ARTICLE IN PRESS

Water Resources and Economics xxx (2017) 1–11

Contents lists available at ScienceDirect

Water Resources and Economics

journal homepage: www.elsevier.com/locate/wre

Does the construction of a desalination plant necessarily imply that water tariffs will increase? A system dynamics analysis

D.J. Crookes

Asset Research, PO Box 144, Derdepark, Pretoria, 0035, South Africa

ARTICLE INFO

Keywords:
Desalination
Invasive alien plants
Dams
Predator-prey
System dynamics

ABSTRACT

The City of Cape Town (the City) is experiencing a water crisis. However, although a major desalination plant has been on the table for a number of years, this continues to be regarded as a 'long term option' due to the apparent high costs associated with this technology. We therefore develop a predator-prey system dynamics model to assess the feasibility of a major desalination plant compared with the baseline scenarios of business as usual: (clearing of invasive alien plants in the Berg and Breede water management areas and renovating and constructing dams). Cost include both capital costs, as well as operational costs. We find that increasing block tariffs (IBTs) do not always benefit the poor, since these are not always the lowest water users in volumetric terms. A major outcome is that, in contrast to expectations, a desalination plant may actually reduce tariffs across the full spectrum of water users. A desalination plant also has the potential to increase access to water by the poorest communities. The finding has implications for other developing countries considering a major water infrastructure investment where there are large disparities in income between wealthy and indigent consumers.

1. Introduction

The City of Cape Town (hereafter used interchangeably with 'the City') is currently facing a water crisis resulting from low rainfall over the ensuing winter rainfall period (June–August). Dams, the primary source of water for the City, are currently at 27%, down from 47% this time last year [1]. This means that, should current consumption and rainfall continue, the City will have no water left in the next 9–12 months [2,3]. For over 100 years, the City of Cape Town (the City) has built dams to meet its water supply needs. A recent study indicates that 98% of all the City of Cape Town's water supply comes from dams [4]. However, a number of challenges exist in continuing with this strategy. Firstly, there are constraints on the availability of suitable locations to build dams in areas that are not ecologically sensitive. Secondly, dams are reliant on rainfall, and if rainfall is low then it affects the entire water supply system. This is the case at present, where low rainfall has placed significant pressure on the availability of water in the City of Cape Town.

The City of Cape Town has been aware of the challenges of supplying water to its population for a number of years. In 1989 the then Department of Water Affairs and Forestry (DWAF), in conjunction with the Cape Town City Council, embarked on the Western Cape System Analysis (WCSA) to evaluate water supply options. The process was concluded in 1995 [5]. A range of options were identified, including the clearing of invasive alien plants, the construction of a desalination plant, and the building of a new dam on the Berg River. Ultimately, it was decided that the additional dam was the most cost effective option. Work on the dam was competed in 2009, at an estimated cost of R1.5 billion rand [6]. However, this has not solved the water crisis in the City.

In order to address the water crisis, the City of Cape Town is considering a number of other water augmentation options. These

E-mail address: dcrookes@outlook.com.

https://doi.org/10.1016/j.wre.2017.11.002
Received 10 August 2017; Received in revised form 13 November 2017; Accepted 13 November 2017
Available online xxxx

Please cite this article in press as: D.J. Crookes, Does the construction of a desalination plant necessarily imply that water tariffs will increase? A system dynamics analysis, Water Resources and Economics (2017), https://doi.org/10.1016/j.wre.2017.11.002

include: 1] encouraging rainwater capture systems potentially combined with grey water at household/estate level; 2] water recycling both as potable water and non-potable water; 3] groundwater from the Table Mountain Group [TMG] aquifer; 4] The City of Cape Town has also for a long time employed water demand management as a strategy for resolving water supply issues; 5] The Berg River to Voëlvlei Dam Augmentation Scheme [7]; and 7] clearing of invasions to secure water from the current supply systems which are all invaded to some degree and will get worse. This is not an exhaustive list but indicates the range of options that are being considered. More recently, the City has tabled an emergency water supply plan to meet the shortfall that includes temporary desalination barges, and reclaiming sewage water. All these options provide, at best, partial and temporary solutions to the problem. However, they are all believed to offer lower cost alternatives to a desalination plant.

Desalination is a process that has gained much traction globally. There are two commercially important technologies [8]: Multistage flash (MSF) and the more economical Reverse Osmosis (RO) distillation. Most of the larger (>5 Ml/d) plants utilise the MSF technology [8]. A recent feasibility study for a 450 Ml/d desalination plant for the City was completed but was shelved due to the high costs and electricity concerns [9]. The feasibility study estimated that it would cost between R14-20 billion rand to construct the desalination plant. However, an equivalent plant using the RO technology could cost between R6-7 billion [10], significantly less than the original feasibility study. It is possible to supply this as a single plant. The technology is continuously evolving with the largest RO plant having a capacity of 326 Ml/d [8]. However, there are also proposals to construct multiple smaller modular desalination plants which could supply 100 Ml/d within 4 months to the City [10]. Another limitation of desalination plants is the purported high operating costs. This is largely due to electricity costs, which comprised 50% of the operating costs in the original feasibility study for the City of Cape Town [9]. New units utilise significantly less electricity, saving on these operating costs. Taken together, these technologies have the potential to result in significant cost savings which were not taken into consideration in the original feasibility study for the City of Cape Town. In addition, a traditional cost benefit analysis cannot effectively model cost recovery through the increasing block tariff (IBT) system. A system dynamic model is needed that can update prices "on the fly" where water supply is evolving over time in a complex system.

Here we assess whether or not desalination is a cost effective option for the City by taking into consideration recent technological advances, as well as cost recovery through employing the economically efficient and equitable IBT rates. We compare this with the current [baseline] approach of building and renovating dams, as well as clearing invasive alien plants. In the next section, we consider the model used for the financial assessment, followed by a theoretical discussion of the options considered. Then, the results are presented, and we conclude with a discussion of the implications of our findings.

2. Material and methods

The model used for the financial analysis is a predator-prey model developed using the system dynamics modelling framework. The use of system dynamics modelling to model predator-prey dynamics was formally proposed by Swart [11] although its use preceded this. The model is widely used and the literature is quite ubiquitous (e.g. Refs. [2,3,12–14]. Although historically the predator and prey were defined from mobile animal species, increasingly the model is applied in other areas as well. Crookes and Blignaut [15] model the steel industry, where vehicle manufacturing is the predator and the steel industry is the prey. Ibáñez et al. [16] develop a model for a competitively exploited aquifer, where groundwater is the prey and the irrigated hectares are the predators. Dendrinos and Mullally [17] develop an urban dynamics model, defining the urban population as the predator, and per-capita income as the prey. For a similar urban dynamics application, Orishimo [18] define population as the prey, and land price as the predator. These studies indicate that actual predatory behaviour is not a requirement for model development, nor is it important which parameter is specified as predator and which is prey. The model is largely associated with neoclassical economics theory [19], which is rare for system dynamics modelling applications [20,21].

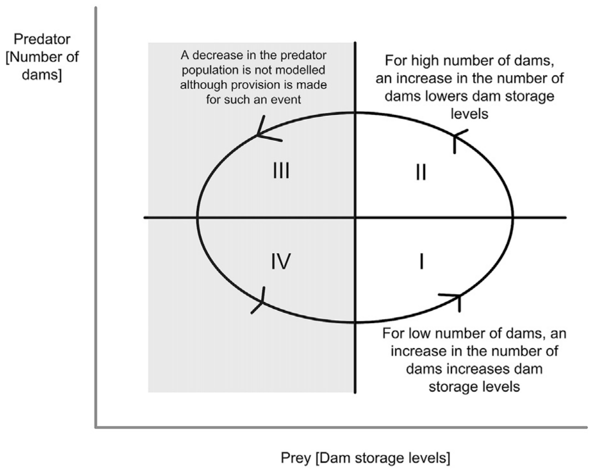

Fig. 1. Dynamics of predator-prey interactions in the model.