FTA 3rd Climate Change Adaptation Workshop - Arlington VA - 3/21/2012

Adaptation Assessment Guidelines

Part 1: Guidelines
Part 2: Case Study

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References (Free Downloads):

For Part 1: http://www.nyas.org:

Climate Change Adaptation in NYC: Building a Risk Management Response (2010)

http://onlinelibrary.wiley.com/doi/10.1111/nyas.2010.1196.issue-1/issuetoc

Appendix B: http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2010.05324.x/pdf

For Part 2:

Response to Climate Change Adaptation in New York State (NYSERDA Report 11-18; Nov 2011)

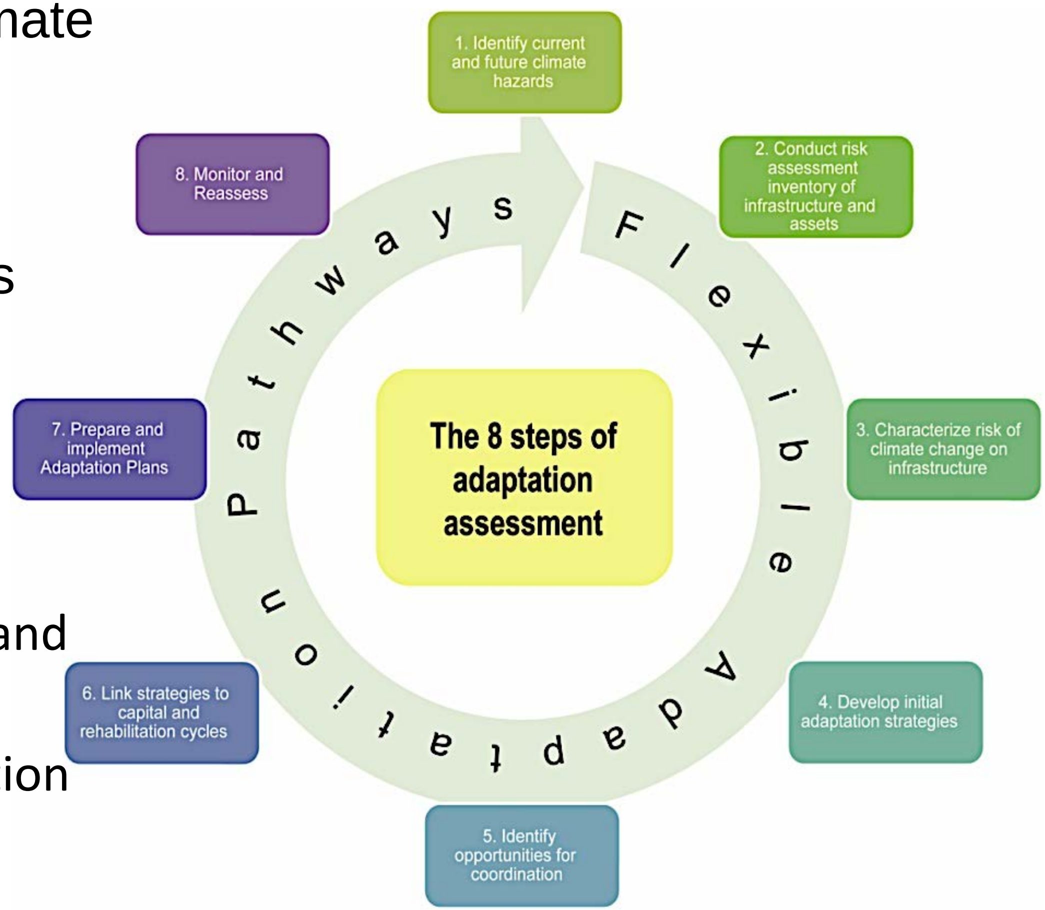
http://www.nyserda.ny.gov/Publications/Research-and-Development/Environmental/EMEP-Publications/Response-to-Climate-Change-in-New-York.aspx

Chapter 9: *Transportation*. Jacob et al. (2011). Case Study, pp. 323 - 354

Adaptation Assessment Guidelines

The Importance of an Overall Framework

1. Identify current and future climate hazards
2. Conduct inventory of infrastructure and assets and begin to identify vulnerabilities
3. Characterize risk
4. Develop initial list of strategies
5. Identify opportunities for coordination
6. Link strategies to rehabilitation and replacement cycles
7. Prepare and implement Adaptation Plans
8. Monitor and reassess



1. Identify current and future climate hazards: NPCC Climate Risk Information

TABLE 1. Baseline Climate and Mean Annual Changes[1]

	Baseline 1971-2000	2020s	2050s	2080s
Air temperature Central range[2]	55° F	+ 1.5 to 3.0° F	+ 3.0 to 5.0° F	+ 4.0 to 7.5° F
Precipitation Central range[2]	46.5 in[3]	+ 0 to 5 %	+ 0 to 10 %	+ 5 to 10 %
Sea level rise[3] Central range[2]	NA	+ 2 to 5 in	+ 7 to 12 in	+ 12 to 23 in
Rapid ice-melt scenario[4]	NA	~ 5 to 10 in	~ 19 to 29 in	~ 41 to 55 in

Source: Columbia University Center for Climate Systems Research

1. Identify current and future climate hazards (contin.)

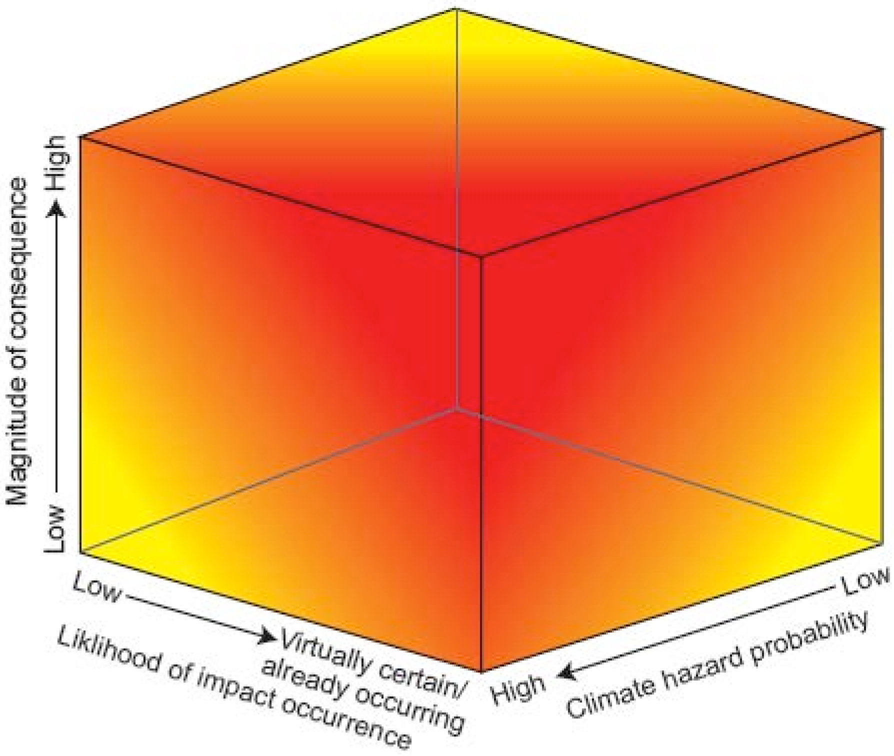
Impacts on Transportation:

- Temperature: **A/C, Rail Buckling, Sagging Catenaries, Aging**
- Precipitation: **Drainage, Pumps, Culverts, Flash-Floods**
- Sea Level Rise: **More Severe, More Frequent Coastal Floods, Permanent Inundation, Saltwater Intrusion**
- Storm Surge: **Coastal Floods, Surge Inundation, Saltwater Intrusion, Erosion**
- Winds: **Bridge Closings, Downed Wires, Signals and Trees**

2. Conduct inventory of infrastructure and assets, and begin to identify vulnerabilities

A	What is the nature and purpose of the infrastructure? What are the principal elements of the infrastructure, including specific elements and classes of infrastructure? ○ Is it considered critical to your mission or to the City? ○ Is it a network (e.g. a pipe, power line) or a point of production or distribution?
B	Location on land (GPS)
C	What is the shortest distance from current shoreline? (In the case of distributed networks, the shortest distance to the coast.) ○ Is this distance likely to change as a result of climate change?
D	Check the elevation and height of infrastructure and its critical components (i.e., primary or back-up generators) against relevant markers to determine risk from flooding. ○ Does the asset currently experience coastal or storm-related flooding? ○ If so, will this be exacerbated by projected climate change impacts?
E	What is the useful life of infrastructure and current rehabilitation/maintenance schedule? ○ Are climate changes likely to occur during the infrastructure's useful life? ○ Are upgrades planned that could incorporate adaptation strategies? ○ Does the rehabilitation/maintenance schedule need to change to account for impacts?
F	What is the current condition of infrastructure, including materials? ○ Will this be affected by increased temperatures and precipitation, rising sea levels, or more frequent and severe extreme weather?
G	Is the infrastructure within any of the following defined areas that may impact potential strategies? For example: FEMA flood plain Historic Districts Wetlands and other protected interior and coastal areas

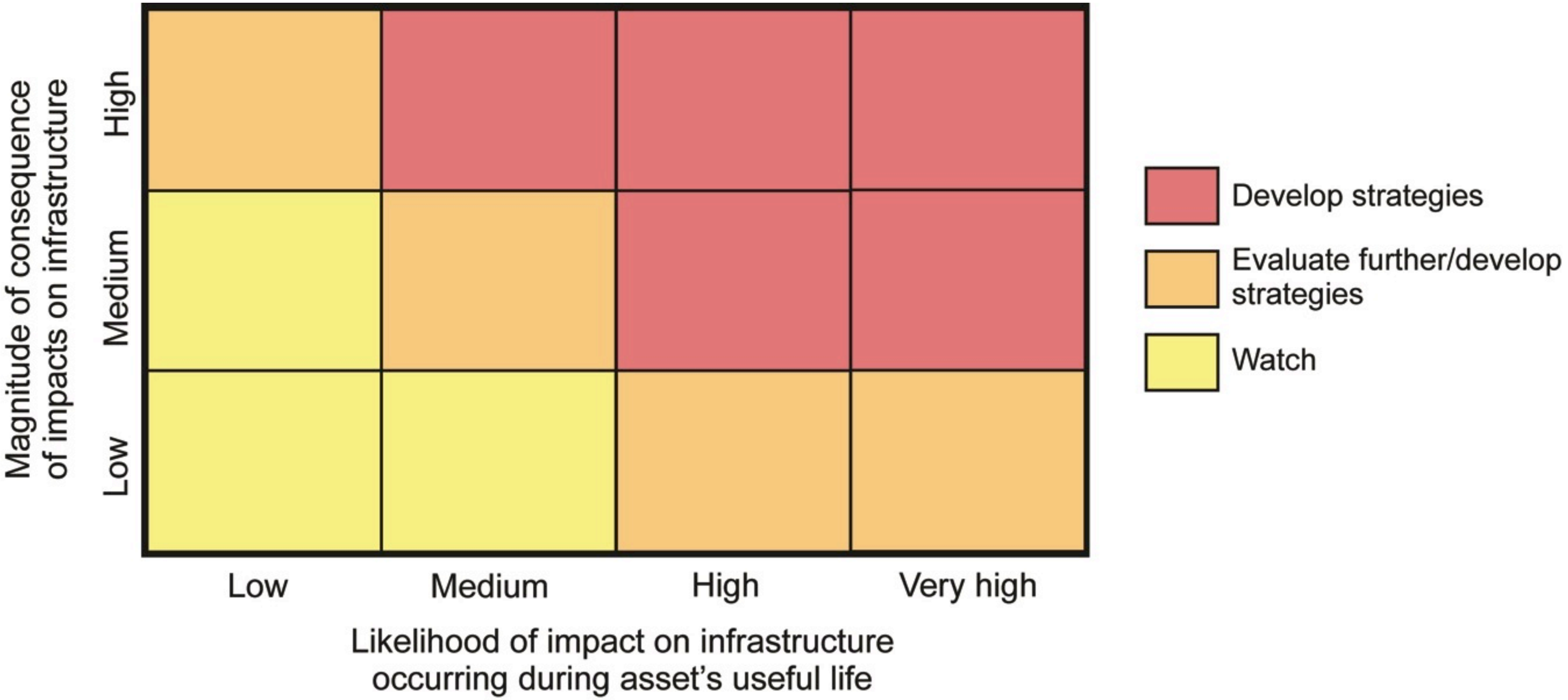
3: Characterize Risk: Theory



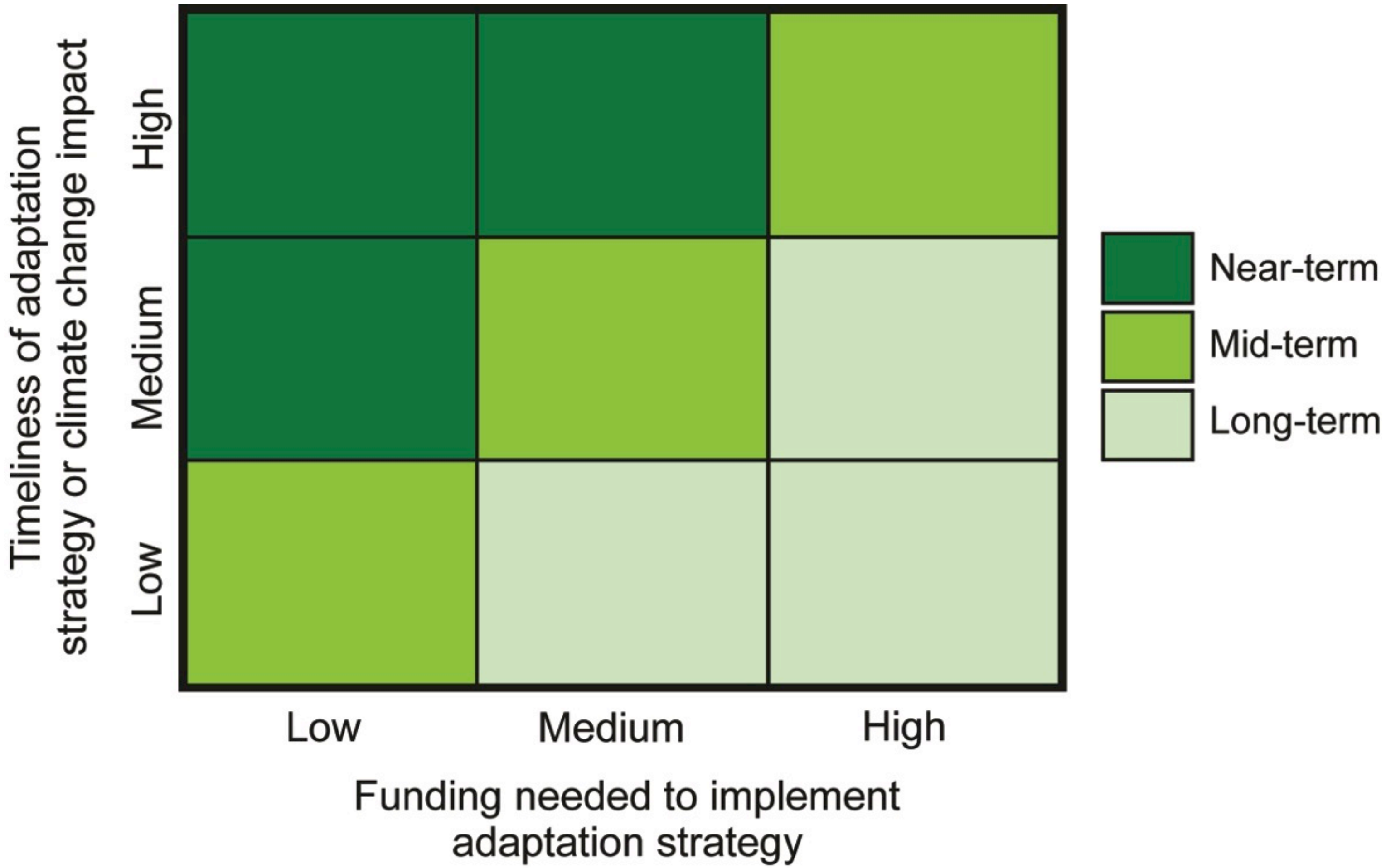
Red: Risks for which adaptation strategies should be developed
Orrange: Risks for which adaptation strategies may need to be developed or for which further information is needed
Yellow: Risks for which impacts should be monitored but which may not need actions at this time

3 (contin.): Characterize Risks: Practice

The Interaction of Theory and Practice



4: Develop Initial Adaptation Strategies



5: Identify Opportunities for Coordination

- Adaptation studies provide an avenue for increased coordination in general
- Within agency
- Between local agencies
- With other jurisdictions
- During different time periods
- Joint financing

6: Link Strategies to Capital & Rehabilitation Cycles (in $1,000)

Sewers	2009	2010	2011
Replacement or Augmentation	23,535	42,586	17,731
Extensions to Accommodate New Development	84.422	74,671	58,390
Programmatic Response to Regulatory Mandates	540	———	9,900
Programmatic Replacement and Reconstruction	196	3,456	23,871
Replacement of Chronically Failing Components	89,025	89,770	70,743
Trunks	2,881	2,489	2,775
Subtotal	200,599	212,972	183,410

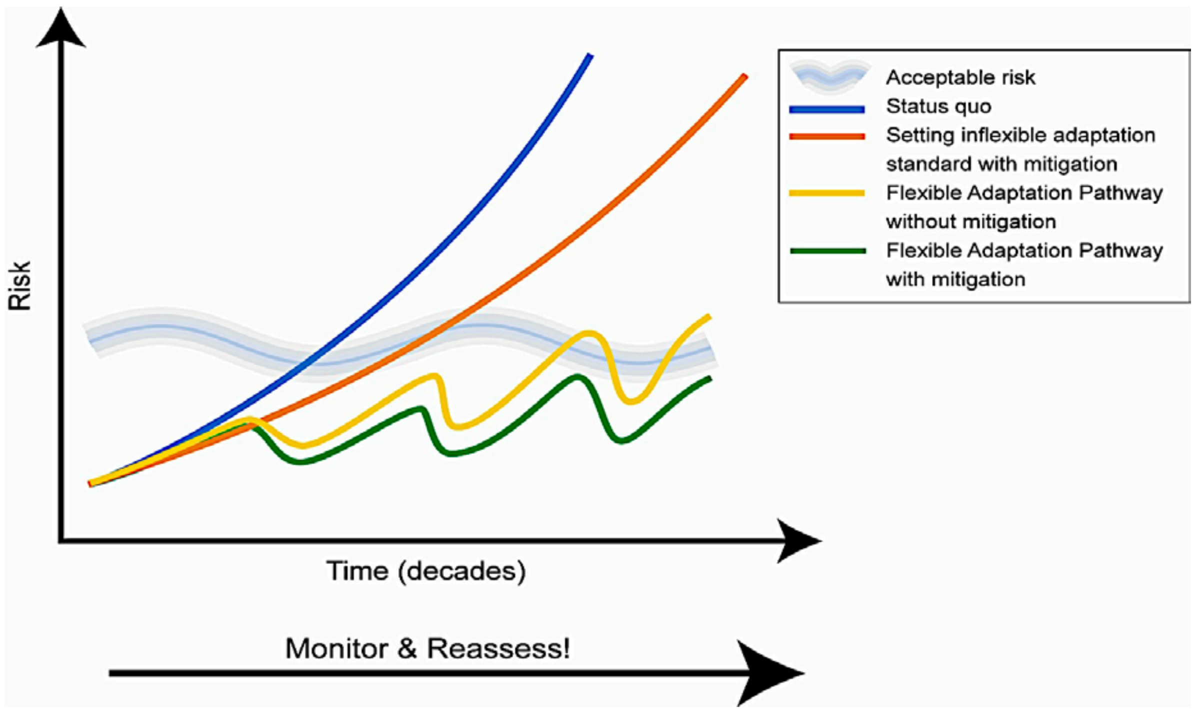
Source: NYCDEP New York City Municipal Water Finance Authority Official Statement 2009
http://nycbonds.org/NYW/pdf/2009/NYW_2009_GG.pdf

7: Prepare & Implement Adaptation Plans

- Adaptation strategies: refine
- Reconfirm costs
- Specifics necessary to implement strategies
- Resources committed to implement the plans
- Timeline for implementation
- Metrics to measure success

7 cont.: Prepare & Implement Adaptation Plans

Flexible Adaptation Pathways: a Useful Principle in Adaptation Planning



Key elements to achieve Flexible Adaptation Pathways are a guiding framework, stakeholder engagement, expert knowledge providers, recurring assessment process, Action Plans by decision-makers, and vertically/horizontally integrated projects with ongoing evaluation

7 cont.: Prepare & Implement Adaptation Plans

Range of Adaptations: NRC 2010. **America's Climate Choices.** Table 3.6, p.84: http://www.nap.edu/catalog/12783.html

Climate change	Impact	Possible adaptation action	Federal	State	Local govt.	Private sector	NGO / Indiv.
Long-term sea-level rise	Permanent flooding of coastal land	Build or enhance levees/dikes for protection	■	■	■	■	
		Elevate critical infrastructure that is at risk for sea level rise	■	■	■	■	
		Abandon/move threatened facilities to higher elevations.	■	■	■	■	
	Loss of barrier islands	Protect and/or relocate newly exposed railroads, highways, bridges	■	■	■	■	
		Switch to alternate shipping methods if waterborne transport cannot use the Intracoastal Waterway or other shipping channels				■	
	Impacts on infrastructure such as bridges or harbors (RFF-PI)[a]	Raise bridge heights and reinforce or relocate harbor infrastructure	■	■	■		
New patterns of prevailing winds	Existing airport runways may become less efficient. Time of travel on long distance flights and transoceanic shipping may	Increase airport runway lengths	■	■	■	■	

7 cont.: Prepare & Implement Adaptation Plans

- Operations and Maintenance Adaptation Examples:
    - Emergency management measures (remote control of signals)
    - Prepositioning of assets
    - Evacuation planning

7 cont.: Prepare & Implement Adaptation Plans

“Soft” Infrastructure: Architects’ Ideas for New York Harbor

- Offshore windmills
- Oyster beds
- Artificial islands
- Subway car reefs
- Offshore piers
- New wetlands
- Piers and slips

Reference: *Rising Currents* exhibit, Museum of Modern Art, NY

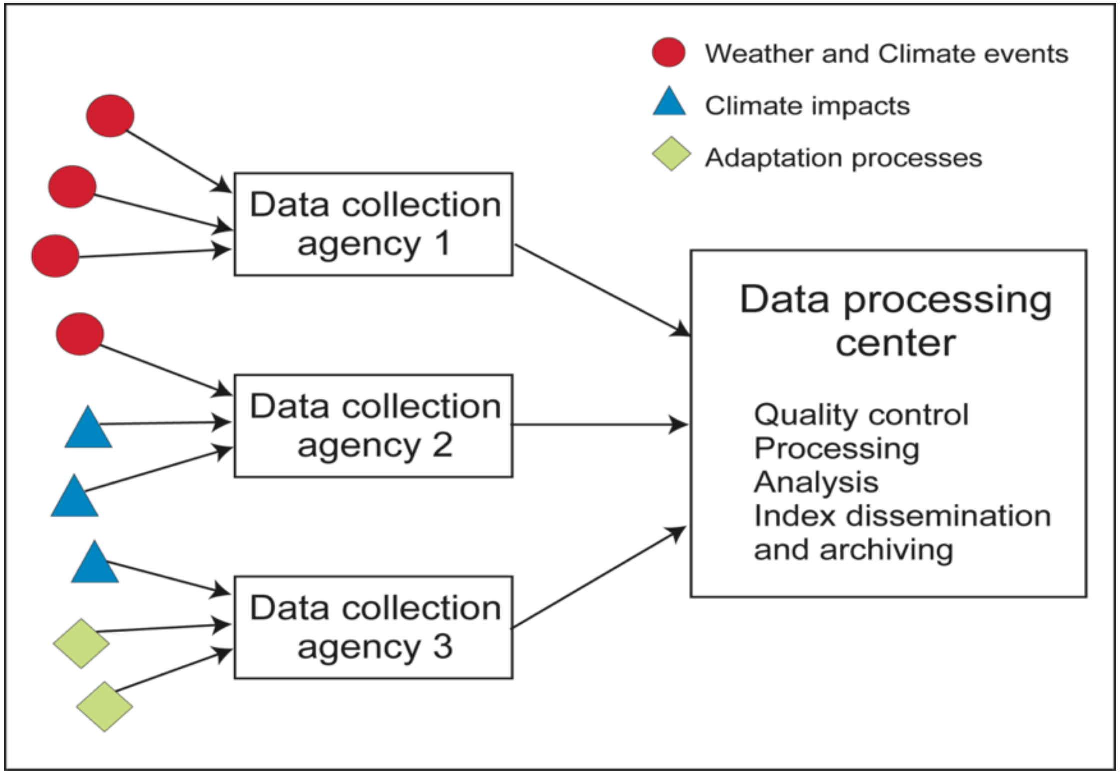
7 cont.: Prepare & Implement Adaptation Plans

Infrastructure: Large Tidal Barrier: the Narrows, New York Harbor

- One of 3 proposed barriers
- Alternative is single barrier further out
- Environmental and other impacts not studied
- Questionable sustainability for continued sea level rise

8: Monitor and Reassess

- Physical climate hazard
- Infrastructure impacts
- Adaptation measures
- New research within each of these categories



The Need for Case Studies

Table 7.5. Benefit Cost Analysis of Potential Climate Change Adaptation: Raising Local Streets Subject to Flooding
Source: adapted from: Multihazard Mitigation Council, 2005b, vol. 2, p.107,Table 5-14.

Activity in Freeport, NY	Total Costs (2002 $M)	FEMA Costs (2002 $m)	Best Estimate Benefits (2002 $M)	Best Estimate Benefit-Cost Ratio	BCR Range
Street grading/elevation	$2.76	$2.07	$6.52	2.4	0.19-9.6

- It is important that more case studies be developed, including cost analysis and analysis of design changes depending on date of implementation

Immediate Needs

- Prepare complete high-resolution LIDAR (Light Detection and Ranging) elevation datasets.
- Provide a detailed inventory of as-built infrastructure within, say, 10 to 20 feet (3m to 6m) of current sea level, calibrated to the current geodetic datum, NAV88.
- Review all large-scale infrastructure projects currently in the planning stage to make appropriate adjustments for adaptation to climate change.
- Develop detailed benefit-cost estimates and required impact statements for different available adaptation options to assist in the development of a climate adaptation plan for various time periods.
- Prepare a set of plans for adaptation, using flexible adaptation pathways for the short, medium and long terms. Review on a regular basis as new information on climate variables accumulates.
- Continue to utilize the latest climate change inputs as a central element in planning for climate adaptation.

Future Prospects

- Effective planning for adaptation to climate change is possible; methods to operationalize the adaptation steps for different circumstances are needed.
- At least the next few decades will be manageable in most situations, but plans for longer periods should be made now
- If humans deal well with mitigation, adaptation will still be needed but on a slower schedule; however:
- If warming continues at a rapid pace, need for adaptation will become more urgent more quickly
- We have time, but the time is now

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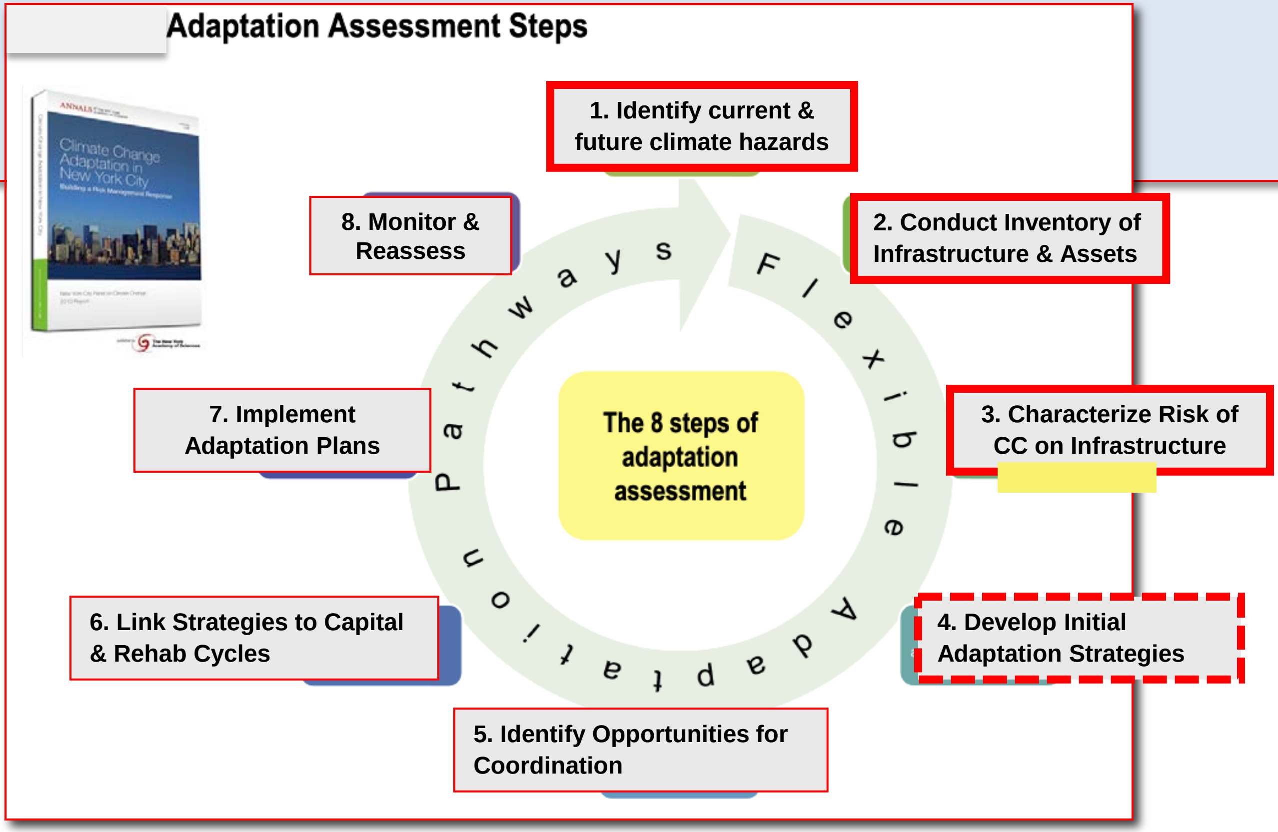
Arlington VA March 21 2012

Adaptation Assessment Guidelines:

Part II: NYC Case Study.



Risk Management Tools: Minimizing the Risk via Mitigation and Adaptation Measures
(Let's use the Risk Equation and GIS-based Models!) :

Risk = Sum (**Hazard x Assets** x Vulnerability)

Mitig.: Reduce GW + SLR Hazards

Adapt.: Land Use Planning & Zoning,
Considerate Placements of new Assets,
Relocation of Essential Assets.
Barriers, Levees & Dams (?).
Sustainability & Equity Issues.

or by **Risk** = Sum (**Hazard x Assets** x Vulnerability)

Adapt.: Good Engineering, Construction Quality-Control,
Codes and Code Enforcement, Retrofitting,
Raising Assets in Place
Reinforcing Barriers, Levees and Pump Stations

1. NPCC Climate Risk Information

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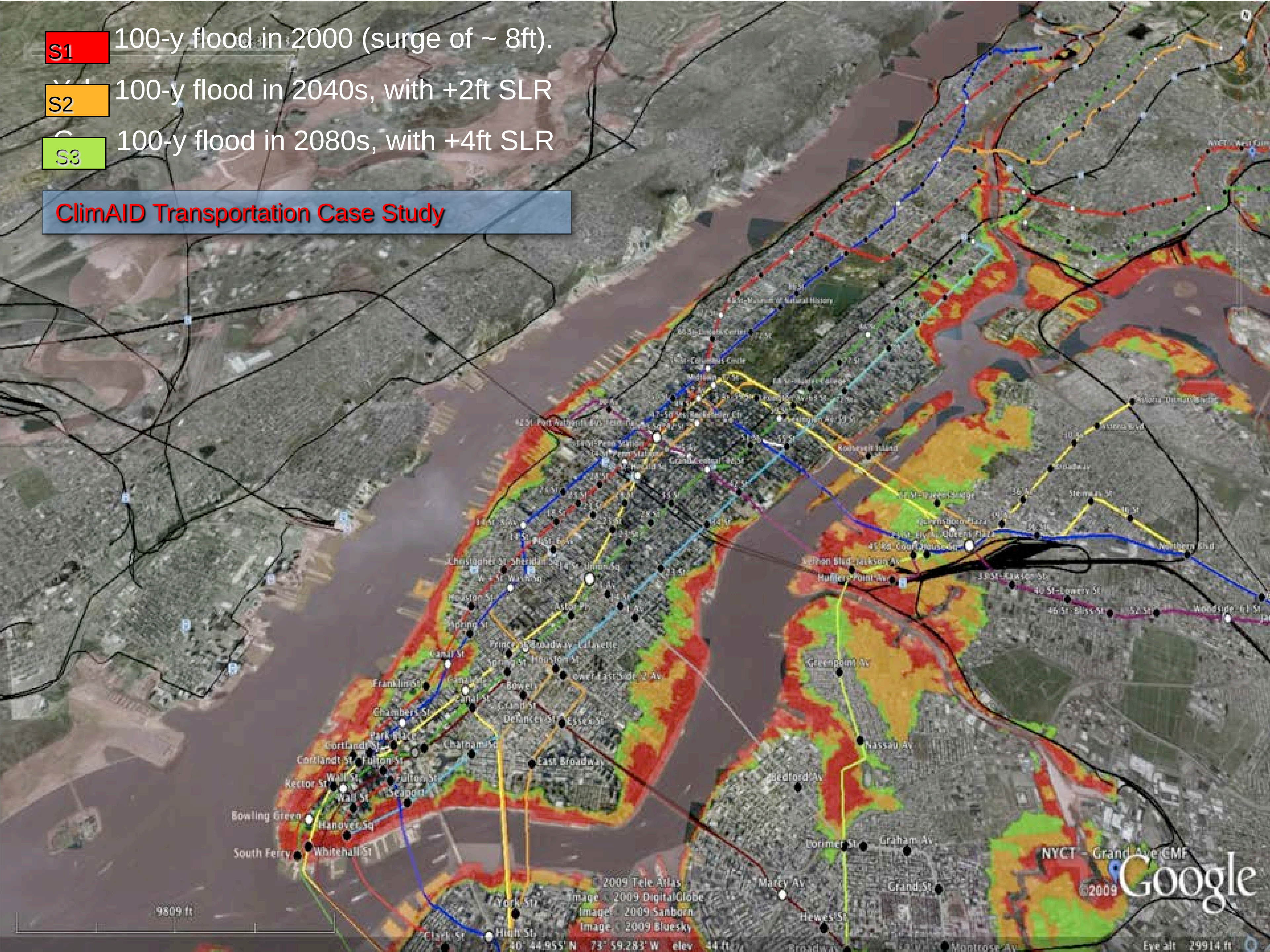
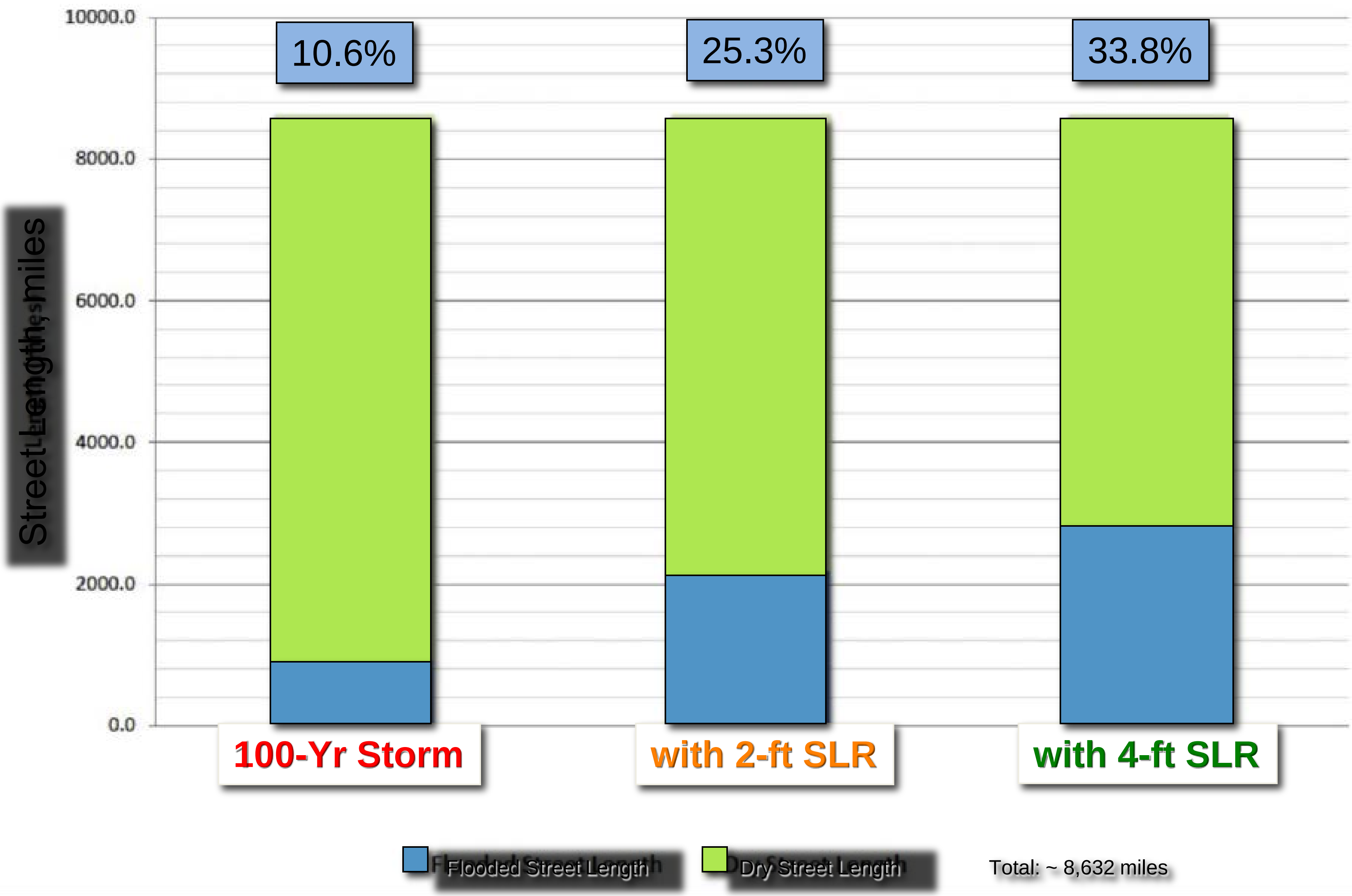
Rapid ice-melt scenario[4]	NA	~ 5 to 10 in	~ 2ft	4ft

Source: Columbia University Center for Climate Systems Research


S1 100-y flood in 2000 (surge of ~ 8ft).
S2 100-y flood in 2040s, with +2ft SLR
S3 100-y flood in 2080s, with +4ft SLR
ClimAID Transportation Case Study
Canal St
Franklin St
Chambers St
Park Place
Cortlandt St
Rector St
Wall St
Bowling Green
Hanover Sq
South Ferry
Whitehall St
Greenpoint Av
Nassau Av
Bedford Av
Lorimer St
Graham Av
Marcy Av
Grand St
Hewes St
York St
High St
Clark St
East Broadway
Roosevelt Island
NYCT - Grand Ave CMF
© 2009 Tele Atlas
Image © 2009 DigitalGlobe
Image © 2009 Sanborn
Image © 2009 Bluesky
9809 ft
Google

NYC Street Length (miles) and % Flooded, for Three Flood Scenarios

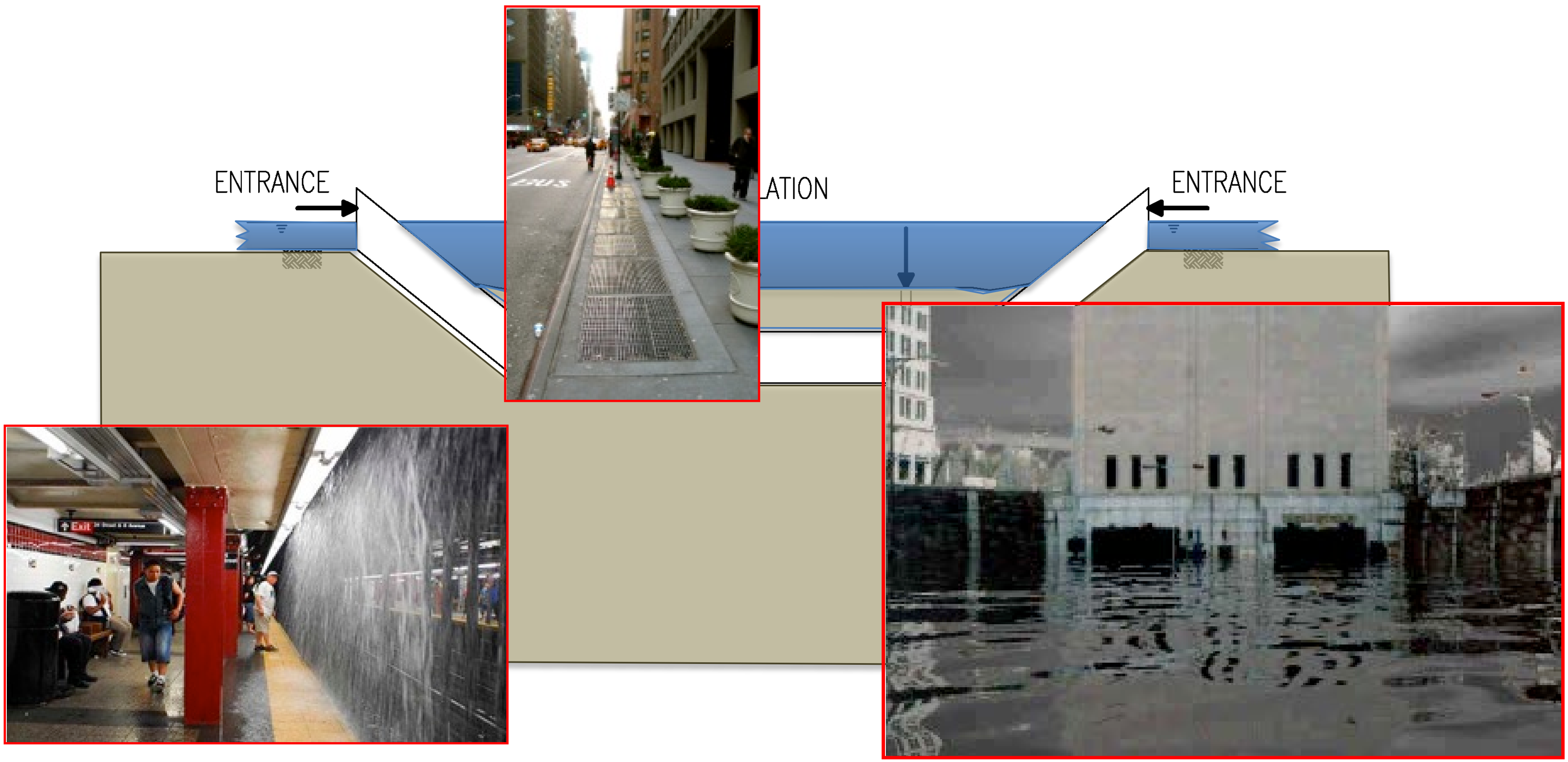


2 Modes of Water Entry into Tunnels

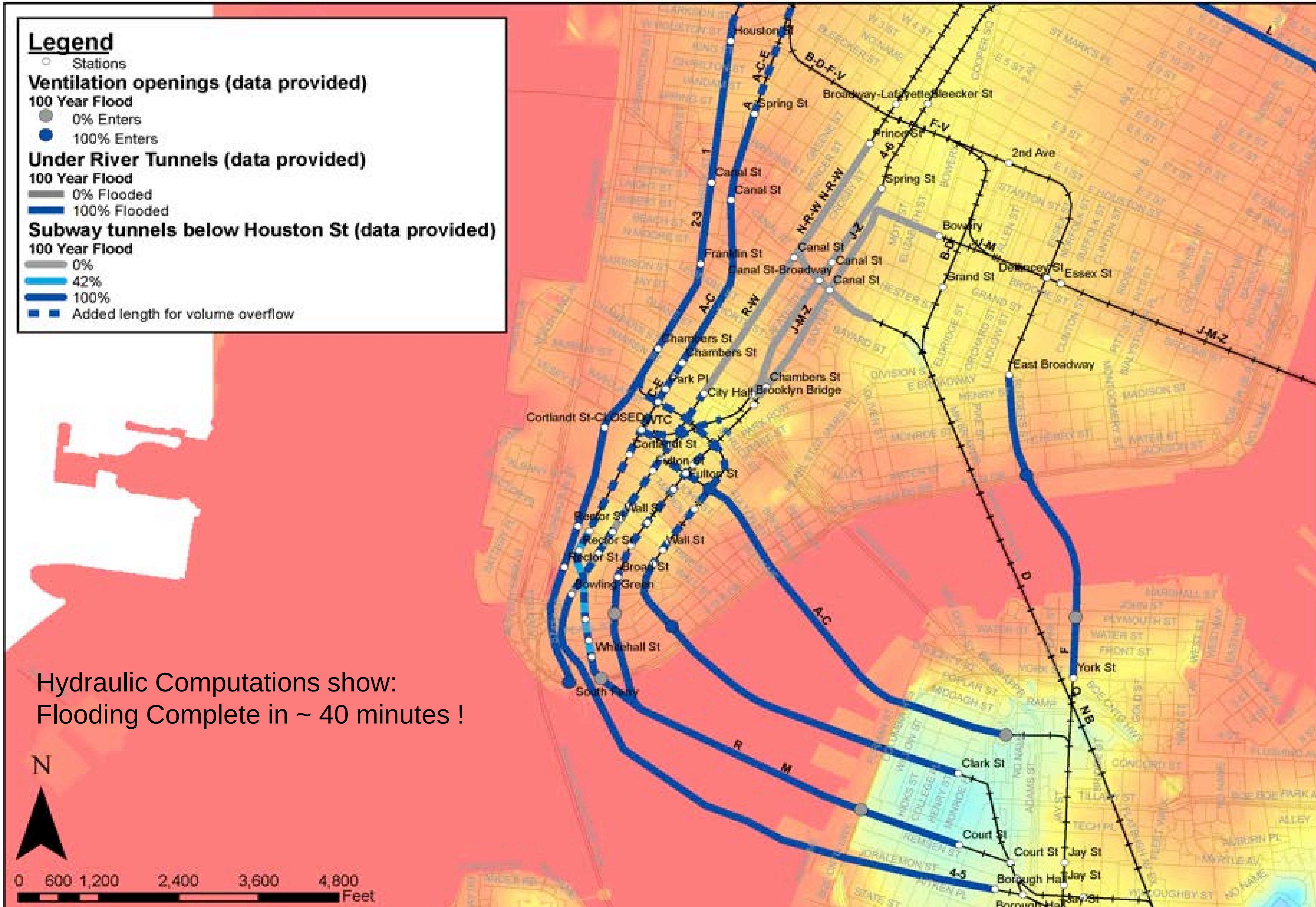
It takes only about 40 minutes to flood the floodable subway tunnels !

a) Mostly Vertically via Subway Ventilation and Entrances

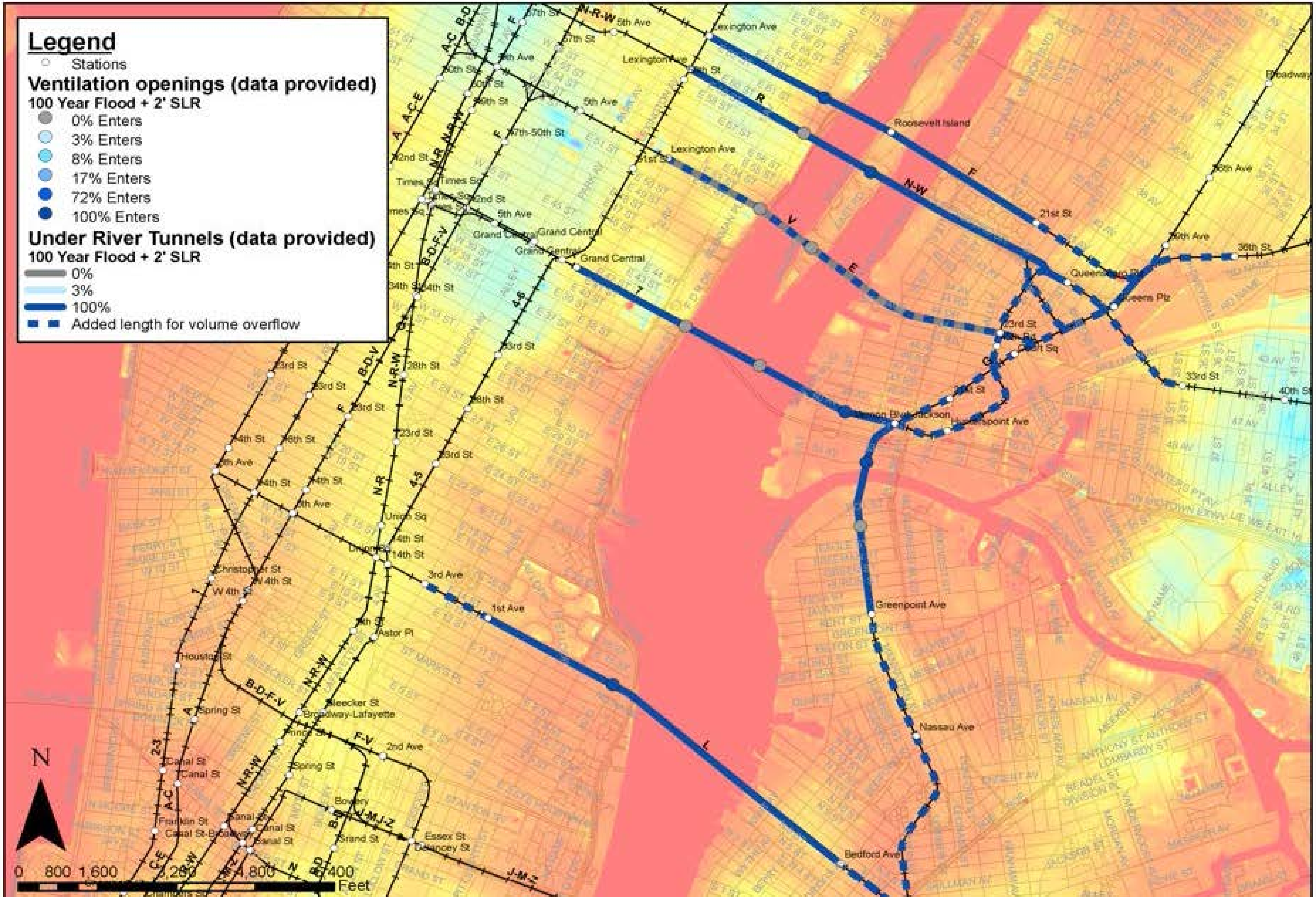
b) Sub-Horizontally into inclined Rail and Road Tunnels



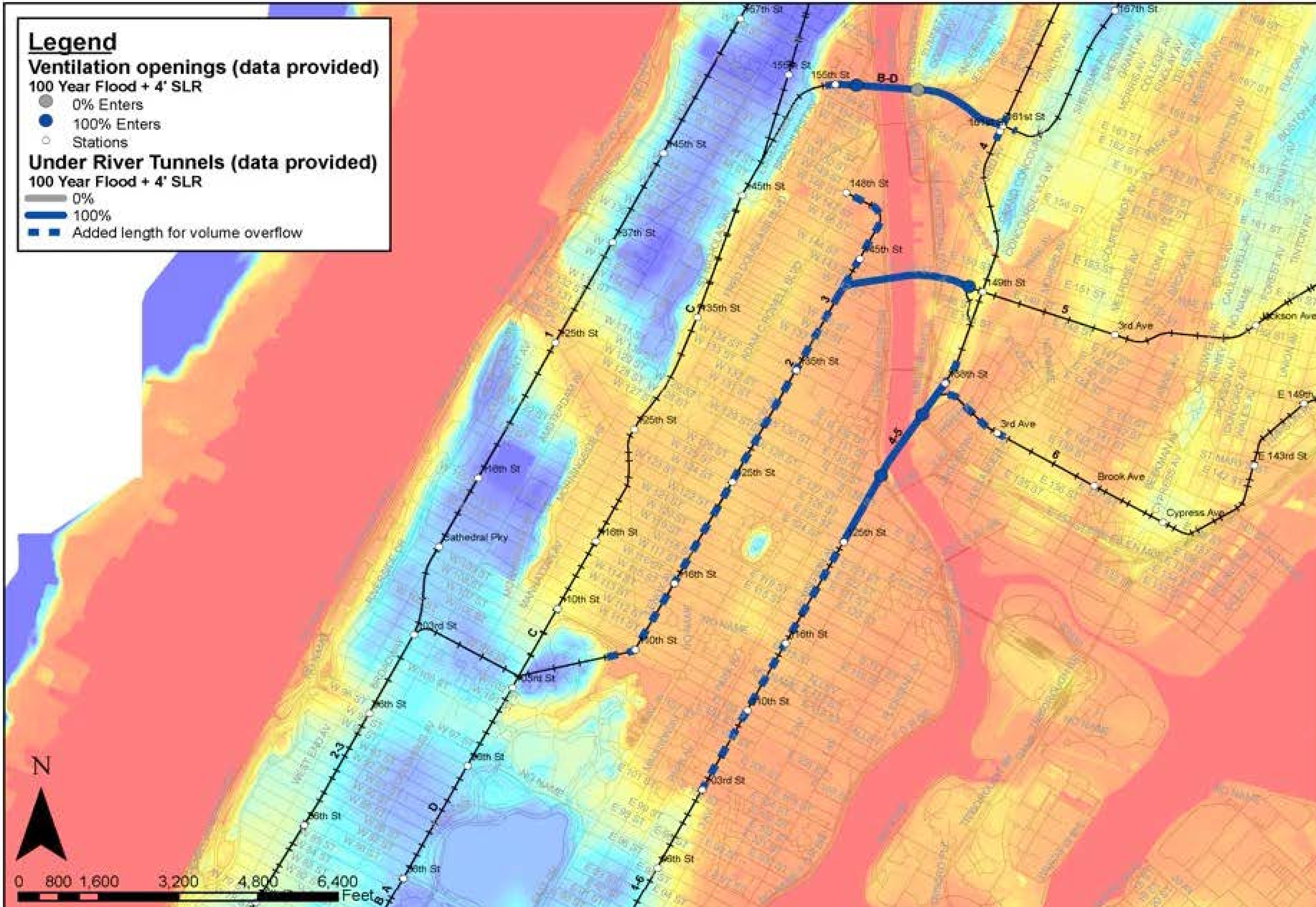
Flooded Subway and Under-River Tunnels, Lower Manhattan, 1% Flood (length overflow)



Flooded Under River Tunnels, Midtown, 1% Flood + 2' SLR (length overflow)



Flooded Under River Tunnels, Harlem River Crossings, 1% Flood + 4' SLR (length overflow)



- **What is the expected direct damage from the flooding of the transportation infrastructure ?**
- **How long will it take for the various components of infrastructure to have their services restored ?**
- **What will be the minimum economic losses from the transportation outages and extended restoration times ?**

Table 9.5 Estimates of number of days contributing to T90, the time needed to restore a transportation system to ~ 90% functionality, without adaptation measures except as noted

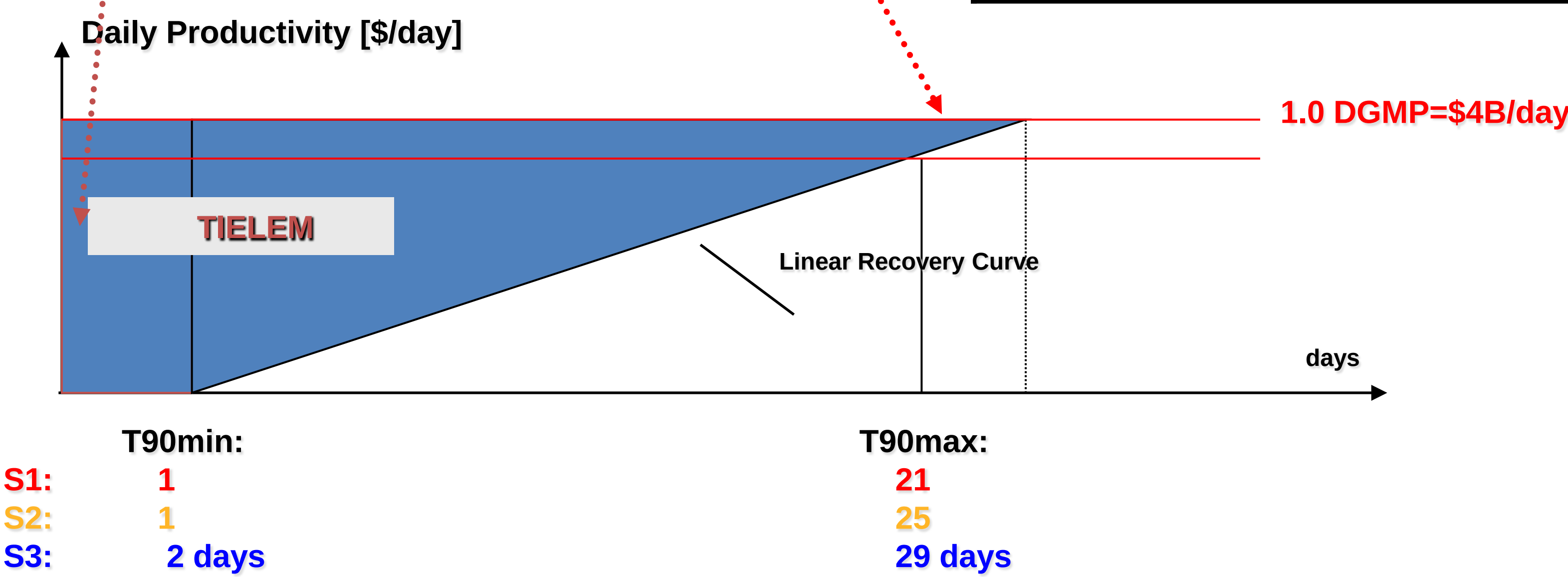
	Type of Delay			1%/y BFE		BFE +2ft		BFE +4ft	
1	Surge Duration, D++			≤1		≤1		≤1	
2	Restore Power, E			≤1		≤1.5		≤2	
3	Logistics Set-Up, L |P>0			≤1		≤2		≤3	
4	Max{D, E, L}			≤1		≤2		≤3	
5	Facility	LCE (ft)	Z_i (ft)	Max{P,A,R}	T90 (days)	Max{P,A,R}	T90 (days)	Max{P,A,R}	T90 (days)
6	Lincoln Tunnel*	22.6*	Z5=9	{0,0,0}	T=1	{0,0,1}	T=1	{0,0,1}	T=2
7	Holland Tunnel*	12.1*	Z5=9	{0,0,0}	T=1	{0,0,1}	T=1	{3,2,6}	T=9
8	Queens-Midtown T.	9.5	Z2=11	{1,1,1}	T=2	{4,2,4}	T=6	{6,2,7}	T=10
9	Brooklyn-Battery T.	7.5	Z1=9	{2,1,2}	T=3	{5,3,6}	T=6	{6,3,7}	T=10
10	PATH System	9.9	Z5=9	{0,1,1}	T=2	{6,3,7}	T=9	{7,3,8}	T=11
11	LIRR/Amtr ERvr 42ndStr T	7.9	Z2=11	{6,3,10}	T=11	{6,3,11}	T=13	{6,3,12}	T=15
12	NJTHudsonTubesPennSt	8.9	Z5=9	{5,3,7}	T=8	{7,3,11}	T=13	{7,3,12}	T=15
13	NJT ARC Tunnel**	11.5	Z5=9	{0,0,0}	T=1	{0,0,0}	T=1	{5,2,7}	T=10
14	LIRR 63rdStrE-River>GCT	11.6	Z2=11	{0,0,0}	T=1	{7,3,11}	T=13	{8,3,10}	T=13
15	to GCT via Steinway T	9.9	Z2=11	{6,3,10}	T=11	{7,4,11}	T=13	{8,5,12}	T=15
16	NYC Subway System	≥5.9	Z5=9	{7,5,20}	T=21	{8,6,23}	T=25	{9,7,26}	T=29
17	MNR Hudson Line along Harlem River (SpuytenDvl.Stn.)	6.6	Z4=8	{0,2,3}	T=4	{0,3,6}	T=8	{0,4,9}	T=12
	Bridge Access Ramps+ to								
18	MarineParkw-Rockaway	6.9	Z8=9	{0,0,0}	T=1	{0,1,1}	T=2	{0,1,2}	T=4
19	CrossBayBrdChnlRockaw.	6.9	Z8=9	{0,0,0}	T=1	{0,1,1}	T=2	{0,1,2}	T=4
20	ThrogsNeck	8.9	Z1=14	{0,0,0}	T=1	{0,1,1}	T=2	{0,1,2}	T=4
21	BronxWhitestone	10.9	Z1-2=12.5	{0,0,0}	T=1	{0,1,1}	T=2	{0,1,2}	T=4
22	RFK (Triboro)	13.9	Z3-2=10	{0,0,0}	T=1	{0,0,0}	T=1	{0,1,1}	T=2
23	Verrazano-Narrows	7.6	Z5=9	{0,0,0}	T=1	{0,1,0}	T=2	{0,1,0}	T=2
	Airports:								
24	JFK	10.6	Z7=8	{0,0,0}	T=1	{0,1,1}	T=2	{1,3,4}	T=6
25	LaGuardia*	10.0*	Z2=11	{2,2,3}	T=3	{3,2,4}	T=4	{3,2,6}	T=8
26	Newark	9.2	Z5a=8	{0,0,0}	T=1	{0,1,2}	T=3	{0,2,3}	T=5
27	Teterboro	3.9	Z5a≤8	{0,1,1}	T=2	{0,2,2}	T=3	{0,2,3}	T=5
28	**Marine Ports:**			Information currently not available					
29				Scenario 1		Scenario 2		Scenario 3	
30	T90 (days)			1 to 21		1 to 25		2 to 29	

TIELEM = **Time Integrated Economic Losses** for the **Entire Metropolitan Region**

DGMP = **Daily Gross Metropolitan Product= $ 4B / day**

Combined economic and physical-damage Losses for the New York City Metropolitan region for a 100-year storm surge, for three sea level rise scenarios (2010 assets and 2010-dollar valuation).

Scenario	TIELEM ($ billion)	Physical Damage ($ billion)	Total Loss ($ billion)
S1, current sea level 2100	48	10	$58
S2 (2-foot rise in sea level) 2040s	57	13	$70
S3 (4-foot rise in sea level) 2080s	68	16	$84



For the Transportation, and Specifically the <u>Subway</u> System, what measures should / could be undertaken to reduce/avoid such losses?

1. In all current and future flood zones, seal all ventilation street grates, i.e. replace passive 'open' ventilation with forced 'closed' ventilation. This requires new ventilation fan plants, and will use more energy.

2. In all flood prone zones, provide safe flood gates at all entrances and ventilation shafts; and/or safer: surround all entrances and openings by sufficiently high **berms and/or levees**: *"Taipei-Solution"*- Go up before you step down !

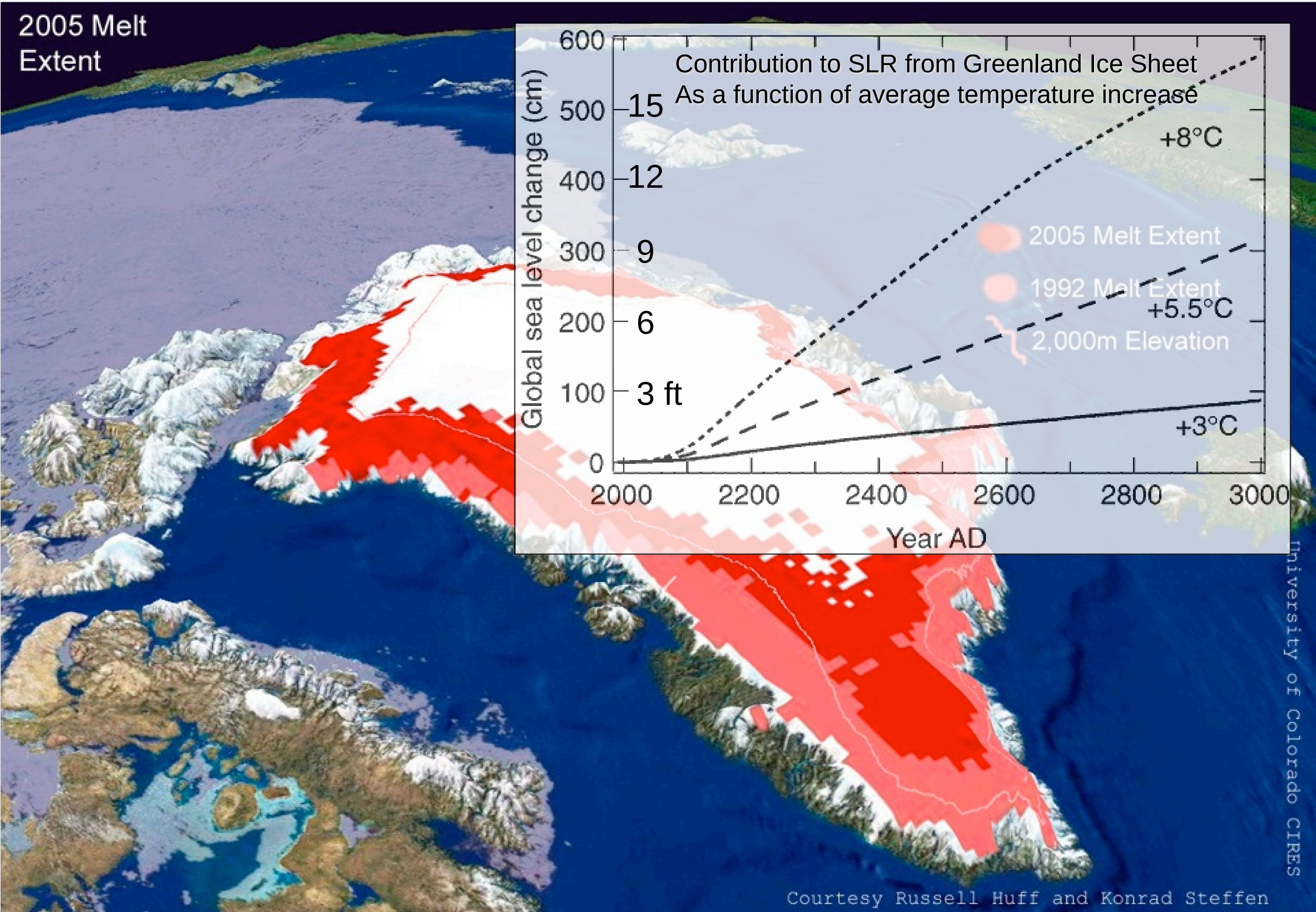
3. What are the Costs? Needs detailed engineering studies, but costs are likely to be at least 25% of the expected avoided losses:

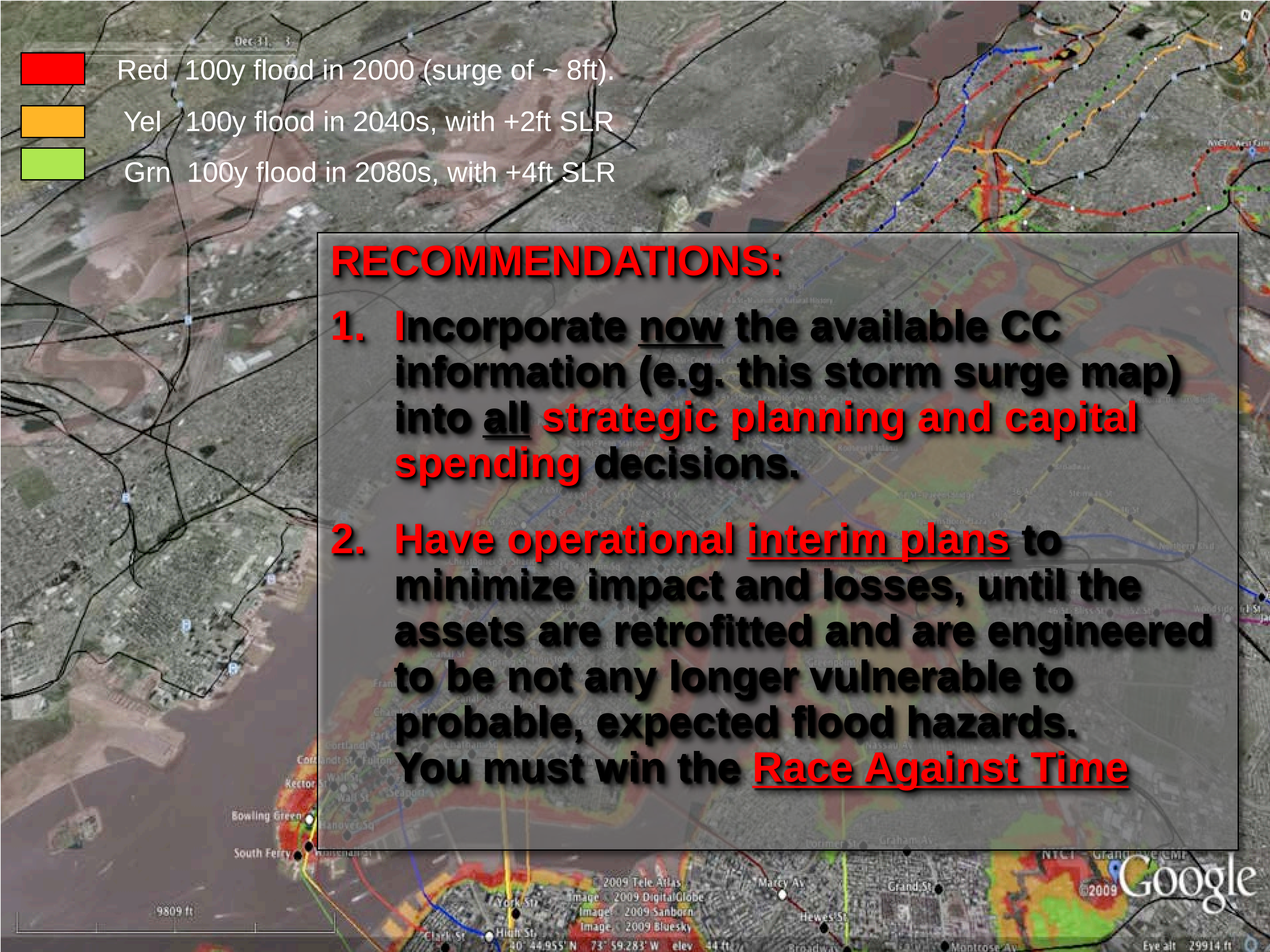
i.e. in excess of $ 15 to 20 Billion (?).

Or:

4. Built **barriers** to protect the entire Inner Harbor and Hudson/Raritan Estuary. **But is this a sustainable solution**?

Structural "Solution": 3 or 4 Barriers. Probably Unsustainable. Why?


2005 Melt
Extent
Contribution to SLR from Greenland Ice Sheet
As a function of average temperature increase
Global sea level change (cm)
600
500
400
300
200
100
0
15
12
9
6
3 ft
2000
2200
2400
2600
2800
3000
Year AD
+8°C
+5.5°C
+3°C
2005 Melt Extent
1992 Melt Extent
2,000m Elevation
University of Colorado CIRES
Courtesy Russell Huff and Konrad Steffen



RECOMMENDATIONS:

1. **Incorporate <u>now</u> the available CC information (e.g. this storm surge map) into <u>all</u> strategic planning and capital spending decisions.**

2. **Have operational <u>interim plans</u> to minimize impact and losses, until the assets are retrofitted and are engineered to be not any longer vulnerable to probable, expected flood hazards.**
   You must win the <u>Race Against Time</u>

Timeliness is of essence.