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"Flood risk appraisal and management in mega-cities: A case study of practice in the Pearl River Delta, China" (Oral presentation)

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Short Abstract

In recent decades, the Pearl River Delta (PRD) region has experienced strong economic and population growth. By 2050 120 million people are expected to live in the region, which currently has eleven major cities, and the emerging mega-city formed by Hong Kong, Shenzhen and Guangzhou. The populous coastal cities and low lying flood plains in the PRD experience flood risk via: (i) intense precipitation from storms, (ii) inland pluvial flooding, (iii) storm surges. Climate change, including global sea level rise forecasts of more than 1 metre by 2100, mean that flood risk is expected to increase in future. Sustainable flood risk management must be adopted to mitigate these risks. Strategies such as the UK's "making space for water" programme seek to tackle flood risk through planning, but such a strategic approach is not evident in the PRD. Recent coastal land reclamation projects in the PRD illustrate the conflict between urban growth pressure and flood risk, and that more comprehensive, or sustainable, flood risk management is not currently practiced. This paper examines flood risk management practice in the PRD. It starts with a theoretical sustainable flood risk appraisal (SFRA) template developed from literature and global best practice, against which PRD practice is benchmarked. The paper discusses a case study in Hong Kong and Shenzhen where in-depth discussions with more than 30 stakeholders were held to understand barriers and constraints to realising sustainable flood risk management. This research seeks to further the practice of sustainable flood risk management in the PRD, and comparable urbanising mega-deltas in the region.

Keywords: Climate change; sea-level rises; and sustainable flood risk assessment strategy

Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that sea level will rise between 0.65m and 1.3m globally by 2100. If the global temperature rises faster than expected, then glaciers in the Arctic will also melt more quickly. Recent research suggests that projected sea level rise may reach 1.9m by 2100, which is up to three times higher than that predicted by the IPCC (Vermeer and Rahmstorf, 2009). Sea level rise will increase the impact of storm surges, causing particular impacts on deltaic regions.

Furthermore, climate change will cause an increase in cyclonic events (e.g. typhoons), which in turn will increase the probability of coastal and inland flooding. Numerous studies have revealed increases in the frequency, magnitude and size of tropical storms in the Pacific region over the last 30 years (Elsner et al., 2008). Storm-related floods account for over 70% of total flood events in Asia's large coastal cities, such as Jakarta and Manila. Sea level rise and storm surge risks are estimated to already affect more than 362 million people in Asia's coastal areas (Fuchs et al., 2011).

In this sense, coastal areas in the Pearl River Delta (PRD) are no different to other deltaic regions under threat from flooding. Big cities in the PRD region including Hong Kong and Shenzhen face increasing flood risk from: (1) sea level rise; (2) increasing frequency of storms and surges, and (3) inland pluvial flooding caused by more intense precipitation. The sea level in the PRD is predicted to rise at a rate of between 4.1 and 4.6 mm/year, which translates to an increase of about 20cm by 2050 (Lam & Lam, 2005). Even this modest forecast rise will lead to inundation of more than 2,000km^2 in the PRD coastal area and a large part of the delta plain will be more vulnerable to tidal inundation. Over 1 million people would be forced to relocate. If sea level rises by 1m, inundation will affect more than 6,500km^2 in the PRD where nearly the whole coastline will be overcome by sea water (Zhang, 2009).

Coastal cities in the PRD, not only experience flood risk from storm surge and global sea-level rise, but will also be influence by intense precipitation from typhoons. The Hong Kong Observatory (HKO) noted that the return period of intense rainstorms has shortened over the last century (Lee et al., 2010). Inland pluvial flooding is thus likely to overload the flood water capacity of the urban drainage system, especially considering recent land-use changes and rapid urbanisation in the region. The PRD region is on its way to becoming a mega-deltaic region with an expected population of over 120 million people by 2050 (Canton, 2011). This urban growth has placed Hong Kong and Guangzhou in the top ten of global coastal cities at risk from climate change (Nicholls et al., 2007). Coastal and inland flood management strategies must cope with these pressures, yet it is evident that in the PRD, appraisal strategies informing such strategies are relatively undeveloped, and neglect to address a broader range of concerns compatible with sustainable development. This means that wider opportunities for flood risk mitigation are overlooked, and hard-engineering solutions continue to dominate.

This research, therefore, aim to addresses the issue of appraisal in flood risk management, with a view to identifying barriers to, and opportunities for, more sustainable flood management strategies in the PRD region.

Methods

A case study approach for understanding sustainable flood risk management (SFRM) practice in the Pearl River Delta was adopted. We focussed on experience of two sites in the Hong Kong region, using a qualitative approach.

A scoping study was first conducted to identify SFRM issues in the PRD. This comprised a review of global flood management practices and literatures so as to develop an idealised SFRM template against which to benchmark PRD practice. . It also included preliminary discussions with relevant stakeholders, such as the Drainage Service Department, Planning Department (DSD) and Civil Engineering and Development Department (CEDD) in Hong Kong, and Water authorities in Shenzhen. Such activities aimed to establish research networks for further field work; and indentify suitable study area(s) upon which to focus.

Two study sites were finally selected; Shenzhen River and Tai O town. These were selected so as to address inland and coastal flood risk management practice respectively. Both sites are important because of their recent flood history and the development and planning issues they face (See **Error! Reference source not found.**).

Table.1 Descriptions of the study sites on flood risk management

Location	Shenzhen River	Tai O
Characteristics	Transboundary River	Local fisherman town
Flood problem	Inland flood	Storm surge
Mitigation works	Hard Engineering	No mitigation works
Ecological and cultural features	Ramsar wetland, main spot for the migration birds	Indigenous fisherman town with high cultural and historic value
Future development	Planning study is in progress	Revitalization development plan is under studied

The Shenzhen River catchment is at the southeast southeast part of the Pearl River Delta, in South South China (See

Figure.1). The catchment is in the sub-tropical climatic region; the annual rainfall is about 1800 – 2200 mm. More than 85% of annual rainfall usually falls in the summer season (April to September). Typhoons can also enhance precipitation and contribute more than 700 mm annually. Intense rainfall that leads to pluvial flooding mostly occurs in the East low-lying floodplain area of Shenzhen and the North West floodplain in Hong Kong along the Shenzhen River (Lam & Lam, 2005). From 1980 – 2003, there were more than 24 flood events in Shenzhen and Hong Kong. On the Shenzhen side alone, 99 people died, and the estimated damage was more than 2.91 billion RMB.

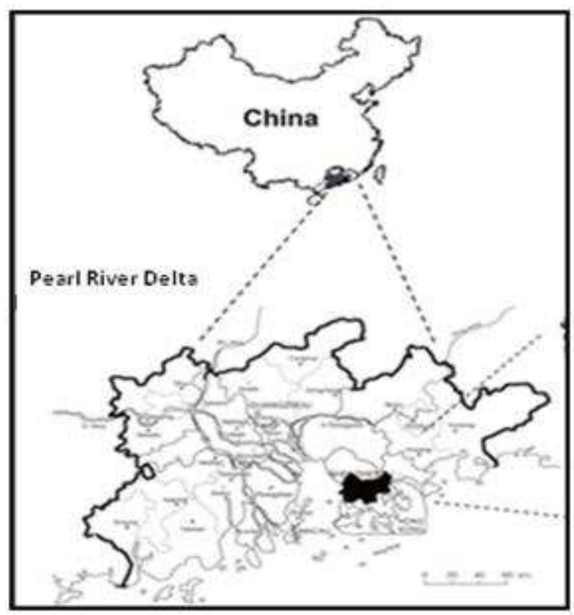

Figure.1 Geographical location of Shenzhen River Catchment area adapted from (Ng et al., in press).

The second study area is Tai O town in Hong Kong (See Figure.2). It is a traditional fisher town in southwest Hong Kong. During 2008 and 2009, typhoons Hagupit and Koppu enhanced storm surges; tidal gauges in the PRD recorded storm surges of 3.02 m to 3.77m (Lee et al., 2010). As a result, Tai O town centre was flooded during both events, and houses, shops, and community infrastructure (school, church, transport facilities) were all damaged.

Semi-structured face-to-face interviews were conducted to gather views of more than 30 stakeholders in these case study sites, including decision makers on FRA practice who could provide a general overview of approaches to flood appraisal and mitigation. Extensive secondary source material (e.g. governmental publications and literatures) is will also be analysed to gain a wider perspective on FRA in the PRD, and place the interview findings in context.

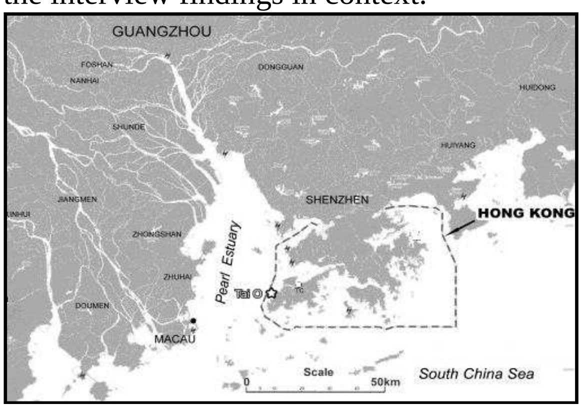

Figure.2 Tai O town location on the star spot adapted from (Wang et al., 2005).

Results

Firstly, the Shenzhen Municipality and the Hong Kong Government (under British administration prior to 1997) began discussing solutions to flooding problems in the early 1980s, and a phased plan to regulate the Shenzhen River was proposed. The Shenzhen River Regulation Office was then established in 1995 with the DSD and the Shenzhen River Board of the Shenzhen Municipal Government working in partnership. The purpose was to implement the Shenzhen River Regulation Project which, in four stages, would realign, widen and deepen about 17km of the Shenzhen River. The project cost was shared by both governments and the flood protection standard was raised to a 50 year/flood return period (Chui et al., 2006). However, both institutions are tackling flood risk through hard engineering perspectives (i.e. flood defence and control structures along the Shenzhen River), but have not yet addressed the core consequences of flood risk i.e. land use changes, planning and climate change.

It is evident that as a result of economic growth in the PRD, land use is changing dramatically. In Shenzhen, two-thirds (63.6%) of the agricultural land had been transformed to industrial and residential area from 1979 to 2005 (See **Error! Reference source not found.**). Rapid urbanisation means that flood risk increases as many more residents and businesses are exposed to flood hazards. Such developments also increase the likelihood of flooding due to human-induced hydrological changes (Shi et al., 2007). Several studies in Europe have indicated it will be difficult in future to mitigate flood risk through flood defense structures alone and so encourage policy makers to consider more holistic flood management policy. Approaches such as "Living with rivers" and "Making space for water", not only encourage provision of space for storing flood water (Hooijer et al., 2004; Johnson et al., 2007), but also conserve natural habitat at the same time. In the UK, government's Planning Policy Statement 25 (PPS 25) requires recognition of climate change and flood risk in development appraisal at local and regional level. PPS 25 seeks to promote proactive flood risk mitigation through planning, by for example, avoiding development in high flood risk areas, and ensuring that flood risk is adequately addressed in planning appraisal at project level (e.g. via Environmental

Impact Assessment) and plan level (via Strategic Environmental Assessment and Sustainability Appraisal).

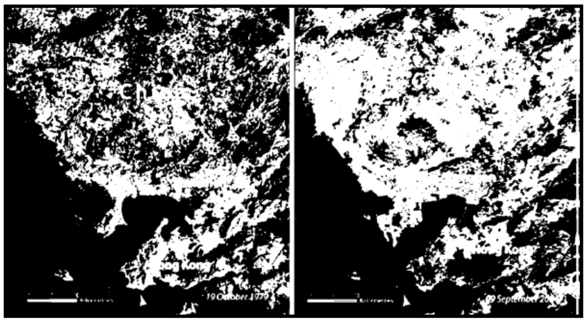

Figure.3 Landuse changes in Shenzhen from 1979 (Left image) to 2005 (Right image). White colour represents the populated area and dark colour represents the vegetation area (source: HKUST)

In Shenzhen, land reclamation along the Shenzhen River estuary means that flood storage capacity has reduced and flood risk will thus increase if no remedial steps are taken. Whilst such large schemes present challenges to flood risk mitigation, it is apparent that the potential of soft engineering approaches, such as pluvial flood attenuation through sustainable urban drainage systems and green roofs has been overlooked. The drainage of large natural wetlands in the Shenzhen area (e.g. Shekou Peninsula, Futian wetland mangrove area and surrounding coasts) for urban development is clearly damaging migratory bird habitat (Ng et al., in press), and further illustrates the phenomenon of "No space for water" in Shenzhen river bank development.

The Hong Kong Observatory (HKO) noted that the return period of intense rainstorms of over 100mm/hour has shortened from 37 years to 19 years over the last century. The HKO also recorded that the intensity of short-term (hourly) heavy rainfall has increased from 110mm to above 140mm, thus both the peak intensity and frequency of intense rainstorms has increased. Annual precipitation and extreme rainstorms are projected to increase over the next century. Hong Kong has recorded heavy rain of more than 200mm over a 24-hour period during some days of every rainy season since 2000, which increases the number of flash floods (sudden-onset flooding) presenting a major problem as the catchment area is mostly located on steep hills (Lee et al., 2010).

Flood protection i.e. channelisation in along the Shenzhen River, set at the 1 in 50 year level, is relatively modest. Although globally flood protection standards vary considerably, protection against 1 in 100 year events is common, and in economically important sites or in countries where flooding is a major hazard (e.g. The Netherlands), flood protection standards can reach as high as 1 in 10000 year floods (Middelkoop et al., 2004). The tail end of Typhoon Chanthu in July 2010 brought torrential rain, where more than 150mm fell in an hour in many parts of Hong Kong. This incident exceeded the planned defensive infrastructure capability. In the floodplain along the Shenzhen River catchment (the Northern New Territories in Hong Kong) there were three deaths caused by flash floods. Given such extremes, it is doubtful whether the current 1 in 50 years flood risk protection level in the Shenzhen River catchment is enough to protect people and property. Fundamentally, one might question the appropriateness of development in such flood prone areas if given only this modest level of protection.

The Tai O site, with its recent flood history reveals that Hong Kong does not yet have an adequate coastal flood management plan. After the Tai O floods, it was realized that the main flood administrative body in Hong Kong—the Drainage Service Department (DSD)—had no responsibilities for coastal flood management. The Government thus appointed the Civil Engineering and Development Department (CEDD) to manage the storm surge problem in Tai O. The CEDD is actually responsible for the Tai O revitalization project, which is intended to preserve the cultural heritage of Tai O, enhance local tourism and employment. The CEDD is building a sea wall at 3.3 metres above the mean sea-level in the Town Centre to mitigate the risk of coastal flooding. The effectiveness of the sea wall is however in question, as the town is surrounded by sea water, and flood risk from storm surges of the scale seen in the past may not be wholly mitigated. In a severe typhoon, such as with Typhoon Wanda of 1962, storm surges could be 4 metres above mean sea-level (Lam & Lam, 2005). Such risks are evident for several other coastal areas in the region which currently lacks a flood risk management policy or plan which recognise the potential impacts from climate change.

Flood problems are further complicated along the Shenzhen River as it marks the boundary between the Shenzhen Municipality and the Hong Kong Government (which was under British administration prior to 1997). The Shenzhen River Regulation Office was established in 1995 with the Drainage Service Department from Hong Kong Government and the Shenzhen River Board of the Shenzhen Municipal Government working in partnership with the aim of managing flood issues along the Shenzhen River. However, it is difficult to determine the extent to which this partnership has tackled sustainable flood risk appraisal and management, due to a lack of public transparency. Flood risk information (e.g. flood risk analysis reports, flood risk maps, etc) are not publicly available. The Northern New Territories in Hong Kong is fully covered under the Drainage Master Plan and mapping by MIKE 11 hydraulic models (Chui et al., 2006). In theory, the Shenzhen River should be subject to a similar systematic flood analysis. However, the actual flood risk data remains confidential and has never been released. Thus residents in new developments along the Shenzhen River, or in the traditional fishing villages on the floodplain cannot identify the flood risk they are exposed to, or how it is changing as development proceeds.

This lack of information is contrary to the general methods of sustainable development, where principles of public participation are valued. It also impedes development of appropriate interventions, such as local flood, preparedness and response measures. Johnson et al. (2007) noted the importance of public participation and transparent flood risk information in the development of sustainable flood risk management in England. Flood risk mapping and related information raises the awareness of flood hazards, and helps local planners, policy makers and developers to consider flood risk and responses to it in the urban planning and development process.

Similarly, if social justice is seen as important (e.g. everyone enjoys a minimum standard of protection from flooding, with particular attention given to the most vulnerable, such as the poor who are least able to recover from flooding) then better public access to flood risk information is needed. Analysis of both sites in this research reveals a lack of transparency on coastal and inland flood risk information. Better access to flood risk information would at least allow a more efficient market in flood insurance products, and improved prospects of flood recovery (Hong Kong Insurance Association, personal communication).

Moreover, public participation (PP) is also seen as crucial to achieving sustainable flood risk management (SFRM). A study in Scotland showed that during the flood alleviation plan process, policy makers benefited from seeking public input in design and decision making process (Kenyon, 2007). As FRM is a complex process and includes inter-temporal issues, plural values and conflicts of interests, PP enhances policy making by seeking views from the public and non-governmental organizations (NGOs) and so can extract a deeper understanding of flood risk problems as a result. PP also reduces conflict, and helps identify a balance between social, environmental and economical interests of stakeholders, thus delivering better local developments. Such practice has the potential to improve current flood defence projects in Hong Kong. However, to date; no NGOs have been invited to work with the FRM institutions in the region.

Our study has been shaped to some degree by the access we have managed to achieve to FRM stakeholders (policy makers, practitioners government officials) in the region. However, our findings to date suggest that there are significant opportunities to improve flood risk appraisal practice in the PRD. Further research will conduct a more detailed benchmarking of PRD practice against the Sustainable flood risk appraisal template, and conduct in depth analysis of our semi-structured interview data so as to better understand the barriers to, and opportunities for, sustainable flood risk appraisal and management in the PRD region.

Discussion and Conclusions

Hong Kong and the PRD region (includes Shenzhen) is already a mega-region and its population and economy are growing. The region is experiencing increasing flood risk from extreme weather events, more intense typhoons, rainstorms and storm surges, which can be expected to have major economic and social impacts. To deal with flood risk in a sustainable way, flood awareness needs to be raised, and authorities need to avoid development on floodplain unless levels of flood protection can offered which recognise the threat posed by climate change. Engineering i.e. hard flood structures may be inadequate, or simply too expensive, to cope with the elevated risk and a sustainable flood risk assessment approach is needed to balance economic, social and environmental objectives relevant to flood risk mitigation in the PRD.

In conclusion, we offer some further reflections on managing flood risks in Hong Kong (HK) and the PRD:

1. The PRD and HK Government have yet to develop climate change adaptation plans, particularly in terms of the coastal flood management planning. It is necessary to consider PRD's flood risk more fully given the threat from the climate change.

2. The PRD and HK authorities need to consider the rising flood risk in the region as a whole, and direct development away from floodplains wherever possible. Strategic development plans that recognise flood risk would help deliver more resilient cities, and

retain the environmental services delivered by undeveloped floodplains.

3. The capacity to appraise the growing flood risk must be integrated into urban and rural planning appraisal processes which consider sustainable development objectives collectively. If not, the social impacts of flooding are likely to be substantial, and the economic cost of mitigation high.

4. Flood risk management that relies solely only on a "hard-engineering" approach is unlikely to be successful in the long term. Sustainable flood risk management needs to consider with wider using of soft engineering approaches, more circumspect development of land, and active engagement with a wider body of stakeholders. Governments should release flood risk information to the public, so as to support development of flood preparedness and recovery measures, including more targeted flood insurance. Engagement with NGOs and other stakeholders with relevant expertise and knowledge should act to promote SFRM practice in the PRD.

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Disclosures

The authors have nothing to disclose.