ARE WATER SECTOR PROFESSIONALS WORRIED ABOUT CLIMATE CHANGE? EXAMINING RISK PERCEPTIONS OF WATER SECTOR PROFESSIONALS THROUGH A SYSTEMATIC LITERATURE REVIEW AND SURVEY

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ABSTRACT

Katherine G. Connolly: Are water sector professionals worried about climate change? Examining the risk perceptions of water sector professionals through a systematic literature review and survey.
(Under the direction of Jamie Bartram)

For water and wastewater utilities to adapt to climate change, water sector professionals must perceive risk from the associated impacts. In order to better understand water sector professionals' risk perceptions, a systematic literature review was conducted, which revealed that risk perceptions toward climate change have increased over time and are linked to behavior and decision-making in the water sector. No identified papers in the peer-reviewed literature have studied professionals from sub-Saharan Africa, therefore, a survey was implemented to examine the perceptions of professionals in this region. We surveyed 90 participants at the African Water Association's Congress in Nairobi, Kenya, and found that water sector professionals are concerned about climate change impacts on utilities, but are also worried about non-climate risks facing utilities. These findings highlight the multiple, competing risks utilities face and the need for adaptation strategies that simultaneously address climate and non-climate concerns of utilities.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1: INTRODUCTION

Climate change will very likely affect water quality and availability worldwide (Cisneros Jimenez et al., 2014). The impacts of climate change on water resources will be more severe in the regions that already face water scarcity and other climate-related challenges (Cisneros Jimenez et al., 2014; Niang et al., 2014). Sub-Saharan Africa is one such region (Niang et al., 2014). Given the projected impacts of climate change in sub-Saharan Africa, as well as existing non-climate issues facing water and wastewater management in the region (rapidly growing demand, insufficient revenues etc.), it is vital for water sector professionals to be planning for future variability and working to minimize the negative effects of climate change on their systems through adaptation[1] strategies. But, for utility professionals to be adequately adapting to current and predicted climate changes, they must first be aware of and perceive risk from its impacts (Arnell & Delaney, 2006; Brettle, Berry, Paterson & Yasvinski, 2015; Moser & Luers, 2009).

However, the literature on utility and water sector professionals' perceptions toward climate change relatively is sparse. Furthermore, no studies have been identified that assess the perceptions of professionals in sub-Saharan Africa. Therefore, a systematic literature review was conducted to assess the state of knowledge on water sector professionals' perceptions, globally, and a survey was implemented in sub-Saharan Africa to examine the perceptions of water sector

[1] Within the context of climate change, *mitigation* actions are those that seek to minimize emissions of greenhouse gases (e.g., through use of alternative energy sources). *Adaptation* actions are those taken to help adjust the to the current or expected impacts of climate change in order to minimize the consequences/damage (e.g., installing flood barriers to protect against future flood events).

professionals in this region. This report presents the results of the systematic literature review and survey in order to answer the following research questions:

1. How do water sector professionals perceive of climate change risks facing water/wastewater management and utilities?
2. How does risk from climate change compare to other risks facing water/wastewater management and utilities?

This section provides a brief overview of projected climate change impacts in sub-Saharan Africa and an introduction to the field of risk perception research to contextualize the findings of the systematic literature review and survey, which will be presented in the following sections.

Climate change and water resources in sub-Saharan Africa

With respect to climate change, water and wastewater utilities face a number of potential water-related hazards, including: droughts, flooding, and water quality concerns (Danilenko, Dickson, and Jacobsen 2010). While it is difficult to project how the impacts of these different climate/weather events will vary across sub-Saharan Africa over the 21st century, global climate models and historical data provide a general picture of past and predicted future change. Data show that most of southern Africa experienced warming over the past century and this trend is expected to continue into the future (Niang et al., 2014; Serdeczny et al., 2016). Rising temperatures may impact water availability for water utilities, as water demand and evapotranspiration rates typically increase with temperature. Warmer temperatures can also create water quality concerns, thereby making water treatment more difficult and expensive (Danilenko et al., 2010).

Estimates show that southern Africa is “very likely” to see an overall decrease in precipitation over the next century, which may bring more frequent and severe drought (Niang et al., 2014, p. 1210; Serdeczny et al. 2016). If global average temperatures increase by 4° Celsius, this could lead to a 30% decrease in precipitation in southern Africa and significant reductions in groundwater recharge (50-75%) in the south and west of sub-Saharan Africa (World Bank, 2013). Decreases in precipitation and more frequent drought would make it more difficult for water utilities to provide an adequate supply of water to rapidly expanding populations. Furthermore, reduced flows make water and wastewater more difficult to treat given a higher concentration of pollutants and nutrients (Miller & Yates, 2006).

In contrast, eastern Africa may experience an increase in precipitation (Niang et al., 2014; Serdeczny et al. 2016). And precipitation is expected to occur increasingly in concentrated extreme precipitation events, which may lead to flooding (World Bank, 2013). Floods can cause a number of problems for utilities, including: infrastructure damage, power outages, increased water turbidity, and overflow or backflow of sewage (Loftus, 2011; EPA, 2015). Wastewater treatment works are particularly vulnerable to flooding because they are often built at low points to decrease pumping costs. In coastal areas, flooding may be exacerbated by sea level rise, which can lead to more powerful storm surges and greater infrastructure damage for utilities (Serdeczny et al., 2016). Additionally, sea level rise can create water quality challenges for water utilities from saltwater intrusion into aquifers (EPA, 2015).

Overall, climate models point to an increase in variability of temperature, precipitation and extreme weather events for sub-Saharan Africa (Niang et al., 2014). Consequently, this could mean that the same region experiences more consecutive dry days and an increase in annual average rainfall. This variability is likely to be compounded by El Niño and La Niña cycles,

which have been linked to precipitation changes throughout Africa (Niang et al., 2014). The predicted increase in variability of precipitation caused by climate change will make long-term planning for water and wastewater utilities in sub-Saharan Africa all the more difficult. Furthermore, many utilities in the region already face non-climate related issues, from rapidly growing water demand, insufficient revenues to cover operations and maintenance for the utility, and non-revenue water (water that is supplied by the utility, but it not paid for by a customer), all of which may be exacerbated by climate change. Given the broad range of challenges utilities face, it is important to know how individuals making decisions with respect to water and wastewater management perceive of these various risks because these perceptions will influence how they are managed.

Risk Perceptions Research

The term risk carries many different connotations. However, for this paper, risk refers to "the probability that exposure to a hazard will lead to negative consequences" (Ropeik & Gray, 2002, p. 4). Risk perception is how an individual perceives and judges a risk, which makes it an inherently subjective and personal construct (Slovic & Weber, 2002).

Over the past 20 years, there have been an increasing number of studies focused on climate change risk perception. This is likely due to the fact that perceiving risk is considered an important antecedent to adaptive behavior change (Brettle et al., 2015; Moser & Luers, 2009). For example, Kettle and Dow (2014) found that higher risk perceptions toward climate change impacts were linked to greater support for adaptation strategies among coastal managers in the United States. O'Connor, Board and Fisher (1999a), and Semenza et al. (2008) showed that climate change risk perceptions are associated with climate change mitigation/voting behavioral intentions and behavior change, respectively, in the U.S.

In terms of the factors that may contribute to perceived risk toward climate change, there are a number of internal and external influences, both at the individual and societal scale, which may play a role. For instance, demographic characteristics such as gender, age, and education may all impact risk perception (O'Connor et al., 1999a; van der Linden 2015). Geographic location, or other factors related to where an individual lives (cultural, socioeconomic, etc.), can influence risk perceptions as well.

Research conducted in the U.S. has found that individuals often recognize climate change as a threat and are concerned about the risks it poses, but assign it relatively low priority in relation to other concerns (Leiserowitz, 2006). With respect to utilities, water sector professionals may exhibit concern regarding climate risks, but these risks could be less concerning compared to the broader portfolio of risks that a utility must address. This may especially be the case given that climate change is often perceived as a psychologically distant risk. Psychological distance refers to "the subjective experience that something is close or far away from the self, here, and now" (Trope & Liberman, 2010, p. 440). Previous research has found that climate change is often perceived as a risk that is far off in time (e.g., impacts being more concerning for future generations) and/or location, with impacts perceived as being more severe for people in other countries, especially developing countries (Leiserowitz, 2006; McDonald, Yi, & Newell, 2015). Perceiving climate change to be a temporally and/or spatially close risk has been linked to having higher risk perceptions (Spence et al., 2012).

Another relevant factor linked to risk perception is the controllability of the risk, which refers to an individual's perception of the extent to which they have control over a risk (Slovic, 1987). Higher perceived control over a risk is associated with lower risk perception. In the context of perceptions of risks that face utilities, those who work for utilities may believe they have

greater control over the impacts of climate change on the utility, compared to others in the water sector, which could contribute to lower perceived risk in utilities workers. Additionally, individuals who work for utilities may have different professional and educational backgrounds than others in the water sector (e.g., a greater proportion of engineers). Each professional field comes with its own perspective, which likely influences risk perceptions, and the water sector employs professionals from many different fields (Dobbie & Brown, 2014).

While this section does not contain an exhaustive list of factors previously found to be related to climate change risk perceptions, those outlined here are deemed to be the most relevant to water sector professionals in sub-Saharan Africa. The next section will present the results of the systematic literature review.

SECTION 2: SYSTEMATIC LITERATURE REVIEW

Systematic Literature Review Research Questions

A systematic literature review was conducted to answer the following questions:

- What factors influence climate/weather related risk perceptions of water sector professionals?
- How do water sector professionals perceive of climate change risks facing water/wastewater management?
- What non-climate related factors do water sector professionals perceive as posing a risk to water/wastewater management?
- Is there evidence to support the influence of risk perception on behavior/decision-making amongst water sector professionals?

Systematic Literature Review Methods

Published literature was searched in March and April of 2017 using Web of Science and Academic Search Premier[2] databases. The following search string was used:

- Climate change OR global warming OR natural hazard OR climate extreme OR weather extreme AND risk perception OR perceived risk OR worry OR concern AND water utility OR wastewater utility OR water system OR wastewater system OR water manager OR water management OR wastewater manager OR wastewater management

[2] Academic Search Premier also included a search within the following databases: EconLit, Environment Complete, Family & Society Studies Worldwide, Global Health, Global Health Archive, GreenFILE, PsycARTICLES

Only articles with the abstract and full text available in English were considered. Papers were included in the review if they assessed risk perceptions (included perceived likelihood or perceived severity) or general concern regarding climate change or extreme weather events amongst water sector professionals. Only original researcher papers involving quantitative and/or qualitative data collection on the perceptions of water sector professionals were considered. 'Water sector professional' was defined to include water/wastewater utility professionals, storm water managers, or others who make decisions regarding the management of water or wastewater resources as part of their job. Farmers and other water users were not included in this category, nor was the general public. The citations of all included papers were scanned for additional references in order to capture any studies not identified through the database search. Three studies not published in academic journals are included in the review, but grey literature was not systematically searched.

For each identified paper, the following data was extracted: study location and population, method and year of data collection, purpose of study or research questions, variable or question used to assess risk perceptions/concern and relevant findings (**Appendix 2**). The relevant findings were categorized under four main themes: factors that impact risk perceptions, risk perception/concern over climate or weather events/impacts, non-climate risks facing utilities, and the influence of risk perceptions on behavior.

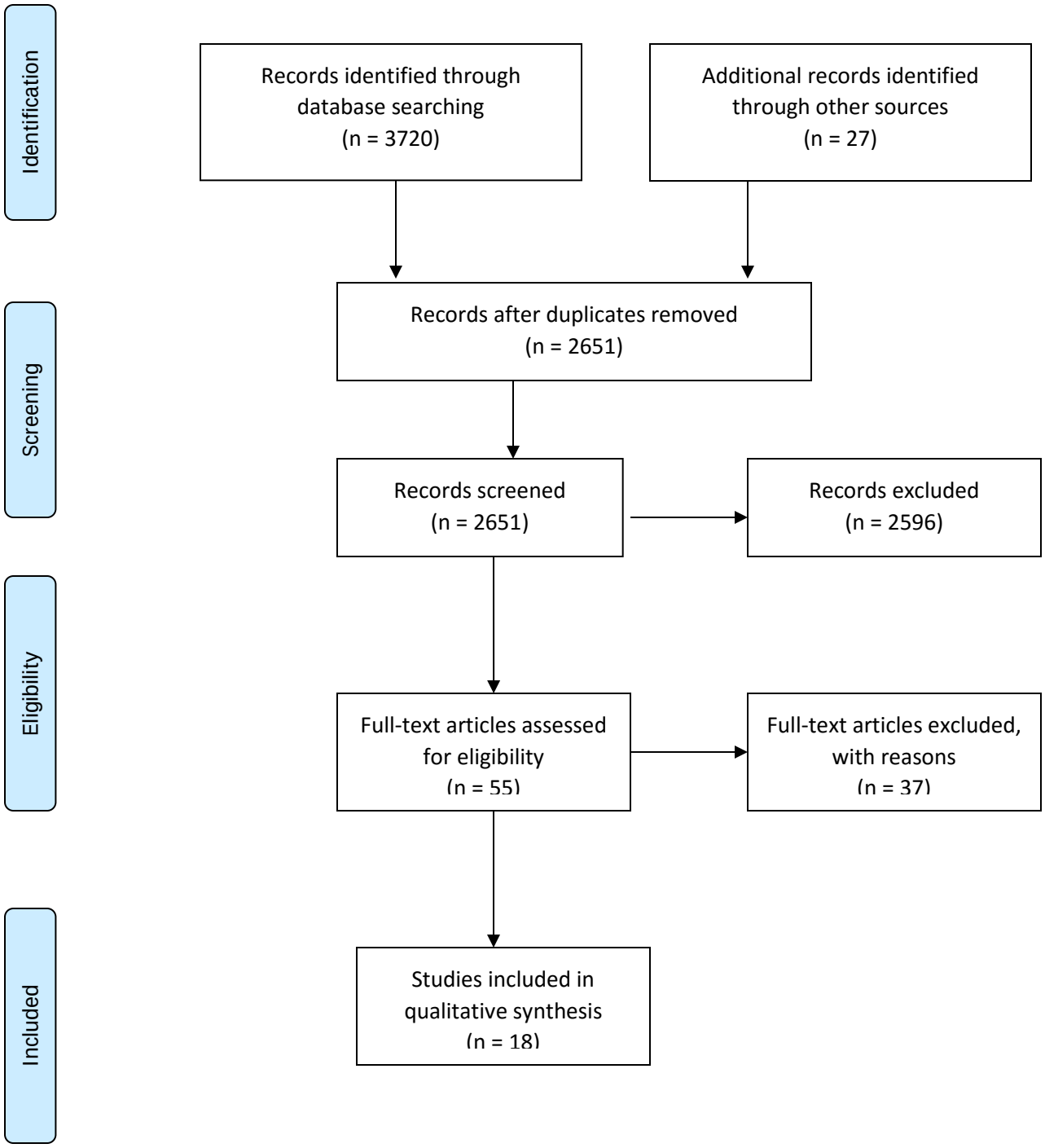

Figure 1: Literature search flow diagram. N indicates the the number of studies included at each stage in the review process.

Systematic Literature Review Results

Search Results

The search yielded 2,651 unique articles (3,747 articles total, 1,096 of which were duplicates). After screening titles and abstracts, 2,596 papers were excluded (2,354 based on title and 242 based on abstract). Fifty-five papers were reviewed in full, 18 of which were deemed relevant for inclusion (**Appendices 1 and 2**). Papers were excluded following a full text review because they did not assess risk perceptions, did not focus on water sector professionals, and/or did not collect qualitative or quantitative data (see **Appendix 1** for a list of all papers excluded after a full text review and reasons for exclusion).

Study Characteristics

Of the eighteen papers included in this review, only one (O'Connor et al., 1999) was published before 2000 and the majority (56%) was published in 2010 or later. Two-thirds (n=12) of the included studies focus exclusively on water sector professionals in the United States and only two studies (Economist Intelligence Unit, 2012; Kirchoff, Lemos, & Engle 2014) include perspectives of professionals from low- or middle- income countries. Neither of these two studies includes professionals from sub-Saharan Africa in their samples. Surveys were used to collect data in 13 of the studies and five of the studies base their analyses on information gathered from qualitative interviews. Sample sizes range from less than 30 respondents to over 650, although not all authors reported their total sample size (**Appendix 2**).

Factors influencing risk perceptions

Several of the identified studies examine factors that influence climate- and weather-related risk perceptions of water sector professionals. For instance, a number of studies found that managers of water systems that rely on surface water as a source for their drinking water supply

are more concerned about climate change and/or perceive their systems to be more vulnerable compared to groundwater systems (Bolson, Martinez, Breuer, Srivastava, & Knox, 2013; Dow, O'Connor, Yarnal, Carbone, & Jocoy 2007). Additionally, Ekstrom, Bedsworth and Fencl (2017) found that reliance on surface water amongst drinking water utilities in California was linked to taking adaptation actions, which may have been motivated by greater perceived vulnerability. Furthermore, a survey of water managers in Arizona found that managers of water systems that rely upon more than one source of water perceive themselves to be less vulnerable to drought (Carter & Morehouse, 2003).

Past (or current) problems related to climate and weather events also appear to impact perceived likelihood of events occurring in the future (Dow et al., 2007), risk perceptions (Lowrey, Ray, & Webb 2009) and adaptation actions taken (Ekstrom et al., 2017). Interestingly, Dow et al. (2007) found that size of a utility is not a significant predictor of climate/weather-related problems that utilities expect to face. However, in a survey of water and wastewater utilities in Canada, smaller utilities were more likely to claim that they have not been impacted by climate change or that they do not know if they had been impacted (Brettle et al., 2015). This unclear relationship between utility size and perceptions is contrary to the expectation that smaller utilities would perceive themselves as being more vulnerable to climate change due to having fewer resources available for adaptation (Dow et al., 2007). But, smaller utilities being less likely to know if they have already been impacted by climate change may be a reflection of lesser capacity within these smaller utilities or greater volatility within these systems, in general, making it more difficult to detect changes in averages.

A survey of storm water managers in the Baltimore-Washington Metropolitan area of the United States looked more at individual-level factors that may influence climate change

perceptions (Wernstedt & Carlet, 2014). It found that higher concern over climate change-related impacts on storm water management was associated with several factors: greater familiarity with climate change, the perception that scientists understand climate change, a greater number of years of work experience, high population growth rate and a greater proportion of impervious surfaces in the area where the individual works, and working with climate change issues as part of one's job (Wernstedt & Carlet, 2014). Belief that scientists understand climate change well and working on climate change issues as part of one's job both had a large, positive correlation with the belief that climate change will negatively affect storm water management in the respondent's jurisdiction (Wernstedt and Carlet, 2014). It seems likely that these two contributing factors are related to one's degree of knowledge about climate change. Lowrey et al. (2009) also found that exposure to scientists and climate information may increase climate-related risk perceptions, which lends further support to the importance of knowledge.

As these studies demonstrate, there are a number of different factors that may be related to climate change risk perceptions of water sector professionals. Consistent with the larger body of literature on climate change risk perceptions, perceptions of water sector professionals seem to be influenced by both internal and external factors[3]. And while exposure to climate/weather events and climate science seem to increase risk perceptions, these factors alone may not spark concern over climate change risks facing utilities.

Climate-related risk perceptions of water sector professionals

Within the identified studies, there was a large degree of heterogeneity in terms of specific variables measured with respect to risk perceptions (**Appendix 2**), which makes comparisons between studies somewhat difficult. However, there are several interesting themes that emerge

[3] Internal factors are personal, individual-level factors such as personal values or beliefs and knowledge; external factors characterize an individual's surrounding environment and may include social/political context, climate, etc.

from the 18 studies, taken as a whole. For instance, there seems to be a general trend of water sector professionals increasingly perceiving climate change as a risk to water/wastewater management over time (**Table 1**). The earliest included study found that only 22% of managers surveyed believed that climate change was real and a threat to their system, whereas the majority (50%) of respondents did not know if climate change was real (O'Connor et al., 1999b). Similarly, Subak (2000), and Carter and Morehouse (2003), found that water utility managers in England/Wales and Arizona, respectively, were not particularly concerned about climate change. In the Carter and Morehouse (2003) study, water providers in Arizona expressed concern over shorter-terms weather factors, such as electrical storms and high winds, as opposed to longer-term events like drought. However, it is not particularly surprising that these earlier studies found a general lack of climate change concern amongst water sector professionals given the state of climate change knowledge at the time the data for these studies were collected.

Looking at the studies conducted in the early 2000s (2000-2010), many of the researchers avoided asking water sector professionals directly about climate change. For instance, in Dow et al. (2007) and O'Connor, Yarnal, Dow, Jocoy and Carbone (2005), studies which use the same survey data, water system managers were asked to rank the perceived likelihood and severity of various climate/weather events disrupting utility service over the next ten years. Managers in both South Carolina and Pennsylvania perceived drought to be a severe problem and those in South Carolina were particularly concerned about hurricanes (Dow et al., 2007). However, it is not clear from the results whether the managers perceived these events as changing in frequency or severity as a result of climate change. Both Lowrey et al. (2009) and Kirchoff et al. (2013) discuss perceived risk of drought, particularly as it pertains to use of climate forecasts/information, but neither quantify perceived risk with respect to drought or climate change in general.

Table 1: Main findings on climate-related risk perceptions from included studies

Author(s)	Year(s) data collected	Main Findings on Climate-related Risk Perceptions
O'Connor et al., 1999	1998	Less than a quarter of respondents perceive climate change as real and a concern, the majority (50%) were unsure whether it is real
Subak, 2000	1998	Climate change reportedly not perceived as a significant concern for most managers
Carter & Morehouse, 2003	1999	Authors conclude there was, overall, a lack of concern about climate impacts and weather-related impacts were also seen as posing little risk
Dow et al., 2007	2000	Water sector professionals were worried about specific climate/weather events like drought and hurricanes, but the study did not assess general climate change concern
O'Connor et al., 2005	2000	Same as Dow et al., 2007 (same survey data analyzed)
Lowrey et al., 2009	2004-09	Perceived risk toward climate change impacts, specifically drought impacts, was mentioned, but not quantified in any way
Arnell & Delaney, 2006	2006 or earlier*	Climate change is seen as one of many problems facing utilities, and seemingly not the most pressing issue in the short-term
Stroup, 2011	2006-07	Climate change was perceived as long-term issue that does not pose an immediate threat
Kirchoff et al., 2013	2009 (US) 2004,10 (Brazil)	Perceived risk of drought was mentioned in the U.S. cases, but general climate change concern was not assessed
de Graaf et al., 2009	2008	Climate change was perceived as one of the top problems facing present day water management
Rajbhanary et al., 2010	2009-2010	Less than one third of respondents perceived that climate change will seriously affect water supply, many (42%) were unsure
Wernstedt & Carlet, 2014	2010-2011	The majority of respondents believe climate change will change rainfall in one's jurisdiction and that climate change will have negative impacts on the natural environment and storm water runoff
Finucane et al., 2013	2011	The vast majority of respondents believe climate change poses a threat to freshwater resources, but most think impacts will not be felt for 10 or more years
Cockerill et al., 2014	2011-2012	Drought was seen as the biggest threat to water availability in region, but not the most important factor in making water allocation decisions
Bolson et al., 2013	2012 or earlier*	The majority of respondents perceived their systems to be at least somewhat vulnerable to both seasonal climate variability and longer term variability or changes
Economist Intelligence Unit, 2012	2012 or earlier*	Climate change was third most frequently selected barrier to supplying water over next two decades out of 13 options
Brettle et al., 2015	2012	The majority of respondents indicated that they did not have information to suggest that climate change will impact various aspects of utility service, however, it was unclear what the measure was actually assessing
Ekstrom et al., 2017	2015	The majority of respondents believe that the climate is changing locally and that is poses a threat to local water quality

*Date of data collection not specified, year of publication or earlier

Amongst studies in the early 2000s that did specifically assess climate change risks, water professionals seemed either unsure about climate change or perceived it as a temporally distance threat. For instance, Rajbhanary, Borisova, Adams, Haynes, and Boyer (2010) found that 42% of water utility professionals surveyed in Florida were not sure whether long-term changes in climate or weather would significantly impact their water supply, while 28% believed it would. Additionally, based off of interviews with water utility managers in England and Wales, Arnell and Delaney (2006) concluded, "climate change is generally seen as one amongst several pressures, and not necessarily the most important in the short term" (p. 252). Similarly, water professionals across four basins in the U.S. generally perceived climate change to be a long-term problem that did not pose a serious threat in the near future (Stroup, 2011). This is not to say that these perceptions are incorrect, because in reality climate change is a long-term and gradual issue, but climate change may also have short-term implications for water resource management and this fact does not seem to be reflected in the perceptions of professionals in these studies.

A clear outlier amongst the pre-2010 studies is the survey of urban water professionals in the Netherlands (de Graaf et al., 2009). In this study, respondents were asked to select what they believed were the two most important problems facing water management in their area and climate change was one of the most frequently selected options. However, the Dutch are particularly vulnerable to climate change and have been especially innovative in addressing it, which may account for this finding.

Looking at studies in which data were collected in 2010 or later, there seems to be an uptick in professionals who perceive climate change as posing a threat to water or wastewater management. For instance, the majority of storm water managers surveyed in the Baltimore-Washington area reported they believe climate change will negatively impact rainfall and the

natural environment in their area (Wernstedt & Carlet, 2014). Additionally, the majority of water professionals in the Oahu watershed of Hawaii believed that sea level rise, droughts, saltwater intrusion into aquifers, hurricanes and storms, and water shortages were very or extremely likely to occur over the next 50 years due to climate change (Finucane et al., 2013). Furthermore, 98% of respondents in this same study believed that there would be 'dangerous' impacts on freshwater resources caused by climate change. However, only 14% reported that these impacts were happening now, whereas 84% believed that these dangerous impacts would not be felt for ten or more years (Finucane et al., 2013). While it is likely that the impacts of climate change will become more severe over time, this finding may point to climate change being perceived as temporally distant.

A survey of individuals responsible for making water resource decisions in western North Carolina revealed that drought is perceived as posing the largest threat to future water availability in the region (Cockerill, Badurek, and Hale, 2014). However, these results do not indicate whether respondents perceive drought as being related to climate change. But, the majority of water resource managers surveyed in three U.S. states perceived their systems to be at least somewhat vulnerable to both seasonal climate variability and longer-term variability or changes (Bolson et al., 2012).

Furthermore, amongst water utility executives surveyed in ten countries (the US, Canada, the UK, Spain, France, Australia, Brazil, Russia, India and China) climate change seemed to be perceived as a serious risk (Economist Intelligence Unit, 2012). For instance, respondents were asked to select the top three barriers to ensuring a sufficient supply of clean water through the year 2030 out of a list of thirteen options and reduced water supplies due to climate change was the third-most selected barrier (34% of respondents selected it in their 'top 3'), after wasteful

consumer behavior (45%) and insufficient resources for capital investment (35%). Additionally, drought was perceived as the most likely and severe risk to impact utilities and pollution and failed infrastructure were perceived as the second and third most severe risks, respectively. Floods, pollution, competition from other water suppliers, and insufficient capital to build future capacity were all tied for second most likely risks to occur (EIU, 2012).

The second most recently conducted study, by Brettle et al. (2015), seems to contradict the trend of increasing climate change risk perceptions of water sector professionals over time. However, a closer examination of the results reveals that this is not necessarily the case. In their survey, Brettle et al. (2015) asked respondents if they had "information that suggests that [water supply, water infrastructure, wastewater infrastructure, etc.] will be impacted by climate change?" (p. 139). The majority of respondents reported that they did not possess such information with respect to: water supply, drinking water treatment, source water quality, drinking water infrastructure, wastewater treatment, or wastewater treatment infrastructure. Based off of these responses, the authors conclude that climate change awareness is low and that "many water utility officials do not perceive that their utilities will be impacted in the future by climate change" (Brettle et al., 2015 p. 131). However, this conclusion may not be warranted based on the measure used in this survey. Given the phrasing of the questions assessing perceptions, it is somewhat difficult to determine whether utility respondents *believe* that they will not be impacted by climate change, which one could infer to mean that climate change is perceived as low risk, or if they simply do not have the relevant information. The latter could be a result of the utility lacking climate simulations for its region, rather than lack of perceived risk with respect to climate change.

The most recently conducted study included in this review is a survey of drinking water utility managers throughout California. The survey revealed that the majority (53%) believes climate change will impact water quality locally (Ekstrom et al., 2017). This recognition of climate change as a local threat indicates that there is concern about climate change amongst these managers; however, more respondents (65%) perceive that water quality will be impacted globally, which may mean that climate change is perceived as a more spatially distant risk.

Overall, these findings seem to show that water sector professionals perceive climate change to be more of a risk to water and/or wastewater management now, compared to managers in the late 1990s, when the earliest identified studies were conducted. Yet, there is also evidence to suggest that climate change is perceived as a psychologically distant risk that does not pose an immediate threat to utilities. A closer look at the non-climate/weather risks facing utilities may help shed further light on these perceptions.

Risk Perceptions of Non-Climate Risks

A common theme that emerged from the literature is that water and wastewater managers have to juggle a number of competing problems, both on a daily basis and in the long-term. While many managers may be aware of and concerned about climate change, it is far from the only threat they face and may not be the most immediately pressing one. For instance, water professionals in a number of studies expressed that population growth and increased demand will make it more difficult to provide adequate water supply service (Arnell & Delaney, 2006; Carter & Morehouse, 2003; Economist Intelligence Unit, 2012; Rajbhanary et al., 2010; Stroup, 2011; Subak, 2000). And, in fact, these demand-side factors were often perceived as posing a larger threat to water availability than climate-related factors, such as drought. For example, the majority (54.8%) of water utility professionals in Florida believed that water customers' inefficient use of

water would impact future ability to meet demands, whereas less than one-third (28%) thought climate change would negatively impact water supply (Rajbhanary et al., 2010). Similarly, although climate change was perceived as a barrier to supplying water amongst utility executives surveyed by the Economist Intelligence Unit (2012), wasteful consumer behavior was selected as a top barrier by 11% more of respondents. This perception of wasteful or inefficient consumer behavior as a serious threat to water sustainability may reflect utility professionals' inability, perceived or actual, to influence (limit) customer water usage.

Financial or infrastructure limitations were also mentioned as a threat in several studies. Water providers in Arizona were concerned that infrastructure could not expand quickly enough to meet demand and water managers in four U.S. basins also cited infrastructure-related concerns as interacting with climate change risks (Carter & Morehouse, 2003; Stroup, 2011). In addition to concerns over wasteful consumer behavior, water utility executives in the Economist Intelligence Unit survey also reported that insufficient capital for investment (selected by 35% of respondents as a barrier), tariffs being too low to allow for investment (33%), funds not covering operations (27%), and inadequate infrastructure (19%) were barriers to supplying future water.

Regulatory and/or political challenges were also cited in several studies. Some of the related challenges/factors mentioned include: the need to upgrade treatment infrastructure to meet regulatory requirements (Brettle et al., 2015), state/federal regulations limiting water access (Cockerill et al., 2014), regulatory/political barriers preventing investments (Economist Intelligence Unit, 2012) and increasing costs from regulatory requirements (Rajbhanary et al., 2010). While the non-climate factors included here are by no means an exhaustive list of all risks water professionals must contend with outside of climate/weather challenges, it does illustrate the number of competing and complex problems facing water and wastewater resource management.

Therefore, it should not be surprising that other priorities may take precedent over climate change management; therefore, water professionals reported that they require adaptation actions that can "buffer the effects of climate change while serving another purpose" (Stroup, 2011, p.417).

Impacts of risk perceptions on behavior

Many of the studies included in this review were concerned with whether water sector professionals perceived risk from climate change, and also how these perceptions impact behavior. Ekstrom et al. (2017) found that drinking water utility managers with higher risk perception toward local impacts of climate change on water quality and drought were more likely to have taken adaptive action. Lowrey et al. (2009) also reported that higher perceived risk of potential future water shortage, as induced by a severe drought in 2002, led water managers in Colorado to look for and use climate information to a greater extent; this finding was also mentioned by Stroup (2011). Additionally, O'Connor et al., (2005) found that risk perception, measured as both perceived likelihood and perceived severity of various climate/weather extremes impacting the utility, was a statistically significant predictor of forecast use among water managers in Pennsylvania and South Carolina. According the results, 73% of managers who anticipate problems for their system as a result of both drought and increasing temperatures use climate and/or weather forecasts to inform public water conservation campaigns, compared to 36% of managers who are not concerned about either (O'Connor et al., 2005). Interestingly, perceived reliability of forecasts was not significant predictor of forecast use, which demonstrates the relative importance of risk perceptions (O'Connor et al., 2005).

In Arizona, perceived risk of drought helped initiate/motivate use of climate information among water managers and this led to a long-term, fruitful relationship with a climate research organization (Kirchoff et al., 2013). This same study also found that, in Georgia, water managers

reportedly started to incorporate limited climate information into decision making in response to a severe drought lasting from 2006 to 2008. However, this use of climate information waned when the drought ended and Georgia water managers began to question whether they needed to be planning for climate change (Kirchoff et al., 2013). The authors note that the Georgia state government is both skeptical of climate change and heavily involved in water resource management throughout the state, which may contribute to lower risk perceptions and use of climate information in Georgia compared to Arizona. Based off these case studies, the authors concluded, "overwhelmingly, individual water manager behavior (e.g., information seeking) and risk perception spur consideration of climate information in planning and decision-making" (Krichhoff et al., p. 6). The Arizona and Georgia cases provide insight into how risk perceptions may influence decision-making within utilities and illustrate how context-specific risk perceptions are; risk perceptions are inconsistent across states in the same country.

However, not all studies included in this review found evidence for a relationship between risk perceptions and behavior; storm water managers in the Baltimore-Washington area reported that their concern over climate change did not motivate their adaptation efforts (Wernstedt & Carlet, 2014). Rather, the impetus for developing climate change adaptation plans was usually citizen concern, economic interest, or political pressure (Wernstedt and Carlet, 2014), although, perceived risk may have subconsciously impacted adaptation efforts, or lack thereof.

While the majority of the studies that examined whether or how risk perceptions impact behavior did find an association, it is worth pointing out these studies have only examined the impact of risk perceptions on a limited number of behaviors, with the majority (two-thirds) looking at climate information/forecast use. Therefore, it is difficult to say whether risk

perceptions would be equally influential when it comes to more significant decisions, such as infrastructure investment or developing new water supply options.

Furthermore, many of these studies avoid using causal language; climate/weather-related risk perceptions may be correlated/associated with behavior, but it is not clear that it causes behavior change. Cockerill et al. (2014), who noted in their study that water resource decision makers who were more worried about drought were also more likely to have a conservation program where they work, summarize this point well:

> "What is not entirely clear is if, how, and when the decision-maker perceptions are influencing policy and program development rather than the presence of a policy or program influencing decision-maker perceptions about water management issues" (p. 100).

Establishing such causal links between perceptions and behavior and determining the direction of such relationships is extremely difficult. The existing body of research seems to indicate that risk perceptions do influence behavior to some extent. However, climate change is one of many challenges that water professionals face and other, non-climate factors may be equally or more influential when it comes to decision-making and behavior in the water sector.

Summary of Systematic Literature Review

Overall, the available literature on climate-related risk perceptions of water sector professionals is sparse and inconsistent in terms of findings and variables assessed. The majority of studies focus on the U.S. and no identified studies examine perceptions of water sector professionals in sub-Saharan Africa.

Based on the 18 papers identified as part of the systematic literature review, risk perceptions of water sector professionals seem to be influenced by external and internal factors. Examining what influences perceptions can help us better understand why water sector professionals do or do not perceive climate change as a risk. While there was little consistency in how climate-related risk perceptions are measured across studies, the body of literature indicates that perceptions of water sector professionals have evolved over time. This evolution is likely due, at least in part, to the scientific community's evolving understanding of climate change and its impacts on the hydrological cycle.

The earliest identified studies found that water professionals were not particularly concerned about climate change and/or did not know if it was real. However, more recently, studies have generally found that the most (or many) water sector professionals are at least somewhat worried about climate change, though it may still be perceived as a psychologically distant risk. But, in many cases, water professionals have a number of competing risks to manage and some of these may pose a more immediately concerning risk than climate change. Therefore, climate and weather-related risks need to be examined within the context of the larger portfolio of risks facing the water sector. This will be especially useful in identifying 'no regrets' strategies that offer near-term benefits to utilities, while also increasing resilience to future changes.

Finally, the literature mostly provides some evidence for a link between climate change risk perceptions and adaptation behavior among water sector professionals. However, there are

several limitations to these findings, including the inability to establish a causal link between risk perceptions and behavior. Nevertheless, the findings of this systematic literature review provide a justification for the need to better understand risk perceptions of water sector professionals, especially in regions where they have not yet been examined.

SECTION 3: SURVEY OF WATER SECTOR PROFESSIONALS IN SUB-SAHARAN AFRICA

Rationale

Based on climatological projections for sub-Saharan Africa (**Section 1**), it is highly probably that water and wastewater utilities throughout the region will be impacted by climate change. The increased variability in the hydrologic cycle caused by climate change makes long-term planning all the more difficult for utilities and adaptation all the more necessary. As described throughout the previous section, being aware of and concerned about climate change risk is seen as a necessary precursor to adaptation action. Therefore, understanding the risk perceptions of water sector professionals can lend valuable insight into the climate change adaptation process in utilities. However, we detected no studies that have looked at the risk perceptions of water sector professionals in sub-Saharan Africa. The present study aims to address this notable gap in the existing literature on climate change risk perceptions.

Survey Research questions

In this study, we examine the risk perceptions of water sector (both utility and non-utility) professionals in sub-Saharan Africa toward climate and non-climate risks facing water and wastewater utilities. We conducted an online survey at the bi-annual congress of the African Water Association (AfWA), a professional organization composed of water sector professionals from all over Africa[4], including utility workers (AfWA, 2015). The survey assessed perceptions of likelihood and severity of various factors that have the potential to disrupt utility water and/or wastewater service in order to answer the following questions:

- How do water sector professionals' perceptions of climate change risks compare to their perceptions toward other non-climate risks facing utilities?
- How do the risk perceptions of utility professionals compare to those of other professionals in the broader water sector?

This paper presents the results of the survey in order to answer these questions and discusses possible implications for the climate change adaptation process among utilities in Sub-Saharan Africa.

[4] AfWA is open to water sector professionals in any African country, however, the vast majority of survey respondents were from sub-Saharan Africa (SSA) and less than 3% reported working in an African country not in SSA (Table 4). Therefore, this report is framed around the water sector and climate change impacts in this region, as opposed to the entire African continent.

Survey Methods

Measures

Table 2: Survey questions used to create measures for analysis

Measure	Question wording
Perceived likelihood of climate/weather events	How LIKELY do you think it is that each of the following weather/climate events will disrupt or interfere with your utility's [with utility] delivery of water or sanitation services [in the region(s) where your organization operates][1] at least once over the next 10 years? Please indicate on the scale below where 0=not at all likely and 100=extremely likely
Perceived severity of climate/weather events	How SEVERE would the consequences be for your utility's [for utility] delivery of water or sanitation services [in the region(s) where your organization operates] if each of the following weather/climate events occurred over the next 10 years? Please rate each event on the scale below from 0=Not at all severe to 100=Extremely severe
Perceived likelihood non-climate factors	How LIKELY do you think it is that each of the following items will disrupt or interfere with your utility's [with utility] delivery of water or sanitation services [in the region(s) where your organization operates] over the next 10 years? Please indicate on the scale below where 0=not at all likely and 100=extremely likely
Perceived severity of non-climate factors	How SEVERE would the consequences be for your utility's [for utility] delivery of water or sanitation services [in the region(s) where your organization operates] if each of the following occurred over the next 10 years? Please rate each item on the scale below from 0=Not at all severe to 100=Extremely severe
Perceived risk toward general climate change	How concerned are you about climate change disrupting or interfering with your utility's [with utility] delivery of water or sanitation services [in the region(s) where your organization operates] over the next 10 years? Please indicate on a scale from 0=Not concerned and 100=Extremely concerned

[1]Portions in brackets indicate change in wording for non-utility respondent version of survey

Organization type

In order to compare the perceptions of utility and non-utility respondents, two different versions of the survey were used: one for individuals who identified their organization type as a water and/or wastewater utility and another for all others (non-utility professionals). The main difference between the two survey versions was question wording; utility respondents were asked

about their perceptions of risk regarding the utility they work for, whereas non-utility respondents were asked about their perceptions of risk regarding the utility or utilities in the region(s) where their organization operates (see **Table 2** for question wording).

Respondents were asked to select the response that most accurately describes their organization from 13 options (including "Other" and "I prefer not to answer"). Respondents who selected an option other than water or wastewater utility were collapsed into one group of non-utility respondents. All utility and non-utility respondents answered questions regarding type and location of the organization they worked for, their position within their organization, perceived likelihood and perceived severity of various climate and non-climate factors, and overall climate change concern.

Risk Perception

Within the context of this study, risk is defined as, "the probability that exposure to a hazard will lead to negative consequences" (Ropeik & Gray 2002, p.4). The way in which an individual perceives and judges a risk is referred to as risk perception (Slovic & Weber, 2002).

Similar to Dow et al. (2007), our survey assessed both perceptions of the likelihood of a given event disrupting utility service over a ten-year planning window and the severity of the consequences if the event occurred. Perceived likelihood and severity were measured as continuous variables on a scale from 0=not at all likely/severe to 100=extremely likely/severe. Measuring perceived likelihood and severity on the same scale allowed for these two dimensions of risk to be combined as a measure of risk perception. Risk perception toward event/factor *C* was calculated as follows:

[Equation 1]

$$\frac{Perceived\ likelihood\ of\ C\ disrupting\ utility\ service \times Perceived\ severity\ of\ consequences\ if\ C\ occurred}{100}$$

Risk perception toward each individual climate and weather event (**Table 3**) was calculated as shown in Equation 1 and then all the items were averaged to calculate overall risk perception toward weather and climate events. The climate and weather events included in the survey were identified through the systematic literature review (Section 2) and using climate projections for the region (Section 1). The items used to calculate overall risk perception were tested and found to have a scale reliability coefficient (Cronbach's alpha value) of 0.914.

In order to compare risk perception toward specific climate/weather events to overall climate change concern, respondents were asked how concerned they are about climate change disrupting utility service over the next ten years (from 0=not concerned to 100=extremely concerned). This second measure is referred to as general climate change concern throughout the paper.

Non-climate risk factors were included in the survey in order to understand the scope of risks facing utilities and how they compare to climate risks. Risk perception was calculated for each of the 13 non-climate factors (**Table 3**) as shown in Equation 1 and overall risk perception toward non-climate factors is the average of the 13 risk perceptions (Cronbach's alpha=0.93). The non-climate factors included in the survey were identified during the systematic literature review (Section 2). In order to capture risk factors not identified in the literature review, respondents were given the option to provide their own "other" climate/weather event and/or non-climate factor that they thought posed a risk to utility service. All data analysis was completed using Stata statistical software (StataCorp, 2015).

Table 3: Risk factors assessed in survey

Climate and weather events	High temperatures for several months; extremely high temperatures for several days or weeks (i.e., heat wave); low temperatures for several weeks; drought; flooding; sea level rise; cyclones; increased precipitation that does not result in flooding; other climate/weather event
Non-climate factors	Water scarcity; decreased source water quality; increased demand for water; increased costs of electricity; increased labor costs; high levels of non-revenue water; aging infrastructure; inadequate capital funding; insufficient revenues for operations and maintenance; personnel turnover; lack of qualified staff; vandalism; other non-climate factor

Survey sample

During the February 2016 AfWA Congress in Nairobi, Kenya, the survey was emailed (via Qualtrics) to all attendees who provided an email address when registering for the congress (n=807). The survey was also advertised in congress sessions and on fliers distributed at the congress to encourage completion. Respondents had the option to take the survey in either English or French. Congress attendees were initially contacted at the beginning of the congress and those who had not completed the survey received four reminder emails. Late registrants (n=228) were initially emailed on the second day of the congress and received two reminder emails. The University of North Carolina's Internal Review Board approved the research prior to implementation of the survey (study #16-0389) and each respondent was required to provide informed consent.

Survey Results

Responses were collected February 22nd through March 5th, 2016. We had an overall response rate of 18% (n=149) and the 90 fully completed surveys are included in this analysis. Water sector professionals are most concerned about the impacts of drought on utilities, followed by increased water demand and water scarcity. Overall, average risk perception toward climate and weather events is lower than average risk perception across the non-climate factors. However, respondents tended to rate their general concern over climate change impacts on utilities closer to 'extremely' concerned than not at all concerned. Finally, non-utility professionals perceive greater risk from the impacts of climate and weather events on utilities than do utility professionals.

Table 4: Survey Respondent Characteristics

Respondent Characteristic	Number of respondents (%)
Utility professional	43 (48)
Type of utility:	
Water	14 (33)
Wastewater	0
Both	29 (67)
Non-utility respondents	47 (52)
Type of organization:	
Government agency	9 (10)
University/think tank	7 (8)
Non-governmental organization	6 (7)
International donor organization	6 (7)
Consulting firm	5 (5)
Regulatory agency	4 (4)
Other	11 (10)
Location where respondent works	
Sub-Saharan Africa	67 (74)
Kenya	50 (56)
Other region	8 (9)
Unspecified	15 (17)

Respondent Characteristics

The proportion of respondents that work for a utility (48%) and for an organization other than a utility (52%) is nearly equal (**Table 4**). The majority of utility respondents (67%) work for a utility that provides both water and wastewater services. Most respondents (74%) work in one or more countries in Sub-Saharan Africa and more than half of all respondents (56%) work in Kenya, where the African Water Congress was held.

Comparison of Climate and Non-climate Risk Perceptions

Water sector professionals had the highest average risk perception toward drought (μ=47.5, σ=36) and flooding (μ=35.3, σ=34.1) out of all the climate and weather events (**Fig. 2**). Of the included climate and weather events, respondents were least concerned about low temperatures (μ=5.9, σ=15.8). Average risk perception across all climate/weather events was 19.3 (σ=17.5) out of a maximum possible 100 points. The average value for concern over general climate change impacts on utilities was 75.7 (σ=23.4) out of 100, meaning that respondents were more likely to be extremely concerned about climate change, as opposed to not at all concerned.

Given that utilities face risks extending beyond climate and weather events, risk perceptions of water sector professionals toward twelve different non-climate factors that may disrupt utility service were measured. Water sector professionals had the highest perceived risk toward increased water demand (μ=44.3, σ=34.8), closely followed by water scarcity (μ=43.9, σ=36.6) out of all the non-climate factors (**Fig. 3**). Of the non-climate factors included in the survey, respondents had the lowest perceived risk toward personnel turnover (μ=16.5, σ=24.8). Average risk perception toward all non-climate factors was 31.4 (σ=24.3) out of a possible 100 points.

To better understand how risk perceptions toward climate and weather events compare to perceptions of non-climate risks across all respondents, all risk factors (20 in total plus 'other' climate and non-climate) were ranked according to level of risk perception (**Fig. 4)**. Average risk perception toward non-climate factors was significantly higher than average risk perception toward climate and weather events (31.4 vs. 19.3, $t(178)=3.84$, $p<0.001$). Of the ten factors with the highest risk perception scores, only two (drought and flooding) were climate/weather events. In contrast, four of the five factors with the lowest risk perception scores were climate and weather events. Drought was the most concerning factor overall, followed by increased water demand and water scarcity, indicating high perceptions of risk toward issues related to water quantity and availability.

Comparison of utility and non-utility risk perceptions

To establish whether risk perceptions of respondents who work for a water/wastewater utility differ from those of other (non-utility) water professionals, the responses of the two groups were separated. Non-utility respondents reported higher perceptions of risk toward each climate and weather event than the utility respondents (**Fig. 5**). Additionally, average risk perception toward climate/weather events was significantly higher among non-utility respondents than utility respondents (24 vs. 14.1, $t(88)=2.75$, $p<0.01$). This same pattern was also observed in the question assessing general climate change concern; average non-utility concern over general climate change impact on utilities ($\mu=80.3$, $\sigma=19.3$) was greater than that of utility respondents ($\mu=70.6$, $\sigma=26.6$; $t(88)=2$, $p<0.05$). There was a statistically significant ten-point difference between utility and non-utility averages for both general climate change concern and average climate/weather event risk perception.

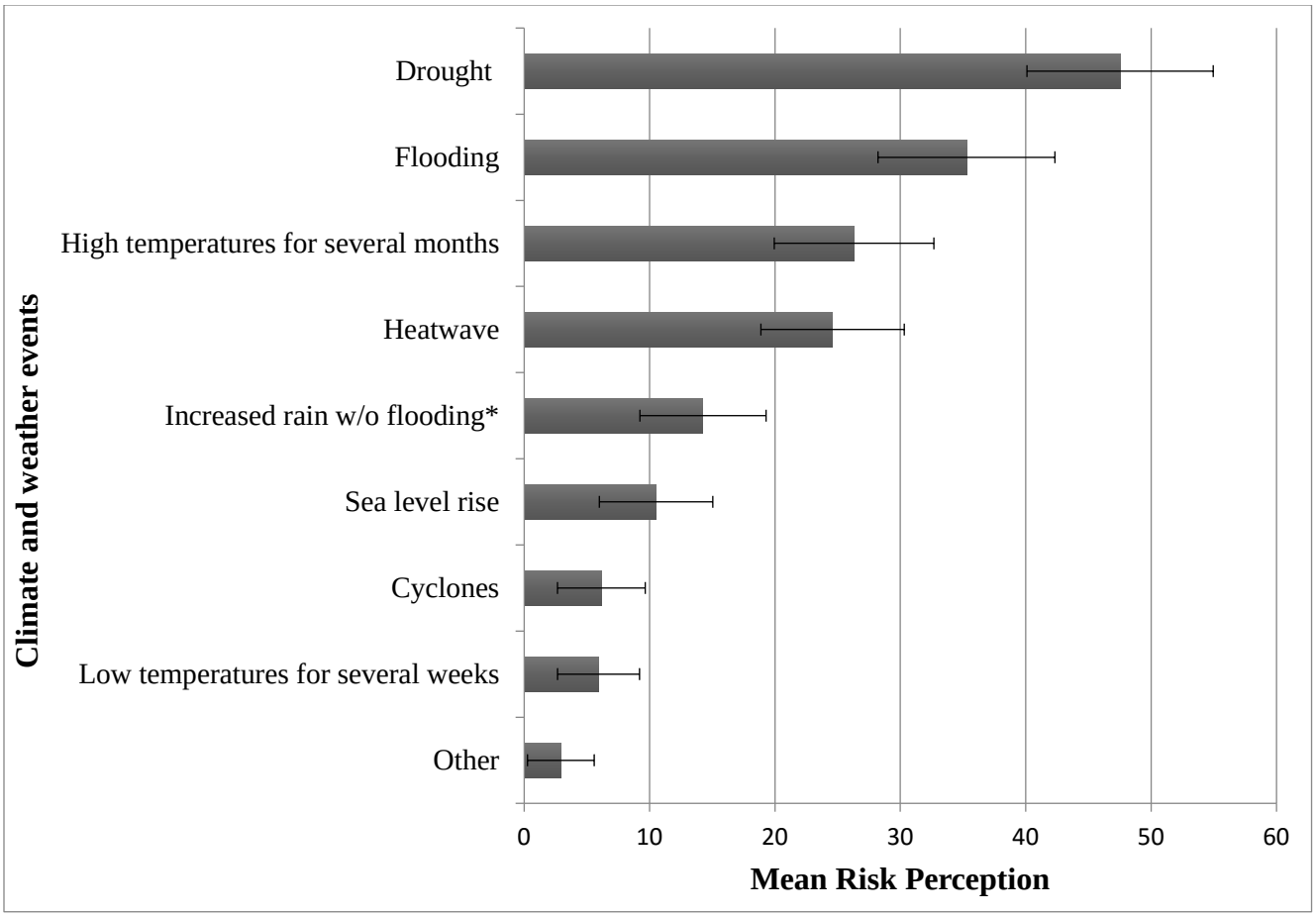

Figure 2: Mean risk perception of water sector professionals toward climate and weather events disrupting utility service (n=90). Risk perception measured on a scale from 0 to 100 and calculated as: (mean perceived likelihood of climate event x mean perceived severity of climate event)/100. Overall risk perception toward weather and climate events is 19.3/100 (σ=17.5). The lines on each bar represent the 95% confidence interval.
*Increased precipitation that does not result in flooding

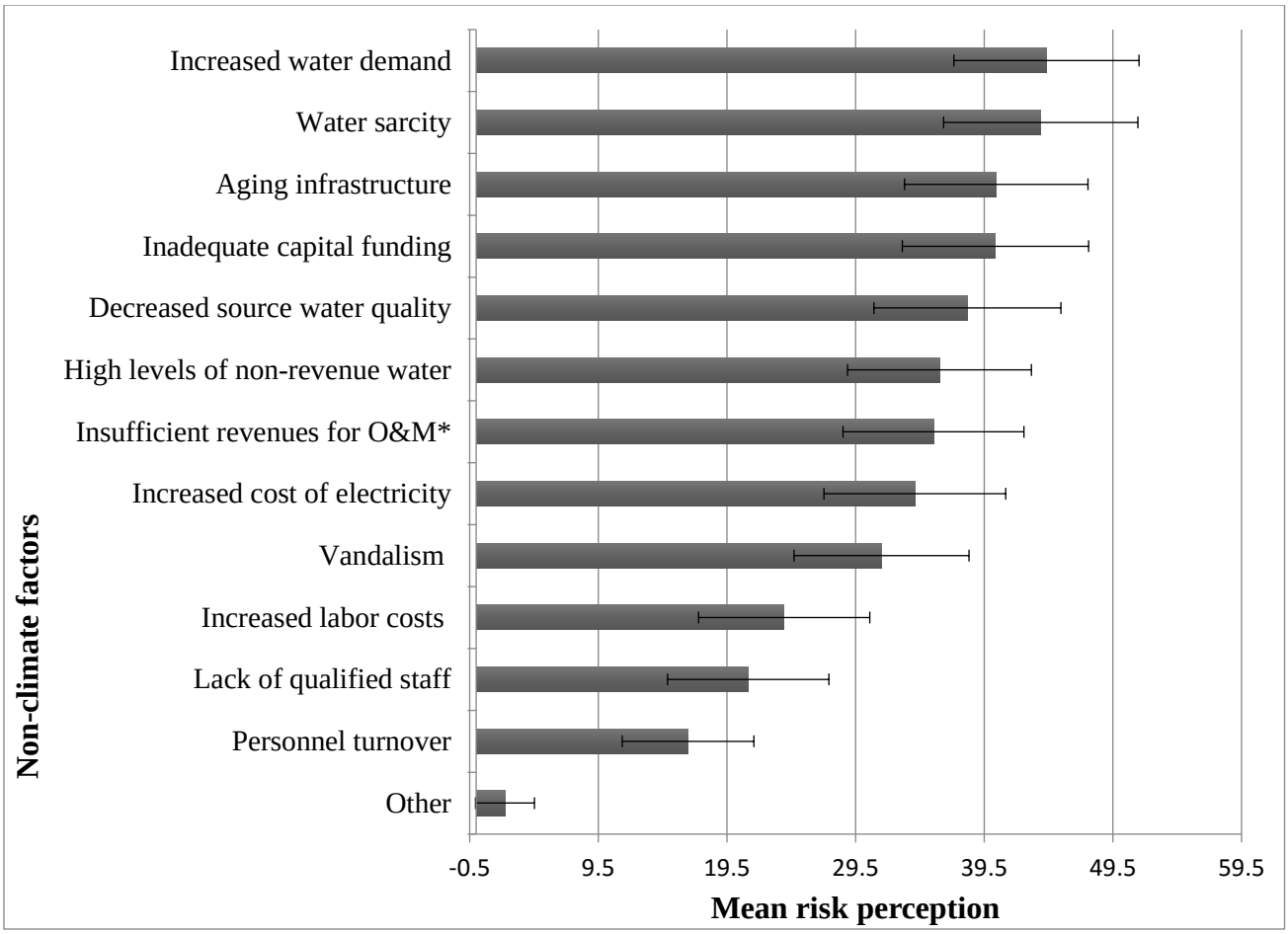

Figure 3: Mean risk perception of water sector professionals toward non-climate factors disrupting utility service (n=90). Risk perception measured on a scale from 0 to 100 and calculated as: (mean perceived likelihood of factor x mean perceived severity of factor)/100. Overall risk perception toward non-climate factors is 31.4/100 (σ=24.3). The lines on each bar represent the 95% confidence interval.
*Insufficient revenues for operations and maintenance

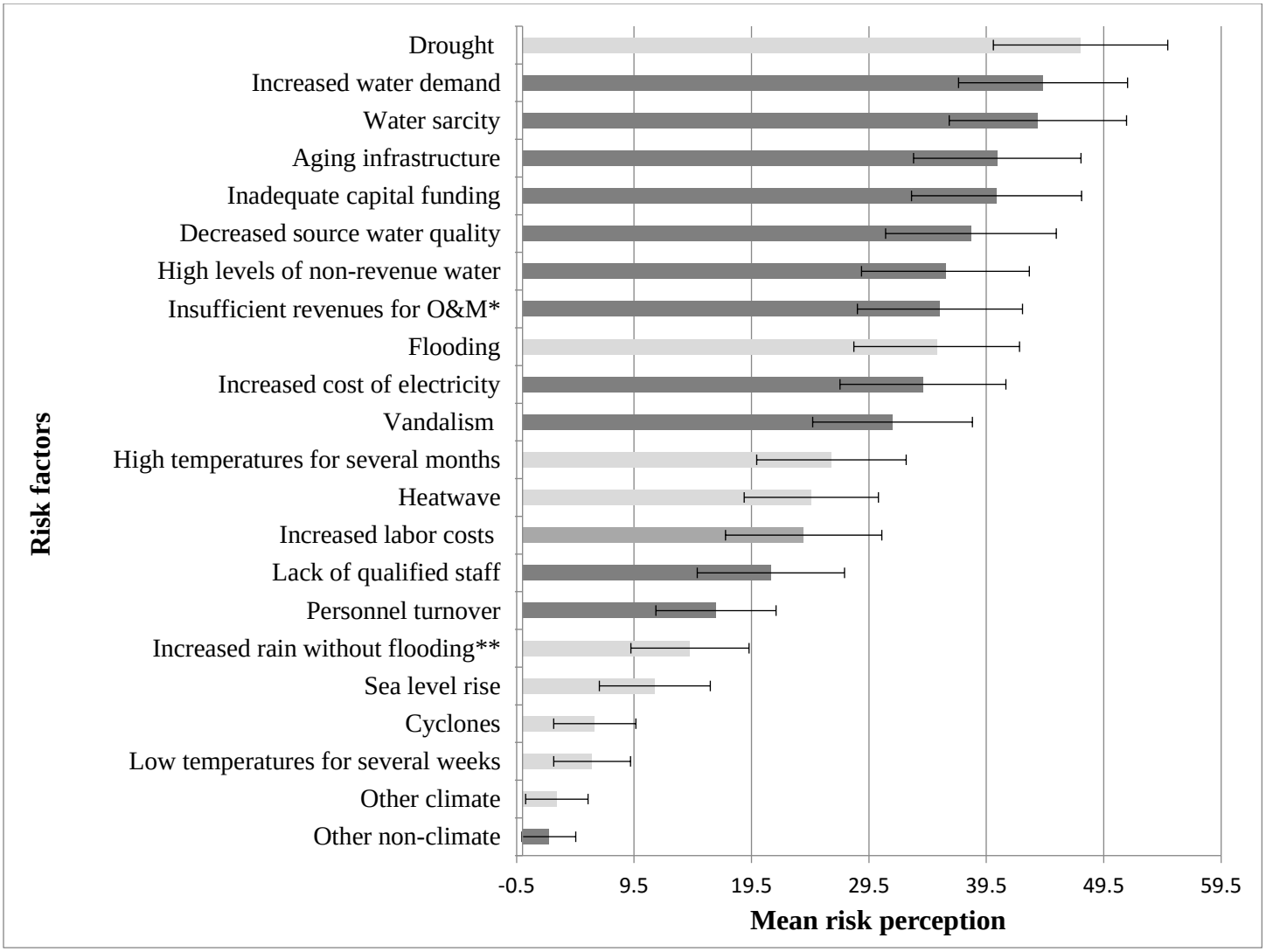

Figure 4: Comparison of water sector professionals' risk perceptions toward climate/weather events (lighter shading) and non-climate factors (darker shading). Factors are ordered from highest risk perception (top) to lowest risk perception (bottom). Risk perception is measured on a scale from 0 to 100 and calculated as: (mean perceived likelihood of factor x mean perceived severity of factor)/100. The lines on each bar represent the 95% confidence interval.
*Insufficient revenues for operations and maintenance
**Increased precipitation that does not result in flooding

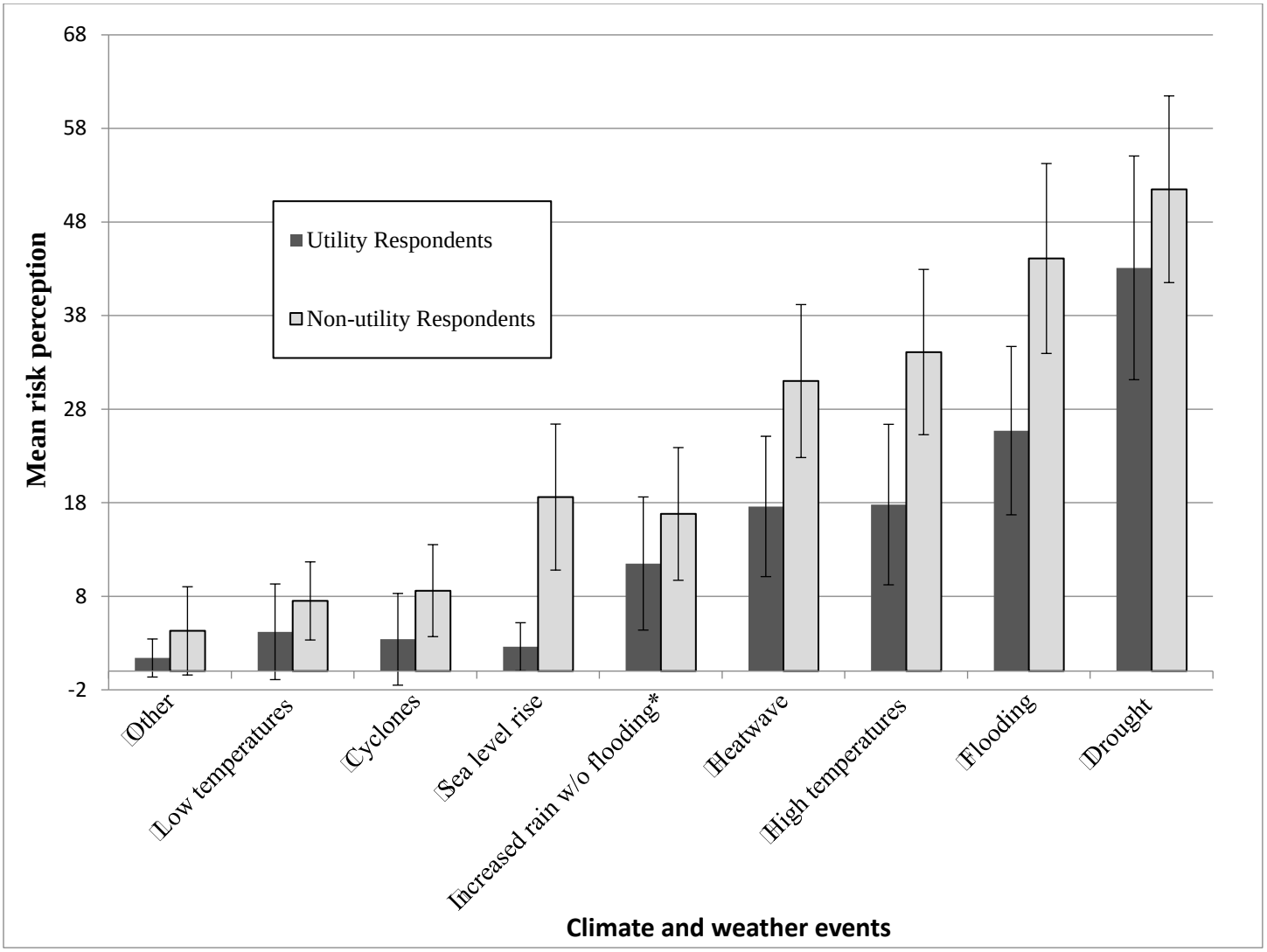

Figure 5: Mean risk perception toward climate and weather events among utility and non-utility professionals. Risk perception is measured on a scale from 0 to 100 and calculated as: (mean perceived likelihood of climate event x mean perceived severity of climate event)/100. The difference between overall climate/weather event risk perception in utility respondents (μ= 14.1, σ=15.1) and non-utility respondents (μ=24, σ=18.4) is statistically significant $t(88)=-2.75$, $p<0.01$. The lines on each bar represent the 95% confidence interval.
*Increased precipitation that does not result in flooding

Discussion

To our knowledge, this study is the first to examine the climate change risk perceptions of water sector professionals in Sub-Saharan Africa. Our findings reveal that water sector professionals in this region are, on average, more concerned about the non-climate change risks facing utilities than risks posed by climate/weather events. However, respondents did express concern over the impacts of climate change on utilities, in general.

Additionally, we found no other study that compared the perceptions of water and wastewater utility professionals to those non-utility professionals within the water sector. Both utility and non-utility respondents ranked climate/weather events as lower risk than most of the non-climate factors, overall; however, non-utility professionals had higher levels of perceived risk toward climate/weather events and greater concern over the general impacts of climate change on utilities compared to utility professionals. Average risk perception toward climate/weather events was 19.3 (out of 100) compared to 31.4 towards non-climate factors among all respondents. Utility respondents' average climate/weather event risk perception value was ten points lower that of non-utility respondents (14.1 vs. 24).

We have shown that risk perceptions of water sector professionals toward non-climate factors are significantly higher than those towards climate/weather events. While drought was the highest ranked risk factor overall, the non-climate factors made up the majority of the factors with the highest risk perceptions (eight out of the top ten). This finding that non-climate concerns may outweigh concerns related to climate/weather events has been observed in other studies; utility professionals England and Wales (Arnell & Delaney, 2006) and Florida (Rajbhanary et al., 2010), expressed greater concern over short-term impacts on their systems, such as increased demand, population growth and customer's inefficient water use, as compared to climate change risks. Additionally, although more than one-third of water utility executives surveyed in ten different

countries (**Appendix 2**) selected reduced water availability due to climate change as a top barrier to supplying water, respondents were more likely to select wasteful consumer behavior or tariffs being too low for investment as barriers (Economist Intelligence Unit, 2012).

However, water sector professionals in sub-Saharan Africa did rank drought and flooding events as relatively high risks. Similarly, water system managers in Pennsylvania and South Carolina ranked drought as one of the most likely and severe climate events facing their utilities, but they were less concerned about flooding (Dow et al., 2007). Additionally, respondents to the Economist Intelligence Unit survey (2012) rated drought as the most severe and likely risk to impact one's utility out of 14 risks. This suggests that drought is a particularly salient issue for utilities in a variety of contexts, whereas flooding may not be. However, drought, flooding, and other climate/weather events are risks for many utilities regardless of climate change and it is not entirely clear whether water sector professionals are worried about 'normal' climate/weather threats or the possibility that these events will change in frequency and/or severity as a result of climate change.

Although water sector professionals had, on overage, higher risk perceptions toward non-climate factors than climate/weather events, they still expressed concern over the impacts of climate change on utilities, in general; the average concern value was 75.7 out of 100, closer to the "extremely concerned" side of the scale. The low ranking of climate/weather events that tend to be associated with climate change seems to be at odds with the concern expressed over climate change, however, it is possible that we failed to capture the climate change risks of greatest concern within the specific climate/weather events questions. But, respondents were given the opportunity to provide additional items of concern in the 'other' category to control for this. Furthermore, a study conducted in Kiribati had a similar finding: households were more worried

about the general threat of climate change than about specific threats to water resources (Kuruppu and Liverman, 2011). The authors theorized that this might be because individuals are overwhelmed by the idea of climate change in the abstract, but feel that they are more capable of dealing with its specific impacts. It may similarly be that those in the water sector perceive climate change, in general, as an unknown and serious risk, but that the individual impacts, such as drought and flooding, are more familiar.

The apparent concern over climate change impacts on utilities, as well as higher perceived risk toward non-climate factors compared to climate/weather events is consistent with the larger trends observed in the literature (**Section 2**). The results of the survey suggest that many water sector professionals in sub-Saharan Africa are at least somewhat concerned about the impacts of climate change on utilities, which is consistent with the more recent studies on water sector professionals' climate change perceptions (Economist Intelligence Unit, 2012l; Ekstrom et al., 2017; Finucane et al., 2013). But, while climate change may be a concern for utilities, it is far from the only threat they face. Similar to several other studies, professionals in sub-Saharan Africa consider increased demand, infrastructure problems, and capital/funding concerns to be important risks facing utilities (Arnell & Delaney, 2006; Carter & Morehouse, 2003; Economist Intelligence Unit, 2012; Stroup, 2011; Subak, 2000). Therefore, while climate change is largely recognized as a threat to utilities, it is not the only risk and water sector professionals may not perceive it to be the most important risk.

Our results also point to significant differences between utility and non-utility perceptions. Non-utility respondents had higher average risk perception toward climate/weather events and greater general climate change concern compared to utility respondents. Previous research has found differences in climate change perceptions between those who directly manage/use a

resource and others involved in the same field. In Mozambique, researchers found that farmers perceived climate-related events to be both less likely and less serious than policy makers (Patt & Schroter, 2008) and wildlife managers in the United States perceived less adverse impacts from climate change on wildlife than researchers or administrators (Hagell & Ribic, 2014). It may be that water/wastewater utility and other resource managers or users feel that they have greater control over the impacts of climate change on the resource they manage or use compared to others in the field, contributing to lower risk perceptions (Slovic, 1987). Additionally, as Dobbie and Brown (2014) noted, the water sector employs diverse professionals with different educational backgrounds and viewpoints that likely influence perceptions. A third possible explanation for this difference is that resource managers (or users, in the case of farmers) operate on different timescales than policy makers, researchers or administrators. Much of a resource manager's time is spent dealing with day-to-day issues, as noted by Moser and Luers (2008), while regulators are often focused on longer term planning horizons.

The majority of studies referenced in this discussion were not conducted in sub-Saharan Africa. While North America, Europe and the South Pacific all have significant climatological and cultural differences compared to sub-Saharan Africa, which is in itself a large and diverse region, these are the most relevant studies that exist. This points to an important gap in the literature at large, as there are so few studies to directly compare this one to.

Limitations

The survey aimed to capture a sample that was representative of AfWA members and, by extension, water sector professionals in sub-Saharan Africa; however, respondents from Kenya were overrepresented in the sample. Additionally, not all of the respondents worked in sub-Saharan Africa. But, their attendance at the AfWA Congress demonstrates an active interest and likely knowledge of the water sector in the region. Therefore, the opinions of those who did not report working in sub-Saharan Africa are still useful to include in the analysis. While the survey did collect data on respondent's country, collecting other personal data, such as age, gender, or education, which are factors that have been linked to risk perceptions in the previous literature, may have allowed us to more thoroughly examine the causes of differences in perceptions. Furthermore, information about utility size (population served, staff) and type(s) of water source for drinking water utilities could have been helpful in explaining differences in perceptions.

Conclusion

This study addresses a significant gap in the literature on risk perceptions. It is the first, to the best of our knowledge, to examine the perceptions of water sector professionals in sub-Saharan Africa. Consistent with previous findings in other regions, results of this survey indicate that water sector professionals in sub-Saharan Africa must manage many competing climate and non-climate risks. Additionally, water and wastewater utility professionals have lower risk perceptions towards specific climate/weather event impacts on their utilities than non-utility professionals in the broader water sector. These findings point to several practical implications for water resource management.

Firstly, as both the systematic literature review and survey have demonstrated, climate change is just one of many issues utilities face and it may not be a number one priority in the short-term given the other non-climate risks that exist. Consequently, it will be much easier for utility managers to justify the use of precious time and other resources for climate change adaptation if adaptation and resilience strategies are built into efforts that address other non-climate concerns. Actions that provide benefits for utilities regardless of the actual climate change impacts are referred to as ‘no regrets’ strategies. This conclusion that ‘no regrets’ strategies are needed is quite common within climate change adaptation literature, however, a more careful consideration of what no regrets strategies are actually available to utilities and when they are most useful is necessary. For instance, a no regrets strategy might be most beneficial when a utility is trying to decide between options for supply expansion to meet growing demands in the near future. If they have two options that are roughly equivalent in terms of cost, one of which is increase withdrawals from a currently used source and the other is to develop an alternative source, then a no regrets framing would favor developing a new source because it provides diversification and increases resilience. Looking for opportunities such as this to increase

resilience without significant additional cost will make the adaptation process much easier for utilities.

The second implication is that water sector professionals seem to be concerned about climate change. Respondents to the survey were largely concerned about the impacts of climate change on utilities, in general; however, it is not clear whether perceived risk toward climate/weather events is driving this concern, especially given that professionals ranked most climate/weather events as lower risk than many non-climate factors. It may be that water sector professionals are not sure what the exact climate change impacts are for their specific utilities because there are no usable climate projections for their basin. This question of what impacts/risks are driving climate change concern bears further investigation in future research, especially as it may reveal important information gaps.

Finally, although the non-utility respondents still largely ranked the non-climate factors higher than the climate and weather events, they were still more concerned about the individual climate/weather events and the impacts of climate change on utilities, compared to utility respondents. This difference in perceptions may be related to non-utility respondents' concerns about the security of their own water supply, because their responses are not only informed by their experience within the water sector, but also by their reliance on these utilities to ensure a safe and sufficient supply of water. It may be that with respect to the first and second implications, utility professionals feel that others in the water sector do not fully recognize the competing priorities they must juggle on a daily basis and that they do not have enough reliable information to act, while non-utility professionals in the broader water sector think utilities are not taking the threat of climate change seriously enough. A change in discourse away from more prescriptive recommendations of what utilities "should" and "should not" do towards an approach

that focuses on what utilities need may be an important first step in addressing this potential communication issue.

This study provides a first look at the climate-related risk perceptions of water sector professionals in sub-Saharan Africa. Consistent with studies in other regions, water professionals are concerned about climate change, but this concern must be placed within the broader portfolio of risks facing the water sector. Identifying better ways for utilities to address short-term, non-climate risks, while also building long-term resilience is the most promising route forward for utility adaptation.

APPENDIX 1: STUDIES EXCLUDED AFTER FULL TEXT REVIEW

Author(s), year	Title	Reason for exclusion
Ackerman, Stanton, & Bueno, 2013	Epstein-Zin Utility in DICE: Is Risk Aversion Irrelevant to Climate Policy?	Does not assess climate-related risk perceptions
Alston, Whittenbury, Western, & Gosling, 2016	Water policy, trust and governance in the Murray-Darling Basin	Study sample not specific to water sector professionals; does not assess climate-related risk perceptions
Bailey & Searle, 2008	Implementing Sustainable Approaches to Water Management.	No qualitative or quantitative data collection; Does not assess climate-related risk perceptions
Balsiger & Ingold, 2016	In the Eye of the Beholder: Network location and sustainability perception in flood prevention	Does not focus on water sector professionals; Does not assess climate-related risk perceptions
Becerra, Saqalli, Gangneron & Dia, 2016	Everyday vulnerabilities and ``social dispositions{"} in the Malian Sahel, an indication for evaluating future adaptability to water crises?	Focus is predominantly on villagers managing water infrastructure for their own supplies, rather than a professional managing supply for the public as part of their job
Bord, O'Connor, Yarnal, Fisher, Shudak & Reenock, 1999	Factors influencing community water system managers' perceived vulnerability to system disruption	Not a published paper-conference proceedings; data covered in other included paper (see O'Connor et al., 1999)
Broad, Pfaff, Taddei, Sankarasubramanian, Lall & de Souza Filho, 2015	Climate, stream flow prediction and water management in northeast Brazil: societal trends and forecast value	Does not measure climate-related risk perceptions
Browning-Aiken, Morehouse, Davis, Wilder, Varady, Goodrich, Carter, Moreno, & McGovern, 2007	Climate, water management, and policy in the San Pedro Basin: results of a survey of Mexican stakeholders near the US-Mexico border	Survey focused on water users; qualitative interviews with 4 water managers interviewed, but does not assess climate-related risk perceptions
Cockerill, 2013	The Water Supply Is Fine: Decision-Maker Perceptions of Water Quantity and Supply-Side Management.	Presents same data as in Cockerill et al., 2014
Cohen, Neilsen, Smith, Neale, Taylor, Barton, Merritt, Alila, Shepherd, McNeill, Tansey, Carmichael & Langsdale, 2006	Learning with local help: Expanding the dialogue on climate change and water management in the Okanagan Region, British Columbia, Canada	Does not focus on water sector professionals; Does not assess climate-related risk perceptions
Delpla, Baures, Jung, Clement & Thomas, 2011	Issues of drinking water quality of small scale water services towards climate change	Does not assess perceptions of water sector professionals
Dobbie & Brown, 2014	A Framework for Understanding Risk Perception, Explored from the Perspective of the Water Practitioner	Not original research-no quantitative or qualitative data collection
Flugman, Mozumder & Randhir, 2012	Facilitating adaptation to global climate change: perspectives from experts and decision makers serving the Florida Keys	Survey sample not specific to water sector professionals
Gasbarro, Rizzi & Frey,2016	Adaptation Measures of Energy and Utility Companies to Cope with Water Scarcity Induced by Climate Change	Sample includes water utilities, but they account for less than 6% of sample and respondents are not disaggregated (i.e. no information about water utility perceptions exclusively)

Hossain, Arnold, Beighley, Brown, Burian, Chen, Mitra, Niyogi, Pielke Sr., Tidwell & Wegner, 2015	What Do Experienced Water Managers Think of Water Resources of Our Nation and Its Management Infrastructure?	Does not assess climate-related risk perceptions
Howe, Yarnal, Coletti & Wood, 2013	The Participatory Vulnerability Scoping Diagram: Deliberative Risk Ranking for Community Water Systems	Does not assess climate-related risk perceptions
Keller, Kirkwood & Jones, 2009	Assessing Stakeholder Evaluation Concerns: An Application to the Central Arizona Water Resources System	Does not assess climate-related risk perceptions
Kirono, Larson, Tjandraatmadja, Leitch, Neumann, Maheepala, Barkey, Achmad & Selintung, 2014	Adapting to climate change through urban water management: a participatory case study in Indonesia	Does not assess climate-related risk perceptions

Kuruppu & Liverman, 2011	Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati	Study population consists of households not water sector professionals
La Jeunesse, Cirelli, Aubin, Larrue, Sellami, Afifi, Bellin, Benabdallah, Bird, Deidda, Dettori, Engin, Herrmann Ludwig, Mabrouk, Majone, Paniconi & Soddu, 2016	Is climate change a threat for water uses in the Mediterranean region? Results from a survey at local scale	Unable to access specific survey/interview questions; does not appear as though survey specifically assessed risk perceptions/concern toward climate/weather events
Larsen, 2011	Risk as a challenge in practice: investigating climate change in water management	Survey respondents are municipal department heads who may help develop river basin management plans, but sample not specific to water sector professionals; did look at factors motivating incorporation of climate change concerns into river basin management plans, but did not explicitly assess climate-related risk perceptions
Larson, White, Gober, Harlan & Wutich, 2009	Divergent Perspectives on Water Resource Sustainability in a Public–Policy–Science Context. Environmental Science & Policy	Does not focus on water sector professionals
Lemos, 2008	What Influences Innovation Adoption by Water Managers? Climate Information Use in Brazil and the United States	Did not assess climate-related risk perceptions of water sector professionals
Lins & Stakhiv, 1998	Managing the nations water in a changing climate	Does not assess risk perceptions of water sector professionals
McIntosh, Lee, Atkinson, Turton, Herbetson, Stupples, Law, Prine, Phillips, & Long, 1993	Water-resources development - A balanced approach	Does not assess risk perceptions of water sector professionals
Ojomo & Bartram, 2016	Adapting drinking-water systems to coastal climate change: evidence from Viet Nam and the Philippines	Does not assess perceptions of water sector professionals
Rabadán & Sáez-Martínez, 2017	Why European Entrepreneurs in the Water and Waste Management Sector Are Willing to Go beyond Environmental Legislation.	Does not assess risk perceptions of water sector professionals
Raneesh, 2014	Impact of climate change on water resources.	Does not assess risk perceptions of water sector professionals
Romsdahl, 2015	Planning for Climate Change Adaptation in Natural Resources Management: Challenges to Policy-Making in the US Great Plains	Sample not specific to water sector professionals
Sharma, Pezzaniti, Myers, Cook, Tjandraatmadja Chacko, Chavoshi, Kemp, Leonard, Koth & Walton, 2016	Water Sensitive Urban Design: An Investigation of Current Systems, Implementation Drivers, Community Perceptions and Potential to Supplement Urban Water Services	Does not assess risk perceptions of water sector professionals
Sivakumar, 2011	Hydropsychology: the human side of water research	Does not assess risk perceptions of water sector professionals

Tarlock & de Wetering, 2006	Western Growth and Sustainable Water Use: If There Are No" Natural Limits, "Should We Worry About Water Supplies?	Does not assess risk perceptions of water sector professionals
Varis & Fraboulet-Jussila, 2002	Water resources development in the lower Senegal River basin: Conflicting interests, environmental concerns and policy options	Does not assess risk perceptions of water sector professionals
White, Corley & White, 2008	Water managers' perceptions of the science-policy interface in Phoenix, Arizona: Implications for an emerging boundary organization	Does not specifically assess climate and weather-related risk perceptions, but more generally discusses uncertainty and its sources
Widener, J; Gliedt, T; Hartman, P	Visualizing dynamic capabilities as adaptive capacity for municipal water governance.	Probes motivation for innovative behavior, but does not assess risk perceptions of water sector professionals
Yarnal, Heasley & O'Connor, 2006	The potential use of climate forecasts by community water system managers	Does not assess risk perceptions of water sector professionals
Yéo, Goula, Diekkrüger & Afouda, 2016	Vulnerability and adaptation to climate change in the Comoe River Basin (West Africa).	Survey sample composed to water users, as opposed to managers/sector professionals

APPENDIX 2: SYSTEMATIC LITERATURE REVIEW EXTRACTION TABLE

Authors	**Location**	**Study population**	**Methods**	**Purpose of study/Research questions**	**Risk perceptions/relevant variable**
Arnell & Delaney, 2006	England and Wales, U.K.	Water supply managers (total n not states	In-depth interviews	This paper examines adaptation to climate change by water supply companies in England and Wales.	Question(s) assessing perceived vulnerability not provided
Bolson et al., 2013	Alabama, Florida & Georgia, U.S.	State-, regional-, and local-level water resource managers who make decisions on water supply or water resource management or who are in a position to influence such decisions (n=143)	Online survey	(1) What are the key management decisions and when are they made? (2) How can water resource managers' awareness and perceptions of currently avail- able weather and climate forecast information be characterized? (3) What weather and climate information are currently used by water managers? (4) What are the barriers, opportunities, and capacities for integrating climate information into water management?	Perceived vulnerability to climate events from seasonal to long-term climate change
Brettle et al., 2015	Canada	Water and wastewater utility officials (n=53)	Survey (did not state online or mail)	To gauge water utility officials' perceptions of the level of preparedness of Canadian water utilities for the impacts of climate change.	Does your utility have information that suggests that [water supply/drinking water treatment/source water quality/wastewater treatment/wastewater physical infrastructure/drinking water physical infrastructure] will be impacted by/face challenges due to climate change?
Carter & Morehouse, 2003	Phoeniz, Tucson, Santa Cruz and Sierra Vista area of Arizona, U.S.	Large water providers (survey n=28, interviews n=22)	Written mail survey and in-depth follow-up interviews	To provide insight into the ways that climate- and weather-related factors affect urban water systems in the southwestern United States and whether and how water providers use climate information in coping with weather- and climate-related events and situations	How likely is it that the daily operations of your water system will suffer climate-related impacts within the next five years? Which factors are most important in limiting the number of customers that you can serve? Given the current population projections for your area, what impact could extreme climate conditions have on your company in 10, 20 years from now?

Cockerill, Badurek, & Hale, 2014	Western North Carolina, U.S.	Elected officials, managers, utility personnel, planners; individuals collectively responsible for making water management decisions and/or making decisions that influence water supply use (n=85)	online survey	To understand how decision- maker perceptions about water availability, growth, and environmental concerns correlate with water allocation and conservation policies	How concerned are you about the potential for each of the following to reduce the amount of water available to your community?
de Graaf et al., 2009	the Netherlands	Urban water professionals, (utilities not) included; policy experts who are working at the local level in urban water management, individuals working at water boards, consultancy firms, branch organizations or elsewhere (n=89)	Online survey	To evaluate the receptivity of professionals to transformative change in urban water management; to develop insights in the potential for transformative change in the Dutch Urban water management sector	Select the 2 most urgent problems in present day water management out of a list of 19 problems (could add 'other')
Dow et al., 2007	Susqehanna River basin, Pennsylvania & South Carolina, U.S.	Community water system managers (n=673)	Mail survey	To address managers' perspectives on impacts of and vulnerability to contemporary climate variation in order to gain insights into current challenges posed by climate and to inform efforts to anticipate consequences of and adaptive strategies for climate change	Below is a list of weather and climate events that might affect operations, such as disruptions of water service or of financial planning. Have you experienced problems from these events in the past five years? Do you expect to experience problems from these events in the next 10 years? How big would the problems be for your system if each of these events (from the list above) were to occur? Responses were reported on a point scale of 1–4: 1= negligible, 2= some, 3= considerable, and 4= catastrophic.

Economist Intelligence Unit, 2012	the US, Canada, UK, Spain, France and Australia, Brazil, Russia, India and China	senior water utility executives (n=244)	survey (did not state online or mail)	To examine the relative preparedness of water utilities across ten major markets to meet future water supply challenges to 2030.	What, if any, are the main barriers to ensuring sufficient clean water supplies to 2030 in the country in which you are based? Please rate each of the following types of risk according to its potential significance/impact for your company by 2030; Please rate each of the following types of risk according to its likelihood for your business by 2030
Ekstrom et al., 2017	California, U.S.	Drinking water utility (n=259)	Online survey	To examine existing water quality threats, perceptions of climate change, climate adaptation activities, and information uses	Based on your experience, what is your utility's largest threat to water quality for its drinking water supplies? Please indicate your level of agreement with the following statements: The global climate is changing; California's climate is changing; Climate change poses risks to water quality globally; Climate change poses risks to climate change locally, for my water utility's supply. Please indicate which of the following climate change impacts are expected to threaten your utility's drinking water supply and its management in the next 50 years? Which of the following climate change impacts do you expect to worsen water quality issues for your utility's surface water in the next 50 years?
Finucane et al., 2013	Oahu watershed, Hawaii, U.S.	Federal, state, and city and county government agencies and private organizations identified as interested in, affected by, or able to affect the management of freshwater resources in the central Oahu watershed.	Online survey (n=43), qualitative interviews (n=23) and workshop (n=22)	To characterize the climate-sensitive decisions being made by freshwater managers in Hawaii (with a focus on the central Oahu watershed) and what information is needed to support those decisions	How likely do you think it is that each of the following will occur in Hawaii during the next 50 years as a result of climate change? Will climate change have dangerous impacts on freshwater resources in the central Oahu watershed? Level of worry about the impacts of climate change on freshwater resources

Kirchoff et al., 2013	Georgia & Arizona, U.S.; Ceara & Santa Catarina, Brazil	Water and disaster managers in Brazil (n=40) water system managers and other water and climate experts in US (n=36)	In-depth qualitative interviews (the study involve a survey component, but risk perceptions not assessed in that)	To explore the role of different (1) institutions and water governance regimes and (2) knowledge support systems in shaping climate information use in the United States (U.S.) and Brazil	Perception of the vulnerability of water resources to climate risks (specific questions not provided)
Lowrey et al., 2009	Colorado, U.S.	Water managers at 6 providers (total n interviewed not stated)	Qualitative data collection through interviews, meetings, workshops and published accounts on water management	To identify the uses and needs for climate information, outlooks, and projections among the 6 large water providers in Colorado and to evaluate the factors affecting annual and long-term decisions.	Perception of risk, especially toward drought (specific questions not provided)
O'Connor et al., 1999	Susqehanna River basin, Pennsylvania, U.S.	Community water system managers (n=506)	Mail survey	To examine the sensitivity and vulnerability of community water systems (CWSs) to weather and climate in the Pennsylvania portion of the Susquehanna River Basin.	Global warming opinions/concern: Global warming is unlikely to happen and therefore I am not concerned about its potential effects; I have heard evidence for and against the case of global warming and I do not know which to believe; Global warming may actually happen but its effects are too far off in the future for me to worry about them now; Global warming is real and I am concerned about its potential effects. How likely is it that in the next five years your water system will suffer disruptions in its daily operations from the following events?
O'Connor et al., 2005	South Carolina and Pennsylvania's Susqehanna River basin	Community water system managers (n=673)	Mail survey	To examine why managers of community water systems (CWS) in two eastern American areas, South Carolina and the Susquehanna River Basin of Pennsylvania, use or do not use weather and climate forecasts.	See Dow et al., 2007
Rajbhanary et al., 2010	Florida, U.S.	Water utility representatives (n=197)	Mail and online survey	To examine water utilities' perspectives on various water conservation strategies	Do you believe that long-run changes in weather patterns (including regional climate change) will seriously and negatively impact your utility's water supply?

Stroup, 2011	Colorado, Platte, Delaware and Everglades basin, U.S.	Water/basin management/water resource decision makers participants (n=54)	Qualitative data collection through observation at relevant public meetings; in-person and over-the-phone interviews; surveys.	To understand how diverse water management participants across the United States perceive and adapt management strategies to local climate challenges.	What impacts of climate variability and change do you anticipate in the short (<two years) and long term (>ten years) in the basin? How do human factors, such as population growth and infrastructure development, interact with the above anticipated changes from climate change and variability?
Subak, 2000	England and Wales	Senior water resource managers and forecasters at ten major water/sewerage companies several managers at 18 smaller companies	Qualitative interviews	To analyze how water suppliers' perceptions of climate variability is effecting supply planning in England and Wales	(1) impact of extreme weather on their operations over the past three decades, (2) their responses to that weather, (3) their perceptions of a changing climate, (4) their views of implications of global warming on water supply and demand in the U.K., and (5) their views on the relevance of the Environment Agency's regional climate change scenario exercise for planning future water supply.
Wernstedt & Carlet, 2014	Baltimore-Washington D.C. metropolitan area, U.S.	Public officials working in different departments that manage issues associated with population growth, storm water, and climate change (n=75)	Online survey	To examine the attitudes of local government officials in the BWMA to this climate change-storm water nexus,	Agreement with: "global climate change will have a noticeably negative impact on the natural environment" in their jurisdiction. Agreement with; "global climate change will have a noticeably negative impact on the amount of storm-water runoff" in their jurisdiction

APPENDIX 3: SURVEY MATERIALS

Intro

Thank you for your interest in taking a brief survey about climate change and water and sanitation service delivery. This survey is being implemented in collaboration with Environment for Development (EfD) Kenya, the University of Nairobi School of Economics, and the Water Institute at the University of North Carolina at Chapel Hill.

This survey seeks to collect information on the perceptions of climate-related risk among water and sanitation sector professionals. If you agree to participate in the survey, we will ask you questions about your professional opinion regarding the extent to which climate-related risks might impact utilities' ability to deliver high quality water and sanitation services. We will also ask you about actions your organization and other organizations are taking to adapt to climate change.

Participation in this survey is voluntary. If you would like to complete the survey, it will take approximately 10-15 minutes to complete. The results of this survey will be kept confidential. We will combine your answers with the answers from all other respondents and produce a report we hope will be useful to national and international policy makers.

Please contact David Fuente (fuente@unc.edu) if you have questions or concerns about the survey. Do you agree to participate in this survey?

- ❍ Yes, I agree (1)
- ❍ No (2)

If No Is Selected, Then Skip To End of Survey

Q1 What is the name of your organization? (Please type in the box below)

- ❍ Organization name (1) _____
- ❍ I prefer not to answer (2)

Q2 What is the position that you hold within your organization? (Please type in the box below)

- ❍ Position name (1) _____
- ❍ I prefer not to answer (2)

Q3 Please select the option below that most accurately describes your organization

- ❍ Water utility (374)
- ❍ Other local/municipal level government agency (375)
- ❍ Regional level government agency (376)
- ❍ National level government agency (377)
- ❍ Consulting firm (378)
- ❍ Foundation/Philanthropic organization (379)
- ❍ International donor organization/aid agency (380)
- ❍ International non-governmental organization (NGO) (381)
- ❍ Domestic non-governmental organization (NGO) (382)
- ❍ University/academic institution (383)
- ❍ Policy think tank (384)
- ❍ Regulator/Regulatory Agency (385)
- ❍ Other-please specify in the box (386)
- ❍ I prefer not to answer (387)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q3b What type of service(s) does your utility supply?

- ❍ Water service (1)
- ❍ Sanitation service (2)
- ❍ Both water and sanitation service (3)
- ❍ I prefer not to answer (4)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q4a What area does your utility serve? Please type your answer in the boxes below and be as specific as possible, if not applicable then write NA

City (1)
Region/State (2)
Country or countries (3)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q4b Where does your organization operate or serve? Please type your answer in the boxes below and be as specific as possible, if not applicable write NA.

City (1)
Region/State (2)
Country or countries (3)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q5a From the list of climate and weather events below, please select all events that have disrupted or interfered with your utility's delivery of water or sanitation services in the past 5 years.

- ❑ Above average temperatures for several months (29)
- ❑ Extremely high temperatures for several days or weeks (30)
- ❑ Below average temperatures for several months (31)
- ❑ Drought (32)
- ❑ Flooding (33)
- ❑ Sea level rise (34)
- ❑ Cyclones (35)
- ❑ Above average precipitation for several weeks or months that did not result in flooding (36)
- ❑ Other climate/weather event, please specify in box below (37) _____
- ❑ None of the above (38)
- ❑ I prefer not to answer (39)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q6a From the list of items below, please select all that have disrupted or interfered with your utility's delivery of water or sanitation services in the past 5 years.

- ❑ Water scarcity (58)
- ❑ Decreased source water quality (59)
- ❑ Increased demand for water (60)
- ❑ Increased cost of electricity/energy (61)
- ❑ Increased labor costs (62)
- ❑ High levels of non-revenue water (63)
- ❑ Aging infrastructure (64)
- ❑ Inadequate capital funding (65)
- ❑ Insufficient revenues to cover operations and maintenance costs (66)
- ❑ Personnel turnover (67)
- ❑ Lack of qualified staff (68)
- ❑ Vandalism (69)
- ❑ Other (please specify) (70) _____
- ❑ None of the above (71)
- ❑ I prefer not to answer (72)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q7a How LIKELY do you think it is that each of the following weather/climate events will disrupt or interfere with your utility's delivery of water or sanitation services at least once over the next 10 years? Please indicate on the scale below where 0=not at all likely and 100=extremely likely

_____ Above average temperatures for several months (17)
_____ Extremely high temperatures for several days or weeks (18)
_____ Below average temperatures for several months (19)
_____ Drought (20)
_____ Flooding (21)
_____ Sea level rise (22)
_____ Cyclones (23)
_____ Above average precipitation for several weeks or months that did not result in flooding (24)
_____ Other climate/weather event, please specify in box below (25)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q5b How LIKELY do you think it is that each of the following weather/climate events will disrupt or interfere with utility delivery of water and/or sanitation services, in the region(s) where your organization operates, at least once over the next 10 years? Please indicate on the scale below where 0=not at all likely and 100=extremely likely

_____ Above average temperatures for several months (17)
_____ Extremely high temperatures for several days or weeks (18)
_____ Below average temperatures for several months (19)
_____ Drought (20)
_____ Flooding (21)
_____ Sea level rise (22)
_____ Cyclones (23)
_____ Above average precipitation for several weeks or months that did not result in flooding (24)
_____ Other climate/weather event, please specify in box below (25)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q8a How LIKELY do you think it is that each of the following items will disrupt or interfere with your utility's delivery of water or sanitation services over the next 10 years? Please indicate on the scale below where 0=not at all likely and 100=extremely likely

_____ Water scarcity (1)
_____ Decreased source water quality (2)
_____ Increased demand for water (3)
_____ Increased cost of electricity/energy (4)
_____ Increased labor costs (5)
_____ High levels of non-revenue water (6)
_____ Aging infrastructure (7)
_____ Inadequate capital funding (8)
_____ Insufficient revenues to cover operations and maintenence costs (9)
_____ Personnel turnover (10)
_____ Lack of qualified staff (11)
_____ Vandalism (12)
_____ Other (please specify) (13)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q6b How LIKELY do you think it is that each of the following items will disrupt or interfere with utility delivery of water and/or sanitation services in the region(s) where your organization operates over the next 10 years? Please indicate on the scale below where 0=not at all likely and 100=extremely likely

_____ Water scarcity (1)
_____ Decreased source water quality (2)
_____ Increased demand for water (3)
_____ Increased cost of electricity/energy (4)
_____ Increased labor costs (5)
_____ High levels of non-revenue water (6)
_____ Aging infrastructure (7)
_____ Inadequate capital funding (8)
_____ Insufficient revenues to cover operations and maintenance costs (9)
_____ Personnel turnover (10)
_____ Lack of qualified staff (11)
_____ Vandalism (12)
_____ Other (please specify) (13)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q9a How SEVERE would the consequences be for your utility's delivery of water or sanitation services if each of the following weather/climate events occurred over the next 10 years? Please rate each event on the scale below from 0=Not at all severe to 100=Extremely severe

_____ Above average temperatures for several months (18)
_____ Extremely high temperatures for several days or weeks (19)
_____ Below average temperatures for several months (20)
_____ Drought (21)
_____ Flooding (22)
_____ Sea level rise (23)
_____ Cyclones (24)
_____ Above average precipitation for several weeks or months that did not result in flooding (25)
_____ Other climate/weather event, please specify in box below (26)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q7b How SEVERE would the consequences be for utility delivery of water and/or sanitation services in the region(s) where your organization operates if each of the following weather/climate events occurred over then next 10 years? Please rate each event on the scale below from 0=Not at all severe to 100=Extremely severe

_____ Above average temperatures for several months (17)
_____ Extremely high temperatures for several days or weeks (18)
_____ Below average temperatures for several months (19)
_____ Drought (20)
_____ Flooding (21)
_____ Sea level rise (22)
_____ Cyclones (23)
_____ Above average precipitation for several weeks or months that did not result in flooding (24)
_____ Other climate/weather event, please specify in box below (25)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q10a How SEVERE would the consequences be for your utility's delivery of water or sanitation services if each of the following occurred over the next 10 years? Please rate each item on the scale below from 0=Not at all severe to 100=Extremely severe

_____ Water scarcity (1)
_____ Decreased source water quality (2)
_____ Increased demand for water (3)
_____ Increased cost of electricity/energy (4)
_____ Increased labor costs (5)
_____ High levels of non-revenue water (6)
_____ Aging infrastructure (7)
_____ Inadequate capital funding (8)
_____ Insufficient revenues to cover operations and maintenance costs (9)
_____ Personnel turnover (10)
_____ Lack of qualified staff (11)
_____ Vandalism (12)
_____ Other (please specify) (13)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q8b How SEVERE would the consequences be for utility delivery of water and/or sanitation services in the region(s) where your organization operates if each of the following occurred over the next 10 years? Please rate each item on the scale below from 0=Not at all severe to 100=Extremely severe

_____ Water scarcity (1)
_____ Decreased source water quality (2)
_____ Increased demand for water (3)
_____ Increased cost of electricity/energy (4)
_____ Increased labor costs (5)
_____ High levels of non-revenue water (6)
_____ Aging infrastructure (7)
_____ Inadequate capital funding (8)
_____ Insufficient revenues to cover operations and maintenance costs (9)
_____ Personnel turnover (10)
_____ Lack of qualified staff (11)
_____ Vandalism (12)
_____ Other (please specify) (13)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q11a Please select the five items below that you think will most negatively impact your utility's delivery of water or sanitation services over the next 10 years.

- ❑ Water scarcity (175)
- ❑ Decreased source water quality (176)
- ❑ Increased demand for water (177)
- ❑ Increased cost of electricity/energy (178)
- ❑ Increased labor costs (179)
- ❑ High levels of non-revenue water (180)
- ❑ Aging infrastructure (181)
- ❑ Inadequate capital funding (182)
- ❑ Insufficient revenues to cover operations and maintenance costs (183)
- ❑ Personnel turnover (184)
- ❑ Lack of qualified staff (185)
- ❑ Vandalism (186)
- ❑ Above average temperatures for several months (187)
- ❑ Abnormally high temperatures for days or weeks (188)
- ❑ Below average temperatures for several months (189)
- ❑ Above average precipitation for several weeks or months that did not result in flooding (190)
- ❑ Drought (191)
- ❑ Flooding (192)
- ❑ Sea level rise (193)
- ❑ Cyclones (194)
- ❑ Other (please specify) (195) _____
- ❑ I prefer not to answer (196)

If I prefer not to answer Is Selected, Then Skip To How concerned are you about climate c...

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected
Carry Forward Selected Choices from "Please select the five items below that you think will most negatively impact your utility's delivery of water or sanitation services over the 10 years."
Q12a Please rank these items from 1 to 5, with 1 being the item that concerns you the most and 5 being the item that concerns you the least. (Please drag the items to reorder)

_____ Water scarcity (1)
_____ Decreased source water quality (2)
_____ Increased demand for water (3)
_____ Increased cost of electricity/energy (4)
_____ Increased labor costs (5)
_____ High levels of non-revenue water (6)
_____ Aging infrastructure (7)
_____ Inadequate capital funding (8)
_____ Insufficient revenues to cover operations and maintenance costs (9)
_____ Personnel turnover (10)
_____ Lack of qualified staff (11)
_____ Vandalism (12)
_____ Above average temperatures for several months (13)
_____ Abnormally high temperatures for days or weeks (14)
_____ Below average temperatures for several months (15)
_____ Above average precipitation for several weeks or months that did not result in flooding (16)
_____ Drought (17)
_____ Flooding (18)
_____ Sea level rise (19)
_____ Cyclones (20)
_____ Other (please specify) (21)
_____ I prefer not to answer (22)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q9b Please select the five items below that you think will most negatively impact utility delivery of water and/or sanitation services in the region(s) where your organization operates over the next ten years.

- ❑ Water scarcity (153)
- ❑ Decreased source water quality (154)
- ❑ Increased demand for water (155)
- ❑ Increased cost of electricity/energy (156)
- ❑ Increased labor costs (157)
- ❑ High levels of non-revenue water (158)
- ❑ Aging infrastructure (159)
- ❑ Inadequate capital funding (160)
- ❑ Insufficient revenues to cover operations and maintenance costs (161)
- ❑ Personnel turnover (162)
- ❑ Lack of qualified staff (163)
- ❑ Vandalism (164)
- ❑ Above average temperatures for several months (165)
- ❑ Abnormally high temperatures for days or weeks (166)
- ❑ Below average temperatures for several months (167)
- ❑ Above average precipitation for several weeks or months that did not result in flooding (168)
- ❑ Drought (169)
- ❑ Flooding (170)
- ❑ Sea level rise (171)
- ❑ Cyclones (172)
- ❑ Other (please specify) (173)
- ❑ I prefer not to answer (174)

If I prefer not to answer Is Selected, Then Skip To How concerned are you about climate c...

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected
Carry Forward Selected Choices from "Please select the five items below that you think will most negatively impact utility delivery of water and/or sanitation services in the region(s) where your organization operates over the next ten years."
Q10b Please rank these items from 1 to 5, with 1 being the item of greatest concern and 5 being the item of least concern. (Please drag the items to reorder)

_____ Water scarcity (1)
_____ Decreased source water quality (2)
_____ Increased demand for water (3)
_____ Increased cost of electricity/energy (4)
_____ Increased labor costs (5)
_____ High levels of non-revenue water (6)
_____ Aging infrastructure (7)
_____ Inadequate capital funding (8)
_____ Insufficient revenues to cover operations and maintenance costs (9)
_____ Personnel turnover (10)
_____ Lack of qualified staff (11)
_____ Vandalism (12)
_____ Above average temperatures for several months (13)
_____ Abnormally high temperatures for days or weeks (14)
_____ Below average temperatures for several months (15)
_____ Above average precipitation for several weeks or months that did not result in flooding (16)
_____ Drought (17)
_____ Flooding (18)
_____ Sea level rise (19)
_____ Cyclones (20)
_____ Other (please specify) (21)
_____ I prefer not to answer (22)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected
Q13a How concerned are you about climate change disrupting or interfering with your utility's delivery of water or sanitation services over the next 10 years? Please indicate on the scale below where 0=Not concerned and 100=Extremely concerned.

_____ Level of concern (1)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected
Q11b How concerned are you about climate change disrupting or interfering with utility delivery of water and/or sanitation services in the region(s) where your organization operates over the next 10 years? Please indicate on the scale below where 0=Not concerned and 100=Extremely concerned.

_____ Level of concern (1)

This next section will ask questions about climate change adaptation, which refers to anticipating the negative effects of climate change and acting to prevent or decrease the damage these impacts can cause.

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q14a What do you think is the single-most effective action your utility can take to adapt to climate change? Please type response in the box below.

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q12b What do you think is the single-most effective action that the water/sanitation utility or utilities in the region(s) where your organization operates can take to adapt to climate change? Please type response in the box below.

Display This Question: If Please select the option below that most accurately describes your organization Water utility Is Selected

Q15a To what extent, if any, has your utility planned for climate change adaptation? Please select one answer below.

- ❍ We already have a climate change adaptation plan (1)
- ❍ We are in the process of creating a climate change adaptation plan (2)
- ❍ We are considering creating a climate change adaptation plan (3)
- ❍ We have no plans to create a climate change adaptation plan (4)
- ❍ I do not know (5)
- ❍ I prefer not to answer (6)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q16a Below is a list of some possible climate change adaptation strategies that a water or sanitation utility may employ. For each of the following, please indicate how effective you think each strategy would be in helping your utility adapt to climate change, from 0=Not at all effective to 100=Extremely effective.

_____ Develop hydrological models to predict precipitation and runoff and incorporate data into planning (1)
_____ Model future water demand and incorporate results into planning (2)
_____ Conduct climate change vulnerability assessment for the utility (3)
_____ Develop a drought plan (4)
_____ Encourage water conservation among customers (5)
_____ Water quality monitoring (6)
_____ Use of recycled wastewater (7)
_____ Implement conservation pricing (8)
_____ Increase water storage capacity (new reservoir/dams, more aquifer storage, etc.) (9)
_____ Use of alternative and/or on site electricity generation to reduce energy demands (10)
_____ Expand current water resources (11)
_____ Reduce non-revenue water (12)
_____ Build green infrastructure (green roofs, rainwater catchment systems, etc.) (13)
_____ Incorporate climate change considerations into infrastructure design/development (e.g. retrofit infrastructure to be flood resistant) (14)
_____ Water use restrictions (15)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q13b Below is a list of some possible climate change adaptation strategies that a water or sanitation utility may employ. For each of the following, please indicate how effective you think each strategy would be in helping the

utility or utilities in the region(s) where your organization operates adapt to climate change, from 0=Not at all effective to 100=Extremely effective.

_____ Develop hydrological models to predict precipitation and runoff and incorporate data into planning (1)
_____ Model future water demand and incorporate results into planning (2)
_____ Conduct climate change vulnerability assessment for the utility (3)
_____ Develop a drought plan (4)
_____ Encourage water conservation among customers (5)
_____ Water quality monitoring (6)
_____ Use of recycled wastewater (7)
_____ Implement conservation pricing (8)
_____ Increase water storage capacity (new reservoir/dams, more aquifer storage, etc.) (9)
_____ Use of alternative and/or on site electricity generation to reduce energy demands (10)
_____ Expand current water resources (11)
_____ Reduce non-revenue water (12)
_____ Build green infrastructure (green roofs, rainwater catchment systems, etc.) (13)
_____ Incorporate climate change considerations into infrastructure design/development (e.g. retrofit infrastructure to be flood resistant) (14)
_____ Water use restrictions (15)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q17a Below is a list of some possible climate change adaptation strategies that a water or sanitation utility may employ. Please select all of the things that YOUR UTILITY has done or is currently doing.

- ❑ Develop hydrological models to predict precipitation and runoff (323)
- ❑ Model future water demand and incorporate results into planning (324)
- ❑ Conduct climate change vulnerability assessment for the utility (325)
- ❑ Develop a drought plan (326)
- ❑ Encourage water conservation among customers (327)
- ❑ Water quality monitoring (328)
- ❑ Use of recycled wastewater (329)
- ❑ Implement conservation pricing (330)
- ❑ Increase water storage capacity (new reservoir/dams, more aquifer storage, etc.) (331)
- ❑ Use of alternative and/or on site electricity generation to reduce energy demands (332)
- ❑ Expand current water resources (333)
- ❑ Reduce non-revenue water (334)
- ❑ Water use restrictions (335)
- ❑ Build green infrastructure (green roofs, rainwater catchment systems, etc.) (336)
- ❑ Incorporate climate change considerations into infrastructure design/development (e.g. retrofit infrastructure to be flood resistant) (337)
- ❑ Other adaptation strategy (please specify) (338) _____
- ❑ We have not employed any climate change adaptation strategies (339)
- ❑ I do not know (340)
- ❑ I prefer not to answer (341)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q18a Where do you look for information/advice on climate change adaptation? Please select all that apply.

- ❑ Scientific, peer-reviewed literature (1)
- ❑ Other water utilities (2)
- ❑ Government officials or agencies (3)
- ❑ Consulting firms (4)
- ❑ Non-profit or non-governmental (NGO) organizations (5)
- ❑ Conferences/workshops (6)
- ❑ Other (please specify) (7) _____
- ❑ I have never looked for information on climate change adaptation (8)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

14b Where do you look for information and advice on climate change adaptation? Please select all that apply.

- ❑ Scientific, peer-reviewed literature (1)
- ❑ Water utilities/service providers (2)
- ❑ Government officials or agencies (3)
- ❑ Consulting firms (4)
- ❑ Non-profit or non-governmental (NGO) organizations (5)
- ❑ Conferences/workshops (6)
- ❑ Other (please specify) (7) _____
- ❑ I do not look for information on climate change adaptation (8)

Q20a/16b Please indicate to what extent you agree with the following.

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
My organization is taking sufficient action to adapt to climate change (1)	❍	❍	❍	❍	❍	❍	❍
Adaptation strategies are effective when it comes to preparing for the impacts of climate change (2)	❍	❍	❍	❍	❍	❍	❍
My organization is capable of successfully employing adaptation strategies (3)	❍	❍	❍	❍	❍	❍	❍
My government is taking sufficient action to adapt to climate change (4)	❍	❍	❍	❍	❍	❍	❍
My government is providing adequate financial support for climate change adaptation (5)	❍	❍	❍	❍	❍	❍	❍
Water and sanitation utilities are taking sufficient action to adapt to climate change (6)	❍	❍	❍	❍	❍	❍	❍
Donor agencies are providing adequate financial support for climate change adaptation (7)	❍	❍	❍	❍	❍	❍	❍

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Selected

Q21a Below is a list of potential barriers that could make it more difficult for your utility to develop and/or implement adaptation strategies. Please rank the following potential barriers from extremely significant (the factor(s)

that would most negatively affect your adaptation efforts) to not significant on the scale below, where 0=Not significant and 100=Extremely significant.

_____ Lack of funding (1)
_____ Corruption (2)
_____ Uncertainty of climate predictions (3)
_____ Climate predictions are not specific enough to be used for policy and management decisions (4)
_____ Not enough information about adaptation strategies and options (5)
_____ Lack of public concern about climate change (6)
_____ Lack of political concern about climate change (7)
_____ More pressing/immediate concerns (8)
_____ Lack of leadership (9)
_____ Lack of organizational capacity (10)
_____ Other (please specify) (11)

Display This Question:
If Please select the option below that most accurately describes your organization Water utility Is Not Selected

Q17b Below is a list of potential barriers that could make it more difficult for the water/sanitation utility or utilities in the region(s) where your organization operates to develop and/or implement adaptation strategies. Please rank the following potential barriers from extremely significant (the factor(s) that would most negatively affect the utility's adaptation efforts) to not significant on the scale below, where 0=Not significant and 100=Extremely significant.

_____ Lack of funding (1)
_____ Government corruption (2)
_____ Uncertainty of climate predictions (3)
_____ Climate predictions are not specific enough to be used for policy and management decisions (4)
_____ Not enough information about adaptation strategies and options (5)
_____ Lack of public concern about climate change (6)
_____ Lack of political concern about climate change (7)
_____ Other competing priorities (8)
_____ Lack of leadership (9)
_____ Lack of organizational capacity (10)
_____ Other (please specify) (11)

Q22a/18b Do you have any comments or reflections that were not addressed in this survey? If so, please share in the box below.

Follow-up: Thank you for taking the time to complete this survey. As someone in the water field, we are interested in your knowledge and opinions. Would you be willing to answer more questions in another online survey at a later date? If so, please provide your e-mail address and name in the spaces below.

E-mail address (1)
Full name (2)

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