RICH DELTA, COSTLY FLOODING

Faith Chan, Christine Loh, Adrian MacDonald, Gordon Mitchell and Olalekan Adekola

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Faith Chan, Adrian MacDonald, Gordon Mitchell and Olalekan Adekola are affiliated with the School of Geography, University of Leeds, LS29JT, UK*

Christine Loh is the CEO of Civic Exchange, Room 701, Hoseinee House, 69 Wyndham Street, Central, Hong Kong

**Corresponding author: Tel.:+44 113 343336*
E-mail address: k.s.chan@leeds.ac.uk

Rich Delta, Costly Flooding

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• Abstract •

Rapid economic development and urbanisation has taken place in coastal regions along the Pearl River Delta (PRD) in cities such as Hong Kong and Shenzhen, as well as in a range of smaller settlements, which now all face potentially major impacts from flooding. A changing global climate is causing rising sea levels and more extreme rainfall events thus increasing flood risk. The strategy of government institutions in the region for ameliorating such risk is unclear, and the Hong Kong and Guangdong authorities should revisit the region's development plan to develop a long-term, integrated flood management strategy that recognises the added risks from climate change and rapid development.

• 摘要 •

珠江三角洲沿海一帶的城市，如香港和深圳，以及區內其他較細小的居地，不但面對著急速的經濟發展與城市化，還同時面對洪水的潛在威脅。全球氣候在變，導致水平面上升以及更極端的降雨量，增加了水浸的風險。然而，珠江三角洲區內的政府機關對如何減低上述相關風險的策略並不清晰，而粵港當局應重新檢討區內的發展計劃，針對因氣候變化和急速發展所帶來的額外風險，訂出一套長遠、綜合的洪水管理策略。

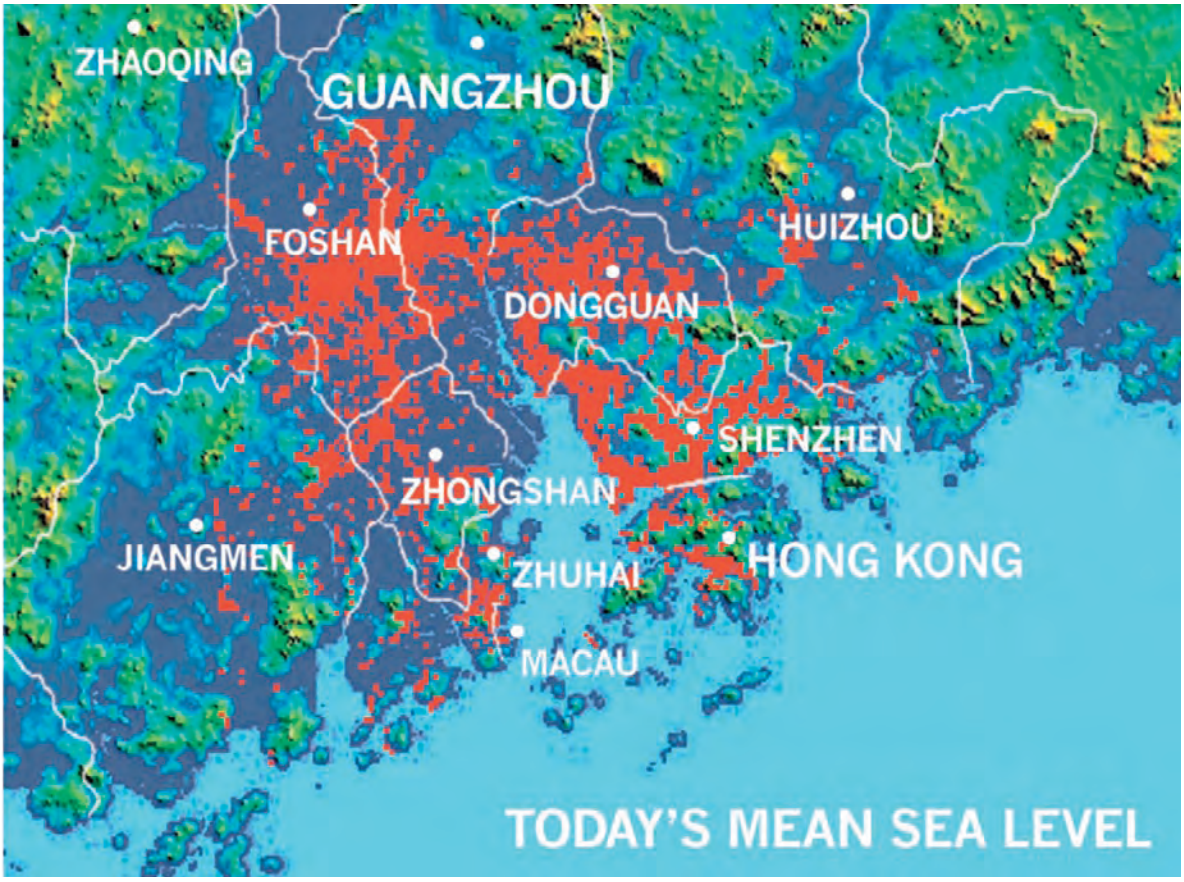
• Climate change and flood risk •

The Intergovernmental Panel on Climate Change (IPCC) estimates that sea level will rise between 0.65m and 1.3m globally by 2100.[1] If the global temperature rises faster than expected, then ice sheets and 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.[2] Sea level rise will increase the impact of storm surges, causing particular impacts on deltaic regions.

Furthermore, climate change will cause a predictable increase in cyclonic events (e.g. typhoons), which will increase the probability of coastal and inland flooding.[3] Numerous studies have revealed increases in the frequency, magnitude and size of tropical storms in the Pacific Ocean over the last 30 years.[4,5]

Tropical storms and surges have caused massive human and economic loss in Asia. Bangladesh had over 1.3 million cyclone-related deaths over the past two centuries.[6] Storm-related floods account for over 70% of total flood events in big coastal cities, such as Jakarta and Manila.[7] Sea level rise and storm surge risks are already estimated to affect more than 466 million people in Asia's coastal areas.[8]

• ***Fig. 1*** *Today's mean sea level in the PRD region (Source: Hong Kong University of Science and Technology, 2006)*

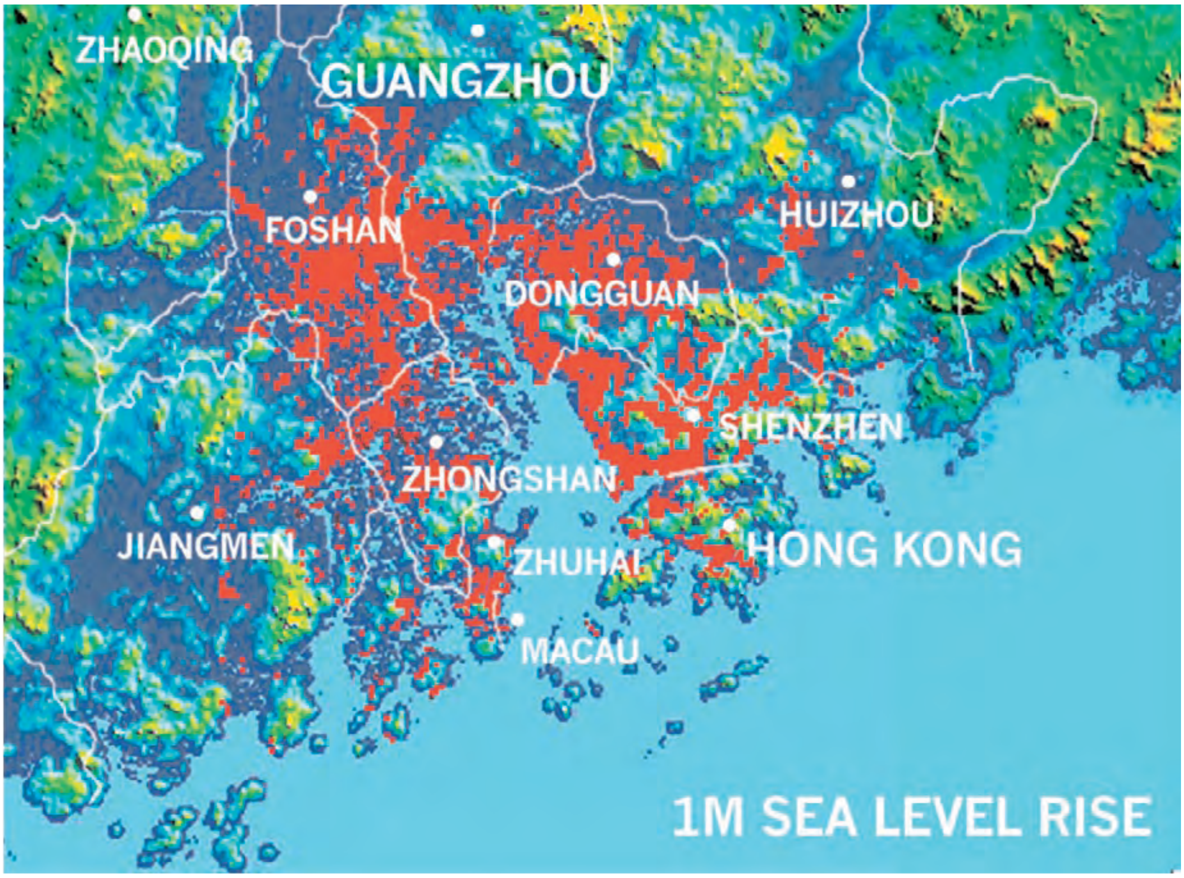


In light of climate change, coastal areas in the PRD are no different to other deltaic regions under the threat from flooding. Hong Kong and Shenzhen face increasing flood risk from: (1) sea level rise; (2) increasing frequency of storms and surges, and (3) inland pluvial flooding caused by more intense precipitation.[9]

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.[10] Even this modest forecast rise will cause sea inundation to affect more than 2,000km^2 in the PRD coastal area and a large part of the delta plain will be vulnerable to tidal inundation.[11] More than 1 million people would be forced to relocate. If the sea level rises by 1m, sea inundation will affect more than 6,500km^2 in the PRD where nearly the whole coastline will be overcome by sea water (see Figs. 1-3).[12]

Typhoons bring high winds, thunderstorms, high waves and surges that lead to seashore erosion. Coastal infrastructure, such as seawalls, may be damaged or destroyed (see Fig. 4). In the last 50 years, the Hong Kong Observatory (HKO) recorded more than 20 storm surges where the water level was raised by more than 1.5m above the mean sea level. Records from the 1950s to the first decade of this century show that the range of maximum sea level rise caused by storm surges in the Pearl River Estuary was between 1.9m and 2.6m. Records

• ***Fig. 2*** *Sea level rise of 1m in the PRD region (Source: Hong Kong University of Science and Technology, 2006)*



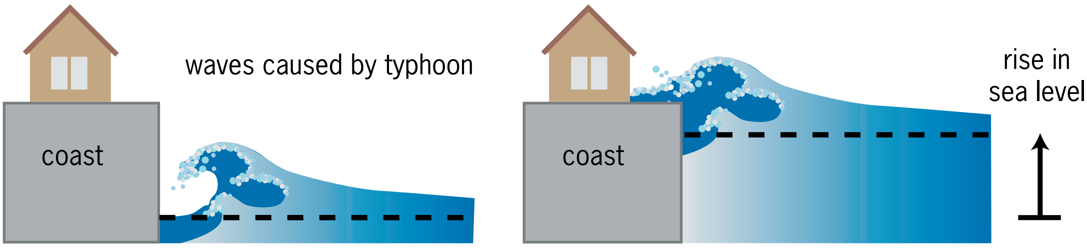
• ***Fig. 3*** *Flood-vulnerable infrastructure in the PRD region (Source: Hong Kong University of Science and Technology, 2006)*

also show that between 1991 and 2005, the coast of Guangdong was affected by more than 41 typhoon-induced storm surges (an average of 2.7 times per year).[12] Tidal gauges in the PRD recorded storm surges of 2.5m to 3.2m as a result of Typhoon Hagupit in August 2008 and Typhoon Koppu in September 2009.

These two typhoons in July 2008 and September 2009 enhanced storm surges, flooding the Town Centre of Tai O and damaging many properties. Tai O Town Centre lies 2.9-3.3 metres above Principal Datum (mPD), but during the typhoons, the HKO recorded a sea level of 3.53mPD to 3.77mPD. Furthermore, 1-3m of sea water from storm-water drains and sewers backwashed into Wing On and Tai Ping Streets in Tai O (see Fig. 5). Storm surges in Hong Kong occurred frequently between 1954 and 2008, generally ranging from about 0.5m-1m in height. This is enough to cause coastal flooding if surges occur alongside astronomical high tides; sea levels of over 3.0mPD have been recorded more than 14 times within that period.[13]

The Tai O storm surges indicate that either Hong Kong has not yet fully implemented its coastal flood management strategy, or that the strategy is insufficient to cope with the new situation. 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 Hong Kong Government has appointed the development board of the Civil Engineering and Development Department (CEDD) to deal with the storm surge problem in Tai O. The CEDD is responsible for the Tai O revitalization project, the aim of which is to

• ***Fig. 4*** *Cyclonic effect (typhoon) to storm surge and coastal flooding (Source: Adapted from HKO, 2010)*

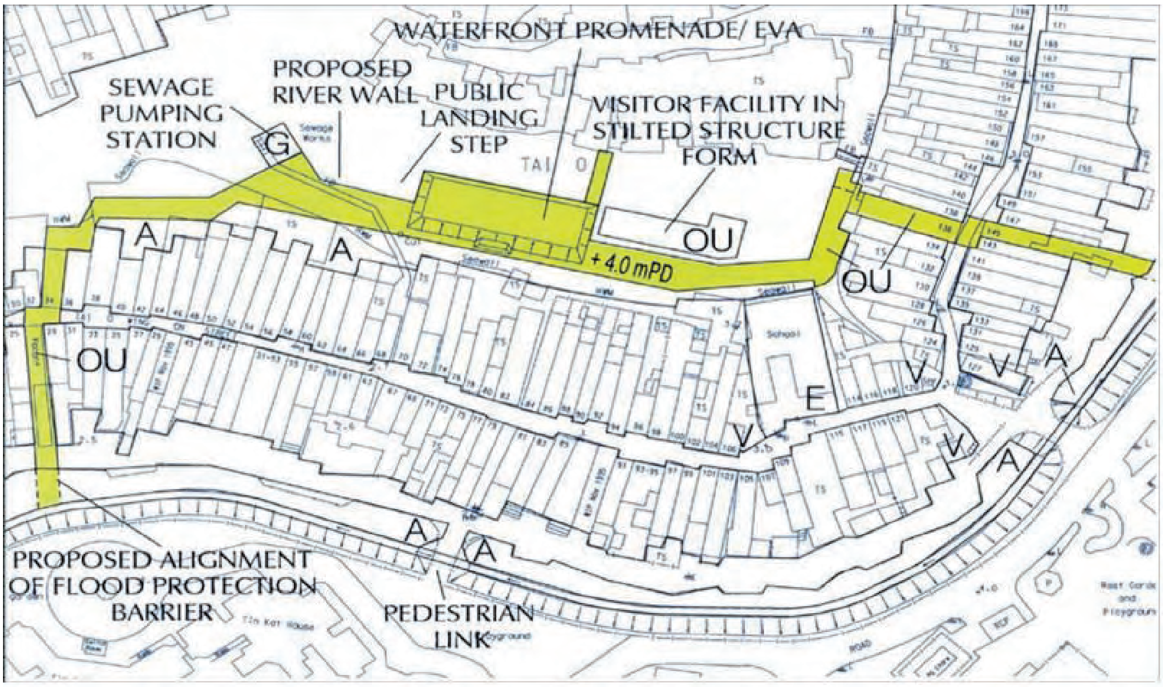


• ***Fig. 5*** *Storm surge and coastal flooding in Tai O on 13.09.2009 (Source: TVB)*

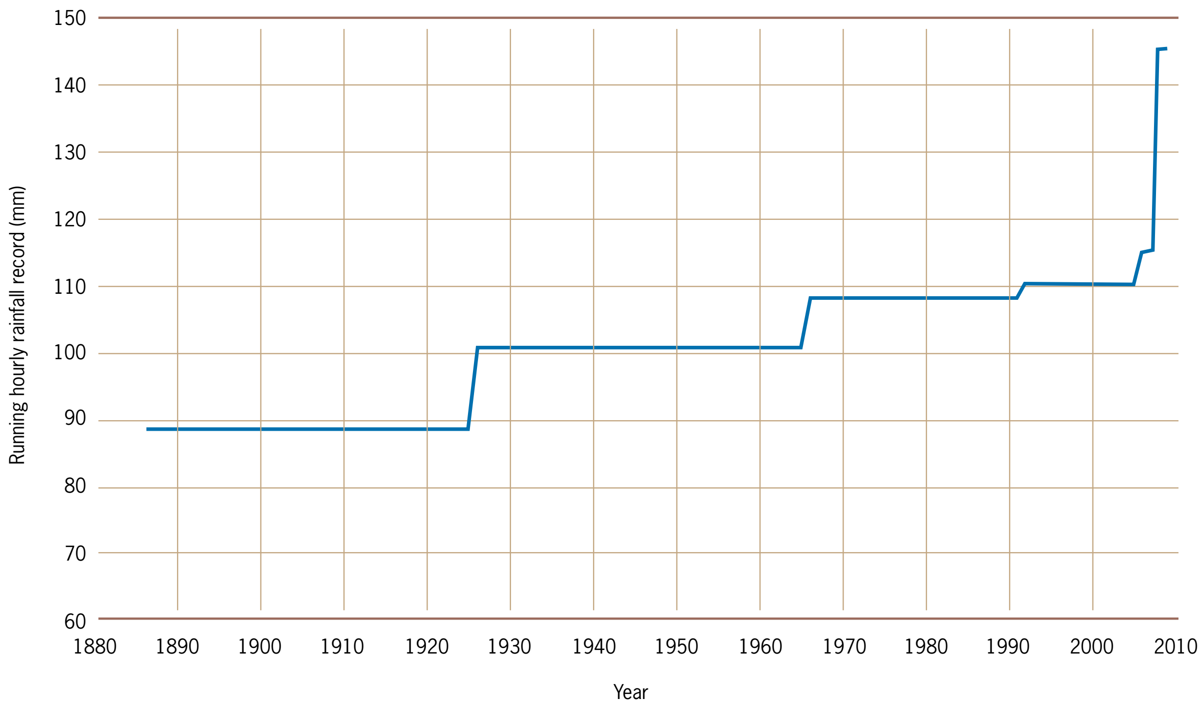
preserve the cultural heritage and natural environment of Tai O, while enhancing its visitor appeal and local employment base by the year of 2013.[14] The CEDD has planned to build a sea wall at 4mDP in the Town Centre to mitigate the risk of coastal floods (see Fig. 6), which will be completed by 2011.[15] The effectiveness of the sea wall is still in question, as the whole town is surrounded by sea water, hence flood risk from storm surges may not be wholly mitigated. In a severe typhoon, such as Typhoon Wanda of 1962, storm surges could be 4m higher than usual.[13]

Inland flooding also occurs as a result of heavy rain. More than 1,700mm of rainfall on average (80% of annual rainfall) is typically recorded from May to September during the typhoon season. The 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 (see Table 1). In the last decade, the HKO also recorded that the intensity of short-term (hourly) heavy rainfall has increased from 110mm to above 140mm. However, as the period of record (from 2000-2010) increases, the probability encountering a higher value from an unchanged distribution (from 1970-2000) also increases (see Fig. 7). Therefore, both the peak intensity and frequency of intense rainstorms has increased.

• ***Fig. 6*** *Proposed sea wall installation in Tai O Town Centre (Source: CEDD, 2009)*



• ***Fig. 7*** *All time record rainfall (hourly) at Hong Kong Observatory, 1885-2009*
(Source: Adapted from HKO, 2010)



• ***Table 1*** *Changes in occurrence of extreme rainfall events based on time-dependent return period analysis (Source: HKO, 2010)*

Element	Return Period in 1900	Return Period in 2000
1 hour rainfall > 100 mm	37 years	19 years
2 hour rainfall > 150 mm	32 years	14 years
3 hour rainfall > 200 mm	41 years	21 years

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) and poses a major problem for the urban drainage system.[16]

The Hong Kong Government's consultation document, *Hong Kong's Climate Change and Action Agenda*, published in September 2010, recognised that the effects of climate change are inevitable and that Hong Kong will be affected. Potential impacts include asset damage as a result of flooding, landslides, wind damage and storm surges.[17] The document points out that the risks can be cushioned or ameliorated by adaptive actions such as developing flood and landslip risk strategies, although specific plans have yet to be published.

• The flood problem in the Pearl River Delta and Hong Kong •

The PRD consists of 41,698km^2 of land, and is smaller than other notable deltas in Asia, such as the Ganges (105,000km^2) and Yangtze (50,000km^2). The PRD region, however, is now the fourth largest economy in Asia, just behind Japan, South Korea and India, and connects the Hong Kong Special Administrative Region, Shenzhen and 9 other cities (Macau, Guangzhou, Zhuhai, Foshan, Jiangmen, Dongguan, Zhongshan, and part of Huizhou and Zhaoqing) making it one of Asia's mega-regions (see Fig. 8).[18]

Hong Kong is China's global city and one of Asia's most important financial and commercial hubs. Hong Kong's per capita GDP stood at US$30,892 in 2008.[19] The PRD served as Hong Kong's export manufacturing hinterland during the early phase of China's economic liberalization. GDP growth clocked 13.4% per year between 2000 and 2008, and double digit growth is expected to continue in the delta. The PRD has experienced high population growth from internal domestic migration. In 2009, its population was 48.3 million (excluding Hong Kong and Macau), and the Guangdong authorities project population to reach 65 million by 2020.[20] The United Nations has recently predicted that big cities such as Hong Kong, Shenzhen and Guangzhou in the PRD will merge into a mega-region, and that its population will reach 120 million by the 2050s.[21]

The urbanisation that follows such economic and population growth can increase flood risk and place many more people in flood-vulnerable areas. The establishment of the Hong Kong Drainage Service Department (DSD) in the 1990s was therefore a big step forward for flood risk management in Hong Kong. It was the first such institution to deal with flooding, and developed the city's first Drainage Master Plan (DMP) in 1996.[22] Under the DMP, a high technological river hydraulic model—MIKE 11—is used to study the flooding behavior of all planned areas in Hong Kong. The purpose of this computational simulation (or flood risk analysis) is mainly to benchmark deficiencies in the drainage system and to rectify them in a systematic and organized approach.[23] Flood risk analysis in the DMP also enables the assessment of catchment areas for their annual exceedence probability of flooding (i.e.1 in 2, 5, 10, 20, 50, 100 and 200 years flood return period). Based on the probability flood water level in the DMP, a predicted area of flood risk can then be mapped out in Hong Kong. The DSD will then use the relevant information to mitigate the flood risk and build flood protection infrastructure. The DSD defines a major flood event in Hong Kong as a 1 in 50 year flood. The DMP therefore adopts a flood protection standard to withstand flood magnitude at this flood risk level.

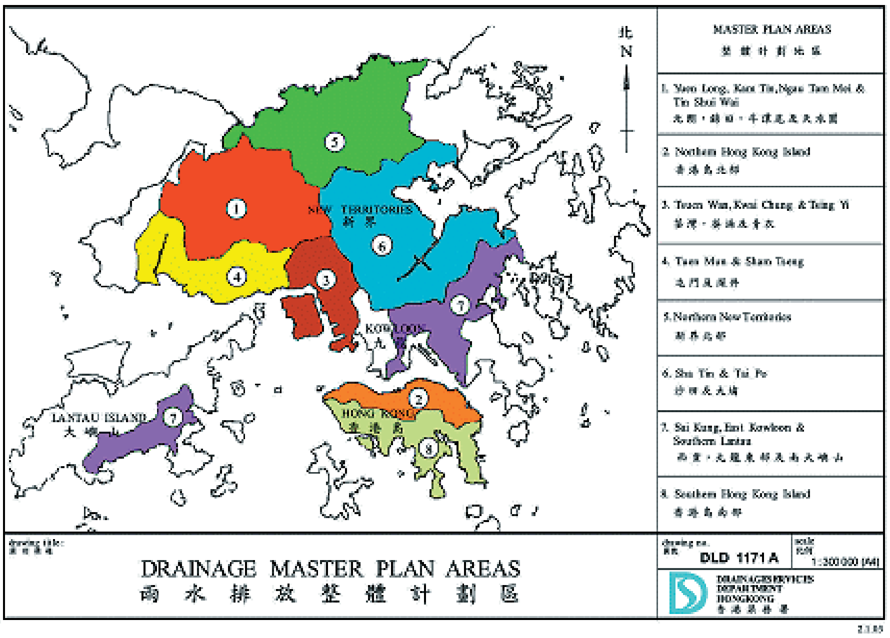
• ***Fig. 8*** *The Pearl River Delta region and cities (Source: Adapted from Yeung, 2010)*

As a result, since the mid-1990s, the DSD has accelerated progress on urban and rural flood management in Hong Kong, particularly in DMP-identified areas or zones (see Fig. 9), with expenditure on flood defense projects amounting to some HK$20 billion.[22] Most of its work has focused on widening, channelizing and straightening streams in the New Territories (e.g. Kam Tin and Shan Pui Rivers), and building underground sewerage and storage ponds for collecting flood water. All flood protection infrastructure is designed to withstand flood magnitudes expected to occur once in every 50 years (1 to 50 years/return flooding).

Consequently, there are few "natural streams" left in Hong Kong, and the benefits that natural rivers offer in terms of amenity, prized assets in many large cities, have been lost. The environmental impacts can also be significant. For example, rivers with bed channels covered by smooth concrete with little or no riparian vegetation mean that many native freshwater fish species are under threat, as they cannot adapt to the channelised environment. [24]

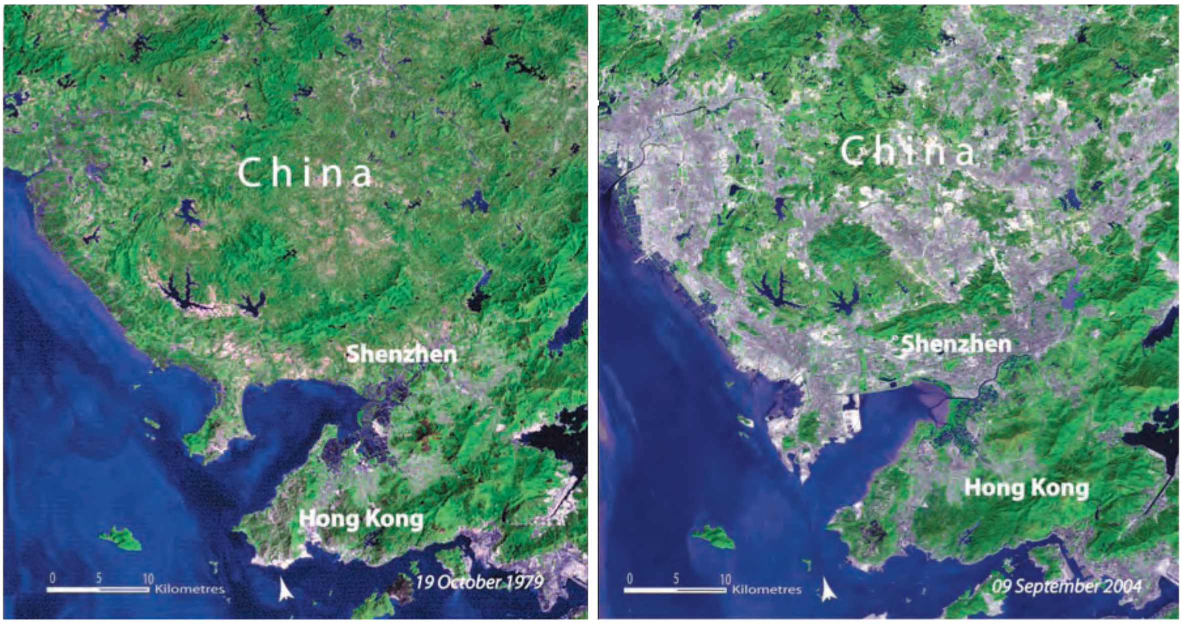
Flood protection in Hong Kong, set at the 1 in 50 year level, is relatively modest. Although globally flood protection standards vary considerably, protection against 1 in 100 year events is common, and in economically important sites or in countries where flooding is a major hazard (e.g. The Netherlands), flood protection standards can reach as high as 1 in 1,000 year floods. However, 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.[25] This incident exceeded the planned defensive infrastructure capability. About 3,000 people were trapped in rural parts of the New Territories, and there were three deaths caused by flash floods. In the urban areas, a key highway section had to be closed for 1.5 hours, and bus passengers had to be rescued as the vehicles were stranded in metre-deep floodwater (see Fig. 10).[26] This incident raises the question of what should be done in light of a changing climate to protect people and property.

• ***Fig. 9*** *The Drainage Master Plan in Hong Kong (Source: www.dsd.gov.hk, 2009)*



• ***Fig. 10*** *Urban area flood in Kowloon district in Hong Kong (Source: Hong Kong Standard, 2010)*

• ***Fig. 11*** *Urbanisation in the Pearl River Delta, 1979-2004 (Source: Hong Kong University of Science and Technology, 2006)*



This flood event in Hong Kong was relatively small compared to the 2010 floods in Mainland China. Major floods started in early May in South China, following torrential rainstorms.[27] Rain intensity was more than 200mm per day in parts of Zhejiang, Fujian, Jiangxi, Henan, Guangxi and other areas of The South. In June 2010, the recorded water level in Wuzhou, west of the Pearl River, was 18.22m, exceeding the severe flood water warning level by 0.22m.[28] Huilai County in Guangdong recorded 603.5mm rainfall within a six-hour period, setting a half-century record.[29] The death toll was 381, and 147 people were reported missing. The floods affected more than 64 million people and caused RMB83.8 billion of economic losses across 22 provinces by the end of June.[30]

The 2010 China flood was the worst of the decade. It killed more than 1,100 people nationwide, and over 12 million people had to be evacuated from floodplain areas along the Yangtze, the Yellow, the Songhua and the Pearl Rivers. The flood destroyed over 1.1 million homes and damaged 9.72 million hectares of farmland.[31] Total financial losses are estimated at tens of billions of US dollars in damage, across 28 provinces and regions from south to north. Other than flooding, the torrential rain triggered landslides. A serious landslide in Zhouqu, Gansu, caused 1,144 deaths with 1,700 people missing, and hundreds of buildings were affected.[32]

• Emerging flood risk from human-induced factors •

As a consequence of economic growth in the PRD, land use is changing dramatically. For example, two-thirds (63.6%) of the agricultural land available in 1979 had been developed for industry, commerce and housing by 2005 (see Fig. 11). This level of urbanisation means that many more residents and businesses are exposed to potential flood hazards. Such developments also increase the likelihood of flooding due to human-induced hydrological changes,[33] which include:

1. Subsidence: coastal areas in the region along the estuary are densely populated, and meeting the demand for water through groundwater extraction lowers the water table, causing land to subside and become more vulnerable to flooding from storm surges and coastal flooding.[34]

2. Dredging: the region relies on dredging to provide construction materials to meet the needs of rapid urbanisation.[35] While river dredging might potentially reduce flood risk by increasing the channel cross section, intensive dredging and abnormal excavation of the river bed disrupts normal flow patterns and exacerbates local river bank erosion, thereby increasing the probability of bank failure resulting in flooding.[36]

3. No space for water: land reclamation along the estuary has narrowed the channel of the lower stream, which means that flood water has less space to discharge and that flood risk is increased if no remedial drainage system is applied. Moreover, natural flood water storage has been sacrificed, as seen in the drainage of large natural wetlands in the Shenzhen area (e.g. Shekou Peninsula and surrounding coasts) for urban development.[37]

• Cross-boundary flood problems and flood governance •

Flood problems in the Shenzhen River along Hong Kong and Shenzhen (in Guangdong) border are a complicated issue for both sides (See Fig. 12). In the last 30 years, Shenzhen has developed from rural farmland into a highly urbanised industrial and commercial city. Rapid development and dramatically changed land use in Shenzhen causes higher runoff, greater flood peak discharge and shorter runoff confluence times, thereby increasing flood risk.[38] It has been reported due to the short length of the tributaries and steep upper section of the river, flood peaks are frequently formed in a short period of time. Flood peaks can reach Shenzhen City within a few hours after a storm, but the flood water cannot be discharged easily downstream because of strong tidal influence from Deep Bay. Thus, districts along the Shenzhen River, i.e. the North Bank of the River, Lo Wu and Futian often suffer from flood damage. Throughout the 1980s, this area flooded on average 1-2 times every year. Most flood events in the Shenzhen River basin also influence Hong Kong. The Shenzhen River is connected to all of Hong Kong's major rivers (i.e. the Ping Yuen, Ng Tung and San Ting). During heavy rainstorms, peak flows reach the Northeastern part of Hong Kong and Shenzhen's Central District within a couple of hours, flooding land along both sides of the river.

The Shenzhen Municipality and the Hong Kong Government (under British administration prior to 1997) started to discuss 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.[39]

Nevertheless, there was limited transparency to the project. Although a joint environmental impact assessment of Phase III of the project was published, information related to up-to-date data (i.e. flood risk analysis, flood risk mapping, etc), records of meetings and official reports were not made available. The Northern New Territories in Hong Kong is fully covered under the DMP mentioned above. Therefore, in theory, the Hong Kong side of Shenzhen River should be subject to a systematic flood analysis, i.e. flood risk modelling and mapping by MIKE 11 hydraulic models.[23] However, the actual flood risk data remains confidential and has never been released to the public. For example, residents of San Tin and Lok Ma Chau villages, beside the Shenzhen River, cannot identify their potential flood risk. This lack of information impedes the rational selection of appropriate intervention, i.e. prevention, preparedness and response for flooding.

• ***Fig. 12*** *Shenzhen River looking south (Source: Wikimedia Commons, 2006)*

After reunification in 1997, the Basic Law enabled the Hong Kong Special Administrative Region to maintain separate political, administrative and legal systems under the "one country, two systems" principle. This means Hong Kong and Guangdong operate under different systems, environmental management systems. To improve coordination, the Hong Kong-Guangdong Joint Working Group now deals with transboundary environmental issues.[40] While this body is a milestone in cross-boundary cooperation,[41] its work still lacks transparency as few details are released. Scholars have called for transparency to better ensure the absorption of stakeholder and public feedback, which would improve policy and programme effectiveness, including work related to flood prevention.[42]

The lack of publicly available information on flood risk is perhaps not surprising. It is politically sensitive, as it has significant implications for the property market and regional landuse planning. The lack of information on flood risk remains an obstacle to the development of infrastructure and raising of community resilience needed in light of climate change.

• Lessons from the UK: Sustainable flood risk appraisal •

Flood management strategies must cope with pressure from rapid development and climate change. Yet, it is evident that in the PRD, appraisals informing such strategies are relatively undeveloped, and sustainable development concerns have been neglected. A comparison with another part of the world in how flood management is approached may offer useful insights. The United Kingdom provides an example of a contrasting approach. British practice has evolved rapidly in recent years in response to development (especially housing) pressures, increasing extreme rainfall events resulting in major urban flooding, and also changing European Union policy.

British development and flood risk policy used to be based on administrative practice stated in Planning Policy Statement 25 (PPS25), which guided local and regional governments on the planning of development strategies and granting of consent to individual projects.[43] PPS25 required developments to not increase flood risk (such as through the use of sustainable urban drainage systems), and urged decision-makers to direct development away from high flood risk areas, such as natural floodplains, wetlands and low-lying coastal areas. However, heavy rainfall and devastating floods in 2007 (and also in subsequent years), described as the most significant natural hazard Britain has faced in 60 years, resulted in the passage of the Flood and Water Management Act.[44] The Act also implemented the European Union's Floods Directive, which became effective the following year, that member states produce flood risk and flood vulnerability maps, as well as provide communities with real-time flood warning information.[45]

The purpose of binding legislation is to provide better, more sustainable management of flood risk for people, homes and businesses, which can help to keep drainage charges down, as well as protect water supplies. The law provides that the environment agency is responsible for managing flood and coastal erosion risk; requires new developments and re-developments to adopt sustainable drainage systems and enhance ecologically-friendly flood management; and enables water supply and sewerage companies to operate concessionary schemes to help relieve the cost burden on the poor.[46]

In addition to the above, there are other reinforcing practices that integrate improved flood risk planning with development management. By integrating good flood risk and planning practices into Strategic Environmental Assessments (SEA) and Sustainability Appraisals (SA) at the strategic level, and Environmental Impact Assessments (EIA) at the project level, the development process can take all factors into account. In cases where SEA/SA or EIA are not required, the Flood and Water Management Act still mandates a separate flood risk appraisal.[47]

Moreover, public participation is also seen as crucial to achieving sustainable flood risk management (SFRM). In developing flood alleviation plans or flood defense projects, the environment agency actively seeks public input in design and appraisals, including views from non-governmental organizations. For example, local residents and The Royal Society for the Protection of Birds were active on the Humber Estuary coastal flood management committee board.[48] This kind of participative management approach certainly takes time but it is also considered vital to delivering better schemes through an open and interactive dialogue in which stakeholders can voice concerns, express community wishes, and provide expert local knowledge (e.g. on ecosystems). As a result, public participation in SFRM seeks to reduce conflict, identify a balance between social, environmental and economical interests of all stakeholders, and deliver better developments. This produces developments that are more sensitive to flood risk, as well as flood defense projects which are in turn more sensitive to wider sustainability concerns.

The lesson learnt in Britain is that flood risk is serious and is being exacerbated by climate change. It can no longer be neglected in the development process. Rather, development must adapt to flood risk, and in the words of a recent influential report, 'make space for water'.[49] The 2007 floods led to the review (Pitt Review)[50] of systemic weakness, looking into structural administrative issues, such as the splitting of responsibilities between the environment agency, local authorities, drainage boards and water companies, and calling for joined-up responses to improve effectiveness.[51]

• Conclusion •

Hong Kong and the PRD face high flood risks as a result of location, topography, climate change and dense development. Many industrial and residential developments have been built on flood prone areas. The authorities on both sides of the boundary have to combat this higher risk amidst rising land prices and an investment climate that encourages rapid urban development in an economically dynamic region. The costs of building flood protection infrastructure, paying compensation, covering emergencies and delivering remedial engineering works will inevitably be high, but given the damage arising from recent floods, such preventative measures as part of a coherent package of hard and soft measures, is likely to be cost-effective. The June 2008 flood in Guangdong damaged more than 10,000 factories at an estimated cost of over RMB3.8 billion; while in Hong Kong, HK$11.6 billion was spent since 2007 on drainage stormwater systems in the New Territories.[22, 52]

There is therefore a strong case for tackling flood risk in development planning, and this necessitates the application of more thorough and open appraisal strategies for development projects that alter flood risk and for flood defense works that seek to mitigate that risk. Flood insurance can be used as one instrument to address the costs of flooding, but this requires flood risk information to be made available to the public and to insurance companies, as is done in the European Union and the US.[53] However, in those countries, flood insurance is only modestly taken up, as most insurance packages are costly and require much governmental financial input in order to ensure their nationwide availability.

In recent years, two flood events in Tai O Town has shown that Hong Kong is vulnerable to coastal flooding. However, governance structures for coastal flood management remain blurred. Relevant institutions for flood management are only interested in their own portion of responsibilities. For example, the DSD is responsible for inland flood protection; the CEDD for sea wall maintenance;[54] and the HKO for tide level monitoring.[55] In light of climate change and emerging flood risks, perhaps it is wise to learn from the UK's experience. Forming a new Strategic Flood Partnership will help ensure that government departments/agencies (i.e. DSD, HKO and CEDD) and local district councils can address flooding issues (including inland and coastal flooding) in an integrated manner.

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

1. The Hong Kong Government's *Hong Kong's Climate Change Strategy and Action Agenda* did not incorporate flood risk assessments commissioned from consultants. The consultant's report is expected to be released, at which time it may be possible to consider Hong Kong's flood risk more fully.

2. There are cross-boundary impacts affecting Hong Kong and Guangdong which can only be properly dealt with if there is a regional flood management plan. Moreover, the authorities need to consider the rising flood risk in the whole region and direct development away from floodplains. Developing a flood-resilient, urban development plan is a vital step in minimising damage and optimising flood management benefits.

3. There are special challenges in identifying the sharing of responsibilities between Hong Kong and Guangdong when each operates under different systems. It may be helpful for each side to have a unit that has the responsibility for flood management. Despite jurisdictional and administrative separation, river and sea natural systems must be treated as integrated entities if an optimum flood plan is to evolve.

4. As the flood risk grows, the capacity to appraise the risk must be integrated into urban and rural planning, and sustainable development must become a driving force rather than remain as rhetoric. If not, both the economic cost of mitigation and the social impact could be substantial.

5. Using a "hard-engineering" approach towards flood risk management is only part of the risk management process, and will likely prove insufficient to deal with the changing flood risk in Hong Kong and the PRD. Flood insurance should be introduced to allow public and private companies to become involved in flood management and to share the financial risk. This will require making public comprehensive information about flood risks throughout the region.

6. The issue of data transparency in the formation of mitigation and adaptive strategies becomes paramount. Public participation should also be integrated into the decision-making process in order to ensure that disaster management and emergency plans are effective.

Hong Kong and the PRD region is already one of China's most significant economic, financial and industrial areas. It is also an important Asian mega-region. Climate change studies show that this region will face extreme weather conditions that include more intense typhoons, rainstorms and storm surges, which will have major economic and social impacts. To deal with higher flood risks, flood awareness needs to be raised, and the authorities need to reconsider where it will permit development and where it should not. Engineering fixes alone will not be enough. The response needs to be evidence-based and inclusive of the people who will be affected.

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Civic Exchange
Room 701, Hoseinee House
69 Wyndham Street,
Central,
Hong Kong
Tel: (852) 2893 0213