The Lessons of Katrina, Learned and Unlearned

Author: Hill, Douglas

Source: Journal of Coastal Research, 28(2) : 324-331

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/11A-00026.1

Journal of Coastal Research	28	2	324–331	West Palm Beach, Florida	March 2012

www.JCRonline.org

EDITORIAL

www.cerf-jcr.org

The Lessons of Katrina, Learned and Unlearned

Douglas Hill

15 Anthony Court
Huntington, NY 11743-1327, U.S.A.
Douglas.Hill@StonyBrook.edu

www.JCRonline.org

ABSTRACT

HILL, D., 2012. The lessons of Katrina, learned and unlearned. *Journal of Coastal Research,* 28(2), 324–331. West Palm Beach (Florida), ISSN 0749-0208.

Originally planned to evaluate storm surge barriers, the New York City Panel on Climate Change (NPCC) instead developed a process for government agencies and private stakeholders to adapt critical infrastructure in New York City to the effects of climate change. In its influential 2010 report, the NPCC ignored the literature documenting the lessons learned from Hurricane Katrina striking New Orleans in 2005. A report by the American Society of Civil Engineers (ASCE) sums up these lessons in 10 calls to action. An examination of the NPCC report suggests that half of these lessons have been learned and half have not. Essentially, the ASCE makes public safety, health, and welfare, not adapting critical infrastructure, its top priorities. The NPCC report fails to quantify the risks, does not address the question of an acceptable level of risk, and does not evaluate the consequences of severe coastal flooding. Although storm surge barriers have been found to be hydrologically and technically feasible, they are dismissed as mere contributions to the discussion that are not needed for at least the next several decades, despite the report's own accounting of the extreme uncertainty and possible effects of severe hurricanes and nor'easters. The NPCC report features Flexible Adaptation Pathways to plan and revise adaptation measures over time, which ignore the possibility of hedging strategies and the well-established precautionary principle. Without an engineering presence, the NPCC also overlooks consideration of lead times in planning major projects. It is concluded that the NPCC report is delaying regional measures against severe coastal flooding, discouraging hedging and the precautionary principle, and deterring adequate measures to protect public safety, health, and welfare.

ADDITIONAL INDEX WORDS: *Coastal zone management, risk management, climate change adaptation, coastal flooding, storm surge, storm surge barriers, New York City.*

On Earth Day, April 22, 2007, the mayor of New York City released "PlaNYC: A Greener, Greater New York," the city's comprehensive plan to prepare for a changing climate and take actions to build climate resilience. Among its 127 planned measures was the creation of a board to advise the city on climate change. As the report stated,

> Storm surge barriers could protect significant swaths of our coastline, but still leave others exposed—and cost billions. Any assessments on that scale will need to be undertaken carefully. That's why we will create a New York City Climate Change Advisory Board. (City of New York, 2007, p. 139)

In August 2008, the name of the board was changed to the New York City Panel on Climate Change (NPCC, after the international Intergovernmental Panel on Climate Change, or IPCC), and so was its purpose:

> The goal of the NPCC is to contribute to an effective, ongoing, and beneficial *process* for responding to the risks that climate change poses to New York City in the coming decades…It has suggested approaches to create an effective *adaptation* program for *critical infrastructure.* (NPCC, 2010, pp. 7, 11) (emphasis added)

The NPCC report released in May 2010 is influential. It provides the principal scientific guidance to the other climate change group convened by the city, the New York City Climate Change Adaptation Task Force, which consists of 32 city and state agencies and private companies that operate, regulate, or control critical infrastructure; assess risks; and develop strategies to increase the city's climate resilience. The NPCC report has been cited in the update of the city's Comprehensive Waterfront Plan, the report of the New York State Sea Level Rise Task Force, and the draft ClimAID report of the New York State Energy Research and Development Authority.

What this report says, matters. Yet despite its ubiquity, the NPCC report seems never to have been critically reviewed.

Strangely, the NPCC report makes no mention of the lessons of Katrina, the hurricane that devastated New Orleans in 2005.

DOI: 10.2112/11A-00026.1 received 24 September 2011; accepted 24 September 2011.

Table 1. *Calls to action of the ASCE Hurricane Katrina External Review Panel.*

ASCE Lesson	Learned	Unlearned
1. Keep safety at the forefront of public priorities		X
2. Quantify the risks		X
3. Communicate the risks to the public and decide how much is acceptable		X
4. Rethink the whole system, including land use		X
5. Correct the deficiencies	√	
6. Put someone in charge	√	
7. Improve inter-agency coordination	√	
8. Upgrade engineering design procedures	√	
9. Bring in independent experts	√	
10. Place safety first		X

Although the NPCC report examines the plans for climate change in three other urban areas—Chicago, London, and King County, Washington—New Orleans is conspicuously missing. Although more than 300 references are cited in several sections of the NPCC report, there is no mention of the three major studies of Katrina:

(1) "Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System," the final report of the Interagency Performance Evaluation Taskforce (IPET) and an evaluation by more than 150 engineers and scientists (U.S. Army Corps of Engineers, 2009)
(2) "The New Orleans Hurricane Protection System: What Went Wrong and Why," a report of the American Society of Civil Engineers (ASCE) Hurricane Katrina External Review Panel, a group of 19 engineers and scientists (ASCE, 2007)
(3) "The New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability and Improving Mitigation and Preparedness," presented by Jeffrey Jacobs of the National Academy of Engineering and National Research Council (NAE/NRC) to the U.S. Senate Committee on Environment and Public Works (NAE/NRC, 2009)

It seems reasonable, therefore, to examine the NPCC report to assess the extent to which the lessons of Katrina have been learned. Those who would argue that New York City cannot be compared with New Orleans because so much of New Orleans is below sea level should be reminded of the 1900 hurricane that struck Galveston, Texas, in which between 6000 and 12,000 people lost their lives (Blake and Gibney, 2011; Larson, 1999). Galveston is above sea level.

The ASCE report in particular culminates in 10 "calls to action"—which I call "lessons"—by which the NPCC report can be evaluated, as shown in Table 1. Although the NPCC report brims with climate change trends, by the standards of the ASCE report, it falls short of analyzing climate change risks. This evaluation is my own and not necessarily that of the ASCE or the State University of New York at Stony Brook.

LESSONS

I limit my remarks to one lesson that seems to have been learned and five others that seem not to have been learned.

ASCE Lesson 1: Keep Safety at the Forefront of Public Priorities

The ASCE would make public safety, health, and welfare its top priorities:

> All responsible agencies in New Orleans and *throughout the nation* should re-evaluate their policies and practices to ensure that *protection of public safety,* health, and welfare is the *top priority* for the infrequent but potentially devastating impacts from hurricanes and flooding. (ASCE, 2007, p. 74) (emphasis added)

In contrast, "The NPCC has suggested approaches to create an effective *adaptation* program for *critical infrastructure*…." (NPCC, 2010, p. 7) (emphasis added). Thus, the NPCC has chosen to focus *only* on adapting critical infrastructure. Examples of critical infrastructure given by the NPCC are subways, bridges, tunnels, and the water supply system.

It is true that the continued functioning of critical infrastructure is essential to protecting public safety, health, and welfare. Moreover, beginning to adapt critical infrastructure to climate change may be the first thing that can be accomplished. The central fact about Katrina, however, is not that the critical infrastructure (as defined by the NPCC) in New Orleans failed but that about 1200 people died when the hurricane hit (Blake and Gibney, 2011, p. 7). They died because the levees failed. A failed levee is like no levee, which is what we have in New York. What is most important is that direct measures begin be taken to protect the public from catastrophic flooding.

In the nightmare scenario for New York City, as described in a government report (U.S. Army Corps of Engineers *et al.,* 1995), hurricane winds would cause windows and masonry from high buildings to fall into the streets. People would rush into the subways, and the subways would then be flooded by the storm surge. Subways in lower Manhattan and elsewhere are below sea level.

The NPCC report is right in including the subway system as critical infrastructure to be protected, but there is nothing in the report to suggest that subways deserve priority nor that this in itself is sufficient to adequately protect public safety. On balance, I give the NPCC report a failing mark on lesson 1.

ASCE Lesson No. 2: Quantify the Risks

In ordinary conversation, "risk" simply means the likelihood of some unfortunate event. However, the NPCC report (2010, p. 31) quantifies risk as follows:

$$\text{Risk} = \text{the probability of an event multiplied by some measure of its consequences}$$

To quantify risk, therefore, it is necessary to quantify both the consequences and the probability of their occurrence. Based on the expected gradual rise in sea level, the NPCC report projects changes in the average recurrence intervals of storms described as 1-in-10-year, 1-in-100-year, and 1-in-500-year floods, together with relative expected increases in flood heights, for three time slices: the 2020s, 2050s, and 2080s. However, it makes a distinction between these storms and

"extreme events," such as intense hurricanes and northeasters. With regard to changes in extreme events, it reports that only qualitative statements can be made; specifically, intense hurricanes are more likely than not to increase, and any change in the severity of northeasters in the 21st century is too uncertain to support even qualitative statements. Moreover, the *consequences* to New York City of these extreme events is neither quantified nor described. Thus, it cannot be said that the NPCC report quantifies the risks.

ASCE Lesson No. 3: Communicate the Risks to the Public and Decide How Much Is Acceptable

The NPCC recommends that New York City's risk management response "include multiple layers of government and a wide range of public and private stakeholder experts to build buy-in and crucial partnerships for coordinated adaptation strategies [and] take account of the private sector in these interactions" (2010, p. 145).

Surely, this qualifies as communicating with the public. However, the NPCC report does not address how much risk is acceptable. The coastal flooding hazard cited frequently in the NPCC report is the so-called 100-year storm, which has a 1-in-100 probability of occurring in any given year. The 100-year storm is defined by the Federal Emergency Management Agency based primarily on the historical record, with the extent of flooding shown on flood insurance rate maps. Perhaps this is to be taken as the NPCC's implicit level of acceptable risk. However, the NAE/NRC report concludes that for heavily populated urban areas, where the failure of protective structures would be catastrophic, the 100-year standard is inadequate. In the Netherlands, where the standard of protection is the 1000-year flood, which implies a greater flood height than that in a 100-year flood, consideration is being given to raising the standard in some critical areas to the 10,000-year flood, which again has a relative increase in flood height (Wolman, 2008). In any event, the NPCC report contains no explicit evaluation of acceptable risk; thus, lesson 3 cannot be considered "learned."

ASCE Lesson 4: Rethink the Whole System, Including Land Use

According to the NPCC report, "The Adaptation Assessment Guidebook [Appendix B of the report] lays out a multi-step process *to help stakeholders* create an inventory of their at-risk infrastructure and develop adaptation strategies to address those identified risks" (2010, p. 235) (emphasis added).

This exclusive focus on stakeholders precludes consideration of *regional* protection measures, since none of the stakeholders are responsible for protecting the entire region.

ASCE Lesson 7: Improve Interagency Coordination

As stated in the NPCC report,

> The City has developed an effective approach to climate change adaptation [including] … development of an evolving dynamic process among City government, public and private stakeholders, and experts to develop a risk-management approach to climate change and to begin to implement Flexible Adaptation Pathways for the city. (2010, pp. 9–10)

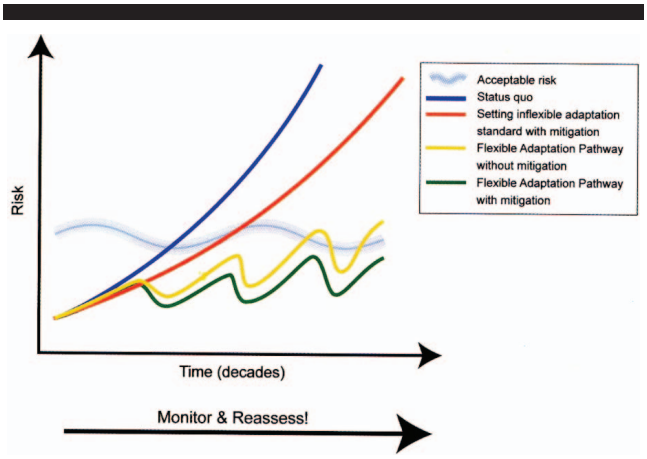

Figure 1. Flexible Adaptation Pathways (NPCC, 2010).

By providing its report through the New York City Climate Change Adaptation Task Force to its 32 members, including 10 city agencies, 8 state agencies and authorities, and 14 stakeholders in the private sector, the NPCC has surely served to improve interagency coordination. But what are "Flexible Adaptation Pathways"?

Flexible Adaptation Pathways are defined as "a sequence of strategies policy makers, stakeholders, and experts develop and implement that evolve as our knowledge of climate change progresses" (NPCC, 2010). The concept is illustrated with a conceptual diagram, adapted from the City of London, "The Thames Estuary 2100 Plan" (2011), and shown in Figure 1.

The light blue line represents what is regarded as acceptable risk (not defined in the NPCC report), which can be expected to vary little over time. As time passes, the status quo would come to exceed this acceptable risk (assuming that it does not already do so). If adaptation plans made now were never changed, the acceptable risk would also be exceeded in time. With Flexible Adaptation Pathways, however, adjustments would be made as new knowledge of the threats developed. Also taking into account the mitigation[1] of the causes of climate change, this periodic readjustment would keep the risks even lower.

What could be wrong with this idea? Surely, it is clear that as new information emerged, adjustments would be made in the measures to be taken. Why does anything so obvious deserve a special name with initial capital letters?

But wait: Don't the measures to be taken have something to do with the severity of the risks that are being undertaken? Yes, says the NPCC report:

[1] The NPCC report (2010) makes the usual distinction between *mitigation* of the causes of climate change and *adaptation* to its consequences.

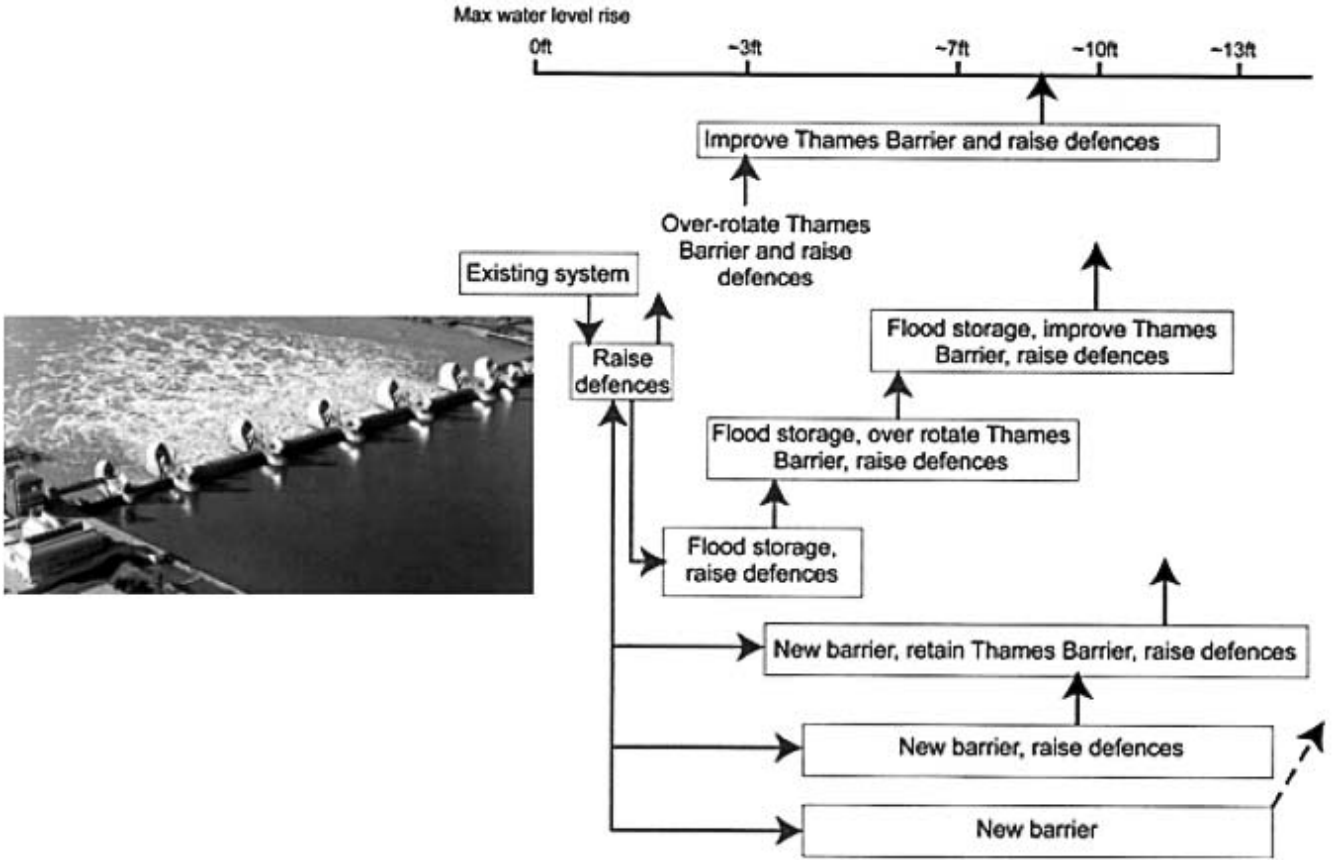

Figure 2. Iterative adaptation strategies to protect London from coastal storms.

> Policy makers can identify tipping points in natural and social systems, perhaps described in terms of critical thresholds of irreversible or particularly deleterious impacts, based on scientific research. These can be an essential part of designing these pathways, *but only if* they can be expressed in terms of timely "triggers" that determine when an adaptation measure is required. (2010, p. 37) (emphasis added)

"But only if" is a Big If. It means that nothing is done unless scientific research turns up new information so precise that the timing of the risk can be quantified. But the NPCC report (2010) also says:

(1) "Many uncertainties about the earth's climate system are so profound that they may never be resolved in a timely fashion." (p. 33)
(2) "Yet decision makers cannot simply ignore highly unlikely triggers that might lead to irreversible impacts or extraordinary consequences." (p. 32)
(3) "In monetary policy, *hedging* strategies have been employed against large risks whose likelihoods and/or consequences cannot be estimated." (p. 32)
(4) "Uncertainty makes the case for near-term actions through *hedging* against climate risks denominated in terms of both monetary damages and other indicators, such as billions of additional people who might be facing hunger, water stress, or hazards from coastal storms." (p. 31) (emphasis added)

Hedging and the Precautionary Principle

Thus, hedging—taking action now to avoid severe future risks, even when they cannot be quantified—is the *opposite* of Flexible Adaptation Pathways as defined in the NPCC report, which requires action only if timely triggers can be identified. This contradiction goes unnoticed in the NPCC report.

Moreover, hedging has a long history in environmental planning, where it goes by the name "the precautionary principle." As it is defined in the NPCC report, "Where threats of serious or irreversible damage to people or nature exist, lack of full scientific certainty should *not* be viewed as sufficient reason to *postpone* measures to prevent the degradation of the environment or protect the health of the citizens" (2010, p. 91) (emphasis added).

This definition is adapted from San Francisco's Environment Code Ordinance, which mandates the adoption of the precautionary principle throughout the city and the county (Bay Area Working Group on the Precautionary Principle, 2011). San

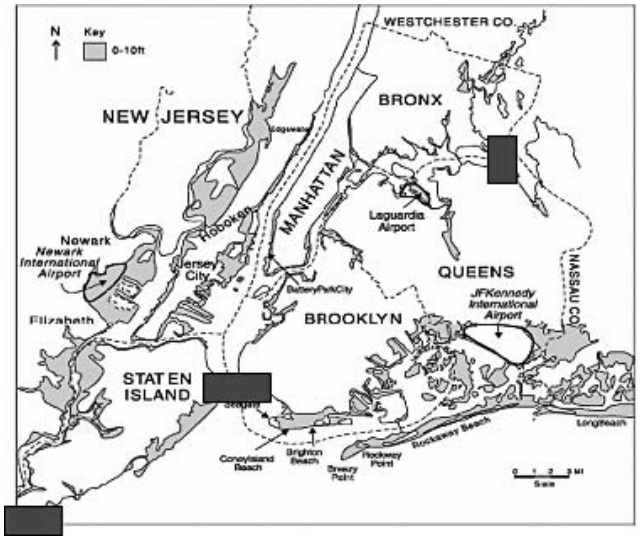

Figure 3. Location of three barriers to protect inner New York City from a storm surge. Gray areas show the extent of the 100-year flood. (Map adapted from Gornitz, 2001)

Francisco is not the only place where the precautionary principle is public policy. In the law of the European Union, the application of the precautionary principle has been made a statutory requirement (Wikipedia, 2011).

Again, the contradiction between the precautionary principle and the Flexible Adaptation Pathways goes unnoticed in the NPCC report. This is important because Flexible Adaptation Pathways might be considered the theme of the NPCC report. These pathways are mentioned throughout the report, and they are touted in the executive summary, conclusions, and recommendations, where hedging and the precautionary principle go unmentioned. Will Flexible Adaptation Pathways then serve only as an excuse for procrastination?

An illustration of using Flexible Adaptation Pathways to protect London is given in the NPCC report (Figure 2). Various improvements in the level of protection are shown according to the expected rise in sea level. These include improving the present Thames Barrier and building a new barrier. A crucial difference, however, is that the choice in London is between protection and more protection, while the choice in New York is between adding protection and continuing to be unprotected.

Storm Surge Barriers

This brings us back to storm surge barriers, ostensibly the reason the NPCC was created. The proposal to protect New York City with storm surge barriers originated at the Marine Sciences Research Center, now the School of Marine and Atmospheric Sciences, at Stony Brook University. In a report (Bowman *et al.,* 2004), the group reported the results of applying a meteorological/hydrodynamic model that demonstrated that much of the New York metropolitan region can be protected with three barriers placed at narrow points in the waterways surrounding the city. These would be placed at the upper end of the East River, across the Narrows, and at the mouth of the Arthur Kill, which separates Staten Island from New Jersey (Figure 3). Another concept would replace the latter two with a barrier extending from Sandy Hook to the tip of the Rockaway Peninsula.

Figure 4. Conceptual design of a storm surge barrier across the Narrows. (Jansen and Dircke, 2009.)

At a March 2009 conference sponsored by sections of the ASCE and the New York Academy of Sciences, four major engineering firms presented conceptual designs of the barriers, and a fifth reported on the geotechnical aspects of the barrier sites, thus establishing their technical feasibility (Abrahams, 2009; Jansen and Dircke, 2009; Lacy, DeVito, and De Nivo, 2009; Murphy and Schoettle, 2009; Padron and Forsyth, 2009). An example is the design of the barrier across the Narrows shown in Figure 4.

If such barriers are ever to protect New York City, steps need to be taken soon for the assessment promised in PlaNYC (City of New York, 2007). This is not because of the time it takes to build such barriers—8 to 10 years, by the experience of similar barriers in Europe—but because of the time of the time it takes to *start* to build them. As seen in Table 2, this has taken two or three decades in Europe. This time period would likely be no shorter in New York when you consider what is entailed: gaining public support, gaining support and funding from the governments involved, making assessments, preparing designs, obtaining permits, preparing the environmental impact statement, holding hearings, fighting lawsuits, *etc.*

This is known as "lead time," a concept that is also missing from Flexible Adaptation Pathways. Lead time is mentioned nowhere in the NPCC report. How could it have been overlooked? Possibly, it was overlooked because of the makeup of the NPCC. As described in the report, the NPCC "consists of climate change and impacts scientists, and legal, insurance, and risk management experts" (NPCC, 2010). Is something missing? People in these professions have never built anything, so the thought of lead time may not have occurred to them. There are no civil engineers on this panel devoted to protecting critical infrastructure. This must be surprising to the ASCE, which, on the national level, takes on the role of the steward of infrastructure, periodically providing a report card on the state of the infrastructure in the United States, with recent grades ranging from C to D-minus.

In the 350-page NPCC report, storm surge barriers are discussed in two paragraphs, the essence of which is as follows:

Table 2. *Delays in constructing storm surge barriers.*

Barrier (country)	Flood	Delay (years)	Start	Construction Time (years)	Completion
Providence (U.S.A.)	1938	23	1961	5	1966
New Bedford (U.S.A.)	1938	24	1962	4	1966
Stamford (U.S.A.)	1938	27	1965	4	1969
Thames River (U.K.)	1953	21	1974	10	1984
Eastern Scheldt (the Netherlands)	1953	14–26	1967–1979	7	1986
Maeslant (the Netherlands)	1953	36	1989	8	1997
Venice (Italy)	1966	37	2003	(11)	(2014)

> At present, conceptual designs of storm surge barriers should be considered as *contributions to the discussion*… [that] would require very extensive study…. New York City could protect against some level of storm surge with a combination of local measures (e.g., flood walls and reclaimed natural barriers), improved storm information and forecasting, and evacuation plans for at least the next several decades. (2010, p. 76) (emphasis added)

The colossal complacency of the latter sentence is belied by sections of the rest of the NPCC report (2010):

(1) "Because the climate processes affecting extreme events, such as hurricanes and nor'easters, may change in the future, prediction of future extremes is generally characterized by higher uncertainty." (p. 57)
(2) "Intense hurricanes will become more likely than not." (p. 57)
(3) "Changes in the distribution of extreme events could have large effects." (p. 58)
(4) "For New York City, the primary near-term risk is coastal flooding from nor'easters." (p. 114)
(5) "Historical nor'easters have reached intensities comparable to category 1 and 2 on the Saffir-Simpson scale." (p. 114)
(6) "The nor'easter of December 1992 had the highest storm surge since modern record keeping was recorded at the Battery." (p. 114)

The aforementioned northeaster of December 1992 completely shut down New York City subways, the Port Authority Trans-Hudson system, Metro North service to Grand Central Station, and portions of the Long Island Rail Road, and it required the rescue of passengers on subways and drivers stalled on the Franklin D. Roosevelt East River Drive. If the storm surge had peaked 2 ft higher, according to a government study, lives could have been lost on the roadways and rail systems (U.S. Army Corps of Engineers *et al.,* 1995, pp. 37–39).

Table 3. *Average return periods of hurricanes striking the New York region.*

Category (hurricane)	Last Occurrence	Average Return Period (years)	Expected Return Date
1 (Bob)	1991	17	2008
2 (Gloria)	1985	39	2024
3 (Long Island Express)	1938	68	2006

Why Were the Lessons of Katrina Ignored?

Why were the lessons of Katrina ignored by the NPCC? Will hurricanes not strike New York City? If they do, will the damage not be significant? In any case, can nothing be done to protect the region from coastal storm damage? Let us examine these possibilities.

Will Hurricanes Not Strike New York City?

In the past, epic hurricanes have struck the city. In the 1815 hurricane, according to the historical record, sea level rose 13 ft/h, flooding everything south of Canal Street. In the 1893 hurricane, a 30-ft storm surge swept across southern Brooklyn and Queens. Hog Island south of the Rockaway Peninsula was obliterated. The 1938 "Long Island Express," which would be classed as a category 3 hurricane today, only brushed New York City but drowned 50 people on Long Island and more than 600 in New England, mostly in Providence, Rhode Island (Wikipedia, 2011).

Moreover, we have the statement of Max Mayfield, the former director of the Tropical Prediction Center of the National Hurricane Center, who told a congressional committee on May 24, 2006, that "It is not a question of *if* a major hurricane will strike the New York area, but *when*…" (Mayfield, 2006) (emphasis his). This statement was quoted in the NPCC report (2010, p. 119). As to when, the National Oceanic and Atmospheric Administration is less guarded than the NPCC in forecasting hurricanes. NOAA has reported on the Web its estimates of the average return periods of hurricanes striking the New York City region (National Hurricane Center, 2011). Table 3 shows the return periods counting from the last hurricane of the same category.

In other words, we have been overdue for hurricanes of category 1 and 3, and we can expect a category 2 within the next two decades. Of course, hurricanes do not return at the average return periods on schedule; otherwise, we would already have had hurricanes of category 1 and 3.

Will the Damage Not Be Significant?

According to modeling done by the New York City Office of Emergency Management, the consequences of a catastrophic storm surge striking the city would be dire. Up to 3 million people would need to be evacuated. More than one-third of the city's land—some in each of the five boroughs—would be inundated, flooding 577 schools, 88 fire and emergency service facilities, and 80 hospitals and nursing homes (New York City Office of Emergency Management, 2009).

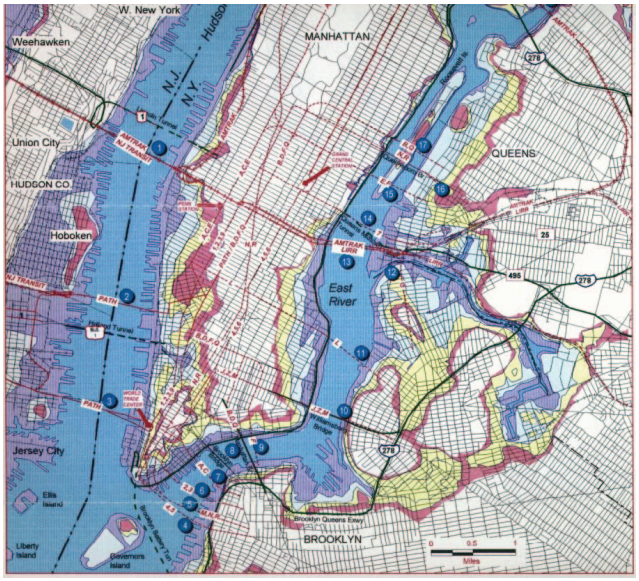

Figure 5. Flooding in the central city from a worst-case hurricane of various categories. Dark blue = category 1, light blue = category 2, yellow = category 3, red = category 4. (U.S. Army Corps of Engineers *et al.,* 1995.)

The consequences to lower Manhattan of a worst-case scenario, in which the eye of the hurricane strikes New Jersey and the city receives the brunt of the high winds and the storm surge, would be disastrous, as shown in Figure 5 (U.S. Army Corps of Engineers *et al.,* 1995). Its effect on the financial community, the heartbeat of New York City's economy—immediately and over the long term—can only be guessed.

A study by the Organization for Economic Cooperation and Development ranked 136 port cities in the world by their exposure and vulnerability to climate extremes (Nicholls *et al.,* 2008). New York City was rated among the top 10 in terms of population exposure. It was rated second only to Miami in terms of "value of property and infrastructure assets." However, Miami does not contain the financial center of the world. In terms of the economic consequences of a disastrous flood, New York City is undoubtedly first.

Can Nothing Be Done To Protect the Region from Coastal Storm Damage?

To answer this question with complete assurance, an assessment of storm surge barriers is needed, as originally promised by PlaNYC (City of New York, 2007).

ASCE Lesson 10: Place Safety First

The NPCC report refers to "needed studies" adding that it is necessary to "conduct feasibility studies of nonstructural and structural citywide protective measures, as appropriate over *future* time periods" (2010, p. 11) (emphasis added). This isn't putting safety first. This is putting safety off.

CONCLUSIONS

In this life-or-death matter, conclusions can be drawn from the lessons of Katrina and the inconsistencies of the 2010 NPCC report:

(1) By focusing only on the critical infrastructure of individual stakeholders, the NPCC report is *delaying* regional measures against severe coastal flooding.
(2) By promoting Flexible Adaptation Pathways, it is *discouraging* hedging and the application of the precautionary principle.
(3) By dismissing storm surge barriers, it is *deterring* adequate measures to protect public safety, health, and welfare.

LITERATURE CITED

Abrahams, M., 2009. East river storm surge barrier. *In:* Khinda, J.S. (ed.), *Against the Deluge: Storm Surge Barriers to Protect New York City*. New York: American Society of Civil Engineers, Metropolitan Section, 151p.

ASCE (American Society of Civil Engineers), 2007. The New Orleans Hurricane Protection System: What Went Wrong and Why. A report of the ASCE Hurricane Katrina External Review Panel. Reston, Virginia: American Society of Civil Engineers.

Bay Area Working Group on the Precautionary Principle, 2011. The Precautionary Principle in Action. http://www.takingprecaution.org/inact_bayarea.html (accessed October 27, 2011).

Blake, E.S. and Gibney, E.J., 2011. The deadliest, costliest, and most intense United States tropical cyclones from 1851 to 2010 (and other frequently requested hurricane facts). NOAA Technical Memorandum NWS NHC-6. August 2011.

Bowman, M.J.; Colle, B.; Flood, R.; Hill, D.; Wilson, R.E.; Buonaiuto, F.; Cheng, P., and Zheng, Y., 2004. Hydrologic feasibility of storm surge barriers to protect the metropolitan New York–New Jersey region, Summary report. Stony Brook, NY: Marine Sciences Research Center, State University of New York at Stony Brook.

City of London, 2011. The Thames Estuary 2100 Plan. http://www.environment-agency.gov.uk/homeandleisure/floods/104695.aspx (accessed October 27, 2011).

City of New York, 2007. PlaNYC: a greener, greater New York. New York: City of New York.

Gornitz, V., 2001. Sea-level rise and coasts. *In* Rosenzweig, C. and Solecki, W.D., (eds.), *Climate Change and a Global City, the Potential Consequences of Climate Variability and Change, Metro East Coast*. Columbia Earth Institute, New York, NY.

Jansen, P. and Dircke, P., 2009. Verrazano Narrows storm surge barrier: a Dutch vision. *In:* Khinda, J.S. (ed.), *Against the Deluge: Storm Surge Barriers to Protect New York City*. New York: American Society of Civil Engineers, Metropolitan Section, pp. 118–127.

Lacy, H.S.; DeVito, A., and De Nivo, A., 2009. Geotechnical aspects of three storm surge barrier sites to protect NYC from flooding. *In:* Khinda, J.S. (ed.), *Against the Deluge: Storm Surge Barriers to Protect New York City*. New York: American Society of Civil Engineers, Metropolitan Section, pp. 73–91.

Larson, E., 1999. *Isaac's Storm*. New York: Crown Publishers.

Mayfield, M., 2006. Written testimony before the Committee on Commerce, Science and Transportation, Subcommittee on Disaster Prevention and Prediction, U.S. Senate, May 24.

Murphy, L. and Schoettle, T., 2009. Arthur Kill storm surge barrier design concept. *In:* Khinda, J.S. (ed.), *Against the Deluge: Storm Surge Barriers to Protect New York City*. New York: American Society of Civil Engineers, Metropolitan Section, pp. 128–134.

NAE/NRC (National Academy of Engineering and National Research Council), 2009. The New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability and Improving Mitigation and Preparedness. http://www7.nationalacademies.org/ocga/testimony/

New_Orleans_Hurricane_Protection_System.asp (accessed January 25, 2011).
National Hurricane Center, 2011. Hurricane Preparedness. Return Periods. http://www.nhc.noaa.gov/HAW2/english/basics/return.shtml (accessed January 25, 2011).
New York City Office of Emergency Management, 2009. Planning for Emergencies: Hazard Mitigation Plan. http://nyc.gov/html/oem/html/about/planning_hazard_mitigation.shtml (accessed January 25, 2011).
Nicholls, R.J.; Hanson, S.; Herweijer, C.; Patmore, N.; Hallegatte, S.; Corfee-Morlot, J.; Château, J., and Muir-Wood, R., 2008. Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes. Paris: Organisation for Economic Co-operation and Development.
NPCC (New York City Panel on Climate Change), 2010. Climate Change Adaptation in New York City: Building a Risk Management Response. Rosenzweig, C. and Solecki, W. (eds.), *Annals of the New York Academy of Sciences*, 1196, 354 p.
Padron, D.V. and Forsyth, G., 2009. NY–NJ outer harbor gateway. *In:* Khinda, J.S. (ed.), *Against the Deluge: Storm Surge Barriers to Protect New York City*. New York: American Society of Civil Engineers, Metropolitan Section, pp. 135–151.
U.S. Army Corps of Engineers, 2009. Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System. Final Report of the Interagency Performance Evaluation Taskforce (IPET). http://www.usace.army.mil/CECW/Documents/cecwe/ipet/v1_final.pdf (accessed January 25, 2011).
U.S. Army Corps of Engineers, Federal Emergency Management Agency, National Weather Service, and New York/New Jersey/Connecticut State Emergency Management,1995. Metro New York Hurricane Transportation Study, Interim Technical Report. Wilmington, North Carolina: U.S. Army Corps of Engineers.
Wikipedia, 2011. Precautionary Principle. http://en.wikipedia.org/wiki/Precautionary_principle (accessed January 25, 2011).
Wolman, D., 2008. Before the Levees Break: A Plan to Save the Netherlands. http://www.wired.com/science/planetearth/magazine/17-01/ff_dutch_delta?currentPage=all (accessed January 25, 2011).