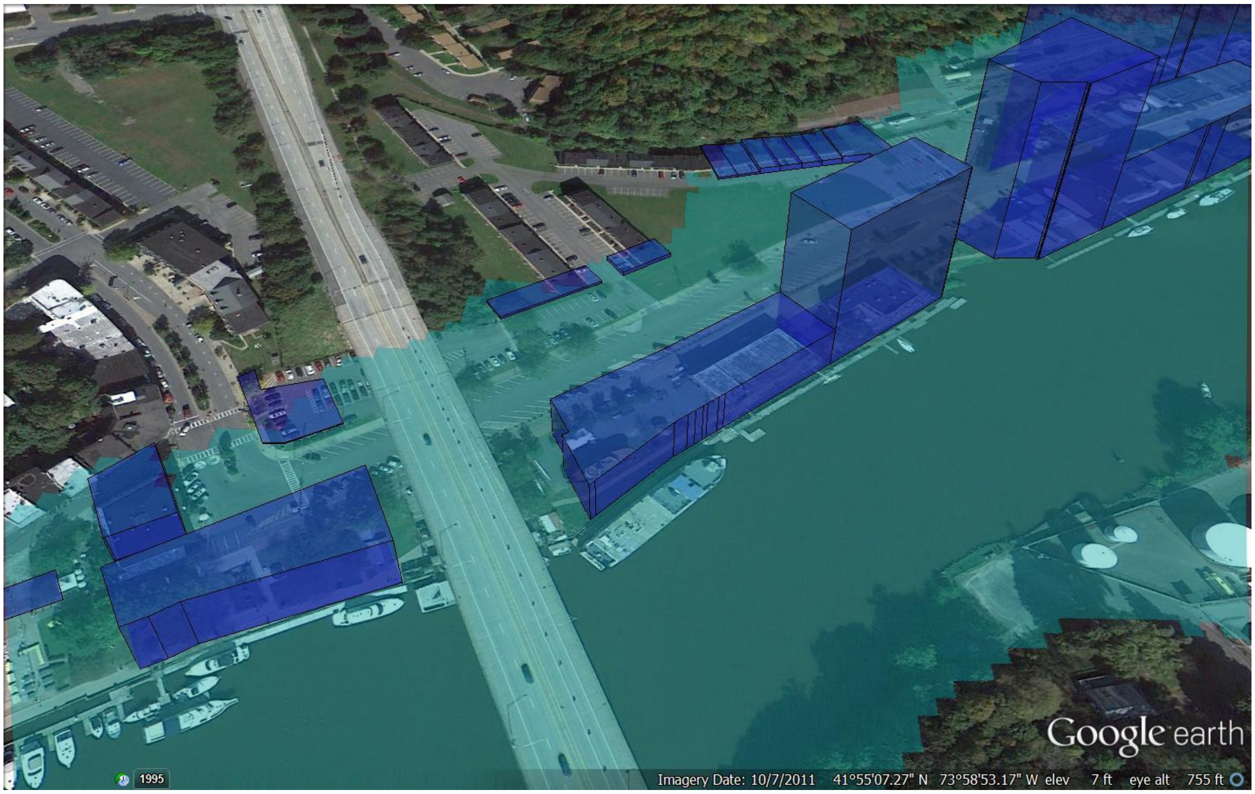
Flooding Vulnerability Assessment for the City of Kingston, NY



With Benefit Cost Analysis of Three Adaptation Options for the Rondout/East Strand Area

- **For 10-year and 100-year Storm Events**
- **With High and Low Sea Level Rise Scenarios**
- **For the Years 2013, 2060 and 2100**
- **Including Predictions for All Cumulative Expected Monetary Damage to Buildings and Real Estate Improvements Using the COAST Tool, and**
- **Predictions for Avoided Damages with Adaptations**

Jonathan T. Lockman AICP
Vice President of Environmental Planning
Catalysis Adaptation Partners LLC
jtlockman@catalysisadaptation.com
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Methodology and Assumptions Used for COAST Model Vulnerability Assessment

COAST is a software tool, whose development was funded by the US Environmental Protection Agency, that is used to predict damages from varying amounts of sea level rise and storm surge. The acronym "COAST" stands for "COastal Adaptations to Sea level rise Tool." The COAST software was run for Kingston by Catalysis Adaptation Partners LLC (CAP), whose principals designed the software, and who use it to help communities throughout the country. COAST is used to calculate the potential damage from one particular storm in the future, as well to calculate the accumulated potential damage from all storms that may occur over a period of years, from today until a point in the future.

For the City of Kingston, the first step was to load accurate elevation data into the model. A LiDAR (Light Detection and Ranging) image of the waterfront area was used, which is a highly accurate map of land elevations made by taking laser measurements from an airplane. The LiDAR image was obtained from the New York State Department of Environmental Conservation (NYSDEC) and was prepared by Scenic Hudson for use by COAST. Once the LiDAR image was loaded, the COAST model could identify the height of any piece of land in the study area. The LiDAR image for the city was made up of a grid millions of squares, each 1 meter by 1 meter (3.28 ft), with a single elevation value in feet for each square. In order to use the COAST model, the LiDAR images were resampled by CAP, with a new grid of 15 feet by 15 feet, with a single elevation value for each square.

The next step was to load the model with the tax map parcels and building values for the city, which were provided by the City planning department and Ulster County. Care was taken to make sure that both the LiDAR images and the tax maps were in the same map coordinate system, and with the same units (feet) for both vertical and horizontal positions. Then water levels were set up for the creation of simulated storms, with scenarios of sea level rise to be added over time. The starting value of the high tide level of the sea today was set at 3.0 feet (NAVD 88 units), as established by Scenic Hudson from a series of other projects.

An "exceedance curve" was established, setting up a prediction of various sized storms and their probability or chances of occurring in any given year. The following values were put into this exceedance curve in the model, for the overall elevation of flood waters and how often such floods might occur. The values were taken from the latest Ulster County FEMA Flood Insurance Study:

Storm Event	Recurrence Interval	Probability in Any Given Year	Surge Height Above MHHW of 3.0 ft. (NAVD 88 units)	Overall Elevation of Flood Waters in Feet (NAVD 88 units)
500 Year Storm[1]	Once every 500 years	0.002	8	11
100 Year Storm[1]	Once every 100 years	0.01	5.2	8.2
50 Year Storm[1]	Once every 50 years	0.02	4.4	7.4
20 Year Storm[1]	Once every 20 years	0.05	3.6	6.6
10 Year Storm[1]	Once every 10 years	0.10	3.0	6.0
[1]From the Ulster County FEMA Flood Insurance Study, 2007				

As set by Kingston Flooding Task Force after extensive consultation with the Planning Team, the scenarios added to the model for sea level rise above today's level were as follows:

Low Sea Level Rise Scenario	High Sea Level Rise Scenario
By the year 2060, an additional 1.67 feet.	By the year 2060, an additional 3.00 feet.
By the year 2100, an additional 2.75 feet.	By the year 2100, an additional 5.67 feet.

The result are ten different scenarios (years 2013, 2060 and 2100, high, low and no sea-level rise, and 10- and 100-year flood levels. These scenarios are listed in the second column in the Table of Results, below.

Now the COAST model had information on:

- the elevation of the land;
- how high the water is today;
- how frequently and how high storm flooding might get in the future, including sea level rise; and
- all the properties with buildings and improvements in harm's way, with their values for derived from tax data.

The final step was to give COAST a guide to how much damage to expect for each building, depending on the depth of the flood waters. A "depth-damage function" was used from the US Army Corps of Engineers. Based on the Army's damage measurements from years of studying floods, the depth damage function is a chart with a predicted percent loss of a structure's worth, depending on the number of feet of depth of the floodwaters that surround it. A depth-damage function was used from a report: US Army Corps of Engineers, Water Resources Report Center, Institute for Water Resources, Report 96-R-12, May 1996, "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, Appendix D – Structure Depth-Damage Functions," page D-1.

Results of the Vulnerability Assessment for City of Kingston

COAST was then run for Kingston, to calculate the damage to the value of buildings from one time future storm events, and for cumulative damages from all storms, up to the years 2060 and 2100 (47 and 87 years from now). The results are summarized in tables on the following pages. A Google Earth project was also created, with the flooding depth and dollar damage estimate available for each individual flooded parcel, for each scenario.

Some important acronyms need to be defined in order to understand the following tables and illustrations:

SLR = "sea level rise"

MHHW = "Mean Higher High Water" – The average of the elevations of the highest tide each day over a specific 19-year period, or a tidal "epoch." For Kingston, the current MHHW is 3.0 feet (NAVD 88).

NAVD 88 = The "North American Vertical Datum of 1988," which is the vertical system of measurement established for vertical control surveying in the US. It sets the zero point against which all elevations are compared. In Kingston, the zero elevation point is 3 feet below MHHW.

Table of Results – Vulnerability Assessment

COAST Model for City of Kingston Modeled Water Levels and Vulnerability Assessment Results										
Year	Sea Level Rise Scenario	Storm Intensity (return period in years)	Predicted Elevation of Flood Height from FEMA Flood Insurance Study, 2007 NAVD88 (ft.)[1]	COAST Model of Sea Level Rise Above MHHW in 2013 Selected by Kingston (in./ft)[2]		COAST Model Total Flood Elevation for Each Scenario NAVD 88 (ft.)	COAST Model Expected Damage to the Value of All Buildings & Improvements From This Single Storm Incident in the Scenario Year ($ Million)	COAST Model Cumulative Expected Value of All Buildings and Improvements Located on Properties Permanently Inundated by Sea Level Rise if No Action is Taken, by this Year ($ Million)[4]	COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements From Sea Level Rise and All Storms, 2013 to Scenario Year ($ Million)	COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements From Sea Level Rise and All Storms, 2013 to Scenario Year ($ Million, with Discounting)[3]
2013	1-No SLR	10 yr	6.0	0	0	6.0	1.0	n/a	n/a	n/a
2013	2-No SLR	100 yr	8.2	0	0	8.2	18.9	n/a	n/a	n/a
2060	3-Lo SLR	10 yr	6.0	20	1.67	7.7	17.3	2.0	85.1	42.5
2060	4-Lo SLR	100 yr	8.2	20	1.67	9.9	23.7	2.0	85.1	42.5
2060	5-Hi SLR	10 yr	6.0	36	3	9.0	20.0	2.0	94.2	48.9
2060	6-Hi SLR	100 yr	8.2	36	3	11.2	26.2	2.0	94.2	48.9
2100	7-Lo SLR	10 yr	6.0	33	2.75	8.8	19.9	2.0	171.6	52.7
2100	8-Lo SLR	100 yr	8.2	33	2.75	11.0	26.0	2.0	171.6	52.7
2100	9-Hi SLR	10 yr	6.0	68	5.67	11.7	1.9	55.3	126.7	50.6
2100	10-Hi SLR	100 yr	8.2	68	5.67	13.9	3.2	55.3	126.7	50.6

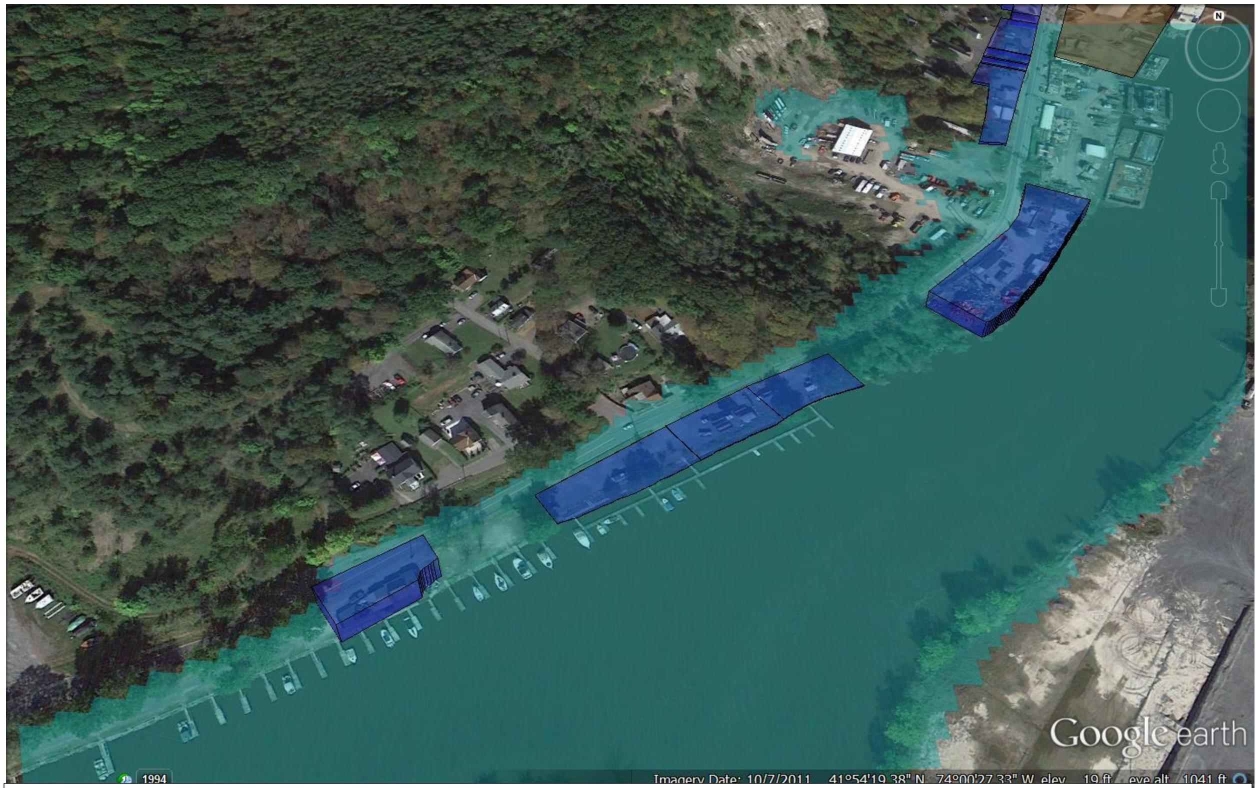
[1]Tidal state is included in FEMA FIS predicted flood elevations for the 10-yr and 100-yr storms.
[2]Elevation of Mean Higher High Water (MHHW) in year 2013 is 3.0 feet (NAVD 88).
[3]Discount Rate of 3.3 percent applied.
[4]See spreadsheet for complete list of properties.

Dates Run: 06/25-30/2013

This project is funded by NYS DEC's Hudson River Estuary Program, with support from the NYS Environmental Protection Fund, in cooperation with NEIWPCC.

Circled Scenario 6 is used in screen shots below.

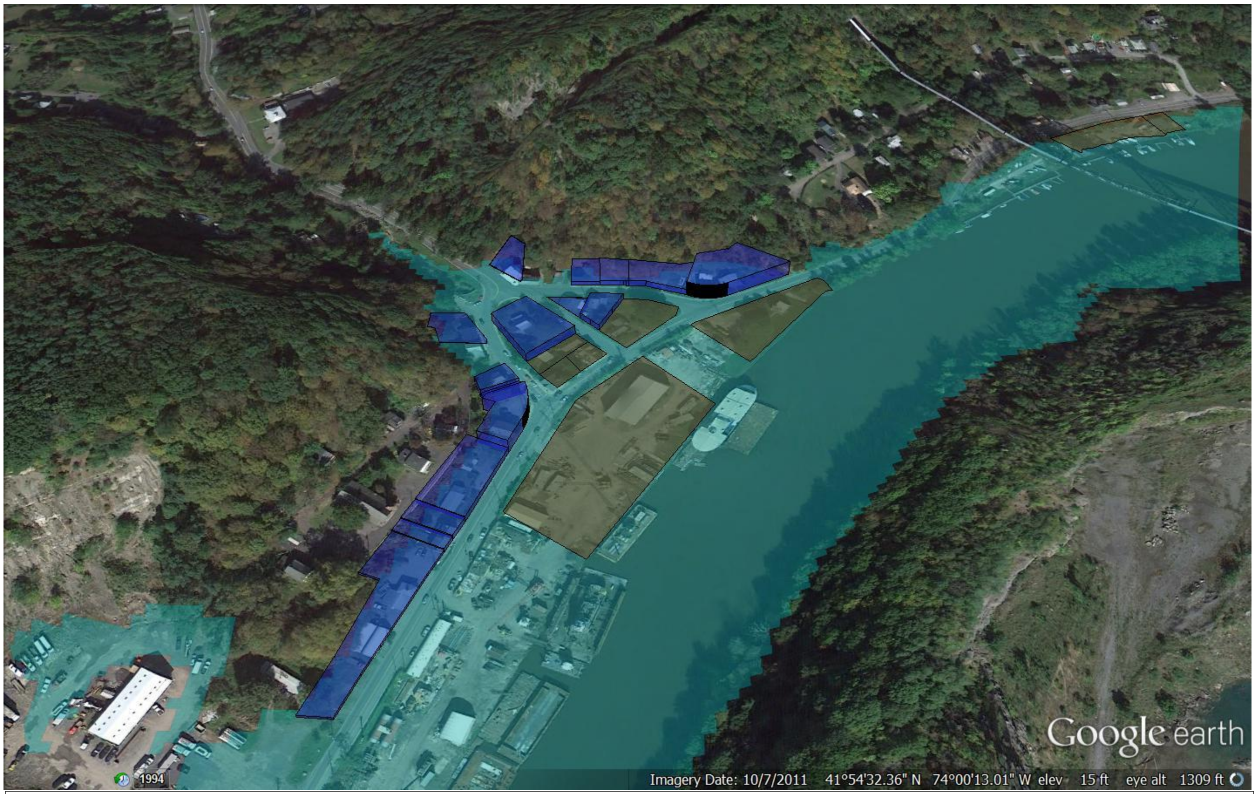
A series of screen shots of this project are found below for scenario #6, (100 Year Storm in 2060 with high SLR) for the entire Kingston waterfront, from west to east. In these illustrations, the relative height of the blue bars indicates the relative amount of damage to the buildings and improvements on that parcel, from the modeled storm scenario. Parcels colored in brown do not show damage bars – these parcels are at low enough elevation that COAST model indicates that they will be permanently inundated from sea level rise by the scenario year if no adaptation action is taken, and would therefore not sustain any additional damage. It is important to note that the values of the buildings and improvements were provided by the latest real estate property tax records from city and county tax offices. For this project, values were inputted into the model without any changes made. Any errors in tax assessment records should be brought to the attention of appropriate city or county offices. Parcels with no buildings or no assessed improvements or no tax data do not have damage assessed, in the images they are shaded a light blue if inundated.



City of Kingston: Recycling Area COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to Sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event

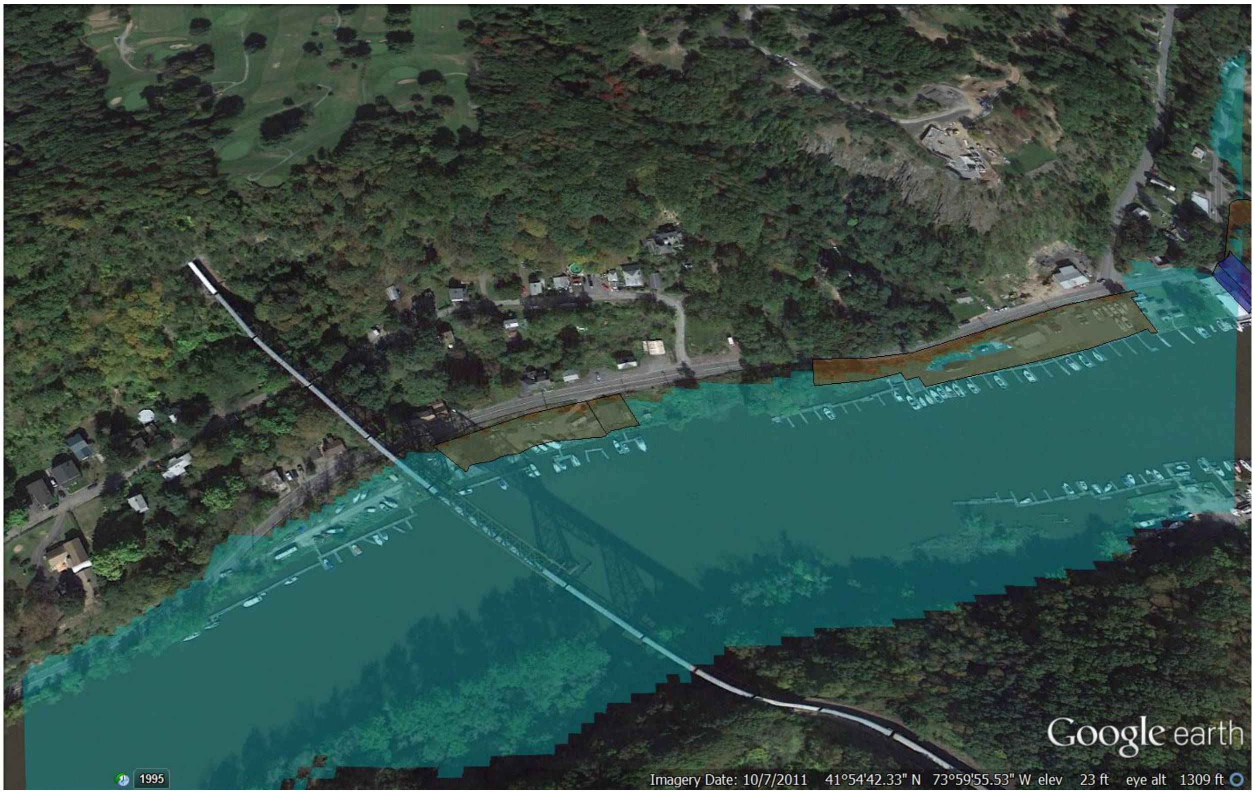


City of Kingston: Wilbur Area

COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to Sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event



City of Kingston: Railroad Bridge Area COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event

City of Kingston: Ballfield Area

COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

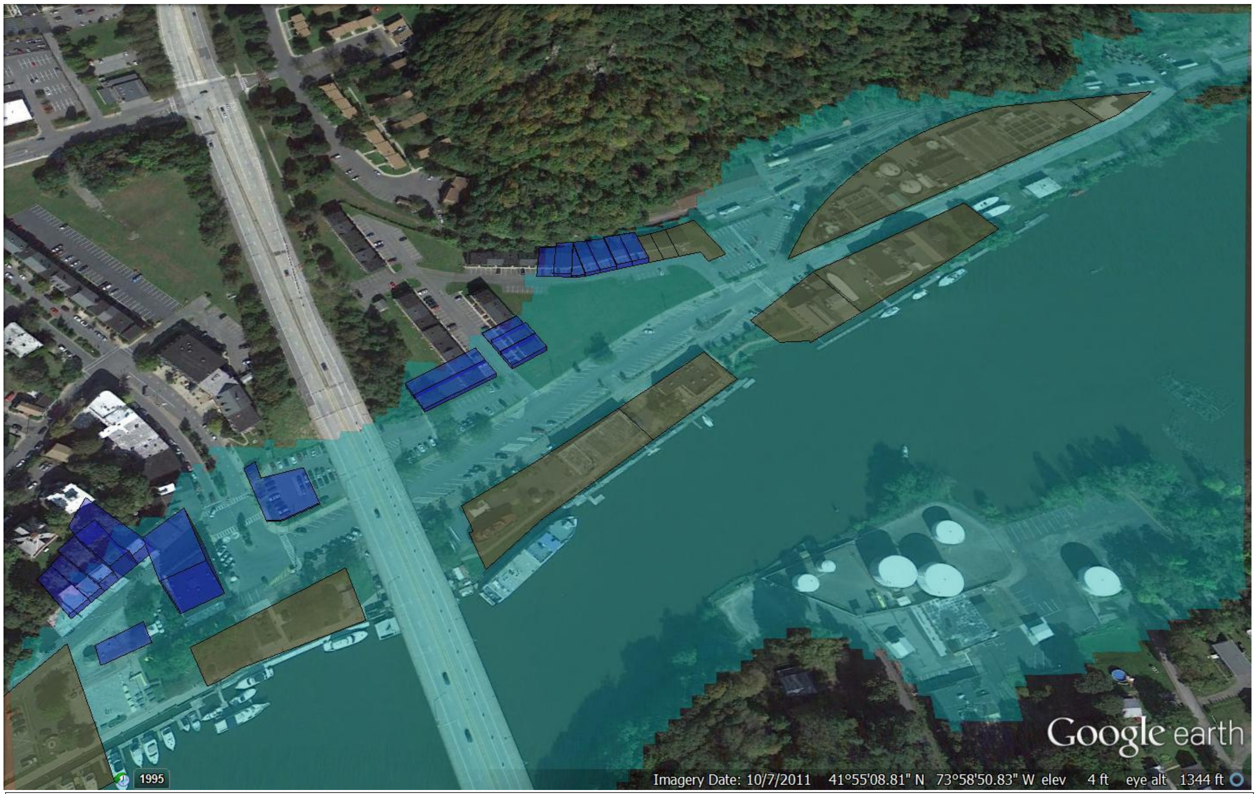
- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event

City of Kingston: West Strand Area — COAST Model Results, Scenario 6: 100 Year Storm in 2060

Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event



City of Kingston: East Strand Area COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

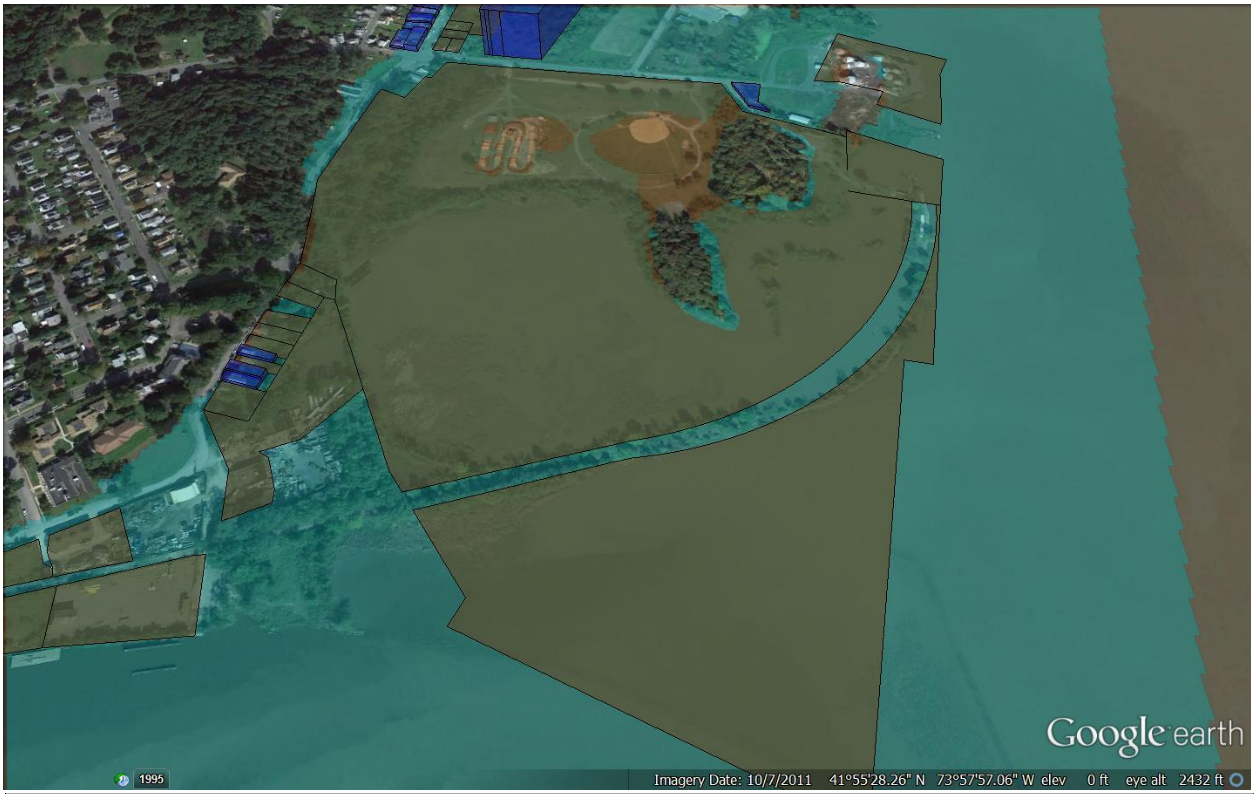
*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event

City of Kingston: Ponckhockie Area COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

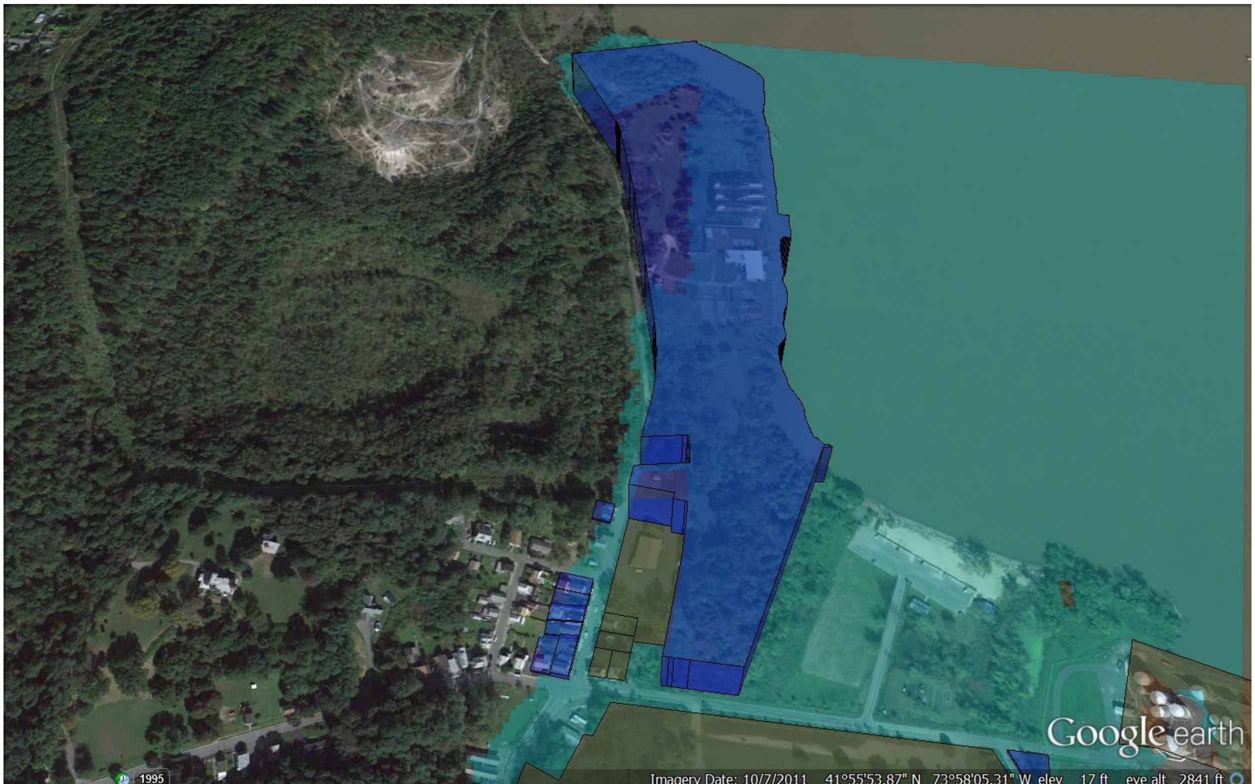
- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event



City of Kingston: Kingston Point Area COAST Model Results, Scenario 6: 100 Year Storm in 2060
Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event



City of Kingston: North Street Area COAST Model Results, Scenario 6: 100 Year Storm in 2060

Total Elevation of Flooding – 11.2 Feet (NAVD 88)

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

- Buildings Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings Permanently Inundated due to sea level rise by this Year, if No Action is Taken
- Extent of Flooding from this Event

Key Points from the Vulnerability Assessment

- The wastewater treatment plant arises as the most expensive building complex needing protection.
- The model is overpredicting the expected dollar damage to the plant, as such a facility is more resilient to flooding than a normal commercial building. Further modeling of the expected damage to the wastewater treatment plan should be undertaken with a specialized depth-damage function.
- Only the tidally-influenced Rondout Creek and Hudson River water level flooding was modeled. Esopus Creek, which forms the northwest municipal boundary of Kingston, and other localized stormwater flows were not included in this analysis.
- Stillwater flooding was modeled (like rising water in a bathtub). Effects of wind, wave or erosion were not included.
- The Ulster County/City of Kingston real property tax assessment data from 2012 were used to assign values for the building(s) and improvements at each parcel location.
- LiDAR data funded by NYSDEC and processed by Scenic Hudson was used to compute the land elevation.
- A depth-damage function from the US Army Corps of Engineers was utilized, to estimate the dollar damage to each building from each foot of flood water. (from "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies," IWR Report 96-R-12, May 1996, see figure V-2)
- A dozen parcels are predicted to be inundated by sea level rise by 2030[1], in either the low or high sea level rise scenarios.
- In the High Sea Level Rise scenario, the COAST model predicts an additional 39 properties to be inundated by Sea Level Rise by 2070, including the wastewater treatment plant, if no action is taken.
- The model indicates that sea level rise will inundate parcels in groupings during certain decades, rather than gradually over time (see gaps in the chart below):

Parcels inundated by sea level rise if no action is taken – Kingston Waterfront				
By the Year	Low Sea Level Rise Scenario		High Sea Level Rise Scenario	
	Number of Parcels	Value of Buildings ($ million)	Number of Parcels	Value of Buildings ($ million)
2020	3	1.3	12	2.1
2030	9	0.8		
2070			39	53.3
Totals	12	2.1	51	55.4

[1]When summing cumulative damages, the software permanently removes properties from the inventory due to sea level rise, beginning at the year ending in zero, when sometime during the prior decade the parcel is inundated daily, at its centroid, to a depth of one foot or more, by the daily high tide. That can happen during any decade during the period when cumulative damage is calculated. In this case the years 2020, 2030 and 2070 were the thresholds when parcels were removed from the inventory, because of inundation by sea level rise. Cumulative damage estimate periods for this project were calculated for 2013 to 2060, and 2013 to 2100.

- Google Earth files in .kml format have been provided to NYSDEC with all of the COAST model output. Screen shots of the Kingston waterfront model output for Scenario 6 appear below, from West to East, beginning at the western-most part of the Rondout in the city, to the area of North Street near the Hudson River waterfront.

Adaptation Strategies and the COAST Tool

Do Nothing, Fortify, Accommodate, or Strategically Relocate

The options for responding to sea level rise and storm surge can be divided into four categories.

Doing nothing is the most common, as it simply involves waiting for a storm incident to happen, and responding afterwards.

Adaptation approaches that "*fortify*" use hard or soft structures to prevent flood waters from reaching community assets. Such armoring can be "hard," such as seawalls or bulkheads, or "soft" structures such as geotextile tubes, which are giant fabric sandbags designed to be replaced after storms. Unfortunately, any wetlands and beaches in front of such structures can disappear as they are pinched out between the rising water levels and the fortifying structures behind them.

Adaptation approaches that "*accommodate*" modify community assets to reduce the impact of flood waters. Accommodation acknowledges that structures will get wet, but action is taken , such as elevating a structure or its critical systems, to make it resilient.

Strategic relocation involves relocating existing structures, people, and land uses away from areas at high risk of flooding to a new location to eliminate the risk of flooding, and allowing wetlands, beaches and natural coastal habitats to migrate landward naturally.

Potential Sea Level and Storm Surge Adaptation Actions		
Fortify	Accommodate	Strategic Relocation
• Revetments • Seawalls • Jetties • Levees • Geotextile Tubes • Automatic Floodgates • Hurricane Barriers	• Dry Floodproofing – Sealing Out Water • Wet Floodproofing – Allowing structures to get wet safely, with minimal damage • Land elevation by fill • Structure Elevations • Dune Restorations • Tidal Marsh Restorations • Tunnel Plugs	• Property Buyouts • Rolling Easements • Relocation of Buildings • Relocation of Infrastructure and/or Facilities • Zoning or Other Regulations to Prevent Fortification, and/or limits on New Construction

Task Force members reviewed many types of strategies in these three categories, as described in the following publications:

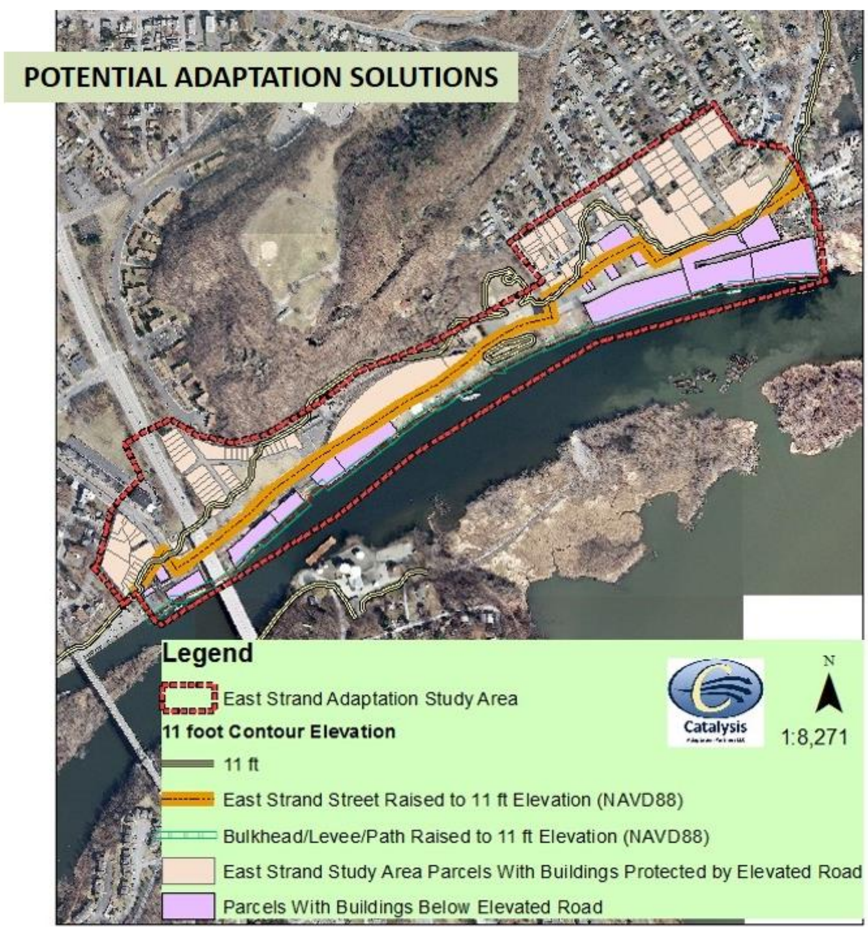
- Georgetown Climate Center Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use

- How Governments Can Use Land-Use Practices to Adapt to Sea-Level Rise, by Jessica Grannis (October 2011).
- Coastal Climate Resilience, Urban Waterfront Adaptive Strategies, prepared by New York City Department of City Planning (June 2013).

Use of the COAST Tool to Perform a Benefit Cost- Analysis for a Proposed Strategy

Once an adaptation strategy has been identified for a community or portion of a shoreline, the COAST tool can be used to evaluate whether the strategy would be a good investment. The COAST model can be run with an adjustment to the depth damage function, to estimate how much cumulative damage might be avoided if the adaptation strategy were installed or put in place. The avoided cumulative damage can be compared to the cost of the potential strategy, creating a benefit/cost ratio. If this ratio is high, i.e., costs are low and benefits are high, then it indicates that the option may will be a good investment, and worthy of further study, and more detailed feasibility plans and construction designs and estimates can be prepared. The Kingston Flooding Task Force asked that COAST to be used to test three adaptation strategies, focused on the East Strand waterfront area (see illustration). This study area included the waterfront on the Rondout from the Gallo Park on the west, to North Street on the east.

Analysis of Three Adaptation Strategies for Kingston to Protect Real Estate



Cost Estimates of Adaptations

Scenario A: Do Nothing. In the do nothing scenario, no public money is spent on any adaptation projects.

Scenario B: Road Elevation. A road surface may be elevated to prevent it from being breached by floodwaters. In the case of West and East Strand Streets, an elevation would also act as a levee protecting the properties on its north, or landward side. The consulting firm Parsons Brinckerhoff provided estimates to CAP for elevating a small portion of West Strand Street from the gazebo in Gallo Park to Broadway, and a portion of East Strand Street from Broadway to North Street, all to an elevation of 11 feet NAVD, or approximately 5 feet higher than the level of the bulkhead which protects the Rondout Creek shoreline, or approximately 8 feet higher than the MHHW level of the Creek. The current average elevation of the road surface is 6.5 feet, so this project would involve raising the road surface up an additional four and a half feet in height, for about 5,000 linear feet (0.95 miles). Using the LiDAR data, spot elevations of the existing road surface were taken every 100 meters, to assist in the estimation of cost. See figures below. The illustration shows the low points that are already prone to flooding at the sewage treatment plant and at Ponckhockie neighborhood. Station 6, at a point along East Strand Street 600 meters east of the Broadway intersection and in front of the sewage treatment plant, is currently at an elevation of only 3.44 feet (NAVD 88) according to LiDAR (less than half a foot above high tide on the Rondout). Station 11, in front of the Riverview Baptist Church in Ponckhockie, reads as having an elevation slightly lower, at 3.41 feet.

East Strand Street – Currrent Elevations Derived from LiDAR Measurements
Measures of the Height of the Existing Road Surface were taken every 100 m from West to East, and labeled as Stations 1 through 15.

Station	Elevation (Meters)	Elevation (Feet)	MHHW (feet)	Height above MHHW (feet)
1	2.51	8.23	3	5.23
2	1.85	6.07	3	3.07
3	1.32	4.33	3	1.33
4	1.45	4.76	3	1.76
5	1.48	4.85	3	1.85
6	1.05	3.44	3	0.44
7	1.34	4.40	3	1.40
8	2.10	6.89	3	3.89
9	1.33	4.36	3	1.36
10	1.39	4.56	3	1.56
11	1.04	3.41	3	0.41
12	2.41	7.90	3	4.90
13	3.77	12.37	3	9.37
14	3.59	11.78	3	8.78
15	2.87	9.41	3	6.41
Mean	1.97	6.45	3.00	3.45
Median	1.48	4.85	3.00	1.85

The total estimate for Scenario B, elevation of East & West Strand Streets, up to an elevation of 11 feet NAVD 88, is summarized in the following table:

Project Element	Estimated Cost
5,000 linear feet of elevation, by an additional 4.5 feet on average	$1,786 per foot x 5,000 = $8.9 million
Handicapped Accessibility Ramps, Sidewalk Adjustments	$0.4 million
Additional Costs for Storm Drainage in Ponckhockie Section	$0.5 million

Total Estimate	$9.8 million

Scenario C: Bulkhead Elevation backed by earthen levee with pedestrian pathway on top. Most of this section of the Rondout Creek waterfront has a pedestrian promenade and bulkhead composed of timbers or sheet pile which can be extended upward. Parsons Brinckerhoff provided estimates for extending the bulkhead upward an additional 5 feet, to create a barrier with an overall height of 11 feet (NAVD 88). The estimate including filling behind the bulkhead for most of its length, with a pedestrian path along its crest, to provide for continued visual access to the water for pedestrians, and for greenway recreation. In areas where buildings are too close to the water to allow backfilling of the elevated bulkhead, the estimate was increased to account for some wall construction, or cantilevered sections where the pathway might extend out over the water. An additional sum was added to allow for softening the bulkhead with vegetation or to employ other techniques to dissipate energy at the water's edge.

The total estimate for Scenario C, elevation of the Rondout Creek Bulkhead, up to an elevation of 11 feet NAVD 88, is summarized in the following table:

Project Element	**Estimated Cost**
Raise Bulkhead height to an elevation of 11 feet. Top with pedestrian path. For majority of length, fill behind bulkhead. For areas close to buildings, build wall behind bulkhead. For buildings in water, cantilever pathway over water. Tie in to West Strand Street at gazebo area on western end, and tie into North Street/East Strand Street intersection area at eastern end.	$338 per foot x 5,050 feet of project length = $1.7 million
Additional costs for one-time replacement and maintenance during the study period, with discount rate applied	$1.5 million
Additional costs for easements, property acquisition, cantilevered or walled sections	$2.0 million
Enhancements to bulkhead to create softer, more resilient shoreline	$1.0 million
Total Estimate	$6.2 million

Scenario D: Rolling Easements. A rolling easement can be purchased from a landowner today, in exchange for a promise to turn over title to the property to the government once it is inundated by sea level rise. Typically, the payment for a rolling easement is the discounted price of the property, based on the net present value of its worth, over the predicted number of years the owner will be able to stay and continue using it before it is flooded. In such situations the government is relieved of financial responsibility for protecting the property from surge and sea level rise, and the owner is prohibited from additional shoreline armoring. The owner benefits from getting a cash payment now, to use in whatever manner, and is allowed to continue using the property until it is inundated. The cash payment may be used as a down payment for relocation of a structure, or for accommodating the property against sea level rise and surge (for example, structure elevation).

CAP modeled purchasing rolling easements today from all properties located at less than 11 feet in elevation, with title to transfer in the year 2060 or when the Rondout reaches 6 feet in elevation (MHHW 3 feet higher than today, NAVD 88), whichever is earlier. Properties already owned by the City of Kingston were not included in the model.

The total estimate for Scenario D, Purchasing of Rolling Easements from Properties less than 11 feet in elevation, is summarized in the following table:

Project Element	Estimated Cost
• Purchase easements from all property owners whose land is at less than 11 feet elevation. • City does not elevate road or bulkhead or otherwise invest in protection measures to mitigate damages over time. • Owners receive a cash payment now and can stay on their property until title transfer at 2060, or when the Rondout reaches a MHHW elevation of 6.0 feet (NAVD 88).	$2.54 million for land and buildings (Total Assessed Value, discounted by 3.3 percent for 37 years)
Total Estimate	$2.54 million

Calculation of Avoided Damages if Adaptation Actions are Taken - Benefits

In the next step the COAST model was run four times for the East Strand Study Area. The first run was for Scenario A, with no adaptation actions taken, to see what cumulative damage to buildings might be expected in this area, by the year 2100, from all storms.

The second run was for Scenario B, with the elevation of West and East Strand Streets in place, so that no damage would occur below 11 feet in elevation, on the north or landward side of the road.

The third run, for Scenario C, calculated the cumulative damage by 2100, if all parcels behind the Rondout bulkhead were protected from damage, until flood waters exceeded 11 feet and overtopped the structure.

The final run, for Scenario D, calculated cumulative damage if rolling easements were purchased for all buildings in this section of the Rondout waterfront, located on properties located at less than 11 feet in elevation. When the model was run for Scenario D, these low-lying properties were removed from the tax assessment rolls in the year 2060, so they would not be subject to damage after that date. The results of the cumulative damage estimates from the COAST model for these four scenarios are summarized in the following table:

COAST Model for City of Kingston
BENEFIT/COST ANALYSIS of Adaptation Strategies

COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements in the EAST STRAND STUDY AREA From Sea Level Rise and All Storms, 2013 to 2100 (Dollars)[1]

Year	Sea Level Rise Scenario	COAST Model of Sea Level Rise Above MHHW in 2013 of 3.0 feet (in./ft)[2]		COAST Model of Total MHHW Elevation for this Scenario Year NAVD 88 (ft.)	Scenario A: WITH NO ADAPTATION ACTION	Scenario B: WITH ELEVATION OF EAST STRAND STREET TO 11 FEET (NAVD 88)	Scenario C: WITH ELEVATION OF BULKHEAD/WITH LEVEE & PATH TO 11 FEET (NAVD 88)	Scenario D: WITH PURCHASES OF ROLLING EASEMENTS, WITH TRANSFER OF TITLE TO CITY AT 2060 OR WHEN MHHW REACHES 6.0 FEET (NAVD 88)
2100	Lo SLR	33	2.75	5.8	46,400,000	4,900,000	241,000	36,900,000
2100	Hi SLR	68	5.67	8.7	44,100,000	4,700,000	446,900	39,576,000

[1]Discount Rate of 3.3% applied.
[2]Does not include purchase of easements at five city-owned properties, and sewage treatment plant remains unprotected.

Analysis of Cumulative Damage Predictions from Different Adaptation Scenarios

It is apparent that in Scenario C, the damage is far lower than in any other, as all properties in the East Strand Study area receive protection by the bulkhead from floodwaters reaching up to 11 feet in elevation. In Scenario B, only properties north or landward of the street are protected. In Scenario D, the properties in the East Strand Study area continue to incur damages from storms until 2060, when titles transfer under the rolling easement, according to the scenario parameters. Scenario D also assumes that payments for the easements are not used by the recipients to eliminate storm damage. Also, in Scenario D, the sewage treatment plant continues to incur periodic storm damage because it is publicly owned and, thus, not included in the rolling easement. This adds to the cumulative damage figures in the model. If individual property owners used easement funds for elevation or other floodproofing measures, and/or the city relocated or effectively fortified the sewage treatment plant with ratepayer or other funding, cumulative damage in this scenario might be reduced.

Comparison of Benefits and Costs for Different Adaptations – Benefit/Cost Ratios

The prediction of cumulative damage avoided over time by employing an adaptation strategy is considered a benefit. The cost estimate for constructing, maintaining, and/or employing the adaptation strategy is the cost. To compare a series of adaptation strategies, economists and policymakers create a benefit/cost (b/c) ratio for each. If the benefits outweigh the costs, the project will have a b/c ratio greater than one. The more cost effective options will have a higher number for the b/c ratio. The b/c ratios for the three adaptation options as calculated by the COAST model, appear in the table below:

Catalysis Adaptation Partners LLC	BENEFIT COST ANALYSIS OF ADAPTATION STRATEGIES – KINGSTON					
	Scenario B: WITH ELEVATION OF EAST STRAND STREET TO 11 FEET (NAVD 88)		Scenario C: WITH ELEVATION OF BULKHEAD/WITH PATH TO 11 FEET (NAVD 88)		Scenario D: PURCHASES OF ROLLING EASEMENTS, WITH TRANSFER OF TITLE TO CITY AT 2060 OR WHEN MHHW REACHES 6.0 FEET (NAVD 88)	
	Low SLR	High SLR	Low SLR	High SLR	Low SLR	High SLR
Cumulative Damage to East Strand Study Area With No Action[1]	46,400,000	44,100,000	46,400,000	44,100,000	46,400,000	44,100,000
Cumulative Damage with Adaptation Strategy in Place[1]	4,900,000	4,700,000	241,000	466,900	36,900,000	39,576,000
Avoided Damage (Row 1 – Row 2) or BENEFIT	41,500,000	39,400,000	46,159,000	43,633,100	9,500,000	4,524,000
Estimated COST of Adaptation Strategy	9,800,000		6,200,000		[2]2,540,000	
BENEFIT/COST Ratio (The higher the number above 1, the more favorable the ratio.)	4.2	4.0	7.4	7.0	3.7	1.8

[1]Discount Rate of 3.3% applied.
[2]Does not include purchase of easements at five city-owned properties, and sewage treatment plant remains unprotected.

Key Results of Benefit Cost Analysis

- The COAST tool and approach are designed to help communities evaluate the merits of various options, and to show which ideas might merit further study.
- Elevation of the bulkhead along the East Strand Study Area appears to have the best b/c ratio of the three scenarios explored in this timeframe, and with these assumptions.
- More rigorous evaluation of potential costs conducted by an engineering firm will be needed before any designs are prepared or actions are taken.
- The experience of Catalysis is that the most cost-effective option is not always the one chosen, when considering adaptations to sea level and storm surge, or when considering any capital

investment. Many communities choose more expensive options when making decisions regarding public safety.