Water supply risks and urban responses under a changing climate: A case study of Hong Kong

Liang Yang, Chunxiao Zhang, Grace W. Ngaruiya

Abstract: Hong Kong is often portrayed as a water abundant city because of its location in the subtropical zone. However, Hong Kong currently imports large volumes from the Dongjiang-Shenzhen Water Supply Project (DSWS Project) due to low local freshwater availability. The water situation is becoming more complicated with the population growth, economic development and difficulties in response/management. In addition, studies show that climate change is likely to increase rainfall variability, flood and drought events and damage water supply infrastructure in Hong Kong. Hence, ensuring sufficient freshwater availability is the major water management challenge for Hong Kong. This article discusses the issues in the current water supply system and also highlights the six interrelated risks within the context of climate change, namely: drought, rainstorm/flood events, sea-level rise, water pollution, social management and policy gaps in Hong Kong. In conclusion, it suggests that for a sustainable future, Honk Kong needs to invest in improving water self-sufficiency, diversify water sources and conduct aggressive public awareness to increase individual adaptation to predicted climate change impacts.

Keywords: Water supply, water risk, climate change, response measure, Hong Kong

[Submitted as Scientific Paper: 12 March 2012, Acceptance of the revised reviewed manuscript: 2 July 2012]

Hong Kong, located in the Pearl River Delta (PRD) in southern China, is often portrayed as a subtropical area with abundant water resource. However, this is only a part of the full picture of the complicated water issues. Theoretically, Hong Kong has access to water resources as it is surrounded by the South China Sea and the city receives high annual rainfall amount. However, Hong Kong had to limit water supply in 1960s because of a serious drought creating a water shortage (Liang, 1997). Although the current water supply system supports the water demand effectively, water shortage in Hong Kong is still a concern (Woo, 1992; Lai & Tao, 2003). Furthermore, global climate change adds new challenges from another dimension (Du, 2009), together with population growth and development activities, rendering the water issue even more complex.

Source: Michael Waibel 2009

Hazy View of West Kowloon

Water system management is both complex and politically difficult, requiring expert knowledge available for decision-making (Hunt, et al. 2007). In order to enrich the response capacity in Hong Kong, it is necessary to understand the characteristics of water supply system and related risks. This article aims to draw a wide, although not exhaustive, picture of the water supply challenges in the context of climate change in Hong Kong. Section 2 gives a brief description of the research methods used and the type of data collected. Secondly, a discussion on the challenges facing water harvesting in Hong Kong is given in section 3. Section 4 deals with climate change trends and its predicted influence in the Hong Kong water supply system. Then, a description of how water supply is managed in Hong Kong is presented in section 5. This enables us to identify the shortcomings in current water supply system which are most likely to trigger risks, in particular in the context of climate change. Then, we suggest. Followed we suggest a framework that analyses the water supply risk elements with their corresponding pathways in section 6.

Method and Data

This paper is based on a field trip to Hong Kong in December 2011 and as well as on secondary literature. Empirical analysis and literature review were taken through the whole work of this paper. Primary data was collected from expert discussions with academic staff, relevant institutional officials and field visits to the study sites. Secondary data was obtained from journal articles and government publications. Data used for climate change trend were derived from the Hong Kong Observatory (HKO), while information on water issues were provided mainly by the Water Supply Department (WSD) of Hong Kong Government.

Current water supply issues in Hong Kong

Even though there are many aspects in dealing with water supply, we chose five main points that are related to the climate change agenda to give an accurate overview of the challenges facing efficient water harvest in Hong Kong.

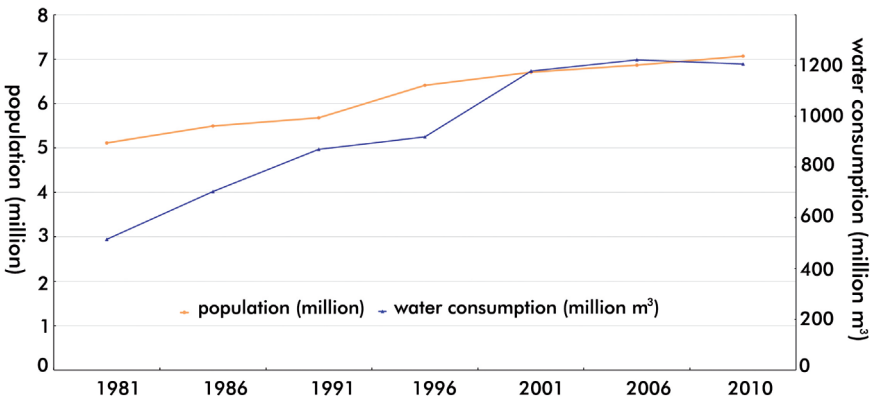
Abundant but hardly usable rainfall: Hong Kong is located in the subtropical monsoon zone with abundant annual rainfall. The average annual precipitation during 1981-2010 was 2398.5mm in HKO's records, which equals an average annual rainfall of 2648 million cubic meters for the whole Hong Kong area. With an actual water consumption of 1206 million cubic meters in the year 2010 (WSD, 2012a), it would appear that Hong Kong could theoretically satisfy its water demands with rainwater. However, it's impossible to collect that high proportion of rainwater in practice because of technical difficulties at the city scale. Another reason is the uneven inner-annual rainfall distribution. 80% is received between May and September while 20% is received in the dry season from October to April (HKO, 2012). Thus, it is a considerable level that current Hong Kong rainwater collection has reached around 10% (WSD, 2012a). Nevertheless, this calls for more focused efforts in efficient rainwater harvesting.

Poor conditions for water storage: The landscape of Hong Kong is made up of several peninsulas and a group of small islands, of which about three quarters are covered by hills and another quarter by urban facilities. Due to the small area involved, rivers rise and end quickly, such as the Shing-Mun River and Shek-Sheung River (less than 5 km). Thus the runoff comprising mainly of surface rain water cannot be used after it drains to the sea. Furthermore, Hong Kong has few and small natural reservoirs, and it lacks underground water storage capacity due to the granite and volcanic rocks (Su, et al., 2008). Therefore, Hong Kong has unfortunate nature conditions for water storage, which gives another reason why the abundant rainwater is hardly usable. Despite these challenges Hong Kong has several artificially constructed reservoirs which play a very important role (see section 5).

High dependence on freshwater import: Hong Kong started to import freshwater from Shenzhen in the Guangdong Province in 1960. This was further developed into the Dongjiang-Shenzhen Water Supply Project (DSWS Project) that transfers Dongjiang water to Shenzhen and then to Hong Kong. Currently, this DSWS Project supplies more than 70% of the freshwater demand in Hong Kong (WSD, 2012a). Implementation of the Dongjiang Water distribution plan by the Guangdong authorities makes this activity sustainable and mitigated the contradiction between freshwater supply and demand in Hong Kong. Even though this water has contributed significantly in rapid development of the city for the past 50 years, it also shows the high overreliance of Hong Kong on the Dongjiang water.

High water demand: The two main water consumers in Hong Kong are the domestic and service sectors like tourism. These sectors consumed 79.7% of the total freshwater in 2010 (WSD, 2012a). Continual population growth has increased water consumption significantly in the last three decades (Figure 1). The graph depicts that the water consumption has increased at a greater rate (2.9%) than population growth (1.1%), suggesting that water use pattern has changed (increasing consumption per capita). Alongside economic development, tourism has also increased, rising further the already high water demand. Records show that in 2011, a total of 41.9 million persons visited Hong Kong, of which 22.3 million are overnight visitors and their average stay is 3.6 nights (TDHK, 2011).

Resident numbers for Hong Kong are high, and they are increasing



Source: Census and Statistics Department and Water Supplies Department, Hong Kong

Figure 1 Population and water consumption of Hong Kong in 1981-2010

further. Future population projection shows that the Hong Kong resident population will increase to 8.47 million in the year 2041 (CSD, 2012). Thus, a much higher water demand could be expected in the future and calls for urgent water supply initiatives.

Poor leakage and maintenance management: Although Hong Kong has a complete water supply system, operational effectiveness is lacking. The major problem is the annual 20% water loss from the aging water pipe network (WSD, 2012a). This network, comprising underground arterial pipes of about 8000 kilometers in length, is subject to internal water pressure and harsh external influences such as road traffic and ground movement/subsidence and is vulnerable to damage. In addition, natural hazards, like flooding and landslides that often occur in heavy rainfall or storm, occasionally damage water supply infrastructures and result in water loss/outage. Whilst upgrading existing mains is critical in the reduction of water loss along major water mains, this could also be strengthened using district monitoring and pressure management technologies.

Impacts of climate change on Hong Kong's water supply

Climate change poses a significant challenge to water resources in numerous regions. Studies have shown that concentrated areas of human society development such as cities are among the most vulnerable regions to climate change impacts (Stern et al. 2006; IPCC 2007). This section gives an overview of climate change and its effects on freshwater resources in Hong Kong.

Precipitation increased by 36 mm per decade for 65 years after World War II (HKO, 2012) (Figure 2). The notable interannual variability indicates that extreme precipitation events occur frequently in Hong Kong during this period (Ginn, et al. 2010). Between 1954 and 2011, the average sea level showed an average increase of 2.8 mm annually at Victoria Harbour (Figure 2). Precipitation projection results indicate that annual rainfall in Hong Kong is expected to rise by the end of the 21st century, and heavy rain events from year-to-year are becoming more frequent (Ginn, et al. 2010). But considering the situation of Hong Kong, more rainfall does not mean more usable water. Without proper management, heavy rainfall would even damage the existing water supply system. Furthermore, future sea level rises near the Pearl River Estuary would exacerbate storm surge flood and the incursion of salty water into fresh water (Wong, et al., 2010).

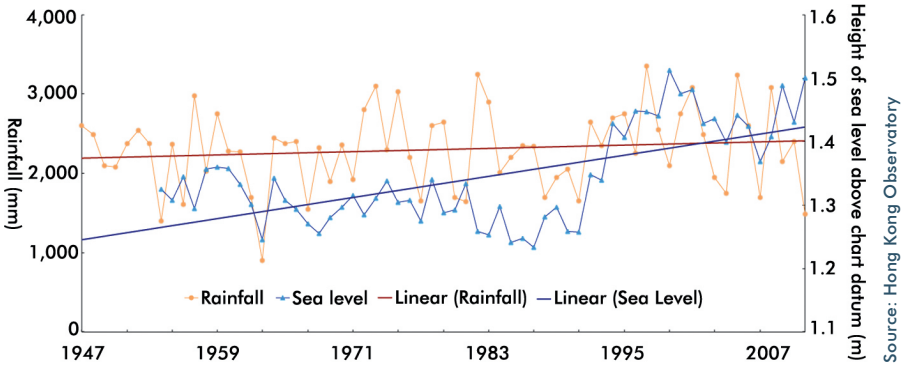


Figure 2 Changes of precipitation and sea level in Hong Kong

Apart from the general trend of climate change in Hong Kong, extreme weather events (e.g. rainstorms, typhoons and landslides, drought, high tides) have even more impacts on the water supply system (Wong, et al. 2011). According to the HKO reports, the increasing frequency of extreme weather events would lead to increased flood probability (Ginn, et al. 2010). Water infrastructure is particularly at risk in some low-lying and poorly drained areas near rivers that are marked as flood-prone areas (Chan, et al. 2010).

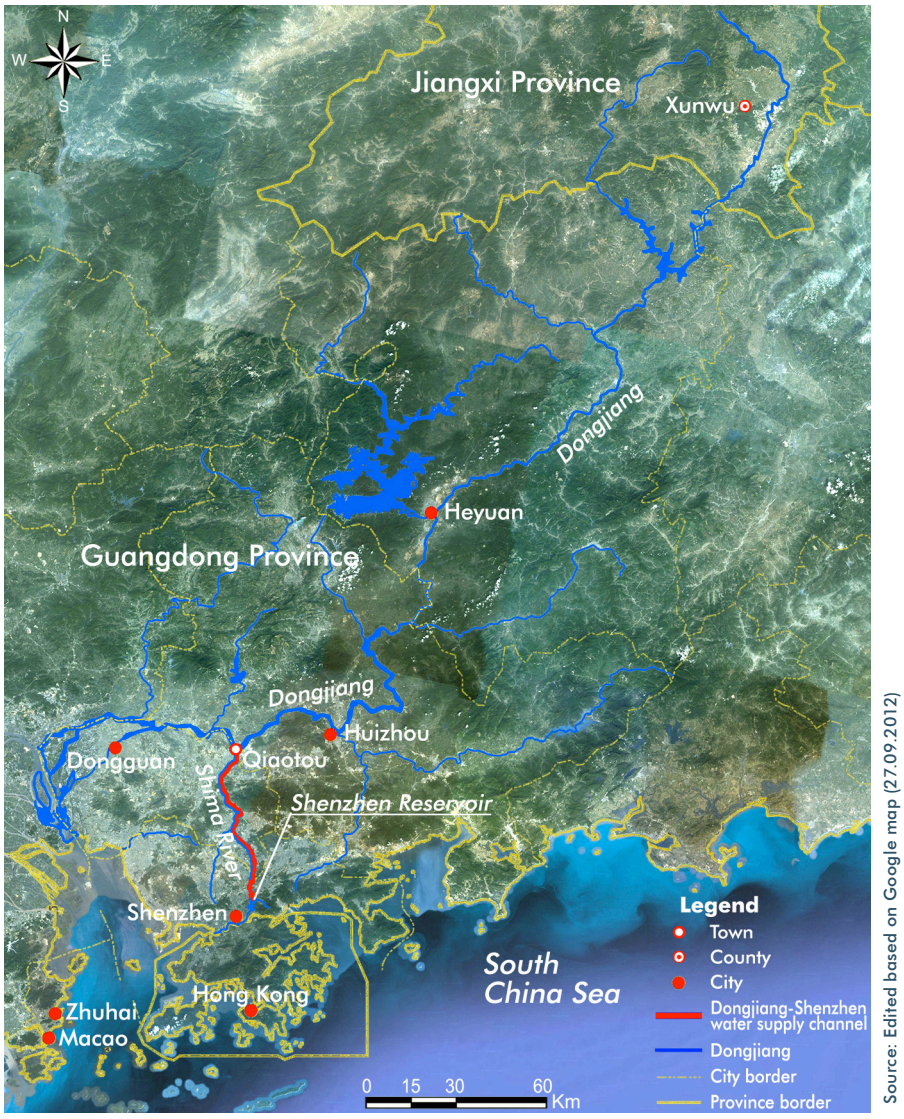


Figure 3 Brief outline of the Dongjiang river system highlighting the DSWS Project

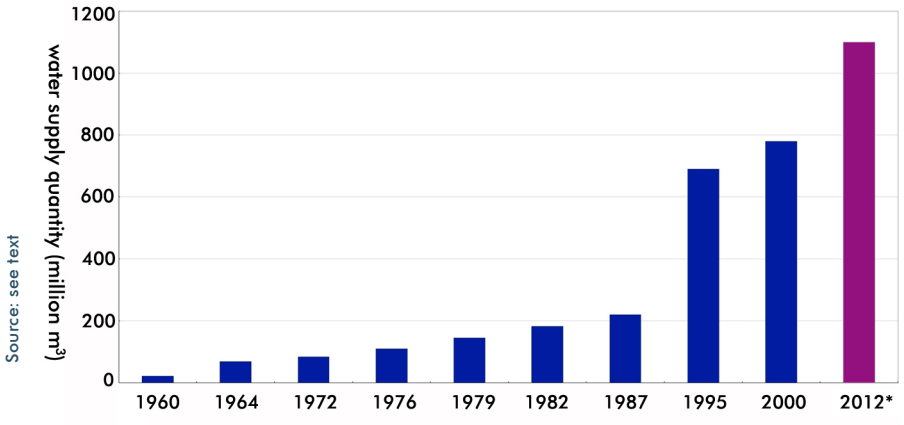


Figure 4 Amount of water supply to Hong Kong by DSWS Project

*The value in 2012 is not the actual water supply value, but the maximum capacity of the DSWS project

This is even more likely to be the case during cyclones when seawater is forced up the rivers, invading freshwater systems or damaging engineering facilities. These disasters intensify water risks in Hong Kong and make water management more complicated. In addition, high evaporation in the subtropical region contributes significantly to water losses (Liang, 1997). This should be in concern if we aware that the average temperature per decade increased from 0.15°C between 1947 and 2011, to 0.23°C between 1982 and 2011 (Hu, et al. 2011), and the trend will continue in the 21st century (Ginn, et al. 2010).

Aspects of water supply management in Hong Kong

The Hong Kong Government has implemented a series of measures to address this water predicament, achieving remarkable success. However, some challenges still exist, which will be elaborated while we introduce the measures in this section.

The Dongjiang–Shenzhen Water Supply Project (DSWS Project): Dongjiang (East River) originates in the Xunwu County of Jiangxi Province, flows through Heyuan city, Huizhou city, Dongguan city of Guangdong Province and drains into the sea. Several branch streams flow from Shenzhen to the mainstream (Figure 3). The DSWS Project starts from Qiaotou town of Dongguan. Water is pumped and pipelined 46 m higher, backwards along the Shima River (a branch of Dongjiang) to the Shenzhen Reservoir and then to Hong Kong.

The water supply to Hong Kong has been increasing in the last 50 years (Figure 4) with a corresponding change in the agreement. The significant increase around 1990 can be attributed to population growth and economic development after adoption of the "Sino-British Joint Declaration on the Question of Hong Kong". The second extension of the DSWS Project in 1987 and the third in 1994 supported this increase in time. Currently, the actual water supply to Hong Kong is 800-900 million m^3 annually, which is nearing the maximum capacity of the project (1100 million m^3 per year) (Hong Kong DNPC, 2011).

However, the project faces significant challenges due to social and economic differences between the cities in the river basin. Economically, the upper cities (Heyuan, Huizhou) have far lower development level (consider GDP per capita and urbanisation rate) than the downstream cities. That means these upper cities are poor, underdeveloped, and have less economic power. The region is also politically complicated. Normally there are four administrative levels (nation, province, city and county), but Hong Kong is a Special Administrative Region between the level of nation and province, and Shenzhen is a Special Economic Zone between the level of province and city. Higher administrative levels have stronger political power. Thus interestingly the Dongjiang water flows down from Xunwu, Heyuan to Huizhou, Dongguan, and is then pumped to Shenzhen and Hong Kong, while the political-economical power goes up in the same city sequence. This means that water resources from the upper area are traded for money or other benefits from the downstream cities, with strong political tint. This system of trade appears to be balanced. But this balance depends highly on both sides' resource quantity (water in the upper cities and money of the downstream cities) and trade intention (whether they would like to exchange). It could easily be broken by a drought or pollution that reduces the available source water, or a change in social /economic field that raises the unwillingness on trade. Thus, should climate change affect the water supply either in terms of quality or quantity then this will affect the relationships between stakeholders.

Increased rainwater harvest: Hong Kong has always looked for more effective uses of its rainwater resources. An ongoing project is the construction of diversion channels on hillsides, which channel precipitation and mountain streams into reservoirs. So far, rainwater is diverted to 17 reservoirs in a third of Hong Kong area. For example, the High Island Reservoir has the largest storage capacity and Plover Cove Reservoir has the largest area. These two large bay reservoirs account for 87 % of total reservoir capacity (5.86 x 108 m^3) in Hong Kong (WSD, 2012b). In addition to saving collected rainwater, the reservoirs also play a role in regulating and storing the water from the DSWS Project.

To further increase rainwater harvest, one proposal is to expand the rainwater catchment's area and storage capacity of reservoirs in Hong Kong. However, this proposal is not favored by the city because land development in the catchment area would be restricted (Ku, 2003). Actually, one-third of the land has been protected as rainwater catchment area in Hong Kong. And, this plan has a complication in that a larger water catchment area could increase surface contaminants flow into the reservoirs. So the proposal is not a prior option in the near future. Recently, a feasible plan initiated by Hong Kong Government is to identify a number of parks and public buildings to collect rainwater for flushing and irrigation. The plan would be spread if the preliminary experiment works effectively.

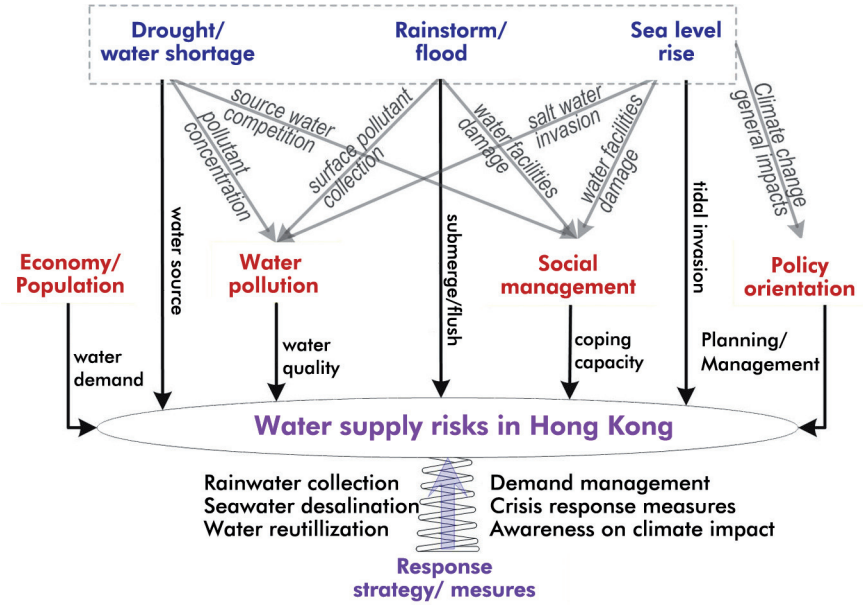
Seawater desalination and utilization: Hong Kong established a desalination plan in 1971. Six groups of desalination equipment were built with the production of 30.3 thousand m3 fresh water per group per day (WSD, 2012c). However, after only operating from 1976 to 1982, it was deconstructed in 1992 due to high running costs and the cheaper and constant water supply by DSWS Project.

Besides desalination, seawater is used for flushing toilets, an activity done from 1950. It is now a major

feature of the urban water supply in Hong Kong. The seawater flushing system has a separate water distribution pipes, pumping stations and service reservoirs. Seawater is pumped and filtered through grids to remove the larger impurities. It is then disinfected to standard quality requirements and distributed to households. Currently the annual consumption of seawater in Hong Kong has reached over 200 million m^3, which saves the same amount of fresh water and accounts for about 18 % of the total water consumed (WSD, 2012b). Since about 80% of the residents use seawater for flushing, this percentage is expected to increase to 90 % in future (WSD, 2012a). In some areas of Hong Kong, seawater has also been used as the municipal fire-fighting water.

Wastewater treatment and reuse: Increasing freshwater production inherently results in increased pressure on wastewater treatment and disposal infrastructure. The Hong Kong Environmental Protection Department issued a "Water Quality Indicators of Wastewater Treatment for Landscape Irrigation" guide in 1994. This contained regulations and methods to promote and inform stakeholders on water reuse in irrigation. However, few treated water reuse projects have been launched in Hong Kong presently, one of them being a project of Hong Kong's new airport on Lantau Island, in which part of the drainage is treated and reused for irrigation. One reason for the low uptake of water reuse initiatives is the absence of water scarcity due to the constant supply by the DSWS Project and seawater flushing. The situation reflects that Hong Kong's strategy of increasing the sources of freshwater does not address wastewater issues in an integrative way. This might change should the water status change with increase in climate change impacts.

Water demand management: Hong Kong uses a multi-level water charging system to promote water conservation. The payment system has several levels of water consumption levels with corresponding increasing prices. Thus, the water cost per household differs according to their consumption in a certain period. The higher the consumption, the higher price charged by the supplier. This payment strategy enhances public awareness of water conservation by reducing waste and in turn reducing household water demand.



Source: Authors

Figure 5 Framework of water supply risks in Hong Kong

Furthermore, the Hong Kong WSD has also developed a number of other water-saving provisions, such as changing water from swimming pools once a year, using water-saving faucets at public places, which all have further contributed to water conservation and reducing water consumption.

Discussion of risks to water supply in Hong Kong

As discussed previously, the water supply situation in Hong Kong faces various challenges from both climate impacts and social activities. Apart from the pressure of increasing water demand by population growth and economic development, we have discussed six major but interrelated risks, namely: drought, rainstorm/flood events, sea-level rise, water pollution, social management and policy (Figure 5). Figure 5 also shows the pathways or area to be addressed for every risk described.

Drought in the water source area: Given the fast development and growing water demand of the upper cities, competition for Dongjiang water is expected to increase. Despite that Hong Kong gets the water supply guarantee by DSWS Project, should there be a significant drought in the Dongjiang River basin (has occurred in 1963) the effects would be severe and might cause tension between upper stream cities and the downstream cities. Even a moderate drought would have a ripple effect in the system, whereby less flowing water would be more vulnerable to pollutants and would result in an increase in pollutant density. Lower reserve volumes would also make water pumping more expensive due to higher electricity consumption which in turn would increase consumer water prices. Thus, additional water sources need to be introduced into the system as a backup measure.

Rainstorm/flood events: The anticipated increases of rainfall amount from climate change might overload the storm water prevention system and increase the number of flood disasters in Hong Kong. Flood from the rainstorms may not only collect surface pollutants and bring them to freshwater but also damage water supply pipe network through associated landslides or soil erosion. Thus there is need to invest in flood alarm and prevention, e.g. regular drainage checks to remove blockage and enhance flow.

Sea-level rise: Hong Kong is a highly urbanized city with significant artificial facilities that are threatened by natural riverbed siltation and climate related sea-level rise. In case the sea water entry into the urban system it would threaten water infrastructure through erosion from the salts and flood flushing. The two largest freshwater reservoirs are especially more vulnerable if offshore pollutants along with salty sea water flow into it. Another suggested course of action includes regular checks in tidal flows and drainage of sea water from the system.

Water pollution: Cities in the upper reaches of Dongjiang River Basin, Huizhou and Heyuan, have accepted setting up of many of the transferred industries from the Pearl River Delta. This combination of industrial contamination, agricultural pollution and dispersive rural sewage is making the water quality of Dongjiang River worse and threatens the supply to Hong Kong and other downstream cities (Liu, et al. 2012). To control water pollution at the source, the upstream cities are restricted in their land development, sewage emission and use of pesticides, which therefore restrict the development of industry and agriculture. Also, Shenzhen and Dongguan demand more water from the DSWS Project but continue to discharge sewage to the Dongjiang River, which makes the situation much more complicated. Even though the upstream cities ask for economic compensation for restricted development and the downstream cities might be willing to compensate them, specific agreement is hardly reached and no comprehensive compensation mechanism exists (Zhou, 2008; He, et al. 2009), partly due to the complexity of this issue. Another pollution risk for Hong Kong water resource is from the surface ground pollutants that may be transported into reservoirs along rainwater. In such complicated situations on pollution, a multidimensional solution is needed to adequately address all sources of pollution.

Social management aspect: Although Hong Kong returned to mainland China 15 years ago, social and cultural conflicts between the two still exist although at low intensity. Hong Kong is highly dependent on fresh water, electricity and food from the mainland, but its citizens used to complain about the air pollution from the Pearl River Delta cities in the mainland (Lu, 2007). On the other hand, many mainland people go to Hong Kong for high quality medical care, education or shopping. Some Hong Kong citizens dislike this movement and view it as a reason for the reduction in Hong Kong's public resources. While the mainland people view this attitude as discrimination. These low level societal tensions could be the beginning of large-scale resources conflicts in the future and need to be addressed soon. Another side of social management is to cope with emergency events efficiently and effectively, for example, in a sever water outrage or pollution event, which has been discussed in section 2.

Policy risk: Due to the abundant Dongjiang water, Hong Kong has not seriously invested in self-sufficiency water supply mechanisms in the latest years apart from the experimental seawater desalination. Also, climate security consciousness is still in its infancy in Hong Kong and there has not been an integrated "climate response" policy between urban development, water supply and climate impacts. Even though the public knows about climate change they lack deeper awareness of possible water supply risks under climate impacts. Thus, many options are available but are not implemented because they are not taken seriously. It would be a potential risk for the city if this policy gap continues as it would bring down the public awareness of risk and reduce measures for precaution.

Researchers suggest that the main goal of all adaptation strategies should be to improve local resilience, or the ability of a community to bounce back quickly from climate impacts (CCAP. 2009). Thus to reduce potential water supply risks, the city needs to implement relevant response measures. The response strategy may be done in two ways. One is to improve the self-sufficiency rate of water supply, which is possible by extending the reservoirs' capacity or seawater desalination. The other is to diversify water source options, for example, water treatment and reuse. These will reduce over-reliance on imported water which is the biggest potential risk. Apart from these, possible strategies to increase resilience include options of demand management technology and crisis response measures. Also, public awareness campaigns on climate change impacts and response strategies need to be undertaken so that people in Hong Kong can prepare for climate change impacts. Finally, further research on urban responses to climate impacts will support decision making to mitigate potential water risks. Following this paper, a risk assessment of the Hong Kong water system is undertaking, and a simulation on the urban responses to climate impact and water risk in the Pearl River Delta has also been proposed using multi-agent model.

Conclusion

Hong Kong is a city with sufficient average precipitation, but it still suffers from water shortage because of natural and social conditions. Most of the drinking water is transferred by DSWS Project from Guangdong, sustained by political and economic power in a water supply agreement. However, should conditions change, like a severe drought or pollution in the Dongjiang River basin, it could become a potential social security problem. In addition, although urban development and water supply-drainage systems are well designed and planned in Hong Kong, natural hazards like extreme weather events could destroy water related infrastructures, especially in the context of global climate change. Lack of public awareness on climate impacts has also made the government take few measures to deal potential climate risks. It's clear that ensuring sufficient freshwater availability is the major water management challenge for Hong Kong. To reduce risks in the future, it's absolutely crucial for Hong Kong to improve its self-sufficiency rate of water supply and diversify water sources

Acknowledgement

The authors are grateful to Prof. Dr. Jürgen Scheffran and Dr. Janpeter Schilling for valuable comments on academic issues and improving the text. Cordial thanks are extended to the two anonymous reviewers for their professional comments and generous suggestions. The research work was financially supported by the China Scholarship Council (CSC) and the Cluster of Excellence 'CliSAP' (EXC177) in Germany.

References

CSD (Census and Statistics Department) of Hong Kong (2012). Hong Kong Population Projections (2012 – 2041).

CCAP (Center for Clean Air Policy) (2009). Ask the Climate Question: Adapting to Climate Change Impacts in Urban Regions. Washington, DC. USA.

Chan, F., Loh, C., MacDonald, A., Mitchell, G., & Adekola, O. (2010). Rich Delta, Costly Flooding. Civic Exchange: Hong Kong.

Du, J. (2009). Analysis on Variation of Water Features and the Corresponding Drought Risk in Dongjiang River Basin. Master thesis, Institute of Geography of Sun Yat-sen University: Guangzhou. In Chinese.

Ginn, W.L., Lee, T.C., & Chan, K.Y. (2010). Past and Future Changes in the Climate of Hong Kong. Acta Meteorology Sinica, 24(2), 163-175.

He, T., Ma, X.L., Peng, X.C, & Li, T.R. (2009). Problems and Contradiction in Water Resources Environmental Management of Dongjiang Basin. Water Resources Protection, 25(6): 5. In Chinese.

Hong Kong DNPC (Delegation of National People's Congress) (2011). Summery Report of the Investigation on Pollution Prevention of Dongjiang Water Source. http://www.npc.gov.cn/npc/gadbzl/xgdbzl_11/2011-04/08/content_1650698_16.htm. Retrieved 3 July, 2012.

HKO (Hong Kong Observatory) (2012). Monthly Meteorological Normals for Hong Kong (1981-2010). http://www.weather.gov.hk/cis/normal/1981_2010/normals_e.htm, Retrieved 21 September, 2012.

Hu, W.Z., Chen, H.X., & Hao, M.Q. (2011). Analysis on inter-daily variability and long-term trend of Hong Kong temperature. Presented in the Twenty-fifth Seminar of Meteorological Science and Technology among Guangdong, Hong Kong and Macao, 26-28 January 2011, HKO Reprint No. 955.

Hunt, J.C.R., Maslin, M., Killeen, T., Backlund, P. & Schellnhuber, H.J. (2007). Introduction Climate change and urban areas: research dialogue in a policy framework. Philosophical Transactions of the Royal Society, 365 (1860), 2615-2629.

IPCC (Intergovernmental Panel of Climate Change) (2007). Working Group II Report "Impacts, Adaptation and Vulnerability" of the fourth assessment report of the Intergovernmental Panel of Climate Change.

Lai, J.C-L., Tao, J. (2003). Perception of Environmental Hazards in Hong Kong Chinese. Risk Analysis, 23(4): 669-684.

Ku, C.C. (2003). Overview on the Integrate Utilization of Water Resource in Hong Kong. International Water Forum in Southern China: Shenzhen, 2003.07.16. In Chinese.

Liang, G.Z. (1997). Water Shortage in Hong Kong and Development of Water Resources in the Dongjiang Basin. Tropical Geography, 17(2), 131-138. In Chinese.

Liu, S., Yang, Y.. Lu, H.Y., Deng, T.C. & Immanuel (2012). Dongjiang Overloaded – 2011 Dongjiang Expedition Report. Civic Exchange: Hong Kong.

Lu, G.H. (2007). Analysis on the Source of Air Pollution in Hong Kong. Wen Hui Po. http://paper.wenweipo.com/2007/04/17/WW0704170006.htm. In Chinese. Retrieved 3 July 2012.

Stern, N. (2006). The economics of climate change: the Stern review. UK Government.

Su, W.X., Deng, L.J., Xiao, W.L. (2008). Hong Kong Geology: A 400-Million Year Journey. Civil Engineering and Development Department, Hong Kong.

TCHK (Tourism Commission of Hong Kong) (2011). Tourism Performance in 2011. http://www.tourism.gov.hk/english/statistics/statistics_perform.html. Retrieved 19 September, 2012.

WSD (Water Supply Department) of Hong Kong (2012a). Annual Report of the Water Supply Department (2010/2011).

WSD (Water Supply Department) of Hong Kong (2012b). Key Facts of the Water Supply Department of Hong Kong. August 2012.

WSD (Water Supply Department) of Hong Kong (2012c). Milestones of Hong Kong Water Supply. http://www.wsd.gov.hk/tc/education/history/wsd_milestone/. Retrieved 19 September, 2012.

Wong, M.C., Mok, H.Y., Lee, T.C. (2011). Observed changes in extreme weather indices in Hong Kong. International Journal of Climatology, 31, 2300-2311.

Wong, W.T., Woo, W.C. (2010). Sea-level Change: Observations, Causes and Impacts. Presented in Hong Kong Institute of Engineers Conference on Climate Change - Hong Kong Engineers' Perspective, 18-19 October 2010, HKO Reprint No. 925.

Woo, C.-K. (1992). Drought management, service interruption, and water pricing: Evidence from Hong Kong. Water Resource Reservation, 28(10): 2591-2595.

Zhou, Y. (2008). Dilemma and Outlet of Ecological Compensation in River Basin Scale – An analysis of the Dongjiang River Basin. Journal of Public Administration, 2:7. In Chinese.

Liang Yang [liang.yang@zmaw.de] is a PhD-candidate within the research group 'Climate Change and Security' (CLISEC), Department of Geography, KlimaCampus, University of Hamburg, Grindelberg 5, D-20144 Hamburg / Germany.

Chunxiao Zhang [chunxiaozhang@cuhk.edu.hk] is a PhD-candidate at the Institute of Space and Earth Information Science, The Chinese University of Hong Kong, Fok Ying Tung Remote Sensing Science Building, The Chinese University of Hong Kong, Shatin / Hong Kong.

Grace W. Ngaruiya [grace.ngaruiya@zmaw.de] is a PhD-candidate within the research group 'Climate Change and Security' (CLISEC), Department of Geography, KlimaCampus, University of Hamburg, Grindelberg 5, D-20144 Hamburg / Germany.

Source : Michael Waibel 2009

Sunset View of Hong Kong Skyline