Decision Making Under Uncertainty: Ranking of Multiple Stressors on Central Arizona Water Resources

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Abstract

We apply a multiple stressor analysis as support for decision making under uncertainty associated with water management policy in the Central Arizona region of the southwestern United States. More specifically, we assess the significance of a variety of stressors in relation with the vulnerability of water supply systems and rank them through a weight-of-evidence approach in the Phoenix Active Management Area (AMA). The stressors on Phoenix AMA water resources are broadly placed in three categories: municipal (outdoor and indoor residential water use), agricultural, and biophysical (urban heat island and climate change). Our analysis shows that water for outdoor residential irrigation is the biggest stressor. Ranked second is the reduction in supply due to loss of water caused by rise in temperature and simultaneous decrease in precipitation due to global warming in the Colorado and Salt/Verde River basin. This is closely followed by inefficient irrigation practices in agriculture. Indoor water use is ranked fourth among the stressors. Higher residential water demand due to increased night time temperature in the urban area is a distant fifth. The analysis and ranking of multiple stressors in the water resources of Phoenix AMA reveal that unlike biophysical stressor which has strong elements of uncertainty, the two biggest stressors which are outdoor water use and inefficient irrigation practices in agriculture are comparably achievable goals that decision makers can address with reasonable certainty.

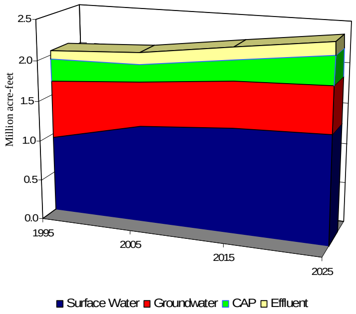
Phoenix Water Supply/ Demand

Estimated water demand based on current use scenario by sector, Phoenix AMA, 1995-2025

Sector	Demand Characteristics	1995	2025
Municipal	- Residential, commercial and institutional uses - Irrigation for parks, & others	869,962	1,395,725
Agriculture	- Indian and Non-Indian demand for growing crops	1,333,885	1,360,743
Industrial	- Industrial, commercial and institutional uses	83,088	137,628
Riparian	- Riparian areas	48,000	48,000
Total water demand		**2,334,935**	**2,942,096**
Population		**2,549,931**	**6,256,500**

Source: TMP-ADWR, 1999 (water demand) and MAG, 2003 (population projection prepared for Central Arizona Project)

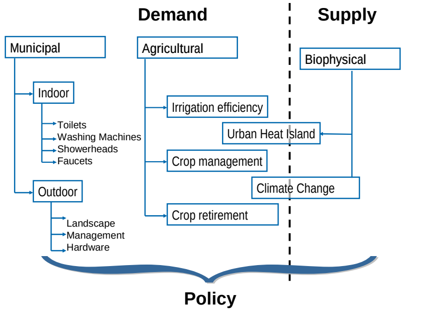
Projected supply by source, 1995-2025 (based on current sources of supplies)



Introduction

Water resource management in the southwestern United States has become increasingly complex as pressures on existing supply continue to mount. Nowhere is the complexity of water management more crucial than in the desert landscapes of central Arizona where limited water supply restricts the structural solutions to its management. The capacity of the region to successfully meet these interrelated challenges while managing its water resources in a sustainable manner will depend, in large part, on relevant knowledge gained through scientific research. Based on extensive literature review and the analysis of secondary data we investigates the effects of multiple factors that stress water resources at present, and, using available data, attempts to extend this analysis to 2025. More specifically, the objectives of this research is to a) identify and provide the scientific basis for study of multiple stressors on the water resources of Phoenix AMA; b) assess the significance of each stressor in its relation with the vulnerability of water systems; and c) generate a ranking of the stressors through a weight-of-evidence approach. The broader goal is to explore the value of multiple stressor analysis as a support for decision making under uncertainty in science policy and in water management.

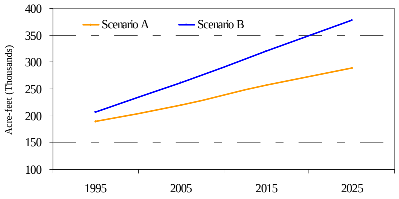
Based on the nature of water supply and the demands placed on its usage, the multiple stressors of the Phoenix AMA can be located within three categories: **a) municipal, b) agriculture, and c) biophysical**. Operating at various levels, these stressors can impact water resources in single, cumulative, or synergistic ways.



Stressor ranking

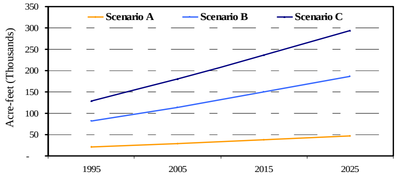
Stressors		Difference between baseline & standard cases by 2025 (af)	Ranking
Inefficiency	**Municipal**	328,180	
	Indoor water use	88,830	**4**
	Outdoor water use	239,350	**1**
	Agriculture	127,022	**3**
Biophysical Stress	**Biophysical**	241,551	
	Additional demand due to UHI	25,357	**5**
	Reduction of surface water due to climate change	216,194	**2**

Municipal: Indoor



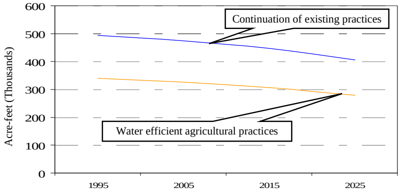
The graph illustrates magnitude of inefficiency of indoor water use scenarios over 30 years. Scenario A assumes an incremental (logistic) adoption of water efficient appliances while scenario B assumes that some fraction of population will never change their appliances and remain inefficient. Following Scenario A, by 2025, indoor water use will be about 23% less than that of Scenario B.

Municipal: Outdoor



The graph illustrates the magnitude of difference of outdoor water use based on three separate scenarios of landscape irrigation. Scenario A assumes that by 2025 all housing units will adopt xeriscapic landscapes; Scenario B assumes a partial conversion, and Scenario C assumes a continuation of turf dominated landscape. In Scenario A the residents save as much as 76% of outdoor water, whereas those from Scenarios B and C save only 45% and 13% respectively.

Agriculture



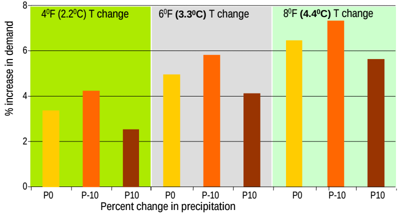
The graph illustrates the magnitude of difference in reduction of agricultural water use between prevailing practice and a combination of water efficient agricultural practice. The latter include i) *irrigation efficiency improvement*, ii) *water efficient agronomic practices*, and iii) *crop adjustment and or retirement*. By implementing efficient agricultural practices 198,818 af of water per year could be saved.

Biophysical (Supply)

Temperature Change (^{0}C)	Negative change in precipitation		Positive change in precipitation	
	% Change in Precipitation	% Change in River Flow	% Change in Precipitation	% Change in River Flow
+1	-1 to -10	-10 to -15	0 to 5	0.0 to 0.7
+2	-6 to -10	-17 to -56	6 to 10	0.6 to -23
+4	-10 to -20	-31 to -41	10 to 20	2 to -9.7

Studies have examined the possible impacts of climate change on the Colorado River Basin and its subbasins using both empirical and General Circulation Models (GCMs). While there is a large degree of uncertainty associated with these models, it is predicted that a decrease of 15% in the flow of Colorado and Salt/Verde Rivers may occur due to the effects of climate change. By 2025 the surface water flow may be reduce between 187,368 and 245,020 af, with average being 216,194 af.

Biophysical (Demand)



Significantly higher temperatures extending longer into the evening due to urban heat island effect UHI) may increase residential water consumption. After accounting for other factors that lead to increased water use, a typical single family home that is affected by UHI effect consumes an additional 1,532 gallons of water a month (in summer) than those who are not directly affected by UHI.

Conclusion

While alteration of hydrological cycle due to the effects of global warming could pose serious stress in the supply of water resources, over and beyond that, there are significant other sources of uncertainty that are demand related and can have more direct impacts on the water resources. An important revelation of this paper, is that reduction in individual and system-wide water demand not only decreases stress on water resources but avoids unnecessary cost on water supply infrastructure and extends the ability of existing supplies to meet current and growing demands. For decision makers such findings greatly reduces uncertainty relating to water supply and demands, and increases opportunities for viable outcomes of implementation. While the question of what approaches and sectors are adoptable from a political and policy perspectives would be the subject of a different study, the ranking suggests that water use in outdoor irrigation and agricultural practices can be reduced substantially. Even literature review on climate change indicates that the loss of water is in the range of half of the available savings that could be achieved on the demand side indicating that adaptation to the impact of such bio physical change for Phoenix AMA is manageable.

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