Urban Waterfront Adaptive Strategies
A guide to identifying and evaluating potential strategies for increasing the resilience of waterfront areas.

**Project Goals**

- To identify the range of possible adaptive strategies to increase the resilience of urban coastal areas to coastal hazards associated with sea level rise, such as high tides, storm surge, and erosion.

- To understand the type and magnitude of costs/benefits associated with each strategy.

- To set up a framework for evaluating the effectiveness and appropriateness of various approaches for various types of coastal areas.
The coastal zone is large and diverse. Different areas face different risks and will require different strategies.
Sea level rise has associated sudden and gradual impacts that will impact different areas in different ways.

**Gradual**
- Regular inundation: Low-lying areas; wetlands
- Increased erosion: Soft shorelines; weakened structures

**Sudden**
- Higher storm surge: Current flood zones
- Flooding: Expanded flood zones
- Wave forces: Areas exposed to open ocean

**NOTE:** Sea level rise may also cause salt water intrusion which could lead to enhanced corrosion of underground structures and foundations. This element is not a focus of this study.
COASTAL CLIMATE RESILIENCE

1. **Understand the Vulnerabilities**
   Create Coastal Area Typologies that are representative of the range of uses, densities, conditions of the city’s coastal zone.
   *Example: Low-density oceanfront beach*

2. **Identify Specific Adaptive Strategies**
   At the scale of the site, neighborhood and reach.
   *Example: Elevating a building*

3. **Develop Resilient Approaches**
   Presents a cohesive strategy which may be a combination of individual strategies.
   *Example: Flood proofing of private homes and building an off-shore barrier reef.*

4. **Evaluation Framework**
   Set up a framework on how to evaluate the overall costs and benefits of strategies for different kinds of neighborhoods.
   *Example: Implementation challenges, un-tested strategy, potential impacts on streetscape*
The Coastal Area Typologies will be used to understand the type and ranges of vulnerabilities and risks of the built environment to existing coastal hazards and to impacts of sea level rise.

Vulnerability refers to the characteristics of an affected area that causes hazards to create unwanted consequences.

Risk is the (financial or operational) impact of the hazards on an affected area, given their vulnerability and the probability of an event.

The built environment is all the physical structures and landscapes that form the city.
And the range of physical characteristics that make strategies more or less appropriate by affecting either the costs or benefits.
To identify the range of these factors we looked at two different systems:

**Geomorphology:**
Physical coastal landforms and geographic features.

**Land Use:**
The types of uses and structures, and the intensity of uses.
Glacial Formations

Landforms created by glacial processes relate to underlying soil composition and land elevation.

Lower-lying areas are generally more vulnerable to storm surge. Softer soils are generally more vulnerable to erosion.

- Outwash plains and filled coastal marshes (low-lying, soft soils)
- Till plains and hills (mid-elevation, mix of soft and hard soils)
- Bedrock hills and ridges (higher elevation, rocky soil)

Sources: Reconnaissance Soil Survey, New York City Soil and Water Conservation District, 2005
Shoreline Condition

Reinforced shorelines are less vulnerable to erosion.

Unreinforced / Natural
- Sandy
- Marshy
- Rocky

Reinforced
- Bulkhead
- Riprap
- Piers filled
- Piers on piles

Sources: Department of City Planning, based on aerial survey, 2011
Exposure to Wave Forces

Areas with a greater distance to an adjacent shoreline ("fetch") are more exposed to waves.

- High Fetch
- Low Fetch

Waves are also highly dependent on the direction of winds during a storm. FEMA’s V zones are mapped to areas where there is a risk of significant wave action.

FEMA Special Flood Hazard Areas

VE 1-in-100 year flood zone with wave action
Geomorphology Categories

Glacial landform       Shoreline Condition       Fetch

Outwash plains        High                  High
                      Unreinforced            1. Exposed outwash plains / High Fetch / Low elevation / Unreinforced soft shorelines
Till plains & hills   Unreinforced            2. Sheltered outwash plains / Low Fetch / Low elevation / Unreinforced soft shorelines
                      Reinforced             3. Sheltered outwash plains / Low Fetch / Low elevation / Reinforced shorelines
Bedrock hills & ridges Low                   4. Exposed outwash plains / High Fetch / Low elevation / Reinforced shorelines

Exposure to:
Surge    Erosion    Wave Forces

NOTE: Doesn’t include combinations not present in NYC.
Geomorphology Categories

1. Oceanfront Beaches
2. Bay and estuary plains, natural shores
3. Bay and estuary plains, hardened shores
4. Oceanfront plains, hardened shores
5. Sheltered Slopes, hardened shores
6. Rocky/Sandy Sheltered Slopes
7. Oceanfront Slopes
8. Sheltered Rocky Bluffs
9. Sheltered Bluffs, reinforced shores
We sampled 65 areas of the city to arrive at coastal area typologies.
We used merged bathymetry and elevation data to create a section for each.

Sources: RAMPP, seamless topographic/bathymetric surface elevation model, 2011, NAVD
And examined the types of land uses and their densities for each.

- One-Two Family Buildings
- Multi-family Walkup Buildings
- Multi-family Elevator Buildings
- Mixed commercial/residential
- Commercial - Office Buildings
- Industrial - Manufacturing
- Transportation - Utility
- Public Facilities - Institutions
- Open Space
- Parking Facilities
- Vacant Land
## Land Use Types

<table>
<thead>
<tr>
<th></th>
<th>Land Use Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>All Open Space</td>
<td>FAR 0</td>
</tr>
<tr>
<td>B</td>
<td>Low / Medium Density Industrial</td>
<td>Largest share of Lot Area &amp; Floor Areas is Industrial or Open Space</td>
</tr>
<tr>
<td>C</td>
<td>Industrial / Low Density Residential</td>
<td>Residential FAR &lt;1</td>
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<tr>
<td></td>
<td></td>
<td>Residential &amp; Industrial &gt;75% of Lot Area/Floor Area</td>
</tr>
<tr>
<td>D</td>
<td>Industrial / Medium Density Residential</td>
<td>Residential FAR &gt;1 (Highest is 2.14)</td>
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<tr>
<td></td>
<td></td>
<td>Residential &gt; 25% Floor Area</td>
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<tr>
<td></td>
<td></td>
<td>Industrial &gt; 25% of Floor Area</td>
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<tr>
<td>E</td>
<td>Low Density Residential</td>
<td>Overall FAR &lt;1</td>
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<tr>
<td></td>
<td></td>
<td>% Lot Area Residential &gt;60%</td>
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<tr>
<td>F</td>
<td>Medium Density Residential</td>
<td>Overall FAR 1-2</td>
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<tr>
<td></td>
<td></td>
<td>Residential &amp; Mixed Use &gt;50% of Total Floor Area</td>
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<tr>
<td>G</td>
<td>High Density Residential / Commercial</td>
<td>Overall FAR 2 – 7 (Highest is 6.63)</td>
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<tr>
<td></td>
<td></td>
<td>Residential &gt; 25% of Floor Area</td>
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<tr>
<td></td>
<td></td>
<td>Residential/Commercial 15-50% of Floor Area</td>
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<tr>
<td></td>
<td></td>
<td>Commercial &lt;50% of Floor Area</td>
</tr>
<tr>
<td>H</td>
<td>Very High Density Commercial</td>
<td>Overall FAR &gt;7 (Highest is 13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residential &lt;25% of Floor Area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial &gt;75% of Floor Area</td>
</tr>
</tbody>
</table>
### Coastal Area Typologies

<table>
<thead>
<tr>
<th></th>
<th>Open Space</th>
<th>Low/Medium Density Industrial</th>
<th>Industrial/Low Density Residential</th>
<th>Industrial/ Medium Density Residential</th>
<th>Low Density Residential</th>
<th>Medium Density Residential</th>
<th>High Density Residential / Commercial</th>
<th>Very High Density Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oceanfront Beaches</td>
<td>Orchard Beach (#527) (also Breezy Point; Great Kills Park)</td>
<td>Midland Beach (#459); Belle Harbor South (#433); Sea Gate (#49); Manhattan Beach (#56)</td>
<td>Coney Island West (#54); Rockaway Beach (#530)</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>Bay and estuary plains, natural shores</td>
<td>Pelham Bay Park (#290) (also Jamaica Bay, portions of Staten Island West Shore)</td>
<td>Kreisherville (#491) (Also Gowanus Bay, Flushing Creek)</td>
<td>Douglas Point (#351); Broad Channel (#393); Edgemere (#405); Far Rockaway (#400); Canarsie (#98)</td>
<td>Marine Park (#71); Starrett City (#531); Coop City (#273)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bay and estuary plains, hardened shores</td>
<td>Bloomfield (#506); Bowery Bay (#318; Newtown Creek East (#529)</td>
<td>Gowanus East (#528); Gowanus West (#24); Red Hook (#21); Newtown Creek West (#2); Greenpoint North (#7); Long Island City (#306); Mott Haven (#205); Greenpoint West (#10); Sherman Creek (#144)</td>
<td>Gerritsen Beach (#68); Great Kills (#471); Howard Beach North (#361); Belle Harbor North (#412)</td>
<td>East Harlem South (#156); East Village (#166); East Harlem North (#152); North Corona (#325)</td>
<td>Chelsea (#120); Soho/Tribeca (#117)</td>
<td>Battery Park City (#115); Lower Manhattan (#171)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Oceanfront plains, hardened shores</td>
<td>Gravesend Bay</td>
<td>Bath Beach</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sheltered Slopes, hardened shores</td>
<td>Flushing Bay (#331); Port Morris (#290); Sunset Park South (#30)</td>
<td>Mariner’s Harbor (#516)</td>
<td>DUMBO (#15); Edgewater (#526); Throgs Neck (#258); Whitestone (#340); Country Club (#266); City Island (#297); College Point (#330)</td>
<td>Bay Ridge (#35); Astoria (#310)</td>
<td>Brooklyn Heights (#18); Kips Bay (#163)</td>
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<tr>
<td>6</td>
<td>Rocky/Sandy Sheltered Slopes</td>
<td>Westchester Creek (#248)</td>
<td>Lower Bronx River (#218)</td>
<td>Riverdale (#191)</td>
<td></td>
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</tr>
<tr>
<td>7</td>
<td>Oceanfront slopes</td>
<td>Butler Manor Woods</td>
<td></td>
<td></td>
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<tr>
<td>8</td>
<td>Sheltered, rocky bluffs</td>
<td>Inwood Hill Park</td>
<td></td>
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<tr>
<td>9</td>
<td>Sheltered bluffs, reinforced shores</td>
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</tr>
</tbody>
</table>
Low-Density Residential / Oceanfront Beaches
Belle Harbor South #433

FEMA Special Flood Hazard Areas
- VE: 1-in-100 year flood zone with wave action
- AE: 1-in-100 year flood zone without wave action

Land Use / Density Factors

<table>
<thead>
<tr>
<th>Building Types</th>
<th>Community Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 story detached homes</td>
<td></td>
</tr>
<tr>
<td>1-2 story semi-detached homes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open Space</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach</td>
<td>Roads</td>
</tr>
<tr>
<td>Neighborhood Park</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Density</th>
<th>Hazard Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>XX du per acre</td>
<td>Gradual</td>
</tr>
<tr>
<td>18,241 ft² built floor area/acre (0.42 FAR)¹</td>
<td>Regular inundation: MED</td>
</tr>
<tr>
<td></td>
<td>Increased erosion: MED</td>
</tr>
<tr>
<td></td>
<td>Sudden</td>
</tr>
<tr>
<td></td>
<td>Storm Surge: HIGH</td>
</tr>
<tr>
<td></td>
<td>Wave Forces: HIGH</td>
</tr>
<tr>
<td></td>
<td>Erosion: HIGH</td>
</tr>
</tbody>
</table>

Hazard Exposure
- Regular inundation: MED
- Increased erosion: MED
- Storm Surge: HIGH
- Wave Forces: HIGH
- Erosion: HIGH

1 FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
2 The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise. All elevations in NAVD.

Base Flood Elevation = 13'
### Medium Density Residential / Oceanfront Beaches

**Location:** Coney Island West #54

#### FEMA Special Flood Hazard Areas

- **VE** 1-in-100 year flood zone with wave action
- **AE** 1-in-100 year flood zone without wave action

#### Land Use / Density Factors

<table>
<thead>
<tr>
<th>Building Types</th>
<th>Residential/commercial buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 story residential buildings</td>
</tr>
<tr>
<td></td>
<td>Community facilities</td>
</tr>
<tr>
<td>Open Space</td>
<td>Parking, Neighborhood Parks, Athletic Fields</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Roads, Boardwalk</td>
</tr>
<tr>
<td>Density</td>
<td>XX du per acre</td>
</tr>
<tr>
<td></td>
<td>67,984 ft² built floor area/acre (1.56 FAR)(^1)</td>
</tr>
</tbody>
</table>

#### Hazard Exposure

- **Regular inundation:** MED
- **Increased erosion:** MED
- **Storm Surge:** HIGH
- **Wave Forces:** HIGH
- **Erosion:** HIGH

\(^1\) FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

\(^2\) The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise. All elevations in NAVD.
Low Density Residential / Bay and estuary plains, natural shores

Edgemere #405

FEMA Special Flood Hazard Areas
- VE: 1-in-100 year flood zone with wave action
- AE: 1-in-100 year flood zone without wave action

**Land Use / Density Factors**

<table>
<thead>
<tr>
<th>Building Types</th>
<th>1-2 story detached homes</th>
<th>1-2 story semi-detached homes</th>
<th>Community Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Space</td>
<td>Beach</td>
<td>Neighborhood Park</td>
<td></td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>XX du per acre</td>
<td>XX ft² built floor area/acre (XX FAR)¹</td>
<td></td>
</tr>
</tbody>
</table>

**Hazard Exposure**

- Gradual
  - Regular inundation: MED
  - Increased erosion: HIGH

- Sudden
  - Storm Surge: HIGH
  - Wave Forces: LOW
  - Erosion: MED

¹ FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

Base Flood Elevation = 8'

2080 High Tide
2080 Low Tide
High Tide
Low Tide
### FEMA Special Flood Hazard Areas

| AE | 1-in-100 year flood zone without wave action |

### Coastal Area Typologies

**Low/Medium Density Industrial/ Bay and estuary plains, hardened shores**

Newtown Creek East #529

<table>
<thead>
<tr>
<th>Land Use / Density Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Types</td>
</tr>
<tr>
<td>1-2 story industrial</td>
</tr>
<tr>
<td>Community facilities</td>
</tr>
<tr>
<td>Open Space</td>
</tr>
<tr>
<td>Parking, Vacant Land</td>
</tr>
<tr>
<td>Infrastructure</td>
</tr>
<tr>
<td>Roads, Elevated Rail Tracks</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>XX du per acre</td>
</tr>
<tr>
<td>XX sq ft built floor area per acre</td>
</tr>
</tbody>
</table>

### Hazard Exposure

- **Gradual**
  - Regular inundation: MED
  - Increased erosion: MED

- **Sudden**
  - Storm Surge: HIGH
  - Wave Forces: LOW
  - Erosion: LOW

1 FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

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**Base Flood Elevation=9’**

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**Coastal Area Typologies**
**FEMA Special Flood Hazard Areas**

- **VE**: 1-in-100 year flood zone with wave action
- **AE**: 1-in-100 year flood zone without wave action

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**Coastal Area Typologies**

**Industrial/Medium Density Residential / Bay and estuary plains, hardened shores**

- **Red Hook #21**

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**Land Use / Density Factors**

| Building Types | 1-2 story industrial  
|                | 3-6 story residential/commercial  
|                | 10-story apartment buildings  
|                | Schools  
| Open Space     | Parking, Neighborhood parks  
| Infrastructure | Piers, Roads  
| Density        | XX du per acre  
|                | 50,763 ft² built floor area/acre (1.17 FAR)¹  

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**Hazard Exposure**

- **Gradual**
  - Regular inundation: **HIGH**
  - Increased erosion: **MED**

- **Sudden**
  - Storm Surge: **HIGH**
  - Wave Forces: **MED**
  - Erosion: **LOW**

---

¹ FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
Coastal Area Typologies

Medium Density Residential / Bay and estuary plains, hardened shores
East Harlem South #156

FEMA Special Flood Hazard Areas

AE 1-in-100 year flood zone without wave action

3F

Land Use / Density Factors

Building Types
- Residential/commercial buildings
- 10 story residential buildings
- Community facilities

Open Space
- Parking, Neighborhood Parks, Athletic Fields

Infrastructure
- Roads, Rail Tracks

Density
- XX du per acre
- 116,932 ft² built floor area/acre (2.69 FAR)¹

Hazard Exposure

Gradual
- Regular inundation: HIGH
- Increased erosion: MED

Sudden
- Storm Surge: HIGH
- Wave Forces: LOW
- Erosion: LOW

Base Flood Elevation = 10'

¹ FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
**Coastal Area Typologies**

**Very High Density Commercial / Bay and estuary plains, hardened shores**
Lower Manhattan #171

**FEMA Special Flood Hazard Areas**
- VE: 1-in-100 year flood zone with wave action
- AE: 1-in-100 year flood zone without wave action

**Land Use / Density Factors**

<table>
<thead>
<tr>
<th>Building Types</th>
<th>Open Space</th>
<th>Infrastructure</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial/office towers</td>
<td>Public piers and esplanade</td>
<td>Elevated highway, Subways, Piers</td>
<td>XX du per acre</td>
</tr>
<tr>
<td>Residential/commercial towers</td>
<td>Sidewalk plazas</td>
<td></td>
<td>501,425 ft² built floor area/acre (11.48 FAR)¹</td>
</tr>
<tr>
<td>4-6 story commercial</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hazard Exposure**

<table>
<thead>
<tr>
<th>Gradual</th>
<th>Sudden</th>
<th>Wave Forces</th>
<th>Erosion</th>
<th>Storm Surge</th>
<th>Increased erosion</th>
<th>Regular inundation</th>
<th>2080 High Tide</th>
<th>2080 Low Tide</th>
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</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td><strong>HIGH</strong></td>
<td><strong>MED</strong></td>
<td><strong>LOW</strong></td>
<td><strong>HIGH</strong></td>
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<tr>
<td><strong>Low</strong></td>
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</table>

¹ FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
FEMA Special Flood Hazard Areas

Low/Medium Density Industrial/ Sheltered slopes, hardened shores

Sunset Park South #30

Land Use / Density Factors

<table>
<thead>
<tr>
<th>Building Types</th>
<th>1-2 story industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-6 story residential/commercial</td>
</tr>
<tr>
<td></td>
<td>10-story apartment buildings</td>
</tr>
<tr>
<td></td>
<td>Schools</td>
</tr>
<tr>
<td>Open Space</td>
<td>Parking, Neighborhood parks</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Piers, Elevated highway, Roads, Rail tracks</td>
</tr>
<tr>
<td>Density</td>
<td>XX du per acre</td>
</tr>
<tr>
<td></td>
<td>54,262 ft² built floor area/acre (1.24 FAR)¹</td>
</tr>
</tbody>
</table>

Hazard Exposure

<table>
<thead>
<tr>
<th>Gradual</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Regular inundation</td>
<td>LOW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased erosion</td>
<td>LOW</td>
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<table>
<thead>
<tr>
<th>Sudden</th>
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<tbody>
<tr>
<td></td>
<td>Storm Surge</td>
<td>MED</td>
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<tr>
<td></td>
<td>Wave Forces</td>
<td>LOW</td>
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<tr>
<td></td>
<td>Erosion</td>
<td>LOW</td>
</tr>
</tbody>
</table>

¹ FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
² The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise.
All elevations in NAVD.

Base Flood Elevation=10'

Coastal Area Typologies
Low Density Residential/ Sheltered slopes, hardened shores
Country Club #266

FEMA Special Flood Hazard Areas
- VE: 1-in-100 year flood zone with wave action
- A&E: 1-in-100 year flood zone without wave action

COASTAL CLIMATE RESILIENCE

Land Use / Density Factors

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<tr>
<td>1-2 story semi-detached homes</td>
</tr>
<tr>
<td>3-4 story residential/commercial</td>
</tr>
<tr>
<td>Community Facilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking, Vacant Land, Beach</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads, Highways, Piers</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Density</th>
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<td>XX du per acre</td>
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<tr>
<td>29,858 ft² built floor area/acre (0.69 FAR)¹</td>
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Hazard Exposure

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<th>Gradual</th>
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<tr>
<td>Regular inundation</td>
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<td>Increased erosion</td>
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<tr>
<td>Storm Surge</td>
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<td>Wave Forces</td>
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<tr>
<td>Erosion</td>
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</table>

1 FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
2 The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise. All elevations in NAVD.
There are many potential adaptive strategies at various scales.

**SITE**
- Dry flood proofing
- Wet flood proofing
- Elevation on fill
- Elevation on piles
- Site protection
- Floating Structures
- Amphibious Structures
- Relocate

**NEIGHBORHOOD**
- Bulkhead
- Seawall
- Revetment
- Living Shoreline
- Fixed Breakwater
- Floating Breakwater
- Elevate Land

**REACH/REGION**
- Floating Islands
- Groin Field
- Levee/Dike
- Beach Nourishment
- Dune Creation
- Elevate Land
- Floodwall
- Surge Barrier
- Artificial Reef
- Wetland Restoration
- Barrier Island Creation
- Bathymetry Modification
- Polder
For each strategy, the catalog will provide the following key pieces of information.

**Beach nourishment**

**Risk Reduction:**
- Reduces risk from frequent inundation and low and high surge events.
- Can reduce risk from strong wave action, though must be replenished after.
- Protects inland area from erosion though the beach itself is susceptible to erosion.

**Best-suited for:**
- Flat to moderately sloped areas.

**Doesn’t work for:**
- Shorelines with high erosion rates.

**Cost:**
- Estimated $7-$18 per cy or $50-600 per linear foot.

**Issues/Barriers:**
- Low initial costs, but requires continual monitoring and maintenance every 2-3 years (typical).
- Can be significantly eroded by large storm events.
- Need a source for sand.
- Temporary disturbance of near-shore environment.

**Benefits:**
- Supports recreational activities.
- Less environmental damage than other coastal structures.
- Easily modified or changed.

**Questions for further inquiry:**
- What is the highest level of surge protection that is feasible for beach nourishment?
- What are the environmental consequences of beach re-nourishment?
- What are innovative approaches to beach nourishment?
Install shield panels to protect doors and windows

**Risk Reduction:**
- Limits or prevents water infiltration through or around doors and windows.
- Provides protection up to a certain height or force.

**Best-suited for:**
- Buildings with a flood elevation lower than the height of the panel

**Doesn’t work for:**
- High flood elevations

**Cost:**
- To be determined.

**Issues/Barriers:**
- Aesthetically challenging to incorporate into a building.
- May be difficult to implement with certain envelope systems.
- Removable panels require adjacent storage space.

**Benefits:**
- Provide some protection against flood-borne missiles.
- Can quickly be positioned in anticipation of flooding.

**Questions for further inquiry:**
- To what extent do shield panels provide protection against wave action?
- Can shield panels compromise the building envelope by transferring flood loads across the façade?
- How much protection does a shield panel provide if the façade has limited waterproofing potential?
### Strategies can reduce risks from multiple hazards.

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Regular inundation</th>
<th>Erosion</th>
<th>Storm Surge</th>
<th>Wave Forces</th>
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**Catalog of Adaptive Strategies**
These strategies can be combined at various scales.

1. Take protective measures beyond the scale of the neighborhood
   - Includes these options:
     - Levee/Dike
     - Surge Barrier
     - Wetland restoration (?)
     - Bathymetry modification (?)

2. Prevent flooding of neighborhood through protective shoreline measures.
   - Includes these options:
     - Bulkhead
     - Seawall
     - Dunes
     - Beach nourishment
     - Groin field
     - Revetment
     - Levee/Dike

3. Protect individual structures and assets through site-specific measures.
   - Includes these options:
     - Dry flood proofing
     - Wet flood proofing
     - Elevation on fill
     - Elevation on piles
     - Site protection

4. Reduce impact of flooding through wave attenuation and protect structures through site-specific measures.
   - Includes these options:
     - Living shoreline
     - Floating islands
     - Barriers
     - Reefs
     - Wetlands
     - Site-specific measures

5. Strategically retreat from at risk areas.
   - Includes these options:
     - Relocate
     - Wetlands
Each comes with its own share of costs and benefits.

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Financial Cost</th>
<th>Potential External Costs (Environment, Public Space, etc.)</th>
<th>Potential External Benefits (Environment, Public Space, etc.)</th>
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<tr>
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<td>Surge Barrier</td>
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</table>

Catalog of Adaptive Strategies
And its own hurdles in implementation.

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Regulatory</th>
<th>Political</th>
<th>Technological</th>
<th>Time</th>
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<tbody>
<tr>
<td>Bulkhead</td>
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At a regional scale, strategies are most suitable for certain types of areas.

- **Suitable**: Addresses hazards present in a cost-effective way and technically feasible given area characteristics.
- **Unsuitable**: Would not address relevant hazards, is not likely to be cost-effective, and/or is not technically feasible.
- **Potentially Suitable**: May be suitable but requires further inquiry or additional strategies in concert.

### Catalog of Adaptive Strategies

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Belle Harbor South #433</th>
<th>Lower Manhattan #171</th>
<th>Red Hook #21</th>
<th>Tottenville #484</th>
<th>Midland Beach #459</th>
<th>Sunset Park South #30</th>
<th>East Harlem South #156</th>
<th>Coney Island West #54</th>
<th>Newtown Creek East #529</th>
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*To be determined*
APPENDIX
COASTAL CLIMATE RESILIENCE

1. Reach strategies

Surge Barriers
- Fixed surge barriers (in combination with levees)
- Mobile surge barriers (in combination with levees)

Landforms
- Constructed wetlands
- Bathymetry modification
- Constructed barrier islands
- Polders

Other
- Inland retreat of wetlands
- Redundancy, multiple lines of defense
- Enhanced emergency evacuation

Maeslant Barrier, Rotterdam, the Netherlands

On the Water Palisade Bay, Architecture Research Office
Neighborhood strategies

**Shoreline armoring strategies**
- Seawalls
- Bulkheads
- Revetments
- Groins
- Beach nourishment
- Levees and dikes

**Wave attenuation**
- Fixed breakwaters
- Floating breakwaters
Neighborhood strategies

Elevate
- Elevating multiple buildings
- Elevating streets
- Elevated pedestrian access areas and public spaces

Flood accommodation
- Floodable parks and open spaces
- Water retention

Enhanced shoreline protection
- Multi-use levees/Superlevees
- Retrofitting elevated shoreline structures as flood barriers

Shoreline protection / Wave attenuation + Habitat
- Living shorelines
- Artificial reefs
- Floating islands/breakwaters

Strategic Retreat
- Relocation
- Acquisition programs
- Rolling easements/setbacks
- No-rebuild
**Bulkheads / Seawalls**

- Bulkheads are vertical retaining walls intended to hold soil in place and allow for a stable shoreline.
- Seawalls are structurally similar, but designed to resist heavy wave forces and prevent flooding of upland areas.
- Different forms include cantilevered, anchored, gravity, relieving platforms, and cofferdams. Common materials are sheet pile, concrete, or timber.
Bulkheads / Seawalls

**Risk Reduction:**
- Bulkheads protect site from erosion. They are not designed to protect from major flood events but do manage daily and monthly fluctuations in tide levels.
- Seawalls protect from erosion and provide site and upland protection from coastal surge.

**Best-suited for:**
- Areas where space in high demand.

**Doesn’t work for:**
- Cantilevered or anchored bulkheads require hard, dense soils suitable for pile-driving.

**Issues/Barriers:**
- Significant environmental disturbance for undisturbed sites.
- Can exacerbate erosion of adjacent soft shorelines.
- Require high level of engineering.
- Extensive permitting process.
- Incremental raising of bulkheads or seawalls to account for sea level rise presents many regulatory challenges and site design constraints.

**Benefits:**
- Less space intensive.

**Cost:**
- Estimated $5,000 to $15,000 per linear foot for a new sheet-pile bulkhead.

**Questions:**
- How can the repair and maintenance of existing bulkheads take into account rising sea levels?
Beach nourishment

- Addition of sand to the shoreline to protect upland property and infrastructure.
- Different forms of beach nourishment can include creation of a berm, dune and grasses, feeder beach, nearshore berm or dune stabilization.

Rockaway Beach
Sandbridge, Virginia Beach
Sand Motor, The Netherlands
Beach nourishment

**Risk Reduction:**
- Reduces risk from frequent inundation and low and high surge events.
- Can reduce risk from strong wave action, though must be replenished after.
- Protects inland area from erosion though the beach itself is susceptible to erosion.

**Best-suited for:**
- Flat to moderately sloped areas.

**Doesn’t work for:**
- Shorelines with high erosion rates.

**Cost:**
- Estimated $7-$18 per cy or $50-600 per linear foot

**Issues/Barriers:**
- Low initial costs, but requires continual monitoring and maintenance every 2-3 years (typical).
- Can be significantly eroded by large storm events.
- Need a source for sand.
- Temporary disturbance of near-shore environment.

**Benefits:**
- Supports recreational activities.
- Less environmental damage than other coastal structures.
- Easily modified or changed.

**Questions:**
- What is the highest level of surge protection that is feasible for beach nourishment?
- What are the environmental consequences of beach re-nourishment?
- What are innovative approaches to beach nourishment?
**Levees/Dikes**

- Levees (also called dikes) are earthen embankments that provide protection from flooding.
- Concrete floodwalls on top of levees are used to increase the height of surge protection.
- “Superlevees” are larger levee structures that can support buildings on top.

---

**Tokyo, Japan**

**New Orleans**
Levees/Dikes

Risk Reduction: Levees can offer protection from a high surge elevation, and when combined with armored rip-rap, can resist heavy storm waves.

Best-suited for: When protection from high surge elevation is desired and there is sufficient land area available.

Doesn’t work for: When space is in high demand.

Cost: New levees are estimated to cost $2,000 per linear foot with annual maintenance costs of $200.


Benefits: Can be strengthened or modified to accommodate rising sea levels. Land area on top of the levee can sometimes be used for other functions, like paths, roadways, or structures.

Questions: How can existing waterfront roadways be adapted into levee structures?
Revetments

- Stone rubble or concrete blocks placed on a sloped surface to protect the underlying soil from erosion and reduce the forces of wave action.

Hudson River, Manhattan

Lake Michigan, Chicago
## Revetments

**Risk Reduction:**
- Protect shoreline from erosion even in areas that experience high wave action.
- Often used in concert with seawalls, bulkheads, or levees to add additional armoring protection.
- Do not on their own protect from coastal surge.

**Best-suited for:**
- In combination with other structures or where there is already a high bank elevation.

**Doesn’t work for:**
- Most effective with stable foundation soil.

**Cost:**
- Estimated $2,000 to $5,000 per linear foot.

**Issues/Barriers:**
- Significant environmental disturbance for undisturbed sites.
- Extensive permitting process.

**Benefits:**
- Very low maintenance required if constructed properly.
- Reduce degree of erosion on adjacent sites than bulkheads.
- More opportunity for intertidal vegetation and habitat.
- Can be more flexible than other strategies.

**Questions:**
- How can revetments be designed to promote the growth of intertidal habitat? In what conditions is this feasible?
- How can existing revetments be adapted to protect from surge?
Living Shorelines

- A more natural bank stabilization technique that uses plants, sand, and limited use of rock to provide shoreline protection and maintain valuable habitat.
- Living shorelines need to include the use of coastal vegetation and usually, but not always, a low-lying structure.

Harlem River Park

Maryland
Living Shorelines

**Risk Reduction:**
- Protects shorelines from erosion.
- May reduce risk from frequent inundation and periodic low surge flooding, although not typically used to do so.

**Best-suited for:**
- Flat to moderately sloped areas with moderate fetch (up to 10 miles).

**Doesn’t work for:**
- Areas with steep slopes or high wave energy.

**Issues/Barriers:**
- Lack of clear guidelines for implementation.
- More space intensive than typical bulkheads.
- Structural features may prevent wetland migration and may lead to loss of adjacent sandy beaches.

**Benefits:**
- Retains intertidal habitat.
- Can retain stormwater and improve water quality.

**Cost:**
- ?

**Questions:**
- How can Living Shorelines survive in high wake conditions?
- What can they do to mitigate the impacts of coastal flooding?
- How might they be designed to work with sea level rise?
Surge Barriers

- Surge barriers cross a waterway to protect coastal areas from surge.
- They are usually integrated into a larger flood protection system including levees and pumps.
- Movable surge barriers remain open in normal conditions to allow water and vessels to pass, but can be closed when water levels rise due to storm surge.
- Various types of flood gates include floating gates, vertical lifting gates, and flap gates.
Surge Barriers

Risk Reduction: • Provide a high level of protection from even the highest level of storm surge.

Best-suited for: • Bays with proximate shorelines.

Doesn’t work for: • Exposed oceanfront shorelines.

Cost: • Costs vary widely depending on types and components. Estimated range of $2 - $11M per linear foot based on costs of existing barriers.*

Issues/Barriers: • Require extensive maintenance and monitoring.
• Can create navigation conflicts.
• Altering water flow changes the chemical, physical and biological properties of estuarine system by altering water flow (temperature, salinity, suspended matter, nutrients); use of movable rather than fixed barriers can reduce these impacts.
• Potential for increased river flooding from backed-up water on the landward side of the barrier, although this can be prevented with proper monitoring and design.
• Relatively inflexible once built.
• Extensive permitting process and high level of engineering required.

Benefits: • Can protect large areas.

Questions: • What can be used in combination with surge barriers other than levees? Is beach nourishment feasible?
• Can surge barriers be designed to be adaptable over time?

* Hillen, Coastal Defence Cost Estimates, Delft University of Technology, 2010
**Breakwaters**

- Offshore structures, typically parallel to the shore and made of stone, concrete blocks or units.
- Can be fixed or floating, submerged or emerged.

![Floating Concrete Breakwater](image_url)
**Breakwaters**

**Risk Reduction:**
- Dissipates and attenuates waves thereby protecting shorelines and upland areas from destructive forces of waves.
- Does not reduce height of surge.

**Best-suited for:**
- Fixed breakwaters very expensive in deep water (more than 4 feet).
- Floating breakwaters are less effective than fixed breakwaters at dissipating waves higher than 6.5 feet.

**Doesn’t work for:**
- High waves in deep water.

**Cost:**
- Estimated $175 - $1,750 per linear foot

**Issues/Barriers:**
- Extensive permitting process.

**Benefits:**
- Minimize erosion of beaches, wetlands, and shoreline structures.
- Create clam water for recreation.
- In right conditions can function similarly to reefs promote growth of vegetation and habitat creation.

**Questions:**
- How effective are breakwaters at dissipating wave action during a hurricane or nor’easter?
- Where in NYC may breakwaters be and effective strategy for reducing wave action?
Artificial Reefs

- Artificial reefs are submerged, or partially submerged, structures made of rock, concrete, or other materials, that are designed to provide marine habitat for plants, invertebrates, fish, and birds, while also attenuating waves.
Artificial Reefs

Risk Reduction:
- Protects shorelines from erosion in areas that experience wave action.

Best-suited for:
- Areas with large shallows and subsurface soils.

Doesn't work for:
- In areas of very deep water.

Cost:
- ?

Issues/Barriers:
- Relatively untested strategy for coastal hazard mitigation.
- Requires extensive monitoring.

Benefits:
- Offshore strategy with low visual impact.
- Creates or restores habitats.
- Provides educational opportunities.
- Recreational benefits.

Questions:
- At what level of wave action are artificial reefs effective?
- At what depths do they become less effective?
- What local conditions make these strategies feasible (wind, wave, soil)?
Vegetated Floating Breakwaters (Islands)

- Buoyant, planted mats or structures that can attenuate waves while providing ecological benefits, such as habitat restoration and improved water quality.

Floating Islands, Baltimore Harbor

Planned DEP Pilot in Jamaica Bay
Floating Islands/ Breakwaters

**Risk Reduction:**  
- Protects soft shorelines from erosive wave forces.

**Best-suited for:**  
- Areas with light to moderate wave exposure.

**Doesn’t work for:**  
- Areas with high wave energy.

**Cost:**

**Issues/ Barriers:**  
- Little is understood about the overall effectiveness of vegetative floating breakwaters in coastal hazard reduction.

**Benefits:**  
- Flexible, low cost, and effective on a smaller scale.
- Offers ecosystem services and educational opportunities.

**Questions:**  
- In what situation is a vegetative floating breakwater best suited?  
- What is their applicability compared to non-planted floating breakwaters?
**Constructed Barrier Islands**

- Constructed Barrier Islands are created with fill offshore.
- Can break up the wave energy generated by storm surges and provide opportunities for development, recreation and habitats.
**Constructed Barrier Islands**

**Risk Reduction:**
- Protects shorelines from wave forces.
- May reduce risk from coastal flooding.

**Best-suited for:**
- Shallow water areas where less fill is necessary.

**Doesn't work for:**
- ?

**Cost:**
- ?

**Issues/Barriers:**
- Space Intensive.
- Potential impacts on hydrology and navigation.
- Requires large upfront capital investment.
- Extensive permitting process.
- Overall impacts on ecosystem are unknown.

**Benefits:**
- Provides coastal protection with ecological services and creation of intertidal habitat.
- Offers aesthetic value and potential recreational opportunities.

**Questions:**
- What are the engineering challenges to barrier islands in New York Harbor?
- In what areas in NYC would this be applicable?
- What is the capacity of a barrier island to reduce the risk of storm surge?
**Constructed Wetlands**

- A new or restored ecosystem in the intertidal zone that uses plants to retain and filter water while creating wildlife habitat.
## Constructed Wetlands

### Risk Reduction:
- Protects shorelines from erosion
- May reduce risk from frequent inundation and periodic low surge flooding.

### Best-suited for:
- Sites with fine grain sediments.
- Sites with light to moderate fetch of less than one mile.

### Doesn’t work for:
- Areas exposed to high currents or wave energy.
- On steep slopes.

### Issues/Barriers:
- Achieving surge reduction requires a mature peat layer, which can take a long time to develop (approx. 30 years)
- Storm surge protection is very site-specific, may be unreliable in all cases.
- Limits certain forms of public access to the water and other construction opportunities.

### Benefits:
- Protects natural resources and creates habitat.
- Controls erosion and improves water quality.
- Comparatively low cost.

### Questions:
- What scale of wetland construction is necessary to have an impact on erosion? Coastal flooding? Storm surge?
- What areas in New York City are best suited for constructed wetlands?
Shallows Restoration or Bathymetry Modification

- Altering the bathymetry of a water body to reduce the extent of storm surge.

**New York Harbor Bathymetry**
## Shallows Restoration or Bathymetry Modification

<table>
<thead>
<tr>
<th>Risk Reduction:</th>
<th>May reduce extent of coastal flooding by altering surge dynamics.</th>
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</thead>
<tbody>
<tr>
<td>Best-suited for:</td>
<td>?</td>
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<tr>
<td>Doesn’t work for:</td>
<td>?</td>
</tr>
<tr>
<td>Cost:</td>
<td>?</td>
</tr>
<tr>
<td>Issues/Barriers:</td>
<td>Strategy is untested in the US.</td>
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<td></td>
<td>Limits navigability.</td>
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<td></td>
<td>Impacts on flooding and sea level rise are uncertain.</td>
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<td></td>
<td>Potential negative environmental impacts and extensive permitting process.</td>
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<tr>
<td>Benefits:</td>
<td>Could be used in combination with wetland restoration to enhance biodiversity.</td>
</tr>
<tr>
<td>Questions:</td>
<td><strong>What scale of shallows restoration is necessary to have an impact on storm surge?</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Has the creation of shallows been used elsewhere to mitigate flood damage? Where might it be appropriate in NYC?</strong></td>
</tr>
</tbody>
</table>
Polders

- A polder is a low-lying tract of land enclosed by levees that form an artificial hydrological entity.
- A traditional Dutch technique that could be used to store and retain flood waters in the event of a coastal surge.

Map of Flevoland Polder in the Netherlands
### Polders

#### Risk Reduction:
- May reduce extent of coastal flooding by diverting surge.

#### Best-suited for:
- ?

#### Doesn’t work for:
- Areas with limited space.

#### Cost:
- ?

#### Issues/Barriers:
- Strategy is untested in the US.
- Can disrupt natural hydrology and ecosystem.
- High walls may limit access and visibility.
- Requires large areas of undeveloped land.

#### Benefits:
- Could provide additional space for temporary uses, playfields, farmland, etc.

#### Questions:
- What scale might be necessary for polders to be effective?
- What is the size of an area that could benefit from that scale?
Site strategies

**Strategies for retrofitting existing buildings**
- Elevate
- Structural resilience
- Limit water infiltration
- Accommodate flooding
- Protect building systems

**Strategies for new construction**
- Dry flood proofing
- Wet flood proofing
- Elevation on fill
- Elevation on piles or open foundation
- Floating/amphibious structures

**Site measures to protect from flooding**
- Elevate/regrade site
- Floodwall
- Temporary protection

**Retreat**
- Relocate
- Demolish

Floating House, Amsterdam
Reinforce foundation

- Adding additional structure increases a building’s ability to withstand flood loads.
- Saturated soil imposes significant loads on buildings that are not experience under dry conditions.
- Unequal lateral and buoyant hydrostatic forces can rupture walls or building foundations.
- Foundation failure can significantly or irreparably compromise a building’s structural integrity.

Illinois

North Carolina
Reinforce Foundation Slab & Walls

Risk Reduction: Reduces the risk of structural failure due to saturated soil given any level of flooding.

Best-suited for: Buildings with basements in flood zones with still water flooding.

Doesn’t work for: Buildings facing wave action; attached structures.

Cost: To be evaluated

Issues/Barriers:
- Where reinforcing involves thickening the exterior wall, it requires space around the structure for excavation and backfill.
- Doesn’t prevent water infiltration unless combined with the installation of a waterproof membrane.
- Does not eliminate the possibility of flooding through the ground floor or through penetrations such as basement windows.

Benefits:
- Can increase structural resilience.
- Does not have negative design or streetscape implications.
- Complements other strategies for armoring buildings.

Questions:
- Can this strategy be used in all soil conditions/qualities?
- Is there an average DFE above which even reinforced foundations fail?
Install shield panels to protect doors and windows

- Guard doors and windows with operable flood-proof panels to limit or prevent water seepage.
Install shield panels

Risk Reduction:
- Limits or prevents water infiltration through or around doors and windows.
- Provides protection up to a certain height or force.

Best-suited for:
- Buildings with a flood elevation lower than the height of the panel

Doesn’t work for:
- High flood elevations

Cost:
- To be determined.

Issues/Barriers:
- Aesthetically challenging to incorporate into a building.
- May be difficult to implement with certain envelope systems.
- Removable panels require adjacent storage space.

Benefits:
- Provide some protection against flood-borne missiles.
- Can quickly be positioned in anticipation of flooding.

Questions:
- To what extent do shield panels provide protection against wave action?
- Can shield panels compromise the building envelope by transferring flood loads across the façade?
- How much protection does a shield panel provide if the façade has limited waterproofing potential?
Replace sidewalk vault

- Many New York City vaults were built without either a waterproofing membrane or doors.
- In some cases, replacing a door or closing mechanism may significantly improve the vault’s protection against low levels of flooding.
- A full replacement of an old or poorly-maintained vault may be necessary to ensure a building’s ability to support flood loads and resist infiltration.
Replace sidewalk vault

**Risk Reduction:**
- Replacing doors reduces risk for low levels of flooding.
- Complete replacement can reduce risk of structural compromise and higher floods.

**Best-suited for:**
- Buildings with old or poorly-maintained sidewalk vaults seeking to renovate.

** Doesn’t work for:**
- Buildings without an existing vault.

**Cost:**
- Estimated $200-250 per square foot for construction only

**Issues/Barriers:**
- Requires ongoing maintenance to monitor and repair sidewalk cracks.
- Can be compromised by the use of certain deicing chemicals.
- Does not negate the need to move mechanical equipment out of the basement.
- Temporary disturbance to streetscape during construction.

**Benefits:**
- Promotes the general upkeep of the building.
- Invisible once complete.
- Improves resistance against groundwater flooding.

**Questions:**
- How many feet of water can the structure of a waterproof vault door support?
- Could sidewalk vaults take on a storm water retention function?
- Are there ways to address energy efficiency and flooding concerns in the same vault replacement?
Raise ground floor and incorporate vents

- Allows water to move freely through the structure.
- Relieves hydrostatic pressure for low levels of flooding without sacrificing living space.
Raise ground floor and incorporate vents

**Risk Reduction:**
- Relieves hydrostatic and hydrodynamic forces on the structure.
- Accommodates low levels of flooding.

**Best-suited for:**
- Buildings where the second floor is more than 7 feet above the DFE.
- Frequent flooding scenarios and building subject to wave action.

**Doesn't work for:**
- Buildings with minimal floor-to-floor heights.

**Cost:**
- To be determined.

**Issues/Barriers:**
- Requires vacating the ground floor during construction.
- Eliminates any habitable space below grade.
- Reduces floor-to-ceiling height of the first floor.
- Creates potential compliance issues for accessibility.

**Benefits:**
- Maintains floor area.
- Accommodates repeated flooding at low levels.
- Provides structural system.

**Questions:**
- What kinds of façade systems can negotiate a raised ground floor and new vents?
- How many buildings have enough floor-to-floor height to implement this strategy?
- Is there an optimal floor area for which this is cost-effective?
Dry Floodproofing

- In dry floodproofing, water-resistant materials are used, in combination with water-tight gates at entry points, to prevent the infiltration of flood waters and resist hydrostatic forces.
- Different materials include concrete, concrete masonry units, and aquarium glass. Gates often made from sheet metal with reinforcement and rubber joints, or inflatable materials.
**Dry Floodproofing**

**Risk Reduction:**
- Protects buildings from flooding.

**Best-suited for:**
- Mixed use or community facility buildings in A zones.

**Doesn't work for:**
- Not allowed by FEMA and Building Code in 100% residential buildings.
- Not allowed by FEMA and Building Code in V zones.

**Cost:**
- Generally more expensive than wet floodproofing.

**Issues/Barriers:**
- Above 3 feet, dry floodproofing may not protect from structural collapse.
- Aquarium glass is expensive, other materials limit transparency of ground floor.
- Mechanical/electrical equipment must be protected or elevated.
- Usually used in concert with other strategies (elevation/wet).

**Benefits:**
- Minimizes impact on streetscape.
- Allows excavation below grade for basements.

**Questions:**
- How can we get a better cost estimate?
- Structural capacity unclear for larger structures.
Wet Floodproofing

- In wet floodproofing, water-resistant materials are used, in combination with flood vents or breakaway walls to allow water to enter and hydrostatic pressures to equalize.
- Different materials include perforated holes and marine-grade plywood.
Wet Floodproofing

**Risk Reduction:**
- Protects buildings from structural damage due to flooding.

**Best-suited for:**
- Low design flood elevations.

**Doesn't work for:**
- Not allowed by FEMA and Building Code in V zones.
- Contents located below the DFE are not protected from flooding.
- Limited uses allowed below the DFE.

**Cost:**
- Generally less expensive than dry floodproofing.

**Issues/Barriers:**
- Generally less expensive than dry floodproofing.

**Benefits:**
- Generally less expensive than dry floodproofing.

**Questions:**
Elevate on Fill

- The building site is raised to a height above the design flood elevation through the addition of fill.
Elevate on Fill

Risk Reduction:  ▪ Protects buildings from flooding.

Best-suited for:  ▪ Large lots and low design flood elevations.
▪ Sloped sites.

Doesn’t work for:  ▪ Small, infill sites.
▪ V zones.

Cost:  ▪ Additional cost of fill.

Issues/Barriers:  ▪ For all besides 1-2 family buildings, requires extensive ramping as design flood elevation increases. May make infill development on a narrow lot infeasible.

Benefits:  ▪ Can reduce impacts on streetscape with appropriate landscaping.

Questions:  ▪ How can we get cost estimates?
**Elevate on Open Structure**

- The building is raised above the design flood elevation through construction on piles or piers that are driven into the soil.
- Frequently used along with breakaway walls beneath the design flood elevation.
- Elevator core below the design flood elevation allowed if dry floodproofed.
Elevate on Open Foundation

**Risk Reduction:**
- Protects buildings from flooding and associated wave forces.

**Best-suited for:**
- V zones

**Doesn't work for:**
- Retail corridors, active streetscapes.

**Cost:**
- ?

**Issues/Barriers:**
- Access complicated.
- Uses below DFE are limited and unprotected.
- Streetscape impacts.
- Enforcement.

**Benefits:**
- High degree of safety
- Allows for waterfront views.

**Questions:**
- How feasible is this for larger structures?
- What are potential uses for below the DFE?
Site Protection

- The use of floodwalls or a berm to prevent water infiltration.
- Can be temporary or permanent.
**Site Protection**

**Risk Reduction:**
- Protects buildings from flooding.

**Best-suited for:**
- Larger sites with multiple buildings.

**Doesn't work for:**
- Small sites.
- Areas with wave action.

**Cost:**
- ?

**Issues/Barriers:**
- Can end up trapping flood waters behind the wall.

**Benefits:**
- May be more cost-effective for larger sites.

**Questions:**
- Can end up trapping flood waters behind the wall.