# *ADAPTING WATER SYSTEMS TO CLIMATE CHANGE: A MULTI ACTOR - MULTIPLE CRITERIA DECISION ANALYSIS IN SOUTH-EAST QUEENSLAND, AUSTRALIA*

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## ABSTRACT

*Australian water systems face a host of threats under climatic change derived from the predicted increase in extreme events. This has been exemplified in the South-East Queensland region, where drought and high volume precipitation events have led to negative social and economic impacts over the last decade. These events, and how they were initially responded to, can provide information and enhance knowledge on how to improve climate change adaptation in the future. This research employs a multiple criteria decision analysis, the analytical hierarchy process technique, to analyse the opinion of decision makers in South-East Queensland on how best to adapt stormwater systems to climate change. These infrastructures are one of the most at risk and potentially costly components of water systems under a changing climate, while these stakeholders have experienced firsthand the types of extreme events that are expected to increase in frequency. The technique has been effective in identifying clear preferences for climate change adaptation among stakeholders in three municipal bodies, elicited from a range of departments. Changes to land use control and design standards were the primarily preferred actions, suggesting an underlying belief that fundamental change is required to combat to climatic change.*

**Keywords:** Climatic Change, Adaptation, Stormwater, Multiple Criteria Decision Analysis,

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## 1. INTRODUCTION

Australia is expected to experience a significant increase in extreme weather events under a changing climate (Meehl *et al*. [1]. Choy *et al*. [2]). These anticipated changes pose adaptation challenges for Australian water systems and how they are managed. Given that it is the world's driest inhabited continent, and also experiences the highest rainfall variability of any continental region (Pink [3]), the nation is at large risk from decreased precipitation volumes and reliability. At the other end of the spectrum, the country also faces risks from extreme precipitation events. High runoff coefficients place strain on stormwater systems, affecting most of the population, with over two-thirds of citizens living in major cities and an 85% urbanisation rate (Pink [3]).

The many extreme weather conditions experienced in Australia during the last 10 years typify those that are expected to increase in frequency due to climate change. The South-East Queensland (SEQ) region has borne a particular brunt of these events, both from drought and severe rainfall. During the Millennium Drought, which ran from 2002-2009, SEQ's surface water supply grid was severely depleted, falling as low as 14% capacity in 2007 (SEQ Water [4]). This gave a clear mandate for governments to implement adaptive measures. State-wide it was legislated that all newly constructed homes install internally plumbed rainwater tank systems, to reduce mains water consumption. This was despite their being little information available to create effective policy. Research has since shown that many of these systems have at best been marginally viable, due to a number of avoidable issues (Stewart [5] and Siems et al. [6]). A desalination plant was also commissioned in SEQ, but has been publicly lamented over its high cost and low utilisation. Water recycling schemes were implemented on smaller scales, but have generally been found to be inefficient and costly (Stewart [7]). This wide range of measures represents a lack of clear direction amongst decision makers at the time on how to adapt water systems for extreme conditions. Even combined, what was done in terms of long term preventative solutions was of relatively small scale, with water restrictions by far the most effective method in maintaining water security. These restrictions are financially and socially undesirable, and are not a viable long term option (Sahin et al.[8]). The need to adapt water systems to cope with this type of climatic events is still present, with 95% of Australia's water supply derived from surface water (Pink [9]). Future climate change accentuates this need. The measures implemented to combat the Millenium Drought can provide insight into how adaptation may occur more effectively in the future.

The next major extreme event to affect SEQ water systems was the 2010-2011 Queensland floods. This affected 2.5 million people, resulted in damages of an estimated $AUD 5 billion value and reduced Australia's GDP by approximately $AUD 30 billion. Stormwater infrastructure was simply unable to cope, flooding more than 29,000 homes (Queensland Floods Commission of Inquiry [10]). Similar damages were again experienced in the 2013 Queensland floods, though most was incurred outside of SEQ. This recent history of adversity raises the question: what is the attitude of decision makers towards future climate change adaption, given they have experienced these extreme events first hand?

In this context this paper focuses on decision maker (DM) opinions in regard to adaption of stormwater infrastructure for climatic change effects in SEQ. These infrastructure systems are regarded as one of the most at risk and potentially costly under a changing climate (Taylor [11]). Currently, local governments base their long life infrastructure (i.e. roads and stormwater) on design standards founded on previous climatic conditions. This suggests that for the goal of reducing future risk (environmental, social, financial etc.), local governments need to prepare new or modified adaptation strategies (Apan et al. [12]). This need is further heightened as SEQ considered one of the six 'vulnerability hotspots' in Australia due to its growing population and proximity to the coast (Hennessy et al. [13]), as exhibited during the recent flooding events.

The selection and implementation of the most effective adaptation solutions to reduce climate change vulnerability is a complex problem. Ideally, in order to make efficient use of finite resources, this process will synthesise input from a range of stakeholders. As explained in ARMCANZ and ANZECC [14], major difficulty arises due to lack of an appropriate sole criterion for the governance of all stormwater systems. Thus, in order to elicit and analyse the opinions of multiple stakeholders in a situation with multiple objectives, multiple criteria decision analaysis (MCDA) tools have been employed, specifically the analytical hierarchy process (AHP) technique. This necessitated the creation of a decision making framework, based on a review of current adaptive options. Three separate DM groups from SEQ were engaged to convey their beliefs and opinions within this framework, to form a three part case study. These groups were the Gold Coast City Council (GCCC), Sunshine Coast Regional Council (SCRC), and Moreton Bay Regional Council (MBRC).

## CASE STUDY

SEQ contains approximately 65% of the State of Queensland's population, in just a fifth of the state's total land area. The region has experienced population growth above the national average over the past decade, which is expected to continue into the 21st century (Pink [3]). Due to this rapid population growth and urbanisation, SEQ has seen a substantial increase in the amount of hard surfaces (ACG & AGO [15]). This, coupled with the runoff problems resultant from heavy precipitation after dry periods, poses a significant issue. The current 3 million population is expected to rise to as much as 4.1 million by 2026 . As such, the exposure of SEQ's stormwater systems to climate change is likely to continue increasing.

This case study has been facilitated under the $AUD 13 million South East Queensland Climate Adaptation Research Initiative (SEQCARI). Stakeholders were engaged through workshops held by SEQCARI, which also allowed stakeholder opinion to be integrated into the development of the decision making framework. A large number of stakeholders contributing to stormwater decision making in SEQ were identified, but including the opinions of so many would be unfeasible. This study primarily engaged end-use professionals that prepare stormwater management plans within three local governments, namely; Gold Coast City Council (GCCC), Sunshine Coast Regional Council (SCRC), and Moreton Bay Regional Council (MBRC). In order to attain a fair representation of opinion within these groups, DMs from three departments were targeted within each of these councils (Engineering Services, Planning and Environment, and Finance).

To facilitate the gather opinion from these DMs on such a complex problem into an analysable out, the MCDA AHP technique was utilised. The underlying concept of the AHP technique is to convert subjective assessments of relative importance to a set of overall scores or weights (Saaty [16]). The AHP, based on three principles as defined by Saaty, is an Eigen value approach to the pair-wise comparison (Schmoldt [17]). Space constraints prevent a full discussion and justification and operation of this technique, however readers are referred to (Sahin et al. [17]) for further reading. AHP employs a unique hierarchy structure to represent a problem in terms of a goal, criteria and alternatives, which was developed for the stormwater adaptation issue in SEQ as shown in Figure 1.

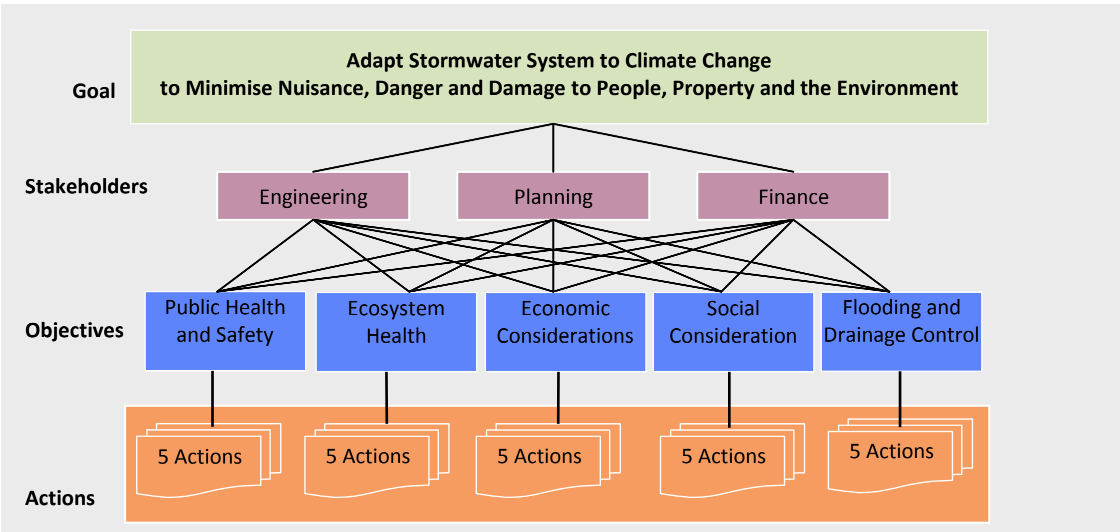



**Fig. 1: AHP structure for adapting stormwater systems to climate change utilised in case study**

The adaptation alternatives (actions) proposed for the AHP analyses were:

1) Increase public awareness and participation
2) Monitor changing climate conditions and use of technology
3) Change operational and maintenance practices:
4) Change stormwater infrastructure design standards
5) Modify Planning and land use control standards

In practical terms, DMs from the three councils were engaged to complete a questionnaire. Participants were required to indicate which of two options were more important, or more influential than another, with respect to the goal, at each level of the hierarchy. For example, at the action level: "Which action has more impact on Public Health and Safety", A) *Increase public awareness and participation*, or B) *Modify Planning and Land Use Control Standards*. Subsequent numerical analysis of these questionnaires under AHP illuminates preferences for stormwater adaptive actions, and more broadly attitude to climate change adaptation.

## 1. RESULTS AND DISCUSSIONS

The first stage of result analysis was to check the consistency of the judgements and opinions conveyed by the DMs. Under AHP this is evaluated through the consistency ratio (CR). Whilst the AHP does not require total consistency (defined as holding an unchanging opinion over the duration of an activity) to determine preferences, there is a threshold of <10% in general, and for environmental problems with high variability up to 20% is acceptable (Saaty and Kearns [18] and Saaty et al. [19]). This consistency of each of the regional councils is shown in Figure 2.

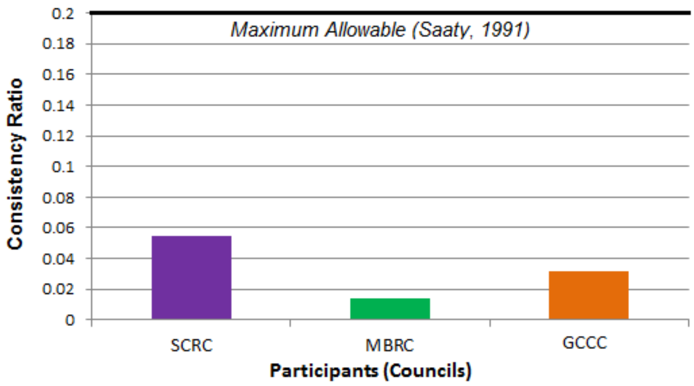
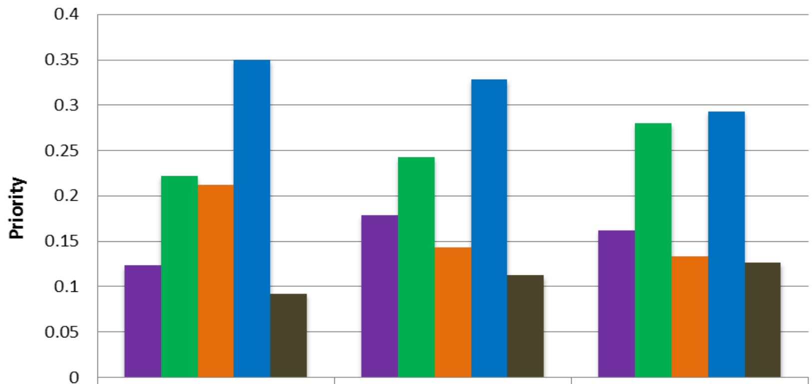



**Fig.2: Consistency ratio with respect to all levels of hierarchy using the DM pairwise comparison**

The survey results showed a CR for SCRC of 5.4%, MBRC of 1.4%, and for GCCC of 3.2%; well within the acceptable level. Aside from clerical error lack of information or understanding of the options being compared is typically the largest course of inconsistency. This was addressed through the SEQCARI workshops and a detailed explanation of the hierarchy composition within the distributed questionnaire, which appears to have functioned effectively. The combined CR of all participants did not exceed 1.9% across all elements of the hierarchy.

Figure 3 graphically presents priorities in terms of the vector values obtained through the AHP, with respect to each DM group and the 5 adaptive actions. The greater the value shown, the greater the priority as compared to the elements on the same level of the hierarchy.




| | SCRC | MBRC | GCCC |
|---|---|---|---|
| Alternative 1 | 0.123 | 0.178 | 0.162 |
| Alternative 2 | 0.222 | 0.242 | 0.280 |
| Alternative 3 | 0.212 | 0.143 | 0.133 |
| Alternative 4 | 0.35 | 0.328 | 0.293 |
| Alternative 5 | 0.092 | 0.112 | 0.126 |

Regional Councils & Adpation Actions

**Fig.3: Priority of adaptation criteria according to judgements from each DM group.**

Using the judgement of all three regional councils, and combined stakeholder judgments, it was found that the most preferred adaptation alternative by a significant margin was *Modify planning and land use control standards*. The second most preferred alternative, again reflected by all individual groups and combined judgement, was *Change stormwater infrastructure design standards*. This suggests a strong consensus that fundamental change is required, rather than 'soft action' measures represented by the other alternatives. It is highly likely that the infrastructure damage from the 2010-2011 SEQ floods, with many dwellings built too close to natural flow paths, has influenced the strength of this opinion. The 2013 floods (after the survey was conducted) would predictably have further strengthened this position. Currently these risk-based type approaches to adaption have been greatly planned and postulated (Hennessy et al. [20]), such as in AGO [1], but there are few cases where they have been actually applied.

The least preferred alternative was *Monitor changing climate conditions and use of technology*, which again was the same across all three stakeholder groups. This result seems unexpected, due to the considerable amount of uncertainty when it comes to regional-scale climate projections. This suggests that these DMs are confident the climate in SEQ will change in a way that negatively affects stormwater systems.

Opinion was remarkably similar between each of the three regional council groups, which again points towards a common understanding on what needs to be done in terms of climate adaptation. Interestingly, when asked "Which department has more impact on decision making for adapting stormwater systems to climate change?", for the top level of the hierarchy (Figure 1), no DM assigned themselves as having the most impact. This indicates that DMs from each department, regardless of which council, believes themselves to have less input that they actually do. It is possible that this stems from a frustration or belief regarding their lack of ability to affect climate change adaptation.

## 2. CONCLUSIONS

In summary, the MCDA AHP model has been effective in identifying the opinions of individual stakeholders, and synthesising these into combined judgments, revealing preferences for climate change adaption that may not have otherwise been apparent. The results indicate that local government professionals in a range of departments believe fundamental change to planning, land use and design standards is required to mitigate the risks of climate change for stormwater systems in SEQ. The opinion of these stakeholders should be viewed in sight of the fact they have experienced numerous extreme events first hand in their regions. These DM opinions, combined with the large financial burden created from recent extreme events in SEQ, should form ample justification for substantial adaption of Australia’s water systems for climate change.

## 3. ABBREVIATIONS

AHP Analytical hierarchy process
DM Decision maker
MCDA Multiple criteria decision analysis
SEQ South-East Queensland

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