WHAT TO DO WHILE THE WATER RISES?

Rising sea levels will eventually threaten many coastal cities. But a dominant focus on the long-term endgame should not unduly restrict our options to deal with the more immediate consequences of climate change, says **Richard Little**.

Superstorm Sandy's aftermath in New York demonstrated unequivocally that extreme weather events are not solely the scourge of developing nations in the tropics. We know that sea level will continue to rise in a warming world and, pending action, substantial parts of coastal cities around the world will eventually be inundated. As with other aspects of climate change, discussion of sea-level rise is often framed in terms of the long-term outlook. For example, we are told that sea level by the end of the 21st century could be higher than the present level by over half a metre[1]. There is much emphasis on emissions reductions; however, not only does this face political obstacles, there are also considerable technical hurdles.

For example, recent work[2] suggests that providing the new electrical generating capacity needed by 2050 and merely maintaining the current levels of atmospheric CO_2 would require the construction of the equivalent of 10,000 new 1 GW nuclear plants in the next 40 years – a technical and financial impossibility. So, despite expectations of an increased frequency of some extreme weather events[3], emissions reductions realistically achievable in the short to medium term would probably have little or no impact on the frequency and magnitude of those events.

Planners should think hard before committing billions on floodgates for New York.

Getting the timescales right

The recognition that mitigation is not going to be sufficient has stimulated much work on climate-change adaptation in the coastal zone. But we remain far from providing the sort of detailed information and forecasts that adaptation policies need. For today's policymaker, risk manager or design engineer, it is not sufficient to know how much sea level might rise by the end of this century or in two centuries. Will the rise be constant and linear or will it be faster or slower at the beginning or end of the time period? What is the probability that a specific increase will be seen within a specific time frame? What can be done to make a community safer from the next storm event? Global averages are not very helpful either. For example, we know that sea-level rise will not be the same in all parts of the world: urban regions located on subsiding deltas will be more vulnerable as will cities in poorer nations. When the options include spending billions for flood defence or abandoning valuable land and infrastructure, such details matter.

Concentrating on what might occur far in the future introduces several complications. For example, it renders our standard economic decision tools less valuable. Economists have a way of valuing future benefits; a practice called discounting. Using this technique, something of great benefit to people in 2100 may not be economically viable – even if morally more appropriate – today. Another complication of a long-term focus is the lack of urgency. Because humans tend to organise for action based on real or imagined deadlines, we find it difficult to muster the will to address something that will occur long into the future. Building a timeline of integrated steps where the role of each generation can be easily discerned may be more effective. Finally, by taking it upon ourselves to "fix" a problem 200 years in the making ignores the ability (or desire) of succeeding generations to develop their own solutions based on what will have been learned in the intervening years as well as technological advances that we cannot foresee.

What would we do if the sea-level rise were solely due to natural factors? Based on past practices, we would most likely build defences to keep water out, construct buildings and infrastructure to withstand the effects of storms and flooding, and ultimately move to higher ground. In current disaster jargon we would become more resilient. Meaningful resilience is achievable without burdening the present unduly or abandoning future generations.

Managing risk

The UN estimates that by 2050 two-thirds of the world's population will live in urban areas[4]. Of these, more than 5 billion will be living in "less-developed regions".[5] This makes coastal cities in the developing world particularly vulnerable.

Two aerial photographs showing a portion of the New Jersey coastal town of Mantoloking, just north of where Hurricane Sandy made landfall.

Remote Sensing Division of the National Oceanic and Atmospheric Administration (NOAA)

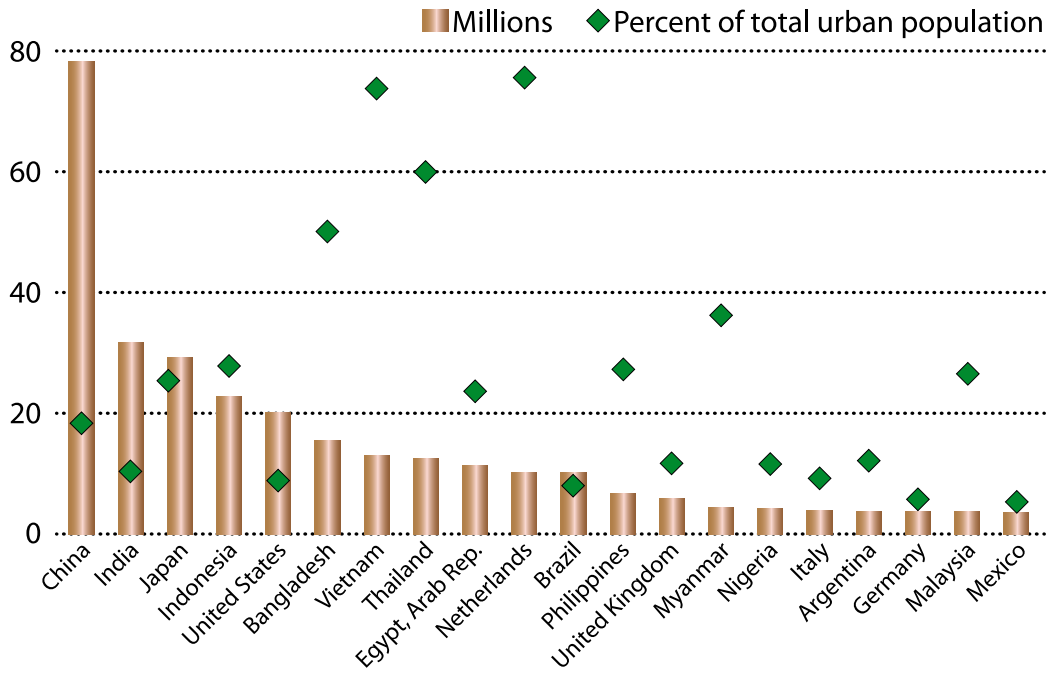

Figure 1. Urban populations at risk. The figure shows countries with the highest urban populations living in low-elevation coastal zones in the year 2000. Modified after Figure 4b from "Cities and climate change: an urgent agenda." The World Bank. December 2010, vol. 10, page 9. http://goo.gl/nTVg5.
Data source: CIESIN (Center for International Earth Science Information Network).

Basic services such as reliable electric power, clean water, and basic sanitation are often lacking, and the absence of proper planning has tended to force the poorest people to occupy the most marginal and susceptible land.

But coastal vulnerability is not solely a problem of the less-developed world (see Figure 1). In 2011, this vulnerability was vividly demonstrated at Fukushima, Japan, and just recently in New York. Achieving a single, globally applicable solution is not likely but this should not preclude the development of a general framework from which nationally or regionally appropriate solutions may be generated.

Because of the great uncertainty of predicting the magnitude of specific events at specific locations, this general framework should be based on a structured approach to risk management that can be summarised in three sequential actions: avoid the hazard if possible, withstand its effects and recover from its impacts.

New Orleans is now hostage to decisions made 100 years ago.

Avoid the hazard

The only way to avoid extreme weather events is not to be there when one occurs. In the case of coastal areas, for example, living outside the possible inundation zone associated with storm surge is perhaps the wisest choice, though certainly not an immediate option for the many people already living in flood-prone areas. However, better identification and delineation of floodways and flood-prone areas coupled with the implementation of appropriate land-use planning and regulatory tools could lead to more resilient development patterns. The location of new facilities and infrastructure should take account of future hazards and when facilities require major reconstruction, relocation to higher elevations should be mandated[6].

Withstand the hazard's effects

Despite the inevitability of rising sea level, it is probably too costly for the foreseeable future to relocate all existing vulnerable developments and infrastructure to safer ground. Levees and flood walls are obvious options, so too is elevating existing structures. Engineers are good at designing and building for known hazards, and building and design codes to improve hazard resistance have proven their effectiveness through countless major events. However, the traditional approach is to design for the worst-case scenario based on previous experience. Although it is comforting to believe that designing for a maximum probable event fully addresses the potential risk, recent history suggests otherwise. The designers of the Fukushima Daiichi nuclear plant in Japan applied what they believed to be a rational tsunami threat scenario; yet, it proved woefully inadequate. To a large extent, engineering design practice for "natural" hazards assumes that the Earth of the future will behave much as it has in the past but this is probably no longer true.

In light of this, planners should think long and hard before committing billions on structural solutions such as floodgates for New York. There are abundant examples of how the installation of physical flood defences creates a dependency from which it is difficult or impossible to deviate. For example, New Orleans and the entire Mississippi River Basin in the US are now hostage to decisions made nearly 100 years ago to install massive levees and flood walls. Not only do these structures require constant care, we have since learned that there are cheaper, more effective and more environmentally friendly solutions that now cannot be implemented. Of course, a city such as New York, London, or Shanghai must be protected but a realistic plan for flood defence must recognise that not everything can be protected equally. Also, we do not yet know, and perhaps never will, the magnitude of the event that we should design for. Under these conditions, flood

defence needs to be flexible and scalable so it can be modified as conditions change and we learn how to better address them.

Recover from the hazard

Despite our best efforts to avoid hazards they occur nevertheless, usually presenting some hitherto unanticipated aspects. How societies recover from them will depend on the degree to which they have invested (mentally, physically and fiscally) in the basic building blocks of a resilient society. The key to resilience is institutional competence. Whether a single government organisation or a collaboration of public, private and NGO elements, there must be an entity committed to ensuring that capacity exists at all levels (e.g., governments, businesses, individuals) to respond to the unexpected in a manner that ensures that the societal organisation will endure. This point is critical. Without such commitment, planning and preparation efforts will prove to be a hollow exercise once an event occurs.

In this regard, Jared Diamond may prove prophetic. In his study of extinct societies he identified four reasons why societies have made disastrous decisions that ultimately caused them to disappear[7]: a) failure to anticipate a problem; b) failure to recognise a problem that's already arrived; c) failure to try to implement solutions; and d) denial of the problem. We have seen all of these stages play out at some point in the climate-change discussion.

Being informed about the risks of climate change can help, though, as indicated by a study published in the journal *Nature Climate Change*[8]. This study modelled the response of coastal areas to climate risk by using a coupled physical and economic model. The results suggest that relative to those with little faith in climate model predictions, informed property owners "invest heavily in defensive expenditures in the near term and then abandon coastal real estate at some critical risk threshold that presages a period of significant price volatility".

Building resilience

Resilience in the face of climate change in general and sea-level rise in particular is a global challenge. Wealthy nations have the resources to address issues of monumental scope and scale so they will have an advantage. However, although many nations in the developing world are particularly vulnerable, there is a path that is not purely dependent on the amount of money available. First and foremost, these nations should strive to develop indigenous capability to organise for improved resilience. Local officials would bring to this task what others cannot: a dedication to bettering their own nation[9]. Indigenous capacity alone will not result in resilient communities but without it, improved resilience will not become reality.

Finally, although climate change will add to the global risks faced by vulnerable populations, it must be remembered that the world has a long history of extreme weather and other natural hazards. Focusing solely on climate change in hazard preparedness and resilience will paint an incomplete picture of the risks and complicate discussions of how best to address them. Although it is obvious that climate change will affect the global risk profile for decades to come, much of what needs to be done is actually independent of it. For example, providing improved emergency warning systems and moving people out of high-risk locations was a priority long before climate change became an issue. How well these changes and their impacts are anticipated and addressed will have a profound effect on the lives and economic wellbeing of hundreds of millions of people now and in the future.

The world has a long history of extreme weather and other natural hazards.

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2. Lewis N S (2007) *Materials Research Society Bulletin* 32(10): 808-820.

3. IPCC (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* Edited by C B Field *et al.* Cambridge University Press, Cambridge, UK, and New York, NY, USA. 582 pp.

4. United Nations, World Urbanization Prospects, The 2011 Revision. March 2012.

5. The less developed regions comprise all regions of Africa, Asia (excluding Japan) and Latin America and the Caribbean as well as Melanesia, Micronesia and Polynesia.

6. Had the emergency electrical generators at Fukushima Daiichi been located above the tsunami inundation zone, much of the resultant radiological disaster would likely not have occurred.

7. *Collapse: How Societies Choose to Fail or Succeed.* Jared Diamond, 2005. Viking.

8. McNamara D E and Keeler A (2013) *Nature Climate Change*, doi:10.1038/nclimate1826

9. For example, Bangladesh has implemented a comprehensive, end-to-end mitigation, warning, evacuation, and sheltering system. Comprising 123 sea- and inland-facing polders, extensive replanting of mangrove forests, early detection, warning, and evacuation supported by more than 2400 purpose-built cyclone shelters, the system is credited with saving thousands of lives.