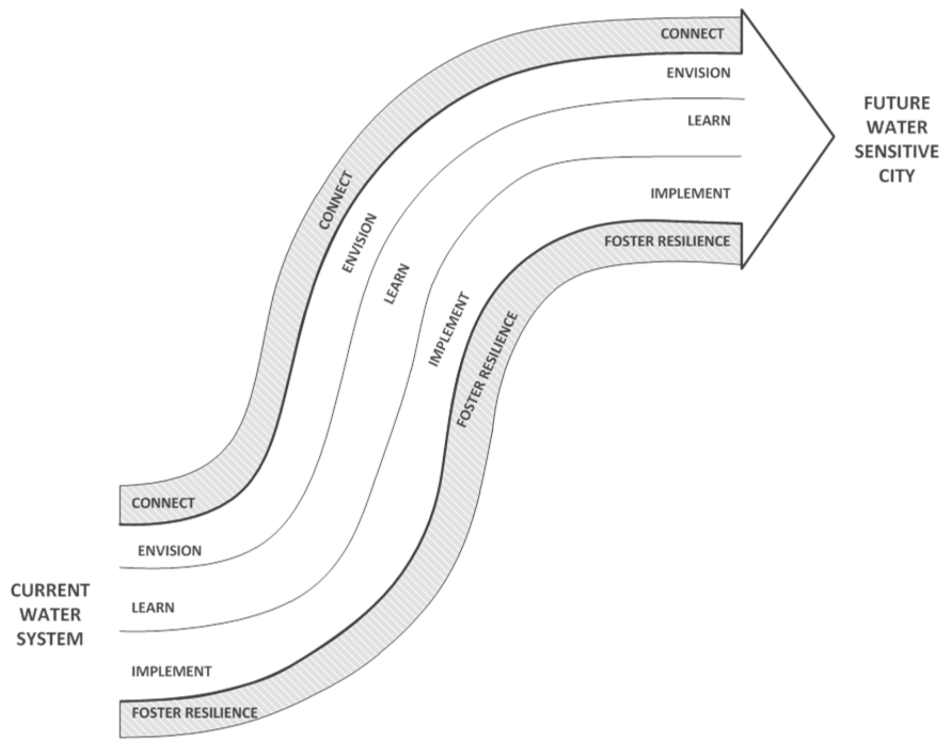
Outputs: A transition agenda that sets out the priority transition paths and recommendations for how they could be operationalised with actions and timelines

Box 17. Example presentation of critical subset of paths to stimulate group discussions



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

Box 18. Example presentation of an overarching transition pathway



Source: Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: Recommendations for Strategic Action. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-13-9.

Conclusion

This Guidance Manual forms one of the key deliverables of the *Melbourne's Transition to a Water Sensitive City* project. It sets out an innovative methodology for translating sustainability principles into practical outcomes for local regions and describes how it should be operationally used.

The methodology is designed to incorporate resilience and transition thinking into strategic planning processes that aim to achieve sustainable water sensitive outcomes. The methodological steps presented in the Guidance Manual are tailored for the urban water context in Melbourne, Australia. It was trialled in two different series of workshops with valuable and inspiring outcomes.

Application of the methodology in other contexts would follow the overall structure described in this Guidance Manual but details of the steps would need to be adapted. In particular, factors such as the project aim and purpose, the intended audience of the project outcomes, the time and other resources available would need to be taken into consideration.

Appendix A: Details of the "Melbourne's Transition to a Water Sensitive Project"

Background and Context

There is a growing international interest by communities, governments, planning sectors and water industries in how water can support the liveability, sustainability and resilience of a city. While these themes do not diminish the importance of traditional water servicing from water supply, sewerage and drainage infrastructure, they do present new challenges for how urban water systems are planned, designed and managed. Strategic planning for large-scale centralised infrastructure is traditionally characterised by an approach which aims to reduce uncertainties and maintain control through emphasising technical solutions and basing decisions on rational cost-benefit assessments made upon consideration of a narrow set of values. This approach often relies on assumptions that key variables, such as rainfall patterns, resource availability and community values, are largely stable and predictable.

Until recently, this approach served the needs of urban water systems relatively well. However, the water sector has become aware that while existence needs of clean water, sanitation and flood protection are critical, society also has broader needs from our urban water system. For example, we value ecological health, amenity, thermal comfort, beauty and equity – characteristics that are considered to make Melbourne 'liveable'. Further, the climatic conditions in Australia over the last ten years have forced the water sector to consider how complexity, variability and uncertainty can be accommodated in the planning and design of urban water systems.

The water sector is therefore exploring the question of how a liveable, sustainable and resilient city can be supported by its water system and there is now broad acknowledgement that the way we plan, design and manage water servicing must move beyond the traditional approach so that we can meet all our urban water needs into the future, regardless of the future conditions experienced. The water sensitive city offers an alternative perspective on how the planning and design of water systems can be undertaken. It focuses on holistic planning and management of the integrated water cycle and emphasises flexibility, diversity and adaptability in its solutions – a radical shift from the traditional strategic planning approach.

The broad goals encompassed by the water sensitive city concept include water security, water conservation, fit-for-purpose use, flood protection, pollution minimisation, urban amenity, broad stakeholder participation, long-term timeframes for planning and strong collaboration between organisations, disciplines, sectors and the community. While these goals are widely shared and a vision for how a water sensitive future would function is starting to emerge from the water sector, there is not yet an accepted set of attributes and indicators to define the specifics of a water sensitive city. Further, there is limited understanding of how strategic planning in urban water systems can facilitate transformative change in the water sector, to move from today's conditions towards water sensitive planning, design, construction, operation, management, governance and evaluation of options.

Against this background, Monash Water for Liveability at Monash University led a research project on the topic of how the transition to water sensitive regions can be enabled through strategic action. The project involved a series of workshops designed to facilitate detailed investigation of how community needs for public health and wellbeing, urban amenity and environmental protection can be met through water sensitive planning and design principles.

Project Aim and Objectives

The aim of the research project was to develop tools that support the latest efforts in science, policy and practice for understanding how strategic planning at the regional scale can enable the transition of urban regions from their current conditions to liveability, sustainability and resilience.

The project objectives were to:

a) Develop a detailed vision for how the social, technical and ecological aspects of local urban regions would function if the principles of a water sensitive city were implemented

b) Explore how strategic actions could achieve the water sensitive vision from current conditions

c) Test the latest international scientific ideas on strategic planning processes and develop an innovative methodology for translating sustainability principles into practical outcomes for local regions

d) Produce deliverables that are accessible and practical for use by community, governments and industry to support approaches to addressing liveability and sustainability challenges

e) Provide a forum in which a diversity of perspectives and rigorous discussion leads to shared understanding, action learning and strategic partnerships amongst broad stakeholders in order to achieve the project objectives

Project Outcomes

This project applied the methodology for two different areas of Melbourne, each covering a cluster of adjacent local government areas. The 'South East Cluster' workshop series followed all the steps described in this Guidance Manual, while the 'Yarra Valley Cluster' series followed a more condensed version due to time constraints.

Outcomes from these applications are reported in the following documents:

- Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: South East Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam, The Netherlands. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-15-3.

- Ferguson, B.C., Frantzeskaki, N., Skinner, R. and Brown, R.R. (2012) Melbourne's Transition to a Water Sensitive City: Yarra Valley Cluster Workshop Series. Dutch Research Institute For Transitions, Erasmus University Rotterdam, The Netherlands. Monash Water for Liveability, Monash University, Melbourne, Australia. ISBN 978-1-921912-16-0.

APPENDIX D. DEVELOPING CONTEXT SCENARIOS AND EXPLORING VISION RESILIENCE

This appendix contains excerpts (Appendix C.2 and B.1) from:

Ferguson, B.C., Frantzeskaki, N., Skinner, R., Brown, R.R. (2012c) Melbourne's transition to a Water Sensitive City: South East Cluster workshop series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, ISBN 978-1-921912-15-3. Available for download from http://www.waterforliveability.org.au/

APPENDIX C.2: CONTEXT SCENARIOS (Ferguson et al., 2012c)

C.2.1. Introduction

This appendix documents the construction of *context scenarios* as an input for the *Melbourne's Transition to a Water Sensitive City* research project, coordinated by the Centre for Water Sensitive Cities. The project aims to develop tools for understanding how strategic planning at the regional scale can enable the transition of urban regions from their current conditions to a future water sensitive city, encompassing themes such as liveability, sustainability and resilience. This appendix outlines the process and results of the development of context scenarios for the project.

C.2.2. Constructing the Context Scenarios

An initial set of contextual drivers and trends were identified by the research team. This list was generated by reading literature and previous reports on Melbourne's Water System (e.g. Howe et al., 2005; Melbourne Water, 2009). The proposed set of drivers and trends was:

- Population Change (low growth, high growth, shrinkage)
- Urban Development (densification, sprawl)
- Personal Values (communal, individual)
- Societal Priorities (knowledge, hedonism)
- Economic Liberalism (globalisation, protectionism)
- Economic Health (wealthy, poor)
- Climate Conditions (historical patterns, extreme patterns)
- Climate Policy (strong action, weak action)

A panel of experts was assembled to review this list of proposed drivers and trends and provide critical feedback. The experts were invited according to the following criteria:

- Experience with scenario work
- Visionary and strategic view of the system's development
- Knowledgeable of different elements/subsystems of the reference system (urban water system including infrastructure and governance)

The experts represented the following organisations:

- Centre for Water Sensitive Cities
- University of Innsbruck
- Melbourne Water
- EPA Victoria
- DSE

The expert panel was asked to rate the proposed drivers according to whether they had High or Low Impact and High or Low Probability. Only drivers which had both High Impact and High Probability were considered relevant for inclusion in the context scenarios (Table C.2.1). Drivers which had High Impact but Low Probability are considered *wildcards*, and are considered in a different part of this project.

Table C.2.1. Selection Criteria for Context Scenario Drivers (Frantzeskaki & Walker, forthcoming).

<table>
<tr><td colspan="2" rowspan="2">External Drivers and Events</td><td colspan="2">PROBABILITY</td></tr>
<tr><td>Low</td><td>High</td></tr>
<tr><td rowspan="2">IMPACT</td><td>Low</td><td></td><td></td></tr>
<tr><td>High</td><td>Wildcards</td><td>Context Scenarios</td></tr>
</table>

In reviewing the proposed drivers, the expert panel recommended that some should be accepted in their current form, that some be rejected as significant drivers and that some additional drivers be included (the outcomes from this step of the process are shown in Section C.2.7).

The research team analysed the outputs from the expert panel and categorised each driver according to its type (condition or policy) and scale (global, national, local).

- Conditions are those drivers that have an indirect impact on the system and cannot be immediately influenced by policy decisions.
- Policies have a direct impact on specific elements of the system and are under immediate control of actors within the system.

The research team also redefined the boundaries of the water system to ensure that each of the drivers could be assessed according to whether it was internal or external to the system.

- Drivers that are external set the *context* for the water system and should be included in the context scenarios.
- Drivers that are internal to the system are considered part of the water system itself and drive the system's internal dynamics.

Table C.2.2 presents the systematic assessment of the list of drivers based on these categories and boundary delineations. Note that there are correlations and interdependencies between some of the drivers in Table C.2.2. The construction of scenarios involves bringing together different drivers that, in synergy, create an uncertain context that will have impacts on the system.

Table C.2.2. Expert List of Drivers and Trends.

Driver	**Trends**	**Type**	**Scale**	**Boundary**
Climatic Behaviour	Historical patterns, extreme patterns	Condition	Global	External
ICT Advancement/Diffusion	Significant, minimal	Condition	Global	External
Economic Health	Wealthy, poor	Condition	National	External
Population Change	Low growth, high growth, shrinkage	Condition	National	External
Energy Price	Major increase, relatively stable	Policy	National	External
Water Price	*Major increase, relatively stable*	*Policy*	*National*	*Internal*
Environmental Health	*Natural, adapted, degraded*	*Policy*	*Local*	*Internal*
Urban Development	Densification, sprawl	Policy	Local	External
Rural Trade of Water	*Protected, unrestrained*	*Policy*	*Local*	*Internal*

As a result of this analysis *Water Price*, *Environmental Health* and *Rural Trade of Water* were not considered to be context scenario drivers; instead these drivers are expected to be considered by the participants during the workshop series when they reflect on the type of policy solutions required for transitioning to a water sensitive city.

Three different types of context scenario drivers were therefore identified: global conditions, national conditions and policies. The final list of context drivers and their associated trends are summarised in Tables C.2.3 and C.2.4.

Table C.2.3. Final List of Context Scenario Drivers.

SCENARIO DRIVERS		Scale		
		Global	**National**	**Local**
Type	**Condition**	Climatic Behaviour (C1) ICT Advancement and Diffusion (C2)	Economic Health (C3) Population Change (C4)	
	Policy		Energy Price (P1)	Urban Development (P2)

Table C.2.4. Description of Trends for 2060 Context Scenarios.

Scenario Drivers	**Scenario Trends**		
C1 Climatic Behaviour	*Stable Climate (historical patterns)* Climate patterns reflect historical trends, with periodic drought and flood within anticipated ranges.	*Extreme Climate (extreme change)* Melbourne is significantly drier on average (-13% precipitation) and hotter (average annual temperature +2.5°C), but with more intense and frequent extreme weather events, including chronic drought, heatwaves, rainfall during storm events. (Source: MW report on climate change)	
C2 ICT Advancement and Diffusion	*New Technologies (significant advancement and diffusion)* Efficiency, optimisation, accessibility and connectivity of systems increase dramatically. New technologies are available for infrastructure developers and users to choose and are designed in such a way that creates the opportunity for new interfaces between users and infrastructures. Technologies are highly diffused through infrastructure sectors and the community.	*Existing Technologies (minimal advancement and diffusion)* Efficiency, optimisation, accessibility and connectivity of systems remain stable. Technologies are not well diffused through infrastructure sectors and the community.	
C3 Economic Health	*Strong Economy (wealthy Australia)* Highly productive society, individual incomes are high, Government and individual debts are low, venture capital is widely available, low unemployment, markets are buoyant, entrepreneurial behaviour, optimistic atmosphere, high living standards, people have 'play money'.	*Weak Economy (poor Australia)* High unemployment, limited access to credit, incomes are low, high levels of debt for individuals and Government, low living standards, people are barely making ends meet, shrinking economy.	
C4 Population Change	*Low Population Growth* Population is 6 million (lowest projection of growth) (Source: ABS)	*High Population Growth* Population is 8 million (highest projection of growth) (Source: ABS)	*Population Shrinkage* Population is 5 million (grows to 7 million but then shrinks due to low fertility rates, migration)
P1 Energy Price	*High Price (major increase on today's price)* Major increase in the price of energy. This limits the availability of this resource.	*Stable Price (stable relative to today's price)* The price of energy remains stable over time (relative to 2012). This resource is available in abundance.	
P2 Urban Development	*Densification* Urban growth boundary fixed at current location, all new developments to occur as urban renewal and densification – development of activity centres, more apartment living, particularly along transport routes. Houses are typically designed to be much smaller and more compact.	*Sprawl* Double the population means double the space required; the urban growth boundary is deleted and growth occurs without limitation. Suburbia sprawls as large houses are built on large blocks of land.	

A typical methodology for constructing scenarios involves finding every combination of drivers to systematically consider each possible scenario before refining them into a consolidated set. However given the list of drivers and trends considered significant for the water system context by the expert panel, this would involve the construction of 96 context scenarios (2^5 x 3^1).

Instead, the research team refined the trends into different types of scenarios that could then be merged into a lower number of context scenarios. The four policy context scenarios are shown in Figure C.2.2; the four global context scenarios are shown in Figure C.2.3; the six national context scenarios are shown in Table C.2.5.

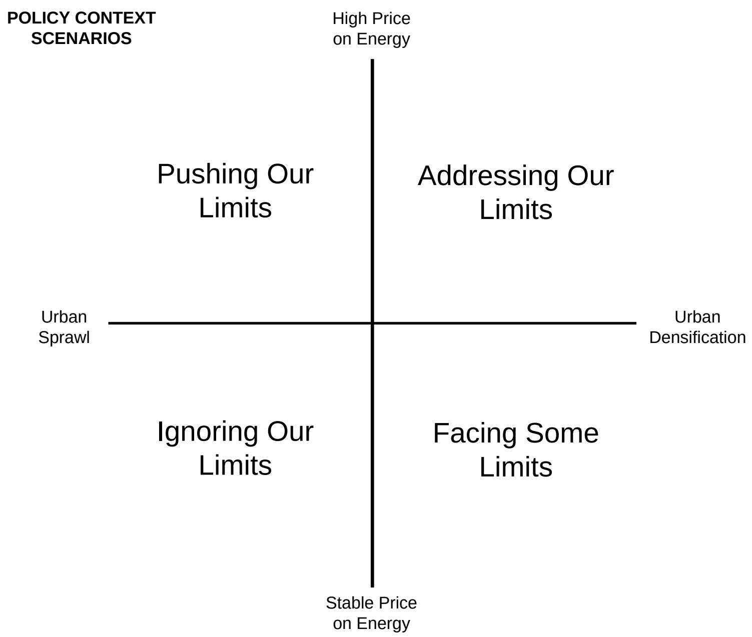


Figure C.2.2. Policy Context Scenarios.

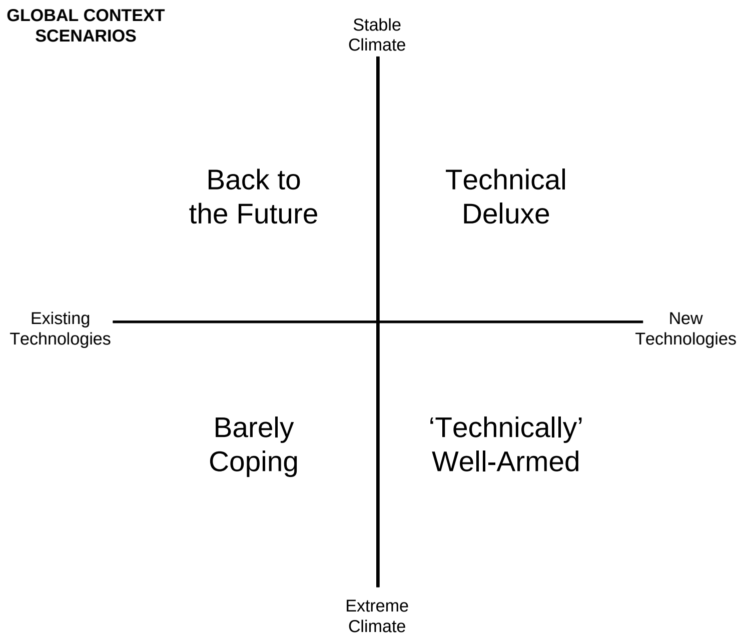


Figure C.2.3. Global Condition Context Scenarios.

Table C.2.5. National Condition Context Scenarios.

National Scenario Drivers		National Context Scenarios
Economic Trends	**Population Trends**	
Strong	Low Population Growth	Seeing possibilities
Strong	High Population Growth	Booming possibilities
Strong	Population Shrinkage	Golden ebb
Weak	Low Population Growth	Trodden paths
Weak	High Population Growth	Cannot provide
Weak	Population Shrinkage	Society diminishes

To merge the condition scenarios further, the research team analysed every combination of national and global context scenarios. This allowed a number of ***families of macro-condition context scenarios*** to be identified, each responding to different types of impacts on Melbourne and the water system.

C.2.3. Presenting the Final Context Scenarios

The final outcomes of the context scenario construction process were six families of macro-condition scenarios (Figure C.2.3 and Table C.2.6) and four policy context scenarios (Figure C.2.4 and Table C.2.7).

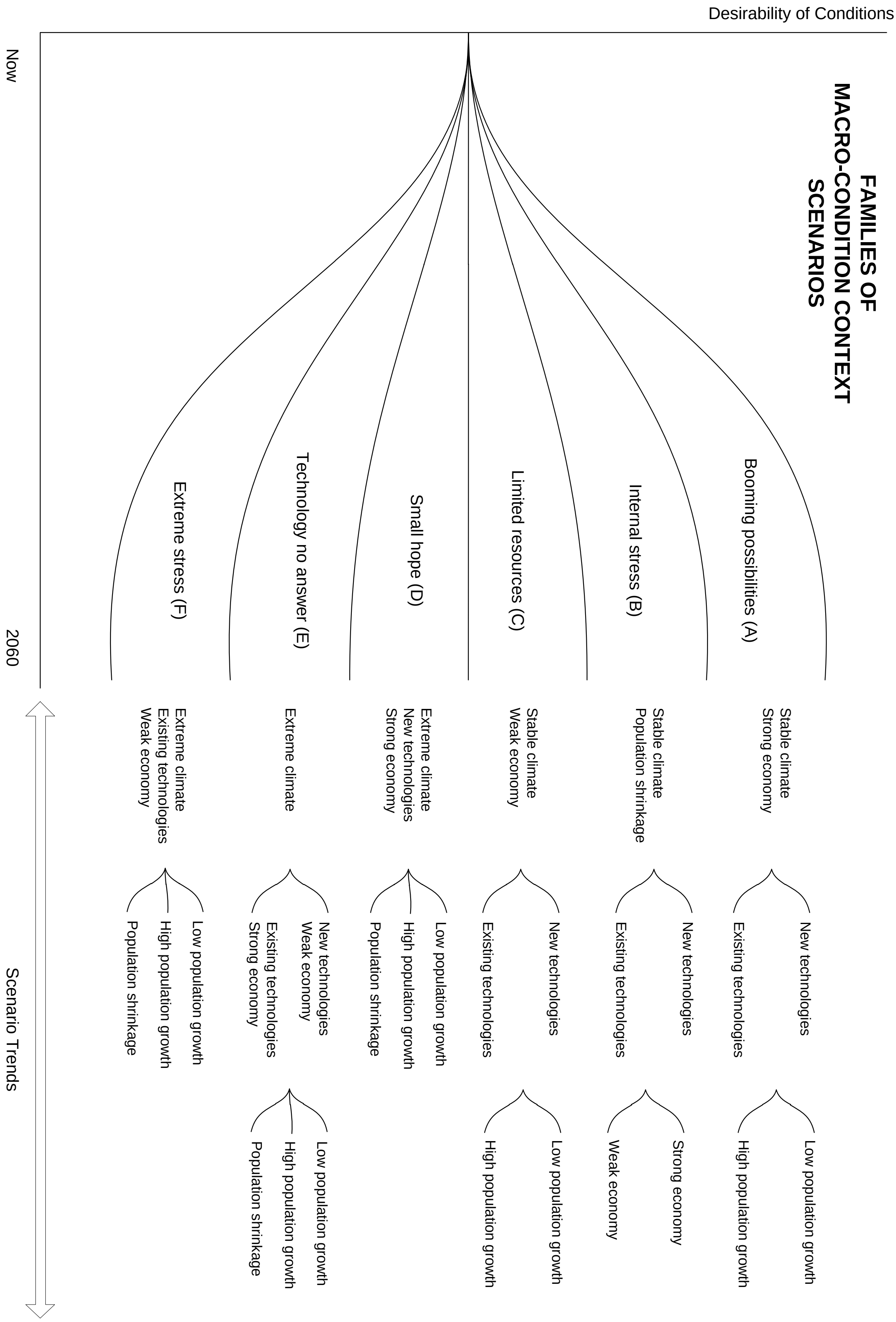


Figure C.2.3. Families of Macro-Condition Scenarios

Table C.2.6. Descriptions of Macro-Condition Context Scenarios.

Context scenario		Key details	Full description
A	Booming possibilities	Prepared with booming possibilities	Stable climate conditions and a strong national economy create the conditions in which Australia can prosper. Periodic drought and flood events occur, however these are within historically predictable patterns. The population has grown (to somewhere between 6 and 8 million, depending on whether the lowest or highest growth projections were realised). Technology has advanced and diffused (to either a minimal or significant degree) but in either version, Melbourne is well prepared to cope with future challenges.
B	Internal stress	Prepared but population dwindles	It is a relief that the climate has remained relatively stable; historical climatic trends can be relied upon as a reasonable predictor of weather patterns. In different versions of this future, the national economy is either strong or weak; however the major concern is that the Melbourne's population is shrinking and is now at 5 million, presenting issues for the city's future developments.
C	Limited resources	Prepared but possibilities are limited	A weak national economy combined with low or high population growth has created a future in which Australia can see some possibilities for the future but is struggling to make them happen. Fortunately the extreme climate predictions have not occurred, so Melbourne can prepare for weather patterns that are relatively stable and within historically anticipated ranges. In such poor economic conditions, the degree of advancement and diffusion of technology has little impact as Australia does not have the resources to utilise any new solutions.
D	Small hope	Challenged but resources bring potential	The worse climate predictions have been realised, bringing significantly drier (-13% precipitation) and hotter (+2.5°) average annual conditions to Melbourne. More intense and frequent extreme weather events occur (e.g. chronic drought, heatwaves and rainfall). While the challenges are immense, the significant advancement and diffusion of new technologies, along with a strong national economy, means Australia has resources available to help cope with the impacts of extreme climate change. Melbourne's population is somewhere between 5 million and 8 million, with all projections from shrinkage, low growth and high growth considered.
E	Technology no answer	Challenged but technology is not the answer	The worse climate predictions have been realised, bringing significantly drier (-13% precipitation) and hotter (+2.5°) average annual conditions to Melbourne. More intense and frequent extreme weather events occur (e.g. chronic drought, heatwaves and rainfall). In one version of this future context, new technologies have been significantly advanced, increasing the potential for efficiency, optimisation, accessibility and connectivity of systems. However the weak national economy means that Australia cannot afford to implement the technical solutions to cope with the extreme climate impacts. In the other version of this future, Australia has a strong national economy but unfortunately the technological developments have been minimal, so technical solutions cannot be relied upon to cope with extreme climate impacts. Melbourne's population is somewhere between 5 million and 8 million, with projections from shrinkage, low growth and high growth presenting different versions of this future
F	Extreme stress	Challenged and with no resources	The worse climate predictions have been realised, bringing significantly drier (-13% precipitation) and hotter (+2.5°) average annual conditions to Melbourne. More intense and frequent extreme weather events occur (e.g. chronic drought, heatwaves and rain). What's worse, the national economy is very weak, so while new advanced technologies may or may not offer potential solutions to deal with climate impacts, Australia is not in an economic position to exploit them. Melbourne's population is somewhere between 5 million and 8 million, with projections from shrinkage, low growth and high growth presenting different versions of this future.

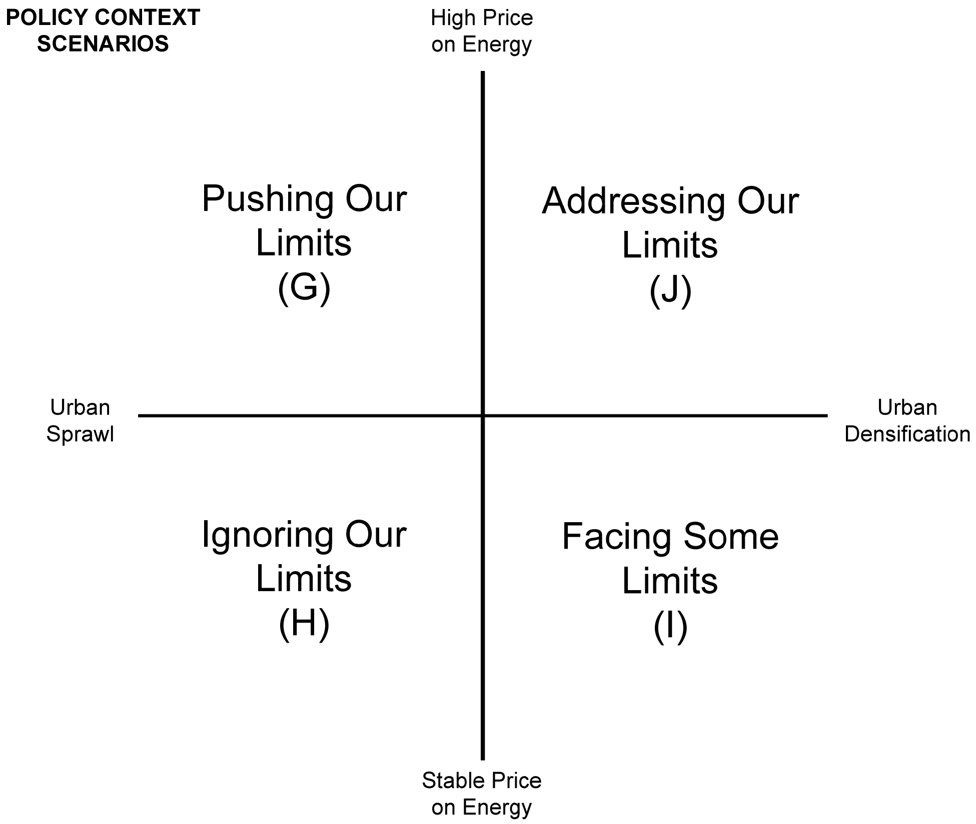


Figure C.2.4. Policy Context Scenarios.

Table C.2.7. Descriptions of Policy Context Scenarios

Context scenario		**Key details**	**Full description**
G	Pushing our limits	High energy price and urban sprawl	High energy prices and no boundary for future urban development is the policy context that pushes limits
H	Ignoring our limits	Stable energy price and urban sprawl	Stable energy prices and strict boundary conditions for future urban development is the policy context that considers some limits
I	Facing some limits	Stable energy price and urban densification	Stable energy prices and no boundary for future urban development is the policy context that ignores limits
J	Addressing our limits	High energy price and urban densification	High energy prices and strict boundary conditions for future urban development is the policy context that addresses limits

C.2.4. Validating and Verifying the Context Scenarios

Prior to their use in the workshop series, the expert panel was invited to provide validation and verification of the context scenarios via a peer review process. In particular, the panel was asked to provide comment on the:

- Screening process and descriptions of scenario drivers
- Scenario construction process
- Scenario descriptions
- Key assumptions made
  - That population growth (high increase and low increase) has a positive impact on economic conditions.
  - That the degree of impact of scenario drivers on Melbourne and its water system is a reasonable basis for clustering individual scenarios into families of macro-condition scenarios.

C.2.5. Using the Context Scenarios

The *Melbourne's Transition a Water Sensitive City* research project for the South East cluster involves a series of five participatory workshops, covering the following themes:

1. Developing guiding principles and reformulating the challenges
2. Building a vision through setting strategic objectives
3. Broadening the vision with context scenarios and identifying transition pathways
4. Building resilience into the transition pathways
5. Forming a strategic agenda for change

The context scenarios developed in this report was fed into the third workshop on the topic of "Broadening the vision with context scenarios". Leading into this session, participants had developed a range of images, defined by strategic objectives, which represent their vision of a future water sensitive city.

Participants were asked to consider uncertainties in how different trends will unfold in the future, and the impact these will have on their future visions. Participants were presented with a subset of the context scenarios. The combination of these families of scenarios reflects the different types of future contexts that would frame the extent to which the vision can be achieved.

Participants then considered how each image and its strategic objectives would need to be broadened in response to the set of context scenarios (broadened vision images include raised, lowered or maintained ambitions with respect to the strategic objectives).

Appendix B.1 of the report documents the outcomes of the application of the context scenarios to the vision images.

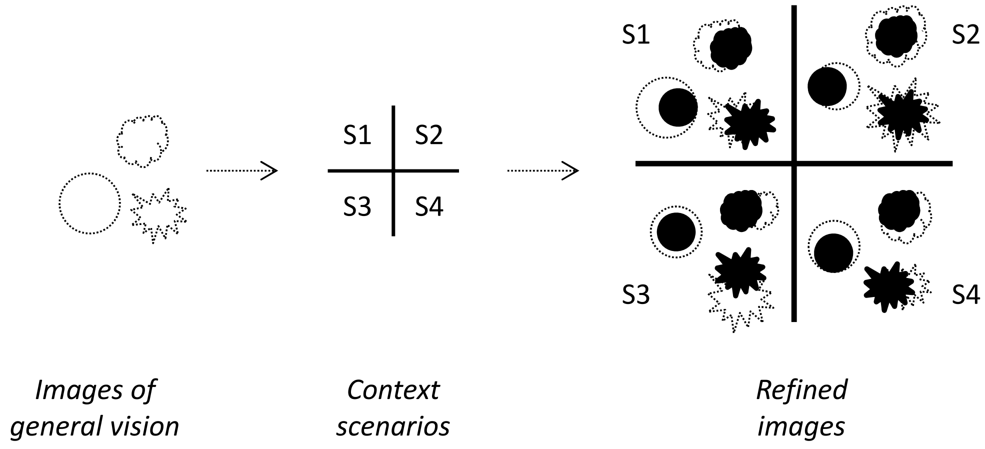


Figure C.2.1. Using context scenarios to explore resilience of the vision and its strategic objectives.

C.2.6. References

Frantzeskaki, N. and Walker, W., (forthcoming 2012). 'Policy analysis methods', in Thissen W.H.A., and Walker, W., (Eds), *Introduction to Policy Analysis*, Springer, Berlin.

Howe, C., Jones, R.N., Maheepala, S., Rhodes, B. (2005). Implications of Potential Climate Change for Melbourne's Water Resources: A collaborative Project between Melbourne Water and CSIRO Urban Water and Climate Impact Groups. CMIT-2005-106, Melbourne.

Melbourne Water (2009). 2009 Melbourne Metropolitan Sewerage Strategy: Final Scenarios Report. Melbourne.

C.2.7. Outcomes from Expert Session

	DRIVERS	IMPACT	PROBABILITY	NOTES
ACCEPTED	Population change	High	High	Generally satisfied with descriptions presented
	Urban development	High	High	Generally satisfied with descriptions presented
	Economic health	High	High	Generally satisfied with descriptions presented. Affordability is related to this driver. It often affects perception rather than logic.
	Climate conditions	High	High	Generally satisfied with descriptions presented
REJECTED	Personal values	Low	Low	Personal values are a significant factor in how we manage and engage with water but not a main driver in itself. Instead, values are deeply set and influence how we respond to situations, rather than driving the direction of change itself. We need to understand people's values and work with them within different contexts.
	Societal priorities	Low	Low	Societal priorities are inherently linked to our personal values and for the same reasons, are not driving forces in terms of change in the water system. Societal priorities tend to reflect particular situations rather than being a trend itself, eg in a crisis situation our priorities change. First sentence of the description should be deleted to remove the value-laden nature of it.
	Economic liberalism	Low	Low	Not clear what the connection between global economics and Melbourne water management is. Global trend towards globalisation in the economy has an impact on political issues but not directly on the water system.
	Climate policy	High	High	Reformulated to be part of the drivers 'Energy Price' and 'Environment Policy'
ADDED	Environment policy	High	High	This driver will directly affect water availability, environmental flows, what happens in the Murray Darling basin etc.*Restore to 'natural' conditions* Vs *Adapted conditions (to human impact) but still providing value* Vs *No formal protection (verging on 'use and abuse')*
	Rural policy	High	High	For Melbourne in particular, the rural-urban relationship has a major impact on water, particularly in terms of water trade, economic interactions. *No rural-urban water trade* Vs *Unrestrained rural-urban water trade*
	Energy price	High	High	Major impact of this driver is the availability of energy *Major increase in energy price (limited availability)* Vs *Low increase in energy price (abundant availability)*
	Water price	High	High	This is very related to how regulated the market is. *Very high price* Vs *Stable price (relative to now)*
	ICT technology advancement and diffusion	High	High	This is about both the diffusion and advancements of technologies (ICT, smart grids, smart meters etc), partly to do with how efficient water systems are and also about how much control individuals have over decisions and how connected they can be to water management through effective communication technologies. *Efficiency, optimisation, accessibility and connectivity of systems increases dramatically* Vs *Efficiency, optimisation, accessibility and connectivity of systems remains stable. High diffusion* Vs *Low diffusion*

APPENDIX B.1: RESILIENCE OF THE VISION (Ferguson et al., 2012c)

B.1.1. Introduction

This appendix documents the application of context scenarios in order to examine the resilience of the vision images and their associated strategic objectives. The context scenarios were formulated by the research team with the input of a panel of experts. The content of the context scenarios and the steps taken in their formulation are introduced and described in Appendix A.

With this step, the group explores the resilience of the vision in different uncertain futures. The context scenarios prompt us to explore the *expression of the vision in different futures*, in order to reflect on and refine the vision images and their strategic objectives. The aim of this exercise is to develop a shared view and group alignment towards the **uncompromised commonly desired characteristics of a water sensitive city**. This appendix outlines the process and results of the resilience testing of the vision that was undertaken during the third workshop.

B.1.2. Using Context Scenarios

In small groups, the workshop examined how the strategic objectives of every vision image would be adapted under different uncertain futures. Each small group was given six different context scenarios. Due to time limitations, all the groups were able to examine the following four scenarios thoroughly:

Table B.1.1. Context scenarios used by all small groups to explore the resilience of the vision.

MACRO-CONDITION CONTEXT SCENARIOS	
Scenario A Booming Possibilities	Stable climate conditions and a strong national economy create the conditions in which Australia can prosper. Periodic drought and flood events occur, however these are within historically predictable patterns. The population has grown (to somewhere between 6 and 8 million, depending on whether the lowest or highest growth projections were realised). Technology has advanced and diffused (to either a minimal or significant degree) but in either version, Melbourne is well prepared to cope with future challenges.
Scenario F Extreme stress	The worse climate predictions have been realised, bringing significantly drier (-13% precipitation) and hotter (+2.5°) average annual conditions to Melbourne. More intense and frequent extreme weather events occur (e.g. chronic drought, heatwaves and rain). What's worse, the national economy is very weak, so while new advanced technologies may or may not offer potential solutions to deal with climate impacts, Australia is not in an economic position to exploit them. Melbourne's population is somewhere between 5 million and 8 million, with projections from shrinkage, low growth and high growth presenting different versions of this future.
POLICY CONTEXT SCENARIOS	
Scenario H Ignoring our limits	Stable energy prices and strict boundary conditions for future urban development is the policy context that considers some limits
Scenario J Addressing our limits	High energy prices and strict boundary conditions for future urban development is the policy context that addresses limits

These four scenarios depict the most stressful for the system contexts (Scenarios F and J) and the most favourable for the system contexts (Scenarios A and H). Under these distinct future contexts, the participants reflected on the way the strategic objectives would be adapted by indicating:

Table B.1.2. Logic for exploring resilience of strategic objectives under different futures.

Examination		Sign used	Meaning
Whether the direction/level of the examined strategic objective can be raised under the context scenario	If yes, then	↗	We can raise our ambitions in this future context (scenario)
Whether the direction/level of the examined strategic objective can be lowered under the context scenario	If yes, then	↘	We can lower our ambitions in this future context (scenario)
Whether the direction/level of the examined strategic objective can remain the same under the context scenario	If yes, then	-	We can maintain our ambitions in this future context (scenario)

Under all scenarios, more information would be needed to make accurate estimates for raising or lowering the desired levels of the strategic objectives. The aim of this process step was to explore which strategic objectives constitute the core of the vision and therefore remain uncompromised (or heightened) under different uncertain futures. The ambition of the group in view of deep uncertainty is also explored, by comparing upwards trends of ambitions as expressed with raised desired levels of strategic objectives.

Table B.1.3. Exploring the resilience of strategic objectives under different context scenarios.

SOCIAL AND ECOLOGICAL HEALTH

1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.

		SCENARIOS			
Strategic Objective		**A**	**F**	**J**	**H**
1A	Everyone lives within 400m of a green corridor	↗	↘	↗	−
1B	Water quality or supply issues never disrupts recreational use of waterways and open space	−	↘	↗	−
1C	Minimised day- and night-time temperature differentials in during Summer	↗	↗	↗	−
1D	All neighbourhoods have access to productive food space	−	↗	↗	−
1E	High rate of participation in sport and recreation activities	↗	−	−	−
1F	Everyone drinks fluoridated water	−	−	−	−

2. Our city is alive, healthy and beautiful; its environmental wellbeing is valued, protected and enhanced.

		SCENARIOS			
Strategic Objective		**A**	**F**	**J**	**H**
2A	Green space is of good quality and plentiful	↗	↗	−	−
2B	Maximised number of green-blue corridors	↗	↘	↗	−
2C	All waterways are rated as good to excellent health	↗	↘	−	−
2D	Everyone makes use of their local green and blue spaces	↗	↘	↗	−
2E	High rate of tree coverage of private land area	↗	↗	↗	↗
2F	High rate of tree coverage of public land area	↗	↗	↗	↗
2G	Green wedge areas, parks and reserves are never compromised for development	−	−	↗	−
2H	High rate of resources allocated to environmental wellbeing	↗	↘	↗	−
2I	High rate of participation in environmental protection activities	↗	↗	↗	−
2J	Green spaces are never subject to waste disposal	−	↗	−	−
2K	Green-blue corridors are never subject to illegal industrial discharges	−	−	−	−

Table B.1.3 (continued). Exploring the resilience of strategic objectives under different context scenarios.

SOCIAL AND ECOLOGICAL HEALTH

3. Our city and people are safe; we are prepared for flooding and water quality threats.

		SCENARIOS			
Strategic Objective		**A**	**F**	**J**	**H**
3A	Full compliance with drinking water quality standards for potable water	↗	↘	↗	−
3B	Full compliance with fit-for-purpose quality standards for non-potable water	−	↘	↗	−
3C	No human fatalities from flood events	↗	↗	↗	−
3D	No critical infrastructure built in flood prone areas (e.g. treatment plants, pump stations, storages, energy supply, telecommunications, hospitals, aged care facilities, emergency services)	−	↗	↗	−
3E	Low frequency of exposure of critical infrastructure to flood risk (e.g. 1:200 years)	↗	−	−	−

CONNECTED COMMUNITIES

4. Our people are educated, engaged and empowered; we feel and take responsibility for our water.

		SCENARIOS			
Strategic Objective		**A**	**F**	**J**	**H**
4A	All schools have broad water-related curriculum	−	−	−	−
4B	All households are water literate and are prepared for surprises (e.g. flood, drought, heatwave)	−	−	−	−
4C	Maximum of 20-40 L/person/day of centrally-supplied water consumed for potable uses in households	−	↘	−	−
4D	Maximum of 50 L/person/day of centrally-supplied water consumed for non-potable uses in households	−	↘	−	−
4E	All households and businesses self-monitor their water use	↗	↘	↗	↗
4F	High proportion of community project budgets funded by public grants	↗	↘	−	−

Table B.1.3 (continued). Exploring the resilience of strategic objectives under different context scenarios.

5. Our water profession is passionate about water; we collaborate with the community to understand and respond to our water needs.

Strategic Objective		SCENARIOS A	F	J	H
5A	Significant representation by informed community members in all decision-making teams about water infrastructure choices (e.g. 20%)	−	−	↗	−
5B	All water infrastructure planning processes provide genuine opportunities for community members to contribute	↗	−	↗	−
5C	High number of community-led water infrastructure projects	−	↗	↗	−
5D	All households are satisfied with water services and the communication provided by the water profession	↗	−	↗	−
5E	All households comply with water-sensitive practices	↗	↗	↗	−

SHARED PROSPERITY

6. Our economy is healthy; prosperity is supported by our water system.

Strategic Objective		SCENARIOS A	F	J	H
6A	Minimised water-related risk (water quality and quantity) to the growth of business opportunities and their positive rate of return	−	↘	−	−
6B	Minimised impact of water solutions on housing affordability	−	↘	−	−

7. Our water system is equitable; we can all afford to meet our basic water needs.

Strategic Objective		SCENARIOS A	F	J	H
7A	All households have access to 90 L/person/day of water for their essential needs	−	↘	−	−
7B	All households can afford water for their essential needs	−	−	−	−
7C	All households have access to water sensitive technology	−	↘	−	−

8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum community value.

Strategic Objective		SCENARIOS A	B	D	F	H	J
8A	All benefits and impacts are identified	↗	↗	↗	↗	−	↗
8B	All benefits and impacts are measured	↗	↗	↗	↗	−	↗
8C	All benefits and impacts are equitably attributed	↗	↗	↗	↗	−	↗

Table B.1.3 (continued). Exploring the resilience of strategic objectives under different context scenarios.

WATER SENSITIVE INFRASTRUCTURE

9. Our water system is smart, integrated, flexible and connected. We manage water cycles to take advantage of different sources in order to meet our own water needs while giving and receiving support to the broader system.

		SCENARIOS					
Strategic Objective		**A**	**B**	**D**	**F**	**H**	**J**
9A	Central capacity to supply 20-40 L/person/day of potable water to households	−	−	↗	−	↗	−
9B	Central capacity to supply 50 L/person/day of non-potable water to households	↗	↘	↗	−	↗	↘
9C	Central capacity to supply sufficient water to businesses to meet their fit-for-purpose water needs in an efficient way	↗	↗	↗	−	↗	↗
9D	Optimised water self-sufficiency at all feasible scales	↗	↗	↗	−	↗	↗
9E	All water-related decisions to be based on data about the water cycle that is reliable, accurate, up-to-date, user-friendly and takes into account future climate projections	↗	↗	↗	↗	↗	↗

10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water, nutrients and physical space are consumed and produced.

		SCENARIOS					
Strategic Objective		**A**	**B**	**D**	**F**	**H**	**J**
10A	Optimised energy efficiency for water infrastructure	↗	↗	↗	↗	−	↗
10B	No net impact of water infrastructure on greenhouse gas emissions	↗	↗	↗	↗	−	↗
10C	Optimised recovery of all minerals and nutrients in wastewater	↗	↗	↗	↗	↗	↗
10D	Optimised recovery of all energy in wastewater	↗	↗	↗	↗	↗	↗
10E	All water infrastructure design processes consider aesthetics	↘	↘	↘	−	↗	↗
10F	No loss of visual amenity loss due to water infrastructure	↘	↘	↘	−	↘	↗
10G	No odour impacts from water infrastructure	↘	↘	↘	−	↘	↗
10H	Optimised adoption of all feasible (multi-)functions of water infrastructure	↗	↗	↗	−	−	↗

B.1.3. Exploring the Resilience of the Vision

Application of the context scenarios to each of the vision images in order to explore resilience of the vision in different uncertain futures offered the following insights:

a) The vast majority of the strategic objectives remain uncompromised, even under stressful context scenarios (Scenarios F and J). Additionally, under favourable context scenarios (Scenarios A and H) the number of strategic objectives that maintain their desired level is the same as those with a raised desired level. These observations imply that the group has formed a shared ambitious vision that is resilient under different futures.

b) Even under stressful scenarios, a large number of strategic objectives were stretched towards higher levels of desired outcomes. This indicates that the group feels that in particularly challenging contexts, we need to be even bolder in addressing our objectives and safeguarding the delivery of water sensitive outcomes.

c) In Table 3 of the report we list the strategic objectives with lowered desired levels under the stressful Scenario F. This may indicate that achieving those strategic objectives may be vulnerable to climatic and economic conditions (tentative finding only).

d) The desired levels of strategic objectives related to amenity are seen to be compromised under different scenarios. This may indicate that in favourable contexts there is less need to be strident in promoting amenity-related objectives (tentative finding only).

The group discussed that the relative levels of affluence in a community is likely to influence the level of ambition in relation to certain strategic objectives (e.g. those related to amenity), as well as the level of effort in achieving these strategic objectives. In contrast, some strategic objectives will remain uncompromised regardless of affluence.

APPENDIX E. DEVELOPING WILDCARDS AND IDENTIFYING RECOVERY STRATEGIES

This appendix contains excerpts (Appendix C.3and B.3) from:

Ferguson, B.C., Frantzeskaki, N., Skinner, R., Brown, R.R. (2012c) Melbourne's transition to a Water Sensitive City: South East Cluster workshop series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, ISBN 978-1-921912-15-3. Available for download from http://www.waterforliveability.org.au/

APPENDIX C.3: WILDCARDS (Ferguson et al., 2012c)

C.3.1. Introduction

This report documents the generation of *wildcards* as an input for the *Melbourne's Transition to a Water Sensitive City* research project, coordinated by the Centre for Water Sensitive Cities. The project aims to develop tools for understanding how strategic planning at the regional scale can enable the transition of urban regions from their current conditions to a future water sensitive city, encompassing themes such as liveability, sustainability and resilience.

This report outlines the process and results of the development of wildcards for the project.

C.3.2. Introducing Wildcards

Wildcards are events that have low probability and high impact on the system. Wildcards are area relevant and specific extremes and surprises. Saritas and Smith (2011, p.295) elaborate on wildcards and define them as: "those surprise events and situations which can happen but usually have a low probability of doing so – but if they do their impact is very high. These situations tend to alter the fundamentals, and create new trajectories which can then create a new basis for additional challenges and opportunities that most stakeholders may not have previously considered or prepared for."

Table C.3.1. Selection Criteria for Wildcards (Frantzeskaki & Walker, forthcoming)

<table>
<tr><td colspan="2" rowspan="2">External Drivers and Events</td><td colspan="2">PROBABILITY</td></tr>
<tr><td>Low</td><td>High</td></tr>
<tr><td rowspan="2">IMPACT</td><td>Low</td><td></td><td></td></tr>
<tr><td>High</td><td>Wildcards</td><td>Context Scenarios</td></tr>
</table>

In this project, wildcards are produced by experts and validated by evinced weak signals. "Weak signals are warnings (external or internal), events and developments that are still too incomplete to permit and accurate estimation of their impact and/or to determine their complete responses." (Hiltunen, 2007 cited by Saritas and Smith, 2011, p.297). Additionally, "weak signals refer to early signs of possible but not confirmed changes that may later become more significant indicators of critical forces for development, threats, business and technical innovation. They represent the first signs of paradigm shifts, or future trends, drivers or discontinuities." (Saritas and Smith, 2011, p.297).

C.3.3. Generating Wildcards

An initial set of wildcards was generated by the research team in three steps: (a) brainstorming (b) sorting the list of wildcards using the STEEP approach (**s**ociety, **t**echnology, **e**conomy, **e**cology, and **p**olitics) and (c) adding to the list and make first validation using published scientific sources.

The following sources have been used:

- *Scientific reports and books, including but not limited to*
  - IPCC (2011), Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), Geneva Environment Network, Geneva, 6 July 2011.
  - Jones, J.A., Verdanian, T.G., and Hakopian, C., (Eds) (2010), Threats to global water security, NATO Science for Peace and Security Series – C: Environmental Security, Springer: The Netherlands.
  - Sustein, C.R., (2007), Worst case scenarios, Harvard University Press.
  - Diaz, H.F., and Murnane, R.J.,(Eds) (2008), Climate extremes and society, Cambridge University Press.
- *Scientific journals, including futuristic and foresight references such as:*
  - Van Notten, P.W.F., Sleeger, A.M., and van Asselt, M.B.A., (2005), The future shocks: On discontinuity and scenario development, Technological Forecasting and Social Change, 72, 175-194.
  - Alexander, D., (2002), Nature's impartiality, Mans' inhumanity: Reflections on terrorism and world crisis in a context of historical disaster, Disasters, 26(2), 1-9.
  - Saritas, O., and Smith, J.E., (2011), The big picture – trends, drivers, wild cards, discontinuities and weak signals, Futures, 43, 292-312.

In total, 26 wildcards were produced representing a variety of challenges, opportunities and threats at global, national and regional levels. We conceptualised and identified two types of wildcards:

a) **Deep Future Wildcards**: Low probability events, but if they occur will have a severe impact on the current system. Those extreme events are not associated with any weak signal at national or regional levels.
b) **Déjà Vu Wildcards**: Low probability events, but if they occur will have a severe impact on the current system. Those events are associated with a number of weak signals at national or regional levels.

The research team chose to generate wildcards using researchers and experts rather than futurists or foresight scholars. Further, the wildcards were not generated as a research activity of its own merit, rather with the aim that they be used as a discursive means to stimulate thinking about strategies that could prepare the system for shocks.

C.3.4. Validating Wildcards

A panel of experts was assembled to review this list of proposed drivers and trends and provide critical feedback. The experts were invited according to the following criteria:

- Experience with scenario work
- Visionary and strategic view of the system's development
- Knowledgeable of different elements/subsystems of the reference system (urban water system including infrastructure and governance)

The experts represented the following organisations:

- Centre for Water Sensitive Cities
- University of Innsbruck
- Melbourne Water
- EPA Victoria
- DSE

The experts were asked to verify and validate every wildcard by providing their expert judgment about:

- Low versus high probability of occurrence
- Weak signals, warnings, signs associated with it
- Impact on the system
- Relevance for the region and nation

The outcomes of the expert review of the generated wildcards were:

- *Elimination of wildcards:* Wildcards were eliminated if they were assessed to be (a) highly probable; (b) trends, rather than events; and (c) highly dependent on other external drivers or events.

- *Emphasis on the local context:* The descriptions of a number of wildcards were revised to reflect their impact on the system at a regional and national level. Wildcards that had an impact on the national and regional were preferred over those that had a global focus.

- *Verification of "Déjà vu" Wildcards:* For the déjà vu wildcards, weak signals found at the national and regional levels were identified prior to the expert session. The experts provided verification of these by indicating additional weak signals.

C.3.5. Presenting the Wildcards

The research team analysed the outputs from the expert panel and refined the initial list of wildcards. Table C.3.2 presents the wildcards and Table C.3.3 presents the description of the wildcards, its aftermath and its associated weak signals as validated by the experts and further verified by the research team.

Table C.3.2. Wildcards systematically categorized based on the STEEP approach and across challenges, opportunities and threats.

Domain	**Challenges**	**Opportunities**	**Threats**
Society (and culture)			(S1) Surge of Climate Refugees
Technology	(T1) Super Crops	(T2) Sponge-on-the-Roof (T3) Water from everywhere (T4) Geoengineering Gods (T5) Mega Urban Farms (T6) Unlimited Energy	
Ecology	(EL1) Scotland Down Under		(EL2) The Blue Plague (EL3) Flood Cataclysm (EL4) Seaquake (EL5) Acid Cloud (EL6) A sizzling state (EL7) Over-dredged Bay
Economy			(E1) China Slows Down (E2) Iron No More
Politics			(P1) Terror on Aqua (P2) New Zealand Invades

Table C.3.3. Wildcards description and associated weak signals.

Wildcard	Description	Weak Signals
(S1) Surge of Climate Refugees	Under global pressure, Australia agrees to host and accommodate climate refugees from the Pacific Islands, Vietnam and Bangladesh. At the same time, there is unprecedented movement of people within Australia, as climate impacts force people to relocate. Within a short period, millions of climate refugees arrive in Melbourne. Climate refugees cannot afford the housing options available and public housing is already beyond capacity. Urban slums emerge. *In the aftermath*, the entire water system cannot deal with the increased water demand, which in turn creates financial pressure for the government. Distribution problems arise that persist for the years to come. The capacity of the water system to also deal with treatment for water supply and with wastewater is overstretched. There is a high risk to the security of water supply and sanitation since the system could be compromised and result in a system failure. Vulnerable communities require attention and social policy for support. Under these social conditions, environmental issues are placed low on the policy agenda.	- Collapse of Perth due to depleted groundwater levels - Australian climate refugees due to sea level rise, storm surges and decline of rural community - Cyclone Yasi - Pacific refugees coming to Australia
(T1) Super Crops	A new strand of crops has been genetically engineered to require very low levels of water and nutrients to grow. These new crops stay in a lethargic state when the growing conditions are not favourable. In this way plants self-organise to preserve the nutrients and root system integrity in every extreme condition. *In the aftermath*, farmers grow super-crops with minimum water. This results in lower demands of water for agriculture and releases the pressure for water used by urban areas. At the same time, the new generation of farming and agriculture boosts the rural economy and communities. The evident environmental benefits are the declined soil erosion and the reduction of devil storms (dust). Export market and community expertise on growing products are changed. Super plants are also used to green roof tops and walls in urban areas, contributing to greening the city. The public is skeptical about the super crops and questions their environmental impacts. Given their resilience, these crops dominate farmlands and do not allow other species to grow close to them. Significant threats for biodiversity are pinpointed by ecologists and NGOs.	- Crop development research - Canola in Northern Australia - Farm Rivers and Markets Projects
(T2) Sponge-on-the-Roof	Scientists and engineers in Australia develop a new material that absorbs all water that touches it. This sponge-on-the-roof material is cheap and widely available. Leading the world, Australia adopts the material as a construction material of choice for all new houses and buildings. All rainwater that falls on urban roofs is captured by the material. Flash floods become a distant memory. *In the aftermath*, flood risks and stormwater on urban waterways are reduced due to the diffusion of this new technology. The intensity of flash floods is significantly lessened. Retrieving water from the roofs or other surfaces (façades) where the material is laid is a new technological challenge.	- Green roofs - Bio-filtration - Rainwater tanks

Table C.3.3. (cont.) Wildcards description and associated weak signals.

Wildcard	Description	Weak Signals
(T3) Water from everywhere	Ground breaking discoveries in botany and nanobiology inspired the development of a technology that purifies water (to potable standards) from all possible sources regardless of the raw water quality. The technology consumes minimum energy and resources and is safe and cost-effective at even the household scale.	- IPR technologies - Low-energy stormwater harvesting - Biofilters - Membrane technology - Superfilters - Purifying tablets - Plasma-purifiers
	In the aftermath, the use of this new technology makes large-scale recycled water plants very attractive, both financially and in terms of performance. The new technology allows distributed decentralised treatment and reuse of all water types. Water treatment costs are reduced and pressure for supply of potable water is lessened. The new technology is also taken up by households that now can be self-providers of water and cities cease to need rural water transfers. The diffusion of this new technology has a rebound effect. Policies and standards for water health are being relaxed, which in turn means industries are less stringent about their wastewater treatment before discharging. Discharge permits on industry are loosened as water will be cleaned upon extraction. Polluting water becomes standard practice since water from streams and stored water can be easily purified.	
(T4) Geoengineering Gods	Scientists and engineers have discovered how to stabilise the climate and control the weather. They have invented cheap and effective technology that can do so. They can make it be as cloudy or sunny as required, rain on demand, and whip up wild winds and storms whenever they like.	- Cloud seeding - Climate super-models
	The climate has stopped changing. Uncertainties in weather patterns are negligible and the amount of annual precipitation can be controlled to a relatively fine degree. Weather conditions can be controlled and this can be used as a weapon. Optimisation of weather conditions for optimising water availability and management is possible. This releases the pressure from the water system and available water resources are sufficient to meet demands. Preferences for weather types vary between sectors (e.g. tourism, agriculture and other economic activities), which leads to conflict and trade-offs with the water-oriented weather-portfolio.	
(T5) Mega Urban Farms	All food belts on the urban fringe have been overtaken by residential developments. The only option left for local produce is urban farming. Food is now produced at small and large scales within the urban boundary. Vertical farming is a reality.	- Green roofs - Permaculture - Community gardens - Urban farms
	Urban farms bring food production closer to urban consumers. This improves the energy budget of food production and micro-climatic conditions in cities. At the same time, new water demands are created even though water is distributed to these vertical farm-levels in a highly efficient and effective way. New pollutants from the urban farms are now introduced into urban areas.	

Table C.3.3. (cont.) Wildcards description and associated weak signals.

Wildcard	Description	Weak Signals
(T6) Unlimited Energy	Australia's energy system is revolutionised. Coal and gas systems have become redundant as new age renewable sources dominate the energy market. New age renewables include more efficient, powerful and reliable wind, solar, solar thermal, tidal, geothermal, biological sources that are cheaper. Storage of energy and meeting peak demands are no longer a challenge. New smart-storage grids transmit and store energy with minimal losses. Australia is now a self-sufficient energy super-power.	- Tidal/Ocean energy - Energy-producing algae - "The technical potential of renewable energy technologies to supply energy services exceeds current demands." (IPCC, 2011)[3]
	The adoption and diffusion of the new age renewables revolutionise the energy sector. Energy supply and energy cost are no longer constraining factors for the water sector. This results in lower costs for waste treatment and a shift from decentralised energy-efficient water systems to centralised and/or energy-intense water systems. Desalination becomes the preferred and dominant option and recycling plants are widely implemented.	
(EL1) Scotland Down Under	Extreme changes in Earth's rotation make the climate change dramatically. Victoria's climate experiences a major shift and now has similarities with that of Scotland – long wet periods, peak temperatures below 25 degrees and 340 days of cloud. Parts of Victoria are covered by snow and ice all year around.	- El Nino, La Nina
	The new climatic conditions affect social behaviour and routines. As a result, water demand is lowered. There is abundant water that improves stream ecology and increases the risk of flooding.	
(EL2) The Blue Plague	A water-born and water-transmitted nano-virus, mutated from deep sea plankton, escapes the reverse osmosis membranes of the desalination plant. The virus enters the water supply and infects anyone who ingests the water. Once a person is infected, the water-plague is transmitted to other people and animals via respiration. A pandemic breaks out. The virus is fatal and there is no known treatment.	- Pandemics - Fear for 'unknown' pandemics
	The pandemic creates a fear for all water sources and panic spreads in the community. In view of the pandemic, the Australian government imports water from Tasmania that is treated and distributed in isolated facilities with extreme measures for avoiding biohazard exposure. Very little water is available for each person. The water supply network gets shut down and water is sourced from local catchments through decentralised solutions. On the short term, demand for bottled water peaks. Low risk approaches to water are preferred.	

[3] IPCC (2011), Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), Geneva Environment Network, Geneva, 6 July 2011.

Table C.3.3. (cont.) Wildcards description and associated weak signals.

Wildcard	Description	Weak Signals
(EL3) Flood Cataclysm	Months of non-stop rain have saturated Victoria's catchments. An extreme rainfall event coincides with a King high tide, creating a flood cataclysm in Melbourne. Major urban centers are underwater. All road and train lines are underwater. Wastewater facilities overflow and raw sewage flows along the city streets. Emergency workers struggle to rescue victims and many people are swept away by the flood. The aftermath reveals all public and private infrastructures have been severely damaged. Clean drinking water is not available and the risk of cholera is high.	- La Nina; El Nino - Queensland floods 2011
	In these apocalyptic times, the city and its water system suffer from the huge impact. Reconstruction of the city's infrastructure and water system becomes a priority. Impacts of the flood are felt for decades to come.	
(EL4) Seaquake	A seaquake creates a tsunami that heads to Melbourne's coast. The coastline along Port Phillip Bay and Western Port Bay are devastated. Buildings and infrastructure vanish under sea water and collapse from the force of the water.	- Japan 2011 Tsunami
	Devastation of coastal areas creates shocks to society. It also creates an opportunity for urban regeneration.	
(EL5) Acid Cloud	Acid deposition through acid rain and dry precipitation is experienced in Australia. Acid falls on crops and water bodies, threatening the life of animals and plants, as well as the health of soils. Water supply reservoirs are contaminated.	- Acid clouds - Volcanic clouds (line caps of volcanic clouds)
	The acid deposition impacts the vegetation and streams leading to a major ecological catastrophe. Water is sourced from non-surface water bodies such as groundwater and desalination, which are stressed in satisfying the extreme water demand.	
(EL6) A Sizzling State	A month-long heat wave strikes. The intensity is phenomenal. The records for January are smashed, with day-time temperatures that climb above 40^{o}C and overnight temperatures that do not drop below 30^{o}C. Peak electricity demands cannot be met. The elderly, asthmatic and people with respiratory problems are at risk of fatality and hundreds of people die. Even more people end in emergency care due to dehydration and heat stroke.	- Weak signals: El Nino, La Nina - Melbourne heat waves - France, August 2003, over 14,000 deaths (IPCC, 2011)
	Electricity peaks result in a struggle for energy supply between the city and utility infrastructure (such as water treatment plants, desalination plant, water pumping stations and wastewater treatment). Infrastructure failures due to the heat are experienced in the transport, water and wastewater systems. Ecological impacts are also severe in urban parks, forests and waterways.	- "Russia, Crippled by Drought, bans grain exports" August 5, 2010, The New York Times
(EL7) Over-dredged Bay	Port Phillip Bay is dredged again to deepen the shipping channel to meet the Government's ambitions for keeping its reputation as a critical port, as ships become larger and larger. Environmental assessments underestimate the impact of the extensive dredging. The ecosystem reaches a tipping point and turns anaerobic. The death of the bay is a sudden but irreversible one.	- Christmas Day Floods
	The ecosystem degradation of the bay is caused by algal blooms and results in beach closures, public health impacts and negative media attention.	

Table C.3.3. (cont.) Wildcards description and associated weak signals.

Wildcard	Description	Weak Signals
(E1) China Slows Down	Global pressure for China to improve its human rights record has gained traction. China, in its quest to become a major player in all aspects of global governance, embraces workers' rights. This shift in priorities comes with a significant impact on its productivity and economic growth, slowing its development frenzy. While supporting China's shift in attitude about human rights, Australia feels the effect of their slowing economy, as imports of coal and other raw materials are put on hold.	- Human rights agenda - Environmental agenda
	The economy suffers. There are less financial resources to invest in water systems and to maintain infrastructures in cities.	
(E2) Iron No More	The mining boom is bust. Raw materials (such as iron, copper, silver, platinum, selenium) have run out. Infrastructure development and construction projects are put on hold. Industry faces severe material shortages and collapses. New scientific discovers reveal there may be reserves in unexplored territories but these are inaccessible within the social, technical or environmental constraints and their extraction would come with high risks and unprecedented impacts.	- Deep drilling for oil - Ocean mining; moon/mars mining// deep-cave mining - Wars for occupying last reserves of materials (Africa, Iraq/Oil Wars)
	Australia's economy experiences a devastating hit. The economy bellies up. There is a growing demand for new types of infrastructures, alternative constructions, materials and recycling.	
(P1) Terror On Aqua	Terrorists target the major water supplies of Melbourne. Within a 24 hour period the desalination plant is bombed and storage reservoirs are contaminated with a bioengineered virus designed to cause widespread illness and death.	
	The terror attack inflicts a crisis of confidence of the system. Rainwater tanks become rescue assets.	
(P2) New Zealand Invades	Without warning or just cause, New Zealand invades Australia. All political leaders go into exile and Centre of Command is established in Melbourne. The rulers impose a class system with unfair exclusive rights to water to the newly settled upper class of the invaders. New rules for the economy are applied.	- East Timor Scenario
	The water system cannot be maintained due to a changed expenditure system and the environmental policy regime is changed. Melbourne becomes backwater under the invaders political regime.	

C.3.6. Using the Wildcards

The *Melbourne's Transition a Water Sensitive City* research project involves a series of five participatory workshops, covering the following themes:

1. Developing guiding principles and reformulating the challenges
2. Building and broadening a vision
3. Identifying transition pathways through backcasting
4. Building resilience into the transition pathways
5. Forming a strategic agenda for change

The wildcards described in this report were fed into the fourth workshop on the topic of "Building resilience into the transition pathways". In this session, participants developed complementary strategies in order to build resilience in communities, institutions, infrastructure, economy and ecology.

Participants were then asked to consider each wildcard and consider strategies that could form additional transition pathways to build resilience.

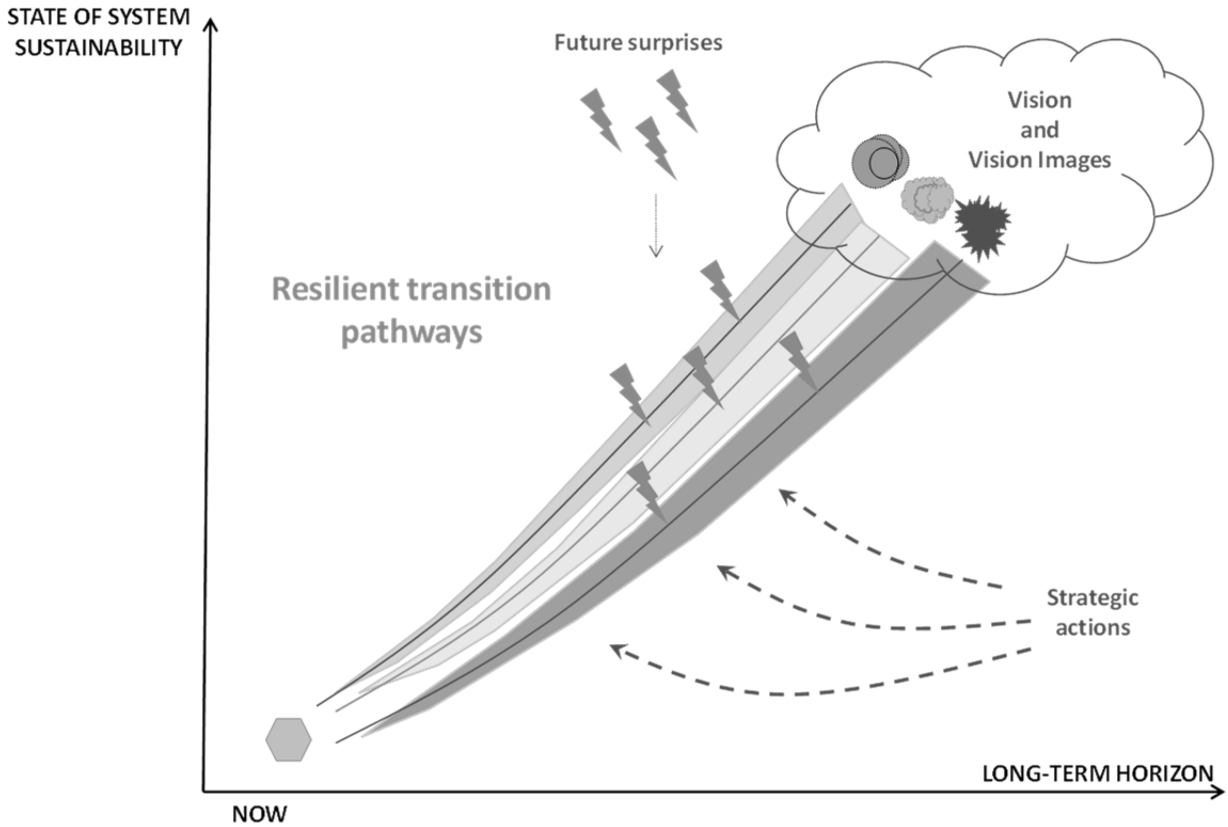


Figure C.3.1. Using wildcards to explore strategies for building system's resilience.

C.3.7. References

Frantzeskaki, N. and Walker, W., (forthcoming 2012). 'Policy analysis methods', in Thissen W.H.A., and Walker, W., (Eds), *Introduction to Policy Analysis*, Springer, Berlin.

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Wardekker, J.A., de Jong, A., Knoop, J.M., and van der Sluijs, J.P., (2010), Operationalising a resilience approach to adapting an urban delta to uncertain climate changes, Technological Forecasting and Social Change, Vol. 77, pp.987-998.

C.3.8. Template for expert input and review.

WILDCARD NUMBER AND NAME:

Comments on the description of wildcard:
Description of impact of the wildcard on the system (overall system and water system in particular):
Do you see any early indications of this wildcard/surprise?
Relevance for Australia and/or water system

APPENDIX B.3: RECOVERY STRATEGIES (Ferguson et al., 2012d)

This Appendix documents the application of the wildcards to generate recover strategies that deal with the aftermath of each extreme wildcard event. Refer to Appendix C.3 for the list of wildcards considered by the group

Table B.3.1. Recovery strategies for each wildcard.

Wildcard	Recovery Strategies
(S1) Surge of Climate Refugees	Identify in advance designated sites in existing residential areas where emergency sanitation and drinking water facilities can be easily brought to Educate communities to provide humanitarian help Relocate how water is distributed Free up water for refugees (short term strategy) Utilise 'unpopular' water infrastructure Have disaster management plans in place
(T1) Super Crops	Confine super crops to particular growing areas Regulate plant type so that known risks of spreading by water, air etc can be overcome Widespread education
(T2) Sponge-on-the-roof	Invest in research to retrieve water Identify appropriate use and placement of the new material Explore fit-for-purpose to ensure good use of the material Assess the risk of the wide application of the material for the greening of the city
(T3) Water from everywhere	Regulate technology risk (technology risk management to wiz bang technology) Educate on barriers and benefits of technology inclusive risk Educate process on how technology is made (e.g. cycle from source to waste production) Ensure policy standards are maintained by educating the public on the why they were developed in the first place
(T4) Geoengineering Gods	Create a (risk) management plan in case of faulty technology at local, national and international levels Enforce regulations and agreements on who has control of technology, when and how they can use it Assess impacts and rebound effects of new technologies Look after mitigation of new technology's impacts
(T5) Mega Urban Farms	Regulate farming pollutants and their impact Educate on farming pollutants and their impacts Introduce hygiene standards Search at alternative ways for water demands to be met
(T6) Unlimited Energy	Demonstrate being a world leader Need to assess the risks of relying on energy intense systems
(EL1) Scotland Down Under	Plan for the new hydrological regime (educate, plan, implement with opportunities, retrofit) Invest in infrastructure that will maintain essential services (e.g. flood proofing, snow clearing of roads) Work with local agriculture to assist in shifts to new planting and forming practices Develop sustainable energy infrastructure to cope with the new energy demand (e.g. demand of more lighting) Protect vulnerable communities Educate communities about how to drive safely under different climatic conditions

Wildcard	**Recovery Strategies**
(EL2) The Blue Plague	Encourage new sources of water Investigate new sources of water (decentralise, catchment, rainfall) Aftermath strategies Isolate people who have been infected Evacuate other people
(EL3) Flood Cataclysm	Establish locally functioning sewage treatment and drinking water systems Flood proof water infrastructure Consider location in planning Risk assessment
(EL4) Seaquake	Set climate disaster policies (local councils level) Set evacuation plans to safeguard communities Establish early warning systems Isolate infrastructure so as not to become contaminated Stop building infrastructure in flood prone areas and coast shores
(EL5) Acid Cloud	Develop technical solutions to increase the capacity of people to respond under extreme pressure Create trust in water authorities Community to understand action for emergency responses Good leadership from government
(EL6) A sizzling state	Increase community support Establish green infrastructure to create shade Establish local economies to minimise commute needs Rely on and create decentralised options and redundancies
(E1) China Slows Down	Search for solutions that are not cost hungry
(E2) Iron No More	Promote resource recovery Create incentives for recycling Crete a business case for recycling Create opportunities for novel ideas about resource use Create new material for function Manage existing infrastructure (e.g. street furniture) Incentivise for change of consumption patterns
(P1) Terror on Aqua	Make immediate options and alternatives ready Understand and plan for risks Higher emphasis on local and decentralised systems Diversity of supply Diversity of suppliers
(P2) New Zealand Invades	Basic water and sanitation only Roof and rain tanks Local solutions Rely on community

APPENDIX F. TRANSITION SCENARIO WORKSHOP SERIES RESULTS

This appendix contains excerpts from:

Ferguson, B.C., Frantzeskaki, N., Skinner, R., Brown, R.R. (2012b) Melbourne's transition to a Water Sensitive City: Yarra Valley Cluster workshop series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, ISBN 978-1-921912-16-0. Available for download from http://www.waterforliveability.org.au/

Ferguson, B.C., Frantzeskaki, N., Skinner, R., Brown, R.R. (2012c) Melbourne's transition to a Water Sensitive City: South East Cluster workshop series. Dutch Research Institute For Transitions, Erasmus University Rotterdam. Monash Water for Liveability, Monash University, Melbourne, ISBN 978-1-921912-15-3. Available for download from http://www.waterforliveability.org.au/

YARRA VALLEY CLUSTER RESULTS (Ferguson et al., 2012b)

Current Underlying Challenges

Absence of long term commitment by either or both political parties.
Long-term commitment to water sensitivity is compromised by different priorities, conflicting agendas and short-term political cycles.

Current economic paradigm has limits.
Current economic thinking values growth, individualism and private interests. There are no drivers or incentives for the water sector to operate differently. Frameworks for valuing long-term intangible benefits do not exist.

No compelling vision to drive change.
The vision does not connect with society's values and beliefs in way that communicates the benefits of a water sensitive city and compels people to act conscientiously.

Legacy of the past inhibits new approaches.
The existing management culture results in a reluctance to revisit assumptions, to raise issues, to manage different types of risks and to adapt to new ways of doing things. While acknowledging the need to change its approach, the water sector faces hurdles due to decades of investment in traditional infrastructure and its associated knowledge, skills and formal rules.

Boundaries and relationships are not defined in a useful way.
Existing arrangements for sharing authority, responsibility, knowledge and resources do not suffice for the new roles that are emerging around water sensitive planning, design and management.

Integration creates new opportunities and complexities.
Integration means that multiple water sources, geographic scales, infrastructure types, ecological assets, as well as a diversity of stakeholders and their interests, need to be considered. These interconnected elements create complexity, but also new opportunities.

Insufficient cultural, technical and social capacity.
New knowledge, new tools and new ways of engaging and collaborating are required to address emerging water challenges. There is currently insufficient capacity to bridge these gaps.

Underlying Challenges	Domains of Change
Absence of long term commitment by either or both political parties	Political commitment to achieve water sensitive outcomes
Current economic paradigm has limits	Definition of success
No compelling vision to drive change	Communication of the need, vision and desires Valuation of water
Legacy of the past inhibits new approaches	Water sector collaboration (internally and externally) Perception and incentives for collective benefits Legislated performance standards of water infrastructure
Boundaries and relationships are not defined in a useful way	Definition of water boundaries Planning of water servicing
Integration creates new opportunities and complexities	Knowledge and tools of the water and planning sectors Community knowledge and attitude towards water
Insufficient cultural, technical and social capacity	Knowledge and tools of the water and planning sectors Risk perception and management Community knowledge and attitude towards water

Vision of a Water Sensitive City (Yarra Valley Cluster)

Guiding Principles:

Social and Ecological Health

1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.
2. Our city is alive, healthy and green; its environmental wellbeing is valued, protected and enhanced. We live in harmony with our natural environment.
3. Our city, people and ecosystems are safe and resilient; we are prepared for surprises and extremes.

Connected Communities

4. Our identity embraces water; we celebrate our water sensitive city and take pride in the path it paves for a sustainable future.
5. We are educated, engaged and aware; we understand and take responsibility for our water. Our water sector collaborates and co-creates understanding and solutions with community and associated sectors. We understand and act upon community water needs.

Shared Prosperity

6. We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system.
7. Our water system is equitable; water is available for us all to meet our basic needs.

Water System

8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum societal value.
9. Our water system is smart, integrated, connected, flexible and adaptive.
10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water and nutrients are consumed and produced.

Vision of a Water Sensitive City (Yarra Valley Cluster)

A Vision of Social and Ecological Health

Narrative

Water is essential for all life forms. We respect the water needs of all species. Our waterways and other ecosystems are in a healthy condition and support our public health and wellbeing. Green landscapes and vegetated corridors support native biodiversity. Water supports the greening of our city's infrastructure. We all live and work within walking distance of a neighbourhood common that has canopy cover to provide retreat from the sun and heat. Water fosters good quality, connected greenscapes. We all have access to waterways and green public open space. It is our place to meet, play and relax. Our people are healthy and active. We enjoy green and blue corridors for community activities such as sport, walking, cycling, and swimming. Our green city has space for us to grow our own fruit and vegetables. We appreciate our environment and connect with nature through a range of experiences. The water we drink and use is safe and of excellent quality. We are prepared for droughts, floods and heatwaves. Our people, ecosystems and property are safeguarded against surprises such as drinking water contamination and sewage overflows. Our community and ecosystems are healthy and resilient.

Guiding Principles

1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.
2. Our city is alive, healthy and green; its environmental wellbeing is valued, protected and enhanced. We live in harmony with our natural environment.
3. Our city, people and ecosystems are safe and resilient; we are prepared for surprises and extremes.

Image

(Therese Keogh, project artist)

Vision of a Water Sensitive City (Yarra Valley Cluster)

Social And Ecological Health

1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.

Strategic Objective

1A Increased number of formal and informal social networks that can provide connectedness and support when needed
1B Everyone identifies and feels connected with their local neighbourhood
1C Everyone feels a strong connection with nature
1D Everyone has access to good quality waterways and their banks
1E Everyone has access to, uses and values public space (e.g. swimming pools, nature reserves, parks, rivers, sport fields)
1F Everyone has access to, uses and values a range of community activities (e.g. physical activity, organised events, passive recreation)
1G Everyone has access to a place to relax (e.g. private garden, local park)
1H Everyone lives and works within walking distance of a neighbourhood parks that has good quality canopy cover
1I Minimised rate of heat-related and respiratory illness

2. Our city is alive, healthy and green; its environmental wellbeing is valued, protected and enhanced. We live in harmony with our natural environment.

Strategic Objective

2A All urban waterways are in “good” to “excellent” condition*
2B All urban development is designed to maintain natural flow regimes (e.g. runoff from impervious surfaces)
2C Green open space is of good quality and plentiful
2D Minimum potable water is used for irrigating green open space
2E Maximum vegetation coverage of active transport corridors
2F More habitats are protected and enhanced to prioritise biodiversity and abundance

* Definition of waterway condition as per the Index of River Condition (www.melbournewater.com.au).

3. Our city, people and ecosystems are safe and resilient; we are prepared for surprises and extremes.

Strategic Objective

3A Everyone has emergency plans and is ready to implement them if needed
3B Efficient system response when conditions change
3C Minimised mortality and morbidity from heat waves
3D No fatalities from flood events
3E Minimised property damage and amenity loss from surprises and extremes (e.g. flood, drought, heatwave, sewage overflows)
3F No negative health impacts from drinking water
3G Wide variety of water sources contribute to city’s supply
3H No biodiversity loss due to the water system
3I All decisions are made in consideration of their impact on the water cycle

Vision of a Water Sensitive City (Yarra Valley Cluster)

A Vision of Connected Communities

Narrative

We feel a connection with nature and to our neighbourhoods. Water links us with the landscape and fosters a sense of identity and community. We identify with water when we see that the water falling around us is used locally. We see how water flows and understand the different phases of its cycle. We celebrate water; people play with water and our urban waterways are used for recreation. We are all committed to a shared water vision and have a clear understanding of its benefits. We are passionate about water and think holistically about our future. We create vibrant community conversations about water. We share a clear understanding of our different roles and responsibilities for achieving our vision. A spirit of cooperation underlies how plans and designs are realised. Community is empowered to contribute and co-create real options with the water sector. Our water profession is able and eager to engage with community and values its input. All professionals involved in planning and management of the water cycle are open to broad perspectives and have a curiosity for new approaches to water. We are all water literate and are capable of preparing and adapting to uncertain futures.

Guiding Principles

4. Our identity embraces water; we celebrate our water sensitive city and take pride in the path it paves for a sustainable future.
5. We are educated, engaged and aware; we understand and take responsibility for our water. Our water sector collaborates and co-creates understanding and solutions with community and associated sectors. We understand and act upon community water needs.

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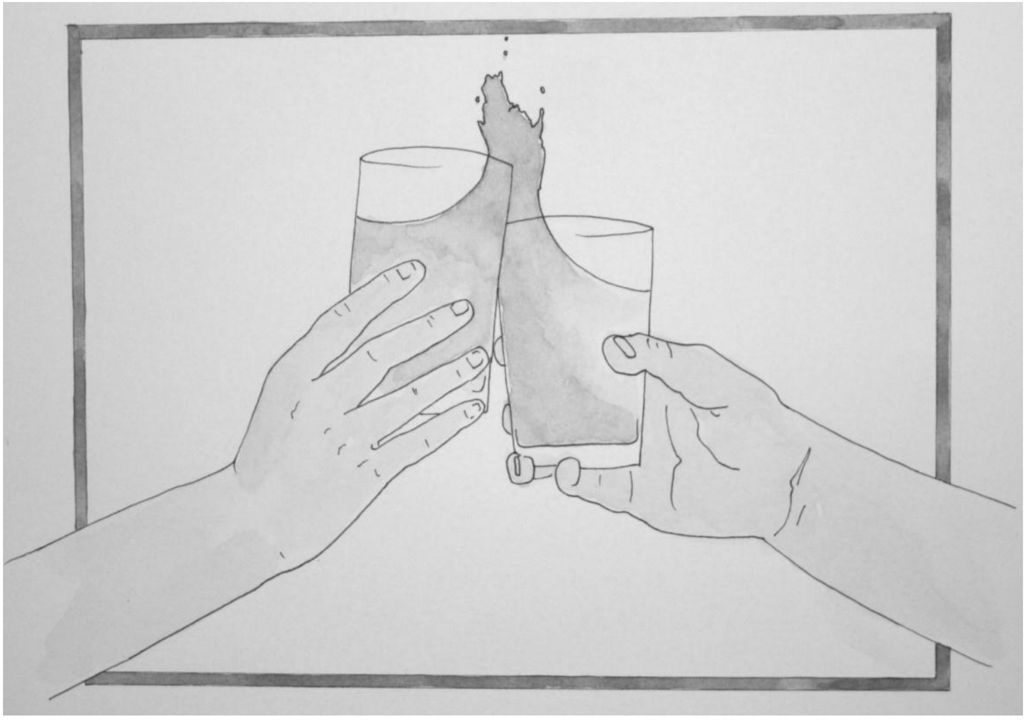

(Therese Keogh, project artist)

Vision of a Water Sensitive City (Yarra Valley Cluster)

Connected Communities

4. Our identity embraces water; we celebrate our water sensitive city and take pride in the path it paves for a sustainable future.

Strategic Objective

4A Everyone is proud of the Yarra's iconic status as a healthy river where people can swim and fish

4B Every community has access to waterways for passive and active recreation

4C Increased visibility of water in urban space

4D All urban runoff has the opportunity to be used

4E Water sensitive infrastructure is everywhere

4F Everyone makes fit-for-purpose decisions about water use

4G Everyone who adopts water sensitive practices are appreciated and celebrated (e.g. business marketing, higher house value)

5. We are educated, engaged and aware; we understand and take responsibility for our water. Our water sector collaborates and co-creates understanding and solutions with community and associated sectors. We understand and act upon community water needs.

Strategic Objective

5A All water-related institutions are transparent, adaptive and collaborative

5B The water sector is more knowledgeable and confident in their communication about the quality and potential uses of water sources

5C High capacity to link expertise across the whole water cycle

5D High diversity of backgrounds of professionals involved in decision-making about water

5E The water sector is better able to engage with the community

5F All organisations have mechanisms to meaningfully involve communities in vision building and decision-making

5G All water solutions are driven by the community's needs and goals

5H More community-led projects enabled and supported by the water sector

5I More water ambassadors in every community

5J Increased awareness and knowledge of people about water issues, decisions and systems

5K Many vibrant community conversations about water and holistic thinking occur

5L Everyone uses a shared language to communicate (e.g. community, water sector and other sectors)

5M Increased diversity of education programs about the water cycle (e.g. schools, universities, life-long training)

Vision of a Water Sensitive City (Yarra Valley Cluster)

A Vision of Shared Prosperity

Narrative

We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system. Investment decisions are made with a long-term perspective, creating a resilient economy. Our decisions are driven by the societal benefits they produce. Water prices represent the true value of water and dynamically reflect local water conditions. Our competitive markets use water efficiently. We can all meet our basic water needs. Our measure of success is based on equity amongst different communities, generations and species.

Guiding Principles

6. We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system.
7. Our water system is equitable; water is available for us all to meet our basic needs.

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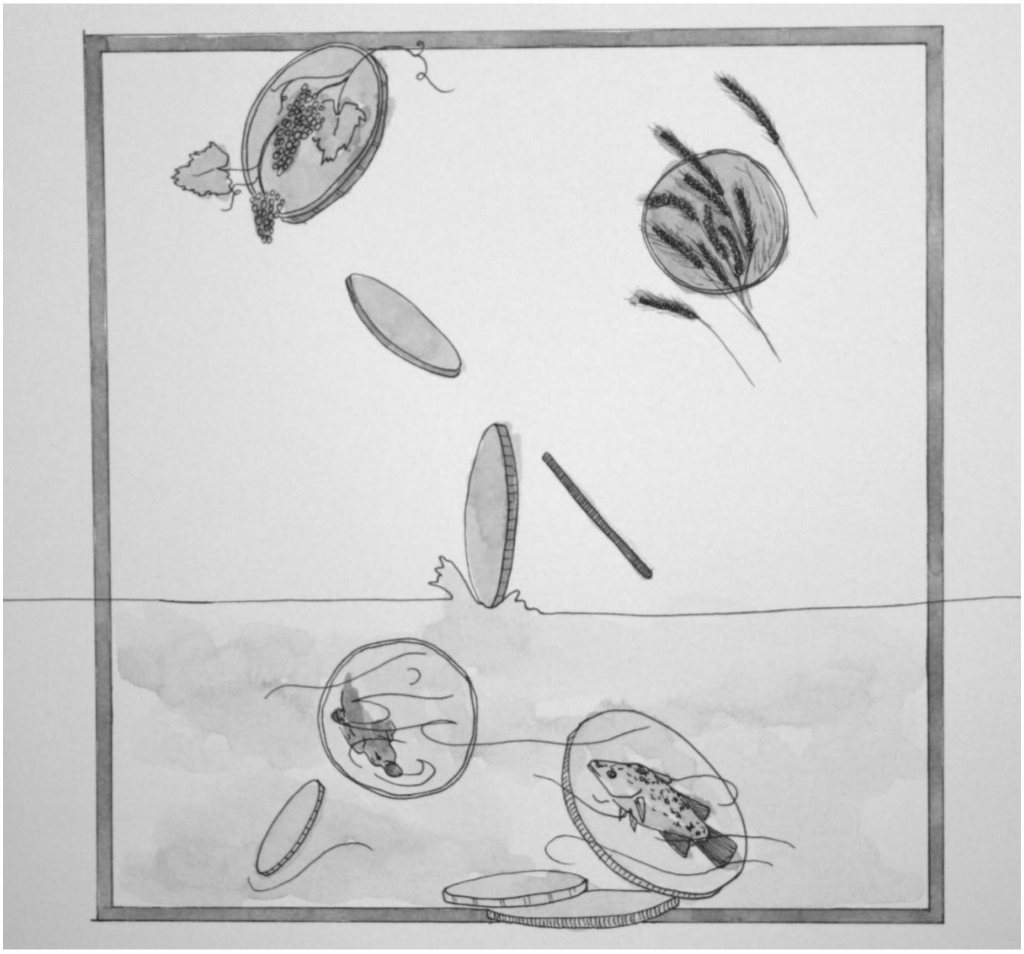

(Therese Keogh, project artist)

Vision of a Water Sensitive City (Yarra Valley Cluster)

Shared Prosperity

6. We live in a prosperous society that has healthy businesses and healthy communities, supported by our water system.

Strategic Objective

6A All water investments are based on a proactive planning approach that transparently considers real options

6B Every infrastructure decision delivers the highest societal and ecological benefit

6C Every water infrastructure decision is based on a lifecycle assessment that includes future options, externalities and local conditions

6D Maximised opportunities for multiple uses of assets throughout their construction, management and renewal

6E Optimised water and resource efficiency for infrastructure development and renewal by all users (e.g. utilities, councils, businesses, agriculture, community)

6F Increased connection of fit-for-purpose sources and uses for business and communities

7. Our water system is equitable; water is available for us all to meet our basic needs.

Strategic Objective

7A Everyone has access to water for basic needs, irrespective of socioeconomic status

7B Ensure equity in the costs of water servicing across the city

7C Everyone has amenity opportunities

7D Healthy ecosystems are maintained in all climatic conditions

7E Environmental flows are never compromised

7F All urban areas are designed to maintain healthy flow regimes (e.g. runoff from impervious surfaces)

Vision of a Water Sensitive City (Yarra Valley Cluster)

A Vision of Our Water System

Narrative

Our water system embraces the many values of water. We transparently identify and measure the benefits and impacts of all the services provided by water. We equitably share these benefits and impacts. We holistically evaluate, plan and design our water systems. We know how much water has been used in the whole life cycle of our products and activities. We consider our impacts on water systems, including those that extend beyond our city's boundaries. The design of our cities and water systems aligns with the characteristics of the local landscape. Our water systems are designed to utilise and provide a diverse portfolio of water sources. We have a smart water grid that matches sources of water to their demands, enhancing our resilience. We readily use recycled wastewater and harvested stormwater. Water sensitive infrastructure is in every neighbourhood street. We optimise our self-sufficiency at different spatial scales. Our water system uses energy efficiently and is supplied entirely by renewable energy sources. Our water system designs enable interconnections between nutrient, mineral, energy, carbon and water cycles and utilise their productive potential.

Guiding Principles

8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum societal value.
9. Our water system is smart, integrated, connected, flexible and adaptive.
10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water and nutrients are consumed and produced.

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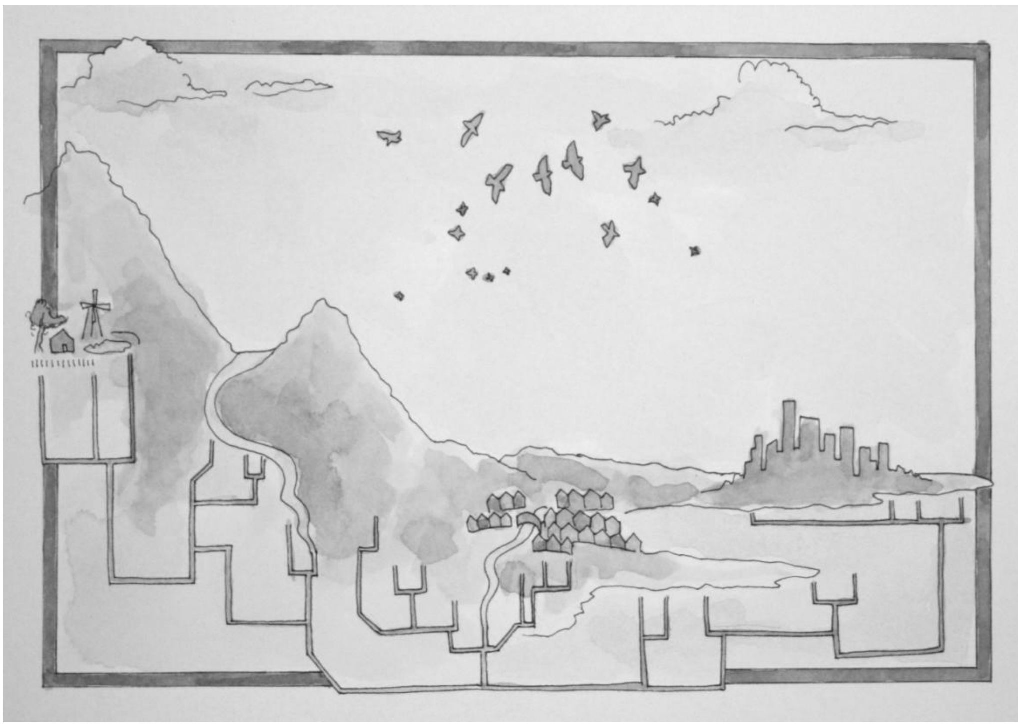


(Therese Keogh, project artist)

Vision of a Water Sensitive City (Yarra Valley Cluster)

Our Water System

8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum societal value.

Strategic Objective

8A All benefits and impacts of water are identified, quantified and communicated (in monetary or non-monetary terms)

8B Infrastructure costs are shared across organisations to reflect the distribution of benefits

8C All urban design decisions consider the total cost of water servicing

8D High levels of transparency about the water consumed in products and services

9. Our water system is smart, integrated, connected, flexible and adaptive.

Strategic Objective

9A High overall efficiency of water infrastructure

9B Minimised impact of the urban environment's water needs on regions outside its boundaries

9C Wide variety of water sources contribute to urban supply

9D Optimised self-sufficiency at all scales

9E All water demands are met by fit-for-purpose sources of water

9F Efficient potable water use

9G No toilet uses potable water

9H Increased use of recycled wastewater and harvested stormwater

9I Every building contributes to our water resources

9J Water sensitive infrastructure is everywhere

10. Our water system uses water efficiently; it has a positive impact on how resources such as energy, water and nutrients are consumed and produced.

Strategic Objective

10A Positive impact of water system on the environment

10B Optimised fit-for-purpose water use to reduce resource consumption

10C All energy and nutrients from water are recovered and used for productive purposes

10D Water system relies entirely on renewable energy sources

10E All urban developments are net neutral in water, energy and nutrients (e.g. nitrogen, phosphorus)

Strategic Transitions Pathways for Achieving a Water Sensitive City (Yarra Valley Cluster)

Pathway A – Foster Community Connections with Water

Path A1 – Build public understanding
Path A2 – Empower communities
Path A3 – Celebrate water

Pathway B – Collaborate for Water

Path B1 – Align objectives of water-related organisations
Path B2 – Communicate a common message
Path B3 – Actively support collaborative approaches

Pathway C – Integrate All Values of Water

Path C1 – Identify and measure water values
Path C2 – Develop evaluation frameworks
Path C3 – Develop incentives based on broad water values
Path C4 – Ensure equity in the distribution of water values

Pathway D – Harmonise Water and Planning

Path D1 – Embed broad water values in planning paradigm
Path D2 – Identify and seize opportunities

Pathway E – Develop a Portfolio of Water Resources

Path E1 – Develop data, knowledge, tools and technologies
Path E2 – Develop guidelines and standards
Path E3 – Develop regulations for fit-for-purpose water supply

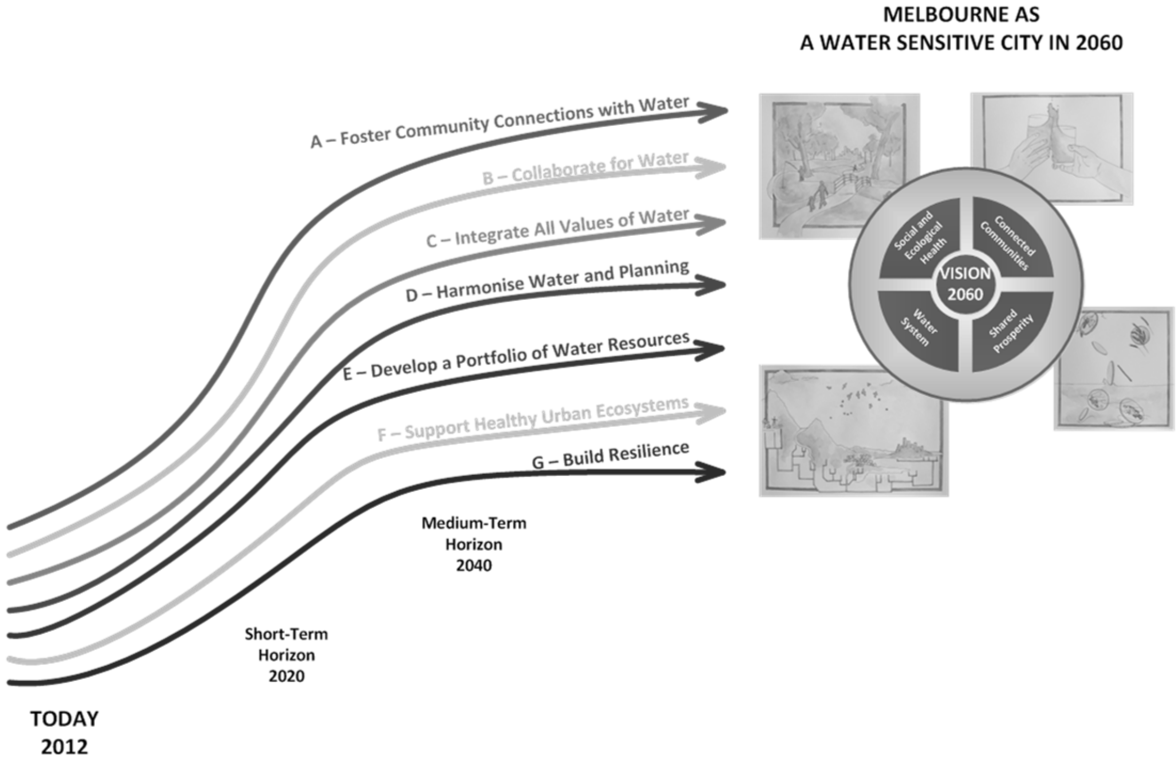
Pathway F – Support Healthy Urban Ecosystems

Path F1 – Manage green space
Path F2 – Enhance biodiversity and urban catchments
Path F3 – Protect environmental flows

Pathway G – Build Resilience

Path G1 – Anticipate and prepare for extremes and surprises
Path G2 – Mitigate for extremes and surprises
Path G3 – Respond and adapt to extremes and surprises
Path G4 – Communicate about extremes and surprises

Strategic Transitions Pathways for Achieving a Water Sensitive City (Yarra Valley Cluster)



SOUTH EAST CLUSTER RESULTS (Ferguson et al., 2012c)

Current Underlying Challenges

No bipartisanship for long term commitment.
Long-term commitment to water sensitivity is compromised by short-term political priorities, agendas and cycles.

No compelling vision to drive change.
The vision does not yet communicate how society's priorities connect with immediate and future benefits of a water sensitive city so as to build on existing good practices and drive new actions.

Existing management culture inhibits innovation.
The water management legacy provides a strong base for dealing with challenges; however the existing culture results in a reluctance to revisit assumptions, to manage different types of risks and to adapt to new ways of doing things.

Boundaries and relationships are undefined.
Existing arrangements for sharing power and responsibility do not suffice for the new roles that are emerging around water sensitive planning, design and management.

Legacy of the past sets hurdles.
While acknowledging the need to change its approach, the water sector faces hurdles due to decades of investment in traditional infrastructure and its associated knowledge, skills and formal rules.

Integration creates new complexities.
Integration means that multiple water sources, geographic scales, infrastructure types, ecological assets, as well as a diversity of stakeholders and their interests, need to be considered. These interconnected elements create complexity.

Underlying Challenges	Domains of Change
No bipartisanship for long-term commitment	Political commitment to achieve water sensitive outcomes
No compelling vision to drive change	How the water sensitive vision is communicated and defined Time horizon of the water sensitive vision framing How water is valued Community's attitude towards water
Existing management culture inhibits innovation	How the water sector collaborates internally and externally How risk is perceived and managed How resources are utilised
Boundaries and relationships are undefined	Definition of water boundaries How water servicing is planned How water plans are implemented
Legacy of the past sets hurdles	Legislated performance standards for water infrastructure
Integration creates new complexities	How the water and planning sectors are equipped Community's attitude towards water

Vision of a Water Sensitive City (South East Cluster)

Guiding Principles:

Social and Ecological Health

1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.
2. Our city is alive, healthy and beautiful; its environmental wellbeing is valued, protected and enhanced.
3. Our city and people are safe; we are prepared for flooding and water quality threats.

Connected Communities

4. Our people are educated, engaged and empowered; we feel and take responsibility for our water.
5. Our water profession is passionate about water; we collaborate with the community to understand and respond to our water needs.

Shared Prosperity

6. Our economy is healthy; prosperity is supported by our water system.
7. Our water system is equitable; we can all afford to meet our basic water needs.
8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum community value.

Water Sensitive Infrastructure

9. Our water system is smart, integrated, flexible and connected. We manage water cycles to take advantage of different sources to meet our own water needs while giving and receiving support to the broader system.
10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water, nutrients and physical space are consumed and produced.

Vision of a Water Sensitive City (South East Cluster)

A Vision of Social and Ecological Health

Narrative

Our people are healthy and active. The water we drink, use and enjoy is safe, of excellent quality and contributes to our physical and mental wellbeing. We all have access to good quality, connected green public open space and waterways. We enjoy these green and blue corridors for organised sport, walking, cycling, swimming, fishing and other recreational activities. It is our space to meet and play. We appreciate and protect our environment. Trees, gardens and water create a thermally comfortable environment. Our ecosystems are healthy and beautiful. Water links us with the landscape and fosters a sense of identity and community. Locally grown food is available for us to consume. We respect natural water flows and local conditions. We are prepared for surprises such as droughts, floods and heatwaves. Our community and environment are healthy and resilient.

Guiding Principles

4. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.
5. Our city is alive, healthy and beautiful; its environmental wellbeing is valued, protected and enhanced.
6. Our city and people are safe; we are prepared for flooding and water quality threats.

Image

(Therese Keogh, project artist)

Vision of a Water Sensitive City (South East Cluster)

Social and Ecological Health

1. Our people are healthy; our physical and mental wellbeing is valued, protected and enhanced.

Strategic Objective	
1A	Everyone lives within 400m of a green corridor
1B	Water quality or supply issues never disrupts recreational use of waterways and open space
1C	Minimised day- and night-time temperature differentials in during Summer
1D	All neighbourhoods have access to productive food space
1E	High rate of participation in sport and recreation activities
1F	Everyone drinks fluoridated water
1G	Downward trend in levels of chronic disease
1H	Upward trend of rates of mental health recovery

2. Our city is alive, healthy and beautiful; its environmental wellbeing is valued, protected and enhanced.

Strategic Objective	
2A	Green space is of good quality and plentiful
2B	Maximised number of green-blue corridors
2C	All waterways are rated as good to excellent health
2D	Everyone makes use of their local green and blue spaces
2E	High rate of tree coverage of private land area
2F	High rate of tree coverage of public land area
2G	Green wedge areas, parks and reserves are never compromised for development
2H	High rate of resources allocated to environmental wellbeing
2I	High rate of participation in environmental protection activities
2J	Green spaces are never subject to waste disposal
2K	Green-blue corridors are never subject to illegal industrial discharges

3. Our city and people are safe; we are prepared for flooding and water quality threats.

Strategic Objective	
3A	Full compliance with drinking water quality standards for potable water
3B	Full compliance with fit-for-purpose quality standards for non-potable water
3C	No human fatalities from flood events
3D	No critical infrastructure built in flood prone areas (e.g. treatment plants, pump stations, storages, energy supply, telecommunications, hospitals, aged care facilities, emergency services)
3E	Low frequency of exposure of critical infrastructure to flood risk (e.g. 1:200 years)

Vision of a Water Sensitive City (South East Cluster)

A Vision of Connected Communities

Narrative

Our community is water literate. We know where our water comes from, goes to and how we should use it. Households and businesses proactively adopt water sensitive practices that use resources efficiently and make the most of water from different sources for different purposes.

Our communities take initiative in meeting their own environmental and water-related needs. We are actively engaged and collaboratively inform water decisions in our city. Our water profession is community literate. We (as water professionals) are responsive to people's water needs and openly collaborate with community to co-create water sensitive choices.

Guiding Principles

7. Our people are educated, engaged and empowered; we feel and take responsibility for our water.
8. Our water profession is passionate about water; we collaborate with the community to understand and respond to our water needs.

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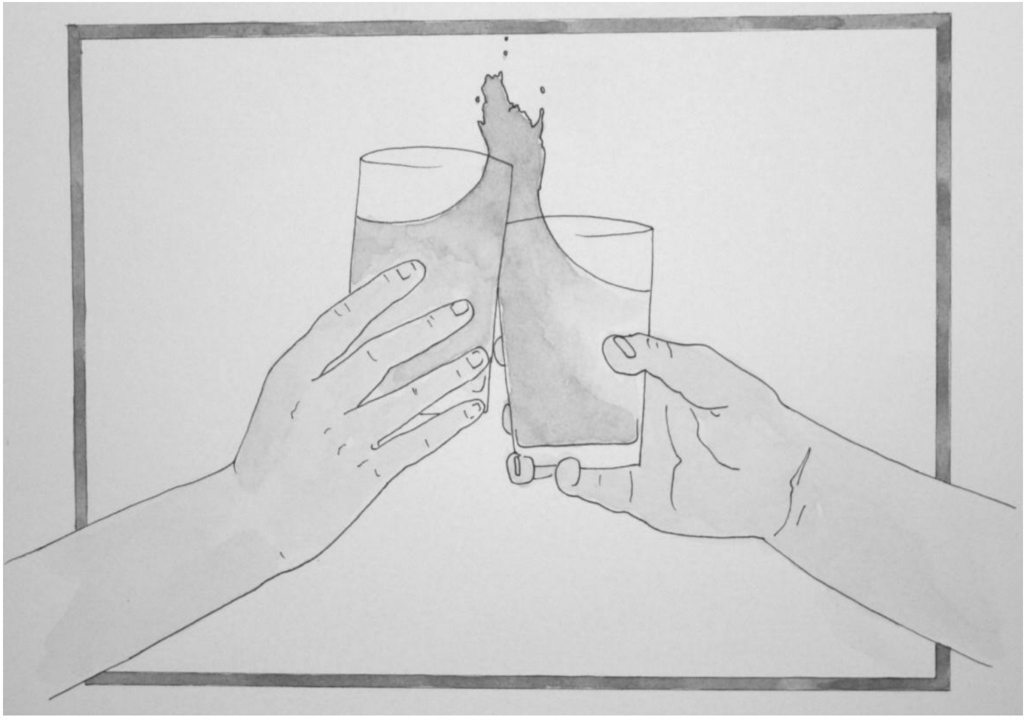

(Therese Keogh, project artist)

Vision of a Water Sensitive City (South East Cluster)

Connected Communities

4. Our people are educated, engaged and empowered; we feel and take responsibility for our water.

Strategic Objective

4A	All schools have broad water-related curriculum
4B	All households are water literate and are prepared for surprises (e.g. flood, drought, heatwave)
4C	Maximum of 20-40 L/person/day of centrally-supplied water consumed for potable uses in households
4D	Maximum of 50 L/person/day of centrally-supplied water consumed for non-potable uses in households
4E	All households and businesses self-monitor their water use
4F	High proportion of community project budgets funded by public grants

5. Our water profession is passionate about water; we collaborate with the community to understand and respond to our water needs.

Strategic Objective

5A	Significant representation by informed community members in all decision-making teams about water infrastructure choices (e.g. 20%)
5B	All water infrastructure planning processes provide genuine opportunities for community members to contribute
5C	High number of community-led water infrastructure projects
5D	All households are satisfied with water services and the communication provided by the water profession
5E	All households comply with water-sensitive practices

Vision of a Water Sensitive City (South East Cluster)

A Vision of Shared Prosperity

Narrative

Our economy is prosperous. Water supports the development of business opportunities without unduly contributing to economic risks. Essential water services are available, accessible and affordable for us all. Water sensitive technology is affordable and easy to adopt for households and businesses. We value water by identifying and measuring the benefits and impacts of all the services provided by water. We have smart economic tools that evaluate the full breadth of water benefits and impacts. We have administrative systems to support equitable sharing of water benefits and impacts between agencies, businesses and communities.

Guiding Principles

9. Our economy is healthy; prosperity is supported by our water system.
10. Our water system is equitable; we can all afford to meet our basic water needs.
11. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum community value.

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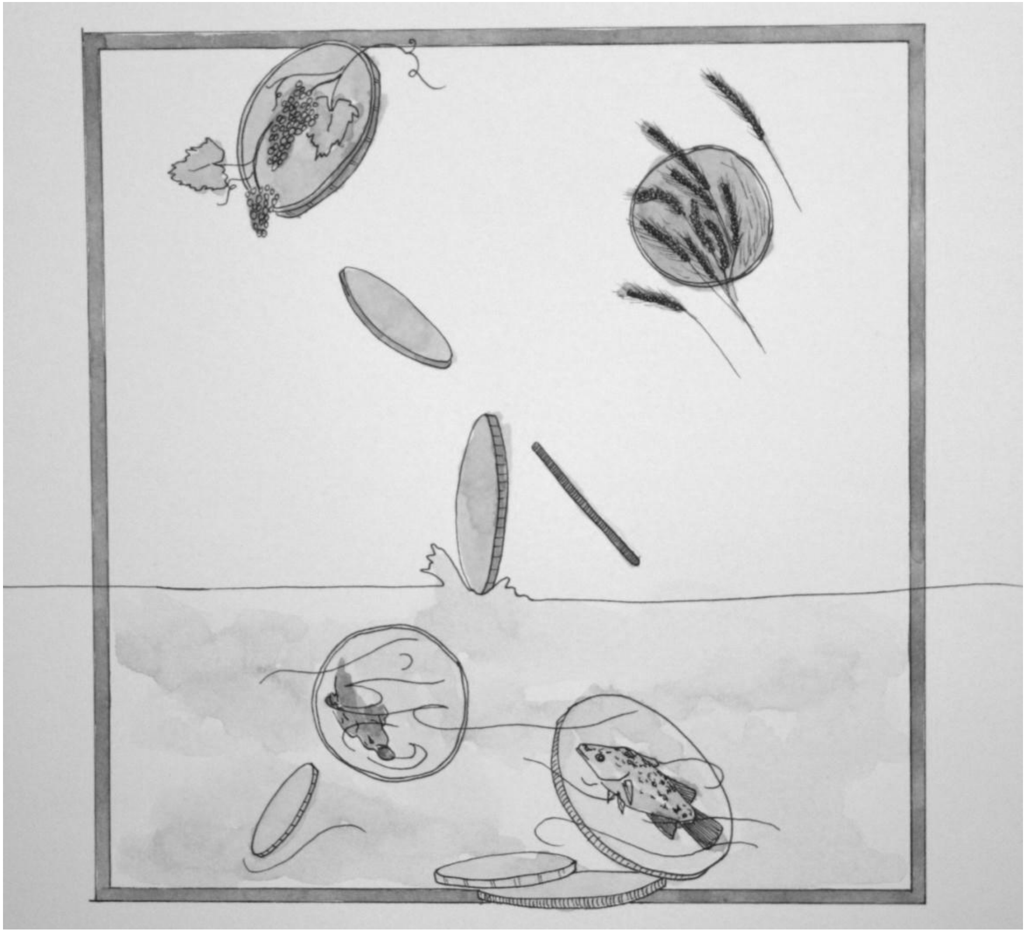

(Therese Keogh, project artist)

Vision of a Water Sensitive City (South East Cluster)

Shared Prosperity

6. Our economy is healthy; prosperity is supported by our water system.

Strategic Objective

6A	Minimised water-related risk (water quality and quantity) to the growth of business opportunities and their positive rate of return
6B	Minimised impact of water solutions on housing affordability
6C	Upward trend in rates of employment

7. Our water system is equitable; we can all afford to meet our basic water needs.

Strategic Objective

7A	All households have access to 90 L/person/day of water for their essential needs
7B	All households can afford water for their essential needs
7C	All households have access to water sensitive technology

8. Our water system embraces the many values of water; benefits and impacts are evaluated to ensure maximum community value.

Strategic Objective

8A	All benefits and impacts are identified
8B	All benefits and impacts are measured
8C	All benefits and impacts are equitably attributed

Vision of a Water Sensitive City (South East Cluster)

A Vision of Water Sensitive Infrastructure

Narrative

Our knowledge about the water cycle is based on information that is reliable, accurate, up-to-date and user-friendly. We have smart tools for using this information to support water planning and management. We plan for contingencies and are prepared for surprises. Our water cycles are planned such that we take advantage of different water sources that are safe and support self-sufficiency at local, neighbourhood and regional scales. In parallel, there is capacity in our city's central system to supply water to meet the basic needs of our households, businesses and communities. We seize the productive potential of different resource streams, in terms of nutrients, minerals and energy. Our water infrastructure is energy efficient and does not have a net negative impact on our atmosphere or biosphere. Our water sensitive infrastructure is designed to provide benefits in addition to its core functions. It adds to the beauty and value of our area.

Guiding Principles

12. Our water system is smart, integrated, flexible and connected. We manage water cycles to take advantage of different sources to meet our own water needs while giving and receiving support to the broader system.
13. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water, nutrients and physical space are consumed and produced.

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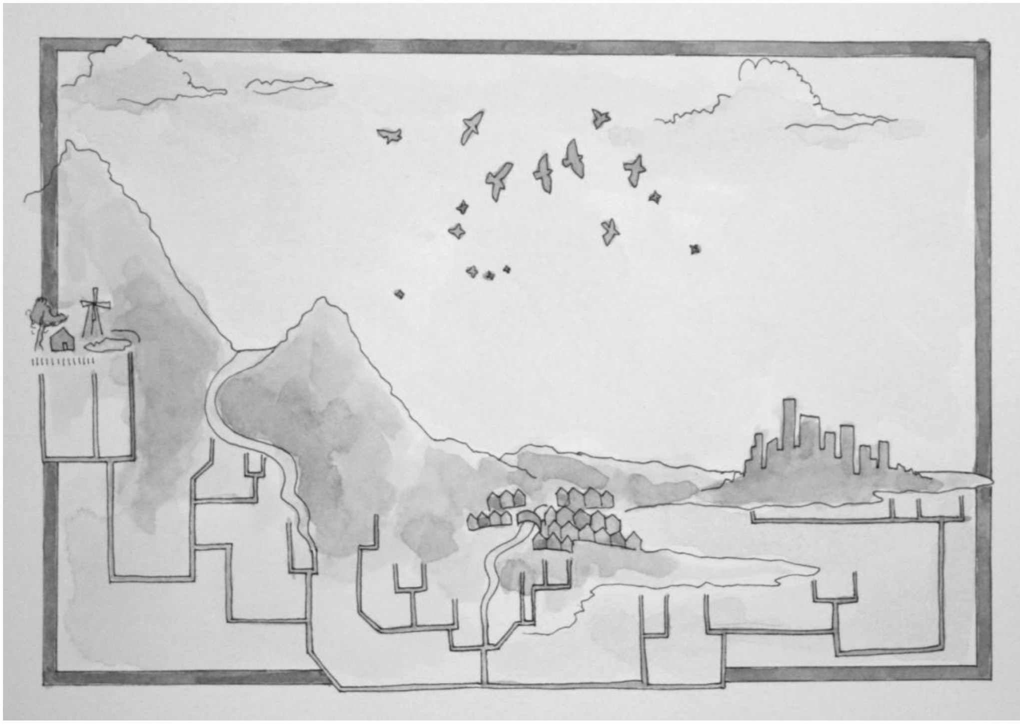


(Therese Keogh, project artist)

Vision of a Water Sensitive City (South East Cluster)

Water Sensitive Infrastructure

9. Our water system is smart, integrated, flexible and connected. We manage water cycles to take advantage of different sources in order to meet our own water needs while giving and receiving support to the broader system.

Strategic Objective	
9A	Central capacity to supply 20-40 L/person/day of potable water to households
9B	Central capacity to supply 50 L/person/day of non-potable water to households
9C	Central capacity to supply sufficient water to businesses to meet their fit-for-purpose water needs in an efficient way
9D	Optimised water self-sufficiency at all feasible scales
9E	All water-related decisions to be based on data about the water cycle that is reliable, accurate, up-to-date, user-friendly and takes into account future climate projections

10. Our water system uses resources efficiently; it has a positive impact on how resources such as energy, water, nutrients and physical space are consumed and produced.

Strategic Objective	
10A	Optimised energy efficiency for water infrastructure
10B	No net impact of water infrastructure on greenhouse gas emissions
10C	Optimised recovery of all minerals and nutrients in wastewater
10D	Optimised recovery of all energy in wastewater
10E	All water infrastructure design processes consider aesthetics
10F	No loss of visual amenity loss due to water infrastructure
10G	No odour impacts from water infrastructure
10H	Optimised adoption of all feasible (multi-)functions of water infrastructure

Strategic Transitions Pathways for Achieving a Water Sensitive City (South East Cluster)

Pathway A – Embed the Water Sensitive City Vision
- Path A1 – Develop the vision
- Path A2 – Communicate the vision
- Path A3 – Build community ownership of the vision
- Path A4 – Build private sector ownership of the vision
- Path A5 – Commit to the vision

Pathway B – Collaborate for Water
- Path B1 – Collaborate amongst disciplines
- Path B2 – Collaborate amongst organisations
- Path B3 – Collaborate with community

Pathway C – Integrate all Values of Water
- Path C1 – Identify water values
- Path C2 – Quantify water values
- Path C3 – Prioritise based on water values
- Path C4 – Incentivise based on water values
- Path C5 – Broaden water markets

Pathway D – Innovate for Water
- Path D1 – Develop a demonstration strategy
- Path D2 – Demonstrate new approaches
- Path D3 – Learn from demonstrations
- Path D4 – Scale up demonstrations
- Path D5 – Lead the innovations

Pathway E – Plan the Water Sensitive City
- Path E1 – Collect data
- Path E2 – Develop knowledge
- Path E3 – Develop tools and training
- Path E4 – Plan across spatial boundaries
- Path E5 – Identify opportunities
- Path E6 – Seize opportunities
- Path E7 – Empower local administration

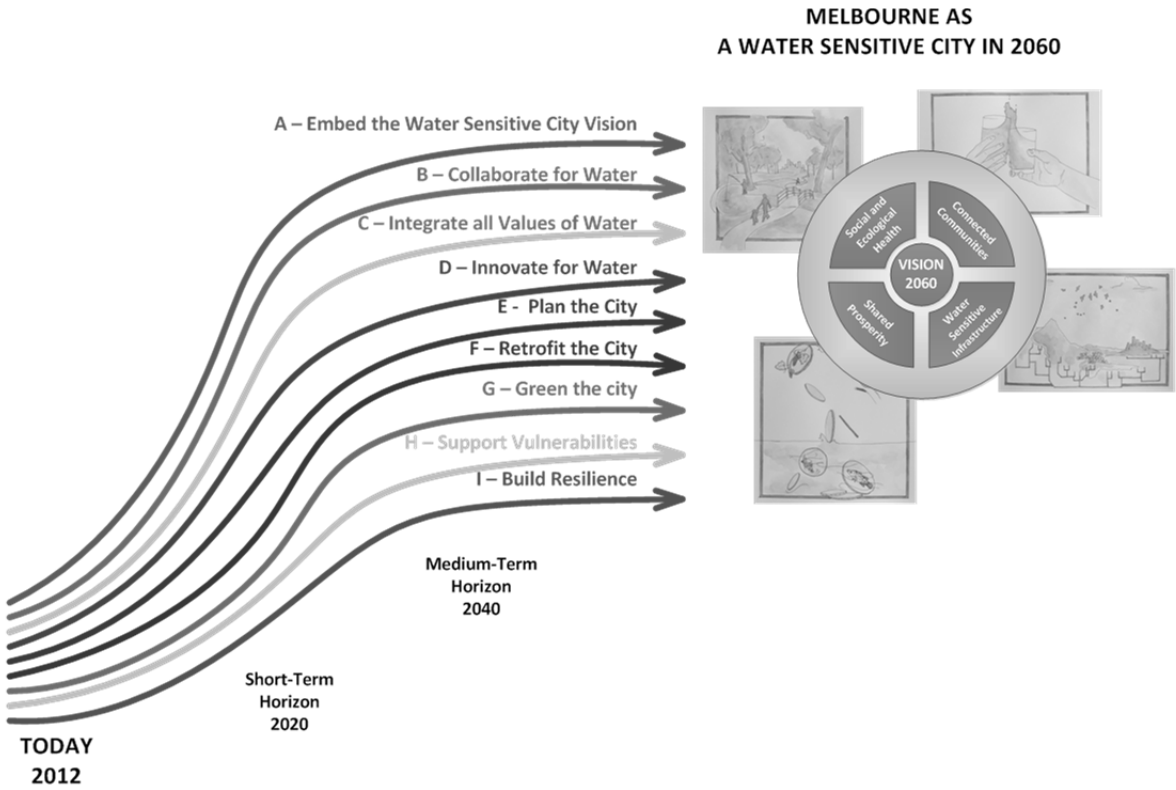
Pathway F – Retrofit the City
- Path F1 – Identify retrofit opportunities
- Path F2 – Retrofit with a fit-for-purpose approach
- Path F3 – Incentivise for private sector retrofitting

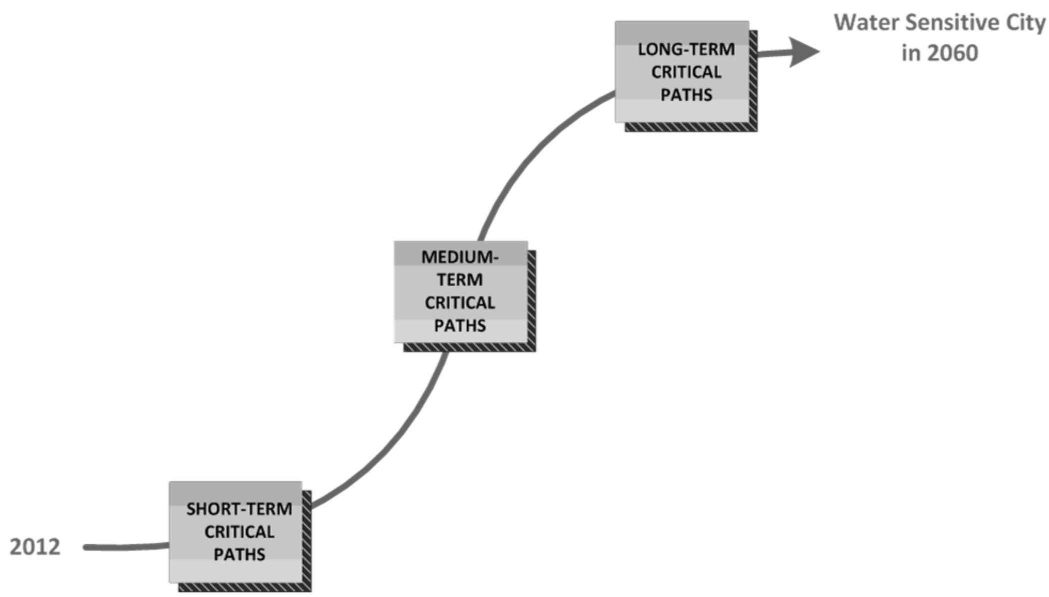
Pathway G – Green the City
- Path G1 – Identify space for green
- Path G2 – Integrate and co-locate green space
- Path G3 – Manage green infrastructure
- Path G4 – Support greening by community

Pathway H – Support Vulnerable Communities
- Path H1 – Identify vulnerable communities
- Path H2 – Develop support schemes

Pathway I – Build Resilience
- Path I1 – Anticipate extremes and surprises
- Path I2 – Mitigate for extremes and surprises
- Path I3 – Respond to extremes and surprises
- Path I4 – Adapt to extremes and surprises
- Path I5 – Communicate about extremes and surprises
- Path I6 – Educate about extremes and surprises
- Path I7 – Prepare for technological surprises

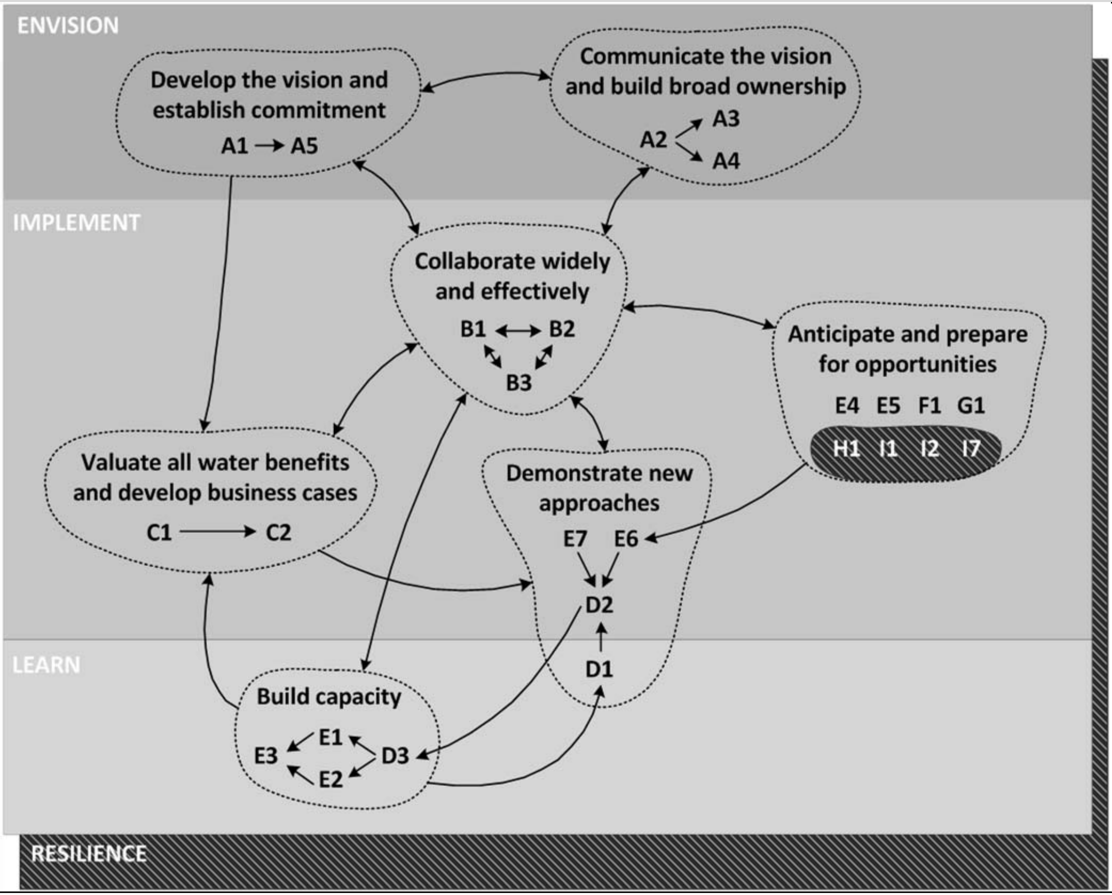
Strategic Transitions Pathways for Achieving a Water Sensitive City (South East Cluster)





Strategic Transitions Pathways for Achieving a Water Sensitive City (South East Cluster)

Short-Term Critical Paths



A **Embed the Water Sensitive City Vision**
- A1 Develop the vision
- A2 Communicate the vision
- A3 Build community ownership of the vision
- A4 Build private sector ownership of the vision
- A5 Commit to the Vision

B **Collaborate for Water**
- B1 Collaborate amongst disciplines
- B2 Collaborate amongst organisations
- B3 Collaborate with community

C **Integrate all Values of Water**
- C1 Identify water values
- C2 Quantify water values

D **Innovate for Water**
- D1 Develop a demonstration strategy
- D2 Demonstrate new approaches
- D3 Learn from demonstrations

E **Plan the Water Sensitive City**
- E1 Collect data
- E2 Develop knowledge
- E3 Develop tools and training
- E4 Plan across spatial boundaries
- E5 Identify opportunities
- E6 Seize opportunities
- E7 Empower local administration

F **Retrofit the City**
- F1 Identify retrofit opportunities

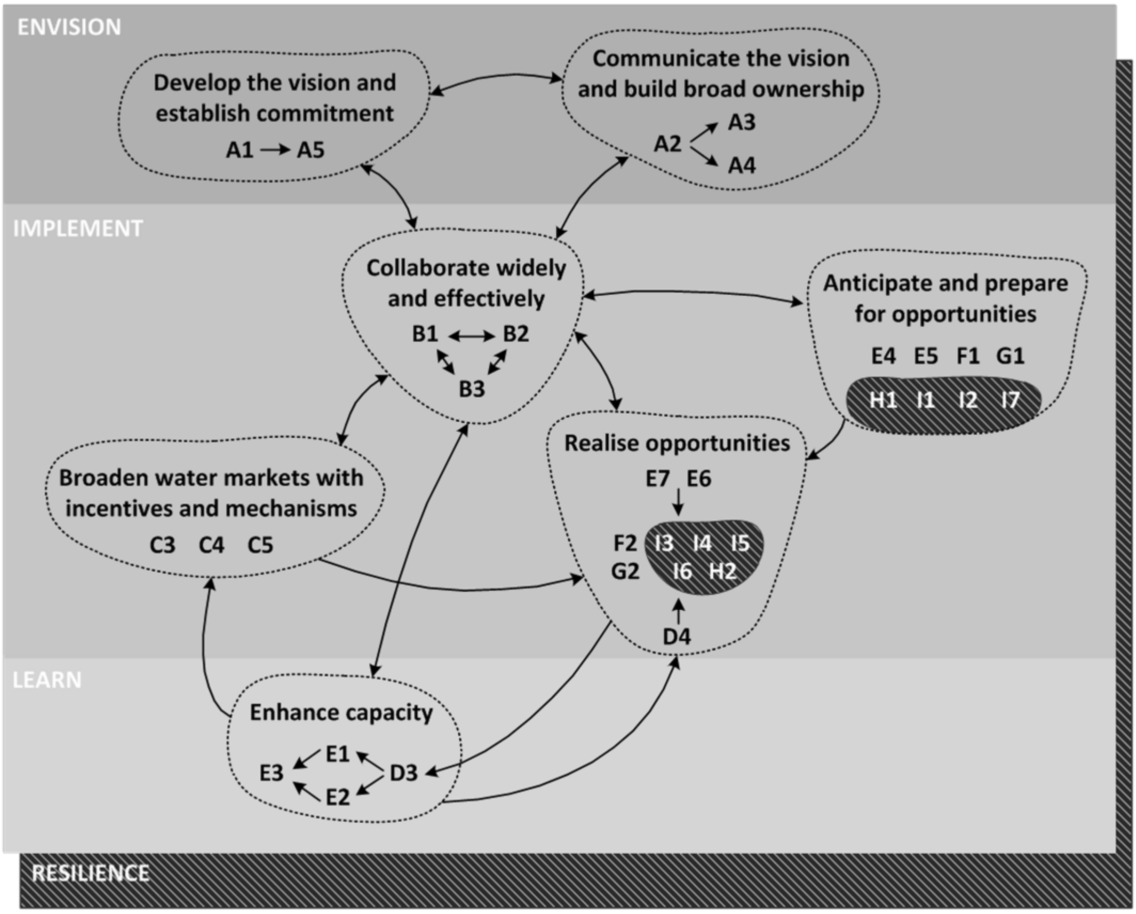
G **Green the City**
- G1 Identify space for green

H **Support Vulnerable Communities**
- H1 Identify vulnerable communities

I **Build Resilience**
- I1 Anticipate extremes and surprises
- I2 Mitigate for extremes and surprises
- I7 Prepare for technological surprises

Strategic Transitions Pathways for Achieving a Water Sensitive City (South East Cluster)

Medium-Term Critical Paths



A Embed the Water Sensitive City Vision
- A1 Develop the vision
- A2 Communicate the vision
- A3 Build community ownership of the vision
- A4 Build private sector ownership of the vision
- A5 Commit to the Vision

B Collaborate for Water
- B1 Collaborate amongst disciplines
- B2 Collaborate amongst organisations
- B3 Collaborate with community

C Integrate all Values of Water
- C3 Prioritise based on water values
- C4 Incentivise based on water values
- C5 Broaden water markets

D Innovate for Water
- D3 Learn from demonstrations
- D4 Scale up demonstrations

F Retrofit the City
- F1 Identify retrofit opportunities
- F2 Retrofit with a fit-for-purpose approach

E Plan the Water Sensitive City
- E1 Collect data
- E2 Develop knowledge
- E3 Develop tools and training
- E4 Plan across spatial boundaries
- E5 Identify opportunities
- E6 Seize opportunities
- E7 Empower local administration

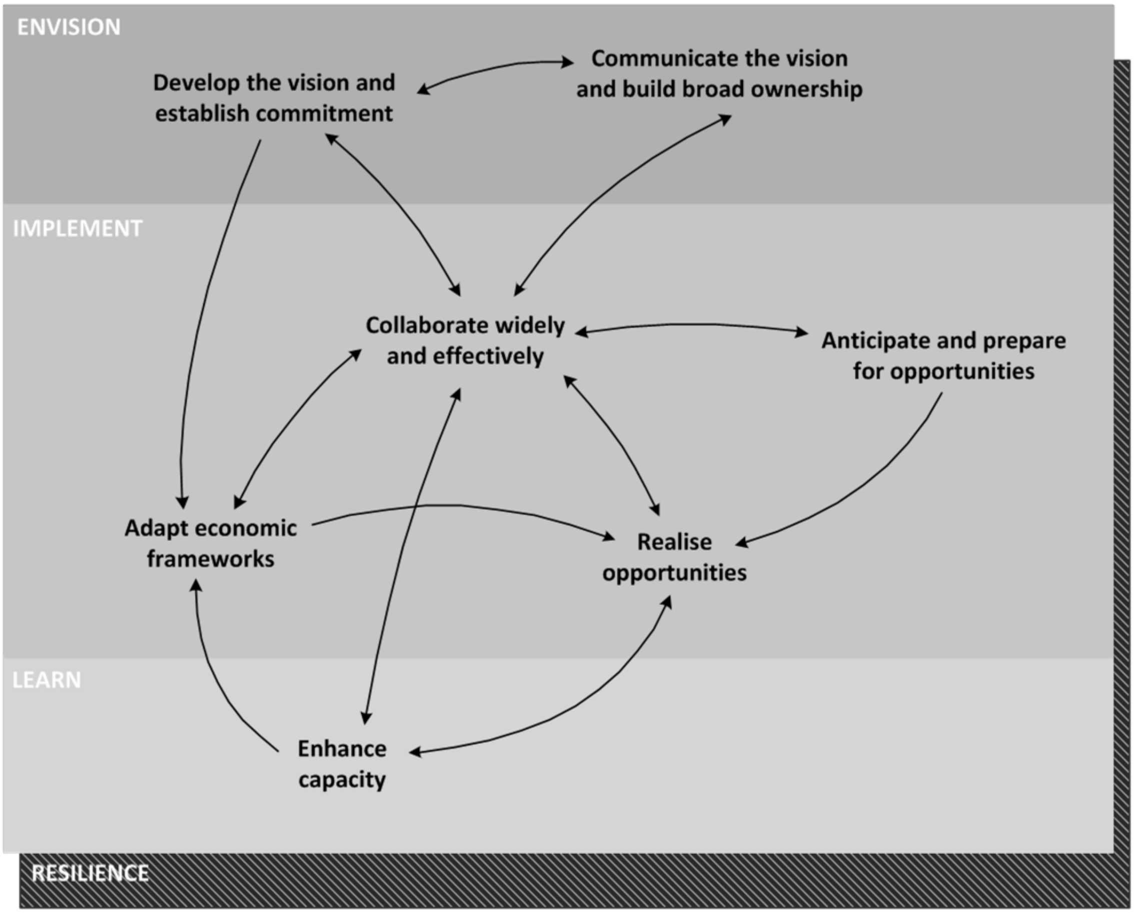
G Green the City
- G1 Identify space for green
- G2 Integrate and co-locate green space

H Support Vulnerable Communities
- H1 Identify vulnerable communities
- H2 Develop support schemes

I Build Resilience
- I1 Anticipate extremes and surprises
- I2 Mitigate for extremes and surprises
- I3 Respond to extremes and surprises
- I4 Adapt to extremes and surprises
- I5 Communicate ab. extremes and surprises
- I6 Educate about extremes and surprises
- I7 Prepare for technological surprises

Strategic Transitions Pathways for Achieving a Water Sensitive City (South East Cluster)

Long-Term Critical Paths



The long-term critical paths embrace an adaptive approach, involving repeated cycles of the short and medium-term paths, based on reviews, iterations, renewal and feedback.